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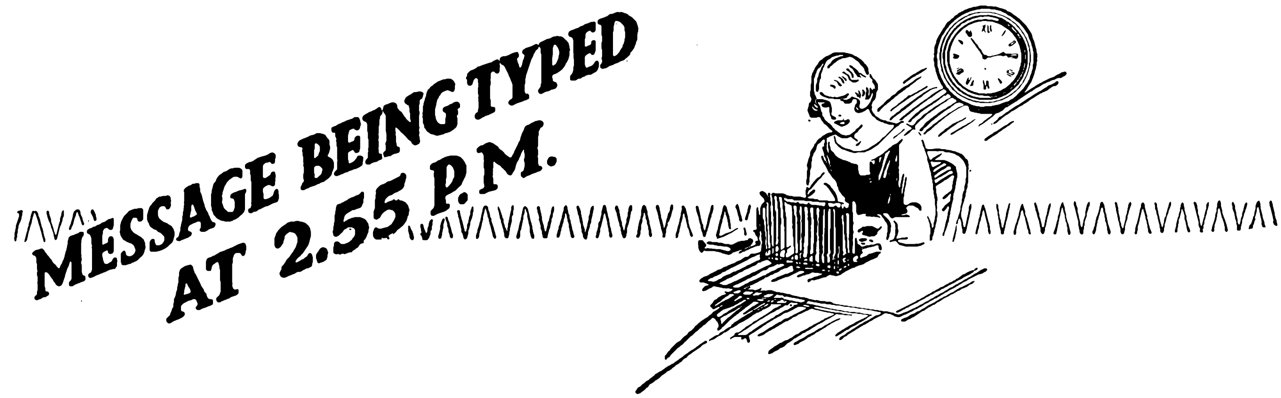

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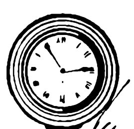


THE
Post Office Electrical Engineers' Journal

THE PASSING OF THE BAUDOT SEXTUPLE DUPLEX.

A. C. BOOTH.

THE last few months have seen the replacement of the Baudot Sextuple Duplex sets which have worked so well on two circuits between London and Birmingham for the last twelve years. On these two circuits were obtained some very noticeable results, which are hardly likely to be excelled or even equalled by any other system. On the 5th February, 1915, one of them dealt with more than 8,000 messages in the day of about 12 hours, and passed 849 messages in one hour. For this reason it is a great pity to see such useful apparatus withdrawn from the service. It has, however, more than justified its installation as it was brought into use at a time when there was a rather strong opposition to the introduction of the Duplex Baudot system, and there was considerable difficulty in keeping the Quadruple Baudot sets in service. The Sextuple Duplex was therefore installed and given close supervision for a month. The results obtained were excellent and from that time forward there was little or no trouble with any Quadruple Duplex set. Although the Sextuple sets were fitted rather for demonstration purposes, the results obtained were so good that they were allowed to remain in use.

The reason for the change that has now been made is due partly to the reduction in the amount of Telegraph traffic to be dealt with on this route, and partly to the economy arising from the use of Keyboard Perforators, which enable a higher speed of working to be obtained. The London-Birmingham service is now given by two circuits, each equipped with four duplex channels fitted with Keyboard Perforators and Transmitters, and each working at a speed of 35 words a minute and giving a maximum output of 140 words a minute each way on each circuit instead of 180, thus saving 4 operators at each end.

The new sets are not Quadruple Duplex but Quintuple Duplex with the fifth pair of channels available for use as an extension to another circuit. It is proposed to make an extension to the fifth pair of channels on the London-Brighton Quintuple Duplex circuit, which is also working with Keyboard Perforators at 35 words a minute.

At present the fifth channel on the London-Birmingham circuit is being used by the Dirigeurs for speaking purposes, utilising the spare receiving instrument and an ordinary 5-key Baudot sender at each end. No difficulty has been experienced in operating the 5-key sender at the higher speed of 210 cadences instead of the usual 180 a minute.

THE TELEPHONE AND TELEGRAPH SYSTEM OF NEW DELHI.

N. F. FROME, B.Sc., A.D.E., TELEGRAPHS.

LOCAL TELEPHONE SYSTEM.—The new capital city of India at Delhi, now nearing completion, has been built to the south of the old city and contains the large buildings of the Government Secretariats, Government House and the Council Chamber, as well as residential and shop areas. The complete telephone system for the whole of the new city was designed in 1923 and installed as the city was being built.

To carry the New Delhi telephone load it was decided that a main automatic exchange should be installed in the new city, and that a second exchange of a similar type should replace the manual C.B. exchanges which had hitherto served the old city and temporary government buildings. This scheme has been carried out; Raisina exchange in New Delhi, Lothian exchange in the old city and a third small exchange at New Cantonments, five miles away, now comprise the local exchange system.

Local Exchanges.—Raisina exchange is of the automatic switch type supplied by the Peel Conner Telephone Works, with 1500 lines equipped and with an ultimate capacity of 3000 lines. It has been installed in the North Block of the Secretariat buildings and was brought into service in September 1925. The distribution frames and switch bays occupy two large rooms on the ground floor above the power, cable, and battery rooms in the basement.

A feature of the exchange construction to deal with local conditions is the provision of double doors and a special dust trap ventilating system in the switch room, which serve as a protection against the severe dust storms often experienced during the hot weather. The switch bays are in addition enclosed in dust-proof cabinets.

An exceptional requirement, probably almost unique in telephone practice, results from the Headquarters of the Government of India moving to the hills for the hot weather. As a result of this, the number of subscribers in Raisina exchange suddenly increases by about 300 % every year in October and falls away again in April. Coupled with this is the exceptional use made of the telephone. With the advent of the Government to New Delhi, with their office establishments in several buildings, the telephone is invaluable, as will be seen from the cold weather busy-hour calling rate, which is approximately 1.7 calls per subscriber. On the whole, considering the difficulties which have to be encountered, complaints are very few and the exchanges deal very satisfactorily with the volume of traffic.

Lothian exchange, 4½ miles from Raisina, in the old city is of the same type as Raisina and is equipped for 1500 lines, 3000 lines ultimate. The exchange is housed in a building built for the purpose and deals with the commercial and residential areas in Old Delhi, most of the subscribers being Indians.

These two main exchanges work interconnected, Raisina working on the two, three and four thousand, and Lothian on the five, six and seven thousand groups.

Features of interest in the exchange operation are that the switches are required to work over a temperature range of from about 100° F. in the hot weather to 40° F. in the cold weather, whilst, during the rainy season, the humidity rises from 25% to 85%. During the hot weather, as is usual with automatic exchanges in India, to avoid expansion troubles it is necessary to make provision for keeping the switchroom at as low a temperature as possible.

No dialling tone is used, and a " disconnect " tone interrupted 120 times per minute is used for " busy " services.

The provision of a good exchange earth is always a matter of difficulty in India, and especially so in New Delhi where the New City has been built on the rocky Ridge of historic fame (the rocky nature of the ground can be seen in Fig. 2). Raisina exchange has therefore been earthed to a near-by well in which there is a permanent supply of water.

The third exchange of the system at New Cantonment is a Relay Automatic P.A.B.X. plant, converted for use as a public exchange, with 30 lines equipped and 60 lines ultimate.

This is connected by cable and overhead junctions to Raisina and works into the Delhi system by the use of an initial digit-8.

In addition, it may be remarked that all the exchanges of New Delhi work unattended at night, whilst the New Cantonment exchange is worked entirely unattended, with only periodical maintenance visits.

Before the opening of the new telephone system in September 1925, steps were taken to educate the public in the use of automatic telephones. Instruction tents were erected in various parts of the old city and fitted with instruments to enable interested persons to call from one tent to another *via* the auto exchange. This was found to be a great help in bringing the system into service and proved a big factor in enabling a very successful cut over to automatic working to be made. In service the automatic exchange system has proved very successful and it appears to be particularly suitable for giving telephone service in the conditions met with in India, and Indian subscribers greatly appreciate its rapidity and accuracy.

FIG. 1.—TELEPHONE CABLES.

Local Distribution System.—In the new city, the distribution from the exchange is, with the exception of the final distributing points, carried entirely underground in armoured L.S.P.C. 10-lbs. conductor cables. The cables (Figs. 1 and 2) are laid direct in the ground but, however, surrounded with a bed of river sand to form some protection against the impregnated soil. Joints are enclosed in bitumen-filled brick chambers and marked above ground by special stones indicating the cable number and position of the joint. The final distribution poles are of the usual Indian Hamilton steel tube pattern and are fitted with fuse and lightning arrestor protection against the heavy thunderstorms experienced in India. It may be interesting to mention here that with the Departmental standard pattern of Hamilton tubes posts can be built from 16 feet to 264 feet high. Of the series of tubes, the first five sections, each 8 feet in length, are tapered and made of rolled steel sheeting. These tubes are so designed that the lower portion of each tube is a driving fit on to the upper portion of the next in the series. The subsequent sections are from 8 to 10 feet in length and are flanged to admit of their being bolted together.

FIG. 2.—TELEPHONE CABLES.

In the new city the final overhead lines in most cases radiate from circular pole brackets to the surrounding subscribers' premises.

The large government buildings of New Delhi have been fitted with an extensive system of block wiring distribution. L.S.P.C. cable is used from the exchange to the distribution boxes and V.I.R. pairs carried in insulated steel conduits provide the leads to the telephone points, the cables and conduits being installed in a trough system used also for the electric light and power distribution. 1040 subscribers will be provided for in this manner. In addition to the telephones, the wiring system in the large buildings is used to provide circuits for a large electric clock system and for the operation of automatic division bells in the Legislative Council Chambers. It is interesting to note that nearly 10 miles of conduit have been installed in the three main buildings.

The cable scheme has, of course, to provide for the annual load variation and in addition is designed to meet any heavy demand arising from future durbars and large Government functions. The New City cable network contains roughly 25,000 miles of conductors.

Long Distance System.—The trunk exchange and central telegraph office in New Delhi are

FIG. 3.—TRUNK LINE.

located in the main Telegraph Department buildings a mile or so to the north of the main government buildings.

The only large overhead line allowed to be erected in the new city terminates at the telegraph buildings and carries the trunk and long distance telegraph lines on open wires to the office (Fig. 3). Shorter and less important lines are brought into the city in underground cables.

Trunk Exchange.—The trunk exchange switchboard (Fig. 4), also supplied by the Peel Conner Telephone Works, contains the trunk operating positions and also the record and enquiry positions for the local telephone system. The board is of a cordless type and has been modified to work on an automatic selection scheme, using relay equipment of the Peel-Conner North Electric variety. Present equipment provides for 20 trunk lines and 10 outgoing junctions to each main local exchange, with an ultimate capacity of 40 trunks without requiring switchboard extension.

Central Telegraph Office.—The telegraph plant fitted in the large Central Telegraph Office (Fig. 5) includes closed circuit, Morse duplex, Baudot and Murray machine telegraphs. The office has been designed in accordance with American practice, the Morse circuit equipment actually fitted on the office tables being confined to keys and sounders only, with a push button

FIG. 4.—TRUNK EXCHANGE, NEW DELHI.

alarm communicating with the test room which contains the remaining apparatus.

The office wiring is carried to the tables in troughing.

The lighting, fan and heating installation of the office and the telegraph buildings was carried out, as usual, departmentally. Insulated conduit is used to carry the wiring. In the telegraph office, semi-indirect lighting has been employed and when the office is full forty-four 200-watt light points and 88 fans will be in service. Some 24 K.W. of heating current will be required during the cold weather.

Test Room.—This room, situated between the trunk exchange and the telegraph office, is equipped for testing and controlling all trunk line and telegraph apparatus. It contains the cable terminations, distributing frames, trunk and telegraph test switchboards, Morse board, duplex apparatus, battery supplies and telephone repeaters. Most of the apparatus of the room was designed and built locally (Figs. 6 and 7).

The trunk test board is of the break-jack type and is equipped for composite trunk line working. The telegraph test board and Morse board are also of the break-jack type, " patch " cords and jumper fields providing cross-connecting facilities and flexibility of apparatus. The circuit and jack systems are so arranged that any duplex set can work on any line or on any position in the telegraph office, whilst additional

FIG. 5.—CENTRAL TELEGRAPH OFFICE, NEW DELHI.
Photo taken at night.
Shows arrangement of lights, fans and tables.

facilities are available, such as the " patching " together of any two duplex sets to form a duplex repeater. Small local telegraph offices in the Delhi area which work duplex to distant stations also use the central office duplex sets, the local office being equipped only with key and sounder. A feature of this arrangement is the saving of batteries and set maintenance and the consequent higher standard of working resulting from the better control which can be exercised over the sets.

From the experience gained of the test room working it is now contemplated to work the Baudot and Murray sets on the same principle, the office instrument tables being only fitted with the keyboards and printers, and it is anticipated

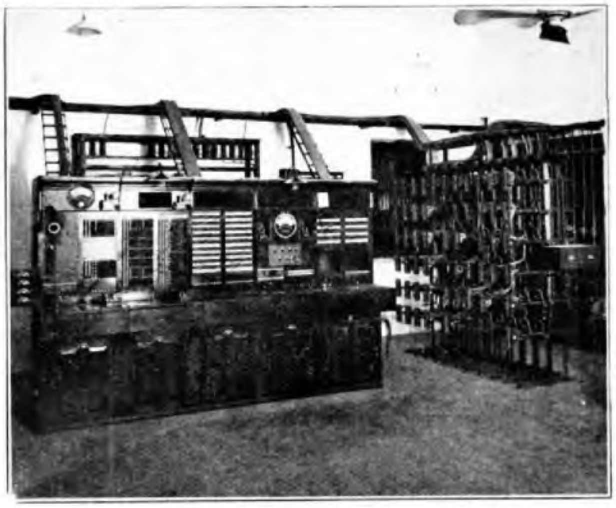


FIG. 6.—TEST ROOM, NEW DELHI.
Shows Test and Morse Board, incoming Cables, M.D.F. and Composite Apparatus Rack.

that the better control obtainable with this system will greatly increase the efficiency of the machine telegraph operation.

In the test room, all battery taps are protected with resistances and heat coils on a battery tap rack; other racks carry the composite sets, composite ringers and telephone repeater balancing networks. Battery power is also supplied to the Railway and Irrigation Canal Telegraph systems from the Central Office plant and has resulted in considerable saving, as batteries previously maintained by the department in these offices have been eliminated.

FIG. 7.—TEST ROOM, NEW DELHI.
Shows Test and Morse Board, Duplex Sets, Cord Circuit Repeaters, Battery Tap Rack and I.D.F.

Such concentration of apparatus in one room under the control of a technical staff, apart from the telegraph office and trunk exchange staff, is a new departure in Indian practice and from the experience which has already been gained it appears to be a long stride forward in the direction of improving facilities for telegraphic communication in India, and when other offices have been fitted in a similar manner even further advantages will be derived from this new system.

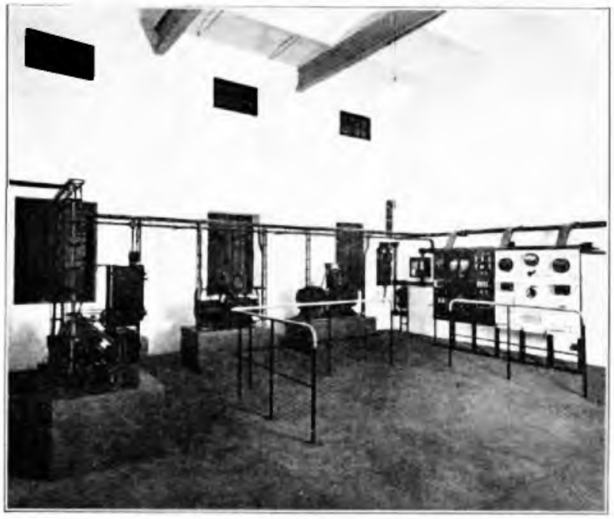


FIG. 8.—POWER ROOM, C.T.O., NEW DELHI. Motor-generators and Switchboard.

The power room of the main telegraph building is shown in Fig. 8 and contains the motor-generator sets for battery charging, control switchboards and 440-volt D.C. power supply. The telegraph switchboard fittings include a battery-reversing switch of a radial pattern and the charging and discharge switches, fuses, etc., for the telegraph and Baudot motor batteries. On the telephone panels are mounted the switchgear and instruments of trunk exchange batteries and repeater batteries.

It will of course be realised that in this short description it is impossible to enter into much detail of the design and circuits of the telegraph and telephone plant or the special difficulties often met with under Indian conditions. It is hoped, however, that enough has been said to show that the Telegraph Department has attempted to provide telegraph and telephone facilities worthy of the new Capital City of the Indian Empire.

FEDERATED MALAY STATES.

REPORT ON THE POSTS AND TELEGRAPHS DEPARTMENT FOR THE YEAR 1926.

THE following extracts from the report of the Secretary for Postal Affairs, Straits Settlements and Federated Malay States, may prove of interest :—

Telegraphs.—During the year 465,516 telegrams were despatched and 509,522 were delivered, increases of 52,004 and 58,004, respectively. The revenue derived from telegrams was $455,579. The revenue shows an increase of $113,562 as compared with 1925. The value of telegrams sent free of charge for other Government departments was $51,337, an increase of $7,366.

Telephones.—The number of subscribers to the telephone exchange on the 31st December was 3,450, an unprecedented increase of 623, *i.e.*, 22 per cent. during the year. In addition there were 1,598 extension lines, extension bells, private circuits, private bell or alarm circuits and tell-tale clock circuits maintained by the department, as compared with 1,401 in 1925.

The revenue derived from telephones was $904,511, an increase of $207,729 or nearly 30 per cent. over 1925. The trunk revenue amounted to $277,253, 30 and 84 per cent. higher than the 1925 and 1924 figures, respectively.

Five new public telephone exchanges were opened. Including the sub-exchange at Maxwell's Hill there are now 42 public exchanges in the Federated Malay States.

Public call boxes are available at 80 post offices.

On the 31st December there were 70 applicants awaiting connection to the telephone system, all very recent applications except for one or two long circuits.

The resources of the department were again strained to the utmost in its efforts to meet the demand, and there were periods of anxiety as to whether equipment could be obtained from England in time to meet public requirements. The coal strike seriously delayed delivery of materials and equipment, and as a result at the end of the year many items on order from the Crown Agents were still outstanding.

Traffic records taken quarterly during the year show the average number of calls per day direct exchange line to have been 12.3, an increase of 11.8 per cent. on 1925. It is estimated that the total number of calls originated in 1926 was approximately 11,400,000, of which 210,000 were junction and 1,200,000 trunk calls. The average number of originated calls handled per day was approximately 39,000, of which 720 were junction and 4,100 trunk calls.

A development study of the Kuala Lumpur Exchange Area has, amongst other preliminary work, been completed during the year. Traffic investigations relative to the proposed Malayan Trunk Scheme, which is also referred to under Engineering, have been delayed by pressure of other work arising from the rapid growth of the system during the year under review.

The exchanges at Kuala Kangsar, Kulala Lipis and Parit were temporarily closed for a few days at the end of the year on account of the floods.

During the year the subject of "party line" telephones has been pursued and a promising adaptation of machine switching equipment is under consideration with a view to trial of the system in the Federated Malay States.

The question of utilising wireless transmission as a telephone link between exchanges to be established on the east coast and the main trunk system has been actively followed up during the year and comparisons of the costs of the various alternatives proposed are now in hand.

Engineering.—On 31st December there were 2,618 miles of telegraph and telephone lines and 19,861 miles of overhead wire in the Federated Malay States, of which 16,872 miles were telephone wires. In addition there were 79 miles of underground cables containing 7,774 miles of wire single line. These figures do not include the poles and wires maintained by the Railway Department for their own use. The Posts and Telegraphs Department also owns and maintains 122 miles of line and 422 miles of wire in Johore. It also maintained in addition to its own lines 1½ miles of pole line for Kedah, 339 miles of wire for Johore, and 23 miles of pole line in Dindings.

The work of laying underground cables was in progress in Kuala Lumpur throughout the year, partly replacement of faulty cables and partly additional cable for development. New underground cables were also laid at Bahua, Ipoh, Kampar, Kuala Kangsar, Kuala Kubu, Kuala Lipis, Port Swettenham, Basa, Raub, Rawang, Rembau, Semenyih, Sitiawan, Taiping and Teluk Anson.

Much damage was done by the serious floods experienced at the end of December to telegraph and telephone pole lines and plant in the valley of the Perak River and throughout Pahang. Kuala Lumpur exchange building was again flooded but the precautions taken during the year proved adequate to prevent serious interference. The exchange was without external electric power supply for several days, during which period batteries were kept charged by means of a petrol motor engine taken from a condemned motor mail van. At Ipoh the only telephone damage was the submersion of a small quantity of subscribers' apparatus. At Kuala Kangsar the water rose to the first floor of the post office and submerged the telephone exchange entirely. All subscribers' apparatus in the town was also submerged, and nearly all the overhead wires were broken down. Most of the underground cables withstood the flood and the exchange system was in consequence speedily restored though, apart from the cables, practically the whole of the plant had to be renewed. At Parit exchange the switchboard was saved by being cut adrift and removed to the first floor of the post office. The main telegraph and telephone route from Selangor to Pahang *via* the Gap was seriously damaged by landslides and falling trees. Communication as far as Raub was, however, rapidly restored by the Kuala Kubu and Raub district staffs, who worked steadily in spite of pouring rains and transport difficulties. Long sections of route were washed away between Raub and Lipis and Raub and Kuantan, and between Kuantan and Pekan.

Reports and estimates in connection with the Malayan Trunk Telephone (Cable) Scheme were received from the Consulting Engineers and the British Post Office towards the end of the year. The estimates are considerably in excess of the original estimate and the scheme is still under consideration.

Shortage of technically trained Asiatic staff is still acute.

Wireless.—Forty-nine temporary licences for the use of wireless receiving apparatus were issued during the year and one experimental transmitting licence.

The British official news broadcast from the British wireless station near Rugby is received at Penang wireless station, retransmitted from Penang by land line, and supplied to the local newspapers on payment of a monthly fee averaged roughly 20,000 words a month.

Workshop.—The workshop has continued to be of great service to the department and there was a considerable increase in the volume of new work undertaken. The output was satisfactory both in quality and quantity. A further reduction in on-costs has been effected.

Stores Branch.—The number of different items stocked was 3,492, an increase of 413 items. The value of stores issued and received in 1926 was $2,183,387, compared with $1,433,000 in 1925.

Under Appointments it is noted that Mr. C. G. Cadman, Telegraph Engineer, Posts and Telegraphs, Federated Malay States, has been appointed to the post of Engineer-in-Chief, Posts and Telegraphs, Straits Settlements and Federated Malay States.

The following table indicates the growth of the system from 1906:—

TELEGRAPH AND TELEPHONE SYSTEM.

Year.	Length of overhead line. Miles.	Length of overhead wire. Miles.	Length of underground cables. Miles.	Length of wire single line in cables. Miles.
1906 ...	1,381	2,509		
1916 ...	2,210	10,461	26½	2,418
1926 ...	2,618	19,861	79	7,774

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH JUNE, 1927.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileage.				Engineering District.	Underground Wire Mileage.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
545,012	539	4,172	52,166	178	London	23,393	61,243	2,009,491	129,671
67,847	1,879	21,704	62,554	1,492	S. East	3,949	42,499	162,166	14,656
72,064	4,380	29,838	50,922	2,423	S. West	16,426	10,396	129,311	54,955
56,524	5,802	34,385	49,138	5,024	Eastern	22,519	34,514	88,330	74,688
89,527	8,657	43,980	55,571	3,814	N. Mid.	23,309	47,775	221,603	122,021
69,555	4,774	28,955	66,313	3,826	S. Mid.	12,832	21,017	140,652	89,082
55,128	4,770	29,378	49,981	2,557	S. Wales	5,753	25,009	101,262	69,929
94,753	8,294	25,571	47,928	4,628	N. Wales	12,886	40,436	228,553	59,747
146,897	1,602	17,050	42,707	2,674	S. Lancs.	12,976	75,645	429,697	46,475
87,057	6,185	30,144	44,778	3,375	N. East	10,571	42,420	206,960	59,712
59,599	3,628	23,483	35,734	2,158	N. West	8,355	31,935	146,974	37,833
44,485	2,530	15,775	23,593	2,724	Northern	4,595	13,417	96,189	51,282
20,193	4,744	7,185	13,192	330	Ireland N.	130	2,288	36,632	1,240
61,415	5,183	24,475	35,569	1,458	Scot. East	3,296	11,666	141,032	47,985
82,273	7,357	24,139	41,598	689	Scot. West	12,159	24,189	210,364	35,299
1,552,329	70,324	360,234	671,744	37,350	Totals.	173,149	484,449	4,349,216	894,575
1,518,776	71,435	357,715	664,668	36,658	Figures at 31st March, 1927.	168,711	469,674	4,173,675	902,782

MECHANICAL TANDEM EXCHANGE.

J. Hedley, M.I.E.E.

ARTICLES appeared in this Journal in July, 1924, January, 1926, and April, 1927, referring to the above exchange. The first by Mr. F. I. Ray, dealt mainly with a description of the circuit operation, the next by Mr. P. B. Frost furnishes details of the Power Plant, and the latter by Col. T. F. Purves, included a general outline of the traffic facilities available.

As the Tandem Exchange has now been brought into service, some further details concerning the equipment and its general development to render it suitable for actual working conditions will probably be of interest.

The introduction into service of the Mechanical Tandem Exchange enables an entire revision of routing of small blocks of junction traffic outgoing from the various manual exchanges in London to be accomplished.

Present Routing Conditions via Manual Exchanges.

Under complete manual working conditions, junction traffic outgoing from an exchange to any other exchange within the same multi office area, is handled in one of the following four methods:—

(*a*) *Straight order wire working.*
Order wire working, with large groups of outgoing junctions associated, terminating on a distant B position, accommodating circuits incoming from the exchange concerned only, for the completion of direct traffic between the two exchanges.

(*b*) *Split order wire working.*
Order wire working with smaller groups of junctions associated than under (*a*) terminating on a distant B position, accommodating circuits incoming from two or more exchanges, for the completion of direct traffic only.

(*c*) *Ringing junction working.*
Junctions not exceeding five in number terminating on a distant B position, accommodating circuits, incoming from two or more exchanges, with small groups of junctions operated on a call and clear signalling basis, for completion of direct traffic only.

(*d*) *Lending junction working.*
Junctions outgoing to a junction centre exchange B position, accommodating circuits, incoming from two or more exchanges, with small groups of junctions, for completing indirect traffic to other manual exchanges.

The design for the Mechanical Tandem Exchange was based on the assumption that the following traffic should circulate *via* that Exchange:—

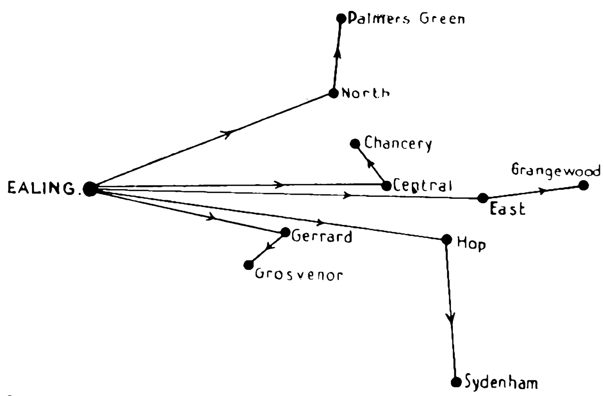
New Routing Conditions via Mechanical Tandem Exchange.

(A) All traffic at present routed under (*d*), *i.e.*, the manual junction centres at

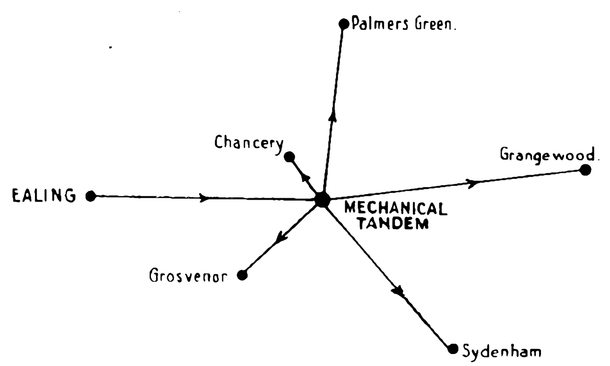
Central, Hop, Gerrard, North, East, and Croydon will be superseded by the Mechanical Tandem Exchange.

Fig. **1** is a typical example for one exchange showing the present and new routing conditions from Ealing, for indirect routing to a few exchanges.

(B) All traffic under (*c*) except short cross country routes between exchanges in comparatively close proximity to each other, where direct routing can be justified



Present method of indirect routing from Ealing, via Junction Centres.



New method of indirect routing from Ealing via Mechanical Tandem

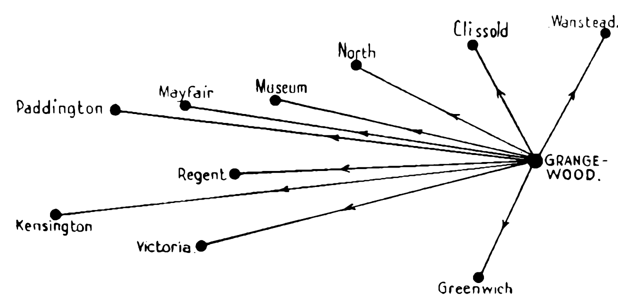
Fig. 1.

on an annual charge basis and all traffic under (*b*) at present carried by junctions not exceeding four in number.

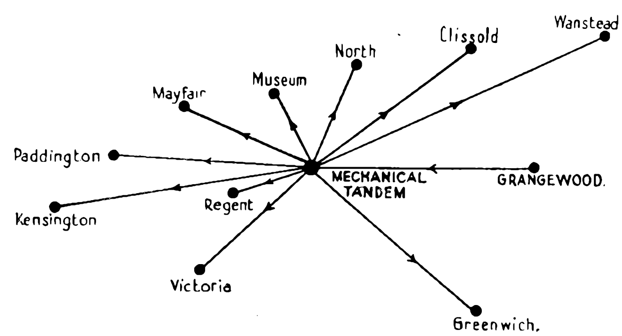
Fig. **2** shows the present direct routing conditions for (*b*) and (*c*) to a few exchanges from Grangewood and the new indirect routing *via* Tandem :—

By collecting the various small groups of traffic under (A) and (B) for each of the exchanges in London, and circulating it *via* the Tandem Exchange, the number of junctions required is sufficient to justify straight order working with large groups of junctions, thus providing more efficient operating and service conditions for all outgoing junction traffic from each exchange in the area.

As all the circuits outgoing from the Tandem Exchange terminate in call indicator equipment at the distant manual exchanges, and Selector Switches at automatic exchanges, the call value to the originating A operator for all junction



Present method of direct routing from Grangewood.



New method of indirect routing from Grangewood via Mechanical Tandem.

Fig. 2.

calls will be equivalent to straight order wire working, thus enabling an overall saving in A operators positions throughout the various exchanges in London.

Similarly the number of B positions in the existing manual exchanges will be reduced by the adoption of a Call indicator working, and the abandonment of lending work in the junction Centre Exchanges.

As regards the facilities for routing traffic, the design of the Mechanical Tandem Exchange is equivalent to that of a Director Automatic Exchange, which requires that the numerical equivalent of the first three letters of all exchange names shall be different, consequently traffic *outgoing* from the Tandem Exchange is confined to exchanges, manual or automatic, within a radius of 10 miles, *i.e.*, to all exchanges within the London multi office automatic area.

For traffic *incoming* to the Tandem Exchange unrestricted facilities are available for the reception of calls from manual and automatic exchanges.

(*a*) Within the 10 mile radius.

(*b*) Outside the 10 mile radius, but within the present London Telephone area.

(*c*) Toll exchanges.

(*d*) Zone Centre Trunk exchanges.

At the outset (*a*) will comprise 79 manual exchanges with 1,849 incoming junctions, and (*b*) 29 exchanges with 368 incoming junctions.

With the development of the Automatic system in London, the 79 manual exchanges under (*a*) will gradually disappear. As each manual exchange is superseded by an automatic exchange, the traffic outgoing from the latter will be routed automatically, by the Director, *via* the most suitable automatic exchange in the network, direct to the call indicator position for manual subscribers, or to selector switches for automatic subscribers. The result will therefore be that eventually the keysending positions, approximately 80, at present accommodating the 79 manual exchanges referred to under (*a*) will be available for the reception of additional traffic from exchanges under (*b*) and for traffic incoming from (*c*) Toll areas and (*d*) Zone centres, from those exchanges having sufficient traffic terminating in the multi office area to warrant order wire working.

