THE Post Office Electrical Engineers' Journal

The New Engineer-in-Chief.

Lt.-Col. A. G. Lee, O.B.E., M.C., B.Sc., M.I.E.E.

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COLONEL LEE, himself the son of a Post Office Engineer, became Engineer-in-Chief to the Post Office on 1st December last. Colonel Lee needs no introduction to the readers of this Journal, but it will not be inappropriate on the occasion of his attaining the highest honour in the Engineering Department to give a short account of his career.

Colonel Lee's early experience in the Service identifies him very closely with the work done on the development and introduction of loading coils on telephone cables, and throughout the whole of his career he has taken a very live interest in the subject of telephone transmission. Some of the earliest articles that appear in this Journal on the subject are from his pen. Later, he assisted the late Mr. Hartnell for a number of years in the work of systematizing the design and testing of cables, particularly the early submarine telephone cables.

Realizing the importance of field experience, Colonel Lee left Headquarters in 1908 to take up duty as an Engineer at Darlington, proceeding a year later to the position of Sectional Engineer at Bolton. He remained at Bolton until 1912, when, following an open competitive examination in that year, he returned to Headquarters as Assistant Staff Engineer on Transmission and Maintenance duties in the Telephone Section. His experience until the outbreak of war was both varied and extensive. Transferring to the Lines Section, he was responsible for the organization required to cope with the urgent economic studies, development schemes, and rapid provision of external plant necessitated by the acute shortage which had arisen with the transfer of the local telephone system from the National Telephone Company to the Post Office.

During the War, Colonel Lee served in the Royal Engineers (Signal Service), being in charge of a Telephone Construction Company, R.E., and later proceeding to the position of O.C., G.H.Q. Signal Area, combining with that the position of Second-in-Command L Signal Battalion.

On his return from the War, Colonel Lee served for a time in the Construction Section and later joined the staff of the Radio Section, where he took a prominent part in the development of the Wireless Station at Rugby. The success of the Department's effort in this enterprise laid the foundation for the building up of the present vast and worldwide wireless telephone network with America and our Dominions. Colonel Lee's part in the development of Trans-Continental and Trans-Oceanic telephony is well known to all telephone engineers. For the last few years he has been responsible for the technical direction of the Telephone and Telegraph, in addition to the Wireless services.

He has been the leader of the British Delegations at several International Radio Conferences. In 1928 he was appointed Chairman of the Radio Research Board, a post to which he brings considerable knowledge of the practical requirements of wireless as well as intimate contact with research methods. His activities in the technical field of wireless were recognized by the United States in 1928, when he was elected Vice-President of the Institution of Radio Engineers of America, an honour which he was the first Englishman to hold.

He was elected Chairman of the Wireless Section of the Institution of Electrical Engineers in 1927 and has been a member of Council of the Institution since 1931. He has been Chairman of Council of our own Institution since June, 1931.

We wish Colonel Lee a happy and successful career in his new position. B.O.A.

Signal Distortion in Telegraph Circuits

E. H. Jolley, A.M.I.E.E.

Synopsis.

Transient phenomena in Telegraph Transmission are dealt with in their relation to Signal Distortion and a method of utilizing steady-state theory in Telegraph Transmission problems is suggested. Signal Distortion is defined and its causes are indicated.

Introduction.

It is evident that for the most efficient and economical engineering of any communication system it is necessary to have some sound basis for determining the overall transmission efficiency of the communication channels. Further, it is necessary that the overall transmission efficiency be determined in such a way that it is directly related to the working performance of the circuit. In a telegraph system, working performance is determined by the rate at which messages may be transmitted and the liability to errors in the received messages, and therefore the overall transmission efficiency must be expressed in terms which are directly related to these factors. Because the communication channels are provided by a variety of means, it is apparent that the efficiency must also be given in terms which are independent of the system whereby the signals are transmitted. The commercial user of a telegraph channel is not concerned as to whether it is provided by means of, say, a D.C. duplex circuit or a D.C. 2-loop simplex circuit or yet a channel of a voice-frequency system, provided that the requisite speed and standard of working are attainable. It would seem that with the extended use of Teleprinter and Telex services where mixed V.F. and D.C. circuits will be utilized, the design and maintenance problems involved make it very necessary that there should be adequate information available as to the telegraph transmission efficiency of the various links.

It is the purpose of the present article briefly to review the principles of Telegraph Transmission Theory from the point of view of their bearing on overall working performance, and then to explain the incidence and methods of defining Telegraph Signal Distortion.

Telegraph Transmission Theory.

It would be almost useless to postulate a method of determining telegraph transmission efficiency unless there existed some connexion between the method and the electric and magnetic phenomena associated with transmission. This connexion is necessary so that the design of the transmission system itself may be carried out in relation to the ultimate working performance of the telegraph circuit. It is also necessary to show why the performance of the circuit cannot be determined directly from the electrical characteristics of the system, either in D.C. or V.F. working.

The difficulties which have attended the practical application of the mathematical solutions for the electric phenomena concerned in telegraph transmission, unfortunately need no introduction. It is well known that these difficulties arise from the fact that direct current telegraph transmission problems are almost wholly concerned with transient conditions, and the mathematical solutions of transient phenomena are complex, and, except in special cases, difficult of application to working conditions. In the case of alternating current transmission, such as in voice-frequency systems, the problem of the line is of course the same in principle as that of telephone transmission. Transient phenomena do arise and have to be considered in the design and working of the system, when, for example, filters are used to enable a large number of separate channels to be worked on one telephone line.

The significance of the Arrival Curve.

The transmission performance of a communication circuit of whatever character, under any given working conditions, is closely related to the corresponding arrival curve, that is to say to the time function of the received current when a steady voltage of a given value is suddenly applied at the sending end; the line being previously in a state of rest, and the sending and receiving impedances being identical with the given conditions. In a similar manner, the response of an electrical quadripole, such as a frequency filter, to an applied E.M.F. is governed by its behaviour on the sudden application of a steady voltage. Thus the arrival curve determines the time required for the building up to the steady-state of the received current for an applied voltage which is a repeating function of time. The duration of the building-up period is determined by the time required for the arrival curve to assume an approximately steady value.

The arrival curve of a typical unloaded line is given in Fig. 1 and the transient time is indicated. A physical conception of the way in which the arrival curve determines the transients may be gained by

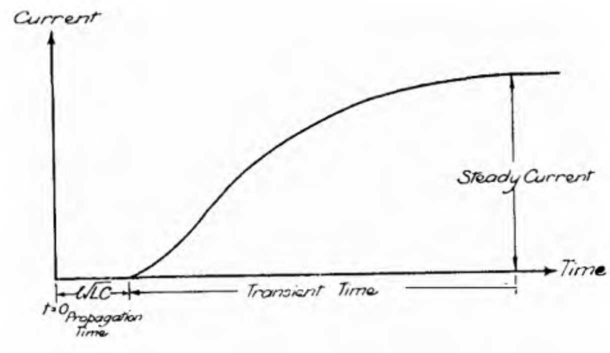


Fig. 1.—Typical Arrival Curve.

utilizing the method of superposition employed by Heaviside. Thus, it is assumed that each increment of voltage, dV, at the sending end results in an arrival curve $dV\ f(t)$ and each decrement $-dV$ an arrival curve $-dV\ f(t)$. The summation of the resulting series of arrival curves gives the shape of the received current. This is illustrated in Fig. **2**, in which the series of arrival curves due to square-topped voltage reversals impressed at the sending end of a line are shown. T is the periodic time of the reversals and they are assumed to be switched on at time $t = 0$, and switched off at time $t = \frac{9T}{2}$. The received current as given by summing the arrival curves is also shown. It will be seen that it is not until the first arrival curve of the series reaches its steady state that the summation becomes a repeating function of time. This is owing to the absence of the tails of previous arrival curves (shown dotted in Fig. **2**) to complete the summation. Also,

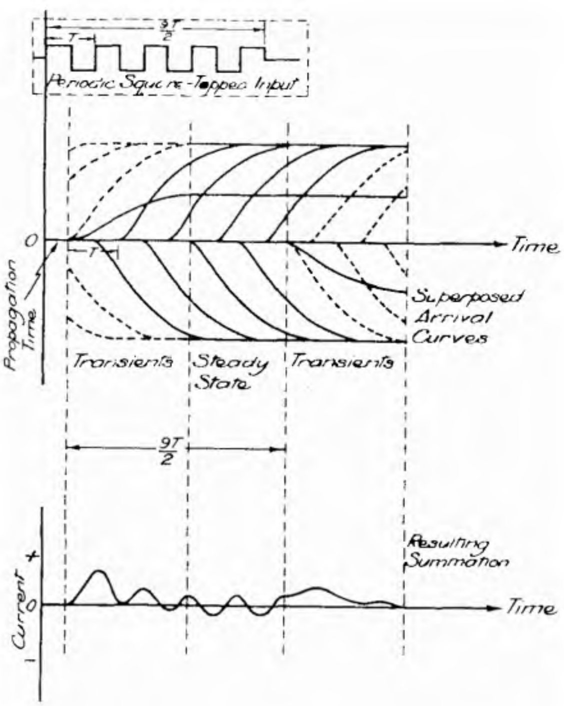


FIG. **2**.—SUPERPOSITION OF ARRIVAL CURVES, SHOWING BUILDING-UP AND DECAYING TRANSIENTS.

the amplitude of the first arrival curve will depend upon the value of the voltage at the instant of switching on and thus the shape of the received current wave during the transient period will depend on this. In a similar manner, transients will occur when the impressed voltage is switched off, due to the absence of the heads of succeeding arrival curves to complete the summation. Transients as described will occur in all circuits unless they are completely distortionless, in which case the arrival curve is square-topped and the transient time is obviously zero.

It is frequently valuable and instructive to consider problems involving transient effects on similar lines to those indicated in the foregoing, and mathematical solutions for transient phenomena are often based on this method of attack. It enables a clearer conception of transient conditions in filters and long telephone lines for example and is therefore useful in voice-frequency telegraph transmission problems as well as D.C. telegraph transmission.

Mathematical Derivation of the Arrival Curve.

According to the foregoing considerations, the first step in determining the transient phenomena in a circuit is the finding of an equation for the arrival curve. Actually this is possible from a consideration of the steady-state solutions, and this fact underlies the statement that a knowledge of transient phenomena can be obtained from the steady-state response of a circuit.

The commonest equation is that for the unloaded line, short-circuited at the receiving end, and with negligible inductance and leakance. This equation was given by Lord Kelvin in 1855, and led to the famous K.R. law. Although this solution has been of considerable utility, the assumption of zero terminal impedances and negligible inductance gives rise to considerable error in many cases. On this account, Dr. H. W. Malcolm[1] developed a more general solution based on the steady-state response of the circuit. Limitations of space prevent this interesting solution being discussed here, but it should be stated that it is useful in that it illustrates the important relation between the steady-state response of a circuit and the transient phenomena.

Heaviside's Expansion Theorem or Operational processes are available for the derivation of the arrival curve, but the solutions obtained, except in special critical cases, are as a rule complex and difficult for the engineer to apply to working conditions.

When the mathematical derivation of the arrival curve is difficult or impossible, it is often convenient to record the curve oscillographically.

Determination of the Received Current for a changing Applied Voltage.

The response of a network when the impressed voltage varies may be determined by means of the Superposition Theorem in a manner similar to that already mentioned. A mathematical solution can be directly deduced in some cases, or, alternatively, a graphical or algebraic summation of the series of arrival curves may be performed. In practice the effects of non-linear distortion and change of constants with frequency are sufficiently small to be neglected.

It is thus possible to determine theoretically, the

[1] See "The Theory of the Submarine Telegraph and Telephone Cable," by H. W. Malcolm, London, 1917. Chap. VIII.

received signals on any given telegraph line. However, similar information can frequently be obtained more easily by use of real or artificial lines and recording the curves and signal shapes by means of an oscillograph.

A number of most interesting methods of relating telegraphic performance and speed of working to arrival curves have been developed from time to arrival curves and the shape of the received signals have been developed from time to time.[2] These methods are valuable from a theoretical point of view and are useful for guidance as to general principles. Such methods alone do not, however, give sufficient information for a determination of the practical transmission efficiency of a telegraph circuit. This question is discussed in a later paragraph.

Use of Steady-state Theory.

The general steady-state solution for the current received at the end of a line for an impressed sinusoidal E.M.F., when the line is terminated by its characteristic impedance may be written :—

$$\bar{I}_r = \frac{\bar{E}}{Z_0} e^{-(\beta + j\alpha)l}$$

where β = attenuation constant.
α = phase constant.
$\bar{I}_r$ = received current (sine wave).
$\bar{E}$ = impressed voltage (sine wave).
Z_0 = characteristic impedance.
l = length of line.

In the case of a line having negligible inductance and leakance, such as an underground telegraph circuit, the equation may be written in the following form :—

$$\bar{I}_r = \bar{E}\sqrt{\frac{C}{R}} \cdot e^{j\frac{\pi}{4}}\sqrt{\omega}\, e^{-(\sqrt{\frac{1}{2}\omega CRl^2} + j\sqrt{\frac{1}{2}\omega CRl^2})}$$

where ω = 2π × frequency.
C = capacity per unit length.
R = resistance per unit length.

When the line is short circuited at the receiving end and is electrically long, so that the reflected wave is suppressed before returning to the receiving end a second time, the received current is doubled and we have :—

$$\bar{I}_r = 2\bar{E}\sqrt{\frac{C}{R}}\, e^{j\frac{\pi}{4}}\sqrt{\omega}\, e^{-(\sqrt{\frac{1}{2}\omega CRl^2} + j\sqrt{\frac{1}{2}\omega CRl^2})} \quad \ldots\ldots\ldots\ldots(1)$$

In as much as equation (1) is representative of the amplitude distortion and phase distortion, it is representative of the transient phenomena and it is therefore interesting to compare it with the approximate equation for the arrival curve, viz. :—

$$I_r = 2E\sqrt{\frac{C}{R\pi t}}\, e^{-\frac{CRl^2}{4}} \quad \ldots\ldots\ldots\ldots(2)$$

Where I_r and E are the values of received current and impressed voltage respectively.

In equation (1) the term $\sqrt{\omega}$ shows that there is an amplitude distortion which is independent of the length of the line.[3] This term causes the amplitude at the higher frequencies to be increased, which will result in a more rapid rise of current during the initial stages of the arrival curve. A similar function is performed by the factor $\frac{1}{\sqrt{t}}$ in equation (2).

In equation (1) the attenuation distortion and phase distortion, which vary with the length of the line, are both related to CRl^2 and this is in agreement with the K.R. law. Based on the K.R. law, empirical formula have been developed from the results of practical experience, of the type :—

$$S = \frac{k_1}{CRl^2} \quad \ldots\ldots\ldots\ldots(3)$$

Where S = maximum possible speed of working,
k_1 = a constant dependent upon the system of working, and the terminal apparatus and shaping networks.

Now if we take the highest fundamental frequency occurring in the signals as having a half period equal to the duration of the shortest element, we may write :—

$$f_m = \frac{k_2}{CRl^2}$$

Where f_m = maximum permissible signal frequency.

Then $\beta l\,(\max) = \alpha l\,(\max) = \sqrt{\frac{1}{2}\omega_m CRl^2} = \sqrt{\pi k_2}$ where $\omega_m = 2\pi f_m$.

This shows that the speed of working a circuit to which formulæ (1) or (2) apply may be related to the steady-state attenuation as well as to the K.R. value.

The similarity between the transient solution as given by equation (2) and the steady-state solution as given by equation (1) for the simple case of the

[2] L. J. Collet; Remarks on the Speed of Telegraph Transmission, Annales des P.T.T., p. 1, Jan., 1927. W. T. Palmer and H. J. Josephs; "Some Notes on Arrival Curves and Theoretical Telegraph Speeds," P.O.E.E.J., Vol. 21, No. 3, 1928. Documents of the First and Second Reunions of the C.C.I.T., 1926, 1927 and 1929. Various Contributors.

[3] This is due to the fact that the line has an impedance, the modulus of which falls as the frequency increases. This compensates to some extent for the increase of line attenuation with frequency. If resistance is inserted between the source of E.M.F. and the line, a point is reached where the drop of voltage in the resistance annuls the above effect. It is therefore desirable that resistance inserted at the transmitting end, either in the battery leads or the line should be limited in value. The detrimental effect of resistance in the line in order to limit the current may be partially overcome by shunting the resistance by a suitable condenser.

short-circuited line without inductance and leakance gives support to the contention that it should be possible to establish a reasonably satisfactory relation between the steady-state characteristics and telegraphic performance in the more complicated cases normally occurring in practice. It is noteworthy that the foregoing transient solution is the only one which appears to have ever been put to any practical use in establishing a relationship between working telegraphic performance and mathematical solutions based on transient conditions. Furthermore, it has only been applied with reasonable accuracy to electrically long lines such as transoceanic cables. On the shorter lines occurring in inland telegraphy, for example, the reflection effects which exist, especially at the lower frequencies, render formula (2) inapplicable. The transient solutions in such cases, where the effect of terminal impedance and shaping networks cannot be neglected, are so complicated that no very useful results have as yet been secured in the attempts which have been made to relate them to practical conditions. The mathematical difficulties are by no means so great if it is desired to obtain the steady-state characteristics of such circuits. Therefore, if satisfactory relations can be established between attenuation, attenuation distortion and phase distortion, and telegraphic performance, there seems to be every hope that the steady-state solutions can be made to give a much more practical basis for the mathematical solution of telegraph transmission problems than has ever been secured by use of transient solutions.

The steady-state response of a circuit to an impressed sinusoidal E.M.F. may be generalized to the form :—

$$\bar{I}_r = \bar{E}\, e^{-(x + jy)l}$$

Where x and y are parameters determining the amplitude and phase relationships existing between the impressed E.M.F., $\bar{E}$, and the received current, $\bar{I}_r$, and take account of line and terminal conditions. In the distortionless case x and $\frac{y}{\omega}$ are constants, but otherwise they are functions of ω and it is the dependency of telegraph signal distortion on these functions which must be determined, if the steady-state solutions are to be used to obtain the telegraphic efficiency of a circuit. Networks can be constructed for the purpose of introducing amplitude and phase distortion independently. By this means, reliable information could be secured as to the effect of such distortion on telegraph signals, information which would be of very great value in the solution of telegraph transmission problems. It would seem that an experimental determination on these lines would be analagous to an experimental determination of the dependency of articulation in telephony on similar effects.

Although, therefore, the steady-state solutions may as yet offer no simple and ready means of exactly determining telegraph transmission efficiency, it can be said that their use permits it to be materially improved. The problem is then simply that of reducing the steady-state attenuation, attenuation distortion and phase distortion over the important frequency range, say, 0 to 35 p.p.s. For example, the action of signal shaping networks such as the shunted condenser and magnetic shunt can by this means be examined, whilst complex attenuation and phase correcting networks may be designed.

If the design of a coil-loaded telegraph line is approached from the point of view of securing minimum phase and attenuation distortion over the working range of frequencies, the principles involved are similar to those of telephone loading. In the telegraph case, complications do arise, however, by reason of the necessity for the inclusion of all frequencies from zero up to the highest frequency required, the upper limit being determined by the speed of signalling desired. Thus, loading alone does not reduce the effective distortion to negligible proportions as in the telephone case. Therefore, in order to secure the best results, an extension of the methods used in telephony is necessary, so as to reduce the distortion at the lower end of the frequency scale.

Fig. **3** gives the dependency of attenuation and phase on frequency of a telegraph line having a resistance of 13Ω per mile and a capacity of 0.115 μF per mile. The corresponding characteristics for the same line loaded with 16-Henry inductance coils at 50 miles spacing are shown also. The circuit is designed for a signalling speed of 50 bauds (25 p.p.s.). Fig. **4** shows the corresponding arrival curves for a 450 mile line (K.R. 0.38 secs.). The received current for an isolated signal of 20 milliseconds' duration is shown in each case. By loading, the amplitude of received current for this signal is increased in the ratio of 5 to 3.

Distortion of Telegraph Signals.

A telegraph signal is normally composed of one or more elements. In inland telegraphy, these elements are of two kinds, positive and negative in double current working, and positive (or negative) and zero in single current working. In voice frequency systems, the elements are usually distinguished by full emission of the transmitted frequency or complete suppression. These elements are not all of the same duration, but the duration of the longer elements is commonly, but not always, equal to some simple multiple of that of the shortest or " unit " element. It has been proposed to use the duration of the " unit " element to define the speed of transmission of successive signals. According to this suggestion the speed is defined as N " Bauds " where the duration of the unit element is equal to $\frac{1}{N}$ seconds. (See C.C.I.T., Avis No. A.1(a), Second Reunion, 1929).

Except on the shortest lines, the received signals cannot be employed to operate the receiving mechanism of the telegraph machine, this being

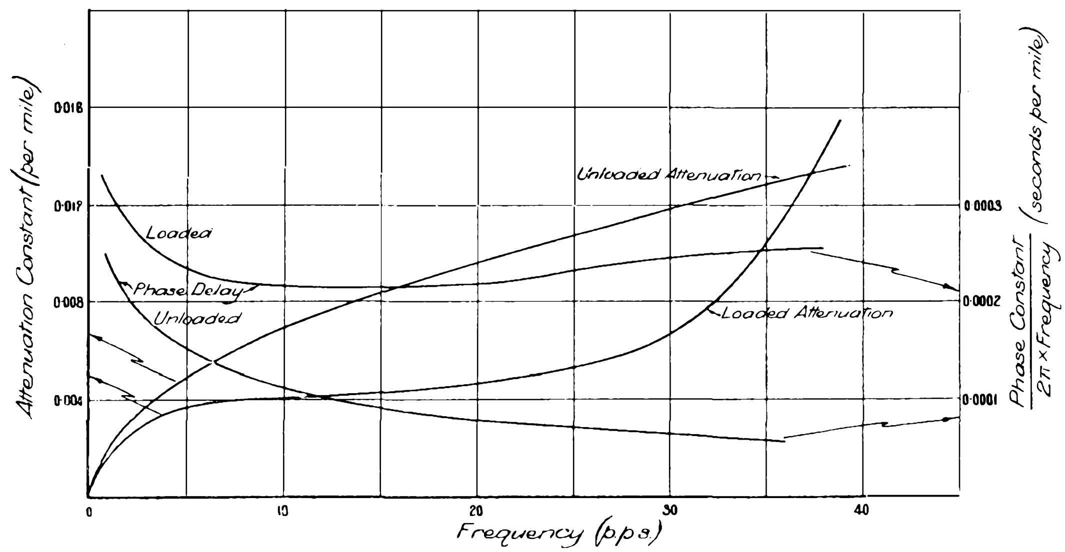


FIG. 3.—ATTENUATION AND PHASE CHARACTERISTICS OF UNDERGROUND TELEGRAPH LINE

(R = 13Ω/mile, C = 0.115 μF/mile).

(a) Unloaded.

(b) Loaded with 16 Henry coils at 50 miles spacing.

done *via* the medium of a relay. The relay restores the received voltage wave to one of square topped formation, but owing to the distortion of the received signals, the elements composing the signals delivered by the receiving relay may be lengthened or shortened. The extent of this distortion is difficult to determine from the actual shape of the signals received in the line. An assumption of a certain

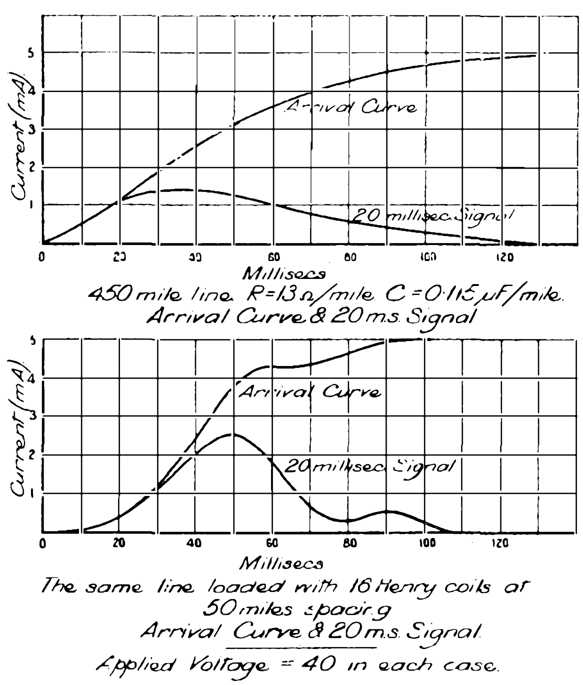


FIG. 4.—ARRIVAL CURVES AND SIGNALS.

fixed operating current for the relay, in order to obtain an exact value for the distortion from an examination of a given received signal shape, does not appear to be justified. The reason for this will be clear from examination of Fig. 5(*a*). The change of operating current is not due to irregular mechanical functioning of the relay (in this case a W.E. Permalloy Relay), as operating points on the corresponding elements of continuously repeated signals are in good agreement when the relay is properly adjusted. It is probable that the effect is attributable to hysteresis in the cores and armature, and also to eddy currents. The precise time of operation of the relay is dependent upon the amplitude of preceding elements and the rate of change of current in the coils. On the other hand, if a Gulstad vibrating circuit is used on the relay, then the latter acts as a very efficient distortion corrector and it can be made to reproduce workable signals when the received line current bears little resemblance to the original. Further, when distortion correcting networks, such as the magnetic shunt or shunted condenser, are used, these are adjusted to working signals so that the combined distortion due to the line and the relay is taken into account. If the line current record in Fig. 5(*b*) is compared with that in Fig. 5(*a*), it will be found that the real reason for the improvement secured by use of the magnetic shunt is due to reduction in the difference in amplitude of the elements, there being no great change in distortion as measured by the time displacements of instants of zero line current. In addition, the practical effect of parasitic currents in the line can only be estimated by determining their actual effect on the relay movements when signals are being transmitted. It is for these reasons that determina-

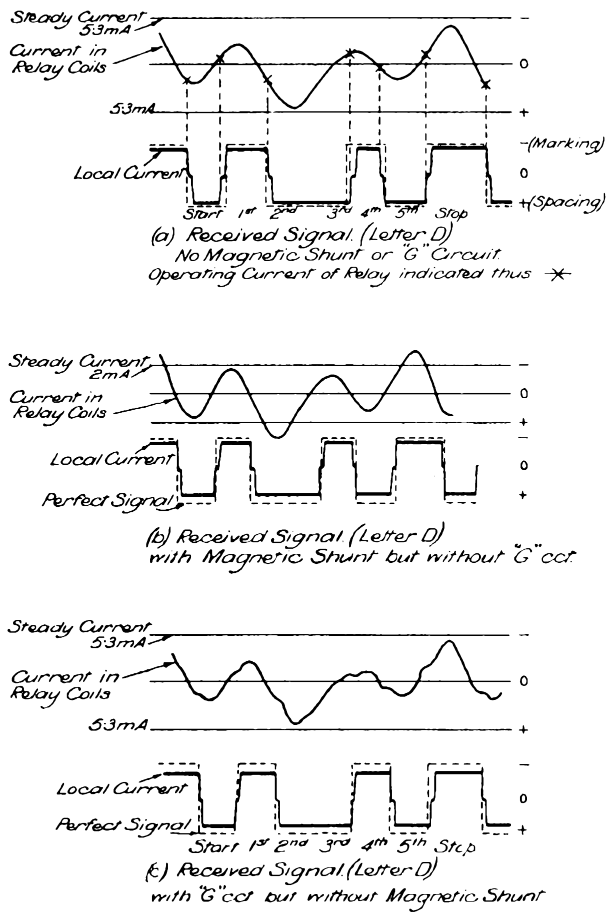


FIG. 5.—OPERATION OF RECEIVING RELAY FOR DISTORTED TELEPRINTER SIGNALS.

tion of the distortion from arrival curves or simple signal shapes is not entirely satisfactory and in practice distortion measurements are not made on the line signals themselves, but on the output of the receiving relay.

In the case of voice-frequency systems, it is only feasible to determine the telegraphic distortion in relation to the movements of the receiving relay or electromagnet. Such distortion is as a rule almost wholly due to transient effects and interference between channels caused by cross-modulation due to non-linear effects, and mainly arises in terminal and repeater equipment.

The character of telegraphic distortion is quite different from that of the theoretical distortion of a transmission line. Thus it is possible to have a circuit which is telegraphically distortionless, although it may be far from distortionless in the true sense of the term. This condition is possible if the duration of the transients is less than the duration of the shortest signal element.

A line or V.F. channel is telegraphically distortionless if the interval of time separating a change at the transmitter from the corresponding movement of the relay armature at the receiving end is the same for every change which occurs during the transmission of signals. When this is so, the lengths of the elements of the received signal are identically the same as those of the corresponding elements of the transmitted signal. When telegraph distortion is present, its practical effect is dependent upon the relative lengthening and shortening of these intervals of time.

The maximum distortion in a telegraph circuit is measured by the difference between the longest and shortest intervals (as defined above) which occur for all the possible combinations of signals which will be transmitted in practice. This difference, measured in seconds, has been called the " Encroachment " (L'Empiétement) by the C.C.I.T., whilst the ratio of the " Encroachment " to the duration of the unit element is called the " Distortion." This ratio is equal to the product of the encroachment (in seconds) and the speed of transmission (in bauds).

Fig. 6 is an example of a badly distorted tele-

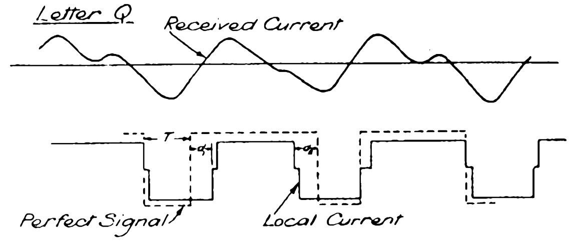


FIG. 6.—EXAMPLE OF BADLY DISTORTED TELEPRINTER SIGNALS.
Distortion equals $\frac{d_1 + d_2}{T}$

printer signal. The encroachment is equal to the sum of the intervals d_1 and d_2 in seconds, and the distortion is equal to the ratio $\frac{d_1 + d_2}{T}$ where T is the duration of the unit element. This ratio is frequently expressed as a percentage.

Classification of Telegraphic Distortion.

Distortion arises in a telegraph transmission system as follows :—

(*a*) In the transmitting mechanism and equipment.

(*b*) In the transmission link.

(*c*) In the receiving mechanism and equipment.

For a full knowledge of the conditions, it is necessary to have independent information under each of these headings.

Distortion is also classified as[4] :—

Characteristic Distortion.
Fortuitous (or Irregular) Distortion.
Bias Distortion.

Characteristic distortion is the regular distortion always occurring for any given series or combination

[4] This method of classifying distortion appears to have been first suggested by Messrs. Nyquist, Shank and Cory in a Paper " Measurements of Telegraph Transmission," J.A.I.E.E., March, 1927.

of signal elements, and is dependent upon the character of the system and transmission line.

Fortuitous distortion is the irregular distortion brought about by parasitic currents in the circuit or by irregular operation of the transmitter.

Bias distortion is due either to the marking or spacing elements of the signals being given preponderance owing to bias in the transmitting or receiving apparatus or batteries or battery circuit resistances.

The combined Characteristic and Bias distortion in a circuit is sometimes referred to as the " System distortion " and the distortion due to all causes is called the " Total distortion."

Distortion in the Transmission Link.

The distortion arising in D.C. working is, of course, dependent upon the method of transmission adopted. The systems in common use are Double-Current, Single-Current, Closed Circuit, Impulse and Central Battery. Each of these systems requires somewhat different treatment and has different characteristics as to the manner in which distortion is produced. It is not possible in this article to enter into a discussion of the problems special to each case, but the distortion effects may be broadly classified as follows :—

(*a*) Characteristic distortion due to attenuation distortion and phase distortion in the line.

(*b*) Fortuitous distortion due to interference from other telegraph circuits or power circuits, and, in a duplex circuit, inequality between the impedance of the line and balance network.

(*c*) Bias distortion due to earth currents.

In sub-audio (composited) systems, the characteristic distortion is augmented by the low-pass filters.

In alternating current transmission where a carrier frequency is modulated by the telegraph signals, if the carrier frequency is in the audio range (*i.e.*, a voice frequency) the problem of elimination of distortion in the line is identical with that of the telephone case and is, in fact, simplified by the fact that the band of frequencies required by a single channel is usually not more than about 100 p.p.s. and equalization of phase and attenuation characteristics over such a restricted band is not difficult to secure. A frequency filter always gives rise to transients, as will be clear from the remarks relative to arrival curves and transients; therefore the use of filters for the restriction of the band width may be attended by characteristic distortion of the telegraph signals. Here, however, the distortion is essentially independent of the length of the line and largely under control, being determined by the design of the filters and the relation of the signalling frequency to band width. Fortuitous distortion arises in multi-channel systems by reason of cross-modulation effects due to non-linear distortion, mainly in the repeaters and terminal equipment. If the line is provided by means of a high-grade telephone circuit, as is usual, little external interference is experienced.

In a V.F. system such as the Telex,[5] a certain amount of interference arises in the exchange connexions and causes fortuitous distortion which has to be catered for in the design of the system. In special systems such as the Telex or the High Speed Duplex V.F. System described in a recent article[6] where a wide range of transmission loss between the sender and receiver has to be provided for, some characteristic distortion, dependent upon the amplitude of the received signal, may be caused by the action of the limiting device provided to prevent overloading on strong signals.

Telegraph Apparatus Distortion.

Some transmitting mechanisms are essentially free from distortion, whilst in others, bias and irregular distortion may both be present. It will be sufficient to say here that transmitters of the rotary brush and distributor or rotary switch type are free from bias distortion and are also almost free from irregular distortion.

Distortion due to hysteresis in the magnetic circuit of the receiving relay has been mentioned already. Bias and irregular distortion will also be present if the relay is not correctly adjusted.

The final source of distortion is the local circuit of the receiving relay, which contains the electromagnet of the receiving mechanism. In an instrument such as the Teleprinter, distortion in the local circuit will cause the intervals between successive movements of the electromagnet armature to be different from the intervals between the corresponding movements of the relay tongue, particularly if the mechanical load on the armature varies during the process of the reception of a character. This latter effect may be considerably reduced if a rapid rise of current is ensured by use of suitable resistances and condensers, care being taken that undesirable transient conditions are not brought about.

When the electromagnet of the telegraph receiver is operated directly by the line current or directly from the V.F. equipment, as in the Telex system, it is preferable that the distortion be determined in terms of the movements of the electromagnet armature.

Conclusion.

The modern method of expressing Telegraph Transmission characteristics in terms of Signal Distortion has been explained and the sources of such distortion mentioned. The problem of applying these principles to a determination of the overall working efficiency of a telegraph circuit including the sending and receiving equipment still remains to be considered and the author hopes to deal with this in a subsequent article.

[5] R. G. De Wardt ; " Telex," P.O.E.E.J., Vol. 25, No. 3, page 177.

[6] J. M. Owen and W. F. Bevis ; " An All-Mains Voice Frequency Single-Channel High Speed Duplex Telegraph System," Ibid, page 182.

Introduction of Voice-Frequency Keysending from Manual A-Positions in London

H. A. Ashdowne, B.Sc., A.M.I.E.E.

THE simplification of Junction Signalling arrangements which results from the Order Wire method of completing a telephone connexion between two exchanges has firmly established this system, but the main disadvantage is the necessity for a second operator to complete a call.

The presence of an automatic exchange at one end of the junction opened up new possibilities, with the result that in many areas adjacent to Non-Director automatic exchanges the manual A-operator sets up the connexion by " dialling-in." This method, however, has its limitations on account of the operating time per call and the electrical characteristics of the junction. In consequence, the order wire method is largely used for traffic incoming to automatic exchanges. The bibliography contains reference to articles dealing with the keysender B-position (order wire) method of working and the various experimental equipments that have been installed.

With the 4-frequency A.C. signalling system, developed by Messrs. Standard Telephones and Cables Ltd. for the London-Leeds trunks, applied to the straightforward junction system, comparatively little additional equipment is necessary at the manual exchange. The existing two-wire junctions, which can be multipled, suffice for signalling and speaking, whilst the only difference in normal A-position operating procedure involved on a junction call is the waiting for the " pip-pip " signal, the depression of a " start " key, and the keying of the digits in place of depressing the order wire key, passing the demand, and receiving the junction assignment.

The universal applicatio of A.C. signalling using speech frequencies over long repeatered circuits considerably increases the potentialities of the system.

