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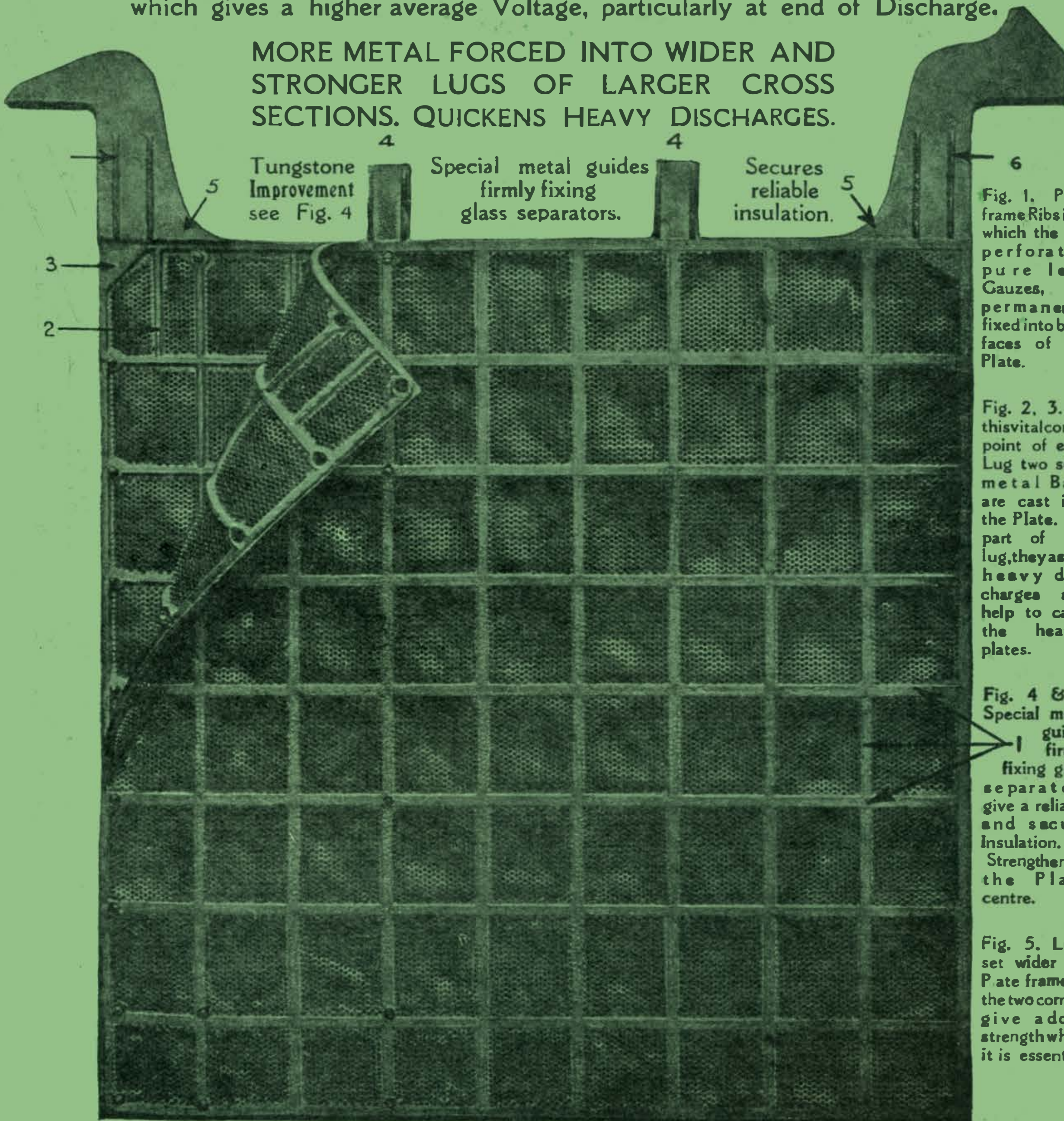

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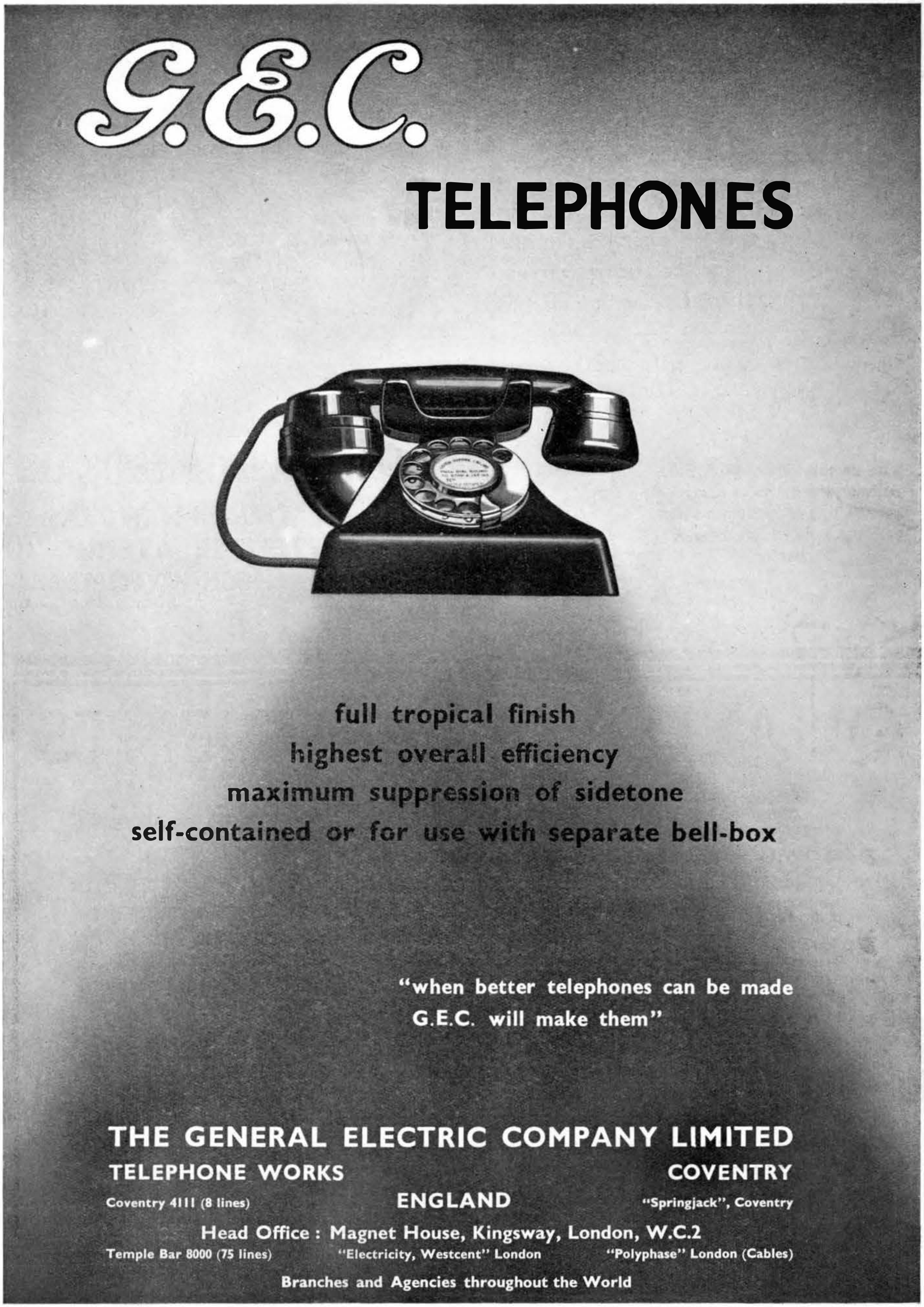
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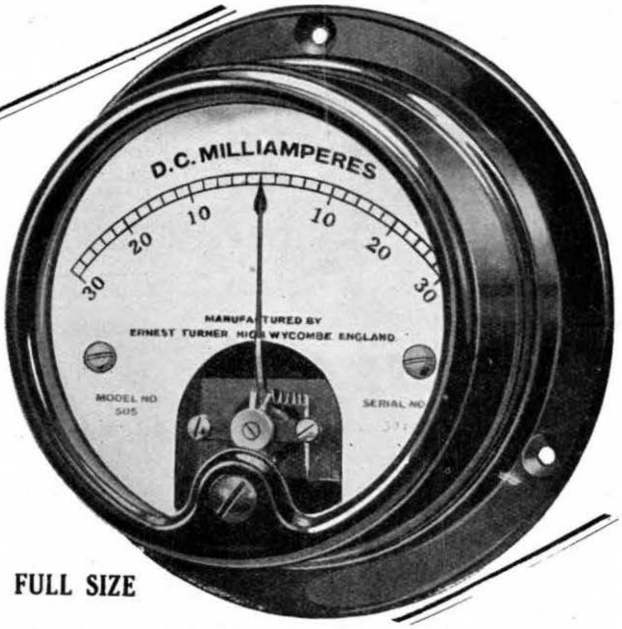

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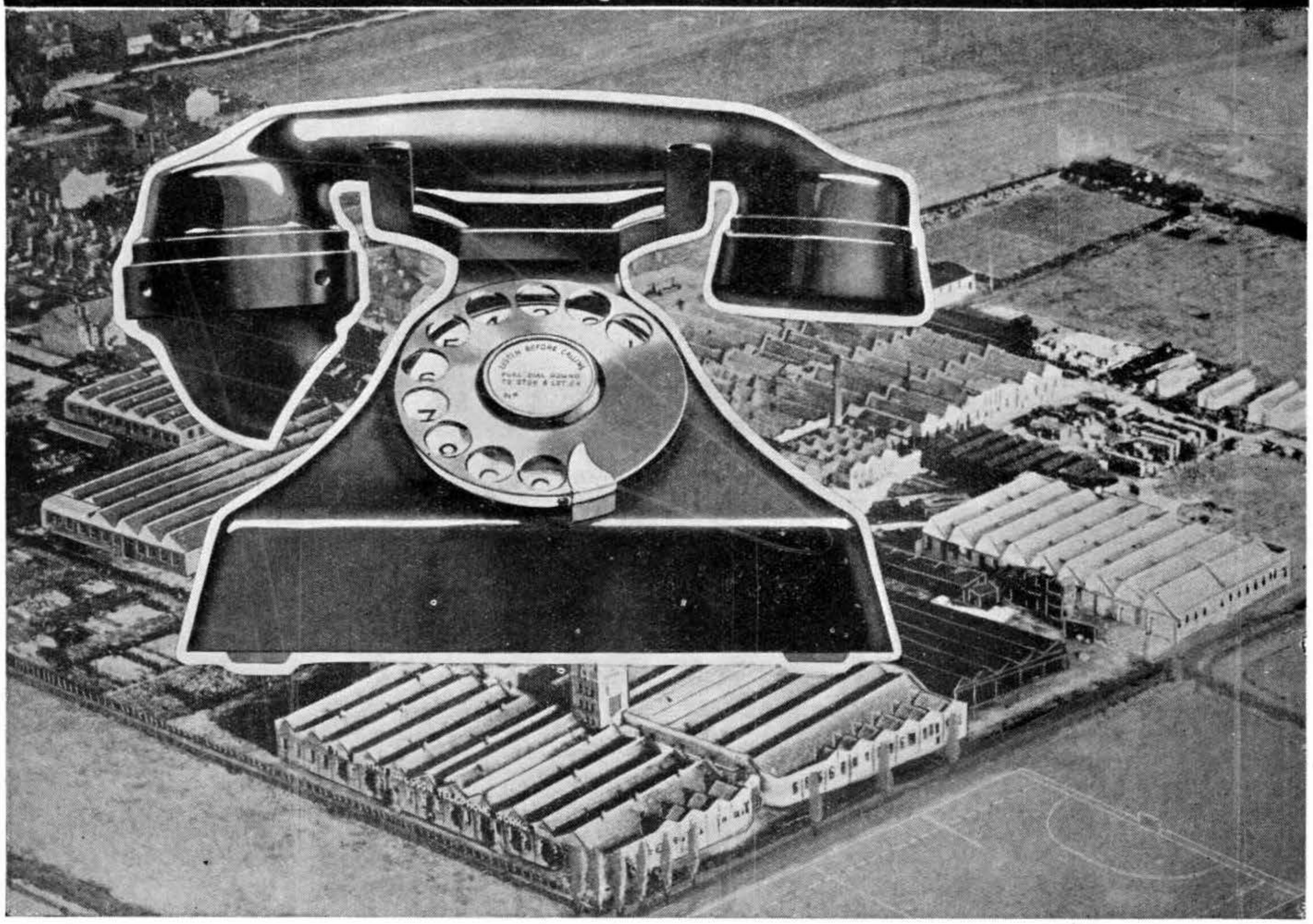

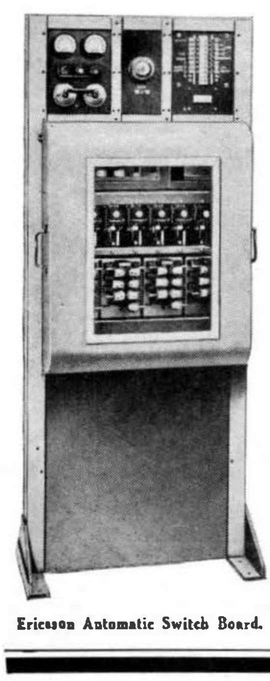

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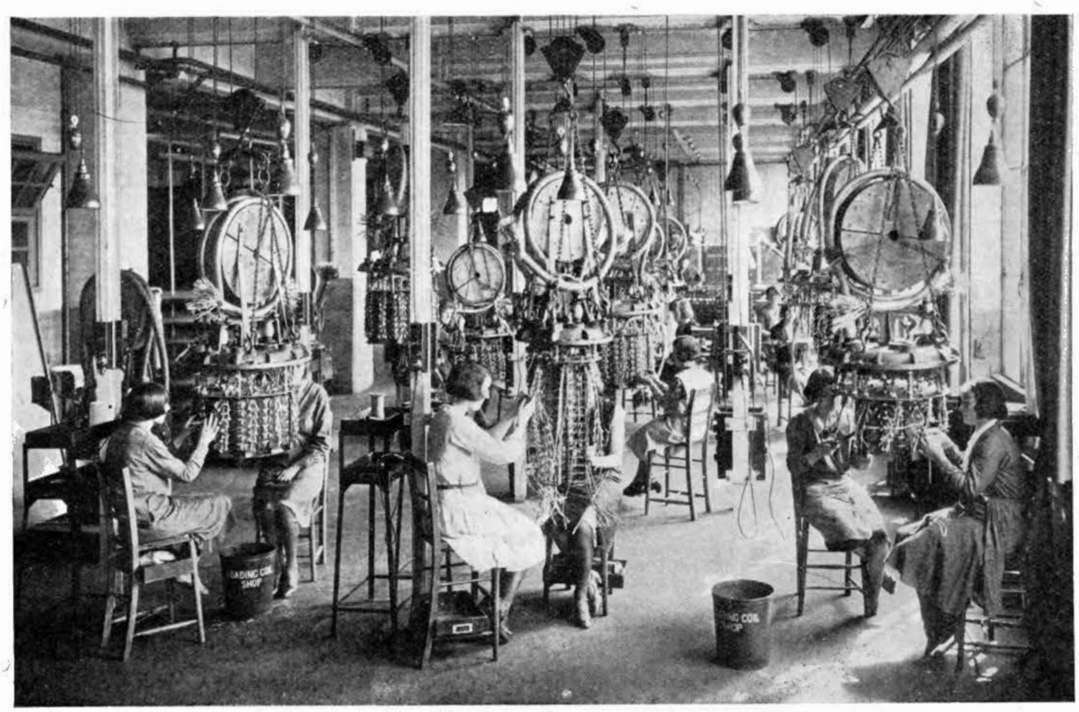

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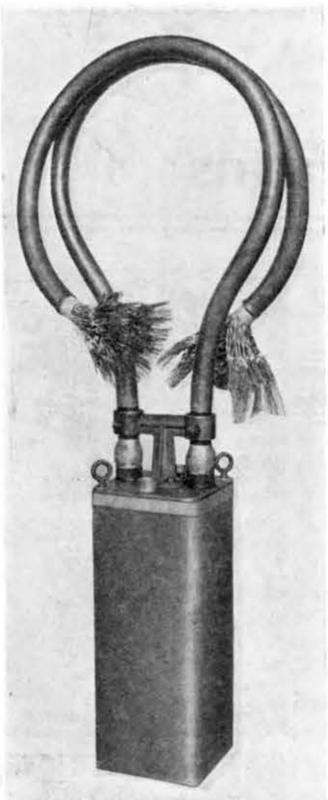

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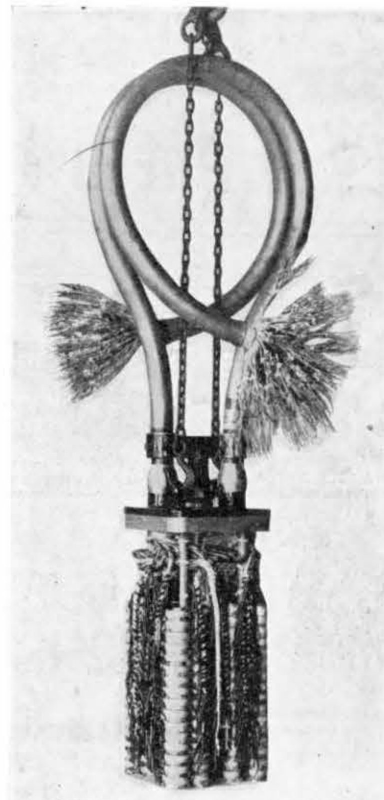

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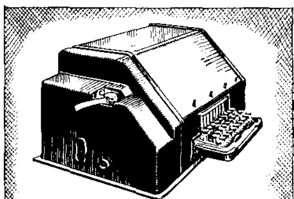

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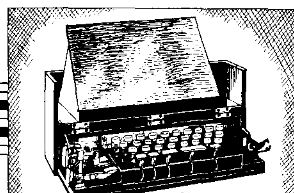

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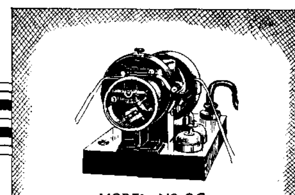

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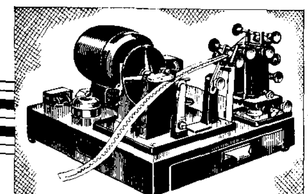

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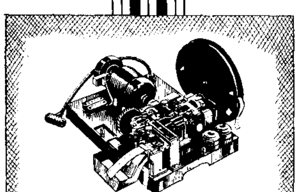

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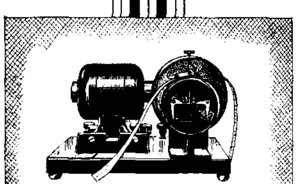

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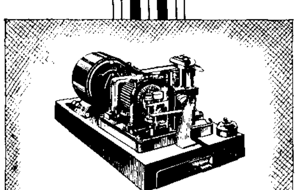

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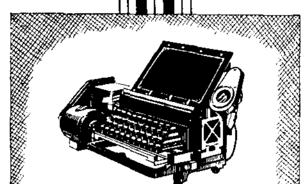

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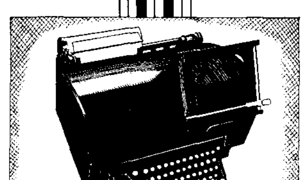

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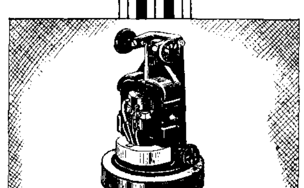

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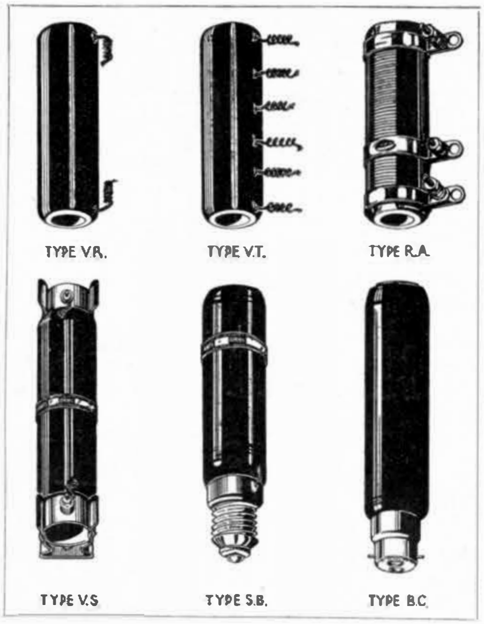

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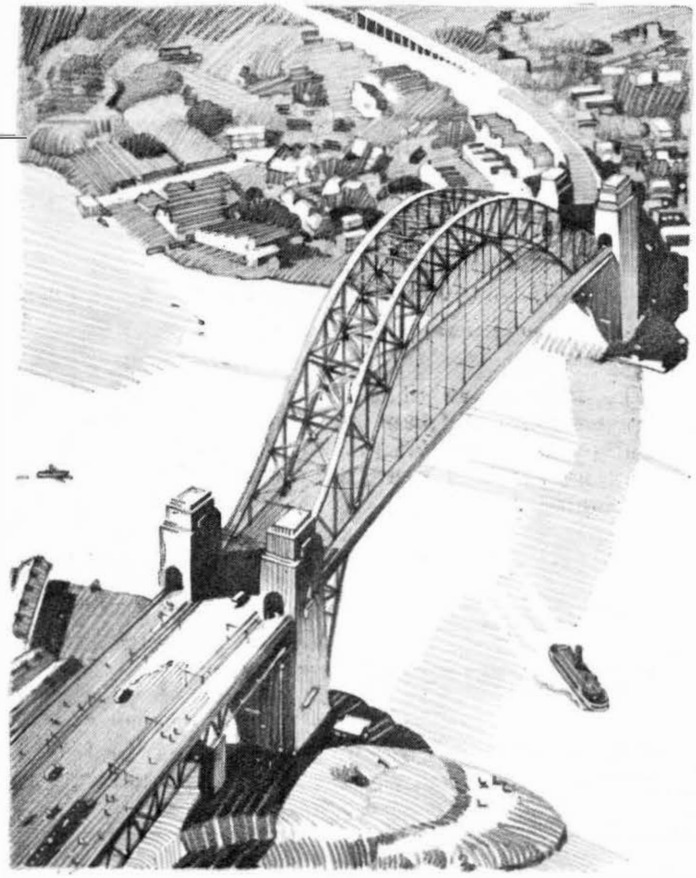

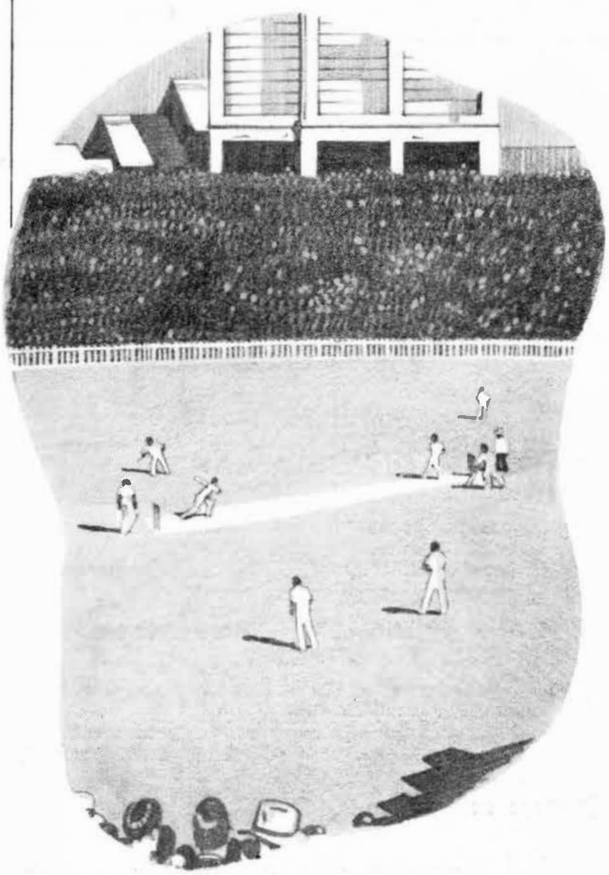

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ELECTRICAL ENGINEERS' JOURNAL

Vol. XXIX January, 1937 Part 4

The Speaking Clock

Part I.—Trunking and Facilities

L. E. MAGNUSSON

In part I of this article the reasons for the provision of a speaking clock are given and the trunking arrangements explained.