Some of the exchanges under (*c*) are:—

Exchange.	*Exchange.*
Aldershot.	Maidenhead.
Ascot.	Maidstone.
Aylesbury.	Margate.
Brighton.	Portsmouth.
Cambridge.	Reading.
Chatham.	Slough.
Chelmsford.	Southampton.
Colchester.	Southend.
Eastbourne.	St. Albans.
Folkestone.	Tunbridge Wells.
Guildford.	Walton-on-Thames.
Hastings.	Watford.
Hertford.	Weybridge.
Ipswich.	Windsor.
Luton.	Woking.

The exchanges under (*d*) are:—

Exchange.	*Exchange.*
Birmingham.	Liverpool.
Bristol.	Manchester.
Cardiff.	Newcastle.
Hull.	Sheffield.
Leeds.	

Quite apart from the magnitude of the equipment provided in the Tandem Exchange, to meet the foregoing requirements, the complexity of the automatic plant and circuit arrangements, not only in the Tandem Exchange, but connected to each call indicator position in the various manual exchanges, was recognised from the outset as representing the most difficult and colossal operation yet undertaken by the British Post Office, and probably by any other administration.

It was in fact realised that the keystone of the London automatic system was the rendering of satisfactory service *via* the Tandem Exchange. Consequently, as a precautionary measure, it was decided to instal an experimental trial installation in order to afford an opportunity for proving from an engineering standpoint that the various new types of automatic and manual call indicator circuit arrangements functioned satisfactorily, and also to enable operating requirements to be improved, before the Tandem Exchange and call indicator positions were opened for public service.

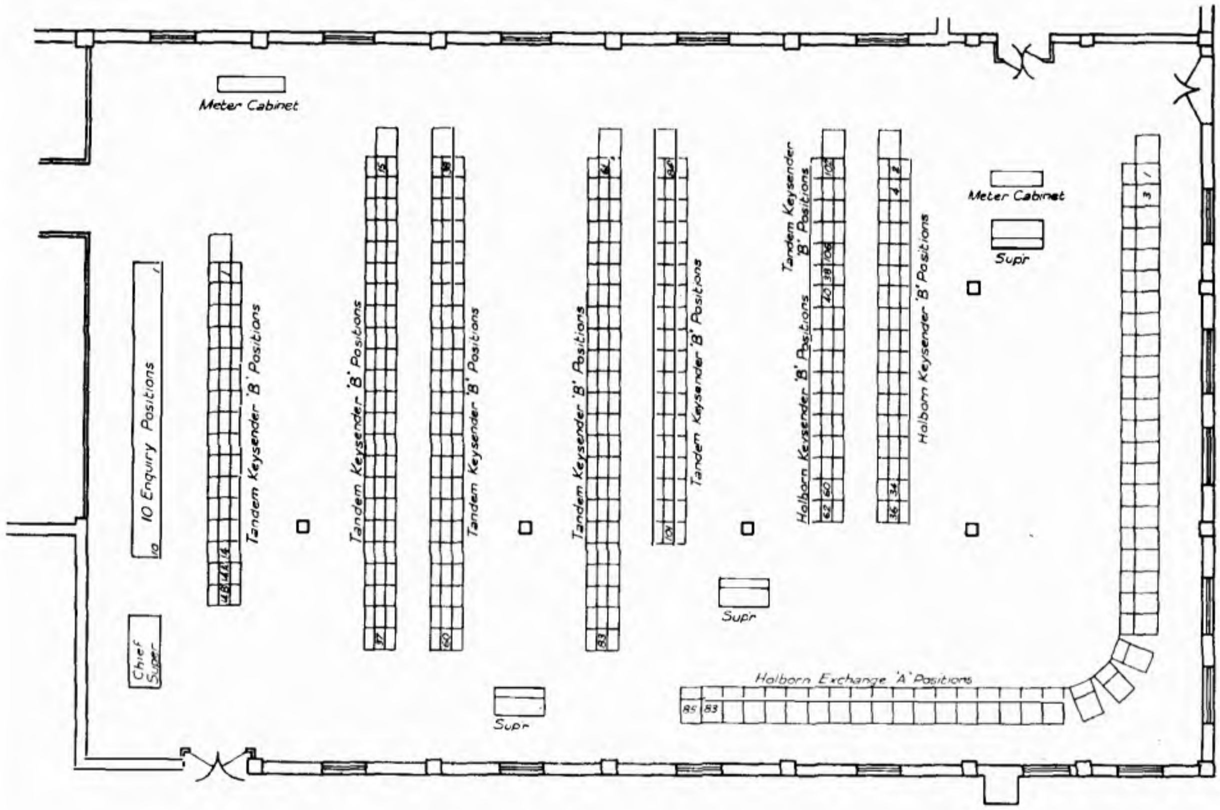
Trial Equipment.

The equipment was located in the City Exchange and comprised the following:—

1. Two Tandem order wire B positions associated with selectors and senders being part of the main equipment of the Tandem Exchange, but fitted temporarily in the City Exchange. Position 1 equipped with 40 incoming junctions and Position 2 with 20 junctions.
2. One Call indicator B position fitted with 36 circuits forming part of the main City Exchange Call indicator group of positions.
3. The A operators in the City Exchange were afforded access *via* 2 order wire keys and 60 junctions in the outgoing junction multiple, direct to the 60 equipments on the two Tandem positions, thus enabling traffic between

two City Subscribers to be circulated *via* the Tandem and Call Indicator equipment at any time.

4. The director equipment in the Engineer-in-Chief's Automatic Training School, was provided with outlets *via* repeaters and Coders direct to the Call Indicator position in the City Exchange, thus enabling calls from Automatic Subscribers to be dealt with.



FOURTH FLOOR

FIG. 3.—LAY-OUT OF MANUAL SWITCHROOM, MECHANICAL TANDEM.

The facilities thus afforded by the trial equipment were similar to those which will obtain in actual practice with the additional advantage that the conditions enabled each and every call to be supervised and traced from start to finish.

The results obtained during the trial may be considered as representative of those under regular public service.

Scheme of Trial.—The following progressive scheme was adopted :—

(1) Complete engineering test out of the equipment.

(2) Application of artificial traffic loads by engineering officers.

(3) Application of artificial traffic loads by engineering officers with the assistance of operators at the A, Tandem, and Call Indicator positions.

(4) Application of artificial traffic loads by the Traffic Staff.

(5) Application of regular traffic between two City Exchange Subscribers.

(6) Application of artificial traffic by Engineering Staff from the Training School Director equipment direct to the Call Indicator position.

This programme was adhered to throughout the trial, small variations being introduced from time to time to meet local traffic and engineering requirements.

Minimum loads were applied in the first instance and these were gradually increased, the effect of the increases on plant operation, operating methods, order wire congestion, and incidence of faults being carefully observed.

Method of operating. The introduction of mechanical tandem working does not vary the existing operating practice, so far as CB order wire working at A positions is concerned. At the terminating Exchange, however, the CB order wire position now becomes a Call Indicator position, and in addition the mechanical tandem operator is interposed between the A and B positions.

The experience gained from the trial equipment indicates that with the introduction of mechanical switching at the intermediate point, together with the fact that the control of the connection is vested in the originating A operator, once the connection has been keyed up by the tandem operator, makes it necessary for more definite operating methods to be adopted.

Under the new conditions one or more of the following operating irregularities may affect the successful connection of a call.

A Operator.

1. Passing wrong number to Tandem operator.
2. Mistaking number of junction assigned by Tandem operator.
3. Taking up wrong junction, either as a result of (2) or otherwise.
4. Withdrawal and reinsertion of plug in junction jack, after call keyed up by Tandem operator (equivalent condition to re-ring under manual operation).
5. Overthrow of speaking key to ringing side during restoration of key to normal.

Conditions (1) to (3) are normal irrregularities which may occur under any system of order wire working, (4) and (5) may also occur but do not result in any permanent interruption to the complete manual connection; but with the control of the Connection in the hands of the A operator a " no display " fault, or lost call, is liable to occur if these two operating methods continue under mechanical tandem working.

Tandem Operator.

1. Mistaking number demanded by the A operator.
2. Keying up wrong number, either as a result of (1) or otherwise.
3. Depressing the assignment key of a junction, other than the one verbally allotted to the A operator.
4. Irregular depression of keys:—
   (*a*) Flicking the keys.
   (*b*) Excessive pause between exchange code and numerical digits.
   (*c*) Keying up before sender associated.
   (*d*) Unequal time interval between digits.
5. Insufficient pause between operation of cancel key and re-keying.

Irregularities (1) to (3) may occur under any system of order wire operation, (4) and (5) result in lost calls but can be guarded against during the normal training of the Tandem operators.

Call Indicator Operator.

1. Irregular engaged testing, *i.e.*, touching the bush of the multiple jack with the ring of the plug, instead of with the tip of the plug only.

This faulty testing may clear the display from the position and result in a lost call, as the subsequent insertion of the plug in the multiple jack is liable to fail to find the junction associated with the calling subscriber. The marker pilot lamp glows, without a display, for the next call and the operator extends to the information desk, by the depression of the service key and decoder release key.

2. A similar condition is liable to occur due to irregular operating, during the process of withdrawing a plug from the multiple on receipt of a clearing signal, by the operator allowing the sleeve of the plug to make contact with the tip of a disengaged plug, or earth on any part of the position.

The above two conditions can only be obviated by operating methods.

Although it is necessary to arrange for more careful operating, it is equally essential that the maintenance of the plant should receive special attention.

The development of automatic routine testing methods for application to the most important parts of the equipment, such as senders, relay groups, etc., and call indicator positions generally, will certainly tend to bring faults under notice more quickly, but more frequent testing of junction lines either by manual or automatic routine methods will be essential in order to detect faults on the external lines themselves and in addition the incoming rotary line switches at the Call Indicator exchanges will need to be proved for correct rotation. Faults on these parts of the equipment may cause the sender in the Tandem Exchange to fail to discharge and result in a " no display " fault and lost call.

The method adopted was for the observer to listen on the order wire. After hearing the number asked for and the Tandem operator's assignment, the observer transferred the listening set to the junction allotted and recorded the progress of the call.

Appendix A. shows the result of calls between November 16th to December 15th, 1926, and December 30th, 1926, and January 8th, 1927.

Routine Indicator.—To enable the engineering staff to observe the operation of the plant,

Fig. 4.—A portion of the Suite of Positions.

Experience under actual working conditions, based on the improved arrangements as regards operating and maintenance testing, shows that the foregoing defects are of very rare occurrence, and the observation results compare most favourably with those under ordinary manual working.

Traffic Observations. — Observations were taken by the Traffic Staff during the regular " traffic " trial.

routine indicator equipment was linked with the Tandem and Call Indicator apparatus as follows :—

Three lamp display panels. The top display indicated the number corresponding to the exchange code sent into the sender, as the result of the Tandem operator keying, the centre display indicated the subscriber's number sent in, and the lower display, the number recorded on the Call Indicator position.

40 Keys and lamps were also provided and linked to the 40 junction circuits on the Tandem position.

By listening on the order wire the observer was thus in a position to check the progress of a call by means of the junction lamps and display signals. In addition, a printing tape machine was associated with the routine indicator—the tape was used primarily to check the correct operation of the digit Keys by the tandem operator—but subsequently it afforded valuable data to be obtained to prove that interruptions in the junction loop were occurring after the circuit had once been taken by the A operator, and also that the Call Indicator operator was making engaged tests incorrectly.

Facilities were available for making the following observations:—

1. A operator's demand on order wire.
2. Tandem operator allots junction and assigns.
3. Junction lamp flashes.
4. A operator plugs in and lamp glows steadily.
5. A operator plugs into wrong junction corresponding lamp flickers whilst lamp of assigned junction flashes.
6. Tandem operator keys up. This appears on two top display lamps whilst correct spacing and depression of keys appears on tape machine.
7. Number appears on Call Indicator position and is duplicated on bottom set of display lamps.
8. Call Indicator operator tests and plugs into number required, both displays released and called subscribed rung.
9. Ringing tone heard and called subscriber answers.
10. Called subscriber engaged. Call indicator operator depresses busy Key—Busy tone heard.
11. Called subscriber clears, junction lamp ceases to glow.
12. Call Indicator operator tests incorrectly, display released but no ringing or busy tone, and junction lamp ceases to glow.

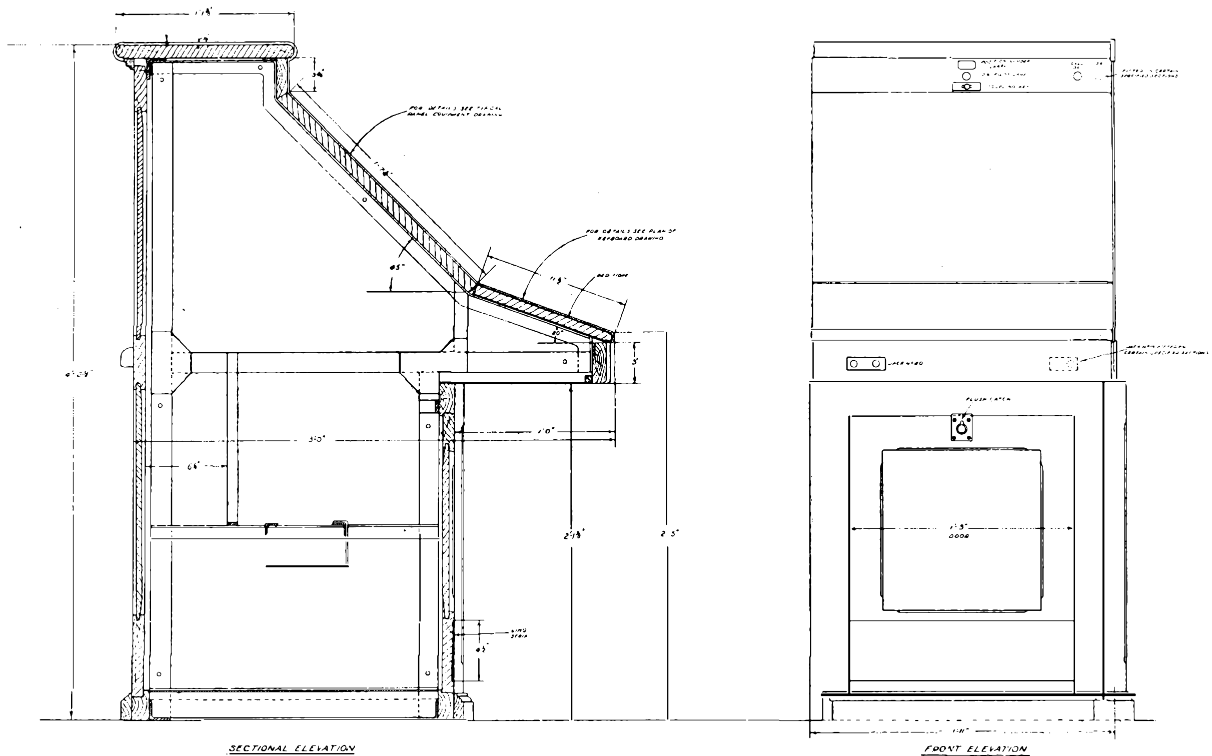


FIG. 5.—CROSS SECTION AND FRONT ELEVATION OF SECTION, CORDLESS B.

APPENDIX A.

RESULTS OBTAINED WHEN PASSING PUBLIC TRAFFIC (CITY EXCHANGE LOCAL TRAFFIC) THROUGH THE EXPERIMENTAL M.T. AND C.C.I. EQUIPMENT.

Item.	Nov. 16 to Dec. 15.		Dec. 30 to Jan. 8.	
	No. of calls.	%	No. of calls	%
1. Calls received at C.C.I. position.				
(a) For which a display was received	35,655	99·44	12,844	99·57
(b) For which only a "Marker-Pilot" was received ...	203	·56	56	·43
(c) Total calls received at C.C.I. position	35,858	—	12,900	—
2. Result of special observations made.				
(a) No. of calls observed ...	15,014	41.8	3,531	27.40
(b) No. of calls O.K.	12,869	85.74	3,075	87.09
(c) No. of calls ineffective due to "no reply"	149	·99	45	1.27
(d) No. of calls ineffective due to "No. engaged"	1,302	8.66	234	6.63
(e) No. of calls ineffective due to "Wrong number" connected	298	1.98	57	1.61
(f) No. of calls ineffective due to "Miscellaneous reasons"...	396	2.63	120	3·40
3. Busy Hour load on C.C.I. position	(Not recorded)		405	

Note.—Period for which order wire was guarded against interruption after depression of assignment key ... 3 seconds. 2 seconds.

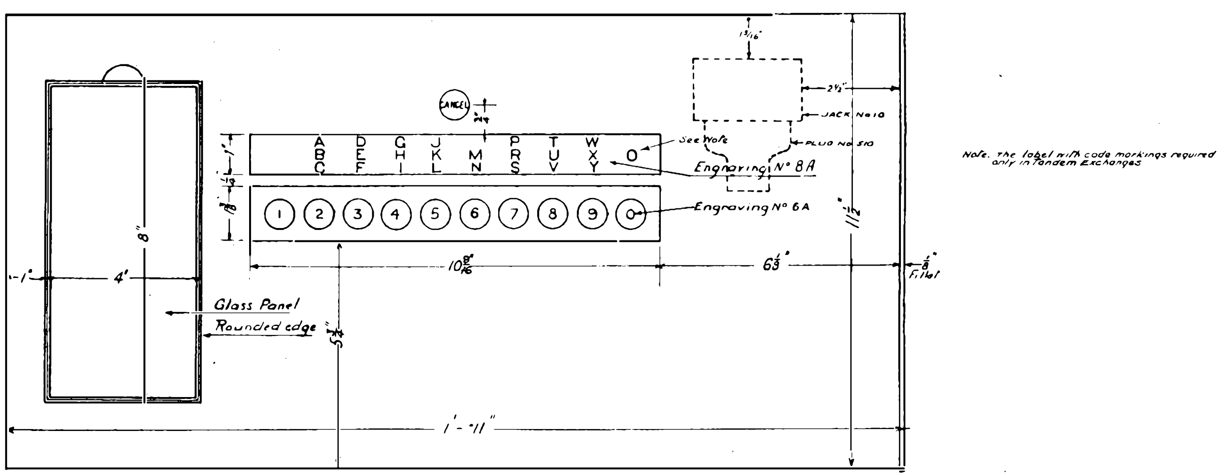


FIG. 6.—KEYSHELF EQUIPMENT, CORDLESS B POSITION.

The experimental trial equipment was completed early in 1926. Tests 1 to 4 under Scheme of Trial followed until the plant was brought into use for public service in September, 1926, and the results obtained have amply justified the preliminary action taken. The arrangements whereby the various items of plant were located in one building were ideal for tracing engineering circuit defects and testing out improved circuit conditions, and also for bringing under notice causes of bad service due to operating and engineering methods, which would otherwise have had to be dealt with during the period of installation and testing out, under the less favourable conditions of the Tandem Exchange equipment widely separated from the distant Manual Call Indicator positions.

In addition to the elimination of defective engineering conditions, from a circuit operation standpoint, three important operating changes were made as the result of the experience with the trial equipment :—

1. Guarding the Tandem operator on the order wire for a definite period varying from 2 to 3 seconds, after the allotment of a junction to the A operator, so as to enable her to be free from demands from other A operators whilst keying up the number.

operator to commence keying up practically immediately after the depression of the assignment key, except on the rare occasions when all senders are engaged. The original scheme provided for the supply of a flashing signal when the sender was found and a steady glow when the A operator picked up the assigned junction. This method tended to delay the keying up by the Tandem operator, as when a sender was found in the dark period of the flashing signal

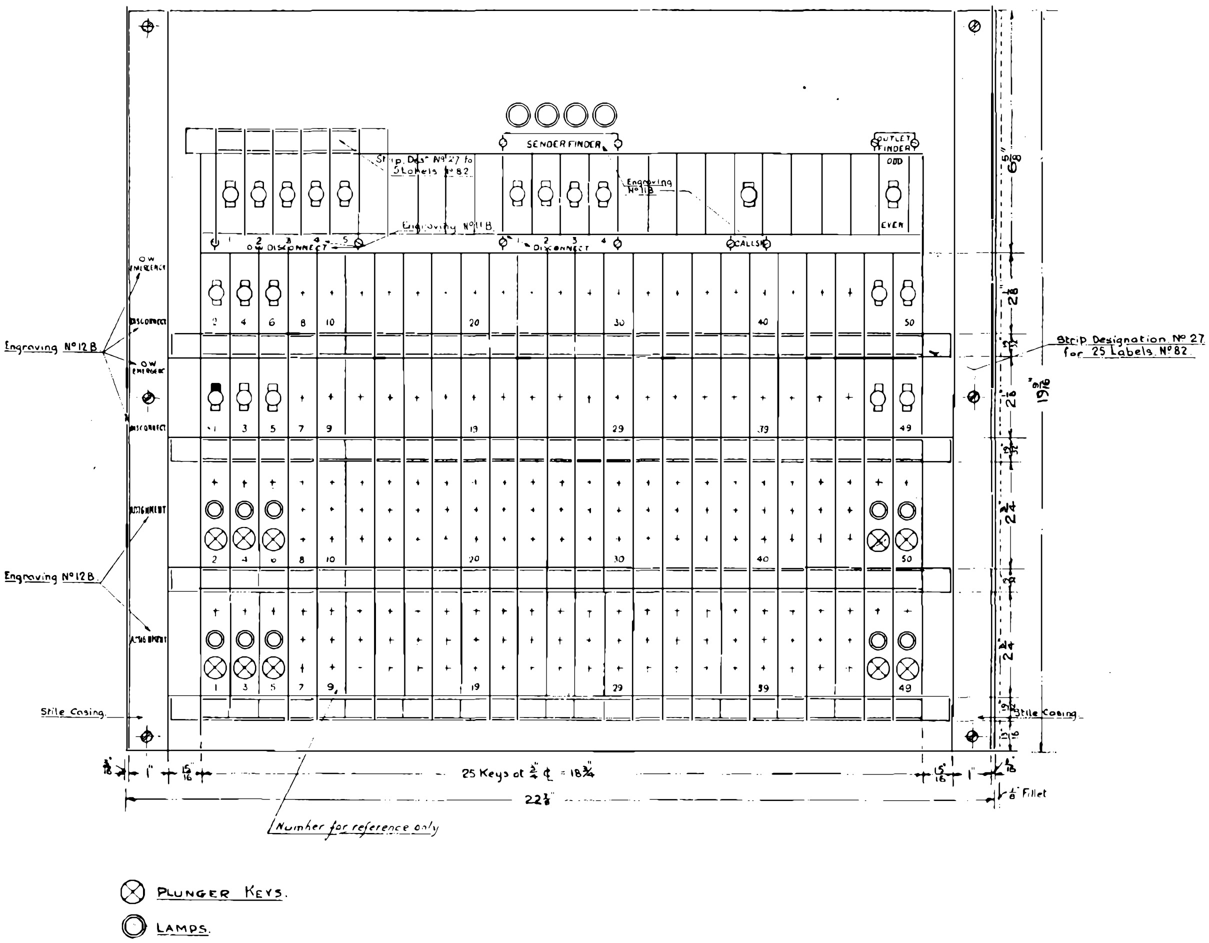


FIG. 7.—PANEL EQUIPMENT, CORDLESS B POSITION.

2. Altering the equipment to make it immune from fleeting disconnections by the A operator, such as those caused by the reinsertion of the plug or overthrow of speaking key, until the call is actually keyed up by the Tandem operator and transmitted to the distant exchange by the sender.

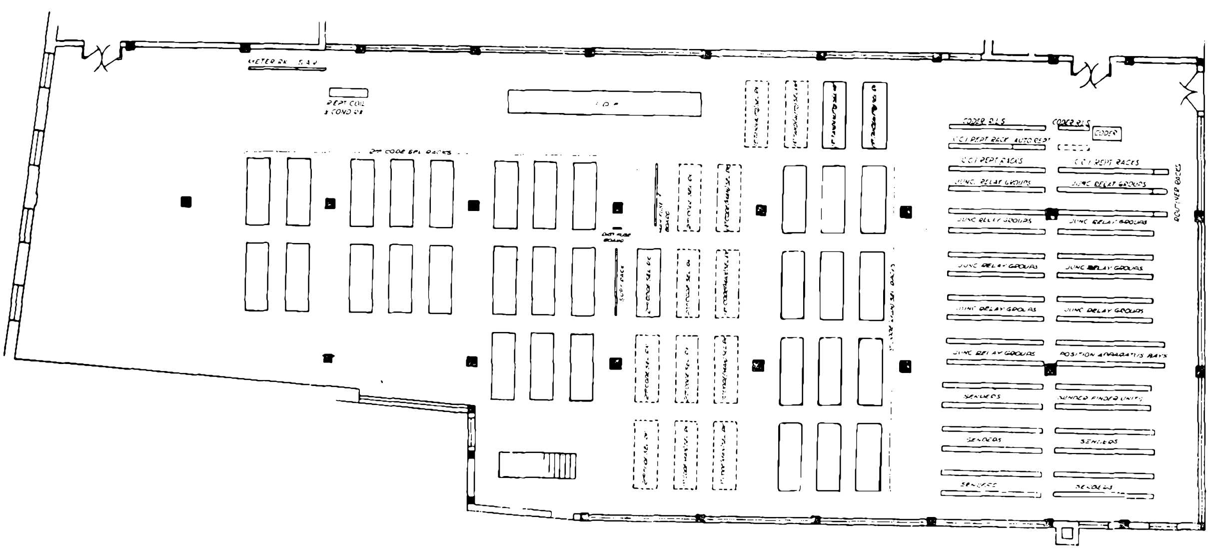
3. Furnishing a steady glow on the assignment lamp of the Tandem position immediately a sender is available, thus enabling the Tandem

the lamp signal might not be received for a maximum of 3/4 seconds.

TANDEM EXCHANGE EQUIPMENT DETAILS.

108 positions have been provided, each with capacity for 50 and equipped for 30 incoming junctions. Fig. **3** shows the lay-out of the manual switchroom, and Fig. **4** a portion of the suites of positions. Fig. **5** is a dimensioned section of a position. Fig. **6** indicates the key-

shelf equipment, the strip of digit keys can be changed, if required, by withdrawal of the plug, attached to the digit key strip, from the jack fitted inside the apron of the keyshelf. Fig. **7** shows the panel of one position equipped for 50 junctions; the two bottom rows of lamps and keys are associated with each junction, for supervision and assignment, the next two rows of keys for disconnecting the junction, and replacing the order wire if faulty; the top row includes 5 keys for disconnecting the order wire when replaced by a junction, 4 sender finder lamps and disconnect keys, a supervisor's call key, and a change over outlet finder key. Fig. **8** shows the disposition in the automatic switchroom, of the junction relay groups,



SECOND FLOOR

FIG. **8**.—LAY-OUT OF AUTOMATIC SWITCHROOM, MECHANICAL TANDEM.

senders, etc., associated with the keysending positions and also the lay-out of the selector racks. The automatic plant includes 6,806 group selectors and 170 senders. Fig. **9** shows a portion of the automatic switchroom. Fig. **10** shows the trunking scheme in use when the exchange was brought into service on August 18th, indicating that provision is available for routing traffic to 100 exchanges. Arrangements are already in hand to extend to 150 outlets.

FUNCTIONS OF LAMPS.

1. *Junction lamp.*—One lamp supervision is provided for each junction, as follows:—

(*a*) When assignment key depressed and a free sender is found the lamp glows and continues to glow whilst the A operator's plug remains connected with the assigned junction.

(*b*) When order wire emergency, or junction disconnect key is operated, the lamp glows.

(*c*) When A operator plugs into an unassigned junction, lamp flickers.

2. *Sender Finder lamp.*—One lamp is provided for each of the 4 sender finders on each position to indicate which of the 4 sender finders are in use.

FUNCTION OF KEYS.

1. *Assignment key.*—One per junction depressed prior to operation of digit keys to bring the sender and position finder circuits into operation.

2. *Disconnect and order wire emergency key.*—One per junction, the downward position is used, for disconnecting the junction from service in the case of a fault, or for releasing the sender should the tandem operator wish to recommence keying after a call has been incorrectly keyed up; the upward position joins the operator's telephone to the junction when the latter is used to replace a faulty order wire circuit.

3. *Order wire disconnect key.*—One per order wire,—5 of which are provided per position —for disconnecting the operator's telephone from the order wire, when the latter is faulty.

Cancel key.—One per position depressed by the operator when the digit keys are known to have been wrongly operated, during the process of keying up. The Sender is released and the operator may immediately recommence keying up, without again depressing the assignment key.

Sender release conditions.—The sender releases after a predetermined period (8 to 16 seconds) or by the depression of a 2nd assignment key, whenever the Tandem operator depresses an assignment key and fails to key up any digits, or keys up incompletely, or after a complete set up by the Tandem operator should the A operator fail to take the junction.

Digit keys free for next call.—Immediately the Tandem operator completely keys up a number, the outlet finder will step to the next

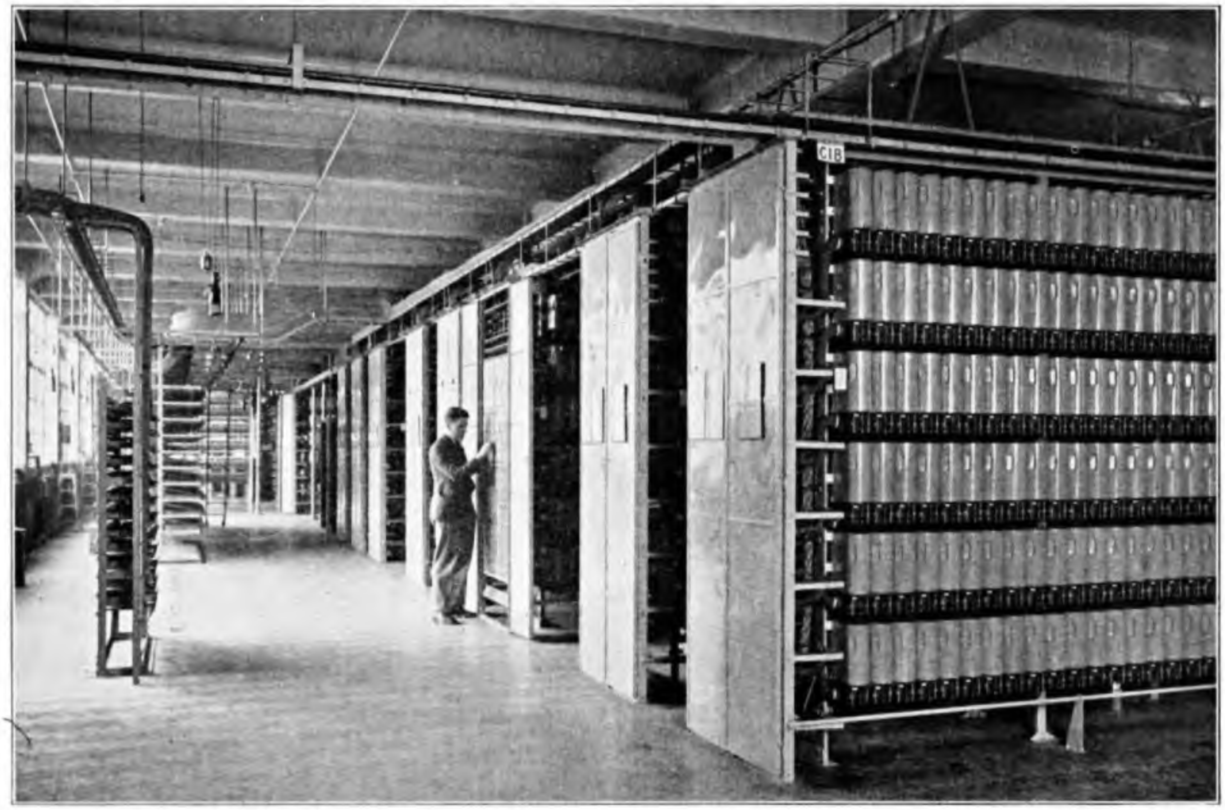


FIG. 9.—A PORTION OF THE AUTOMATIC SWITCHROOM, MECHANICAL TANDEM.