During 1930, experimental equipment was installed at Clerkenwell manual and National automatic exchanges. The results of the trials were

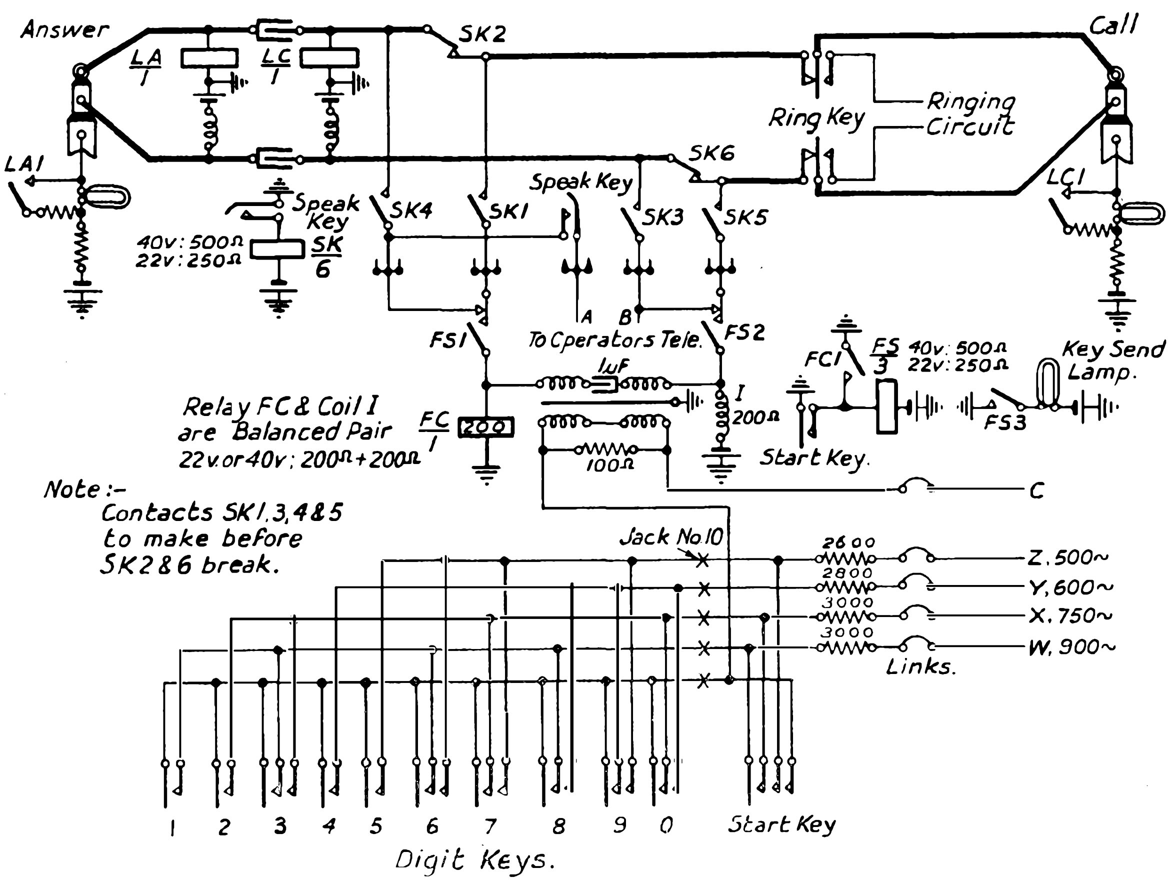


Fig. 1.—Position Equipment and Typical A-position Cord Circuit modified for A.C. Keysending.

satisfactory and the engineering and operating advantages of the system were such that it was decided to proceed with the conversion of all existing keysending B-position equipment in London.

Outline of the System.

The setting up of the call is controlled by means of alternating currents of four frequencies. These are known as W, 900 ∾; X, 750 ∾; Y, 600 ∾; and Z, 500 ∾. The term "Voice Frequency" is therefore derived from the fact that these frequencies are within the band used for the transmission of speech. Each digit, 1, 2, 3.........0, is allocated one or two of these frequencies so that the depression of, say, digit key 3 will connect the W and X frequencies to the junction. The actual combinations used for the various digits are shown in Fig. **1**. At the automatic exchange, the frequencies are applied to four special relays known as W, X, Y and Z.

It will be seen from Fig. **2** that the V.F. relay is

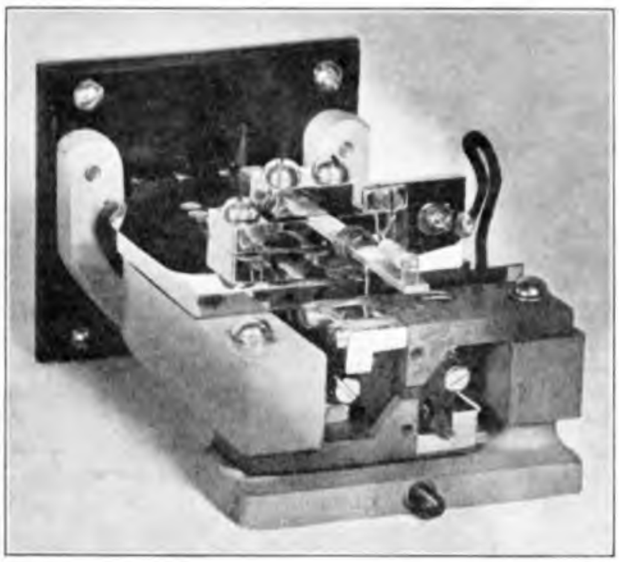


Fig. **2**.—Voice Frequency Relay.

polarized and has a "balanced armature" movement. The armature is connected by a stiff wire to a metal reed accurately tuned to the frequency to which the relay is required to respond. A light cylindrical weight or "bobble" is supported from wire loops, one at the end of the reed and one on a fixed pillar. When alternating current of the same frequency as that to which the reed is tuned is applied to the coils of the four relays, only that relay with its reed tuned to the frequency received can operate by virtue of the resonant characteristics of the reeds.

The vibration of the "bobble" causes the contact resistance between the small cylindrical weight and its supports to increase, thereby removing the short circuit across the relay connected across these points. This relay, which controls the storage in the sender, must have special characteristics and sensi-

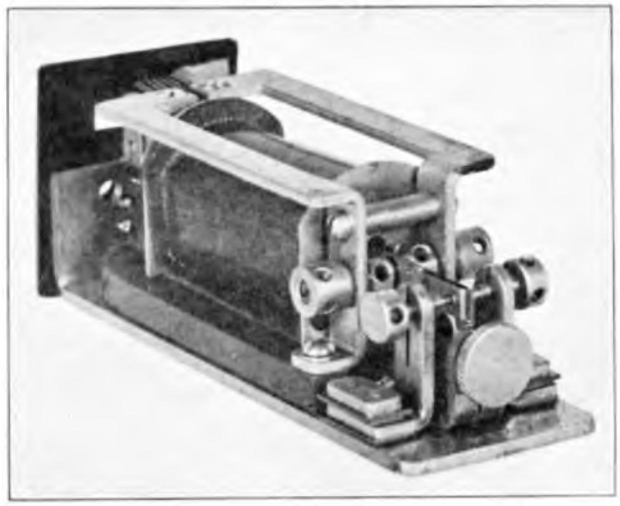


Fig. **3**.—Polarized Relay used as Auxiliary to V.F. Relay.

tivity. In consequence, polarized relays as shown in Fig. **3** are used. The operate and release currents of this relay are controlled by a bias spring which normally retains the armature against the back contact. The milled-edged knob shown on the front of the relay controls the tension of the bias spring.

A straight line diagram of the through circuit is shown in Fig. **4**.

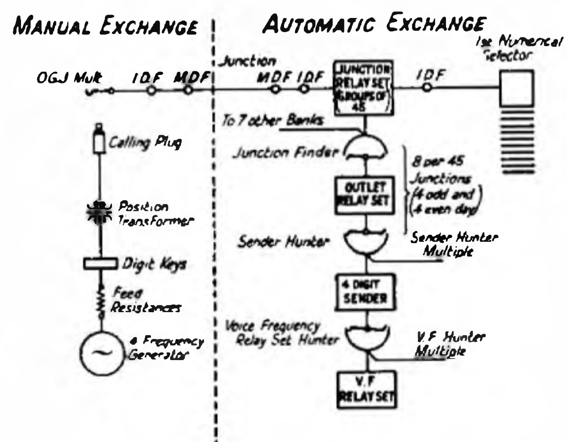


Fig. **4**.—Four-digit A.C. Keysending over Straightforward Junction System.

The four frequencies are supplied by two motor generators that run at 3,000 r.p.m. and have special governors to maintain the speed correct to within ± 0.3%. The D.C. motor is shunt-wound and is provided with three field windings :—

(1) The main field.

(2) An opposing field fed *via* a ballast lamp to ensure that the speed of the machine does not change appreciably with variation of the exchange voltage.

(3) The third field assists the main field and is introduced when the governor contacts close, so that the speed cannot vary by more than 0.3%.

The frequencies are generated at 20v with a permissible variation of 19v to 21v. This is stepped down to about 2.0v on the secondary of a transformer on each position. Single frequency signals at this point are about 7.5 db. above 1 milliwatt.

These frequencies were chosen because on long repeatered circuits such as trunks, for which the system was originally developed, the attenuation is practically constant between 500 and 1,500 cycles per second. Four frequencies had, therefore, to be chosen within this range such that the harmonics of one frequency would not coincide with one of the higher frequencies, but with the frequency separation as wide as possible to prevent " overlap." (Overlap is the false operation of a V.F. relay when a frequency appropriate to any one of the other three relays is applied). From the curves in Fig. **5**, it will be seen that the Z relay (500 ∿) will operate when it receives 600 ∿ A.C. (Y frequency) at a level of 0.8 db., but this will vary with the extent to which the relay may be off-tune and with any variation in the frequency applied.

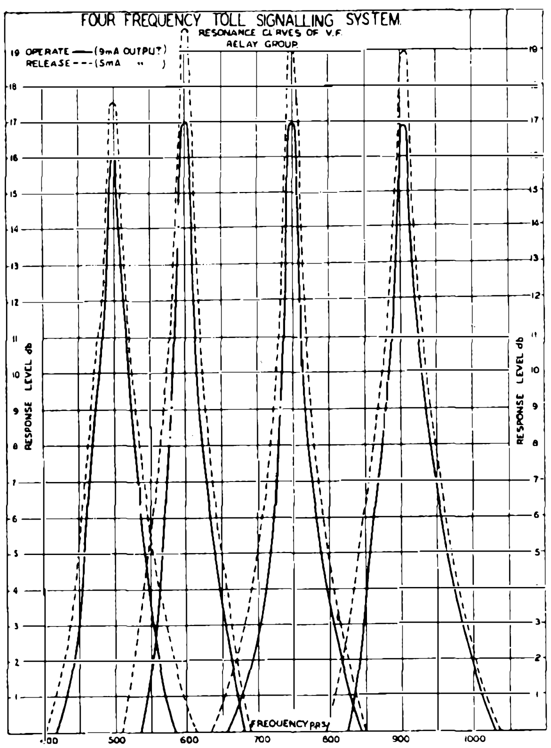


FIG. **5**.—VARIATION IN RESPONSE OF V.F. RELAYS WITH FREQUENCY.

Fig. **6** shows how the output power from a V.F. relay will be affected by load and input power.

A power of one milli-watt is regarded as the standard of reference when the received level of any frequency is considered.

The signalling power with the above arrangement is not greater than normal speech and in consequence overhearing of the signals does not occur.

The 4-frequency power board is shown in Fig. **7**. Two ten-pole double-throw knife switches will be observed in the bottom of the panel for the purpose of providing the following distribution to the positions :—

(i) Generator No. 1 to " odd " and " even " positions.
(ii) Generator No. 2 to " odd " and " even " positions.
(iii) Generator No. 1 to " odd " and Generator No. 2 to " even " positions.
(iv) Generator No. 2 to " odd " and Generator No. 1 to " even " positions.

The distribution is taken by twin 40-lb. rubber-insulated lead-covered cable *via* isolating links at the back of the 4-frequency power board. The distribution to odd positions is separated from that to even positions, and additional links are provided to isolate each position. The lead covering, which is effectively earthed, prevents electrostatic induction in other wiring.

The frequencies corresponding to the digits keyed are connected to the primary of the position transformer through series resistances to prevent feed back of the frequencies and mixing on the distribution. Band pass filter arrangements would be expensive and would occupy considerable space. The " stopper " resistance method is quite satisfactory.

Idle junctions are selected by the normal engaged test augmented, where there are more than 8 junctions in the group, by a " group engaged " test facility. Two short periods of N.U. Tone (400-cycle) are transmitted to the operator and calling subscriber as soon as keying may commence. Coincident with reception of the tone, the calling supervisory lamp in the cord circuit is darkened.

It will be seen from Fig. **1**, showing the position circuit, that a start key is provided to associate the digit keys with the cord in use. A lamp is illuminated as soon as the start key is depressed and is extinguished by a signal from the sender at the automatic exchange as soon as a digit is received in the last storage relay group in the sender. An immediate indication is consequently given to the A-operator should a fault cause sending to commence before the four digits are keyed.

The start key is also arranged to transmit W, X and Z frequencies which, by a special arrangement in the voice frequency relay-set and sender at the automatic exchange, will cause the cancellation of any initial storage in the sender that can be produced by operation of any combination of V.F. relays due to a surge from the line condenser in the V.F. relay-set when the latter is seized. The start key may, therefore, be used to cancel a partially set up call when a keying error is recognized.

The special arrangement of the SK relay contacts

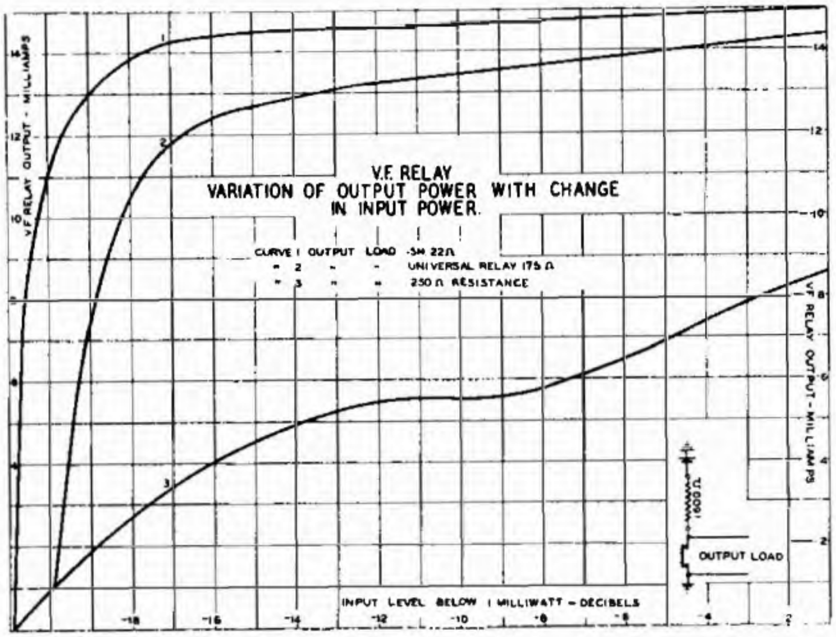


FIG. 6.—VARIATION OF OUTPUT POWER WITH CHANGE IN INPUT POWER.

has an advantage in that the connexion can be held for tracing purposes in the event of a fault.

Each group of 45 junction relay-sets is served by eight outlets, four of which can be brought into use on " even " days and the other four on " odd " days. Immediately one of the four working outlets is engaged, it is replaced by its idle partner in the other four outlets. In this way, four outlets are always available to associate any one of the 45 junctions with any sender. The junction finder and sender hunter are each " non homing " and, as the associated hunters of four outlets search simultaneously from different points round the banks, the effective hunting time is very small.

resulted from the elimination of " clicks " transmitted to the calling subscriber and the A-operator when the " speak " key was thrown. When the tip and ring leads each had one set of make-before-break contacts to replace the operator's telephone circuit by the position transformer, the sequence of operation of the speak key contacts with respect to one another and with respect to the SK relay contacts produced a momentary disconnexion in the circuit to the calling cord. Contact bounce was also found to exist on the SK relay which could be overcome by an adjustment, but it was considered desirable to use separate make and break contacts to effect the change over, together with the removal of the speak key contacts from the tip of the calling cord.

At the automatic exchange, the junction is terminated in a relay-set provided with battery feed and signalling facilities to the manual exchange. At this point, provision is made for attenuators or " pads " to be inserted in the circuit so that the A.C. signals will be between 4 and 9 db. below 1 milli-watt at the V.F. relays. The circuit arrangement provides for these pads to be short circuited after the keying is completed. The overall attenuation of the junction with attenuator must therefore be about 14 db. at any of the four frequencies.

In the junction relay-set, the busying earth is retained on the P-wire during the releasing period of three relays for uniformity with the requirements in the case where a train of tandem selectors immediately associated with the junction relay-set must be held until the selectors in the distant automatic exchange have had time to release. The P-wire is accordingly extended from the junction relay-set to the associated selector. In 4-digit keysending, however, this feature is unnecessary for this purpose, but

Front. Rear.

FIG. 7.—4-FREQUENCY MANUAL POWER BOARD.

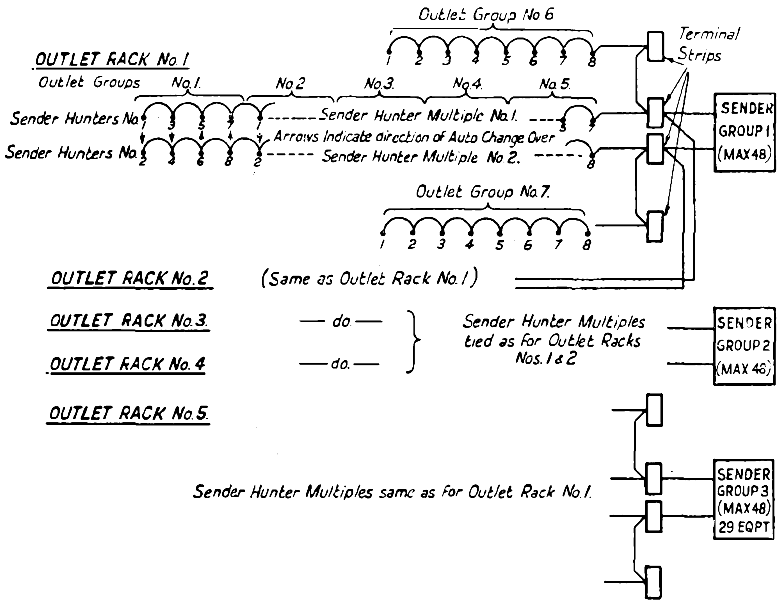


FIG. 8.—GROUPING OF SENDER HUNTER MULTIPLES ON 5 OUTLET RACKS TO SERVE 125 SENDERS (3 GROUPS) USING STANDARD OUTLET RACKS. NOT FULL AVAILABILITY.

racks, this method will mean that, if all the outlet racks are completely equipped and working, one group of senders can carry the traffic from only 1/5th of the junctions, but if the fifth outlet rack is only partly equipped—as is the more probable case—the proportion is even smaller. In consequence, the provision of senders to deal with the smaller amount of traffic from the fifth outlet rack cannot be so economical as for the traffic from the first two pairs of outlet racks, and the whole arrangement cannot be so economical as for one common group of senders. The increased provision of senders compared with the use of one common group (a facility for which the circuit is specifically designed) may become important on account of space considerations and the additional cost of the extra senders, with their racks, routiner access equipments, etc., required.

There are four sender hunter multiples provided on each outlet relay-set rack which can be equipped with seven groups of outlet relay-sets. Two of the sender hunter multiples (20 sender hunters each) provide for the "odd" numbered outlets and "even" numbered outlets in the first five groups, whilst outlet groups Nos. 6 and 7 each have a separate sender hunter multiple. Groups 6 and 7 may, therefore, work to a separate group of senders for straightforward junction working to B-positions, whilst outlet groups Nos. 1 to 5 may be working to senders associated with voice frequency relay-sets. It is therefore an easy matter to transfer a group of outlets and associated junctions from S.F.J. B-position to V.F. working when the manual exchanges are ready for V.F. keysending.

The sender hunter multiples for groups 6 and 7 on each outlet rack would, of course, be tied to the main sender hunter multiple for groups 1—5 in cases where there is entirely V.F. working.

It will be seen that, so long as only two groups of senders are required, the two sender hunter multiples can be tied from one outlet rack to another and all the senders are available to all the outlets. If, however, the number of senders exceeds 48 (*i.e.*, two sub-groups of 24) it becomes necessary to tie sender hunter multiples on the outlet racks to form two groups as shown in Fig. **8**. With five outlet

Fig. **9** is based upon the principle that full availability to a group of senders is provided if one, two or four sender hunters from each outlet group are allocated to a sender hunter multiple serving a sub-group of senders. The number of sender hunters per sub-group multiple is limited to 1, 2 or 4, because the eight outlets per 45 junctions are divided into "odd" and "even" day groups with automatic change-over to the idle partner outlet as soon as an outlet is engaged.

The number of sub-multiples cannot, therefore, be greater than the number of outlets (a condition not likely to arise because more than 192 senders would be involved) and the eight outlets must be completely divisible by the number of sender sub-groups; *i.e.*, the number of sender sub-groups can be 1, 2, 4 or 8.

The use of outlet relay-sets avoids the provision of a sender hunter on each junction, but the cost of the outlet rack, outlet relay-sets, automatic routiner

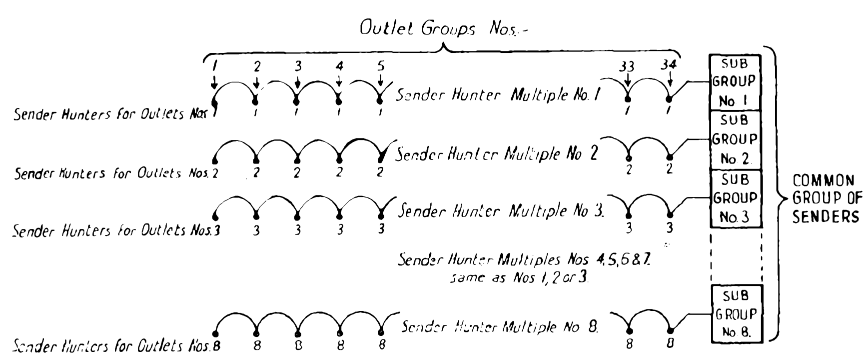


FIG. 9.—ARRANGEMENT OF SENDER HUNTERS TO PERMIT MORE THAN 48 SENDERS IN ONE GROUP.

and associated access equipment, etc., incur a greater cost per junction, where the number of junctions is small, than the provision of a sender hunter per junction.

The outlets involve additional maintenance, and a faulty outlet, until found and put out of service, is liable to affect a considerable proportion of the traffic. In future, the circuits will provide for a sender hunter per junction as standard.

As soon as a sender is engaged by an outlet, a " non-homing " hunter searches for and establishes connexion with a disengaged voice frequency relay-set. The incoming junction is then connected *via* the transmission bridge in the junction relay-set through the outlet and sender to auxiliary relays of the voice frequency relay-set and two short periods of N.U. Tone are transmitted to the A-operator. On completion of this signal, the voice frequency relays W, X, Y and Z are placed across the line ready to receive the A.C. signals from the digit keys.

When the storage in the sender is complete, the voice frequency relay-set is released and the necessary impulses are passed to the first numerical, second numerical and final selectors. The sender and outlet are then released.

The supply to the voice frequency relay-set routiner is obtained over a junction from a manual exchange selected to serve all automatic exchanges in an Engineering Section. One supply circuit is equipped for each routiner. The frequency or combination of frequencies sent is determined by the position of the wipers of a uniselector controlled by the automatic routiner or for manual tests by the dial on the test panel.

Conversion Work at Manual Exchanges.

The whole of the work at the 65 manual exchanges, involving the wiring, modification of cord circuits and fitting of position equipment on just over 2,000 positions has been undertaken by the Department. The fitting of about 40,000 cord circuit and position relays was involved and to do this where no multiple existed on the A-positions, it was necessary to make spare a few positions at a time by temporarily transferring the subscribers to other positions; where a subscriber's multiple existed, an auxiliary pilot was used on an adjacent position and the subscribers were answered in the multiple.

A review of the estimated completion dates for each stage of the work at the automatic exchanges together with the amount of junction equipment prepared in each stage permitted the 65 manual exchanges concerned to be arranged in seven groups with the latest completion dates that were required for each group.

The week-end demand of the 4-frequency motor generator will exceed the ampere-hour capacity of the exchange batteries in several small exchanges. Where possible, the battery capacity is being increased, but in four cases this is not possible without increasing the size of the power plant and the 4-frequency generator must be run from a mains-driven dynamotor with facilities for running No. 1 or No. 2 4-frequency generator from the dynamotor or the battery.

It is, of course, not economical to provide for A.C. keysending from manual exchanges due for conversion to automatic working within the next three years and these exchanges will continue to dispose of their traffic on an order wire basis or on an S.F.J. B-position basis to automatic exchanges.

Toll B and Trunks will continue to dispose of their traffic on an order wire basis for the present, except in certain cases where only Toll B junctions remain after the conversion and the number of these junctions does not constitute an operator's load. In these cases, the Toll B junctions are being arranged to work on a jack-ended basis to the auto manual switchboard. Arrangements are being made for the trunk operators to dial in to London automatic exchanges.

Conversion Work at Automatic Exchanges.

The whole of the conversion work at each automatic exchange will be carried out by the Contractor who installed the original equipment. The recovery of the B-positions and the installation of the V.F. relay-set rack and relay-sets will, however, be carried out by the Department.

As much as possible of the order wire keysending equipment is being used for the straightforward junction equipment, but the outlet relay-sets and voice frequency hunters are new. Spare keysender B-position equipment was available at most exchanges and, to facilitate the contractor's work, that available at all of one contractor's exchanges was regarded as a " pool " and placed at his disposal.

In order that the existing junction relay-set and sender routiners could be modified, it was necessary to effect recoveries for the pool from exchanges with fewer than 45 junction relay-sets and fewer than 10 senders, but in some cases it was necessary to exceed these quantities to obtain the required number of routiners in the pool. The recovered routiners were replaced by temporary portable testers. At other exchanges, the sender and junction relay-set routiners can be recovered for conversion when the order wire equipment has been reduced to a similar amount of equipment, or as soon as special routine testing arrangements are provided.

With the initial quantities in the contractor's pools and the amount of spare junction relay-set and sender rack space at each exchange known, it was essential to prepare a programme embodying all the exchanges with which each contractor was concerned to ensure the most expeditious and economic order of proceeding with the conversion.

It was necessary to give special attention to the number of senders required for the amount of junction equipment modified at each stage of the work in an exchange, because the number of order wire senders that can be recovered at each stage is smaller than the number of S.F.J. senders that must be installed. This is on account of the relatively smaller traffic-carrying capacity of small groups of senders. There was consequently the possibility that the pool would become depleted or that the spare space available for modification on the sender racks would be insufficient for the number of S.F.J. senders required at some stage of the work.

It is desirable to utilize the existing cable to the I.D.F., to retain the same order of numbering on the I.D.F., and to ensure that all the straightforward junction relay-set cabling can be accommodated in the existing space on the I.D.F. between the positions on which the work is commenced and the last keysender B-position that is required for the order wire junctions remaining after conversion. The work must consequently commence with the installation of the last S.F.J. junction relay-set groups on spare racks corresponding with the last B-positions. Where there are no spare B-positions or suitable junction relay-set rack space, lay-out and space determine whether a rack recovered from another exchange and modified is temporarily or permanently installed to permit the work to commence. Wiring for an additional outlet group is necessary in cases where the junction relay-set rack is only temporary. The contractor's work is continued on racks made spare by bringing the first stage equipment into service.

Spare C.C.I. keys or change-over strips are connected in each keysender B junction scheduled for the approaching transfer and at the date and time agreed between the engineering and traffic staffs it is only necessary to operate the keys or to change over the wedges. It is essential that this work be completed well in advance of the commencement of the call through tests, but as it is necessary to associate the tester used for the call through test with the outgoing side of each junction relay-set in turn, the jumpers to the first numerical selectors cannot be run until after the successful completion of the test.

Every available spare first numerical selector is then associated with the junction relay-set allocated to the routes scheduled for the approaching transfer. The number of first numerical selectors and bank capacity available may seriously limit the number of junction routes that can be prepared at any one time, unless special arrangements can be made to increase the number of selectors available for the period of the transfer.

Testing.

Before the introduction of V.F. keysending from any manual exchange, a successful call is obtained over one junction to a nearby automatic exchange from every cord, and every digit key is proved by means of the digit key test circuit. A successful call is obtained over every junction to the automatic exchange concerned before a junction route is offered for traffic trials. When other routes to automatic exchanges are subsequently transferred to a V.F. keysending basis, it is only necessary to carry out the junction tests.

The 4-frequency power boards were subject to the usual electrical and heating tests and mechanical inspection, but, as the generators are to be run continuously and must maintain their speed and voltage within very close limits, every machine had to pass successfully a continuous run for six days.

It was originally intended that one 4-frequency generator should normally serve both odd and even positions, whilst the other generator remained idle as a standby, but, until a large number of tests had been made, it was somewhat uncertain whether the time required for a generator to attain steady and satisfactory speed when started up from cold would make it necessary to keep both generators running. It has now been proved that, if the standby machine is in correct adjustment, calls can be successfully completed within two minutes after starting up from cold.

As far as the automatic exchanges are concerned, the usual adjustment, sectional and call through tests are made on the junction relay-sets, outlets and senders, but as the voice frequency relay-sets installed by the Department must be included, it is necessary to prove their performance by the automatic routiner and manual test just before the " call through."

Before the call through test, a " flood " test is at present applied to ensure that the voice frequency relay-sets will give satisfactory service. For this test, arrangements are made for a number of operators to pass about 250 calls per voice frequency relay-set to selected numbers. It is preferable to confine the traffic to a few proved outlets and senders. The spare subscribers' lines used are terminated on indicators on the auto-manual switchboard and each call is answered. The records of wrong numbers obtained are kept by the operators and are subsequently analysed.

For the purpose of the call through test, one junction from a selected manual exchange is connected to the incoming side and a tester J or 61 to the outgoing side of each junction relay-set in turn. The attenuator, appropriate to the junction used, is clipped in place of the normal junction relay-set attenuator and as a successful call is passed the attenuator is moved to the next junction relay-set. The attenuators normally required by the junction relay-sets may be fitted by the Department before the call through, but until the equipment has passed this test one side should be left disconnected. The use of tester J or 61 permits the digits sent out by the sender to be read from the display and failures due to the exchange switching equipment are thereby eliminated. Moreover, a comparison of the number sent with that received is some guide as to whether the fault is due to the V.F. relay-sets or to the junction relay-set, outlet or sender.

When satisfactory results are obtained from the foregoing tests, each junction from the manual exchanges concerned in the approaching transfer are tested under V.F. keysending conditions. The junction routes successfully tested are then offered to the London Telephone Service for their trials and subsequent transfer to carry public traffic.

Standard junction relay-set attenuator resistance values for different ranges of junction equivalents had been determined from the Clerkenwell-National experimental equipment, but, when the conversion work was sufficiently advanced for tests to be made, it was found necessary to ensure that the A.C. signal with single frequencies is within 4—9 db. below 1 milliwatt instead of within 5—10 db. because transient release of the polarized relay is liable to occur during the signal at levels lower than 10 db.

At present, ± 1 db. is allowed for the variation in the A.C. 4-frequency generator output, the variation of the junction characteristic with temperature, and the difference in loss due to junction terminating equipment. In consequence, junctions are being attenuated by resistance to ensure a received level between 5 and 8 db. for single frequencies.

Fig. 10 shows the results of measurements on junctions from a number of manual exchanges to Bayswater and Shepherds Bush automatic exchanges, and is reproduced to indicate the necessity for choosing a resistance such that the different attenuations of the four frequencies do not result in the level at the V.F. relays being outside the range 5 db.—8 db. with any of the four frequencies. The measured received levels of any of the four frequencies taken singly over the junctions indicated at the foot of the diagram varied between the top and bottom end of the vertical lines.

It will be observed that the variations due to frequency differ with each junction and that for a given attenuator value the loss is not necessarily greater on the junction with a larger equivalent. Many cases have been found where an attenuator resistance suitable for one junction will produce a loss just outside the limits on another junction with the same equivalent.

For the junction routes shown on the graph, it will be seen that 1,800Ω is required for junctions above 5.5 db. and up to 6.5 db., 1,500Ω for junctions above 6.5 db. and up to 8.0 db., and 1,200Ω for junctions above 8.0 db. and up to 10 db.

The margins shown as "Voltage Correction Factor" and "Resistance Correction Factor" represent possible variations in received level due to the permissible variation in machine voltage and the ± 5% variation allowed in the resistance of the attenuators. The horizontal lines at 4.0 db. and 9.0 db. represent the working limits of the V.F. relays and those at 5.0 db. and 8.0 db. the safe range within which the received level must be kept to allow for the above variations with a margin of 0.35 db.

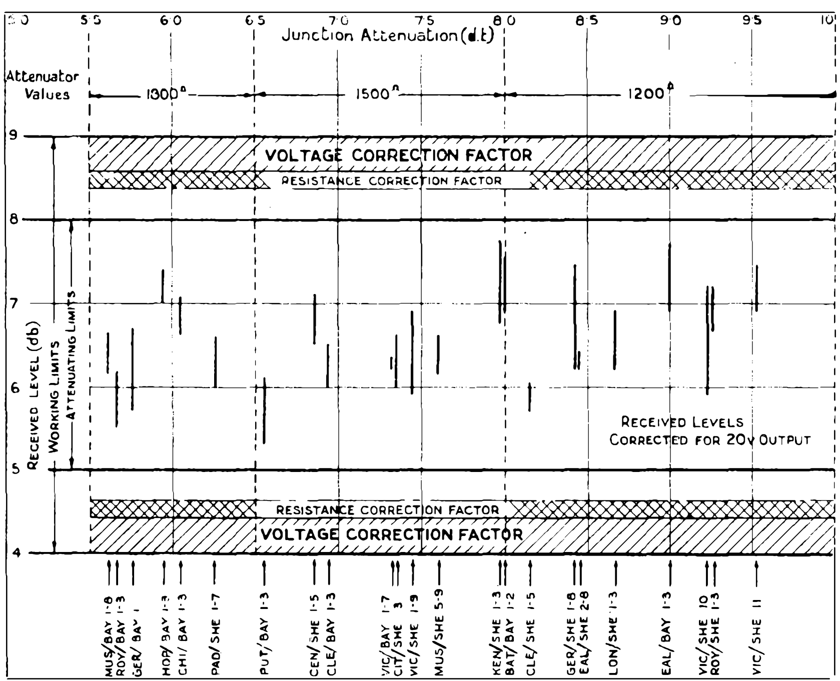


FIG. 10.—TYPICAL ATTENUATOR VALUES REQUIRED TO KEEP ATTENUATION OF THE 4 FREQUENCIES OVER DIFFERENT JUNCTIONS WITHIN THE RANGE 5 DB. TO 8 DB.

For maintenance and economic reasons, it is necessary to reduce the number of attenuator resistance values required to the minimum and it is, therefore, necessary to allocate each resistance value with a wide range of junction equivalent values.

The possibility of using a "Universal Attenuator" is receiving attention. The total resistance will be the maximum required for a zero junction, but it is doubtful whether the number of tappings required can be provided on a resistance with satisfactory dimensions for the positions in which they are mounted. The chief advantages of a universal attenuator would be in cases where junction diversions suddenly became necessary and the reduction in the number of resistances that it will be necessary to maintain in Normal Stock for issue at short notice.

It appears that the present practice of determining the required junction attenuator resistance by measurement must continue and the provision of portable transmission testing sets may be found to be necessary in order that, immediately a new route or a junction diversion takes place, the junction and routiner attenuator resistance values may be determined with speed and precision.

Four attenuators in the voice frequency relay-set automatic routiner must be determined by measurement, but before this can be done the most suitable feed resistances in the supply circuit at the manual exchange must be obtained. To do this, a variable resistance is inserted in each of the frequency leads in the supply circuit.

The best procedure was found to be as follows :—

(*a*) Replace the two 600-ohm and the two 400-ohm feed resistances by rheostats F, set to the same values as those replaced, and only use one winding in series with the condenser on the secondary side of the transformer.