Introduction.

AN electrical clock, which is designed to provide verbal announcement of the time of day, was brought into use in London on the afternoon of July 24th, 1936. Previous to this date subscribers requesting the time were informed of the time as shown by the exchange clock. It was not, of course, possible for the operator to give the time with any precision, say, to within less than half a minute, due to the types of clock employed in the exchange switch room and the methods employed in correcting the clocks. In spite of these limitations, about 26,500 requests for time were received in the London area every week.

In recent years the public have been provided with a time service by the British Broadcasting Corporation in such a form that precise setting of watches or clocks can be accomplished. The utilization of this service involves listening at specified times when the time signal is radiated, and such a service is unlikely to appeal to business people and a large number of residential people to whom the radiation times are not convenient.

Electrical speaking clocks, to which access is gained via the telephone switching system, have already been introduced with success in some continental countries and according to the large amount of traffic carried by these clocks, it is evident that the service is very popular. In view of the fact that there was already an appreciable demand for a time service in this country under the old system, it was reasonable to assume that an increased demand would result from the introduction of an electrical speaking clock which would give a really accurate time service on demand and in such a form that the exact time could be easily ascertained. Accordingly a decision was made to introduce an electrical speaking clock in London with the extension later to certain provincial centres.

From experience of the manual time service, it was apparent that the "time" traffic would not coincide with the ordinary telephone traffic and that

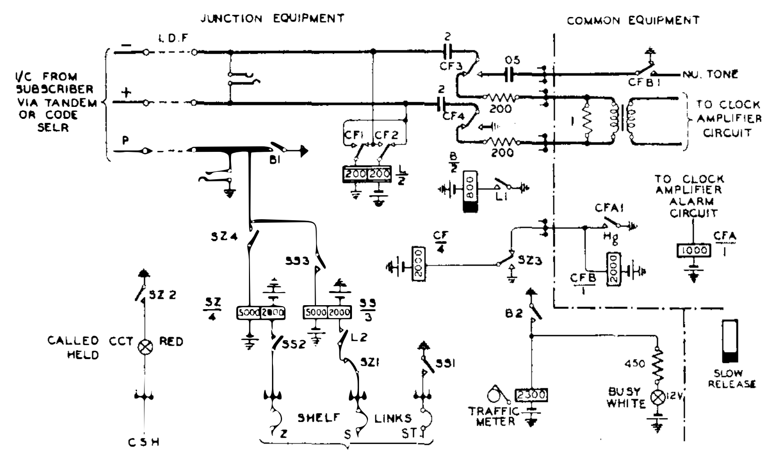

FIG. 1.—JUNCTION TERMINATING EQUIPMENT.

the normal trunking network would be capable of carrying the additional traffic without any extra switching plant except that necessary for actual connexion to the clock. This has in fact been borne out in practice, for approximately 94 per cent. of the clock traffic occurs outside the busy hour with traffic peaks at about 9 a.m. and between 12 mid-day and 1 p.m.

Trunking and Facilities.

In order to obtain access to the clock, subscribers connected to automatic exchanges dial the first three letters of TIMe and subscribers connected to manual exchanges ask their local operator for " time." All the calls are routed via the normal trunking network to the Holborn Tandem exchange where the clock is situated. The calls terminate on a special relay set, the circuit arrangement of which is shown in Fig. **1**.

This relay set provides the following facilities.

(a) The battery feed to the line is reversed in order to cause registration of the subscriber's meter if the call is from an automatic exchange or to darken the cord circuit supervisory lamp on a call from a manual exchange.

(b) A guarding earth is placed on the " P " wire to hold the tandem selectors.

(c) A lamp is lit to indicate that the relay set is engaged.

(d) A traffic meter, associated with the relay set, is operated each time the relay set is taken into use in order to indicate the total traffic carried.

(e) The calling party is disconnected from the clock after a period of 60 to 120 seconds. The provision of this facility is due to the fact that the total number of relay sets provided to carry the clock traffic was based on the anticipated number of demands and on the average holding time of one minute. It will be appreciated that any increase in this holding time will adversely affect the grade of service. Sufficient time is allowed under the minimum clear-down time to hear 8 complete announcements and this number should be more than sufficient for ordinary purposes. Since the introduction of the clock, it has been found that the average holding time is approximately 22 seconds and about 16 percent. of the calls are being disconnected due to the holding time exceeding one minute. The application of the time pulse is controlled by an associated equipment which is caused to operate immediately the relay set is seized and this equipment transmits two pulses, with an interval of 60 seconds between the pulses, to the relay set. The first pulse prepares the clear-down circuit and the second makes the clear-down effective. The " forced release " period has been made flexible so that the cleardown times may be varied if experience indicates that this is necessary. An alarm lamp, associated with the relay set, is caused to glow under forced release conditions in order that the engineering staff may take the necessary steps to have the connexion cleared. In addition a clearing signal is given in the cord circuit supervisory lamp on a call from a manual exchange.

(f) A number unobtainable tone is connected to the line in place of the time announcement if the complete breakdown of the clock occurs. Normally, in the event of the clock failure, automatic change-over to the stand-by clock will be effected, but in the event of a failure of both the regular and stand-by clocks an alarm condition is transmitted from the clock apparatus to the relay set to cause the application of the tone. In addition, the battery feed to the line is reversed so that registration of the subscribers' meters shall not take place, and also, on calls from a manual exchange, to give a clearing signal on the cord circuit supervisory lamp.

It has not been possible to give call offices connected to automatic exchanges direct access to the clock, due to the fact that it would be possible for the caller to hear the announcement without the necessity of pressing button "A" to release the coins. Access to the clock can, however, be effected by call office users via the manual board.

Special arrangements for the Opening.

Due to the large amount of publicity given to the clock in connexion with the Golden Voice competition, broadcasts and press notices, it was anticipated that a considerable amount of curiosity traffic would be experienced at the opening The switching plant is not designed to carry this additional traffic and therefore arrangements were made whereby the time announcement was transmitted over special junctions to manual exchanges and connected to the multiple jacks. In addition a service was provided on a Mayfair exchange number from which manual exchanges could obtain access to the time announcement. These arrangements were made with the object of relieving the load on the Tandem relay sets during the first few days of the opening and the temporary equipment has since been recovered.

Traffic dealt with by the Clock since the opening.

The traffic to the clock during the first week was about 398,000 calls, but this dropped during the second week to a little more than 199,000 calls. There has been a steady increase since and the average number of calls per week during October, 1936, was approximately 214,000. It is interesting to note that 89 per cent. of this traffic originates from subscribers connected to automatic exchanges and in view of the fact that not more than 58 per cent. of the total exchange lines inside the 10 mile circle are automatic, it is apparent that the time service is more popular where subscribers are able to dial the clock direct.

Time Service in Provincial Centres.

It has been decided to proceed with the introduction of the new time service at selected provincial centres. For economic reasons, it is not proposed to install separate clocks at these centres, but to radiate the time announcements from the London clock over trunk lines. These lines will be tapped at the points where the time service is required and connected to relay sets similar to those provided at the London Tandem exchange.

Part II.—The Clock Mechanism

E. A. SPEIGHT Ph.D., A.R.C.S., and O. W. GILL

Part II gives details of the design of the clock and its associated apparatus.

Conditions to be met.

In order that the accuracy of the announcements should not compare unfavourably with existing public services it was decided that the time announced by the clock should not be more than ± 0.1 second in error. This accuracy is believed to satisfy the needs of the majority of users of the service.

To reduce the quantity of apparatus required for distributing the service the announcements should be made frequently. This condition is met by providing six complete announcements per minute.

In deciding upon the wording of the announcement the main requirements were simplicity, clarity, naturalness of the speech and the avoidance of engineering complications in its reproduction. The form finally adopted is illustrated by four typical announcements.

(1) At an exact hour:
" At the third stroke it will be ten o'clock precisely."

(2) At (say) 10 seconds past the hour:
" At the third stroke it will be ten o'clock and ten seconds."

(3) At an exact minute past the hour:
" At the third stroke it will be ten, twenty-five precisely."

(4) At other intermediate times:
" At the third stroke it will be ten, twenty-five and twenty seconds."

Each phrase is followed by three 1,000 c.p.s. " pips," the last of which indicates the time as announced.

Preparation of Sound Records.

Choice of Recording System and Form of Record.

Most recording systems are mechanical, magnetic or photographic in principle. The recording process for the photographic system is perhaps the most complicated, but against this the quality of the reproduced sound is good, the noise level is low and the system permits the use of a form of record which is not subjected to mechanical wear.

Good reproduction of frequencies up to at least 10,000 cycles per second can be obtained from ordinary sound film travelling at the normal speed of 18 ins. per second relative to the reproducing head. To record separately each different announcement in the 12-hour period at this film speed would require nearly 8 miles of sound track, which is obviously impracticable. It is necessary, therefore, to divide the announcement into words or short phrases and, by switching from one record to another, to make each serve for as many announcements as possible. For example, the same record of " At the third stroke " is used for every announcement. The sub-division must introduce no unnatural pauses and this is conveniently arranged by using records in the form of concentric circular tracks on flat glass discs, reproduced by rotating the discs in front of a stationary optical system. For various reasons it was necessary to limit the overall diameter of the discs to 12 ins., and the diameter of the outermost sound track is therefore 11 ins. The radial width of the tracks is 2 mm.

By trial it was found that the time required for speaking the longest of the " minutes " words plus that required for switching gave a speed of one revolution per second. Without loss of quality in reproduction the circumferential length of the innermost track can therefore be 18 ins. and two discs are thus required for the 60 " minutes " records.

In spite of this and although the complete announcement is divided into five parts, four discs only are required, since two discs each perform two functions. Thus, one disc carries the following records:

Outermost track—" At the third stroke "
Six inner tracks—" Precisely "
" and ten seconds "
etc.

The time taken to speak the longest of these is only 1.7 seconds. To simplify the mechanical arrangements, however, a speed of one revolution in two seconds was chosen.

Another disc serves for the " hours " portion of the announcement, and carries records arranged as shown in Table I.

This arrangement avoids the necessity for the reproducing system to make a large movement in returning from " it will be twelve " to " it will be one." The passage from one hour to the next normally involves a movement of two track-widths, i.e., 4 mm., but at each end of the half-cycle of operations a single 2 mm. movement is required. This principle is applied to each disc and greatly simplifies the mechanical design.

TABLE I.
Order of tracks on " hours " disc.

Track No.	Phrase.	Track No.	Phrase.	Track No.	Phrase.
(1) (outside)	It will be 6	(10)	It will be 11	(18)	It will be 15
(2)	,, ,, ,, 7	(11)	,, ,, ,, 1	(19)	,, ,, ,, 22
(3)	,, ,, ,, 5	(12)	,, ,, ,, 12	(20)	,, ,, ,, 16
(4)	,, ,, ,, 8	(13)	,, ,, ,, zero	(21)	,, ,, ,, 21
(5)	,, ,, ,, 4	(14)	,, ,, ,, 13	(22)	,, ,, ,, 17
(6)	,, ,, ,, 9	(15)	,, ,, ,, 24	(23)	,, ,, ,, 20
(7)	,, ,, ,, 3	(16)	,, ,, ,, 14	(24)	,, ,, ,, 18
(8)	,, ,, ,, 10	(17)	,, ,, ,, 23	(25)	,, ,, ,, 19
(9)	,, ,, ,, 2			(inside)	

In general any particular record could be the outermost or the innermost track. In this case, however, with the arrangement chosen, should the 24-hour time system be required later, the change could be accomplished without need for further recordings.

The slow speed of this disc causes some attenuation of the highest speech frequencies of the inner tracks but, actually, the loss is negligible up to 6,000 cycles per second.

The next disc is used for the " even minutes " records, the place of " zero minutes " being taken by the words " o'clock."

The remaining disc carries the " odd minutes " records as well as a short recording, lasting 0.1 second of a 1,000 c.p.s. note. The three " pips " are obtained by reproducing this note three times in succession.

Recording Process.

To build up the complete announcement requires close control of the duration of each word and accurate placing of each record on the disc. The early trials showed that it was not possible to produce satisfactory discs by direct recording, and the speech required was therefore first recorded on standard sound film.

The master disc negatives were made on sensitized flat glass plates. The plate was held in a mounting and rotated at constant speed about a central axis at right angles to the face and the slit of a sound-recording oscillograph was focussed as a short radial line on the plate. Each film record was reproduced in turn and the output from the reproducing amplifier was fed to the oscillograph element. By this means the word or phrase recorded on the film was re-recorded on the plate.

Simultaneously with the speech currents fed to the recording oscillograph a D.C. bias was automatically applied so that the width of the sound track tapered to zero both at the beginning and at the end. A black area was thus produced on the positive prints which avoids noise due to shuttering whilst the gradual build-up and die-away avoid noise as the track enters and leaves the reproducing beam of light.

Layout of System.

The clock mechanism and associated equipment is necessarily composed of a number of correlated units,

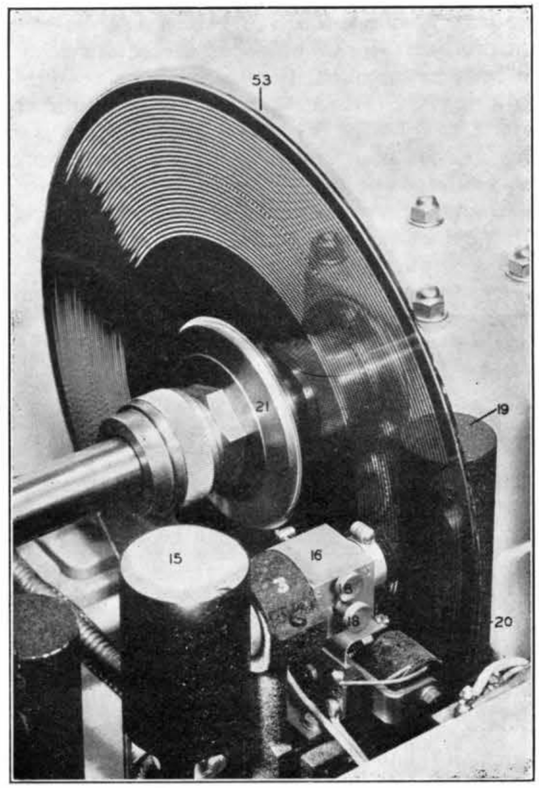

FIG. 3—" EVEN-MINUTES " DISC AND OPTICAL UNIT.

the interlinking of which is shown in Fig. 2. The components are dealt with separately in the following paragraphs.

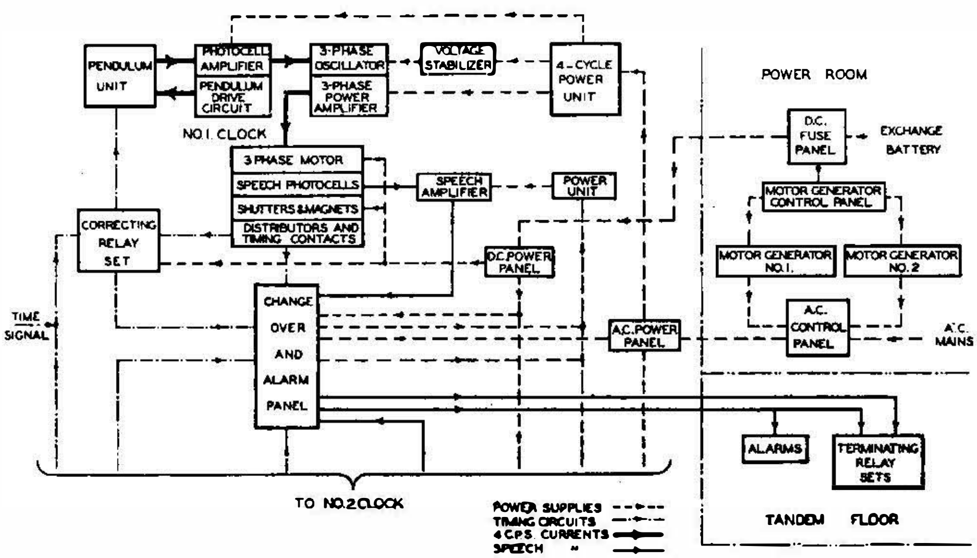

FIG. 2.—SCHEMATIC DIAGRAM OF CLOCK AND ASSOCIATED EQUIPMENT.

REPRODUCTION OF THE SPEECH.

The type of optical unit used for reproducing the speech is illustrated in Fig. 3. The exciter lamp (15), and the optical system itself (16) are provided with the usual adjustments. The photocell is contained within the tubular shield (19) which is perforated to pass the reproducing beam of light.

The circuit of the speech amplifier Fig. **4** shows little departure from standard practice. The cathodes of all six photocells are connected together and to terminal (**7**) of the amplifier. Since individual cells may differ considerably in sensitivity, the outputs are equalized by controlling the voltage applied to the anode of each cell and the overall gain is adjusted by means of the variable potentiometer between the first and second stages.

Although low-capacity screened cable is used for the photocell leads some loss of the upper audio frequencies occurs. To reduce this loss the input impedance of the amplifier is kept low and a tone-correcting circuit is included between the first and second stages.

To avoid losses due to the capacitance and resistance of the leads to the relay sets the main secondary winding of the speech output transformer in the amplifier gives a step-down ratio of 4 :1, and a second output transformer, mounted on the relay set rack gives the final step-down of 20:1 which, in conjunction with a 1-ohm resistance connected directly across the secondary winding, provides the correct load for the output valves. With this arrangement there is earthed via contact D1, an alarm bell is sounded and subscribers cannot be connected to the amplifier.

Additional means are necessary to indicate failure of one only of the output valves. The separate anode feeds to the output valves are therefore taken through the differentially wound relay C. If the output stage becomes unbalanced this relay operates and earths terminal (16). A pilot lamp glows as long as a satisfactory output is being given.

The shortest-lived components in the reproducing systems are the exciter lamps, failure of one of which would cause an incomplete sentence to be sent out. To obviate this the filaments are series connected so that a partial failure is impossible. The lamps are rated at 10 volts but, to increase their life and to reduce the possibility of hum, the six are run from a 50-volt A.C. supply. Each lamp is shunted by a 50-volt low power switchboard lamp which glows if the corresponding exciter lamp fails.

The Clock Mechanism.

The essential requirements of the clock mechanism are accuracy and reliability. To this end the mechanical parts are as few as possible in number

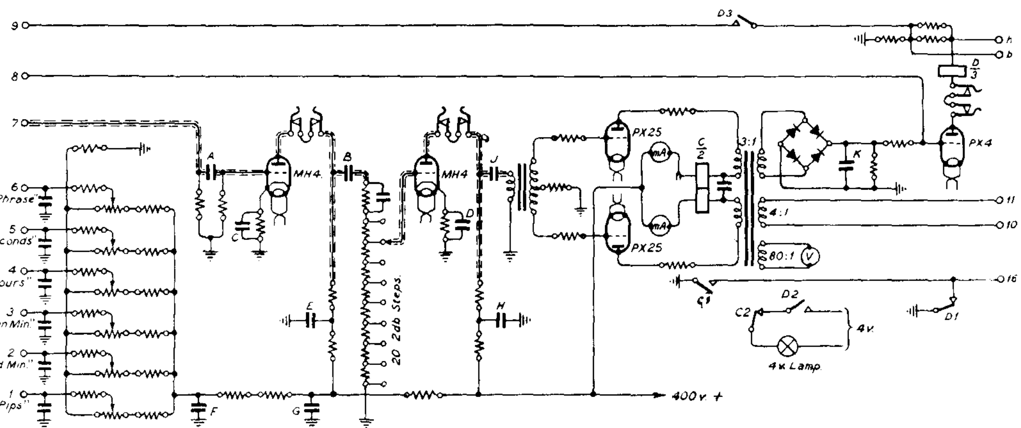

Fig. **4**.—Speech Amplifier Circuit.

no detectable difference in volume whether 1 or 100 subscribers are connected.