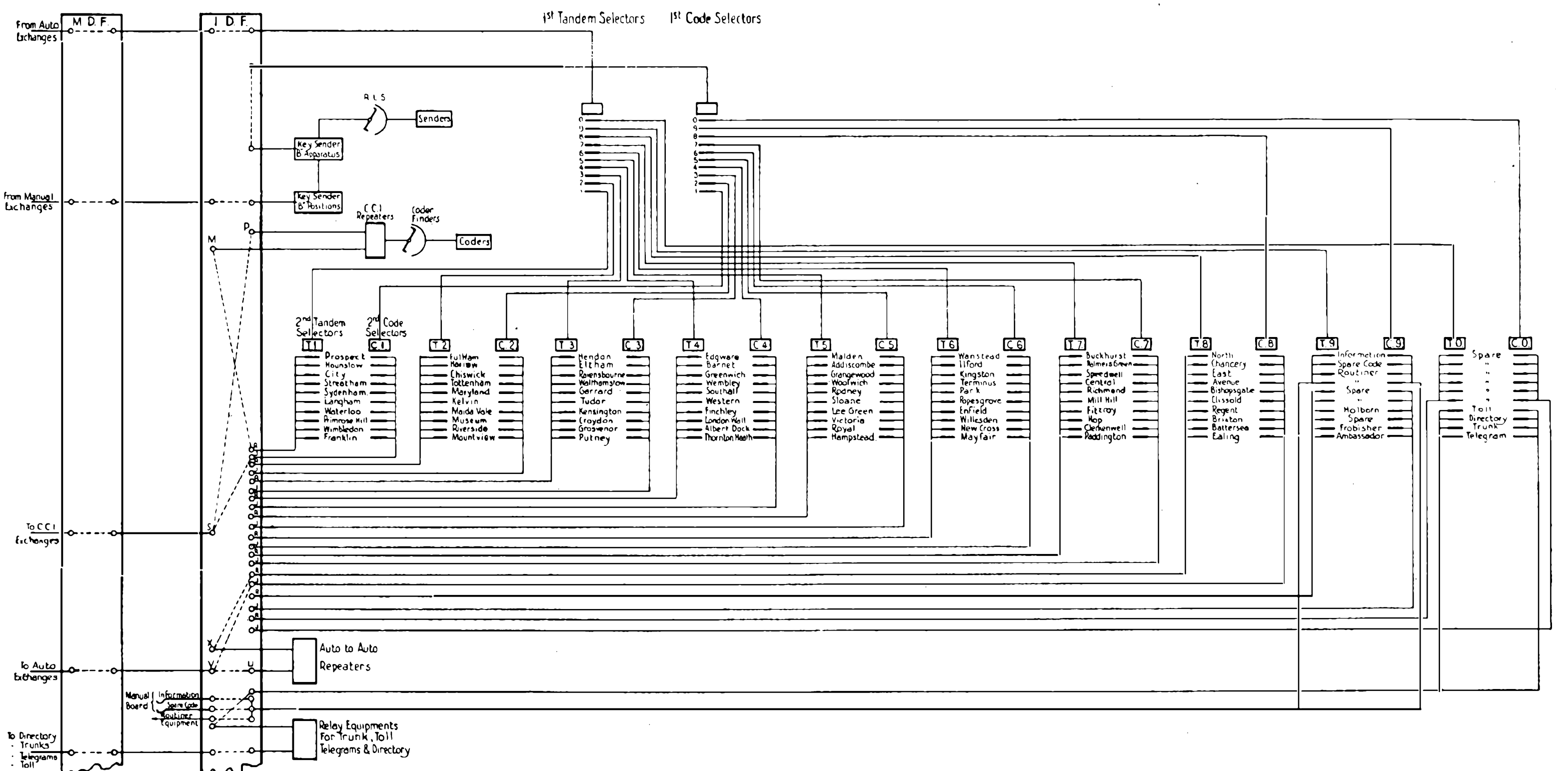
contact, to connect the key strip to an idle sender finder, thus permitting the operator to set up another call.

Sender Finder key.—Four per position used for engaging the outlets to 25 senders, if the outlet is faulty. The associated sender finder lamp glows.

Outlet Finder key.—One per position. Two sets of 4 outlet finders are provided per position. The upward position of the key is associated with one set and the downward position with the other. The position of the key is changed each day so that one set of outlet finders is available in case of a fault.

Grouping of Senders.—Capacity exists for 200 senders. Each half of the positions has access to 100 senders—85 of which are provided.

The key set is connected to a sender *via* a position outlet finder which controls 4 outlets per position, *i.e.*, 4 "junction" finders and 4 sender finders. Each sender finder has access to a maximum of 25 senders, consequently each



Typical Jumpering Scheme on I.D.F. shown dotted.		
Route	To Manual Exchanges.	To Auto Exchanges
Incoming from Tandem "B" Positions	J to S	J to V
" " Automatic Exchanges	R to M and P to S	R to X and U to V.

FIG. 10.—TRUNKING DIAGRAM. MECHAGICAL TANDEM EXCHANGE.

position has access to any sender in its own group of 85.

At this stage a brief statement of the operating facilities will probably be helpful.

Manual Subscriber calls an Automatic Subscriber obtained via the Tandem Exchange.

The A operator passes the call over the order wire to the Tandem operator, the latter allots a junction to the A operator, and at the same time depresses the assignment key associated with the junction.

Junction assigned. — Junction and sender finder switches operate simultaneously, to find the assigned junction, and first free sender. The Tandem operator's telephone is disconnected from the order wire, and a tone is placed on the latter for a period of approximately two seconds, for the purpose of protecting the Tandem operator from interruption during the process of keying up the exchange code and number demanded by the A operator.

Junction lamp glows.—When an idle sender is found, the junction supervisory lamp glows, as an indication to the Tandem operator to commence the operation of key sending. The junction lamp will glow throughout the call until the A operator withdraws the calling plug. No disconnecting work by the Tandem operator is necessary.

Junction lamp flickers.—Should the A operator insert the calling plug before the Tandem operator depresses the assignment key, or should a junction be plugged into other than that allotted by the Tandem operator, the lamp will flicker. The continuance of a flickering lamp signal is an indication to the Tandem operator to route the call to the Monitor by keying up INF.

Operation of Sender.—As the first three digits always concern the exchange code portion of the number demanded, the sender is arranged to operate the group selector code switches as soon as the 3rd digit has been set up. The sender translates the 3 digits of the exchange code to route *via* the desired levels of the 1st and 2nd code switches. The 2nd code switch rotates automatically to find a junction to the desired exchange.

When the operator has keyed up 7 digits, 3 for the exchange code and 4 for the subscriber's number, the sender automatically sends ordinary dial impulses to the distant automatic exchange selector switches. When the 4 digits of the subscriber's number have been transmitted, the called subscriber is rung from the final selector in the automatic exchange and the sender returns to normal, the junction circuit is also transferred from the sender to the calling subscriber so that conversation may proceed.

Standard supervision and busy flash is afforded to the originating A operator.

Manual Subscriber calls a Manual Subscriber obtained via the Tandem Exchange.

The operation by the Tandem operator does not differ, but the sender instead of transmitting ordinary dial impulses, for the 4 digits of the subscriber, translates them into coded signals to operate decoding relays associated with the call indicator equipment in the manual exchange. The decoding relays translate the signals into the numerals of the required subscriber's number, which are displayed on a lamp display panel on one of the call indicator positions. The operator at the latter point inserts any idle cord into the multiple jack of the displayed number.

Arrangements for rendering Public Service.

The scheme of transfer from the existing manual conditions to mechanical tandem and call indicator working must necessarily be a gradual one. Quite apart from the magnitude of the engineering work involved in arranging for the installation and testing of 78 exchanges with call indicator equipment on 316 positions, it will no doubt be appreciated that the education of the staff in the new operating methods has also necessitated an immense amount of intensive study and training by all concerned.

The Engineer-in-Chief's Training School has helped very considerably by affording facilities to all grades of the engineering and traffic staff to obtain tuition and first hand information under ideal conditions. Mr. Anson's article in the July, 1925, issue of the Journal supplies full details of the School equipment.

Frequent meetings were held in order to arrange for the closest co-operation between the engineering and traffic staffs, and it was finally agreed that the scheme of transfer should be as follows :—

1. Divide the call indicator exchanges into 7 zones, corresponding to the existing manual junction centres.
2. Complete the call indicator equipment in zone order, commencing with Croydon and its two associated exchanges at Thornton Heath and Addiscombe and following with—

East	and	7	associated	exchanges.
North	,,	8	,,	,,
Hop	,,	16	,,	,,
Central	,,	8	,,	,,
Gerrard	,,	18	,,	,,
and the				
City	,,	10	,,	,,

3. Artificial traffic to be operated for staff training purposes.
4. Public service to be operated when 3 zones completed, following with the remaining zones.

Artificial traffic under (3) was commenced on Feb. 11th, 1927, by arranging for the incoming junctions on certain Tamden positions to be permanently engaged by the distant A operator. The Tandem operator then assigned and keyed up numbers from a schedule to one of the Call indicator exchanges, say Croydon. The numbers received at the distant exchange were subsequently checked against those keyed up from the schedule in the Tandem Exchange.

Public service under (4) commenced on Aug. 18th, 1927, to the 18 exchanges in the Croydon, East and North zones.

It will be realised from the foregoing description that for the first few years after the introduction of automatic working in London, the Tandem Exchange will be the only general "clearing house" for all indirect traffic within the London area, commencing with the reception of traffic from all the manual exchanges *within* the 10 mile radius, and routing to *manual* exchanges only.

As automatic exchange working develops other "clearing houses" for the reception of indirect traffic from automatic exchanges will be introduced, until ultimately the Tandem Exchange will be utilised mainly for the reception of traffic from manual operators at exchanges *outside* the 10 mile radius, and routing *to automatic* exchanges only.

This article would be incomplete without making reference to the great improvement in speech transmission which has resulted in consequence of the introduction of the Tandem Exchange. This has been achieved by means of new cables, loaded in many cases, provided between the Tandem Exchange and the various exchanges in the London area. A distinct improvement in the service throughout the London area will therefore be afforded, as the worst transmission for any connection *via* the Tandem Exchange will not exceed 30 miles of standard cable.

SUBSCRIBERS' APPARATUS IN AUTOMATIC AREAS.

H. G. S. PECK, B.Sc. (Hons.), M.I.E.E.

PART I.—TELEPHONE AND IMPULSE CIRCUITS.

THE object of this present article is to describe the circuits that have been standardised for use at subscribers' offices on lines connected to automatic switching equipment and to refer to the various conditions that have governed their development.

Various aspects of this subject have already been dealt with from time to time chiefly by Col. Purves in his paper "The Post Office and Automatic Telephones," read before the Institution of Electrical Engineers on 5th March, 1925, a summary of which can be found in Volume XVIII. of this Journal.

The impulses by which the automatic switches are controlled have their origin in the dial on the subscriber's telephone and it will be useful to state at the outset, even at the risk of a charge of plagiarism*, what is a standard impulse and to describe the cause and the results of distortion of such impulses.

A train of standard impulses consists of a series of " breaks " of .067 second separated by " makes " of .033 second. The movement of the mechanism in the switching equipment is determined by the number of breaks which corresponds to the digit dialled.

Variation in the total duration or period of an impulse or what amounts to the same thing in the number of impulses per second, can only arise from variation in the speed of the dial. The " standard " rate of impulsing is 10 per second, but in practice dials are maintained in service provided the rate of impulsing is not less than 9 nor more than 11 per second.

Departure from the ratio of 2 : 1 for the break and make portions of a train of impulses is known as impulse distortion. It may arise from faulty construction or adjustment of the dial, or from the effect of relay lag or from the circuit conditions as described below.

If the length of the breaks in a train of impulses sent into an automatic switch be increased at the expense of the makes, a point will be reached at which their duration has been so reduced, and consequently the magnetisation of the B relay so attenuated that it will fall away during the train of impulses and prematurely complete a circuit for the operation of the release magnet of the switch.

If the breaks be shortened either by increasing the makes or by increasing the rate of impulsing, the time of energisation of the vertical and rotary magnets will be reduced and a point will be reached when this period has become so short that the switch mechanism will fail to count the impulses, which condition will arise in the step-by-step system through lack of sufficient time for the mechanism to move past the " dog " which retains it in its stepped position after each impulse.

The speed of a dial may be reduced very considerably before the switching mechanism will fail, which failure will occur owing to the fall back of one or other of two slow release relays, resulting in either the operation of the release magnet or the premature change over from vertical to rotary movement.

The truthfulness with which a train of impulses is reproduced by the contacts of the line relay in the switching equipment will vary with the resistance, leakage, capacity and inductance in circuit with the impulsing contacts of the dial and the relay.

Resistance by reducing the magnitude of the current tends to delay the pull up of the line relay. It also makes it more ready to fall away and the combined effect of these two tendencies is to shorten the time of the make of the relay contact and to lengthen its break. Leakage by maintaining a small current whilst the impulsing contacts of the dial are open has the reverse effects and so lengthens the time of make and shortens the break.

An inductance in series would delay both the pull up of the relay and its fall off. The effect on the times of make and break of the relay due to capacity between the lines depends upon its magnitude and distribution in relation to the other constants of the circuit. In general the make is increased, although a lumped capacity gradually increased from zero actually decreases the time of make until a critical value of about $\frac{1}{4}$ or $\frac{1}{3}$ microfarad is reached, after which the make increases at an average rate of $2\frac{1}{2}\%$ per microfarad.

The connections of the telephone also have an effect upon the character of the impulses. The transient effects that occur at the make and break of the dial are of great interest and importance and are conveniently studied by the aid of Figs. **1**, **2** and **3**. It was the proper understanding of these effects that finally led to the standardisation of the impulse circuit shown in Fig. **3**.

The diagrams have been drawn to show the connections with the receiver off the hook and the dial in the normal position. The open arrow heads represent the off normal or auxiliary contacts of the dial which are operated as long as the dial is away from its position of rest. The solid arrow-heads represent the impulse contacts which are interrupted as the dial returns to normal, the number of interruptions or im-

* *See C. W. Brown, I.P.O.E.E.J., Jan.* 23. *Vol. XV., p.* 303.
do. do. July, 24. *Vol. XVII., p.* 128.
L. H. Harris, I.P.O.E.E.J., Jan. 25. *Vol. XVII., p.* 293.

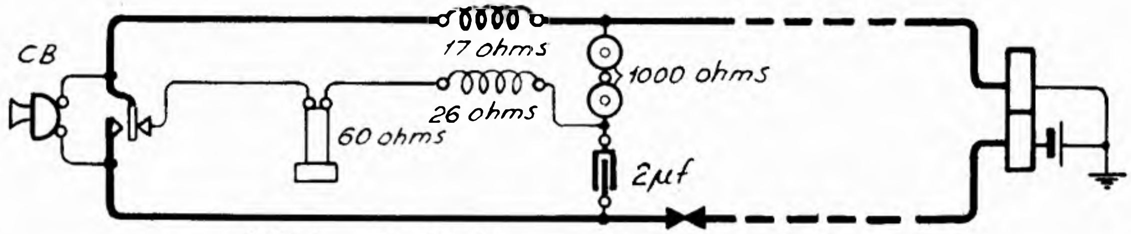


FIG 1. TYPICAL EARLY CIRCUIT.

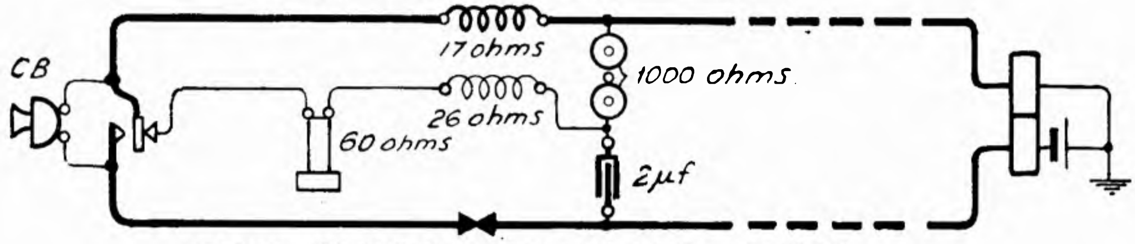


FIG 2. STANDARD TELEPHONE OF 1922.

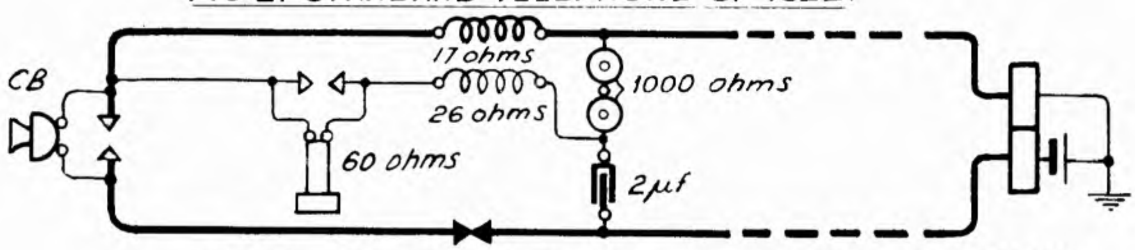


FIG 3. PRESENT STANDARD AUTOMATIC TELEPHONE.

FIG 4. PRIVATE BRANCH EXCHANGE.

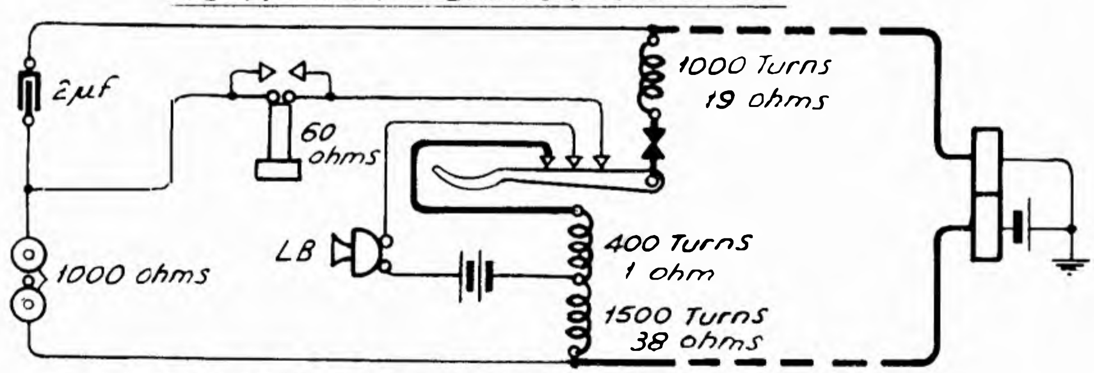


FIG 5. LOCAL BATTERY TELEPHONE.

▷◁ or ▷|◁ indicates off normal contacts of dial.
▶◀ indicates impulsing contacts of dial.

pulses depending upon the angle through which the dial has been turned by hand before being released to return under the control of its spring and governor.

The relay, line and telephone together make up a circuit containing resistance inductance and capacity and the usual conditions referring to the rupture of a current in such a circuit apply when the impulse contacts of the dial are opened. The energy stored in the magnetic circuit of the line relay is then released and is eventually dissipated in the resistance of the circuit.

Immediately on the opening of the impulse contacts the magnetisation of the line relay commences to die away and whilst doing so sets up an electro-motive-force in its winding. The magnitude of this E.M.F. depends upon the rate of fading of the magnetisation and this is related to the rate at which the current falls. The direction of the induced E.M.F. is such as to tend to maintain the current and if, as in Fig. **1**, the circuit be disconnected at a point where very little or no capacity is left across the relay the current is forced to die away at a very rapid rate and a correspondingly high E.M.F. will be induced in the relay winding. The energy is then dissipated in the form of a spark or in leakage current through the insulation.

Tests made in the Research Section showed that with this circuit the induced E.M.F. at the break of the dial contacts was 1,050 volts when the connection between the telephone and a line relay of the A.T.M. Co.'s horizontal type was made by 0.1 mile of 10 lb. cable. In practice, however, the capacity of the subscriber's line and multiple connections are generally sufficient to prevent potential differences greater than 900 volts being reached, and when one mile of cable is in circuit the peak P.D. is about 400 volts. Such high P.D.'s as these are liable to cause breakdowns of insulation and to give rise to sparking at any weak point in the wiring.

In Fig. **2** the bell and condenser in series are left in circuit across the relay and line when the impulse contacts are broken, but owing to the impedance of the bell there is no great reduction in the foregoing P.D.'s, a maximum peak value of 700 volts still being reached.

Numerous variants of Fig. **1** were experimented with in connection with the earlier automatic systems. In one the transmitter and receiver were connected in a simple series arrangement which was short-circuited by a single pair of off-normal springs on the dial, the bell being disconnected by the switch-hook; in another there were no off-normal springs at all on the dial, whilst in a third there was one pair of off-normal springs which short-circuited the receiver.

The first of these had a poor transmission efficiency, with the second the dialling impulses were heard in the receiver, whilst in both the second and the third the dialling circuit was completed *via* the transmitter. No deleterious effect on the transmitter could be traced to its inclusion in the impulse circuit, but owing to the possibility of variation in transmitter resistance arising from accidental cause or from future change of design, it was considered advisable that it should be excluded from the impulse circuit.

Four-conductor cords were required with table telephones wired to the circuit, shown in Fig. **1**, and it was with the object of enabling a three-conductor cord to be used that the circuit shown in Fig. **2** (used at that time by the A.T. & T. Co. in the United States) was standardised in November, 1922. Unfortunately, however, this arrangement was found to suffer from two very serious defects in that "bell tinkling" was introduced whilst, as already stated, the peak value of the dialling voltage was not materially reduced.

"Bell tinkling" arises from the variations in the P.D. between the top side of the bell and the Exchange side of the impulsing contacts (Fig. **2**) that occur as the impulse contacts are opened and closed. In the closed condition this P.D. will be less than two volts, on the opening of the contact it may rise to the peak value of 700 volts referred to above falling rapidly off to the P.D. of the battery which is nominally 50 volts, to be again reduced to two volts when the contacts are closed once more.

There is thus a sudden and heavy charge transferred to the plates of the condenser on the break of the dial and a sudden but less heavy discharge on the make. The resulting transient currents flow through the bell coils and their effects are similar to those of the ringing current. The current impulse at the break is greater than at the make and it was thought that, by fitting a "biassing" spring to the bell and making the connections in such a way that the impulse at the break tended to attract the armature to the pole to which it was already held by the spring, the effect of the transient current might be masked, but it is possible with such a circuit that the initial surge may be sufficient to transfer to the plates of the condenser a greater charge than they would carry at their final P.D., and if this occurs there will be a following discharge or series of oscillations.

It was possible in some conditions and with some bells to eliminate tinkling by biassing, but the effect of fluctuations in the P.D. of the ringing bus-bars, the difference between the voltage of the main battery when newly charged and when discharged, the variations in the resistance and composition of lines and the use of extension telephones and extension bells, all combined to render impossible the commercial production and efficient maintenance of bells on which the biassing spring could be so adjusted that whilst a bell would respond to legitimate ringing currents in their weakest condition it would be unaffected by dialling impulses at their strongest.

The circuit shown in Fig. **3**, which has now been adopted for the standard telephone, was first suggested by Mr. R. L. Bell, of the Engineer-in-Chief's Office, in October, 1919. Trouble was then being experienced with breakdowns of insulation and the circuit was suggested as a method of avoiding the creation of high dialling P.D's. Tests were made to determine its efficiency in this respect and it was found that the maximum value of the dialling P.D. did not exceed 180 volts under any practical condition.

The impulses as repeated at the contacts of the line relay were also found to be less distorted when using this circuit than with the earlier circuits, and since all switching equipment supplied up to that time had been developed for use with telephones connected to the earlier circuits the various manufacturers concerned (viz., Messrs. Siemens Bros. & Co., the Western Electric Co. and The A.T.M. Co.) were supplied in February, 1920, with a copy of the proposed new diagram and asked to say whether a change in telephone circuit from Fig. **1** to Fig. **3** would adversely affect the operation of their various equipments.

The circuit shown in Fig. **3** did not, as originally suggested, provide for short-circuiting the transmitter, but for reasons already stated this feature was subsequently added. A Research Report of January, 1920, in referring to the inclusion of the transmitter in the impulse circuit stated " In any case, by fitting an extra contact on the dial, connections could be arranged so that the transmitter is short-circuited as well as the receiver while the dial is rotating." It is, of course, also possible to arrange for the short-circuiting of the transmitter by an additional contact on the switch-hook as is done in A.T.M. Co's patent No. 177130 (application date 29 Aug., 21).

It was the need with this circuit for an additional contact on either the switch-hook or the dial that delayed its introduction until after the difficulties with tinkling and biassing of bells had made themselves apparent in practice. It would in all probability have been adopted much earlier had the dials in use or available been considered capable of operating two independent pairs of off-normal contacts. The dial which eventually permitted of this refinement was developed by Messrs. Siemens Bros. & Co. in collaboration with the Post Office and was described by Col. Purves in his paper referred to above.

When the dial is " off-normal " the impulse contacts in Fig **3** are bridged by a 2 microfarad condenser in series with the 26 ohm winding of the induction coil and when these contacts are opened a circuit of comparatively low impedance is left across the line relay. Its energy is thus dissipated without any considerable rise of potential and sparking at the dial contacts is practically eliminated. The bell circuit, so far as the resulting current surges are concerned, is shunted by the two coils of the induction coil in series and the tendency to tinkle is so reduced that biasing is rendered unnecessary.

The conversion of the energy of the line relay into a current surge with this circuit as compared with a potential surge in the earlier circuits is extremely interesting. The existence of the current surge is demonstrated by the shape of the oscillograms on page 134 of Vol. 17, where the reversal of the line current on the break of the impulse contacts is clearly exhibited.

Following on the decision to adopt as standard the telephone of Fig. **3**, tests were made to obtain suitable arrangements for dialling circuits on manual boards at private branch exchanges, and it was found that the essential condition for the production of similar impulses was the connection of a 2 microfarad condenser across the impulse contacts, but that unless some resistance were connected in series with the condenser there was a liability for the impulse contacts to become blackened and pitted. For this reason a 100 ohm non-inductive resistance has been connected in series with the condenser and the circuit of Fig. **4** which was adopted in February, 1925, has been included in all private branch exchange diagrams since that date.

A local battery telephone for use on long lines in automatic areas has also been developed. Its connections are shown schematically in Fig. **5** and it will be seen that with the dial in the off-normal position the impulse contacts in series with the receiver winding of the induction coil are shunted by a 2 microfarad condenser. The whole of the induction coil windings are included in the impulsing circuit—the effect of this, however, in the character of the impulses is negligible.

A novel and interesting feature of this new local battery telephone is the use of a three winding induction coil connected on the auto-transformer principle. The primary object aimed at was the inclusion of the receiver in a local circuit in order to avoid (or reduce to a negligible value) any demagnetisation of the receiver by a reversed line current and so render it unnecessary to maintain the identity of the A and B wires of the line, but it was also found on test that the three winding coil had a greater transmission efficiency than the standard two winding local battery induction coil. For these two reasons a similar telephone without a dial has been standardised for use on long lines in C.B. manual areas.

The advantages gained by the use of the dialling circuit of the new telephone are clearly demonstrated by the fact that a switch adjusted to operate through 1200 ohms on the old circuit will function satisfactorily through 1500 ohms on the new. If the time of "make" of a line relay on a zero line with 50,000 leak be compared with that on a 1200 ohm line without leak, the variation with the new telephone is only 35% of that with the earlier type.

These gains are of such value in ensuring the stability of operation that it has now been decided that all impulse contacts shall be shunted by two microfarad condensers.

A "POINT SOURCE" OF SOUND.

W. West, B.A., A.M.I.E.E.

THE use of distortionless apparatus for converting sound energy into electrical energy and vice versa is practically a necessity for general acoustic measurements. Actually no truly distortionless apparatus exists, though the ideal has almost been attained. With the development of the art of precise acoustic measurement, however, the demands from such apparatus become increasingly more exacting. The problem of the design of sound generators is considerably more difficult than that of sound detectors, since the mechanical forces and displacements must necessarily be vastly greater, amplification being confined to the electrical circuits; interest in this problem extends beyond those who are immediately concerned with sound measurements.

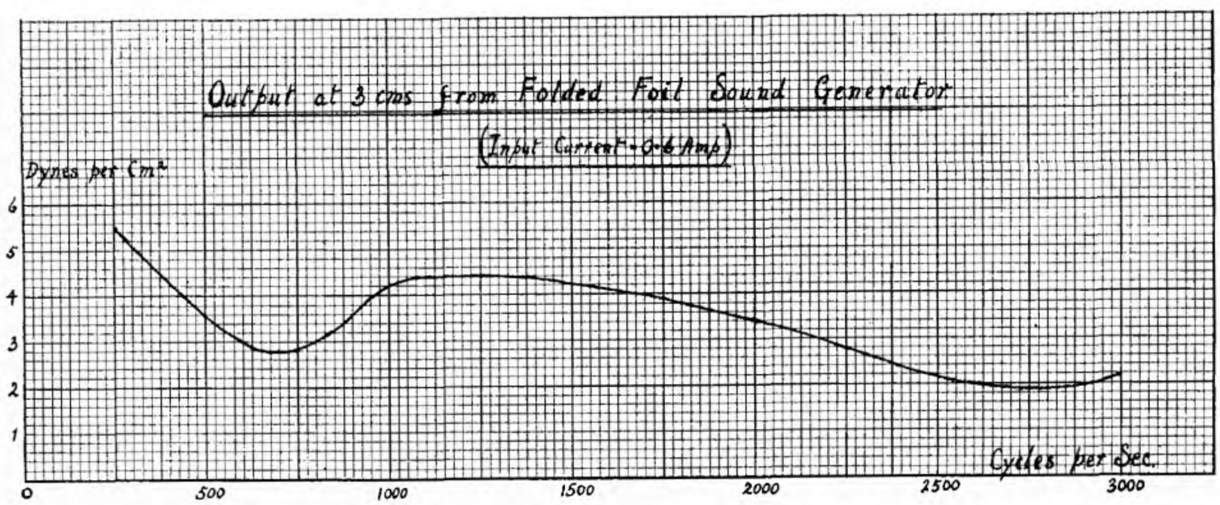
The instrument to be described was recently devised in the Post Office Engineering Research Section, and as far as the author is aware the design is novel. In this design, in addition to the usual requirements of a flat frequency characteristic and absence of amplitude and non-linearity distortion, a further desirable feature was aimed at, namely, that the sound should be emitted from a small space, so that at even a few centimetres distance therefrom the generator may be considered in effect as a point source of sound.

The instrument may be considered as a development of the "Band Loud Speaker,"*

* *W. Schottky: Elektrische Nachrichtentechnik,* 1925, *Vol.* 2, *p.* 157.

which operates by the motion of a thin metal foil strip placed in a steady magnetic field, and carrying the audio frequency electric currents. A very much longer strip is used, but this is folded into a compact unit which is held in place between the poles of a strong magnet.

It will be convenient to explain the construction with reference to a particular instrument, which, though merely an experimental model, has been useful for the purpose of investigating the frequency characteristics of commercial transmitters. In this instrument the magnet has an air-gap of about 2 cms. cube, with a flux density of about 2,500 lines per sq. cm. The strip is of soft aluminium foil, about 0.02 m.m. thick, 2 cms. wide and 80 cms. long, folded at 2 cm. intervals (*i.e.*, pleated), and mounted



with the alternate folds fairly evenly spaced, about 1 m.m. apart, in the air-gap of the magnet. The width of the strip lies in the direction of the magnetic flux, and the forces set up, due to an alternating current in the strip, therefore tend alternately to compress and rarefy the air contained in the folds, which communicates directly with the outer air. The front and back faces of the folded strip are separated by a baffle, or by encasing the instrument so that only the front face is exposed.

In common with the Band Loud Speaker, there is a choice of two evils in terminating the edges of the strip. Either the edges may lie in close proximity to thin insulating plates placed between the magnet poles and the folded strip—in which case the whole strip is free to move, but there is of necessity a loss due to leakage of air past the edges; or the edges may be cemented to the insulating plates—thus eliminating leakage, but imposing constraint on a portion of the strip. The latter method is preferred with a very soft and flexible strip, such as the one under consideration, and it results in a reasonably robust and stable structure.

Although no complete record of the performance of the instrument has been taken, the acoustic output has been measured over the frequency range of 250 to 3000 cycles per second. This is shown in the figure in terms of acoustic pressures at a distance of 3 cms. from the instrument, with an electrical input of about 0.6 amp.; since the resistance of the strip was 0.1 ohm, the power input was 0.036 watt. There is also evidence that the general level of the curve is well maintained at considerably higher and lower frequencies. It is significant that, owing to the small mass of the vibrating part, and the direct manner of application of force thereto, there is a complete absence of sharp peaks or valleys in the curve, which is therefore capable of fairly accurate levelling by simple means, such as by bluntly tuned circuits in the amplifier.

The efficiency of this instrument is somewhat low, and it is of interest to consider possible means of increasing the acoustic output. The use of a stronger magnet will, of course, achieve this object, but the dimensions of the strip and air-gap have also to be considered. The thickness of the strip affects both the flexibility and the electrical conductivity of the material, and since, in practice, the thinnest foil which can be obtained in adequate lengths is used, this dimension will be taken as fixed. The input power (I^2R) and the magneto-motive force will also be taken as constant, that is to say it will be assumed that there is no appreciable drop in M.M.F. in the iron circuit of the magnet for the variations in the air-gap under consideration.

Let l = total length of strip

d = width of strip.