(*b*) Connect two rheostats F in series for one of the routiner attenuators, say the 2.5 db., and operate the associated key.

(*c*) Connect the transmission test set across the coil tags of one of the V.F. relays and set the routiner access switch to the V.F. relay-set chosen.

(*d*) Each frequency is applied in turn to the V.F. relay-set and the rheostats connected in the routiner are adjusted to produce attenuations of 2.5 db. and 10 db. The following values were obtained in an actual case :—

	2.5 db.	*10.0 db.*
W	6,000Ω	21,000Ω
X	5,500Ω	20,000Ω
Y	4,500Ω	12,000Ω
Z	4,300Ω	15,000Ω

With supply circuit feed resistances :—

W, 2,400Ω; X, 2,400Ω; Y, 2,600Ω; Z, 2,600Ω.

An inspection of the resistance values required for each level indicates that considerable variation will occur over the four frequencies if the two average resistance values are used. The W and X feed resistance values should then be interchanged with the Y and Z. If the resistance values for each frequency to produce a given level vary by more than about 200Ω for 2.5 db. and 1,000Ω for 10 db., one or more feed resistances should be altered by about 100Ω at a time until satisfactory results are obtained at the automatic end.

(*e*) Average values for 2.5 db. and 10 db. can now be tried and provided that the difference between the measured and the required level is not greater than ±0.4 db. at 10 db. and ± 0.3 db. at 2.5 db., the resistance values may be considered to be satisfactory. The resistances should be chosen to the nearest 50Ω for 2.5 db. and 100Ω for 10 db. It is generally better to arrange for a level not higher than 2.3 db. to prevent overlap, even if a variation up to 2.9 db. is involved.

(*f*) No further changes are necessary to the feed resistances at the manual end and the attenuator resistances for 5.0 db. and 7.5 db. can be determined on similar lines.

The above procedure must be carried out immediately after any change is made in the junction used for the V.F. supply to the automatic exchange.

The V.F. relay-set routiner requires a test panel in addition to the voice frequency supply circuit at the manual exchange. The supply circuit is associated with the last junction from the manual exchange acting as a supply centre to the automatic exchanges in one engineering section. The supply circuit and test panel are installed by the Department and close co-operation with the contractor's installer is required to ensure that the supply circuit uniselector is stepped under control of the dial on the test panel and that the tones are successfully received at good volume on both the routiner and V.F. relay-set test jacks.

The determination of the routiner attenuator values cannot be carried out until the functioning of the test panel has been proved. If a 5,000-ohm resistance is temporarily provided in both the 2.5 db. and 10 db. resistance positions, some indication can be obtained regarding the functioning of the automatic routiner. It is consequently unnecessary to wait until the routiner attenuator values are determined before the general condition of the routiner is ascertained.

Maintenance.

The maintenance procedure and adjustments required by the 4-frequency generators and voice frequency relays is somewhat different from that to which the staffs at the manual and automatic exchanges have been accustomed and the system has not been in use long enough or on a scale sufficient to permit the final detailed maintenance instructions to be issued.

A maintenance handbook has been supplied by the contractor with each 4-frequency power board. It is very desirable that the responsibility for the daily maintenance of this plant be definitely assigned and that a regular routine should be observed for cleaning, and checking the speed and output voltages of the machine.

It is particularly important to maintain the speed and output voltage correct and at least once a fortnight to clean the carbon deposit from the governor cups. A disconnexion of the governor circuit due to a fault or the removal of the brush on the governor cup will completely ruin the governor contacts in a few seconds.

It is unlikely that a machine will suddenly fail without first showing signs of instability and if a log book is kept near each power board for the purpose of entering the results of every routine performed, a failure can generally be foreseen and a breakdown of service avoided.

As an emergency arrangement, however, two 4-frequency generators have been obtained for use at any London manual exchange. The characteristic variations of each machine necessitate special settings of the power board resistances and care will be necessary, when bringing an emergency machine into service, to ensure that the proper settings have been made or that the specially adjusted resistances supplied with each machine are used to replace the corresponding resistances at the back of the 4-frequency power board.

An ammeter is provided on the 4-frequency power board so that periodic readings of the motor current of either machine can be obtained as an indication whether any fault is developing, such as the governor cup loose on the shaft, etc. The machine speed will not remain correct with variation of exchange voltage unless the voltage across the ballast lamp is correct. This voltage is readily measured by means of a detector No. 4, but the final adjustments cannot be made with certainty that it will remain constant unless the machine has been running continuously for four hours.

Each voice frequency relay-set will have a fault card and will be identified by a number such as TEM. V. 16 for No. 16 relay-set originally delivered to Temple Bar. This card indicates the date and time of any cleaning or adjustment made, together with the movement of the set, *i.e.*, when sent to or received from another exchange or when returned to the manufacturer.

From the time that the V.F. relay-sets are delivered to the exchange and have passed the initial automatic routine and manual tests three routine tests per day are carried out by the exchange staff. It is desirable to have the results of each test recorded on the relay-set log book. The automatic routine test is first applied and particulars of any failures are recorded. This is followed by a manual test by means of the test panel to determine whether " flicker " occurs due to transient release of the polarized relay during continuous application of the frequency and if so, whether at 10 db., 7.5 db. or 5.0 db. The manual tests should invariably be made at 10 db. before 7.5 db., at 7.5 db. before 5 db., and at 5.0 db. before 2.5 db. The manual test is also carried out for combinations of two and three frequencies to determine whether " overlap " occurs.

This test is carried out at 2.5 db. It must be remembered that no frequency lamps should be illuminated when W, X and Z frequencies are applied because this is the cancel condition.

The results of the manual tests are tabulated in the log book. When a relay-set fails on automatic routine test or when noticeable " flicker " occurs, as shown by the W, X, Y and Z lamps on the test panel, the relay-set should be " busied out " by means of the " busy key " until such time that it can be given attention.

The only operations that should be carried out by the local maintenance staff are a general inspection and adjustment of the polarized relays, and cleaning of the voice frequency relay " bobble " contacts, which is done by carefully drawing a loop of cotton thread, previously soaked in pure benzine, through the wire loops of the " bobble " supports. The slightest trace of grease on the " bobble " supports is very detrimental to the performance of the relay and great care must be taken to avoid touching the " bobble " with the fingers or with any portion of the thread previously held.

The primary functions of the manual test panel associated with the voice frequency relay-set routiner are to enable the current adjustments of the polarized relays to be made and to determine at what level the combination of polarized relay and voice frequency relay fails when a relay-set is shown faulty on an automatic routine test. Its regular use following the automatic routine test has, however, been introduced as a means of determining whether " flicker," as explained above, occurs. The automatic routiners will, however, be modified to include a test for " flicker " which will be shown by a " split signal " lamp. When this feature is included, it may not be necessary to continue the use of the manual test panel as part of the regular routiner tests.

If the voice frequency relay-set for digit key test purposes is subject to suspicion at any manual exchange, it will be temporarily interchanged with a good relay-set at the nearest automatic exchange, where its performance can be checked by the routine test facilities available and any necessary cleaning of the tuned relay or adjustment of the polarized relays can be carried out.

Conclusion.

A large and continually increasing number of junction routes is being successfully operated on a voice frequency keysending basis. In some cases, the observation results show that the service is approximately 2% better than that obtained under keysender B conditions. This will undoubtedly improve as experience of the system is increased.

The system is being extended to seven-digit keysending from selected manual exchanges to nearby automatic exchanges in the outer London area, with a view to relieving semi-mechanical tandem.

Experiments with A.C. keysending between London and Leeds have been successful and in the near future the system may be extended to the London-Leeds route.

The writer wishes to express his thanks to Messrs. Standard Telephones and Cables, Ltd., for the use of the curves and photographs shown in Figs. **2**, **3**, and **4**.

BIBLIOGRAPHY.

" Junction working between Automatic and Manual Exchanges," by Messrs. I. H. Jenkins, A.M.I.E.E., and J. S. Patterson. P.O.E.E. Journal, Vol 18, Part 3, October, 1925.

Summary of Col. Sir Thomas F. Purves' paper before the I.E.E. P.O.E.E. Journal, Vol. 18, Part 4, January, 1926.

" Press Button Type Dialling Equipment for A positions," by Mr. J. Hedley, M.I.E.E. P.O.E.E. Journal, Vol. 19, Part 1, April, 1926.

" Messrs. Siemens Automatic Impulse Sender," by Mr. J. Innes, B.Sc. P.O.E.E. Journal, Vol. 20, Part 2, July, 1927.

" Mechanical Order Wire Operation," by Mr. D. A. Christian. P.O.E.E. Journal, Vol. 21, Part 2, July, 1928.

" V.F. Keysending," by Mr. I. H. Jenkins, A.M.I.E.E. P.O.E.E. Journal, Vol. 23, Part 4, January, 1931.

Telephone Communication with the Channel Islands

A. C. TIMMIS, B.Sc., A.M.I.E.E.

UP to the end of 1930 the islands of Jersey and Guernsey were connected with the mainland by two telegraph cables only, telephone facilities being limited to local systems operated by two separate companies. The telegraph service has always been operated by the Post Office.

Of the two telegraph cables, one is a 3-core gutta percha cable which runs from Compass Cove, a typical Devonshire cove near Dartmouth, to Guernsey and on to Jersey. The other, a single-core gutta percha cable of unusually heavy gauge, has a history which is worth mentioning. It was originally part of a German cable to the Azores, was " captured " during the War, and relaid between Compass Cove and Jersey. It formed part of a telegraph circuit between London and Jersey until early in 1931, when rearrangements were made which enabled the 3-core cable to take all the telegraph traffic, with a proviso that if this cable broke down the single-core cable would be taken for telegraph purposes.

The engineering problem of providing telephone communication with the mainland therefore consisted of two parts : First, to make use of the single-core cable (the 3-core being useless for telephony) as a telephone cable, and second, to provide a sub-audio telegraph channel to Jersey to be used in case of breakdown of the 3-core cable or in any traffic emergency.

Although the single-core cable was not led into Guernsey, it fortunately passed close to the island and it was not a difficult matter to cut it into two portions—Compass Cove to Saints Bay (Guernsey), 80 nauts, and Saints Bay to Plemont (Jersey), 18.7 nauts. Before this was done, however, the electrical characteristics of the cable were measured and one-way conversations were carried on between London and Jersey with a hand-switched amplifier at Compass Cove.

It was evident from the attenuation-frequency curve (see Fig. 1) that a two-way telephone circuit over the 80 nauts of cable between the mainland and Guernsey would require voice-operated stabilizing devices and balances of a very high order.

Carrier working was obviously quite impracticable owing to the steeply-rising attenuation. It was accordingly decided to proceed with the telephone circuit first. Traffic conditions indicated a London-Guernsey trunk with facilities for extension to Jersey. From the point of view of construction only, the most favourable arrangement would have been a 4-wire circuit from London to Compass Cove, with voice-operated stabilizers on the mainland and also incorporated in a terminal repeater at Guernsey; a second terminal repeater being also provided for the Guernsey-Jersey cable. But it seemed inadvisable, from the maintenance point of view, to complicate the Guernsey apparatus more than absolutely necessary, and it was therefore decided to use a stabilizer on the mainland only.

The limiting factors in the problem are (1) the accuracy with which balances, simulating the cable over the audio range, can be maintained at the cable huts and (2) the amount of stabilization, or excess of amplification over the normal singing point, which it is practicable to use with unattended apparatus. The stabilization on the long wave transatlantic radio circuit amounts to 80 db., but elaborate terminal apparatus and skilled attention is justified in such a case. For the Guernsey circuit, it was obvious that any voice-operated devices must be capable of working with no more attention than ordinary repeaters.

Experiments were therefore begun with a view to estimating the effect of seasonal temperature changes on the impedance of the cable. A balance network was made up to simulate the cable impedance as closely as possible and was joined to a differential transformer, specially selected for accuracy of balance, to form a two-wire/four-wire termination at the cable end. The apparatus was enclosed in a special air-tight box with a quantity of calcium chloride to ensure dryness. Cable huts are notoriously damp, and previous experience of the unattended repeater in a cable hut on the shore of the Pentland Firth was found useful in this case. The cable was still in use for telegraphy at this time, and was temporarily connected to the apparatus once a month for test. The four-wire circuit was made up between Bristol and Compass Cove so that measurements could be made conveniently from

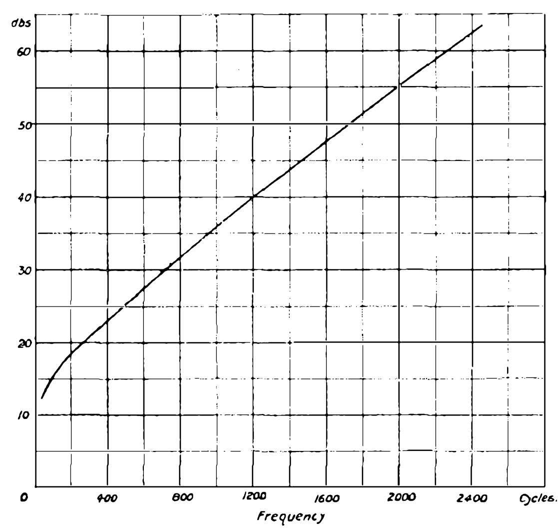


FIG. 1.—ATTENUATION FREQUENCY CURVE FOR SEA CABLE.

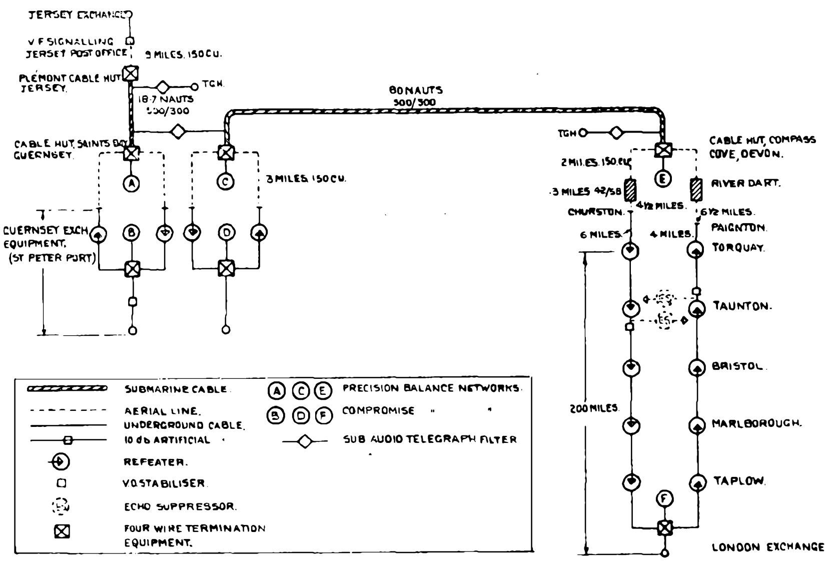


FIG. 2.—LINE DIAGRAM OF CIRCUIT.

the Bristol test desk. This four-wire circuit will be referred to in detail later.

Two measurements were taken. First the loss round the termination with cable and balance on was measured, Bristol sending on the " go " and receiving on the " return " line, at several frequencies. Then the lineman at Compass Cove, by a simple arrangement of U links, replaced the termination by an attenuator of 40 db. of artificial cable between " go " and " return " lines. Bristol took another series of measurements, from which the loss round the termination (*i.e.*, the singing point of cable and balance) could be obtained independently of the attenuation in the four-wire circuit. These tests extended over a year or more, but the results were somewhat chequered owing to the occurrence of one or two cable repairs which necessitated alterations to the balance network. Nevertheless, it was proved that a singing point better than 40 db. over practically the whole audio range could be maintained. This corresponds to a maximum difference of 2% between the impedances of cable and balance. It might be possible to maintain a singing point considerably higher than 40 db., but, seeing that the four-wire circuit consists of aerial wires for the first eight miles from Compass Cove, and in Guernsey there are three miles of aerial line between the cable hut and the repeater station, the cross-talk between the " go " and " return " circuits at either end of the cable might then be comparable with the singing point. Further, if very elaborate balances were made, it would be a troublesome matter to alter them after every cable repair. A singing point of 40 db. was therefore assumed in designing the London-Guernsey circuit. The Guernsey-Jersey circuit was felt to be a comparatively simple problem, and attention was, in the first place, concentrated on producing the best possible circuit between London and Guernsey.

It was evident that a satisfactory overall attenuation at the higher audio frequencies would require stabilization to the extent of 15 or 20 db. in each direction, and to demonstrate the practicability of such a trunk circuit, a model was made up with the aid of an artificial submarine cable having very similar characteristics to those of the actual cable. A two-wire repeater was connected to one end of the artificial cable (in London) and to the other end was connected a London-Newport four-wire circuit. Newport thus represented the London end of the London-Channel Isles trunk. Voice-operated stabilizers were inserted at Gloucester, as this happened to be a convenient place for them. The exact position of the stabilizers in the four-wire circuit is not of great importance.

From experiments with this model the main requirements of the stabilized circuit were determined, and the lay-out was finally decided. It is shown in Figs. **2** and **3**, the latter giving details of the stabilizer. The operation of the stabilizer can be conveniently explained as part of this circuit, but it

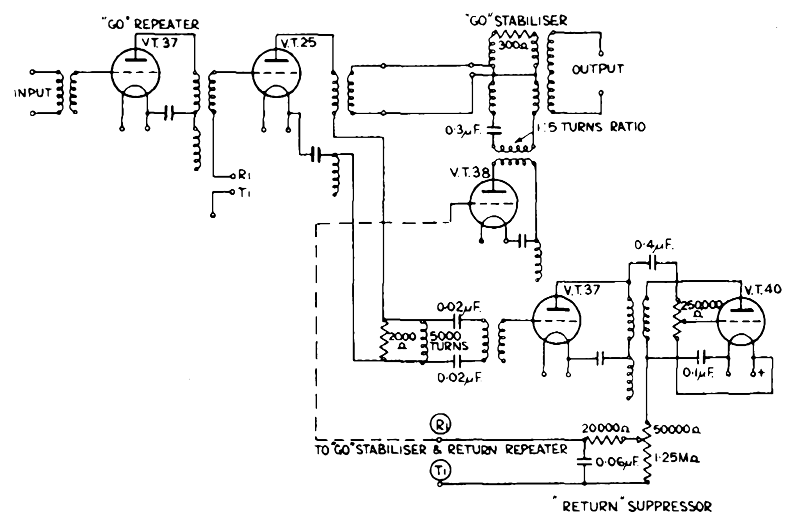


FIG. 3.—STABILIZER ARRANGEMENTS AT TAUNTON.

will be evident that the principle may be applied to any four-wire circuit in which the amplification has to be increased beyond the normal limit of stability.[1] When London speaks to Guernsey, for instance, the echo suppressor at Taunton is operated by the speech current in the " go " line and first suppresses the " return " line. Then, a few milliseconds later, the same voltage which suppressed the " return " repeater, by making the grid of its second stage valve negative, also makes the grid of the impedance valve (VT 38) in the " go " stabilizer negative. The plate-filament impedance of this valve then rises to a very high value, unbalances the differential transformer to which it is coupled through the 1 :5 transformer, and so reduces the loss in the output circuit of the " go " repeater to about 6 db. Speech then passes through at the normal level, as the 6 db. loss is taken care of in the amplification of the repeaters. Singing is prevented by the timing of the grid voltage effects on the two valves concerned. The essential requirement is that, at any instant, the loss introduced by the suppression of the repeater shall be greater than the gain produced by the action of the stabilizer valve.

When Guernsey speaks to London, a precisely similar action takes place on the " return " line, the whole arrangement being symmetrical. When no one is talking on the circuit, the two stabilizers are adjusted to introduce a loss, in the singing path, which is roughly equivalent to the net excess of gains over losses throughout the audio frequency range. Each stabilizer has to introduce only half the total stabilizing loss so that any clipping effect which might be noticeable at the beginning of speech (due to the lag of the stabilizer) will be only half as great as if one stabilizer had been used to provide the whole stabilizing loss. Further, the adjustment of the loss to about the minimum value required—ranging from 0 at 400 cycles to 20 db. in each direction at 2,000 cycles—has rendered the clipping effect quite inappreciable in practice. This variation with frequency is obtained by the 0.3 μF condenser in series with the 1 :5 transformer. The echo suppressors are of the Post Office type, each consisting of an amplifier and a diode rectifier, except that the three-electrode valve used as the diode has its grid connected to a resistance-capacity circuit in such a way that the rectified current produced by speech is limited to a certain value.[2] This current produces a change of grid voltage which persists, owing to the discharge time of the .06 μF condenser and its associated resistances, for about $\frac{1}{4}$ second. This interval is called the hang-over time, and must not greatly exceed $\frac{1}{3}$ second or, after speech has passed in one direction, the other direction will be blocked sufficiently long to interfere with a quick reply. The suppressors at Taunton are adjusted so that they operate definitely with barely audible speech, but the hang-over is not excessive when a loud talker is connected directly to the end of the trunk.

The chief difficulty in obtaining a satisfactory trunk circuit was due to the high attenuation of the cable at frequencies in the neighbourhood of 2,000. To make the overall equivalent the same at 2,000 as at 800 cycles would have needed an excessive amount of stabilization. It was therefore decided to allow a rise of 7 db. between these two frequencies. After 2,000 cycles the overall equivalent rises, but not so rapidly as in the case of a low cut-off loaded circuit. Articulation is quite satisfactory.

The level and attenuation figures, (all in decibels) in the two diagrams of Fig. **4** will make the position clear. It will be noticed that the gains of the Guernsey repeater are quite moderate. This was necessary because of the decision to have no stabilizer in the Island, and necessitated the high levels at Torquay. At 800 cycles, the incoming level from Guernsey (at Torquay) is -30.5. The echo suppressors are tuned to round about this frequency and care was therefore necessary to avoid cross-talk or any " pick-up " between Compass Cove and Torquay, which might falsely operate the suppressors and so block the circuit in the direction London-Guernsey. The open wires were run as a twisted square between Paignton and Dartmouth, but for the last mile or so, where the telegraph wires serving the 3-core cable follow the same route, the four wires were run " straight " owing to a misunderstanding. They were used as diagonal pairs in this section, however, and a cross was inserted halfway. No trouble has been experienced from telegraph induction, but power induction (from the Torquay-Paignton tramways) caused serious interference. This was cured by using an underground pair for the " return " between Paignton and Churston, at which point a transformer was inserted. The " go " pair is, of course, not so sensitive to disturbance, as the speech level is high.

In addition to precautions against noise, steps were taken to ensure that cross-talk attenuation between " go " and " return " was high compared with the loss round the terminations, both at Compass Cove and Saints Bay.

Between Torquay and Paignton, a special 2-pair cable was run, and the short sections of cable across the Dart and leading in to Dartmouth exchange were found quite satisfactory as regards cross-talk. On the mainland and in Guernsey, where the open wires are in twisted square formation, the cross-talk between the diagonal pairs is negligible. The fact that cross-talk is worse between pairs in adjacent squares was illustrated by slight overhearing from the Guernsey-Jersey trunk, the " go " and " return " pairs of which are in square between Guernsey exchange and Saints Bay. The trouble was cured by changing over the pairs so that the outgoing pair of the Guernsey-Jersey trunk was not parallel to the incoming (return) pair of the London-Guernsey trunk.

The repeaters in Guernsey are ordinary four-wire

[1] Patent 268906.

[2] Patent 362364.

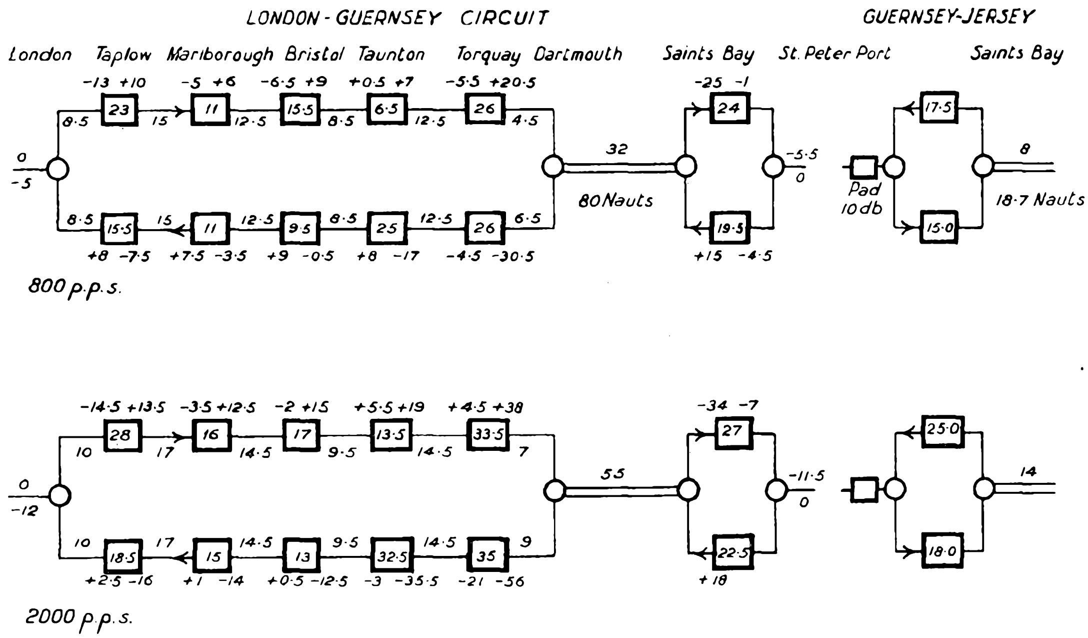


FIG. 4.—ATTENUATIONS AND LEVELS AT 800 P.P.S. AND 2,000 P.P.S.

repeaters, made by the General Electric Co. At Torquay similar repeaters were installed, but the equalizing components had to be modified to secure the necessary increase of gain between 800 and 2,000 cycles, and, as already mentioned, a special push-pull amplifier was added on the " go " side.

The attenuation rise in the sea-cable could not be wholly compensated in the Torquay and Guernsey repeaters. The compensation was therefore shared among the equalizers at Taplow, Marlborough, Bristol and Taunton, certain modifications being made to adapt them to the unloaded attenuation curve of the sea cable instead of the loaded curve for which they are designed. It will be noticed from the level diagrams of Fig. 4 that there is very little equalization in the Guernsey repeaters. In the absence of a stabilizer, no better adjustment could be obtained, and the main burden of equalization had to be thrown upon the stabilized four-wire circuit on the mainland. Moreover, the loss round the termination at Saints Bay falls below the critical value at high and low frequencies. A single-section band-pass filter is therefore fitted in series with the return repeater, and increases the loss sufficiently to prevent singing, below 300 cycles and above 2,200 cycles. Particulars of this filter are given in Fig. 5 and impedance-frequency curves for both ends of the cable are given in Fig. 6.

The overall equivalent of the London-Guernsey circuit is approximately

5·5 db.	at	400 cycles,
6 ,,	,,	800 ,,
10 ,,	,,	1600 ,,
12.5 ,,	,,	2000 ,,

The circuit has now been working for more than a year without any trouble. The stabilizer requires no special attention beyond the ordinary maintenance of an echo-suppressor, and in no case has a talker connected to the trunk failed to operate the stabilizer unless he was quite inaudible.

The stabilizer is used under rather extreme conditions on this particular circuit. In other cases, where less stabilization is required, the differential transformer is not used. The impedance valve is simply shunted across the line, through a transformer, and will provide a stabilization of 8 to 10 db.

The Guernsey-Jersey circuit was a comparatively simple matter. Since a very accurate balance was obtainable at Saints Bay, and the cable attenuation is only 7 or 8 db., the minimum overall equivalent is not far from zero. A band-pass filter is inserted, as in the case of the London circuit. The arrangement

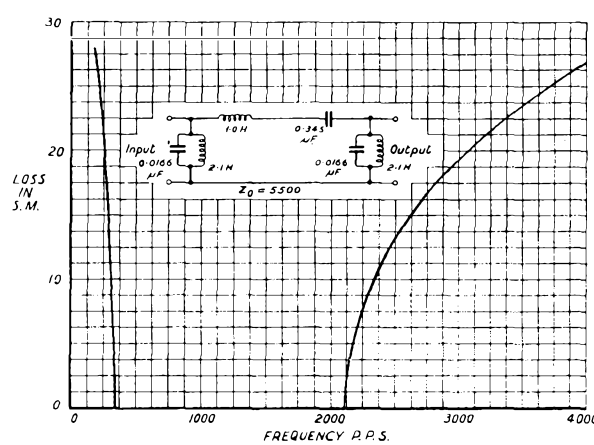


FIG. 5.—GUERNSEY REPEATER FILTER, BAND PASS TYPE.

Modern Telephone Trunk Lines

R. M. Chamney, B.Sc., A.K.C., A.M.I.C.E.

Ever since the telephone became a practical instrument, engineers have endeavoured to extend its utility by increasing the distance over which speech can be audibly and intelligibly transmitted.

In the early days, transmission was effected by aerial wires used singly with an earth return or later used in pairs so as to avoid cross-talk between circuits and also noise from parasite earth currents.

In time, cable technique became sufficiently advanced to enable relatively effective transmission to be given through underground cables over short distances. Inventors have spent many years trying both to produce methods of eliminating cable losses and to amplify the power of the feeble speech currents during their passage over the lines.

Eventually, loading was brought to a sensible degree of efficiency and later the telephonic repeater became a practical proposition.

In all cases, the dream of the inventors was to produce a telephone line without loss in attenuation or intelligibility. The methods by which the problems have been solved are now well known to those engaged in line and repeater design, but are perhaps worthy of a little notice since a large number of readers of this Journal are not in direct contact with the details of the work.

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 line 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 600Ω.

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. 1 shows a diagrammatic representation of a circuit terminated by 600Ω. When the operator enters the circuit, the indicator and resistance are disconnected so that no transmission loss is involved. This actual arrangement was suggested to the Author by Mr. G. Manning.

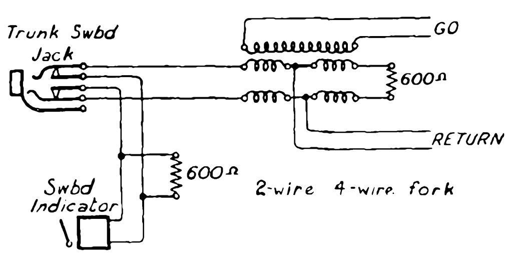


Fig. 1.—600-ohm Circuit Termination.

The same system can be used for upgrading all 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 realized.

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.

No additional maintenance difficulties have been noticed due to the change, and the benefit in transmission has been very marked and has, in fact, been commented upon in the Press more than once.

At present, all the circuits used on the International multiple designed solely for extending calls from Europe to the Provinces are worked on a zero basis. On the Inland side, over 100 zero backbone trunks are in operation.

It is proposed to cover the whole country as soon as possible so that all zone to zone trunks shall have no transmission loss.

The effect on transmission generally has so far been that the complaints on long distance calls have decreased in a very marked manner and also operating time has been saved due to calls being handled more quickly since cord repeaters are not necessary for zero circuits and difficult calls requiring the operator's supervision have become very rare.

A further economy will be effected later, since the less important links may in future be supplied by lighter gauge wires than would have been possible under the old conditions.

The use of zero loss circuits will greatly facilitate alternate routings, thereby increasing in effect the efficiency of existing traffic groups.

In conclusion, it may be stated that the importance of the latest step in the upgrading of transmission lies chiefly in the abolition of transmission engineers' problems as regards long trunks. Transmission in the future will be designed so that the groups of exchanges in each transmission zone are treated as entities complete in themselves. If transmission conditions are fulfilled in each zone, no further care is necessary as the zone links will have no loss.

to the line core in the two-core cable. The stability of the telephone circuit was unaffected by the filters, but the ringing between Guernsey and Jersey had to be changed from 17 cycle to voice frequency. As a matter of convenience, 500/20 ringing—as used between London and Guernsey—was arranged. The exchange at St. Helier (Jersey) is magneto and telegraph batteries are available at the Post Office, nearby. A valve oscillator and receiving set for the voice frequency signal was therefore installed at the Post Office with a simple relay arrangement to interrupt the 500 cycle current.

Rather more trouble was experienced with the telegraph circuit. In the first place it was found necessary to restrict the sending voltage, and provide smoothing filters at Exeter and Jersey in order to make the telegraph signals quite inaudible on the telephone. Any audio frequency disturbance, even though barely audible, is liable to cause false operation of the stabilizer. As a precaution against cross-modulation or "flutter," special dust cores (DU type) were used for the low pass filter coils. It will be seen from the filter diagrams that the capacity of the telegraph circuit is considerably increased. This, together with the inductance in the low pass filters, considerably modified the duplex telegraph balances at Exeter and Jersey. The latter balance contains networks simulating the filters at Plemont and Guernsey. Nevertheless duplex teleprinter working is quite reliable with 24 volts at each end, and Post Office standard receiving relays. A certain amount of telegraph interference is experienced on the land line, and is neutralized by means of a second line earthed at Churston and connected to a compensatory winding on the relay at Exeter.

The telegraph circuit may be used for Wheatstone working instead of Teleprinters. Although intended for use as a reserve circuit in emergency, it has proved fully as efficient as the working circuits.

The successful working of the Channel Isles trunk has demonstrated the value of voice-operated stabilizers in a typical case of two-way communication over a cable of very high attenuation. If the traffic justifies another cable to the Channel Isles, it may be found cheaper to design a cable having a high attenuation, and to use two-wire working with stabilizers, rather than adopt four-wire working or a loaded cable of moderate attenuation on which ordinary two-wire circuits could be worked.

More generally, a reliable voice-operated stabilizer makes it practicable to work a two-way telephone circuit, whether cable or radio link or both, at an overall equivalent better than zero. The long wave transatlantic circuit is often so adjusted, (though of course the stabilizing devices are more elaborate, and skilled attention is provided the whole time) in order to make up for the losses in the land lines on either side of the Atlantic. With an unattended stabilizer the same result could be obtained by including in the circuit an attenuator, to be cut out manually or automatically during extension to other circuits.

Telegraph and Telephone Plant in the United Kingdom.

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH SEPT., 1932.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
778,447	626	8,958	43,726	2,863	London	42,915	179,598	3,441,377	149,042
93,503	1,931	17,661	41,396	3,239	S. Eastern	4,089	50,015	344,021	41,122
107,966	4,246	36,829	64,747	3,811	S. Western	23,691	28,578	272,788	60,078
73,499	4,700	39,670	62,260	8,373	Eastern	19,720	53,089	154,492	47,315
119,091	7,272	51,807	51,011	5,928	N. Mid.	32,163	127,315	323,147	74,620
94,505	3,986	32,549	62,081	2,657	S. Mid.	16,075	43,721	277,028	79,610
67,153	3,423	30,871	51,500	5,372	S. Wales	6,882	39,705	164,313	53,242
130,191	6,624	29,993	53,879	5,365	N. Wales	16,409	59,816	403,458	120,805
179,985	916	12,823	24,547	4,889	S. Lancs.	13,426	112,631	614,886	80,978
110,272	5,231	30,573	36,843	6,701	N. Eastern	20,437	70,970	315,099	49,913
74,142	4,289	23,428	25,377	4,282	N. Western	6,781	45,951	234,312	55,903
56,732	2,141	17,182	20,913	4,107	Northern	10,417	35,464	175,100	37,722
27,336	3,600	11,051	11,240	619	Ireland N.	224	4,095	61,303	6,508
80,086	4,652	32,686	38,201	1,986	Scotland E.	9,261	33,545	175,909	41,999
102,419	5,526	24,314	29,868	1,890	Scotland W.	8,677	40,746	255,166	36,089
2,095,327	59,163	400,395	617,589	62,082	Totals	231,167	925,239	7,212,399	934,946
2,083,679	57,450	403,700	607,666	59,033	Figures as at 30 June, 1932.	235,419	899,545	7,109,891	940,735

Modern Telephone Trunk Lines

R. M. Chamney, B.Sc., A.K.C., A.M.I.C.E.

EVER since the telephone became a practical instrument, engineers have endeavoured to extend its utility by increasing the distance over which speech can be audibly and intelligibly transmitted.

In the early days, transmission was effected by aerial wires used singly with an earth return or later used in pairs so as to avoid cross-talk between circuits and also noise from parasite earth currents.

In time, cable technique became sufficiently advanced to enable relatively effective transmission to be given through underground cables over short distances. Inventors have spent many years trying both to produce methods of eliminating cable losses and to amplify the power of the feeble speech currents during their passage over the lines.