Alarms.

An alarm is necessary should the speech output fall below a predetermined level. For this purpose speech currents derived from a fourth winding on the main output transformer are rectified by a bridge-connected metal rectifier and charge the condenser K (Fig. **4**). In consequence the associated valve PX4 normally operates at substantially zero bias and anode current flows holding relay D in the operated condition. Should the speech output fall, negative bias is applied to the valve, the anode current falls and relay D drops out. If the valve itself fails D again drops out. To hold the relay operated during the silent period between announcements the grid of the valve is brought to zero bias by means of contacts closed by a cam on the clock mechanism and connected to terminals (8) and (9). A contact D3 of relay D is included in this circuit so that the relay cannot be operated except by the correct speech output. Unless relay D is operated terminal (16) is and are designed with a large margin of safety. Further, the general layout permits ready replacement or adjustment of any of the few parts which might become defective in service.

The main functions of the mechanism are determined by the manner in which the announcements are made on the one hand and by the necessity for accurate timekeeping on the other. These functions may be considered in greater detail under four main headings.

(1) Driving the sound discs.
(2) Building up each announcement.
(3) Changing from one announcement to the next.
(4) Operating contacts for checking and controlling the timekeeping.

Rotation of the Discs.

Since the pip signal which indicates the exact time is recorded on and reproduced from the " odd minutes " disc the speed of this and hence of all the discs must be accurately controlled. Further, for good speech reproduction the speed must be uniform throughout each revolution. A special motor running at 60 r.p.m. was therefore developed for this purpose. This motor is shown (51) in Fig. 5, which depicts the general layout of the clock mechanism.

Since the " odd " and " even minutes " discs—(52) and (53) respectively—also rotate at 60 r.p.m., a direct drive is used. The "hours" and "seconds" discs—(54) and (55) respectively—rotate on a separate shaft coaxially with the " minutes " shaft, but a 2:1 reduction gear (22) is interposed to give the speed required—30 r.p.m. Smooth running and maintenance of accurate focussing of the discs with absence of whip or vibration are essential to good sound reproduction. Helical gears of fine pitch are therefore used in the gearbox to avoid " flutter " due to backlash, and the main shafts are made of 1 in. diameter precision-ground mild steel. Ball bearings are used throughout the mechanism.

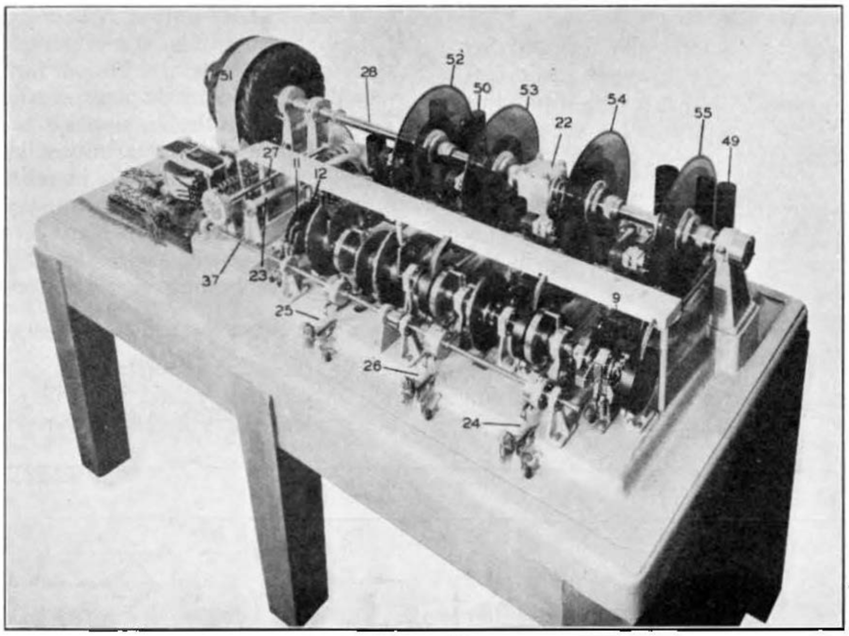

Fig. 5.—Clock Mechanism.

The discs are mounted on flanged gunmetal hubs, the tapered ends of which are split and contracted on to the shaft by means of nuts. Lines are scribed on the shafts, hubs and discs to facilitate correct reassembly should the necessity arise for replacement. One of the hubs is shown (21) in Fig. 3.

Building up the Announcement.

The discs are rotating and the exciter lamps are energized at all times. Switching is therefore necessary in order that speech shall be reproduced from only one disc at a time and in the correct order for building up the proper announcement. This is preferably performed optically.

Electromagnetically-operated shutters are interposed between the optical systems and the sound discs. These shutters normally prevent the passage of the beam of light to the disc and no output is produced by the corresponding photocell. The announcement is built up by causing the discs to " speak " in turn by opening the corresponding shutters in the correct sequence. This is done by means of a series of contacts operated by cams which are rotated by means of a 10:1 reduction gear from the main shaft.

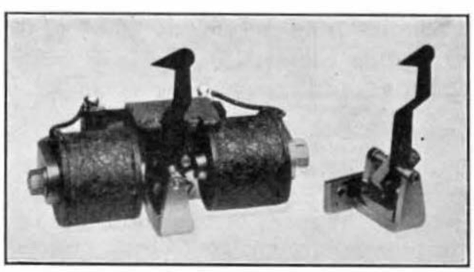
Fig. 6.—Shutter Mechanism.

To avoid noise the shutters open just prior to the commencement of the sound tracks and close just after the end of these. For the reproduction of the " pips " the track passes the optical system three times and the associated shutter therefore remains open for just over two revolutions of the main disc shaft.

The method of mounting the shutters in relation to the optical system is shown in Fig. 3 (20) and the mechanism is shown in greater detail in Fig. 6.

Change from one announcement to the next.

Simply expressed, the change from one announcement to the next merely involves moving one or more optical systems so as to reproduce different sound tracks, but the evolution of a truly satisfactory design for this part of the mechanism involved many major difficulties. For example, the plane of movement of the optical system must be accurately parallel to the face of the disc to avoid imperfect focusing with consequent loss in articulation. The extent of each movement of the optical system must be exact since the radial spacing between adjacent sound tracks is only that which arises from the fact that the maximum modulation of the track-width is 80 per cent. The movement must take place smoothly in order to avoid undue mechanical wear yet must be completed during the short silent period between announcements.

the eccentric to a swinging arm which is freely mounted on the camshaft and a pawl carried on this arm engages with a 60-tooth ratchet wheel (40) which is pinned to the camshaft. The throw of the eccentric is such that, when the clutch makes one complete revolution, this wheel advances one tooth

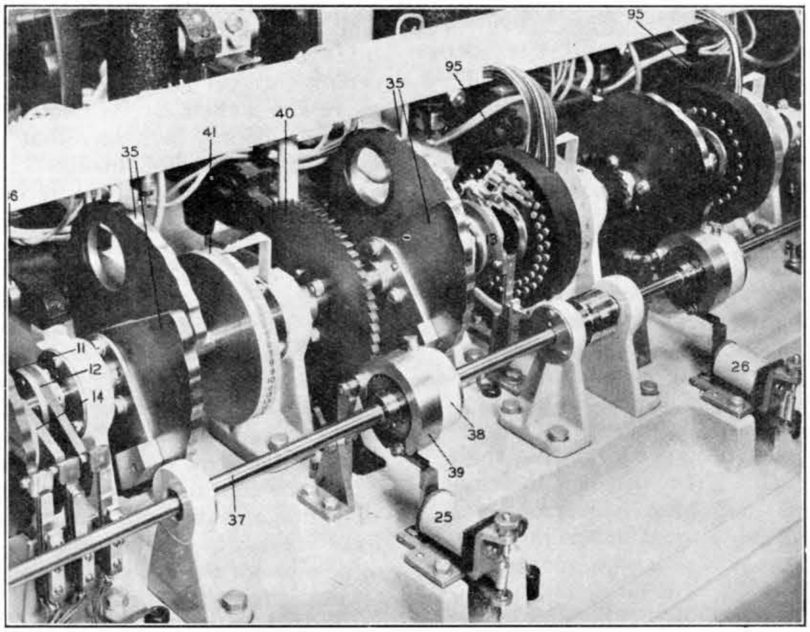

FIG. 7.—" MINUTES AND HOURS " CAM SHAFTS.

and the cams move the carriages the appropriate distance. The time of movement—½ second—is slow enough to avoid damage due to rebound.

In the final design each of the four movable optical units is mounted on a carriage which runs on ball-bearing rollers on two horizontal cross-guides situated below the disc shafts and is moved by means of a steel cam working on a ball-bearing follower mounted on the carriage. Contact between the cam face and the follower is maintained by spring pressure. Owing to the asymmetrical contour, the manufacture of the cams involved a considerable amount of hand shaping after which the cams had to be hardened to avoid the development of inaccuracy through wear. To avoid distortion during hardening " Nitralloy " steel was used.

In the " minutes " cams the circle swept out by the cam proved to be inconveniently large. Accordingly, each of these cams is split into two portions using a smaller radial scale for the outer portion of the travel, but keeping the lift of the steps the same. The two composite cams (35) Fig. **7** are mounted on a single camshaft so that the central radii of the steps of one lie midway between the steps of the other. The 60 positions required to cover the minutes are thus obtained by the use of 30 steps only on each complete double cam.

The method of imparting the correct angular movement to the " minutes " cam can also be seen in Fig. **7**. The shaft (37) is driven continuously at 60 r.p.m. by skew gearing from the main shaft. Mounted freely on this shaft is an eccentric (38), the sheave of which is integral with a special clutch (39). A connecting rod couples the strap of

A light aluminium drum (41) suitably engraved and pinned to the camshaft, in conjunction with a fixed pointer indicates visually the track being reproduced at each setting of the cams. The bakelite cam (11) operates a changeover contact which permits the operation of either the " odd minutes " or the "even minutes " shutter according to the setting at any instant.

The clutch (39) which turns the eccentric sheave through exactly one revolution as required is shown more clearly in Fig. **8**. The main body of the clutch (39) is freely mounted on the shaft (37) to which is pinned the ratchet wheel (42). The pawl (43) carried on the body of the clutch is normally held out of engagement with the ratchet wheel by the armature (44) of the electromagnet (25). On passing a momentary current through the coil the armature is withdrawn from the projecting end of the pawl which is is then thrown by the spring (45) into engagement with the ratchet wheel. The whole assembly is thus locked to and rotates with the shaft. When the current ceases the armature is returned to normal by the spring (46). On the completion of one revolution, the projecting end of the pawl (43) strikes the armature, is thrown out of engagement with the ratchet wheel and the whole assembly comes to rest. A spring-loaded lever (47) bearing on a roller (48) holds the clutch in this position in readiness for the next operation.

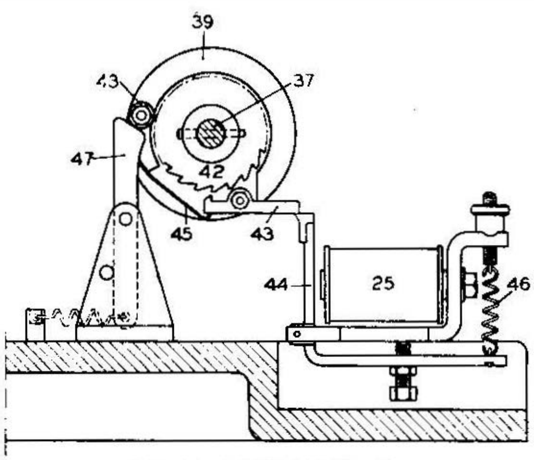

FIG. 8.—CLUTCH MECHANISM.

The carriages associated with the "hours" and the " seconds " discs are moved similarly. The mechanism is seen in the foreground in Fig. 5.

The sequence of operations of this mechanism is as follows:—

Immediately after the third pip of each announcement, a contact (1) operated by a cam on the shaft (23) is momentarily closed. This energizes the electromagnet (24) and the " seconds " portion of the announcement is changed in the manner just described. When the " seconds " carriage moves into the position to reproduce " and 50 seconds " a contact associated with the "seconds" cam-shaft closes and connects the magnet (25) in parallel with (24). After the third pip of this particular announcement, both magnets are momentarily energized and simultaneously the " minutes " carriage moves to its next position and the " seconds " carriage to the " precisely " position. Similarly at " 59 (minutes) and 50 seconds " the magnet (26) is paralleled with the other two. Following this announcement, the " hour " changes to the next, the " minutes " to " o'clock " and the " seconds " to " precisely " as before.

The introductory phrase " At the third stroke " and the three pip signals are common to all announcements. The optical systems used to reproduce these are shown at (49) and (50) respectively, Fig. 5.

METHOD OF DRIVE.

The requirements of the method of drive are unusually stringent. It is obviously desirable to use one driving motor for the whole mechanism if possible, and although the power required to drive the discs only is small, the peak requirement which occurs once per hour, i.e., when all three cam-shafts move simultaneously, is relatively large.

It has already been seen that the speed of rotation must be accurately controlled. Since the maximum error permissible is ± 0.1 second, the gain or loss per hour, assuming hourly correction, should not exceed 0.05 second. This necessitates some form of continuously operating control in spite of which, however, an error exceeding 0.1 second could ultimately accumulate. A periodical over-riding check is therefore required to correct this error. Since Greenwich Mean Time is naturally the standard against which the clock would be compared in service, the periodical check employs the signal transmitted exactly at each hour from the Observatory.

For the continuous control, however, various possible methods are available. Many of these methods were investigated and the most suitable was found to be a motor the speed of which is under the control of an accurate free pendulum.

Development of a New Free Pendulum.

For the development of the pendulum control a Clock No. 36 was used.

The count wheels, etc., were removed and the

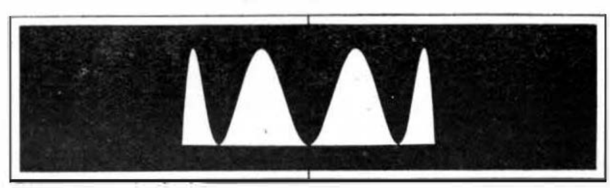

FIG. 9.—PHOTOGRAPHIC TRANSPARENCY OF WAVE TRACE.

length of the arc of swing measured. A photographic transparency shaped as shown in Fig. 9.

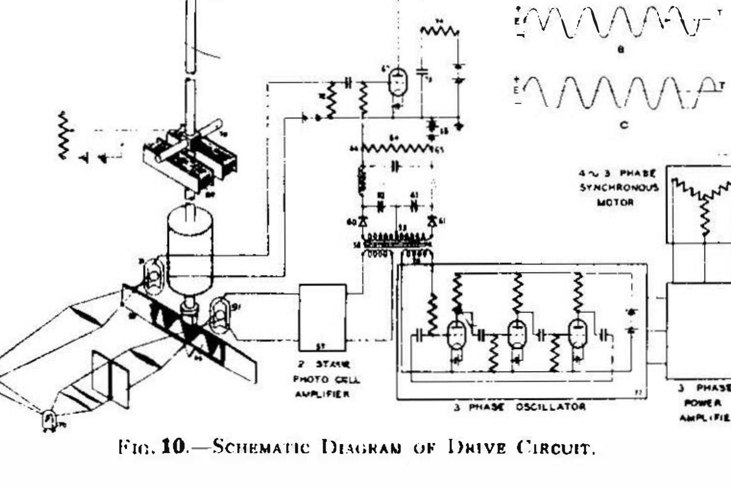

FIG. 10.—SCHEMATIC DIAGRAM OF DRIVE CIRCUIT.

was mounted at the bottom of the pendulum and the image of a vertical narrow illuminated slit was focused centrally on the transparency when the latter was at rest. The base of the transparent area is equal to the arc of swing and the shape is such that when the pendulum is swinging normally the amount of light passing through the trace and falling on a photocell varies sinusoidally at 4 cycles per second. If, however, the arc of swing is incorrect the wave form will be distorted. This distortion is utilized to restore normal amplitude of swing without the use of any mechanical or electrical contacts with the pendulum, i.e., by allowing the pendulum to swing freely (in the horological sense). This ideal is attained in the manner illustrated by Fig. **10** which is a schematic diagram of the whole method of drive.

If the amplitude of swing is slightly too small the wave form obtained is similar to (B) whereas if the amplitude of swing is too great the shape shown in (C) is produced. The output from the amplifier (57) is applied to a transformer (58) one secondary winding (59) of which has a centre tap. By means of rectifiers (60) and (61) the condensers (62) and (63) receive charges due respectively to the positive and the negative half cycles of the current. The *difference* in potential between the two condensers, after smoothing, is applied to the resistance (64). When the amplitude of swing of the pendulum is correct and the wave form symmetrical (A) the charges on the condensers are equal, there is no P.D. between points (65) and (66) and the potential of the point (66) relative to the earth line, i.e., the effective bias applied to the grid of the gas-filled relay (67) is simply that due to the battery (68). As the amplitude of swing falls the wave form becomes unsymmetrical (B) and the charges on the condensers become unequal. In consequence a difference of potential appears between points (65) and (66) of such sign that the effective negative bias on the gas-filled relay is reduced. This change of bias is utilized to permit application of a driving impulse to the pendulum as required and at the correct point in the swing.

At the mid point in each left-to-right swing of the pendulum a shutter (69) allows a narrow beam of light from the source (70) to fall on the photocell (71). An increase then occurs in the photoelectric current flowing through the resistance (72) as a result of which there is a momentary rise in the potential of the grid of the gas-filled relay (67). When the amplitude of swing of the pendulum is correct this rise in potential is insufficient to make the relay conducting. When, however, the amplitude has fallen by a predetermined permissible amount the reduction in effective steady bias produced by the P.D. appearing across the resistance (64) is such that the relay becomes conducting at the instant of application of the impulse from the photocell (71). The condenser (73), which is charged through a high resistance (74), then discharges through the energizing coils of the magnet (75) which, attracting the armature (76), applies a driving impulse to the pendulum and restores normal amplitude of swing.

(It will be apparent that this form of pendulum drive, depending as it does upon slight distortion mainly of the cycles generated at the extremities of the swing, will be more positive in action at low frequencies. The frequency employed—4 c.p.s.—is therefore a compromise between this factor and the comparatively greater ease of designing the remainder of the apparatus to work at a higher frequency.)

A practical trial of this scheme extending over several months showed that the hourly error rarely exceeded ± 0.05 second. Such larger errors as did arise were ultimately traced to variations in ambient temperature. By maintaining the pendulum cabinet at constant temperature, the departure from the mean rate of the pendulum did not exceed 0.05 second and rarely exceeded 0.02 second per hour over long periods.

Before discussing the utilization of this method of control the construction of the pendulum unit as finally used will be described.

Pendulum Unit.

A photograph of the pendulum unit with cover removed is shown in Fig. **11**. The iron casting (81)

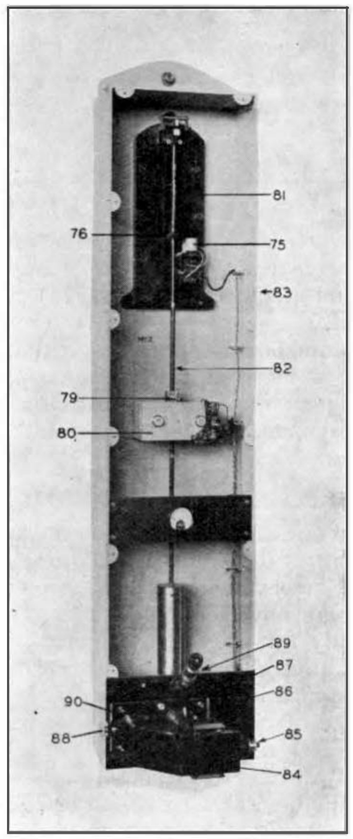

Fig. **11.** —Pendulum Unit.

carrying the pendulum (82) and impulsing magnet (75) is mounted within an aluminium box (83) built up on a steel framing. The box is supported on substantial rag bolts let into a main foundation wall of the basement of the Holborn Telephone Exchange building. The effects of vibration are thereby minimized. The pendulum for the second clock is mounted similarly on an adjacent wall at right angles to the first.

The optical system (84) is carried directly on the front of the box and adjustments are provided for accurately focusing and centring the whole system. To simplify these adjustments a low-power microscope (89) is fitted for inspecting the image of the slit on the wave trace. Fig. 12 shows the wave trace (56) and photocell screens (71) and (91) in greater detail.

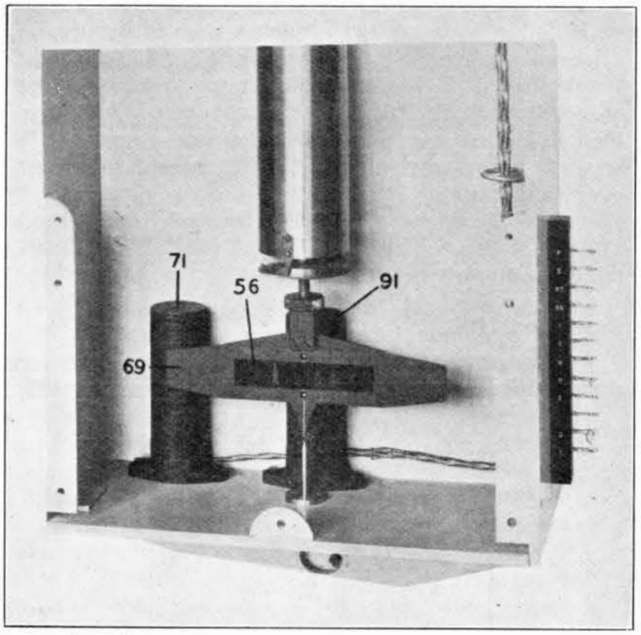

FIG. 12.—WAVE TRACE AND DRIVE PHOTO CELLS.