Suppose that a portion of this width = k remains fixed (this portion being independent of the width but dependent mainly on the flexibility of the strip), while the remainder vibrates with an amplitude of displacement = a; then $l(d-k)$ is the vibrating surface. Actually the strip does not vibrate exactly in this fashion, but an appropriate value for k will give equivalence to the actual motion. The electrical resistance $R \propto \frac{l}{d}$, and since the input power is fixed, the current $I \propto \sqrt{\frac{d}{l}}$

If it be assumed that the resistance to motion is made up of inertia, frictional and radiation components, each of which is proportional to the surface area in motion, then at any given frequency the mechanical impedance Z is proportional to this area;

$$i.e., \ Z \propto l(d-k)$$

For a constant M.M.F. the flux density $B \propto \frac{1}{d}$

The force F on the moving part $\propto B.\ l.\ I.\frac{(d-k)}{d}$

since $I\frac{(d-k)}{d}$ is the current in the moving part. Hence the amplitude of motion $a \propto \frac{F}{Z}$

$\propto \frac{1}{d\sqrt{ld}}$ and the volume of air displaced =

$a.l.(d-k) \propto \sqrt{\frac{l}{d}}\left(1-\frac{k}{d}\right)$ This is a maximum for variations of d, when $d = 3k$.

Thus the efficiency may be expected to increase with the length of the strip, and, for a given length, to attain a maxmium for a particular width which depends mainly on the thickness and physical properties of the material. This maximum is, however, not very critical. The length of strip may be increased by increasing the lateral dimensions of the air-gap, or by closer folding, which, however, should not reach the limit when attenuation of sound between the folds becomes appreciable.

The further development of this design for other purposes is under consideration.

COLLAPSE OF A BUILDING IN CORNHILL.

H. C. Stone, M.I.E.E.

On the morning of Sunday, August 7th, the Sunday papers published the startling announcement that part of a great block of offices, five stories high, had collapsed in Cornhill, one of the most used thoroughfares in the City of London. The collapse occurred just before midnight on Saturday, and the writer—having been advised in the early hours of Sunday morning by the City Police—was by the time the reports were published actively engaged in endeavouring to ascertain the extent of the damage to the Post Office main route along Cornhill.

Since the war extensive reconstruction works have been carried out in the City of London and numerous offices have been rebuilt, the older properties being replaced by palatial structures of steel, reinforced concrete and stone. In Cornhill, premises had been acquired by Lloyds Bank for the purpose of extending their Head Offices and for the past few months demolition of the old properties and extensive excavation works were in hand. The site, which had been excavated to a depth of approximately 50 ft., had been suitably timbered and the roadway side shuttered and supported, the work being in the hands of a firm of high repute in the City of London. The site adjoins the property of the Commercial Union Assurance Company, and it is probably well known to many of my readers that one of the properties demolished in order to provide for the Bank extension was the renowned "Birch's" Chop House. This house was one of the few remaining links with old

Fig. 1.—Site immediately after Collapse of Building.

London and there was universal regret that such an interesting building had to be removed. The shop front has, however, been preserved and is now in the London Museum.

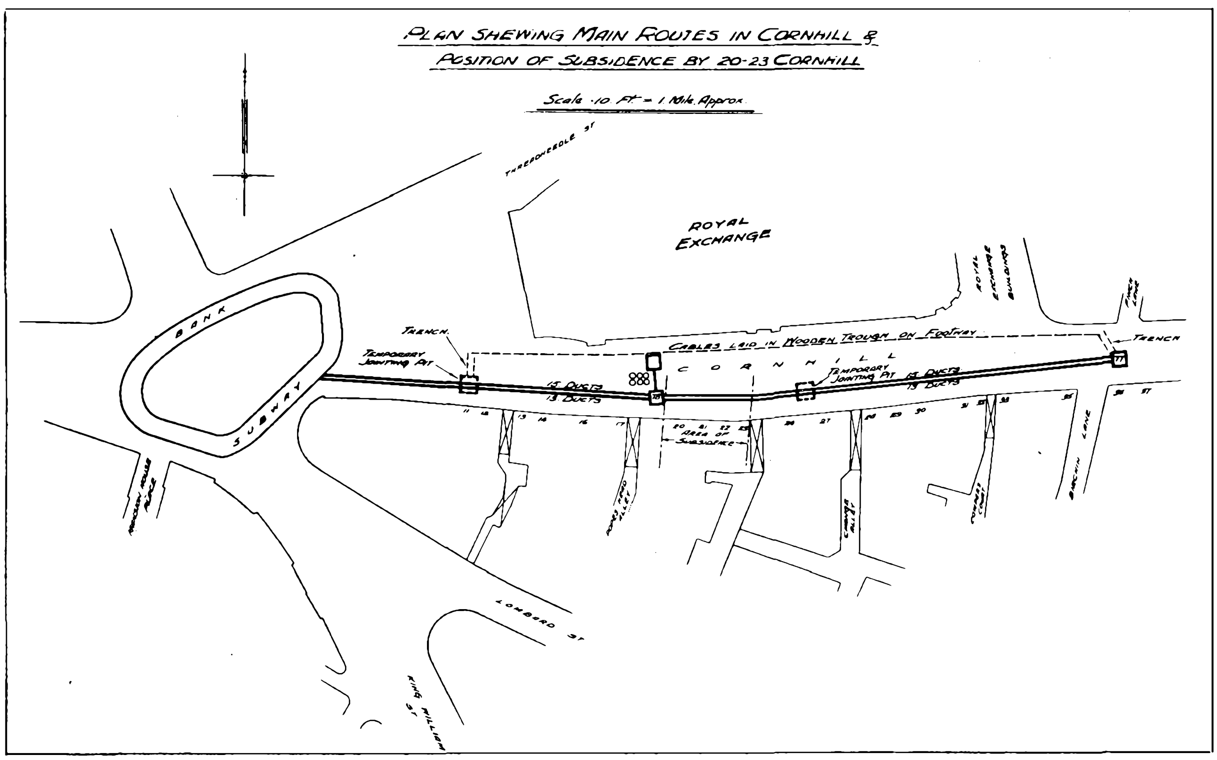
On the Saturday afternoon settlements were observed in the West wing of the Commercial Union Offices and precautionary steps were at once taken. The settlement, however, developed during the evening and in spite of all efforts the West wing unfortunately collapsed about midnight. The falling building swept away the whole of the footway and the roadway shuttering, with the result that a miniature landslide occurred on the road side, the subsoil falling into the pit, leaving only 12″ of concrete as the support of the roadway at this spot. Figs. **1** and **2**.

Beneath the roadway concrete, at a depth of 5′ to 6′, the Post Office had two main lines of ducts lying adjacent to each other. Fig. **2**. The first line was laid in 1900-1, consisting of a nest of 13 octagonal ducts in concrete. The second line of 15 octagonal ducts was laid some 15 years ago, making 28 in all. The Cornhill route provides one of the main Trunk and Junction arteries between the City, East London and the Eastern Counties and it contains three trunk cables—London-Brentwood-Marks Tey, London-Southend and London-Romford, one main Telegraph Cable from the Central Telegraph Office, ten junction cables and 6 subscribers' main cables, in all close upon 7000 lines. In addition to the above, there were 6 Pneumatic Tubes to Branch Offices in the City, three of which were broken down, and the cables serving subscribers in adjoining buildings.

Fig. 2.—Post Office Main Duct Route beneath roadway after subsidence.

It will be seen from Fig. **2** that both duct lines have gradually sunk with the falling away of the subsoil, the greatest depth of the curve from the roadway level being about 15 feet. It was indeed a fortunate circumstance that the roadway concrete withstood the shock of falling masonry, as otherwise the telephone plant must inevitably have been destroyed, with disastrous results. As it was the cables took up the strain, supporting the surrounding ducts and concrete over a distance of 60 feet. The cables remained in working order after the subsidence and were maintained under these exceptional circumstances until the diversions were effected. This is clearly seen in Fig. 2. At the time of writing it has not been possible to examine the cables position with the bearers hanging and in several instances the joints had been drawn up the duct so that the centre point of the jointing sleeve was at the duct face.

As a result of this survey it was decided to construct a temporary route on the north footway of Cornhill, using 800, 600 and 300-pair lead covered cables. Pits were opened in the roadway over the duct lines at two points on either side of the subsidence, approximately 80 to 100 feet from the same. (See plan). These pits were excavated down to the duct lines, the



as there is danger of a further subsidence of the subsoil should there be any movement of the cables in the route.

An examination of the manholes on either side of the subsidence showed that the cables had been considerably strained. In the manhole on the east side at Birchin Lane, the cables originally rested on bearers built up from the floor level, the ducts entering the manhole approximately two ft. above the highest cable tier. The cables in this manhole, which was 140 yards away, were lifted into a horizontal concrete surrounding the ducts broken away and the cables exposed. Trenches from these pits were cut through the roadway concrete, across Cornhill to the north footway to meet the temporary route. The wooden trough for the protection of the lead covered cables was constructed with 9″ × 3″ timbers, braced at 18″ intervals by 7″ × 1½″ boards as stiffeners. This formed a strong troughing and it was well that such provision had been made, as in the subsequent operations of other contractors engaged upon building restoration work, the cables

FIG. 3.—OPERATIONS IN CORNHILL SHOWING CABLES IN TROUGHING.

From Fig. 2 it will be realised that the stress on the cable route was a serious factor and likely to cause trouble as the process of changing over the cables progressed and the making spare of the old route necessarily released the cables. To guard against any sudden collapse of the route during changing-over operations, the pit which had been opened at the point nearest the subsidence was strongly timbered and two 5″ × 4″ steel girders sunk in a vertical position and lashed to the "walings" in the excavation. Each cable in the route was then secured by means of stranded steel flexible scaffold ties and fastened to the steel girders. This precaution was amply justified, as upon cutting spare the last conductors in the first cable changed over the old cable slipped quite 6″, that is, until the stress was taken up by the scaffold tie. The same thing happened with other cables so that the route was secured throughout the whole of

would undoubtedly have been badly damaged on the temporary route by the heavy baulks of timber and girders which were brought on to the site for shoring purposes. The troughing, with the diversion cables in position, will be seen in Figs. 3 and 4. The troughing contains 12 main cables, into which have been diverted the whole of the lines from the 20 main cables in the original route. For further protection the cable troughing has been closely boarded, as will be seen in the foreground of Fig. 6.

It should perhaps be mentioned that it was originally intended to divert the cables at a point 80 ft. east of the area of subsidence, but owing to subsequent trouble, which necessitated the shoring-up of part of the Insurance building, it was deemed inadvisable to continue at this spot and the jointing position was shifted further east to the nearest manhole by Birchin Lane. (See plan).

FIG. 4.—TROUGHING LOOKING EAST TOWARDS BIRCHIN LANE.

the operations. There have necessarily been many anxious moments during the diversion period, but by careful attention to points of detail and "safety first" devices the route was ecured from total collapse and a successful transfer effected with but very few faults on working circuits.

There is, however, a humorous side which should perhaps be recorded. During the first week following the subsidence, newspaper reporters were very active in securing copy and before coming on duty and just mentioned that he had apparently been bitten by a mosquito. Also one poor, misguided rat, somewhat scared, escaped along Cornhill. The high tension main was enclosed in a 3″ pipe and, although passing through one corner of the jointing pit, was protected with concrete, whilst the gas arose from the sourness of the soil often met with during excavations adjoining gas mains where leakages have been remedied. Following the reports, however, the writer received many

FIG. 5.—THE POST OFFICE TAKES POSSESSION OF CORNHILL.

the men employed upon the work were qu s-tioned by individuals thirsting for information.

A somewhat alarming report appeared in several daily papers that the jointers on the work were seriously troubled with mosquitoes and rats, and were in danger of electrocution by exposed high tension mains or asphyxiation by gas.

The truth is that one jointer reporting for the night shift had been working in his garden

letters of sympathy from well meaning persons, advice for dealing with mosquito scourges, household remedies, etc., together with visits from commercial travellers eager to bring to notice cures for all insect troubles and vermin destructors.

Two interesting photographs have been taken showing the Post Office activities in Cornhill shortly after the trouble occurred. Figs. **4** and **5** showing the drums of cables and cable trough—" the Post Office takes possession of Cornhill "—and a recent picture (Fig. 6) showing Cornhill spanned by a derrick with the area of subsidence in the distance, literally " Cornhill in splints."

The trenches across the roadway have now been plated over with half inch boiler plate and covered with 12" of strong concrete, so that lorries containing timber and building material can pass over to the site. At the point where the cables leave the trench for the troughing, baulks of timber, measuring 12" × 12", act as fenders screening the cables from traffic dangers. In addition, a guard rail has been provided, as the footway on the north side of Cornhill has been opened for pedestrian traffic.

In conclusion, it should be mentioned that the City Engineer considerably assisted matters by immediately granting facilities for opening the ground so as to get access to plant. My thanks are also due to my Assistant Engineers, Chief Inspectors and all who so readily and unsparingly gave up what would normally be their recreation time in order to further the work of restoration and last, but not least, to the jointers and mates who worked so loyally to restore and secure communications over this important route.

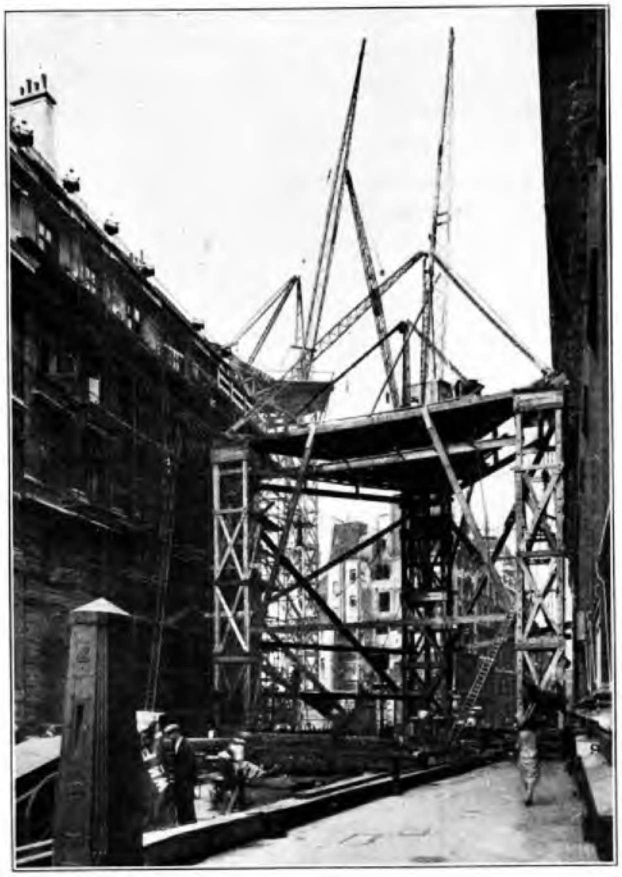


Fig. 6.—Cornhill in Splints. Cable troughing in foreground.

AIR SPACE, PAPER CORE TELEPHONE CABLES OF THE TWIN, MULTIPLE-TWIN AND QUAD TYPES.

A. Morris, A.R.C.Sc., D.I.C., Wh.Ex., M.I.E.E.

Synopsis.—Gives the history of Twin, Multiple Twin and Quad type cables. Compares the direct and mutual capacity ratios and discusses the utilisation in the various core types of their direct capacities for circuit purposes. Gives representative figures for capacity deviations and capacity unbalances of factory lengths of modern high-grade cables. States the features governing the linear dimensions of telephone cables. Describes the electrical requirements of the various classes of telephone circuit—local, junction and long-distance — and discusses the technical and economic features governing the choice of cable type.

General.—Underground telephone cables in general utilise paper lappings for the purpose of securing an air-space separation between the conductors. Such cables are referred to industrially as " Dry Core " cables in contradistinction to the impregnated cables of power systems. They are more completely described as " Air Space, Paper Covered " cables in particular reference to the compound dielectric which consists principally of dry air.

The modern dry-core cable represents the present stage of development of cable communication circuits in which a relatively small electrostatic capacity and low energy loss in the dielectric as well as great economy of space are combined with considerable immunity from electrical disturbance. Compared with the gutta-percha covered, and other early types of cable, they are in all the respects enumerated, a considerable improvement.

The general construction of dry-core cable, from the point of view of the provision of the dielectric is essentially universal. Such cables are classified into types according to the formation or mode of relative arrangement of the conductors into units or cores, whilst cables of the same type differ from each other only in respect of their make up, *i.e.*, size or gauge of the conductor and the arrangement of the unit cores into layers.

twinning of conductors for the formation of telephone cable circuits was in general use by the year 1887 and was the outcome of the principles enunciated in 1879 by Prof. Hughes[1] in a paper dealing with interference in aerial lines.

Multiple Twin Cables.—Another type of core may be obtained by the successive twinning of pairs or basic type cores in the manner described by Frank Jacob[2] in 1882. Thus for a two-pair or four-wire Multiple-Twin core, two pairs are twisted together; for a four-pair or eight-wire Multiple Twin core, two such two-pair cores are twisted together and so on. Multiple-Twin cores consisting of more than two pairs are now

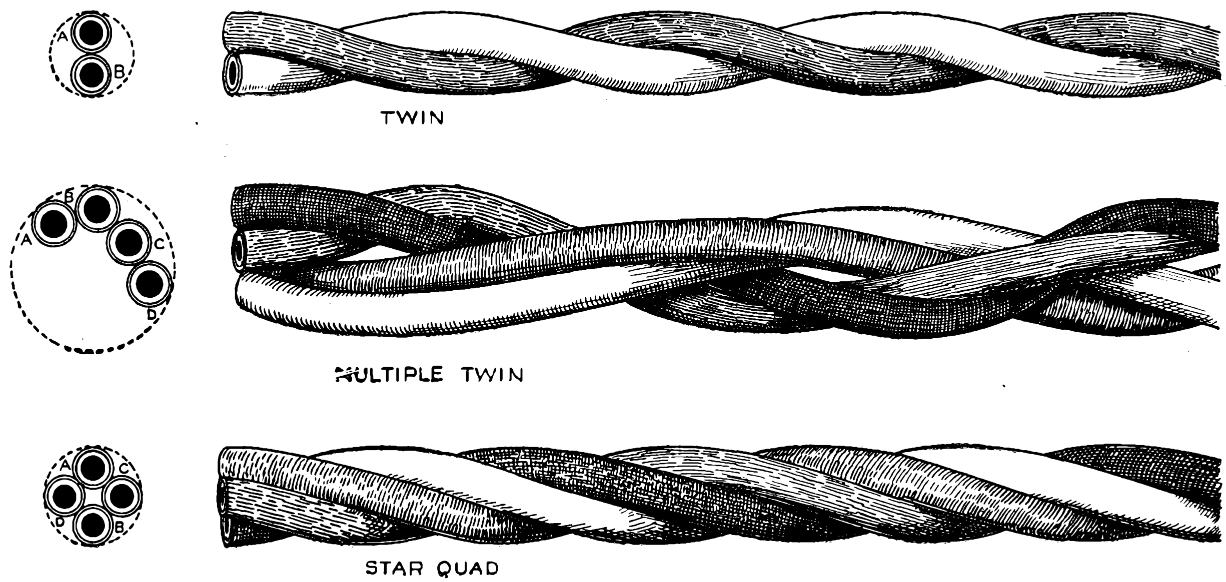


Fig. shows make-up of Twin, Multiple Twin and Star Quad Conductors.

Each type of telephone cable is built up by cabling a number of unit cores into layers, care being taken in modern cables to avoid interference by arranging for adjacent cores to have different lays. The cores are arranged in each layer in the form of helices, all the cores of any particular layer being spiralled in the same direction with the same pitch. The spiralling of adjacent layers is of different and reversed pitch.

Twin Cables.—The basic type of core in all modern telephone cables is the two-wire unit or Twin type core, in which two conductors are taken and twisted or twined together—as in the manufacture of rope—to form a pair. This

obsolete, the two-pair Multiple-Twin cable described in 1903 by Dieselhorst and Martin,[3] in which two pairs of different lay are twisted together with a lay, different from either of the pairs, being the standard Multiple-Twin type. In the British Isles such cables are referred to as "M.T." type, on the Continent of Europe as "D.M." (Dieselhorst-Martin) type, and in America as "Duplex" type cables. In all cases physical circuits are formed upon the constituent twin pairs.

Quad Cables. — If four conductors are arranged at the corners of a square and then stranded together in one process about a common axis with a definite lay, as in the early gutta-percha covered telegraph cables of the year 1882, a four-wire unit called a Quad type core is obtained. Such a core is generally regarded as constituting a basic type, although a similar four-wire lay-up may be secured in a two-pair Multiple Twin core in which the pair and multiple pair lays are the same.

Since their inception it has been the practice to arrange for each pair of diagonally disposed conductors of a Quad to form a physical circuit, and in recent years Quads worked in this manner have been referred to as "Star Quads."(4) In some modern Quad cables physical circuits have, however, been formed upon adjacent conductors as in the Jordan-Haugwitz Quad. Quads worked in this manner are referred to as "J.H." Quads.(9) If the Quad type core is regarded as a Multiple-Twin core of equal wire and pair lays, then the J.H. Quad utilises each of the constituent twin pairs as a complete physical circuit, whilst the Star Quad forms each of its physical circuits upon one wire of one pair and one wire of the other pair. In addition, for J.H. Quad working, such constituent twin pairs would have wire crosses inserted in them at certain intervals of their length, for reasons given later.

Great difficulty was experienced in securing symmetry of formation of the early Quad type core when applied to dry-core cables, with the result that considerable interference difficulties were encountered. The interference resulted from the unstability of make-up, and such a large amount of testing work was involved in ascertaining by trial the crosses necessary to neutralise the disturbances, that underground A.S.P.C. Quad cables fell into disuse for telephone purposes shortly after their introduction, although they survived for telegraph purposes for a period of about ten years.

The Quad type as originally designed for gutta-percha telegraph cables and as constructed for short gutta-percha telephone cables in 1891, did not give rise, in a very marked manner, to this interference difficulty. This was due in some measure to the fact that steps were taken to secure stability by forming the quad on a centring of hemp. This mode of construction although followed in the early dry-core Quad cables did not give the desired results, owing to the non-rigid nature of the loosely paper-wrapped wires constituting the cores. In the modern design, a stiffening of the paper tubes has resulted in the accurate and permanent centralisation therein of the conductors, whilst a central string upon which the covered conductors are bedded is used for the purpose of ensuring symmetry of the cores. This extremely important feature of centralisation of the conductors within the paper tubes may be secured either by the use of specially creased or corrugated surfaced paper wrappings or by a spiral whipping of string directly next the conductor, over which the insulating paper is tightly wrapped. 28 miles of 19 Quad, 150 lb. conductor cable(10) was manufactured in the year 1898 and laid between Cricklewood and Eddlesborough, as part of a London to Birmingham non-loaded telephone cable. With modern methods of manufacture, Quad Cables have been revived in Germany under the general title of "Spiral-four" cables, the two methods of working which have, as already indicated, been referred to as "Star" and "J.H."

Side circuit working upon adjacent conductors of a Quad is accompanied by inherent interference difficulties, quite apart from manufacturing irregularities, owing to the fundamental electric and magnetic coupling of the side circuits. This objection has been overcome by Drs. Jordan and Haugwitz, of the A.E.G., in their J.H. Quad, in which wire crosses have been inserted in each side circuit at intervals of about three metres. The crosses extend over a distance of a few centimetres and are inserted during manufacture by means of a special machine. A cross in one side circuit is located at a different place along the core from the cross in the associated side circuit.

Careful consideration has recently been given to the use of Spiral-four cables by the Telephone Administrations of Europe and such cables have been brought into use in certain countries, notably in Holland and Norway. A Quad cable containing 254 pairs of 40 lb. conductors was manufactured in England in 1925 for the British Post Office, and laid between London Toll Exchange and Ealing, a distance of about 10 miles. Several other similar cables have recently been manufactured for the Department. A Quad cable between Utrecht and Rotterdam, a distance of 57.2 kilometres, containing 1.29 and 1.67 mm. conductors, was completed for the Dutch Administration in 1926. The J.H. cable has during the last few years been utilised together with M.T. cable in the German long-distance network.[9] It is also understood that a J.H. Quad cable has been installed between Brussels and Aix la Chapelle, a distance of about 150 kilometres.

Star Quad cores are employed in modern continuously loaded, paper insulated, double lead sheathed, Submarine type cables. The air space in such cables is relatively small, the dielectric consisting almost wholly of paper. The Anglo-Dutch Nos. 2[11] and 3[12] the Anglo-Belgian (1926)[13] and Anglo-French (1926)[14] cables are examples of this type.

Direct and Mutual Electric Capacities.—The direct and mutual electric capacities of the cores of telephone cables have been defined in a previous article.[16] It is shown therein how the magnitudes of the direct capacities differ within certain limits for the various cores of a given multi-core cable and how such capacities may differ within even wider limits for the cores of different cables of the same type and of essentially the same side circuit mutual capacity. It has also been shown in the article just referred to how the direct capacities of a M.T. core combine in constituting the side and phantom circuit mutual capacities. In a more recent article[17] the case of Quad cables has been considered. For the purposes of the present article, general average figures, based upon actual measurements, for the direct and mutual capacity ratios of balanced cores of Twin, Multiple Twin and Star Quad type cores are given in Table No. I. Estimated average figures for these ratios in the case of balanced J.H. Quad cores have also been included in the same Table. Throughout this Table, m is the direct capacity between the wires of a pair circuit, w is the direct capacity between the wires of the different pair circuits of the same core, and a is the direct capacity of each wire to all other cores of the cable, assumed connected to the earthed lead sheath. S, the mutual capacity of a side circuit, is equal to $(m + a/2)$ in the case of a Twin core and to $(m + w + a/2)$ in the case of each of the other three core types, P the phantom circuit mutual capacity for such types being equal to $(4w + a)$.

The modern Star Quad utilises the direct capacity network of a four-wire core in the most efficient manner for the production of a side circuit of minimum relative capacity. Alternatively for a Star Quad core of the same side circuit capacity as for a M.T. core, the space occupied is smaller. It is in this respect that the principal advantage of the Star Quad cable lies, although this advantage is only obtained at the expense of a very much greater phantom circuit capacity.

The J.H. Quad permits of a more equitable utilisation of the direct capacities of a Quad core for side and phantom purposes respectively, and as far as can be seen it is in this respect that it presents advantages over the Star Quad. It has no advantage over the M.T. type in this respect. Neither has it the advantage over M.T. cable that the Star Quad has in respect of space. An economic advantage over M.T. cable in respect of cost of manufacture and a technical advantage in respect of uniformity of mutual electric capacity have been claimed for the J.H. Quad.

TABLE No. I.

GENERAL AVERAGE CAPACITY RATIOS FOR TELEPHONE CABLE CORES OF VARIOUS TYPE.

Core type.	Capacity ratios.				Remarks.
	m/S	w/S	a/S	P/S	
Twin	0.47	—	1.06	—	Test values.
Multiple Twin	0.36	0.18	0.92	1.64	do. do.
J.H. Quad	0.35	0.23	0.84	1.76	Estimated values.
Star Quad	0.10	0.42	0.96	2.64	Test values.

Mutual Electric Capacity Deviations of Factory Lengths.—For two-wire duplex telephone repeater working of cable circuits, an important item of the repeater equipment is the line balancing network. This electrical network simulates the impedance of the line to which it is connected, at those frequencies of the audio frequency range which it is necessary to transmit in order to ensure the desired quality of the received speech. The extent of impedance-frequency correspondence of the line and its normal basic network will depend upon the uniformity of length distribution of the electrical constants of the line. In modern cables the length distribution of conductor resistance and of leakance is normally essentially uniform. Furthermore, the inductance of loading coils and the lengths of loading coil sections of cable deviate only very slightly from their respective average values. Owing, however, to the special features of multi-core telephone cable design and manufacture it is seldom possible to obtain the same value for the mean mutual capacity of the circuits of each layer of any particular cable length, or the same value for the mean mutual capacity of the circuits of a particular layer in each length of a complete cable. Furthermore, the mutual capacity of any circuit of a cable length will generally differ from the mean mutual capacity of all similar circuits in the same layer of the same length. These differences are referred to as capacity deviations and are conveniently classified into " Circuit " and " Length " deviations. Such deviations are inherent to commercial processes and, unless they are maintained within narrow limits, will cause instability of the system. Length deviations of the electrical constants of a circuit give rise to deviations of the actual impedance-frequency characteristics from the mean characteristics for that circuit. The magnitude of these latter deviations, at the higher frequencies within the cut-off point, may be such as to give rise to a value for the singing-point gain of the associated two-wire telephone repeater, which is too low in comparison with that of the normal working gain of the repeater. The direct consequence of this would be a decrease in the working range of the circuit.

Circuit Deviation.—The electric capacity deviation of a circuit is the difference of capacity of that circuit from the average capacity of all similar circuits of the same group in the same cable length, expressed as a percentage of the average capacity of the same group of circuits in the same length.

Length Deviation.—The length deviation of capacity of a group of circuits of a cable length is the difference between the mean electric capacity of the circuits of that group of that length and the average mean capacity of the circuits of that group, of all the lengths of the complete cable, expressed as a percentage of that average mean mutual capacity.

The International Specification for M.T. cables specifies 4% as the maximum value for the mean circuit deviation of the pair or phantom circuits of a factory length, and 12½% as the maximum value for the maximum circuit deviation of any pair or phantom circuit of any factory length of a complete cable. This Specification does not deal directly with length deviations of capacity, but narrow limits are secured in this respect by the practical operation of the clauses limiting the actual magnitude of the mean mutual capacity of side and phantom circuits.

As far as the pairs of M.T. cables manufactured in this country are concerned no difficulty is experienced in meeting the above circuit deviation figures, whilst average length deviations of from 1.5% to 3% are obtained. Phantom circuits of M.T. cables are invariably more uniform for capacity than the pair circuits.

Very large capacity deviations occur in the manufacture of Twin cables, the actual magnitudes occurring in practice being much greater, especially in respect of circuit deviations, than those quoted above for M.T. cable.

Quad type cable appears to lend itself to great uniformity of mutual capacity, experience to date in this country indicating smaller deviations of the pairs of Star Quad than for those of M.T. type. Table No. II. gives representative figures for the M.T. and Star Quad types.

The necessary capacity requirements of repeater sections of cable are secured in modern cables almost entirely by limiting the circuit and length deviations of capacity in the manufacturing stage. In conjunction with the exercise of this manufacturing control, grading or the allocation of factory lengths to definite loading coil sections is the final expedient for minimising length deviations of capacity of loading coil sections. Alternatively the addition of electric condensers may be employed for this purpose. By means of crossing during the jointing of factory lengths into loading coil sections, almost any desired degree of circuit uniformity within such loading coil sections may be obtained, thus ensuring, with the consequent similarity of total capacity of such circuits, a standard basic network, which with minor adjustments may be applicable to the whole of the circuits of a particular group.

TABLE No. II.

MUTUAL ELECTRIC CAPACITY DEVIATIONS IN 176 YARD FACTORY LENGTHS OF UNDERGROUND A.S.P.C. TELEPHONE CABLES.

Cable Type.	Circuits.	Circuit deviations.				Length deviations.	
		Average		Maximum			
		Mean.	Max.	Mean.	Max.	Mean.	Max.
Multiple Twin	Pairs ...	1.88	5.37	3.25	9.45	1.24	4.07
	Phantoms ...	1.12	3.14	2.13	5.90	0.75	2.23
Star Quad ...	Pairs ...	0.87	3.96	1.25	5.22	0.58	2.39
	Phantoms ...	0.65	4.78	0.75	5.63	0.42	2.51

Capacity Unbalances in Factory Lengths of Underground A.S.P.C. Telephone Cables.—Asymmetry in the make-up of telephone cables gives rise to inequalities in the direct electric capacities of the cable cores. Thus, in the case of a single 176 yard length of M.T. cable, these inequalities may average 27 parts in 1000, whilst they may exist to the extent of as much as 80 parts in 1000 in some cores which have been badly crushed during stranding operations. These inequalities are referred to as capacity unbalances; they give rise to unequal electric induction between the wires of different circuits, the direct result of which is cross-talk.

Extensive manufacturing experience of M.T. cables has resulted in exceptionally good capacity balance of this type, not only between the pairs but between phantom and pair and phantom and phantom circuits. The earth balance of the circuits of M.T. cables is also very good.

High grade M.T. cable is much better than Twin cable for balance between pairs and greatly superior for earth balance of pair circuits. It is thought that Twin cables could be improved in this respect, despite the 15% (approximately) greater direct earth capacity of Twin cables as compared with M.T. cables of the same side circuit mutual capacity.

In Star Quad cables the unbalance between pairs not in the same quad is much smaller than between pairs associated in the same quad. Furthermore, the unbalances between non-associated pairs are, on the average, smaller in Star Quad than in M.T. cables. The unbalances between the associated pairs of the cores of Star Quad cable are, however, as far as experience to date in this country is concerned, greater than between adjacent pairs of Twin cables and much greater, particularly in respect of maximum values, than in M.T. cables. This circumstance is explainable since with equal pair circuit mutual capacity in the M.T. and Star Quad types, the direct capacities (w) upon which the pair to pair unbalances depend are about two and one third times those of the M.T. type core. The earth unbalance of the pairs is also greater in Star Quad cables than in those of M.T. type, and this may be accounted for to some extent by the somewhat greater direct earth capacity. Extended experience of Quad cables will undoubtedly result in improved capacity balance, by reason of the inherent symmetry of this type as compared with the M.T. type.

