No. 153

The Institution of Post Office Electrical Engineers.

Modern Developments in Telephone Transmission Over Lines

By

J. STRATTON, A.C.G.F.C., A.M.I.E.E., and W. G. LUXTON

Read before the London Centre of the Institution on the 10th October, 1933, and at other Centres during the Session.

The objects of the Institution of Post Office Electrical Engineers are to promote the general advancement of electrical telegraphic and telephonic science and its application, and to facilitate the exchange of information and ideas on these and allied subjects amongst the members; but, in furthering these objects by the publication of selected papers read at meetings of the Institution, the Council does not accept responsibility for the statements made, or the opinions expressed, by the author of any such paper.

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Modern Developments in Telephone Transmission Over Lines

In this paper the Authors hope to give a general survey of modern transmission over telephone lines, showing the method of using the external plant in this Country and its adaptation to the revised standards of transmission.

The paper is divided into the following subdivisions :—

(1) Line Construction. A short history of past methods leading up to modern practice.

(2) Local line allowances for subscribers' installations with regard to developments in modern telephone instruments.

(3) Traffic circulation and control, with special reference to the " Demand " System.

(4) A brief history of past standards of transmission leading up to the revised standards that are about to come into operation.

(5) Application of modern methods of line construction to attain the revised transmission standards.

Line Construction.

Historical.

Our task in this respect has been rendered comparatively easy, owing to the pioneer work of F. G. C. Baldwin, from whose work " The History of the Telephone in the United Kingdom " the majority of the following facts have been gleaned.

As far back as 1837 the first practical form of Needle Telegraph was made by Sir Charles Wheatstone and Fothergill Cooke. The first transmission of articulated speech by electrical means was accomplished by Prof. Graham Bell in 1875-76. Musical notes had previously been transmitted.

Following this, telephones were first introduced into this Country by Prof. Graham Bell in 1877, and in the following year the first Telephone Company was floated, namely the Telephone Co., Ltd. (Bells Patents). One of the earliest exchanges in this country was opened in London in August, 1879, at 36, Coleman Street, with seven or eight subscribers all connected by single wires. Before the end of 1879 two more exchanges were opened in London, and the system served about 200 subscribers.

In 1877 Edison patented his carbon transmitter and in 1878, in order to test the efficiency of this transmitter, a trial was made over the existing telegraph line of Messrs. J. & J. Coleman, between Norwich and Cannon Street, London. This was one of the first occasions on which " long distance " transmissions was attempted in this Country. The line concerned was a single wire 115 miles long on the Great Eastern Railway.

From the overhead structure that surmounted the house of 36, Coleman Street, the first overhead wires associated with the telephone exchange service of London began to radiate, and it was here that the huge overhead system which was eventually built up in London, had its beginning. At first the length of wires was limited to a few hundred yards from the exchange, but as the service developed, the length of line increased.

The wires generally used were composed of 3/16 stranded galvanised iron wire. Arms as used to-day were not at first commonly employed. The wires were attached to insulators secured direct to the uprights of roof poles. The insulated wires used in those days for leading in at exchanges and for leading in at subscribers' premises were composed of single 18/7½ gutta percha insulated copper wire. Early aerial cables in London were formed of these gutta percha insulated conductors bound together by hand with tape, but the number of wires increased and accommodation of existing roof structures became inadequate, and the need for a more substantial form of aerial cable become somewhat pressing.

Aerial cables were made by hand by laying together twenty single 18/9 gutta percha insulated wires on a core of 3/16 galvanised iron stranded wire and binding them securely together with prepared tape. At a later date as the demand for aerial cable still increased, the manufacture of gutta percha insulated cable was undertaken in the factory by the Silvertown & Henley Company.

At 36, Coleman Street the gutta percha insulated wires which were employed for leading-in the subscribers' lines from the wires to the exchange were at first terminated direct on the switchboard, but as the number of incoming lines increased, the need for intermediate testing facilities became apparent, and a form of test board was evolved.

In 1881 the London and Globe Telephone Maintenance Company, Ltd.,, began a competitive exchange service. The most interesting feature is that their system appears to be the first in which central batteries were used in the place of independent batteries on subscribers' premises and subscribers' lines were provided as loop circuits. In the course of a few years from the inception of the telephone in London when the business had become firmly established, the rapidly increasing number of wires and the introduction and employment of aerial cables erected across the public thoroughfares of the city began to excite public notice and comment. The unsightliness and alleged danger of the net-work of overhead wires above the streets and above the roofs of the City caused lengthy and frequent comments in the technical and general press. Questions were raised as to whether Public Authorities possessed power to enable them to force some measure of control over the Companies and compel them to obtain permission for the erection of wires either along or across public thoroughfares. The matter was taken to Court, and a decision was given in favour of the Telephone Companies.

As far as can be ascertained, the earliest exchanges established in the United Kingdom were those summarised below :—

Glasgow, March, 1879.
London, 36, Coleman St., August, 1879.
London, Lombard Street, September, 1879.
Manchester, October, 1879.
Liverpool, October, 1879.
Sheffield, 1879.
Halifax, 1879.
Edinburgh, October, 1879.
Birmingham, December, 1879.
Bristol, December, 1879.
Belfast 1880.
Sunderland, 1880.

The dates are approximate.

It is interesting to note that the majority of these towns have retained their importance in the telephone system and are now the principal zone centres as described later in the paper.

The Post Office during this period had a system of ABC Telegraphy which could be switched. The utility of the telephone and the advantages which it possessed over the ABC telegraph soon became recognised, and the Post Office soon began to supply telephones on terms similar to those adopted for ABC telegraphs.

At first the telephone instruments were fitted in addition to telegraph sets, switches being provided at the renter's premises and also at the Post Office, whereby either the ABC set or the telephone instrument might be connected to a single earth circuit line, the idea being that should the telephone fail, resort might be had to the telegraph. The lines were single with earth return and worked satisfactorily under ordinary conditions, but sometimes trouble was caused by telegraphic induction which seriously interrupted the conversation at busy periods.

A Post Office telephone exchange system was opened at Swansea, in March, 1881, followed by Cardiff in August, 1881, and during the few years following these dates, numerous ABC telegraph exchange systems situated in various parts of the country were converted to telephone working.

The majority of the companies throughout the country erected single wires for subscribers' lines. Overhearing and induction are inherent difficulties with single wire telephone circuits and these difficulties became more pronounced with the increasing number of subscribers. To obtain satisfactory service, loop construction therefore became essential. This commenced generally in 1894 and in the larger towns where the aerial routes were congested opportunity was taken to introduce underground systems.

As a consequence a large portion of the line plant in many towns was remodelled and a considerable amount of overhead plant taken down.

Trunk Lines.

In 1896 the P.O. acquired the trunk lines owned by the National Telephone Co. Subsequently in 1912 the Post Office purchased the whole of the local exchange systems and thus obtained the control of all telephones (except Hull Corporation).

The early telephone trunk construction naturally followed closely the construction that had been developed for long distance telegraph circuits—the recognised practice being overhead routes erected along main roads with underground sections through towns, where difficulty was experienced in carrying them overhead.

Gutta-percha insulated wires were used for the underground portions, but with the advent of the practical form of dry core paper cable about 1891, with its lower electrostatic capacity and consequent better transmitting properties G.P. wires ceased to be standard construction for underground cables.

It is interesting to note here, that the first experimental long distance telephone cable (not only in this country but the world) was laid by the Post Office between London and Birmingham during 1897-1899. As expected in a pioneer work of this nature innumerable difficulties were experienced, particularly that of crosstalk. Messrs. Martin and Tremain, by a selection of conductors for jointing evolved a method of reducing the crosstalk to within practical limits. (Vide Sir William Noble—" The Long Distance Telephone System of the United Kingdom," Journal of the I.E.E. Vol. 59, No. 300, April, 1921).

The dry core paper cable has developed continuously up to the present day practice. Modern methods of construction are given in Paper No. 144, given before this Institution by Messrs. Buckland and Franklin. (See bibliography).

The general size of wire for the shorter aerial trunk was 150 lb. copper. For the longer circuits heavier gauges were necessary and copper wire up to 800 lb. per mile was used, *e.g.,* the old London-Glasgow aerials.

With the development of trunk traffic, these aerial lines became congested and it became increasingly difficult to provide additional circuits, particularly for shorter circuits in the vicinity of large towns. The practical application of the loading coil first described by Pupin in 1899, made it possible to provide lines within a limited distance by means of loaded underground cables with a reasonable transmission efficiency.

By 1912, owing to the development of loaded cables and the use of phantoms or superposed circuits, it was found necessary to reconsider cable design and the method of balancing by selection of conductors for jointing. The question of balancing was investigated by the Research Section of the Post Office Engineering Dept. A method was evolved which differed, in degree and detail, but not in principle, from that previously adopted by Messrs. Martin and Tremain.

In 1913 a cable was laid by the Department between Leeds and Hull and balanced by the means evolved by the Research Section of the Post Office Engineering Dept., using a bridge made up of special non-reactive resistance and condensers designed by Mr. C. E. Hay. So successful was the experiment that it was agreed to lay the London-Birmingham-Liverpool cable in 1914. This cable was similarly balanced and was constructed with 300 lb. 200 lb., 150 lb., and 100 lb. conductors, according to the distance and the circuit requirements (this being typical of transmission design on a "copper basis"). All the cables at this period were loaded with 136 mH coils spaced at approximately 2½ miles.

After the War, during which period a large amount of work had been carried out with repeaters in order to supplement existing channels of communication, it was found that when using repeaters on loaded cable it was necessary to look much more closely into conditions of loading in order to obtain efficient circuits with good articulation.

For the information of those not regularly dealing with transmission problems it may be desirable to remark that the effect of loading is to improve transmission over a certain range of frequencies accompanied by a rather sharp cut off of frequencies above that range. The effect of this cut off on articulation first came into serious consideration during this period, and it was found that the cut off given by the cables loaded with 136 mH coils at 2½ miles was too low. Fig. 1 shows the attentuation—frequency

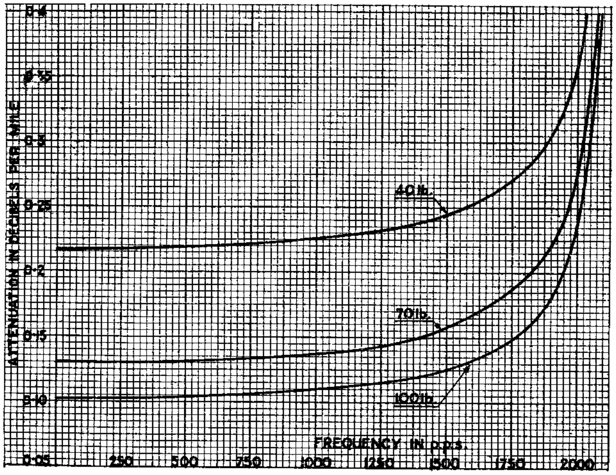


Fig. 1.—Variation of Attenuation with Frequency 40.70 and 100 lb. Cable loaded with 136 mH Coils at 2.6 Miles Spacing.

curves for the 136/2.6 loading and attention is drawn to the difference in attentuation at 2,000 and 800 cycles per second. For a distance of one mile this difference is .12 db. for 70 lb. cable but for a distance of 50 miles the figure is 6.0 db. From a study of Fig. 1 it is seen that transmitted frequency range hardly exceeds 1600 cycles per second.

The first long distance cable laid after the War was a 40 lb. cable from London to Manchester with repeaters at Fenny Stratford, Leicester and Derby, and it was also the first cable to be laid in this country for repeater working throughout. The spacing was decreased from 2.5 to 1.6 for this cable in order to raise the cut off frequency. The loading coil value was increased to 176 mH, at which the spacing of 1.6 m showed a higher cut off than on old cables, but reduced attenuation between Repeater Stations to a reasonable figure having regard to the fact that it was necessary to adopt a somewhat cautious policy. This cable did not entirely fulfil expectations, and a number of further experiments were undertaken before the next main cable was laid. It was found that unequal spacing of loading coils and uneven distribution of mutual capacity gave rise to inequalities in the impedance frequency curve of each circuit and this in turn reduced the efficiency of the 2 wire repeaters due to the impracticability of producing an efficient balance.

The Leeds-Catterick cable was the first repeatered cable on which the mutual capacity was balanced with a view to obtaining a better impedance frequency curve for repeater balances. This gave very good results and mutual capacity balancing became the standard method in connection with this type of cable.

It was considered that the main problems of cable construction as then appreciated had been solved, and the main line underground network was laid down on the basis of 20 lb. and 40 lb. conductors loaded at a spacing of 1.136 miles with loading coils of inductance values not exceeding 176 mH but otherwise chosen with due regard to the conditions to be fulfilled, such as circuits for the transmission of music, pictures, or voice frequency telegraphs, etc.

Modern Trunk Cables.

There are two main types of cable used for trunk work in this country, namely, the Multiple Twin and the Star Quad. The M.T. cable originally patented by Martin and Dieselhorst, consists of two wires twinned to form a pair, and two pairs twinned to form a quad. This produces two metallic circuits in which the wires are uniformly spaced and are not parallel to one another for any considerable distance. Thus unequal induction effects between wires are largely avoided and consequently mutual interference between circuits is reduced. By a suitable system of balancing, the capacity inequalities are evened out and a cable is produced which is suitable for providing long distance trunks on both the side and phantom circuits. (I.P.O.E.E. Paper No. 126).

The Star Quad formation is somewhat different and has its origin in the "quad-pair" type of cable patented by Tremain. Four insulated wires are rotated uniformly throughout their length to form a quad; the diagonal wires forming pairs. This construction is more symmetrical than that the M.T. cable and gives a better space factor, and as a consequence a larger number of quads can be accommodated in a given diameter.

There is a further difference between the two types in that the capacity of a phantom circuit in a M.T. cable is only 1.62 times that of the side circuit. In the Star Quad formation, however, the wires lie closer together, and the phantom capacity is as much as 2.6 times that of the side circuit, giving a greater attenuation of the phantom circuit as compared with the Multiple Twin phantom. Further, the Star repeater circuits, both 2-wire and 4-wire. In the former case, if signalling be magneto or direct current, a 1 μF condenser is inserted in series with the 600Ω resistance.

" All repeater circuits in the Country are now being terminated so as to be stable in the idle condition and are being upgraded accordingly. Where echo suppressors are available, 4-wire circuits are made zero. In the 2-wire case, an average of 1 to 2 db. gain in efficiency can be realised.

The first tests on zero circuits were made in April, 1931, on two London-Aberdeen and two London-Edinburgh trunks. These tests proved quite successful and some months later the remaining London-Edinburgh and the London-Glasgow both-way trunks were modified."

It is essential on all four-wire lines which work without attenuation loss to insert an echo suppressor so as to ensure that no disturbance due to the echo effect is heard by the subscriber. This is important, particularly on long distance calls, and calls that are completed over more than one zone-zone link; a condition that probably will occur more frequently in the future owing to the greater use of alternative routing, as explained later.

Echo suppressors are described in detail in I.P.O.E.E. Paper No. 99.

The modern 4-wire repeater has a further function to perform owing to the fact that the cable frequency-attenuation curve is not flat. As each section of line is added distortion arises from this cause so that speech would become unintelligible on a long line with several repeater stations intermediate.

In order that the gain may vary with frequency in such a manner that the combination of line and repeater gives a substantially flat curve, devices called attenuation compensators, or equalisers, which are in effect tuned circuits, are fitted to repeaters. The work of Messrs. C. A. Beer and G. J. S. Little is referred to in this connection, I.P.O.E.E. Paper No. 99.

Phase Distortion.

It is well known that every line transmits current at a speed depending on the frequency.

In the case of the complex wave conveying speech the low frequencies arrive at the far end before the higher frequencies. A period elapses before a steady state is reached and this is called the transient period. The audible result is a peculiar whistling sound accompanying each word.

This form of distortion is known as " phase distortion." The heavier the loading the greater the effect.

No such phenomena are audible on the lines in use in this country, mainly owing to their short electrical length; but in Europe and U.S.A. where considerably longer circuits are used, the matter has become serious. Special means have been devised to overcome the trouble. The usual method is to insert at intervals, of, say, several hundred miles, a network containing inductance and capacity giving the reverse characteristics to those of the line.

Phase correctors are used in this country on picture transmission lines where the distortion is noticeable in its very early stage.

Owing to the speed with which the International Service to Europe has grown during the last decade, it became necessary to establish international agreement concerning the methods by which lines should be set up, together with the range of frequency to be transmitted and the actual speed of transmission. The last effect will come into prominence more in the future if the cable system is extended for several thousands of miles.

It is clear that the delay between the speaker's voice and the reception at the far end will become important since the time taken for the reply to be received is liable to give the impression that the listener has not heard what has been said. The C.C.I. recommendation is that the total transmission time must not exceed 250 millisecs. A large number of experiments were carried out by the British, Dutch, German and Swedish Administrations concerning the desirable features of long cable lines and these discussions were crystallised at Dusseldorf in 1930 at a meeting of the C.C.I. At this meeting circuits set up on various types of loading were demonstrated in such a manner that the cut off could be altered so as to give different degrees of articulation. The main decision of this meeting was that the maximum frequency which need be transmitted on a telephone line was 2,400 cycles per second. It is obvious, however, that the line must transmit a more extended range since the implication is that transmission must be reasonably level up to the frequency mentioned. It was following this decision that the loading in this Country was standardised on a basis of 120 mHs spaced at 1.136 miles. This gives a theoretical cut off frequency of 3340 and allows lines to be set up and maintained with a uniform attenuation frequency curve between the frequencies of 300 and 2,500 cycles per second.

