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A VOICE FREQUENCY MULTI-CHANNEL TELEGRAPH SYSTEM.

J. M. Owen and J. A. S. Martin.

VOICE Frequency Telegraphy, as the name implies, is a system of Telegraphy worked with alternating currents and at frequencies within the Voice Range. For a number of years the question of telegraph transmission by means of such a system has been considered by telegraph engineers, but until recently no great progress was made.

The great extension of loaded underground cables in this country and the completion of the main underground routes have emphasised the need for some new system of telegraphy which would facilitate successful working of telegraphs and telephones in the same cable.

Although there is a fairly comprehensive telegraph underground network in this country, a considerable number of telegraph circuits are accommodated in the new trunk cables. The question of maintaining the greatest degree of non-interference between the two systems is therefore a matter of the utmost importance. At present the telegraphs are worked on unloaded pairs and the power used, as compared with that on a telephone circuit, is considerable and makes the conditions very exacting.

Further, in the light of present developments it would not appear to the authors to be economical to provide separate unloaded pairs for telegraph purposes except in short cables, as it is now possible to use loaded pairs for multi-channel Voice Frequency working or alternatively for simultaneous telegraph and telephone working.

Under these conditions the cross-talk between the telegraph and telephone circuits will be of the same order of magnitude as that permissible between normal telephone circuits.

At present there are three known methods of working telegraphs on loaded underground conductors, viz.:—

(*a*) Phantom superposed working.

(*b*) Sub-audio frequency or composited working.

(*c*) Voice Frequency working.

(*a*) This system is adapted for use on the phantom of the two side circuits of a telephone quad. It is the same as that normally used in superposed working with the exception that special arrangements by means of smoothing and impulse equalising circuits are made, whereby the telegraph interference in the telephone circuits is reduced or superposed entirely. For long distance working arrangements must be made to bye-pass the D.C. telegraph signals at the telephone repeater stations. This system has its disadvantages, since the telegraph circuit—when loaded phantom circuits are used—is replacing a telephone circuit, and, further, the speed of the telegraph circuit is limited, owing to the use of the various smoothing devices. This system could be employed where magneto signalling is used on the telephone loops.

(*b*) Sub - Audio Frequency working is a system in which high and low pass filters are used. The telegraph and telephone circuits work on the same pair. The low pass filter cuts off all frequencies above 40 cycles in the telegraph circuit (*i.e.*, an equivalent Wheatstone speed of approximately 100 words per minute), and the high pass filter system cannot be employed where magneto signalling is used on the telephone circuit. Arrangements must be made to use, say, 500 cycle ringing.

(*c*) Voice Frequency Multi - Channel telegraphy is a system working on a principle similar to that of a four-wire repeated telephone circuit, and may have six or more channels each way, each of which is capable of working at approximately 100 words per minute.

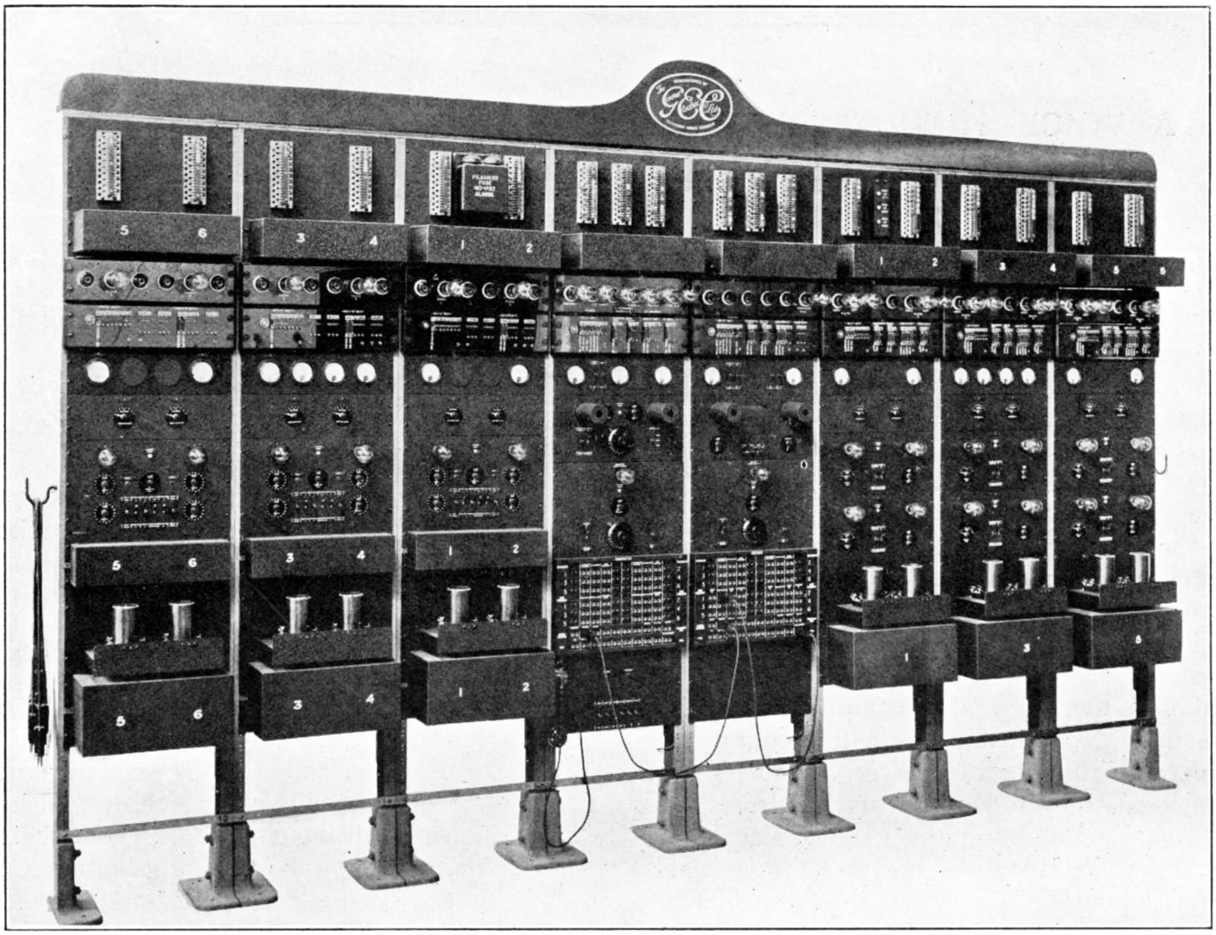

FIG. 1.—FRONT VIEW OF COMPLETE INSTALLATION.

prevents the telegraph signals from entering the telephone circuit. This arrangement gives a working telegraph speed of about 70 words per minute.

This system is certainly economical, but the maximum speed of working is comparatively low. It will, however, be invaluable on minor circuits. This

It follows, therefore, that any telegraph system which does not require a speed in excess of this can be worked on any of the channels. Since this system works on a telephone principle as regards power, etc., it can be readily appreciated that the interference resulting in other circuits will not exceed that normally met with between telephone circuits in a loaded underground cable.

Furthermore, as the ordinary telephone repeaters are used, this system can be worked on any telephone circuit normally adapted for four-wire working. Although this system makes use of a circuit that could be used for telephone purposes it must be remembered that six separate high speed circuits are provided for telegraph working.

It is proposed here to deal with a Voice Frequency System developed by the General Electric Coy. with the co-operation of the Post Office.

General Principles.

In this system oscillations are generated in six oscillating circuits by means of valve controlled tuning forks* at $\omega = 2500$, 4000, 5500, 7000, 8500 and 10,000 respectively. These frequencies are applied to the primary windings of six input transformers through the local contacts of telegraph relays, the secondary windings being joined in series and connected to the grid of a common transmitting amplifying valve (see Fig. **7**). The operation of one or all of the telegraph relays, which are actuated by D.C. signals from the telegraph office, impresses oscillations on the grid of the common transmitting amplifying valve. Amplified oscillations are passed out to line and received at the distant end on the grid of a common receiving amplifying valve. From the anode of this valve, the amplified oscillations are passed to six band-pass filters connected in parallel. After passing through their respective filters the oscillations are again amplified, the amplified signals being rectified by another valve. The rectified signals operate a telegraph relay, signals being passed to the telegraph office by means of a local battery and the tongue of the relay.

The complete installation is made up of eight bays, each 7′ 7½″ high and 1′ 8¼″ wide. Two transmitting channels occupy one bay, the six channels therefore being accommodated on three bays. Similarly, two receiving channels occupy one bay, the six occupying three bays. Separate bays are provided for the common transmitting amplifier and the common receiving amplifier, remaining space on both bays being occupied by subsidiary apparatus which will be described later.

* *Under the patents of Messrs. Eccles and Jordan.*

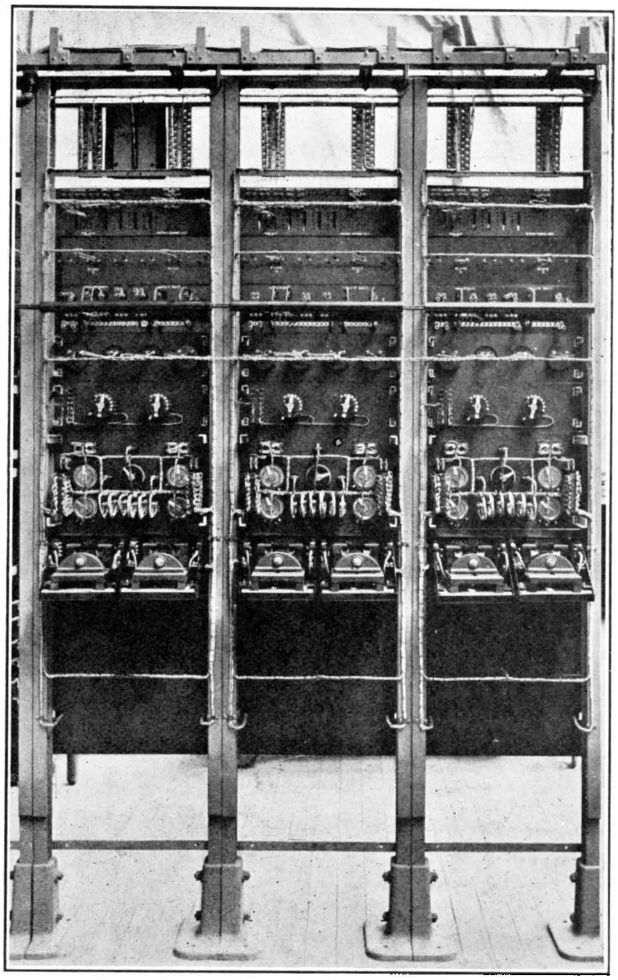

Fig. **2**.—Back view of Transmitting Bays.

The telegraph relays are of the P.O. Standard " B " type fitted with flexible spring tongues. This type of relay prevents chattering at the relay contacts. Contact pillars and springs are fitted to enable the relays to be slipped in and out at will and so permit changes of relay to be made quickly.

Transmitting Bay.—Fig. **2** shows a back view of the three sending bays with the covers removed. Each transmitting bay consists of two transmitting units. The upper part of the bay is occupied by connection strips, resistance spools and alarm relays, battery lamps and battery panel complete with fuse mountings.

The fittings for the telegraph relays, together with subsidiary apparatus are fitted on the lower portion of the bay. See left of Fig. 1. The centre of the bay carries the telegraph galvanometers and rheostats for controlling the current received from the telegraph office. On this panel we also have the valves, together with their battery cut-off and ammeter keys, and two keys by means of which the telegraph relays are operated for test purposes. A filament alarm lamp is fitted above the battery and ammeter keys, and an alarm lamp is fitted above each relay test key as the operation of that key disconnects the telegraph office from the relay. In addition to the telegraph galvanometers, the second bay carries an ammeter and milliammeter serving all transmitting bays, in order to measure filament, anode and fork magnetising currents. The tuning forks are mounted on massive brass bases at the back of the bay. They are insulated mechanically by means of Sorbo rubber, each fork being separately electrically screened. Polarisation is effected by an electromagnet. The anode grid and output coils are the same for all frequencies. The supports for the tuning forks are adjustable, as they have to accommodate forks of different lengths according to the frequency required. The fork unit is connected to the circuit by means of plugs and cords, and is therefore easily detachable for test purposes or for replacements. Fig. 3 shows a tuning fork mounting. The necessary condensers for anode and grid coils are fitted on the shelf which carries the fork mounting.

Control of the magnetising current is effected by a rheostat 0-350 ohms, and by throwing a switch a milliammeter, common to all transmitting bays, is brought into circuit. The valve filaments are heated in series from a 24 volt

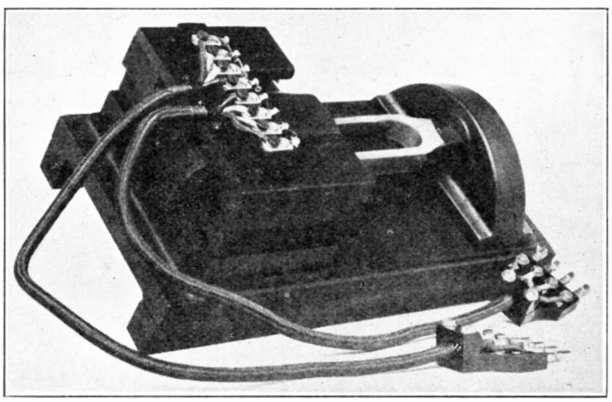

Fig. 3.—Tuning Fork Mounting.

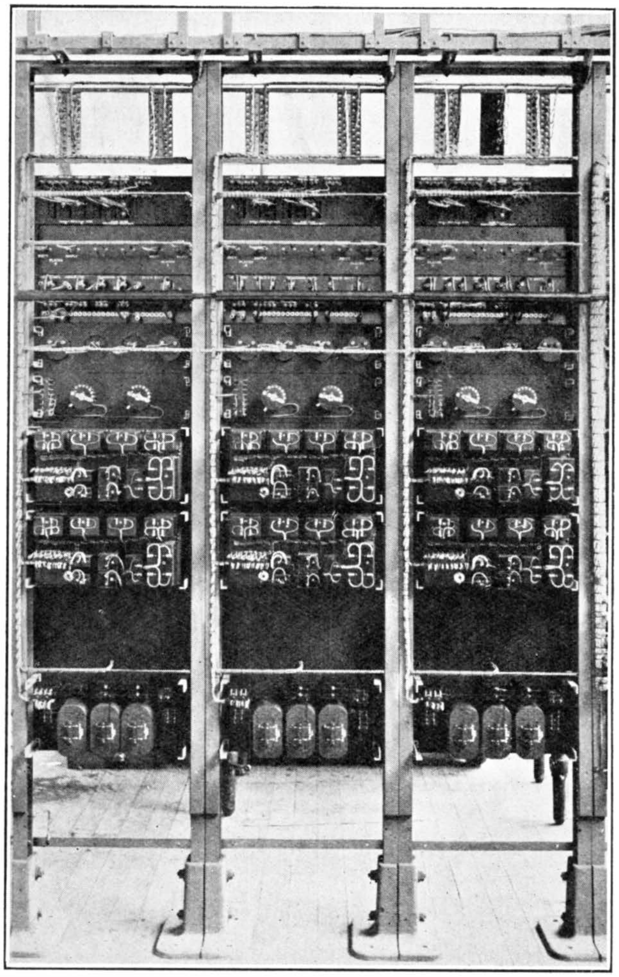

Fig. 4.—Back view of Receiving Bays.

battery; grid priming is derived from the filament circuit, and a 150 volt battery is used for the plate circuits. The valves used are the P.O. Standard V.T. 25 type.

No filters are used at the transmitting end, as the output is sufficiently free from harmonics to permit of transmission direct to the common transmitting amplifier.

Receiving Bay.—Fig. 4 shows a back view with the covers removed.

The receiving bays are similar in design to the transmitting bays, the connection strips, alarm relays, resistance spools, battery resistance lamps, battery panel, telegraph galvanometers and relays occupying similar positions.

Each receiving bay carries two receiving units, each unit consisting of an amplifier and a rectifier, the amplifying valve being an Osram

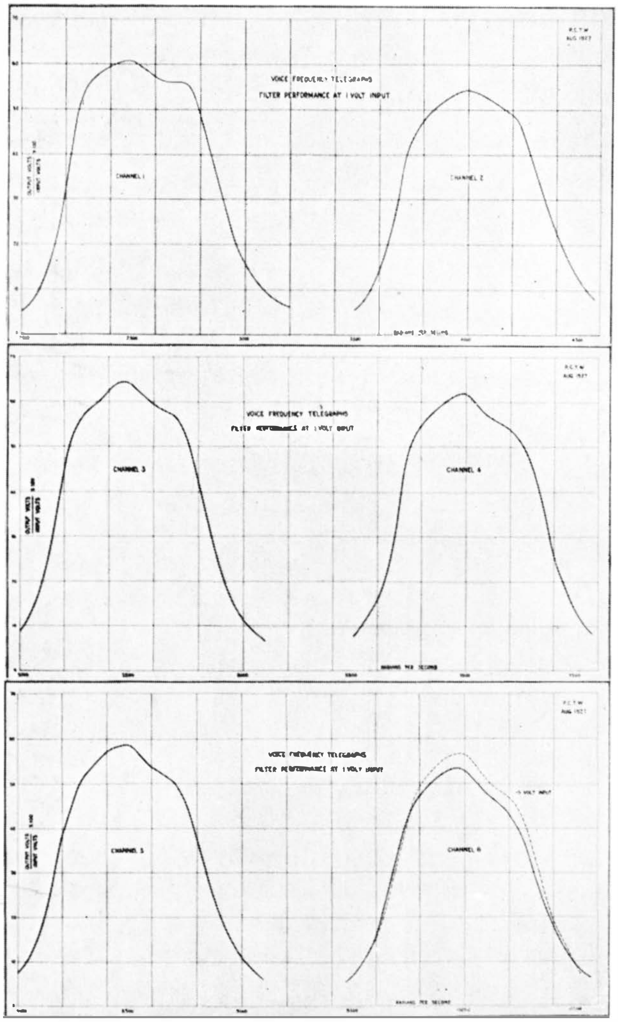

FIG. **5**.—FILTER EFFICIENCY CURVES.

L.S.5B, and the rectifier an Osram L.S.5A. See right of Fig. **1**. The filters for the two circuits are fitted at the bottom of the bay, one at the front and the other at the back. The middle of the bay is occupied by the valves and their respective battery and test keys, filter output controls and filament rheostats. As in the case of the transmitting bay, an ammeter and milliammeter are fitted on the second bay, both instruments being common to all receiving bays. Transformers and other subsidiary apparatus are accommodated on the back of the bays. With the exception of the filter, each receiving unit is identical for all channels. The priming for the rectifying valves is supplied from a special 100 volt grid battery which is carried on the back of the frame. A 24 volt positive and negative earthed battery is used for the locals of the telegraph relays. Apart from these the battery arrangements are similar to those of the transmitting bays.

Efficiency curves for the respective band pass filters are shown in Fig. **5**, from which it will be seen that there is no overlapping of the bands.

Common Amplifier Bays.—Fig. **6** shows a back view of the two common amplifier bays.

Both the common transmitting and receiving amplifiers, together with subsidiary apparatus, occupy separate bays and are placed between the

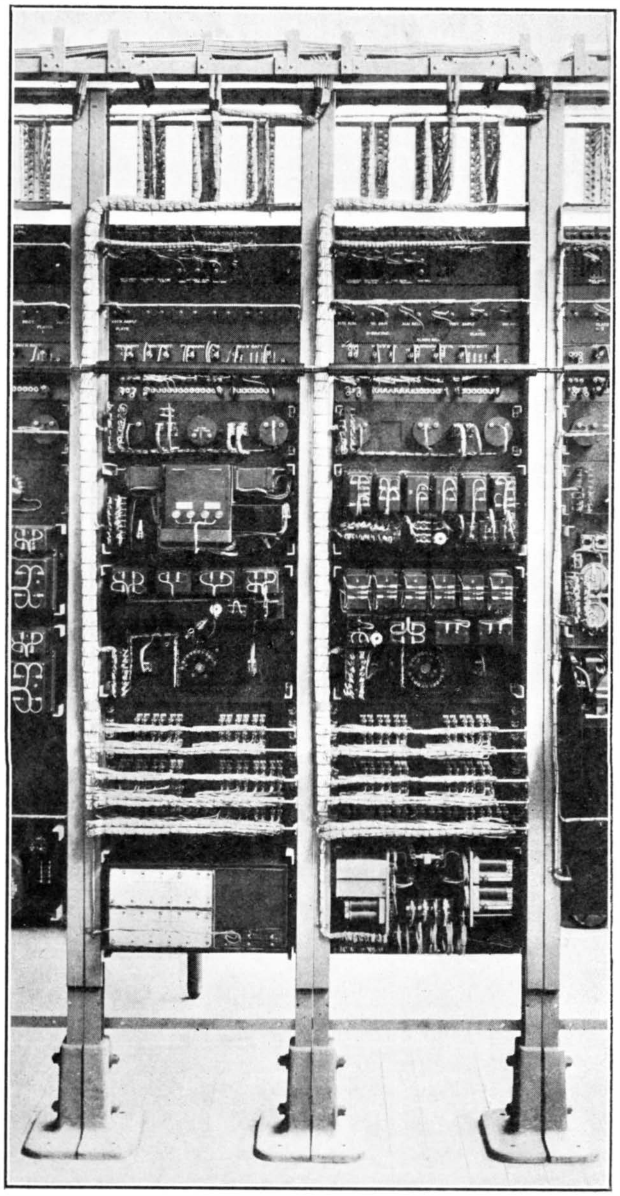

FIG. **6**.—BACK VIEW: COMMON BAYS.

transmitting and receiving bays. As in the case of the other bays, the top is occupied by connection strips, alarm relays battery lamps, battery panel and other minor apparatus. At the bottom of each bay is a series of branching jacks, (See centre bays in Fig. 1) which in conjunction with a valve voltmeter enables tests and measurements to be made at different parts of the circuit and also provides cross-connecting facilities for the various channels. Below the test jack panel on the left hand bay there is a telephone panel which provides for the termination of two speaker lines, and is similar to that normally fitted on two-wire repeater circuits. One of the telephone circuits is for communication between the terminal voice frequency stations, and is worked on the phantom circuit of the " go " and " return " pairs. The other telephone provides communication with the local telegraph office. The centre of the common transmitting bay is occupied by a simple telegraph test set and an ammeter and milliammeter which are common to both bays. On this bay there is also a calibrated two valve testing amplifier, below which is the common transmitting amplifying valve together with battery keys and adjusting apparatus. A graduated artificial cable, calibrated in T.U.'s is provided for adjustment of the power level and to control the output. The centre of the receiving bay is occupied by a battery voltage testing set, and a valve voltmeter (Tinsley pattern) for measuring A.C. voltages. Below these are the common receiving amplifier valve and battery keys together with a filament rheostat. A potentiometer, graduated in T.U.'s, is fitted on this bay to control the input level from line.

Test Amplifier.—The calibrated test amplifier is used in conjunction with a non-reactive artificial cable, to provide a testing circuit enabling transmission gains up to 34 T.U.'s or losses up to 27 T.U.'s to be obtained for testing the operation of the transmitting and receiving circuits.

The gain characteristic of the test amplifier over the frequency range is flat.

The test amplifier can also be used as an end repeater and in the case of a breakdown, if an aerial line is used as a substitute, the installation can be made to function within the limits specified above.

Valve Voltmeter.—The valve voltmeter used is a Tinsley Portable Reflecting Galvanometer 0-5 microamps (resistance approximately 700 ohms), fitted with an 18 v. Osram lamp, and is used in conjunction with two V.T. 25 valves. By means of a key the secondary of the input transformer can be so arranged that the scale can be varied to read 0-1, 0-2 and 0-10 volts.

Telegraph Test Set.—The telegraph test set consists of two keys and a galvanometer and is provided to enable simple tests to be made on the local telegraph lines, between the voice frequency office and the telegraph instrument room. One key provides for sending a marking or spacing current to line *via* the galvanometer. The other key, in one position puts a loop or earth on the line and in the second position sends a current to line through the test galvanometer.

Transmission of a Signal.—This may be followed from Fig. 7 which shows a schematic diagram of the system.

The transmitting frequency is maintained throughout by a valve maintained tuning fork and a definite portion of the output is tapped off by means of the potentiometer (0-350 ohms), the circuit being closed through the primary of the input transformer and the tongue and marking stop of the telegraph relay. A signal from the telegraph office passes through the adjustable resistance (0-250 ohms), galvanometer, line coils of the telegraph relay to earth or back on the " B " line.

When the telegraph relay is operated, the tongue is moved over to the marking contact and so closes the output circuit. The secondary of the input transformer, which is in series with the secondaries of the input transformers associated with the other transmitting units, is connected to the grid of the common transmitting amplifying valve. The anode of this valve is coupled *via* an output transformer to a non-reactive adjustable artificial cable (0-10 T.U.'s), which is connected to the primary of a line transformer. Signals received on the grid of the common transmitting amplifier are amplified and passed to line *via* the adjustable non-reactive artificial cable. It is therefore possible to control the power level at the sending end.

At the receiving end of the line the incoming oscillations are passed to the grid of the common receiving amplifying valve *via* a line transformer, potentiometer calibrated in T.U.'s

(0-10), and an input transformer. From the anode of this valve the amplified oscillations are passed to their respective band filter *via* the secondary of an output transformer in the anode circuit. The six filters are connected in parallel. Across the output end of each filter there is a potentiometer so designed that for each step, one eighth of the filter output can be passed to the receiving unit. After passing through the relative filter the oscillations reach the grid of impulse in the secondary in the reverse direction, and the relay is operated accordingly. The relay is so arranged in the circuit that the impulse generated during the rise of current operates it in the "marking" direction. It follows therefore that the impulse generated during a decrease of current will operate the relay in a "spacing" direction. Signals are passed to the telegraph office from a local battery *via* the relay tongue, galvanometer and an adjustable rheostat. The

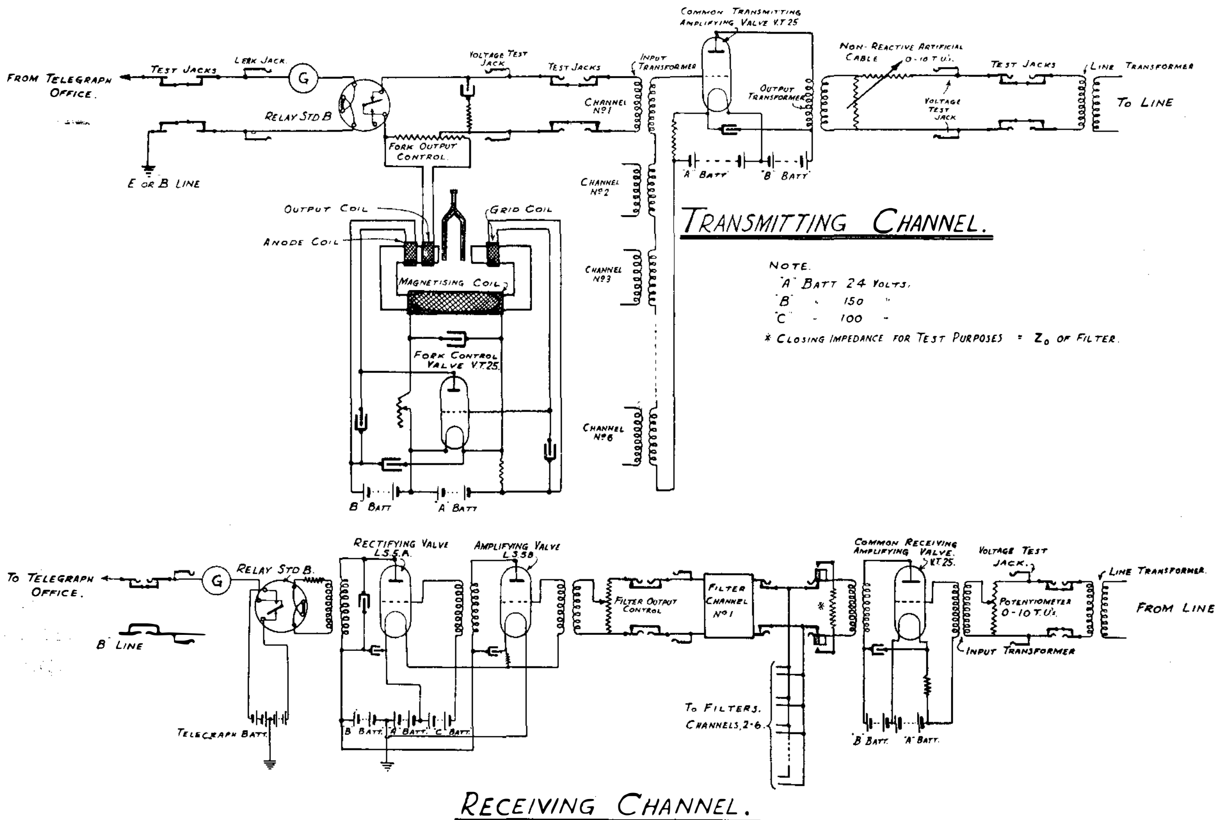

FIG. 7.—SCHEMATIC DIAGRAM OF SYSTEM.

the amplifying valve of the particular receiving unit *via* an input transformer. This valve is transformer-coupled to a rectifying valve, in the anode of which is the primary of a transformer, the secondary being closed by a telegraph relay. A bye-pass condenser is connected across the primary of the transformer in order to pass the A.C. component of the rectified current. Rise of current in the primary of the transformer generates an impulse in the secondary, and the relay, which is normally set neutral, is actuated. Decrease of current in the primary generates an positive and negative voltages for the relay contacts are supplied from an earthed battery.

Speed Trials.—Two complete sets forming the necessary equipment for two ends were made by the General Electric Company and, after satisfactory acceptance tests had been carried out, were installed in the Repeater Room Trunk Exchange, London, and the Telephone Repeater Station, Leeds.

A four-wire circuit was provided with repeaters at London, Fenny Stratford, Derby and Leeds, details of which are given in Tables 1 and 2.

TABLE No. 1.

CIRCUIT DETAILS.

Pairs. Go	Pairs. Return.	Cable.	Type and Loading.	Miles.
103	104	London-Derby.	20lbs. Side Circuits loaded with 78 mH. coils. 2000 yds. spacing.	127.474
45	46	Derby-Leeds.		69.538

TABLE No. 2.

REPEATER SETTINGS.

Circuit.	Trunk Exchange London.			Fenny Stratford.			Derby.			Leeds.		
	Potentio-meter	Equaliser	Gain S.M.	Potentio-meter	Equaliser	Gain S.M.	Potentio-meter	Equaliser	Gain S.M.	Potentio-meter	Equaliser	Gain S.M.
Go	$6/5\frac{1}{3}$	$A_1B_1C_5$	9	8/5	$A_1B_1C_5$	17.2	$11/5\frac{2}{3}$	$A_1B_1C_5$	32.3	$8/4\frac{2}{3}$	$A_1B_1C_5$	18.3
Return.	6/4	$A_2B_3C_{12}$	9	$9/9\frac{2}{3}$	$A_1B_1C_5$	31.5	9/7	$A_1B_1C_5$	26.2	6/6	$A_2B_2C_{11}$	9.

With the circuit so lined up, a zero loop was provided for transmission between London and Leeds and a small loss between Leeds and London.

As the phantom of this circuit was already in use, a temporary two-wire circuit was allocated as a telephone speaker during the trials.

The output of the Voice Frequency sets at London and Leeds was adjusted to 0.2 volts per channel. The several adjustments under these conditions to give a rectified current of approximately 10 m-Amps are shown in Tables 3 and 4.

TABLE No. 3.

VOICE FREQUENCY SETTINGS AT LONDON.

Channel.	Tuning Fork Output Volts.	Volts sent to Home Repeater.	Filter Output Volts.	Filter Output Potentiometer Setting.	Rectified Current Milliamps.
1	0.31	0.2	0.35	5	10
2	0.27	0.2	0.35	6	11
3	0.28	0.2	0.35	5	10.5
4	0.28	0.2	0.32	5	11
5	0.28	0.2	0.34	5	11
6	0.29	0.2	0.32	6	10

Total Volts sent to Home Repeater = 0.48 Volts.
Total Volts received from Home Repeater = 0.32 volts.
Output from receiving master amplifier = 1.56 volts.

TABLE NO. 4.

VOICE FREQUENCY SETTINGS AT LEEDS.

Channel.	Tuning Fork Output Volts.	Volts sent to Home Repeater.	Filter Output Volts.	Filter Output Potentiometer Setting.	Rectified Current Milliamps.
1	0.28	0.2	0.68	5	10.5
2	0.28	0.2	0.52	5	10
3	0.29	0.2	0.61	5	10
4	0.27	0.2	0.60	5	11
5	0.26	0.2	0.59	5	11
6	0.27	0.2	0.53	5	10.5

Total volts sent to Home Repeater = 0.475 volts.
Total volts received from Home Repeater = 0.48 volts.
Output from Receiving Master Amplifier = 2.4 volts.

Settings Common to both ends.

All Filament Currents 0.83 amps.

Fork Magnet Polarising Current 25 milliamps.

Attenuating Network at Sender Output 2 T.U.'s.

Receiving Potentiometer 2 T.U.'s.

Wheatstone trials were first carried out at both ends, using P.O. type Wheatstone Transmitters and Receivers, a shunted condenser of 2μF. and 2000 ohms being connected in series with the coils of each receiver.

Slip was run continuously on each channel for one hour, with all other transmitters running reversals and occasional slip. Good signals were received on each channel at 100 w.p.m.

Trials were next carried out, using Creed Perforators and Printers under the same conditions as before. On each channel "Creed" working was obtained at 100 w.p.m.