Table No. III. gives representative unbalances for British manufactured 40 lb. conductor cables of 100 pairs or more and also includes the figures of the International Specification for M.T. type cables. The pair-to-pair, pair-to-earth and phantom-to-earth unbalances of this Table follow the universally accepted definitions of such quantities. The phantom-to-pair unbalances are in accord with the pair-to-pair unbalances, one unit of either producing the same amount of cross-talk, *i.e.*, they are the usual $2\ [(p + q) + u]$ quantities of cable unbalance nomenclature.

Table No. III.

CAPACITY UNBALANCES (ALL OTHER CORES EARTHED) IN 176 YARD FACTORY LENGTHS OF UNDERGROUND A.S.P.C. TELEPHONE CABLES.

Cable Type.			Capacity Unbalances in M.M. Fds. Pair to Pair. Same Core.	Pair to Pair. Adjacent Cores.	Pair to Pair. Alternate Cores.	Phantom to Pair of same Core.	Pair to Earth.	Phantom to Earth.
Twin		Mean	—	20	—	—	162	—
		Max.	—	78	—	—	1310	—
Multiple Twin	Avge.	Mean	13	13	1	46	39	125
		Max.	38	43	9	208	151	433
	Max.	Mean	16	15	7	70	66	190
		Max.	62	60	25	485	280	700
Star Quad ...	Avge.	Mean	27	5	—	127	77	—
		Max.	116	61	—	538	334	—
	Max.	Mean	37	6	—	—	96	—
		Max.	170	105	—	—	550	—
International Specification for M.T. Cable	Max.	Mean	33	—	—	125	125	—
		Max.	125	—	—	625	600	—

Linear Dimensions of Various Cable Types.—From the complicated nature of the capacity network associated with the wires of multi-core A.S.P.C. cables, the usual formulæ for the capacity between parallel conductors are inadequate for the purposes of dimensional design. (See Chap. VII., "The Propagation of Electric Currents," Prof. J. A. Fleming.) The application of first principle considerations to this problem is also rendered difficult by reason of the uncertainties attending the determination of the specific inductive capacity of the compound dielectric, its thickness and the mean distance apart of the wires in the completed cable. Furthermore, owing to the relative closeness of the wires, the usual assumptions as to uniform distribution of the electric charges over the surfaces of the conductors are upset by reason of their relatively great mutual attractions. In practice the determination of the leading dimensions of a cable of a given type containing a given number of circuits of a given gauge and mutual electric capacity is founded upon practical data previously obtained as a result of experience in the manufacture of similar cables. Rational empirical formulæ based upon theoretical considerations and embodying practical data have been evolved for the determination of cable dimensions. The constants of such formulæ take account of the effect of nearness of the wires of the cores, the proximity of the various cores and the effective specific inductive capacity of the air-paper dielectric. Their magnitudes depend upon the type of core, *i.e.*, whether Twin, Multiple Twin or Quad, the thickness, electrical properties and mode of application (*i.e.*, whether longitudinal or spiral lapping) of the insulating paper, the arrangement of the cores into layers, the degree of permissible compression of the outer layers of the stranded cable during the sheathing operations and the atmospheric conditions—hygrometric state and temperature—existing during manufacture. Various design formulæ have been published from time to time. References (6), (18), (19) and (20) apply.

In any particular cable the actual average space per core will depend upon the mutual capacity, the total number of pairs in the cable and upon their arrangement in layers, *e.g.*, whether a one, two, three or four core centre is adopted. The number (a) of unit cores in the centre and the number (n) of succeeding layers in a cable containing a given total number (N) of cores may be arrived at from Tables or generally from the relations :—

$$(3n + a)(n + 1) = N, \quad \ldots\ldots\ldots\ldots(1)$$

for values of a equal to 2, 3 or 4. If a is equal to unity then :—

$$3n(n + 1) = (N - 1) \quad \ldots\ldots\ldots\ldots(2)$$

In some instances in practice, particularly in the case of Twin cables, it will be found that for the values of a and n which exist, the total number of cores calculated from the above is less than the number actually employed. This is because cores additional to those provided for in the above expressions have been added to the outer layers. Some degree of crushing naturally results from this practice. In this connection it may be mentioned that the capacity requirements of Twin cables for subscribers' circuits are not very exacting. The problem in this case is mainly one of maintaining adequate dielectric strength whilst securing the largest number of pairs beneath a given diameter sheath.

The ratio of paper to air space and the actual disposition of the paper with respect to the conductors also influence the magnitude of the average space per core. For this and for the other reasons which have been given, therefore, consideration of the relative economic merits of the various cable types for a specific purpose is perhaps most rational when confined to a comparison of the actual diameters underneath the lead sheath of commercially manufactured cables of the Twin, Multiple Twin and Quad types, containing about the same number of physical circuits of equal mutual electric capacity and conductivity. The figures quoted in subsequent pages in regard to this aspect of telephone cables are, except in regard to those for the J.H. type, based upon such a comparison of British manufactured 40 lb. conductor cables. Such figures have definite limitations, inasmuch as that for the purpose of a valid comparison adjustments have been made in the dimensions of the various types considered, on account of their differing mutual capacities. Thus, whereas the modern M.T. cables selected for the comparison averaged 0.062 microfarads per mile and were characterised by small circuit deviations, the Twin cables were of about 0.065 microfarads per mile, with large circuit deviations. The average mean mutual capacity of the Star Quad cables, so far manufactured in this country, is in the neighbourhood of 0.068 microfarads per mile. In making the adjustments the approximate relation expressed by :—

$$D = A\sqrt{N}\,10^{\frac{B}{C}} \quad \ldots\ldots\ldots\ldots(3)$$

has been used. D is the diameter of the cable core, C the mutual capacity of, and N the number of pairs. A and B are constants for similar cables of the same type and construction and of the same gauge conductor, whose mutual capacities do not differ by more than about 10%. The application of the relative figures obtained in this manner must, of course, be restricted to the general discussion of the relative economic merits for specific purposes of the various cable types.

Classification of Cable Circuits.—A.S.P.C. cable circuits are usually divided into three main classes in accordance with their respective functions in the cable network of a telephone system. The leading technical requirements of each class of circuit are stated below, together with the main general features governing the type of cable to be utilised in each case.

C.B. Subscribers' Circuits.—For Common Battery subscribers' circuits adequate conductivity of the loop as well as high resistance and electrical strength of the insulating medium are the main considerations; mutual electric capacity, inductance and leakance, provided of course that they are not of abnormal value, being relatively unimportant. Such simple requirements are easily secured by the use of cables, the materials of which conform to the usual standards. In addition, these and other desirable features are ensured in the manufacturing stage by effectively insulating each wire and by utilising the smallest possible space for each circuit, consistent with dielectric strength, reasonable freedom from interference and ease of handling during constructional operations.

Twin cables have in the past been exclusively utilised for this service. The reason for this is probably to be found in the circumstance that at relatively large values of mutual capacity, a very much greater degree of freedom from interference between adjacent circuits is obtainable than in other types. Since over a fairly wide range the magnitude of the circuit capacity is of little importance in this case, the advantage of the consequent permissible decreased diameter of such high capacity Twin cables has been utilised. Such cables, at least for capacities in excess of about 0.07 microfarad per mile also appear to be superior to four-wire core cables of equal mutual capacity, from the point of view of dielectric breakdown voltages. For equal pair circuit capacity up to about 0.07 microfarad per mile the Star Quad cable, although at present generally inferior to the Twin type in respect of interference between side circuits, is superior to it in regard to space, 30% or more additional pairs being available for a given diameter cable. Such cables have accordingly a distinct advantage in regard to manufacturing cost per circuit, since for the provision of a given number of physical circuits a smaller diameter Star Quad cable could be utilised, than if the requirement were met by either the Twin or M.T. types. Such types for equal side circuit mutual capacity would be from 12% to 18% larger in diameter.

The superiority of Star Quad cables over the Twin type, in regard also to earth balance of the circuits furnishes another reason for the use of such cables in those cases where interference from earthed circuits of any description is to be apprehended. In regard to constructional costs, a measure of wire-to-wire capacity balancing of the Quad cable as at present manufactured would be necessary in order to reduce the interference between associated side circuits of the quads, to the same average value as exists between adjacent pairs in Twin cable.

Junction and Short Trunk Circuits.—For loaded junction and short trunk circuits the magnitude of the average attenuation (β) per unit length, and the characteristic impedance (Z_o) at the mean speech frequency, are the leading features. Provided the leakance is normal, *e.g.*, a value for the dielectric damping constant G/C of between 15 to 25, such values of β and Z_o will be governed by the equivalent uniform average magnitudes per unit length of the capacity (C farads, mutual wire-to-wire of the line), the resistance (R ohms, loop, line and loading coils) and the inductance (L henries, loading coils and line) of the circuits. For cable of normal design, loaded in accordance with the standard schemes, speech transmission over such commercial circuits may be computed on the assumption that they are electrically uniform and homogeneous or smooth, in which case and assuming half loading section cable terminations, Z_o and β are approximately given by:—

$$Z_o = \sqrt{L/C}. \quad \ldots\ldots(4)$$

$$\beta = \tfrac{1}{2} R \sqrt{C/L} = \tfrac{1}{2} (R/L) \sqrt{CL} = R/2Z_o. \quad (5)$$

at least so far as the transmission of currents of frequency necessary to intelligibility in such cases is concerned. The factor R/L of the expression for β may be regarded as the conductor damping constant and includes the damping of the line and loading scheme. The factor involving the dielectric damping constant has been omitted from equation (5) for reasons previously given.

For the transmission of currents of frequency outside this range the line cannot be regarded as smooth and the characteristic of a coil loaded line of "cutting off," or of enormously attenuating currents of frequency above a certain value, must be taken into consideration.

The value of β for a circuit would appear from (5) to depend upon the ratio of C to L for that circuit; this is true only if the actual values of C and L are of such magnitude as to ensure that the frequency band which it is desired to transmit with an average attenuation of β is well within the band beyond which "Cut-off" occurs. The frequency (f_o) of cut-off is given by:—

$$f_o = 1/\pi \sqrt{L_1 C_1}. \quad \ldots\ldots(6)$$

where L_1 is the inductance of individual coils loading the circuit and C_1 is the total capacity of the cable section between two loading coils. Its actual magnitude is of considerable importance since, amongst other features, it imposes the limit for the usefully transmitting frequency range of the circuit. The ratio of any transmitted frequency (f) to the cut-off frequency is of frequent occurrence in what follows, and for convenience will subsequently be referred to as w, thus:—

$$w = \pi f \sqrt{L_1 C_1}. \qquad \text{.................................(7)}$$

From the foregoing it will be understood that equations (4) and (5) are valid only in so far as cable capacities of normal value are employed and the usual standard loading schemes in regard to coil inductance and spacing are not departed from. Furthermore they apply only to frequencies which are well within the cut-off, and for which the energy losses in the dielectric are relatively unimportant. The loading schemes referred to have of course been evolved as a result of the above considerations.

For equal attenuation (β) of side and phantom circuits of a four-wire core, the loading coil inductances, cut-off frequencies and wave-length constants of the respective circuits will be related each to each, in a manner depending upon the magnitude of the phantom to side circuit capacity ratio (P/S). Similarly for loading coil inductances and attenuation as well as characteristic impedances in the case of equal cut-off frequencies and wave-length constants of such circuits. These relations, for frequencies within the cut-off, are given in Table No. IV. in a general form and also in a numerical form for the general average case of M.T. and Star Quad type cables.

As far as the line only is concerned, the requirements of junction and short trunk cables, additional to those of Subscribers' cables, relate to a sufficiently small average value of electrostatic capacity of the circuits consistent with space occupied and electrical stability of make-up, and to small loss in the dielectric, *i.e.*, low power factor ($G/2\pi fC$). This latter feature has been assumed in the approximate expression for β given in (5). In addition, a degree of electrical balance of the circuits superior to that of the previous case is required in order to counteract the augmenting effect of the loading upon the interference between the circuits. Furthermore, if phantom circuits are to be worked, a cable type which is essentially free in the manufacturing stage, from interference between its phantom circuits must be utilised, since it is not at present practicable to arrange for the systematic elimination of such interference during the constructional stage of the work. Finally, similar type circuits in the same cable should preferably have essentially the same average electrical constants, in order that they may give similar performance; with modern manufacture of the M.T. and Quad types, no special steps require to be taken to ensure this feature to the degree which is adequate for this case.

TABLE No. IV.

THE LOADING OF SIDE AND PHANTOM CIRCUITS OF TELEPHONE CABLES.

Loading design.	Circuit characteristics.	Side Cct.	Phantom circuit. General Case.	Phantom circuit. M.T. Case.	Phantom circuit. Star Quad Case.
For equal attenuation of side and phantom circuits.	Loading	L	LP/4S	0.41L	0.66L
	Attenuation constant ...	β	β	β	β
	Wave-length constant ...	α	αP/2S	0.82α	1.32α
	Cut-off	f_0	$f_0 2S/P$	$1.22f_0$	$0.76f_0$
	Impedance	Z_0	$Z_0/2$	$Z_0/2$	$Z_0/2$
For equal cut-off of side and phantom circuits.	Loading	L	LS/P	0.61L	0.38L
	Attenuation constant ...	β	βP/2S	0.82β	1.32β
	Wave-length constant ...	α	α	α	α
	Cut-off	f_0	f_0	f_0	f_0
	Impedance	Z_0	Z_0S/P	$0.61Z_0$	$0.38Z_0$

Multiple Twin cables have in the past been extensively used for this purpose. Disregarding the availability of its phantom circuits, the M.T. type meets the whole of the electrical requirements in so complete a manner as to offset any slight advantage in respect of manufacturing cost per circuit of ordinary Twin cable. On the other hand the economic advantages of Star Quad cables in this connection become of extreme importance. For the provision of a given number of physical circuits an approximately 15% larger diameter would be required for a M.T. cable than for one of the Star Quad type. With lead sheathed, armoured cables such as are extensively used on the Continent of Europe an even greater reduction in the cable price per pair, than in the case of the lead sheathed cables laid in earthenware ducts in this country, would result from the use of Star Quad cable. The economic gain resulting from the use of Quad cables for junctions and short trunks is minimised only very slightly by reason of the superior capacity balance of the factory lengths of M.T. cables, since a measure of field balancing of the associated pairs would be resorted to in the constructional stages of either type.

The commercial loading of side and phantom circuits is based upon equal cut-off (this involves equal velocity of propagation within the cut-off) for each. From Table No. IV. it will be seen that this entails in M.T. cables, an inductance for the phantom coil of about 0.61 times that of the side coil; an 18% smaller attenuation and consequently a superior phantom circuit of characteristic impedance 39% smaller than that of the side circuit resulting. In order to obtain equal cut-off for the circuits of Star Quad cables, a phantom coil of inductance about 0.38 times that of the side coil must be used. The attenuation of such a phantom circuit would be about 32% greater than, whilst its characteristic impedance would be 62% smaller than that of the side circuit. An increase of inductance of the phantom coil in this case, with a view to improving the attenuation of the lower frequencies, would result in a reduction in the cut-off frequency. For example, the use of standard M.T. loading units for Star Quad cables would result in a cut-off frequency for the phantom circuit, about 21% smaller than that of its associated side circuit, whilst its average attenuation over the lower frequencies of this decreased transmitting range would be about 4% greater, and its characteristic impedance 52% smaller.

As a result of the above considerations, it seems to have been generally concluded that phantom circuit working in Star Quad cables is quite out of question. In this connection the availability of such circuits—of the same cut-off frequency as the side circuits, but of 32% greater attenuation per unit length—for either an overall lower grade circuit or a shorter equally efficient circuit, for use between intermediate stations, should not be lost sight of when dealing with the economics of the case.

Assuming side and phantom circuit working in M.T. cables, but side circuit working only in Star Quad cables then for the provision of a given total number of circuits by means of a M.T. cable, a smaller diameter could be utilised than if the requirement were met by the Star Quad type. The Star Quad type would be about 7% larger in diameter and would require 50% additional conductors. The same total number of loading coils would of course be required in the two cases, although for the M.T. circuits one-third of the total number would be of the more expensive phantom type. Furthermore, transformers to the number of four-thirds of the total circuits, as well as additional apparatus for any special signalling system which may be utilised, would be required for use at the terminals of the M.T. cable. Owing to the increase of resistance of the side circuits of the M.T. core by reason of the inclusion of the phantom circuit coils, equal attenuation of the side circuits in the two cable types would be ensured by something less than a 50% additional weight of copper in the Star Quad type. The choice of M.T. or Star Quad cable in this case would be determined mainly on economic grounds, in respect of which only the more obvious features have so far been dealt with. The question of the greater convenience of side circuit working as well as considerations relating to fault maintenance of the two cable types should also affect the choice.

Assuming that the spiral four cable is actually superior to the M.T. type from the point of view of manufacturing cost, it would appear from the foregoing that this advantage, as well as that of greater uniformity of mutual capacity, could be most economically secured in the general case by the use of this type in the form in which its phantom circuit can best be utilised, *i.e.*, in the J.H. Quad form. For a given number of circuits provided by M.T. and J.H. Quad types respectively, the latter type cable would perhaps be slightly smaller in diameter than the former, and might therefore show some economic advantage on this account also. As an offset to this feature, the Quad phantom circuit would be inferior to the M.T. phantom circuit owing to its somewhat greater mutual capacity.

Long Distance Repeatered Circuits.—For a coil loaded circuit the complete expression for characteristic impedance[21] is less simple than that given in equation (4). It contains resistance and reactance components, the magnitudes of which are dependent upon the length of the end cable section and upon frequency. The complete expression is necessary for the purpose of calculations relating to long-distance circuit working. If the length of cable situated between the end of the line and the first loading coil, expressed as a fraction of a normal loading section length, be equal to x, the resistance (A) and reactance (B) portions of the characteristic impedance, at a frequency f are given by[22]:—

$$A = \sqrt{(1-w^2)L/C}/[1-4x(1-x)w^2]. \quad \ldots\ldots(8)$$

$$B = \sqrt{L/C}\,(1-2x)w/[1-4x(1-x)w^2]. \quad \ldots(9)$$

It can be shown from these expressions that the resistance component will continually increase or decrease with increase of frequency up to the cut-off according to the value of x. The reactance component will behave in a like manner, except that whereas A shows a falling characteristic for values of x from zero up to 0.17, a practically constant value at 0.17 and a rising characteristic for values above 0.17 and up to 0.83; B shows a positive and rising characteristic for values of x from zero up to 0.5, a practically zero value at 0.5 and a negative and falling characteristic for values of x beyond 0.5. For a value of x equal to 0.5, *i.e.*, with a half section termination, the effective resistance increases with frequency to a very large value in the neighbourhood of the cut-off, whilst as already stated the reactance has practically zero value over that frequency range. The characteristic impedance in this case at a frequency f, may be written :—

$$Z_0 = \sqrt{(1 - w^2)L/C}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

When referring subsequently to the characteristic impedance of the line, a half section termination will be assumed and Z_o will have the value given in equation (10).

The complete expression for the attenuation per unit length of a coil loaded line to currents of frequency f is given by :—

$$2\beta = \left[(R - \frac{2}{3}w^2 r)\sqrt{C/L} + G\sqrt{L/C}\right] / \sqrt{(1-w^2)}. \quad \ldots(11)$$

$$\text{or } \beta = \frac{\left(R - \frac{2}{3}w^2 r\right)}{2Z_o} + \frac{G Z_o}{2(1 - w^2)} \quad \ldots\ldots\ldots(12)$$

where R, L, G and C represent the same quantities as in equation (5), and r is the loop resistance per unit length of the conductor only.

It will be evident that unless f_o is considerable, the attenuation of the higher speech frequencies will be much greater than that of the lower, and that generally the smaller the magnitude of the cut-off frequency the greater will be the rate of change (*i.e.*, of increase) of attenuation with frequency. For long circuits the accumulative effects of attenuation distortion (*i.e.*, of the differing degrees of attenuation of the various frequencies transmitted) per repeater section is a serious matter and in such cases it is necessary to ensure a high cut-off. Since, however, with the standard loading schemes, the higher the cut-off, the greater the actual magnitude of the attenuation at any particular frequency, the amplification in very long repeatered circuits must be greater and they will, for this reason and also from considerations of repeater stability, require to be of the four-wire type. In reference to the latter statement it may be deduced from (6) and (11) that :—

$$\beta = \frac{\pi R C_1}{2} \times \frac{(f_o^2 - \frac{2}{3}\frac{r}{R} f^2)}{\sqrt{(f_o^2 - f^2)}} \quad \ldots\ldots\ldots(13)$$

For long trunk circuits employing telephonic repeaters, the reduction of attenuation of the transmission line is of lesser importance than the actual overall quality of transmission. This matter of quality constitutes in fact the chief problem of long distance transmission; it involves not only attenuation-distortion but also phase-distortion.

The differing velocities of propagation of currents of different frequency, the duration and its variation with frequency of the building-up time of the received current to its steady state value, as well as the actual rate of building-up of the current near to or at the final steady state value, govern the question of phase-distortion. In regard to these latter features, a circuit, which from the point of view of the steady state condition is essentially distortionless, may be very unsatisfactory from the point of view of the quality and intelligibility of the received speech. References (21) to (28) apply.

The design of the loading scheme in relation to the design of the cable directly controls distortion in a long distance circuit, and hence the cable requirements for such networks cannot be considered without reference to the loading system. In all cases the cut-off frequency must be maintained at a high value, not only for the reasons already given but particularly for the purpose of minimising the "transients." The adverse auditory and psychological effects of "echo" can be eliminated by the use of "echo suppressors." With the relatively low inductance and closely spaced coils of the "Half Medium Heavy" or "Extra Light Heavy" loading schemes, a sufficiently high cut-off for circuits up to eight or nine hundred miles in length, equipped with various apparatus auxiliary to the repeaters, is secured by the use of normal capacity cable, at least as far as the side and phantom circuits of M.T. cables are concerned. The relatively high capacity of the phantom circuits of Star Quad cables gives rise to difficulties which have already been pointed out in the section relating to junction and short trunk working. This same feature is, however, of so much greater importance in regard to the above aspect of long-distance networks that as far as present-day practices are concerned the use of such circuits is precluded.

The mean attenuation-frequency ($\beta - f$) and impedance-frequency ($Z_0 - f$) characteristics over the designed transmitting range, as well as the extent of the deviations of the actual $\mathbf{Z}_0 - f$ characteristics from their mean values, constitute criteria for two-wire repeatered circuits. Such circuits are accordingly required to be uniform in respect of their electrical constants, not only as far as the average values per unit length for similar circuits are concerned but also and particularly in regard to distribution along the length of such circuits. The reasons for this have already been given. In this connection it should be observed that neither a technical nor an economic advantage results from an extreme degree of length uniformity, since the attenuation length of the cable between repeater stations and the repeater gains are limited in practice by the control which it is necessary to exercise upon the power levels along a circuit on account of interference difficulties. The factory lengths of modern high grade M.T. cables are very uniform, but it is probable that the higher amplification possible with a more uniform cable, working in conjunction with two-wire repeaters of suitable impedance, could be effectively utilised.

Finally the balance of the circuits from the interference point of view will require to be very exact, since only very slight cross-talk can be tolerated in repeatered circuits. The unbalances between the oppositely transmitting circuits (*i.e.*, "Goes" and "Returns") for four-wire working must be very small and this feature is ensured in the manufacturing stage of long-distance cables, although additional immunity from interference between such circuits is secured by special separation of the cable units into groups during the constructional operations.

General Summary of considerations affecting choice of Cable type.—The technical essentials and the cable requirements for the principal classes of telephone circuit have already been described. These requirements, taken in conjunction with the data previously given in respect of what is possible of achievement in modern commercial cable manufacture, furnish information which directly affects the question of the most suitable type to be adopted for each of the various services. There is another most important feature, however, governing the actual choice of cable type, namely, the cost or economic aspect. (See Chap. XII., "Telephonic Transmission," J. G. Hill). In some cases the economic considerations are quite simple to apply and the determination of the best cable type is a perfectly straightforward matter. In other cases, the question of relative costs is much more complex and a detailed study involving manufacturing and constructional costs of cable and line plant as well as relative maintenance and other costs is necessary before a decision can be made. In this connection consideration should also be given to permissible departures from present-day standard practice, in relation to any economic gains which may accrue therefrom. Such studies will of necessity be based upon costs, which vary not only in different countries but also from time to time in the same country. Decisions arrived at in this manner will accordingly be of neither universal nor perpetual application. In the case of long-distance networks a very large proportion of the total cost of the system is expended in the line and line plant, and the economic aspect of cable type is accordingly of prime importance. Now, frequent changes of cable type in the same system or differences of type in adjoining systems will give rise to considerable technical difficulties. If, therefore, a preliminary study points to the desirability of a change of type, the difficulties introduced thereby will require to be assessed as additional costs and a further study made on this basis. In those cases where the introduction of such difficulties result in an inherent reduction of overall efficiency of the system, they must be obviated, despite the economics of the case. On the other hand, the initial design and lay-out of the system in combination with future developments of the communication art, may permit of any economic advantages accruing from a change of cable type being secured.

Bibliography.—The various sources of information which have been freely drawn upon in the preparation of this article are given grateful reference in the attached bibliography. The data contained in Tables II. and III. has been included by the courtesy of Colonel Purves, Engineer-in-Chief. The author acknowledges with thanks the assistance derived from discussions on the subject of the article with his colleagues both within and outside the Service.

BIBLIOGRAPHY.

(1) *"Experimental Researches into Means of Preventing Induction upon Lateral Wires." D. E. Hughes. Journal of the Society of Telegraph Engineers*, 1879, *Vol.* 8, *p.* 163.

(2) *British Patent No.* 3,281 *of* 1882. *Frank Jacob.*

(3) *British Patent No.* 12,526 *of* 1903. *W. Dieselhorst and A. W. Martin.*

(4) *"Star Cable." Dr. H. Jordan. "Long-distance Telephony," Berlin*, 1923; *also E.T.Z., May 8th*, 1924.

(5) *"Star Formation of Associated Pairs of Telephone Cables." Annales des Postes Telegraphes et Telephones, Vol.* 14, *No.* 2, *Feb.*, 1925.

(6) *"Star and Dieselhorst—Martin Cables." Dr. F. Luschen, Fernkabel, Feb.*, 1926.

(7) *"The Introduction of Star Cores in the Manufacture of Telephone Cables." Dr. H. Jordan, Fernkabel, Feb.*, 1926.

(8) *"Possibilities of Utilising D.M. and Star Cables." H. W. Droste, Fernkabel, Feb.*, 1926.

(9) *"The J.H. Quad, a new Four-wire Cable Core." Otto Haugwitz, E.T.Z.*, 30*th June*, 1926.

(10) *"The Long-distance Telephone System of the United Kingdom." Sir William Noble, J.I.E.E.*, 1921, *Vol.* 59, *p.* 389.

(11) *"The Anglo-Dutch No.* 2 *Continuously Loaded Submarine Telephone Cable." Electrician, September* 5*th*, 1924.

(12) *"The Anglo-Dutch No.* 3 *Continuously Loaded Submarine Telephone Cable." A. B. Morice, J.I.P.O.E.E., Vol.* 19, *Part* 3, *Oct.*, 1926.

(13) *"The Anglo-Belgian* (1926) *Continuously Loaded Telephone Cable." W. T. Palmer, J.I.P.O.E.E., Vol.* 19, *Part* 4, *Jan.*, 1927.

(14) *"The Anglo-French* (1926) *Cable, Lead Sheathed, Paper Core, Continuously Loaded." W. Cruickshank, J.I.P.O.E.E., Vol.* 20, *Part* 2, *July*, 1927.

(15) *"Some Relations Between the Partial Capacities of a Quad." H. Droste, E.T.Z., Vol.* 44, *p.* 809, 1923.

(16) *"Some Aspects of the Electric Capacity of Telephone Cables." A. Morris, J.I.P.O.E.E., Vol.* 20, *Part* 1, *April*, 1927.

(17) *"Quad Telephone Cables." A. Morris, Electrician, July* 29*th*, 1927.

(18) *"Electric Cables, their Construction and Cost." Coyle and Howe. Spon.*

(19) *"Cables, Paper Core, Telephone." S. Handford, J.I.P.O.E.E., Vol.* 7, *Part* 3, *October*, 1914.

(20) *"Paper Core Telephone Cables." S. Handford, J.I.P.O.E.E., Vol.* 14, *Part* 2, *July*, 1921.

(21) *"Loaded Lines in Telephonic Transmission." G. A. Campbell, Phil. Mag., March*, 1903.

(22) *British Patent Specification No.* 18,018 *of*

1913, *and No.* 179,736; *Western Electric Co.*

(23) *"Problems in Connection with Long-distance Underground Loaded Repeater Circuits." J. G. Hill, J.I.P.O.E.E., Vol.* 16, *Part* 1, *April,* 1923.

(24) *"The Anglo-Dutch No.* 1 *Coil Loaded Telephone Cable." E. F. Petritsch, J.I.P.O.E.E., Vol.* 16, *Part* 4, *March,* 1924

(25) *British Patent Specifications, Nos.* 222,829, *and* 225,506; *Siemens and Halske.*

(26) *"The Increase in Range of Loaded Lines by the use of Echo Suppressors and by Phase Correction." K. Kupfmüller, E.N.T., Vol.* 3, *No.* 3, *March,* 1926.

(27) *"Transient Phenomena in Loaded Lines and their Reduction." Kupfmüller and Mayer, Scientific publications of Siemens and Halske, Vol.* 5, *Part* 1, 1926.

(28) *"Echo Suppressors for Long Telephone Circuits." A. B. Clark and R. C. Mathes, J.A.I.E.E., Vol.* 44, *p.* 618, *June,* 1925.

DESIGN AND STANDARDISATION OF COIL-LOADED TELEPHONE TRUNK CABLES.

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I. THE TYPES OF LOADING EMPLOYED AT THE PRESENT TIME FOR INTERNATIONAL TELEPHONE CABLE CIRCUITS.

TWO methods of loading long-distance telephone cable circuits are recommended by the C.C.I. as being both equally suitable for international circuits. These two methods relate to cable circuits in which the phantoms are used. The following are the main properties of circuits comprised in both systems:—

Type of Loading.	Gauge of Conductors. *mm.*	Type of Circuit.	Capacity. $\mu F/km$.	Length of Loading Section. *km.*	Coil Inductance. H.	Maximum Conductor Attenuation per *km* at 800 p.p.s.	Natural Frequency.
Method I.							
Medium-heavy ...	0.9	Side	0.0385	1.830	0.177	0.0217	2,900
		Phantom	0.0625		0.063	0.0228	3,600
	1.3	Side	0.0385		0.177	0.0121	2,900
		Phantom	0.0625		0.063	0.0125	3,600
Method I. Extra-light ...	0.9	Side	0.0385		0.044	0.0390	5,800
		Phantom	0.0625		0.025	0.0328	6,000
Method II.							
Medium-heavy ...	0.9	Side	0.0335	2.000	0.200	0.0197	2,750
		Phantom	0.0540		0.070	0.0210	3,670
	1.4	Side	0.0355		0.190	0.0097	2,750
		Phantom	0.0570		0.070	0.0101	3,520
Method II. Extra-light ...	0.9	Side	0.0335		0.050	0.0307	5,340
		Phantom	0.0540		0.020	0.0350	6,840

In respect to attenuation and natural frequency—the two most important electrical properties as far as transmission is concerned—there is no appreciable difference between the two systems. Such slight differences as occur are manifestly not due to a fundamentally different conception, but rather to the fact that in each method a round figure for the units of length normally used in the countries where the respective systems originated—6,000 feet (= 1830 metres) in America and 2 km. in Germany—has been chosen as the distance between loading coils. Inasmuch as both systems, independently of each other, have led to approximately the same electrical values, we may perhaps assume that the systems corresponded in the fullest measure, at the time when they were designed, with the existing state of knowledge and experience.

In the meantime, cables in which the phantom circuits are not used (so-called "Star Quad" cables), have been laid in Holland. These possess the following properties:—

Type of Loading.	Gauge of Conductors. *mm.*	Type of Circuit.	Capacity. $\mu F/km$.	Length of Loading Section. *km.*	Coil Inductance. H.	Maximum Conductor Attenuation per *km* at 800 p.p.s.	Natural Frequency.
Medium-heavy	1.0	—	0.0365	1634	0.200	0.014	2,860
	1.0	—	0.0365	1634	0.155	0.015	3,260
	1.6	—	0.0365	1634	0.155	0.008	3,260
Extra-light	1.0	—	0.0365	1634	0.050	0.025	5,800

It is noticeable that in this case a natural frequency has been chosen which lies between the natural frequencies of the physical and phantom circuits of methods I. and II.