Amplifiers.

The advantages of repeatered circuits and the experience gained with repeaters used in connection with main line cables fostered the hope that an inexpensive and simple type of repeater or amplifier could be evolved for use with light gauge cables for the provision of shorter trunks.

This has been found possible by a practical trial made on a cable between London and Brighton with amplifiers at London, Crawley and Brighton. The cable is a 74 pr/10 lb. Star-quad with 120 mH loading coils spaced at 1.136 miles. Simple 4-wire single stage amplifiers made up from mass produced components and capable of working from the mains are used.

" Amplifier " stations do not provide all the facilities given by repeater stations. Such facilities as correction for phase distortion or frequency-attenuation irregularities are not necessary in connection with the short trunks for which the amplifier is intended.

There is an interesting article by Capt. Timmis, entitled " The Toll Repeater," in the *P.O.E.E. Journal* for April, 1933, which describes the amplifier.

Quad formation which gives a large number of side circuits with practical freedom from cross talk does not enable the phantoms to be used for telephone purposes in an economic manner. It has been found, however, that the phantoms can be used successfully for D.C. Telegraph circuits or By-product circuits as they are termed.

It may be assumed that a Star Quad cable can contain practically 50 per cent. more pairs than a multiple twin cable. If one assumes that a Multiple Twin cable contains N pairs, the telephone channels available are 1.5 N on account of the phantoms. The number of double phantoms available for telegraph circuits is 0.25 N, or in other words half the number of available phantoms.

In a Star Quad cable, the side circuits number 1.5 N and the phantoms available for by-product channels equal 0.75 N, or three times the number obtainable in a Multiple Twin cable.

At the present time the comparison between Mulitple Twin and Star Quad cables for the main underground system, viewed from the telephone service standpoint, is generally in favour of the Star Quad type. If the telegraph requirement be taken into account the advantage is more definitely in favour of the Star Quad.

Repeaters.

The progress thus shown to have occurred in the design and construction of cables was essential for the commercial application of the telephonic repeater.

Several papers have been read before this Institution concerning telephonic repeaters and their methods of use. The first repeaters in this country to be used on commercial lines were of the Receiver Transmitter pattern. These were inserted experimentally on lines between London and Glasgow in the early part of 1914. The thermionic valve soon replaced the receiver transmitter type and enabled the first commercial repeater station to be installed at Birmingham in May, 1916, on the old London-Liverpool cable. Fig. **2** shows that repeater station

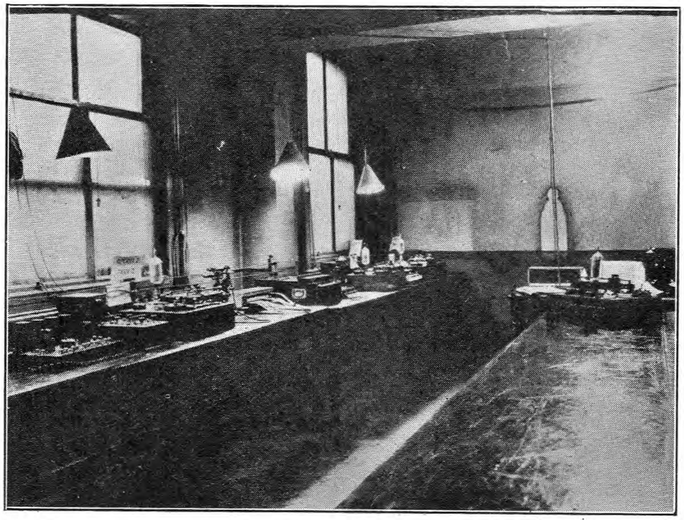


Fig. **2**.—The First Commercial Repeater Station, Birmingham (1916).

as it was then. Repeaters at this period were worked on the single valve type of apparatus in which line was made to balance line. It was soon realised that when more than one repeater was inserted in a line the relayed energy passing in both directions from the repeater gave rise to echoes and eventually to oscillation. This forced the development of the double valve type of repeater described in I.P.O.E.E. Papers No. 75 and 76. In this type of repeater, energy is transmitted in one direction only, and in consequence echoes are largely avoided. Owing to the difficulty of producing good artificial balances the double valve repeater was soon stretched into the four wire system described in I.P.O.E.E. Paper No. 83. The four wire repeater circuit is now standard for all long distance work, owing to its great stability. It is possible to work these circuits without any attenuation loss and this is described in an article by R. M. Chamney, "Modern Telephone Trunk Lines," in the P.O.E.E. Journal of January, 1933, part of which is reproduced here.

"Any properly designed 4-wire line using modern cables can be made stable and free from distortion and echo at an overall efficiency of 3 db. If a higher efficiency be attempted, the lines will oscillate due to reaction when in the idle condition, since the balance at the 2-wire 4-wire fork is extremely bad. The line side of the 2-wire end is open and the corresponding side of the differential transformer is closed with 600 ohms.

"When the circuit is closed by means of a telephone at each end, an overall efficiency for the trunk of 2 db. better than zero is possible. The line can therefore be safely operated at zero if the idle condition can be met. This has been done by shunting the switchboard indicator by 600Ω which keeps the line stable when idle and does not impede signalling since on all 4-wire lines the generator or battery for operating the indicator is supplied by the home station.

"Fig. **3** shows a diagrammatic representation of a circuit terminated by 600Ω. When the operator enters the circuit, the indicator and resistance are

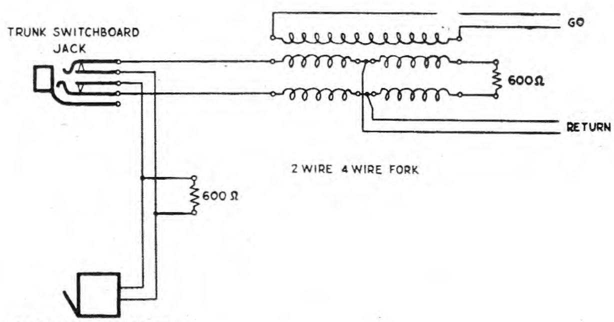


Fig. **3**.—600-ohm Circuit Termination.

disconnected so that no transmission loss is involved. This actual arrangement was suggested to the Author by Mr. G. Manning.

"The same system can be used for upgrading all

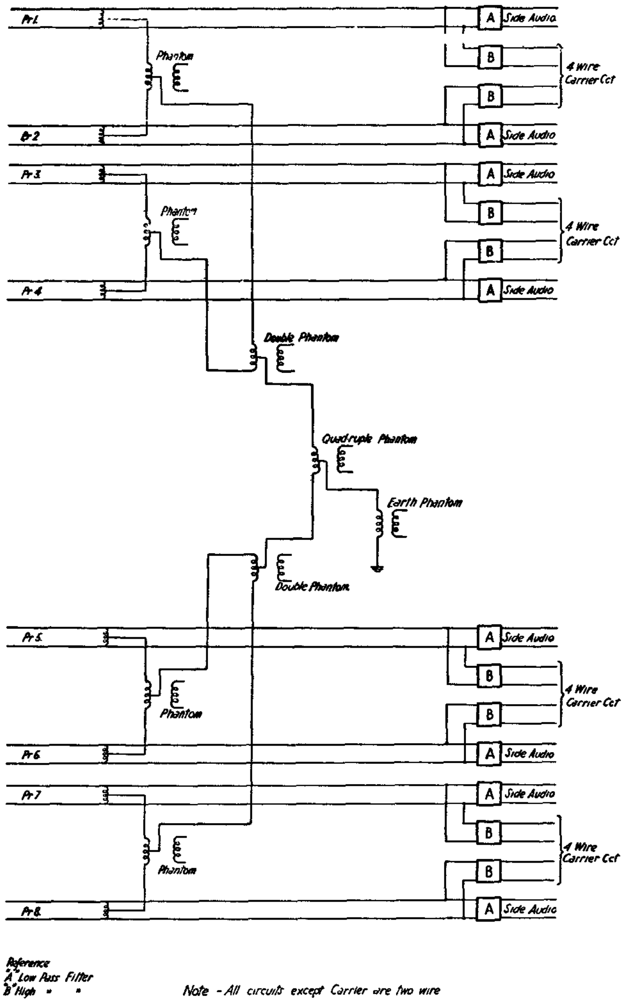


FIG. 4.—ALDEBURGH-DOMBURGH CABLE NO. 3. CIRCUITS OBTAINED.

As a result of the London-Brighton experiment it is intended to provide light gauge cables and amplifiers for the shorter circuits as will be explained later in this paper.

Carrier Current Apparatus.

Carrier current telephony has been employed in this country since 1921, when the first " carrier current " circuit was put into service between London and Bristol, and has since been used to provide circuits on a number of aerial routes.

Some of these routes have since been included in the main cable network and the earlier type carrier current apparatus has been recovered.

In co-operation with the Dutch, six additional channels have been provided recently by means of " Carrier " on two of the Anglo-Dutch cables. On one of these cables a total of 20 telephone channels is provided from 16 wires as shown diagramatically in Fig. 4.

The Research Section of the Post Office Engineering Department has recently developed a simple " Carrier " system which can be worked from the electric mains. This is described in the *P.O.E.E. Journal* for July, 1933, in an article by R. J. Halsey, entitled " A Simplified Carrier Telephone System for Open Lines." The system so described should prove useful particularly where temporary lines are required at short notice.

Local Line Allowances.

A new comprehensive Instruction dealing with the subject of local line transmission is being prepared and will soon be issued by the Department.

We have been given permission to make use of some of the information that will be included in the Instruction so far as it affects the subject dealt with by this paper.

Hitherto the local line allowances have all been related to the standard C.B. No. 1 circuit. These local line allowances were fully described in a paper by J. S. Elston, " Applied Telephone Transmission," given before this Institution in 1922. The standard C.B. circuit is shown for reference in Fig. 5.

Briefly, the 1922 allowances were referred to the standard telephone with a " Zero " subscriber's loop and an allowance was made for the resistance of the subscriber's line, *i.e.*, for a 300 ohm loop, 12 db. (10 db. sending + 2 db. receiving) was allowed.

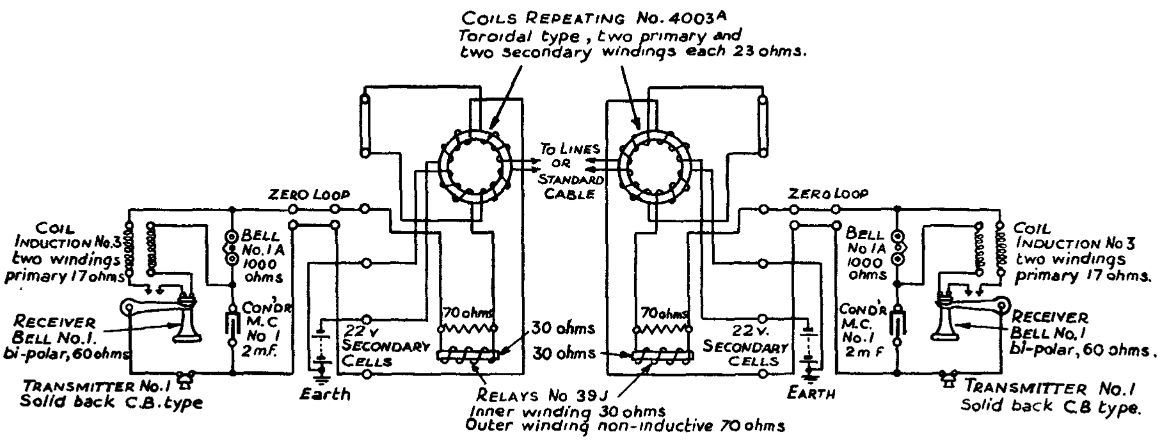


FIG. 5.—STANDARD TRANSMISSION CIRCUIT.

In the revised transmission scheme it is proposed to relate to the performance of the standard telephone associated with a 300 ohm subscriber's loop.

Considerable improvements have been made with the development of subscriber's instruments and the new hand micro telephone (Tele. No. 162) is now well known. That instrument is proposed as the standard instrument of the future.

Fig. **6** shows the sending and receiving allowance curves of the old and new standards for comparison purposes.

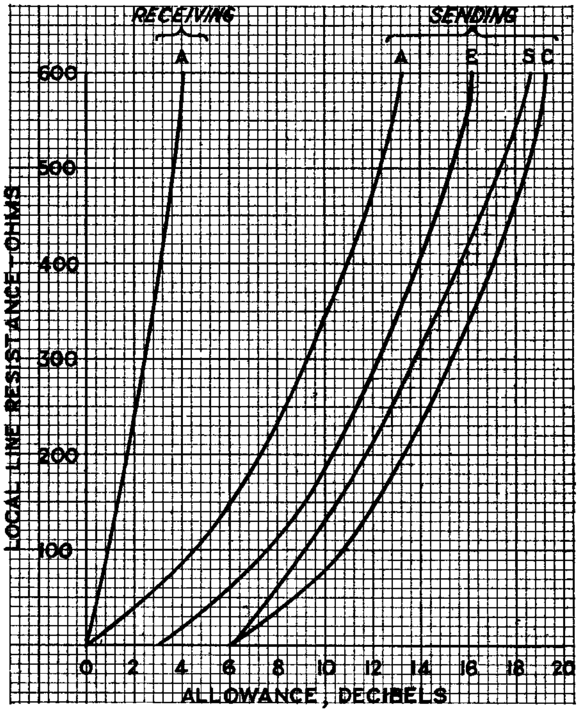


Fig. **6**.—Local Line Allowances. System 22v.

(*a*) *Sending.*

Curve A shows the sending allowance of the standard C.B. No. 1 transmitter, and curve S shows the sending allowance of the standard transmitter Inset No. 10 (the transmitter of a Tele. No. 162). It will be seen that for a local line of 300 ohms the new standard is 4.6 db. worse than the old standard. In practice this is not so for the following reasons :—

(1) As the result of (*a*) the limits allowed under old specification and (*b*) investigations by the Research, Telephone, and Test Sections of the Post Office Engineering Department, it has been found that in practice the average transmitter No. 1 is at least 3 to 5 db. worse than the standard figure. Curve B assumes a 3 db. degradation.

(2) In making the measurements with the standard circuit the speakers were close to the transmitter, *i.e.,* with lips touching the mouthpiece. In practice it is found that few subscribers speak with lips touching the mouthpiece and it is more likely to be correct if a distance of $\frac{1}{4}''$ between lips and mouthpiece be assumed. In that case the transmission is found to be degraded 3 db.

Curve C shows the allowances that would be expected having regard to the practical conditions just enumerated.

(*b*) *Receiving.*

The receiving allowances are assumed to be the same for both instruments.

Bearing in mind, therefore, that the H.M.T. instrument does not permit the subscriber to vary the distance between lips and the mouthpiece, to the same extent as with pedestal type instrument, it can be assumed quite safely that the new standard telephone will represent at least a 1.4 db. improvement on the old standard.

Appendix 1 gives a brief outline of the present method of obtaining sending and receiving allowance curves.

The allowances so far discussed refer to direct exchange lines only. It is particularly important that the case of private branch exchanges and instruments with plan number extensions be kept in mind when planning exchange areas. For these it will be necessary to make an allowance for the additional bridging and series losses and, in general, the effect will be a reduction in the permissible line resistance in a given exchange area. If, in planning an exchange area it is known where P.B.Xs. and external extensions will be required, then the use of heavier gauge conductors than normal may be necessary in order to secure the desired transmission conditions.

Appendix 2 gives some notes on P.B.X. losses, the details of which are expected to be published later in the new P.O. Engineering Department Technical Instructions.

A new comprehensive Instruction dealing with external plant (other than subscribers' lines) and the transmission lay-out of the country has been prepared and will shortly be issued. We have been given permission to make use of some of the information included in that Instruction in so far as it affects the sections of the paper that follow.

Circulation and Control of Traffic.

In order to appreciate fully the standard of transmission, it is necessary to deal in the first place with traffic circulation and control, but it is proposed only to deal with this briefly. Anyone who is interested or wishes to deal more closely with this aspect of telephony can obtain more detailed information from Telephone Service Instructions, Section E, and Technical Instructions.

Zones.

The British telephone system is divided up into zones for the purpose of the circulation and control of traffic. A selected exchange in each zone serves as the zone centre exchange and the zone is designated by the name of that exchange; for instance, Newcastle is a zone centre and the area controlled by that exchange is known as the Newcastle zone.

Groups.

Each zone is sub-divided into groups with a main exchange from which the group derives its name. The ideal from a transmission point of view is for each exchange in a group to have direct circuits to its group centre. This is not possible in all cases on economic grounds. Those exchanges which have direct circuits to a group centre are known as minor exchanges. Those exchanges which have no direct connection with a group centre are known as dependent exchanges. Fig. **7** shows the arrangements of the Hereford group. Exchanges such as Leominster and Burley Gate are minor exchanges, while exchanges such as Irvington are dependent exchanges.