The set made by the General Electric Co. and described in this article is the first of its kind to be installed and, with the exception of the Siemens Halske system, which is working between London and Manchester, is the only system of voice frequency multiplex telegraphy at present used in this country.

The possibilities of voice frequency telegraphy are varied, and its applications are numerous, but it is considered that these questions do not come within the scope of the present article. It may be mentioned, however, that it is possible to work a single channel system (on 20 lb. loaded underground conductors) at 300 words per minute, and at the other end of the scale, by closing up the filter bands, a twelve channel system giving about 60-70 words per minute per channel could be used. The first should prove useful where high speed working is required on small gauge underground conductors, whilst the second is essentially suited for start-stop telegraph systems.

In conclusion, the authors would like to thank Colonel T. F. Purves and Mr. S. A. Pollock for permission to use certain information contained in this article, and they are also indebted to Sir W. Noble and Capt. Hannam-Clark, of the General Electric Co., for the loan of photographs and diagrams.

CARRIER CURRENT TELEPHONY.

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I.—Historical.

Under the inaccurate but expressive name of "wired wireless" the system of telephony or telegraphy now described as carrier current working was generally known, though not used commercially, for some years before the war. Immediately after the war rapid developments took place in America, Germany and this country, for very different reasons.

In the U.S.A. there are many long telephone lines on which the value of an extra channel of communcation is sufficient to justify the use of very expensive terminal equipment.

In Germany, for some time after the end of the war there was a serious shortage of copper and an urgent demand for new circuits which could be met only by using the carrier current system on existing aerial lines. The extensive system of underground cables and repeater stations which now covers Germany has replaced practically all these carrier circuits. They were only economical as a means of tiding over a special difficulty.

In this country also it is, in general, more economical to provide the longest circuits by means of cables and repeater stations than by superposing carrier channels on the aerial lines. There are, however, special cases where the traffic does not justify laying a cable or where for some reason the cost of a physical circuit is unusually high. For instance, the cost of a submarine cable between England and the Continent is sufficient to justify very expensive terminal apparatus in order to provide additional circuits by means of carrier working. At the present moment there are 10 carrier telephone circuits working on aerial lines in Great Britain. They vary in length from 60 to 200 miles.

Recently a special low frequency carrier system has been developed for use on continuously loaded paper core submarine cables of the type in use between England and the Continent, and schemes are now in hand for working carrier circuits on other submarine cables. A special type of cable has been designed for multi-channel carrier working over considerable distances.

In France and elsewhere on the Continent carrier working on aerial lines has been introduced with success by the International Standard Electric Corporation (using American sources of inspiration). A carrier circuit has the great advantage that it is comparatively unaffected by induction from power lines. This induction is becoming a serious difficulty on long aerial lines on account of the rapid growth of high voltage power distribution systems, especially on the Continent.

In Germany and America carrier current telephony is being increasingly used for communication over power lines, the telephone system being coupled to the high-voltage wires by means of special condensers, or a wire run for a few spans underneath the power wires.

In America progress has been very rapid.

About 200,000 channel-miles of carrier telephone circuits are working on aerial lines, and in many cases three channels of carrier are worked on one physical circuit in addition to sub-audio telegraphs, etc. A six-channel carrier telephone system is working on a single core submarine cable across the Catalina Channel.* This constitutes the highest development of carrier current telephony, as far as the writer is aware, and has been made possible by the American Telegraph and Telephone Co.'s patented system of " single side band " working.

As regards carrier telegraphy, although it is technically a simpler matter than carrier telephony, no circuits have been tried as no demand has arisen in this country. It has recently been proposed, however, to use carrier telegraphy on several of the cross-channel cables. In America a large number of carrier telegraph circuits are in use.

II.—General Principles.

In a paper read before the I.P.O.E.E. by Taylor and Bradfield† the general principles of carrier current telephony were briefly explained. It is necessary, therefore, only to generalise and extend the information there given as regards recent developments in the art.

The essential difference between carrier current telephony and wireless telephony or broadcasting is in the medium used for transmission. In both cases a carrier current is modulated (*i.e.*, made to vary in amplitude in accordance with speech) at the transmitting end and demodulated or " detected " at the receiving end.

In the case of line transmission, however, the carrier frequency is generally much lower and the well known laws of transmission at audio frequencies apply strictly. The so-called constants of the line must of course be known for the frequency in question. Inductance and capacity do not change appreciably, but in the case of open lines and cable circuits the resistance and leakance increase rapidly in the ordinary carrier frequency range of 7 to 30 kilocycles. Cross-talk, or over-hearing, becomes much more serious than at audio frequencies. In some cases this effect is so pronounced that at certain frequencies the attenuation of a circuit may be doubled or trebled by the absorption of energy through cross-talk to another circuit.

The attenuation of cable circuits at carrier frequencies is much higher than that of aerial circuits, and coil-loaded cables of the type generally used for telephony are out of the question for carrier working.

By using carriers of different frequencies several channels of communication may be superposed on the same physical circuit, and prevented from interfering with each other by the use of filters. Unfortunately, owing to the lower frequencies which must be used, this separation cannot be accomplished by means of simple tuned circuits such as those used in wireless telephony. To explain this, it is necessary to consider in some detail what is involved in a modulated carrier current.

If we send to line a steady A.C. at a frequency of, say, 10 kilocycles and demodulate or " detect " it in the ordinary way, nothing will be heard in the receiver. But if the amplitude of the 10 kilocycle carrier be varied sinusoidally at a frequency of, say, 1000 cycles, a note of this frequency will be heard in the receiver. At first sight it would appear that the line current is simply an A.C., having a constant frequency of 10 kilocycles but a varying amplitude; so that the receiver could be tuned very sharply to 10 kilocycles and be unaffected by another carrier frequency of, say, 10.5 kilocycles. This is a fallacy, as can be shown very simply: Let $A \sin \theta t$ represent the unmodulated carrier whose amplitude is to be varied in accordance with an audio frequency, $\sin \phi t$, between the limits $A(1+k)$ and $A(1-k)$, k being less than 1.

The modulated wave will be:

$$A \sin \theta t\,(1 + k \sin \phi t)$$
$$= A \sin \theta t + Ak \sin \theta \sin \phi t$$
$$= A \sin \theta t - \frac{Ak}{2}\cos(\theta+\phi)t + \frac{Ak}{2}\cos(\theta-\phi)t$$

= carrier + upper side band + lower side band
(carrier + audio) (carrier − audio)

* " *Carrier Current Communication on Submarine Cables,*" *by H. W. Hitchcock. Bell Telephone Laboratories. Reprinted B.222, Nov., 1926.*

† " *Some Experiments on Carrier Current Telephony,*" *by C. A. Taylor and R. Bradfield. I.P.O.E.E. Paper No. 86.*

That is, reverting to the numerical example above, the line carries a frequency of 10 kilocycles and in addition frequencies of 9 kilocycles and 11 kilocycles:—the lower and upper side bands respectively.

Therefore the tuning of the receiver must be broad enough to cover the range from 9 to 11 kilocycles, which is twice the audio frequency. It is beyond the scope of this article to attempt a complete mental picture of what happens when a carrier wave is modulated, but it is essential to realise that amplitude cannot be changed at any finite rate without entailing a change of frequency, and *vice versa*. This change of frequency and amplitude is exactly equivalent, electrically, to the addition of the side bands.

If we take the highest audio frequency required to be transmitted as 2500 cycles, the essential frequencies to be transmitted will occupy a range of 5000 cycles, and the difference between two carrier frequencies to be transmitted on the same line must be somewhat greater than 5000 cycles. It will be evident that the necessary selectivity cannot be obtained so simply as in the case of wireless broadcasting. In practice, band filters are always used to separate the different carriers, and the number of such carriers is very limited.

There are, broadly, two methods of superposing carrier circuits (or channels) on a physical circuit, which may be called the "balanced" and the "grouped" system, respectively. In either case, filters must be provided to separate the audio from the carrier channels, and the latter must be arranged for two-way working in order to be used as commercial telephone circuits.

When the balanced system is used, the same carrier frequency is employed for transmitting in each direction and interaction between the transmitter and receiver at each end of the line is prevented by a differential transformer and line balance, exactly as in the case of audio two-way repeaters.

In the grouped system different frequencies are used in the two directions, and interaction between transmitter and receiver is prevented by filters.

The balanced system has the advantage that it only uses one frequency per channel, and more channels can therefore be worked within the ordinary range of, say, 7 to 30 kilocycles. On the other hand very accurate balancing, or simulation of the line impedance, is necessary and the system is only practicable on comparatively short and uniform lines. The grouped system can be applied to longer lines and uniformity is not so important. But, other things being equal, only half as many channels can be superposed on one physical circuit, as compared with the balanced system. Further, a carrier circuit using the same or different frequencies for the two directions may be divided between two physical circuits, one being used as a "go" and the other as a "return." This is the equivalent of a four-wire telephone circuit.

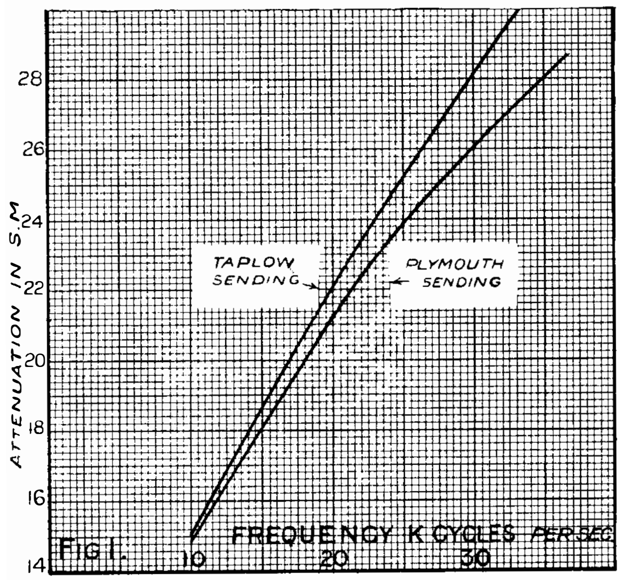
The application of either system of carrier working is facilitated by the use of single side-band working. This system, originated by J. R. Carson, of the American Telegraph and Telephone Co., is an inspiring example of the direct application of high mathematical analysis to the solution of an engineering problem. Stated very briefly the system is as follows:—Modulation of the carrier is effected in such a way that the two side bands (see above) are produced without the carrier frequency. One side band is then filtered out, and only the other side band transmitted over the line. At the receiving end this side band is added to a locally generated carrier, of the right frequency of course, and made to reproduce the original speech or other modulating frequency. By this means the width of the frequency band required for each channel is approximately halved, and certain difficulties which arise when carrier and side bands are transmitted in the usual way disappear. It is not proposed to deal with this system in detail, however, as the main purpose of the present article is to describe some of the research work recently undertaken by the British Post Office in connection with ordinary carrier working.

III.—Transmission.

The characteristics of aerial lines, paper-core cables, and G.P. cables at carrier frequencies have been measured in this country and in America. A paper read before the A.I.E.E. in 1921 by Colpitts and Blackwell* contains much

* "*Carrier Current Telegraphy and Telephony.*"

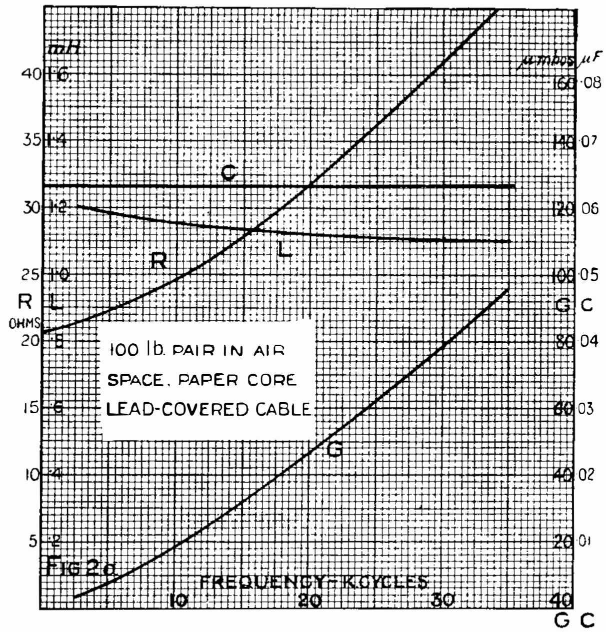
valuable information, which is confirmed and extended in an article by Affel, Demarest and Green in the Bell Technical Journal, July, 1928. Measurements recently made here agree fairly well with the American results, allowance being made for the different type of line construction. Fig. 1 gives the attenuation-frequency characteristic of an aerial line (twist system throughout) between Taplow and Plymouth, a distance of 200 miles. The measurement was made on a fine summer night. The same line was also measured when the conditions of humidity were extraordinary, even for our much-abused climate, and the attenuation was almost doubled. Such an effect is fortunately rare. The conditions were so bad, in fact, that the ordinary aerial



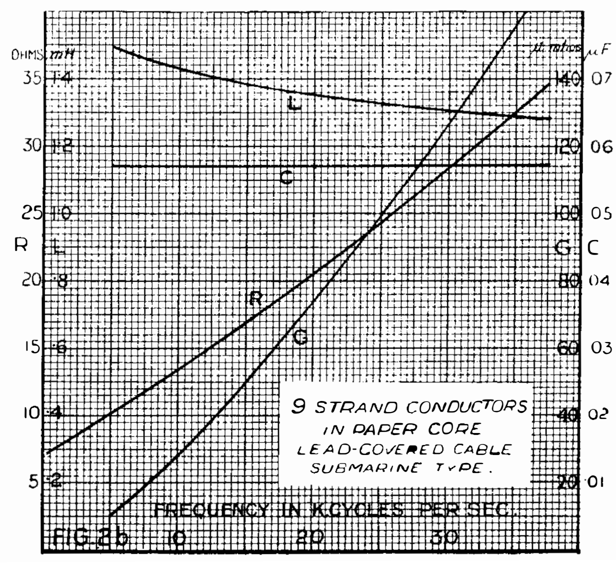
trunks were noticeably affected. For aerial lines of such a length that carrier working is economical it is generally impracticable to use frequencies much above 30 kilocycles. This limit does not necessarily apply to cables, however, where the cross-talk may be very much less, though the attenuation is generally much higher.

The factors governing the attenuation of cable pairs will be dealt with in some detail, as they have been fully investigated with a view to designing submarine cables on which carrier working may be possible over considerable distances.

The four constants, R, L, G and C, were



determined from impedance measurements on short lengths of cable (30 to 180 yards) with the far end of the tested pair open and closed. Two measurements at each frequency were therefore required. As the lengths were extremely short, electrically, the closed impedance could be taken as $(R + j\omega L) \times$ length and the " open " impedance as $\frac{G + jC\omega}{\text{length}}$. A proof of this will be found in J. G. Hill's " Telephonic Transmission," p. 246. The measurements were made by a substitution method, using a bridge of very high quality, with a heterodyne detector unit in



place of the usual telephone receiver. This was adjusted to give a balancing note of about 1000 cycles. It was found essential to use the Wagner earthing device, which enabled the detector to be brought to Earth potential at each balance of the bridge, but no specially elaborate screening arrangements were used. The resistance, which proved to be the most important factor determining attenuation at high frequencies, was generally a matter of two or three tenths of an ohm, and great care was necessary to measure it accurately.

Similar measurements were made in 1922 by Messrs. Taylor and Bradfield, using only 10 ft. of submarine cable. Their method was different in detail but the results agree very well with the recent measurements now being described. Curves showing R, L, G and C for some typical cases are given in Fig. **2** (*a*, *b*, and *c*). These results have been verified by direct measurement of the attenuation of various cables *in situ*.

Two important facts emerge from these measurements:—(1) At frequencies over 6 or 7 kilocycles the characteristic impedance of any cable pair becomes approximately non-reactive. The same thing also applies to aerial lines. (2) The rise of effective resistance with frequency is very rapid, on account of the skin effect in solid conductors and eddy current losses in the sheath or (in the case of submarine cables) the armouring and surrounding sea water. The rise of resistance with frequency is shown by the curves for R in Fig. **2**.

It is evident that the attenuation of cables at

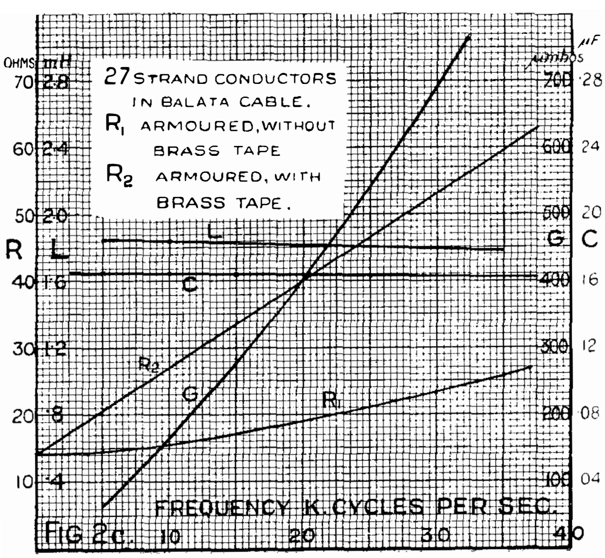


FIG 2c.

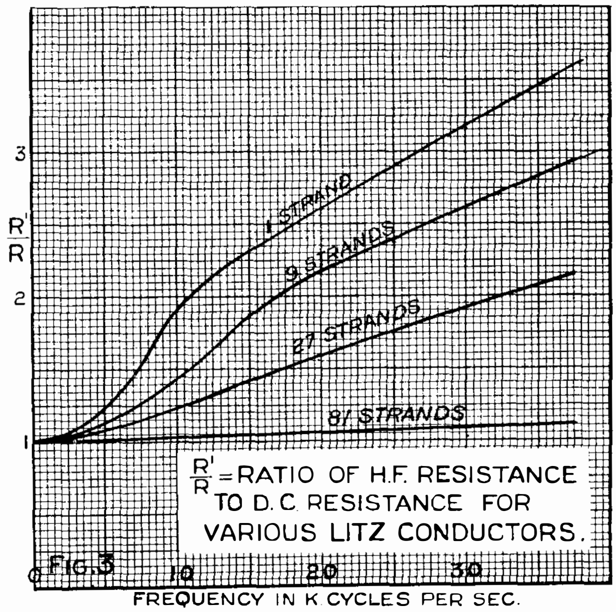


FIG. 3

high frequencies can only be reduced to manageable values by reducing effective resistance. The skin effect can be almost wiped out by making the conductor of 3^n strands, in what is known as "Litz" formation. Three wires are first stranded together. This group of three is stranded with two similar groups, and so on. (Obviously the number of strands must be a power of 3). The effect is that each strand occupies in turn all possible positions from centre to outside. It was thought that the increase of resistance in a Litz conductor would be merely that corresponding to one strand. But it was found, at any rate for carrier frequencies, that this is only true for conductors of 81 strands or more.

The next lower number possible (27) is very nearly as efficient and not impracticable from the point of view of size and jointing.

Fig. **3** shows the relative efficiency of 1, 9, 27 and 81 strands. $\frac{R^1}{R}$ is the ratio of total resistance to D.C. resistance, and the total weight of the conductor is 350 lbs. per mile in each case. For the same weight a Litz conductor has the disadvantage of greater diameter than a solid conductor, or one stranded with parallel wires as is usual in submarine cables for mechanical reasons. The greater diameter means increased capacity and eddy current losses in the sheath. To decide whether the advantages of Litz conductors would outweigh their disadvantages, two lengths of paper-core lead-covered cable were made up. One contained four conductors in star quad

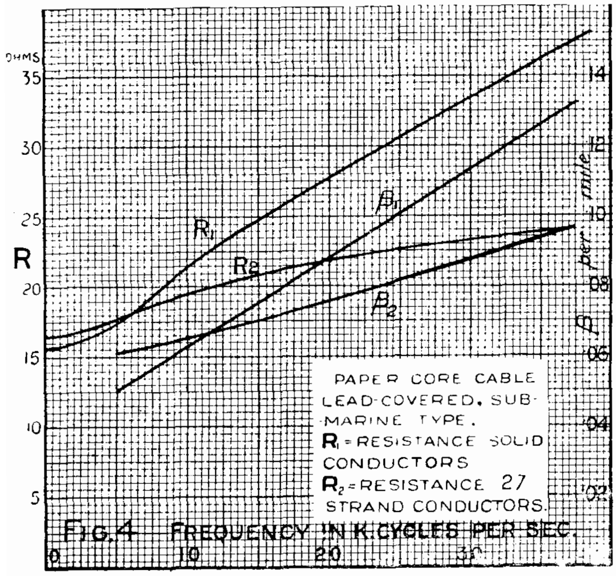


FIG. 4 FREQUENCY IN K.CYCLES PER SEC.

formation, each having 27 strands of No. 26 S.W.G. The other was similar as regards formation, thickness of paper, etc., but contained solid conductors of the same weight—160 lbs. per naut. Fig. **4** shows R and β for both these cables, and the advantage of the stranding is evident at high frequencies.

The laws governing these eddy current losses are still very obscure, but certain facts are clear; *e.g.*, the closer the conductors and the greater the diameter of the sheath the less the eddy current loss. In the case of G.P. submarine cables the Litz conductor is essential for reasonable high-frequency attenuation, but the type of sheathing also has a very important effect. For instance, the brass tape usually wound over the core to prevent damage by the teredo worm is responsible for most of the resistance rise.

In co-operation with Messrs. Siemens Bros., many different types of armouring have been tried. The most surprising of all the results was that a cable covered with steel armouring wires and no brass tape gave a lower attenuation than the same cable unarmoured; both being tested immersed in salt water.

Fig. **5** shows the attenuation, calculated from measurements of R, L, G and C on a short length of a Balata cable, 4—27/26 conductors, armoured, no brass tape.

The matter cannot be discussed in more detail at this stage, but the position may be summarised thus:—

(1) For lead-covered cables (land or submarine) conductors formed of 27 strands in Litz formation and stranded into a star quad, with suitable thickness of paper insulation, will give reasonable attenuation at carrier frequencies up to 30 kilocycles or more.

(2) In cases where G.P. cables must be used, similar conductors, armoured but not covered with brass or other metallic tape, are indicated. Balata would generally be used, except at the shore ends, instead of G.P., as the dieletcric losses are much lower at audio and somewhat lower at carrier frequencies. The risk of damage by teredos varies greatly in different waters. To meet cases where this risk is considerable, various forms of protection which will not increase the eddy current loss are being considered.

Continuously loaded cables.—The attenuation of continuously loaded cables increases rapidly as the frequency is increased from about three kilocycles, mainly owing to eddy current losses in the loading material. A typical attenuation-frequency curve (taken from the Anglo-Dutch No. 3 cable) is shown in Fig. **6.** It was evident from measurements of this kind, together with cross-talk measurements made at carrier frequencies with a special amplifier, that only a

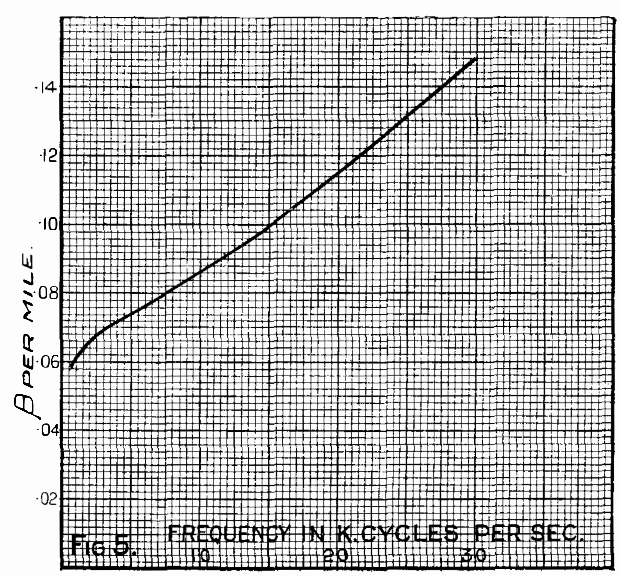


FIG 5. FREQUENCY IN K.CYCLES PER SEC.

relatively low carrier frequency could be used on the continuously loaded cables between England and the Continent. Taking 2500 as the highest frequency for good speech, and a carrier frequency of 6000, the lower side-band extends down to 3500, leaving a margin of 1000 cycles between the audio and carrier channels. It has been found quite practicable to work with a 6000 cycle carrier, and the system is now emerging from the experimental stage. The arrangement of the apparatus will be described in the next section.

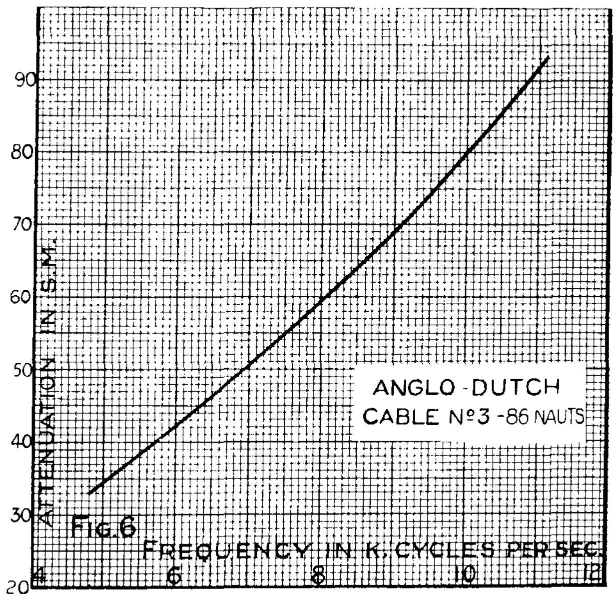


Fig. 6

IV.—Apparatus.

The apparatus at present in use for carrier telephone circuits on aerial lines in this country is a somewhat improved version of that described in Taylor and Bradfield's paper, referred to in Section II. This apparatus is giving satisfactory service for single channel working, but the design of improved sets, using high-frequency filters and adaptable for two-channel working, is now in hand. For carrier working on continuously loaded cables at a frequency of 6000, special arrangements are necessary to obtain a satisfactory separation of the audio and carrier channels. High-pass and low-pass filters are used at both ends. At the transmitting end a special form of modulating circuit is used to separate the audio from the carrier frequency. In view of the high line attenuation to be dealt with (over 40 S.M.) there is perforce an unusually great difference of level between the carrier and the physical circuit, and it would be a difficult matter to provide the necessary separation by means of filters alone. Special precautions have to be taken to prevent audio to carrier cross-talk through the repeater station common batteries supplying filament and anode current to the sets. The general arrangement is given in Fig. **7**, which shows the apparatus for one carrier circuit superposed on one quad of the cable. Three physical circuits are working; two sides and one phantom, with two-wire repeaters. The carrier is worked as a four-wire circuit, the " go " on one side circuit and the " return " on the other. One end of the cable only is shown. The other

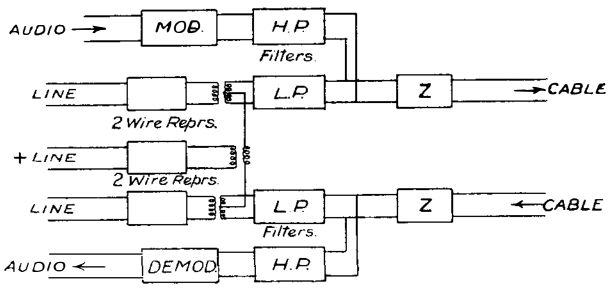


Fig. **7**.

is exactly similar, except that modulator and demodulator are interchanged. The audio extensions of the carrier may be connected to a four-wire circuit on the land side, or combined by means of the usual differential transformer to form a two-wire circuit. Considering the physical circuits first: These have been shown as two-wire repeater circuits because most submarine cable circuits are worked in this way. In the case of four-wire circuits the problem is simplified by the absence of balances. An impedance adjusting network (Z in the figure) is inserted in each cable pair to make the impedance approximately non-reactive. The HP and LP filters are so designed that the whole arrangement viewed from the line side of the terminal transformer has an impedance which is very nearly non-reactive over the audio frequency range. The repeater on each side circuit is therefore balanced (on the cable side) by a simple resistance connected through a transformer corresponding to the terminal transformer. The phantom circuit repeater is balanced by a network containing inductance. If signalling is by means of voice frequency currents, there are no difficulties, but in some cases 16-cycle or 25-cycle ringing is still used. Certain modifications have then to be made in the impedance adjusting networks to allow the low frequency currents to pass. Signalling over the carrier circuit must be done by voice frequency currents.

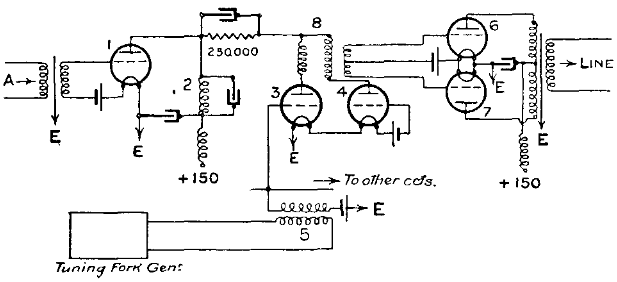


FIG. 8.

The carrier current is generated at each end of the cable by a 6000 cycle valve-maintained tuning-fork, which supplies all the carrier channels. It is found that the carrier frequencies at the two ends must not differ by more than 2 or 3 cycles per sec., but no difficulty is anticipated in this respect in view of the exteme constancy of which tuning-fork generators have been proved capable.

The arrangement of the modulator is shewn in Fig. 8. Speech entering at A is amplified by the valve 1 and varies the voltage across modulating choke 2. This variation of voltage controls the carrier output of valve 3 (to the grid of which carrier frequency is supplied through the transformer 5) in accordance with the speech. Valve 4 is arranged to act, through the transformer 8, to balance the audio-frequency effect by which the speech currents tend to pass straight through the modulator, with amplification, and so to line. The valves 6 and 7 act simply as a push-pull amplifier of the modulated carrier, which then passes through the H.P. filter to line. The discrimination between audio and carrier frequencies afforded by the balancing valve (4) and the H.P. filter is such that cross-talk from the carrier to the physical circuit is better than 80 S.M. The normal carrier current sent to line is about 15 milliamps, and the modulation factor 50% for ordinary speech. The main object in using a push-pull amplifier is to improve the balance to earth of the output transformer. If a balanced and screened output transformer is used with one half of the primary left disconnected at the outer end, a single valve, or two valves in parallel, may be used for the amplifier with satisfactory results.

The modulating choke is shunted by a condenser and the combination forms a parallel resonant circuit having a high impedance over the audio frequency range. The 250,000 ohm resistance cuts down the effective anode voltage of valve 3 to a suitable value for modulating. Carrier frequency is supplied through the balanced-and-screened transformer 5 to the grids of the transmitting valves on each carrier circuit, all the grids being in parallel. Interference is avoided by adjusting the grid bias so that grid current never flows, and by the use of " neutrodyning " condensers where necessary.

The demodulator, or carrier receiver (Fig. 9) consists of an amplifier valve (1), followed by a rectifying valve (2), which is primed to act as a bottom-bend rectifier. The output from transformer 3 consists of audio frequency with a 6,000 cycle ripple. This is practically eliminated by the line, or the normal filters used in two-wire repeaters, in most cases. Otherwise, a L.P. filter is connected in the output circuit.

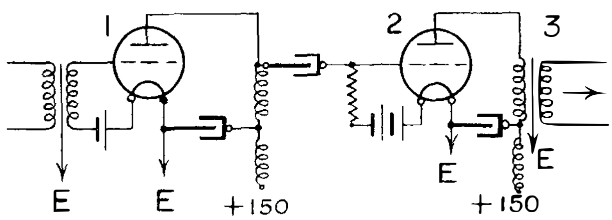


FIG. 9.

The efficiency of the rectifying circuit can be improved by using two rectifiers joined in the well-known manner to give full wave rectification, and in this case the ripple has a frequency of 12,000 cycles, which facilitates filtering. Incidentally, a Westinghouse metal rectifier, consisting of four elements arranged in bridge fashion for full wave rectification, was found to give satisfactory results. In this case also the frequency of the ripple was 12,000 cycles, in consequence of the full wave rectification.

No details of battery supply to the filaments have been shewn in the diagrams, since the exact arrangement depends on the batteries available, but in practice the ordinary repeater station batteries are used for heating and anode supply.

Where the grids cannot be primed from resistances in the filament circuit primary cells are used.

In applying this carrier system to such cables as the Anglo-Dutch and Anglo-Belgian, where the carrier attenuation is about 40 S.M., there are four main difficulties to be overcome:—

(1) Battery cross-talk between one carrier current and another, and between carrier and audio.

(2) Cross-talk from carrier to audio due to the non-linear magnetic characteristics of the loading material, which tends to rectify the carrier currents and make them audible on the physical circuit.

(3) Cross-talk from audio to carrier, due to modulation of the carrier current by speech currents, the latter varying the permeability of the loading material and hence the attenuation of the carrier current, so modulating it in accordance with the speech on the physical circuit.

(4) Carrier to carrier cross-talk between different quads of the cable.

Of these difficulties the first was overcome by special smoothing arrangements in filament and anode circuits. The second and third fortunately proved of insufficient magnitude to cause much trouble. The last has proved the most serious, since it is governed almost entirely by the construction of the cable, and very little can be done to improve matters after the cable is laid. A trial under working conditions is the only safe method of deciding on which of the quads in a large cable the system can be worked satisfactorily.

The same type of apparatus will shortly be applied to single and double channel carrier working on aerial lines and possibly unloaded cables, where higher carrier frequencies can be used; but at present all the indications point to submarine cables, of the unloaded or continuously loaded type, as the most promising field of development.