Eventually, loading was brought to a sensible degree of efficiency and later the telephonic repeater became a practical proposition.

In all cases, the dream of the inventors was to produce a telephone line without loss in attenuation or intelligibility. The methods by which the problems have been solved are now well known to those engaged in line and repeater design, but are perhaps worthy of a little notice since a large number of readers of this Journal are not in direct contact with the details of the work.

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 line 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 600Ω.

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. 1 shows a diagrammatic representation of a circuit terminated by 600Ω. When the operator enters the circuit, the indicator and resistance are disconnected so that no transmission loss is involved. This actual arrangement was suggested to the Author by Mr. G. Manning.

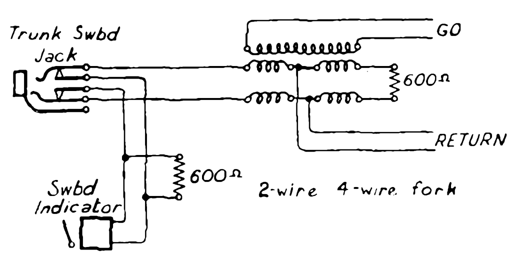


Fig. 1.—600-ohm Circuit Termination.

The same system can be used for upgrading all 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 realized.

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.

No additional maintenance difficulties have been noticed due to the change, and the benefit in transmission has been very marked and has, in fact, been commented upon in the Press more than once.

At present, all the circuits used on the International multiple designed solely for extending calls from Europe to the Provinces are worked on a zero basis. On the Inland side, over 100 zero backbone trunks are in operation.

It is proposed to cover the whole country as soon as possible so that all zone to zone trunks shall have no transmission loss.

The effect on transmission generally has so far been that the complaints on long distance calls have decreased in a very marked manner and also operating time has been saved due to calls being handled more quickly since cord repeaters are not necessary for zero circuits and difficult calls requiring the operator's supervision have become very rare.

A further economy will be effected later, since the less important links may in future be supplied by lighter gauge wires than would have been possible under the old conditions.

The use of zero loss circuits will greatly facilitate alternate routings, thereby increasing in effect the efficiency of existing traffic groups.

In conclusion, it may be stated that the importance of the latest step in the upgrading of transmission lies chiefly in the abolition of transmission engineers' problems as regards long trunks. Transmission in the future will be designed so that the groups of exchanges in each transmission zone are treated as entities complete in themselves. If transmission conditions are fulfilled in each zone, no further care is necessary as the zone links will have no loss.

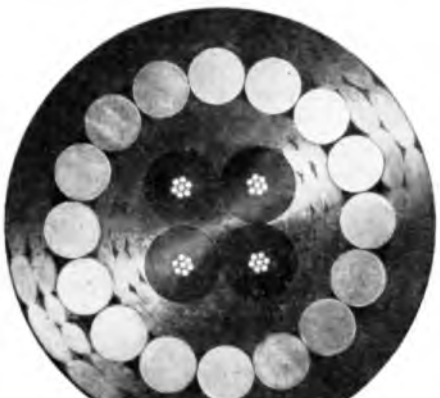
The Anglo-Belgian (1932) Telephone Cable

A. Rosen, Ph.D., A.M.I.E.E.
(Siemens Brothers & Co., Ltd., Woolwich).

Previous Cables.

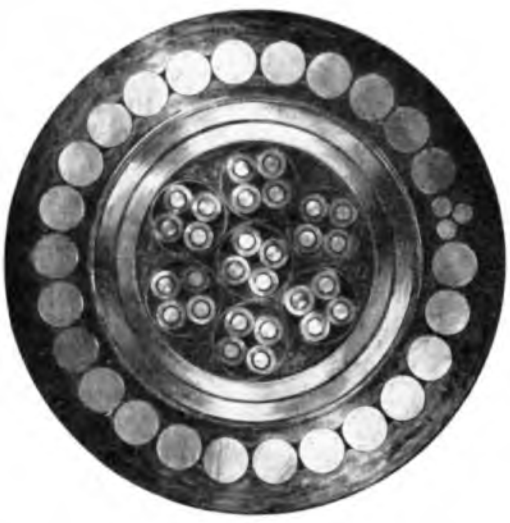
THE telephone cables that have been laid between England and Belgium represent successive stages in the progress of submarine telephone communication. The earliest cable was laid between St. Margaret's Bay and La Panne, Belgium, in 1902; this was before loading had become practicable, and the cable consisted of four plain copper wires each weighing 160 lb. per naut insulated with gutta percha weighing 300 lb. per naut, Fig. 1, its overall attenuation at 800 cycles per second for a 50-mile length being about 2.85 nepers. After loading of submarine cables had been proved possible by the laying of the coil-loaded Anglo-French cable in 1910, a coil-loaded cable was laid between St. Margaret's Bay and La Panne in 1911.[1] This likewise contained 4 cores, Fig. 2, but was insulated with the newly-discovered low-leakance material balata; moreover, a further improvement on the Anglo-French Cable was effected in that, for

[1] Journal P.O.E.E., 1912, Vol. 5, p. 50.



1902.
Fig. 1.

1911.
Fig. 2.



1926 and 1930.
Fig. 3.

1932.
Fig. 4.

Figs. 1-4.—Successive Anglo-Belgian Telephone Cables.

the first time, the phantom circuit of a submarine cable was also loaded. The attenuation of the physical circuits at 800 cycles was 0.85 nepers and the cut-off frequency was 2,500 cycles. (This cable was picked up recently and the new cable has been laid over the same route. Two additional similar coil-loaded cables that were laid during the War between the same landing places, and a further cable of the same type laid in 1923, have all since been picked up).

At that time the rival claims of coil and continuous loading were decided in favour of the former on account of the higher inductance which it was possible to obtain with coils, and the correspondingly lower cost. The position was greatly altered when thermionic repeaters were introduced after the War; firstly, the added amplification permitted values of attenuation for the submarine cable section which could easily be obtained by continuous loading; secondly, the two-wire system with balancing networks necessitated a smoother impedance/frequency characteristic, which was more readily obtained with continuously-loaded cables; thirdly, the smoothness of the impedance/frequency characteristic of continuously-loaded cables was not altered when additional lengths were introduced during repairs, whereas in coil-loaded cables such additional lengths would upset the uniformity of the coil spacing, and the impedance/frequency curve would become correspondingly irregular. The Anglo-Belgian cable which was laid in 1926[2] was accordingly continuously loaded, and contained seven quads, Fig. **3**. Further, the use of paper-insulated lead-covered cables in tidal waters had been proved possible two years earlier by the laying of such a type between England and Holland, and this form of construction was adopted for the cable between Dumpton Gap and La Panne. Like its prototype, it had two lead sheaths, separated by a thin layer of compound; the low attenuation constant (0.0275 neper per naut) permitted the repeater station on the English side to be located inland at Canterbury, and the line was continued by an identical cable laid in ducts between Dumpton Gap and Canterbury, the land cable, however, having only one lead sheath and no external armouring. The overall attenuation for the 64.6 naut length between Canterbury and La Panne Repeater Stations is 1.73 nepers at 800 cycles per second. The growth in traffic to the Continent was such that a duplicate cable, having the same number and size of conductors was laid in 1930.[3] In order to increase the carrying capacity, superphantom circuits are used on these cables, and carrier circuits with a carrier frequency of 5,800 cycles per second have been successfully worked.

Recent Developments.

During the last few years, the constantly increasing length of international circuits has imposed more and more stringent demands upon the sections composing these circuits; in particular, a higher degree of immunity from interference and a wider range of frequencies are now considered essential for the transmission of speech. In each repeater section of the cable, the level of interference from another circuit should be at least 6.5 nepers below the received speech at that point, and the circuit must transmit frequencies up to 2,400 cycles per second. These conditions are best met by the four-wire system in which complete separation between " Go " and " Return " channels is effected by providing separate pairs of wires for each direction, suitably shielded from each other. Accordingly, when a further Anglo-Belgian cable was called for to be laid between a new repeater station at St. Margaret's Bay and La Panne in 1932, it was decided by the Post Office that it was to be suitable for four-wire working, to have an overall attenuation not greater than 4.2 nepers at 2,400 cycles and to give a margin of at least 6.5 nepers between cross-talk and speech levels.

Four-Wire Circuits in Submarine Cables.

The design of a submarine cable for four-wire working presents an entirely fresh set of problems. On account of the high degree of interference immunity desired, phantom circuits for the audio channels cannot be realized, and hence only one-third of the number of channels can be obtained, as compared with a two-wire phantomed cable having the same number of conductors. In other words, a much larger number of pairs are required, which may, however, be of smaller gauge, as the permissible attenuation per repeater section is higher in the case of the four-wire circuit. The limit in size of conductor is set by the consideration of safe mechanical strength, and the limit to the number of conductors is governed, firstly, by the size and weight of cable that can be handled by a repairing ship, and, secondly, by the time taken to make a joint at sea.

The four-wire system does not require such rigorous regularity of impedance/frequency characteristics, and, in consequence, the objections to the coil-loaded type on that account no longer hold. Coil-loaded cables designed for four-wire working have been laid in the Baltic Sea and are working successfully, notably the Sweden-German cable, which contains 42 quads and a screened pair specially designed to transmit broadcast music.[4] On the other hand, the weight and size of the insertions containing a large number of loading coils would make the handling of such a cable in the tidal waters of the North Sea and English Channel difficult, particularly during repairs.

As a result of repairs, the spacing of coils is unavoidably altered, and the cut-off frequency thereby lowered. To allow for this effect it is advisable to design a coil-loaded cable with a margin of 25%,

² Journal P.O.E.E., 1927, Vol. 19, p. 355.

³ Journal P.O.E.E., 1931, Vol. 23, p. 301.

⁴ Europäischer Fernsprechdienst, 1931, pps. 93 and 197.

e.g., if transmission is possible to within 90% of cut-off and it is desired to transmit all frequencies up to 2,400 cycles per second, the cut-off must not fall below 2,700 cycles and the cable as laid should have a cut-off of say, 3,500 cycles.

It was therefore felt that a solution was to be found in a design which would retain the mechanical and electrical uniformity of the continuously-loaded cable. Investigations soon showed that a continuously-loaded cable containing 30 quads with an attenuation of 4.2 nepers at 2,400 cycles per second could be made at a cost per circuit not greatly in excess of a coil-loaded cable having a cut-off of 3,500 cycles, and when the probable costs of maintenance over a period of, say, 10 years were considered, the prices were about equal. Further studies were made with a view to reducing the cost of the continuously-loaded cable, and it may be useful here to set out some of the factors involved :—

(*a*) The gauge of conductor to be covered was considerably smaller than had been used hitherto for such cables, *e.g.*, the size considered was 0.036" as compared with 0.080" for the 1926 and 1930 cables. Now the cost of loading material increases rapidly as the size of the loading wire is decreased, on account of the expense of drawing fine wires, so that using an economical size of loading material, the ratio of diameter of loading to diameter of conductor is greater than in previous cables.

(*b*) The number of quads was to be more than four times as great as in the largest previous cable, and 120 × 50 = 6,000 miles of conductor would be required for a 50-mile length (three times the length of an Atlantic cable). The cost of the application of the loading wire is a considerable proportion of the total cost of the cable and, furthermore, the time required to load 6,000 miles of conductor has to be taken into account.

(*c*) The design was to be based on the transmission of the highest frequency required, viz., 2,400 cycles per second, instead of the mean frequency of 800 cycles per second which was the basis of previous designs. At the higher frequency the losses in the loading material become important; these can be reduced by subdividing the wire, *e.g.*, by using two layers each of half the thickness, but this would add considerably to the cost.

Intermittent Loading.

It was found that if the space occupied by loading wire were replaced by copper along part of the length of the cable, the attenuation would not be increased, in fact in some cases it would be reduced; the capacity remains uniform throughout, and the loss in inductance is offset by the reduction in resistance due to the greater copper section of the non-loaded portions. This is shown graphically in Fig. **5**, in which the attenuations corresponding to various proportions of loaded conductor are plotted. The values are calculated for two frequencies, 800 cycles and 2,400 cycles, and it is evident that the advantage in omitting the loading over a portion of the length is somewhat greater at the higher frequency. It can be shown that the controlling factor is the ratio of iron to copper space in the cross-section of the loaded conductor, and that there is more benefit in intermittent loading when this ratio is high.

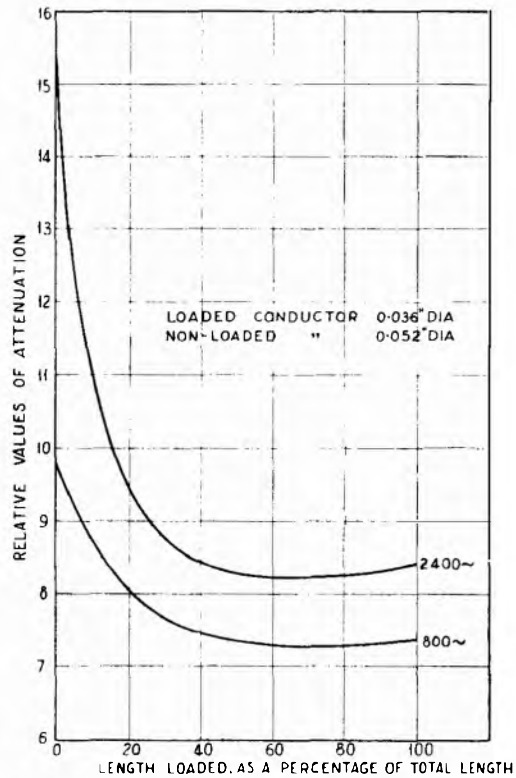


Fig. 5.—Variation of Attenuation with Percentage of Loading.

The reduction in loading is of advantage in saving the difference between the cost of loading and that of the added copper, and also in effecting a substantial reduction in the time required for the manufacture of the cable.

Design of the New Cable.

After all the factors had been considered, a design was prepared adopting equal proportions of loaded and non-loaded conductors. In order to avoid reflection effects, the alternate lengths of the two types of conductor had to be small; the length chosen was $\frac{1}{8}$ nautical mile for each section, and thus the equivalent loading coil section length is $\frac{1}{4}$ nautical mile, and the cut-off frequency in the neighbourhood of 30,000 cycles per second. These lengths were kept short so that if after repair the sequence were disturbed by the addition or omission of a loaded section, there would be no deleterious effect on the transmission properties of the cable. This was borne out by subsequent experiments.

Advantage was taken of the fact that the lengths of loaded and non-loaded conductors are equal by incorporating equal numbers of loaded and plain quads together in the cable. Every $\frac{1}{8}$th nautical mile, the loaded quads are joined to the non-loaded quads in the adjacent length and vice versa (Fig. **6**). The cross-section of the cable is thus uniform throughout its length.

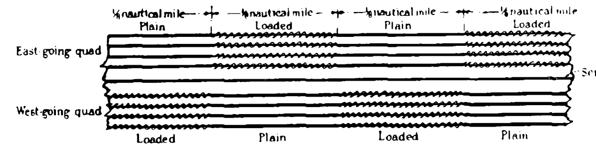


FIG. **6**.—INTERMITTENT LOADING.

printed at frequent intervals along the length of the paper tape covering each one, and the loaded quads are distinguished by a continuous line in addition to the number. A paper tape marked every 10 centimetres is laid up with the cable so that wherever the cable is cut it is possible immediately to determine the distance to the nearest joint. This makes it easier to preserve the correct sequence when lengths are joined together during repair, and renders it unlikely that a whole loaded section will be completely omitted or added.

The sheathings of the cable follow previous practice in that there are two continuous lead-antimony-cadmium alloy sheathings and the armouring is of 28 round iron wires 0.232″ diameter.

Messrs. Siemens Brothers, Limited, Woolwich, were awarded the contract to make and lay $50\frac{1}{4}$ nauts of cable plus 5 nauts of spare, and the following

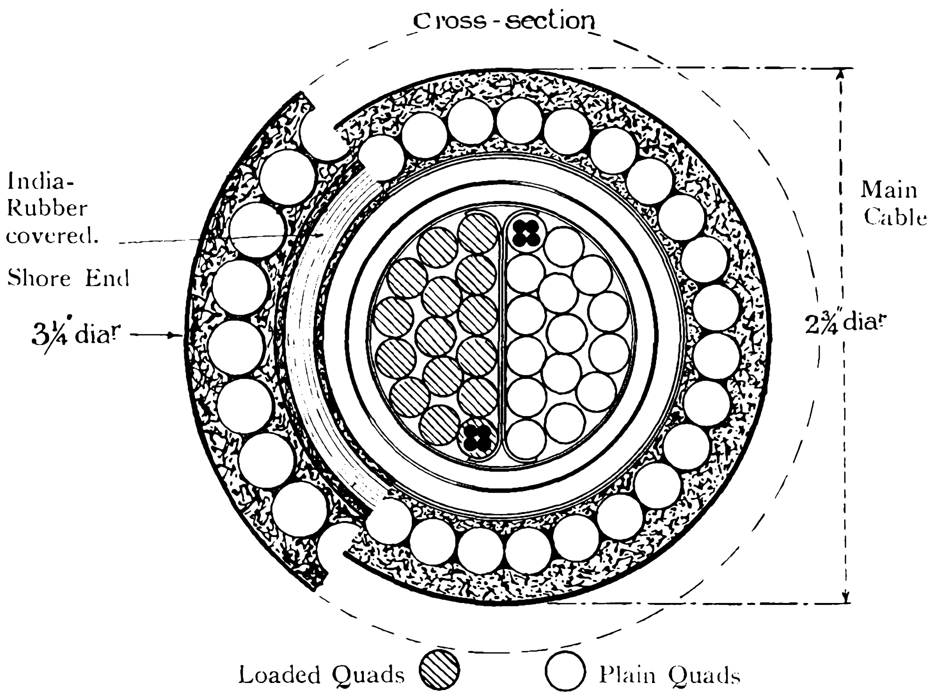


FIG. **7**.—CROSS-SECTION OF MAIN CABLE AND ENGLISH SHORE-END.

Each conductor is whipped with a helix of cellulose yarn and then with two layers of paper; for the A and B conductors the outer paper is coloured red and for the C and D conductors it is white, the A and C wires being further distinguished by a black line. The four insulated wires are stranded to form a quad and as the diameter of the loaded conductor over the loading is the same as that of the non-loaded conductor, the insulation thicknesses and the size of the quad are made the same in both cases.

The separation of the " Go " and " Return " circuits is effected by a metallized paper screen placed diametrically across the section of the cable; the loaded quads are on one side and the non-loaded quads on the other side of the screen (Figs. **4** and **7**). The quads are identified by means of a number

electrical guarantees were imposed :—

Attenuation per naut : At 800 cycles, 0.074 nepers; 1,600 cycles, 0.079 nepers; 2,400 cycles, 0.084 nepers; 3,000 cycles, 0.087 nepers; 6,000 cycles, 0.118 nepers.

Cross-talk : The logarithmic mean of the cross-talk attenuations at 640, 800, 1,100 and 1,900 cycles to be greater than 10.5 nepers. This figure applies to near-end cross-talk between " Goes " and " Returns " and to distant-end cross-talk between any two " Go " circuits or any two " Return " circuits.

Impedance regularity : The maximum deviation from the smoothed impedance/frequency curve of any pair measured between 300 and 2,400 cycles not to be greater than 10%. The mean characteristic impedance curves of any pair to be within the limits of plus and minus $7\frac{1}{2}\%$ of the average for the whole cable.

D.C. Insulation resistance of each wire against all the other wires and earth to be greater than 15,000 megohms per naut after 1 minute electrification.

The repeater station at St. Margaret's is situated at the top of a hill, and the section down the slope, 570 yards in length, was single lead-alloy-covered and drawn into ducts. On account of the rocky nature of the English landing place additional protection to the submarine shore end was considered necessary, and for a length of half a mile the cable was provided with a water-tight sheath of rubber over the lead, the size of the armouring wires being increased to 0.280″ diameter.

Some particulars of the cable are given in Table 1 below.

TABLE 1.

No. of quads	30
Diameter of loaded conductors	0.036″
One layer of loading wire, diameter	0.008″
Diameter of loaded conductors over loading ...	0.052″
Diameter of non-loaded conductors	0.052″
Diameter over lead sheathings	1.83″
Diameter of completed cable, main section	2.74″
Weight per naut	30 tons
Diameter of completed cable, English shore end ...	3.27″
Weight per naut, English shore end	38 tons

Fig. **8** shows in diagrammatic form the proportions by weight of the various constituents in the main cable and shore end, and illustrates the relatively small weight of the " active " materials, copper and loading wire.

LAYING OPERATIONS.

The cable was laid by Messrs. Siemens Brothers cable ship " Faraday " assisted by two small

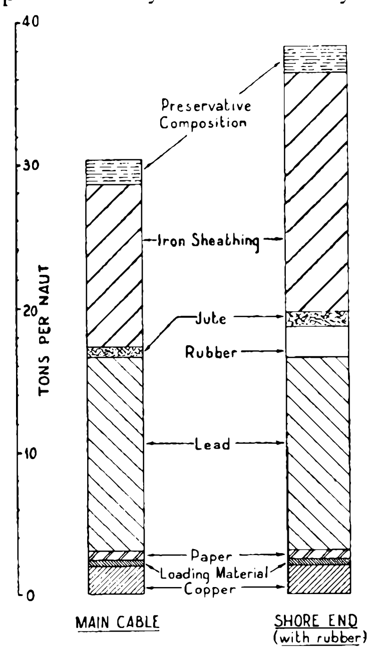


FIG. **8**.—RELATIVE PROPORTIONS BY WEIGHT OF MATERIALS USED.

auxiliary vessels, the operations being finally completed on October 18th. While testing was in progress, a heavy storm occurred on October 23rd and a ship, dragging her anchor, fouled the new cable and completely severed it. The " Faraday " carried out the repair which was completed on November 7th, the work being delayed by bad weather.

ELECTRICAL DATA.

A full statement of the results of the electrical tests after laying is not available at the time of writing; it is hoped that an article will be published in a subsequent issue of the Journal giving these in detail and also a description of the methods of testing employed. A summary of the more important tests after laying is given herewith in Table 2.

TABLE 2.

Length of cable between Repeater Stations	49.1	nauts
Insulation Resistance per naut ...	44,000	megohms
*Conductor Resistance per naut loop at 60°F, D.C.	69.3	ohms
*Conductor Resistance per naut loop at 800 cycles	70.2	,,
*Conductor Resistance per naut loop at 2400 cycles	74.4	,,
*Inductance per naut loop at 800 cycles	23.2	millihenries
D.C. Mutual Capacity per naut ...	0.0734	μF.
Attenuation per naut at 800 cycles	0.0598	nepers
,, ,, ,, ,, 1600 ,,	0.0634	,,
,, ,, ,, ,, 2400 ,,	0.0665	,,
,, ,, ,, ,, 3000 ,,	0.0692	,,
,, ,, ,, ,, 6000 ,,	0.0903	,,
Near end crosstalk between " Goes " and " Returns " ... ... mean	14.5	,,
min.	12.6	,,
Distance end crosstalk between any two "Goes" or any two "Returns" mean	13.4	,,
min.	11.4	,,

* Tests taken in factory.

NOTE.—It was found that the cross-talk attenuation measured at 1100 cycles was very nearly the same as the logarithmic mean of the cross-talk attenuations measured at 640, 800, 1100 and 1900 cycles. The cross-talk figures given in the table are the values measured at 1100 cycles.

The impedance deviations complied with the terms of the specification. An impedance/frequency curve giving values up to 7,000 cycles is shown in Fig. **9** and the attenuation/frequency curve for the overall length up to 10,000 cycles is shown in Fig. **10**.

CARRIER WORKING.

The possibility of the use of carrier circuits is governed by the shape of the attenuation/frequency characteristic. In a coil-loaded cable the curve is generally flat with a sharp rise close to cut-off, and the cut-off frequency determines the number of channels that can be obtained. In a continuously-loaded cable there is no definite cut-off, but the curve rises slowly at first and more rapidly at the higher frequencies due to the losses in the loading and the insulating materials. The former are the more important, and of these the eddy current losses predominate over the hysteresis losses, so that the added resistance varies approximately as the square

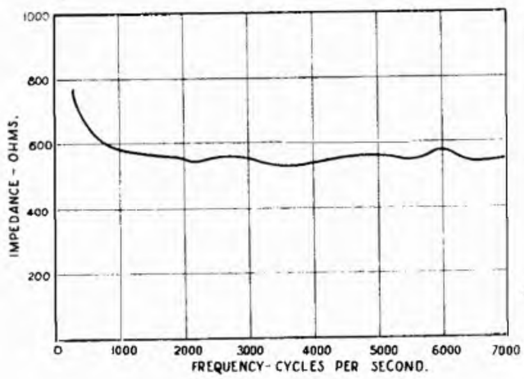


FIG. 9.—IMPEDANCE/FREQUENCY CURVE.

of the frequency. In the new cable the ratio of constant to variable resistance is high, and consequently the attenuation/frequency curve is comparatively flat; further by making the alternate sections sufficiently short, the cut-off frequency has been raised to such a value as to be well outside any carrier frequencies. In Fig. **10** the attenuation/frequency characteristic of the new cable is compared with the corresponding curve for the 1926 continuously-loaded Anglo-Belgian cable. It will be seen that the new cable will easily permit of one carrier channel per quad.

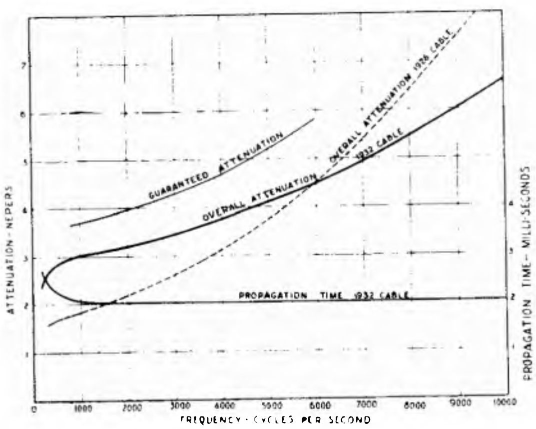


FIG. 10.—ATTENUATION AND PROPAGATION TIME FOR OVERALL LENGTH.

Other considerations which affect carrier working are cross-talk between carrier channels and between carrier and audio channels. In the new cable the near-end cross-talk between " goes " and " returns " is kept low by the separating electrostatic screen; the distant-end cross-talk between circuits in the same direction, which is caused principally by capacity unbalances, is kept low by suitable design and by maintaining regularity during manufacture of the quads. Representative figures show that the worst cross-talk at 5,000 cycles is 11.6 nepers, so that with a carrier frequency of 6,000 cycles using the lower side band, the margin between speech and cross-talk levels is at least 7.6 nepers. The cross-talk between carrier and audio channels arises from cross-modulation effects in the loading material. Tests which have been carried out on the new cable demonstrated that there was no appreciable cross-talk of this nature when the carrier frequency was suppressed. The 1932 cable should therefore provide 30 carrier channels, which makes a total of 60 speech circuits in all.

MUSIC CIRCUITS.

The growing importance of the transmission of broadcast programmes over telephone circuits has led to the provision of special circuits for this purpose in recent cables. The requirements are the transmission of all frequencies up to 10,000 cycles and the absence of interference from and with other circuits. The broadcast transmissions over the continuously-loaded Anglo-Belgian cables have been conspicuously successful, and Fig. **10** shows that the new cable will be even more suitable for the transmission of the higher frequencies. The power level at which music is sent into the line is generally higher than for speech, and it is advisable to have a greater margin than 6.5 nepers between the levels of mutually interfering music and speech. The test results show that all the circuits provide a margin of at least 8.4 nepers at 1100 cycles and that there are about 50% in which the margin is at least 9.0 nepers. Inasmuch as music circuits are only in use occasionally, it is an advantage to have the choice of a number of normal speech circuits which are suitable for broadcast transmissions.

TRANSIENT EFFECTS.

In a coil-loaded cable trouble is sometimes experienced from transient effects, particularly when the loading is heavy. These are due to the different times of propagation of the various frequencies; they can be overcome by inserting phase-compensating networks which bring all the propagation times up to the value of the highest. In a continuously-loaded cable transient effects are absent as the propagation times are the same for all frequencies. This applies also to the new cable within the working range and Fig. **10** shows the propagation times calculated up to 10,000 cycles. It is based on the relation $t = \alpha/\omega$ where α is the wave-length constant which was measured on representative factory lengths of armoured cable. It will be seen that the transmission time for a fifty-mile length is about 2 milli-seconds, and that very long circuits could be constructed with this type of cable without the need for phase-compensating networks.

CONCLUSION.

The test results and curves shown herewith demonstrate that the Intermittent type of loading is equivalent electrically to continuous loading over a wide range of frequencies; applications other than to submarine cables are possible where a broad frequency band is desired, *e.g.*, carrier and music transmission, and also in situations where loading coils have to be avoided.

Considerations in the Manufacture of Telephone Cables

CHARLES F. STREET, M.I.E.E., A.M.I.C.E.
(Messrs. Johnson & Phillips. Late Engineer-in-Chief's Office, G.P.O.).

THE electrical requirements of a modern telephone cable demand a degree of precision in manufacture which is not usually appreciated and the following notes endeavour to illustrate some of the more important points to be observed in the manufacture of a satisfactory cable.

Wire.

In order that the conductor wires, which are generally of copper, shall readily take up and retain the position assigned to them during manufacture, the wire must be soft. Any hard or springy wire, either partly or wholly, is undesirable because such wire will resent taking up its desired position in the cable. Uniformity of annealing is therefore of importance. Furthermore, it will be appreciated that the wires should be straight. The presence of waves, bends or kinks is clearly undesirable.

One method of straightening wire is to cause it to pass between a number of pegs placed so as to make the wire take a diminishing zig-zag course. The pegs are so placed as deliberately to put " waves " in the wire and to take them out by the passage between subsequent pegs placed more nearly in a straight line. This method is employed for wire used in the manufacture of pins and needles. It is not suitable for wire intended for cable manufacture, as the wire is liable to become hardened and possibly stretched in its passage between the pegs. Moreover, the effort required to draw the wire through the pegs is considerable and difficult to arrange for in telephone cable machinery, because at the point of " haul off " the wire is paper-covered and the paper tube is flattened on the " haul off " wheel if the tension is too great.

A modified form of this straightener has been employed in telephone cable work in which the pegs were replaced by a series of grooved pulleys about 1 inch in diameter. The results were not satisfactory and in many instances not only was the wire stretched, which was objectionable for electrical reasons, but quite frequently the straightener actually put more waves in than it took out.

The most satisfactory method known to the author is to pass the wire about three times around a pulley with a diameter of about 1 foot, and to allow another weighted flat-edged pulley to lie on the wire on the first-mentioned pulley. This device is part of the paper covering machine and the wire is not handled again after straightening. Such a straightener also acts as a measuring device. The first-mentioned pulley can be made with a circumference of one yard and, by means of a revolution counter, the length of wire passed into the covering machine is known accurately. This method displaces the earlier process of either weighing or measuring in a separate machine.

Dielectric.

The field for the selection of the dielectric is very small. On account of the importance of a low capacity, air is used universally as the dielectric. It is, of course, necessary to prevent the conductors from coming into contact with one another, and for this purpose paper is used. It is convenient to think of the air as the dielectric with the paper incidentally employed to prevent contacts between the conductors.

Wire Covering.

In the early forms of wire covering, and indeed until recently on low-grade cables, the copper wire was merely wrapped with either a helical or a longitudinal wrapping of paper. In a high-grade cable, however, it is necessary that the conductor shall be accurately placed at the centre of a paper tube and that this tube shall be capable of resisting a mechanical crushing load such as is imposed on the covered wires when they are laid up in a complete cable. Various methods have been employed to secure this result. In considering these methods, it is necessary to bear in mind that the design should include as much air and as little paper as possible, having regard to the resulting mutual capacity of the pair.

One of the earliest forms of covering was known as " Ballooning." This consisted of wrapping a rather stout paper somewhat loosely around the conductor. A helix of strong thread was then tightly wrapped around the paper covering, producing the form of construction shown in Fig. 1. The

FIG. 1.—EXAMPLE OF BALLOON-TYPE COVERING.

construction resulted in the formation of a long narrow arch taking a helical course around the conductor and capable, to some extent, of resisting a crushing load. It involved the use of rather thick paper, which was originally applied longitudinally along the wire and closed round it. This was objectionable, as it gave rise to a double thickness of paper longitudinally along one side of the finished article where the overlap occurred.

This was minimized by using what was known as semi-spiral wrapping. The paper was put on with a spiral of about 18-inch pitch, the idea being to prevent the ridge of double thickness of paper from persistently occurring on the same side of the paper tube. Longitudinal covering is now superseded by spiral wrapping with a pitch of $\frac{3}{4}$ inch or so.

Another type of covering was to use crinkled paper. The depressions of the crinkles rested on the conductor and assisted in maintaining a more or less rigid paper tube uniformly spaced around it. This was accomplished by using a paper slightly wider than a slit through which the paper had to pass immediately before being wrapped round the conductor.

A more scientific method of doing something of the same sort, and known as Smith type covering, was to pass the paper through an ingenious die, so constructed that it actually turned one edge of the paper completely over for a width of about 1/16 inch. One edge of the paper therefore consisted of a double thickness. This edge was arranged to be on the under paper of the spiral wrapping, so that the covering paper was held away from the conductor by an inner spiral of two thicknesses of paper.

All these types of covering necessitated the use of fairly stout paper which, for a given available space, resulted in a higher mutual capacity than desired.

One of the most satisfactory types of covering in use in this country is to wrap a fine cellulose thread or spacer around the conductor helically with a pitch of about $\frac{1}{4}$ inch and to wrap a thin paper over the cellulose thread. This form of construction arranges for the conductor to be localized centrally within the tube for a minimum amount of paper and a maximum amount of air. There is on record the case of an experimental cable which was made in this way in which the outer wrapping of paper was omitted, presumably for the purpose of minimizing the amount of paper in the dielectric. This form of construction would naturally give rise to risk of contacts between the wires in the cable. Whether the outer wrapping of paper be employed or not, it is of interest to point out that in order to keep two adjacent wires accurately spaced from one another it is desirable that the spiral threads on adjacent conductors should lie obliquely to one another, otherwise the threads around one conductor will be liable to lie between those around the adjacent conductor.

A little consideration will show that the desired condition is most likely to be achieved by applying the spiral thread on each wire with the same sense of twist, not with the opposite sense as has sometimes been suggested. It may be remarked also that the use of two threads on the conductor, one over the other with opposite senses, fails, as the resulting covering is oval instead of circular.

Threads used for this purpose should preferably contain three " ends " as they are more uniform in diameter than threads having only one " end." The thread is generally applied to the wire by passing the wire upwards through a holding die and revolving the thread round it at a speed of anything up to 3,500 r.p.m.

Although the thread is very fine (.012 inch diameter), it is found in practice that it will actually bend the wire at the point of application of the thread and, if the thread be afterwards removed, the wire will be found to contain permanent waves of the same pitch as the removed thread. Such waves are detrimental to the characteristics of the cable. Their formation can be minimized by increasing the tension in the wire as far as can be done with safety in other respects, and by making the point of application of the thread as near as possible to the supporting die as shown dotted in Fig. 2.

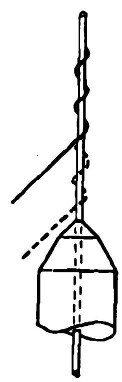


FIG. 2.—HOLDING DIE.

It may be mentioned that, to secure uniformity of the four wires of a quad, it is not sufficient to cover each wire through dies of the same size, but to cover each of the four wires of a quad through the same die.

Identification.

In a cable containing a number of wires, it is necessary to have some means of identification whereby any particular wire or quad can be picked out at each end of the cable without testing electrically. Primarily, a quad is localized by stating the layer in which it exists, *i.e.*, either centre, first, or second layer, etc. As each layer contains two specially-marked quads known as Marker and Reference, any particular quad can be identified at both ends of the cable by counting from these Marker and Reference quads. One Marker quad is inadequate, as it does not enable the direction of counting to be indicated.

Until some years ago, a quad was made up with one pair of wires covered with, say, blue paper and the other pair covered with, say, white paper. The individual wires of the pairs were recognized by wrapping coloured threads around them. The coloured papers were under suspicion for some years as being a contributory cause of capacity unbalances and consequently of electrical interference between one circuit and another.

The mechanical properties of coloured papers generally differ from those of white paper, as the figures in Table I. show.