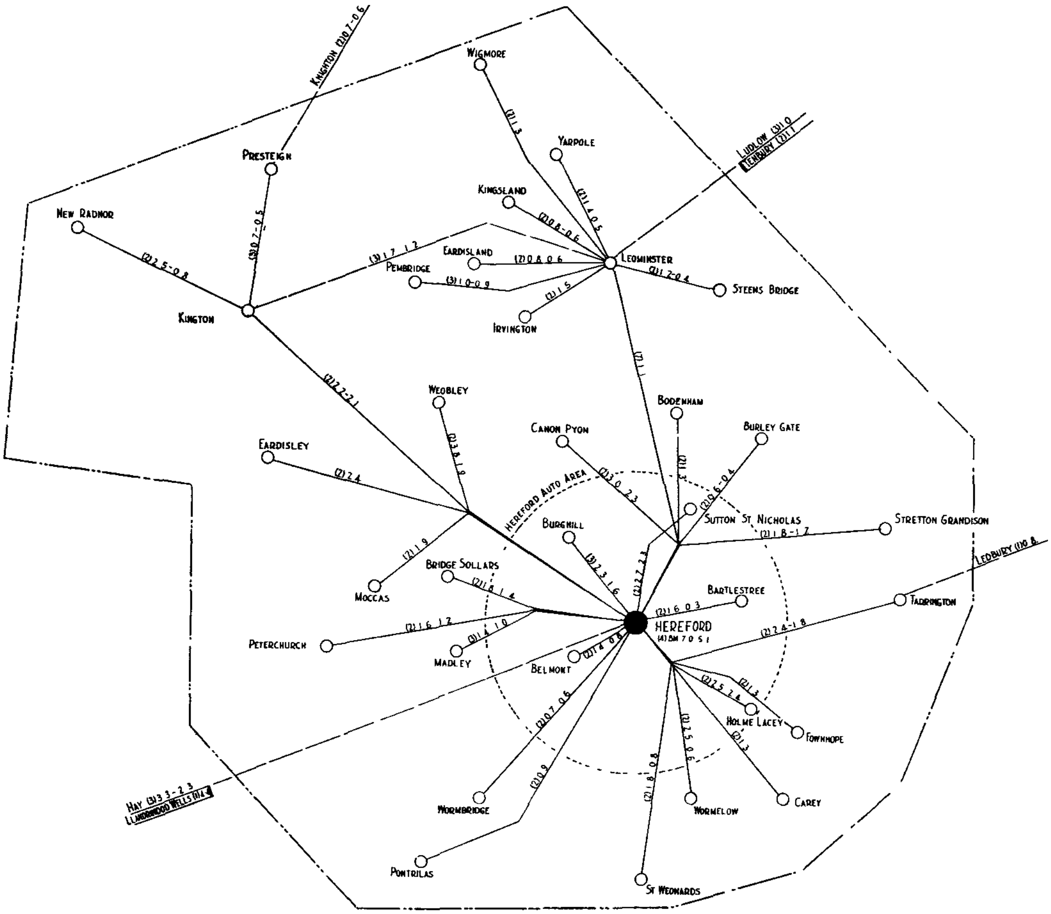


FIG. 7.

Fig. **8** shows the zones into which the British telephone system is divided. This assumes that demand working has come into force at all the zone centres,—Carlisle, for instance, is at present a group centre in the Newcastle zone, but when demand working is introduced at Carlisle it will become a zone centre.

Fig. **9** shows the Birmingham zone and its groups.

Traffic Circulation.

Normally, traffic from one exchange reaches another exchange *via* its own group and/or zone centre. In the figure showing the Birmingham zone, the inter-group connections and zone to group connections are indicated. Traffic from an exchange in the Hereford group to an exchange in the Wellington group would circulate *via* Hereford and the zone centre, Birmingham. Traffic, however, from the Hereford group to the Gloucester group would circulate over the direct Hereford-Gloucester circuits, since the traffic is of a volume sufficient to justify direct connections. Traffic from all the groups (with certain exceptions, examples of which are given below) to any other zone circulates *via* the zone centre, Birmingham.

Derby has direct connections to the Leeds, Leicester, Liverpool, London, Manchester, Nottingham and Sheffield zone centres. Traffic from Derby to those zones circulates over the appropriate direct connection.

Derby also has direct circuits to Hanley which is a group centre in the Manchester zone. Traffic between the Derby and Hanley groups circulates over those circuits, and traffic from the Derby group to the remainder of the Manchester zone circulates over the Derby-Manchester circuits as explained above.

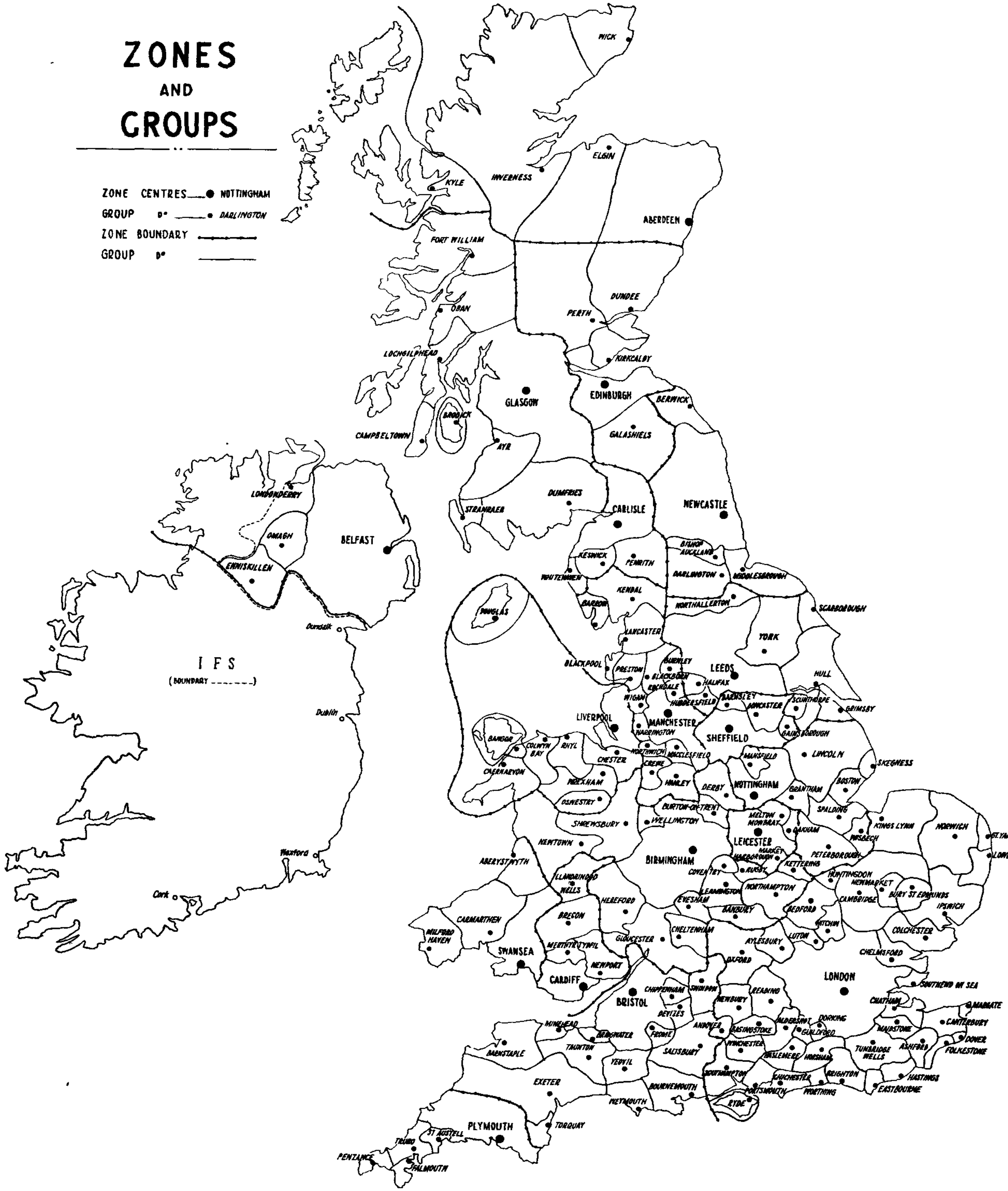


FIG. 8.

When there is sufficient traffic between any two exchanges in the system to justify a direct route, its provision is considered.

Classification of Traffic.

D Traffic.—Comprises all calls between the subscribers on exchanges which have direct communication with each other.

G2 Traffic.—Comprises all calls between subscribers situated in the same multi-exchange area, excluding calls classed above as D Traffic.

A multi-exchange area may be taken as an area within a five mile radius of a main exchange (usually automatic), which has several dependent exchanges within that area. The five mile limit is more or less

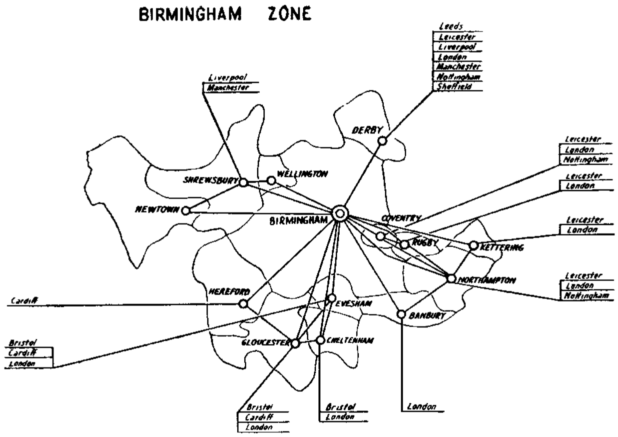


FIG. 9.

arbitary and in the case of large automatic areas such as London, Birmingham, Manchester, etc., it is extended.

G Traffic.—Comprises all calls excluding D and G2 traffic as defined above between subscribers.

(*a*) Within a group; (*b*) in adjacent groups, and (*c*) in the same toll area (see below).

Z Traffic.—Comprises all trunk calls between subscribers when the call circulates through a zone centre.

Circuits should be described in accordance with the highest class of traffic to be carried, *i.e.,* D, G2, G or Z type circuits. The actual transmission equivalent of circuits of similar type will vary with economic and engineering conditions applicable to the form of construction adopted in each case, but the overall line efficiencies should fall within the appropriate allowances as shown later. When the volume of traffic between any two exchanges permits of economic division, arrangements are made to divide the traffic into two or more classes. Circuits of suitable transmission equivalents are then provided to carry each class of traffic.

Traffic Control.

Prior to 1931 there were two main methods of handling traffic (*a*) No Delay; (*b*) Delay.

(*a*) " No Delay " service was in operation on junction and most short trunk routes and in some cases over trunks of up to 30-35 miles radial length. The main feature was that the subscriber waited on the line while an attempt was made to complete the call, the control being normally taken by the A operator at the originating exchange. Extensive " No Delay " areas have been built up around zone centres and industrial centres. In such cases as London, Manchester, etc., the " No Delay " area extends beyond the 35 mile radius and has a collecting centre, apart from the zone centre, which is termed a toll exchange and the area concerned a toll area.

(*b*) " Delay." All long distance traffic was operated on a " delay " basis and was, with few exceptions, circulated *via* the zone centre of the originating exchange, being controlled at the originating centre for within zone calls and at the zone centre for inter zone calls. The subscriber booked his call with a local or record operator who recorded the details of the required call and requested the subscriber to replace his receiver. The call was completed later on outgoing (or bothway) lines from the controlling exchange. The standard delay on zone-zone traffic prior to 1930 was 30 minutes and after 1930 was reduced to 15 minutes. If this delay was regularly exceeded additional circuits were provided.

As early as 1913 a combination of these methods was introduced on certain routes under a system called " Special Control." " Delay " working was in force during specified hours (the busiest periods) and " no delay " working was in force during the slack periods, the trunks being multipled in front of the recording operators.

Towards the end of 1931 the long distance " Demand " service was inaugurated on the London-Birmingham route and has since been introduced on most zone-zone routes as indicated in Fig. **10.**[1] In

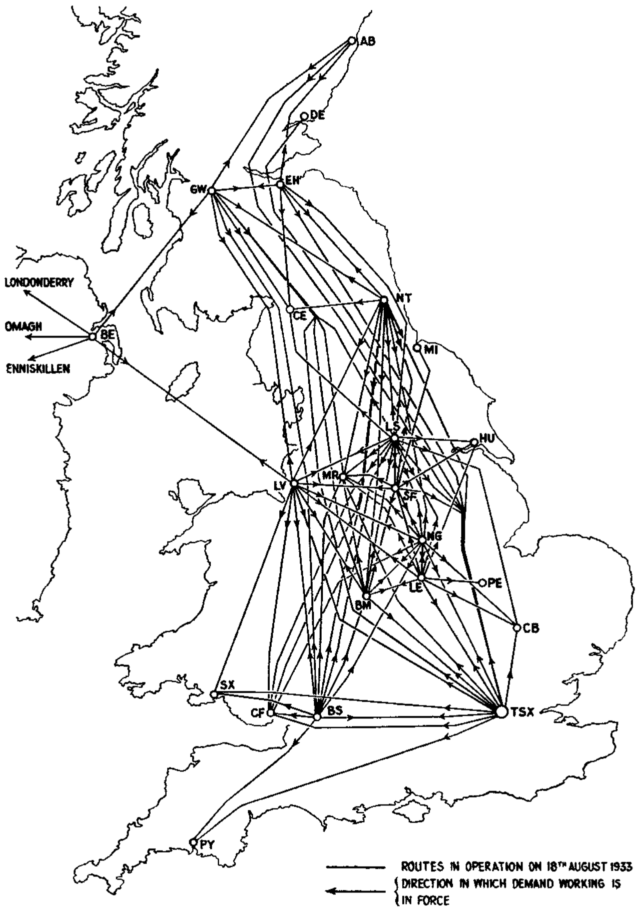


FIG. 10.—DEMAND TRUNK WORKING ON LONG DISTANCE ROUTES. (ZONE TO ZONE).

this system the aim is to dispose of a very high percentage of the busy hour traffic on demand or without the originating subscriber replacing the telephone.

[1] By February, 1934, all zone-zone routes were operated on a " Demand " basis.

It is claimed for the system known as " Demand " working that no additional lines are required compared with the 15 minute " Delay " system. This is possible owing to organization and technical aids admitting a complete change in operating procedure.

Under " Delay " working each operator had a specified number of trunks with which to deal, usually all to the same distant exchange. After having received tickets from the record operator she completed calls in rotation according to booking time. She obtained the called subscriber as soon as a trunk line was available and then the calling subscriber over a junction to the local exchange concerned. In some cases, however, owing to the fact that all zone centres are not directly connected, a through connection was required at an intermediate zone centre. This involved two trunk operators at the intermediate centre, the two trunk lines concerned being connected by a transfer circuit, which introduced an additional cord circuit and consequently an additional bridging loss.

In the " Demand " system the outgoing trunks are multipled, new switchboards generally being necessary. A long distance call is now completed by the operator recording the call, providing a trunk circuit is available. If, owing to such causes as trunk or distant subscriber being engaged it is impossible to complete the call within a prescribed period, the subscriber is requested to replace his receiver and the ticket is passed to a delay position. Here the call is dealt with as under the " Delay " system.

There are several aids to operating, such as Visual Idle Indicating[1] Lamps in the outgoing trunk multiple, Chargeable Time Indicators, Visible Index Files, readily available to each operator and giving routing information, etc. These have been fully described elsewhere.

It will be seen, therefore, that under " Demand " working the operating time has been reduced considerably.

It has been found in practice that the time during which conversation takes place, expressed as a percentage of the holding time of a circuit, has increased under " Demand " working as shown by the following average figures.

Further the time in which a trunk is carrying revenue (paid time) has been increased under " Demand " working.

	Delay (April-June, 1931).	*Demand* (April-June, 1933).
Conversation Time	66.8%	72.6%
Paid Time ...	79.2%	85.1%

" Demand " working and Line Construction.

The long distance aerial lines referred to in the first part of the paper gradually deteriorated due to the insertion of various short lengths of underground cable, owing to building operations, crossings by power lines, etc., which necessitated the removal of portions of the open route. Eventually it was decided that wherever underground circuits (mostly repeatered) existed that were of better efficiency than the aerial, the underground circuits should be brought into use in place of the aerial, the latter being retained as reserves. This ensured that the available line plant in the country was being used to the best advantage.

The decision to divert the long distance aerial trunks to underground was desirable on account of the advent of " Demand " working. On routes where all the circuits were not of equal efficiency and the worst had fallen below standard, a certain amount of discrimination by operators was possible under " Delay " working. Under " Demand " working the operator must plug into the first circuit available and no discrimination is possible. The inferior aerial circuits would, therefore, be a serious drag on the service and be an even greater source of complaint than they were under the " Delay " system.

It should perhaps be emphasised that the revised transmission standard required these diversions and the fact that the introduction of " Demand " working coincided with the necessity to work to a better standard added weight to the arguments for the immediate use of the best available plant in the Country, and placing the inferior plant in the reserve or spare category.

The upgrading by these means of the zone-zone routes was of vital necessity for the introduction of " Demand " working and we venture to think has played no small part in the successful beginning of that system.