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., 1928.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
598,538	517	4,043	51,575	130	London	24,522	68,949	2,315,957	99,413
77,349	2,158	21,416	65,578	1,854	S. East	4,023	49,018	197,457	32,733
80,662	4,348	30,906	56,402	3,253	S. West	20,631	12,403	152,815	59,303
63,471	6,063	37,291	59,494	5,473	Eastern	23,380	38,125	114,523	70,585
96,677	8,608	44,988	58,941	3,819	N. Mid.	29,518	54,017	241,480	113,174
78,862	4,786	29,938	72,085	4,604	S. Mid.	12,104	23,364	188,791	88,454
58,124	4,343	29,868	52,341	3,146	S. Wales	6,360	26,189	119,572	71,931
103,366	8,060	26,421	49,736	4,213	N. Wales	13,564	41,286	274,658	61,333
157,826	1,492	16,465	43,270	2,459	S. Lancs.	13,637	79,224	473,518	48,360
92,800	6,234	30,595	46,565	3,270	N. East	11,714	46,188	232,479	72,670
64,085	4,029	24,300	37,744	2,186	N. West	8,303	33,623	165,187	31,722
47,235	2,514	16,204	25,440	2,556	Northern	4,700	15,013	109,327	50,682
21,391	4,568	8,453	13,921	543	Ireland N.	134	2,324	40,346	1,577
65,533	5,472	26,141	37,485	1,443	Scot. East	3,954	12,906	151,144	47,260
87,699	7,274	24,310	42,862	1,089	Scot. West	12,077	24,606	224,278	37,189
1,693,618	70,466	371,339	713,439	40,038	Total	188,621	527,235	5,001,532	886,386
1,668,098	70,768	370,327	707,061	38,951	Figures as at 30th June, 1928.	184,835	517,854	4,859,655	897,031

TELEPHONE REPEATERS AT NEW DELHI.

N. F. FROME.

INTRODUCTION.—The small cord circuit telephone repeater installation described in the following account is that of the repeaters in use in the New Delhi trunk exchange. The apparatus includes one or two novel circuit arrangements which are illustrated in the diagrams. Examples of typical line and network impedance curves are shown.

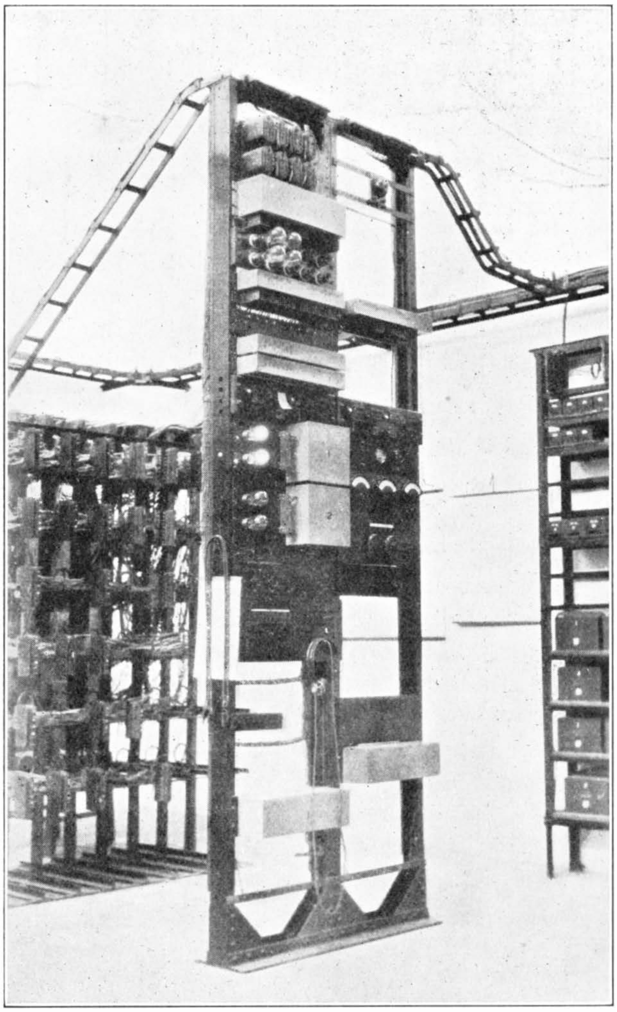


FIG. 1.—GENERAL VIEW. CORD CIRCUIT REPEATERS.

Repeaters.—The repeaters are of the General Electric Company's type No. 12A (Fig. 1). They are installed in the test room (described in Vol. XX., Part 3, page 163), which is adjacent to the trunk exchange. One or two small modifications have been introduced on the repeater bay, viz.—

(1) The filament circuit is operated from the 40 volt trunk exchange battery instead of from the usual 24 volt battery.

(2) Lamps have been fitted in the potentiometer relay circuits to light in conjunction with the relays and indicate the step on which the repeater is being worked. The latter addition enables the test room staff to keep a constant watch on the repeater operation.

Cord Circuits.—Fig. 2 shows the repeater cord circuit which is designed to operate in conjunction with the cordless trunk switchboard. The latter is of a semi-automatic type in which connections are set up in relay selection circuits by the operation of selection keys and key-controlled link circuits. The repeater link switchboard fittings are exactly similar to those of the ordinary links with the addition of the potentiometer keys. "Control" keys are used for line selection and designation. "Ring," "Split," and "Speak" keys for ringing, temporarily terminating through calls, and speaking, respectively. A repeater call is set up as follows:—As a result of throwing the "Control" key CX, and pressing the selection key of a particular line, the line is connected to XT, XR, and XS; relay (9) is operated over the tens and units locking wires, relay (1) is energised and connects the line through to the X side of the repeater. The second line connection is similarly made using the CY key, relays (10) & (6) operate, completing the second line circuit to the Y side of the repeater. The filament start relay is energised *via* the contacts of (9) and (10), the lamp TSL indicating to the operator that the filament circuit has been completed.

The operation of the "Speak" key closes the circuit of relay (15) and connects the operator's telephone set to the monitoring winding of the repeater. To speak to one terminal station only, the "Split" key is thrown to SX or SY,

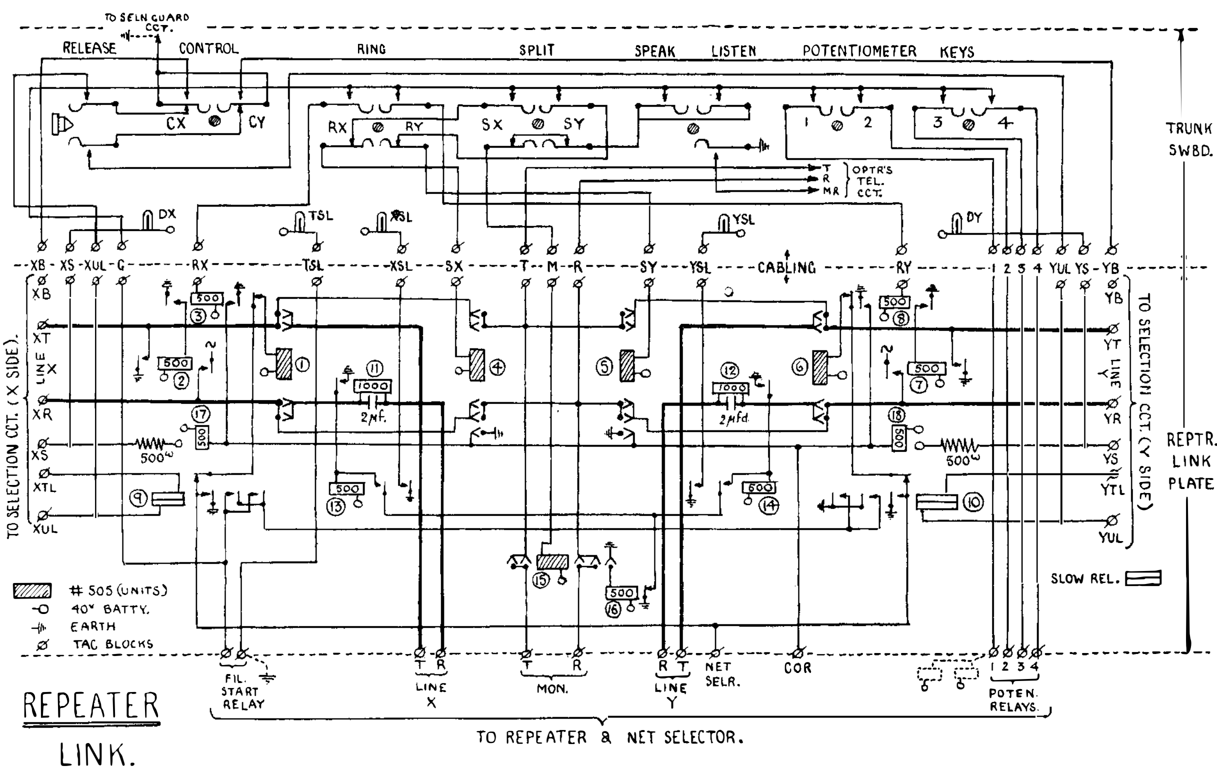


FIG. 2.—REPEATER CORD CIRCUIT.

operating relay (4) or (5) connecting the operator's telephone set to the one line. At the same time the repeater cut-off relay is energised, and the input transformers short-circuited, while relays (17) or (18) opens the circuit of (1) or (6) as the case may be.

Outward ringing on the X line results from the operation of the RX key and relays (3) and (2). Relay (3) in energising releases (1) disconnecting the repeater, and operates the repeater cut-off relay. Similarly RY controls the outward ringing to the Y line.

For inward ringing and supervision, relays (11) and (12) are arranged to respond to the incoming 16 cycle ringing current. Relay (13) is energised by (11) and locks to an earth on relay (16), at the same time lighting the supervisory lamp XSL. (13) is released by the operation of (15) and (16) as the operator answers. The Y side supervision is operated in a similar manner.

It will be noticed that in this link circuit all speech path connections are made through multipled contacts on special relays. The latter are the North Electric Company's "Units" relays, which have an arrangement of springs giving a wiping contact. (See Fig. **3**). This special provision has been found to be necessary to ensure that the efficiency of the repeaters is not decreased by contact losses in the auxiliary apparatus. The ordinary relay contact is liable to give trouble from the effects of the dust which

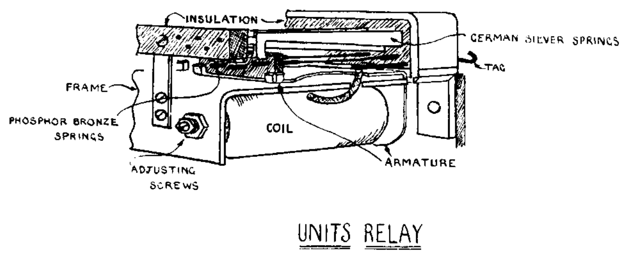


FIG. **3**.

is very prevalent in the plains of India, and experience has shown that in reducing the number of dirty contact faults the doubled wiping contact is by far the most successful system.

Network Selection Apparatus.—Simultane-

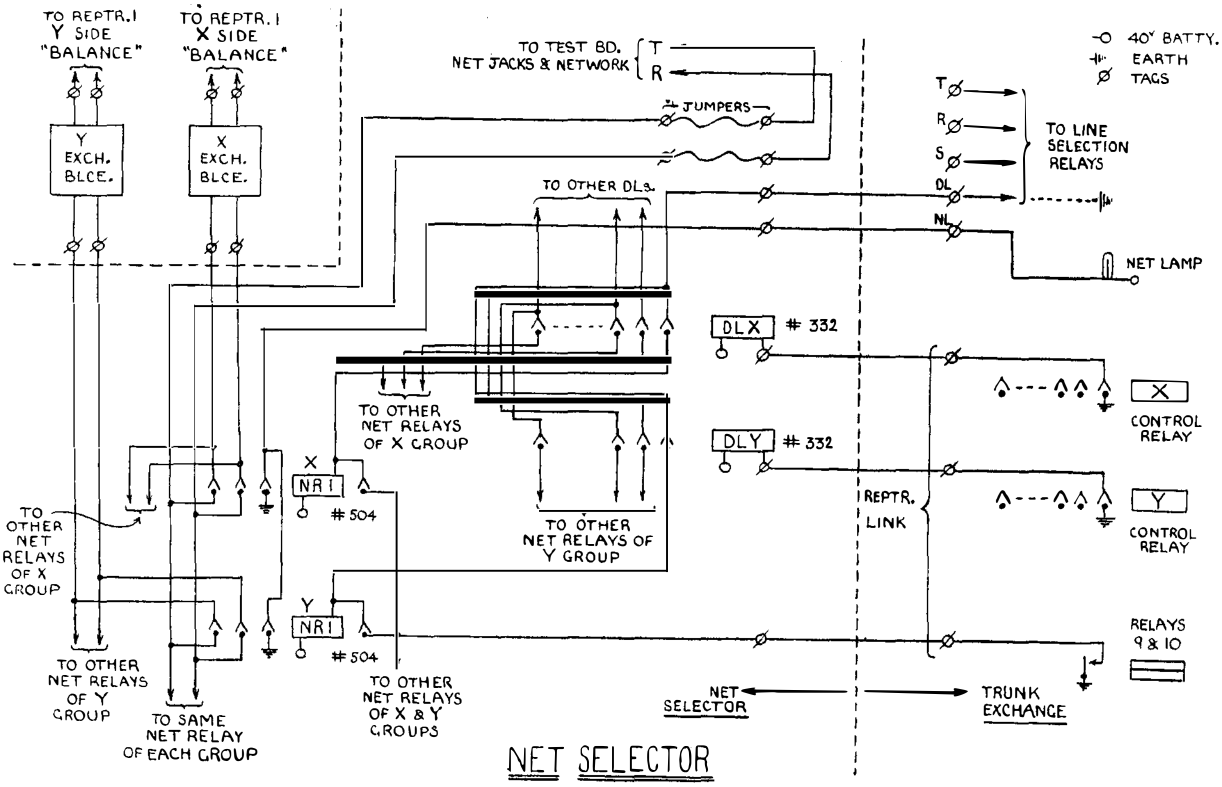


FIG. 4.

ously with the connection of the line to the repeater link the associated balancing network is automatically connected to the "Balance" side of the repeater. A schematic diagram of the network selection circuit is shown in Fig. 4, the apparatus itself being seen on the right of the network rack in Fig. 5. The operation of the circuit is as follows:—

When the repeater link "Control" key is thrown to the X side, the control relay in the line selection circuit is energised and one of its contacts is used to operate the DLX relay in the net selector. The contacts of DLX are arranged to connect thirty "DL" wires through from the line selection apparatus to the network relays. As the selection key on the switchboard is pressed, the DL wire of the line selected is earthed, the corresponding net relay (NR) is operated by that earth and locks to an earth on relay (9) in the repeater link. After selection, the "Control" and "Selection" keys are normalled, and relay DLX is released. The operation of the network relay connects the line balance to the X "Balance" side of the repeater and also lights a lamp on the switchboard, over the line equipment concerned, to indicate to the operator that the network has been correctly selected. The Y side connection is made in a similar manner by the operation of DLY and the net relay in the Y group.

Release:—With the release of the repeater link, relays (9) and (10) are de-energised and the net relays are released. The relays used in the network selection circuits are the "Units" relays previously mentioned, thirty-two point "Tens" relays being used for DLX and DLY.

Balancing Networks.—The balancing networks are built up on the unit principle. The units of the network are mounted on a rack as shown in Fig. 5, and cabled *via* a jumpering field on the rack to break-jack strips fitted on the trunk line test board. The cables terminate on the outer springs of the break-jacks, the inner springs being wired to tag-blocks in the test board as shown in Fig. 6. Jumpers on these tag-blocks cross-connect the network

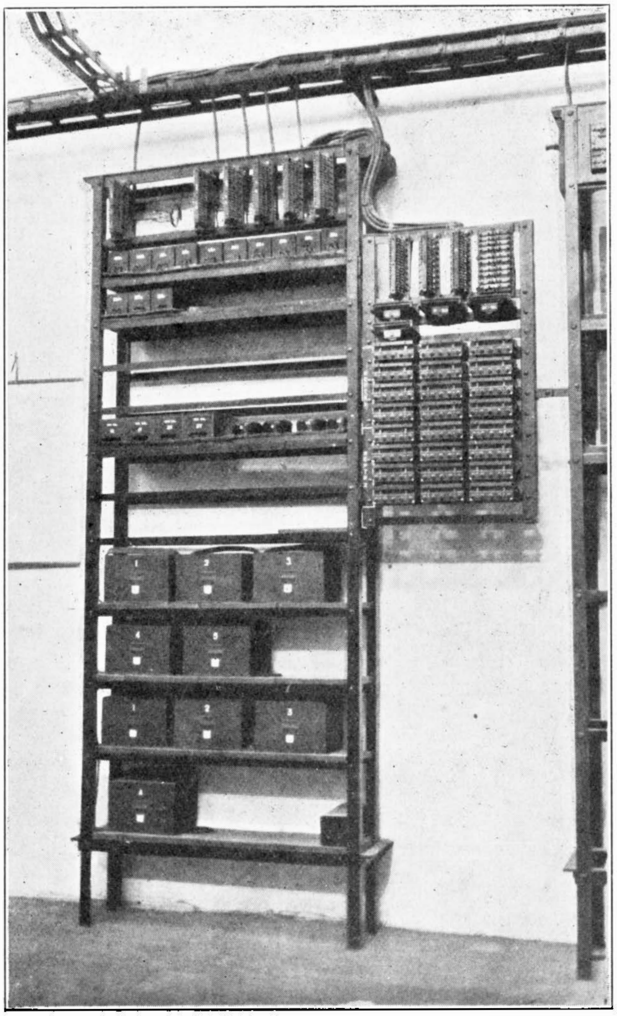


FIG. 5.—NETWORK RACK AND SELECTOR.

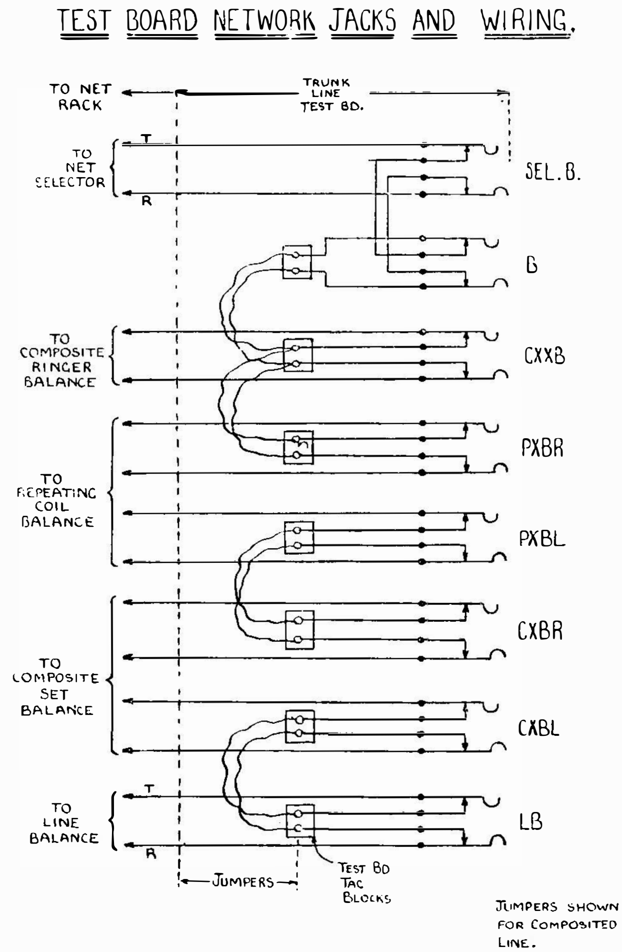


FIG. 6.

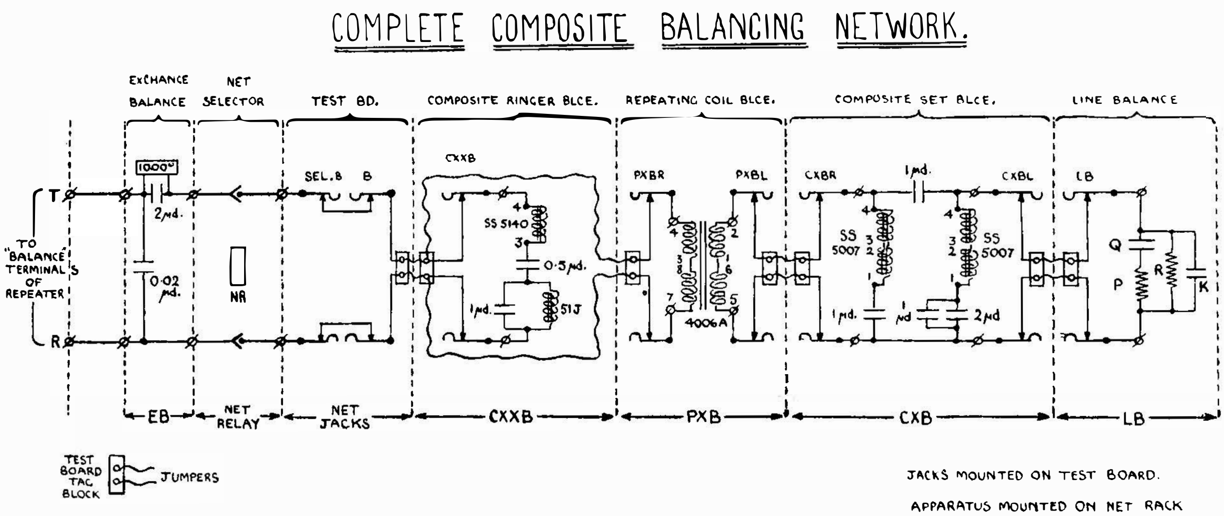


FIG. 7.

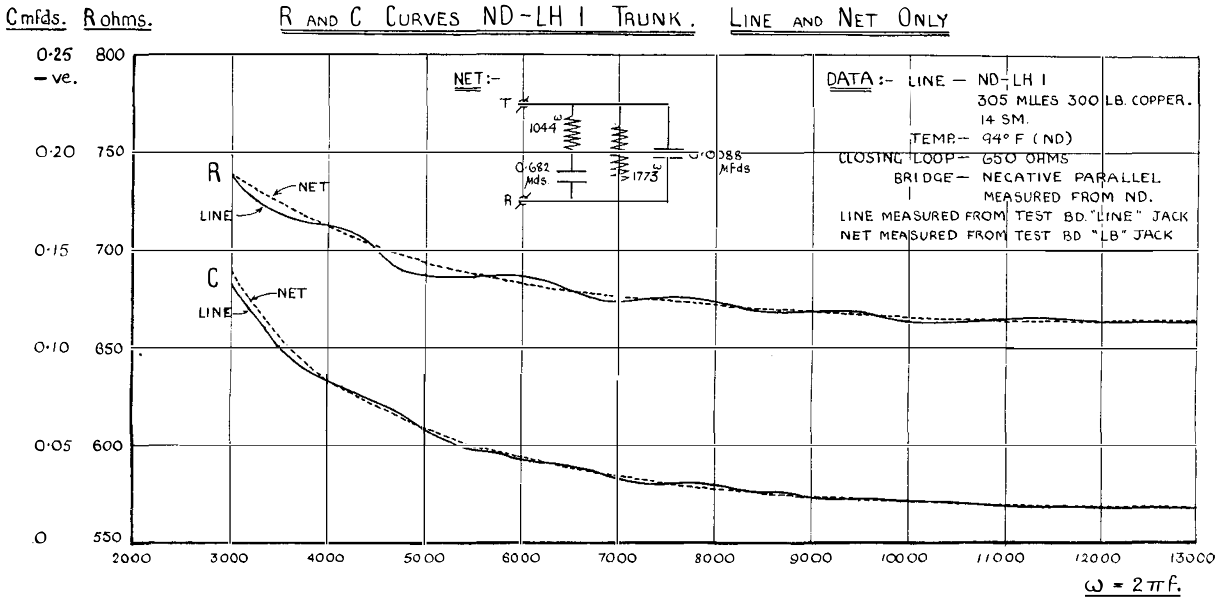


FIG. 8.

units as required for permanent line arrangements;—Fig. 6 illustrates the jumper connections on a composited line. For temporary line arrangements patch-cords plugged into the jacks remove or introduce the composite balancing units as required. For example,—a patch-cord from "Sel B" to "PXBR" and the second cord from "PXBL" to "LB" take the

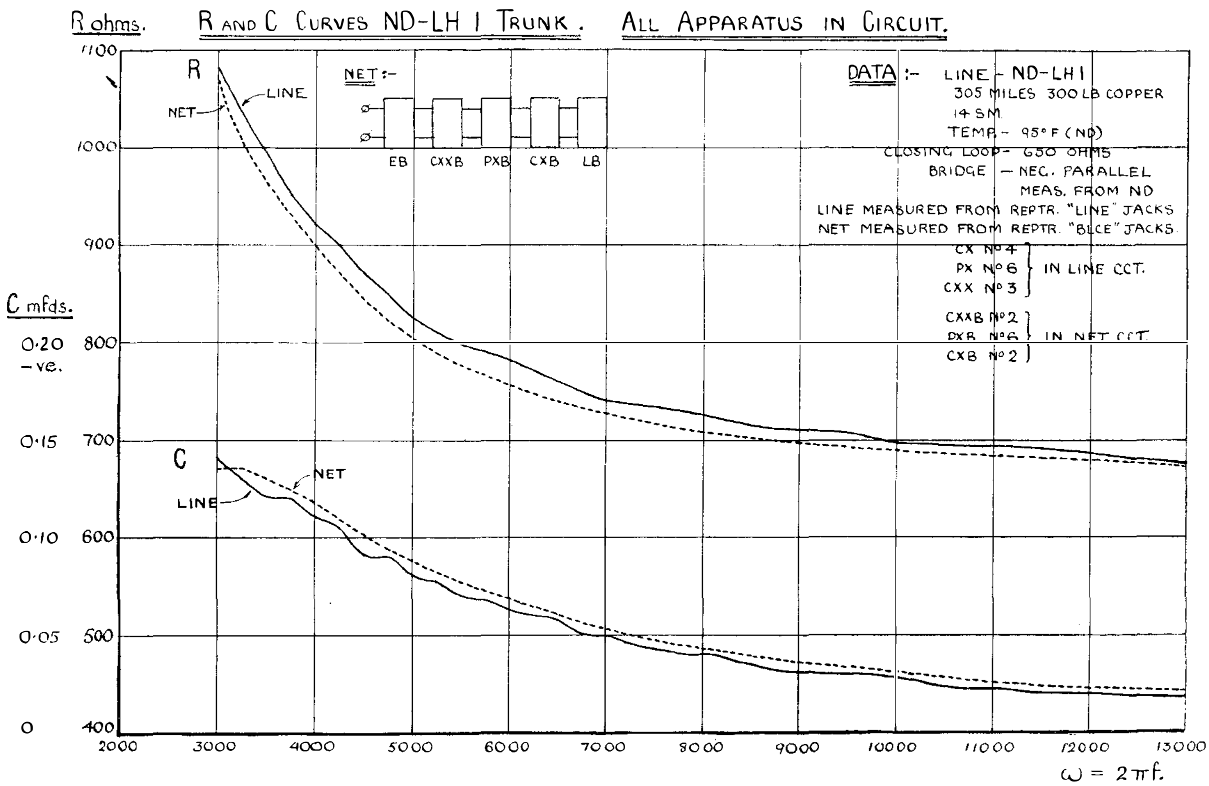


FIG. 9.

composite set and ringer balances out of circuit.

Fig. **7** shows a complete network on a composited line. The exchange balance "EB" in the leads from the repeater to the net selector balances the repeater link apparatus and exchange cabling, the remaining units in the chain balancing the various line apparatus. The line balance shown is of the "parallel"* type, the actual values of the components of a typical balance being given in Fig. **8**. The latter diagram and Fig. **9**, illustrate typical impedance curves of a composited trunk with and without its auxiliary apparatus. The curves in Fig. **8** are plotted from measurements made with a capacity A.C. bridge from the "Line" jack of the trunk line test board and the "LB" jack of the balancing network. Those in Fig. **9** are measured from the "Line" and "Balance" jacks of the repeater and indicate the degree of balance with all apparatus in circuit.

Singing-point tests taken on the line illustrated show a singing-point above the gain figure obtained on the fourth step of the potentiometer, *i.e.*, something over 15 T.U. As a check on balance conditions, singing point tests are made as a matter of routine in addition to the usual voltage, current, and gain measurements, etc., while special attention is paid to the operation and testing of auxiliary apparatus owing to the importance of the latter in the working of single long distance trunks.

* *"Testing of Telephone Circuits and Apparatus with Alternating Curents," by E. S. Ritter and G. P. Milton, I.P.O.E.E. Paper No.* 110.

THE ROUTINE TRANSMISSION TESTING OF SUBSCRIBERS' INSTRUMENTS AT THE EXCHANGE AND AT THE SUBSCRIBERS' OFFICE.

A. Hudson, B.Sc., A.C.G.I.F.C.

INTRODUCTION.—In the July, 1924, number of this Journal a description was given of apparatus, called a Volume Tester, for measuring the sending efficiency of a subscriber's instrument at the exchange without the knowledge of the subscriber and during the progress of an ordinary call. This apparatus, however, used by itself has serious limitations, when considered as a means of assisting maintenance. These may be briefly summarised thus:—

(1) The sending efficiency only is measured.
(2) The efficiency of the subscriber's talking is included.
(3) In the case of a P.B.X. there is uncertainty as to which instrument is being used.
(4) Calculations involving the circuit allowance of the subscriber's loop are necessary to determine the loss.

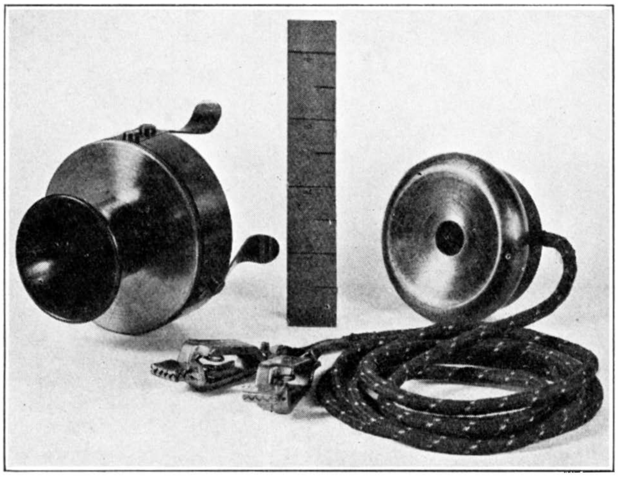
No. (2) can be an advantage when the instrument is used in another fashion, as will be described later.

Since the date of the first article a considerable amount of research has been carried out with a view to evolving a simple and rapid means of measuring the true efficiency of both the receiver and the transmitter in terms of the Department's standard without disturbing the subscriber's telephone. A considerable measure of success has been attained, and the value of the method proved in an extended series of tests made at Portsmouth and Willesden exchanges.

Description of Method of Test.

The basic idea underlying the test is that of comparison with a standard. A standardised receiver is connected to the line terminals of the subscriber's installation and the A.C. voltage generated by this receiver is compared with that generated by the test transmitter and receiver, on being spoken into in turn. A valve voltmeter of the potentiometer type called a "Telephone Efficiency Tester," located at the exchange, is used for this purpose.

A standardised receiver and an artificial ear are the only pieces of apparatus which it is strictly necessary for the lineman to carry with him for the test, and in bulk the set is about 3″ diameter by 4″ long and weighs about 2 lbs. See the illustration.



STANDARDISED RECEIVER AND ARTIFICIAL EAR.

The artificial ear is so named because when applied to a receiver it produces the same degree of diaphragm damping and modification of resonance as would be produced when the receiver is applied to a human ear. In this case the artificial ear has a mouthpiece attached to it on the reverse side to the receiver, acoustical connection being made by means of a number of small holes in the back of the artificial ear. This enables the lineman to talk into the standard receiver.

The artificial ears and standard type receiver so far used are not entirely satisfactory since they require frequent recalibration, but it is hoped as a result of further research shortly to produce types which will only require occasional calibration.

The method of use is then as follows:—

(1) The standardised receiver, which is of the electromagnetic type, is connected to the line terminals of the subscriber's instrument, the test receiver being on the hook. The test clerk at the exchange then adjusts the line current to some predetermined value, which is always the same, so that the equivalent of a 300 ohm local line is obtained. In the case of a line over 300 ohms battery is added to bring the current to the correct value.

(2) The lineman then counts 1, 2, 3, 4, 5, about 7 or 8 times, pauses and then repeats it into the artificial ear which is attached to the standard receiver. The test clerk measures the A.C. voltage delivered to the exchange during this talk by means of a constant deflection valve voltmeter. This he effects by setting the potentiometers of the voltmeter (which are arranged to give a range from 0 to 70 S.M. in 1 S.M. steps) to some value (given with the standard receiver) and noting the deflection obtained. All further measurements on the same test are then made by altering the potentiometers so as to obtain this deflection. This method thus gives the efficiencies direct in S.M.

(3) The lineman disconnects the standard receiver from the line and, taking the test receiver off the hook but *not* holding it to his ear, he repeats his talk into the transmitter at the same volume as before. The test clerk measures this voltage by adjusting the potentiometers.

(4) The lineman then cuts out the transmitter either by short-circuiting it for C.B. circuits or disconnecting the cells for L.B. circuits. He then applies the artificial ear to the test receiver and talks into it, again at the same volume. This voltage is also measured by the test clerk by adjusting the potentiometers.