The C.C.I. at its last meeting in November, 1926, expressed the opinion that from the technical point of view Star-quad cables are just as suitable for the international telephone service as the Dieselhorst-Martin cable ordinarily used, provided they satisfy the general conditions laid down for factory lengths and repeater sections.

There can be no doubt that it is not desirable to admit for the international telephone service the use of a number of different types of cable. The necessity for examining from time to time the suitability of all types is also generally recognised. The C.C.I. in dealing with transmission questions has therefore proposed to examine the question, amongst others, whether since the time when the two methods of loading referred to above were adopted experience has shown that an alteration in the type of circuit, hitherto regarded as normal, could be made which might lead to a uniform system.

Detailed investigations have lately been carried out in the Central Laboratory of the Werner Works of Messrs. Siemens and Halske with respect to the most suitable system of loading, and it is now proposed to discuss the most important aspects of these researches. We purpose also to examine the requirements of telephone circuits which this investigation has indicated at the present stage of development of telephone technique concerned with the design of long distance circuits. In the light of these requirements, a proposal will be made for the loading of future telephone cables which may perhaps serve as a basis for further discussion.

II. General Aspects of the Selection of the most suitable Type of Loading.

The fundamental object of long-distance telephone engineering is to provide telephone circuits equipped in such a way that the quality of the transmission between any two subscribers at different places is not inferior to the quality of the transmission usually obtained within the area of one and the same town. This is essentially the quality of transmission which corresponds to the electric and acoustic properties of the telephone apparatus itself. It is also required, as in all technical problems, that this object shall be achieved with the minimum cost. In the selection of the most suitable type of loading, therefore, the economic point of view has to be considered as well as the engineering aspect. Telephone engineering at the present time has itself all the means necessary for attaining, to almost any degree of perfection, the object referred to above, even when we have to deal with very long circuits. The higher the degree of perfection, however, the more rapid is the increase in cost. It follows that for every measure contemplated the question must be examined whether the improvement attainable is worth the additional cost involved. In order to render possible such examination and estimation, it is necessary to introduce a measure for the quality of transmission. We employ for this purpose in the following paragraphs the so-called "syllabic intelligibility." This is defined as the ratio of the number of unconnected syllables correctly received to the total number of such syllables which have been transmitted by word of mouth—the whole being arranged on a systematic basis. Strictly speaking, it is true that in telephoning we are generally concerned with the transmission of coherent sentences, so that it would be more accurate to use "sentence intelligibility" as a measure of the quality of transmission. It can be shown, however, that "sentence intelligibility" on the one hand is not so easily reproducible, because the size of the figures representing it depends largely upon the nature of the sentences, upon the themes, and upon the intellectual capacities of the observers. On the other hand, it cannot convey more than "syllabic intelligibility," because, generally speaking, we cannot of course estimate what, for example, is to be interpreted from the fact that, say, one of a hundred sentences has not been correctly understood.

It is also very important in this connection to note whether the conversations on the part of both subscribers have been made in a common mother tongue. Experience has shown that even slight differences of dialect reduce "sentence intelligibility." The difference is still greater with conversations in a foreign language. Although the connection between "sentence intelligibility" and "syllabic intelligibility" is not simple and unambiguous, it is, however, a fact, agreeing with all observations made hitherto, that "sentence intelligibility" increases with "syllabic intelligibility." We are, therefore, quite justified in regarding "syllabic intelligibility" as a practicable measure for quality of transmission.

We now propose to examine the individual factors which affect intelligibility, and thus obtain definite requirements for the design of coil-loaded circuits. Strictly speaking we cannot regard any of these factors as being wholly independent of the others; they have all a mutually dependent relation. For example, the dependence of intelligibility upon the width of the frequency band transmitted cannot be investigated unless, at the same time, the distortion and noises otherwise occurring or the sound volume be taken into consideration. We cannot express an opinion with respect to the necessary volume without premising something with respect to disturbing noises. In the case under consideration, however, we are not concerned very much with stating the precise figure for the quality of transmission finally to be attained, but we can, by considering individual causes and their effect upon intelligibility, deduce some important rules which must necessarily be followed if the object as stated above is to be attained to the greatest possible extent.

The C.C.I. has recommended for a series of properties of telephone circuits definite values which are based on theoretical considerations and practical experience. These are mostly minimum values, as, for example, the permissible overall attenuation, the permissible cross-talk attenuation, and the minimum width of the frequency band to be transmitted. These minimum values are to some extent determined purely by the technical appliances available and will be re-examined as telephone engineering progresses. It is therefore constantly necessary to adapt these values to this progress. We will deal first with volume and the requirements which result therefrom.

(1) *Volume.* The volume at the receiving end of a telephone circuit is determined by the electro-acoustic efficiency of the apparatus itself and by the attenuation of the line system between the sets of apparatus. In the case of the telephone apparatus generally used the efficiency is such that with a line attenuation of $b = 0.5$ to 1.5 we obtain approximately the same volume in the receiver as in the case of normal direct conversation. The intelligibility decreases from this point onwards with increasing attenuation.

If the transmission itself is distortionless and free from interference, the diminution of intelligibility is determined especially by the intensity of the noises in the rooms in which the speaking apparatus has been installed. Fig. 1 shows the relation between intelligibility and line attenuation when ordinary central battery apparatus is used and when room noises on the average correspond to what occurs in practice. The maximum attenuation between two subscribers as recommended by the C.C.I. has the value $b = 3.3$. It will be seen from Fig. 1 that this

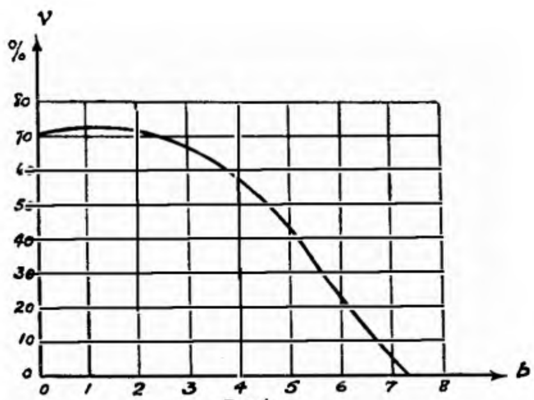

Fig. 1

Dependence of Intelligibility V upon Line-attenuation b

value in fact must represent the outside limit permissible. Intelligibility in this case is already several per cent. lower than when the attenuation is $b = 2$. It would be desirable, therefore, to go as much below this as possible. This is, however, a question of economics because the costs of large town systems increase rapidly if the attenuation is reduced.

An interesting point for our observations is the question how to distribute most suitably the value of attenuation between the trunk line and the local lines. From a technically operative point of view, it would apparently be desirable that the trunk line itself had no attenuation. The local system could then be designed in accordance with the maximum permissible attenuation, and the volume of transmission within one and the same town area would have in the most unfavourable case about the same value as between any two subscribers in different towns. We have, however, to consider in the first place that the costs of the trunk lines themselves increase as attenuation decreases if we are tied down to definite requirements in respect to quality of transmission.

An important factor in this connection is that echo disturbance under otherwise similar conditions increases with a reduction in attenuation and an increase in the total amplification. Thus Fig. 2 shows how in an ordinary 2-wire circuit with two repeaters the intensity of the "speaker echo" increases if the overall attenuation is reduced.*

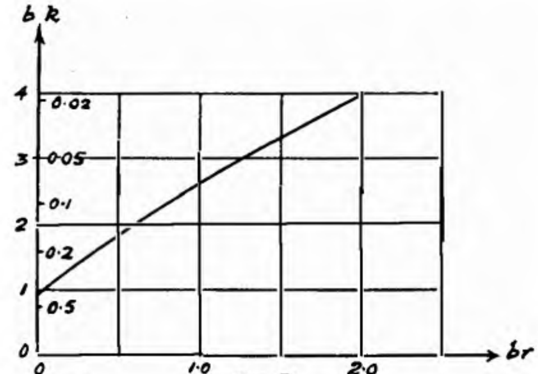

Fig. 2

Dependence of Echo attenuation b and relative Echo strength k upon Overall attenuation br

When dealing with small overall attenuations on telephone circuits, we must, therefore, employ means for reducing echo disturbances either by using echo-suppressors or complicated balancing networks in the compensation circuits, or in order to reduce the transmission times of echo currents by increasing the natural frequency of the line. These means therefore increase the cost of the telephone line in proportion as the overall attenuation of this line is to be reduced. Strictly speaking, we must therefore reduce to a minimum the sum of the costs of the local lines and those of the long-distance lines by suitable distribution of the overall attenuation. This, of course, cannot generally be done. An additional factor here is that with the means at present at disposal both in the case of 4-wire and 2-wire circuits we cannot go below a certain

* *We use the word "echo" for all disturbing phenomena which arise from the fact that portions of the speech currents traverse by-passes with the time lag at the speaker or the listener even if the transmission time is so short that an echo in the lag sense of the term can no longer be perceived, as, for example, in the case of short 2-wire circuits.*

overall attenuation without appreciably reducing reliability of working.

These, therefore, are minimum limits, which experience has confirmed. The C.C.I. has laid down $b = 1.3$ as the minimum value for overall attenuation. In almost all international circuits recently brought into service, efforts have been made and with success to obtain somewhat lower attenuation values. In the present circumstances, a reduction to $b = 1.0$ should generally be quite possible. This figure will therefore be taken as a basis in this paper. The volume of extraneous disturbances—and therefore, of cross-talk and power-current induction—is determined (in addition to transmission volume) by the choice of the overall attenuation. From this relationship definite limiting values are shown in the following section of this paper for the attenuation between two successive repeaters in the long-distance circuits.

(2) *Disturbances.* In consequence of the differences of the transmission level at various points in the long-distance circuit the intensity of cross-talk between two subscribers is generally different from the intensity of cross-talk in cable circuits themselves.

In addition to the speech currents, the induced cross-talk currents are amplified by the repeaters in the circuit. The more the repeater section attenuation is increased, the greater must be the amplification with a given overall attenuation; the more unfavourable, therefore, will be the conditions in respect to cross-talk disturbance. With a given intensity of cross-talk between the cable circuits themselves we must not therefore exceed a certain value of repeater section attenuation if the intensity of the cross-talk at the subscribers' stations is not to exceed a definite amount.

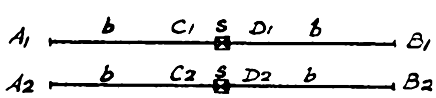

Fig. 3.

Cross-talk in two adjacent two-wire circuits.

We see this in the simplest way by considering two adjacent 2-wire circuits A_1, B_1, and A_2, B_2 (Fig. **3**). When speaking at A_1 and listening at A_2, there are two common paths available for cross-talk currents, the first through the couplings of the two line sections A_1, C_1, and A_2, C_2; the second from A_1 through C_1, repeater to D_1; from there through the couplings of the second line section D_1 B_1 to D_2, through the repeater of the second circuit to C_2 and back to A_2. The second path is here of special interest. The overall attenuation b_n for this part is, according to Fig. **3**,

$$b'_n = b - s + b_n - s + b,$$

if b_n denotes the cross-talk attenuation between the two ends of the line D_1, D_2. For the subscribers A_1 and A_2 we have therefore the cross-talk attenuation

$$b'_n = 2b - 2s + b_n \quad \text{.........................} (1)$$

The amplification s is now determined by the required overall attenuation. According to the foregoing section of this paper this should be 1.0. We must therefore have

$$2b - s = 1.0$$

or

$$s = 2b - 1.0$$

Consequently, from equation (1),

$$b'_n = b_n - 2b + 2.0 \quad \text{.........................} (2)$$

The C.C.I. has recommended the limiting value $b_n = 7.5$ for the cross-talk in long-distance circuits. As is seen by Fig. **1**, this figure corresponds in fact to a volume at which, in normal circumstances, intelligibility practically ceases.

We have therefore

$$b_n - 2b + 2.0 > 7.5$$

With modern telephone cables we may assume that b_n is always greater than 8.5. We thus finally get

$$b < 1.5 \quad \text{...} (3)$$

The attenuation of a repeater section for 2-wire circuits must therefore be less than 1.5 in order that the conditions which have to be laid down in respect to freedom from cross-talk shall be fulfilled. This does not, of course, mean that this value represents a sharp limit which must not be exceeded in any circumstances. As the foregoing deduction shows, the permissible repeater section attenuation depends in great measure on what cross-talk attenuation had been attained in the cables and repeaters. This generally will be greater than the value laid down. The repeater section attenuation depends further upon the value of the cross-talk which is to be required for the whole circuit; this in turn depends upon the intensity of other transmission interference, for example, upon noises. We shall therefore have to regard the value $b = 1.5$ as the attenuation which on the average should not be exceeded. With such a limiting value practicable conditions are also obtained for other inductive disturbances. For example, if in the line section D_2, B_2, noise currents arise from any causes, *e.g.*, from power supply installations, having a noise voltage V, we have at

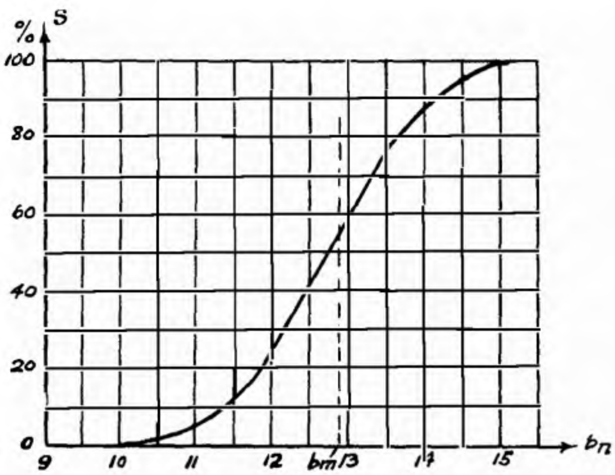

Fig. 4.

C_2 a noise voltage Ve^s. The subscriber at A_2 will therefore hear noises of intensity

$$V' = Ve^{s-b}.$$

If we put here as we have already done

$$s = 2b - 1 \text{ and } b < 1.5$$

it follows that

$$V' < Ve^{0.5}$$
$$V' < 1.7 \times V.$$

The noise disturbance in practice is not, therefore, appreciably greater at the subscriber's apparatus than it is directly on the lines.

The same conditions apply to 4-wire circuits. In this case the circuits are separated in the usual way into two equal and opposite parts for speaking in both directions. In this manner higher cross-talk attenuations between cable circuits are obtained than in 2-wire circuits. Figs. **4** and **5** thus show the extent of cross-talk attenuation between speech circuits in both equal and opposite directions in a modern cable. The curves have been obtained on half a repeater section, so that approximately $b = 1.3$ must be added to the attenuation values (far-end cross-talk) shown in Fig. **5**. The average values then amount **to:**

$b_m = 12.9$ for cross-talk between speech circuits in opposite directions, $b_m = 13.8$ for cross-talk between speech circuits in the same direction (far-end cross-talk) and in practice all attenuation values of near-end and far-end cross-talk exceed $b_n = 10.5$.

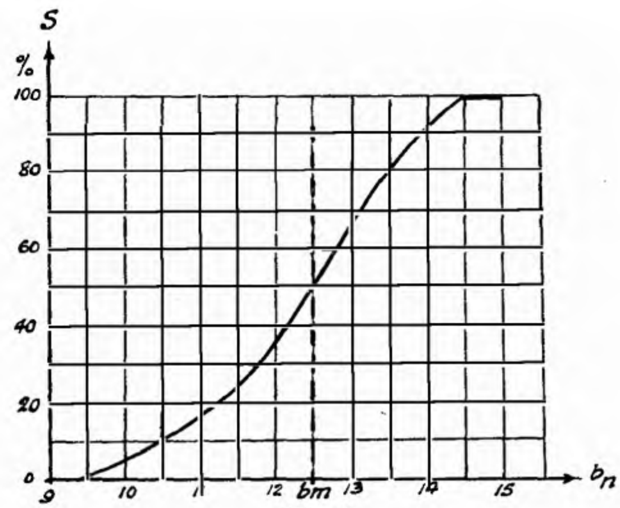

Fig. 5.

According to Fig. **6**, we have, in the case of 4-wire circuits, as above,

$$b'_n = 2b^0 - 2s + b_n \quad \text{.......... (4)}$$

The amplification s chosen must be so great that

$$b_1 - s + b - s + b_1 = 1.0$$

or

$$s = b_1 + \tfrac{1}{2}b - \tfrac{1}{2} \quad \text{.......... (5)}$$

If we insert this in equation (4) it follows that

$$b'_n = b_n - b + 1.0 \quad \text{.......... (6)}$$

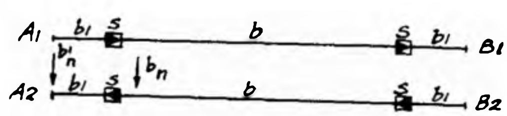

Fig. 6.

Cross-talk in two adjacent four-wire circuits.

At this point we must remember that in 4-wire circuits we have to deal for the most part with circuits of great length in which many successive repeater sections are inserted. The cross-talk currents in each of the sections have then to be added, which according to measurements and theoretical considerations thus reduce cross-talk attenuation by 0.3 to 0.5. We have then, approximately,

$$b'_n = b_n - b + 0.5.$$

If, again, we put

$$b'_n >= 7.5. \text{ and } b_n = 10.5,$$

we obtain

$$b. < 3.5 \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The average attenuation of a repeater section should therefore amount to as much as 3.5. This is appreciably more than is permissible in present day practice. It has, however, to be considered that with telephone cables equipped with repeaters the line costs are, of course, reduced as the repeater section attenuation increases, that, however, the repeater costs themselves rise with the necessary amplification and especially if an additional repeater valve is necessary. These economic considerations will induce us to adopt a lower limit—a limit appreciably below that given in equation (7). Even in respect to other inductive disturbances, for which the same considerations apply as for 4-wire circuits, it appears to be desirable not to take advantage of this limit to the full. Further important aspects of the calculations made for telephone cable circuits arise from the consideration of distortion, that is, those disturbances which the transmission system, as such, provokes.

(3) *Distortion.* Long-distance circuits from an electrical point of view are distinguished from short local circuits particularly by the fact that they transmit a limited frequency band. The C.C.I. recommends the transmission of the following ranges of frequency :—

2-wire Circuits	300—2000 p.p.s.
4-wire Circuits Medium-heavy loaded.	300—2000 p.p.s.
4-wire Circuits Extra-light loaded.	300—2500 p.p.s.

Fig. **7** shows what effect this restriction of the frequency band emitted from the transmitter has upon intelligibility. The intelligibility values have been arrived at with normal central battery apparatus over a distortionless line with attenuation $b = 1.0$. Frequencies below 300 p.p.s. have been eliminated by means of a high-pass filter. The upper limit of the frequency range of transmission is represented by the abscissæ. For purposes of comparison, a curve made bv H. Fletcher, which applies to distortionless transmitting and receiving apparatus, is also reproduced. In the case with which we are dealing, however, we are concerned with values obtainable with commercial apparatus.

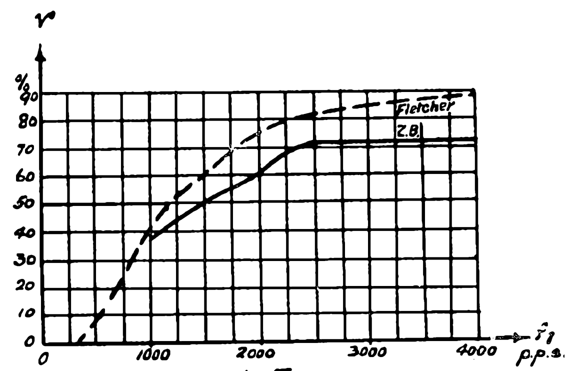

Fig. 7.

Dependence of Intelligibility r upon the higher limit f1 of the transmission range.

The following values of intelligibility have been obtained with the frequency range referred to above :—

Type of Circuit.	Frequency Range	Intelligibility.
2-Wire Medium-heavy loaded.	300 – 2000 p.p.s.	59%
4-Wire ,, ,,	300 – 2200 ,,	64%
4-Wire Extra-light loaded.	300 – 2500 ,,	71%

It will be seen that even slight differences in the width of the frequency band have considerable effect upon intelligibility. The employment, even at the present time, of such different widths of frequency band is due to the fact that, with a given type of circuit, every extension of the frequency band transmitted involves an increase in other disturbances, for example, echos in 2-wire circuits or so-called "phase distortion." Experience has now provided data for definite frequency ranges at which transmission efficiency is greatest, applicable to to every type of circuit and for all distances with which we are able to cope in practice. These are precisely the ranges given above. This explains the apparent arbitrariness in the requirements for various types of circuit. The large differences in transmission efficiency of telephone circuits to which this gives rise are, however, no longer justified for the future. It must be required that in all circuits at least the frequency range shall be transmitted within which the oscillation components of the speech currents, which determine intelligibility, are comprised. To exceed this would, moreover, be uneconomical, as every extension of the frequency range involves an increase in natural frequency and therefore enhances the cost of the plant. Fig. **7** shows that an increase of the high limit of the transmission range beyond 2,400 p.p.s. gives only a slight increase in intelligibility, and that in this case, therefore, the maximum transmission efficiency has practically already been obtained. Transmission within a range of frequencies up to 2,400 p.p.s. sounds more natural, even from the observer's point of view, than within a band up to only 2,000 p.p.s. The lower limit of the transmission range has very little influence. An increase from 300 to 400 p.p.s. causes only a small percentage reduction in intelligibility. On the other hand, practically no difference has been found between transmission when the lower limit of frequency is unrestricted and when the latter is limited to 300 p.p.s. The following fundamental requirement therefore results:—In all circuits the same band of frequencies shall be transmitted; this range shall be between 300 and 2,400 p.p.s.

In conjunction with this stipulation some further requirements have to be considered; these are based on phase distortion and echo disturbances.

A measure for phase distortion is afforded by the "building-up time" of the alternating currents. This is determined by the difference in the transmission time for the single frequencies. The nearer frequencies transmitted approach the natural frequency of the line, the longer is the duration of the "building-up" phenomena and the greater, therefore, is the alteration in the acoustic formation, and therefore, also the greater is the reduction in transmission efficiency. A natural frequency must, therefore, be selected which is sufficiently high to impose a certain higher limit on the highest frequency to be transmitted, and this limit depends upon what reduction in transmission efficiency may or can be permitted.

The manner in which the acoustic character of the volume of speech is disturbed by phase distortion will be seen from Fig. **8**.

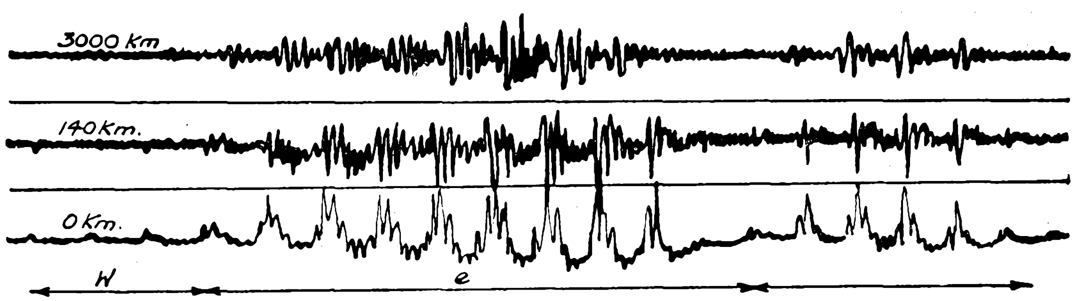

Fig. 8.

Effect of phase distortion upon character of sound.

This shows an oscillogram of the word "wer" at the beginning of a medium-heavy loaded long-distance line (lower curve); behind the first repeater, *i.e.*, at about 140 km. (centre curve); and at a distance of 3,000 km. (upper curve). It will be seen how strongly after the first repeater section the fundamental oscillations are weakened in comparison with the higher oscillations by the restriction of the frequency band, and how, further, volume formation itself appears to be, to some extent, changed by phase distortion. At 3,000 km. we find only slight similarity to the signals transmitted. With such a length the "building-up time" for the highest frequency transmitted is about 100 milliseconds. It is, however, astonishing that even with so pronounced a distortion a comparatively large amount of what is spoken is intelligible. Fig. **9** shows the dependence of intelligibility upon " building-up time " for the highest frequency transmitted, viz:—the frequency f = 2100 p.p.s. With small " building-up times" the intelligibility corresponds roughly with the frequency band transmitted. At 10 to 15 milliseconds it falls off by about 1 to 2%; it then falls gradually and at 100 milliseconds amounts to about 50%. It must, of course, be noted in this connection that even from about 20 to 30 milliseconds the speech transmitted is accompanied by incidental sounds, of which the volume and duration increase with increasing " building-up time," and cause more and more

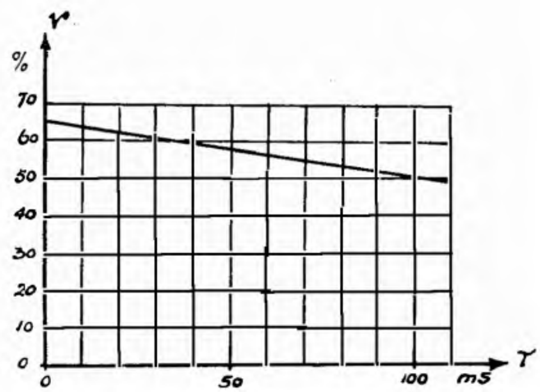

Fig. 9.
Dependence of Intelligibility V upon building-up time T.

disturbance to the listener. This phenomenon is particularly disturbing from about 50 milliseconds upwards. It is then somewhat similar to the disturbance which is felt by the presence of a strong listener-echo in short circuits. It follows from these observations that it would be desirable to make the " building-up times " in long-distance circuits somewhat less than 10 to 15 milliseconds, and on the other hand to avoid entirely " building-up times " beyond 30 to 40 milliseconds. On account of the similarity of the disturbances caused by phase distortion to echo disturbances, the latter must be taken into consideration in the final choice of one of these figures for the " building-up time."

4-Wire circuits are practically free from echo disturbances with the use of echo-suppressors; the latter suppress all echo-effects which are due to compensation arrangements at the ends of the circuit. Only a portion of the echo-currents persist, these being caused by cross-talk between the " go " and " return " lines. We have premised above that the attenuation of these cross-talk currents is greater than $b = 7.5$. When they are of this value they are practically no longer perceptible. In 4-wire circuits, therefore, the phase distortion constitutes the only disturbance to transmission efficiency; this increases with the length. In this case we can, therefore, permit somewhat longer " building-up times."

In 2-wire circuits, on the other hand, the elimination of echos is not possible by simple methods. In a 2-wire circuit having n successive repeaters we have to consider n principal echo paths for the speaker and $\frac{n}{2}(n-1)$ for the listener. The listener-echo therefore increases appreciably as the length of circuit increases. The amplitude of the echo is chiefly determined by variations in the impedance of the lines. These variations are again dependent upon the distance of the frequency in question from the cut-off frequency, and, of course, they increase on the average as the cut-off frequency is approached; this is shown in Fig. **10**. It cannot generally be stated how great are the variations themselves, because they are mainly dependent upon unavoidable incidental circumstances, for example, upon the necessity of making one loading section somewhat longer or shorter than the others. In order to attain adequate reliability, the cut-off frequency f_0 must therefore be sufficiently high. The curve in Fig. **10** shows that from about $f/f_0 = 0.7 - 0.75$ upwards echo disturbances increase materially. It is, therefore, politic not to exceed this limit. In conjunction with the figures laid down above for the frequency range transmitted, this means that the cut-off frequency of 2-wire circuits should not be below 3,200 to 3,400 p.p.s. Further, on account of the additional echo disturbance the permissible " building-up time " is put somewhat lower than for 4-wire circuits. In accordance with the foregoing, 10 to 15 milliseconds for 2-wire circuits and 20 to 30 milliseconds for 4-wire circuits are regarded as suitable limiting values for the " building-up time."

The well known formula for the relation between "building-up time" and cut-off frequency serves for determining the latter itself. This relation is shown in Fig. **11**.

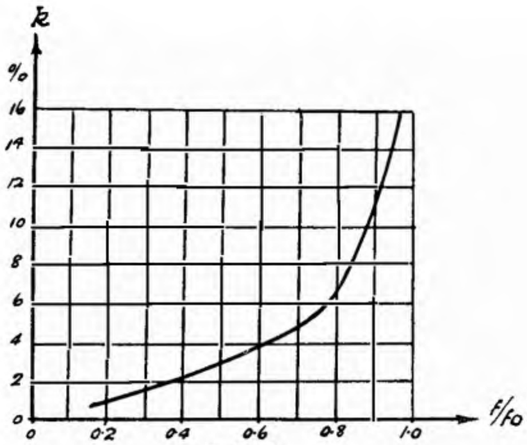

Fig. 10.

Dependence of relative echo strength, k, upon the ratio f/fo of frequency transmitted to cut-off frequency.

In this l denotes length of line, s length of loading section, f_1 the maximum frequency to be transmitted, t the "building-up time," f_0 the cut-off frequency. If, for example, $s = 2.0$ km., $f_1 = 2{,}400$ p.p.s. and t 0.01 milliseconds, and $l = 600$ km., then $\frac{l}{s\,f_1\,t} = 12.5$. and according to Fig. **11** $f_0/f_1 = 1.45$. The cut-off frequency f_0 must in this case therefore amount to 3,500 p.p.s. For a circuit 5,000 km. long $\frac{l}{s\,f_1\,t}$ would be equal to 104; therefore according to Fig. **11** $f_0/f_1 = 2.6$. The cut-off frequency must be at least $f_0 = 6{,}200$ p.p.s.

In this manner the lowest cut-off frequency, which is necessary for attaining the desired transmission efficiency, could be determined for every length of circuit. It is at once seen that such a method is not applicable in practice. We must be content to employ only a few types of circuit. How such types of circuit can be most suitably selected will be examined in the next section of this paper. In respect to distortion, we have so far considered only the so-called linear distortions. In addition to these, as is well known, transmission disturbances occur by reason of the fact that the electrical properties of the various parts of the long-distance circuits depend upon strength of current. Non-linear distortions have, however, no effect upon the questions under consideration because they can be reduced sufficiently by suitable construction of repeaters and lines.

III.—Cut-off Frequency and Repeater Section Attenuation.

If a coil-loaded circuit is to have a definite cut-off frequency and a definite attenuation, all other dimensions, for example, gauge of conductors, length of loading section, etc., must be deduced from the requirement that both these required properties shall be obtained at minimum cost. We have, therefore, first to lay down the cut-off frequency and the attenuation values between any two successive repeaters.

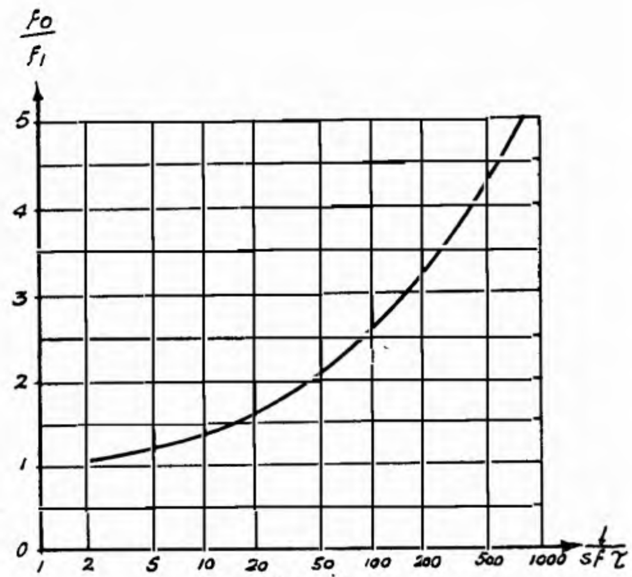

Fig. 11.

Determination of cut-off frequency.

(1) *Cut-off frequency.* On 2-wire circuits it has been stated above that the cut-off frequency should be greater than 3,200 to 3.400 p.p.s. For the greater of these two figures $f_0/f_1 = 1.42$; hence, according to Fig. **11** $\frac{l}{s\,f_1\,t} = 11$.

If we put $f_1 = 2{,}400$ p.p.s., $t = 0.01$ up to 0.015 seconds, $s = 2$ km., we obtain $l = 530$ to 800 km.

If the phantom circuits are to be brought to the same attenuation as the side circuits, we obtain a cut-off frequency of $f_0 = 4{,}200$ p.p.s., corresponding to a maximum length of circuit of 1,200 to 1,800 km. For the side circuits, therefore, we get an average range of about 650 km. and about 1,500 km. for the phantom circuits. In the present state of telephone engineering, 2-wire circuits do not enter into consideration for long distances. On the other hand, these circuits are of great practical importance by reason of the fact that they are appreciably cheaper than 4-wire circuits. It must not be overlooked that the maintenance of 2-wire circuits demands increased care and attention, and that perhaps also the uniformity obtained for new lines, on installation, cannot be fully maintained. It appears at the present time, however, that we are not justified in treating them as of less importance than 4-wire circuits. For this reason, in the foregoing paragraphs the same range of frequency has been presupposed for 2-wire circuits as for 4-wire circuits. If this frequency range is to be transmitted for the longest possible distances, it is necessary in accordance with the foregoing considerations to fix the cut-off frequency at about 3,400 p.p.s. To exceed this would only afford a slight advantage while unnecessarily increasing the cost of plant.