There is another aspect of " Demand " working that necessitated the upgrading of zone-zone circuits and that is the question of alternative routing. It is extremely important that there should be good alternative routes between all zone centres, particularly for those on which only a few circuits exist, in order that the maximum amount of traffic can be disposed of on a " Demand " basis.

This is where the " Zero Loss " circuit is of such importance because with several circuits in series the resulting transmission equivalent (T.E.) is still zero. It does not follow, however, that indiscriminate alternative routing is possible. Only authorised alternative routes should be followed or the main line plant of the Country would be used in an uneconomical manner, and it might be found that a route was closed to its primary traffic owing to its full occupation with alternatively routed traffic.

It should perhaps be pointed out that some of the aerial circuits thrown spare will be useful for providing efficient shorter circuits and this is being done wherever possible.

It is intended to work on a " Demand " basis all long distance traffic previously dealt with on " Delay." Under " Demand " working the control of all long distance traffic will be undertaken at the originating group centres, (except of course those situated in the same town as a zone centre, when the latter undertakes control for its own group).

Calls originating at exchanges within a group area, which can be completed on " Demand " will be controlled at the A positions of the group centre exchange. Where " Zone Centre " groups are concerned the long distance calls will be segregated from the short distance calls and controlled by special

[1] Recently renamed " Free Line Signal."

" Demand " service operators. Calls which cannot be completed on " Demand " will be set up and controlled from " Delay " positions at the group centre exchange (or Zone centre exchange where a " Zone centre " group is concerned).

Incoming long distance calls will be dealt with at incoming positions at group centre exchanges where a form of subsidiary control will be exercised.

The operating procedure briefly is as follows :

After recording the particulars, the A, or " Demand," operator, proceeds forthwith to set up a long distance trunk call. If the calling subscriber is connected to the group centre exchange, or an auto exchange directly connected to the group centre exchange, the call is set up in a similar way to a " no delay " call.

If the calling subscriber is connected to any other exchange, *i.e.,* manual or R.A.X., not directly connected to the group or zone centre exchange, the local connection is reversed as explained later, in order to secure standard supervisory signals, control of the timing device, and a high grade circuit for the completion of the call.

Examples of hypothetical calls from subscribers in the Hereford group to a subscriber on Shipton exchange in the York group are given below. Particular attention is drawn to the direction of the arrows which indicate the direction of setting up the individual links in the chain of connections.

(*a*) A call from a subscriber on Hereford exchange would be routed as shown in Fig. **11**(*a*).

(*b*) A call from a subscriber on Fownhope, an R.A.X. directly connected with Hereford, is routed as shown in Fig. **11**(*b*). The subscriber dials the appropriate code and is connected with an A position at Hereford, the call being completed on the Fownhope-outgoing Hereford-incoming circuit that was used for booking.

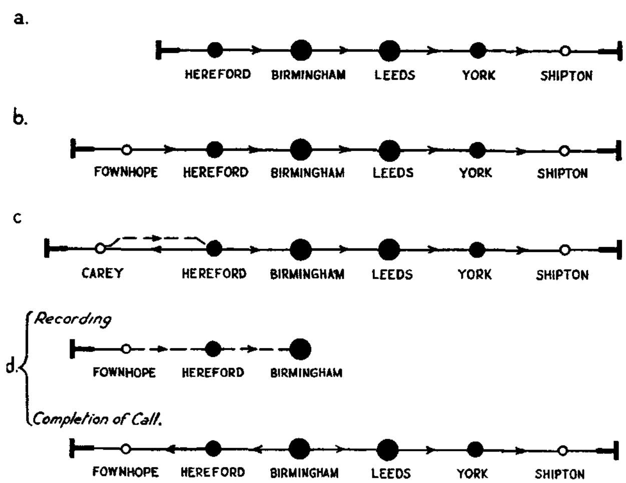


FIG. **11.**

(*c*) A call from a subscriber on Carey, a manual exchange in the Hereford group, would be routed as shown in Fig. **11**(*c*). The circuit, Carey-outgoing, Hereford-incoming, is used only for record purposes. The signalling conditions do not permit through clearing from the subscriber to Hereford and the final connection is set up on a Z type circuit from Hereford to Carey. The subscriber meanwhile has not replaced his receiver and the B operator at Carey is requested to ignore the engaged signal on the subscriber's line and to " overplug " the calling subscriber's number. The record line is then cleared.

(*d*) For comparison purposes the call dealt with, example (*b*), is shown as routed under the " Delay " system. In this case the calls are set up from and controlled at the originating zone centre BM.

Under the " Delay " method of working, where the control of traffic was undertaken at zone centres, the high grade or Z type circuits were all worked in the direction from zone centre to dependent exchange. Under the " Demand " method of working it is essential that Z circuits should exist in both directions in all links except (*c*) above. It appears, therefore, that in order to introduce demand working more Z type circuits are required. It has been found, however, that in practice sufficient highest grade circuits exist in the majority of cases. On the routes with only a small number of circuits, bothway working is more extensively used. On the routes with a larger number of circuits, particularly in the case of multi-office areas where the line plant has been provided on an underground cable basis, there has been no practical difference in the allowable gauge for Z and G type circuits, and therefore sufficient of the highest grade circuits are available. A slight adjustment, however, has to be made in planning for the future.

It is the policy with the " Demand " system to work trunks on a bothway basis, and this has been carried out on the majority of zone-zone routes.

Another feature of " Demand " working that affects the line plant lay-out is that since the control is undertaken at the group centre, only the group centre exchanges need be connected to their respective zone centres. Under " Delay " working if an exchange in a group had sufficient long distance traffic through a zone centre to warrant direct circuits, they were provided and the group centre was used for the circulation of specified G grade traffic. Under " Demand " working either (*a*) the circuits between the minor exchange and the group centre will be upgraded to carry Z type traffic and the circuits between the minor exchange and the zone centre exchange released or used for " No delay " traffic if possible, or (*b*) the minor exchange concerned will become a group centre (and take over the control of long distance calls), if the volume of long distance traffic warrants this course. The latter has been done in a number of cases and accounts for the increase in group centres consequent upon the introduction of " Demand " working.

Transmission Standards.

For the purpose of arriving at a figure for the standard of transmission it can be assumed that the loss from subscriber to subscriber is made up of three main parts.

(*a*) The losses in the subscribers' instruments and local lines and their relative exchanges.

(*b*) The losses due to transmission bridges in the intermediate exchanges; referred to hereafter as switching losses.

(c) The overall transmission equivalent of all the links in the connecting chain of trunk and junction circuits.

Brief Survey of Past Standards.

It has already been seen that the earlier trunks in this Country were based on overhead line construction. The transmission, therefore, with a given gauge of conductor was directly dependent upon the length of the circuit. The traffic to be carried was, in the first instance, almost solely between the commercial centres. It was to meet this traffic that the earlier trunks were designed.

It is worth noting that even now most of the traffic on a zone-zone route terminates within the local fee area at either end.

The trunks had to link up the trunk exchanges of the local networks originally provided by the various companies. These local networks eventually came under the control of the National Telephone Company and had agreed allowances for their transmission absorption.

The allowances in operation in 1912, when the National Telephone Company was taken over by the Post Office, were in force for a short time afterwards. In 1915, transmission allowances were defined with reference to the then existing system of traffic circulation and control, and the values adopted were based on the audibility being not worse than that given by two standard telephones separated by lengths of standard cable dependent upon the class of traffic. In the section of this paper which deals with local line allowances, a description of the standard circuit is given.

Line Allowances : 1915 *Basis.*

Class of Service.	*Standard.*
(1) Between stations in the same urban area.	20 Miles of Standard Cable (M.S.C.).
(2) Between (*a*) stations in the same zone and (*b*) stations in adjacent zones and not more than 200 miles apart. Between (*c*) stations in any two large commercial centres where traffic is sufficient to justify direct lines between local exchanges, *i.e.*, London-Birmingham, London-Liverpool, Bristol-Cardiff.	25 M.S.C.
(3) Between (*a*) stations in adjacent zones and more than 200 miles apart, *e.g.*, Ipswich-Exeter; (*b*) stations in different non-adjacent zones and not more than 300 miles apart. Between (*c*) stations at central exchanges in any two large commercial centres from 300 to 400 miles apart, *e.g.*, London-Dublin, London-Glasgow.	30 M.S.C.
(4) General standard for long distance communication between stations in Great Britain and Ireland, and not included in any of the foregoing.	35 M.S.C.

It will be noticed that as the distance increased, so did the permissible Transmission Equivalent (T.E.). This, of course, was an essential feature, until repeatered circuits were more generally used. Further, advantage was taken of the psychological fact that the longer the distance the fainter the speech was expected to be. This fact, however, cannot be taken so much notice of now for two main reasons.

(*a*) The education of the public in matters relating to transmission of speech and music by the development of wireless broadcasting, and

(*b*) the development of continental and overseas telephony.

In 1922, J. S. Elston read a paper before this Institution dealing with the lay-out of the Country from a transmission viewpoint. This lay-out was then based on a general standard of audibility of not worse than that obtained from two standard telephones separated by 35 miles of standard cable. The standard telephone then in use was based on the assumed performance of a standard C.B. Telephone No. 1. The curves giving the transmission equivalents in that paper and later in T.I.XXI were prepared on a mileage basis; the circuit being based on underground unloaded conductors up to 70 lb. for short distances, followed by circuits based on underground loaded conductors up to 70 lb., and longer circuits based on aerial construction up to 300 lb. copper. For the basis of these curves, it was assumed that zone to zone circuits would be 5 db. repeatered circuits, an ideal that has only just been generally realised, although on certain routes 5 db. has been improved upon, as will be shown later.

A specimen sheet showing the conditions existing in 1922 for certain zone to zone routes, best circuits only, is given in Appendix 2 of J. S. Elston's paper, and is reproduced in this paper as a matter of interest. The present conditions on the same routes on the bothway or long distance circuits at the time of writing are shown as a matter of comparison. See Appendix 3.

It will be obvious that the general standard of transmission would not have been approached on the longest connections without amplification. Cord circuit repeaters (C.C.R.) were developed to give this amplification, and were installed at main zone centres and a few group centres.

The first cord circuit repeaters were installed in London Trunk Exchange in 1923 and have proved extremely useful. Fig. 12 shows the theoretical diagram of the complete cord circuit of this type of cord circuit repeater. Similar repeaters were installed at Glasgow, Aberdeen, Bristol and Inverness.

Several repeaters were associated with one position in the trunk exchange and the long distance lines for which balances had been obtained were available on that position. Any call that required

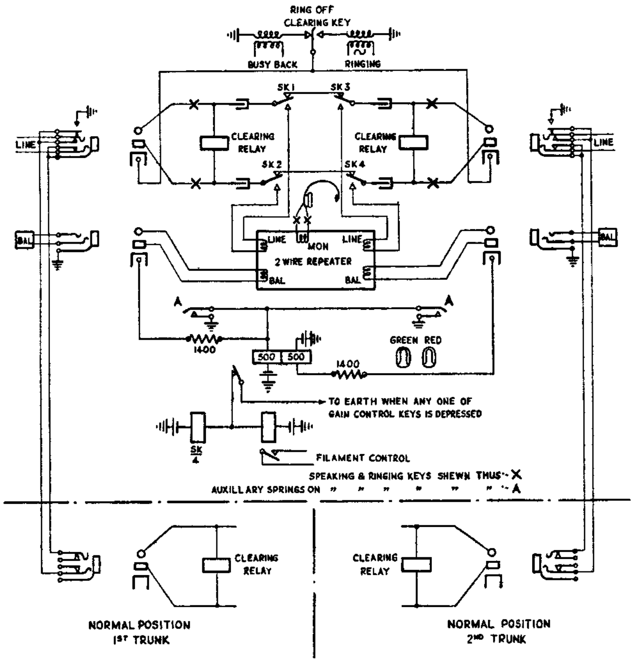


FIG. 12.—C.C.R. CORD CIRCUIT (LONDON TRUNK EXCHANGE).

C.C.R. assistance had to be completed on balanced lines and controlled by the C.C.R. operator. The lines and balances were associated by means of a double plug.

These repeaters worked satisfactorily for a time, but owing to the fact that the control was not taken by the normal trunk operator and special traffic arrangements had to be made, a certain amount of delay and inconvenience occurred. The result of this was the development in 1929 of the semi-automatic cord circuit repeater shown in Fig. 13. Here the control is kept by the normal trunk operator and the C.C.R. operator has only to insert the C.C.R. between two trunks, which have been balanced and appear in the jack field of the C.C.R. position. When the call is finished the operator receives a clearing signal and withdraws the repeater.

There are limits to the gain that can be obtained from a C.C.R. determined by the singing point of the lines to be connected. With the older type of repeater the gain was adjusted by the operator. With the semi-automatic type, however, the gain is predetermined. It has to be assumed that any two balanced circuits on the C.C.R. position may be associated. The gain is controlled by networks or pads (of which there are several values) which are inserted with each line and have a value dependent upon the singing point of the line concerned. The maximum gain given by the repeater is determined by the worst two lines that can be associated. It is possible, therefore, that when the lines with good singing points are used the maximum gain then possible is not obtained. It is very important, therefore, that lines with low singing points should not be connected or the gain from the C.C.R. will be seriously restricted.

Where upgrading has taken place on zone-zone routes, giving circuits of short electrical length and with consequently larger current reflected from the far end, it has become not only unnecessary, but wrong, to give C.C.R. assistance. Apart from the limitation to the gain given on other circuits the articulation tends to become poor.

With the introduction of " Demand " working and the extra need for quick operating the saving of the extra time involved in obtaining C.C.R. assistance has become much more desirable. Further, the economy in staffing and switchboard accommodation is considerable. Zone centres have been reviewed bearing in mind the above and taking into consideration the upgrading that has been possible, C.C.R. assistance has been, or will shortly be unnecessary at Leeds, Leicester, Glasgow, Edinburgh, Swansea, Birmingham, Nottingham and Bristol, and at the group centres Hull and Dundee.

Where C.C.R. assistance has ceased, no trouble has so far been experienced.

The introduction of the repeatered circuit with a zero overall T.E. in 1931, only two years after the development of the semi-auto C.C.R., made the latter obsolescent after a very short life : the good has had to give way to the better.

The Revised Transmission Standard.

Within recent years it has become increasingly important that transmission should be as nearly as possible uniform between any two telephones in the Country. A study of the conditions, as shown by J. S. Elston's paper in 1922, will show that this was not possible at that period. A new overall standard has now been determined together with a redistribution of losses between the three constituent parts of a subscriber-subscriber connection.

(*a*) There has been an improvement in the local line conditions as already described.

(*b*) There has also been considerable development in the design of switching apparatus and a reduction in exchange losses. This is due to the development of the sleeve control cord circuit.

It will be remembered that with the bridge control cord circuit, (the condition that obtained in 1922), a figure of 1.5 db. was found suitable to represent the average switching loss.

The basic principle of the sleeve control system lies in the use of a simple " straight through " cord circuit suitable for universal use and association with any type of line (trunk or junction).

The signalling equipment proper to the type of line is associated with the line itself as terminal equipment. This apparatus operates calling signals in the usual way, but after the cord plug has been inserted in the line jack, the line signals are transmitted from the line over the 3rd (or sleeve) conductor to lamp signals in the cord circuit. Hence the expression " sleeve control."

It would perhaps be of advantage to summarise the advantages of the system here.

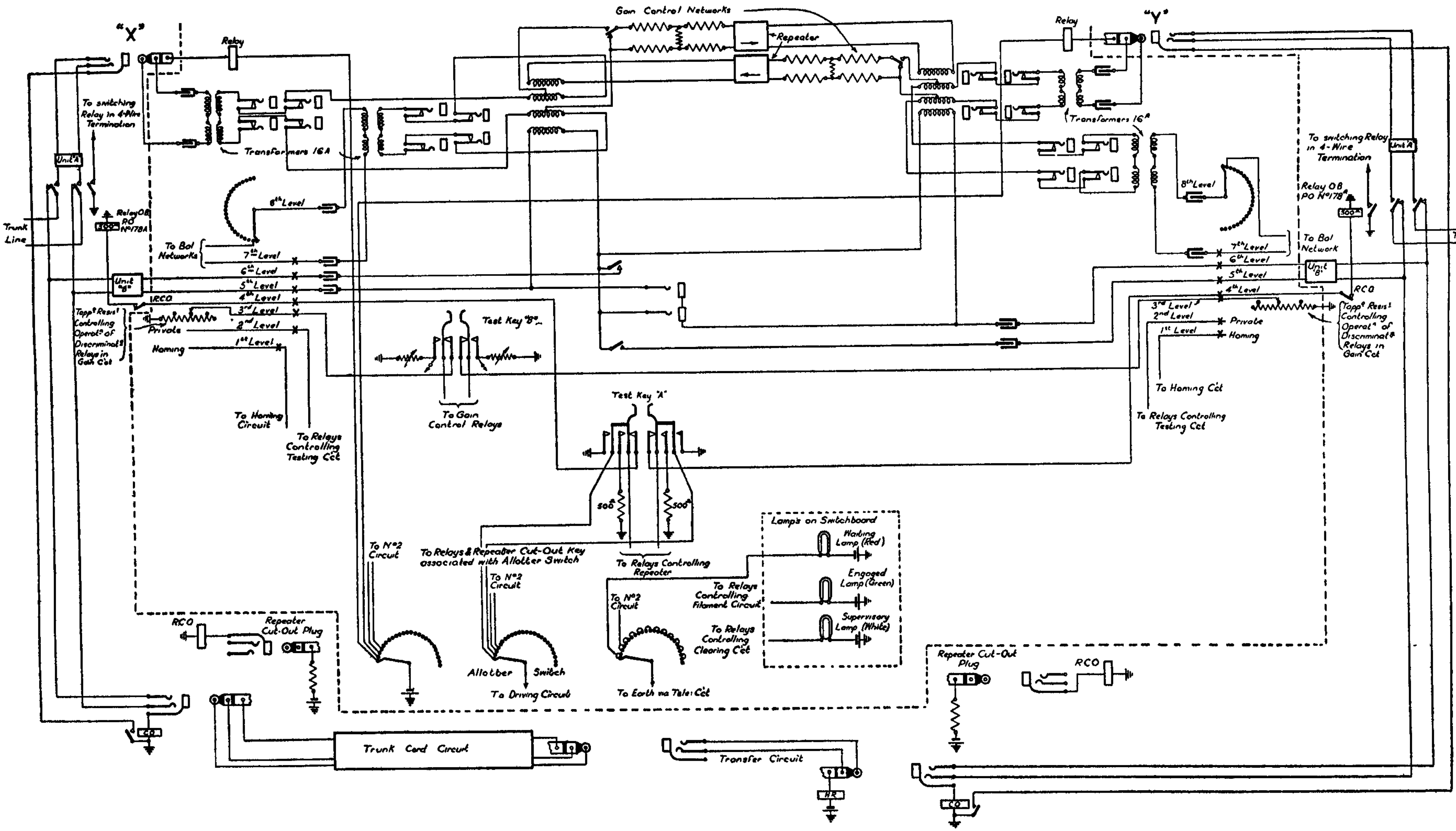


FIG. 13.—SEMI-AUTOMATIC CORD CIRCUIT REPEATER, CONTROLLED FROM ORDINARY TRUNK POSITION.