The pendulum box is contained within a wooden cabinet fixed to the wall and the atmosphere within the cabinet is maintained at substantially constant temperature by means of heaters and a thermo-regulator.

Application of Pendulum Control.

There are various ways in which a pendulum can be used to control the speed of a motor. In the present instance, however, it appeared to be very attractive to take the novel course of using the 4 c.p.s. current directly for driving the motor. The major problem was naturally that of securing efficient and adequate amplification at this low frequency. By a suitable choice of circuit values, however, a simple and effective design was evolved.

The first form of output stage employed two triodes in push-pull. Valves dissipating 75 watts at an anode voltage of 1,000 were used and delivered at 4 c.p.s. output of 36 watts into the load.

This output was used to drive an experimental single-phase synchronous motor at 60 r.p.m. Since this motor was ultimately superseded, it is necessary only to state that its measured characteristics were very close to the calculated figures and that its efficiency at full load was over 80 per cent. When used to drive a sound disc, however, a slight " wobble " was detectable in the reproduced speech due to slight speed fluctuations arising out of the inherently pulsating nature of the torque produced. To avoid this defect the scheme was modified to employ a 3-phase motor.

The basis of the modification was the 3-phase sinusoidal oscillating circuit devised by Van de Pol (Physica, 1934, Vol. 1, p. 437). As this circuit does not appear to be widely known, it may be considered briefly. The basic circuit is shown schematically as item (77) in Fig. 10. The three unit-stages are identical. Any disturbance originating at the grid of the first valve will reappear in the anode circuit with a phase change of 180°. In passing to the grid of the second valve a further phase change will be sustained in the condenser-resistance network and so on. At one definite frequency the interstage phase change will be 60° and (neglecting the effect of transformer winding (78)) the disturbance will return to the first grid in phase with the initial disturbance. Under suitable conditions sustained sinusoidal oscillations will therefore occur at a frequency determined simply by the value of the coupling components and the alternating E.M.F.'s appearing at the 3 anodes will be in a balanced 3-phase relationship.

A practical trial of this circuit showed that with suitable values it functioned satisfactorily, but that the actual frequency varied somewhat with changes in anode voltage. This variation was eliminated by the addition of a neon-tube voltage stabilizer, but, even with this addition, the natural frequency was insufficiently constant for the present purpose. The frequency is therefore stabilized by injecting into one of the grid circuits a small E.M.F. derived from a winding (Fig. 10, item 78) of the output transformer of the 4 c.p.s. photocell amplifier (57). (The oscillator frequency is previously set as near to 4 cycles per second as possible and the voltage stabilizer is retained.)

Mention may be made of a key which, when thrown to one side or the other of its normal position, cuts out the pendulum control and alters the resistance values in the oscillator circuit so that the speed of the clock mechanism is increased or decreased by approximately 10%. This feature is very useful when starting or restarting and setting a clock which has been stopped for any reason.

The output stage consists of three 75-watt triodes followed by a single 3-phase output transformer in order to avoid D.C. magnetization of the core. The three secondary windings are star-connected with the neutral point earthed. Under normal conditions the 4 c.p.s. component in the main H.T. supply to the whole amplifier is negligible and no undesirable feedback effects have been noticed.

The amplifier is capable of supplying an undistorted output exceeding 50 watts although the consumption of the motor is normally only 20 watts.

Four-cycle three-phase Synchronous Motor.

In view of the low frequency employed it was decided to design the motor to run at the same speed as the main disc shaft, i.e., 60 r.p.m. An 8-pole rotor was therefore required. The pole shoes were made detachable for convenience in winding but, apart from these, the rotor was milled from a single solid billet. To reduce slot ripple and improve the wave form of the back E.M.F. the pole shoes were skewed.

The stator windings are full-coil, star connected

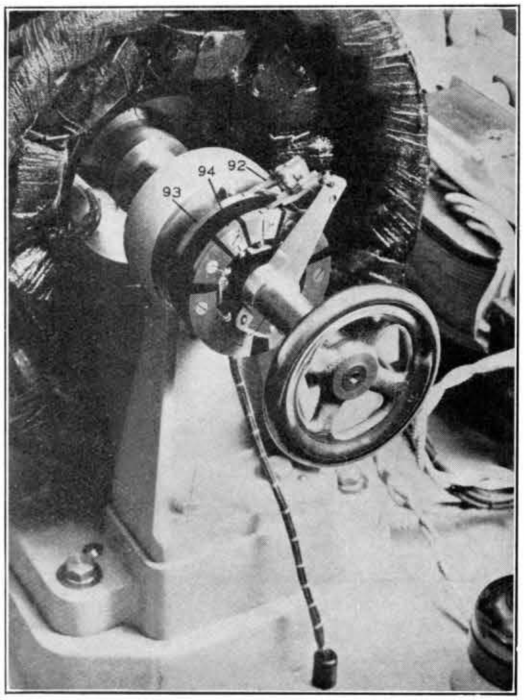

FIG. 13.—MOTOR AND DISTRIBUTOR (CORRECTING) EQUIPMENT.

and contained in 48 slots. The neutral point is not earthed. When the motor was driven as a generator at 60 r.p.m. the measured and calculated characteristic curves of stator voltage against rotor excitation on open circuit and under load showed very good agreement.

TIME CONTROL.

The necessity for a periodic check of the timekeeping of the clock has been mentioned. The operations of this check are two-fold, viz.: (a) detection, and (b) correction of the error. The maximum permissible error having been settled as ± 0.1 second it was decided that in order to provide a margin of safety a correction should be applied for any error exceeding ± 0.05 second, but that smaller errors should be ignored. For errors between 0.05 and 0.1 second a correction of 0.1 second is applied and for errors between 0.1 and 0.2 second the correction is 0.2 second. Errors exceeding 0.2 second represent definite faults for which no automatic correction is applied.

Apart from certain cam-operated contacts concerned mainly with hourly resetting the correcting circuit and a contact which is closed from 0.4 second before to 0.4 second after the beginning of the third pip of each announcement, the most important part of the correcting equipment incorporated in the clock mechanism is a distributor mounted on the motor bearing pedestal, as shown in Fig. **13**. The rotating brush (92) bridges across from the continuous ring (93) in turn to each of several short segments (94), which are connected to relays in the correcting equipment proper. The circuit of this is shown in Fig. **14**.

The operation of the circuit is as follows. Providing that the error, if any, of the clock does not exceed 0.4 second the contact operated by cam (8)

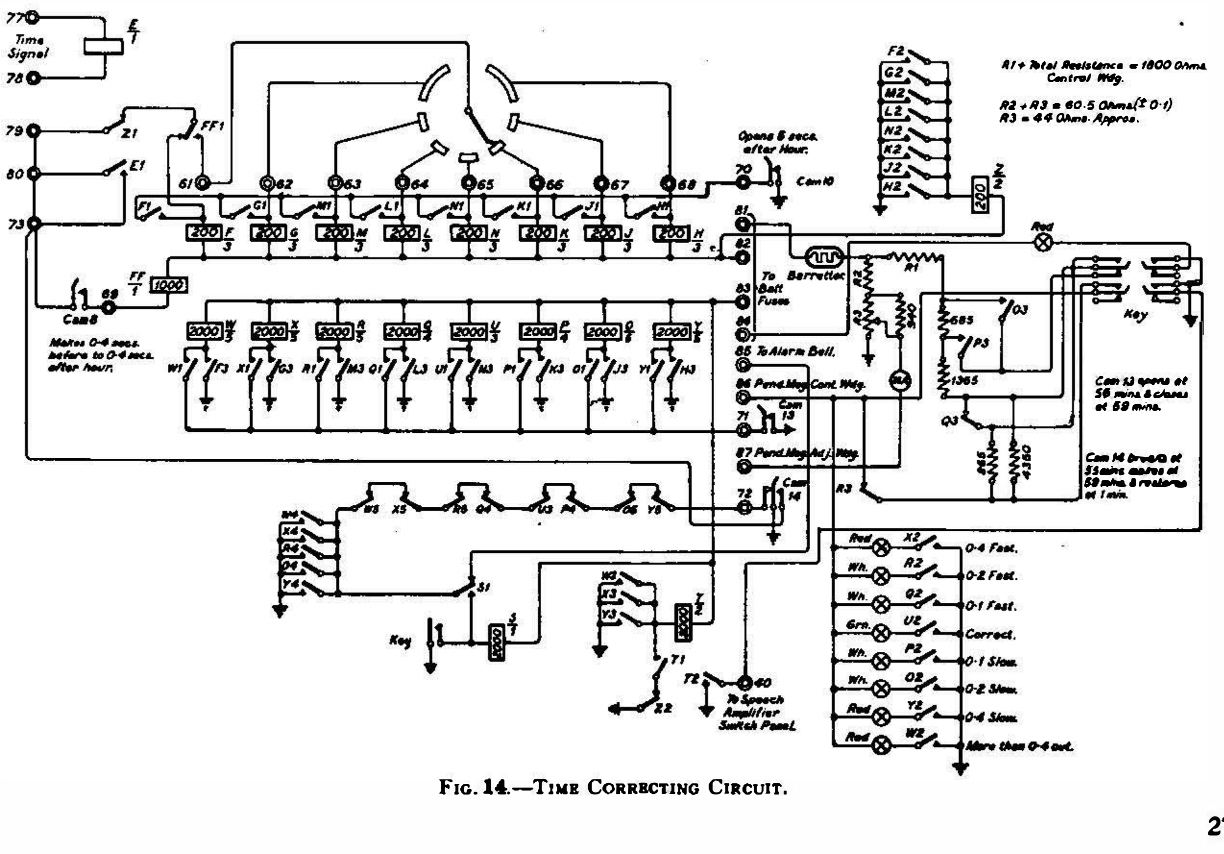

FIG. 14.—TIME CORRECTING CIRCUIT.

will previously have closed, relay FF will have operated and contact FF1 changed over. Terminal (73) will also be earthed via cam-contact (14) (on "minutes" camshaft). On the arrival of the time signal relay E operates and contact E1 closes. The particular contact segment over which the rotating brush is passing at this moment will therefore be connected to earth and the corresponding one of the relays F to N will operate. If, for the sake of argument, the clock should be between 0.05 and 0.1 second slow this will be relay K. By means of its first contact it will lock in and by means of the second contact operate the low resistance relay Z. The Z1 contact of the latter removes the earth from the rotating brush and so prevents the time signal (which lasts one second) operating any other relay connected to the contact segments.

The closing of the third contact of the relay K operates the corresponding high resistance relay P which then locks in via its own first contact. To avoid overheating of the low-resistance relays they are released 5 seconds after the hour by the opening of cam-contact (10) which, together with cam-contact (8) is on the main contact camshaft.

The second contact of P lights a lamp which gives a visual indication of the error and the third contact applies the necessary correction in a manner shortly to be described. The remaining contact appears in the chain of series-connected contacts associated with cam-contact (14). If no time signal should arrive at any hour none of these contacts will have operated. On the restoration of contact (14) at one minute past the hour an earth connexion will thereby be extended to terminals (85) and thence to the alarm bell which will then ring.

The operation of relay Q if the error is between 0.05 and 0.1 second fast is similar as also is that of relay U if the error does not exceed ± 0.05 second with the exception that the latter relay does not apply a correction.

An error between 0.1 and 0.2 second will lead to the operation of relay O if slow or R if fast. This is abnormal, but not necessarily a serious condition. The fourth contact of these relays makes the alarm connexion. This draws the attention of the attendant, but does not automatically remove the clock from service.

The operation of relays Y or X if the error is between 0.2 and 0.4 second or of relay W if the error exceeds 0.4 second represents a definite fault condition which is indicated by an alarm. No automatic correction is applied for such errors but, by the closing of the third contact of one of these relays, relay T operates and in turn extends an earth to the change-over panel. T locks in via one of its own contacts and the second contact of relay Z. By this means the service is disconnected from, and cannot be reconnected to this clock until some subsequent time signal has shown the clock to be within the permissible range of error, i.e., until Z2 has released T and the latter has not again been operated by W, X, or Y. The alarm bell can, however, be silenced by throwing a key which operates relay S.

Five minutes before the hour the cam-contact (14) opens (to avoid giving the " no time signal " alarm) and one minute later cam-contact (13) (also on the " minutes " camshaft) opens and restores all the relays (except T) to normal in readiness for the next check.

Method of Correction.

In order to avoid sudden changes of speed which might affect the pitch of the voice, the correction is applied gradually by slightly altering the rate of swing of the pendulum.

The rate of swing of a free pendulum (of fixed dimensions) is determined by the gravitational force acting on the pendulum. By varying the current in the coils of a suitably placed electromagnet a variation in effective gravitational force, and hence in the rate of swing can be produced without apparent dis-

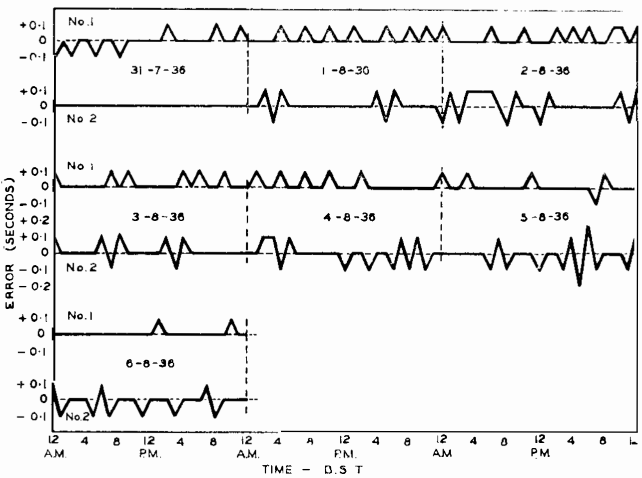

FIG. 15. HOURLY ERRORS DURING WEEK 31/7/36 TO 6/8/36.

turbance of the normal operation of the pendulum.

The arrangement used is shown in Fig. **11** (79) being the soft iron armature attached to the pendulum rod and (80) the correcting magnets. Normally a certain current flows in the coils. If the clock tends to run slow the closing of contact O3 or P3 (Fig. **14**) increases this current and slightly accelerates the rate of swing, while if the tendency is to run fast the opening of contact Q3 or R3 reduces the current and retards the rate. In either case the alteration persists for the succeeding hour and effects the necessary correction.

The operation of the time control is illustrated by Fig. **15**, which shows the errors recorded on both clocks during the second week of public operation of the service. Later adjustments made after the pendulums had settled down to a steady rate have resulted in even better timekeeping.

Alarm and Stand-by Arrangements.

In order to preserve continuity of the service, stand-by equipment, which can be brought into service in an emergency, is provided wherever possible. Two complete duplicate clocks are therefore installed.

It is not possible to start up an idle clock, adjust it to give correct time and bring it into service by any simple and rapid means of automatic change-over. Both clock mechanisms are therefore always running and in correct adjustment, but only one speech amplifier is in operation and supplying the service. If a fault develops in the working clock (only) the service is transferred to the stand-by clock in a manner which will be understood from Fig. **16**.

It may be assumed that No. 1 is the working clock and the functions of relays V and VV and their contacts may be ignored for the moment. Under normal conditions the output to the subscribers' relay sets (terminals (17) and (18) is taken from terminals (10) and (11) of the Speech Amplifier No. 1 via the changeover switch A1 contact. On the appearance of a fault in the speech amplifier terminal (16) is earthed causing operation of the relays A and AA. Contact AA2 closes operating the alarm bell and A2 connects the mains to the stand-by speech amplifier and to the corresponding indicator lamp. Until the stand-by amplifier warms up no output is available and terminal (16) of this amplifier is also earthed. Since AA1 has closed the relay B also operates. Contact B1 earths terminal (35) which is connected to the relay sets and causes " Number Unobtainable " tone to be sent out to subscribers. Contact B2 causes the corresponding indicator lamp to light. In the unlikely event of the stand-by amplifier also being faulty or out of service, this condition persists until the prime fault has been cleared. In general, however, as soon as the stand-by amplifier is hot and giving output the earth is removed from its terminal (16), relay B restores and the standby takes over the service via the change-over contact A1. Upon manual operation of the change-over switch No. 2 becomes the working clock, relays A and AA restore and attention may be directed to clearing the fault on No. 1. For adjustment purposes a tumbler switch shunting the mercury contact A2 can be closed to switch on the standby speech amplifier if required. Loud speakers are provided for monitoring purposes.

If the working clock develops an excessive time-error a similar change-over occurs except that terminal 40 receives the earth connexion. Under " No time signal " conditions the alarm is given by the earthing of terminal (85), but there is no change-over since, if the indication is genuine and not due to a cause such as a dirty contact, the actual fault will probably be external to and will affect both clocks simultaneously.

The operations just described can deal only with the small errors registered at the hourly checks. Under abnormal conditions, however, a large error might arise and go undetected until the next check. Thus a failure in the pendulum equipment would permit the oscillator to run uncontrolled or faulty operation of a clutch mechanism might immediately produce a large error. Since it is extremely unlikely that such errors would arise in both clocks simultaneously the fault condition would be indicated by the clocks running out of step. This is detected by means of distributors associated with each camshaft, two of which are shown (95 in Fig. **7**.) The number

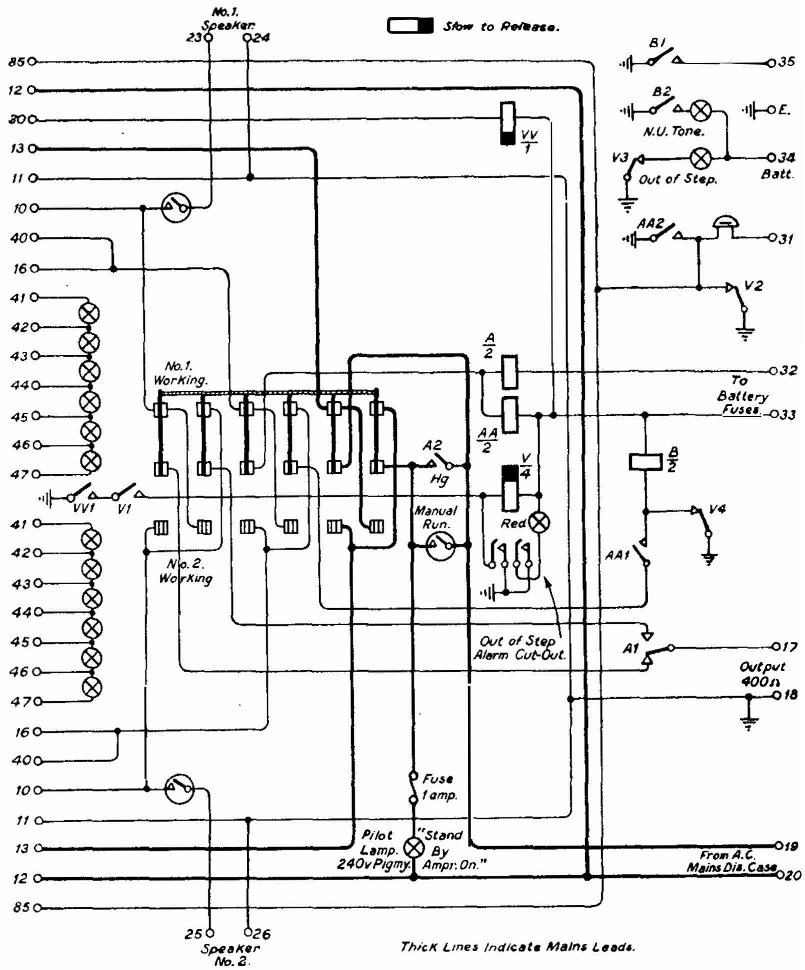

Fig. **16**.—Speech Amplifier Switch Panel.

of contacts on each is the same as the number of teeth on the corresponding ratchet wheel. Corresponding contacts on the two sets of distributors are wired together and the rotating brushes are connected so that a continuous circuit involving all these distributors exists between earth and terminal 30 as long as the two clocks are in step whereby the slow to release relay VV is held operated. In the out-of-step condition this relay drops out, followed by the similar relay V which is not self-resetting. The second contact of V rings the alarm bell, the third lights an alarm lamp and the fourth causes relay B to operate, whereby the service is discontinued and " Number Unobtainable " tone is sent out. There is no change-over, since there is no automatic means of telling which clock is at fault. An out-of-step alarm cut-out key is provided for re-setting after clearing the fault and also to prevent an alarm condition arising if the standby clock is deliberately stopped for any reason.

General Layout of the Installation.

The whole of the equipment so far described is installed in a room adjoining the power room at Holborn Exchange. On one side of the room are the amplifiers and control racks and the pendulum associated with No. 1 clock. On the other side of the room are the two clock mechanisms and monitoring loud speakers, and on the end wall is mounted the pendulum associated with No. 2 clock.

The racks are shown in Fig. **17.** From left to right of the photograph the first two bays are the two 4 c.p.s. equipments. The separate units, from top to bottom, are respectively photocell amplifier, meter panel, three-phase oscillator and power amplifier, power unit and, finally, voltage stabilizer unit. The third bay contains, at the top, the two timing relay sets, below these the D.C. distribution panel, then the A.C. distribution panel and, finally, the main switches. At the top of the right-hand bay are the two speech amplifiers, below these the change-over and alarm panel and, finally, the two power units for the speech amplifiers.