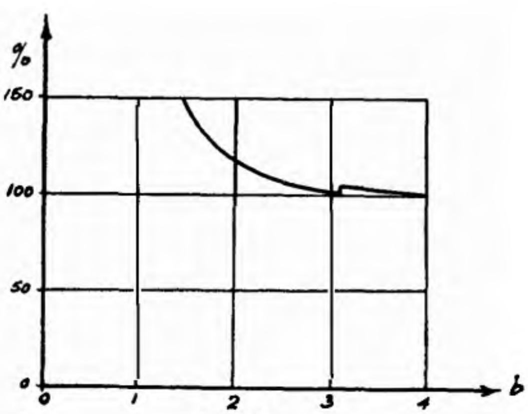

Fig. 12.
Dependence of costs of a four-wire circuit upon repeater section attenuation.

The decision in respect of 4-wire circuits is somewhat more difficult because we cannot with safety overlook the question of the lengths which mainly enter into consideration. It would meet the object in view to select two cut-off frequencies for the side-circuits; one for the maximum lengths of circuits which have to be dealt with and the other for moderate distances as has been done in Methods I. and II. recommended by the C.C.I. In these two methods of loading, the cut-off frequency for extra-light loading is selected to be of such dimensions that the length of repeater sections are half as great as with medium heavy-loading. We should recommend that this principle be adhered to, because in this manner all 4-wire circuits may have conductors of a single gauge. The ratio between cut-off frequencies of extra-light and medium-heavy loading in this case is approximately 2.1. If the maximum length is given for one of these two types of circuit up to which it is to be applicable, we can immediately calculate the cut-off frequency, because the "building-up time" is already determined. The cut-off frequency for the other type of loading is self-evident. For the phantom circuits we then obtain further 1.25 times the cut-off frequencies of the side circuits. If we regard the cut-off frequency of the side circuit in the medium-heavy loaded type as 1, we have therefore, altogether, the cut-off frequencies 1.0, 1.25, 2.0 and 2.5.

If we suppose that 2-wire circuits are employed for distances up to 600—1,000 km., we must, therefore, introduce 4-wire circuits at about 800 km. The cut-off frequencies referred to above must then be such that we can cover a distance of between 800 km., and the longest distance normally occurring. If the lowest cut-off frequency were selected at such a figure as to correspond with a range of about 800 km., almost all circuits would have to be formed of extra-light loaded lines, which are expensive. On the other hand, if the lower cut-off frequency were selected so as to correspond to a very long range, too costly lines would have to be employed for the intermediate distances. The plant and operative costs must therefore be the minimum for quite a large series of cut-off frequencies.

For what cut-off frequencies we obtain this minimum cost depends, of course, entirely upon the question of the extent to which the various lengths of circuit are used. For example, if the shorter lengths occur more frequently compared with the long distances, the cut-off frequencies must be lower than in the opposite case. In the present stage of development of long-distance telephone communication in Europe, we have little to guide us with respect to the extent to which circuits over 800 km. in length occur. It is, however, very probable that lengths up to about 1,800 to 2,000 km. occur more frequently than those of greater distances. It would therefore be politic to select the medium-heavy type of loading because it is practicable up to about these limits of distance. For this $\frac{l}{s\, f_1\, t} =$ 12 – 21, if the "building-up time" is kept at the limiting values laid down above. Fig. **11** shows in that case $f_0/f_1 = 1.45 - 1.75$ or $f_0 =$ 3,500 to 4,200. If we take the cut-off frequency $f_0 = 3{,}400$ p.p.s. for the side circuits, we have $3{,}400 \times 1.25 = 4{,}250$ p.p.s. for the phantom circuits. We would, therefore, in this case, be able easily to cover the necessary range of distance. We may therefore take the frequency 3,400 p.p.s. as the minimum cut-off frequency for both medium-heavy loaded 4-wire circuits and 2-wire circuits. Altogether we have then for 4-wire circuits, according to what has been stated above, the cut-off frequencies 3,400, 4,250, 6,800 and 8,500 p.p.s. as disposal.

(2) *Repeater Section Attenuation.* For the higher limit of attenuation between two successive 2-wire repeaters we have found (Section II.) the value $b = 1.5$. In 2-wire circuits there is generally a most favourable value for the repeater section attenuation at which reaction and echo effects are at a minimum. This most favourable value is, however, dependent upon a large number of circumstances; for example, upon the impedances of the subscribers' apparatus and lines, and upon the distribution in space of the electrical irregularities in cable circuits, so that no figure of general application can be given; it lies approximately between $b = 1.0$ and $b = 2.5$. Within this range all values of attenuation, on the average, may be regarded as electrically equivalent. Inasmuch as line costs rise as attenuation falls, we have here no reason to go appreciably below the value $b = 1.5$. In order to be sure, to some extent, of observing condition (3) we put $b = 1.4$ as the attenuation for 2-wire circuits. In 4-wire circuits the attenuation $b = 3.5$ should be regarded as the limiting value on account of the freedom from disturbance (see page 215) at the higher limits. We must here take account of the fact that in order to obtain the necessary amplifications with such an attenuation, repeaters having several stages of amplification are necessary. If the sum of the plant and operative costs of lines and repeaters is calculated, a curve is obtained for the various attenuation values, b, of the repeater section, such as shown in Fig. **12**. It will be seen in the first place how the costs fall with increasing attenuation. From $b = 3.1$ upwards an additional valve is necessary in the repeaters. We thus obtain at this point a certain increase in the total costs. It is not economical to exceed this limit. In order also to be reasonably safe we put the attenuation of 4-wire circuits at $b = 2.85$, so that finally we obtain the following general technical conditions for long distance cable circuits:—

Cut-off frequency for 2-wire circuits—
Side f_0 = 3400 p.p.s.
Phantom f_0 = 4200 p.p.s.

Cut-off frequency for 4-wire circuits—
medium-heavy—
Side f_0 = 3400 p.p.s.
Phantom f_0 = 4200 p.p.s

Cut-off frequency for 4-wire circuits—
extra-light—
Side f_0 = 6800 p.p.s.
Phantom f_0 = 8500 p.p.s.

Repeater Section attenuation:—

2-wire ... ... $b = 1.4$.
4-wire ... ... $b = 2.85$.

Transmission frequency range for all circuits:
300-2400 p.p.s.

IV.—Proposal for the Loading of Telephone Cables.

From the cut-off frequencies and repeater section attenuations all other data for telephone circuits may be calculated. If we regard, for example, the length of repeater sections, it is clear that with a given attenuation either the distances and the gauge of conductors may be made small, or long distances may be chosen and the gauge of conductors correspondingly enlarged. In the first case very many repeaters are required for a given length of circuit, and in the other case much material must be used for the conductors. For a quite definite length of repeater section there is a minimum expenditure on plant and operation. This also applies to the other data of the plant, for example, length of loading section, coil inductance, capacity of cable circuits, etc. What dimensions these data should have is a question of course to which a general answer cannot be given. The costs of construction will vary with the locality of manufacture and laying of the cable, and also with the time of year. In one country raw material is cheap and wages are high; in another country, the reverse. The cable costs largely depend upon variations in the price of raw materials. Coil and repeater costs depend, on the other hand, to a large degree upon wages; this also applies to operative costs. In the Central Laboratory of Messrs. Siemens & Halske careful calculations with respect to the most economically favourable dimensions to be given to telephone cables have been carried out on the basis of various price-ratios. With the values laid down above for cut-off frequency and repeater section attenuation, the following average figures have been obtained for lengths of repeater sections, loading sections, and gauge of conductors:—

Type of Circuit.	Gauge of Conductor. *mm.*	Length of Loading Section. *km.*	Length of Repeater Section. *km.*
4-Wire ...	0.8 – 1.0	2.0 – 2.5	90 – 110
2-Wire ...	1.2 – 14	1.5 – 2.0	100 – 110

The extent of the total costs, however, even with great deviations from these most favourable dimensions show only comparatively small variations. If, for example, the length of the repeater section is increased 50%, in which case of course all the other dimensions, corresponding to the conditions in respect of cut-off frequency and repeater section attenuation, must be changed at the same time, costs for the whole speech circuit show only a small percentage increase. This fact is important because it involves no change in regard to repeater stations already installed in most countries if the new requirements laid down above are introduced.

The calculations in accordance with which operative costs were capitalised, on the basis of 5% interest and 4.6% depreciation, showed a further appreciable difference in price between 4-wire and 2-wire circuits, and this was in favour of the latter. 2-Wire circuits, on the average, are about 25% cheaper than 4-wire circuits. This justifies the principle, laid down above, that 2-wire circuits ought to be made applicable to the longest possible distances, and brought into conformity with 4-wire circuits in respect to their electrical characteristics.

In Germany and most other countries, the average lengths of repeater section are 70 and 140 km. These distances, therefore, give with sufficient approximation the most favourable economic conditions. If they are taken as a basis, we obtain the proposal for the calculation of data for telephone cables shown in the following table here reproduced for purposes of discussion. This proposal contains the following possibilities:—

(1) In conjunction with medium-heavy loaded 4-wire circuits, circuits for compensating phase displacement can be employed. These circuits give an additional attenuation per repeater section of b = 0.1 to 0.15. The attenuation of the total line system between two repeaters is then b = 2.95 to 3.0. It lies, therefore, still within the value which can be attained without additional repeater valves. It is then, for example, possible within the range of distance determined for these circuits to increase intelligibility by reducing the "building-up times" or to extend the range of distance to all lengths which have to be dealt with.

(2) 2-Wire circuits of greater length can also be equipped with phase compensation. The conditions (3) for repeater section attenuation are not affected thereby because the phase compensation circuits themselves can be freed from cross-talk. We could therefore in this case use phase compensation circuits of greater attenuation, *i.e.*, about b = 0.2 – 0.25.

(3) For medium-heavy loaded 4-wire and 2-wire circuits identical coil inductance and identical coil impedance are presupposed, so that for this type of circuit a single type of coil can be used.

The German Post Office Administration intends in the course of this year to load a repeater section in accordance with the proposal made, so that it will be possible by means of this to study the various questions dealt with in this paper.

PROPOSAL.

Type of Circuit.	Cut-off Frequency.	Length of Repeater Section. *km.*	Cable Constants.			Coil Constants.		Average Repeater Section Attenuation. *b.f.*=800	Length of Loading Section. *km.*	Approximate Range. *km.*
			Gauge. *mm,*	Capacity. μF/*km.*	Leakance. μS/*km.*	Inductance. H.	Effective Resistance. *f* = 800			
4-Wire Medium-heavy Loaded.										
Side	3450	140	0.9	0.0335	0.8	0.140	6.0	2.85	1.7	1500
Phantom	4300	140	0.9	0.054	1.4	0.056	2.5	2.85	1.7	3000
4-Wire Extra-light Loaded.										
Side	7700	70	0.9	0.0335	0.8	0.030	1.5	2.8	1.7	6000
Phantom	9300	70	0.9	0.054	1.4	0.012	0.6	2.8	1.7	6000
2-Wire Medium-heavy Loaded.										
Side	3400	140	1.4	0.0355	0.8	0.140	6.0	1.4	1.7	700
Phantom	4300	140	1.4	0.0575	1.4	0.056	2.5	1.4	1.7	1100
4-Wire with phase compensation	3450	140	0.9			0.140	6.0	3.0	1.7	6000
2-Wire with phase compensation	3400	140	1.4			0.140	2.5	1.65	1.7	1100

NOTES & COMMENTS

THE following extract from "The Times" report of the general meeting of W. T. Henley's Telegraph Works, Ltd., held on the 1st July under the presidency of Sir George Sutton, M.I.E.E., Chairman of the Company, may prove of general interest:—

"TELEPHONE CABLES.

"In my reference to the expenditure on capital account, I referred to one new building for which employment might be far to seek. I had in mind a fine new building and plant we have put down to enable us to increase our output of telephone cables. We are disappointed at the small amount of work we get for these cables. We relied upon the Post Office developing rapidly the use of the telephone in this country, and it was a duty for us to provide for the demand we expected they would make upon us.

"How often have I heard abroad that as an engineering proposition there was nothing in the world to surpass the system constructed by our Post Office engineers, and yet we are so far behind other countries in developing the commercial side. What we want is that the Treasury should realise that if they cast their bread upon the waters it will return to them after many days, and not very many days at that."

Even allowing for the zeal of the canvasser in pressing the sale of his wares, we must admit there is some cause for the plaint of Sir George. One can quite understand the need for reducing the enormous annual expenditure to which the country has been committed since the war, but it is not quite so clear why the issue of capital to be used in remunerative work should be curtailed. A study of the commercial reports of the Postmaster-General for the past few years will show that in addition to paying interest on capital and on maintenance and replacement charges—which are equivalent to the dividends earned by a private company—considerable profits have been secured from the operation of the public telephone service. It is true the main underground trunk networks have practically been completed, but the traffic is rapidly overhauling the plant equipment and there are still important areas to which the benefit of a stable trunk cable service is denied. The Department is committed to considerable expenditure in connection with the conversion of the London area to automatic working—which incidentally involves the laying down of much new underground cable plant and the diversion of many junction routes—but in spite of this it is considered unwise economy to limit the issue of capital in lean commercial years, which as far as can be foreseen is almost certain to bring in a fair and ample return. Work in cable factories reacts on many other industries, and operates to the general well-being of the community.

We cannot pass from the subject matter of the above extract without thanking the Chairman for his meed of praise for the work done by the P.O. Engineering Department. A statement like this goes far towards assuaging the disgruntled feelings produced by the many cheap and flippant comments in the lay press.

PROFESSIONAL TECHNICAL COURSES AT THE PARIS TRAINING CENTRE.

M. Suchet, Engineer of the French Administration of Posts and Telegraphs, describes in "Annales des Postes Telegraphes et Telephones," of July, pp. 597-611, the technical courses given at Les Ateliers du Boulevarde Brune, Paris, to the various grades of officials. The classes cover Line Construction in all its varied branches, and maintenance of all kinds of telegraph and telephone apparatus, including automatic telephones. Practical instruction is given to pupils of the "Ecole superieure" as well as to Junior mechanics and linemen. The professors and instructors number 35 and deal with some 500 pupils a year. A detailed description of each course with photographs of the pupils at work is given.

TESTS OF THE BAUDOT-VERDAN RADIO APPARATUS.

A description of this very ingenious adaptation of the Baudot telegraph system for dealing with Radio work when atmospherics are causing difficulties was given in "Annales des Postes Telegraphes et Telephones," in 1925, p. 645. There is now published in the same journal in the July issue of this year, pp. 562-581, a detailed description of tests made between Paris and Tananarivo, Madagascar, in September, 1926, with a Baudot Triple set. A short description with diagrams of the arrangements used is given as well as photographs of the printed signals which were recorded on the Baudot apparatus. Messages were received when Morse working was totally interrupted due to a thunderstorm near the receiving station. A comparison is then made of the advantages of the 5-unit code over the Morse, and the Telautograph methods for Radio work. A concluding note emphasises the facility with which "Unison" between the two Distributors at Paris and Tananarivo was maintained.

ROTTERDAM MUNICIPAL TELEPHONE SERVICE.

In the January, 1927, number of this Journal some data were quoted from the Annual Report for 1925 of the Rotterdam Municipal Telephone Service. The Annual Report for 1926 has now been received and it may be of interest to consider the progress of the system during the past year.

The total number of lines on the 31st December, 1926, was 19,752—an increase of 949 during the year. Of the three exchanges, Botersloot, with 12,552 subscribers, is still manual, but Vlaggemansstraat, with 2,916 subscribers, is now completely automatic, while of the 4,284 subscribers on Thorenaarstraat, 2,389 are full automatic. It is expected that the conversion of Botersloot to full automatic working will take place during 1928.

The automatic plant continues to fulfil expectations, and again it is recorded that no serious fault has occurred.

Local traffic increased during the year by 9%, but, on the other hand, traffic with other cities diminished by 3.5%.

From our point of view, the large increase of traffic from England—from 42,195 to 57,544 calls is very gratifying. As would be expected, however, the bulk of the foreign traffic is with Germany (280,940 calls) and Belgium (125,115 calls). France is a bad fourth with 3,963 calls.

Subscribers' complaints averaged 3.32 per subscriber per year, as against 3.40 in 1925 and 3.60 in 1924. Actual faults, however, were only 2.33, as against 2.36 in 1925 and 2.54 in 1924.

The profit on the year's working amounted to nearly 918,000 florins.

Mr. R. A. Dalzell, C.B., C.B.E., Director of Telegraph and Telephone Services, has retired after forty-seven very active years of service. He was the first occupant of the post of Director and he has set a very high standard for his successors to follow. In the N.T. Company's administration the district manager was also the engineer—or should we not rather say the engineer was also district manager? In both these capacities Mr Dalzell secured valuable experience and displayed conspicuous energy and ability, and from 1905 until the Company was taken over he was Provincial Superintendent of the Western Province. The administration in the G.P.O. North speedily recognised the practical value of Mr. Dalzell's wide knowledge of the requirements of the service, from the administrative, engineering, and even the subscribers' view points, and it was only fitting that when the demand arose in 1922 for a commercial manager for the telegraphs and telephones the Postmaster-General should turn to his Chief Inspector of Traffic, who possessed the necessary qualifications for the post. Although sixty-two years old, Mr. Dalzell is full of vigour and he retires with the best wishes of everyone he came into contact with for a long spell of good health and happiness.

John Lee has also gone. His career is dealt with elsewhere in this Journal. A charming personality, debonair and witty, with a wide and sympathetic knowledge of men and things, he achieved wonderful results in the C.T.O., which used to be a notoriously difficult place to handle, and his successor, Mr. J Stuart Jones, will find the way much smoother than it otherwise would have been had not an administrator like John Lee first occupied the controller's chair. We offer now our best thanks to Mr. Lee for the many courtesies and services he so willingly rendered to us, and a message of congratulation to his successor.

The following letter from Colonel Clay is interesting to our present day telephone engineers. It gives a good instance of the initiative and resource of the old-time Company's men. We leave it to our readers to find the name of the manager who was so conveniently lost for a time.

Hurst,
Sundridge Avenue,
Bromley, Kent.
25th July, 1927.

THE EDITOR, *Post Office Electrical Engineers' Journal*.

Dear Sir,

In your Journal for April Mr. Shea shows several interesting ancient line structures. A few notes on the Sunderland one may be of interest. I do not remember the cost or by whom it was built, but the circumstances were that the Company were restricted to a wooden structure. There was no chance of staying otherwise than on the one house. The previous structure was on similar lines but not properly braced, and although it had only been erected five or six years it was unsafe.

To *get leave* to erect a new structure was hopeless. This new one was erected in the road where it was made; every piece numbered and taken down. Then the manager went away and left no address. His deputy, Mr. G. F. Preston, was requested to get the old structure down and the new one erected in the shortest possible time and not to let anything stop the work. This he certainly did.

The owner's solicitor was soon at the office asking for the manager, who, however, could not be found. The solicitor said the work must be stopped. Mr. Preston had other views; it was not safe to do so. The work was completed by the time the manager returned, or perhaps it would be more correct to say the manager returned when the work was completed and had a very hot time. He will never forget the interview with the owner's solicitor, but, as your illustration shows, the structure remained sound to the end.

It was designed by a local architect under instructions from Mr. Preston and myself. The fact that it did its work for forty years and was only removed because it was no longer required shows, as Mr. Shea says, "It was built like a rock."

Yours truly,
C. B. CLAY, Lt.-Col

THE LATE MR. W. H. WINNY.

The following description of the funeral of the late Mr. W. H. Winny is taken from the "Daily Telegraph" of the 6th June:—

The funeral of Mr. W. Humphris Winny, O.B.E., Knight of Grace, late Commissioner of the No 1 (Prince of Wales) District of the St. John Ambulance Brigade, took place on Saturday at the City of London Cemetery, Ilford. The first part of the service was held at St. Paul's, Camden Square, N.W.

In addition to the members of the family and a large number of the No. 1 District, the congregation included Major-General Sir Percival Wilkinson, representing the Order; Chief Superintendent R. J. Halford, representing the City Police; Mr. Dundas Grant, representing the G.P.O.; Colonel Moore, representing the Chief Commissioner of the St. John Ambulance Brigade; Major Darvil-Smith, representing the Brigade Headquarters; and Sir Dundas Grant, a great personal friend. A guard of honour was formed by the members of the No. 1 District. The new Commissioner, Lieut.-Colonel F. A. Brooks, who read the Lesson; his Assistant Commissioners, Dr. MacFadden, Dr. N. Corbet Fletcher, Dr. G. W. Kendall, the District Surgeon, Dr. R. Connon Robertson, and his District Staff acted as pall-bearers. District Officer S. J. Warren carried the late chief's decorations on a cushion.

In addition to the family wreaths there were wreaths from No. 1 District, from the Venerable Order, from Mrs. Lancelot Dent, Lady Superintendent of Brigade Overseas, from his colleagues in the Post Office Engineering Department, from Sir James Dundas Grant, and many others.

Mr. Winny was a fine chemist and was for several years in charge of the testing laboratory at Mount Pleasant. He became an Assistant Staff Engineer by examination and was attached to the Test Section. For many years he was on the teaching staff of the Northampton Polytechnic Institute. He rendered very valuable services during the air raids on London during the war and was awarded the order of Officer of the British Empire for his work with the St. John Ambulance organisation.

HEADQUARTERS NOTES.

EXCHANGE DEVELOPMENTS.

The following works have been completed:—

Exchange.	Type.	No. of Lines.
Wakefield	New Auto.	945
Sandal	,,	250
Llandudno	,,	1140
Colwyn Bay	,,	1220
Sheffield Central	,,	6300
Beauchief	,,	800
Owlerton	,,	800
Sharrow	,,	1500
Broughty Ferry	Auto. Extn.	275
Dundee	,,	915
Ecclesfield	,,	90
Torquay	,,	300
Govan	New. Manual	660
Walton-on-Thames	,,	1040
Doncaster	Manual Extn.	340
Rusholme	,,	460
Wimbledon	,,	1820
Birmingham Test Deck	,,	—
Bradford	,,	560
Reigate	,,	800
Worcester	,,	720
Buckhurst	,,	480
Cambridge	,,	420
Harrow	,,	1530
Bristol Corporation	P.A.B.X.	90
Lipton Ltd.	,,	100
Asquith Ltd.	,,	30
Dunlop Rubber Co.	,,	80
Middlesbro Co-op. Society	,,	50
Plymouth Corporation	,,	210
Shell Mex Ltd., Strand	P.A.B.X. Extn.	40
Butler & Co.	P.A.B.X.	30
Accles & Pollock	,,	50
Liverpool Warehousing	,,	60
Royal Berks Hospital	,,	50
W. Goodyear & Sons	,,	30
E. S. & A. Robinson	P.A.B.X. Extn.	—

Orders have been placed for the following new Exchanges:—

Exchange.	Type.	No. of Lines.
Archway	Auto.	3200
Southend	,,	3040
Gt. Wakering	,,	300
Hadleigh	,,	420
Leigh-on-Sea	,,	1950
Marine	,,	1430
Rochford	,,	175
Thorpe Bay	,,	760
Hillside Park	,,	2400
Reliance	,,	2700
Croydon M.F.	,,	—
Maida Vale	,,	7500
Cowley	,,	200
Headington	,,	200
Summertown	,,	600
Haxby	,,	85
Temple Bar	,,	7900
Langham	,,	8050
Dringhouses	,,	180
Liverpool Observation Desk	Manual.	—
Upminster	,,	440
Chigwell	,,	520
Ambassador	,,	2000
African & Eastern Corporation	P.A.B.X.	60
Barrow Corporation	,,	40
Brinton & Sons	,,	40
Waring & Gillow	,,	170
Meccano Ltd.	,,	50
British Electrical Federation	,,	80
Steel Nut & Hampton	,,	30
Pendleton Co.-op. Society	,,	30
Shell Mex Ltd., Weaste	,,	20
Reading Co-op. Society	,,	20
Electra House Ltd.	,,	230
Shell Mex Ltd., Aberdeen	,,	20
Midland Bank, Piccadilly	,,	40
Nelson Co.-op. Society	,,	6
Ocean Coal Co.	,,	10
Shropshire Power Co.	,,	40
Wood Green Council	,,	40

Orders have been placed for extensions to existing equipments as follows:—

Exchange.	Type.	No. of Lines.
York	Auto.	465
Giffnock	Manual.	800
Belfast Relief	,,	—
Berkhamsted	,,	580
Cambuslang	Manual	280
Bristol Relief	,,	1700
Sale	,,	420
Salisbury	,,	460
Windsor	,,	300
E.S. & A. Robinson	P.A.B.X.	—
Daily News	,,	30

LONDON DISTRICT NOTES.

During the quarter ended 30th June, 1927, the nett increases in the number of Exchange Lines, Extensions, and Stations respectively were—4993, 5220 and 8414.

Mileage Statistics.

The following changes have occurred during the June quarter:—

Telegraphs.—A nett decrease in open wire of 4 miles and a nett increase in underground of 84 miles.

Telephones (Exchange).—A nett decrease of open wire (including Aerial Cable) of 23 miles, and a nett increase in underground of 72,892 miles.

Telephones (Trunk).—A nett increase in open wire of 42 miles, and in underground of 309 miles.

Pole Line.—A nett increase of 63 miles, the total to date being 5,728 miles.

Pipe Line.—A nett increase of 333 miles, the total to date being 8,887 miles.

The total single wire mileages at the end of the period under review were:—

Telegraphs	24,689
Telephones (Exchanges) ...	2,062,444
Telephones (Trunk) ...	66,658
Spares	129,849

Internal Construction.

The Extension at Reigate Exchange, which was commenced on 13th April, was completed on the 30th July and proposals are now in hand to instal a new suite of Boards (22 positions) to extend to the full capacity of 2,780.

An extension at Harrow Exchange by 1,100 locals plus 3,000 Multiple has been completed and brought into use on August 10th.

Work is proceeding on the Automatic Exchanges at Holborn, Bishopsgate, Sloane, Western, Bermondsey and Monument. The former is practically completed and hopes are entertained of this Exchange being ready in October or November.

New Exchanges for Barnes (to be named Prospect), Merstham and Hatch End are in course of installation.

General.

Tandem Exchange.—On August 18th there occurred what must be regarded as one of the most outstanding events in the history of the Telephone. This event was the opening for public service of the new Tandem Exchange. Widespread interest has been aroused in connection with this exchange. A full description appears elsewhere in this issue.

During the two months preceding the opening the apparatus was subjected to the most rigorous tests; over one million calls were passed under "artificial traffic" conditions; routine testing was also carried out daily at all exchanges.

On the opening day the utmost interest was displayed by all concerned and the results watched with great care by Engineers and Traffic Officers alike. The opening of Tandem is the preliminary step to the conversion of the London area to automatic conditions and if the subsequent changes from the manual to the automatic system are equally satisfactory there is no doubt that the capital of the Empire will be provided with a telephone system which will rank second to none.

MR. THOMAS PLUMMER, M.I.E.E.

MR. T. PLUMMER.

By the retirement of Thomas Plummer, or "T.P." as his intimates preferred to call him, at the end of July, the Engineering Department has lost an outstanding personality and one who was devoted to it. His association with the Post Office may be said to have commenced at birth, his mother having been a Head Postmistress.

Born at New Ross, Co. Wexford, he was educated at Pocock College, Kilkenny, where he gained a scholarship tenable for three years, followed by another for one year at Santry School, Co. Dublin. He early developed a leaning towards science and obtained certificates in the advanced stage of Physics and Mathematics.

After a short period on the Postal side he entered the Engineering Department at Cork in August, 1885, as a Junior Clerk in the office of Mr. H. Pomeroy, then Superintending Engineer of the Southern Ireland District. As there were only three clerks in the office the training was of an all-round character. His interest in technical telegraphy was aroused, and in 1886 he was awarded the City and Guilds Bronze Medal and £5 prize in the Honours Stage of Telegraphy. At a later date, when Telephony had become a separate subject, he added to his previous success the Silver Medal and £5 prize with First Class Honours in that subject; he also took similar honours in Electric Lighting and Power and Electro-Metallurgy.

His promotion to a Second-Class Engineership came in 1893, and three years later he was selected by the Engineer-in-Chief to assist in the transfer of the Trunk Telephone Service from the late N.T. Company to the Post Office. He was so engaged at Sheffield, Glasgow and Blackburn; and for a time was attached to the old N.W. District at Manchester to supervise the fitting of new Trunk equipment in most of the towns in that District.

Promoted to a First Class Engineership in 1897, he served under the late Mr. M. Cooper in the Telephone Section at Headquarters, where he took an active part in the development of the Post Office telephone service in London and the Provinces. Further promotion to Second Class Technical Officer came in 1900, and a few years later (1906) in accordance with the policy at that time which required Headquarters officers to obtain provincial experience, his activities were transferred to Liverpool as Assistant to Sir William Slingo, Superintending Engineer of the N. Wales District, whom he eventually succeeded in 1911.

A rearrangement of Districts led to Shrewsbury becoming the headquarters of the District. Liverpool and its environs passed to the S. Lancs. District, and North Wales absorbed a portion of the old S. Midland District, including Birmingham, the Black Country and The Potteries.

His long association with the N. Wales District gave him an intimate knowledge of its staff and affairs which was not surpassed, and which impressed all who had occasion to discuss them with him.

His membership of the Superintending Engineers Advisory Committee since 1913 entailed a detailed knowledge of many and diverse details of everyday work, and his close application to these was at once an inspiration and an example. In the midst of his many activities he was never too busy to examine any matter placed before him.

As Chairman of the N. Wales Branch of the

I.P.O.E.E. his active personal interest was largely responsible for the well-attended meetings and the high percentage of its membership. He was rarely absent from a meeting, took a leading part in the discussions and himself contributed many interesting papers.

His membership of the I.E.E. extended over thirty years, and he served on the Committee of the Birmingham Local Centre, acted as Vice-Chairman and was prevented from accepting the Chairmanship only by residence in Shrewsbury.

In spite of these pre-occupations he had numerous outside interests, being on the Committee of the Shropshire Philosophical Society and also its Chairman for a session. The local Radio Society also claimed his attention and services as Chairman.

Rowing and "Rugger" were his relaxations in earlier years, and they typify the vigour of his later years. To the day of retirement he was an active cyclist, undeterred by any weather.

The leisure which retirement affords will doubtless enable him to enjoy fully his membership of the Caradoc Field Club, which caters for the geologist, the botanist and the archæologist in the beautiful country around Shrewsbury where he will continue to reside. His many friends hope that these pursuits may enable him to regain the sound physical health which he had enjoyed until recently. B. J. GILL.

EDWIN JOHN ELDRIDGE, M.I.E.E.

MR. E. J. ELDRIDGE.

MR. E. J. ELDRIDGE, Superintending Engineer of the South Western District, retired on the 30th September, 1927, after completing 40 years' service.

Mr. Eldridge commenced his career in July, 1881, as a telegraphist in the Central Telegraph Office, where he remained 4 years, passing thence to the Registry Branch of the Secretary's Office, and, subsequently, in 1887 became a Junior Clerk in the Engineering Department. From this time onwards he rose successively through the ranks of Engineer, Technical Officer, Asst. Superintending Engineer to Staff Engineer, and in 1911 he became Superintending Engineer of the North Midland District. In 1915 he went to the South Western District headquarters at Bristol, where he remained until the date of his retirement.

About 1893, when relieving the engineer of the Western District of London, Mr. Eldridge was associated with an American engineer in carrying out experiments with the "Telautograph" between the Engineer-in-Chief's Office and the W.D.O. Four wires were then in use for the purpose, but reasonably satisfactory results were obtained only as long as an expert was in attendance.

One instance of the difference between the past and present day methods is exemplified by the following narrative, which Mr. Eldridge relates with much interest. As a 2nd Class Engineer he was deputed to overhaul the Metropolitan Police System (then an A.B.C. installation). At Woodford Police Station he found that repairs to the keys of the transmitters had been carried out in a very crude manner and he asked for the name of the lineman who had done the work. The Inspector in charge of the station replied:—"We never trouble the lineman. If anything goes wrong we get the potman from the Pub. over the road to come across and put things right!"

He undertook, among many other special duties while in the London District, the first change-over in TS. from primary to secondary cell working, and in Oct., 1898, in association with the late Mr. J. Leyshon (affectionately known as " Uncle " by all who knew him), was employed under the late Sir (then Mr.) John Gavey in making what was then described as a telephone survey of London, together with the preparation of estimates, paving schedules, reports, etc, for the Secretary. During the progress of the works were authorised subsequent to the survey, difficulties arose in the supply of stores in sufficient quantity to carry out the work expeditiously, and Mr. Eldridge was appointed by Mr Gavey to act with the late Mr. W. H. Allen—representing the Controller of Stores—to determine the orders to be placed, the rates of delivery, etc.