The test should be made as quickly as possible in order that the lineman may be able to keep his volume constant, but where the test is interrupted, for instance, to change a transmitter or receiver a check on the standardised receiver is necessary.

Two or three minutes is about the time taken when the test is carried out by skilled men under favourable conditions.

Two calibration figures are required to determine the actual efficiencies of the instruments, those of the standard receiver in terms of the Department's standard receiver and the standard receiver plus artificial ear in terms of Department's standard transmitter. Call these two quantities " A " and " B " respectively. Let the potentiometer settings obtained by the test clerks be

" S " for the standard receiver.
" T " for the test transmitter.
" R " for the test receiver.

Then the transmitter efficiency will be

B + S − T worse than Department's standard; and for the receiver:

A + S − R worse than Department's standard.

When these expressions are negative the efficiencies are better than standard.

A + S and B + S will be constants for any combination of artificial ear and standardised receiver, so that it will be seen that the efficiencies are obtained very simply. Any case of low efficiency should be further investigated at the time of the test.

Very little difficulty has been experienced so far in carrying out the test with the linemen who have been employed. Careful training is necessary, but after about a week's experience it is found that they can generally be relied upon to give consistent results.

Accuracy of Test.

Laboratory tests of the accuracy of this method are very difficult to carry out. The standard method of testing an instrument involves an elaborate cable balance, carried out six times by three different observers over a period of time of from 20 to 30 minutes. The new method uses one balance, with a talking period of about 15 seconds. This implies that only a limited degree of agreement of results by the two methods can be expected in the case of transmitters. From the nature of the test, however, it is apparent that the efficiency of the transmitter, at the time of the test, is obtained. It has been decided that the transmitter must be tested exactly as it stands without tapping or shaking in any way beforehand. The resultant figure will not necessarily be the same as that which would be obtained on removing the transmitter and re-testing it in the laboratory; the apparent error is of the order of $\pm 1\frac{1}{2}$ S.M. on the average.

In the case of the receiver, the errors are caused by factors different from those that govern the transmitter efficiency. On holding a receiver to an ear, the cap and diaphragm become warmed up much more quickly than the body of the receiver, with the result that the diaphragm is stressed, causing movement either towards or away from the magnet poles and thus altering the efficiency. When the receiver is placed on the artificial ear no such action can take place as the ear is at the same temperature as the surrounding air. The errors due to this cause are in the neighbourhood of 2 or 3 S.M. and will vary according to the clamping of the diaphragm.

Another source of error is line noise. The attenuating P.D. delivered to the exchange by the receiver is very small and may, in the case of a low efficiency receiver, be commensurate with the voltage of line noise. When the line noise voltage is sufficient to interfere with the test it may be considered that the noise is excessive and steps should be taken to eliminate it.

Circuit Arrangements.

The valve voltmeter set used at Portsmouth and Willesden is mounted so as to be readily portable and can be used in any exchange; it is self-contained as regards batteries, etc.

Another type suitable for installation in exchanges and to be used for routine testing is under design at the moment. The apparatus is mounted entirely on racks and is independent of the test desk, although it is proposed to use it in conjunction with the test desk.

From the nature of the test it will be apparent that a clear line, free from D.C. bridges, is necessary, but that apart from this the resistance of the line is immaterial. Consequently it is possible for the voltmeter set to be placed at a central exchange, serving several others *via* junctions. It is desirable that the A.C. loss due to the junctions should not exceed 5 S.M.

In the case of P.B.X.'s a double-plugged cord is used. Series indicators as used in cordless boards do not affect the test.

Proposals for Future Use.

The subscriber's output measuring set, which has been called the " Volume Tester," is most suited for observation testing, though it can be used for any case where the volume level of speech is required to be known.

It is proposed to install an experimental Volume Tester and a " Telephone Efficiency

Tester " at an exchange with a view to trying out various methods of using both sets. The volume tester will be used for observation purposes. In this way a check can be kept on the general level of volume in the exchange and cases of bad speaking investigated by checking the volume level of all calls made by the complainant.

With regard to the telephone efficiency tester the question of providing every internal lineman and fitter in the exchange area with a lineman's unit is under consideration, a test being made every time a subscriber's premises are visited, unless a visit has been made just previously.

The volume tester used in the above fashion provides an easy method of detecting faulty installations apart from subscribers' complaints.

The telephone efficiency tester enables the test clerk readily to test faulty and new installations, every lineman being available for making a test when required. Whether sufficient work of this nature will be carried out by each lineman to enable him to keep in practice from a talking point of view remains to be determined from the tests. The talking is an essential part of the test, and though apparently difficult to carry out correctly becomes comparatively easy when sufficient practice is given.

MEASUREMENTS OF THE ACOUSTICAL IMPEDANCES OF HUMAN EARS.

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

SUMMARY. — In Part I. a method of measurement of the acoustical resistance of lightly absorbing surfaces is described, together with the results of tests on the resistance components of the impedances of normal (male) ears when held to a standard type ear-cap. Frequencies ranging from 370 to 2600 cycles per second are used.

Details of a similar method, applicable to the reactance component, are given in Part II., together with test results at frequencies of 500, 1100 and 1600 cycles per second.

Part III. contains comment on the results of the investigation, and is concluded by two appendices in which equations required in the text are derived.

1. *Introduction.*—An acoustical determination of the performance of a telephone receiver under working conditions demands a means for measuring the pressures developed with the receiver held in position either to a real ear, or to an artificial ear which is acoustically equivalent. In order that the latter alternative may be available, it is first necessary to obtain some data on which may be based a specification for the acoustical impedance of such an artificial ear, either as an average value, or at least as lying within the range of variation to which the acoustical impedances of normal ears are liable.

Hitherto the method employed has been to adjust the impedance of the artificial ear until the electrical impedance loop of a receiver held thereto resembles closely that of the same receiver when held to a real ear. This method, though not quantitative (in the absence of knowledge of the mechanical properties of the receiver) enables an adequate impedance match to be obtained at the resonant frequency of the receiver. The present investigation aims at a quantitative determination of the acoustical impedances of a reasonable number of normal (male) ears over a considerable frequency range. The methods employed use acoustical resonators, observations being made of the acoustical impedance at resonance.

It must be understood that the impedance measurements relate only to the condition when the ear is held to the Post Office standard receiver ear-cap, *i.e.*, to the impedance as viewed through the aperture of the ear-cap.

There are, of course, two components to the impedance, namely, resistance and reactance. The former is probably the more important in the testing of commercial receivers, since it plays a part in determining the magnitude of the pressures developed at resonance. The effect of the latter is to alter the frequency at which this resonance occurs.

Acoustical impedance is defined as the ratio of alternating pressure to alternating rate of volume displacement, *i.e.*, if a piston of area S is vibrating with velocity v and a pressure p is developed at its surface due to its contact with the medium (air), the acoustical impedance, Z equals $\frac{p}{Sv}$ which is in general a complex quantity. The analogue to the electrical circuit is: p to E.M.F. and Sv to current, or v to current density. [Note that a mechanical impedance differs since it is the ratio of total force to linear velocity, *i.e.*, $\frac{S.p.}{v}$. The difference of these two conceptions of impedance lies in the fact that in some problems, as in the present investigation, pressures are measured without reference to the area over which they are applied, whereas in others it is the total force only that is dealt with. In either case the power developed equals $S.p.v$ where p and v are the in-phase components. Thus a Mechanical impedance = impedance per unit area multiplied by the area (dimensions $M T^{-1}$) and an Acoustical impedance = impedance per unit area divided by the area (dimensions $M T^{-1} L^{-1}$). In what follows the word "impedance" is used to refer to the acoustical impedance, unless otherwise defined.]

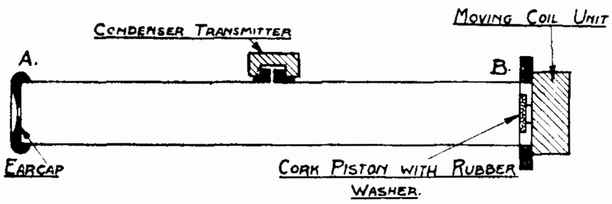


FIG. 1.

PART I.—RESISTANCE COMPONENT.

2. *Apparatus and Method of Test.*—Apparatus was assembled as shown in Fig. 1. A brass tube, 3 ft. long by $2\frac{3}{4}$ ins. internal diameter and $\frac{1}{8}''$ wall, was closed at one end, A, by a standard ear-cap, from which the threaded portion had been removed, and at the other end, B, by a moving coil unit driving a cork piston $2\frac{1}{4}$ ins. in diameter. The seal round the rim of the piston was effected by thin sheet rubber. At the centre of the length of the tube a hole about 3 mm. in diameter communicated with the diaphragm of a condenser transmitter, which was connected through an amplifier to a voltmeter.

The method broadly consists in applying at end A in turn the impedance to be measured, and two known impedances and adjusting the frequency each time to give the maximum value for E (the voltage output from the condenser transmitter).

If it be assumed that the motion of the piston is the same in each case, sufficient data are available to evaluate separately the absorption due to the tube and that due to the impedance under test, and thence the non-reactive component of this impedance. One of the known impedances was simply obtained by sealing the hole in the ear-cap with a plug of plasticine or lead, a condition sufficiently close to that of an infinite resistance. Others were used as described in the following section.

The assumption that the strength $(S.v)$ of the source of sound remained constant is justified by its construction and by the fact that the absorptions of the impedances tested were small as compared with that in the tube (which was found to be largely due to the rubber seal at B). The reactive components also necessitated only very slight alterations in frequency (less than 0.5%) for tuning to resonance.

3. *Calibrations.* — The calibration of the apparatus consists in determining the absorption within the tube, since when this is known a simple comparison of the voltages when end A is closed, and opened to the impedance under test, respectively, suffices to determine the resistance component of this impedance.

For this purpose it was decided to attempt to obtain the condition of a semi-infinite, rigid-walled tube leading from end A of the resonator tube; this would provide a known standard acoustical resistance. With this end in view a 12 ft. length of $\frac{3}{8}''$ (internal diameter) brass pipe was obtained.

A bundle of 24 strands of medium weight darning wool (varying in length between 1 ft. and 4 ft. in order to offer gradually increasing absorption) was drawn through to the far end of the pipe, and the near end was provided with a small plasticine flange for sealing to the ear-cap at A. A test for reflection effects from the far end was made at each frequency used, by tuning to resonance and observing the value of E (output of condenser transmitter) while the wool bundle was drawn back through the pipe for a distance greater than half a wave-length. In no case could any variation be detected and no change was observed when the far end was closed and opened.

With this tube in position at end A, then, the reflection factor for amplitude at end A of the resonator tube is* $g_1 = \frac{S-\sigma}{S+\sigma}$ where S= sectional area of main tube and σ that of the pipe, *i.e.*, $g_1 = 0.964$. If it be assumed that the absorption in the main tube is concentrated at end B, where most of it undoubtedly lies, it can be allowed for by considering that the reflection factor at end B $= g_0$ and that there is no loss in the tube except at the ends.

It can be shown, as in Appendix I., that at resonance (having a pressure loop at the centre of the tube) the ratio D of the value of the pressure on the condenser transmitter (or the voltage output) with the test resistance at A, to the value with the end stopped ($g=1$) is given by

$$D = \frac{(1-g_0)(1+g_1)}{2(1-g_1 g_0)} \quad \text{..........................}(a)$$

* *c.f. Rayleigh § 351, p. 331. Equation 9.*

The calculated value of g_1 assumes that the velocity of the wave is unchanged after its entrance into the pipe; no sensible error is to be expected from this cause, but it was thought desirable to obtain an alternative method of calibration to verify results obtained with the pipe. The method adopted depends on altering the reactance at end A, leaving the resistance unchanged (infinite). The ear-cap at end A was removed and a brass cup (equivalent to a 1 cm. extension to the tube) was used to terminate the tube. The cup had $\frac{1}{8}''$ walls and the flat surfaces were faced. A test was made by smearing the end of the tube with a little mineral jelly, holding the flat face of the cup to the end of the tube with strong hand pressure, tuning to resonance and noting the voltage E_0. The cup was then reversed and held in a similar manner, thus extending the length of the tube by the depth of the cup, namely, 1 cm.; the voltage E_1 was observed without altering the frequency.

It is shown in Appendix I. that if $\frac{E_0}{E_1} = F$ and if $\frac{(F^2-1)^{\frac{1}{2}}}{\tan kl} = K$, where l is the length (1 cm.) added to the tube and $k = \frac{\omega}{c} = \frac{2\pi}{\lambda}$

$$\text{then} \quad g_0 = \frac{K-1}{K+1} \quad \text{..................................}(b)$$

The following table shows the results of calibrations carried out by these two methods:—

TABLE I.

ω	*fcy.*	Equation (*a*)		F	Equation (*b*)		
		D	g_0		*tan k*	K	g_0
2300	370	1.26	0.87	1.38	0.068	13.2	0.86
4700	750	1.16	0.795	1.53	0.138	8.5	0.79
7020	1100	1.16	0.795	2.0	0.208	8.3	0.785
9370	1500	1.11	0.715	1.98	0.282	6.05	0.72

The agreement in the values of g_0 so obtained is close. These values were lower than was expected; that this feature was largely due to the rubber washer was shown when, later in the investigation, the rubber was coated with a smear of jelly and it was found that the values of g_0 then exceeded 0.9.

4. *Test Results.*—The procedure of test was as follows:—A Bell receiver was first held to the ear to be measured in order that the sensation of normal pressure and position might be memorised. The ear was then placed against the ear-cap at the end of the tube, and the voltage E_1 at peak of resonance was noted. The end of the tube was then closed by a plug covering the aperture of the ear-cap and the voltage E_0

at peak of resonance again noted. From the value $D=\frac{E_1}{E_0}$ and from the value g_0 obtained from calibration, the value of g_1, due to the absorption by the ear, was calculated from equation (a).

It is shown in Appendix I. that the acoustical resistance of the ear is

$$R=\frac{\rho c}{S}\left(\frac{1+g_1}{1-g_1}\right) \quad \text{(C.G.S. units)}$$

where ρ = density of air and c = velocity of sound in air (ρc=40.8) and S = sectional area of the tube = 38.3 sq. cms.

Since slight variations in the value of g_0 were observed from time to time; check tests of this value were made at intervals throughout each series of tests on individual ears. The results of series of tests at five different frequencies, each series including about twelve ears, are summarised in Table II. A series of tests on twelve additional ears was also made at 1100 cycles per second and included a wide range of ages, since it was thought that there might be variations in resistance with the age of the ear. No such variations were, however, observed, and the results were found to be in close agreement with those recorded in Table II.

TABLE II.

Frequency.	*Extreme Resistances.*	*Mean Resistance.*
370	100—300	175
745	90—350	175
1100	105—190	140
1500	80—145	105
2600	13—125	36

PART II.—REACTANCE COMPONENT.

5. *Apparatus and Method of Test.* — The resonator tube used for the Resistance tests was deliberately made moderately large in order to reduce the effects of different reactances at end A. It was therefore unsuitable for Reactance tests, and fresh apparatus was assembled. A ½ inch diameter tube, about 1 ft. long, was terminated at one end by a standard receiver ear-cap, and at the other end by a plasticine plug with two small holes on opposite sides of the tube, communicating respectively with a condenser transmitter and a watch type receiver, used as a source of sound.

In outline the method consists in adjusting the frequency to a resonance of the tube with the reactance under test at the end of the tube, measuring the frequency, and comparing its value with those obtained when a variable, calculable reactance is used. This calibrating reactance was made in the form of a short length of 1.75 cm. diameter, internally threaded brass cylinder, with a threaded brass plug carrying a graduated rod from which the position of the plug in the cylinder could be read. The cylinder was held against a standard receiver ear-cap, a plasticine seal being used at the joint, and the volume contained, at different positions of the plug, was measured by admitting water through the hole in the ear-cap from a burette. The volume could be varied from 0.5 to about 10 c.c.

It is shown in Appendix II. that the (elastic) reactance is $X=\frac{-\rho c}{kQ}$ where Q is the volume and ρ, c and k have the same meaning as previously employed. It remained therefore to determine the reactance of the ear in terms of the volume Q.

Accordingly the cylinder was placed in position on the ear-cap, the peak of resonance observed from the condenser transmitter output, and the frequency measured. This value was plotted against the corresponding value of Q. The cylinder was then replaced by the ear under test, held with normal pressure, and the frequency at peak of resonance again observed. The value of Q was obtained from this frequency reading from the calibration curve.

6. *Test Results.*—Test series were carried out on about 12 normal ears at frequencies near 1100 and 1600 cycles per second. At 1100 cycles per second the mean value of Q=3.3 c.c. (X = −61), the extremes ranging from 1.0 to 5.0 c.c. At about 1600 cycles per second the mean value of Q was 3.8 c.c. (X = −37), the extremes ranging from 2.0 to 5.0 c.c. It was further observed that when resistance damping, equivalent to that of a normal ear, was permitted, the calibrating reactance values were not appreciably affected.

A test series was next carried out at about 500 cycles per second, and it was found that many ears gave a negative value of Q, *i.e.*, a mass reactance* at this frequency. In order to confirm this phenomenon an alternative method was sought.

Accordingly a method was used employing mechanical resonance (instead of acoustical) and aural detection of the resonant frequency (instead of instrumental). The diaphragm of a Bell receiver was loaded at its centre with a mass of lead to reduce its resonant frequency to the neighbourhood of 500 cycles per second. This receiver was then held to the ear and the frequency adjusted to resonance, as judged by an observer listening externally, and the adjustment was then made again with the ear under test as judge of the resonant frequency. Calibration was carried out by means of the adjustable cylinder previously used, there being no difficulty in ascertaining the resonant frequency by listening externally. With some ears there was also no difficulty in determining the resonant frequency and agreement between both methods was good. The range in the values of Q so obtained extended from 0 to 3.5 c.c. With other ears, however, (about an equal number) there was considerable difficulty and there is no doubt that, as judged by either method, two resonant peaks existed, one above and one below normal. This phenomenon of double resonance may be observed when two resonant systems, whose natural frequencies are equal, or nearly so, are coupled together. It is illustrated by an experiment of Mallett and Dutton (*J.I.E.E.*, Vol. 63, May, 1925, p. 510, Fig. 12), who observed the acoustic output from a Bell type receiver at frequencies in the neighbourhood of the fundamental resonance, when the back of the diaphragm was exposed to a closed air column whose length was adjustable.

It was concluded therefore that a non-reactive impedance or a mass reactance at this frequency was obtained with some ears (this effect is discussed in Appendix II.) and a further test series was carried out on the resonator tube—this time under two conditions with each ear, namely, normal pressure and an increased pressure between ear and cap, (in order to ascertain the effect of leakage of sound). The results showed that with normal pressure a mean value of $Q = -0.5$ c.c. with a range of about ± 4 c.c. was obtained, but with increased pressure the mean value was $+1.7$ c.c. and the range about 0 to 4 c.c.

The results at normal pressure are very variable, as may be expected from the fact that these are critical to ear pressure, and an estimation of normality by sensation is necessarily somewhat crude. It is not therefore to be expected that an individual ear will give very consistent results on repetition. There is also the presence of the slot in the standard ear-cap, which may occupy any position relatively to the ear, and thus adversely affect consistent observations on an individual ear.

Part III.—Comment.

7. No attempt has been made to ascertain the nature of the forces operating to absorb sound in any individual ear. It is probable that the absorption is to a large extent accounted for by transmission of vibrations into the exposed flesh, from the nature of which it is to be expected that the extent of penetration will be small. The expenditure of energy can only be considered as useful in so far as it is located at the drum of the ear. From the observed differences in absorption which are liable as a result of slight differences in the position of the ear relative to the cap, it may be inferred that appreciable absorption takes place at the outer ear. The amount of sound energy that escapes into the outer air is not considered to be appreciable when there is a normal pressure between receiver and ear. It is shown, however, in *Appendix* II. that a small leakage can have a very considerable effect on the reactance component, and it may therefore exert an indirect influence on the resistance component. For example, if the leakage is such that its mass reactance is equal to the elastic reactance of the enclosed air chamber, a condition of resonance obtains, which has the effect of creating a larger impedance at the opening of the ear-cap. Under this condition the quantity of sound which enters the chamber is reduced and a smaller absorption is to be expected. The reactance component for an average ear is found to become zero at a frequency

* *The terms "Mass Reactance" and "Elastic Reactance" may conveniently be used to describe positive and negative acoustical reactances; c.f. "Inductive and Capacity Reactances."*

of about 500 cycles per second, and it is observed further that, at frequencies in this vicinity, the absorption is low and the variations with different ears are somewhat large, as may be expected when a critical effect such as resonance is introduced.

It seems not improbable that a similar effect may account for the high values of absorption observed at 2600 cycles per second. Such an effect would involve resonance of the elastic reactance of the air chamber with a mass reactance at the opening at the ear-cap, resulting in an abnormally low impedance at this opening. The necessary data to confirm this supposition are not at present available.

Although the variations in impedance appear to be accountable to a great extent on purely acoustical grounds, it is not to be expected that the mechanical properties of the texture of the ear can be ignored. During the investigation two ears, which were abnormal in that their hearing faculties were known to be below normal, came under observation. In both cases the impedances were found to be abnormal, one giving an exceptionally high value and the other an exceptionally low value of absorption at 1100 cycles per second. The former was also tested for reactance and was found to give a mass reactance at a frequency where normal ears all gave an elastic reactance.

It should be noted that the resistance and reactance components should be considered as acting in parallel. This may be seen from the manner in which the tests were carried out. It follows therefore that the rate of absorption of energy by the ear may be found from the equation: Power $= \frac{p^2}{R}$ where p = applied sound pressure and R is the resistance component of the impedance of the ear. It does not, of course, follow that this figure represents the rate of expenditure of energy in doing useful work.

Appendix I.

Acoustical Impedances applied to Tube Resonators.

a. With reference to Fig. **2**, suppose first that end A of a tube of sectional area S is closed by a partially absorbing plug, the reflection factor for pressures or velocities at this end being g.* Let the source of sound at end B be represented by a piston moving with velocity $= V_0\epsilon^{i\omega t}$. Suppose that the absorption along the tube and at end B is negligible as compared with that at end A. The length x of the tube refers to the distance between surfaces at which reflection takes place without change of phase.

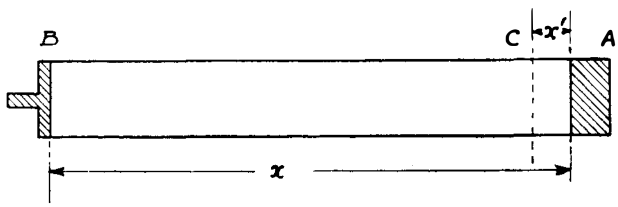


Fig. **2.**

The air velocity at B = piston velocity

$$= V_0\epsilon^{i\omega t}.$$

The pressure at B of the first wave (B to A)

$$= \rho c V_0 \epsilon^{i\omega t}.$$

The pressure at B of the second wave (A to B)

$$= g\rho c V_0 \epsilon^{i(\omega t - 2kx)}.$$

The pressure at B of the third wave (B to A)

$$= g\rho c V_0 \epsilon^{i(\omega t - 2kx)}.$$

and so on.

$$\therefore \text{ Total pressure at } B = \rho c V_0 \epsilon^{i\omega t}\left\{1 + 2g\epsilon^{-2ikx} + 2g^2\epsilon^{-4ikx} + \ldots\right\}$$

$$= \rho c V_0 \epsilon^{i\omega t}\left\{\frac{1 + g\epsilon^{-2ikx}}{1 - g\epsilon^{-2ikx}}\right\}$$

Whence the impedance at B $\left(= Z = \frac{p}{Sv}\right)$

$$Z = \frac{\rho c}{S}\left[\left\{\frac{1 - g^2}{1 + g^2 - 2g\cos 2kx}\right\} - i\left\{\frac{2g\sin 2kx}{1 + g^2 - 2g\cos 2kx}\right\}\right] \quad \ldots\ldots\ldots\ldots\ldots(1)$$

This equation applies to the impedance at B or at any section of the tube half a wave-length therefrom. It is capable of a number of useful applications, the first of which is to determine the relationship between the factor g and the acoustical resistance R at end A.

* *See previous article in this Journal on the Measurement of Absorption of Sound, Vol. 20, Part 2, July, 1927, p. 127.*

If x is put $=0$, $R=\frac{\rho c}{S}\left(\frac{1+g}{1-g}\right)$ ....(2)

Further applications will be made in Appendix II.

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b. Next suppose that there is absorption at B as well as at A, the reflection factor at B being g_0. A general equation can be obtained on the same lines, but for the present purpose it is only necessary to obtain the result when the tube is in resonance, *i.e.*, $\epsilon^{-2ikx}=1$.

As before, by summation of the separate waves, the pressure at B is proportional to

$$1+g+gg_0+g^2g_0+g^2g^2_0+\ .\ .\ .\ .\ .$$

i.e., $p=P\ (1+g)\ (1+gg_0+g^2g_0^2+\ .\ .\ .\ .)$

(Where P is a constant including a term for the velocity of piston).

$$\therefore\ \ p=\frac{P(1+g)}{(1-gg_0)} \qquad \text{.........(3)}$$

If the absorbing plug at A be replaced by a non-absorbing surface ($g=1$), the pressure at B becomes

$$p^1=\frac{2P}{1-g_0}$$

The ratio $\frac{p}{p^1}=D=\frac{(1+g)\ (1-g_0)}{2\ (1-gg_0)}$ ....(4)

---

c. If now the absorbing surface be retained at B, and a non-absorbing surface be placed at A, the general equations for the velocity and pressure at B, for any value of x, may be derived as follows :—

As before, the piston velocity $=V_0\epsilon^{i\omega t}$.

The air velocity at $B=v=V_0\epsilon^{i\omega t}-V_0\epsilon^{i(\omega t-2kx)}+gV_0\epsilon^{i(\omega t-2kx)}-\ .\ .\ .\ .$

$$=V_0\epsilon^{i\omega t}\left(\frac{1-\epsilon^{-2ikx}}{1-g_0\epsilon^{-2ikx}}\right)$$

[Note that this is not the same as the piston velocity, since the supposition of absorption by the piston presumes relative motion between piston and air.]

The pressure at B=

$$p=\rho cV_0\epsilon^{i\omega t}\left\{1+\epsilon^{-2ikx}+g_0\epsilon^{-2ikx}+g_0\epsilon^{-4ikx}+\ .\ .\ .\right\}$$

$$=\rho cV_0\epsilon^{i\omega t}\left\{\frac{1+\epsilon^{-2ikx}}{1-g_0\epsilon^{-2ikx}}\right\}$$

[The acoustical impedance of the tube at B is therefore

$$Z=\frac{\rho c}{S}\left(\frac{1+\epsilon^{-2ikx}}{1-\epsilon^{-2ikx}}\right),\ \text{independent of } g_0.]$$

For a prescribed constant motion $V_0\epsilon^{i\omega t}$ of the piston

$$p=\rho cV_0\epsilon^{i\omega t}\left\{\frac{(1-g_0)(1+\cos 2kx)-i(1+g_0)\sin 2kx}{1+g_0{}^2-2g_0\cos 2kx}\right\}$$

The modulus is proportional to

$$\left[\frac{2(1+\cos 2kx)}{1+g_0{}^2-2g_0\cos 2kx}\right]^{\frac{1}{2}}$$

Let F = ratio of this value when $\cos 2kx=1$ to that when $\cos 2kx=\cos 2kl$.

$$\text{Then } F=\left(\frac{2}{1-g_0}\right)\left[\frac{(1-g_0)^2+4g_0\sin^2 kl}{4\cos^2 kl}\right]^{\frac{1}{2}}$$

$$=\left[1+\left(\frac{1+g_0}{1-g_0}\right)^2\tan^2 kl\right]^{\frac{1}{2}} \qquad \text{..............(5)}$$

$$\left.\begin{aligned}\therefore\ \ \frac{[F^2-1]^{\frac{1}{2}}}{\tan kl}&=\frac{1+g_0}{1-g_0}=K\\ \text{and } g_0&=\frac{K-1}{K+1}\end{aligned}\right\} \qquad \text{.................(6)}$$

APPENDIX II.

Acoustical Impedances applied to Helmholtz Resonators.

d. Equation (1) of Appendix I. may be used to find the acoustical (elastic) reactance of a small, rigid walled chamber whose dimensions are small as compared with a wave-length—such for example as the calibrating cylinder referred to in Part II. of the text. When $g=1$, the impedance at end B of the tube is

$$Z=-\frac{i\rho c}{S}\cot kx.$$

For small values of kx, $\cot kx=\frac{1}{kx}$.

$$\text{Whence } Z=-\frac{i\rho c}{Skx}=-\frac{i\rho c}{kQ} \qquad \text{................(7)}$$

where Q = volume of the chamber.

[The operator i signifies pure reactance and the negative sign that the reactance is elastic.]

The equation applies to a chamber of any shape, provided that each dimension is small as compared with a wave-length, and that absorption is inappreciable.

If now the piston at B is replaced by a thin wall with a small aperture, diameter d, the acoustical mass reactance of the aperture is $+\frac{i\rho\omega}{d}$

The reactance at the aperture (dropping the operator i) is therefore

$$\left.\begin{aligned} Z &= \frac{\rho\omega}{d} - \frac{\rho c}{S}\cot kx \\ &= \frac{\rho\omega}{d} - \frac{\rho c}{kQ} \text{ (for small values of } kx) \end{aligned}\right\} \ldots(8)$$

(This equation is given by Richardson, Proc. Phys. Soc., Vol 40, Part 4, June 15, 1928).

At resonance the impedance at the aperture becomes zero (if dissipation is neglected), and

$$\frac{\rho\omega}{d} = \frac{\rho c}{kQ}$$

$$\text{or} \quad \omega^2 = \frac{dc^2}{Q} \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

The usual formula for resonance of a simple resonator.

e. The effects of leakage of sound, when an ear is held to an ear-cap, on the reactance at the ear-cap may be deduced by substituting for the mass reactance of the leakage sound, that of an aperture, diameter d, in a thin wall. Let this wall then occupy end A of the tube.

If absorption at the aperture is neglected, reflection will take place as if from a solid surface (*i.e.*, the magnitude of the reflected wave = that of incident wave). Owing to reactance at end A this surface will not be at A, let it lie at C, where $AC = x^1$. Now when $x = x^1$, since the impedance at C is, by hypothesis, infinite resistance, the tube becomes a Helmholtz resonator, whence from (9) $x^1 = \frac{d}{Sk^2}$, and the impedance at A is, in general.

$$Z = -\frac{i\rho c}{S\tan k(x - x^1)}. \quad \ldots\ldots\ldots\ldots(10)$$

The tube resonates (giving a maximum pressure at end B) when $x - x^1 = \frac{n\pi}{k}$, where n is an integer.

Two important effects of leakage sound may be deduced: (1) The presence of leakage raises the frequency of resonance of the tube, since $k = \frac{n\pi}{x - x^1}$, which is greater than the value at resonance with no leakage, namely, $k = \frac{n\pi}{x}$; and (2) This effect of leakage becomes greater as the mass reactance of the aperture, $\frac{\rho ck}{d}$, becomes smaller as compared with the elastic reactance of the air chamber, $\frac{\rho c}{kQ}$; that is as k^2 becomes smaller as compared with $\frac{d}{Q}$.

Suppose, as a numerical example, that the tube is terminated by a chamber whose volume is 4 c.c., and which has an aperture 0.04 cm. diameter in one wall. The reactance of the chamber is $X = \frac{\rho c}{kQ_0}$ where $Q_0 = 4 - Sx^1 = 4 - \frac{0.04}{k^2}$.

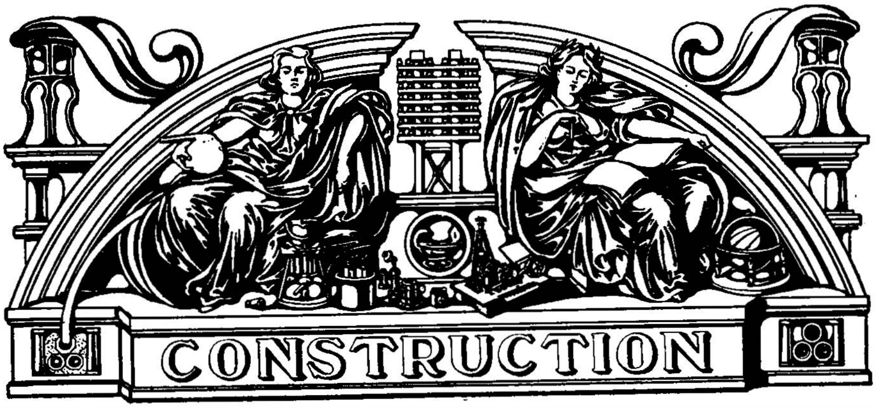
When therefore $k = 0.1$ (540 cycles per sec.) $Q_0 = 0$ and the impedance is non-reactive.

When $k < 0.1$ the impedance has mass reactance.

When $k = 0.2$ (1080 cycles per sec.) $Q_0 = 3$ c.c.

When $k = 0.4$ (2160 cycles per sec.) $Q_0 = 3.75$ c.c.

This example gives results which are quantitatively similar to the observed reactances of the space included between the ear and the standard cap.



RENEWAL OF LAND LINES AT FAYAL, AZORES.

AN engineering operation of an interesting character has been carried out recently at Fayal, Azores. These islands in the Atlantic, belonging to the Republic of Portugal, are conveniently placed on the routes of several Transatlantic cables. Two of these cables, led in and out at Fayal, belonged originally to the German Government and were taken over after the Armistice as part of the reparations, one by the British Administration (this cable being known to-day as "Imperial No. 1,") whilst the other is operated for the French Government.