TABLE I.

Paper.	Breaking Load.	Elongation.
White	9.9 lb. per inch per mil	5.3%
Blue	6.5 ,, ,, ,, ,, ,,	3.0%
Red	6.8 ,, ,, ,, ,, ,,	3.8%
Green	6.4 ,, ,, ,, ,, ,,	3.5%

One method of effecting a colour balance is worthy of record. It was required that the wires of the two pairs in a four-wire quad should all have the same paper wrapping, yet one pair should be readily distinguishable from the other. A solution (Author's Patent No. 223,740) was to use bi-coloured paper, that is, paper which was, say, blue on one side and, say, white on the other. This same paper was used on each of the four wires, but with one pair the paper was put on with the blue side out and with the other pair with the white side out, thus providing identical covering for all wires, but one pair was readily distinguishable from the other by its external appearance.

The idea was advanced some years ago and before the introduction of Star Quad cable. The scheme was given a trial on a whole loading coil section of 96/40 M.T. cable (Glasgow-Carluke). A comparison of test results of cables made with bi-coloured paper and those made with the multi-coloured papers on the same contract is shown in Tables II. and III.

TABLE II.

CAPACITY UNBALANCES (MEAN FOR 176 YARDS).

	Multi-coloured papers.	Bi-coloured paper.
No. of Quads examined.	192	288
p — q	22	14
U	229	182
V	282	159
u	179	115
v	213	99

TABLE III.

MUTUAL CAPACITY.

Variation % from mean of cable.	Multi-coloured paper.	Bi-coloured paper.
No. of Pairs examined.	384	576
	Percentage of pairs in the cable.	
3%	31	49
5%	55	73
7%	72	86
10%	90	97
15%	100	100

The actual figures are not good as compared with the present day standard, but they indicate an improvement in the unbalances and a superiority in the number of small-deviation quads for mutual capacity in favour of the bi-colour arrangement.

No superiority is shown in the case of the maximum, and this is probably due to some other cause which masked the improvement effected by colour balancing.

The latest practice is to abolish coloured paper altogether and to use white or neutral papers throughout, identifying the wires by other means. The use of the coloured thread around the covered wire was abandoned in favour of a black ink line, $\frac{1}{8}$ inch wide, along the whole length of the paper on one wire of each pair. The selection of the ink must be made with care. Ordinary carbon printing inks are quite unsuitable for the purpose. The use of such inks results in low insulation and a cable which will not respond to treatment by either dry air or heat.

Table IV. shows the relative D.C. insulation resistance of papers marked with unsuitable ink.

TABLE IV.

(*a*)	Through un-inked paper	655	megohms
(*b*)	,, inked ,,	181	,,
(*c*)	,, un-inked ,,	950	,,
(*d*)	,, inked ,,	217	,,

Carbon printing inks generally contain one or more of the following ingredients which, of course, are quite unsuitable for a high-grade cable :—Carbon, Gum Arabic, Glycerine, Non-drying oils such as Castor Oil, Varnish, Linseed Oil, Turpentine. The most suitable material is an aniline dye.

It is now thought that even the use of any type of ink mark on one paper only and not on the other wire of the pair is objectionable on electrical grounds and the latest scheme is to put the same amount of ink on each paper, but to distribute the ink differently on each of the four wires in the form of codes, so that each wire is readily distinguishable from the other three.

Quadding.

Quadding is the name given to the association of the four single wires to make a four-wire core or quad. From what has been stated in the previous paragraphs, it will be appreciated that a very accurate disposition and maintenance of the four wires is required.

For mechanical reasons, the four wires are laid up round a central cellulose thread. This thread should be of a softer type than that used for wrapping round the conductor. Its diameter should be rather greater than that of the circle which can be inscribed within the four covered wires, so that the wires may become slightly embedded in the thread to assist in the preservation of the square formation.

The four associated wires are passed through a square revolving die to localize them finally, and the quad is then whipped with a thread to keep the individual wires in position.

A process which requires attention in the quadding (and other) operations is that of maintaining a constant tension on a wire while it is being drawn off a bobbin. If the bobbin be fitted with a brake drum with an ordinary brake band giving a constant restraining torque to the drum, then the tension in the wire which is being drawn off the bobbin will increase as the bobbin empties and the effective radius of the pull of the wire diminishes. The effective diameter of the wire on the bobbin when nearly empty may be only one half the value when the bobbin is full, with the result that the tension on the withdrawn wire will be twice as great as when the bobbin is full.

Many ingenious devices have been adopted to compensate for this effect due to the emptying of the bobbin. Probably the simplest arrangement of all and applicable to most operations is shown in Fig. **3**.

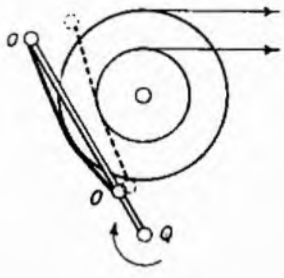


Fig. **3**.—Constant Tension Bobbin Brake.

A metal frame carries a wide band of webbing O.O. which rests on the wire itself on the bobbin. The frame is pivoted about a point Q and by means of a spring the frame tends to twist in the direction of the arrow with practically a constant torque for all working positions of the frame. By this means, the restraining torque on the drum diminishes as the drum empties and the tension on the wire is substantially constant. In fact, the tension on the wire is equal to the restraining force of the band of webbing which is practically constant whether the bobbin be empty or full.

A photograph of a modern quadding machine is shown in Fig. **4**. The machine is of the vertical type and can be used for either Multiple Twin or Star Quad cable. The photograph shows the machine as used for star quad cable. Four bobbins of covered wire are mounted in the lower portion of the machine, each bobbin being equipped with the constant tension device referred to above. The four covered wires are led up through four bell-mouthed holes D, thence through separate holes in the lay head L, and then through the square revolving die referred to earlier.

Immediately after leaving the square die, the quads are whipped with a thread to keep the wires in their correct position. The quad then passes to the " haul off " wheel O.

The spool of cellulose thread for the centre of the quad is mounted on a cage V. This cage is equipped with a special device which emits a " clicking " noise as it rotates and pays out the thread. The cessation of the clicking noise is a signal to the operator that the thread has broken.

Stranding.

The bobbin containing the completed quads are placed in the familiar laying-up or stranding machine and stranded to form the completed cable. Probably the greatest point of controversy in the stranding process is whether " fixed " or " floating " bobbin machines should be employed. The two types are shown diagrammatically in Figs. **5** and **6**. The effect of using the two different types is summarized as follows :—

(*a*) With the fixed-bobbin machine, the quads are themselves twisted on their own axes so that the resulting pitch of quadding is either increased or decreased according to whether the stranding pitch is in the same sense as the quadding pitch or not.

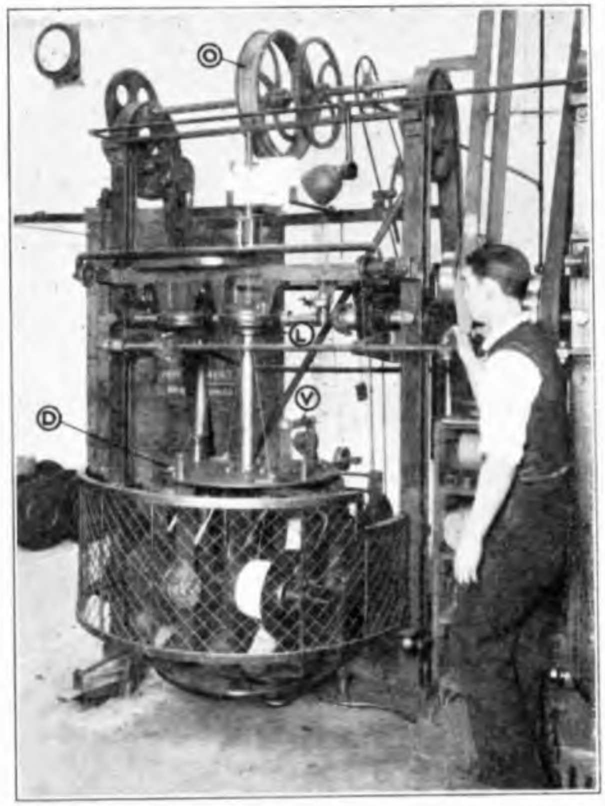


Fig. **4**.—Quadding Machine.

With the floating-bobbin machine, the pitch of quadding is not altered by the process of stranding.

(*b*) With the fixed-bobbin machine, adjacent quads in the same layer are not twisted with regard to one another, whereas with the floating-bobbin machine they are.

(*c*) With the fixed-bobbin machine, the quads in any layer are not twisted with regard to any

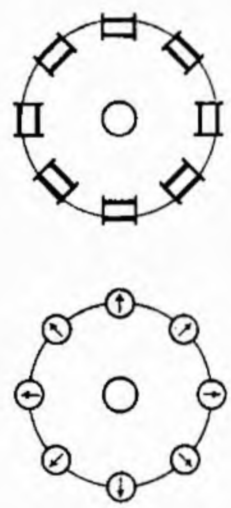


Fig. **5**.—Fixed-bobbin Laying-up Machine.

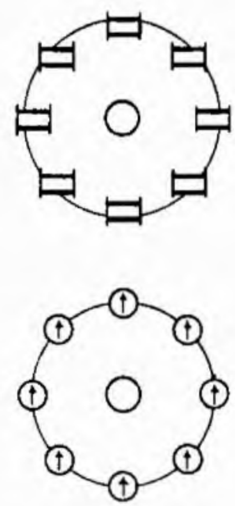


Fig. **6**.—Floating-bobbin Laying-up Machine.

point inside the cable enclosed by the layer in question, but they are twisted with regard to any point outside the layer.

The converse applies with regard to quads laid up in a floating-bobbin machine.

It will be seen that quads laid up in the two types of machines have characteristics of their own. The floating-bobbin machine is more generally favoured, but is more expensive than the fixed-bobbin machine and the latter is quite commonly used.

The Selection of Sense and Magnitude of Twisting Pitches.

It will be appreciated from the foregoing that the ideal condition is to manufacture a cable in which the mutual capacity per mile of cable for all pairs is the same and the electrical interference between all pairs is nil. The following is a resumé of the difficulties experienced in accomplishing this.

The length of pairs or quads in the outside layer may be of the order of 2.5% longer than those in the centre of the cable. So that if all quads were identical and the mutual capacity uniform per unit length of quad, there would be a variation of 2.5% per unit length of cable due to this cause.

Moreover, it is not possible to make all the quads identical because if the same pitch of quadding be employed, interference will occur between one quad and another. In practice, it is necessary to employ seven or eight different quadding pitches.

The use of different quadding pitches at once introduces variations in mutual capacity as the latter is dependent upon the quadding pitch. An analysis of about one thousand pairs of 254/40 P.C.Q. cable showed the mean capacity of quads of different pitches to be as set out in Table V.

TABLE V.

Quadding Pitch in inches.	Relative Mutual Capacity.
16.6	98.9
11.98	100.0
8.98	100.9

The deviations in mutual capacity become much more acute as the pitches become shorter.

Another reason for differences in quads arises from the fact already mentioned that, for mechanical reasons, the alternate layers in a cable are stranded clockwise and anti-clockwise respectively. If all quads are made with the same sense and laid up in a fixed-bobbin machine, then the resultant pitch of the quads will be altered according to whether the sense of the stranding pitch is the same or opposite to that of the original quadding pitch.

To prevent this objection, some makers alter the sense of the quadding so as to be the same as the stranding pitch. That is to say, the quads for the 1st, 3rd, and 5th layers will be quadded right-handed and stranded right-handed, whereas the quads for the 2nd, 4th, and 6th layers will be quadded left-handed and stranded left-handed.

The use of two senses for quadding does not make things any easier in the shops and the point arises that, if this alteration in sense of quadding is necessary, is it not equally necessary that the sense of all the earlier operations shall also be reversed in alternate layers? That is to say, the sense of paper covering, the thread on the conductor, and possibly the sense of twist of the thread itself shall be reversed.

One school of thought on this matter believes in using the same sense of quadding in all layers and in using a fixed-bobbin laying-up machine. If the quadding pitches be long, then the change effected in the quads due to stranding is comparatively small, whereas if short quadding pitches be employed, then the effect of superimposing the stranding pitch will have a much more marked effect on the capacities of the quads. Since adjacent quads in the same layer must have different pitches to prevent interference between them, at least two quadding pitches are required. If, however, the number of quads in a layer is odd, then a third quadding pitch must be introduced, otherwise the last (odd number) quad in the layer will be adjacent to number one quad in the layer.

It is found by experience that quads of the same pitch in adjacent layers are liable to interfere with one another and this gives rise to another set of three quadding pitches.

When, however, a cable happens to have a four-core centre, four distinct quadding pitches are necessary. A four-core centre cannot be considered as an ordinary layer containing an even number of quads. If this were done, quads numbers 1 and 3, which are not adjacent in the same layer, would have the same pitches. The fallacy of this has been brought to light by large interference between quads 1 and 3 in a four-core centre. The explanation is that although these quads are not next to one another in the same layer, they are diagonally opposite one another in a four-point square and are near enough to one another to cause abnormal interference between them.

This consideration gives rise to four quadding pitches for the centre and three for the even layers, making a total of seven altogether.

A range of seven pitches causes an appreciable difference in magnitude between the minimum and the maximum pitch with a consequent fundamental difference in mutual capacity of the corresponding quads. For this reason, the use of long quadding pitches is an advantage as the change in capacity with quadding pitch is much more acute when the pitches are short. Long quadding pitches also increase the machine output.

The limiting feature of a quadding machine is the speed of rotation of the circular table carrying the four bobbins of insulated wire. For a given speed of rotation, the output of twisted quad varies directly with the quadding pitch.

For 40 lb. wire, the author has used pitches of over 20 inches, but a 16-inch pitch appears to be about the limiting value as quads of this pitch are more susceptible to derangement due to handling. Pitches of 13 inches have, however, proved quite satisfactory.

The most common form of derangement is that the centre cellulose thread gets out of its central position and lies outside the four-square formation.

Variations of Unbalances with Cable Length.

Space does not permit, nor is it necessary to describe in detail the precise meaning of the many symbols referring to capacity unbalances.[1] It is sufficient to state that if a cable be designed and manufactured accurately with perfectly uniform components, the capacity unbalances complained of would not be present. It is desirable, however, to give an indication of the degree of accuracy demanded in a high-grade cable.

Consider, for example, the question of the within-core unbalance, represented by the well-known symbol $p - q$. This is equal to $(w - x) - (z - y)$. By design, w, x, y, and z should all be equal and in a length of 176 yards the specified mean/max value for $p - q$ is 33/125 $\mu\mu$F. Bearing in mind that w, x, y, and z have a value of about 3,300 $\mu\mu$F each, the permissible tolerance in the value of these quantities is about 0.5% if the maximum permissible value of $p - q$ is not to be exceeded.

Although the necessary limits of unbalance are fixed by specification for a standard 176-yard length of cable, difficulties and anomalies arise when it becomes necessary to express what the limits of unbalance should be on a cable of the same quality but of a different length.

In order to consider this question, it is necessary to classify unbalances according to the cause from which they occur. Firstly, there is the type of unbalance which occurs regularly along the length of the cable. This may be due to a bias in a machine or a persistent irregularity in one of the components. Suppose, for example, the A-wire of a pair AB was regularly covered throughout its length with a thicker paper than the B-wire. Its capacity to earth would then be greater than the B-wire. The unbalance known as u, which is the difference between the capacity to earth of the A and B wires $(a - b)$, would therefore be positive and its magnitude would vary with the length of the cable. Unbalances due to causes of this kind are generally the largest in the cable.

The other type of unbalance is due to normal irregularities which occur in the dimensions and properties of the paper, thread, wire, etc. Unbalances due to these causes will not regularly affect only one wire nor will they persistently have the same sign. For this reason, their magnitude will not be proportional to the length of the cable.

The position is probably best understood by considering two standard lengths of cable of the same quality and mean unbalance.

[1] Details of these will be found in Technical Instructions, Lines, Underground, Section G, published by the Post Office Engineering Department.

The mean capacity unbalance of each of these lengths is obtained by tabulating the unbalances of all the quads and taking the arithmetical mean. Each of these unbalances has an algebraic sign which the arithmetical mean ignores. If now these two cables be jointed together, the arithmetic mean unbalance on the double length will not be double that on the single length. Such a condition could only be arrived at by jointing the pairs so that negative is joined to negative and positive to positive. Neither will the unbalances on the double length be zero, because this could only be achieved by jointing all the minus quantities to the positive quantities so that they cancelled one another.

When the quads are joined together and the quantities are added at random, the resulting unbalances on the double length will be somewhere between zero and double those of the single lengths. It has been shown mathematically that as a result of such a random combination the mean unbalances on the greater length will probably be related to those on the single length by the square root of the ratio of the lengths. In other words, the arithmetical mean unbalance on a double length of cable is the mean of the algebraic sum of the component lengths. It is not the sum of the arithmetic means of the two lengths.

As a result of this consideration, the mean of certain unbalances of a length of cable are expected and specified to be a square root function of the length of the cable.

In practice, however, the unbalances vary somewhere between the square root and the linear function of the length. Table VI. shows the mean unbalances of a length of cable which was cut into fractional lengths and the unbalances measured in each part. The original length of the cable was 138 yards which was cut into two lengths of 69 yards each, and again into four lengths of 34.5 yards.

TABLE VI.

Length.		Ratio of Mean Unbalances.	
Yards.	Ratio.	(p — q)	u and v
138/69	2	1.8	1.99
138/69	2	1.77	2.00
69/34½	2	1.27	2.05
69/34½	2	1.18	1.84
Mean.	2	1.5	1.97
138/34½	4	2.24	4.09
138/34½	4	2.09	3.68
Mean.	4	2.16	3.85

It will be seen that with a length ratio of 2, the unbalance ratios were 1.5 and 1.97 for $(p - q)$, and u and v respectively. They both lie between the square root and linear function, the $(p - q)$ nearer the square root and the u and v nearer the straight line. The same remarks apply when the length ratio of 4 is examined.

The failure of the cable to follow the square root law gives rise to certain difficulties and anomalies. A long length of cable in which the unbalances are a linear function of its length may fail to comply with the specified unbalances for that length. If, however, the cable be cut, say into two equal parts, each length may comply with the specified requirements because these latter are now $\sqrt{0.5}$ times their original value whereas the actual unbalances are but 0.5 of the value of the double length.

The foregoing notes do not, of course, cover the whole realm of cable manufacture, but are cited as being among the most interesting and important of its features.

Notes on Wireless History

J. E. Taylor, M.I.E.E.

It has been suggested to the writer that on the eve of his retirement from the Post Office it would be appropriate to supplement somewhat the previous articles published in this Journal over twenty years ago on " The Early History of Wireless Telegraphy." In acceding to this request, it should be made clear that no claim to expert knowledge or close practical touch with the developments of recent years is put forward. Those who look for information or instruction in this connexion may, it is feared, be disappointed.

The articles referred to above were written before the days of the thermionic valve or the development of continuous wave radiation. Consequently, wireless telephony as we know it to-day was not in being nor had broadcasting even been mooted. Spark telegraphy was the only practicable method of wireless communication. The introduction of the three-electrode thermionic valve put so vastly different a complexion on the art and opened up so large a field just before the War, that an entirely new era was entered upon. This renders it a little difficult to pick up the threads of the previous articles and to decide just how to supplement them. Obviously, however, the evolution and introduction of the thermionic valve, which occurred during the writer's close association with wireless, calls for some observation. Moreover, the pre-valve period subsequent to the early history was not entirely uneventful, as it was in this period that the historic Marconi Contract for Imperial wireless stations and the no less historic Marconi Committee excited public interest. There was also the development of Trans-Atlantic communication by the Marconi and other Companies, the application of the Poulsen arc for transmission by continuous radiation, and a great activity in the invention of appliances and methods, practicable and impracticable,—the latter predominating. The use of wireless installations on ships for greater security in navigation was also, at this time, being rapidly extended. On the theoretical side, though the " copper sky " still had many notable adherents, a more reasonable view of upper atmosphere conditions in relation to wave propagation was evolving itself. Systematic research work and measurements of wave effects had been stimulated by Duddell's work and was beginning to make headway. Practical developments were mainly in the direction of utilizing longer and yet longer waves with larger aerial networks and greater transmitting machinery adapted to deal with huge puffs of radiated energy for the purpose of bridging the maximum possible distances. Concurrently, however, some headway was being made with continuous wave radiation, either by special high-frequency alternators, of which the Alexanderson alternator and the ingenious Goldschmidt machine were notable examples, or by the more unobtrusive oscillating arc originally investigated by Duddell, developed for high frequencies by Poulsen, and further adapted under the auspices of the Federal Wireless Company, U.S.A., by Elwell and De Forest to deal with large powers of transmission. In this development, Duddell had been misled by theoretical considerations into surmising that wireless frequencies were unlikely to be attainable whilst Poulsen appears to have been of opinion that a single arc could only deal effectively with a limited amount of power. The writer's association with the arc transmitter will be referred to later.

Referring back again to the old filings-coherer receiver days, there are two points which may be worthy of putting on record. The first has reference to the invariable practice, which then obtained, of including in the circuit of the coherer a single dry cell, or its equivalent, having an approximate voltage of 1.4. Much of the erratic behaviour of the filings coherer would have been avoided and a longer useful life obtained if the applied voltage had been limited to half a volt, a relay of sufficient sensitivity being, of course, also used. The disadvantage of adding a potentiometer was overcome by the writer by the use of a dry cell in which the zinc container was replaced by a similar brass receptacle and in these circumstances any moderately well constructed filings-coherer will act reliably and with precision. The second point has reference to the mistaken view that a filings-coherer operates between a certain range of varying resistance somewhat similar to the way in which a carbon microphone behaves. Coherers which have been damaged by the use of rather excessive voltages certainly do tend to this condition and are liable to erratic action, but the healthy coherer is a practically perfect insulator to voltages of the order of unity. The Lodge mercury coherer had an even more pronounced aversion to 1.4 volts, but with 0.5 volt as used by Sir Oliver Lodge it behaved in a very stable manner.

Much controversy arose in the spark telegraphy days as to the relative degrees of syntony attainable on different systems of working, notably on the question of whether to "earth" or not to earth. It would hardly be profitable, at this stage, to dilate on the arguments used, but it is now clear that there was not much to choose. It is, however, beyond doubt that the extravagant claims put forward in some quarters for the secrecy attained by high syntonization had no substantial foundation. Syntonic developments were wrapped in an atmosphere of great secrecy. There is little doubt, however, that the development in the British Navy of the use of tuned shunts and filters had a profound effect on securing selectivity. This development was kept secret for many years and the writer believes it was not public property at the outbreak of the War. There is also reason to believe that a special and efficient method of securing the connexion to earth (or hull of the vessel) had a marked influence in Naval wireless. A simple connexion by the shortest route to the inner side of the hull, though a perfectly good method for steady or low frequency currents, does not cater efficiently for high frequencies. Owing to the skin effect, such currents have to traverse a devious path inside the vessel before reaching the outside of the hull and the surface of the sea. This involves appreciable and unnecessary dissipation losses which can be obviated by leading the aerial connexion in to the signalling cabin through a cage of wires which can be connected to any suitable part of the hull above decks. In this way, the high frequency electric field is confined between the aerial and the wire cage, and dissipation losses are largely reduced.

Reverting again to the question of filters it should be remarked that the Marconi "X-Stopper," when suitably arranged, performed the functions of a filter, though its primary function, perhaps, was the reduction of interference by atmospheric disturbances.

Among the multitudes of wireless appliances and methods which flooded the Patents records in an almost reckless gamble at this stage were some which contained the germs of future development. The large majority were destined for oblivion, but among these were some rather remarkable conceptions. Thus it was seriously proposed to take advantage of the phenomenally high specific inductive capacity of pure water by immersing a miniature aerial system in a well or other receptacle. In this way it was claimed that a small transmitter could be made to replace a much larger transmitter in air. The notoriety gained by some of the obviously unworkable arrangements, such as automatic wireless repeaters, was often quite remarkable. The Bellini-Tosi directional wireless system was one of the former category and, though hardly a practicable device in its original form, was undoubtedly correct in principle. Its main weakness lay in the necessity of accurately tuning the two aerial loops to the same periodicity and ensuring that there was no coupling between them. This condition could hardly be maintained in practice, especially in stormy weather when it was important that the system should be accurate. When taken in hand by the Marconi Company and the system of tuned aerials replaced by simple closed wire loops, it became a valuable asset to navigation.

The outstanding example of a patent device, which though not having any great immediate value, contained the germs of a far-reaching development, was the Fleming vacuum valve. This will be dealt with in more detail later.

A matter of some theoretical interest which seems to crop up occasionally has reference to the question of complete screening of a receiver when in a metal-covered enclosure. It will be remembered that in the very early days Marconi stated that he was able to operate his receiver inside a closed copper box. This, however, was contested on theoretical grounds and the assumption was that if the receiver responded it was due to incomplete enclosure. At a much later date, the writer was assured by a competent observer that the response obtained in a metal-covered cabinet was a residual effect which he was satisfied had penetrated the metal. Theoretically, of course, the law of decay of high-frequency current inwards is such that any residual effect could be effectively wiped out by a further microscopic increase of thickness of the metal covering. In view of the very definite statement made and the quarter from which it came, it might be interesting to have the point finally settled.

With the supercession of the coherer receiver and Morse printer, there came into competition for popular favour a number of detectors of the type requiring a telephone receiver for the reception of signals by ear. Chief among these were the magnetic, electrolytic, and various forms of crystal detectors. In America, Fessenden ran the "Barreter," a form of thermal detector depending upon the heating, and consequent change of resistance, of a very short length of excessively fine wire by the oscillation produced in the receiver. In addition to its capability of reproducing signals in a telephone, Fessenden laid considerable stress on the fact that it gave quantitative results enabling the strength of received signals to be measured with some degree of accuracy. Probably its greatest utility lay in the latter quality, as its robustness and power to withstand atmospheric shocks must have been limited, though the writer cannot claim to have any practical experience with it. The Marconi magnetic detector, by reason of its stability and robust construction, largely held the field in marine signalling. About the year 1906, De Forest brought out the two-electrode rectifying vacuum valve, adapted for use with a telephone to give audible signals, under the name of "Audion," and so far as the writer is aware this was the first time the device had been brought into prominence. The effect made use of was originally discovered by Edison, who had found that the rarefied gas in a carbon filament incandescent lamp showed some conducting power when the filament was heated by a current. Dr. (now Sir Ambrose) Fleming afterwards investigated this conduction and discovered its unilateral (rectifying) property. He patented it as a wireless receiving appliance in 1904, but no particular merit seems to have been attached to it as a wireless detector until the advent of the Audion. Even then, it was but a competitor in the field with crystal and other detectors which it did not succeed in displacing. The writer was rather impressed with its potentialities as a sensitive measuring device for testing and developing wireless methods, and was instrumental in procuring from the Marconi Company the first vacuum valve receiver used by the Post Office. This would be about 1911, and it was not by any means the standard receiver for wireless stations either in the Marconi Company or elsewhere at that time. The silicon crystal detector with potentiometer and priming battery was then largely used in the Marconi long-range stations so far as the writer is aware.

About this time, the Poulsen arc system using continuous-wave transmission was making headway and the writer was privileged to see this in operation first at Cullercoats on the Northumbrian Coast and later in Denmark. Its advantages in the direction of securing high selectivity between stations, as compared with spark methods, were obvious, and it was perceived to be a serious competitor for long-distance work provided that it could be developed to give ranges of communication comparable with those being given by powerful spark stations. In this connexion, the question of the most suitable system for a chain of Imperial wireless stations was under review and it had been decided that they should be individually capable of bridging distances of approximately 2,000 miles. The Poulsen system was not then equipped with sufficiently powerful plant, nor was any assurance forthcoming that would warrant its being seriously considered for so long a range. In these circumstances, a contract for the required stations was arranged with the Marconi Company under guarantee of satisfactory communication for a stated number of hours per day, spark transmitters and crystal receivers or their equivalent being catered for. The contract was, however, subject to ratification by Parliament. So far as the writer was concerned, objections to the contract on the ground that the Marconi Company had not given any sufficient or convincing demonstration of their ability to carry out the scheme to a successful issue, were over-ruled by higher authority. In the light of present day knowledge, it will probably be agreed that there was some ground for objecting. In the writer's view, the scheme amounted to a belief by the Marconi Company in their ability to blast a passage in spite of known difficulties. Before ratification of the contract, news was received of a development and extended application of the Poulsen system in America, communication having been established between San Francisco and Honolulu by the Federal Wireless Company. In company with Commander (now Admiral) Payne, R.N., the writer was deputed, in September, 1912, to pay a hurried visit to San Francisco for the purpose of investigating the claim on the spot and furnishing a report. This was done in what is probably the record Post Office time for a visit to the Pacific Coast and back. Less than five weeks was occupied. With the kindly advice and assistance, in New York, of Mr. J. J. Carty, of the A.T. & T. Co., a route across the Continent was selected and plans made, San Francisco being duly reached after almost continuous day and night travel. A rather humorous incident of this journey is perhaps worth relating, though it redounds more to the credit of the American than the British Telegraphs. The writer was surprised while on the train somewhere in the region of the Rockies, to receive from a telegraph messenger a service telegram re-directed from the New York offices of the A.T. & T. Co. apprising him that a cablegram sent from New York to his home address was undelivered "address insufficient"!! Though the route for the journey as originally arranged had been departed from, the service message was successfully delivered,—a fitting rejoinder to the failure to deliver the cablegram in London.

By the kind offices of the British Vice-Consul in San Francisco, a test message to be transmitted *via* Honolulu wireless, and consisting of a somewhat lengthy extract from the confidential instructions to British Consuls, was arranged for through the intermediary of the British Consul at Honolulu, instructions as to the extract to be selected being sent by coded cablegram. In due course, the extract arrived over the wireless at about ten o'clock the same evening. It had some relation to swine fever.

Though confirmation of the largely increased range of the Poulsen System for night transmission was thus forthcoming, the distance bridged being 2,100 miles, this was not held to be sufficient to justify the assumption that it could be adapted to operate by daylight over this range. At this time, there was also a fixed idea that long ranges of communication were much more easily obtained in the Pacific than elsewhere. The Federal Company expressed themselves as satisfied that, with the higher-powered transmitters which they had under construction, they would have no difficulty in maintaining day time communication. So far as the writer recollects, the power supplied to the arc transmitter at Honolulu was about 30 kW. as compared with very many times this amount for the proposed Spark transmitters. The receiver used in the trials was of the slipping contact type. The signals heard in the telephone had no musical tone, but might be described as a brushing sound, not difficult to read, but rather liable to be drowned at times by atmospheric noises, these latter being strongly in evidence.

By far the most important development shown by the Federal Company on this occasion, however, was an incipient form of the three-electrode thermionic valve connected up to give amplification of received signals. This was successfully demonstrated on signals received from one of the nearer land stations of the Company and the writer at once recognized its import. He was informed that the device was due to Dr. De Forest. The president (Mr. Beach Thompson) and officials of the Company extended every assistance and facility to the British delegates, and special mention should be made in this connexion of Mr. Elwell and Mr. Veeder.

It will be gathered that the writer was favourably impressed with the potentialities and value of the Poulsen method and was specially alive to the advantages to be expected in the future by the adoption of systems which did not unduly monopolize the ether and permitted the operation of a larger number of individual long-range communications than was likely to be possible with any spark system —a view which did not seem to carry much weight in the ultimate decision arrived at.

The rest of the story is a matter of Committees and of political ends to be served; it is also a matter of general knowledge. There is sometimes a suspicion that Committees do not always arrive at satisfactory conclusions as in the case of the inquiry into the Titanic disaster in which conflicting evidence was given as to happenings on the Californian, which vessel was practically within hail when the Titanic sent out her first distress signals. So far as the press record of the inquiry is concerned, this conflict of evidence would not seem to have been satisfactorily pursued. Both vessels were, of course, equipped with wireless apparatus, the magnetic detector being used for reception. The latter device required the clock-work train to be running to make it responsive to wireless signals and also required very occasional winding up. Had the Californian responded to the Titanic's S.O.S. or to the rocket signals of distress, the toll of life taken might have been greatly minimized. The factors concerned suggest a line of enquiry which does not seem to have been taken up. There is also the more recent case of the inquiry into the R101 disaster which hardly furnished a convincing conclusion, but which does not concern Wireless history.

A valuable aspect of the development of wireless communication, perhaps ultimately the most valuable, lies in the impetus it gives to the theoretical and physical side of electric wave propagation. The effects concerned touch on the fundamentals of electromagnetic theory and offer a stepping-off point from which the whole range of that theory can be reviewed, and, if necessary, revised. In a large degree, Heaviside built up his treatment of electrical problems on this basis. After Faraday and Maxwell, it is the writer's view that the outstanding personality in advancing the theory of wave transmission is Oliver Heaviside. Faraday's exposition of the active part played by the insulating medium together with his conception of fields of force may be regarded as the starting point in wave transmission theory. Clerk Maxwell developed this view mathematically and precisely, and arrived at the conclusion that electromagnetic effects need not be confined to regions centred about conductors and magnets, but that the activity could be exhibited in purely insulating media and in free space. From this followed his dynamic theory of the electromagnetic field and the electromagnetic theory of light. Heaviside developed the idea still further and showed how the electric current in conducting circuits was a condition derivable from an initial wave propagation through a building-up process which ended at the setting up of a constant magnetic field embraced by the circuit, or, in the case of an open circuit, of a constant electric field held by the conductors. In other words, not only free space effects, but also the ordinary manifestations of current flow and electric charges, were, fundamentally, all wave effects. This, in the writer's view, is the burden underlying Heaviside's theoretical treatment. It deserves almost, if not quite, to rank on a par with Maxwell's theory. On this basis, he expounded the problems of transmission of impulses along wires and cables, and developed his theory of the distortionless circuit for telephone speech, thereby fully confirming and putting to the test the correctness of his basic views. It is not often that a theoretical prediction of this magnitude and complexity stands the test of actual realization. If this feat had emanated from Cambridge, one wonders whether its import would have been more quickly appreciated. Even now it is not clear that his theoretical views are wholly acceptable to the modern academic school else we should hear less of the flow of electricity and drifts of electrons.

Following Heaviside, the writer has always resisted the contention that electrons are pushed along a conductor by the circuit E.M.F., either bodily or in the shape of an electronic drift constituting current. That something in the nature of an electronic or ionic drift may occur where imperfect conductors and electrolytes are concerned, is not denied, but it cannot be an effect conforming to the law of circuitality of electric currents since it must, obviously, cease in the dielectric part of the circuit through which the current flow must pass in its variable stage, especially when that dielectric part is a perfect vacuum and no discharge occurs. Moreover, since the E.M.F. falls to zero as the resistance is decreased to the vanishing point in a closed circuit and yet the current has then grown to a maximum, whilst it has also contracted to an indefinitely thin " skin " on the surface, it surely becomes illogical to assume that a flow or motion of any kind along the conductor is other than a convenient mathematical assumption. The fallacy seems to lie in the assumption that there can be reality in a " flow of electricity."

At first sight, it may appear that there are insuperable difficulties in applying Heaviside's views to the explanation of the laws of electric currents in all their aspects, but it will be found that these difficulties largely disappear as the matter is pursued. As an illustration, let it be assumed that conducting substances are such that a vanishingly small volume has the characteristic of exhibiting dielectric properties at one instant of time followed by non-dielectric (*i.e.,* conducting) properties at another instant and that it is constantly changing as between the two states, there being no intermediate condition between the perfect dielectric and the perfect conductor. When in the former state, it is capable of sustaining an electric field and will therefore permit the entry of a wave; whilst in the latter, it has no facility for holding a field and therefore entirely obstructs its entry. On this view, resistance is simply a function of the average time during which its elements are in the dielectric state. This view may be considered as an amplification of Heaviside's argument that a conductor is a wave obstructor, and is in keeping with the fact that a closed conducting circuit obstructs the escape of associated magnetic energy linked with the circuit, either partially or completely obstructing it according as the circuit has resistance or is perfectly conducting.