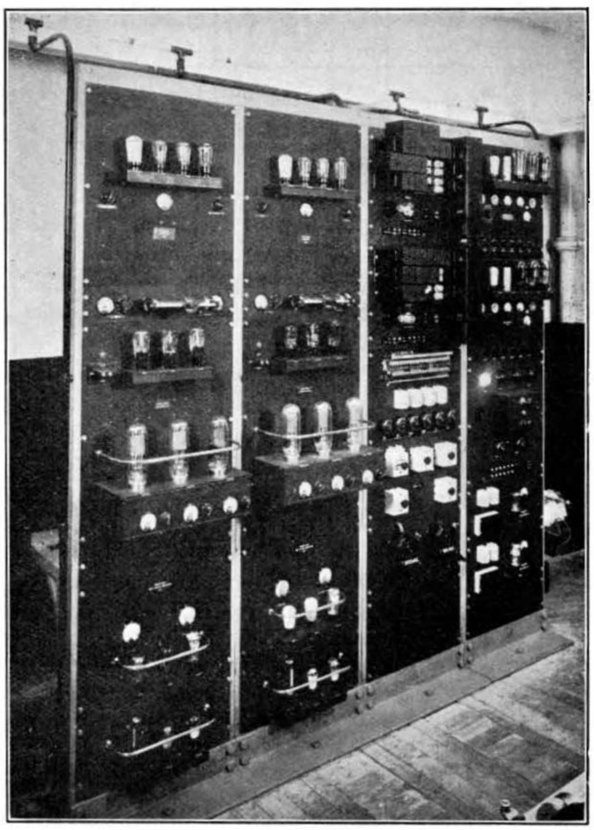

Fig. 17.—Amplifiers and Control Equipment.

Fig. **18** shows the apparatus racks on the left and the two clock mechanisms on the right. In the background can be seen one of the monitoring loud speakers and the pendulum cabinet for No. 2 clock. The clock mechanisms are carried on substantial tables and protected from dirt by glass panelled covers.

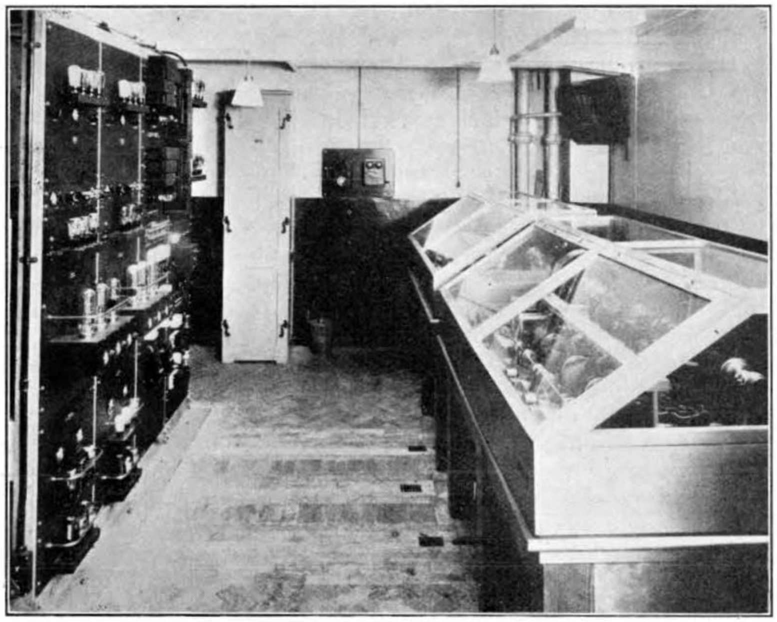

Fig. 18.—General Layout of Installations.

It has been found by experience that the gas-filled relays in the pendulum drive circuit function erratically at extremes of ambient temperature. For this reason the artificial ventilation and heating arrangements are arranged to permit thermostatic control of the room temperature at a few degrees below the temperature within the pendulum cabinets.

Power Supplies.

The main requirements of the power supplies are simplicity and reliability. All the D.C. equipment, i.e., the rotors of the synchronous motors, the relays, the pendulum control, shutter and clutch magnets and the alarm lamps and bells are worked from the 50-volt exchange battery. No standby is provided, since a failure of this supply is most unlikely and, in any case, would prevent any calls being made to the clock. The total consumption is about 250 watts.

The amplifiers, exciter lamps and pendulum heaters are worked from the A.C. public supply mains and together consume about 1,800 watts under normal conditions. In this case a standby supply is necessary and is provided by two motor generator sets of 2.5 K.V.A. capacity. One of these is always running light on the exchange battery. In the event of the mains voltage—normally 200—falling below 170 the generator takes over the load. The load automatically returns to the mains when the voltage of the latter exceeds 190. Repeated tests under artificial fault conditions have shown that change-over and restoration of the power supply occur smoothly and without introducing errors of time-keeping.

Conclusion.

Apart from the distributing relay sets the equipment was designed, constructed and installed by the Research Branch. In this connexion the the authors wish to acknowledge the many helpful suggestions made by their colleagues and by Mr. E. J. Wender, late of Messrs. British Acoustic Films, who carried out the sound recording.

Notes on the Design of Communication Equipment

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Of the Indian Posts and Telegraphs Department

The climatic conditions in tropical countries subject communication equipment to a severe test. The author gives details of the steps necessary to minimize the difficulties encountered in India and suggests that apparatus designed to function satisfactorily in tropical and sub-tropical countries has advantages which render its use in more temperate zones worth consideration

Introduction.

THESE notes briefly indicate the working conditions and some of the difficulties to be overcome in designing and maintaining communication equipment in India, and, since many of the problems involved are reproductions in an intensive form of difficulties which occur in countries with more temperate climates, the notes may be of general interest.

The design of telephone and telegraph plant for use in India is, of course, largely influenced by the climatic conditions which vary very considerably in different parts of the country. Apparatus conforming to standard specifications has to withstand high temperatures at most stations, a considerable annual variation of temperature inland, and low temperatures in the hills. The relative humidity encountered also shows varying characteristics in different areas and may either be fairly constant throughout the year or extend over a considerable range, often with high percentages of humidity coinciding with high temperatures for considerable periods (Fig. **1**). Equipment is also frequently exposed to the effects of the very prevalent dust storms which occur in the drier parts of the country. In addition, as would be expected in a developing system, the average standard of skill of the maintenance staff available is not high, and this feature combined with the severity of the climate provides working conditions which very quickly indicate any weak points in materials or design.

To meet these conditions it is necessary that good quality components with a high standard of insulation resistance be used, that the construction be simple and robust, and that the equipment be easy to operate and maintain.

The materials employed in the construction of apparatus and the special methods of protection of the components used are largely regulated by the requirements of the term "tropical finish." This implies that wherever woodwork forms part of a design well-seasoned teak must be used, teak being the only suitable wood which will withstand the attacks of white ants and which will not readily shrink or warp. Metal work, particularly iron and steel, must be given a finish which will not deteriorate under any of the climatic conditions encountered, while all equipment must be rendered more or less dust proof and be protected against the ingress and attacks of insects. Small openings admit dust and insects of various sorts which may be the cause of a variety of faults, while large openings giving access to the working parts of apparatus may cause serious trouble—instances have occurred where a house lizard has found its way into equipment and has caused a complete shut-down by short circuiting the mains bus-bars in the apparatus. Wool insulation is unsuitable for use in the tropics and will last only a short time before being eaten away, while small holes on the surface of parts of equipment not in constant use are favoured by the mason bee as suitable sites for plugging with mud and so should be avoided. In brief, the mechanical design of equipment must be such that not only will the materials used withstand the effects of the climate but, in addition, the apparatus must be rendered proof against damage by a number of other agencies peculiar to tropical countries.

Factors influencing the electrical design of various components are dealt with in more detail in the following paragraphs.

Apparatus Working Conditions.

Fig. **1** shows the annual variation of the maximum and minimum shade temperatures and relative humidity at three stations in India and illustrates

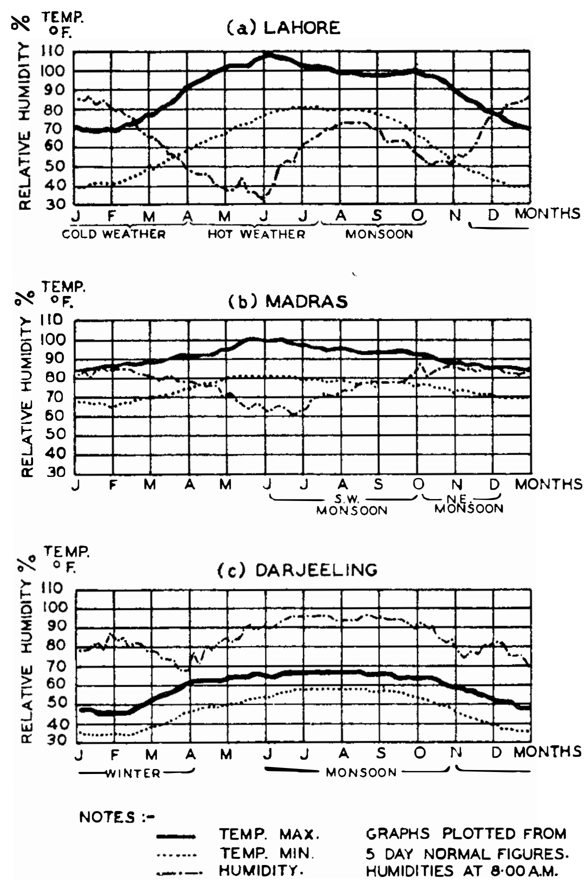
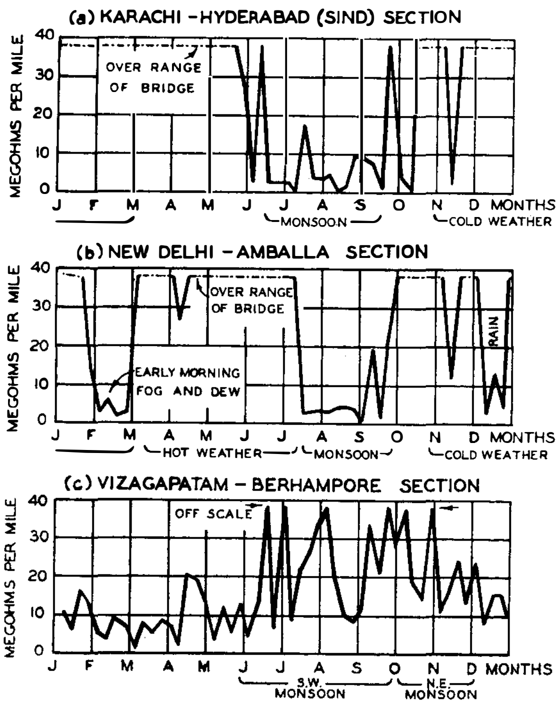


FIG. 1.—ANNUAL VARIATION OF HUMIDITY AND MAXIMUM AND MINIMUM TEMPERATURES.

some of the climatic conditions which occur. Lahore is more or less typical of a dry inland plains station, Madras of the coastal areas, and Darjeeling of hill stations. The readings given are meteorological observations and refer to outdoor conditions, but indicate in a broad sense the climatic conditions to which indoor equipment is subject. The temperatures and humidities are normal readings, and the ranges illustrated, therefore, will frequently be exceeded.

Line Conditions.

The line wires to which communication equipment is connected are all of overhead construction and, naturally, are subject to climatic variations of a more severe form than the indoor plant. Fig. 2 (a) illustrates the annual variation of the insulation re-



NOTES :-

	WIRE No	LENGTH OF SECTION	TYPE OF INSULATOR
A	371	110 MILES	OIL
B	201	131 MILES	S 38
C	61	176 MILES	OIL

ALL TESTS TAKEN BEFORE SUNRISE

FIG. 2.—ANNUAL VARIATION OF LINE INSULATION RESISTANCE.

sistance of a line from Karachi to Hyderabad (Sind) where salt and sand encrustation on the line insulators occurs during the monsoon, necessitating the use on this route of insulators of a special oil-filled type. Graphs are given for a Delhi-Amballa circuit, Fig. 2 (b), which is typical of an inland plains section, and for a line on the direct Calcutta-Madras route, Fig. 2 (c), indicating the conditions obtained adjacent to the coast. It is evident that the apparatus operated on such circuits must be capable of dealing with wide variations of line working conditions. Severe electrical storms which frequently occur at certain times of the year in India also affect the line circuits and adequate protection of the plant in telephone exchanges, repeater stations, and telegraph offices from lightning discharges is required.

Telephone Exchange Equipment.

Both manual and automatic telephone exchanges are used in the telephone network in India. The former satisfy the requirements of simplicity and ease of maintenance more than the latter but there are advantages in automatic operation which outweigh these considerations—chiefly from the point of view of economy in working, in overcoming language and operating difficulties, and in providing a 24-hour service. In consequence, automatic exchanges have been in use in India since 1913 and most new exchanges are of this type, the equipment installed being of standard designs and being usually required to carry heavy traffic. Figures up to 0.085 Traffic Units originated per subscriber in the busy hour are recorded and the number of switches required to deal with traffic loading of this order is correspondingly high.

The manual exchanges installed are usually Magneto or C.B. Points of design of these which may be mentioned are the standard of insulation of the components and the necessity for excluding dust from the exchange apparatus. Illustrative of the former, switchboard cords are tested after one hour's immersion in water, and must show an absolute insulation resistance of at least 1,000 megohms on a length of 18 inches.

Effects of Dust.

In both manual and automatic exchanges steps must be taken to overcome the deleterious effects of dust. Dust covers on individual relays or groups of relays are necessary and in addition, automatic equipment is usually installed in dust proof cabinets. In small automatic exchanges of the unit type (U.A.X.'s) which are often installed in very dusty situations, experience has shown that faults are reduced if the cabinet is opened as little as possible. For this reason the Indian Posts and Telegraphs Departmental specification concerned with this type of equipment requires that the subscriber's line and exchange testing equipment be mounted outside the cabinet. Link busy lamps and link busying switches are fitted so that the linesman can test all the exchange links and busy a faulty unit without opening the cabinet, there being sufficient links provided to allow for one or two being out of service and these are corrected during the maintenance visit of a supervisor from a main exchange.

The fine dust which is usually very much in evidence in the plains of India is the primary source of relay and switch contact faults, and of low cross insulation on the apparatus components in damp weather. The use of twin contacts on relay springs and the mounting of relays with the springs in the vertical plane (as in the B.P.O. 3,000 type relay) greatly reduces the number of contact faults due to dust—both twin contacts and springs wired in parallel have been used for some years with good effect in overcoming such trouble. When jacks are used in apparatus test panels it is usual to fit one jack per wire with the tip and ring springs in parallel to secure double contact operation.

To reduce the possibility of faults and circuit noises being caused by the lowering of the cross insulation resistance due to the deposit of moisture on dusty insulating surfaces, it is necessary to mount apparatus units so that they collect a minimum amount of dust on the insulating parts—tag blocks wherever used, for instance, are preferably mounted vertically rather than horizontally for this reason. (Incidentally it is easier for inexperienced staff to solder wires on tag blocks mounted vertically and fewer faults from wire cuttings and pieces of solder occur). In this connexion it seems a pity that the two-motion step-by-step switch is not fitted on its side to reduce the area which can collect dust on and between the bank contacts and on the bank wiring. Uniselectors mounted with the contact arcs in the vertical plane have some advantage in this respect, as also have two-motion switches with split banks, and those of the vertically hunting type, in which the insulation surface between the positive and negative line contacts is omitted.

In maintaining exchanges special care has to be taken to keep all the equipment as free from dust as possible, double doors, dust trap ventilating systems, and vacuum cleaners are used in large exchanges for this purpose. It has also been found to be of advantage to use rubber-covered floors to prevent the collection of dust in joints and cracks in the floor which may be stirred up by the movements of the maintenance staff, and to minimize the possibility of trouble from the same cause no equipment is mounted within, at least, one foot from the floor.

Although not directly connected with dust troubles, it may be mentioned here that components on which either a clip or screw-fastened contact arrangement may be used are preferably fitted by the latter method; tubular fuse holders with U-ends held under screws on M.D.F. line-protector strips, for example, have been found more satisfactory than clip-in types.

Temperature Effects.

High temperatures alone do not, as a rule, cause much difficulty in exchange plant but all the apparatus units must be capable of working efficiently over the temperature range which occurs—*vide* Fig. **1**. Instances have occurred where the expansion of dissimilar metals operating with a small clearance on two-motion switches has caused the switches to be sluggish and jam in the hot weather. Trouble has also been experienced due to the material used in compound-filled units not having a sufficiently high melting point—there should be no liquification at temperatures up to 130° F. while at the lowest temperatures encountered the compound should not shrink or crack. Similarly, the substance employed for insulating studs, such as are used in relay springs, should not shrink in hot dry atmospheres—difficulties have been caused by studs dropping out of relay springs due to this fault. The materials used for insulating panels, component mouldings, or wherever composition is employed, should be free from any tendency to shrink or warp in the hot weather; allowance must be made also for the high shade temperatures encountered when dealing with the temperature rise of the machines used for battery charging or those incorporated in the exchange equipment.

Insulation of Components.

As would be expected, breakdown of the insulation of apparatus is most in evidence during the monsoon rains when the humidity is excessive, temperatures are still high, and condensation can be caused by a small drop in temperature. At inland stations, the monsoon follows the high temperatures and low humidity of the hot weather and during the latter the equipment is subject to conditions which favour a thorough drying of the components and such shrinking, cracking, or perishing of materials as can occur. Dust storms, during which it is difficult to prevent the deposit of dust on apparatus, are also most frequent at this time of year, so that on the advent of the monsoon, conditions are such that moisture can readily form leakage paths which may develop into actual points of breakdown. It is the usual practice to use heaters in the switchboards and under distribution frames at large exchanges during the monsoon to keep the apparatus as dry as possible, but in many situations (e.g., at small exchanges or subscribers' premises) it is not feasible to take any special precautions, and the use of equipment which will fully withstand the hot weather and the monsoon conditions at such places is the only method of avoiding insulation faults.

The various Indian Posts and Telegraphs Departmental specifications for components indicate the design and insulation standards which have been found to give the best results in hot and humid atmospheres. Relay windings, coils, and similar units must be suitably impregnated or protected to prevent the absorption of moisture which may cause corrosion of the winding, and all cable conductors and wiring must be insulated to withstand the climatic conditions. For switchboard cables an insulation resistance of at least 200 megohms per mile is specified, the cable consisting of enamelled conductors, double silk and single cotton covered, the whole being impregnated with beeswax. For wiring components, enamelled wires with two wrappings of silk and an outer covering of cotton braid impregnated with beeswax have proved the most satisfactory, braid having advanges over the ordinary cotton covering as it does not fray out when the wires are being soldered to tags and so cause low cross insulation. Where switchboard cable or wiring forms are laced, the lacing should be only just tight enough to keep the wires in place—tight lacing has been found to be a fruitful source of insulation breakdown—and forms should not be in direct contact with any metal work of the equipment. It is interesting to note regarding wires and cables of various types that conductors with green coloured insulation often seem most subject to low insulation trouble—*vide* Table I—and it would appear that when a choice of colours is possible, as in the internal wiring of apparatus components, green is best avoided.

Subscribers' Telephone Instruments.

Robustness and good quality components are important requirements for subscribers' instruments. These often receive rather rough handling, especially

TABLE I.

A SELECTION OF TEST RESULTS SHOWING THE TENDENCY FOR GREEN COLOURED INSULATION ON WIRES TO SHOW A LOWER INSULATION RESISTANCE THAN OTHER COLOURS.

	Insulation Resistance in Megohms per Mile.								
	Blue.	Orange.	Green.	Brown.	Slate.	Red.	White.	Black.	Remarks.
4-conductor rubber compound insulated under-water cables	1,232 2,182	— —	855 954	— —	— —	1,232 2,182	— —	1,005 2,185	
10-pr. rubber compound insulated cable	2,182	2,182	954	1,981	—	2,182	1,842	2,185	
House Wiring Cables. (Impregnated paper, conductors enamelled)	1,072 440	— —	851 403	— —	— —	1,072 450	1,072 500	— —	
5-conductor rubber compound insulated telegraph instt. room cable	1,202	—	1,100	—	—	1,480	1,284	1,603	
Switchboard cables (conductors enamelled, single silk and double cotton covered, beeswaxed)	624 20	710 27	331 12	662 11	666 —	690 15	566 30	— —	Faulty cable.
Switchboard wires (conductors enamelled, double silk and single cotton covered, beeswaxed)	302 308	469 —	203 184	508 219	— —	563 300	— 250	— —	Test Samples.
4- and 7-pair L.S. Cables (conductors enamelled, double cotton covered, paraffin waxed)	435 433	404 476	359 211	— 231	— 302	403 243	407 —	— 475	

The spacing between terminals and tags, jack and relay springs, switch contacts, etc., should be ample, otherwise the surface leakage in damp weather across small clearances will cause low insulation faults. The insulating material used for the separation pieces between springs should also be non-hygroscopic—faults on relays have occurred due to the swelling of separating strips causing distortion of the springs and, in extreme cases, causing fracture of the spring assembly. Similarly, switchboard plug sleeves should also be of non-hygroscopic material to prevent them bulging and splitting.