The land lines at Fayal associated with these two submarine cables were in urgent need of renewal and the position was becoming the more serious because of earthquake disturbances,—a frequent visitation at the Azores. When it became known that the British and French land-line cables were to be renewed, it was ascertained that the Eastern Telegraph Company also desired to have similar work done, and it was agreed that the British Post Office Engineering Department should undertake the whole of the operations. This included the design, laying and testing of the British and French armoured cables, and also the laying and testing of two armoured cables for the Eastern Telegraph Company, all the work to be done in a common trench; the total length concerned being $1\frac{3}{4}$ miles.

The works estimate was prepared in London and dependence placed upon such information as could be obtained by correspondence with local representatives of the Cable Companies in regard to measurements, wayleaves, contours, sub-soil, pavings, obstructions, transport, labour, and other details attending the construction of underground work in a foreign country;—matters which, though not troublesome in like circumstances at home, may loom large when there is no one to whom to appeal, or Acts of Parliament to invoke!

The cable designed for the replacement of the British and French land lines is of a special type and was supplied by Messrs. Siemens. A section of the cable is shown in Fig. 1. It

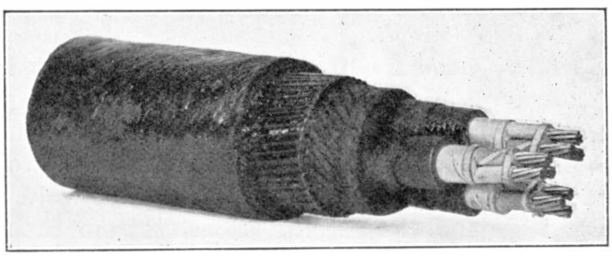


FIG. 1.—SECTION OF CABLE.

consists of three separate tri-core lead covered cables formed into one armoured cable of an overall diameter of $2\frac{1}{4}''$. The conductors are made up of a strand of seven copper wires of equal diameter, the weight and resistance per statute mile of each stranded conductor being 300 lbs. and 3.03 ohms respectively. Each stranded conductor is covered with four lappings of paper, the outermost being coloured red, blue or white for identification of the individual cores. The three conductors are so laid up as to form a compact and cylindrical cable and finally wrapped overall with two lappings of insulating paper. The cable thus formed is lead sheathed and covered first with a coating of compound, then with a double wrapping of impregnated paper and a final coating of compound. The three lead sheathed cables are laid up on a central core of tarred jute yarn, wormed and served with sufficient tarred jute yarn to receive the sheathing of 45 galvanised iron wires of No. 12 S.W.G., each of which had been separately coated with preservative compound before application to the cable. The armouring is covered overall with two servings of stout three-ply tarred jute yarn alternating with two coats of compound, and the finished cable whitewashed. The electrostatic capacity from each wire to earth is 0.3 microfarads per mile, and the insulation resistance 5,000 megohms per mile per wire.

A special type of jointing coupling has also been used in connection with the work and details of this fitting are shown in Fig. **2**. It consists of a cast iron box, with specially designed conical clamp fittings at each end to grip the armouring wires. Any strain coming on the armouring of the cable is transmitted across the box by means of mild steel bolts. Three lead sleeves are accommodated in the jointing coupling. The joints are staggered as shown in Fig. **2** and ordinary wiped joints made in each case. In order to maintain high insulation, each of the lead sleeves is filled with paraffin wax, and when the joints have been completed, the box itself is filled with compound. An earthing bond is provided in order to maintain continuity between the armouring of the lengths of cable on each side of the coupling.

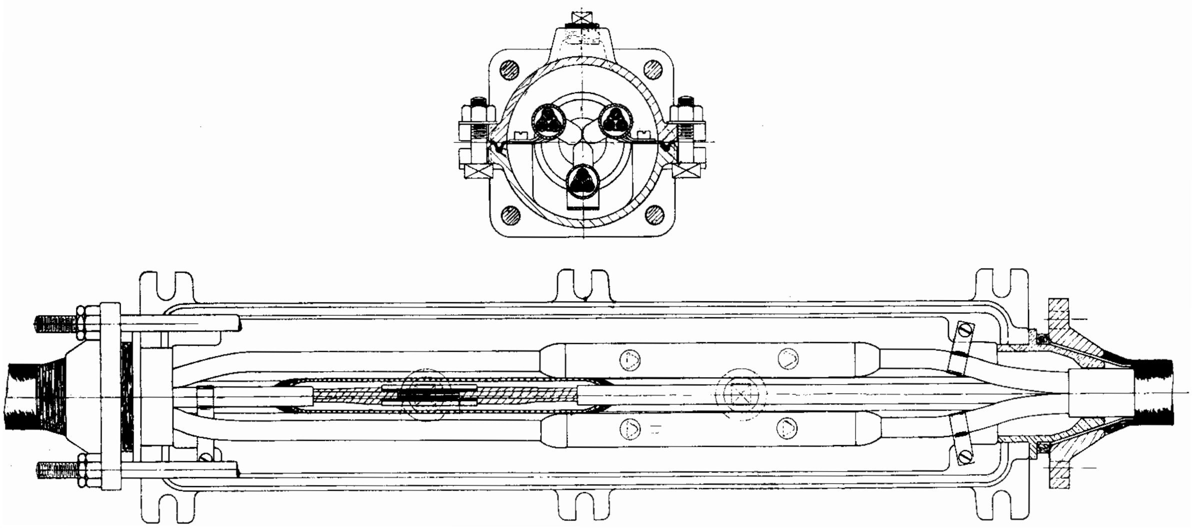


Fig. 2.—Straight Joint Box.

A special type of terminal box has also been designed for the termination of the British and French land lines at the cable hut and cable station respectively. An open and closed view of the terminal box is shown in Fig. **3**. The three individual lead covered cables are brought out from the armoured cable and led into separate brass glands at the bottom of the box. The paper cables are sealed with compound at the back of an ebonite panel. Each conductor is brought through this panel by a long ebonite bush to the front portion of the box so that leakage is prevented, and the terminations to the apparatus made of single leads of "Maconite." The arrangement proved an efficient and accessible termination of the armoured cables.

The transport arrangements at Fayal are of the most primitive order; practically all haulage work is done by bullock teams. It is understood that a mechanical tractor was once left at Fayal by a firm of contractors, but the alleged reason for this is that the taxes imposed by the public authority were so heavy that it paid the contractors to leave the machine behind!

It was impossible to rely upon any local help in the supply of tools and small stores for the work, and all such items had to be shipped from England. The term "Subsidiary stores" became an important matter; there was no convenient section stock stores round the corner from which deficiencies could be made good!

There is no direct steamship service between London and Fayal and the bulk measurement of 65 heavy drums of cable, 30 bulky cases and many loose bundles was considerable. The question also arose as to the possibility of shipping all the goods on one small steamer. If not, a delay

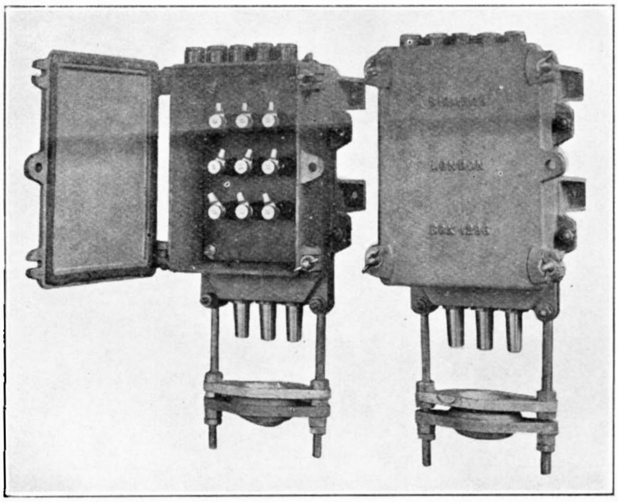


FIG. 3.—SPECIAL TERMINAL BOX.

of a month or so between the arrival of different steamers would be exasperating, and probably the items most urgently required would miss the first boat. Luckily, the Post Office stores were the first to be handled at the docks and all were safely stowed under hatches on the same steamer.

Mr. J. Churchman, a Chief Inspector with a wide knowledge of underground work in the London Engineering District, was sent out in charge of the work and he had with him two experienced plumber - jointers in Messrs. Wheatley and Lilburn, also of the London District. A local gang of 50 was engaged for the unskilled work. The foreman or charge-hand engaged at Fayal understood both English and Portuguese and acted as interpreter, and he also succeeded in getting the best results out of the men. At the outset there was considerable difficulty experienced in securing permission to land the stores and tools at Fayal without paying exorbitant import taxes and municipal dues; the original claim was made that 120 per cent. of the value of all stores and tools should be paid to the Portugese authorities. Through the help of His Majesty's Ambassador at Lisbon it was finally agreed that the government and municipal taxes would be waived.

According to a law in operation at the Azores, it is laid down that if a workman is killed whilst at work, the employer is required to maintain the widow for life and also the children until they are self-supporting. If the workman is permanently injured, a large proportion of his wages is payable for life to his wife. In view of these legal obligations, combined with the facts that inexperienced labourers were being employed, that blasting work had to be done, also that heavy cable drums had to be transported on hilly roads rising 1 in 4, local arrangements were made to insure the workmen with a Portugese Insurance Company and the responsibilities for life pensions, etc., transferred to other shoulders. The only accident had to do, not with the workman, but with a cow which fell into the trench! The cow injured itself so severely that it had to be destroyed and the owner claimed damages. Although the trench was roped off and the cow was a trespasser, it was agreed with the Vice-Consul to pay a small sum to the native owner rather than to dispute the claim in the courts and probably waste time.

A demand was made at the outset by the night watchman engaged on the work that firearms should be issued to them because of the lonely nature of the roads at night time and possible visits of thieves. The application was considered, but the probable consequences from the use of revolvers far outweighed those from loss of tools, and the request was not granted. It is fair to say that there were no losses of tools to report.

A "cable drum carrier" was made in England and taken out for the handling of the drums of cable. This device, which consists of a pair of wheels and a special axle, enabled the drums to be lifted from the ground, taken to the site

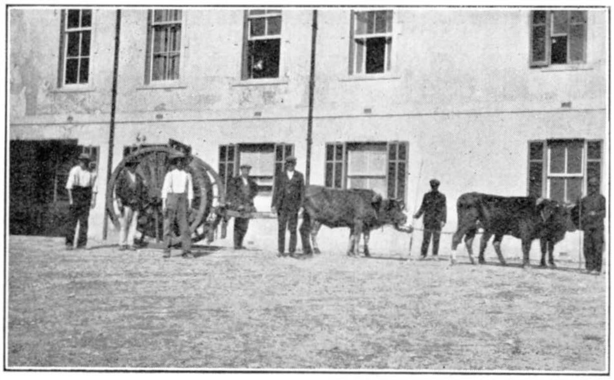


FIG. 4.—CABLE DRUM CARRIER.

and the drum revolved for the delivery of the cable at the trench. Bullock teams were used for transport purposes. Fig. 4 shows the cable carrier and its team of four bullocks ready to start work.

"Skids" had been provided with the cable carrier for use as brakes on hilly roads, but the municipal authorities declined to allow the skids to be used because of the loose nature of the roadway surface. The local custom is to use bullocks as brakes and this method was adopted in transporting heavy drums of cable down hill. Ropes were extended from the rear of the cable carrier and fixed round the necks of two bullocks who took the strain whilst moving slowly forward. The animals seemed to understand what they were required to do, and as a result, loads weighing nearly three tons were taken down some particularly steep hills. Fig. 5 shows this living brake in action.

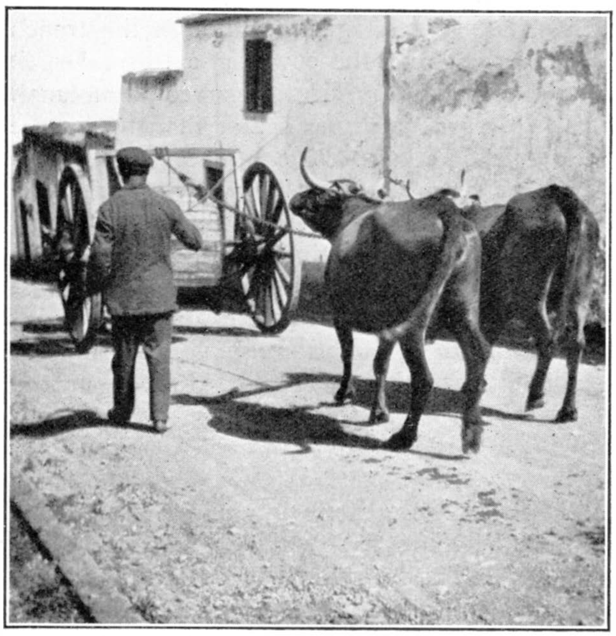


FIG. 5.—THE BULLOCK BRAKE.

Cable rollers were used in order to facilitate the running out of the cables in lengths of 220 yards. These rollers, which consist of a curved metal wheel free to revolve on a wooden base, were fixed at intervals alongside the trench; the cable paid out from the drum and placed on the rollers and finally the cable lifted into position in the trench. A sketch of the cable roller is shown in Fig. 6. A portion of the trench work in progress is shown in Fig. 7.

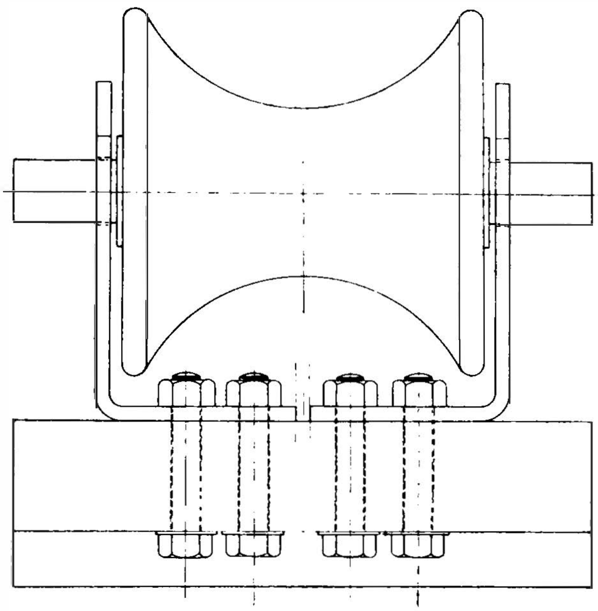


FIG. 6.—CABLE ROLLER.

Reference has already been made to the frequency of earthquakes at the Azores. Whilst the Post Office work was in progress shocks were experienced on two separate occasions. In the first instance a violent shaking of the ground occurred,—noises resembling rolling thunder attended by falling masonry and the screams of women and children. Later in the same day another disturbance occurred which resembled the knocking of a heavy steam hammer underground and causing violent movement of the earth. Fortunately no serious damage was done by these visitations. Two views of damage caused by former earthquakes are shown in Figs. **8** and **9**. Fig. **8** shows a deep fissure in one of the streets at Fayal, and Fig. **9** indicates the serious damage caused to one of the churches.

The nature of the sub-soil on the trench route varied from soft sand, loose stones, pumice stone, to hard rock. The latter was really hard and crumpled up the points of steel wedges without making any impression on the rock, and blasting had to be done. Some 70 yards of rock was treated in this way, often in roads with houses on either side which had already been cracked and dilapidated through recent earthquakes. In

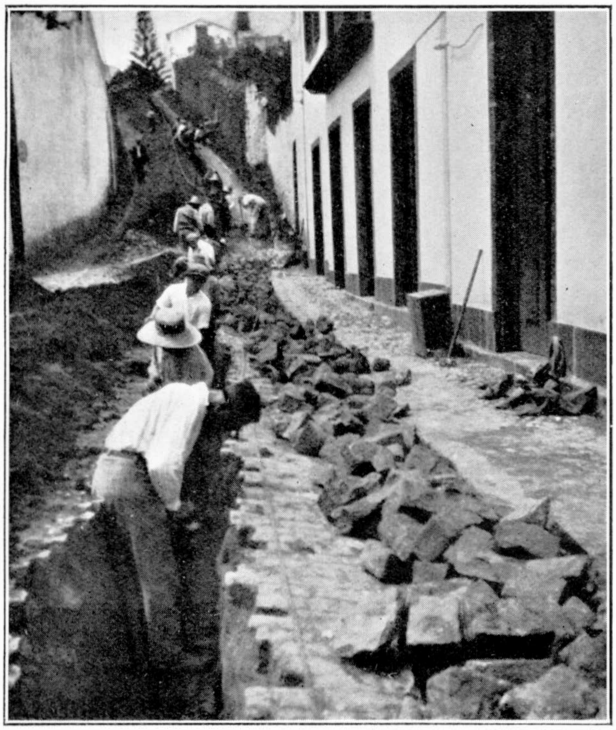


Fig. 7.—Trench work at Fayal.

one instance, a house was occupied by the military authorities in which gun-powder was stored. The trench had to be cut within six feet of the wall of the building which was already very much cracked. Gummed paper was placed across the cracks in this instance before the blasting started and this paper was found to be intact after the explosion, otherwise it was feared that a claim for extensive repairs might have been made against the Department!

The reinstatement of roads after trenching caused some anxiety, as according to the

Fig. 8.—Fissure caused by Earthquake.

municipal laws in operation at Fayal, the whole width of the road is required to be remade after a trench has been cut. After a discussion with the Civil Governor on this subject, it was agreed that, where the road was good and the trench carefully reinstated, so that the camber of the road was maintained, he would not insist on the application of the letter of the law. The authorities were satisfied with this arrangement in connection with the reinstatement of some 1,300 yards of trench, but in a length of ¾ mile, the reinstatement had to be effected to the whole width of the roadway, ranging from 15 feet to 20 feet. This involved digging over the entire surface and placing thereon two to three inches of "Saibro," a fine red volcanic sand which had to be dug and sifted at a quarry nearly 2½ miles away and carted by bullock wagons to the points required. On one occasion the Department had as many as 17 wagons and 34 bullocks employed on this work.

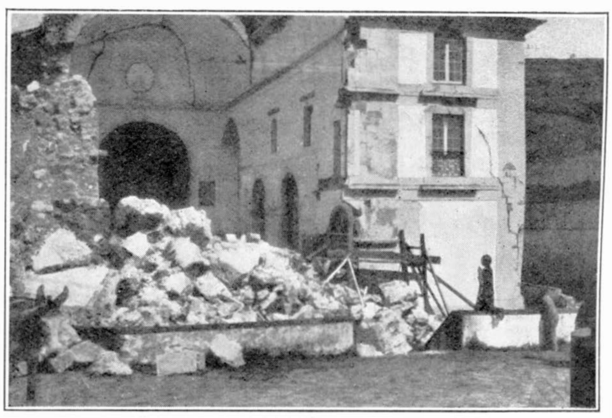


Fig. 9.—Damage done to Church by Earthquake.

An antiquated roller, some 7 feet long and 4 feet in diameter was hired for the reinstatement work. This looked like an old marine boiler provided with a door at each end so that the roller could be filled with earth. A centre pole was fitted and the machine drawn by bullocks. In some portions of the road, with gradients of 1 in 4, eight bullocks were required and formed

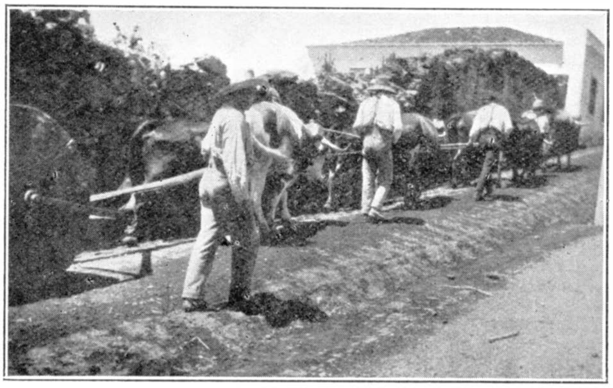


FIG. **10**.—REINSTATEMENT WORK IN PROGRESS.

quite a procession, as a goader or driver was required for each pair of bullocks; in addition, men followed up with shovels in order to keep the surface of the roller clean. Fig. **10** shows the roller, complete with bullocks and drivers.

Generally speaking the native labourers were found to be hard working, eager, and good time keepers. As an example of this, the night watchmen, whose duty did not commence until 5 p.m., were in the habit of assisting in the digging and the performance of odd jobs for two hours before they were due to commence work on their night watching operations. In passing, it should be mentioned that the pay of the labourers engaged on the work was based on rates paid for similar work by the cable companies and was in advance of the normal labourer's wage at Fayal; there was much competition for employment. It is interesting in this connection to note that the casual labourers at Fayal sometimes have a stroke of luck when a whale is sighted off the coast. The appearance of the whale is reported by the firing of a gun from one of the hills and when this signal is heard every man throws down his tools and rushes off to chase and kill the whale. This operation usually takes about three days to accomplish and, as a result, local labour is at a standstill until the great adventure is over. Fortunately, no whales were signalled during the progress of the Department's operations and the work was carried through without interruption from start to finish.

The writer desires to express his thanks to Mr. Churchman for much assistance in the preparation of this article and, in particular, for the photographs of the operations at Fayal.

A. O. G.

THE MEASUREMENT OF INDUCTANCE AND EFFECTIVE RESISTANCE OF LOADING COILS.

L. E. RYALL, B.Sc., Eng.

BOTH the inductance and the effective resistance of the loading coils in underground lines affect the characteristics of the line considerably, and hence the accurate measurement of these quantities is important.

As the attenuation of a loaded line is approximately proportional to the resistance of the line, (for the same type of loading) the effective resistance of the loading coils inserted in the line must be made as small as possible. If we assume that 40 lb. conductors, with 177 mH. loading at 1.125 miles spacing, have unit attenuation if the loading coils have no resistance, in practice, with the loading units at present in use, attenuations of 1.25 units at 1000 p.s. and 1.40 units at 2000 p.s. are observed. The effective resistance of these units at various frequencies is shown in Fig. **1**.

The accurate measurement of the inductance

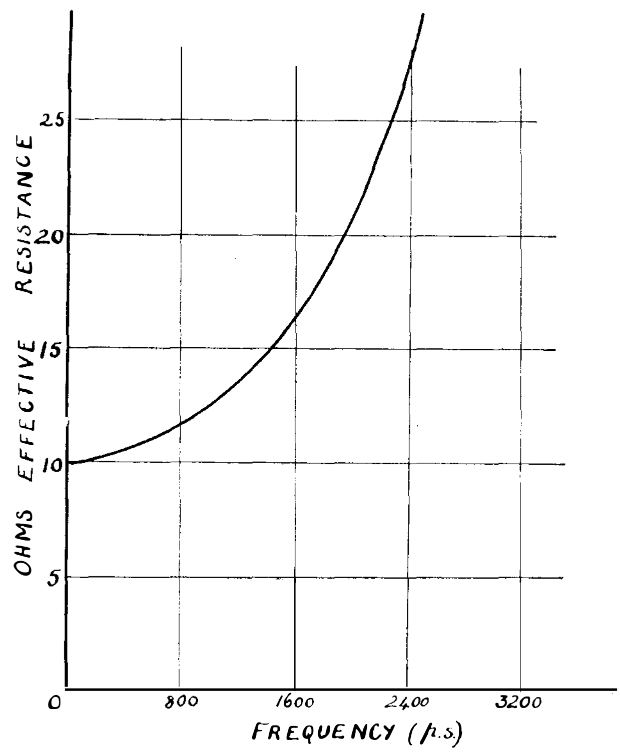


FIG. **1**.—EFFECTIVE RESISTANCE OF 177 MH. LOADING COIL.

of loading coils presents little difficulty and can be performed satisfactorily by a number of the a.c. bridge methods, provided that the Wagner earthing device for maintaining the telephone receiver at earth potential be used.

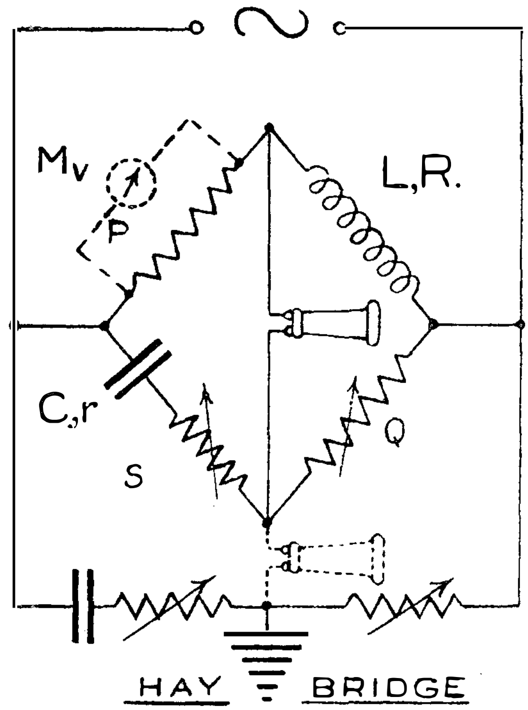


FIG. **2**.

The effective resistance of the modern dust core loading coil is very small, and the angle of the impedance is nearly 90°. Hence, unless the resistances, condensers, etc., comprising the bridge are pure, the value of the effective resistance obtained may be very different from the true value.

The Hay bridge, Fig. **2**, is very suitable for measuring inductances with good angles. The usual formulæ for the inductance, L (henries), and effective resistance, R (ohms), if the bridge resistances and condensers are pure, are as follows :—

$$L = \frac{PQC}{1+\omega^2C^2S^2} \quad \ldots\ldots (1)$$

$$R = \omega^2 LCS \quad \ldots\ldots (2)$$

$$= \frac{\omega^2C^2PQS}{1+\omega^2C^2S^2}$$

These formulæ are correct only :—

(*a*) If the rheostats used in the bridge are non-reactive, and

(*b*) If the condenser has no loss.

The condition (*a*) can be met sufficiently if the highest grade rheostats are used. It is important, however, that these rheostats should have a maximum value not greater than about 1100 ohms, as the addition of a "thousands" dial, even if not in use, is liable to introduce slight capacity errors in the instrument. These capacity errors reduce the value of the bridge resistance S, and this reduction is independent of the frequency. As the effective resistance to be measured is a function of $\omega^2 S$, the error introduced in the effective resistance is proportional to (frequency)^2. This error, however, is negligible up to 3000 p.s. if the highest grade rheostats are used under the conditions specified above.

Condition (*b*) can only be satisfied by using a condenser with air dielectric. The best mica condensers have a power factor of between 0.0002 and 0.0003, which gives an error of between 4% and 6% in the resistance measurement of a dust core loading coil, at a frequency of about 1600 p.s. This condenser loss can be represented by a resistance *r*, placed in series with the pure capacity of the condenser, so that the power factor of the combination is the same as that of the mica condenser under consideration. This equivalent resistance *r* of the mica condenser can be determined by making measurements of a coil, using the series resonance bridge in conjunction with the Hay bridge.

The Series Resonance Bridge.

The circuit diagram is shown in Fig. **3**. In general the resistances N, P and Q are each 100 ohms.

If the resistances N, P and Q are assumed to be non-reactive, the values of L and R, for equal values of P and Q, are given by the equations

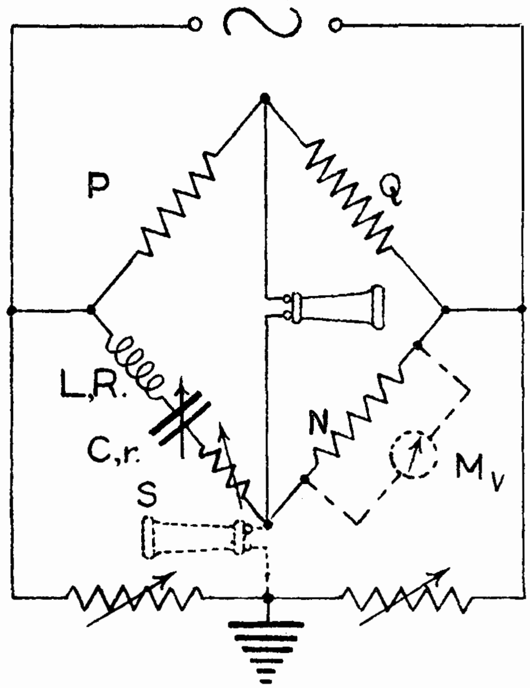
$$L = \frac{1}{\omega^2 C}$$

and $R = N - S - r$.

where *r* is the equivalent resistance of the condenser of capacity C.

It is seen that the true resistance, determined by this bridge, is *less* than the apparent resistance, if the resistance component *r* of the condenser, C, is neglected.

If now, the value of R is determined by the Hay bridge, using the same capacity C of the condenser, and balancing the bridge by varying P, Q and S, then



SERIES RESONANCE BRIDGE.

Fig. **3**.

$$R = \omega^2 CL(S+r)$$

i.e., $R = S + r$

since $\omega^2 CL = 1$.

Thus the true resistance is *greater* than the apparent resistance if *r* is neglected. Hence, if the mean of the two values of R, as found by the series resonance bridge and the Hay bridge, be taken, the error due to the resistance of the condenser is eliminated.

Use of Air Condenser in Hay Bridge.

To facilitate the measurement of loading coils, a large air condenser, of capacity 0.04 microfarads was made up. It consisted of two sets of brass plates, (50 plates per set), each plate being 12 inches square and 0.045 inches thick. The clearance between adjacent plates was approximately 0.070 inches. Each set of plates was securely mounted on four stout brass pillars and rigidly clamped to, but insulated from, a cast aluminium base. Each set of plates was turned through an angle of 45° with respect to the other set. The condenser was completely screened and mounted in a cubical case, its overall dimensions being 21 inches.

The resistance of this condenser, as determined by the two bridge methods described above, was found to be less than 0.1 ohms. Hence the values of the resistance and the inductance of loading coils can be found accurately using only the Hay bridge, since the large size condenser needs comparatively small resistances for the bridge arms, P and Q, and thereby rheostat errors are reduced to a minimum.

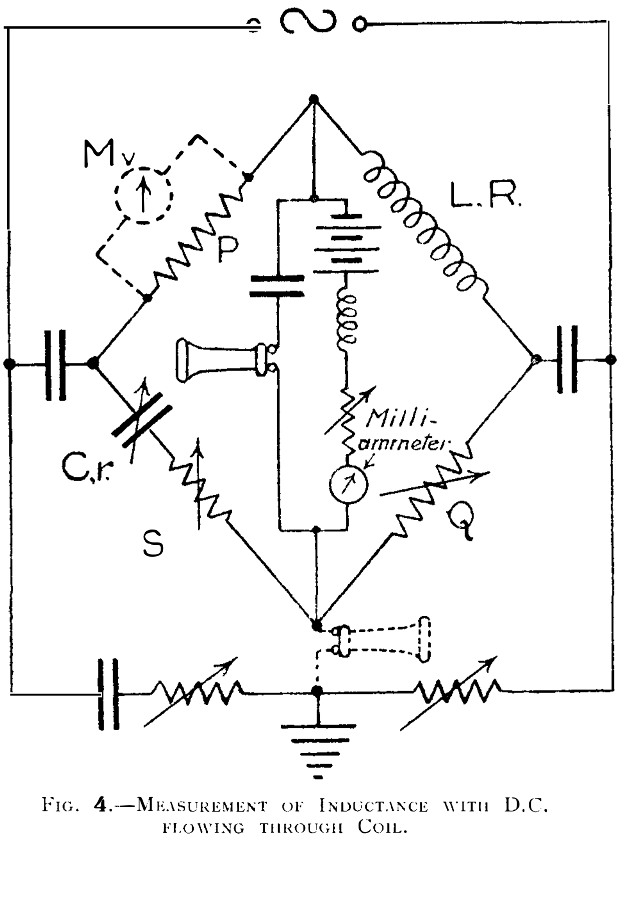


Fig. 4.—Measurement of Inductance with D.C. flowing through Coil.

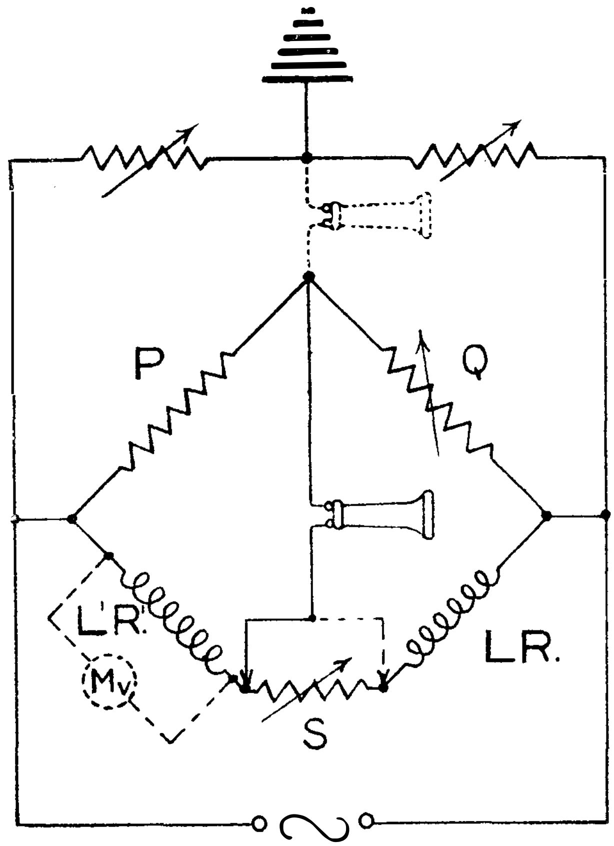


Fig. 5.—Slide Wire Comparison Method.

Measurement of Inductance with D.C. flowing through the Coil under Test.

The modifications necessary in the Hay bridge to enable the inductance of a coil with D.C. flowing through it to be measured are shown in Fig. 4. A low resistance choke is inserted in the battery leads to prevent the telephone receiver being short-circuited.