(1) One type of cord circuit is used for all classes of line circuits and hence " team " working between positions of all types presents no difficulty.

(2) Operating procedure is uniform and is reduced to basic principles throughout the whole exchange.

(3) Through signalling arrangements are facilitated between lines of similar or varying signalling principles.

(4) Full flexibility can be obtained in regard to line signalling schemes, both as regards existing methods of signalling and developments.

(5) Transmission losses are minimised, especially in cases of repeatered lines, where they can be eliminated for practical purposes because the signalling equipment is then associated with the line circuit and the transmission losses introduced can be included in the overall transmission equivalent of the lines and not as a switching loss as heretofore.

Advantage (5) is the most important advantage as far as a transmission scheme is concerned, since in connection with the " Demand " scheme, zone centre and group centre exchanges are being converted to the sleeve control method of working. A considerable improvement, therefore, can be expected as far as switching losses are concerned.

The revised transmission standard has been agreed as follows :

" The audibility shall not be worse than that obtained from two standard telephones (Telephone 162) each with a 300 ohm subscriber's line *via* specified feeding bridges and a total line loss of 15 db. in the chain of trunks and junctions between the terminal exchanges."

For the purpose of comparison, it is convenient to regard the traffic links which may be required to connect one subscriber's line to another as falling within three categories—

(1) *Zone Centre to Zone Centre Circuits.*

These circuits form the most important link and generally are the most expensive per mile to provide and maintain. They are, however, the least numerous.

(2) *Zone Centre to Group Centre Circuits with which may be included Group Centre to Group Centre Circuits.*

These circuits are generally shorter and of a less expensive type, but they are provided on a more liberal basis as compared with those in category (1).

(3) *Circuits radiating from Group Centres.*

These are relatively short and much more numerous than the circuits in categories (1) and (2). The total value of the plant necessary to provide these circuits and the subscribers' exchange lines as compared with those in categories (1) and (2) combined is approximately in the ratio of 3.5 : 1. If, therefore, it can be arranged to reduce the overall transmission loss in the longer line links at relatively small cost, considerable savings can be effected in respect of plant provision for the circuits in category (3); or, combined with some external plant savings, a general improvement in the standard of transmission can be arranged when new plant is designed.

The development in telephone transmission technique now renders it possible to make the foregoing conclusions effective to a reasonable extent.

In order to limit the total line loss to 15 db. mentioned above the losses scheduled below should not be exceeded.

Circuit.	*Type.*	*T.E. (db.).*
Zone Centre to Zone Centre	Z	0
Zone Centre to Group Centre in another Zone	Z	3
Zone Centre to Group Centre in the same Zone ...	Z	3
Group Centre to Group Centre	G	3
Group Centre to Minor Exchange	Z and G	4.5
Group Centre to Dependent Ex. *via* Minor Exchange	Z and G	4.5
Group Centre to Minor Exch. (Multi-exch. area)	G2	6.5
Group Centre to Minor Exchange	D	12
Minor Exchange to Minor Exchange	D	12

The conditions on typical calls are given in Fig. **14**.

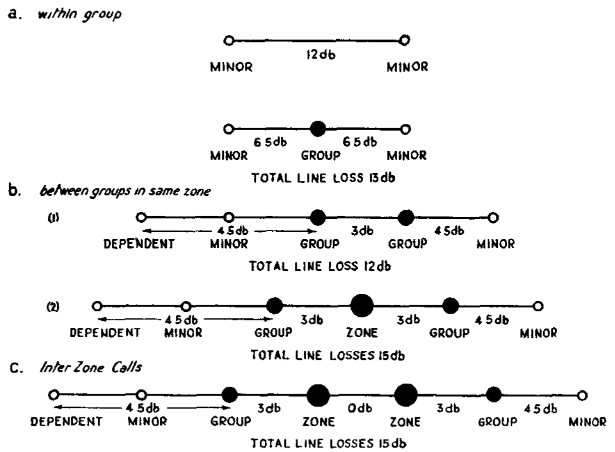


FIG. **14**.—TYPICAL CALLS. REVISED TRANSMISSION STANDARDS.

The Probable Means of Attaining the Revised Transmission Standard.

The subscriber's line and switching losses have already been dealt with, it therefore remains to show how the trunks and junctions, throughout the system, can be brought within the new limits.

It may well be that the time may never arrive when every subscriber's station will, on any connection, conform to the transmission standard, since there must always be places and conditions which would render this ideal, not only uneconomic, but also unnecessary. To provide ideal conditions for calls between some of the remote places in the Country would be to spend large sums on the possibility of a call that is unlikely to mature.

Owing to the upgrading that has taken place in the last few years and is in hand on zone-zone connections, the majority of calls will be within the ideal in the next year or two, whilst the number outside even now is not a large proportion of total calls.

New plant will be designed to meet these standards. Existing plant will be modified wherever practicable.

(*a*) By loading existing cables, including those at present in use for telegraphs, where VF working is to replace D.C. telegraphs.

(*b*) By the use of amplifying devices associated with existing cables.

(*c*) By re-loading existing cables.

(*d*) By the diversions already mentioned, and plant rearrangements.

It is now proposed to show how it is probable that circuits conforming to the new standard will be provided having due regard to the existing plant and future planning.

(*a*) *Zone to Zone Circuits.*

Circuits in this category will be provided by 4-wire underground circuits of zero overall transmission equivalent. It will be seen from Fig. **16** that all the zone centres are on the main underground system of the Country.

This figure shows the main underground repeater system and the zone centres have been marked. A great deal will be done towards obtaining the new standard if all the zone to zone circuits are made " zero," particularly as every zone is not directly connected to every other zone. This ideal of direct connection will be of less importance in demand working as soon as all zone to zone circuits are upgraded to zero.

At the time of writing there are 1026 zone to zone circuits of which

(1) 88 are 4-wire zero.

(2) 186 are 4-wire 3 db. and will be made zero in due course by the addition of echo suppressors.

(3) 378 are 2-wire repeatered.

(4) 257 are cable (unrepeatered).

(5) 117 are aerial.

The circuits falling in categories (3), (4) and (5) will be made 4-wire zero as soon as plant conditions permit. The majority of these circuits are on the shorter routes where it is possible to get approximately 5 db. circuit by one of the following means :—

(*a*) A 2-wire repeatered circuit.

(*b*) An underground unrepeatered circuit.

(*c*) An overhead trunk.

Fig. **15** shows the zone to zone routes on which

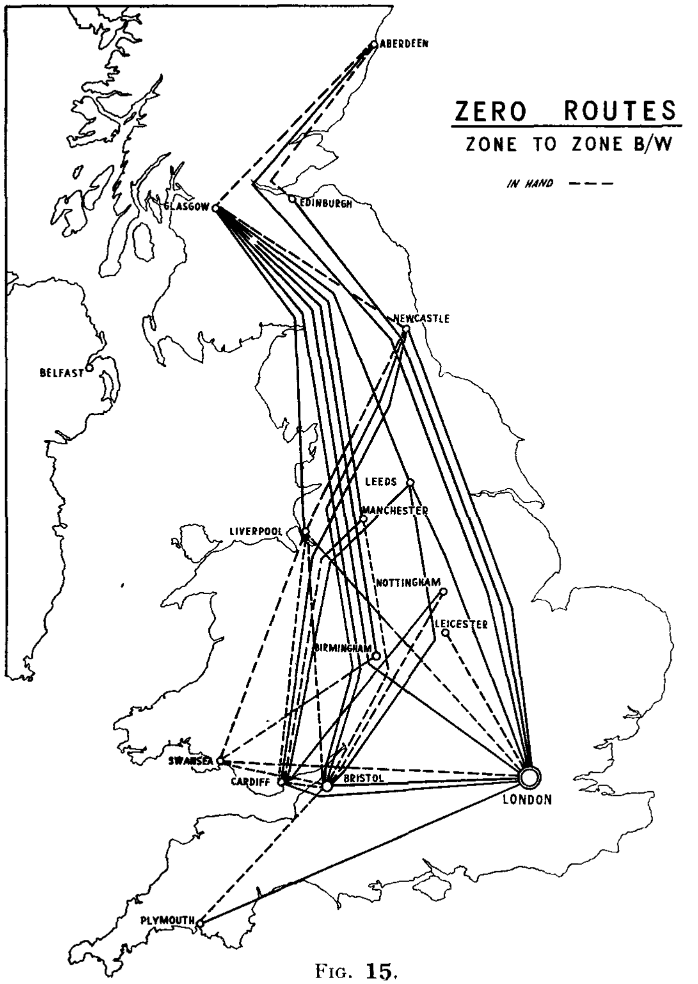


FIG. **15**.

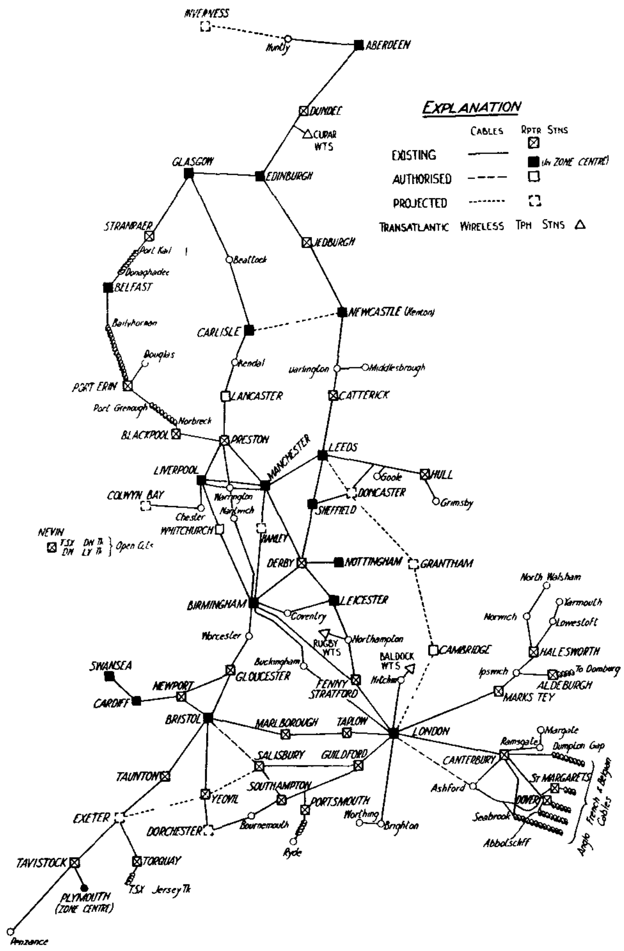


FIG. **16**.—MAIN UNDERGROUND SYSTEM.

zero circuits exist or are about to be made zero with the insertion of echo suppressors.

(*b*) *Zone to Group Centre Circuits.*

A number of these can also be included in the main underground network and can be upgraded to 3 db.; the shorter on a 2-wire basis. A transmission equivalent of 3 db. can be obtained where one repeater only is concerned. In cases where extremely good balances are obtained and two repeaters are concerned, a transmission equivalent of 3-5 db. can be expected. The inherent instability of 2-wire circuits does not permit of a lesser attenuation. The remainder will probably be designed as cable circuits with amplifiers on a 4-wire basis. Fig. **17** shows the make up of some typical circuits giving the limiting conditions.

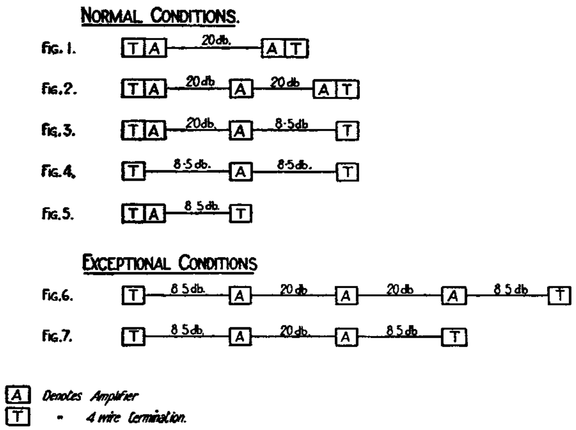


FIG. **17**.—ZONE GROUP CIRCUITS.
MAKE UP TO OBTAIN OVERALL T.E. OF 3 DB.

Fig. **18** shows how the 8.5 db. and 20 db. links between the amplifying stations can be obtained.

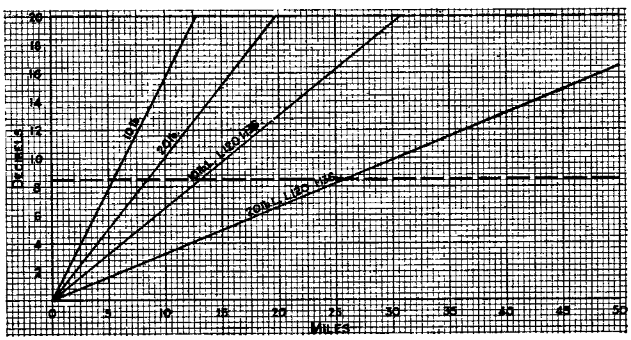


FIG. **18**.—CIRCUITS BETWEEN ZONE CENTRES AND GROUP CENTRES.
WEIGHT OF UNDERGROUND CONDUCTOR PERMISSIBLE.

(*c*) *Circuits radiating from Group Centres.*

These, in all probability, will be provided by means of underground cables, loaded where necessary. The minimum length for loading with 1.136 spacing is 3.5 miles (*i.e.*, 3 complete loading sections).

The gauge of conductor which will have to be employed in order to provide the circuits concerned is shown in Fig. **19**.

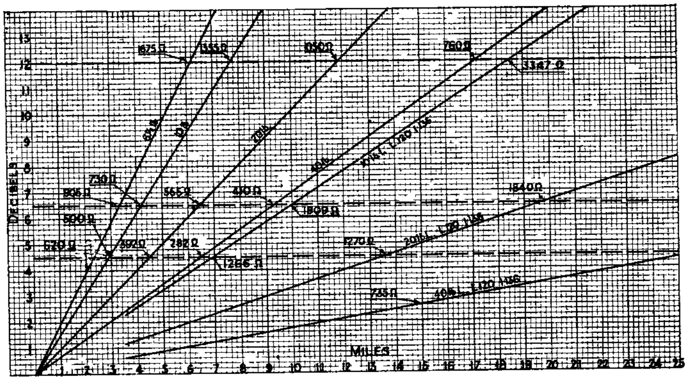


FIG. **19**.—CIRCUITS RADIATING FROM GROUP CENTRES.
WEIGHT OF UNDERGROUND CONDUCTOR PERMISSIBLE.

Only underground conductors are shown. This, of course, assumes an ideal that will probably never be reached, since in areas where development is small aerial routes are still the most economical and will be maintained. The curves shown should, however, be borne in mind when considering lengths of underground in aerial circuits, *i.e.*, the probable extension of the underground at some future date should be envisaged and arrangements made accordingly.

Circuits made up of amplifiers and underground cables similar to those described in (*b*) will be probably only a small proportion of the circuits radiating from group centres, but where the length and economical construction permit, they should be provided.

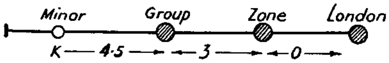
It is not possible to deal with the economics of line provision in this paper, since that subject is a study in itself, and further, the figures for annual charges at present available in respect of amplifiers will probably be modified in the light of experience gained during the next year or so.

The International Service.