Condensers must be of high grade to avoid trouble and the Indian Posts and Telegraphs Departmental specification concerned, therefore, requires a high standard of insulation and electrification performance. This has been found to be necessary to prevent breakdown during the monsoon period, considerable difficulty having been experienced in this respect in the past in all types of communication equipment in which condensers are employed. The actual tests to which condensers are subject require the application of 300 volts to the terminals for two minutes, and after one minute the unit must indicate an insulation resistance in megohms such that when multiplied by the capacity in microfarads the product is not less than 1,000. The difference in galvanometer readings at the beginning and end of the second minute must not be less than 20 per cent. of the first minute reading, and the insulation resistance between the tags and the case must not be less than 1,000 megohms.

in bazaar areas, and to meet such conditions the mouldings for H.M.T. sets, for instance, should be strongly made, particularly the cradle-switch horns. Dials should be robust—the use of stainless steel finger plates has been found advantageous in this respect. The oiled silk protecting diaphragm used to exclude moisture on transmitter insets very quickly proved unserviceable in India, becoming soft and spongy—tinfoil protecting diaphragms have, so far, been found the most satisfactory. Instrument components such as condensers and cords must have a high insulation performance to give good service—instrument cords are tested to the same standards as switchboard cords, and as in exchange equipment, telephone instruments should be designed to exclude insects, any openings in the casing being closed with wire gauze.

High efficiency telephones with a good transmitter output and receiver performance are used in both the large and small exchange systems. There are added advantages to be gained in the use of such instruments in small exchange systems in that, in a developing telephone network, it may occur that the transmission standards to remote stations are below normal until the general transmission scheme has sufficiently developed to deal with these places, and high efficiency subscribers' sets help in overcoming this difficulty. It is interesting to note, however, that abnormally high output levels are obtained with modern handset telephones when particular words of Indian languages are spoken by Indian subscribers, so much so that it has been found necessary to instal input limiting devices on long distance carrier equipment to prevent trouble from this effect.

Long-Distance Equipment.

Of the general points of design of telephone repeater and carrier equipment the necessity to avoid wiring forms as much as possible may be mentioned—open point-to-point wiring of the components with a minimum of laced forms having been found the best arrangement in avoiding low insulation difficulties (Fig. 3). Forms of tag connexions in which the wires are held in position by the solder alone, instead of through holes or deep notches in the tags, have been found satisfactory in avoiding dry joint troubles. Telephone repeater installations in India at the present stage of development consist at the most of only three or four repeater units at each station, so that low current consumption and saving of floor space are not very important if advantages can be gained otherwise. Simplicity of operation for both voice frequency and carrier apparatus is an important factor.

Equipment operated directly from power mains supplies is subject to difficulties due to abnormal variations in the mains voltage in a number of the smaller stations and it is necessary to take special precautions to minimize the possibility of faults from this cause such as, for example, the fitting of regulating devices in the current supply circuits of telephone repeater and carrier plant.

Transmission measuring apparatus for use both on long distance circuits and in local exchange systems is usually required to be in a portable form and should be very robust, the damage which can be done to such apparatus which does not fulfil the latter condition has to be seen to be believed. Direct-reading instruments are normally preferred to forms of balance or null-reading types and, for small portable sets, attenuation indicators using copper oxide rectifiers have been found more suitable than types employing valves. In this connexion it may be remarked that the value of transmission measurements, in a country at such a stage of development as India, lies as much in the comparison of routine test results as in obtaining absolute readings.

Telegraph Equipment.

The principles of design enumerated for telephone equipment apply equally to telegraph equipment. Simplicity and ease of operation and maintenance account for the large use made of Baudot apparatus in the Telegraph system in India. Teleprinters have now been introduced but the tendency is, at present, to employ start-stop machines operating on electrical principles rather than mechanical types. As an example of simple apparatus fulfilling the working conditions, the considerable use which is made of closed circuit operation on minor out-station lines in India may be cited. These circuits, using Dubern sounders, have met all the requirements for some 40 odd years and have not yet been subject to the introduction of better components or a different system of working.

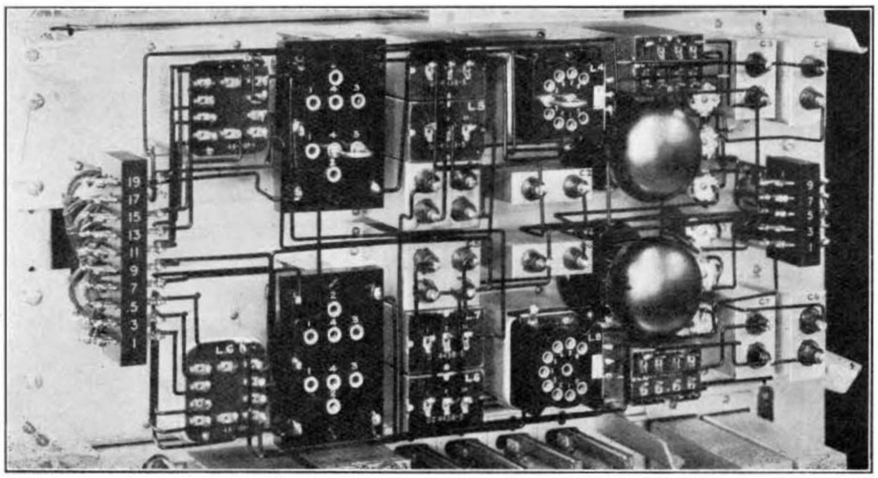


FIG. 3.—REPEATER PANEL SHOWING OPEN WIRING.

Conclusion.

As a method of minimizing the insulation difficulties which occur with communication equipment in tropical countries the question of air conditioning is often raised. This can readily be applied to large telephone exchanges but not ordinarily to the small installations which comprise the greater part of the equipment in India. Apart from the question of the comfort of the maintenance staff, however, it is a debatable point whether air conditioning should be considered as a corrective to apparatus troubles due to adverse climatic conditions—the better policy seems to be to improve the design of the components to meet the exigencies of the climate. It is often found that apparatus specially designed to function satisfactorily in tropical and sub-tropical countries has advantages which render its use well worth while in more temperate zones.

Passenger Lifts at Telephone House, Birmingham

J. G. BEASTALL, B.Sc. (Eng).

A description is given of the lift installation at Telephone House, Birmingham. An interesting feature of the equipment is the dual voltage controller utilizing telephone type relays.

Introduction.

IN buildings in which it is necessary to cater for heavy passenger traffic it is essential that the performance of the lifts should be adequate to deal with the traffic so that passengers do not have to wait beyond a reasonable time. A certain measure of flexibility is also necessary when there are periods during which the peak load is particularly heavy, while at other times the number of passengers may be extremely small.

At Birmingham Telephone House these conditions obtain and a lift service embodying speed, flexibility and ease of operation has been installed. Three 20 cwt. passenger lifts have been provided, each capable of carrying twelve passengers at a maximum speed of 300 feet per minute. In order to provide flexibility the lifts are equipped with dual control, that is car switch and automatic push-button control. The car switch is for operation by an attendant during the busy periods, but the control is switched over to automatic operation when the service of an attendant is unnecessary.

Each lift serves six floors, the travel being over 70 feet. In order to obtain the necessary rapid acceleration and retardation without the discomfort frequently obtaining due to abrupt changes from high to low speed the well-known Ward Leonard system has been adopted. The floor selecting and levelling is such that no time is wasted in levelling and no skill is required on the part of the operator to bring the lift accurately to the required floor level.

Owing to the nature of the building special consideration has been given to the design of the lifts from an architectural point of view, especially of the two lifts in the main entrance hall. Double sliding metal doors have been installed in the landing openings of these lifts, interconnected in such a way that the movement of one door effects a similar movement in the other. The doors and car gates are finished in bronze and the cars have been designed to harmonize with the surroundings. The interiors of the cars are panelled with mahogany, bordered by an ebonized mahogany line. Illuminated floor position and direction indicators are fitted over the doors to enable passengers to use the service to the best advantage.

The third passenger lift is constructed in a stairwell, and although it posesses no exceptional architectural features, the gates have been finished in bronze and the car designed to harmonize with the surroundings. The interior of this lift is illustrated in Fig. 1.

The electricity supply to these lifts is 400 volts, 3 phase, A.C. which is utilized to feed the motor generators, but the controllers operate from a 40 volt supply obtained by means of transformers and metal rectifiers connected across the phases.

The most interesting feature of the installation is the dual voltage controller operated by telephone relays which is used on each lift. The lifts were installed by the Express Lift Company Ltd., who hold the patent rights for the dual voltage type of controller described in this article.

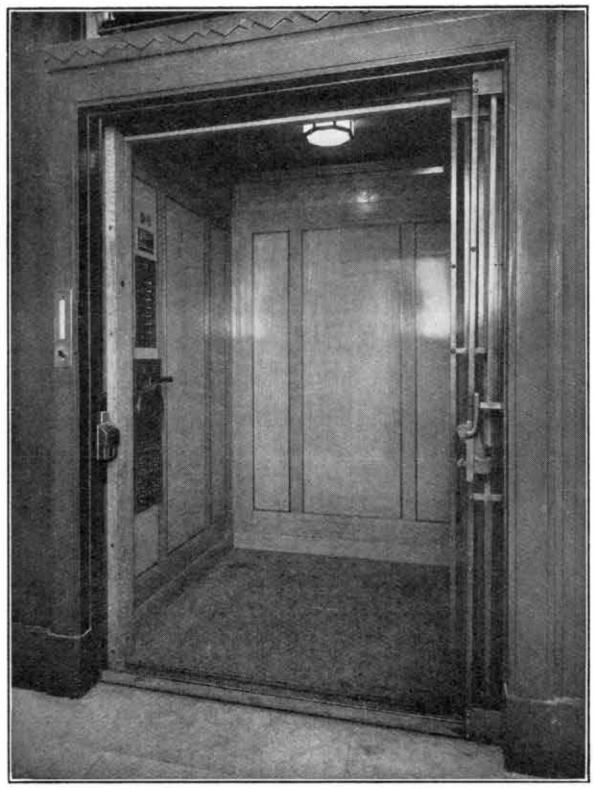


FIG. 1—INTERIOR OF CAR OF STAIRWELL LIFT.

Variable Voltage Speed Control.

A 400 volt A.C. supply is fed to a squirrel cage motor which runs at constant speed driving a D.C. generator and an exciter, all three machines being mounted on one shaft and in one frame. The output from the D.C. generator is fed to a D.C. motor which drives the traction sheave through a worm reduction gear.

The exciter provides a constant voltage D.C. supply for the separately excited field winding of the D.C. motor. Speed control is achieved by varying the excitation of the generator, thus varying the voltage applied to the hoisting motor. This produces exceptionally smooth changes of speed owing to the smoothing effect due to the inherent delay in the response of the generator field to changes in excitation current. The stopping speed of the lift is approximately 30 feet per minute which makes it possible to achieve accurate landing levels. Provision for automatic slowing and stopping is embodied in the control circuit.

The principle of the control system is that of using two distinct working voltages. The line pressure of 400 volts is carried only by the contacts of the main contactors feeding the motor generator. The exciter voltage of 230 volts is used to operate the brake and certain control circuits, but the other circuits including the coils of the circuit breakers, main reversing contacts, gate contact relays etc., work on the 40 volt D.C. supply.

The front of the controller is illustrated in Fig. **2**. The telephone relays are protected by metal covers and cannot be seen.

register a call on the car annunciator when the lift is operating on car switch control. In the car there is also a switch for the remote control of the motor generator set, provision being made in the controller to prevent the lift from being operated until the motor generator has attained full speed.

When the lift is being operated on push-button control a time-lag device provided on the controller is operated by the closing of the car gate and prevents interference from the landings by rendering the landing pushes inoperative for a period of five seconds after the passenger has closed the car gate.

When the lift is being operated by the car switch, the attendant moves the switch to the full speed, up or down, running position and the car starts and accelerates smoothly to full speed. When the car approaches the required landing the attendant centres the car switch handle causing automatic slowing and stopping devices to be connected. The car does not decelerate until it reaches the point at which it must slow down in order to stop at the required floor. Successive reductions in speed are brought about automatically and the car stops level with the landing. In order to travel from one floor to the next the attendant moves the handle over in the required direction and releases it as soon as the car starts. The car accelerates to a suitable speed and automatic devices function to slow and stop the car at the next landing level.

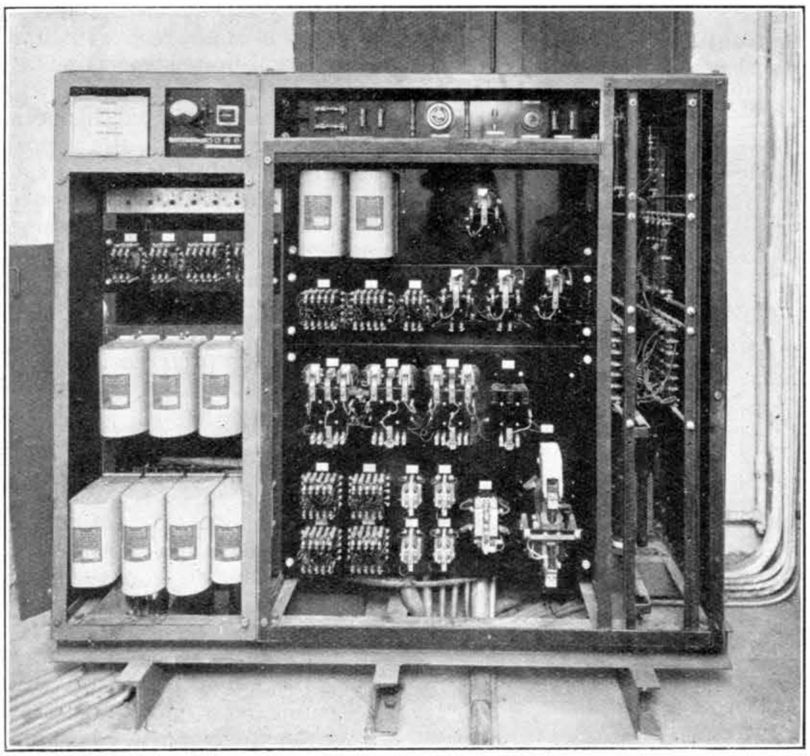


FIG. **2**—FACE OF DUAL VOLTAGE CONTROLLER.

Method of Operation.

The lift may be controlled either by the operation of push-buttons or by an attendant operating the car switch. A self centring car switch and a push-button box containing buttons corresponding to each floor served by the lift, are provided in the car. An emergency stop button and a transfer switch on the controller to enable the control to be changed over to full automatic push-button control or vice-versa, are also fitted in the car. On each landing is a single push-button to call the car to that level when the lift is being operated on push-button control or to

When the lift is being operated on push-button control, momentary pressure on either a car or landing button will cause the car to start and accelerate to full speed. When the car reaches the point at which it must slow down in order to stop at the required floor successive reductions in speed are brought about automatically and the car stops level with the required landing. The stop button enables the car to be stopped instantly at any time.

To eliminate appreciable motor-generator standby losses during slack periods an automatic shut down device has been provided, so adjusted that if no calls are registered for a period of 15 minutes the motor-generator set is automatically shut down until a car or landing button is depressed. On receiving a call the car does not start until the motor-generator has reached full speed. The device is automatically disconnected when the lift is operated by the car switch.

The essential features of the installation are indicated diagrammatically in Fig. **3**.

As a comprehensive and detailed description of the working of the controller is not possible in the space available brief descriptions of the more novel features

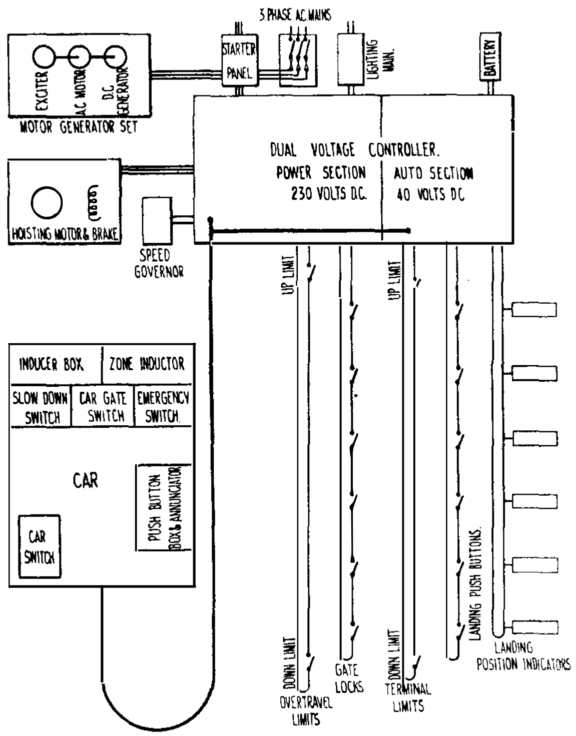


Fig. 3—Schematic Diagram of Lift Installation.

of the installation are given. These include the inductor system of floor selection, the inducer system of automatic floor levelling and time delay features.

Lift Position Indicator.

The position of the car in the shaft is communicated to the controller by means of a zone inductor switch, the construction of which is shown in Fig. **4**. The inductor consists of a permanent magnet which exerts a pull on a laminated armature holding the inductor contacts open against the restraining influence of a spring. The inductor is fixed on the top of the car with the slot overhanging the edge and a series of iron plates is located in the lift well so that as the car travels the plates pass through the slots in the inductor. When an inductor passes an inductor plate the magnetic lines of force are cut and the tension spring closes the contacts. The contacts

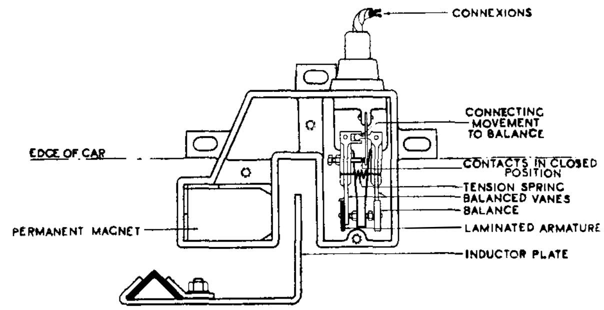


Fig. 4—Zone and Stopping Inductor.

re-open as soon as the inductor has passed the plate. Zone inductor plates are fixed approximately midway between each floor and as the car travels up and down the shaft, the switch in the zone inductor makes and breaks each time a plate is passed. The impulses from the zone inductor operate two relays in a definite cycle which operate relays in the controller corresponding to the position of the lift. There is a relay corresponding to each floor served by the lift the function of which is described later.

When the lift is being operated by the car switch, the inductor switch is bye-passed while the car switch is maintained in the " on " position, but as soon as the handle is released the switch contacts are operated by the next inductor plate to be passed. The use of this in preference to mechanical types ensures silence of operation. A similar inductor is also used for stopping the lift.

Calls registered by a landing button energize a relay which holds the circuit and allows the landing push-button to be released. The motor and brake are then connected automatically to the mains and the lift travels towards the calling floor. The controller is isolated from further car and landing calls, and a circuit is completed preparatory to stopping the car. As the car approaches the calling floor the zone inductor plate is passed and the lift position indicator portion of the control circuit becomes energized operating relays preparing the circuit for a thermostatic relay, the purpose of which is to open after the car has stopped and so allow a time interval to elapse before the circuit to the push-buttons is restored and the car can be re-started. A circuit is also prepared so that the stopping inductor will operate as it passes the stopping inductor plate, cut off the motor and brake from the mains and stop the car at the required floor. The controller then becomes prepared to receive further calls but cannot operate until the thermostatic relay has broken. This allows passengers time to open the landing gates and secure control of the car. The controller then returns to the state it was in when the original call was registered, with the exception that the relay corresponding to the floor at which the car now stands is energized in the lift position indicator portion of the controller.

The essential features of the lift position indicator portion of the controller are shown in Fig. **5**, which shows the state of the circuit as the car passes from the first to the second floor. The heavy line indicates the live portion of the circuit.

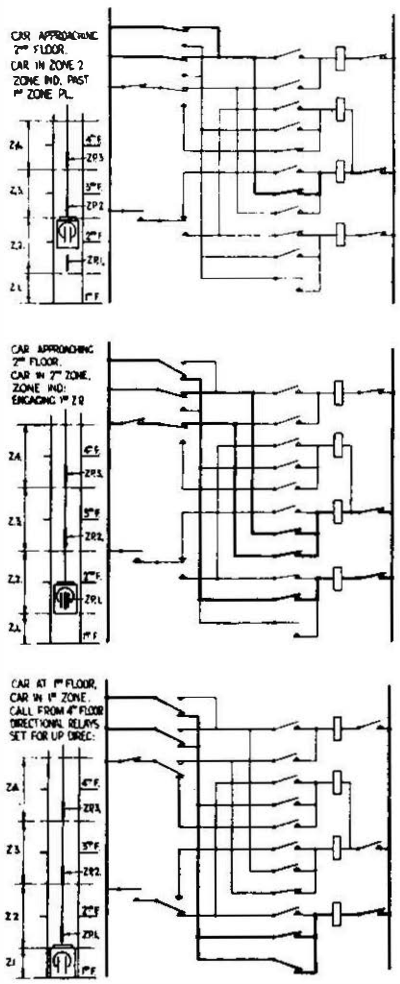


Fig. 5.—Essential Features of Lift Position Indicator Portion of Controller Circuit.

Floor Levelling.

In order to ensure that the car shall be brought to rest automatically at floor level, irrespective of loading conditions and without recourse to a crawling speed, an inducer levelling system is incorporated in the controller. The inducer box, which is illustrated in Fig. **6**, consists of a series of small coils which project over the edge of the car, a pair of adjacent coils constituting a working unit. One coil of each pair is energized with A.C. inducing a voltage in the neighbouring coil. This induced voltage is applied to a valve amplifier in such a way that no plate current passes to the slowing and stopping relays. A series of iron inducer plates is spaced in the lift well in line with the gaps between the pairs of coils. When a pair of coils passes one of these plates the induced voltage is cut off by the shielding action of the inducer plate and plate current passes from the valve amplifier and energizes relays which cause the car to slow down and come to rest accurately at floor level. The landing call indicator relays cut off the plate current to the slowing and stopping relays unless the car is in the zone in which it is required to stop.