The value of the testing current (a.c.) is most satisfactorily measured by reading the voltage across the resistance P with a Moullin type thermionic voltmeter M. The voltmeter should be removed before final adjustment of the bridge is made.

Slide Wire Comparison Method for the Measurement of Inductance and Resistance.

For rapid testing of large numbers of coils (*e.g.*, acceptance tests), a slide wire comparison test can be made.

The circuit diagram is shown in Fig. 5.

The coil L,R, to be measured is compared with a standard coil L′R′.

The values of L and R are given by the formulæ—

$$L = L' \frac{Q}{P}$$

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

If $R < R' \frac{Q}{P}$, connection to resistance S from the telephone should be made as shown by the dotted lines, and then,

$$R = R' \frac{Q}{P} - S$$

If the standard coil has approximately the same angle as the coil under test, the resistance S will be very small or zero, and errors due to the reactive component of this resistance can be neglected.

Further, provided the inductance of the standard coil is of the same order as the test coil, the resistance P will be of the same order as resistance Q, and, if these resistances are of the same type (and practically non-reactive), the angles of these resistances will be the same, and no error will be introduced in the value obtained for the inductance L and the effective resistance R of the coil under test.

A good quality loading coil forms a satisfactory standard coil, and should be calibrated, as described previously, with specified a.c. test currents. The a.c. test current can be ascertained by measuring the voltage across the standard coil with a Moullin type thermionic voltmeter, which should be disconnected before making final bridge adjustments.

It is important that no direct current should be passed through the standard coil, as the inductance would be altered by so doing.

Summarising these results, it is seen that for accurate measurement, by means of the Hay bridge, of the effective resistance of loading coils, the bridge rheostats must be as non-reactive as possible, and the bridge condenser must be an air condenser of large capacity, or else its resistance must be determined. The Hay bridge is then satisfactory for loading coil measurements, using frequencies up to 3000 p.s. It is estimated that the inductance can be measured with an error of less than $\pm 0.5\%$ and the resistance can be measured with an error of less than $\pm 2\%$.

For rapid routine testing a slide wire comparison method may be used. A standard loading coil, of which the inductance and effective resistance are known, is then required.

This article gives details of measurement by means of capacity bridges only, as previous work on bridges using inductance had indicated that accurate results could not be obtained without specially made (and very expensive) inductance coils, in the use of which elaborate precautions are necessary to avoid errors due to stray magnetic fields and capacity effects.

NOTES & COMMENTS

PROFESSIONAL CIVIL SERVANTS.—The dinner of the Institution of Professional Civil Servants was held at the Connaught Rooms on Thursday, 29th November. Sir Samuel Hoare, Secretary of State for Air, was the principal guest and proposed the toast of the Institution. Sir Richard Redmayne, President of the Institution, replied.

Mr. F. A. A. Menzler, Chairman of the Council of the Institution, proposed "The Guests," and Sir Russell Scott, Controller of Establishments at the Treasury and Chairman of the National Whitley Council, and Professor Julian Huxley replied.

There were 330 present, and amongst the guests were:—Sir Evelyn P. Murray, K.C.B., Secretary, Post Office; Sir Brodie H. Henderson, K.C.M.G., C.B., President, Institution of Civil Engineers; Lt.-Col. K. Edgecumbe, R.E.(T.), President, Institution of Electrical Engineers; Professor Julian S. Huxley, President, Association of Scientific Workers; and Mr. C. B. Fisher, C.B.E., President, Surveyors' Institution.

The Civil Service Arts Magazine.—We are pleased to note that the Arts movement in the Civil Service will soon have its own Magazine. An influential Editorial Committee, representing the various arts, has been formed to produce an illustrated Quarterly, "The Civil Service Arts Magazine," price sixpence, the first number of which will appear early in the New Year. The Committee is as follows:—Sir Cecil Harcourt Smith, C.V.O., L.L.D.; Prof. W. Rothenstein; Dr. Arthur Somervell, Mus. Doc.; Mr. N. Curtis-Bennett, C.V.O.; Dr. G. F. Herbert Smith, D.Sc.; Mr. C. J. G. Tate, O.B.E.; Mr. F. M. Chapman; and the Editor is Mr. S. McKechnie.

"The Civil Service Arts Magazine" will publish announcements and reports supplied by the various Societies, and a great deal of space will be devoted to lengthy and authoritative criticisms of Dramatic Performances, Art and Photographic Exhibitions, Concerts, etc., with illustrations. Articles on the different arts and book reviews will be a prominent feature, and for these the Magazine is assured of the services of many notable writers. The art paper and high-class printing will make the Magazine a record of their activities and achievements which members of Societies will be proud to treasure. The Magazine, of course, will also appeal to the general reader with an interest in the various arts.

Communications from those willing to act as Agents or assist in any way should kindly be sent to the Editor, "The Civil Service Arts Magazine," Room 208, Treasury Chambers, London, S.W.1.

Mr. H. M. Pease has relinquished the position of Managing Director of Standard Telephones and Cables, Limited, due to the pressure of work occasioned by his position as Vice-President and General Manager in Europe of the International Standard Electric Corporation.

Mr. Frank Gill has been appointed Chairman of the Board and Mr. E. S. Byng Managing Director of Standard Telephones and Cables, Limited.

Mr. Reginald Alexander Dalzell, formerly Director of Telegraphs and Telephones, died at Dulwich Village on Tuesday, 27th November, at the age of 63. The following notice is taken from *The Times* of the 28th November:—

"Mr. Dalzell was the son of the late Mr. Nicholas A. Dalzell, Conservator of Woods and Forests, and was born at Poona in 1865. He was educated at Dulwich College, and in 1881 entered on his long connexion with the telephone service, first with the Globe Company, then with the United Company, and afterwards with the National Telephones. When the National Company was taken over by the State in 1912, Mr. Dalzell, who was then Provincial Superintendent for the West of England, was transferred to the Post Office, and in 1916 became head of the Traffic Section. In 1922 he was promoted to be Director of Telegraphs and Telephones, and Mr. Kellaway, who was then Postmaster-General, in announcing the new appointment, described Mr. Dalzell as one of the ablest men on the telephone side. One of the most important developments during his tenure of office was the opening of the Transatlantic telephone service. By his friends at the Post Office his death will be felt as a real personal loss, for they had learnt to know him not only as a very competent departmental chief, but also as a very lovable colleague. He retired from the service only in July of last year. Mr. Dalzell leaves a widow and one daughter."

The Telephone Development Association has taken a large space at the Schoolboys' Own Exhibition in the New Horticultural Hall, Westminster, from December 29th till the 5th January, for educational work in connection with the use of the telephone. An actual working board of automatic apparatus is being shown, as the Association is of the opinion that that type of apparatus will be universal when the youngsters are old enough to have an office or house of their own. Side by side with this exhibit, are shown early models of telephone parts and apparatus, Graham Bell's first telephone, etc., lent and arranged by the South Kensington Science Museum, to demonstrate the enormous advances made in telephone engineering during the last fifty years.

The Association has been pressing upon the Government the desirability of increasing capital expenditure on telephone works, which, it is argued, can be made revenue earning without undue loss of time by an energetic publicity campaign. Figures are quoted from the Commercial Accounts of the Post Office, showing that during the past five years the net surplus from the telephone service, after paying Interest on Capital, Administrative and operating expenses, maintenance, depreciation, pensions, etc., has amounted to £3,833,137, which amount, of course, has reverted to the Treasury. There were lean years earlier, however, before the rates were raised, and Sir Henry Bunbury has pointed out that the capital cost per station is continually rising. A publicity campaign to induce subscribers to use their telephones oftener would also be of value.

The High Commissioner for Canada in London communicates the following paragraphs prepared by the Natural Resources Intelligence Branch of the Department of the Interior at Ottawa:—

Canadian Trans-Continental Telephone Line. Western Link Completed.

On November 6th last, telephone conversations were exchanged between Edmonton, Alberta, and Victoria, B.C., in order to mark the completion of the western link in the "All-Canadian" trans-continental telephone line.

From Edmonton Dr. William Egbert, Lieutenant-Governor of Alberta, conversed with R. R. Bruce, Lieutenant-Governor of British Columbia at Victoria. The Hon. F. S. Tolmie, Premier of British Columbia, was switched through from Victoria to Dr. Egbert at Edmonton and the Hon. J. E. Brownlee, Premier of Alberta, who was in Vancouver, got in touch with the Hon. V. W. Smith, Minister of Railways and Telephones, at Edmonton. The Mayor of Vancouver also conversed with the Mayors of Calgary and Edmonton. The line was in perfect working order and the transmission was so good that all the conversations were heard as easily and distinctly as if between adjoining rooms, instead of over long ranges of mountains in two Provinces.

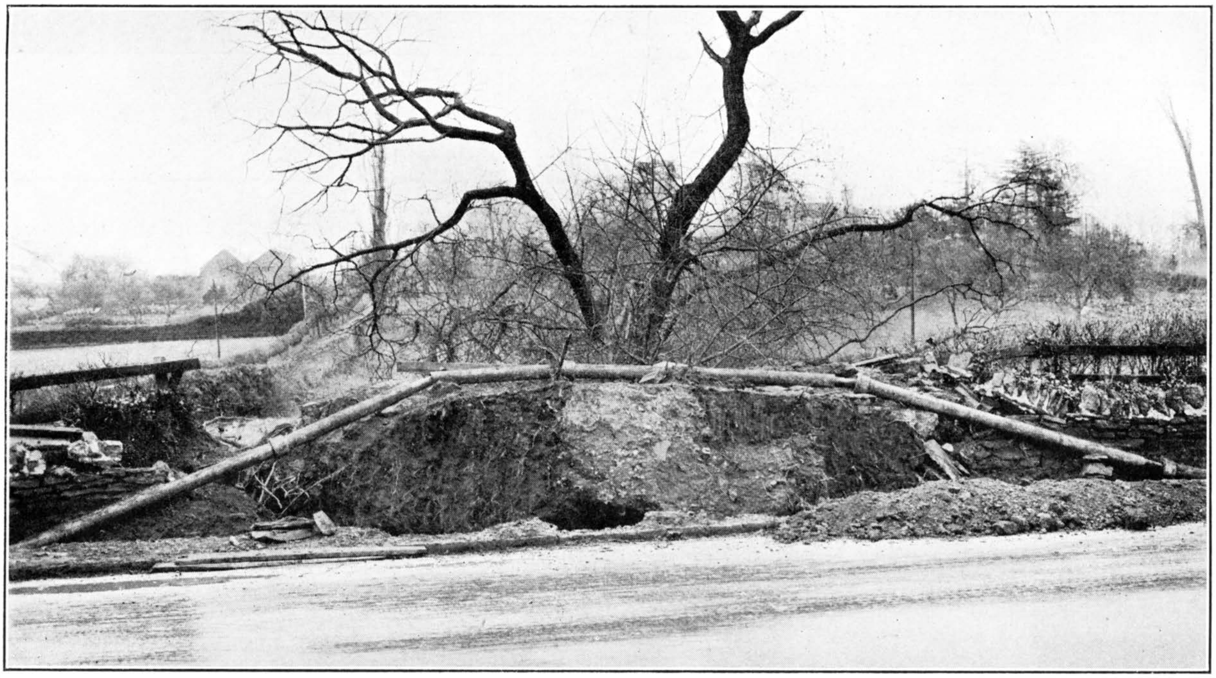
The completion of the new line not only enables Calgary, Edmonton, Vancouver, Victoria and other points in Alberta and British Columbia to converse with each other and with points in central Canada over all-Canadian wires, but with the last link between Quebec and New Brunswick nearing completion, forms an important link in a coast to coast service which is assured in the near future, with no foreign point touched.

Radio Telephone Service Proposed for British Columbia Coast.

The British Columbia Telephone Company contemplates the installation of a radio telephone service to outlying points along the Pacific coast of Canada where conditions render the ordinary ground lines prohibitive owing to their cost.

The cable is a composite one, being made up of the following conductors:—28 pr./100 Q.P. +6 pr./100 Tw. + 15 pr./150 Tw. + 22/200 S.S. +42/70 S.S. It is approximately 3½" in diameter, and is carried in a 4" C.I. pipe. The pipe was laid over 20 years ago, at a depth of 14", and the roots of the elm tree had grown around it.

The position into which the pipe and cable were raised on the roots of the tree is shown in the photograph. The pipe and cable were lifted from the ground for a distance of 10 yards, the maximum height above the footway level being 4 ft. The maximum horizontal displacement was 4 ft. 6 inches. In order to avoid the increase in the strain on the cable which appeared likely to result from the settling down of the fallen tree, the trunk of the tree was sawn off near the roots. After roots and soil had been removed sufficiently to permit of the work being carried out, the pipe and cable were lowered to their former position so far as this could be done. The cable slack which resulted from the strain could be only partially taken up in the trench.



WESTERN UNDERGROUND PIPE AND CABLE LIFTED BY ROOTS OF FALLING ELM NEAR BRISTOL.

A Unique Occurrence.—The severe gale which swept over England on the 16th of November uprooted many trees. At Brislington, a suburb of Bristol, the Western underground pipe and cable in the footway were lifted out of the ground by the roots of a large elm tree which was blown down. The tree, which fell into the adjoining field, stood immediately on the field side of a low wall which forms the boundary of the footpath.

A coupling existed at a distance of 23 yards from the fallen tree on the Bristol side, and it was desired to examine the conditions at this joint without delay. Another large elm tree stood in the roadside bank at this point, however, and cracks in the footway, due to the strain to which the tree had been subjected by the gale, showed that the ground could not safely be disturbed until the tree had been felled.

When the cable was examined at this coupling point it was found that it had been drawn a distance of 4″, and that the plumber's wipe was jammed against the shoulder of the coupling. On opening up the joint it was apparent that the displacement of conductors and sheathing, respectively, had been unequal, and that the conductors had drawn through the sheathing. The nearest joint on the Bath side was 93 yards distant from the uprooted section of cable, and it was found at that point that the displacement of the cable was 2″.

It is remarkable that notwithstanding the extraordinary strain to which the cable was subjected no faults resulted. Five pipes were badly fractured, and the cable sheathing was heavily indented in several places and otherwise damaged. It was decided to replace the damaged cable over a length of 40 yards and this work has been carried out.

A. RATTUE.

HEADQUARTER'S NOTES.

EXCHANGE DEVELOPMENTS.

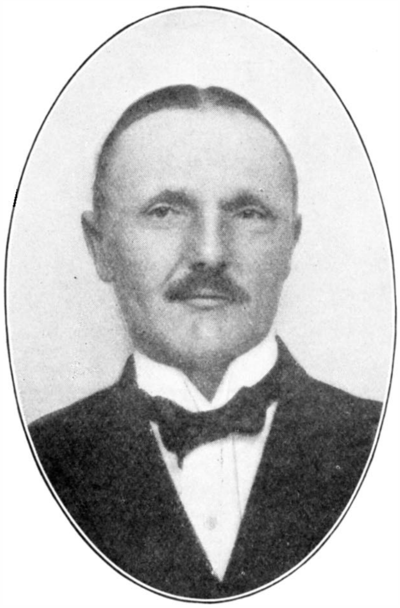
The following works have been completed :—

Exchange.	Type.	No. of Lines.
Bermondsey	New Auto.	2600
Monument	,,	10000
St. Marychurch	,,	317
Brighton	Auto Extn.	—
Cheltenham	,,	535
Hove	,,	—
Leeds	,,	—
Portslade	,,	90
Rottingdean	,,	80
Southwick	,,	570
Bishops Stortford	New Manual	460
Byfleet	,,	700
Chigwell	,,	520
Fleet	,,	520
Harpenden	,,	700
Horsham	,,	720
Norbury Relief	,,	1000
Rainham (Essex)	,,	740
Tudor Relief	,,	3500
Bristol	Manual Extn.	1700
Cambridge (Advance)	,,	1480
Mansfield	,,	460
Port Talbot	,,	180
Purley	,,	1020
Putney	,,	1040
Smethwick	,,	580
Streatham	,,	660
Sydenham	,,	400
Willesden	,,	1700
Broome and Foster	P.A.B.X.	30
Dudley Guardians	,,	30
Fleetwood Co-op. Society ...	,,	20
Gonville & Caius College ...	,,	20
Jarrow & Hebburn Co-op. ...	,,	30
Manchester Corporation ...	,,	300
May & Co. T.	,,	20
Morris Garages, Ltd.	,,	20
Pearson Dorman Long ...	,,	40
Ratcliffe & Ratcliffe	,,	20
Reading Co-op. Society ...	,,	20
Trade Union Congress ...	,,	100
Walter Martin, Ltd.	,,	20
Wimbledon Motors, Ltd. ...	,,	30
Illustrated London News ...	P.A.B.X. Ex.	50
Jeager Co., Ltd.	,,	—
Outram & Co.	,,	20
Royal Arsenal Co-op.	P.A.B.X. Ex.	30
Synthetic Ammonia, Ltd. ...	,,	200
Walsall & W. Bromwich Union	,,	20
West Riding C. Council ...	,,	40
Wiggins & Co.	,,	30

Orders have been placed for the following works :—

Exchange.	Type.	No. of Lines.
Blackfriars (Manchester) ...	New Auto	9700
Livingstone	,,	3000
Manchester	Auto Manual	200 (Posns.)
Cwmbran	Auto Extn.	127
Exeter	,,	760
Harrogate	,,	1700
Newport (Mon.)	,,	400
Redhill	New Manual	1264
Skegness	,,	620
Bournemouth	Manual Ext.	680
Brixton	,,	800
Canterbury	,,	700
Derby	,,	1060
Greenwich	,,	1080
Norwich	,,	380
Broome & Foster	New P.A.B.X.	30
Davis Theatre, Ltd.	,,	30
Edwards Ringer & Bigg, Ltd.	,,	30
J. Garner & Sons	,,	30
Gonville & Caius College ...	,,	20
Jarrow & Hebburn Co-op. ...	,,	30
Manchester Corporation ...	,,	300
Preston Corporation	,,	20
Southern Oil Co.	,,	20
Universal Grinding Wheel Co.	,,	30
Wimbledon Motor Works ...	,,	30
Dunlop Rubber Co.	P.A.B.X. Ex.	10
Illustrated London News ...	,,	50
Jaeger Co., Ltd.	,,	—
Lloyds Packing Warehouses...	,,	30
London Express Newspaper ...	,,	40
Royal Arsenal Co-op.	,,	30
Walsall & W. Bromwich Union	,,	20
West Riding C. Council ...	,,	40
Wiggins & Co.	,,	30

LIEUT-COL. A. S. ANGWIN, B.Sc., D.S.O., M.C., T.D.



LIEUT.-COL. A. S. ANGWIN, D.S.O., M.C., T.D.

LIEUT.-COL. A. S. ANGWIN, who succeeded Lieut.-Col. A. G. Lee as Staff Engineer in charge of the Radio Section at headquarters in June, 1928, graduated B.Sc. (Engineering), at London University from East London College after winning a Whitworth Exhibition scholarship in 1902. He was apprenticed to Messrs. Yarrow and Co., the well-known engineers and shipbuilders, and passed through their shops and drawing office.

He entered the P.O. service as Second Class Engineer by open competition in 1906, and after probationary training in Hornsey Section he was appointed to Glasgow Construction Section. From 1909, he acted as sectional engineer in charge of underground and exchange construction for new Glasgow exchanges and transfer of N.T. Coy.'s plant.

Always an enthusiast in military matters, he raised the Lowland Division Telegraph Coy., on the formation of the Territorial Force and was gazetted Captain in command of the Company. This company was comprised, officers and men, almost entirely of Glasgow P.O. officials, telegraphists, linemen, etc. The unit was mobilised in 1914, and formed into the 52nd Divisional Signal Company with Captain Angwin, promoted Major, as Officer in Command. He served through the war with the unit in Gallipoli, Egypt, Palestine and France. Major Angwin was mentioned in despatches five times, and was awarded the M.C., and the D.S.O. After the war he commanded the 44th (Home Counties) Divisional Signal Coy. until 1927, when he was awarded the T.D. (20 years' service). He is now serving as Deputy Chief Signal Officer, Eastern Command.

Col. Angwin returned to Glasgow after the war for three months, but was transferred to the Engineer-in-Chief Office Wireless Section in connection with the work at Leafield and Cairo Wireless Stations, which were to form part of the Imperial Chain. He was appointed Executive Engineer in April, 1920, and twice renewed his acquaintance with Egypt over the building and operation of the Cairo Station. He was largely responsible for the construction of the Rugby Masts and Aerial Systems and in conjunction with Mr. Walmsley he was awarded the Telford Premium by the Institution of Civil Engineers for a paper on that subject read before the Institution.

Col. Angwin was promoted Assistant Staff Engineer in March, 1925. He was closely associated with the construction of the Radio Beam Stations, supervising the contracts with the Marconi Coy., checking the work in progress and carrying out experimental and research investigations. Along with Messrs. Shaughnessy and Lee he had been engaged in the development of Transatlantic Telephony in collaboration with the A.T. and T. Company, and last year he paid a visit to the States in connection with the provision of additional channels to be operated on Short Waves to carry the growing traffic.

He is an Associate Member of the Institution of Civil Engineers, and a Member of the I.E.E.

LONDON DISTRICT NOTES.

Telephones.—The following figures shew the changes in the number of exchange lines, extensions, and stations during the three months ending 30th September, 1928, and the total at the same date: —

	Increase.	Total.
Exchanges lines ...	5,777	347,598
Extensions ...	4,515	292,170
Stations	9,836	583,567

External Plant.—During the same period the changes shewn below have occurred in mileage:

Telegraphs.—A nett decrease in open wire of 20 miles and a nett increase of 325 miles in underground.

Telephones, Exchange.—A nett decrease in open wire (including aerial cable) of 2 miles and a nett increase of 64,591 miles in underground.

Telephone, Trunks.—A nett increase in open wire of 7 miles and a nett increase of 909 miles in underground.

Pole Line.—A nett increase of 19 miles, the total to date being 5,887 miles.

Pipe Line.—A nett increase of 281 miles, the total to date being 10,041 miles.

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

Telegraphs	... ...	25,780
Telephones—Exchange	...	2,368,307
,, Trunk		74,188
Spares	... ...	99,542

Telephone Exchange Progress.

The following information will give an indication of the progress that is being made in providing new Telephone Exchanges in the London Area.

The Monument Automatic Exchange, with Mansion House Hypothetical working thereon, was opened for traffic on the 3rd November. The exchange is situated in the present Royal Exchange building, and is equipped for 9450 lines.

The following Manual Exchanges have been opened recently:—

Chigwell, No. 1 C.B., type equipped with 520 lines, opened October 18th.

Rainham, No. 1 C.B., type equipped with 740 lines, opened October 28th.

Tudor, No. 1 C.B., type equipped with 5,000 lines, opened November 1st.

Molesey and Sutton New Manual Exchanges are rapidly nearing completion and will be opened early in January.

The following New Exchange Buildings are being equipped:—

Auto Exchanges.		Manual Exchanges.	
Exchange.	No. of equipped lines.	Exchange.	No. of equipped lines.
Welbeck	8700	Pollards (Relief)	1900
Beckenham	3000	Valentine (Relief)	1500
Temple Bar	7700	Hornchurch	880
Reliance	2700		
Metropolitan	9500		
National	9500		
Western	7100		
Maida Vale	7500		
Archway	3100		
Edgware	1300		
Hendon	3100		
Flaxman	9900		
Fulham	7500		

New Exchanges on which building construction work has been commenced.

Addiscombe.
Amherst (Hackney Area).
Emberbrook (Ditton Area).
Hillside.
Ilford.
Gulliver (Kentish Town).
Livingstone (Norwood).
Loughton.
Macaulay (Nine Elms)
Mitcham.
Pollards (Norbury).
Primrose Hill.
Prospect (Barnes).
Redhill.
Shepherds Bush.
Stanmore.
Terminus (King's Cross).
Upminster.

New Exchanges on which building construction is on the point of being started.

Ingrebourne (Harold Wood).
Leytonstone.
Romford.
Theydon Bois.
Whitehall.

In addition to the above cases, sites for 21 new exchanges have been secured, and searches for suitable sites are being made in 14 other cases.

Power Work.

Following the adaptation of the old Letter Office at Mt. Pleasant for Parcel work, 19 band conveyors have been installed to facilitate transport of parcels and bags between the sorting points, loading platforms, and the chutes leading to the P.O. Railway Station. The conveyors have bands varying from 30″ to 36″ wide, running at a speed of 200 feet per minute and capable of carrying total loads varing from 1,040 to 4,400 lbs.

The erection of a new 800 k.w. motor converter of the La Cour type in the Mt. Pleasant Sub-station is practically complete, and tests *in situ* will shortly be made. The set takes current at 6600 volts 3-phase 50 cycles on the A.C. side and delivers at 440 volts D.C.

Telegraphs.

The Public Telegraph Office at the G.P.O. West has been removed from the rear to the front of the building in St. Martin's-le-Grand. This has involved the shifting of tubes, telephones, etc. The improved general appearance and accessibility of the Office should bring about a considerable increase of business.

The well-known " Centre " in the C.T.O. has now been surrendered by the builders, who have constructed a new floor, supported by a bridge across the southern half of this telegraph gallery. Three multiplex sets have already been restored and the opportunity is being taken to supersede the old metal-framed tables by wood tables of solid construction. It is hoped that by this means vibration will be practically eliminated. Collection of messages by band carriers is to follow.

Additional four-slip electrical perforators have been installed to displace a number of old style pneumatic punchers.

The number of Teleprinters continues to increase. These are chiefly of the 3-A type. The necessity for adapting the machines to alternating current working has arisen and instruments fitted with alternating motors are now being tried on a London circuit.

There has been an appreciable increase in the number of Teleprinters fitted in London for private wire renters.

Pneumatic Tubes.

It may not be generally known that the pneumatic power supplied for tubes which are provided for renters is measured in terms of time. Meters are fitted and governed by contact points which function when the valves are operated. A new type of meter is now under trial.

Many complaints have been received about the noise occasioned in instrument rooms by pneumatic tube working. India-rubber carriers are about to be extensively tried, on both large and small house-tubes. The experimental carriers have been found quieter in working and it is hoped that the noise will be materially reduced.

Telephone Kiosks.

There are now 1,119 Kiosks in the London area. The increase last quarter was over 20 per cent.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

LONDON CENTRE.

THE meeting of the Centre on Tuesday, the 13th November, was favoured by the presence of Dr. T. A. Watson, who was on a visit to this country from the United States and who had kindly consented to give an address on "The Birth of the Telephone." The Engineer-in-Chief, president of the institution, presided and introduced Dr. Watson to the packed audience in a felicitous speech. The audience stood up *en masse* when Dr. Watson rose to speak and received him with loud and continued applause. At the close of his address, which was delivered in a charming manner with many bright personal touches, Dr. Watson was awarded a very cordial vote of thanks.

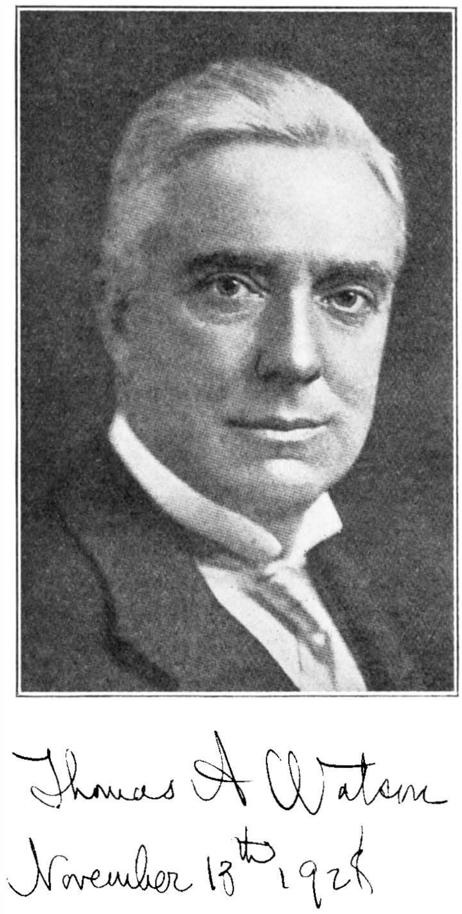
THE BIRTH AND BABYHOOD OF THE TELEPHONE.

DR. WATSON'S ADDRESS.

I am to speak to you of the birth and babyhood of the telephone, and something of the events which preceded that important occasion. These are matters that must seem to you ancient history; in fact, they seem so to me, although the events all happened in the years 1874 to 1880.

The occurrences of which I shall speak, lie in my mind as a splendid drama, in which it was my great privilege to play a part. I shall try to put myself back into that wonderful play, and tell you its story from the same attitude of mind I had then—the point of view of a mere boy, just out of his apprenticeship as an electro-mechanician, intensely interested in his work, and full of boyish hope and enthusiasm. Therefore, as it must be largely a personal narrative, I shall ask you to excuse my many "I's" and "my's" and to be indulgent if I show how proud and glad I am that I was chosen by the fates to be the associate of Alexander Graham Bell, to work side by side with him day and night through all these wonderful happenings that have meant so much to the world.

The Williams' Electrical Workshop.—I realize now what a lucky boy I was, when at 13 years of age I had to leave school and go to work for my living, although I didn't think so at that time. I am not advising my young friends to leave school at this age, for they may not have the opportunity to enter college as I did at 40. There's a "tide in the affairs of men," you know, and that was the beginning of its flood in my life, for after trying several



vocations—clerking, bookkeeping, carpentering, etc.—and finding them all unattractive, I at last found just the job that suited me in the electrical workshop of Charles Williams, at 109, Court Street, Boston—one of the best men I have ever known. Better luck couldn't befall a boy than to be brought so early in life under the influence of such a high-minded gentleman as Charles Williams.

I want to say a few words about my work there, not only to give you a picture of such a shop in the early '70's but also because in this shop the telephone had its birth and a good deal of its early development.

I was first set to work on a hand lathe turning binding posts for five dollars a week. The mechanics of to-day with their automatic screw machines, hardly know what it is to turn little rough castings with a hand tool. How the hot chips used to fly into our eyes! One day I had a fine idea. I bought a pair of 25 cent. goggles, thinking the others would hail me as a benefactor of mankind and adopt my plan. But they laughed at me for being such a sissy boy and public opinion forced me back to the old time honored plan of winking when I saw a chip coming. It was not an efficient plan, for the chip usually got there first. There was a liberal education in it for me in manual dexterity. There was no specializing in these shops at that time. Each workman built everything there was in the shop to build, and an apprentice also had a great variety of jobs, which kept him interested all the time, for his tools were poor and simple and it required lots of thought to get a job done right.

There were few books on electricity published at that time. Williams had copies of most of them in his show case, which we boys used to read noons, but the book that interested me most was Davis' Manual of Magnetism, published in 1847, a copy of which I made mine for 25 cents. If you want to get a good idea of the state of the electrical art at that time, you should read that book. I found it very stimulating and that same old copy in all the dignity of its dilapidation has a place of honour on my book shelves to-day.

My promotion to higher work was rapid. Before two years had passed, I had tried my skill on about all the regular work of the establishment — call bells, annunciators, galvanometers, telegraph keys, sounders, relays, registers and printing telegraph instruments.

Individual initiative was the rule in Williams' shop—we all did about as we pleased. Once I built a small steam engine for myself during working hours, when business was slack. No one objected. That steam engine, by the way, was the embryo of the biggest shipbuilding plant in the United States to-day, which I established some ten years later with telephone profits, and which now employs more than 4,000 men.

Such was the electrical shop of that day. Crude and small as they were, they were the forerunners of the great electrical works of to-day. In them were being trained the men who were among the leaders in the wonderful development of applied electricity which began soon after the time of which I am to speak. Williams, although he never had at that time more than 30 or 40 men working for him, had one of the largest and best fitted shops in the country. I think the Western Electric shop at Chicago was the only larger one. That was also undoubtedly better organized and did better work than Williams'. When a piece of machinery built by the Western Electric came into our shop for repairs, we boys always used to admire the superlative excellence of the workmanship.

Experience with Inventors.—Besides the regular work at Williams', there was a constant stream of wild-eyed inventors, with big ideas in their heads and little money in their pockets, coming to the shop to have their ideas tried out in brass and iron. Most of them had an "angel" whom they had hypnotized into paying the bills. My enthusiasm, and perhaps my sympathetic nature, made me a favourite workman with those men of visions, and in 1873-74 my work had become largely making experimental apparatus for such men. Few of their ideas ever amounted to anything, but I liked to do the work, as it kept me roaming in fresh fields and pastures new all the time. Had it not been, however, for my youthful enthusiasm—always one of my chief assets—I fear this experience would have made me so sceptical and cynical as to the value of electrical inventions that my future prospects might have been injured.

I remember one limber-tongued patriarch who had induced some men to subscribe 1,000 dollars to build what he claimed to be an entirely new electric engine. I made much of it for him. There was nothing new in the engine, but he intended to generate his electric current in a series of iron tanks the size of trunks, to be filled with nitric acid with the usual zinc plates suspended therein. When the engine was finished and the acid poured into the tanks for the first time, no one waited to see the engine run, for inventor, "angel," and workmen, all tried to see who could get out of the shop quickest. I won the race as I had the best start.

I suppose there is just such a crowd of crude minds still besieging the workshops, men who seem incapable of finding out what has been already done, and so keep on year after year, threshing old straw.