London is the collecting centre or Tête de Ligne for all calls to places outside the British Isles. A standard of transmission has been laid down by the International Consultative Committee (C.C.I.) which recommends " (1) that for an international connection between any two subscribers in the same Continent the reference equivalent of the National Sending System should not exceed 2 nepers or 17 decibels, and the reference equivalent of the National Receiving System should not exceed 1.3 nepers or 11 decibels. (2) that it is desirable in future when setting up new networks or when modifying existing networks, that an endeavour be made so that for about 90% of the subscribers the reference equivalent of the National Sending System should not be greater than 1.7 nepers or 15 decibels, and the reference equivalent of the National Receiving

System be not greater than 1.2 nepers or 10 decibels." The reference equivalent of a subscriber's instrument with a 300 ohm local line can be taken as 7.9 db. sending.

Under the revised transmission standards a call on a minor exchange would reach London as shown in Fig. **20**. It will be seen that the total losses are 15.4 db. sending.



Total line loss = 7.5 db.
Total loss " sending " 7.5 + 7.9 = 15.4

FIG. **20**.

It can be taken that 90% of the subscribers requiring Continental calls will be associated with group centre or zone centre exchanges, and assuming the former, the total losses will be 10.9 db. sending. It will be seen, therefore, that the revised transmission standards comply with the requirements of the C.C.I. for international calls, as far as the sending allowance is concerned.

The receiving conditions appear to be slightly worse than the C.C.I. recommendations. European countries generally seem to have experienced similar difficulties in meeting these conditions and as a result the C.C.I. is reconsidering the receiving standard.

In preparing a paper covering so much ground it has been necessary to obtain information from many officers who are experts in their own branches. They are too many to mention by name and perhaps they will accept this acknowledgement and forgive us, if, in the compression which has been necessary, we appear to have dealt inadequately with certain phases of the subject.

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Appendix I.

Notes on the method of obtaining Sending and Receiving Allowances for Subscribers' Instruments and Local Lines.

The original tests were laboriously made by actual speech comparisons. In 1925 a method was evolved in which the use of a single frequency (800 p.p.s.) was found to give reasonably accurate results. Later developments make use of an instrument called the Telephone Instrument Tester (T.I.T.) which applies a rhythmic tone from an oscillator. This tone varies between 600 and 1600 p.p.s. and is modulated with an imposed frequency of 180 p.p.s.

A summary of the method to obtain Receiving and Sending Loss curves using the T.I.T. follows. It should be noted that no direct tests are made to obtain the Sending Loss curves. These curves are built up in the manner to be described.

Receiving Allowance Curves.

The standard of reference is the performance of the standard receiver on a 300 ohm local loop.

The modulated tone is applied as shown in Fig. **21**.

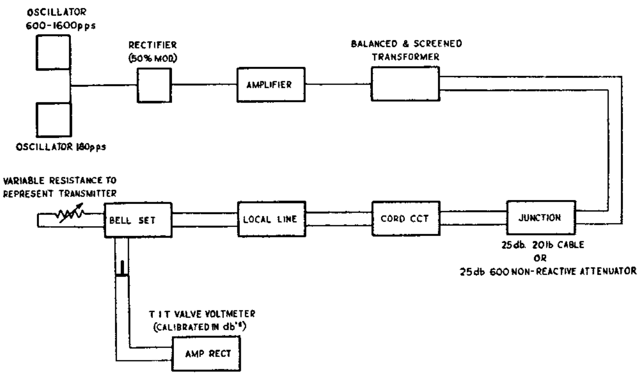


Fig. **21**.

By varying the local line resistance and the resistance to compensate for variations in transmitter resistance various readings of the valve voltmeter at the receiving end are obtained. The valve voltmeter is calibrated in decibels and with the performance on the 300 ohms loop as the basis the readings give allowances relative to the standard circuit. Fig. **22** gives the curves for a Telephone 162 (equal to specifition average) on a 22v C.B. circuit, and Fig. **23** shows the variations of transmitter resistance. The receiving curves of Fig. **22** show a performance better or worse than the standard and do not indicate the real receiving loss. This is an important point and will be referred to later when the Sending curves are considered.

Sending Allowance Curves.

In order to obtain the Sending curves it is necessary, first to obtain the relation between the E.M.F. (A.C.) across the transmitter and the transmitter current (D.C.). The apparatus in Fig. **21** is rearranged to measure the transmitter E.M.Fs. (A.C.) corresponding to various values of currents (D.C.) and the E.M.Fs. are expressed (as in the Receiving

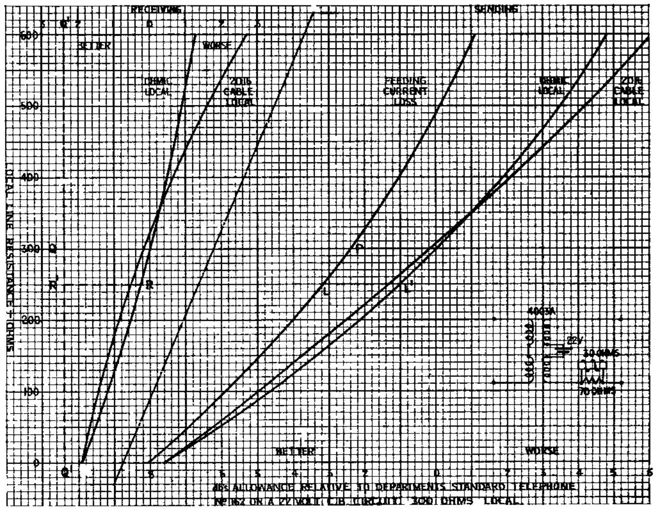


Fig. **22**.—Local Line Allowances for Telephone No. 162 (equal to Specification Average) on 22 volt C.B. Circuit.

curves) in decibels either better or worse than the performance under the standard condition. The following example will make the method clear.

Taking the 300 ohm loop and the 22v standard cord circuit, the line current will be approximately 51 mA. This is given by

$$C = \frac{22v}{(300 + 84 + 46)\text{ ohms}}$$
$$= 51 \text{ mA.}$$

The total resistance is made up as follows :—

4003 coil repeating = 46 ohms
Coil induction
No. 14 Bell Set I. = 17 ,,
Supervisory Relay
39J = 21 ,,

Total 84 ohms.

Transmitter resistance = 46 ohms.

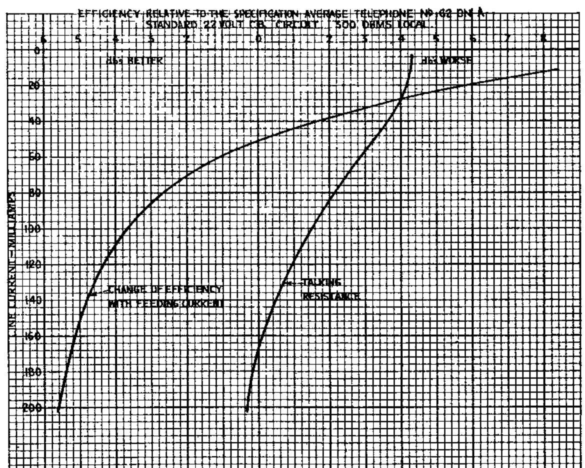


Fig. **23**.—Feeding Current Loss for Telephone No. 162 (equal to Specification Average). Feeding Current Loss and Resistance.

With a line current of 150 mA the total circuit resistance is composed of 31.5 ohms for the transmitter, 84 ohms for apparatus, 31 ohms for local line. Total 146.5 ohms.

Under these conditions, *i.e.,* transmitter current 150 mA corresponding to 31 ohms local line, the E.M.F. measurements previously referred to indicate that in relation to the 300 ohms loop the performance is 5 db. better than standard.

In Fig. **23** the curve marked " Change of Efficiency with Feeding Current " shows this relationship. The reference point is 0, 51 mA. The complete curve has been built up from a number of similar tests at different current (D.C.) values.

To build up the Sending curve the following relation is used :—

Sending Loss = Feeding Current Loss
+ Receiving Loss – ①.

Referring to Fig. **22**, the standard conditions imply that the S.A. curve must pass through the point 0, 300.

To fix the position of the Feeding Current Loss curve mark back from this point, 2.4 db. This gives a point P on the Feeding Current Loss curve. The 2.4 db. is the A.C. loss in the standard circuit when the local line is 300 ohms and includes cord circuit, local line and Bell Set and is the A.C. loss previously referred to in connection with the Receiving curves.

The location of the Feeding Current curve in Fig. **22** at the point 0, 300 has thus been determined from equation ① rearranged in the form :—

Feeding Current Loss = Sending Loss
– Receiving Loss.

To plot the other points consider the previous example for a line current of 150 mA. This condition gives a feeding current gain of 5 db. and the local line has been found to be 31 ohms.

Commencing at point P mark off horizontally the 5 db. gain. Descend vertically to the point 31 ohms and this is a point on the Feeding Current curve. Proceeding thus for other values, we build up the complete curve. It remains to find the actual Receiving Loss in decibels in order that this may be added to the Feeding Current Loss and so give the Sending Loss.

It has just been stated that the Receiving Loss, *i.e.,* the actual alternating current loss for the point (0,300) is 2.4 db. This is represented by the point Q (2.4, 300). All points on the receiving curves measured from the line Q′QQ′ give the actual receiving losses for the various local lines. Thus at a point R, RR′ is the A.C. loss.

By virtue of the relationship ① this is added to the Feeding Current Loss at point L and gives L′ as a point on the Sending Loss curve.

The various combinations of Bell Sets and Telephones in common use are treated in a similar manner to the method just described for the Telephone 162 and efficiency curves are prepared for all types.

The method is reasonably quick and tests against speech give results in good agreement.

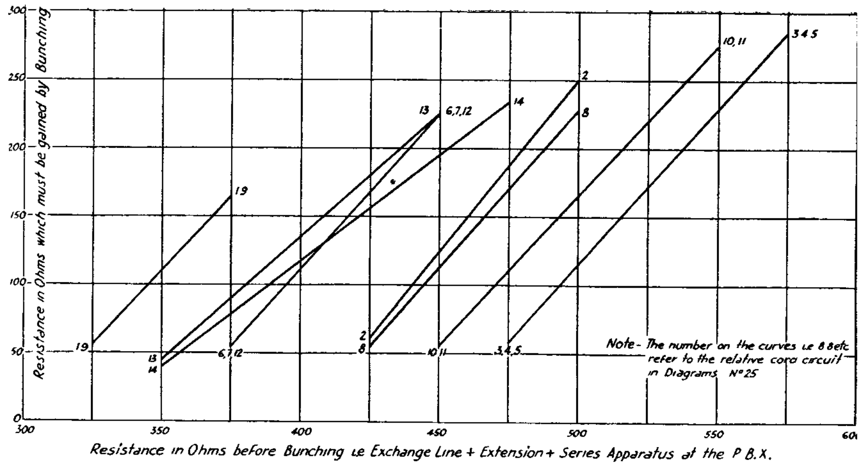
Appendix 2.

Private Branch Exchanges and Plan Number Extensions.

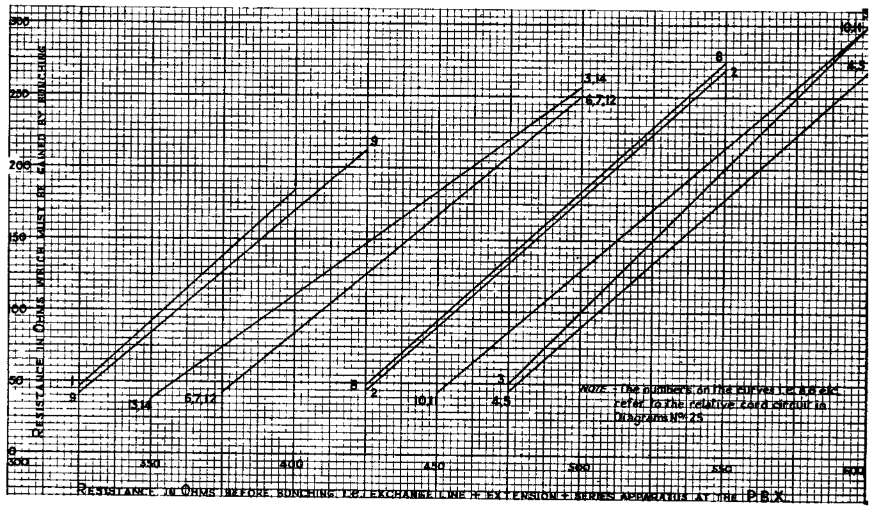
1. *Extension Instruments fed from main Exchange Battery.*

Where Private Branch Exchanges or Plan number extensions are concerned, it is necessary to make an allowance for apparatus in series or in parallel, and in general the effect is to reduce the maximum permissible line resistance in a given exchange area. If in planning an exchange area, it is known where Private Branch Exchanges and external extensions will be required, then the use of heavier gauge conductors than normal may be necessary to effect the desired transmission conditions.

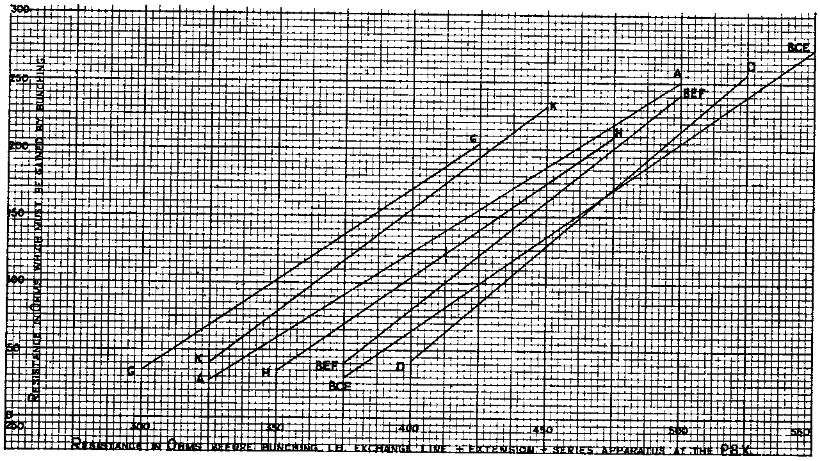
In present practice, all exchange to extension connections, except those with divided cord circuits at the P.B.X, are arranged for feeding current to the transmitter without intermediate apparatus in shunt. Under this condition it has been found that the transmission loss introduced at the intermediate switching point (P.B.X. or main station in a Plan number extension) is adequately compensated for when the limiting resistance selected for the exchange area is not exceeded by the resistance of the exchange and extension conductors, plus the resistance of the series apparatus at the switching point. The following table shows at a glance the resistances which should be allowed for various circuits. These resistances should be deducted from the maximum allowance for the exchange to enable the design of exchange line plus extension to be pursued.



Auto. Exchanges (20 lb. Lines).

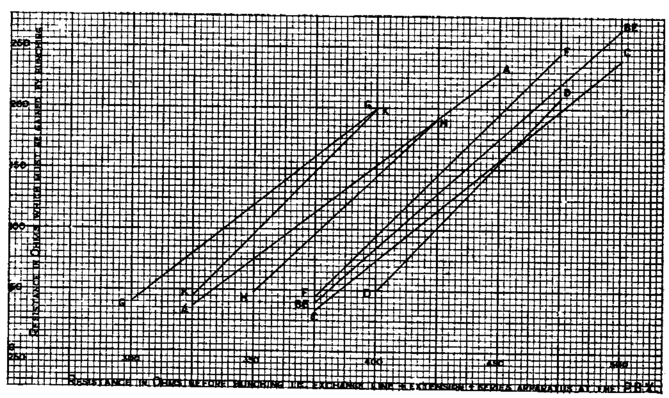


Auto. Exchanges (6½ and 10 lb. Lines).



C.B. Exchanges (6½ lb. and 10 lb. Lines).

Fig. 24.



C.B. Exchanges (20 lb. Lines).

TABLE.

RESISTANCE TO BE ALLOWED FOR SERIES APPARATUS—P.B.X. LINES AND PLAN 7.

Switchboard Diagram No. or Plan No.	Type of Apparatus or Switchboard.	Resist. (ohms).
C.B. 873 (N. 930)	Relay 119A.	12
C.B. 935 (N. 936)	,, 119B.	21
A.T. 1800 (N. 1080)	,, 500A.	14
C.B. 887 (N. 932)	Relay 119A. Indicators 2700A	78
	,, 119B. ,, 2700A	87
A.T. 1810 (N. 1090)	,, 500A. ,, 2700A	80
C.B. 1536 (N. 1110)	Indicators No. 3300B.	66
Plan No. 7	Bell Set 4. ,, ,, 20.	50

A special tolerance may be useful for cases of this sort. When the resistance limit cannot be met in a normal manner, two pairs could be bunched to obtain the standard grade of transmission. When pairs are bunched, the special tolerance should not be applied, because the longer line then used introduces a degradation in reception.