Thus the tendency is for conducting obstacles in the path of an advancing wave field, in so far as they constitute partial circuits, to hold or retain the wave so that the electromagnetic energy in some degree subsides into its individual stationary components showing electric and magnetic forces in different phase. In other words, the energy becomes reactive in such manner that the on-going portion of the wave is weakened whilst the on-coming part is strengthened. Telephone engineers will be familiar with a somewhat similar happening in the case of speech transmission along cables which have a strong capacity reactance giving strong side tone or " back tone " into the speaker's ear and resulting in the heaping up of the input energy at the transmitting end, the effect being a function of both capacity and resistance. Similarly in the case of radio, there is a heaping up of energy in the relatively near neighbourhood of a ground transmitter. Within a few wave lengths, the ground resistance prevents the complete wave development; the electric and magnetic fields are not entirely in phase and the energy is correspondingly reactive. At greater distances, the ground resistance becomes less effective due to the spread of the wave over the surface.

In a fully-developed wave, the electric and magnetic components are equal and in phase. In these circumstances, the electromagnetic energy is entirely non-reactive and the direction of propagation is, of course, strictly linear. Any change in the character of the medium encountered by the wave tends to throw the two components out of phase and, to the extent that this occurs, the wave energy becomes reactive; that is, it tends to produce a new wave source. When this occurs, a new resultant direction of propagation may be imposed so that linearity may be departed from. This appears, in fact, to be the case when radiated waves meet with ionization in the upper atmosphere. It is also very markedly the case with any wave energy near the ground, in which case it is quite superfluous to call upon diffraction as an explanation of the facility with which wireless waves bend over hills or ignore the earth's curvature. Poynting's theory unfolds in some measure the manner in which wave energy is transferred through the medium associated with a conducting circuit whatever its shape, though it is necessary to extend this theory somewhat to explain the equality of current flow at all parts of the circuit. Poynting's theory is therefore a theory of wave guidance by conductors and is applicable, in a modified form, to explain wave guidance by the earth's surface.

The facts disclosed by the further development in recent years of short wave transmission, the investigations of Appleton and others, and more especially the full confirmation of " skip distance " effects, justify Sommerfeld's method of treating wireless waves as divisible into ground waves and space waves of which in the past the writer has been prone to be sceptical having perhaps laid undue stress on the guidance principle.

The effects of ionization in the upper regions of the atmosphere is still receiving much attention, short-wave transmission being largely used in the investigations. If, as now appears to be the case, several atmospheric layers are concerned, it seems not unlikely that the investigations may lead to further light being thrown on the still mysterious wireless " strays." In this connexion it would be interesting to ascertain whether, in addition to the known normal potential gradient of the atmosphere, which appears to terminate at about the high cirrus level, there is not another reverse gradient beyond. This would, of course, be in keeping with the division between layers of ionization, since the maintenance of a potential gradient would only be consistent with the relative absence of ionization in that part of the atmosphere. The determination of the point might also have a bearing on the theory of thunderstorms.

Carrier Noise in Short Wave Transmitters

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Abstract.

UNWANTED modulation of the carrier frequency of short wave transmitters may originate in the frequency control stages from ripple on the power supplies. It is shown that the percentage modulation may be vastly increased at single valve frequency multiplier stages operated so as to produce the largest second harmonic content in the anode circuit. It is also shown that the modulation may be eliminated by saturation at the doubler stages. The problem of introducing required modulation for radio telegraphy is then discussed. The effects of unwanted modulation are illustrated by some oscillographic records.

Introduction.

The carrier noise referred to in this note is that due to unwanted modulation of the carrier frequency of short wave transmitters. This is usually produced by variations of the power supplies, but may also occur due to instability in one of the stages of the transmitter or, more infrequently, due to more than one frequency being generated at the crystal oscillator controlling the transmitter frequency. The latter sources of noise are not normal and can be avoided by correct adjustment of the transmitter, but, unless care is taken in the design of the equipment, the first cause may lead to a deep modulation which appears as a " hum " on the carrier and, in some instances, may adversely affect the quality of the outgoing signals. Obviously, if the strength of the unwanted modulation on the carrier of a transmitter used for telephony is at all comparable with the strength of the speech modulation, it will sufficiently degrade the circuit to cause the transmission to fall below the commercial level. On the other hand, if the transmitter is used for telegraphy and the hum is pronounced and at a low frequency, broken signals may result.

In telephone transmitters the power supplies to the frequency control stages are commonly derived from D.C. generators and in these cases the hum may be caused by the commutator ripple on the cathode heating or grid bias supply. In telegraph transmitters, while the high tension and grid bias supplies may be from machines or from rectified A.C., the cathodes are often heated from raw A.C. through transformers connected to the A.C. mains and this may introduce a modulation at the frequency of the A.C. supply. The ripple on D.C. generators for short wave transmitters is less than 1 per cent., and the ripple due to A.C. heated cathodes or rectified supplies is usually of the same order or less if normal precautions are taken in the way of earthing the centre point of the cathode heating supply and smoothing the rectified sources. A depth of modulation of the carrier of this order would not be unduly serious, but a large increase in the ripple modulation may be introduced, however, by the method of operating the frequency multiplying stages which raise the frequency of the control oscillator to the required carrier frequency.[1] A similar increase in modulation may be experienced in subsequent amplifier stages operated for high efficiency and the final modulation of the carrier may be complete.

Effect of supply ripple on output.

The modulation of a high frequency wave by variation of the potential of the grid of an amplifier valve with respect to its cathode is shown in Fig. 1

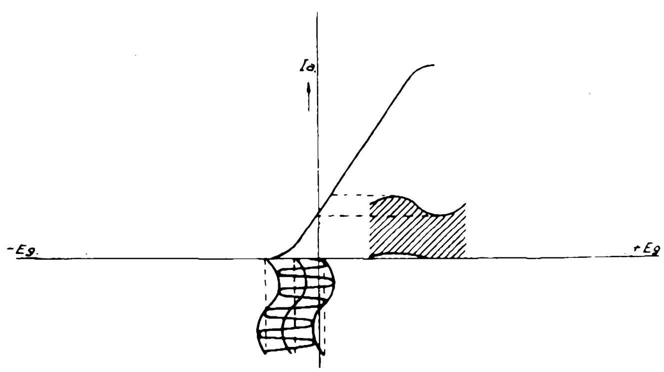

FIG. 1.—MODULATION BY VARIATION OF GRID POTENTIAL.

which may be taken to represent an idealized characteristic curve for, say, the amplifier following the crystal oscillator. The variation of the mean grid-cathode potential may be due to ripple on the grid bias supply or, if raw A.C. is used for cathode heating, to a-symmetrical potentials at the two ends of the cathode with respect to earth. In practice the output from the crystal oscillator is not sufficient to provide a high value of excitation to the grid of the amplifier valve and hence the ripple may be an appreciable percentage of the excitation. The envelope of the anode current will be modulated at the ripple frequency when the valve is operated as

[1] See " Frequency Control Equipment of Post Office Short Wave Transmitters," P.O.E.E. Journal, Vol. 24, p. 228, Oct., 1931.

shown in the diagram and the high frequency output will therefore also be modulated.

Gain of modulation in frequency multiplier stages.

The frequency multiplying stages are normally operated as frequency doublers; and in order to secure good efficiency, the valves are worked with a high value of grid bias potential and a large grid excitation so that anode current flows during only a short part of the complete high-frequency cycle. The operation can best be followed by reference to Fig. **2**, which

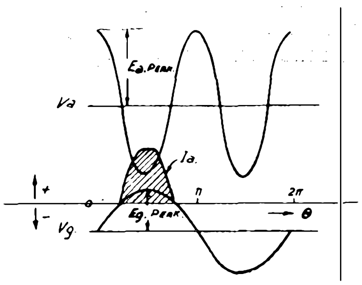

Fig. **2**.—Operation of Frequency Doubler.

shows an excitation $E_g \sin \theta$ superimposed on the negative bias V_g, the anode supply potential being from three to four times the grid bias voltage. Anode current begins to flow a short time before the grid potential becomes positive and continues to flow until the grid voltage falls to a similar value. The alternating component of the anode potential $E_a \cos 2\theta$ falls as I_a increases, a cycle is completed in half the period of a complete grid excitation cycle, and a further cycle is maintained by the oscillatory circuit while the excitation covers its negative half cycle. The total anode current flowing is represented by the shaded area in Fig. **2**, the envelope being flattened at $\theta = \frac{\pi}{2}$ due to the fall in anode voltage. It has been calculated[2] that, for maximum efficiency, this anode current should flow for rather less than a quarter of the excitation cycle; and to achieve this, assuming sinusoidal excitation, the peak value of the grid exciting voltage must be at least three times the voltage required to cover the working part of the valve characteristic. This is brought out more clearly in Fig. **3** where, assuming an idealized valve characteristic and anode current flowing for one quarter of the grid cycle, the peak value of the grid exciting voltage is 3.3 times that part of the voltage required to cover the working part of the characteristic V_c to V_s.

Fig. **4** illustrates two cases of doubler operation in which it is assumed that the excitation is modulated at a low frequency. In A the positive peak value of the modulated voltage applied to the grid just equals the saturation potential V_s while in B the positive peak value is such that when the reverse peak of the modulation cycle occurs the instantaneous potential of the grid is nearly equal to the saturation potential. The envelope of the resultant flow of anode current in the two cases is represented by the shaded areas A and B respectively.

In the case shown at A it will be seen that there will be a gain in modulation approximately in the

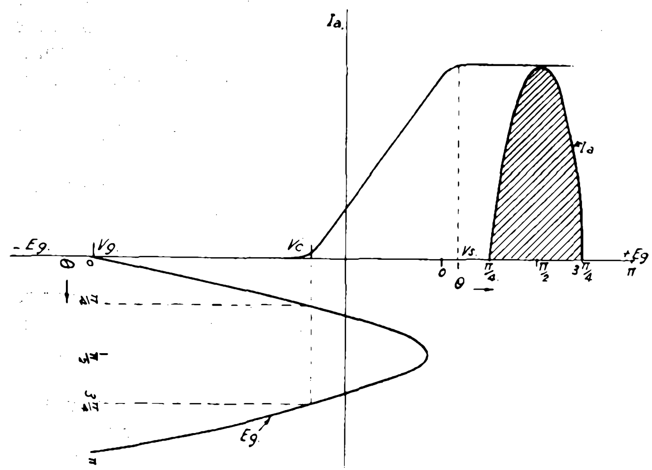

Fig. **3**.—Doubler Operation.

ratio V_sV_g to V_sV_c or about three times. If two similar stages of frequency doubling are used in cascade the gain in modulation percentage will be nine times and with three stages it will be twenty-seven times. (Three stages is the maximum number of doublers commonly used in cascade). It is therefore obvious that a small percentage ripple on the supply can readily be enhanced so that it becomes a prominent noise on the carrier.

In the case shown at B, it will be seen that the modulation percentage is reduced and, indeed, can be largely eliminated by operating the doubler stages—

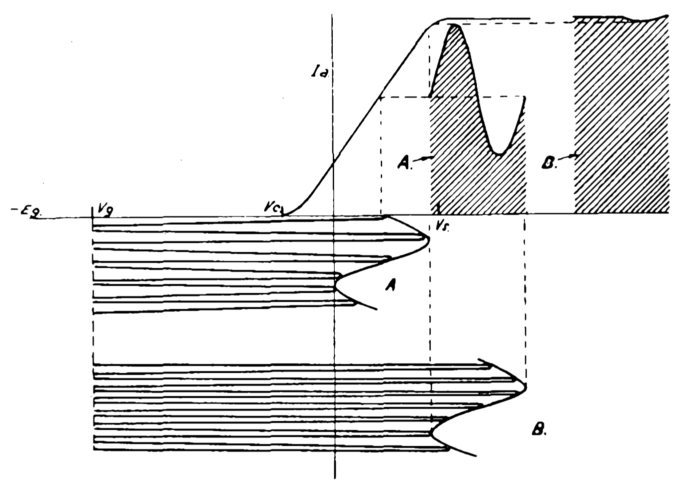

Fig. **4**.—Doubler Operation; Excitation Modulated at Low Frequency.

[2] "Sur le Calcul D'Un Doubleur de Fréquence," B. P. Asseéf. L'Onde Electrique, 10. 109. 36. Jan., 1931.

and particularly the first doubler stage—so that the valve is passing its total emission current for an appreciable portion of each high frequency cycle. This may be brought about by an increase in excitation, a decrease in grid bias, or by a reduction in the saturation value of anode current through lowering the cathode temperature. Any of these alterations will, however, lead to a reduction in efficiency of the stage as a second harmonic generator. For this reason the first method is to be preferred since the anode voltage can possibly be raised to compensate for the decreased output which would otherwise result. The third method, that of lowering the cathode temperature, will normally reduce the output from the frequency control stages to such an extent that the power output from the final stage of the transmitter will be seriously reduced.

Reduction of ripple.

It will be noticed from Fig. 1 that the percentage of unwanted modulation is appreciable at the output of the first amplifier only because the grid excitation to that stage is small. It could be reduced by the choice of a suitable amplifying valve so that the maximum peak value of the grid exciting voltage is sufficient to cause saturation current to flow in the valve. Under this condition, however, the amplifier would be taking considerable grid current and thus loading the crystal oscillator which would be undesirable from the point of view of frequency stability—particularly in telegraph transmitters which are keyed at the grid of the first amplifier stage. Further, at stations where, owing to the heavy intermittent loads thrown on the supply mains by the operation of high power transmitters, the regulation is poor, the cathode temperatures of the frequency multiplier stages may fluctuate and vary the saturation potential. With bright emitting cathodes operating at high efficiency the variation in the saturation potential may be sufficiently critical to make the certain elimination of hum by saturation at the doubler stages very difficult. In telephony transmitters therefore, where even a low percentage carrier hum is inimical, it is usual, in addition to operating the doubler stages into saturation, to attack the problem at the source by fitting additional smoothing circuits in all the supply leads to the frequency control stages of the transmitter. In all transmitters the cathode heating circuits should be designed so that grid bias and high tension return leads can be connected to a point symmetrical with regard to the ends of the filament in order to avoid ripple from the cathode heating supply.

Wanted and unwanted modulation.

In telegraph transmitters the problem of eliminating unwanted modulation is complicated by the practice of intentionally modulating the carrier with a low frequency of the order of 1000 cycles per sec. in order to reduce the effects of selective fading at the receiving station. It is desirable to introduce the intentional modulation at a low power level—thus economising in equipment and running costs. For this reason the 1000 cycle modulation could most readily be injected into the amplifying stage following the crystal oscillator. From the foregoing considerations, however, it will be apparent that any steps taken to eliminate unwanted modulation in the frequency doubling stages will also result in the partial or complete removal of the wanted modulation. It is therefore almost imperative to introduce the intentional modulation after the high frequency multiplication has been completed unless effective steps have been taken to eliminate ripple at the source. Unfortunately the power level is then so high that the oscillator generating the modulation tone must be followed by two stages of amplification,

FIG 5 TELEGRAPH REVERSALS BROKEN BY 50~/SEC. RIPPLE

FIG 6 TELEGRAPH REVERSALS AS IN FIG 5 BUT WITH SATURATED EXCITATION TO DOUBLER STAGES

FIG 7 CARRIER HUM FROM 50~/SEC MAINS

FIG 8 ELISION OF WANTED 1000~/SEC MODULATION BY UNWANTED 50~/SEC RIPPLE

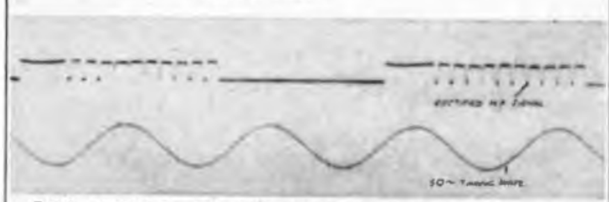

FIG 9 ELISION OF REQUIRED MODULATION FROM TELEGRAPH SIGNALS

and these, as in the crystal amplifier, are again potential sources of unwanted modulation. Precautions are necessary, therefore, in the design of the smoothing equipment to the power supplies of these stages and in their operation so that supply ripple is minimised and is not disproportionately amplified.

In telephone transmitters the necessity for providing a perfectly linear relationship between the applied low frequency modulation and the modulated high frequency output precludes the injection of speech modulation before the high frequency multiplier stages. Hence low frequency amplifiers are again required and care must be taken that these introduce no unwanted modulation.

Oscillograph records of the effects of unwanted modulation.

The effects of unwanted modulation are well illustrated by the accompanying oscillograph records, all of which were taken using a telegraph transmitter which derived all its power supplies from 50-cycle alternating current. Raw A.C. was used for filament heating and the low frequency ripple on the rectified grid and anode supplies did not exceed 2 per cent. Fig. **5** shows the mutilation of dots when the transmitter is sending reversals at a speed nearly equivalent to a 50-cycle/sec square-topped wave. The reversals are slightly out of phase with the 50 cycle/sec supply and it will be noticed that the splits in the dots occur at regular intervals after the commencement of a dot and increase in depth as the split comes into phase with the negative peak of the 50 cycle wave. This suggests that the excitation is beyond saturation for a definite time after the incidence of a " mark " and then falls below saturation and allows the 50-cycle modulation to take effect. The transient effect at " mark " is probably due to poor regulation at the rectifiers supplying the keying bias. On increasing the excitation to the doubler stages good signals are obtained as shown in Fig. **6**.

Hum on the carrier is shown in Fig. **7**, which is a record of the carrier wave taken simultaneously from a monitoring rectifier and a battery-fed receiver with a separate heterodyne oscillator.

The elimination of the wanted modulation at the frequency of the unwanted modulation is shown in Fig. **8**, which is record of a carrier modulated at 1000 cycles/sec (the modulation being introduced before the doubler stages) taken simultaneously from the rectifier and the beating oscillator receiver.

Fig. **9** shows the removal of required modulation from telegraph signals and serves to illustrate how critical the effect is inasmuch as the transient effect at mark is shown and the absence of elision at the end of the second signal is pronounced.

Conclusion.

Carrier hum is increased by doubler circuits adjusted to operate at good efficiency and may limit the commercial effectiveness of the transmitter. In telephone transmitters, where the carrier hum must be at a very low level, it is best to eliminate the ripple at the source by adequate smoothing arrangements and the use of D.C. supplies wherever possible. In telegraph transmitters A.C. hum may be saturated out at the doubler stages and required modulation applied at their output. The saturation point in bright emitting cathodes of high efficiency is fairly critical and the effect of using valves of higher gain with dull-emitting filaments is being investigated.

Ultra-Short Radio Waves and the Cardiff-Weston-super-Mare Radio Link

F. E. Nancarrow, A.R.C.Sc., A.M.I.E.E., M.I.R.E.

FOR some time past the Radio Section has been carrying out experimental work in connexion with the commercial utilization of radio waves in the region of three to ten metres wave-length, and, as a direct result of this work, it was decided to set up on an experimental basis an ultra-short-wave radio circuit connecting Cardiff and Weston-super-Mare, which could be linked up with the inland telephone network. This circuit was first established on August 27th last and, by co-operation with the Traffic Branch, was brought into experimental service under traffic conditions on the 6th October.

There are two reasons why this region of three to ten metres has a very particular significance. Primarily, because waves of less than ten metres wave-length appear not to be reflected from the ionized upper layers of our atmosphere, thus making reception only possible from the directly propagated wave. Distant communication using wave-lengths above 10 metres, on the contrary, is possible only because of the fact that such waves do suffer reflection from the ionized upper layers. The fact that waves below about 10 metres suffer no reflection has two immediate results; one is that the range of effective propagation is greatly reduced, necessitating an optical path for best results, and the other is that there is no fading of signals. On these wave-lengths, natural atmospherics are entirely absent, so

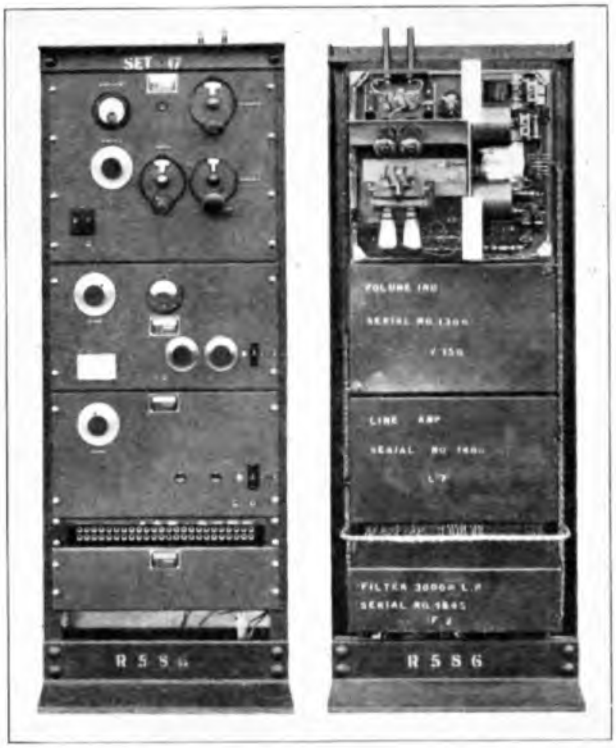

FIG. 1.—EXPERIMENTAL RECEIVER AND MEASUREMENT EQUIPMENT.

that from the point of view of stability and freedom from noise the etheric path is comparable to a good wire circuit. Unfortunately, although nature blesses such circuits by decreeing a freedom from atmospherics, man can neutralize the blessing in the form of disturbance arising from the ignition systems of motor cars and aeroplanes, if such be allowed near the receiving system.

The second factor which contributes to the uniqueness of this range in the frequency spectrum is that it becomes increasingly difficult to cause the normal type of commercial valve to oscillate efficiently at wave-lengths much below three metres. The first factor indicates that the application of these waves is in the field of short distance communication, and the second factor limits the range of waves which can be exploited in this connexion. It was on this basis that the development of apparatus and the study of the conditions attending its commercial application were undertaken.

Short distance communication implies the use of simple apparatus of small power and requiring the minimum of maintenance if it is to compare economically with other tried means of effecting such communication. Any radio telephone channel must, of necessity, take the form of a four-wire circuit and the conditions governing the stability of such circuits are precisely those governing that of the repeatered four-wire physical circuit.

The conditions governing the development of the apparatus were that it must require the minimum of maintenance and be capable of maintaining its adjustment for long intervals. This implies that the overall gain of the four-wire radio circuit must not exceed a figure set by the balance obtained in the combining equipment and, whenever set, must not vary. This in turn imposes the conditions that the output of the receiver should be practically independent of the strength of the incoming field and unaffected by changes in power supplies, and that the frequency drift of the transmitter and variation in tune of the receiver must be kept within small limits.

Much experimental work was done in developing apparatus to meet these conditions and in studying the behaviour of propagation over short distances, and this has been detailed in various official reports. Fig. 1 illustrates the type of experimental receiver as finally used. The upper panel consists of a super-regenerative type of high-frequency receiver, the middle panel is a volume indicator, and the lower panel a low-frequency amplifier. The panel below the jack strip is a 3,000-cycle low pass filter

The super-regenerative receiver is capable of very large gain and is of a type peculiarly suitable for the reception of very high frequencies. The large gain is due to the fact that the decrement of the receiving circuit is made negative for a portion of a cycle

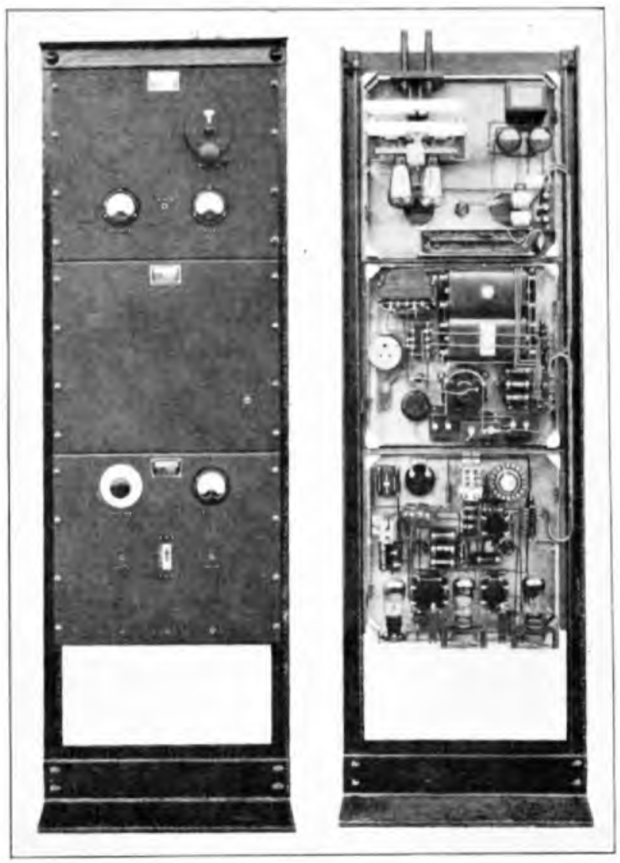

FIG. 2.—EXPERIMENTAL TRANSMITTER.

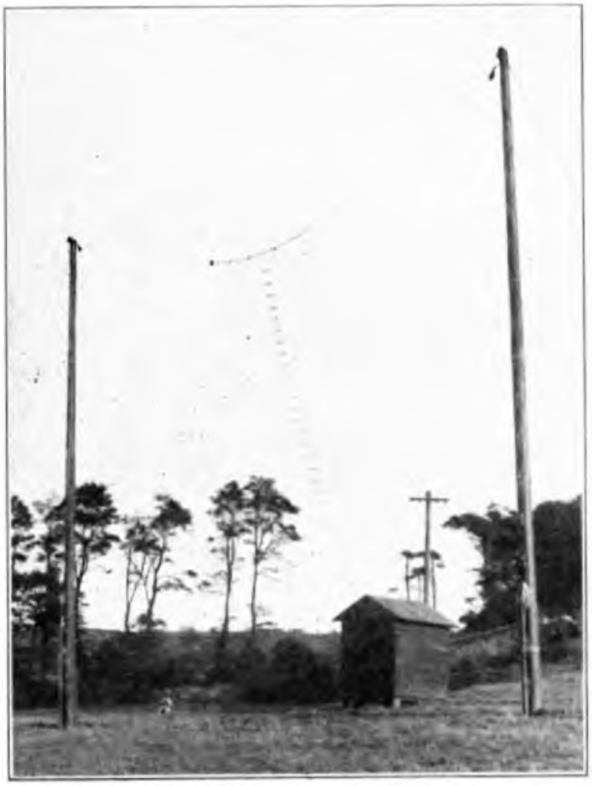

FIG. 3.—TRANSMITTING TERMINAL.

whose frequency is ultra-audible, this cyclic feature being obtained by means of an auxiliary oscillator having this ultra-audible frequency. A special feature in this receiver is that means are incorporated to ensure that the gain is maintained constant and independent of variation in supply voltages.

The experimental transmitter is shown in Fig. 2 and is in general make-up similar to the receiver. The bottom panel contains the low-frequency amplifier, which serves to amplify the incoming speech; the centre panel contains rectifying equipment, since this transmitter was designed to operate directly off the A.C. mains; and the upper panel contains the oscillator and the final modulating valves. The modulation is by the system known as " high-power " and both the oscillating and modulating valves are of the type V.T. 24.

The two terminals seen at the top of the unit serve to connect to the transmission line feeding the antenna.

Fig. 3 gives a picture of the housing of the transmitter and the antenna system of the radio terminal at Hutton, on the Weston-super-Mare side of the circuit. As will have been previously noted, the equipment is quite small and, for experimental purposes, is quite conveniently housed in a battery hut; Fig. 4 shows the transmitter as installed. The antenna is a simple half-wave horizontal oscillator, actually about seven feet of half-inch diameter copper rod, and it can be seen as the thick portion in the centre of the triatic slung between the tops of the 50-foot wooden poles. The transmission line is connected directly to the antenna and is led in through the hut to the terminals on the transmitter. Precautions have to be taken that the impedance of this transmission line does not vary with weather conditions, and, as will be seen by reference to the picture, the line is braced with numerous insulating spacers.

The masts were so arranged as to allow of the use of a beam antenna, but it was found unnecessary with this particular circuit to call on the reserve which such antennæ would have provided.

The radiation from such a simple antenna, however, is directive, having a figure-of-eight form in the horizontal plane, the direction of maximum radiation being at right angles to the length of the antenna. To utilize this property involves, therefore, the correct setting up of the poles. The radiation, besides being directional, is horizontally polarized and thus requires an antenna system at the receiving end capable of responding to horizontally polarized radiation. Both these factors contribute to the privacy of transmission using these wavelengths.

The antenna system for the receiver is similar to that for the transmitter and the receiver is installed in another battery hut, the two huts being spaced some 100 yards apart to minimize cross-talk. A picture, not too clear it is feared, showing the com-

FIG. 4.—TRANSMITTER INSTALLED IN HUT.

plete installation is shown in Fig. 5. The two pairs of wire circuits connecting to the Weston Exchange are brought in on overhead lines and the terminating pole can be seen in Fig. 3. This pole route also allows of the carrying in of the 240 v. A.C. power supply. Cables provide the necessary connexions between the two huts.

FIG. 5.—COMPLETE INSTALLATION.

The equipment at the Cardiff side of the circuit is similar to that already described. The radio terminal at Hutton is some three miles from the Weston Exchange, and that at Lavernock about five miles from the Cardiff Exchange.

The four-wire circuit is completed by physical extensions to the respective exchanges where termination is effected in the normal manner by means of hybrid transformers, and the circuit extended to the A and B Positions. Ringing is provided over the circuit by means of the interrupted 500-cycle equipment normally used for repeatered circuits.

The circuit is maintained in use primarily to allow of the collection of data as regards stability and maintenance, but at the same time it provides a circuit which gives superior service to that possible by the present circuitous land connexion. Records to date indicate that maintenance of such a single circuit would be mainly confined to valve replacement. For instance, for the two months following the 27th August neither the transmitter at Hutton nor the corresponding receiver at Lavernock has required adjustment or attention, the actual operating time during this period being 900 hours. The breaks in the record of the other leg of the circuit have been on account of valve failure and line faults.

The working of this circuit has amply demonstrated its possibilities and it is proposed to construct apparatus of commercial type for multiple channel working. Whilst the circuit has been in operation, some thousand or so measurements have been taken of the relative field strengths at numerous sites in the areas surrounding both terminals and these results have yielded much useful information as to the behaviour of the terrain upon the propagation.

Whilst perhaps it is not the function of an engineer to prophesy, it is definitely his function to look ahead and so organize experimental work that both present needs and future developments are covered. It seems that radio communication over short distances will grow rapidly in the years ahead and that waves not only in the region of three to ten metres but also in the region below one metre will be utilized.

There appear to be two well-marked methods of utilization; one in which a single carrier is used and multiple channel operation achieved by modulation at a different high frequency for each channel; and the other in which a separate carrier is used for each channel, differentiation being obtained by frequency spacing of the carriers. The first method can be likened to a multiple-core cable connexion, in which, if a major fault occurs, all the circuits are out of action, whilst the second is similar to a series of distinct cable connexions.

The main disadvantage of the first method, at least as the art stands at present, is that the major part of the carrier energy is wasted and that the wastage increases with the number of channels. It would appear, however, that communication utilizing oscillators working below one metre and using the Barkhausen-Kurz type of oscillation, would necessarily have to be carried out by this method. In this type of oscillation, the generated frequency depends on the velocity and spatial movement of electrons between the electrodes of the valve and thus upon the construction of the valve itself. It would thus appear to be extremely difficult to predetermine the actual frequency of oscillation or to control it with sufficient accuracy to allow of multiple carrier working.

Operation in the region three to ten metres using normal type valves is not inhibited in this way and it would appear at present more suitable to utilize separate channel working in this range. The number of possible channels is not unlimited, but it would be vastly increased if, in the future, it becomes possible to utilize oscillators controlled on their working frequencies by quartz or tourmaline crystals.

Research

THE following notes give brief details of a number of the investigations that have been completed or have been in progress during the past three months.

TELEGRAPHS.

Provision of Sub-Audio Telegraph Circuit on Channel Islands Telephone Cable. Trials of working between London and Jersey with a repeater at Exeter have now been undertaken. Successful duplex Teleprinter working was established and the circuit was handed over for traffic trials on Monday, 5th September. The traffic trials are still proceeding and it is understood that very satisfactory results are being secured.

Joint investigation with the Telegraph Section of Anglo-German cables with a view to establishment of Teleprinter working. These tests were carried out following a request for co-operation from the German Government. It was found that, whilst taking distortion measurements, kicks of as high as 80% were recorded. The main causes of this distortion were considered to be (*a*) Duplex balance error, (*b*) Sending end crossfire, (*c*) Receiving end crossfire, (*d*) External causes such as earth currents, power induction, etc., and (*e*) Characteristic distortion due to transmission over the cable.

Tests proved that the major part of the signal distortion arose from receiving end crossfire. The Research Section designed a network, which when inserted at Emden and North Walsham reduced the receiving end crossfire to 15% to 25% of what it was previously.

Due to a fault in the cable, and in order to permit the German Administration to make up certain apparatus, the work has been temporarily suspended, but will be resumed later when more detailed experiments will be carried out.

TELEPHONE LINES TRANSMISSION, REPEATER AND CARRIER WORKING.

Precision Heterodyne Oscillator. The development and testing of a working model of this oscillator is now nearly complete and it appears clear that its use should be considered by the Department as an alternative to other oscillators. Although intended for laboratory or other similar use, its cost—of the order of £150 to £200—is considerably less than that of present repeater station oscillators.

This oscillator has been simplified materially by the application of a novel metal rectifier circuit operating in shunt across any suitable terminals. This circuit, applicable to any oscillator or valve device, corrects to the extent of nearly 10 db. the even harmonic content introduced in a non-push-pull valve system.

Portable Trunk Line Transmission Testing Set. The two models made by the Research Section have been usefully employed for investigating transmission complaints. Draft specification data have been forwarded to the Lines Section in connexion with the bulk supply of these sets by contractors.

TELEPHONE APPARATUS TRANSMISSION.

Noise at Telephone Booths at Charing Cross District Railway Station. Some measurements of the noise at the open telephone booths at the above station have been made and test calls made. One of the telephones (Tele. No. 164) is fitted with Siemens 3-winding anti-side-tone coil. Tests have been made of the relative side tone with this coil and with Telephones No. 162 as fitted in the remaining booths. The noise is so great (65 to 90 units) that even if no side tone were present the articulation would be reduced by 50%. It can be shown, therefore, that, although the 3-winding coil is definitely better than the transformer 35A, under these severe noise conditions telephony is not satisfactory.

Effective Transmission. The apparatus for the investigation into the various factors concerned in determining the "effective transmission" over a telephone circuit by means of observations of the number of repetitions required in a given conversation time has been installed at the Denman Street P.B.X. and observations are in progress. A considerable time, however, will be required before sufficient data has been collected to enable any conclusions to be drawn. At present the comparison is confined to the old and new type telephones.

SIGNALLING EQUIPMENT.

Reduction of Resistance of Relays and use of Ballast Resistance in the Stone Transmission Bridge in 50 volt Automatic Telephone Exchanges. A considerable economy in local line cost with the same standard of sending efficiency or, alternatively, an improved sending efficiency with the same local line cost, would be effected by reducing the resistance of the transmission bridge relays to 50 + 50 ohms and including ballast resistances to maintain the feeding current constant at approximately 100 mA irrespective of the local line resistance. The transmission bridges for Final Selectors and First Code Selectors incorporating these new features have been developed and examined from the following aspects :—

(*a*) Impedance and Impedance Unbalance.
(*b*) Heating under faulty line conditions.
(*c*) Life of Ballast Resistances.
(*d*) Gain in Transmission efficiency.
(*e*) Clicks during the setting up and clearing down of a connexion.

A specification for the Ballast Resistances has been prepared.

Valve Circuit for Detecting Distortion of Impulses, for use with Auto-Routiners. This is an improvement on the present method in use for the detection of impulse distortion introduced by repeaters and similar apparatus. The method consists of stepping a selector mechanism which is adjusted so that it will not operate with impulses which differ a little in timing from the normal. The principle of the new method is to charge two condensers through a high resistance, one with six standard impulses and the other with six of the impulses to be tested. The condensers are then connected in series so that their voltages are opposed and the resulting difference applied to the grid of a valve. This voltage will control the current through two relays in the anode circuit, and these relays will or will not operate, depending upon the difference of the charge on the two condensers. This valve scheme works entirely on the 50-volt exchange battery and is ready for a practical trial on an automatic routiner.

Demand Working on Trunks. The voice frequency signalling system developed for this purpose and referred to in the Journal for October has now reached the stage at which a commercial trial may be given.