The "Harmonic Telegraph."—All the men I worked for at that time were not of that type. There were a very few different. Among them, dear old Moses G. Farmer, perhaps the leading practical electrician of that day. He was full of good ideas, which he was constantly bringing to Williams to have worked out. I did much of his work and learned from him more about electricity than ever before or since. He was electrician at that time for the United States Torpedo Station at Newport, Rhode Island, and in the early winter of 1874, I was making for him some experimental torpedo exploding apparatus. That apparatus will always be connected in my mind with the telephone, for one day when I was hard at work on it, a tall, slender, quick-motioned man with pale face, black side whiskers, and drooping mustache, big nose and high sloping forehead crowned with bushy, jet black hair, came rushing out of the office and over to my work bench. It was Alexander Graham Bell whom I saw then for the first time. He was bringing to me a piece of mechanism which I had made for him under instructions from the office. It had not been made as he had directed and he had broken down the rudimentary discipline of the shop in coming directly to me to get it altered. It was a receiver and a transmitter of his "Harmonic Telegraph," an invention of his with which he was then endeavouring to win fame and fortune. It was a simple affair by means of which, utilizing the law of sympathetic vibration, he expected to send six or eight Morse messages on a single wire at the same time, without interference.

Although most of you are probably familiar with the device, I must, to make my story clear, give you a brief description of the instruments, for though Bell never succeeded in perfecting his telegraph, his experimenting on it led to a discovery of the highest importance.

The essential parts of both transmitter and receiver were an electro-magnet and a flattened piece of steel clock spring. The spring was clamped by one end to one pole of the magnet, and had its other end free to vibrate over the other pole. The transmitter had, besides this, make-and-break points like an ordinary vibrating bell which, when the current was on, kept the spring vibrating in a sort of nasal whine, of a pitch corresponding to the pitch of the spring. When the signalling key was closed, an electrical copy of that whine passed through the wire and the distance receiver. There were, say, six transmitters with their springs tuned to six different pitches and six receivers with their springs tuned to correspond. Now, theoretically, when a transmitter sent its electrical whine into the line wire, its own faithful receiver spring at the distant station would wriggle sympathetically but all the others on the same line would remain coldly quiescent. Even when all the transmitters were whining at once through their entire gamut, making a row as if all the miseries this world of trouble ever produced were concentrated there, each receiver spring along the line would select its own from that sea of troubles and ignore all the others. Just see what a simple, sure-to-work invention this was; for just break up those various whines into the dots and dashes of Morse messages and one wire would do the work of six, and the "Duplex" telegraph that had just been invented would be beaten to a frazzle. Bell's reward would be immediate and rich, for the "Duplex" had been bought by the Atlantic and Pacific Telegraph Company, giving them a great advantage over their only competitor, the Western Union Company, and the latter would, of course, buy Bell's invention and his financial problems would be solved.

All this was, as I have said, theoretical, and it was mighty lucky for Graham Bell that it was, for had his harmonic telegraph been a well behaved apparatus that always did what its parent wanted it to do, the speaking telephone might never have emerged from a certain marvellous conception, that had even then been surging back of Bell's high forehead for two or three years. What that conception was, I soon learned, for he couldn't help speaking about it, although his friends tried to hush it up. They didn't like to have him get the reputation of being visionary, or—something worse.

To go on with my story; after Mr. Farmer's peace making machines were finished, I made half a dozen pairs of the harmonic instruments for Bell. He was surprised, when he tried them to find that they didn't work as well as he expected. The cynical Watson wasn't at all surprised for he had never seen anything electrical yet that worked at first the way the inventor thought it would. Bell wasn't discouraged in the least and a long course of experiments followed which gave me a steady job that winter and brought me into close contact with a wonderful personality that did more to mould my life rightly than anything else that ever came into it.

I became mightily tired of those "whiners" that winter. I called them by that name, perhaps, as an inadequate expression of my disgust with their persistent perversity, the struggle with which soon began to take all the joy out of my young life, not being endowed with the power of Macbeth's weird sister to

"Look into the seeds of time,
And say which grain will grow and which will not."

Let me say here, that I have always had a feeling of respect for Elisha Gray, who, a few years later, made that harmonic telegraph work, and vibrate well-behaved messages, that would go where they were sent, without fooling with every receiver on the line.

Most of Bell's early experimenting on the harmonic telegraph was done in Salem, at the home of Mrs. George Sanders, where he resided for several years, having charge of the instruction of her deaf nephew. The present Y.M.C.A. building is on the site of that house. I would occasionally work with Bell there, but most of his experimenting in which I took part was done in Boston.

Bell's Theory of Transmitting Speech.—Mr. Bell was very apt to do his experimenting at night, for he was busy during the day at the Boston University, where he was Professor of Vocal Physiology, especially teaching his father's system of visible speech, by which a deaf mute might learn to talk—quite significant of what Bell was soon to do in making mute metal talk. For this reason I would often remain at the shop during the evening to help him test some improvement he had had me make on the instruments.

One evening when we were resting from our struggles with the apparatus, Bell said to me: "Watson, I want to tell you of another idea I have, which I think will surprise you." I listened, I suspect, somewhat languidly, for I must have been working that day about sixteen hours, with only a short nutritive interval, and Bell had already given me, during the weeks we had worked together, more new ideas on a great variety of subjects, including visible speech, elocution and flying machines, than my brain could assimilate, but when he went on to say that he had an idea by which he believed it would be possible to talk by telegraph, my nervous system got such a shock that the tired feeling vanished. I have never forgotten his exact words; they have run in my mind ever since like a mathematical formula. "If," he said, "I could make a current of electricity vary in intensity, precisely as the air varies in density during the production of a sound, I should be able to transmit speech telegraphically." He then sketched for me an instrument that he thought would do this, and we discussed the possibility of constructing one. I did not make it; it was altogether too costly, and the chances of its working too uncertain to impress his financial backers—Mr. Gardiner G. Hubbard and Mr. Thomas Sanders—who were insisting that the wisest thing for Bell to do was to perfect the harmonic telegraph; then he would have the money and leisure enough to build air castles like the telephone.

June 2nd, 1875.—I must have done other work in the shop besides Bell's during the winter and spring of 1875, but I cannot remember a single item of it. I do remember that when I was not working for Bell I was thinking of his ideas. All through my recollection of that period runs that nightmare—the harmonic telegraph, the ill working of which got on my conscience, for I blamed my lack of mechanical skill for the poor operation of an invention apparently so simple. Try our best, we could not make that thing work rightly, and Bell came as near to being discouraged as I ever knew him to be.

But this spring of 1875 was the dark hour just before the dawn.

If the exact time could be fixed, the date when the conception of the undulatory or speech-transmitting current took its perfect form in Bell's mind would be the greatest day in the history of the telephone, but certainly June 2nd, 1875, must always rank next; for on that day the mocking fiend inhabiting that demonaic telegraph apparatus, just as a now-you-see-it-and-now-you-don't sort of a satanic joke, opened the curtain that hides from man great Nature's secrets and gave us a glimpse as quick as if it were through the shutter of a snap-shot camera, into that treasury of things not yet discovered. That imp didn't do this in any kindly, helpful spirit—any inventors knows he isn't that kind of a being—he just meant to tantalize and prove that a man is too stupid to grasp a secret, even if it is revealed to him. But he hadn't properly estimated Bell, though he had probably sized me up all right. That glimpse was enough to let Bell see and seize the very thing he had been dreaming about and drag it out into the world of human affairs.

The Telephone Born.

Coming back to earth, I'll try and tell you what happened that day. In the experiments on the harmonic telegraph, Bell had found that the reason why the messages got mixed up was inaccuracy in the adjustment of the pitches of the receiver springs to those of the transmitter. Bell always had to do this tuning himself, as my sense of pitch and knowledge of music were quite lacking—a faculty (or lackulty) which you will hear later became quite useful. Mr. Bell was in the habit of observing the pitch of a spring by pressing it against his ear while the corresponding transmitter in a distant room was sending its intermittent current through the magnet of that receiver. He would then manipulate the tuning screw until that spring was tuned to accord with the pitch of the whine coming from the transmitter. All this experimenting was carried on in the upper story of the Williams building, where we had a wire connecting two rooms perhaps sixty feet apart looking out on Court Street.

Realization.—On the afternoon of June 2nd, 1875, we were hard at work on the same old job, testing some modification of the instruments. Things were badly out of tune that afternoon in that hot garret, not only the instruments, but, I fancy, my enthusiasm and my temper though Bell was as energetic as ever. I had charge of the transmitters as usual, setting them squealing one after the other, while Bell was retuning the receiver springs one by one, pressing them against his ear as I have described. One of the transmitter springs I was attending to stopped vibrating and I plucked it to start it again. It didn't start and I kept on plucking it, when suddenly I heard a shout from Bell in the next room, and then out he came with a rush, demanding, "What did you do then? Don't change anything. Let me see!" I showed him. It was very simple. The contact screw was screwed down so far that it made permanent contact with the spring, so that when I snapped the spring the circuit had remained unbroken while the strip of magnetized steel by its vibration over the pole of its magnet, was generating that marvellous conception of Bell's—a current of electricity that varied in intensity precisely as the air was varying in density within hearing distance of that spring. That undulatory current had passed through the connecting wire to the distant receiver which, fortunately, was a mechanism that could transform that current back into an extremely faint echo of the sound of the vibrating spring that had generated it, but what was still more fortunate, the right man had that mechanism at his ear during that fleeting moment, and instantly recognized the transcendent importance of that faint sound thus electrically transmitted. The shout I heard and his excited rush into my room where the result of that recognition. The speaking telephone was born at that moment. Bell knew perfectly well that the mechanism that could transmit all the complex vibrations of one sound could do the same for any sound, even that of speech. That experiment showed him that the complex apparatus he had thought would be needed to accomplish that long dreamed result was not at all necessary, for here was an extremely simple mechanism operating in a perfectly obvious way, that could do it perfectly. All the experimenting that followed that discovery, up to the time the telephone was put into practical use was largely a matter of working out the details.

We spent a few hours verifying the discovery, repeating it with all the differently tuned springs we had, and before we parted that night Bell gave me directions for making the first electric speaking telephone. I was to mount a small drumhead of gold beater's skin over one of the receivers, join the centre of the drumhead to the free end of the receiver spring and arrange a mouthpiece over the drumhead to talk into. His idea was to force the steel spring to follow the vocal vibrations and generate a current of electricity that would vary in intensity as the air varies in density during the utterance of speech sounds. I followed these directions and had the instrument ready for its trial the very next day. I rushed it, for Bell's excitement and enthusiasm over the discovery had aroused mine again, which had been sadly dampened during those last few weeks by the meagre results of the harmonic experiments. I made every part of that first telephone myself, but I didn't realize while I was working on it what a tremendously important piece of work I was doing.

The First Telephone Line.

The two rooms in the attic were too near together for the test, as our voices would be heard through the air, so I ran a wire especially for the trial from one of the rooms in the attic down two flights to the third floor where Williams' main shop was, ending it near my work bench at the back of the building. That was the first telephone line. You can well imagine that both our hearts were beating above the normal rate, while we were getting ready for the trial of the new instrument that evening. I got more satisfaction from the experiment than Mr. Bell did, for shout my best I could not make him hear me, but I could hear his voice and almost catch the words. I rushed up stair and told him what I had heard. It was enough to show him that he was on the right track, and before he left that night he gave me directions for several improvements in the telephones I was to have ready for the next trial.

I hope my pride in the fact that I made the first telephone, put up the first telephone wire and heard the first words ever uttered through a telephone, has never been too ostentatious and offensive to my friends, but I am sure that you will grant that a reasonable amount of that human weakness is excusable in me. My pride has been tempered to quite a bearable degree by my realization that the reason why I heard Bell in that first trial of the telephone and he did not hear me, was the vast superiority of his strong vibratory tones over any sound my undeveloped voice was then able to utter. My sense of hearing, however, has always been unusually acute, and that might have helped to determine this result.

The building where these first telephone experiments were made is still in existence. It is now used as a theatre. The lower stories have been much altered, but that attic is still quite unchanged and a few weeks ago I stood on the very spot where I snapped those springs and helped test the first telephone thirty-seven years and seven months before.

Mr. Watson Heard the Fist Sentence Ever Spoken Over the Telephone.—Of course, in our struggle to expel the imps from the invention, an immense amount of experimenting had to be done, but it wasn't many days before we could talk back and forth and hear each other's voice. It is, however, hard for me to realize now that it was not until the following March that I heard a complete and intelligible sentence. It made such an impression upon me that I wrote that first sentence in a book I have always preserved. The occasion had not been arranged and rehearsed as I suspect the sending of the first message over the Morse telegraph had been years before, for instead of that noble first telegraphic message—"What hath God wrought?" the first message of the telephone was: "Mr. Watson, come here, I want you." Perhaps, if Mr. Bell had realized that he was about to make a bit of history, he would have been prepared with a more sounding and interesting sentence.

Soon after the first telephones were made, Bell hired two rooms on the top floor of an inexpensive boarding house at No. 5, Exeter Place, Boston, since demolished to make room for mercantile buildings. He slept in one room; the other he fitted up as a laboratory. I ran a wire for him between the two rooms and after that time practically all his experimenting was done there. It was here one evening when I had gone there to help him test some improvement and to spend the night with him, that I heard the first complete sentence I have just told you about. Matters began to move more rapidly and during the summer of 1876, the telephone was talking so well that one didn't have to ask the other man to say it over again more than three or four times before one could understand quite well, if the sentences were simple.

The Centennial Exposition.—This was the year of the Centennial Exposition at Philadelphia, and Bell decided to make an exhibit there. I was still working for Williams, and one of the jobs I did for Bell was to construct a telephone of each form that had been devised up to that time. These were the first nicely finished instruments that had been made. There had been no money nor time to waste on polish or non-essentials. But these Centennial telephones were done up in the highest style of the art. You could see your face in them. These aristocratic telephones worked finely, in spite of their glitter, when Sir William Thompson tried them at Philadelphia that summer. I was as proud as Bell himself, when I read Sir William's report, wherein he said after giving an account of the tests: "I need hardly say I was astonished and delighted, so were the others who witnessed the experiment and verified with their own ears the electric transmission of speech. This, perhaps, the greatest marvel hitherto achieved by electric telegraph, has been obtained by appliances of quite a homespun and rudimentary character." I have never forgiven Sir William for that last line. Homespun!

However, I recovered from this blow, and soon after Mr. Gardiner G. Hubbard, afterwards Mr. Bell's father-in-law, offered me an interest in Bell's patents if I would give up my work at Williams' and devote my time to the telephone. I accepted, although I wasn't altogether sure it was a wise thing to do from a financial standpoint. My contract stipulated that I was to work under Mr. Bell's directions, on the harmonic telegraph as well as on the speaking telephone, for the two men who were paying the bills still thought there was something in the former invention, although very little attention had been given to its vagaries after the June 2nd discovery.

I moved my domicile from Salem to another room on the top floor at 5, Exeter Place, giving us the entire floor, and as Mr. Bell had lost most of his pupils by wasting so much of his time on telephones, he could devote nearly all his time to the experimenting. Then followed a period of hard and continuous work on the invention. I made telephones with every modification and combination of their essential parts that either of us could think of. I made and we tested telephones with all sizes of diaphragms made of all kinds of materials—diaphragms of boiler iron several feet in diameter, down to a miniature affair made of the bones and drum of a human ear, and found that the best results came from an iron diaphragm of about the same size and thickness as is used to-day. We tested electro magnets and permanent magnets, of a multitude of sizes and shapes, with long cores and short cores, fat cores and thin cores, solid cores and cores of wire, with coils of many sizes, shapes and resistances and mouthpieces of an infinite variety. Out of the hundreds of experiments there emerged practically the same telephone you take off the hook and listen with to-day, although it was then transmitter as well as receiver.

"Talking" from Boston to Cambridge.—Progress was rapid, and on October 9th, 1876, we were ready to take the baby out doors for the first time. We got permission from the Walworth Manufacturing Company to use their private wire running from Boston to Cambridge, about two miles long. I went to Cambridge that evening with one of our best telephones, and waited until Bell signalled from the Boston office on the Morse sounder. Then I cut out the sounder and connected in the telephone and listened. Not a murmer came through! Could it be that, although the thing worked all right in the house, it wouldn't work

under practical line conditions? I knew that we were using the most complex and delicate electric current that had ever been employed for a practical purpose and that it was extremely "intense," for Bell had talked through the circuit composed of 20 or 30 human beings joined hand to hand. Could it be, I thought, that these high tension vibrations leaking off at each insulator along the line, had vanished completely before they reached the Charles river? That fear passed through my mind as I worked over the instrument, adjusting it and tightening the wires in the binding posts, without improving matters in the least. Then the thought struck me that perhaps there was another Morse sounder in some other room. I traced the wires from the place they entered the building and sure enough I found a relay with a high resistance coil in the circuit. I cut it out with a piece of wire across the binding posts and rush back to my telephone and listened. That was the trouble. Plainly as one could wish came Bell's "ahoy,"* I ahoyed back, and the first long distance telephone conversation began. Sceptics had been objecting that the telephone could never compete with the telegraph as its messages would not be accurate. For this reason Bell had arranged that we should make a record of all we said and heard that night, if we succeeded in talking at all. We carried out this plan and the entire conversation was published in parallel columns in the next morning's *Advertiser,* as the lastest startling scientific achievement. Infatuated with the joy of talking over an actual telegraph wire, we kept up our conversation until long after midnight. It was a very happy boy that travelled back to Boston in the small hours with the telephone under his arm done up in a newspaper. Bell had taken his record to the newspaper office and was not at the laboratory when I arrived there, but when he came in there ensued a jubilation and war dance that elicited next morning from our landlady, who wasn't at all scientific in her tastes, the remark that we'd have to vacate if we didn't make less noise at nights.

* *"Ahoy!" was the telephone shout, and was used during the experiments, but "hello!" superseded it when the telephone got into practical use.*

Tests on still longer telegraph lines soon followed—the success of each experiment being in rather exact accordance with the condition of the poor, rusty-joined wires we had to use. Talk about imps that baffle inventors! There was one of an especially vicious and maligant type in every unsoldered joint of the old wires. The genial Tom Doolittle hadn't even thought of his hard drawn copper wire then, with which he later eased the lot of the struggling telephone men.

Our Many Visitors.—Meanwhile the fame of the invention had spread rapidly abroad and all sorts of people made pilgrimages to Bell's laboratory to hear the telephone talk. A list of the scientists who came to the attic of that cheap boarding house to see the telephone would read like the roster of the American Association for the Advancement of Science. My old electrical mentor, Moses G. Farmer, called one day to see the latest improvements. He told me then with tears in his eyes when he first read a description of Bell's telephone he couldn't sleep for a week, he was so mad with himself for not discovering the thing years before. "Watson," said he, "that thing has flaunted itself in my very face a dozen times within the last ten years and every time I was too blind to see it. But," he continued, "if Bell had known anything about electricity he would never have invented the telephone."

Two of our regular visitors were young Japanese pupils of Professor Bell—very polite, deferential, quiet, bright-eyed little men, who saw everything and made cryptic notes. They took huge delight in proving that the telephone could talk Japanese. A curious effect of the telephone I noticed at that time was its power to paralyze the tongues of men otherwise fluent enough by nature and profession. I remember a prominent lawyer, who, when he heard my voice in the telephone making some such profound remark to him as "How do you do," could only reply, after a long pause, "Rig a jig jig and away we go."

Telephone Installation.

We began to get requests for telephone installations long before we were ready to supply them. In April, 1877, the first out door telephone line was run between Mr. Williams' office at 109, Court Street, and his house in Somerville. Professor Bell and I were present and participated in the important ceremony of opening the line and the event was a headliner in the next morning's papers.

Fiancial Problems.—At about this time Professor Bell's financial problems had begun to press hard for solution. We were very much disappointed because the President of the Western Union Telegraph Company had refused, somewhat contemptuously, Mr. Hubbard's offer to sell him all the Bell patents for the exhorbitant sum of 100,000 dollars. It was an especially hard blow to me, for while the negotiations were pending I had had visions of a sumptuous office in the Western Union Building in New York which I was expecting to occupy as Superintendent of the Telephone Department of the great telegraph company. However, we recovered even from that facer. Two years later the Western Union would gladly have bought those patents for 25,000,000 dollars.

But before that happy time there were lots of troubles of all the old and of several new varieties to be surmounted. Professor Bell's particular trouble in the Spring of 1877, arose from the fact that he had fallen in love with a most charming young lady. I had never been in love myself at that time and that was my first opportunity of observing what a serious matter it can be, especially when the father isn't altogether enthusiastic. I rather suspected at that time that that shrewd but kind-hearted gentleman put obstacles in the course of that true love, in order to stimulate the young man to still greater exertion in perfecting his inventions. But he might have thought as Prospero did:

> "They are both in either's power; but this
> swift business
> I must uneasy make, lest too light winning
> Make the prize light."

Bell's immediate financial needs were solved, however, by the demand that began at this time for public lectures by him on the telephone. It is hard to realize to-day what an intense and widespread interest there was then in the telephone. I don't believe any new invention could stir the public to-day as the telephone did then, surfeited as we are now with the wonderful things that have been invented since.

Telephone Lectures.—Bell's first lecture, as I have said, was given before a well-known scientific society—the Essex Institute—at Salem, Mass. They were especially interested in the telephone because Bell was living at Salem during the early telephone experiments. The first lecture was free to members of the society, but it packed the hall and created so much interest that Bell was requested to repeat it for an admission fee. This he did to an audience that again filled the house. Requests for lectures poured in upon Bell after that. Such men as Oliver Wendell Holmes and Henry W. Longfellow signed the request for the Boston lectures. The Salem lectures were soon followed by a lecture in Providence to an audience of 2,000, by a course of three lectures at the largest hall in Boston—all three packed—by three in Chickering Hall, New York, and by others in most of the large cities of New England. They all took place in the Spring and early Summer of 1877, during which time there was little opportunity for experimenting for either Bell or myself, which I think now was rather a good thing, for we had become quite stale and needed a change that would give us a new influx of ideas. My part in the lectures was important, although entirely invisible as far as the audience was concerned. I was always at the other end of the wire, generating and transmitting to the hall where Professor Bell was speaking, such telephonic phenomena as he needed to illustrate his lectures. I would have at my end circuit breakers—rheotomes, we called them—that would utter electric howls of various pitches, a lusty cornet player, sometimes a small brass band, and an electric organ with Edward Wilson to play on it, but the star performer was the young man who two years before didn't have voice enough to let Bell hear his own telephone, but in whom that two years of strenuous shouting into mouthpieces of various sizes and shapes had developed a voice with the carrying capacity of a steam calliope. My special function in these lectures was to show the audience that the telephone could really talk. Not only that, I had to do all the singing, too, for which my musical deficiences fitted me admirably.

My Telephone Entertainers.—Professor Bell would have one telephone by his side on the stage where he was speaking, and three or four others of the big box variety we used at that time would be suspended about the hall, all connected by means of a hired telegraph wire with the place where I was stationed, from five to twenty-five miles away. Bell would give the audience, first, the commonplace parts of the show and then would come the thrillers of the evening—my shouts and songs. I would shout such sentences as, "How do you do," "Good evening," "What do you think of the telephone?" which they could all hear, although the words issued from the mouthpieces rather badly marred by the defective talking powers of the telephones of that date. Then I would sing "Hold the Fort," "Pull for the Shore," "Yankee Doodle," and as a delicate allusion to the Professor's nationality, "Auld Lang Syne." My sole sentimental song was "Do Not Trust Him, Gentle Lady." This repertoire always brought down the house. After every song I would listen at my telephone for further directions from the lecturer, and always felt the artist's joy when I heard in it the long applause that followed each of my efforts. I was always encored to the limit of my repertoire and sometimes had to sing it through twice.

I have always understood that Professor Bell was a fine platform speaker but this is entirely hearsay on my part for, although I spoke at every one of his lectures, I have never yet had the pleasure of hearing him deliver an address.

First Sound-Proof Booth.—In making the preparations for the New York lectures I incidentally invented the sound-proof booth, but as Mr. Lockwood was not then associated with us, and for other reasons, I never patented it. It happened thus: Bell thought he would like to astonish the New Yorkers by having his lecture illustrations sent all the way from Boston. To determine whether this was practicable, he made arrangements to test the telephones a few days before on one of the Atlantic and Pacific wires. The trial was to take place at midnight. Bell was at the New York end, I was in the Boston laboratory. Having vividly in mind the strained relations already existing with our landlady, and realizing the carrying power of my voice when I really let it go, as I knew I should, have to that night, I cast about for some device to deaden the noise. Time was short and appliances scarce, so the best I could do was to take the blankets off our beds and arrange them in a sort of loose tunnel, with the telephone tied up in one end and the other end open for the operator to crawl into. Thus equipped I awaited the signal from New York announcing that Bell was ready. It came soon after midnight. Then I connected in the telephone, deposited myself in that cavity, and shouted and listened for two or three hours. It didn't work as well as it might. It is a wonder some of my remarks didn't burn holes in the blankets. We talked after a fashion but Bell decided it wasn't safe to risk it with a New York audience. My sound-proof booth, however, was a complete success, as far as stopping the sound was concerned, for I found by cautious inquiry next day that nobody had heard my row. Later inventors improved my booth, making it more comfortable for a pampered public but not a bit more sound-proof.

"*The Supposititious Mr. Watson.*"—One of those New York lectures looms large in my memory on account of a novel experience I had at my end of the wire. After hearing me sing, the manager of the lectures decided that while I might satisfy a Boston audience I would never do for a New York congregation, so he engaged a fine baritone soloist—a powerful negro, who was to assume the singing part of my program. Being much better acquainted with the telephone than that manager was I had doubts about the advisability of this change in the cast. I didn't say anything, as I didn't want to be accused of professional jealousy, and I knew my repertoire would be on the spot in case things went wrong. I was stationed that night at the telegraph office at New Brunswick, New Jersey, and I and the rest of the usual appliances of that end of the lecture went down in the afternoon to get things ready. I rehearsed my rival and found him a fine singer but had difficulty in getting him to crowd his lips into the mouthpiece. He was handicapped for the telephone business by being musical, and he didn't like the sound of his voice jammed up in that way. However, he promised to do what I wanted when it came to the actual work of the evening, and I went to supper. When I returned to the telegraph office, just before eight o'clock, I found to my horror that the young lady operator had invited six or eight of her dear friends to witness the interesting proceedings. Now, besides my musical deficiencies, I had another qualification as a telephone man—I was very modest; in fact, in the presence of ladies, extremely bashful. It didn't trouble me in the least to talk or sing to a great audience, provided, of course, it was a few miles away, but when I saw those girls, the complacency with which I had been contemplating the probable failure of my fine singer was changed to painful apprehension. If he wasn't successful a very bashful young man would have a new experience. I should be obliged to sing myself before those giggling, unscientific girls. This world would be a better place to live in if we all tried to help our fellow-men succeed, as I tried that night, when the first song was called for, to make my musical friend achieve a lyrical triumph on the Metropolitan stage. But he sang that song for the benefit of those girls, not for Chickering Hall, and it was with a heavy heart that I listened for Bell's voice when he finished it. The blow fell. In his most delightful platform tones, Bell uttered the fatal words I had foreboded, "Mr. Watson, the audience could not hear that. Won't you please sing?" Bell was always a kind-hearted man, but he didn't know. However, I nerved myself with the thought that that New York audience, made sceptical by the failure of that song, might be thinking cynical things about my beloved leader and his telephone, so I turned my back on those girls and made that telephone rattle with the stirring strains of "Hold the Fort," as it never had before. Then I listened again, Ah, the sweetness of appreciation! That New York audience was applauding vigorously. When it stopped, the same voice came with a new note of triumph in it. "Mr. Watson, the audience heard that perfectly and call for an encore." I sang through my entire repertoire and began again on "Hold the Fort," before the audience was satisfied. That experience did me good, I have never had stage fright since. But the "suppostitious Mr. Watson," as they called me then, had to do the singing at all of Bell's subsequent lectures. Nobody else had a chance at the job; one experience was enough for Mr. Bell.

My baritone had his hat on his head and a cynical expression on his face, when I finished working on those songs. "Is that what you wanted?" he asked. "Yes." "Well, boss, I couldn't do that." Of course he couldn't.

An Exhibition in Lawrence.—Another occasion is burnt into my memory that wasn't such a triumph over difficulties. In these lectures we always had another trouble to contend with, besides the rusty joints in the wires; that was the operators cutting in, during the lectures, their highest resistance relays, which enabled them to hear some of the intermittent current effects I sent to the hall. Inductance, retardation, and all that sort of thing which you have so largely conquered since, were invented long before the telephone was, and were awaiting her on earth all ready to slam it when Bell came along. Bell lectured at Lawrence, Massachusetts, one evening in May, and I prepared to furnish him with the usual program from the laboratory in Boston.

But the wire the company assigned us was the worst yet. It worked fairly well when we tried it in the afternoon, but in the evening every station on the line had evidently cut in its relay, and do my best I couldn't get a sound through to the hall.

The local newspaper generally sent a reporter to my end of the wire to write up the occurrences there. This is the report of such an envoy as it appeared in the Lawrence paper the morning after Bell's lecture there:

"Mr. Fisher returned this morning. He says that Watson, the organist and himself occupied the laboratory, sitting in their shirt sleeves with their collars off. Watson shouted his lungs into the telephone mouthpiece, 'Hoy! Hoy! Hoy!' and receiving no response inquired of Fisher if he pardoned for a little 'hamburg edging' on his language. Mr.

Fisher endeavoured to transmit to his Lawrence townsmen the tune of 'Federal Street' played upon the cornet, but the air was not distinguishable here. About 10 p.m., Watson discovered the 'Northern Lights' and found his wires alive with lightning, which was not included in the original scheme of the telephone. He says the loose electricity abroad in the world was too much for him."

Waiting for Watson.—The next morning a poem appeared in the Lawrence paper. The writer must have sat up all night to write it. It was entitled "Waiting for Watson," and I am very proud of the only poem I ever had written about me. I am going to ask your permission to read it. Please notice the great variety of human feeling the poet put into it. It even suggests missiles, though it flings none.

Lawrence, Mass., *Daily American,* Tuesday, May 29, 1877.

WAITING FOR WATSON.

To the great hall we strayed,
Fairly our fee we paid,
Seven hundred there delayed,
But, where was Watson?

Seven hundred souls were there,
Waiting with stony stare,
In that expectant air—
Waiting for Watson.

Oh, how our ears we strained,
How our hopes waxed and waned,
Patience to dregs we drained,
Yes, we did, Watson!

Give but one lusty groan,
For bread we'll take a stone,
Ring your old telephone!
Ring, brother Watson.

Doubtless 'tis very fine,
When, all along the line,
Things work most superfine—
Doubtless 'tis Watson.

We know that, every day,
Schemes laid to work and pay,
Fail and "gang aft a-gley"—
Often, friend Watson.

And we'll not curse, or fling,
But, next time, do the thing
And we'll all rise and sing,
"Bully for Watson!"

Or, by the unseen powers,
Hope in our bosom sours,
No telephone in ours—
"Please, Mr. Watson."

My last Public Appearance.—But my vacation was about over. Besides raising the wind, the lectures had stirred up a great demand for telephone lines. The public was ready for the telephone long before we were ready for the public, and this pleasant artistic interlude had to stop; I was needed in the shop to build some telephones to satisfy the insistent demand. Fred Gower, a young newspaper man of Providence, had become interested with Mr. Bell in the lecture work. He had an unique scheme for a dual lecture with my illustrations sent from a central point to halls in two cities at the same time. I think my last appearance in public was at one of these dualities. Bell lectured at New Haven and Gower gave the talk at Hartford, while I was in between at Middletown, Conn., with my apparatus, including my songs. It didn't work very well. The two lecturers didn't speak synchronously. Gower told me afterwards that I was giving him, "How do you do," when he wanted "Hold the Fort," and Bell said I made it awkward for him by singing "Do Not Trust Him, Gentle Lady," when he needed the trombone solo.

The "Gower-Bell" Telephone.—In the following August, Professor Bell married and went to England, taking with him a complete set of up-to-date telephones, with which he intended to start the trouble in that country. Fred Gower became so fascinated with lecturing on the telephone that he gave up an exclusive right Mr. Hubbard had granted him for renting telephones all over New England, for the exclusive privilege of using the telephone for lecture purposes all over the United States. But it wasn't remunerative after Bell and I gave it up. The discriminating public preferred Mr. Bell as speaker—and I always felt that the singing never reached the early heights.

Gower went to England later. There he made some small modification of Bell's telephone, called it the "Gower-Bell" telephone, and made a fortune out of his hyphenated atrocity. Later he married Lilian Nordica, although she soon separated from him. He became interested in ballooning. The last scene in his life before the curtain dropped showed a balloon over the waters of the English Channel. A fishing boat hails him, "Where are you bound?" Gower's voice replies, "To London." Then the balloon and its pilot drifted into the mist for ever.

Developing a Calling Apparatus; the Watson "Buzzer."—As I said, I went back to work, and my next two years was a continuous performance. It began to dawn on us that people engaged in getting their living in the ordinary walks of life couldn't be expected to keep the telephone at their ear all the time waiting for a call, especially as it weighed about ten pounds then and was as big as a small packing case, so it devolved on me to get up some sort of a call signal. Williams on his line used to call by thumping the diaphragm through the mouthpiece with the butt of a lead pencil. If there was someone close to the telephone at the other end, and it was very still, it did pretty well, but it seriously damaged the vitals of the machine and therefore I decided it wasn't really practical for the general public; besides we might have to supply a pencil with every telephone and that would be expensive. Then I rigged a little hammer inside the box with a button on the outside. When the button was thumped the hammer would hit the side of the diaphragm where it could not be damaged, the usual electrical transformation took place, and a much more modest but still unmistakable thump would isue from the telephone at the other end.