In June, 1905, he was called upon by Mr. J. Gavey to prepare for him, in readiness for the evidence he was to give before the House of Commons Committee, an estimate of the valuation of the National Telephone Company's plant which was to be acquired by the Department in 1912. Ducts, cables, switchboards, subs. apparatus, open wires and buildings were to be valued separately, and as only a week was available for the purpose, neither Mr. Eldridge nor Mr. A. E. Chandler, who assisted him, found the time hanging on their hands!

The amount arrived at was £13,270,125.

Some 7 years later, after a very detailed valuation, the Arbitrators assessed the replacement value at £13,059,827, with a depreciated value of £12,515,264. Each set of figures excluded the Private Wire business of the Company, which was dealt with independently. Such a close approximation as that arrived at by Mr. Eldridge was undoubtedly a very satisfactory forecast, and must have been of great assistance to the then Engineer-in-Chief during the detailed investigations carried out prior to the arbitration proceedings.

After spending 4 years as Asst. Superintending Engineer in the North Metropolitan District, Mr. Eldridge returned to Headquarters in April, 1909, as Staff Engineer. During his stay at Headquarters he was for some weeks, consequent on the illness of the Superintending Engineer, Mr. E. Catley, in charge of both the North Metropolitan District and the Headquarter Construction Section, spending the forenoon in the former and the afternoon at Headquarters.

In January, 1911, Mr. Eldridge was appointed Superintending Engineer and from this date until the date of his retirement he remained in the Provinces.

During the War Mr. Eldridge's unflagging activity found wide scope owing to the heavy demands of naval and military requirements in the District.

In addition, in 1916 he was connected with the hurried provision of the Repeater Station at Penzance. The Imperial Cable connecting Halifax, Nova Scotia, with Penzance and London was formed by means of an ex-German Atlantic cable, and within six weeks of the necessity for the Repeater Station at Penzance becoming known the Office had been established, and the underground cable connecting Penzance with Mousehole—a distance of 3½ miles—completed, the latter being the landing place of the submarine cable. The Repeater Station premises (then a billiard room) were required under D.O.R.A., were adapted and equipped and a fisherman's unroofed shed or tank was made suitable for a Cable Hut, and utilised accordingly.

The interests and activities of Mr. Eldridge was not confined to service organisations. Outside the Service he is well known and held in high esteem, and among his varied interests outside official life are the following:—

- Fellow of the Royal Colonial Institute and Member of Council, Bristol Branch.
- Member of Committee of Institute of Electrical Engineers (Western Area).
- President of both West of England (Civil Service) Bowling Association and Bowling Club.

He is fond of gardening and has recently taken to golf, and with his usual cheery optimism is looking forward to reaching championship form in the near future.

Time has dealt kindly with him and he retires full of vigour and in good health. His retirement was a matter of regret to all who served under him, and it is the wish of his many friends both inside and outside the Service that he may live many years to enjoy his freedom from official cares.

A.E.C.

JOHN LEE.

John Lee entered the Liverpool Post Office in 1883. His first appointment was on the Telegraph side, but he became associated with the working of the trunk telephone lines at Liverpool on their acquisition by the State in 1896. In his new work he lost no opportunity of personal discussion with subscribers, and in this way he acquired an insight into the public attitude not only towards the new service but also to Government control in general This was of particular value to a man who, as time went on, developed an ever-increasing interest in the problems of Public Administration.

In 1906, Lee became Chief Clerk at the Birkenhead Post Office, but this was regarded generally as a provisional appointment and his promotion in the following year to one of the new Assistant Traffic Managerships at Headquarters created no surprise. The new work afforded great scope to a man of Lee's ability. The trunk telephone system had from the first grown very rapidly, but the opening of Local Exchanges by the Post Office in London and elsewhere as the result of the recommendations of the House of Commons Committee of 1898 gave it a remarkable impetus. Little research work on the traffic aspects of long distance working could, however, be carried out until an expert body had been created at Headquarters to co-ordinate the studies which were being made in the Trunk Exchanges up and down the country.

In 1909, John Lee was sent to India to advise on the working of the Railway Telegraph System, and in 1911 he went to the United States, in company with Colonel Purves, Luart Jones and the late A. W. Martin, to study and report on the working of the American telephone system.

In September, 1911, he became Telegraph Traffic Manager, in April, 1916, Deputy Chief Inspector of the reorganised Telegraph and Telephone Traffic Section at Headquarters, in 1917, Postmaster of Belfast and finally, in 1919, Controller of the Central Telegraph Office in London.

Of special tasks, John Lee had his full share. Some have already been mentioned. In 1917, he was largely responsible for the arrangements for the employment of women telegraphists and telephonists on the lines of communication in France, in 1920 he attended the Paris Conference in connection with the restoration of European communications, and in 1925 he was appointed Head of the British Delegation to the International Telegraph Conference at Paris. His task at the latter was particularly exacting, as he was nominated as President of the important Règlement Committee. The Conference had not met for 17 years and after war economic conditions had created problems the solution of which needed more than ordinary ability. John Lee carried out his task with striking success. There was no more popular man at the Conference and at the termination of the work of his Committee he was given a reception which no one present will easily forget.

As an office chief John Lee has had few equals in the Post Office. He has a genius for leadership. No one has tried more earnestly to make Whitleyism a success. It has always been his endeavour to carry his staff with him even in minor changes. He is not one of the "strong silent" men about whom many people cherish romantic illusions. He positively revels in discussion. His first move when anything special was in hand was, not to bar himself in his room and indulge in hard thinking, but to get together all those concerned and start a sort of communal thinking aloud. Presided over by a man with Lee's wealth of ideas and extraordinary quickness of perception, such meetings could be remarkably effective, as those who served under him at Paris in 1925 can testify. He did not lose sight of the educational value of committee work to the more junior men, whom he frequently appointed to serve on the committees he set up in his own office.

John Lee has always had many interests outside the official world. He is a keen Churchman and a lecturer and writer on many subjects. A man with the widest sympathies, he has interested himself extensively in Industrial Welfare and has acted as Chairman of several conferences on the subject.

Shortly before his retirement, Lee became seriously unwell, but the latest news of his health is reassuring and there is every reason to hope that he will be able to continue some at any rate of his activities of the past, in addition to his new responsibility as a Director of the Automatic Telephone Company and its associated concerns.

H.G.T.

G. F. MANSBRIDGE.

MR. G. F. MANSBRIDGE.

THE following bald statement of facts extracted from "Who's Who in Engineering" gives a record of the career of one who, although never actually in the Engineering Department, is endowed to his finger tips with the instinct and spirit of the engineer and is perhaps one of the best known P.O. men in engineering circles outside the service:—

George Frederick Mansbridge, O.B.E., M.I.E.E., M.Soc.C.E. (France): Vice Controller, Stores Department, G.P.O. since 1924; born 1867; educated at the Haberdashers Schools; some time assistant to Prof. Daniell; assistant to Sir Wm. Slingo, science school, C.T.O.; in charge Test, C.T.O. Land lines 1887-91 and Submarine Cables 1892-4; Chief of Testing Department (Materials) 1895-1902; Assistant Supt. and Supt. Telegraph Factories 1903-13; Assistant Controller, P.O. Stores Department 1914-24; Principal of Electrical Engineering Department, Croydon Polytechnic 1897-1916; Triple Medallist Electro-Technology; Patentee Static Condensers, Inductance Standards, Cables, etc.; Consulting Engineer to Mansbridge Condenser Co. Ltd.

It is perhaps in connection with the invention of the paper foil condenser that Mr. Mansbridge's name is usually associated, but that far-reaching innovation was only one episode in a very busy official life. The Mansbridge condenser was brought into the world a little too soon from one point of view since the patent rights had expired before the popular arrival of broadcasting, which opened an enormous field for the use of condensers. Nevertheless, the new process of manufacture was adopted quickly throughout the world under the fostering care of the earliest licencees—The Western Electric Coy. and the British Insulated and Helsby Co.—and prices for paper condensers came tumbling down to about a quarter of their previous figures. Another piece of apparatus, now widely used as a tuner in radio sets, especially in America, and called erroneously a variometer, was introduced first by Mr. Mansbridge in his "Variable standard of Self-Induction," and here again his product was ready before the big market had developed.

One portion of his work Mr. Mansbridge looks back upon with a justified degree of satisfaction—for the whole business was a labour of love with him—was in connection with the vocational and general education of working lads. It may be of interest to mention that the work done at the P.O. factories stimulated the educational authorities to embark on similar schemes, and that the Holloway Factory workshop allocated for this purpose was reproduced by the L.C.C. in their advertising posters as an illustration of what could be and was being done, though of course without disclosing the origin.

Mr. Mansbridge is so much younger than his years, busy years though they were, that he cannot now sit down quietly and take his ease.

He is, we understand, joining the board of the Phœnix Telephone and Electric Works Ltd.

On the 1st September he was presented with a silver cigar cabinet and a silver rose bowl for Mrs. Mansbridge by his colleagues in the Stores and other departments. The presentation was made by Mr. Sparks, Controller, before a large gathering at Bedford Street. Congratulatory and reminiscent speeches were delivered by representative men from the Stores and Factories, and Mr. S. A. Pollock testified to the esteem in which he was held by the Engineering Department. A letter of regret from Col. Purves for his unavoidable absence was read. Mr. Mansbridge made a characteristic reply, and Mrs. Mansbridge in a short charming speech said she was glad in one sense that her husband had retired as she was confident and hopeful she would now have him longer at home than he had been during his official career.

LOCAL CENTRE NOTES.

[*The following notes were received too late for inclusion in the July issue.*—EDS., *P.O.E.E.J.*]

SOUTH MIDLAND CENTRE.

On the 23rd February, 1927, Major E. C. Harris read his paper on "The Training of Inspectors," and dwelt upon the numerous qualifications and essentials of a good Inspector.

In opening the discussion Mr. Roach mentioned the courage required to read such a paper. It seemed to him, however, to be largely advice to aspirants and to set forth ideals. He agreed with what had been said, but would prefer to take the Secretarial files as a standard for reports rather than Macaulay as advocated by Major Harris. Mr. Roach regarded the particular weakness of Inspectors to be in their dealing with Wayleaves; he suggested preparedness as an essential and mentioned the importance of prompt transport.

Mr. Gilpin enquired regarding Advice Notes and the limit of £100 and also the division between "C.S." work and development.

Mr. Bolton asked whether the proposals were actual requirements or were just pious aspirations. Mr. Cook's remarks were mostly criticism. He failed to see any particular method of training in the paper, but regarded it rather as notes for would-be Inspectors. The present system put the onus on the man who adopted a "trial and error" method and he was often left without guidance. The Inspector's job was a difficult one, it embraced a great variety of subjects and required agility of mind. He recommended the study of mathematics as a very suitable means of mind training. He also enquired as to the means of edifying the skilled workmen whom he divided into two types—those who sought advancement and those who would not be bothered. He advocated a course for selected workmen similar to that now given to probationary Inspectors and also the holding of round table conferences to which difficulties could be discussed and advice given.

Mr. Lewis was anxious with regard to the treatment of new entrants. He regarded the present "Youth-in-Training" system as unsound, inasmuch as educated youths were employed haphazardly for some time and there was a danger of the benefit of their academic education being lost. They were not being trained at present and he advocated a system similar to that adopted in the Admiralty Dockyards where during the first four years of their service the apprentices were employed half time on practical work and half on theoretical training. The system, he contended, had produced many Whitworth Scholars.

Mr. Gravill congratulated the lecturer, but regarded the paper as a statement of the duties of an Inspector and of his qualifications before appointment. The question of how they were to be trained was still unanswered and he suggested attaching them to a skilled officer for six weeks where they would have easy access to the regulations, deal with the correspondence and see the execution of works. He was also disappointed with the present system of training youths and emphasised the importance of tuition on internal work, the care of motor vehicles, the systems of loose-leaf diagrams, cable records, and Inspectors' duties generally. Mr. T. Martin also congratulated the speaker and enquired as to the avenues for the advancement of

Draughtsmen to the Inspectors' class. He considered that experience as Draughtsmen made them very suitable for development work. Mr. Pendry enquired regarding the use of Technical Instructions and forms and also of credit for Engineering work. He hoped for a paper on these lines.

Major Harris suitably replied to the speakers and the meeting concluded with a vote of thanks to him.

At the meeting held on the 30th March the Chairman presented a cheque and a certificate to Mr. F. V. Padgham of Guildford, awarded for his essay. "Transmission Testing Sets," and a certificate of merit to Mr. N. V. Knight for an essay entitled, "Automatic Exchanges—Non-Director Areas." In congratulating the winners, the Chairman expressed his pleasure that the prestige of the South Midland District had been maintained in the 1926-27 competition.

Mr. S. Moody read a paper "Advice Notes."

The steps which it was necessary to take immediately after an A.N. is received were stated and Mr. Moody made suggestions which, it was claimed, would shorten the period between the enquiry for telephone service and (if an agreement is signed the receipt by the Inspector of instructions to proceed. An amendment to the W.I. forms was also proposed.

The author was of the opinion that unnecessary records were sometimes kept in local offices.

The question of making a survey in the case of smaller works was investigated at some length and definite suggestions were made in this connection and a new type of survey form proposed.

Mr. Moody ended with a promise that the execution of the work would form the subject of another paper.

Messrs. Dwyer, Wakefield, Mullens, Gilpin, Beaumont, Halton and H. W. Peck took part in the very interesting discussion and the Chairman thanked the author for his efforts.

The latter part of the meeting was devoted to a paper: "Advice Note work from an Engineering point of view," given by Mr. W. L. Taylor.

After describing an A.N., the necessity for promptitude in carrying out the work was stressed, particular attention being given to the negotiation of wayleaves, adequacy of staff and supply of stores.

Mr. Taylor passed on to demonstrate the importance of preventing annoyance to a Subscriber by giving close attention to details of the work required for his connection. A plea that development schemes should be extended to overhead plant and not confined to proposals for underground conductors was put in and the author did not agree that the work of preparing development studies should be transferred from the District Managers to the Engineering Department.

Proposals to convert the Ford vans into carriers of light poles and also alteration of a method of leading-in were explained.

Points to be watched when running internal wires were set out and the paper ended with three maxims.

Various items for discussion were initiated by Messrs. Halton, Dwyer, Capt. Linsell, Messrs. Beaumont, Bolton and the Vice-Chairman, and the last mentioned thanked Mr. W. L. Taylor in the name of the audience.

At the final meeting of the 1926-27 Session, which took place on the 27th April, Mr. P. J. Campbell lectured on "Power Plant, Acceptance Testing." The paper covered the tests applied to apparatus, machines, oil engines, and secondary cells installed in telephone exchanges.

The voltmeters, ammeters, watt-hour meters, circuit breakers and motor starters were in turn described and the precautions which should be taken in using those instruments were given in some detail.

D.C. charging motor generators were then defined and the standard tests explained, the influence of temperature being specially examined.

Two types of ringing machines and direct coupled oil engines and generators next received attention and the paper ended with useful practical details about secondary cell installations.

The 21 slides were of great assistance to the audience in following a lecture which covered so many different types of apparatus.

In the discussion Messrs. Atkins, W. L. Taylor, Capt. Linsell, Messrs. Wakefield, Lines, Major Harris and the Vice-Chairman took part and many requests were made for copies of the paper to be circulated. The Vice-Chairman, in the absence of the Chairman, who had to leave before the close of the meeting, promised that members would see a copy of the paper and, amid applause, heartily thanked Mr. Campbell.

A.W.L.

NORTH WALES CENTRE.

The sixth and final meeting of the Session was held at Shrewsbury on 23rd March, 1927, when Mr. H. W. Green read a paper entitled, "The protection of the Department's overhead plant against contact with power circuits."

The lecturer first rehearsed the various powers under which tramways and light railways are erected and described the procedure adopted during the passage of Tramway Bills in Parliament to ensure that the Postmaster-General's rights are safeguarded. He then proceeded to describe the guarding arrangements required by the Ministry of Trasnport regulations and to exhibit slides showing diagrams of the guard wires required for various weights of conductors and spacings of wires. The use of insulated wires for crossings over low pressure systems was also covered. The audience numbered 80 and a good discussion followed the reading of the paper.

The membership of this centre is 165, or 91% of the eligible staff, and the atendances at last Session's meetings have been between 75 and 100. The local committee is this year in the fortunate position of having a full programme of lectures already offered for next Session.

J.G.K.D.

BOOK REVIEWS.

"Questions and Solutions in Telegraphy and Telephony."

By some mischance the name of the publisher of "Questions and Solutions," by H. P. Few, was omitted from the review in the July number of the Journal.

The publishers are S. Rentell & Co., 37c, Maiden Lane, W.C.2. Copies can also be obtained direct from Mrs. Few, 110 Sussex Road, West Harrow, Middx.

"Automatic Telephony." By Charles W. Wilman, A.M.I.E.E. (Lecturer in Telephony at the Coventry Muncipal Technical Institute). Crosby Lockwood & Son. 7/6 net.

This book should prove very useful to those already experienced in the practice of Automatic Telephony, also particularly to beginners and students on account of the author's careful enunciation of basic principles. The earlier chapters deal, amongst other useful matter, with Relays and their time elements, types of Switches, and Subscribers' Equipment, the latter including a very good description of the Dial mechanism. Preselectors, Group and Final Selectors are carefully described and their relevant functions and Circuit Diagrams explained in detail. The detached contact diagram method is used and the explanations are extremely lucid and easy to follow. Two very readable and informative chapters are devoted to Trunking principles and another to Exchange Equipment and Wiring. Others describe shortly Private Automatic Exchanges, and Private Automatic Branch Exchanges, Party Line working and other miscellaneous and auxiliary arrangements.

Later chapters deal with multi-office areas and the London Director system, with a brief description of the Controller system. In addition to the foregoing, much useful information in respect of the application of general principles to modern practice is given. The size of the volume restricts the amount of detail possible, but very effective descriptions are achieved. The book is well printed, containing 223 pages and 76 diagrams and is a useful addition to the literature of Automatic Telephony.

W.D.S.

"The Elements of Telephone Transmission." By H. H. Harrison, M.I.E.E., M.I.R.S.E. Longmans, Green & Co., Ltd. 147 pp., 72 diagrams. 5/- net.

This book is intended as an introduction to the subject and has been written for the use of elementary students. The division of the book into four chapters facilitates logical treatment of the subject. The physical and the general mathematical aspects of transmission have been dealt with. The preliminary mathematics leaves something to be desired and in this respect fulfilment of the avowed objects of the book has not been achieved.

Chapter I. is exclusively mathematical and as far as its scope or range is concerned it meets the requirements of the succeeding chapters. In regard to the actual presentation, there is considerable looseness of expression and at times, and apart from typographical errors, actual inaccuracy of statement. Such features are undesirable in any text-book; in a book for beginners they are very regrettable. In this connection and in view of the concluding remark in the preface in regard to the manuscript and proofs, it is difficult to account for the presence of such statements as the following, namely:—

" . . . if $y = x^2$, then $\frac{dy}{dx} = 2x$ means that the increase of y with respect to x^2 is $2x$, or that y increases $2x$ times as fast as x^2." Or " . . . the curves $y = x^2$ and $y = 4x^2$ are identical in shape. . ."

The chapter on alternating currents, except for a few obvious errors, will be found very instructive.

Chapter III. gives a very clear description of the manner in which alternating currents are transmitted along wires and this is followed by a very good explanation of velocity of wave propagation and of attenuation and wave-length constants. The nature and effects of reflections from free and closed terminals is also dealt with. There would be less obscurity and the value of this section would be greatly enhanced if certain symbols (*e.g.*, Z, I, A, etc.) were used exclusively for certain definite quantities, instead of assigning different meanings to them in different parts of the same chapter.

Chapter IV. deals, as far as the line is concerned, with the transmission conditions met with in practice. The various factors contributing to attenuation are clearly explained, as well as the phenomena of cut-off in a coil-loaded line. The tables of data relating to various classes of actual telephone circuits should be of great value to the student. Referring to Table III., the value of 5 micro-mhos for G is rather large. The same remark applies to the G of the cable circuit of Table I., page 69. The practical conditions would be more truly represented in this case by interchanging the leakances of the 200 lb. cable and the 200 lb. open wire. The proof (pp. 129, 130) of the design rule for loading-coil spacing is unfortunately very obscure for reasons similar to those noticed in Chap. III.

On the whole the book is good value and it is rather a pity that in its present form it requires to be read with some discrimination. The text is clearly and fully illustrated, although errors appear in both. An index adds to the utility of the work. A.M.

"Electrical Engineering Practice." By J. W. Meares, C.I.E., F.R.A.S., and R. E. Neale, B.Sc., Hons. (London). Volume II. Chapman & Hall, Ltd. 25/- nett.

This book, which is the second of a series of three volumes, contains a large amount of information on subjects which are of interest and importance to the electrical engineer, but which up to the present do not appear to have been adequately treated in other books on Electrical Engineering.

At the present time the question of using electricity instead of gas and coal for household purposes is exercising the minds of many people and in such a consideration this book is likely to prove a distinct help. It describes the essential features of the various popular systems of surface and conduit wiring and discusses their particular applications and disadvantages. In other chapters valuable information is given relating to electric lighting fittings and accessories. A most interesting chapter appears on electric heating, in which details of the construction and operation of all type of domestic heating appliances and commercial heating systems are reviewed. A comparison made between electrically heated equipment and similar fuel burning apparatus shows under what circumstances electricity is a serious rival of fuel for heating purposes.

A large portion of the book is devoted to a consideration of the transformation and conversion of electrical energy and although this subject has been previously dealt with extensively by other authors it will be found well worth reading.

The book is well printed and illustrated, and should make a useful addition to the library of those interested in power Electrical Engineering. H.C.J.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to.	Date.
Batchelor, Major W. M.	Asst. Suptg. Engineer, E. District.	Suptg. Engineer, S.W. District.	1-10-27
Weaver, R. A.	Asst. Suptg. Engineer, London Dist.	Suptg. Engineer, N.Wales District.	7-8-27
Simmance, J. H.	Executive Engineer, E.-in-C.O.	Asst. Staff Engineer, E.-in-C.O.	27-6-27
Cheshire, F. W.	Executive Engineer, E. District.	Asst. Suptg. Engineer, E. District.	To be fixed later.
Brown, James	Executive Engineer, London District.	Asst. Suptg. Engineer, London Dist.	8-8-27
Calveley, W. H.	Assistant Engineer, E. District.	Executive Engineer, E. District.	8-7-27
Lonnon, W. U.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	8-7-27
Rattue, A.	Assistant Engineer, S.W. District.	Executive Engineer, S.W. District. (in place of Mr. A. C. Phillips, who refused promotion).	31-7-27
Burbridge, W. C.	Assistant Engineer, N. Wales Dist.	Executive Engineer, London District.	To be fixed later.
Cobbe, T.	Assistant Engineer, E. District.	Executive Engineer, E. District.	,,
Jackson, D.	Chief Inspector, Testing Branch.	Asst. Engineer, Testing Branch.	20-7-27
Kemp, A.	Chief Inspector, S. Lancs. District.	Asst. Engineer, S.Lancs. District.	4-8-27
Chambers, L. W....	Chief Inspector, S.Mid. District.	Asst. Engineer, S.Wales District.	24-7-27
Cattell, F. T.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	4-8-27
Evans, G.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	27-6-27
Dodge, J. C.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	4-8-27
Gibson, W. W. M.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	27-6-27
Mortimer, H.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	8-7-27
Kerr, J.	Chief Inspector, Scot. East District.	Asst. Engineer, Scot. East District.	16-8-27
Stollard, A. E.	Chief Inspector, N. Wales District.	Asst. Engineer, N.Wales District.	To be fixed later.
Skinner, E. J.	Chief Inspector, London District.	Assistant Engineer, E. District.	,,
Rumley, B. C. H.	Chief Inspector, S.W. District.	Assistant Engineer, S.W. District.	16-8-27
Beaumont, G. W.	Chief Inspector, S.Mid. District.	Assistant Engineer, S.Wales District.	To be fixed later.
Gill, L. P.	Chief Inspector, N. Ireland District.	Asst. Engineer, N. Ireland District.	,,
Brown, A. H.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	5-7-27
Hedges, E. W.	Inspector, Radio.	Chief Inspector, Radio.	1-3-27
Robinson, R. P.	Inspector, Radio.	Chief Inspector, Radio.	19-8-27
Wain, S. W.	Inspector, Radio.	Chief Inspector, Radio.	4-9-27
McPhail, W. S. S.	Inspector, Scot. West District.	Chief Inspector, Scot. West District.	25-6-27
Evans, W.	Inspector, London District.	Chief Inspector, London District.	17-7-27
Ellis, F.	Inspector, London District.	Chief Inspector, London District.	2-8-27
Read, H. W.	Inspector, S.W. District.	Chief Inspector, S.W. District.	16-8-27
Taylor, H. M.	Inspector, London District.	Chief Inspector, London District.	30-8-27
Robertson, A.	Inspector, Scot. West District.	Chief Inspector, Scot. East District.	To be fixed later.
Bell, T.	Inspector, Scot. West District.	Chief Inspector, Scot. East District.	,,
Lester, J. R. B.	Inspector, Eastern District.	Chief Inspector, S.Mid. District.	,,
Preston, S.	Inspector, N. East District.	Chief Inspector, N.East District.	26-8-27
Shaw, H.	Inspector, N. East District.	Chief Inspector, S.Lancs. District.	28-8-27
Stradling, W. A.	Inspector, London District.	Chief Inspector, E.-in-C.O.	9-7-27
Gregory, G.	Wireless Opr., E.-in-C.O. Radio.	Inspector, St. Albans Radio Station.	9-6-27
Leaper, L. L.	Telegst., C.T.O.	Inspector, St. Albans Radio Station.	9-6-27
Jones, V. H.	Telegst., C.T.O.	Inspector, St. Albans Radio Station.	9-6-27
Lee, J. W.	S.W. Class I., N.E. District.	Inspector, N.E. District.	15-6-27
Allies, H. J.	Wayleave Officer, N.W. District.	Inspector, N.W. District.	18-6-27
Parkinson, J. W.	S.W. Class I., N.E. District.	Inspector, N.E. District.	14-7-27
Still, W.	S.W. Class I., Met. Power District.	Inspector, Met. Power District.	1-5-27
Smith, W. T.	S.W. Class I., London District.	Inspector, London District.	19-4-27
Hawkes, D. J.	S.W. Class I., London District.	Inspector, London District.	2-8-27
Matthews, R. F.	S.W. Class I., London District.	Inspector, London District.	28-5-27
Scarborough, W. H.	S.W. Class I., London District.	Inspector, London District.	4-5-27
Drew, F. G.	S.W. Class I., S.W. District.	Inspector, S.W. District.	11-6-27
Kennedy, I.	S.W. Class I, Scot. West District.	Inspector, Scot. West District.	23-3-27
Kirkland, J.	S.W. Class I, Scot. West District.	Inspector, Scot. West District.	28-6-27
Ruffell, W. R.	S.W. Class I, Scot. West District.	Inspector, Scot. West District.	20-6-27
Coe, W. J....	S.W. Class I., E. District.	Inspector, Eastern District.	20-6-27
Ware, W.	S.W. Class I., Radio.	Inspector, Bodmin-Bridgwater Radio Station.	5-3-27
Powning, S. H.	S.W. Class I., Radio.	Inspector, Rugby Radio Station.	10-12-26
Crank, F. G.	S.W. Class I., Radio.	Inspector, Devizes Radio Station.	30-3-27

PROMOTIONS.—continued.

Name.	Grade.	Promoted to	Date.
Woodhead, H. C.	S.W. Class I., Radio.	Inspector, Bodmin-Bridgwater Radio Station.	12-3-27
Ade, A. F....	S.W. Class I., Radio.	Inspector, Rugby Radio Station.	3-7-26
Cook, G. H.	S.W. Class I., Radio.	Inspector, Rugby Radio Station.	6-3-26
Lloyd, H. H.	S.W. Class I., Radio.	Inspector, Rugby Radio Station.	27-2-26
Symonds, A. E. J.	S.W. Class I., Radio.	Inspector, Northolt Radio Station.	28-3-27
Addis, C.	S.W. Class I., Radio.	Inspector, Oxford Radio Station.	16-7-27
Sutherland, J. C. C.	S.W. Class I., Radio.	Inspector, Stonehaven Radio Station.	12-6-26
Walker, N. M.	S.W. Class I., Scot. W. District.	Inspector, Scot. West District.	23-3-27
Copland, J. L.	S.W. Class I., Scot. W. District.	Inspector, Scot. West District.	22-8-27
Dolton, H. J.	Probationary Inspector, E.-in-C.O.	Inspector, E.-in-C.O.	1-9-27
Hogbin, A.	Probationary Inspector, E.-in-C.O.	Inspector, E.-in-C.O.	,,
Watt, J.	Probationary Inspector, E.-in-C.O.	Inspector, E.-in-C.O.	,,
Rudeforth, S.	Probationary Inspector, E.-in-C.O.	Inspector, E.-in-C.O.	,,
Bradley, T.	Probationary Inspr., London District	Inspector, London District.	,,
Sherriff, L.	Probationary Inspr., N.Wa. District.	Inspector, N.Wales District.	,,
Clibbon, H. A.	Probationary Inspector, E.-in-C.O.	Inspector, E.-in-C.O.	,,
England, A. G.	Probationary Inspr., N.Wa. District.	Inspector, N.Wales District.	,,
Smithers, F. A.	Probationary Inspr., S.E. District.	Inspector, S.E. District.	,,
Cameron, C J.	Probationary Inspr., N.Wa. District.	Inspector, N.Wales District.	,,

DEATHS.

Name.	District.	Grade.	Date.
Livingstone, A. P.	Northern.	Inspector.	30-6-27
Burton, F. G.	London.	,,	14-8-27

TRANSFERS.

Name.	Grade.	Transferred. From.	Transferred. To.	Date.
Broomhead, A.	Assistant Engineer.	N.Mid. District.	S.E. District.	
Pattison, B. C.	Inspector.	N.Wales District.	E. District.	9-6-27

REVERSION.

Name.	From.	To.	
Chambers, L. W.	Asst. Engineer, S.Wales District.	Chief Inspector S.Mid. District.	At own request.
Phillips, A. C.	Exec. Engineer, South East District.	Assistant Engineer South West District	

RETIREMENTS.

Name.	District.	Grade.	Date.
Plummer, T.	N. Wales.	Superintending Engineer.	31-7-27
Greenstreet, R.	Testing Branch.	Assistant Engineer.	19-7-27
Smith, D.	Scotland East.	,,	4.8-27
Brown, G. H.	London.	Chief Inspector.	30-6-27
Holmes, W. E.	London.	,,	31-7-27
Hindmarsh, J. E.	Northern.	Inspector.	9-6-27
Taylor, J. M.	South West.	,,	10-6-27
Way, E.	South East.	,,	30-6-27

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TRANSFERS.

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PROMOTION

Name.	Grade.	Promoted to	Date.
Dean, W. H.	C.O.	H.C.O. London.	12-8-27

OTHER CHANGES.

Name.	Grade.	District.	Cause.	Date.
Parish, G. J.	H.C.O.	Met. Power.	Superannuation.	22-7-27
Salter, E. J.	,,	London.	Death.	23-8-27

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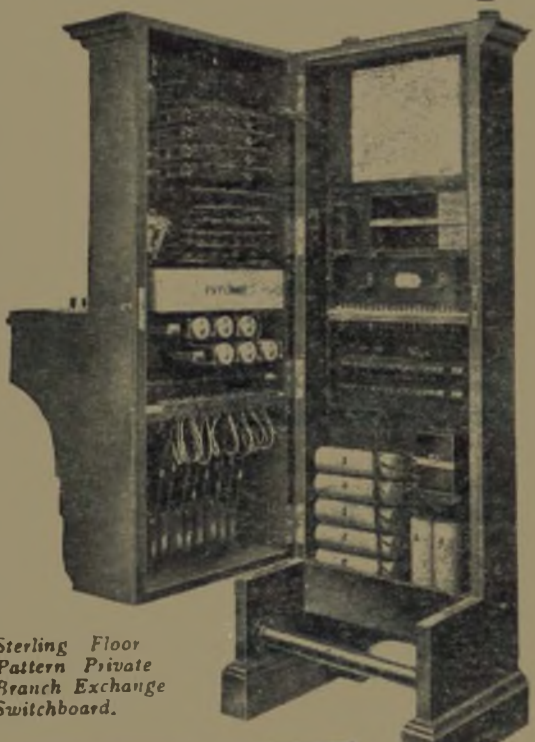

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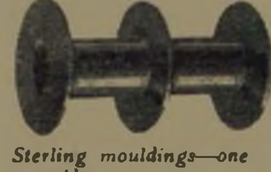

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