The amount by which the resistance of the exchange line and/or extension should be reduced by bunching is shown graphically in the curves of Fig. **24** for C.B. and Auto exchanges. The following table and diagrams of Fig. **25** are the references which enable the curves to be identified :—

Reference letter in Fig. 24.	Voltage of Exchange System.	Conditions at Main C.B. Exchange. Transmission Bridge. Type of Cord Circuit.	Voltage.	Description.	Diagram Nos. C.B.	K.
A	22	Subscriber	22	Repeating coil	350 1462	201
B	24	,,	30	Repeating coil Condensers and 50 ohms coils	933	212
C	24	,,	24	Condensers and 50 ohms coils	349 1462	200
D	90	,,	40	Condensers and 200 ohms coils	542 1462	202
E	22 & 24	Junction	30	Repeating coil Condensers and 50 ohms coils	902 906 1086 1227 1323 1463	204 301 218
F	40	,,	40	Repeating coil Condenser and 150 ohms coils	900 905 914 1226 1324 1463	203 208 307
G	22 & 24	C.C.I.	22 & 24	Repeating coil Condensers and 200 ohms coils Junction side and 50 ohm coils on Sub's side	—	—
H	22 & 24	C.C.I.	30	ditto	—	—
K	40	C.C.I.	40	Repeating coil Condenser and 200 ohms coils	—	—

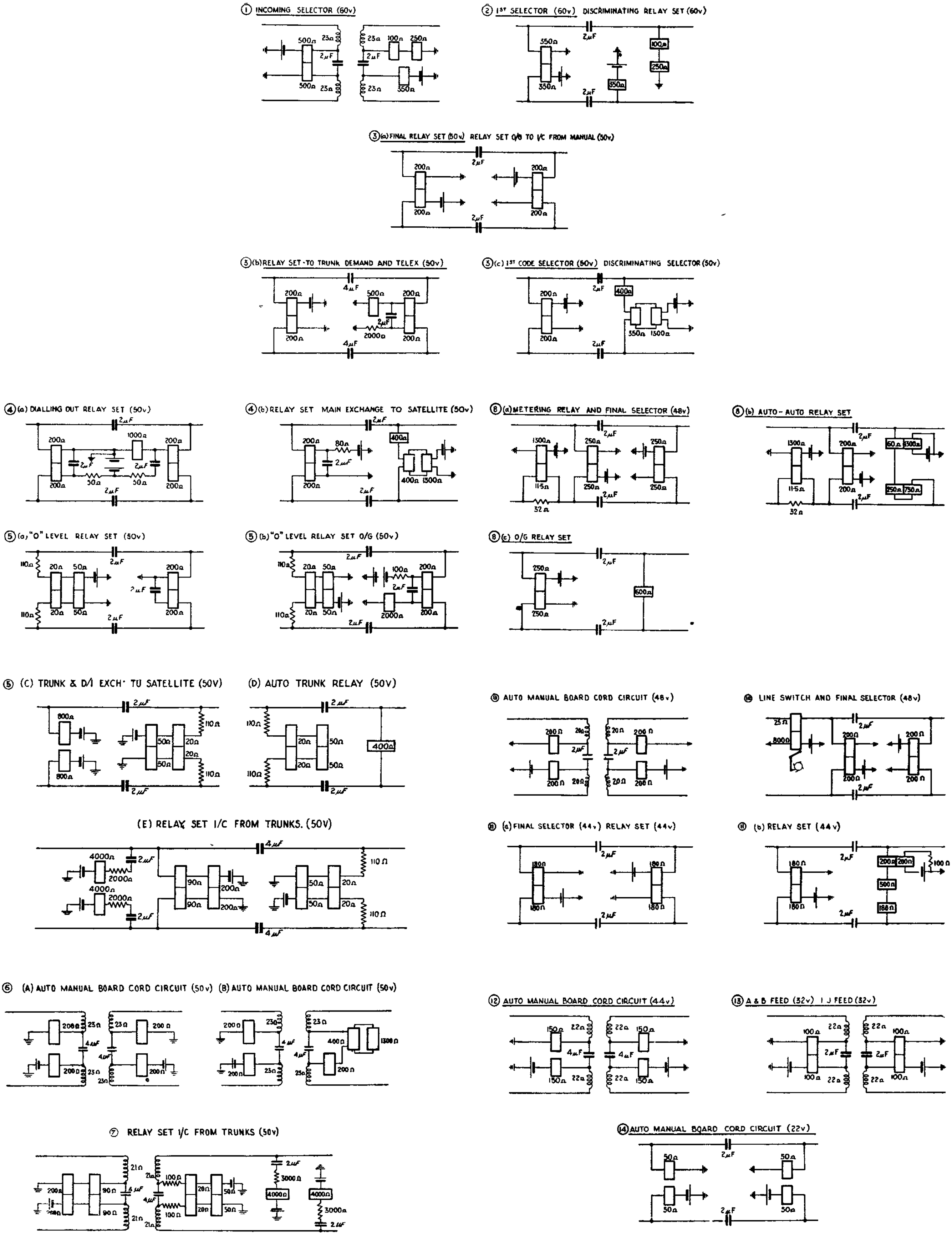

① INCOMING SELECTOR (60v)
② 1ST SELECTOR (60v) DISCRIMINATING RELAY SET (60v)
③(a) FINAL RELAY SET (50v) RELAY SET O/G TO I/C FROM MANUAL (50v)
③(b) RELAY SET-TO TRUNK DEMAND AND TELEX (50v)
③(c) 1ST CODE SELECTOR (50v) DISCRIMINATING SELECTOR (50v)
④(a) DIALLING OUT RELAY SET (50v)
④(b) RELAY SET MAIN EXCHANGE TO SATELLITE (50v)
⑧(a) METERING RELAY AND FINAL SELECTOR (48v)
⑧(b) AUTO-AUTO RELAY SET
⑤(a) "O" LEVEL RELAY SET (50v)
⑤(b) "O" LEVEL RELAY SET O/G (50v)
⑧(c) O/G RELAY SET
⑤ (C) TRUNK & D/I EXCH' TO SATELLITE (50V)
(D) AUTO TRUNK RELAY (50V)
⑨ AUTO MANUAL BOARD CORD CIRCUIT (48v)
⑩ LINE SWITCH AND FINAL SELECTOR (48v)
(E) RELAY SET I/C FROM TRUNKS. (50V)
⑪ (a) FINAL SELECTOR (44v) RELAY SET (44v)
⑪ (b) RELAY SET (44v)
⑥ (A) AUTO MANUAL BOARD CORD CIRCUIT (50v) (B) AUTO MANUAL BOARD CORD CIRCUIT (50v)
⑫ AUTO MANUAL BOARD CORD CIRCUIT (44v)
⑬ A & B FEED (32v) I J FEED (32v)
⑦ RELAY SET I/C FROM TRUNKS (50v)
⑭ AUTO MANUAL BOARD CORD CIRCUIT (22v)

Fig. 25

2. *Divided Cord Circuits at P.B.X's.*

A large number of Private Branch Exchanges are provided with divided cord circuits, *i.e.*, cord circuits which are used to supply the extension telephone with feeding current. This is the distinction from the previous cases which have been considered, because all the earlier results are based on the extension telephone receiving current from the main exchange battery.

Under the divided cord circuit condition, the sending and receiving losses must be obtained from the relative sending and receiving curves for the type of cord circuit in use. To the sending and receiving losses so found must be added the alternating current loss in the exchange line and the exchange cord circuit.

The success of the divided cord circuit as far as transmission is concerned, will, therefore, depend upon the degree to which it overcomes the disadvantage of the more or less fixed A.C. losses of exchange line and cord circuit. The higher the P.B.X. voltage which can be maintained, the lower will be the sending loss.

All types of Private Manual and Automatic Branch Exchanges have been considered and the investigations have yielded the following :—

(i) *The P.M.B.X.*

With C.B. main exchanges the divided cord circuit was of benefit, *i.e.*, gave an increase in the maximum permissible local line resistance to meet standard conditions, in only a few cases. These few cases all required the P.M.B.X. voltage to be of the order 20-24v and the line construction to be of 20 lb. cable. These requirements are not usually met in practice.

With Automatic Main Exchanges no case occurred in which the divided cord circuit equalled the standard grade of transmission.

(ii) *The P.A.B.X.*

Three types of P.A.B.X's have been considered :—

(1) The general type which has (100 + 100) ohms feed coils and 24v battery.

(2) Siemens—(350 + 350) ohms and 60v.

(3) S.T. & C.—(200 + 200) ohms and 50v.

For C.B. main exchanges the results showed that divided cord circuits could in a number of cases meet the standard for the type of exchange. Thus approximately 48% of the results were satisfactory, but these again required a uniform line construction of 20 lb. cable.

For the automatic main exchanges the divided cord circuits gave no advantage. In fact even with 20 lb. cable construction the maximum resistance of exchange line plus extension was approximately 125 ohms less than the normal.

The foregoing results indicate that there is no case on transmission grounds for the use of divided cord circuits in either C.B. or Automatic areas and the next step is, wherever possible, to modify divided cord circuits so that on exchange to extension calls the minimum of apparatus is left in circuit.

The decision to modify divided cord circuits comes opportunely at a time when another decision in connection with " Demand " working requires " through clearing " to be provided. Divided cord circuits do not lend themselves to the facilities necessary for " through clearing " and hence the decision to modify on account of transmission is doubly welcome.

Appendix 3.

Specimen Sheet.

Zone-Zone Transmission.

Direct circuit or with best circuit one Zone Centre intermediate.

Comparison between conditions in 1922 and 1933.

Route. From To	1922. Traffic.	1922. Line S.M.	1922. Allowance.	1933. Traffic.	1933. Line db.	1933. Allowance.
Belfast-Dublin	Direct	3.19	5.0	Direct	0	0
Belfast-Glasgow	,,	14.96	5.0	Direct	5.0	0
London	*Via* DN	25.40	15.0	,,	7.0	0
Newcastle ...	,, GW	22.39	15.0	*Via* GW	8.0	0
Birmingham-Bristol ...	Direct	5.50	5.0	Direct	3.0	0
Cambridge ...	,,	5.02	5.0	,,	5.0	3
Cardiff	,,	4.65	5.0	,,	3.0	0
Glasgow	,,	12.65	15.0	,,	0	0
Leeds	,,	4.09	5.0	,,	3.0	0
Liverpool ...	,,	7.38	5.0	,,	3.0	0
London	,,	7.80	5.0	,,	3.0	0
Manchester ...	,,	6.79	5.0	,,	3.0	0
Newcastle ...	,,	9.62	10.0	,,	3.0	0
Nottingham ...	,,	4.30	5.0	,,	3.0	0
Bristol-Birmingham ...	Direct	5.5	5.0	,,	3.0	0
Cambridge ...	*Via* BM	10.52	10.0	*Via* BM	8.0	3
Cardiff	Direct	6.58	5.0	Direct	3.0	0
Glasgow	*Via* Leeds	14.2	15.0	,,	0	0
Leeds	Direct	7.05	10.0	,,	3.0	0
Liverpool ...	,,	8.21	5.0	,,	3.0	0
London	,,	10.10	5.0	,,	0	0
Manchester ...	,,	19.75	? Repeater value	,,	3.0	0
Newcastle ...	*Via* BM	15.12	15	,,	0	0
Nottingham ...	,,	9.8	10	,,	3.0	0

Cambridge ceases to be a Zone Centre under " demand " working, but has been included for comparison purposes.

SOME NOTES OF THE DISCUSSION.

Capt. J. G. Hines :

I think I shall be expressing the views of all present when I say that we owe a debt of gratitude to the authors of this paper—not only because of the matter contained in it, but also for the way in which it has been delivered.

I suppose it is true to say that there is not one present who is not concerned directly or indirectly with the subject of telephone transmission. It has been necessary to specialise to a very large degree, and because of this specialisation we are rather inclined to lose our sense of perspective. It is good therefore to be brought back now and again to consider one of the fundamental matters with which we have to deal. There can be nothing more fundamental than the question of transmission since, what we exist for as a telephone administration, is to allow any one who desires to do so to converse with any other subscriber as clearly as if he were meeting the subscriber face to face instead of being separated by dozens, hundreds, or thousands of miles. We have not yet arrived at that stage, but we are approaching it.

It is rather interesting to remind some of the younger members that it is only in the lifetime of some present to-night that the telephone was invented and that about four years ago we had the privilege of listening to a gentleman who was the first to hear the human voice over the telephone, and a very thrilling moment it must have been for him.

It is interesting to recall how quickly we have developed and how far we have gone. As the authors have pointed out, that has been largely due to three main things. One was the introduction of the low-capacity cable; another was the addition of inductance to lines, and the third was the thermionic valve.

When some of us entered the Department it was only possible to speak over a few miles of underground conductor, and for long distances, it was necessary to use wires with conductors $\frac{1}{4}''$ diameter. The three main developments above mentioned have inter-acted on one another. When inductance was added to wires in order to counteract the deleterious effect of electrostatic capacity, the cross-talk between cable pairs was accentuated, and this led to improvements in cable manufacture. When the repeater came along that still further indicated the need for a more uniform construction of cable and spacing of loading coils, as not only was speech amplified, but cross-talk and other noises induced in the pairs were also amplified.

The introduction of the 2-wire repeater, as the authors mentioned, brought with it certain disadvantages because it was necessary at the end of each repeater section to employ an artificial cable which simulated the characteristics of the line in all respects. Apart from the cable itself being somewhat irregular in manufacture, it was found impossible to put the loading coils exactly where we wished and that introduced irregularities which it was found impracticable to match in the artificial cables. It was necessary to consider other means of overcoming this difficulty, so we went over to four-wire working which got rid of the necessity for using an artificial cable at the end of each repeater section. It was then necessary to have a balance at the end of the circuit only. I am not satisfied, however, that the four-wire method is the final solution for long distance working.

One of the disadvantages of the heavily-loaded circuit was the time of propagation, which was relatively long and led to echoes being received, so that the speaker had the impression that he was being interrupted. These echoes were amplified in the repeater and set up singing noises. This led to the introduction of echo suppressors.

The improvement in cable and the alteration in the ratio between the cost of repeaters, loading coils and cables is leading us to the view that possibly the future lay-out of the cable system will take the form of either unloaded cable or very lightly loaded cable with repeaters closer together. One of the advantages is that carrier circuits can be obtained on these cables and additional channels obtained at less average cost. If the cable is not loaded it is more easy to make a balance which correctly simulates the characteristics of the cable itself and this may facilitate two-wire working. There are many working hard on the development of a two-wire repeater which has not the disadvantages of the two-wire repeaters at present used. It may be on a rather different principle and there are indications that good progress is being made. In laying out the plant described in the paper we have not only endeavoured to use existing knowledge, but also to provide for the future probable developments.

There has also been a change in the method of providing local circuits. It is known that the volume of speech depends on the strength of the current that passes through the transmitter, and this depends on the voltage impressed on the line at the exchange. An obvious remedy would appear to be to increase the voltage of the exchange battery, but that is not so simple as it appears as on a short line the high voltage might not only be too great for clear speech, but might cause danger to apparatus. In the automatic system a 50 volt battery is used, but it has been necessary to put in the cord circuit two 200 ohm bridging coils for preventing cross-talk and to limit the current on short lines. Means have been achieved for reducing the resistance of these coils to 50 ohms while the inductance is maintained. This increases the voltage applied to the lines, but the disadvantage of excessive current on short lines remains. This difficulty has been overcome by the use of a " ballast " resistance, which is a device which increases in resistance with the amount of current passing through it, and thus limits the flow to a certain value. The net result is that the resistance of subscribers' lines can be increased without loss of transmission efficiency, in other words, smaller and cheaper conductors can be employed.

The authors have indicated how important it is that the engineer shall have a full grasp of traffic matters if he is to design his circuits efficiently. On the other hand, it is necessary for the traffic officers to have a general grasp of how the engineer achieves his results. That is why a paper like this is so valuable; it brings the two together, and it is essential that we collaborate so as to get the maximum efficiency.

I feel sure that the manner in which the subject has been dealt with by the authors will create fresh interest in the subject of transmission and will stimulate the endeavour in this Country to get the best possible transmission at the least cost.

Mr. J. N. Hill:

As Captain Hines said, we are all interested in transmission and the authors have given us a very interesting review of the past and some peeps into the future. The authors state that within the limits of their paper they have been unable to deal with the economic aspects of the case, but, as Captain Hines said, we are responsible for providing a good standard of transmission at a reasonable cost and perhaps I might be allowed to say a word or two on the economic aspect of the case.

Of course, in the days when all lines were provided on a copper basis only a small proportion of the overall allowance could be made available for local lines. The possibility of providing long wires of zero loss on amplified circuits of light gauge conductors has made it possible to allocate to the local lines a more substantial proportion of the allowance.

I understand the new transmission standard is to be based on the new hand-micro-telephone with the 300 ohm line connected to the 22 volt repeating coil system and allowance is to be made for other transmission circuits. This appears to be a big step forward as it enables advantage to be taken of improvements in circuit design. It is interesting to note the effect of increased resistance limits on the economic size of exchanges. As an example, for a telephone density of 1,000 per square mile with a 300 ohm local line allowance the economic size of automatic exchange is about 5,000 lines. If the local line allowance is increased to 500 ohms the economic size becomes 6,000 lines and the average cost per line is reduced by £0.14 per annum, so that approximately £800 per annum is saved. Part of the saving is due to buildings and equipment. As the density increases the differences in cost become less marked. It is interesting to note that in London at any rate variations in the local line allowance have practically no effect on direct junction costs. The average length of D type circuits is only about 4 miles and signalling limits impose a more severe limitation on the type of conductor than the transmission equivalent.