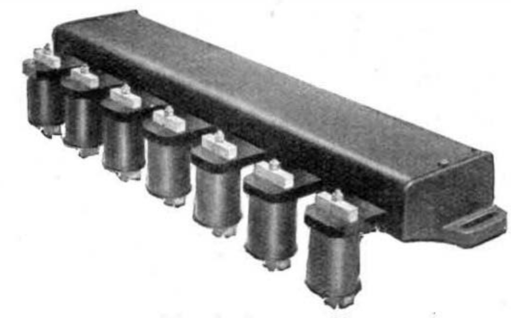


Fig. 6—Inducer Box.

The inducer box mounted on top of the car is illustrated in Fig. **7** on which some inducer plates can also be seen.

The operation is somewhat similar to that of the inductor switch, but the absence of any contacts in the inducer box ensures instantaneous action and response by the associated relays which is essential for good levelling of high-speed lifts.

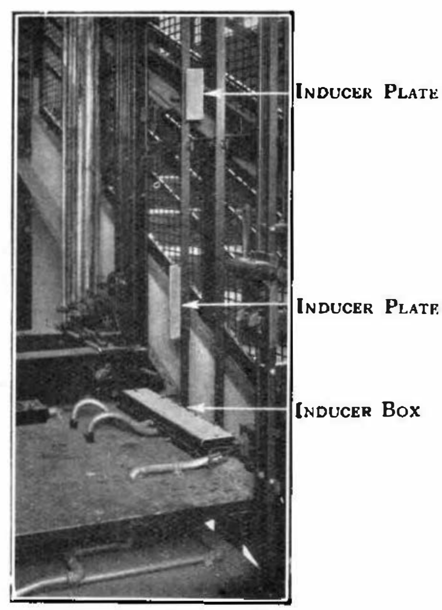


Fig. 7—Inducer Box and Plates.

Floor Selection.

The up and down direction of the car is controlled by means of two relays arranged as shown diagrammatically in Fig. **8**. The heavy line shows the current carrying portion of the circuit, the car being shown at rest at the bottom floor.

When the car is stationary at any floor and the controller is in the normal position and no calls have been registered, the up and down relays are short circuited as shown. When a call is registered at, say, the third floor, the relay contacts operated by the call registering relay break so that the short circuit is removed from the " up " relay as shown in diagram B of Fig. 8, resulting in the up relay being energized and the car starting to travel to the third floor. When the car stops at the third floor the

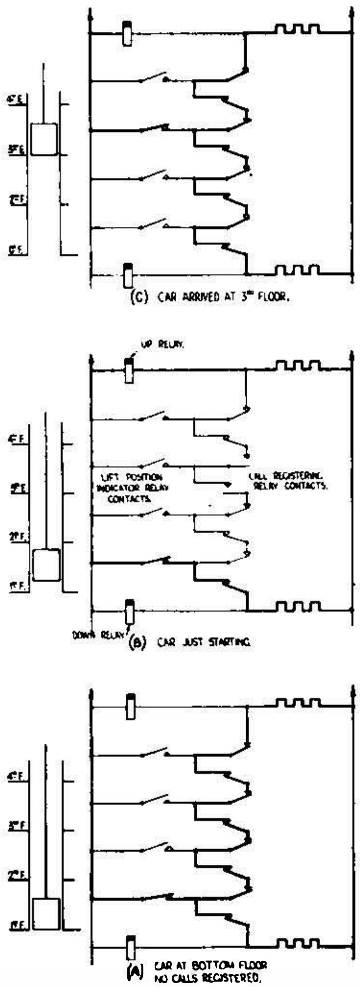


FIG. 8—FLOOR SELECTOR CIRCUIT.

relays operated by the lift position indicator portion of the controller cause the up relay to be short circuited again and the conditions shown in diagram C of Fig. 8 obtain, in which state the controller is ready to respond to either up or down calls.

Time Delay Features.

Should the car or balance weight be stopped by an obstruction it is desirable that the supply should be cut off from the controller and a condenser is arranged which will discharge through a neon lamp should the controller remain energized for a period equivalent to that taken for a double journey. The discharge current operates a relay and cuts off the supply to the controller and brake.

A similar device is brought into operation when the car gate is closed and isolates any landing calls for a period of five seconds to prevent interference

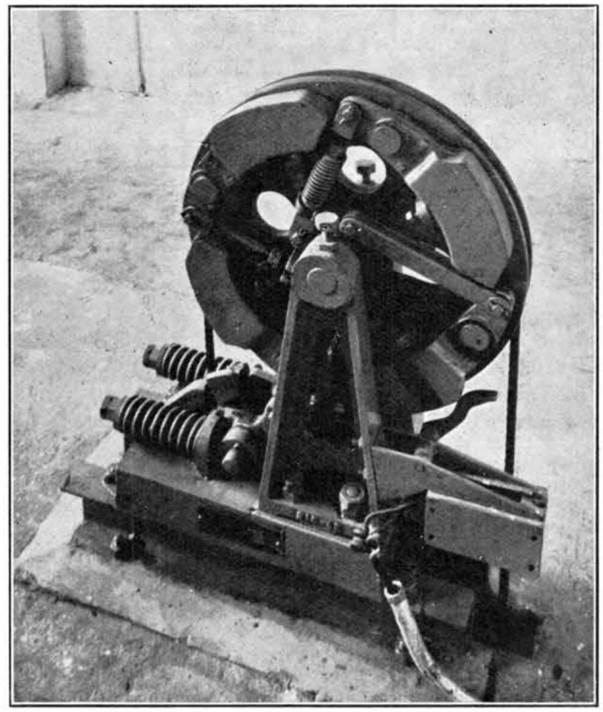


FIG. 9—SPEED GOVERNOR.

from the landing buttons before the passenger has obtained control from the car.

The same expedient is utilized to shut down the motor generator should no calls be registered for a period of 15 minutes.

Speed Governor.

The usual safety devices are incorporated in the circuit and in addition a safety governor which is illustrated in Fig. 9, driven from the car is fixed in the motor room and will operate to put the motor into slow speed if the car overspeeds by 10 per cent. Also it pulls in the safety gear and brings the car to rest locked on the guides should the ropes break or should the car reach 20 per cent. above its normal maximum speed.

The External Modernization of Valentia Radio Station

L. L. HALL

A description is given of the work of replacing the old tubular masts at the Valentia Radio Station with new masts of the lattice type

Introduction.

ON the island of Valentia off the extreme south west corner of Ireland stands the most remote of British radio stations. It is built on the side of a mountain, which slopes gently down to the sea on the north side and terminates in precipitous cliffs on the westerly side. The station buildings are approximately 100 yards from the westerly cliffs and the latter, jutting out into the sea at this point, form a headland approximately 200 feet high over which, during westerly gales, spray is frequently swept. As a matter of interest it should perhaps be stated that the transatlantic telegraph cables, owned by the Western Union Telegraph Co., are brought ashore on this island, the shore ends terminating in a little hut half a mile from the radio station.

The general layout of the station is shown in Fig. 1. The old masts were erected one on each side of the station buildings, the span between them being 300 feet. The main aerial slung from the mast heads was of the "T" type and Bellini Tozi direction-finding loops were also attached to the westerly mast.

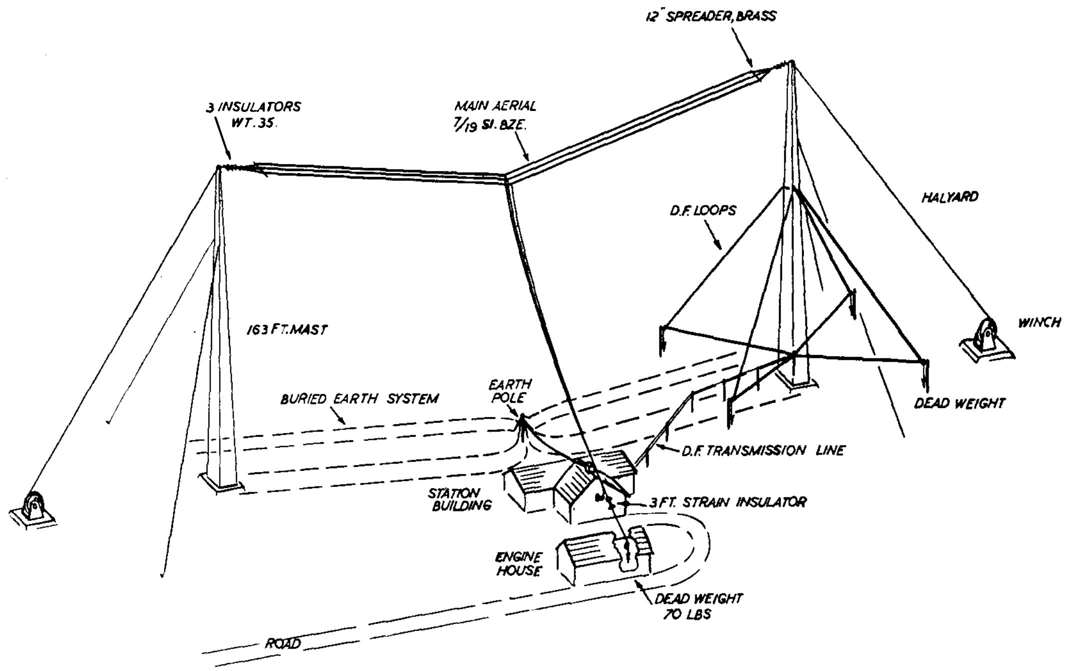


FIG. 1—GENERAL LAYOUT OF STATION.

The Old Masts.

The old masts, erected in 1914, were of the tubular type, 2′ 0″ in diameter, built of eighteen 10′ 0″ sections bolted together end to end and stayed in four directions at right angles, the stays being attached to the tops of the 8th, 14th and 18th sections. For erection purposes each 10′ 0″ cylindrical section was made in halves bolted together longitudinally and provided with a circumferential flange at each end. Between the circumferential flanges of adjacent sections circular diaphragm plates $1\frac{1}{2}''$ thick were inserted. Each set of three stays was tied down to a main anchor block and provided with chains and bottle screw tighteners at the bottoms. This type of mast is comparatively light and strong, but unfortunately access could not be obtained to the interiors of the Valentia masts rendering it impossible to protect the insides of the shells against the corrosive influence of the sea atmosphere.

Periodical inspections of the masts had revealed the fact that in recent years a considerable quantity of rust had fallen down inside the masts. In 1934 it was noticed that both masts had developed perceptible deflections and a special examination was made. This gave some idea of the extent of the internal corrosion, and several cwt. of scale that had fallen down inside the masts and accumulated at the bottom were removed through the bottom fid hole. The examination of the exteriors of the masts also revealed considerable corrosion of the shell, particularly underneath the horizontal circumferential flanges. This was no doubt due to water dripping off the flanges on to the shell. It was therefore considered that the masts were approaching an unsafe condition, and in view of the internal re-organization of the station it was decided to replace the external plant as soon as possible.

The New Masts.

The new steel masts are of the self-supporting lattice type 163′ 0″ in height and of square section, tapering from 10′ 0″ side at the base to 6″ at the top. They are designed to withstand a mast head load of one ton and a simultaneous gale of 100 m.p.h. acting in the same direction as the mast head load and normal to any one face. The lattice type of construction gives a comparatively light but strong structure, with the additional advantage that every part can be examined and painted.

The masts are constructed of steel angles bolted together, each face of a mast being a tapering Warren truss. The four post angles vary from 4″ × 4″ × $\frac{1}{2}$″ at the bottom to $2\frac{1}{2}$″ × $2\frac{1}{2}$″ × $\frac{1}{4}$″ at the top, and the bracing angles from 3″ × 3″ × $\frac{1}{4}$″ to 2″ × 2″ × 3/16″. All the steel is of "A" quality in accordance with B.S.S. for structural steel, Report No. 15. The bolts are turned barrel, one spring washer being supplied with each, and all bolt holes are drilled. The tolerance allowed on the bolts and holes is ± 1/500″.

The loading which the masts are designed to withstand would produce a tensile load in each windward post of about 24 tons and it is to withstand this pull that the foundations must be designed. In normal firm earth not containing rock, the foundations would consist of four blocks of concrete of the type indicated in Fig. 2, in each of which four steel rods

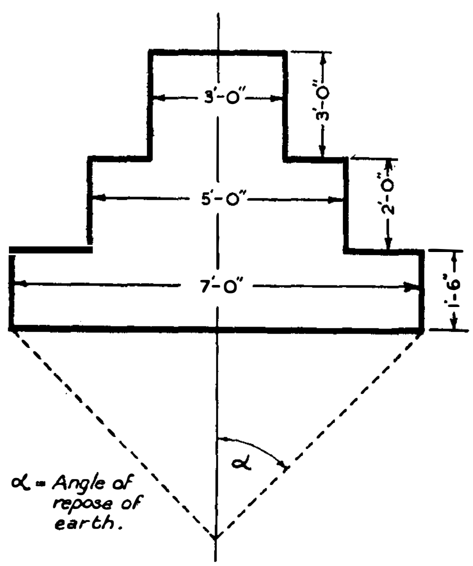


FIG. 2.—NORMAL TYPE OF FOUNDATION BLOCK.

$1\frac{1}{8}$″ diameter, carrying plates at their lower ends, would be embedded. The upward pull resisted by any one such block is equal to the weight of the block, plus the weight of the inverted frustum of a pyramid of earth (the apical angle of which is twice the angle of repose of the earth), plus the suction of the concrete on the earth under the bottom of the block. This last factor is generally neglected as it is indeterminate. If hard rock were encountered the foundation holes would be made only large enough to permit of the steel rods being sunk to the requisite depth to get an adequate grip.

At Valentia the ground was known to consist of earth and soft rock overlaying the solid rock of the mountain, but the actual depth of the layer was unknown.

Erection of the New Masts.

The positions for the new masts were laid out on a line parallel to that joining the old masts and 100′ therefrom laterally. As the ground sloped at approximately 10° the tops of the new and the old masts were approximately in the same horizontal plane. This lay-out enabled the new masts and aerials to be erected and joined up to the transmitter before the old masts were felled.

Foundations. Operations were commenced on the foundations for the new masts. This necessitated the excavation of four holes each 4′ square and 6′ 6″ deep, the centres of these holes being at the corners of a square of 10′ 0″ side. Excavation was commenced in the normal way utilizing picks, bars and shovels, but before this had proceeded far separate large pieces of rock were encountered, either entirely within the boundaries of the holes or jutting in through the sides. When such a piece of rock was encountered entirely within the boundaries of the hole it was excavated and removed by a derrick and Weston chain blocks. Some of these pieces weighed up to 5 cwt. Hard rock was excavated only in order to sink the hole to the required depth so that rock which jutted through the side of the holes, but which did not impede the excavation, was left *in situ*. Some trouble was caused by the inflow of water which drained down the mountain side, and it was necessary to keep a pump working most of the time. An armoured hose was available and this enabled water to be syphoned downhill out of the holes. An attempt made to divert some of this surface water from the foundations by excavating a drainage trench a few yards uphill of the foundation holes, was only partially successful, so that considerable flooding of the holes was experienced.

The rock was of a slaty character, becoming harder and more solid as excavation proceeded, until in all the holes excepting one, a solid rock bottom was reached at an average depth of 6′ 6″. At about 5′ 0″ depth a shelf of hard rock 1′ 0″ thick was encountered but this did not extend over the whole area of the foundation, so that it was possible to chip the edges away and make a hole large enough to accommodate the $1\frac{1}{8}$″ steel foundation rods. Below this hard stratum was a 6″ layer of soft rock and this was excavated, especially under the edges of the hard stratum, in order to obtain the best "keying" between concrete and rock.

In one hole only, a solid layer of hard rock extending over the whole area of the hole, was met at a depth of 4′ 6″. This could not be penetrated except by blasting, and it was not desired to recourse to explosives owing to the possibility of the solidity of the ground being disturbed. The surface of this layer of rock was therefore scrupulously cleaned and the adhesion of concrete to rock depended upon to resist the possible tensile load on the mast post.

The other holes had not been undercut at the bottom due to the solidity of the walls and in-jutting rocks, but in this hole, in order to get as large an area as possible for the concrete to adhere to, the comparatively soft rock overlaying the hard stratum was undercut so that an area of 5′ 0″ square was exposed.

To withstand a pull of 24 tons, adhesion amounting to $\frac{24 \times 2240}{25 \times 144} = 15$ lbs./in.² is required. Adhesion tests were made with the cement actually used, and it was found that after allowing the cement to set for only a week a value of 50 lbs./in.² was obtained. Before concreting this hole a slurry of neat cement was run over the cleaned surface of the rock bottom.

The material excavated from the foundation holes was utilized in making short roads across the site from the main road so that the concreting materials and the steel work could be brought up to and unloaded near the foundations.

By the time the foundation holes had been excavated the foundation steel work for the masts had arrived. As previously mentioned, this, for each hole, consisted of four steel bars $1\frac{1}{8}''$ diameter by 6′ 6″ long to the bottoms of which could be screwed flat steel plates 1″ thick, 4″ wide The $1\frac{1}{8}''$ bars had to be positioned correctly so that ultimately the post angles of the masts could be anchored to them by gusset plates. A wooden template was therefore constructed having holes bored in it at the correct spacings to receive the steel bars and this was laid horizontally over the foundation holes.

When dealing with normal firm earth, the bars would be simply hung from the template and the bottom plates screwed on, the holes then being filled with concrete. In this case, however, due to the peculiar lay of rock shelves, the bars with bottom plates attached would not have hung vertically, so the plates were not put on to the ends of the bars. Instead, the ends of the bars were heated and bent so that the bent portions could be inserted into the recesses underneath the in-jutting rocks and shelves. The bottom plates were then laid over the bent ends of the rods, and as far as possible passed under the shelves of rock.

In the 4′ 6″ deep hole, the bars had to be bent almost in the middle, and when hung from the template the bent ends were splayed towards the outsides of the hole. A considerable amount of extra steel reinforcing was therefore put into this hole.

The water which had drained into the holes served at least one useful purpose. As the water was syphoned and bucketed out, it was splashed and swirled against the sides of the holes, thereby cleaning the sides of most of the earth and loose material, so that ragged but clean walls were exposed for the final concreting.

During the final stages of excavation and the setting up of the foundation steelwork, the concreting materials were arriving and being dumped near the foundations. An ample supply of clean water for concrete was available in the drain trench. When all was ready, one hole after another of the mast foundations was pumped dry, and concrete mixed and filled in as rapidly as possible. On occasions, this became a race with the inflowing water, but the work was expedited by utilizing some of the hard rock which had been excavated, the latter being cleaned with wire brushes and put back into the hole with the concrete. The replacement of these pieces of rock effected a very considerable saving in concreting materials besides expediting the work and enabling the concrete to be brought above the level of the inflowing water fairly rapidly.

The concrete was filled in up to within about 2′ 6″ of the top of the steel bars and then left to set. Later, concreting was continued up to within 9″ of the top of the bars, the section being reduced to 3′ 0″ square, this necessitating the use of shuttering.

Winches. The old main aerial halyards were led over blocks at the mast heads and down to winches. These winches were in good condition so it was decided to utilize them for the new aerial system, and in the erection of the new masts. Accordingly the old main aerial halyards were removed from the winches and anchored to the concrete winch bases, thus permitting the winches to be shifted to their new positions about 30 yards from the foundations of the lattice masts, where they were bolted down to their new beds which had been made as early as possible.

Masts. When the concreting of the mast foundations had been completed, the template (which incidentally had been carefully levelled so that the tops of the $1\frac{1}{8}''$ bars were in the same horizontal plane) was removed. The bars were screwed at the tops and to each set of 4 a triangular base plate was clamped horizontally by nuts on the bars, the latter passing through holes in the base plate. The post angles of the mast were to be attached to these base plates by gusset plates and angles, so due care was exercised to arrange the base plates in one horizontal plane.

All was now ready to commence the actual building of the mast. The post angles were in lengths of about 33′ 0″ for the first four sections, the last two being approximately 20′ 0″ each. It was decided to construct the lowest two sections of the mast, i.e., about 66′ 0″, by building opposite sides flat on the ground, pivoting the bottoms on single bolts passed through the gusset plates attached to the triangular base plates, and raising each side separately into the vertical plane by a 40′ 0″ derrick planted in the centre of the foundations. When both flat sides had been constructed, they were raised separately by means of the derrick and winch mentioned previously, and temporarily guyed. The derrick was then removed. The bracing for the two open sides had then to be bolted on in separate angles, so light snatch blocks and lines were rigged on the post angles of the two complete sides, and each bracing angle in turn was raised and bolted into position It should be mentioned that before any angles were bolted together they were brushed with wire brushes and the areas immediately surrounding the bolt holes were painted with a red lead paint.

When the bottom 66′ 0″ section of the mast was complete, the temporary guys were removed and a 26′ 0″ derrick raised to the top of this section. This derrick consisted of a light pole fitted with a wheel and spindle at the bottom and a snatch block at the top. A steel wire rope, made fast to a post angle at the top of the 66′ 0″ section, was passed under the wheel at the foot of the derrick, and up over a block attached to the top of the diagonally opposite post angle, whence it was led away to the winch. By this means the derrick could be raised as required. A hemp rope was passed over the snatch block at the top of the derrick pole, for raising post angles.

By taking in the steel rope on the winch, the derrick pole was raised until its top was level with the top of the 66′ 0″ mast section, when four 200′ 0″ lengths of steel wire rope were attached to the top of the derrick to act as stays, these being laid out mutually at right angles. Four short lengths of rope were also attached to the foot of the derrick pole to position it in the centre of the mast when it was ultimately raised to its final position.

The raising of the derrick pole was then carefully continued, the four main stays being fed through suitable anchorages about 150′ 0″ from the mast, until the top of the pole projected about 20′ 0″ above the top of the 66′ 0″ mast section, and over one post of the mast. The winch was then locked, the main stays made fast and the foot of the derrick positioned by the short lengths of rope attached thereto. One end of the hemp rope which passed over the block at the head of the derrick was led down to the ground outside the mast and the other end fed down the middle of the mast and through another block at the foot.