The system uses two frequencies only, about 1,300 p.p.s. and 1,700 p.p.s., and the signalling is effected by the actions of currents of these frequencies on tuned valve circuits permanently across the lines. The basic principle of the system lies in the fact that if one or other of the relays working from these valve sets is operated alone some signalling effect is produced, but if both operate together no effect results. Consequently speech, which operates both simultaneously, does not interfere with the signalling.

A full demonstration to the officers of the interested Departments has now been given when the following demonstrations were made :—

(*a*) Manual to Manual Call with full automatic signalling.

(*b*) Dialling-in from a manual to a non-director area.

(*c*) Keysending to a director area with an electrically-operated keysender at the manual exchange.

(*d*) Transfer facility to the manual operator at the automatic exchange.

(*e*) Through signalling *via* two trunk lines in tandem.

(*f*) Keysending to a director area using the four-frequency V.F. equipment at the automatic exchange.

All these demonstrations employed two-frequency signalling.

Details of the manual to manual condition are completed and steps are now in hand for an immediate commercial trial. The manual to automatic conditions will then also be given a commercial trial.

Replacement of Signalling Tones by Speech. At the demonstration referred to in the previous section, the opportunity was taken of showing an arrangement whereby the words " number engaged " or " number unobtainable " were put on the circuit instead of the corresponding tones. A sound film of these words is clamped round a continuously-rotating drum and the equivalent electrical output obtained by means of a photoelectric cell. This output is applied by the usual tone transformer in the standard manner.

The tone of the actual ringing of a bell can also be given instead of the usual ringing tone.

The reproduction was excellent and the adoption of such an arrangement would obviate any difficulty due to the possible confusion of tones.

Interference.

Inductive Interference due to Earth Currents from Cable Systems. In the case of a power cable, the major part of any residual current returns through the sheath so that the earth current is only a small proportion of the total fault or leakage current. Accordingly, induction from a cable is very much less than that from an overhead line. It has recently been shown from a series of field experiments on the C.E.B's Woolwich-Eltham cable that this screening effect of the cable sheath is very large. The methods and apparatus used for the tests on overhead lines at Shap were utilized, and, in addition, measurements were made with short-circuit currents up to 250 amperes in the cable. For the cable configuration in question—two 33 kV. cables in the same trench—the induction was less than 1 per cent. of that from an open line at 2,000 p.p.s. and did not exceed 25 per cent. at $16\frac{2}{3}$ p.p.s. At 50 p.p.s. the figure was about 10%.

The work was carried out in co-operation with the British Electrical and Allied Industries Research Association and the results have been validated by the Commission Mixte Internationale.

Chemical and Physical Investigations.

Coloured Enamel finishes for Hand-Microtelephones. Coloured hand-microtelephones are to be supplied by the Department to subscribers, and specification tests are required which will determine the resistance to wear of the enamel finish and also ascertain whether the colour is fast to sunlight. The method of test adopted for determining the wear resistance is one in which carborundum powder of uniform particle size, carried by an air blast, is made to impinge on the surface. The fastness of the colour is determined by exposure to the light of a quartz tube mercury vapour lamp. Specification limits, based on the results obtained, are suggested for each kind of test.

Specification tests for Synthetic Resin Varnish Paper Boards. Investigation has been made of the following properties, water absorption, bending, tensile, surface and volume resistivity, softening, and dilation; the samples being obtained from a large number of different sources. The results obtained enabled specification limits to be set for the purchase of material for Departmental uses. Other tests, carried out jointly with a firm of manufacturers, have been designed with the object of enabling the Electrical Research Association to recommend one simple test as a criterion of the quality of the material.

Vibration and Shock Tests of Electric Lamps. The Department uses specially constructed lamps in hand-lamps and in situations where ordinary electric lamps give an unduly short life owing to the failure of the filament. Vibration and shock tests carried out in order to discriminate between the lamps supplied by various manufacturers have shown marked differences. These results are being collaborated by a B.S.I. Committee with results obtained by the Admiralty from similar tests.

Notes and Comments

Presentation to Colonel Sir T. F. Purves

ON December 20th, 1932, the beautiful and spacious Goldsmiths' Hall, London, provided a fitting setting for the farewell presentation to Sir Thomas and Lady Purves. Lt.-Col. A. G. Lee occupied the Chair and was supported by Sir Evelyn Murray, Sir Raymond Woods, Major H. Brown, Mr. A. B. Hart, Col. A. S. Angwin, and Mr. H. Sparkes.

Addressing the large audience, Col. Lee briefly reviewed the outstanding features of the developments in Communication Engineering during Col. Sir T. F. Purves' decade of leadership of the Post Office Engineering Department. The Chairman referred particularly to the part taken by Col. Purves in the development of Telephony from a national system to a world-wide international network of communications. It has been necessary to overcome many difficulties between the various nations in attaining this position, and much of the credit for this achievement could be given to Sir Thomas, whose charming personality and dynamic vigour had broken down barriers of national prejudice and mistrust, encouraged scientific research, and fostered the technical development of new methods and systems.

Sir Evelyn Murray, Major Brown, Mr. Hart, Captain Cohen (on behalf of the Staff Engineers and Headquarters Staffs), Mr. Atkinson (on behalf of the Superintending Engineers and Provincial Staffs) and Mr. Shepperd (on behalf of the Clerical Staffs) paid tribute to the regard in which Sir Thomas was held by his Staff. Expressions of esteem and farewell received by letter and telegram from Provincial Districts were read by the Chairman.

On behalf of the Staff, Col. Lee then asked Lady Purves to accept a gold wrist watch and presented Sir Thomas with a roll top desk, filing cabinets, sections of expanding bookcase, a barometer, and a pair of binoculars; and wished Sir Thomas and Lady Purves long life and prosperity in their new sphere.

Sir Thomas, replying, thanked the Staff for their gifts and assured the Chairman that the memories of the last ten years would never fade. Although taking up a fresh career, he was still to be associated with Communication Engineering, but from a commercial rather than a technical aspect. By the same token, he would still be in touch with his old colleagues and the bitterness of parting would be considerably alleviated.

After a hearty vote of thanks to the Wardens of the Goldsmiths' Company in appreciation of their action in lending their Hall for the occasion, the meeting terminated.

Copies of Earlier Volumes of the Journal

The Board of Editors has on hand a number of copies of earlier issues of the Journal. Copies of Vols. 1, 5, 6, 7, 8, 9, 10, 11, 13, 14, 16, 17, 21, 22 (Parts 3 and 4 only), 23, 24 (Parts 2, 3 and 4 only) may be obtained, price 1/- per Part, on application to the Managing Editor.

"Sands, Clays and Minerals"

We have received the September issue of this magazine and find it to be informative and interesting, particularly in its description of the recovery of the rarer metals and stones. The article on "The Modern Roadstone Quarry" and its products has a bearing also on Post Office road works. The magazine is published quarterly by Algernon Lewin Curtis, P.O. Box 61, Chatteris, England, the annual subscription being 5/- per annum.

Errata

The title of Fig. 2 on page 198 of the October issue should read, "Showing the practical value of eliminating side tone completely at the receiving station."

By an oversight, the name of the writer of the article on the "Edinburgh Multi-Exchange Area" on page 246 of the same issue was omitted; it should have been shown as W. V. Ryder.

Colonel Sir Thomas Fortune Purves

THE retirement of Sir Thomas from the position of supreme control of the Post Office Engineering Department takes place after ten years of unparalleled development in the art of Electrical Communications. Side by side with this statement of fact it is equally incontestable that the kindly and gracious personality of the Chief has endeared him to everyone. Not only has he done a great work for his day and generation, but he leaves us, full of honours, with the affectionate regard of every member of the staff who has been fortunate enough to come into personal contact with him. Although it cannot be said that he suffered fools with any great manifestation of gladness, yet he certainly tolerated them with that kindly and broadminded toleration which is one of his outstanding characteristics. He was always willing to listen with patient consideration to views and arguments with which he might not agree and to give full weight to other points of view. Even an adverse decision was robbed of much of its sting by the direct yet kindly manner in which it was communicated. The Chief's actions, due probably to the clarity and accuracy of his thought processes, were always clean cut and implemented by a strong and powerful will. And so it is no wonder that he has always enjoyed the personal regard and the loyalty of every man with whom he has been associated.

In social and friendly intercourse the Chief was a truly delightful man to meet. The brilliance of his after dinner speeches will long be remembered by those who have had the pleasure of hearing them, but after all they merely reflect the essential characteristics of a personality happy in itself and radiating an atmosphere of confidence and good-will. On the Continent the Chief was equally popular—in fact, Sir Thomas was *persona grata* everywhere.

During the Chief's period of office he was called upon to make a decision which determined the future of automatic telephony in this Country. He decided that the Strowger step-by-step system should be adopted, and carrying our minds back to the times in which this decision had to be taken, it will be appreciated how momentous the issue was. It was, in fact, one of the most important and far reaching decisions that any Electrical Engineer has ever been called upon to make and the results have amply justified his action.

Turning now to the career of our Chief, we proceed to a rather more formal statement :—

Colonel Sir Thomas Fortune Purves, Engineer-in-Chief of the British Post Office, retired from the service of the Government at the end of November after slightly more than 43 years' service. He is a native of the Scottish borders; born at Blackadder Mount, Berwickshire, on 31st December, 1871. He entered the Civil Service by open competition in 1889 and was transferred to the Engineering Department of the Post Office in 1892. He became a Technical Officer on the headquarters staff in 1900, Assistant Superintending Engineer in 1905, Staff Engineer in 1907, Assistant Engineer-in-Chief in 1919, and Engineer-in-Chief on 1st June, 1922.

He served during the war as Major in the Royal Engineers and was entrusted with the special duty of studying continuously the adaptation of electrical communication systems to the developing and novel conditions of modern warfare, designing special apparatus and technical equipment for the use of the Signal Units of the armies, and organizing the producing resources of the Post Office and of telegraph and telephone contractors for the supply of such equipment in vast quantities.

He is one of the few British Officers who has the honour of having been mentioned by name in the Government's official history of the War where, in Vol. V., Chapter IV. (page 72) the following reference appears :—

> " Both in providing personnel and stores, and in designing instruments—particularly exchanges, switchboards, test panels and frames, telephone sets and linemen's instruments—to meet the various requirements of trench war-

fare, the General Post Office rendered great and unstinted assistance.

Early in 1915, Colonel T. F. Purves, the head of the Designs Section of the Post Office (later, Sir Thomas Purves, Engineer-in-Chief, General Post Office) visited France at the suggestion of Major General J. Fowler, the Director of Signals, to make a systematic study of war conditions, with a view to replacing the many instruments developed by local ingenuity by standard and improved designs: and henceforward he acted as technical adviser and as liaison officer between the British Expeditionary Force and the General Post Office."

He received a Knighthood in 1929, and in the same year was elected President of the Institution of Electrical Engineers. He has been President of the Institution of Post Office Electrical Engineers since 1922. On retiring from the presidency of the Institution of Electrical Engineers he was appointed Chairman of the Engineering Joint Council, a body which was set up in 1922 by the four principal Engineering Institutions of Great Britain—the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, and the Institution of Naval Architects, in order to govern and co-ordinate the joint action and interests of the British Engineering profession at home and abroad.

Other positions which he has held include :—

Assessor to the Advisory Council of the Department of Scientific and Industrial Research, since 1920; Member of the General Board of the National Physical Laboratory, since 1929; Corresponding Member of the Electrotechnische Verein, since 1929; Chief British delegate at the International Radio Conference, Washington, 1927; Chief British delegate on the standing international Committee on long distance Telephony, since 1923; President of the Robert Burns Club of London, 1931-32. He is well known in electrical engineering circles and as an author on electrical communication-engineering subjects. In that connexion he has presided at many gatherings of historic interest, such as the simultaneous twelve-city meeting of the Institution of Electrical Engineers, to which he delivered his Presidential address in 1929; and a joint meeting of the British and Australian Standards Associations, linked by radio telephony in 1932. He arranged, and took a prominent part in, the joint meeting of the British and American Electrical Engineering Institutions in 1928, on which occasion the two assemblies were linked by radio telephony.

No account, however brief, of his professional and official activities, would be complete without a reference to the important part he played in the development of telephony in its international aspects. It is well-known that this development, since the conclusion of the war, has been phenomenal. It forms, indeed, an interesting chapter in the history of telephony.

The invention of the thermionic valve and other devices resulted in the possibility, on the conclusion of the war, of a European telephone network of dimensions which had never been contemplated in pre-war days. All the elements were favourable for the establishment of an extensive European System, provided that national boundaries could be disregarded. The problem had therefore become a political rather than a technical one.

Monsieur Paul Laffont, Under-Secretary of State of the Posts and Telegraphs of the French Post Office, issued at the beginning of 1923 invitations to Great Britain, Italy, Spain, Belgium and Switzerland to send delegates to a "preliminary" international conference to discuss unification of methods of construction, and maintenance and operation of international telephone circuits and to increase the speed and security of such communications by the establishment of new telephone lines "judiciously constructed and maintained." This was the genesis of the international committee for long-distance telephone communication which subsequently filled such an important role in the development of European and, subsequently, world-wide telephone communications.

It will be observed that this invitation did not include countries which had been at war with the "Allies." In Germany, the attention of its technicians had been devoted, with great success, to the development of devices for the improvement of long-distance telephony. It was evident that, without the collaboration of Germany, the development of a truly international European telephone network would be very incomplete and the proceedings of this "preliminary" conference were, therefore, more or less of a formal nature.

It was at this point that the diplomatic gifts of Sir Thomas Purves proved invaluable. On the occasion of conversations with the Germans, for the purpose of establishing telephone communications between England and Germany, he met, for the first time after the war, representatives of the German Administration on neutral territory at the Hague, in March, 1924, and succeeded in persuading the German Administration to send delegates to the first real *international* telephone conference, which took place in April of that year. To this conference, the Administrations of 18 European countries sent delegates. Since then, conferences of the "C.C.I." (a well-known contraction for the "Comité Consultatif International des Communications Téléphoniques à Grande Distance,") have been held every year. At these conferences problems have been discussed which have arisen in connexion with the unification of telephone lines and plant throughout Europe. While attending all of them as Chief British Delegate, Sir Thomas has purposely abstained from accepting the role of General President, but has been content with fulfilling the functions of vice-president in charge of the main purpose of the Committee—the resolution of purely technical problems. These conferences gave rise on many occasions to thorny questions in connexion with which there was a tendency for the international prestige of the chief countries to dominate purely technical considerations. It was here that the personal qualities of Sir Thomas—his geniality and good-humour calming the nerves of opposing factions—played such an important part.

While upholding the interests of his administration, he always had at heart the interests of international telephony as a whole and these have no national boundaries. The retirement of a figure of the type of Colonel Sir Thomas Purves from these international deliberations will be very seriously felt throughout Europe, where his name and prestige have been for many years synonymous with technical efficiency combined with good manners, good humour, and good comradeship. His place indeed will be extremely difficult to fill.

He has held the position of Engineer-in-Chief to the British Post Office for a longer period than any of his predecessors during the past 50 years, and has been in control of the Engineering Department throughout a time of unparalleled technical progress. At the time of his appointment in 1922, he prophesied that the coming ten years would see many remarkable developments which at that time appeared fantastic,—including full intercommunication between the telephone systems of Great Britain and the United States,—but all of them have been duly accomplished. A brief review of the developments during his period of office appears elsewhere in this issue.

And so, having dealt with the genial personality of the Chief and the honours conferred upon him, this note concludes with our sincere and heartfelt good wishes for the long life, prosperity, and happiness of Sir Thomas and Lady Purves.

T.E.H.

Developments of the Past 10 Years

TEN years ago the telephone trunk system of the Post Office consisted almost entirely of aerial lines, and communication with places abroad was inefficient and was confined to Paris and Brussels and a few towns in their vicinity.

Now, telephone communication *by wire* is maintained with the whole of Europe, except Turkey and Greece, and extends (by cable across the Straits of Dover and Gibraltar) as far as Ceuta in North Africa.

The development of " radio links " in telephony has added the whole of the North American Continent, as well as Australia, New Zealand, South Africa, Buenos Ayres and Egypt, to the intercommunicating systems reached directly from the British Post Office system, while communication at favourable times with Java, Bangkok, Saigon, Morocca and Sardinia can also be obtained *via* radio links under foreign control. Telephone communication with ocean liners at sea is also available, and communication with India only awaits the provision of suitable transmitting and receiving radio stations. It is now possible to communicate by telephone from Great Britain with more than 93% of the telephone subscribers of the world.

In the developments of technique which have led to this result, the British Post Office has played a leading part, and Great Britain has become the switching centre through which Europe and America communicate with each other and with the British Dominions.

The inland trunk system has since the war been practically transformed and a fully developed system has been built in which all main centres are interconnected by a stable system of underground cables equipped with loading coils and telephone repeaters. In the development of underground cable technique, the Post Office has from the beginning held a pioneer place, and it is also foremost in the development still going on. It has contributed towards the development of the telephone repeater (over 5,000 of which it has installed) and such essential recent adjuncts as " electrical filters," " echo-suppressors," etc., were invented by its Engineering Department. It is the only administration which has been able to connect its main commercial centres together by telephone circuits which transmit speech between the trunk terminal points without any overall loss of energy.

Its recently developed system of light gauge " star quad " trunk cables, with simplified repeaters, provides the most economical type of circuit yet devised for inclusion in a " long-distance " trunk network. The copper conductors in those cables weigh 10 lb. per mile, as compared with 300 lb. per mile in the cable laid in 1916 (before repeaters had been devised) between London and Liverpool, which was, at that time, the finest in the world.

The Post Office was also a pioneer in the recent introduction of continuously-loaded, lead-covered, paper-insulated submarine cables, now used for connexion with France, Belgium and Holland, and it has led the way in the application of " superposed " and " carrier channel " systems to those cables.

The Post Office also took a leading part in the establishment, in 1924, of an international technical committee for the co-ordination of telephony in the countries of Europe, and has since been one of the main contributors to the success of that committee, to which the recent remarkable progress of international telephony in Europe has been primarily due.

In 1922 the results of the practical experiments which the Post Office had been making in automatic telephony were comprehensively reviewed and decisions were arrived at regarding the selection and development of systems for installation in London and the provinces. The basic system adopted was one which had been invented in America. Several expert contractors have co-operated in the subsequent development of this system, under the control of the Post Office engineers, who have themselves initiated many notable features of present day practice, including the " grading " of circuit outlets, automatic recording of traffic, automatic routiners for continuously testing the plant, observation services, multiple registration, time registration, key-sending from manual exchanges, etc., as well as vast numbers of circuit plans : they have also designed automatic exchanges for the service of rural communities. The installation of the automatic system in all parts of the country is being actively and successfully pursued, involving the expenditure of about £2,000,000 per annum in new automatic exchange plant, and effecting an appreciable over-all economy, in addition to improving the service.

The outstanding position which the Post Office Engineering Department has achieved in radio telegraphy and telephony is generally understood and admitted. The Rugby telegraph station which can communicate with all our Dominions, and with any properly equipped ship on the seas of the world, is one of the assets of the British Empire, and the same applies to the more recently established services of radio telephony.

The Post Office radio systems include many important devices invented and developed within its own organization; one of these is a directive aerial array more economical, in cost and in space, than any other yet introduced, and another is the unique, and extremely efficient, Transatlantic receiving system installed at Cupar, Fifeshire. The highly successful system of maintaining accurate wave-length by tuning-fork control is also a Post Office invention, and the Post Office has led the way in the development and use of " demountable " valves of high power output.

In the technical equipment of its telegraph system, the Post Office long enjoyed the reputation of holding the leading place. Its Morse system (High speed Wheatstone, duplex and quadruplex circuits) has now been superseded by the development of printing telegraph machines, and it is now introducing a system (invented by its Engineering Department) whereby it will be possible to combine public communication by " teleprinter " with the lines and switchboards of the telephone organization. This development has attracted much interested attention abroad. The whole method of apparatus lay-out and mounting in telegraph instrument rooms has also been redesigned recently on novel lines.

The importance of Research in relation to Communications Engineering need not be stressed, and the Post Office has been fully alive to the necessity of exploring the possibility of applying the discoveries of modern Physical Science to the communications art and to provide the means of studying the general engineering problems which arise from day to day. For these purposes it maintains a well-equipped Engineering Research Station staffed by experts in the many specialized branches of Communication Engineering. In the laboratories investigations have been undertaken which have led to direct and far-reaching improvements in apparatus and systems. The design and development of a cheap and high-efficiency telephone repeater is one example of such work and other investigations that are now taking place promise to do much towards speeding up the signalling operation on Trunk services by the introduction of multi-frequency signalling systems.

Much of the work of the Research Station involves the construction of new and special apparatus and a fully-equipped workshop is maintained in which all work from the purely laboratory stage to the completely finished model for practical trial under working conditions can be constructed.

Other important work carried out in the Research Station is in connexion with the study of materials, and continual search is made for substances of improved mechanical and electrical characteristics which, by incorporation in the plant, can raise the level of performance and lead to longer life or economies in cost.

Electrical contacts are used in millions in modern automatic telephone exchanges and large numbers of investigations have been carried out in which the possibility of replacing the expensive platinum contact with cheaper metals or alloys has been thoroughly explored. As a result of these investigations it has been found that for many circuits silver may be employed and considerable economies effected. Similar investigations with regard to the materials of parts subjected to wear have been carried out with the result that improvements in materials have been introduced and it is now possible to forecast the life of telephone plant with great accuracy.

Another important activity of the Research Station is in connexion with the investigation of causes of trouble or failure of plant and much has been done in the past few years in the development of new methods of studying such questions as the electrolysis of cables and the interference to communication circuits by Power lines. In the latter connexion, extensive field tests have been carried out in many parts of the Country and data collected which will, in future, enable accurate calculation to be made of these effects in a given locality.

In connexion with studies of telephone apparatus transmission it has been necessary to investigate fundamental methods of acoustic measurements and these investigations have become of world-wide reputation.

Mr. J. E. Taylor, M.I.E.E.

The retirement of Mr. J. E. Taylor on 8th November, 1932, marks the loss to the Post Office of another link between the telegraph pioneers whose daily work compelled them to face basic problems and the later generations of engineers who have concentrated on the technical application and further investigation of established principles. Born of Northumbrian stock in 1872 Mr. Taylor was the nephew and nearest living male relative of the late Sir John Taylor, K.C.B., for many years Chief Architect to H.M. Office of Works. Consequent on his father's profession as Clerk of Works on new buildings which led to frequent changes of residence in various parts of the North of England, Taylor had only about five years' attendance at school and, owing to removal to London, he was unable to retain the scholarship he had won at Halifax where he first began to experiment in electricity.

He entered the Central Telegraph Office as a telegraph learner after competition in 1888, and studied at the Telegraphists' School of Science under Mr. (afterwards Sir William) Slingo and Mr. Brooker. Later he became a member of the Telegraphists' Scientific Society and for a number of years attended evening courses mainly at Finsbury Technical College in Physics and Mathematics. In 1891 he was loaned to Holloway Instrument Factory where he was subsequently appointed as Sub-Engineer. He came under the notice of Sir William Preece by reason of proposals he put forward for a modification of the quadruplex system and contributions to the correspondence columns of the "Electrical Review," and was transferred to the Engineer-in-Chief's Office (Room 40) where he assisted in the early trunk line developments, the transfer of the trunk lines from the National Telephone Company, and the development of loaded cables. He was deputed to investigate and report on Marconi's proposals to utilize Hertzian waves for wireless telegraphy when the inventor first came to England. He assisted in the early trials and at the inventor's request accompanied him to Italy for demonstrations in Rome. Thereafter he was actively engaged for many years in various investigations and trials of wireless appliances in the Engineering Department, in the course of which he collaborated with S. A. Pollock in a long series of experiments between Holyhead and Howth. As First Class Staff Engineer he had charge of the first Wireless Section in the Engineer-in-Chief's Office. He was the author of numerous contributions to the technical press including reviews of works on Wireless Telegraphy and Telephone Engineering generally. He made a special study of the work of Oliver Heaviside and read papers on wireless and kindred matters before the Royal Society, the Institution of Electrical Engineers, the Royal Society of Arts, and the Institution of Post Office Electrical Engineers. For about seven years Mr. Taylor was Examiner in Telephony for the City and Guilds of London Institute and was a member of the original Board of Editors of this Journal. His services were lost to Headquarters during periods when he was Assistant Superintending Engineer in London and Cambridge and from 1921 until his retirement he held with distinction the position of Superintending Engineer in the South Midland District.

The writer looks back for over 30 years, in the earlier and later parts of which he was closely associated with Mr. Taylor and experienced the attraction of his charming personality. Brimful of ideas, in discussion a good listener, always possessing a reserve of knowledge, a wise counsellor, Mr. Taylor was one of the most highly skilled investigators produced by the British Post Office. In the field Mr. Taylor was ever applying theory to practical ends. As Superintending Engineer he was kindly and considerate in his aim to secure the highest technical efficiency. The high esteem in which he was held was exhibited clearly at the large gathering in his honour at Reading on 8th November. The writer feels that all who worked with Taylor will join in wishing him many happy years in which to pursue the problems in electricity and physics which have been so near to his heart throughout a long and eventful career.

E.G.

District Notes

London Engineering District

GROWTH OF TELEPHONE SYSTEM.

Direct Exchange Lines	455,199
Telephone Stations	762,652

Increase during Quarter: 1,279 exchange lines and 2,958 stations.

MILEAGE STATISTICS.

During the three months ended 30th September, 1932, the following changes occurred:—

Telephone Exchange. Nett increase in overhead and underground respectively of 1,072 and 54,042 miles.

Telephone Trunks. Nett increase in overhead and underground respectively of 3 and 2,235 miles.

Telegraphs. Nett decrease in overhead and underground respectively of 104 and 303 miles.

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

Telephone Exchange	3,485,896
Trunks	189,938
Telegraphs	44,378
Spare Wires	151,994

Mayfair Building

FARM STREET.

E. J. Markby.

Introduction.

Mayfair Building, as it is officially called, stands in the heart of London's most wealthy residential district. The locality around the building abounds in historical interest. Edward I. granted the privilege, to the inmates of the Leper Hospital, of holding Annual Fairs during the month of May in a field which once existed a few yards south of Farm Street, hence the name of Mayfair. The Domesday Book mentions the locality as the Manor of Neyte, a farm which was given to Geoffrey de Mandeville by William the Conqueror.

The building is designed to harmonize with the surrounding property and is located between the famous Farm Street R.C. Church and a public house. The ground on which the public house stands is the property of the Crown and is required for ultimate extension of the Exchange building. Fig. 1, the view from Mount Street Gardens, shows the French doors and balconies which give the structure a pleasing appearance. A cable tunnel of approximately 66 yards has been constructed between Mount Street and the Exchange Cable Chamber. As the gardens were originally a burial ground, it was necessary to obtain Parliamentary sanction before the work could be carried out.

Fig. 1.—Mayfair Building.

The building has six storeys with the following allocation of floors:—

- Basement. Batteries, cable chamber, heating apparatus, and a 6,000 volt static sub station owned by the Supply Authorities.
- Ground. Power plant, stores and engineering staff rooms.
- 1st Floor. Test desks and Mayfair equipment.
- 2nd Floor. Regent and common equipment.
- 3rd Floor. Grosvenor, Langham, common equipment, ventilating plant and offices.
- 4th Floor. Manual switchroom, and London Telephone Service quarters.

Equipment and Lay-out.

The building at present houses four Automatic Telephone Exchanges of the Director type—MAYfair, REGent, GROsvenor and LANgham, manufactured and installed by the Automatic Electric Company, Limited. Langham will work as a temporary exchange in the Mayfair building, but the equipment is so arranged that when the Langham subscribers are transferred to their permanent exchange it can be re-allocated and graded in as part of the Grosvenor Unit.

The present and ultimate capacities of the units are:—

		Present.	Ultimate.
MAYfair	...	8800	10,600
REGent	...	7000	10,400
GROsvenor	...	2800	10,150
LANgham	...	3400	—

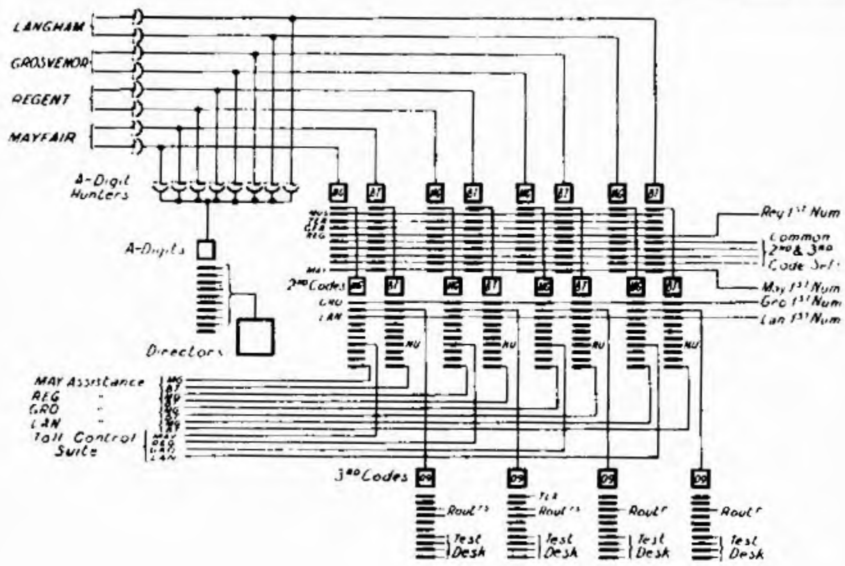

FIG. 2.—TRUNKING DIAGRAM.

FIG. 3.—TYPICAL GRADING.

The equipment is of the Post Office standard type. Similar equipment has already been the subject of an article in this Journal.[1] The equipment and layout are, however, unique inasmuch as any apparatus which could be made common to the four exchanges has been so arranged. Each exchange has its own Uniselectors, 1st Code Selectors, "C.O." Level, Second Code Selectors, "C.00" Third Code Selectors, Numerical Selectors and Final Selectors. The banks of the 1st Code Selectors are cabled out to a common 1st Code Trunk Distributing Frame where

[1] "Acorn Exchange," by B. Houghton Brown. P.O.E.E. Journal, Vol. 24, Parts 1, 2, and 3.

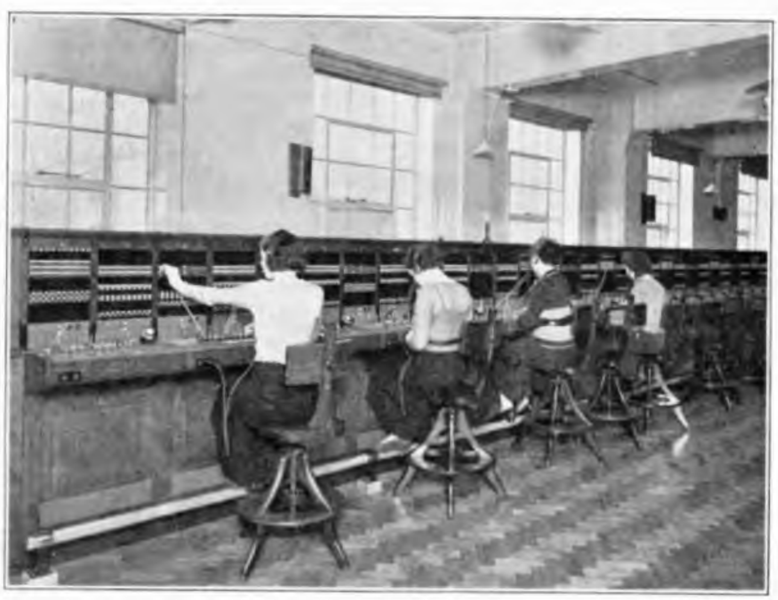

FIG. 4.—TOLL CONTROL SUITE.

FIG. 5.—GENERAL VIEW, MAYFAIR FLOOR.

all Levels, except "0," are graded into a common group of Second Code Selectors or Junctions. The A-Digit Hunters are treated in a similar manner and graded into a common group of A-Digit Selectors which are served by a common group of Directors. Fig. **2** shows, in skeleton, the trunking diagram.

Although a group of switches may be common as a whole, several early choice switches in the group are individual to one of the exchanges. Fig. **3** shows a typical grading.

As previously stated each exchange has its own "C.O." Level, Second Code Selectors, Ordinary and Barred Trunk, in order that the Traffic Staff may deal with assistance and TOLl Calls on a separate exchange basis. Thus, in the manual switchroom, there are three assistance suites—Mayfair, Regent, and Grosvenor and Langham combined. There is also a Toll Control Suite, Fig. **4**, to deal with calls outgoing from the Mayfair building to Toll and a suite of five keysending B-positions working on a straightforward junction basis to deal with calls incoming from Toll and nearby manual exchanges scheduled for replacement by automatic equipment in the near future.

Junctions outgoing to automatic and manual exchanges are worked in common groups, hence there is a common group of C.C.I. repeaters and coders.

Incoming junctions must, of course, work on a separate exchange basis, but there is no reason why the junction relay-sets, in the incoming manual junctions, should not be grouped and served by a common group of senders and voice frequency relay-sets. This has been accomplished. The outgoing sides of the junction relay-sets are connected, *via* a Common Junction I.D.F., to 1st Numerical Selectors in the exchange they serve.

The whole of the incoming and outgoing traffic passes through the junction I.D.F., which also serves as a jumpering field for miscellaneous circuits. Three other I.D.F's are provided for cross-connecting subscribers' main frame and final selector banks to uniselectors on each of the three 10,000 line units.

Each exchange has its own 1st Numerical, 2nd Numerical and Final Selectors. In the design of the Final Selector Numbering and Grouping Scheme, several large Private Branch Exchanges such as Messrs. Selfridge & Co., Ltd., with 110 lines, had to be accommodated as well as other subscribers in the same hundred group. The difficulty could have been overcome by changing the subscribers' numbers, but as this was not thought advisable, 3rd Numerical Selectors were introduced to serve "over 20" P.B.X. Final Selectors, as well as "10 Line" Final Selectors—a new type of switch consisting of a relay group and uniselector giving the same facilities as one level and rotary action of an ordinary 2-motion 2-10 P.B.X. Final Selector.

Fig. **5** shows a wing of the 1st floor. In the foreground will be noticed racks of "over 20"

FIG. 6.—DIRECTORS.

Fig. 7.—Mayfair and Junction M.D.F.

P.B.X. Final Selectors equipped with Vertical Banks in connexion with the re-search feature. Behind these racks are the numerical selectors serving the Mayfair unit. The Power Distribution Bars can also be seen between the top of the racks and the ventilating duct. On the second suite of racks the Power Distribution Fuse Box for this and the first suite will be noticed. A duplicate unconnected fuse is provided in each box for quick replacement should a distribution fuse blow.

Fig. **6** shows a close-up view of five Directors, one half of a standard 4′ 6″ open type rack. There are 46 of these racks.

Routiners have been provided for practically every type of switch and where necessary, owing to the large amount of equipment, they have been provided in duplicate.

The power plant, common to the four exchanges, consists of four 10,000 ampere hour 50 volt Secondary Cells each with an ultimate capacity of 12,470 ampere hours. Charging is effected by means of three motor-generator sets, each having an output of 1900 amperes at 57 volts. The Power Board provides for charging two batteries simultaneously, but independently of each other. The ringing current and tones are provided by two direct-coupled power-driven ringers. The usual stand-by battery-driven ringers are also available. One pair of ringers serves the Mayfair equipment whilst the other pair serves the Regent, Grosvenor, Langham and common equipment. The positive and negative power distribution to the three apparatus floors is common and carried by aluminium bars. The joints between the busbar section were made by facing the contact surfaces, applying petroleum jelly and clamping together with mild steel clamps. Some of the joints can be seen in Fig. **6**.

The subscribers and junction cables are fed from the Cable Chamber to the Main Distribution Frames on the 1st and 2nd floors through vertical ducts built into the walls. The Distribution Frames, each of 120 verticals, are situated one immediately above the other, and are provided with pipes in the floor to enable frame to frame jumpering to be carried out.

Fig. **7** shows the Mayfair and junction Main Distribution frame. The lighting beneath the mezzanine platform was temporarily provided to assist transfer operations.

Subscribers and junction testing facilities are provided by a 25 position common suite of Test Desks and equipped for the "ENG." Repair Service.