I am glad to see the authors indicate that in designing the lay-out of external plant allowance should be made for Private Branch Exchanges. It will be necessary to take into account the density of P.B.X's and extensions as it is obviously not economical to make the same class of provision in suburban areas as may be necessary in business areas.

On the question of amplified circuits I quite agree with the authors that it is difficult to present the economic aspects of the case at the present stage as costs are anything but stable, but in London some preliminary investigations are being made to determine the possibility of using amplified circuits of light gauge for G2 type circuits.

Mr. H. Townshend:

There are necessarily a considerable number of points I am not qualified to discuss, but the authors have taken a very broad and comprehensive view of their subject and I am very glad to accept the Chairman's invitation to speak as a visitor and try to bring out one or two points.

First, I would like to congratulate the authors on the extraordinary clearness in which they have set out a number of complicated factors in due proportion.

My first point is about the relationship between "Demand" working and the Transmission scheme. Some of my friends have asked me whether it was necessary to go on with the transmission scheme in order to have demand working or the other way on, that is simply the classic question of the hen and the egg. The authors have made it clear that these are just two parts of our general scheme of trunk improvement which the Department is pushing ahead with all possible speed and they fit into one another.

The paper gives examples of cases where awkward difficulties have been overcome, I think Capt. Hines suggested that that is not altogether due to a series of lucky coincidences. People have worked closely together, each one keeping the aims and objects of others before him.

Since "Demand" working is so mixed up with the transmission scheme I will give one or two general figures showing the extent to which the demand scheme has been carried. Of all the old trunk calls that used to be handled by the delay method about 60% are now handled by the demand method. We hope to have abolished the delay system by next summer. Of all the calls handled by the new demand method in the busy hour, roughly 75% go through on demand which means within 100 seconds on the average. On the remaining 25% the delay is as low as an average of five minutes in some centres and is about 10 minutes at others. That 25% includes calls on which the distant telephone is found to be engaged. It also includes roughly 5% of calls on which the trunk lines are engaged. Demand working is not no-delay working.

The authors touch on the important economic question of paid time, but I have not very much to say in that except that in general we get at least as much paid time with the demand system as with the 15 minute delay system; the subject is being studied in detail at the moment.

I think the Engineers working on these things must be interested in the public reaction. I should like to give some figures on that, but it is difficult to measure public reaction. The obvious thing to do is to count the number of complaints about trunk calls, but that is a bad way of measuring, it may be that it never entered a man's head to make a complaint because he supposed it would not do any good. Unfortunately, I have not any analysis with me; I can only give you a general impression based on having read through a lot of complaints and the associated papers.

Trunk complaints are not all transmission complaints, although we do get a fairly big sample of such, but we are getting a smaller and smaller proportion in general. The short distance complaint and the cross country one rather stand out. On the short distance side the sort of thing you get is a grouse, for instance, a person has a most satisfactory conversation from his London home with his people at Aberdeen; he cannot hear his office in the City. I do not know if the authors can give us any more information about the actual present position in the local network. They refer to the factor that the public has been accustomed to expect worse transmission on the long distance calls; that now means that they expect super transmission on short distance calls. I have the impression that if one could analyse the transmission complaints a very considerable proportion would turn out to be due to the subscribers' telephone. A large number of reports state that " the telephone has been changed and the conditions are now satisfactory." Then there is misrouting, but that we hope will be reduced in the next few months. Another class of case is where the engineering report is that the transmission is within the standard and commercial speech ought to be obtainable, but is very near the border line. If, for any reason, two or three db. are lost, the transmission becomes on the wrong side of the border line and one is not very clear what is the remedy here. I do not know if it would be possible for the authors to give us some more information about the position in regard to the upgrading of the two-wire circuits. I cherish the hope that something rather better than one or two db. improvement may become possible in the future. It would make a most extraordinary difference to the public reaction to our service.

Another reason also for hoping for the assimilation of the transmission standard on the group centre routes to that obtained on the inter zone routes is, that under the demand working system the distinction is artificial; modern group centres can, of course, act as zone centres.

Probably most of you know that instructions are about to be issued setting up new procedure for dealing with transmission complaints. I hope the effect of this, at the outset, will be an increase in complaints; we want people to tell us their troubles so that we can put them right.

A number of complaints are said to be due to " fading," I do not know what fading is, it is apparently a transient fault and when the engineers get on it it is no longer there.

I have one other point and that is concerned with the classification of circuits. I observe there are still four classes; is there any hope of getting that number reduced? As one speaker suggested, the difference between the two leading classes of circuit is becoming less in practice.

I very much appreciate being offered the privilege of raising a few points in this discussion.

Dr. G. W. Sutton :

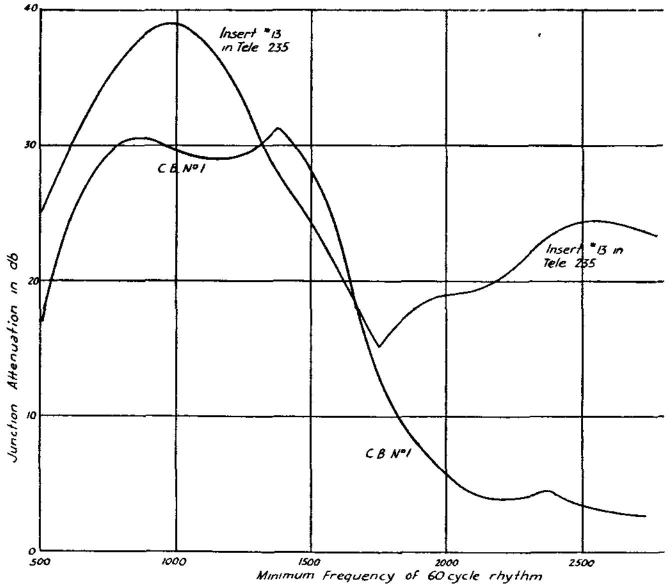
I should like to congratulate the authors on their paper and to take up a point raised by Capt. Hines.

Communication efficiency is rather a question of intelligibility than of loudness. Faint, intelligible speech is generally to be preferred to loud, less intelligible speech; and if we ignore for the moment non-linear distortion and the masking effect of noise, the question of intelligibility resolves itself into one of the distribution of the sound output over the useful frequency range.

Experience shows that the apparent loudness of transmitted speech is chiefly dependent on the output which lies, very approximately, within the band of frequency from 500 to 1500 c.p.s. A specification based purely on loudness may readily be fulfilled by apparatus possessing no output at all above the higher limit. Yet it has been shown that the elimination of all frequencies above 1550 c.p.s. reduces the articulation efficiency of a system by approximately the same amount as the elimination of all frequencies below 1550 c.p.s.

The above remarks apply particularly, of course, to voice-ear testing specifications. When we turn to mechanical testing, by which the apparatus manufacturers' products are now judged, we find that the nominal frequency range of the testing plant employed (and known as the Telephone Instrument Tester) is from 600 to 1600 c.p.s. This appears to me to be quite inadequate from the point of view of ensuring the production of apparatus capable of providing the high standard of communication efficiency demanded at the present day. It should be feasible to divide the frequency spectrum into, say, 3 bands (600-1600, 1200-2200, and 1800-2800 c.p.s. are suggested) and to specify a minimum output in each band.

Perhaps I can illustrate my remarks best with the aid of a slide. The curves shown were obtained with a modified form of T.I.T. and represent the outputs, over the useful frequency range, of a No. 1 C.B. transmitter together with one of the latest H.M.T. transmitters (No. 10). The rhythmic frequency band width used was about 60 c.p.s. and this band was raised in steps from 500 c.p.s. to 2800 c.p.s. Everyone is now acquainted with the difference, in ordinary use, between these two transmitters; the new one is louder and also provides higher articulation efficiency. The increase in loudness is illustrated by the 7 to 8 db. gain on the left hand side of the graph, while the much more important increase in articulation may be associated with the 20 db. gain on the right hand side. Attention is confined, however, in present specifications (both V.E. and T.I.T.) almost entirely to the lower half of the fre-



quency spectrum, and apparatus is quoted as being so many db. " Better " or " Worse " when the tests merely prove it to be " Louder " or " Fainter."

Mr. H. G. S. Peck :

The authors state that the average Transmitter No. 1 is at least 3 to 5 db. worse than the theoretical figure. I should like to ask how it is that these transmitters are so much worse than they should be? Is it due to age? I think not, because transmitters recently fitted were as inferior as those that had been in use for many years. Is it due to the specification, the testing or the manufacture? Is the deficiency likely to arise with the new transmitter?

In their opening remarks the authors referred to a private wire rented by Messrs. Coleman between Norwich and London, used in experimental long-distance telephony in 1897. It is interesting to note that this was replaced by a teleprinter circuit during the last few weeks.

Mr. L. B. Luget :

I have been asked by Mr. H. G. Trayfoot, who apologises for his absence, to read a few of his remarks.

With regard to the general question of trunk line transmission emphasis should be laid on the effect of patchy transmission, as until a recent date there was a marked difference between the trunk lines forming particular routes.

The regular subscribers were well-aware of the various deficiencies. Consequently a demand was made for the best. The opening of the London-Birmingham-Liverpool cable may be regarded as an event of the greatest importance in the development of the long-distance service of this Country. The traffic doubled in five years and the average annual increase was about 15%. The recent introduction of the zero loss circuit will entirely eliminate the unsatisfactory conditions which previously existed on all the important routes. Under the old conditions an operator could never be quite sure whether a conversation could be regarded as satisfactory, and this led to considerable loss of revenue. When, however, it was certain that all calls could be regarded as going through efficiently the amount of supervision could be reduced. Had the present conditions existed in 1931 there could be no doubt that the percentage of revenue-earning time would be higher than 79. There can be no doubt that the introduction of demand working had been greatly facilitated by improved transmission conditions. 99.4% of the calls were classified as good from a transmission point of view, 0.5 as poor and 0.1 very bad.

Multiplicity of switching is one of the most important causes of unsatisfactory transmission and the provision of a large number of direct circuits has been an advantage. Under the " Demand " scheme the number of group centres has been considerably increased and this should effect an improvement.

Alternative routing. On page 13 it is stated that under " Demand " working there should be good alternative routes between certain centres. Such alternatives have long been specified for all important routes.

Cord circuit Repeaters. The elimination of cord circuit repeater equipment has much assisted in the operation of long-distance circuits and is a good illustration of the rapid advance of telephone technique. A few years ago the C.C.R. was regarded as a means of salvation.

(End of written contribution).

The authors stress particularly that the long-distance links and the zone to group links are going to be up-graded, but there is a wider question. At zone centres, with separate trunk positions we are having separate circuits to the minor exchanges for long-distance traffic. When we come to the group centres another position arises; we have to use mixed groups of circuits and it has been the practice to classify these. If, for instance, we have a group of nine circuits we get three Z, three G and three D. Underlining is very good in theory, but in practice it does not work well. I remember going to a large group centre some years ago and being told that the markings were not up-to-date. I suggest we take every possible means in our power to ensure that the circuits are all of the same efficiency. It would be an immense boon from the traffic point of view.

With regard to the question of paid time, it should be remembered that at the moment we are only dealing with very simple traffic, and we do not know what effect the extension of control to group centres will have. There are two other points which may be of interest and which affect the plant lay-out. We have a study in hand at the moment of the possibility of taking away the control of timed traffic from a very large number of exchanges in the Country. If the scheme, which is intended to facilitate the provision of timing equipment is adopted, it will mean that a number of the cross-country routes will be eliminated and more traffic will be thrown on to the backbone routes.

Apart from the demand scheme there has been a considerable expansion of the no-delay areas in the past 12 months. The Manchester and Liverpool areas are two cases in point. I have been associated with Mr. Stratton on a number of the committees dealing with the introduction of "Demand" working at various centres and the agility with which some of the required circuits have been produced has been remarkable.

MR. W. G. TITE:

The authors in their reference to the adoption of the sleeve control system bring out very clearly the advantages gained by placing the signalling equipment directly in the lines, but I would like to suggest that if the full advantages of this method are to be obtained, it will be necessary for all transmission measurements to be taken from the exchange side of the relay set, instead of the termination of repeatered line.

This is very important when it is considered that unless zero transmission from exchange to exchange termination is maintained, the standards laid down for overall transmission equivalent when alternative routing is concerned, may considerably exceed these limits and no deviation from the normal zero transmission equivalent can be allowed. I shall be glad if the authors can give any information as to the method to be adopted in the future for overall transmission testing.

The introduction of sleeve control exchanges also indicates quite clearly that we are moving very rapidly towards the time when the present separation which exists between the repeater termination and the exchange equipment will be abolished and the whole repeater termination and signalling apparatus associated with the lines will be combined in one apparatus room. By this means we should achieve full flexibility for the development of the future.

MR. E. J. BARNES:

It is noticeable in working out the new transmission scheme that the volume efficiency alone has been considered; several speakers have already emphasised that volume is not everything that matters, in fact the quality of the transmission is of even greater importance, and all the various impairments, such as distortion, noise, etc., must be considered. For practical purposes it would be of great convenience if all the impairments could be measured in a common unit. There is considerable difficulty in evaluating the various impairments in this fashion, but a number of proposals have been made with this object, and the most promising of these are being tested. These experiments are by no means complete, but as far as they go they indicate that the difference between the old and new transmitters is not about 1.4 db. as has been assumed, but from 5 to 15 db., depending on other circuit conditions.

Another speaker has asked if the new instruments keep their efficiency in service. They have of course not been in use for very long, but all the indications we have show that they are very reliable. Means for testing transmitter efficiencies *in situ* are in course of production, by which it will be possible to keep a better check on any deterioration which may occur.

It should be possible to effect economy and make the transmission throughout an area more uniform by using the older and less efficient transmitters on the shorter subscribers' lines.

MR. J. STRATTON (*Authors' reply*):

In compiling a paper of this nature, the authors realised that it could only be a survey. Separate papers could be written about each sub-section, and in point of fact many have been, as will be seen by referring to the bibliography. In the excellent discussion that followed, much that had to be omitted in one hour's reading has been added, and we have been given a comparatively easy task in replying, in so much as most of the contributions to the discussion have been in the nature of additions rather than criticisms, and some of the later speakers have answered queries raised by the earlier speakers.

Capt. Hines gave a brief summary bringing out the outstanding developments, together with indications of the trend of future development. He stressed one point which we think cannot be too fully emphasised, and that is the necessity for full co-operation between the traffic and engineering staffs.

Mr. Hill touched on the economic side of the paper which, as we stated, we could not deal with in the time at our disposal.

Mr. Townshend gave us some very interesting features from the administrative and "Public reaction" points of view, and it would be very interesting to see a summary of complaints. As he pointed out, it would show us the weak spots in the system and facilitate the application of the remedy. As regards fading, that appears to be rather a fashionable complaint. It is rather like an epidemic, for instance, if there is a lot of influenza about as many illnesses as possible are attributed to that cause. In like manner, we are afraid that fading is rather a vague and comprehensive term used by most people with regard to complaints which are rather difficult to classify. Of course, it is rather impossible to expect an engineer to deal with a complaint which disappears as soon as he gets anywhere near a circuit.

Another point of Mr. Townshend's is in connection with the various grades of circuits. We think it will be seen from the paper that Z and G grades are approximately equal, and in effect we have only three grades as far as transmission efficiency is concerned, and with the probable further development of amplifier circuits, distinction between the remaining grades is likely to diminish.

Dr. Sutton has added some very useful information, explaining to a certain degree the advantages of the Telephone 162 over the old standard. We quite agree with his remarks on intelligibility. There comes a point where an improvement in volume is offset by the intelligibility or rather the lack of it. We consider that we are approaching a stage in volume improvement where considerable attention must be paid to the improvement of intelligibility. This opens a wide field for study.

We agree with Mr. Tite about the measuring of trunk circuits. They should be measured from the exchange side of the relay set in order to reap the full benefit of the sleeve control system. This is not being done at the moment, but the method of testing is being developed.

Mr. Trayfoot makes some interesting remarks and helps to show clearly the relation between transmission efficiency and demand working.

We agree with Mr. Luget to a certain extent about the efficiency of underlining, but it is obviously uneconomical to provide all circuits of the highest grade. We know there is a tendency on the part of operators if all the high grade circuits are engaged to make use of a lower grade one. They have to get rid of the traffic and they, rightly or wrongly, will take a lower grade circuit and hope for the best.

Mr. Barnes dealt with the points raised by Mr. Peck with reference to the efficiency of the new transmitters after a period of use. He also emphasised the importance of considering other factors besides volume. As indicated previously, we entirely agree, but for practical purposes volume is the most convenient basis for measurements. Some of the other factors, *e.g.,* frequency range, etc., are taken into account in the initial design.

It is interesting to note that approximately 10 years ago Capt. Hines, in a paper read before this Institution, predicted the advent of circuits with zero overall transmission equivalent. At that time, he was rather taken to task and told that that prophecy was unlikely to be fulfilled, but eight years afterwards, as already stated, we had the London-Aberdeen circuits on a four-wire basis, giving a zero loss. This should not be finality, and one of the dreams of the transmission engineer is to get zero overall transmission equivalent with a two-wire circuit. We venture to think that dream will come true in time.

In conclusion, we should like to thank you for the way in which you have received the paper, and also for the very valuable additions given during the discussion.

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