That was the first calling apparatus ever devised for use with the telephone, not counting Williams' lead pencil, and several with that attachment were put into practical use. But the exacting public wanted something better, and I devised the Watson "Buzzer"—the only practical use we ever made of the harmonic telegraph relics. Many of these were sent out. It was a vast improvement on the Watson "Thumper," but still it didn't take the popular fancy. It made a sound quite like the horseradish grater automobile signal we are so familiar with now-a-days, and aroused just the same feeling of resentment which that does. It brought me only a fleeting fame for I soon superseded it *by a magneto-electric call bell* that solved the problem, and was destined to make a long-suffering public turn cranks for the next fifteen years or so, as it never had before, or ever will hereafter.

Perhaps I didn't have any trouble with the plaguey thing! The generator part of it was only an adaption of a magneto shocking machine I found in Davis' Manual of Magnetism and worked well enough, but I was guilty of the jingling part of it. At any rate, I felt guilty when letters began to come from our agents reciting their woes with the thing, which they said had a trick of sticking and failing on the most important occasions to tinkle in response to the frantic crackings of the man who wanted you. But I soon got it so it behaved itself and it has been good ever since, for I have been told that nothing better has ever been invented, that they have been manufactured by the millions all over the world, and that identical jingler to-day does practically all the world's telephone calling.

"Williams' Coffins."—For some reason, my usual good luck I presume, the magneto call bells didn't get my name attached to them. I never regretted this, for the agents, who bought them from Williams, impressed by the long and narrow box in which the mechanism was placed, promptly christened them "Williams' Coffins." I always thought that a narrow escape for me!

The first few hundreds of these call bells were a continuous shock to me for other reasons than their failure to respond. I used on them a switch, that had to be thrown one way by hand, when the telephone was being used, and then thrown back by hand to put the bell in circuit again. But the average man or woman wouldn't do this more than half the time, and I was obliged to try a series of devices, which culminated in that remarkable achievement of the human brain—the automatic switch hook—that only demanded of the public that it should hang up the telephone after it got through talking. This the public learned to do quite well after a few years of practice.

The Blake Transmitter.

You wouldn't believe me if I should tell you a tithe of the difficulties we got into by flexible cords breaking inside the covering, when we first began to use hand telephones!

Then they began to clamour for switchboards for the first centrals, and individual call bells began to keep me awake at nights. The latter were very important then, for such luxuries as one station lines were scarce. Six to twenty stations on a wire was the rule, and we were trying hard to get a signal that would call one station without disturbing the whole town. All of these and many other things had to be done at once, and, as if this was not enough, it suddenly became necessary for me to devise a battery transmitter. The Western Union people had discovered that the telephone was not such a toy as they had thought, and as our 100,000-dollar offer was no longer open for acceptance, they decided to get a share of the business for themselves, and Edison evolved for them his carbon-button transmitter. This was the hardest blow yet.

We were still using the magneto transmitter, although Bell's patent clearly covered the battery transmitter. Our transmitter was doing much to develop the American voice and lungs, making them powerful but not melodious. This was, by the way, the telephone epoch when they used to say that all the farmers waiting in a country grocery would rush out and hold their horses when they saw any one preparing to use the telephone. Edison's transmitters talked louder than the magnetos we were using and our agents began to clamour for them, and I had to work nights to get up something just as good. Fortunately for my constitution, Frank Blake came along with his transmitter. We bought it and I got a little sleep for a few days. Then our little David of a corporation sued that big Goliath, the Western Union Company, for infringing the Bell patents, and I had to devote my leisure to testifying in that suit, and making reproductions of the earliest apparatus to prove to the court that they would really talk and were not a bluff, as our opponents were asserting.

Then I put in the rest of my leisure making trips among our agents this side of the Mississippi to bring them up to date and see what the enemy were up to. I kept a diary of those trips. It reads rather funnily to-day, but I won't go into that. It would detract from the seriousness of this discourse.

Wire Troubles.—Nor must I forget an occasional diversion in the way of a sleet storm which, combining with our wires then beginning to fill the air with house top lines and pole lines along the sidewalks, would make things extremely interesting for all concerned. I don't remember ever going out to erect new poles and run wires after such a catastrophe. I think I must have done so, but such a triffling matter naturally would have made but little impression upon me.

Is it any wonder that my memory of those two years seems like a combination of the Balkan war, the rush hours on the subway and a panic on the stock market?

Turning to Other Activities.

My connection with the telephone business ceased in 1881. The strenuous years I had passed through had fixed in me a habit of not sleeping at night as much as I should, and a doctor man told me I would better go abroad for a year or two for a change. There was not the least need of this, but as it coincided exactly with my desires, and as the telephone business had become, I thought, merely a matter of routine, with nothing more to do except pay dividends and fight infringers, I resigned my position as General Inspector of the Company, and went over the ocean for the first time.

When I returned to America a year or so later, I found the telephone business had not suffered in the least from my absence, but there were so many better men doing the work that I had been doing, that I didn't care to go into it again.

I was looking for more trouble in life and so I went into shipbuilding, where I found all I needed.

Before Mr. Bell went to England on his bridal trip, we agreed that as soon as the telephone became a matter of routine business he and I would begin experimenting on flying machines, on which subject he was full of ideas at that early time. I never carried out this agreement. Bell did some notable work on airships later, but I turned my attention to battleships.

My Greatest Pride.

Such is my very inadequate story of the earliest days of the telephone so far as they made part of my life. To-day when I go into a central office or talk over a long distance wire or read the annual report of the American Telephone and Telegraph Company, filled with figures up in the millions and even billions, when I think of the growth of the business, and the marvellous improvements that have been made since the day I left it, thinking there was nothing more to do but routine, I must say that all that early work I have told you about seems to shrink into a very small measure, and, proud as I always shall be, that I had the opportunity of doing some of that earliest work myself, my greatest pride is that I am one of the great army of telephone men, every one of whom has played his part in making the Telephone Service what it is to-day.

I thank you.

LOCAL CENTRE NOTES.

LONDON CENTRE.

The Session was opened on the 9th October by Mr. E. J. Woods, A.M.I.E.E., who read a paper on "The Main Underground System of Great Britain." The paper dealt exhaustively with the development of the system and the procedure at Headquarters, and was illustrated by lantern slides showing the progress that had been made particularly since the War. There was a good attendance and an interesting discussion.

The second meeting of the Session was regarded with keen interest. Mr. H. G. S. Peck, B.Sc., M.I.E.E., gave a paper entitled "The Director Exchange in Practice" before a crowded audience, who fully appreciated the excellent reading of the paper and the lucid description of the lantern slide illustrations.

The second half of this meeting was presided over by the President, Col. Purves, who introduced Dr. Thomas Watson, the assistant to Alexander Graham Bell in the invention and development of the telephone, with his customary felicitousness.

Dr. Watson's address "The Birth of the Telephone," was listened to with intense interest and, as he unfolded the enthralling story of the early history and the struggles to develop the telephone system, one could not help but realise how much was due to the pioneers of those far-off days. The Lecture Theatre of the Institution of Electrical Engineers can seldom have held so large an audience and certainly no lecturer can have had a more interested and enthusiastic one. The evening will be a pleasant memory to all for many long years. (*Dr. Watson's address is given in the preceding pages*).

The discussion on Mr. Peck's paper was resumed on Tuesday, the 4th December, and proved of great interest and value. Many of the speakers came from the Contractors' side and expressed their views on circuit design and relay requirements. Mr. Peck ably replied.

Informal Meetings.

The first Informal meeting was held on October 23rd, when Mr. P. J. Ridd, M.I.E.E., gave a lecture on "Transmission Efficiency Tests on Subscribers' Apparatus, London District." The subsequent discussion was opened by Mr. Hudson, of the Research Section, who later demonstrated the apparatus on view.

Many members took part in the discussion and it was only the operation of the time limit that enabled the Chairman to close the meeting at the usual time.

Mr. Ridd replied to many of the points raised and many of the members remained behind to explore the mysteries underlying the testing of subscribers' apparatus.

The second meeting was held on 27th November, when Mr. Cowie, M.I.E.E., gave a talk on "Staff Characteristics, Character judging. Talk on personal characteristics." Owing to Mr. Cowie's recent illness the paper was read by Mr. Geer. As was generally expected the matter was both grave and gay and the illustrations were interesting and apposite.

The subsequent discussion was opened by Capt· Hines. Many other speakers followed and it is very encouraging to see that more of the younger members are taking advantage of these meetings to air their views in public.

Mr. Cowie replied with his usual facility and it is the sincere hope of everyone that he will soon be completely restored to health.

T.H.

SCOTLAND WEST CENTRE.

The opening meeting of the session was held in the Society's Room, Royal Technical College, Glasgow, on 1st October, when Mr. H. J. McNamara delivered a lecture on " Ineffective Time."

At the outset, the lecturer stated that it was not intended in the lecture to cover all the points which might be embraced by the title, but rather to confine his remarks to consideration of ineffective time in regard to fairly small development works affecting, say, a city block of buildings, and so leave time for the meeting to discuss the question in all its aspects.

The lecturer pointed out the growing difficulties in regard to safe accommodation for stores and handcarts required for the work, the gradual adoption for garage purposes of areas formerly available, and the increasing necessity for limiting the extent of interference with road traffic, all of these circumstances having a tendency to increase ineffective time. Half a mile was stated to be not an unusual distance between the scene of operations and the point of storage. Methods of conducting the work with a view to limiting ineffective time were dealt with.

After considerable discussion on the points raised by the lecturer, the meeting was thrown open to general discussion of the subject. The prevailing view appeared to be that improved motor transport would do more than anything else to reduce ineffective time in the outlying areas, while improved facilities for storage and transport would improve matters in the city areas.

The second meeting of the Session was held ine the Societies' Room, Royal Technical College, Glasgow, on 28th November. After the routine business had been transacted the film " Voices across the Sea," illustrating the operation of a wireless call between San Francisco and Plymouth, was exhibited.

Mr. E. J. Woods, A.M.I.E.E., Engineer-in-Chief's Office, then read his paper entitled " The Main Underground Trunk Cable System of Great Britain."

Members of the local centre are reminded of the fixture on 2nd February, at 7.30 p.m. under the auspices of the Scietific Society of the Royal Technical College, when Mr. E. S. Ritter, of the Engineer-in-Chief's Office, will deliver a lecture on " Picture Telegraphy," to which I.P.O.E.E. members are specially invited.

H. C. M.

NORTHERN CENTRE.

The opening meeting of the Session was held on the 17th October, when Mr. J. R. Edwards read a paper on " The Output of the Worker, and Suggestions for Improving." Mr. Edwards mentioned co-ordination, supervision, suitability of men, energy and zeal, methods of regulations, and tools as being the leading factors governing the output of the worker, and after making comments under each of these heads he proceeded to suggest :

That no gang should contain more than five men, including the Foreman.

That Local or Advice Note gangs should be comprised of three or four men, including the Foreman.

That more motor vans could be used with advantage, the vans being made to seat four or five men, and be fitted with drum barrows for running off line wire. The fitting of a light crane and winch for pole erections, and the carrying of a telescopic ladder, were also suggested.

Respecting the hours of duty of workmen, Mr. Edwards suggested that during the summer months the 48 hours should be spread over five days only, the author regarding Saturday morning as being an unprofitable work day, and as regards the winter months, it was suggested that eight hours should be worked on each of the six week days. The giving of a bonus to gangs on completed units of work was also suggested. To avoid the loss of time in locating split couplings under made pavements, it was suggested that where conduits are laid on footpaths the line of trench should be marked on the surface by metal studs. The use of short, tubular, galvanised, iron poles in selected areas was also suggested as a measure of economy, as was also the use of a special insulator which would obviate the necessity for "binding-in." As was expected, the paper provoked a brisk discussion.

At a representative gathering held on the 22nd instant, Mr. H. R. J. Dunthorne of this District, who has been promoted to fill the Executive Engineer's vacancy at Canterbury, was presented with a handsome canteen of cutlery. The Superintending Engineer, Mr. J. R. M. Elliott, in making the presentation, referred to the zeal, energy, and conspicuous ability with which Mr. Dunthorne had discharged his duties, and assured Mr. Dunthorne that he carried with him the good wishes of the staff of the Northern District.

Owing to office changes, Mr. T. E. Preston has had to relinguish the duties of Local Librarian, and at the last general meeting a hearty vote of thanks to Mr. Preston, for the ungrudging services he has rendered, was carried with acclamation. Mr. J. W. Kenyon has consented to act as Librarian, and applications for periodicals, etc., should be made to him.

NORTHERN IRELAND CENTRE.

A very pleasant and interesting Social function took place at the Post Office Ex-Service Men's Association Headquarters, Belfast, on the evening of the 14th September last when a large attendance from the Engineering Department and other branches of the Service met to say farewell to Mr. H. H. Broomhead, Assistant Engineer, Belfast, who retired from the Service on the 20th August last, having reached the age limit.

Major Comport, M.C., M.I.E.E., R.E., Superintending Engineer, presided, and was supported by Mr. G. Laslett, Sectional Engineer. After a few pleasing musical numbers, the Chairman introduced the main item of the evening by a feeling reference to the many excellent qualities possessed by the guest, which sentiments were subscribed to by a large number of the Company representing all branches of the Engineering Department. Major Comport on behalf of the Staff asked Mr. Broomhead to accept a wallet of Treasury Notes as a token of the high esteem and regard in which he was generally held throughout the District, together with their best wishes for his future happiness and prosperity. Mr. Broomhead thanked the Company for their kind expression of good wishes and their handsome present and stated that after having been nearly a quarter of a century in Belfast in close touch with the many activities of the Department he could hardly realise that he had ceased to be an active member, and so keenly did he feel this severance from his old colleagues that he had decided to return to the old country, but he would ever cherish the memory of the many good friends he was leaving in Ireland.

It is with deep regret we announce the death under sudden and tragic circumstances of Mr. R. H. Gilliland, Inspector, a prominent and enthusiastic Member of the Institution.

Mr. Gilliland complained of feeling unwell shortly after commencing duty on the 8th December. He suddenly collapsed and died within a short time.

The sympathy of the Committee and Members of the Institution was conveyed to the widow and relatives, and the funeral, which took place on the 11th December, was attended by representatives of all grades of the Service.

NORTH WESTERN CENTRE.

The opening meeting of the 1928-29 Session was held at Preston on the 16th October, 1928, when a paper entitled "The Main Underground Trunk Cable System of the British Isles" was read by Mr. E. J. Woods, A.M.I.E.E., of the Engineer-in-Chief's Office. The Chairman of the Centre (Mr. J. M. Shackleton, M.I.E.E.) presided.

Mr. Woods opened his paper with a brief summary of the growth of the Main Cable System with reference to the more important cables laid up to December, 1927. He then proceeded to review the development of the present high-grade cable, also touching upon the earlier types of cable. Headquarters procedure in relation to cable schemes was explained and the following items covered: — Development Study, Lay-out of cables, etc., District procedure, Duct and Manhole Construction, Boring Machines, Cable Manufacture and Laying, Specifications, Phantom Circuits, Loading Coils, Carrier Wave Telephony, etc. The paper was illustrated by lantern slides and followed by a discussion.

On the 12th November, 1928, a paper was read by Mr. W. S. Procter, of the District Headquarters Technical Section, entitled "Cordless B. Key-sending Positions in Director and non-Director Areas." The paper opened with a general review of the objects of Cordless B. Key-sending Positions and a comprehensive description of the actual equipment and its operations. Mr. Procter then dealt with the arrangement of the apparatus in the Exchange and explained at length the functions of the component parts. The paper was illustrated by lantern slides and there was a discussion.

The third meeting of the Session was held at Preston on the 10th December, 1928, when Mr. T. E. Tootell read a paper entitled "Some Notes on the Maintenance of Machine Telegraphs." Mr. Tootell reviewed the systems leading up to the machine telegraphs now in use and described in general terms the functions of the various machines. The details of the Wheatstone Perforator, Transmitter and Receiver, the Baudot, Teleprinter 2A and 3A, etc., were explained and the maintenance of the apparatus fully described. The paper was illustrated by lantern slides, and a discussion followed.

D.B.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS NOTICES.

BOOTH-BAUDOT AWARD.

The Council wishes to call attention to the "Booth-Baudot Award" of £5 which is now offered annually for the best improvement in Telegraph, Telephone or Wireless Apparatus or Systems. The award for the year 1928 is governed by the following conditions:—

1. The Award will be restricted to employees of the British Post Office.
2. Applications for the Award should be made between 1st January and 31st March, 1929, and such applications should refer to improvements made, or suggested, during the twelve months ending 31st December, 1928.

   Attention is drawn to the fact that recipients of Awards *via* the Post Office Awards Scheme in respect to any improvement in telegraph, telephone or wireless apparatus or systems are eligible to apply for the Booth-Baudot Award in respect thereto.
3. The Award may be withheld at the discretion of the Council of the Institution of Post Office Electrical Engineers if, after full consideration of the applications received, the adjudicators appointed by the Council are of the opinion that no award is warranted.
4. Applications for the Award, accompanied by full details of the improvement, should be addressed to the Secretary, The Institution of Post Office Electrical Engineers, G.P.O. (Alder House), London, E.C.1.

R. V. HANSFORD,
Secretary,

December, 1928.

LOCAL CENTRE PROGRAMMES.

SCOTLAND WEST CENTRE.

1928.
1 Oct. or 5 Nov. H. J. McNAMARA.
"Underground Construction."

28 Nov. E. J. WOODS, A.M.I.E.E. *(E.-in-C.O.)*.
"The Main Underground Trunk Cable System of the British Isles."

1929.
4 Feb. A. THOMSON.
"Strowger Automatics." (Supplementary to last year's paper).

4 Mar. A. ARNOLD.
"Glasgow Repeater Station."

2 Apl. A. HUDSON. *(E.-in-C.O.)*.
"Routine Testing of Subscribers' Transmitters and Receivers for Efficiency in Situ."

SCOTLAND EAST CENTRE.

1928.
27 Nov. E. J. WOODS, A.M.I.E.E. *(E.-in-C.O.)*.
"The Main Underground Trunk Cable System of the British Isles."

18 Dec. R. GOODFELLOW.
"Training of Youths."

1929.
15 Jan. G. H. DOUGLAS.
"Notes on Battery Course, May, 1928."

19 Feb. H. BURGHER.
"Cabling and Jointing."

19 Mar. Short papers and informal discussions.

16 Apl. *To be arranged.*

NORTH IRELAND CENTRE.

1928.
6 Nov. Chairman's Address.
4 Dec. (*a*) Film—" Voices across the Sea."
(*b*) W. S. Keown.
" Beams, Girders and Reinforcements as used in Underground Construction."

1929.
15 Jan. *To be arranged.*
12 Feb. R. T. Robinson. (*E.-in-C.O.*).
" Motor Transport."
12 Mar. E. J. Woods, A.M.I.E.E. (*E.-in-C.O.*).
" The Main Underground Trunk Cable System of the British Isles."
16 Apl. A. S. Renshaw. (*E.-in-C.O.*).
" Some considerations relating to the Clerical Organisation of the Engineering Department."

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

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

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

R. Badenach, Esq., B.Sc. (Melb.),
Chief Electrical Engineers Office,
Postmaster Generals Department,
Treasury Gardens,
Melbourne,
Australia.

H. C. Brent, Esq.,
The Laboratory,
G.P.O.,
Wellington, N Z.

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

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

A. J. Kellaway, Esq.,
Department of Posts and Telegraphs,
P.O. Box 366,
Pietermaritzburg,
South Africa.

MR. J. W. ATKINSON, M.I.E.E.

MR. J. W. ATKINSON.

MR. J. W. ATKINSON, who, on 1st June last, was promoted to the Superintending Engineership of the North-Eastern District, with headquarters at Leeds, entered the service of the Post Office as a Telegraph Learner in April, 1893. After six years' work as a telegraphist he was transferred to the Engineering Department as a Junior Clerk; and, in July, 1900, was promoted to a Clerkship in the Engineer-in-Chief's Office, where he served under Mr. R. McIlroy, (now) I.S.O., who at that time was personal assistant to the Engineer-in-Chief, Mr. J. Hookey.

In 1902, Mr. Atkinson competed for a Second Class Engineership at Headquarters and was assigned to the Examination Section, under the late Mr. H. Hartnell, M.I.E.E.,: a few months later he was selected to act as personal assistant to the late Mr. Martin F. Roberts, M.Inst.C.E., Assistant Engineer-in-Chief, thus coming into close contact with the numerous engineering and administrative problems associated with the pre-1911 London Telephone System.

In September, 1907, Mr. Atkinson took charge of the Sutton and Epsom Section, transferring to Kingston in March, 1908; and in October, 1910, he was promoted to a First Class Engineership in charge of the Bristol Section. A year later he was assigned to one of the " Groups " formed for the purpose of checking the National Telephone Company's plant inventory and for collecting data for use in the valuation proceedings.

In 1911, Mr. Atkinson was nominated by the Engineer-in-Chief (Major W. A. J. O'Meara, C.M.G.) for an Assistant Staff Engineership and, after examination by the Civil Service Commissioners, was appointed on 9th December, 1911, to the Construction Section, the Staff Engineer being Mr. J. Sinnott, (now) O.B.E.

In March, 1926, having expressed a desire to refresh his knowledge of District activities, Mr. Atkinson was transferred to the London Engineering District and (in his own words) thus had the pleasure of renewed association with Mr. McIlroy.

It is Mr. Atkinson's ideal that the British P.O. Communication Services shall be equal, at least, to those of any other administration in the world; and it may be assumed that this explains his marked interest in the work of the Institution of Post Office Electrical Engineers. He was one of the founders of the Society of Post Office Engineers, whose intended work in the sphere of technical education was taken over by the Institution; he acted as Secretary to the Institution " Formation Committee " and for the first two years to the Institution itself; and since then has served as Honorary Treasurer to the Institution, and as a Member and also as Chairman of the Board of Editors of this Journal.

MR. H. WILSON.

MR. H. WILSON.

MR. WILSON retired from the Service on the 31st July, but returned to Cardiff in the first week in October, where he was entertained by the South Wales District and presented with a half-hunter gold watch and a grandfather's clock fitted with Westminster chimes, and also with an inkstand from the office Cricket Club. Taking the keenest interest in the welfare of the staff—it is said he was known personally by and knew the idiosyncracies of every member of the South Wales district—he was immensely popular and consequently secured the enthusiasm and best efforts of all grades of the service, and his retirement after one year's extension was deeply regretted throughout the district.

He entered the service as a telegraphist at Newcastle-on-tyne on the 17th July, 1882, and immediately began to take an interest in the technical side of the work. He found time, however, to join the volunteers and for ten years he was an active member of the Tynside Division of Submarine Miners. Later in life this training bore fruit and he rendered valuable service in the volunteer signal corps raised in London during the war and known colloquially as "Gunton's Gurkhas." Mr. Wilson, in 1892, was appointed a Relay Clerk at Morfa Nevin, and four years later he was promoted to Second Class Engineer in charge of Carmarthen Section. When the P.O. started the telephoning of London, selected engineers were chosen from the districts for the work, and Mr. Wilson came to Hampstead as First Class Engineer in June, 1902. He was nominated to sit at a competitive Civil Service examination, and in 1908 he was appointed Staff Engineer Second Class in the Designs Section. During his service at headquarters he acted as guide, philosopher and friend to various batches of young engineers recruited from outside the service and initiated them into the mysteries of telephone and telegraph practice. He was also a member of the Awards Committee, P.O. representative on the B.E.S.A. Committee which drew up the specification for materials used in and the construction of Chemical Fire Extinguishers, and for twenty years he was lecturer in Telegraphy and Telephony at Battersea Polytechnic. Second in command to the present Engineer-in-Chief in the Designs Section, Mr. Wilson rendered very valuable service during the war period and assisted Col. Purves in the design and supply of new signal apparatus for the armies in the field. He has many humorous incidents to tell of his experiences with inventors, whose ideas were not always so indispensable to the Department as their authors imagined.

In April, 1924, Mr. Wilson went to South Wales as Assistant Superintending Engineer and three months later he took charge of the district as Superintending Engineer.

In spite of his forty-six years strenuous service, Mr. Wilson does not think he requires a rest. He has joined the firm of Thomas Watson and Son, Dudden Hill Lane, scientific instrument makers, as consultant and technical representative, and is carrying on with his unfailing energy and good humour.

W. S. TINSLEY, M.I.E.E.

MR. W. S. TINSLEY.

MR. W. S. TINSLEY, Sectional Engineer at Bradford, retired at the end of October after completing forty-three years' service. Mr. Tinsley commenced his service in the Telegraph Department at Hull in 1885, and in 1894 he was nominated to a Junior Clerkship in the Engineering Department at Liverpool. This was followed by promotion to Newcastle in 1896. Five years later he was promoted to Engineer in London, and in 1909 a further step was taken when he took charge of the Bradford Section.

Mr. Tinsley was in charge of the Bradford Section for nineteen years. It is well known that this section is a heavy one. To estimate Mr. Tinsley's services to the Department one must visualise the conditions existing in the West Riding some years ago, when Bradford was served mainly with overhead wires, when the Exchanges were worked by systems since displaced, and overloaded routes of open wires crossed the moorland in all directions. All these things are better tŏ-day, and the knowledge that he has helped, materially, towards this improvement is Mr. Tinsley's most satisfactory reward.

As a mark of esteem from colleagues and friends, Mr. Tinsley was presented with a silver tea service and a gramophone, at a complimentary dinner in Bradford. The chair was taken by Mr. J. C. Walker, Assistant Engineer. Those present included the Superintending Engineer, Mr. J. W. Atkinson; the late Superintending Engineer, Mr. T. B. Johnson; Mr. W. J. Bailey, Staff Engineer, London; Mr. G. S. Wallace, Assistant Superintending Engineer; Mr. G. Richardson, Sectional Engineer, Birmingham; Mr. Bell Smith, Postmaster of Bradford; Mr. T. A. Bates, District Manager, and Mr. H. B. Sutcliffe, late District Manager.

It is the wish of his many friends that Mr. Tinsley will be happy in the years to come. Judging by his variety of interests, such as golf, bowls and music, there should be little doubt in the matter. As Honorary Secretary of the Bradford Musical Union he has a wide circle of friends. Mr. Tinsley will not be leaving Bradford, and there will be much opportunity of meeting him in the future. This will be a particular pleasure to his old friends in the N.E. District.

G.M.B.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	Grade.	Promoted to	Date.
Pink, E. A.	Executive Engineer, Bristol Section, S. West District.	Assistant Staff Engineer, Construction Section, E.-in-C.O.	23-9-28
Upton, S.	Executive Engineer, Preston Section, N. West District.	Assistant Superintending Engineer, N. West District.	15-8-28
Cornfoot, T.	Executive Engineer, Liverpool External Section. S. Lancs. District.	Assistant Superintending Engineer, S. East District.	3-1-29
Wise, Capt. F. H.	Executive Engineer, Exeter Section, S. West District.	Assistant Superintending Engineer, S. East District.	1-3-29
Wildgoose, G. H. A.	Assistant Engineer, Technicla Section, S. Lancs. District.	Executive Engineer, Technical Sect. S. Lancs. District.	21-11-28
Buchanan, J.	Assistant Engineer, Preston Section, N. West District.	Executive Engineer, Preston Sect., N. West District.	21-11-28
Coxon, J.	Assistant Engineer, Power Section, N. Wales District.	Executive Engineer, Technical Sect N. Wales District.	29-11-28
Clack, C. W.	Assistant Engineer, Designs Section, E.-in-C.O.	Executive Engineer, Designs Sect., E.-in-C.O.	1-12-28
Akast, A. C. S.	Chief Inspector, London Engineering District.	Assistant Engineer, London Engineering District.	21-11-28
Nichols, J. C.	Chief Inspector, S. Midland District.	Assistant Engineer. N. Mid. District.	To be fixed later.
Chapman, F. G.	Chief Inspector, Stonehaven Radio.	Assistant Engineer, Leafield Radio.	To be fixed later.
Stevens, F.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	21-11-28
Soper, R. E.	Chief Inspector, S. West District.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Carr, A. S.	Chief Inspector, N. West District.	Assistant Engineer, N. West District.	21-11-28
Corkett, H.	Chief Inspector, London Engineering District.	Assistant Engineer, London Engineering District.	21-11-28
Woodhouse, B. W.	Chief Inspector, London Engineering District.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Cohen, A. J.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	21-11-28
Mabey, H.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Hewett, J. E.	Inspector, S. Wales District.	Chief Inspector, S. Wales District.	To be fixed later.
Wood, W. T.	Inspector, S. Lancs. District.	Chief Inspector, S. East District.	To be fixed later.
Bines, H. T.	Inspector, London Engineering District.	Chief Inspector, London Engineering District.	To be fixed later.
Beal, F. F.	Inspector, London Engineering District.	Chief Inspector, London Engineering District.	To be fixed later.
Storey, W. J.	Inspector, S. Lancs. District.	Chief Inspector, S. East District.	To be fixed later.
Hopper, E.	Inspector, N. West District.	Chief Inspector, N. West District.	1-12-28
Taylor, S. A.	Inspector, N. West District.	Chief Inspector, London Engineering District.	To be fixed later.
Lisle, R.	Inspector, N. Wales District.	Chief Inspector, S. Midland District.	To be fixed later.
Mitchell, C. A.	Inspector, Eastern District.	Chief Inspector, Eastern District.	To be fixed later.
Pendry, S. D.	Inspector, S. Midland District.	Chief Inspector, S. Midland District.	To be fixed later.
Beazer, F. C.	Inspector, London Engineering District.	Chief Inspector, London Engineering District.	To be fixed later.
Hourigan, H. F.	Unestablished Skilled Workman Testing Branch.	Inspector, Testing Branch.	14-11-28

RETIREMENTS.

Name.	Grade.	Districts.	Date.
France, W. M.	Staff Engineer.	E.-in-C.O.	31-10-28
Francis, F. W.	Assistant Staff Engineer.	E.-in-C.O.	30-11-28
Tinsley, W. S.	Executive Engineer.	N. Eastern.	31-10-28
Greening, A. C.	Assistant Engineer.	London.	31-10-28
Wenman, H. E. A.	,, ,,	London.	30-11-28
Jones, H.	Inspector,	S. Wales.	5-9-28
Reed, W.	,,	Northern.	28-9-28
Sly, W. B.	,,	S. Midland.	13-10-28
Williams, W. R.	,,	S. Lancs.	18-10-28
Roberson, H. T.	,,	London.	20-10-28
Holliday, R. W.	,,	London.	31-10-28

DEATHS.

Name.	Grade.	District.	Date.
Hartnell, G. T.	Chief Inspector,	E.-in-C.O.	10-11-28
Robinson, H. E.	Inspector.	S. West.	8-9-28

TRANSFERS

Name.	Rank.	From.	To	Date.
Fletcher, Capt. J. E.	Executive Engineer.	S. Lancs. Dist.	N. East Dist.	1-11-28
Jackson, D.	Assistant Engineer.	Testing Branch	E.-in-C.O.	1-12-28
Jackson, J. M.	,, ,,	N. West Dist.	S. Lancs. Dist.	1-11-28
Horn, C. O.	,, ,,	Rugby Radio.	E.-in-C.O.	7-11-28
Manning, G.	,, ,,	E.-in-C.O.	L.E.D.	25-11-28
Pritchard, E. J.	Inspector.	N. Wales.	E.-in-C.O.	28-10-28
Gill, F. W.	,,	S. West.	,,	25-11-28
Hawkins, N. A.	,,	S. East.	,,	25-11-28
Campbell, P. J.	,,	S. Mid.	,,	1-11-28
Collman, E. L.	,,	N.	E.-in-C.O.	11-11-28

APPOINTMENTS.

Name.	From.	To	Date.	
Vickers, G. H.	Assistant Officer-in-Charge Cairo Radio.	Assistant Engineer, Rugby Radio.	23-11-28	
Knowers, A. D. V.	Inspector E.-in-C.O.	Probationary Assistant Engineer, E.-in-C.O.	To be fixed later.	*Limited Competition.*
Berkeley, G. S.	,, ,,	Probationary Assistant Engineer, E.-in-C.O.	14-11-28	
Turner, H. M.	Inspector, S. Lancs.	Probationary Assistant Engineer, S. Lancs.	26-11-28	
Chew, W. G. N.	Inspector, E.-in-C.O.	Probationary Assistant Engineer, E.-in-C.O.	14-11-28	
Jones, C. E. P.	,, ,,	Probationary Assistant Engineer, E.-in-C.O.	13-11-28	
Morrell, F. O.	,, ,,	Probationary Assistant Engineer, London.	24-11-28	*Open Competition.*
Howard, J. L.		Probationary Assistant Engineer, E.-in-C.O.	3-12-28	
Jarvis, R. F. J.		Probationary Assistant Engineer, E.-in-C.O.	To be fixed later.	
Franklin, R. H.		Probationary Assistant Engineer, London.	23-11-28	

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	From	To	Date.
Smalley, A. T.	Acting Executive Officer. E.-in-C.O.	Executive Officer, E.-in-C.O.	29-9-28
Gordon, F.	Clerical Officer, E.-in-C.O.	Acting Executive Officer, E.-in-C.O.	29-9-28
Crawford, G. W. J.	Higher Clerical Officer, Scotland West District.	Staff Officer, Scot. West District.	1-11-28
Bailey, W. R.	Clerical Officer, Scotland West District.	Higher Clerical Officer, Scot. West District.	1-11-28
Airey, J.	Clerical Officer, N. West District.	Higher Clerical Officer, Scot. East District.	11-11-28

RETIREMENTS.

Name.	Rank.	District.	Date.
Crotch, A.	Staff Officer.	E.-in-C.O.	31-12-28
Elener, G. A.	,, ,,	Scot. West District.	31-10-28
Pym, W. H.	Higher Clerical Officer,	Scot. East District.	25-10-28
Riley, R.	,, ,,	S. Midland.	4-12-28

COMMUNICATIONS.

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

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