Fig. **8** is included to convey some idea of the density and quantity of equipment located in the building. The following schedule, will, no doubt, be of interest :—

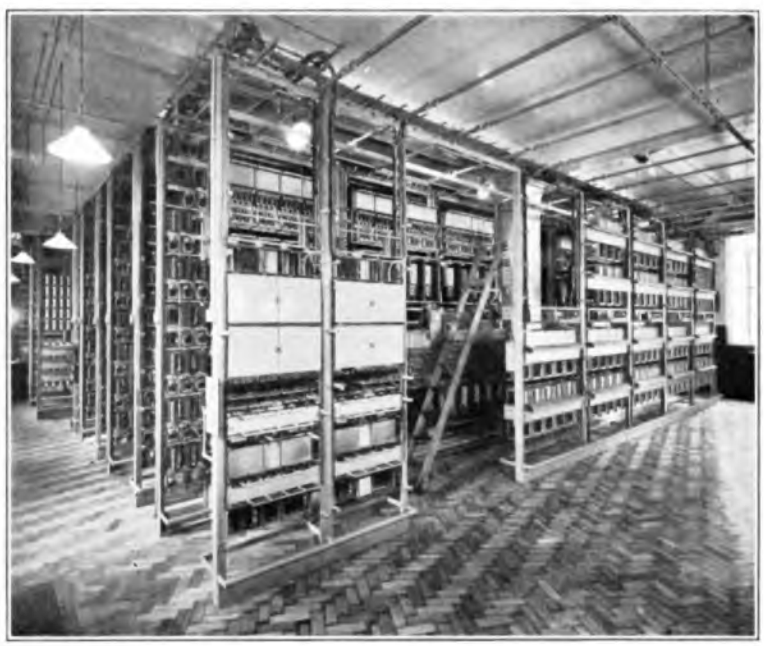

Fig. 8.—General View of Director Racks.

	MAY.	REG.	GRO.	LAN.	Common.	Total
Uniselectors	8300	6160	2480	2680	—	19620
First Code Selectors ...	1234	883	359	327	—	2803
Second Code Selectors	102	164	77	66	1475	
Third Code Selectors ...	10	10	5	6	235	
First Numerical Selectors...	1007	1310	570	669	—	10691
Second Numerical Selectors...	1654	1051	428	485	—	
Third Numerical Selectors...	305	63	—	—	—	
Ordinary Final Selectors...	—	—	—	—	—	
2/10 P.B.X. Final Selectors...	1505	1040	368	536	—	4805
11/20 P.B.X. Final Selectors...	182	210	52	46	—	
21/—P.B.X. Final Selectors...	418	109	101	46	—	
10 Line	84	108	—	—	—	
A-Digit Selectors ...	—	—	—	—	288	288
Directors	—	—	—	—	412	412
C.C.I. Repeaters ...	—	—	—	—	900	900
Coders	—	—	—	—	75	75
Junction relay-sets S.F.J. & V.F. ...	—	—	—	—	1500	1500
Senders	—	—	—	—	90	90
V.F. Relay-Sets ...	—	—	—	—	39	39
"A" Assistance Positions ...	46	29	22		—	97
B. K.S Positions ...	—	—	—		5	5
Toll Control Positions.	—	—	—		26	26

Opening.

The Regent equipment was cut into service on the 5th November, 1932. The official opening took place on the following Tuesday. Visitors were invited to the proceedings which were opened by the Controller, London Telephone Service—Mr. W. H. U. Napier, C.B.E. The Right Hon. Sir H. Kingsley-Wood, M.P., His Majesty's Postmaster-General, addressed the visitors and declared the building open. As a symbol of opening and cutting away the old exchange the Postmaster-General severed the last pair in an opened cable before him with a pair of gold plated pliers presented to him by Sir Alex. Roger, Chairman of the Automatic Electric Company, Limited. Mr. E. Gomersall, O.B.E., M.I.E.E., the Superintending Engineer, explained the engineering features of the telephone equipment. Following the formal opening, visitors were conducted round the building on tours of inspection by the District staff.

The Mayfair unit was brought into use on November 19th, 1932, and it is hoped that the Grosvenor and Langham unit will be "cut over" early next year.

In conclusion, the writer wishes to thank the Automatic Electric Company, Limited, for the photographs shown in Figs. **5**, **7** and **8**.

Scotland East

PORTABLE POWER-DRIVEN PUMP FOR MANHOLE DRAINAGE, ETC.

J. McIntosh.

Small power-driven pumps of the portable type have not enjoyed a very good reputation in the past. A power-driven pump with an improved centrifugal action has, however, been designed by a Glasgow firm, Messrs. Drysdale & Co., and trials of this pump carried out in the Scotland East District indicate that the earlier objections to this class of pump have been overcome and that the plant produced is eminently suitable for emptying water from manholes and other similar situations.

Engineers will appreciate a quick and efficient means of drying out manholes on the occasions of tracing cable faults and the following is a description of the plant.

The set as it appears with the cover removed when ready for use after attaching the hoses, is shown in Fig. 1.

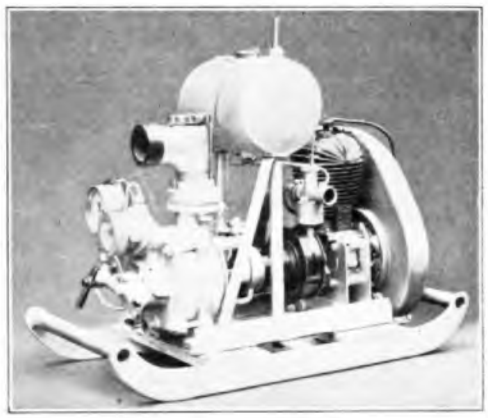

Fig. 1.—Pump ready for Use.

The pump, which is named by the makers "Wee-Mac," has a cast iron casing, bronze impeller, and special steel spindle. The spindle is supported by a ball bearing on the driving side, and on the outer side a grease-lubricated bush is provided.

The pump has a shrouded type impeller with the blade ends and passages so arranged that it can handle air as well as water. Its usefulness in pumping foul air out of manholes may be considered as an important factor, but time has not permitted of its ability in this respect being tried out. Provided that the casing is primarily filled with water, the pump can, by internal circulation of this water, evacuate the suction pipe and thus prime itself. Once primed it operates in a similar manner to a normal centrifugal pump, but with the advantage that, due to the special form of the blades and passages, a greater head is obtained for a given impeller diameter and speed.

The driving unit is an air-cooled, two-stroke, petrol engine, manufactured by the Villiers Engineering Co. It is of very simple construction, having no valves or auxiliary drives. The magneto is incorporated in the flywheel, which also carries a fan for promoting the stream of cooling air.

The lubrication of the engine is on the petroil system, the lubricating oil being mixed with the petrol in the tank in suitable proportions.

The drive to the pump is transmitted by a flexible coupling, the engine half of this coupling being made in the form of a pulley. The pulley serves for starting the engine—a cotton band being wound round, and the free end pulled to rotate the engine.

The pump and engine are mounted on a light mild steel frame provided with tubular lifting handles at either end.

The petrol tank is carried on supports at a suitable height above carburettor level.

On the suction and discharge branches of the pump, screwed hose connexions are fitted, that on the discharge being adjustable so that it can be swung round to any desired angle for the discharge of the water in any suitable direction. The screwed hose connexions are made suitable for attaching the Department's present type of standard hose.

A small vacuum gauge is provided which indicates if the pump is evacuating the suction pipe. The scale is clearly marked and indicates "inches of mercury." As the pump gradually primes, the indicator rises from zero to about 15 to 17 at which point it remains during the period of water discharge. This operation takes less than two minutes.

The set with canopy, but without wheels, *i.e.*, in the condition it would be man-handled, weighs 2 cwts. 1 qr., the wheels and axles adding a further 40 lb.

If the set is being used frequently during one day, the canopy need not always be replaced after each time of use. The set can be quite easily lifted by two men and placed in the motor, as shown in Fig. **3**, and sits very conveniently lengthwise across the floor of a Morris Utility Van, still leaving sufficient accommodation for men to be comfortably seated when the set is loaded.

Wheels and axles are provided to make the set more portable when pumping operations are being carried out at various points along a road. The axles are pushed through the tubular handles, and the wheels fixed on either side by a simple locking device as shown in Fig. **2**.

A sheet steel cover (canopy), through which the rod on top of the petrol tank projects, is provided to enclose the set completely. A padlock is fixed through a hole in the rod, thus providing complete immunity from unauthorized interference at all times when the set must be stored, or left unattended.

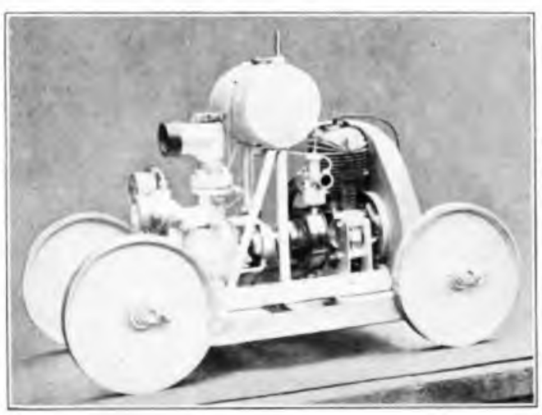

Fig. 2.—Pump with Wheels and Axles in Position.

Fig. 3.—Man-handling the Pump.

The pump is designed to deliver 60/80 gallons of water per minute (3600/4800 gallons per hour) from a level of 12 to 20 feet below the roadway, when running at 2000/2200 r.p.m.

The engine is capable of developing about 2.5 B.H.P. at the above speed and, as the power absorbed by the pump is well below this figure, the set should be capable of the desired output throughout a long period of service.

The graph shown in Fig. **4** illustrates the pump

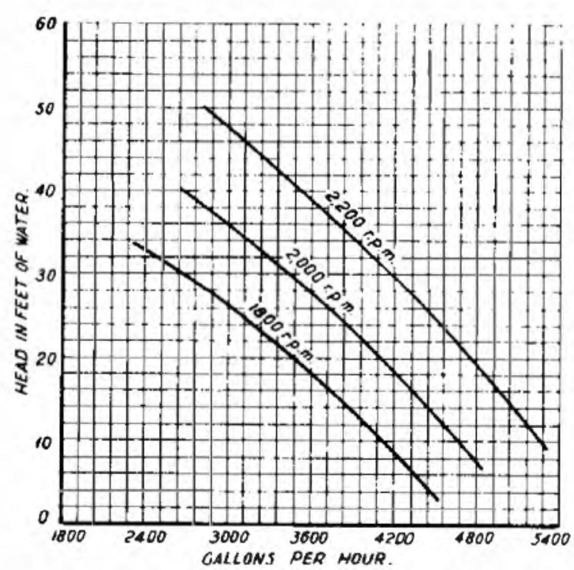

Fig. 4.—Performance Curves.

performance and trials have shown that these results can be easily obtained under all circumstances.

Two men only are required to handle this plant and when once connected it only requires the intermittent attention of one man, generally the driver of the motor vehicle. The small size of the set makes it very suitable for operation on country roads with fast traffic or for busy city streets.

Trials have shown that RCC11 manholes with five feet depth of water can be emptied in about half an hour from the time of the arrival of the men, and the time thus saved in getting at the cables for tracing faults is invaluable in saving time in the restoration of the service.

The tank is capable of holding two gallons and the fuel consumption is aboot 2.5 pints per hour.

Scotland West

MAJOR JOHN CAMERON, O.B.E., M.I.E.E.

A notable retirement took place on the 30th September last when Major John Cameron, O.B.E., Assistant Superintending Engineer, Scotland West District, ceased his official connexion with the Post Office after 46 years' service. The same evening he was honoured at a function held in the Grand Hotel, Glasgow, when colleagues of all grades, and friends from other departments, from all parts of Scotland, met to speed the parting guest. As evidence of the Major's popularity judged both by numbers and representative character the meeting was unique in the local annals of the service. Mr. T. R. Shankland, Secretary of the Post Office Engineering Union, occupied the chair and was supported by Mr. C. Whillis, M.I.E.E., Superintending Engineer, Mr. D. S. Currie, Assistant Postmaster, Major W. R. Roberts, Assistant Surveyor (Scotland West), Messrs. A. E. Coombs and W. Thyne, District Managers, Mr. D. W. Weir, Chief Superintendent (Telegraphs), Lt.-Col. F. L. Robertson, M.C., Royal Corps of Signals, and others.

In handing over a writing bureau and two easy chairs from the engineering staff Mr. Whillis referred to his happy association officially and unofficially with Major Cameron and paid high tribute to him as an able administrator, a highly skilled technician, and the possessor of those human qualities which made him a friend to all.

Mr. D. S. Currie, deputising for Col. F. N. Westbury, who was unable to be present through indisposition, dwelt on the cordial relations existing between the commercial and engineering branches, due in no small measure to Major Cameron, whom he was proud to claim as a fellow highlander.

Lieut.-Colonel Robertson praised the work of Major Cameron in connexion with the Corps of Signals during the war when he was awarded the O.B.E., (Military) for services in France and since the war in organizing the Supplementary Reserve of Signal Officers in Scotland.

Major Roberts and Mr. Weir also contributed warm appreciations. Mr. Weir referred particularly to Major Cameron's early career in the telegraphs and his active participation in the work of the telegraph ex-service men's association. Mr. Weir, on behalf of his branch, handed over a set of steel-shafted golf clubs and expressed the wish that Major and Mrs. Cameron, who had also been associated with the telegraphs, should enjoy a long and happy journey down the " fairway " of life.

Speaking for the rank and file, Mr. Duncan MacDougall, Chairman of the local P.O.E.U., said that never at any previous similar function had he spoken with greater truthfulness than that night in expressing the men's admiration for their chief. In his army career, said Mr. MacDougall, Major Cameron got the salute to which his rank entitled him, but it was of vastly greater significance that, in the moment of official farewell, his relationship with the staff had earned for him in all sincerity the salute—" Pass Friend, all's well."

Mr. W. Lang, captain of the Engineering Department Golf Club, on behalf of the members of the Edinburgh and Glasgow Clubs asked Major Cameron to accept a set of books and at his request the Major presented the " Cameron Cup " to this year's winner, Mr. George Nimmo of the Glasgow Office Staff.

Major Cameron was obviously moved by the warmth of the demonstration and replying thanked one and all for their kindness. He had always endeavoured to do the best for the men under him and notwithstanding these days of change and uncertainty he was firmly of the opinion that if the work were properly organized there would be no need for any discharges of men in the engineering department. Adverting to his early days in the telegraphs he said, it was a striking fact that almost without exception every holder of the post of Engineer-in-Chief had been recruited from the telegraphs and if ever any had been a failure it certainly was not one of those who had come from the telegraphist ranks. He disapproved strongly of the modern policy which barred the door on promotion from the telegraph branch to the engineering department.

G.T.

The Institution of Post Office Electrical Engineers

The rules of the Institution now provide for the retention of membership, by members retiring under the normal operation of the Service regulations at a commuted fee of £2 2s. od. Retired members may continue to borrow books from the Central Library and may attend Centre meetings. They have also the option of receiving the issues of the P.O.E.E. Journal instead of the Printed Papers. Members who desire to take advantage of the arrangement should apply to the Secretary of the Local Centre.

The following applications for Corresponding membership have been approved by the Council :—

A. H. Hackett, Box 263, Gatelfonica de Barranguilla, Colombia.

A. Attard, 3, Strada Forni, Valletta, Malta.

W. S. Bailey, Divisional Engineer's Office, P. & T., Baghdad.

H. T. Millar, Egyptian State Telephones, Sharia Mulika, Nazzi, Egypt.

A. H. Horner, Divisional Engineer's Office, P.M.G's Dept., Rockhampton, Queensland.

K. L. M. McLean, P.O. Box 391, Salisbury, S. Rhodesia.

J. Maloney, Telephone Dept., Kingston, S. Vincent, B.W.1.

C. W. Heyward, District Telegraph Engineer's Office, Auckland, N. Zealand.

Local Centre Notes

South Lancashire

The opening meeting of the Session was held on 3rd October, 1932, at the Geographical Society's Hall, Manchester, when the Chairman, Mr. T. E. Herbert, gave an address on " Progress and Development in the Engineering Department." The results of recent research were outlined and coming developments were foreshadowed. The Chairman referred in appreciative terms to the heavy programme of work which had been carried through by the District staff during the past two years. The meeting concluded with a hearty vote of thanks to the Chairman for a most interesting address.

At the second meeting of the Session held on the 7th November, 1932, Mr. H. W. Powell, the District's Efficiency Engineer, read a paper on " Labour Costs " in which he gave some of the results of his investigations. The author indicated the lines along which reductions of construction and maintenance costs should be sought, and the recent introduction of a crane lorry for erecting poles was illustrated by films loaned by the Engineer-in-Chief. The good discussion which followed was evidence of the interest taken by the staff.

North Midland

There was a good attendance at the opening meeting of the new Session on Monday, October 3rd, when the Chairman, Mr. A. B. Gilbert, presided.

A paper was read by Mr. G. Nixon, of Leicester, on " The Installation of Subscribers' Services on up-to-date lines."

A very interesting account was given of the organization of Advice Note works in the Leicester City area, covering approximately 60 square miles and including the Central Exchange, 4 Satellites and 4 Magneto Exchanges.

The arrangements for daily programmes of work were explained together with the procedure followed in connexion with preliminary advices (C.M.1011) to enable completion to be effected without delay on receipt of the Advice Note.

Interesting details were given with diagrams and sketches showing the difficulties experienced and the ingenuity required in erecting kiosks behind the building line.

Other points dealt with were as follows :—

- Co-ordination of reports and enquiries by the Foreman Fitter at 2 p.m. daily.
- Economic use of Motor Transport.
- Special arrangements for completion of lines at Satellite Exchanges.
- Circulation of W.I. forms.
- Use of covered drop wire with suggestions for extended use at D.P's, etc.

A large number of members took part in the discussion and it was generally agreed that the subject had been dealt with in a very interesting and profitable way.

RETIREMENT OF MR. A. H. BULLOCK.

Mr. A. B. Gilbert in referring to the retirement of the Assistant Superintending Engineer, Mr. A. H. Bullock, expressed his great appreciation of the assistance he had received from Mr. Bullock and stressed the valuable services he had rendered to the Engineering Department. Entering the service as a Telegraphist at Birmingham in September, 1888, Mr. Bullock joined the Engineering Department in 1899 and after service in London and Ireland joined the old Midland District in July, 1911. He was Sectional Engineer at Leicester from that time to December, 1928, when he came to Nottingham as Assistant Superintending Engineer. A resolution expressing the good wishes of the members to Mr. Bullock in his retirement was carried unanimously.

On his retirement on October 31st, Mr. Bullock was presented with a self-contained portable radio set as a token of the good will of the Staff of the North Midland District.

Junior Section Notes

Centres have been established to date with a total membership of approximately 2,200. A table giving the names of the various officers of the Centres is appended in continuation of those which appeared in the July and October issues :—

Reg. No.	Name of Centre.	Number of Members.	Chairman.	Vice-Chairman.	Hon. Secretary.	Hon. Treasurer
38.	Shrewsbury ...	35	F. W. Harvey.	*	P. S. Coss.	H. A. Bishop.
39.	Ipswich	27	O. A. Palmer.	F. L. Nunn.	A. A. Hard.	H. A. Fulcher.
40.	Colchester ...	18	A. Halsey.	C. W. Wilkinson.	A. G. Edwards.	A. G. Edwards
41.	Guildford ...	32	L. A. Tuck.	*	F. V. Padgham.	F. B. Amery.
42.	Norwich ...	34	D. M. Smith.	H. Duffield.	L. Brown.	R. H. Chapman
43.	Cambridge ...	32	T. C. Loveday.	W. E. T. Andrews.	H. Kitteridge.	C. R. Blyth.
44.	Fenny Stratford	12	F. H. Cowley.	R. J. B. Bell.	R. Lawson.	J. R. Sunderwall
45.	Bury St. Edmunds	15	J. Ilett.	S. O. Loates.	E. N. Clark.	A. T. Smith.
46.	Leicester	35	E. R. B. Gardiner.	*	R. W. Dickman.	D. E. H. Stafford
47.	Reading	28	H. J. Ebbage.	*	C. F. Richardson.	S. Powers.

* Not yet appointed.

The Vice-Chairmen at the following Centres have been appointed :—28, Bradford :—H. Brook; 29: Grimsby :—C. A. Hartley; 32, Halifax :—E. Godfrey; 33, Leeds :—C. H. Farrand; 37, Aldershot :—J. D. Hunt.

Reference was made in the October issue of the award of prizes by the Institution for the five best papers written and read by members of the Junior Section. The Institution has now issued the following regulations governing the awards :—

"Annual Award of prizes, of £2 2s. od. each for *five* best papers written by members of and read at meetings of the Junior Section.

Any Junior Section Centre Committee may submit to the Local Centre Committee of the I.P.O.E.E. any two such papers read during the session.

Any Local Centre Committee of the I.P.O. E.E. may submit to a Committee, specially appointed as detailed below, any two such papers which it considers suitable for consideration for the Award.

A special Judging Committee will be appointed each year to judge the papers submitted by the Local Centre Committees of the I.P.O.E.E., and will report to Council its recommendations. The personnel of the Committee will consist of three officers of the Department. The Council will appoint the Chairman who will be empowered to appoint the two other members of the Committee. The Council will endeavour so to distribute the judging annually that each of the I.P.O.E.E. Centres shall in some year or other, provide the personnel of the Judging Committee.

The awards will take the form of cheques for £2 2s. od. and Institution certificates. The Awards for each year will be presented to the prize winners the following session at the first meeting of the respective Local I.P.O.E.E. Centres.

All papers selected by the Local I.P.O.E.E. Centre Committee each year must be forwarded to the Judging Committee not later than the 31st May, which Committee shall forward its report to the Council by not later than 31st August.

The Selection of the Centre of the I.P.O.E.E. to provide the Judging Committee will be made each year, at the March meeting of the Council and suitable notice thereof will be made to all concerned as soon as possible after the meeting.

A paper submitted for the consideration of an award of a Junior Section Prize and also submitted in the Essay Competition shall not be eligible to receive both awards.

The Council reserves the right to refrain from awarding all or any of the Prizes, if in the opinion of the Judging Committee the papers submitted do not attain a sufficiently high standard."

Research Centre

Interest in the Junior Section has steadily increased since the inaugural meeting held in May, 1932. The call for papers hase been responded to in a manner which exceeds the highest expectations and a successful and interesting session has been assured. A representative selection of the papers offered has been made with a view to ensuring that a great variety of subjects is fully dealt with.

Mr. E. H. Wilkinson dealt with an "Outline of Automatic Telephony" at the first meeting of the session held on 11th October, and Mr. J. Hudson-Davies gave a lecture on "Developments in the design of Automatic Selectors" at the second meeting on the 10th November. An "Introduction to the Principles of Telephone Transmission," by Messrs. R. G. Mann and J. Queen, formed the subject of the lecture on the 15th December. Considerable interest was shown by the large attendance of members.

Edinburgh Centre

The first meeting was held on the 3rd October, when a paper entitled "Baldock Radio Station" was read by Mr. D. F. Imlach.

A further paper, entitled " Secondary Batteries," was delivered by Mr. G. Macleod on the 7th Nov.

A visit to the Portobello Power Station on the 12th November proved full of interest and much useful information was obtained.

Dundee Centre

A visit was made to the office of the " Dundee Advertiser " on Thursday evening, 20th October, and on the 26th October Mr. W. V. McWalter read a paper on " Voice Frequency Telegraphy."

All the meetings were well attended and the papers evoked good discussions.

Ipswich Centre

The inaugural meeting was held on 21st September, 1932. 27 members were enrolled initially, and this number has since been increased.

The first meeting was held on October 20th, 1932, when Mr. F. T. G. Townsend read a paper entitled " An Elementary Consideration of A.C.," which proved of great interest and evoked much discussion, the author ably replying to the questions put to him.

On November 3rd, 1932, a paper entitled " The Telex Service " was read by Mr. A. A. Hard. Numerous questions were asked, and the ensuing discussion, which was contributed to by several members, proved most interesting. At this meeting opportunity was taken to make a presentation on behalf of the Staff to Mr. R. J. Nunn, Chief Inspector, who recently retired.

Cambridge Centre

The inaugural meeting was held at Petersfield Lodge, Cambridge, on Saturday, October 15th. All classes were well represented and 32 members were enrolled.

Mr. W. M. Osborn, the Sectional Engineer, took the chair for the evening, and Mr. J. Hopkinson, Secretary of the parent body, also attended.

All present were enthusiastic and promises were forthcoming for papers on various subjects.

Owing to pressure of engagements, Mr. Osborn was unable to accept nomination as Chairman.

Southend-on-Sea Centre

The first meeting was held on 24th October, 1932, in the Linemans Room at Marine Automatic Exchange, Southend-on-Sea, at 7.30 p.m. Major Starkey occupied the Chair. Excerpts from the paper by Messrs. Semple and Boocock, on " Cable laying by means of a Mole Drainer " were given by Mr. L. G. Semple, B.Sc. (Eng.), who was in the vicinity on official business. The lecture was illustrated by about 30 lantern slides. There was a very good attendance, and a keen discussion ensued in which a large number of the members took part.

The enthusiasm shown for the movement is so far very encouraging, the membership having increased from a total of 20 at the time of registration, to the present total of 28, with, it is hoped, a prospect of still further increase.

Bury St. Edmunds Centre

The inaugural meeting of the Junior Section was held in the Linemen's Room on 22nd October.

Mr. J. Ilett, Inspector, who had taken a keen interest in the formation of the Centre, presided over a well attended and enthusiastic meeting, and was later unanimously elected Chairman.

Mr. Ilett opened the meeting by explaining the much regretted absence of the Sectional Engineer, Mr. W. M. Osborn, and he then proceeded to explain the objects of the Junior Section.

The election of officers was followed by a call for papers for subsequent meetings, and the support forthcoming in this direction quickly provided an interesting programme for the session.

The following papers have been given to date :— 19-11-32, " Rural Automatic Exchanges," E. N. Clark; 17-12-32, " Wireless Interference," E. Turner.

The Local Branch is comparatively small, comprising only 15 members, but this number and the hope of a further increase in membership is very encouraging from such a small Area.

Book Reviews

" Modern Radio Communication." By J. H. Reyner. Sir Isaac Pitman. 5/- nett.

This manual, although of modest dimensions and reasonable price, outlines the principles underlying nearly all features of modern radio practice. The book commences with a simple exposition of elementary principles, and from these the general theories used in radio communication are built up. The work is essentially non-mathematical and formulæ are usually quoted rather than derived. The majority of useful formulæ are given, however, and several numerical examples involving the use of these are set at the end of the respective chapters.

Naturally, since the book covers a very extensive range, it has been impossible for the author to deal in great detail with any particular subject; and some matters—*e.g.*, valve transmitters—are dismissed rather too briefly. In many cases, however, the author supplements his own remarks on specialized subjects by references to professional papers.

The work is thoroughly up-to-date and descriptions are admirably concise. It should prove of great value to the student of wireless who wishes to develop a general knowledge of the theoretical side of radio work, and will prove particularly illuminating to those whose present experience is confined to practical results. As the text embraces all items covered by the City and Guilds of London Institute syllabi for the Radio Communication papers, the book constitutes a useful text-book for prospective candidates for these examinations.

J.A.G.

Staff Changes.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	From.	To.	Date.
Lee, Col. A. G., O.B.E., M.C. ...	Asst. E.-in-C.	Engineer-in-Chief.	1-12-32
Angwin, Col. A. S., D.S.O., M.C., T.D.	Staff Engr., Radio, E.-in-C.O.	Asst. E.-in-C.	10-12-32
Gill, A. J.	Asst. Staff Engr., E.-in-C.O.	Staff Engr., Radio, E.-in-C.O.	10-12-32
Arundel, D. S.	Exec. Engr., N. Mid. Dist.	Asst. Staff Engr., N. M.	1-11-32
Innes, J.	Exec. Engr., Equip., E.-in-C.O.	Asst. Staff Engr., Equip., E.-in-C.O.	1-12-32
Darke, J.	Exec. Engr., N. Mid. Dist.	Asst. Suptg. Engr., S. Lancs. Dist.	9-11-32
Martin, P. C.	Actg. Exec. Engr., N.E. Dist.	Exec. Engr., N.E. District.	14-11-32
Richardson, T.	Asst. Engr., Scot. E. Dist.	Exec. Engr., Scot. W. District.	1-12-32
Friday, F. W.	Asst. Engr., Lines, E.-in-C.O.	Exec. Engr., Scot. W. District.	18-2-33
Horn, C. O.	Asst. Engr., N. Mid. Dist.	Exec. Engr., N. Mid. District.	14-11-32
Manning, G.	Asst. Engr., S. Wales Dist.	Exec. Engr., N.W. District.	15-1-33
Cook, A. G.	Asst. Engr., S. Mid. Dist.	Exec. Engr., N.W. District.	13-1-33
Hines, R. J.	Asst. Engr., E. District.	Exec. Engr., S.W. District.	6-2-33
Lynn, B.	C.I., Telephones, E.-in-C.O.	Asst. Engr., Teles., E-in-C.O.	24-10-32
Markey, J. M.	C.I., Telephones, E.-in-C.O.	Asst. Engr., Teles., E-in-C.O.	26-10-32
Ind, G. E.	C.I., Testg. Branch, Birmingham.	Asst. Engr., Test., E.-in-C.O.	10-11-32
Pate, H. S.	C.I., Lines, E.-in-C.O.	Asst. Engr., Lines, E.-in-C.O.	To be fixed later.
Smith, S. J.	C.I., Equip., E.-in-C.O.	Asst. Engr., Equip., E.-in-C.O.	25-11-32
Robinson, O. W.	Inspector, E. District.	Asst. Engr., E. District.	To be fixed later.
Smith, V.	Inspector, S. Mid. District.	Asst. Engr., S. Mid. District.	"
Skeete, T. S.	Inspector, N. Mid. District.	Asst. Engr., N. Mid. District.	"
Diack, W. H.	Inspector, Equip., E.-in-C.O.	Asst. Engr., Teles., E.-in-C.O.	25-11-32
Spears, G.	Inspector, Teles., E.in-C.O.	Asst. Engr., Teles., E.-in-C.O.	25-11-32
Wright, J. S.	Inspector, Equip., E.-in-C.O.	Asst. Engr., Teles., E.-in-C.O.	25-11-32
London, T. G.	Rept. Officer, Class II., N. Dist.	C.I., Teleghs., E.-in-C.O.	1-8-32
Blackhall, F. W.	Inspector, E. District.	C.I., E. District.	1-9-32
McNeill, A.	Inspector, Scot. W. District.	C.I., E. District.	27-11-32
Last, S. G.	Inspector, E. District.	C.I., E. District.	31-8-32
Smith, G. W.	Inspector, S.E. District.	C.I., S.E. District.	6-9-32
Matthews, W.	Inspector, S.W. District.	C.I., N.W. District.	27-11-32
Sheppard, R.	Inspector, N. Wales District.	C.I., N. Wales District.	6-9-32
Cameron, C. J.	Inspector, Testing Branch.	C.I., Testing Branch.	10-11-32
Channon, C. G.	S.W. I., Testing Branch.	Inspector, Testing Branch.	22-9-32
Greenwood, E.	S.W. I., S. Lancs. District.	Inspector, S. Lancs. District.	18-9-32
Griffiths, G. J.	S.W. I., N. Mid. District.	Inspector, N. Mid. District.	12-10-32
Harbage, H.			11-9-32
Morgetts, A. W.	S.W. I., N. Wales District.	Inspector, N. Wales District.	20-2-32
Tunnicliff, T.			2-9-32
Hasnip, A. G.	S.W. I., N. Mid. District.	Inspector, N. Mid. District.	12-6-32
Williams, J. F.	S.W. II., S. Lancs. District.	Inspector, N. Ire. District.	30-10-32
Lumsden, R. S.	S.W. I., Scot. E. District.	Inspector, Scot. E. District.	1-9-32
Chance, A. H.	S.W. I., E.-in-C.O.	Inspector, E.-in-C.O.	21-5-32
Wheatley, E. K.			4-6-32
Spice, W. H. J.			14-2-32
Abbott, G. A.			14-2-32
Humphrey, E. E.			14-2-32
Knott, H. H. R.			14-2-32
Banks, W. R.			25-6-32
Johnson, S. W. J.			21-11-31
Corkett, R. H.			9-1-32
Barratt, L. W.			2-12-31
Wilkinson, E. H.			1-1-32
Cook, A. E.			3-4-32
Boon, J. W. H.			28-6-32
Seymour, H. G. B.			20-3-32
Myers, T. R.	S.W. II., E.-in-C.O.	Inspector, E.-in-C.O.	26-6-32
Perry, W. H.	S.W. I., S. Wales District.	Inspector, S. Wales District.	
Bird, A. V.	S.W. I., Testing Branch.	Inspector, Testing Branch.	12-11-32
Baird, E.	S.W. I., Scot. W. District.	Inspector, Scot. W. District.	27-11-32
Larner, F. L.	S.W. I., Testing Branch.	Inspector, Testing Branch.	To be fixed later.
Whitehurst, J. F.	Mech.-in-Charge, M. T. Section.	Tech. Asst., M. T. Section.	To be fixed later.
Cadge, E. R.	Mech.-in-Charge, M. T. Section.	Tech. Asst., M. T. Section.	

Deaths.

Name.	Rank.	District.	Date.
Geddes, W.	Inspector.	Scot. E.	3-12-32
Berry, P. W.	"	N.W.	27-11-32
Maltby, D. H.	"	London.	23-10 32

Transfers.

Name.	From.	To.	Date.
McDonald, C. G. A.	Exec. Engr., Leafield Radio.	Exec. Engr., N. Wales District.	3-11-32
Ashdowne, H. A.	Asst. Engr., E.-in-C.O.	Asst. Engr., S.E. District.	5-12-32
Epps, H. F.	Asst. Engr., E.-in-C.O.	Asst. Engr., London District.	19-12-32
Morrill, A. E.	Asst. Engr., London District.	Asst. Engr., E.-in-C.O.	19-12-32
Trussler, H.	Inspector, E.-in-C.O.	Inspector, S.W. District.	1-11-32
Gaunt, G. L.	Inspector, Leafield Radio.	Inspector, Scot. E. District.	
Turtle, G. R.	Inspector, E.-in-C.O.	Egypt (loan).	3-11-32

Retirements.

Name.	Rank.	District.	Date.
Purves, Col. Sir Thomas F. ...	Engineer-in-Chief.	——	30-11-32
Taylor, J. E.	Superintending Engineer.	S. Mid.	8-11-32
Walters, E. H.	Assistant Staff Engineer.	E.-in-C.O.	30-11-32
Bullock, A. H.	Assistant Suptg. Engineer.	N. Mid.	31-10-32
Lockharte, Capt. J.	Executive Engineer.	Scot. W.	30-11-32
Jones, E. P.	Assistant Engineer.	London.	31-12-32
Waller, J.	,, ,,	E.-in-C.O.	31-12-32
Herbert, C. M.	,, ,,	S. Lancs.	31-12-32
Hebden, E. W.	,, ,,	E.-in-C.O.	30-11-32
Marshall, G.	Chief Inspector.	N.	31-12-32
Churchman, J.	,, ,,	London.	31-12-32
Humphreys, E.	,, ,,	London.	30-9-32
Dickenson, H.	,, ,,	S. Mid.	31-12-32
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Turvey, G. H.	,,	London.	31-10-32
Gant, J. S. P.	,,	S. Mid.	25-10-32
Moses, H. J. H.	,,	London.	30-9-32
Robb, A. R.	,,	Scot. E.	22-9-32
Swan, R. J.	,,	E.	16-9-32

CLERICAL GRADES.

Retirements.

Name.	Rank.	District.	Date.
Gill B. J.	Staff Officer.	N. Wales.	8-12-32
Harrop, F. N.	,, ,,	S. Wales.	1-1-33

Promotions.

Name.	From.	To.	Date.
Baldwin, G. V.	Clerical Officer, London District.	Higher Clerical Officer, Lond. Dist.	1-10-32
Smith, A. C.	Higher Clerical Officer, S. Mid. Dist.	Staff Officer, N. Wales Dist.	11-12-32
Jones, J. W.	Higher Clerical Officer, S. Lancs. Dist.	Staff Officer, S. Lancs. Dist.	1-1-33
Thomas, W. R.	Clerical Officer, S. Lancs. Dist.	Higher Clerical Officer, S. Lancs. Dist.	1-1-33

COMMUNICATIONS.

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