By means of the four long stays to the derrick head, the derrick could be canted over each post of the mast in turn for raising the post angles of the next sections. The sections of post angle were then hoisted aloft, one at a time, and bolted in position; fairly calm weather was essential for this operation as such long angles when supported only at their lower ends sway rather alarmingly in a wind. Accordingly the post angles were raised and the bracing angles of the new sections were bolted on as fast as possible.

The remaining sections of the masts were built in a similar fashion until the top section was reached. As this was short and comparatively light, two sides were built completely on the ground and raised in turn, the remaining bracing angles for the open sides being fixed subsequently.

After both masts had been built, the steelwork was thoroughly cleaned with wire brushes and painted. Three coats of paint were applied, the first being a red lead filler and the others different shades of grey, particular attention being paid to the junctions of the angles, where rain might creep in and cause rusting to take place.

Final plumbing of the masts was accomplished by adjusting the nuts on the $1\frac{1}{8}$″ anchor bolts, and then concrete was added to the tops of the main blocks and finished off flush with base plates.

Aerial. The new aerial was to be of the T type, but owing to the abnormally severe gales experienced in this locality, a rather generous dip in the top portion was allowed. It consisted of three wires of 7/19 bronze, connected in parallel and slung from two 12′ 0″ brass spreaders: the latter were electrically connected to the wires and formed part of the aerial. A string of insulators behind the spreader straps effected the best insulation of the aerial. The lead-in was loaded with a dead weight of about 70 lb., which not only kept the aerial tight under all conditions, but permitted such a degree of flexibility as to render the aerial safe from overloading even in a 100 m.p.h. gale.

The direction finding loops were simultaneously transferred to the westerly mast, the outer corners of the loops being dead weight loaded to give similar flexibility under gale conditions. A new buried wire earth system was also installed, this following the general shape of the main aerial.

Felling of the Old Masts.

The felling of the old masts was accomplished by releasing one or more sets of stays.

An endeavour was made to remove the nuts from the anchor bolts at the bases of the masts, but it was found that they were too rusted to move easily, and since the day fixed for the felling was providentially calm, it was decided to let the masts fall and either break off at the bottom, or tear away from the anchor bolts. Accordingly, the uphill stays of the westerly mast were anchored with wire rope to one shackle, the latter having a driving pin passing through the main bow in the anchor block, and the strain was transferred from the old chains to the shackle by unscrewing the bottle screw tighteners.

The pin of the shackle was then driven out with a sledge hammer, and the stays swung in to the mast. To one watching from this anchorage, the mast appeared to stand still for a few seconds, as though it were undecided as to what to do, and then slowly, the mast head moved away. Quickly gathering speed, however, and yet keeping almost straight, the mast hurtled downwards, until with a tearing sound (proclaiming the fracture of the mast near the base) followed immediately by a thud which shook the ground, the great tube hit the earth, sending soil into the air on each side. The mast had broken just below the upper circumferential flange of the bottom 10′ 0″ section; in this section the stress had been highest and at that particular point in the section, corrosion had been worst. This remaining piece was released from the anchor bolts subsequently The mast as a whole was somewhat flattened, particularly near the mast head, where the impact had been greatest.

The easterly mast presented a slightly more difficult proposition, as it had to be dropped between the station buildings and the gate, necessitating the release of two sets of stays. If one only of the two sets of uphill stays had been released, the mast would have fallen either across the station buildings or the gateway. Accordingly it was decided to release first the stays which would permit the mast to fall across the gate, and then when the mast was definitely moving, release the other stays, permitting the mast to fall more directly downhill clear of the gate.

Both sets of uphill stays were therefore anchored with wire rope to shackles as previously described and men stood ready at each anchorage to release the stays. The stays which would permit the mast to fall across the gate were then released as before, the mast head hesitated and then commenced to move slowly. Directly definite movement towards the gate had been established, the second set of stays was released. From the second anchorage in mid air, due to the widely differing accelerations and velocities of the parts of the mast, but in this case a considerable restraining influence on the lower part was effected by the base anchorage.

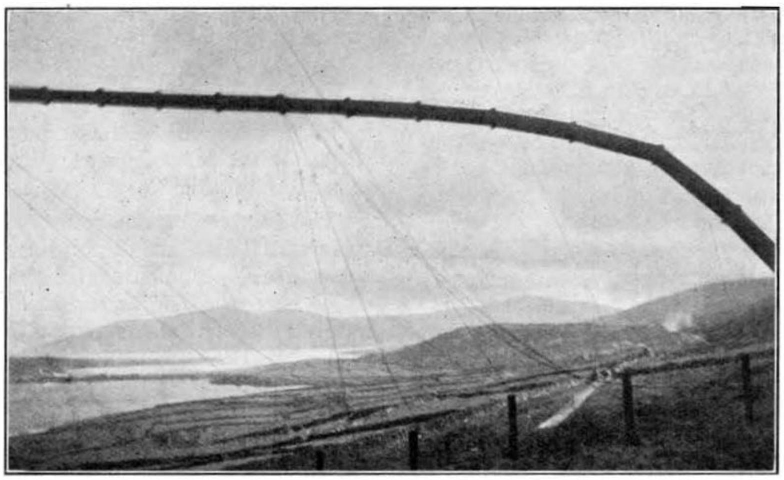


FIG. 3—EASTERLY MAST FALLING.

this appeared to produce a sudden cessation of motion towards the gate and for a moment it seemed as though the mast were going to alter its course drastically, but a second or two later it was seen that the mast was falling straight downhill between the gate and buildings. Fig. 3 shows the mast a fraction of a second before striking the earth, and illustrates the effect of not releasing the foundation bolts. Sometimes during felling, such masts break

The masts, as felled, were sold as scrap and removed by the purchaser.

Conclusion.

It is desired to express the sincere appreciation of the British P.O. Engineering Department to the Department of Posts and Telegraphs, Irish Free State, for the help and co-operation which the latter so generously afforded and which so greatly facilitated the work.

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 SEPTEMBER, 1936.

Number of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraphs.	Trunk.	Exchange.*	Spare.		Telegraphs.	Trunk.	Exchange.†	Spare.
995,891	279	4,534	52,381	6,777	London	37,397	275,193	4,045,580	74,667
123,344	1,791	14,183	53,326	8,592	S. Eastern	5,989	115,302	400,114	38,437
146,355	2,838	34,400	98,737	8,430	S. Western	25,248	90,956	318,002	89,715
101,402	3,419	36,973	85,039	14,043	Eastern	15,555	92,865	203,826	61,376
117,511	3,430	30,781	63,008	19,181	N. Midland	5,699	187,230	257,611	88,707
125,684	1,995	20,361	77,148	16,499	S. Midland	10,014	139,873	358,685	77,970
83,349	1,936	25,201	70,499	9,866	S. Wales	6,901	84,022	172,696	71,926
166,895	3,122	17,047	70,480	20,315	N. Wales	10,126	161,774	491,117	93,549
206,854	1,067	3,435	30,991	9,065	S. Lancs.	7,979	144,810	734,509	57,248
90,405	793	7,834	33,845	20,286	N. Western	6,599	113,027	270,846	72,424
34,842	2,964	11,568	16,101	1,125	N. Ireland	413	8,725	87,214	20,625
226,009	5,114	38,219	85,975	21,816	N.E. Reg.	16,654	251,082	692,869	120,813
231,758	6,958	43,997	94,708	21,074	Scot. Reg.	12,531	198,810	493,154	113,867
2,650,299	35,706	288,533	832,238	177,069	Totals	161,106	1,863,669	8,526,223	981,324
2,602,217	36,182	295,162	807,957	170,296	Totals as at 30 June, 1936	157,549	1,727,218	8,493,500	987,810

* Includes low gauge spare wires (*i.e.*, 40 lb. in open routes and 20 lbs. or less in aerial cables).
† Includes all spare wires in local underground cables.

Growth of Teleprinter Private Services

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

The private telegraph facilities which could be offered to the public were reviewed in 1931. This article gives the progress which has been made in the application of private teleprinter service since that date

Introduction.

IT is perhaps opportune at the present time, when so much effort is focused upon popularizing the public telephone service and upon developing new systems of operation, to review the progress which has been achieved in the development of those telegraph facilities which are grouped under the generic title of teleprinter private services.

Teleprinter private services may be defined as those services where the operation of the terminal teleprinter is carried out by non-Post Office personnel. Prior to the introduction of the teleprinter into the public service, the main users of private telegraph services were the cable companies and the news interests, and the operating staff had to be skilled in the art of telegraphy. The teleprinter, however, opened up an entirely new field for exploitation, since with its use a subscriber could carry out his own telegraph communication, employing staff no more experienced than that required for the typing of his correspondence.

Services Offered.

The types of circuits which could be offered for rental and the charges for the same were reviewed by a Committee appointed for this purpose which reported in 1931. These fundamental circuits are given in the Table below, and upon these have been built a structure of private services of various types which bids fair in the future to rival in size the public service, and which is not only remunerative to the Post Office, but of great utility to the business and commercial world.

Type of Service.	Annual Rental.	Remarks.
Tariff A ..	£275 up to 40 miles. £300 40-50 miles. Then £1 per mile up to 150 miles. £0.5 „ 150-300 miles. £1 „ after 300 „	Simplex Teleprinter service, Post Office providing apparatus. Rent includes teleprinter at each end of circuit and maintenance. Type 7 teleprinter used either tape or page, but mainly page printing.
Tariff B ..	Approx. £1 per furlong up to 30 miles. £350 40-50 miles. Then £150 each step of 10 miles up to 110 miles, then in graduated steps up to £1,000 for 300 miles.	Service provides for channel capable of working up to 100 words per minute but no apparatus. Renter can provide own apparatus (except where teleprinter is used). Mainly used by cable companies and news interests, with the exception that for short distances it provides a cheap alternative to Tariff A.
Tariff C ..	Approx. £1 per furlong up to 32 miles. Then graduated £390 48-50 miles. £640 77-80 „ £800 95-100 „	Service provides for channel capable of working above 100 words per minute, but no apparatus. Renter can provide own apparatus. Mainly used by cable companies and news interests. Service is being substituted by Tariff B.
Tariff D ..	Teleprinter rental of £50 per teleprinter. Charges are approx. £8 per mile.	This is a private telephone service with the facility of switching over to teleprinter working, at will.
Telex ..	Teleprinter rental of £50, plus normal telephone call charges.	Service allows connexion between subscribers on telephone network and subscribers to send telegrams direct to Instrument Rooms.

The services can be roughly divided into two types (a) those which use direct current into and out of the subscribers' apparatus; (b) those which use alternating current. The latter include all services which operate over the telephone network, such as the Telex and Tariff D teleprinter services, while the former embrace the Tariff A and the Broadcast Services.

Tariff A Service.

This service is the backbone of the Teleprinter Private Services and one which is playing quite an important part in the re-shaping of business methods. In its essential form it allows simplex teleprinter communication between two offices, and the circuit arrangement is such that the operated teleprinter also records, in multiplicate if necessary, the transmitted message and the receiving office can interrupt, when desired, the transmitting office.

The apparatus in each subscriber's office comprises a teleprinter mounted on a table with arrangements for utilizing the local power supply to drive the teleprinter motor. The local ends of the circuit are brought through what are known as Tariff A

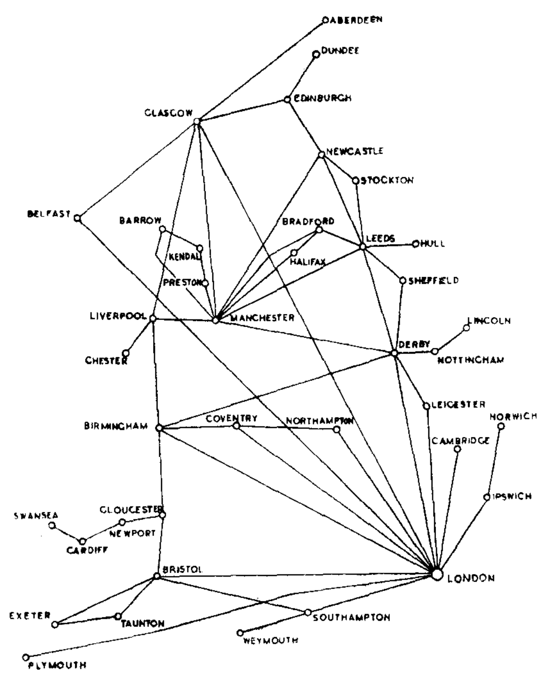


FIG. 1.—DISTRIBUTION OF TARIFF A TERMINALS.

terminals, which are rack mounted assemblies of relays and associated apparatus the purpose of which is to supply the local record and interruption facilities and the line current. A description of the circuit arrangement has already appeared in this Journal.[1] The terminal apparatus is designed on a unit basis and is of two types, the larger being capable of serving six circuits, and the smaller two circuits. The smaller type is installed at terminal offices where the demand for Tariff A services has been slight or where the accommodation available is not suited for the larger type which requires racks 10 ft. 6 in. in height.

Fig. **1** shows the present distribution of Tariff A terminals throughout the country and these are added to as demand necessitates. The connexion between the centres is made by utilizing by-product circuits of the telephone network, single screen conductors when such are available in the reconditioned cables, or channels of the voice frequency telegraph network. The connexions between the terminals and the subscribers are usually by pairs in the local telephone cables. The original intention was to utilize by-product circuits for this service, but it has been so well received by the business community that its progressive growth has necessitated the provision of blocks of multi-channel voice-frequency circuits specially for its needs.

Opened in 1933, the growth-rate has maintained its value from the commencement, until at the present time there are between 600 and 700 subscribers connected through the various channels representing 300 to 350 Tariff A circuits. Fig. **2** is a chart which shows the distribution of the stations. The figure within any square indicates the number of circuits in operation between the centres directly above and to the right of the square. It will be noted, as a matter of interest, that 80 per cent. of the circuits terminate in London. The reason for this fact appears to be worthy of study by those whose business it is to sell the service. This chart is used for engineering development studies and in its completed form shows the plant installed, the engineering spares and the estimated annual growth at each terminal.

Every endeavour is made to ensure that the apparatus and the circuit availability is in advance of the demand and, in order to meet the present position, voice-frequency channels between London and Manchester, London and Leeds, London and Glasgow, Liverpool and Glasgow, and London and Belfast have been provided.

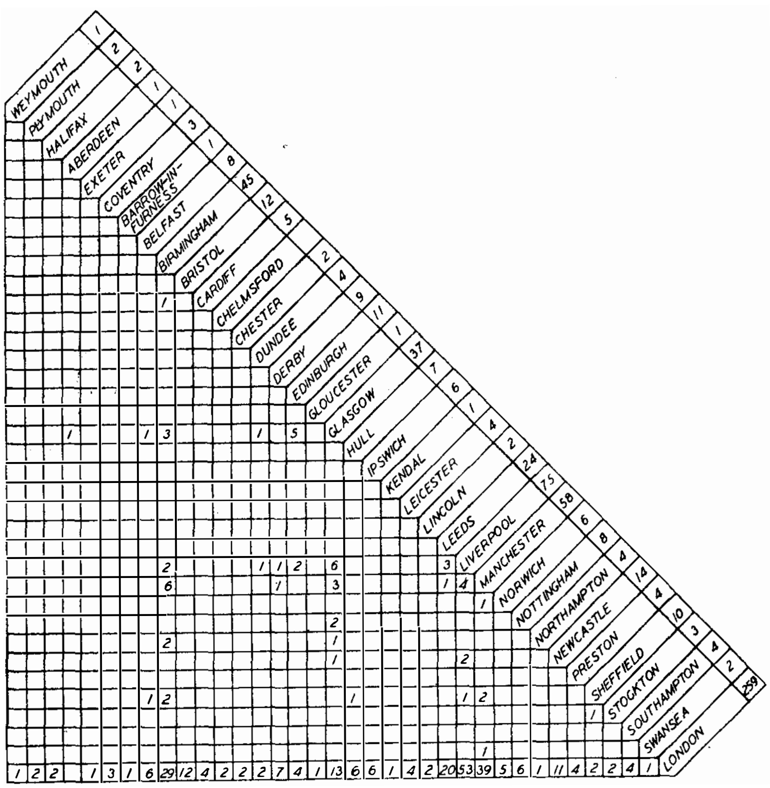


FIG. **2**.—NUMBERS OF TARIFF A CIRCUITS BETWEEN THE VARIOUS TOWNS.

The service does not appear to be a competitor of the public telegraph service, but necessarily it must have some effect, abeit slight, upon the postal business done by those who use it. It has allowed rather the reorganization of the methods previously in force for dealing with correspondence, and has permitted developments in business methods which would not have been possible but for its availability.

Tariff B Service.

When a subscriber desires a connexion between two points less than 35 miles apart, the Tariff B rate is more economical to the subscriber, and in such cases direct connexion is provided between the renters, the circuit being operated with alternating current. The circuit does not pass through the Tariff A terminal points, and the renter's apparatus includes a "Converter" whereby the teleprinter causes alternating current of 1,500 c.p.s. frequency to be sent to line. At the incoming end of the circuit the 1,500 c.p.s. current is amplified and rectified to operate the electro-magnet of the receiving teleprinter. A local record is obtained at the sending teleprinter by passing some of the outgoing current into the home converter.

Certain banks and financial houses in the London city area have circuits to the offices of the various cable companies. The circuits are terminated on a concentrator board at the renter's premises to enable control by a single operator. In order to make the arrangements as simple as possible and to conform with the existing practices in the cable companies' instrument rooms, these circuits are worked on a direct current closed loop basis.

[1] Teleprinter Private Wires on By-product Circuits. Vol. 26, p. 83.

Broadcast Services.

A natural development of the point-to-point communication given by the Tariff A service is one whereby a central office can communicate simultaneously with a number of others. Schemes have been developed for the operation of such services both on a direct current and an alternating current basis, and one such scheme has already been described in this journal.[2] At the present moment there are 8 systems in operation, all working on a direct current basis, of which 6 are police systems, one is operated by the British United Press, and another by the Ministry of Labour. Alternative telephone communication is provided in two of the police systems. In all there are some 130 stations connected, of which the Ministry of Labour's system, which is the largest system so far in operation, accounts for 34. All the connexions between the Central Office and the outstations are by physical lines and the distances are short, the longest being 60 miles.

There is undoubtedly a future for this type of service, but, since in each case a number of stations are concerned, with corresponding charges for lines and apparatus, the economics require detailed study on the part of a prospective user, and one cannot expect so spectacular a growth as has occurred with the Tariff A service. There are signs, however, that Broadcast Systems, with a wider radius of action, will be sought for and a scheme has already been devized whereby Tariff A type circuits can be concentrated upon a broadcasting centre.

Tariff D Service.

This is a private telephone service, but the facility can be provided whereby telephone or teleprinter may be used, at the normal rental charge of a teleprinter. At the moment, between 90 and 100 subscribers have availed themselves of this facility, *i.e.*, there are 180 to 200 teleprinters rented on this type of service. Alternating current of a frequency of 1,500 c.p.s. is used as in the case of Tariff B circuits.

Telex.

This service aims at providing teleprinter working between any subscribers to the telephone service. The general principles and circuit arrangements are described in Vol. 25, p. 177 *et seq* of this Journal. Originally, the service was operated on a frequency of 300 c.p.s., but in order to line up with the internationally agreed frequency of 1,500 c.p.s. for this type of service and also in order to secure advantages which this latter frequency has over the lower, it was decided to change to 1,500 c.p.s. for all teleprinter working operating on alternating current. All London subscribers and those in the provinces who work in conjunction with London subscribers were changed over to 1,500 c.p.s. during the August Bank Holiday week-end, and the change-over of the rest of the country was completed at the end of November, 1936.

The growth of this service has been retarded because it was found that there were transient disturbances in the telephone network which were liable to cause false operation of the teleprinter. The main source of these transients was found to be the bridging of contacts by wipers of selectors in automatic telephone exchanges, and the steps which have been taken to remove this cause have led to the possibility of good commercial working on this basis on the inland telephone system. Work has also had to be done to ensure that echo-suppressors and ringers used on trunk circuits should function equally well for teleprinter as for telephone.

Subscribers to this service have the facility of obtaining direct communication to a telegraph instrument room for the transmission and reception of telegrams. This service is known as "Printergrams." That this facility is appreciated will be understood when it is stated that nearly 5,000 telegrams are dealt with daily in this manner, of which some 3,000 are handled in the Central Telegraph Office. At the C.T.O. some 28 positions are set apart solely for dealing with such traffic, and centres also exist at Birmingham, Liverpool, Manchester, Glasgow, Edinburgh, Leeds, Sheffield, Nottingham, Newcastle and Bristol.

At the moment there are some 230 subscribers to this form of service, without taking into account the numerous official subscribers. The horizon of utility of this service cannot be seen at the present, but there seems to be no reason why it should not grow in the same way as the Tariff A service and serve as a parallel service.

On May 1 last, a Telex service was opened between subscribers in London and subscribers in The Hague, Amsterdam, Rotterdam and Eindhoven, and now that the change to 1,500 c.p.s. has been completed, the service to those places has been extended to all Telex subscribers in Great Britain. Already the service has been found to be of great utility to business firms which have interest both in this country and in Holland.

Experiments are in train to extend this service to Belgium and Sweden, and negotiations are in progress as to the best way in which to link up the Telex service in Great Britain with the similar service operated on a direct current basis which is in vogue in Germany. It is of interest to note that for the Olympiad there was set up a Telex service operated over the telephone circuits between London and Berlin which operated most successfully.

It is perhaps a commonplace to say that we are on the threshold of a great expansion of the use of private telegraphs in the business and commercial world, and that the Post Office realizes its responsibility in this connexion.

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[2] A Teleprinter Broadcast System. Vol. 28, p. 10.

International Telegraph Consultative Committee (C.C.I.T.), Warsaw, October 1936

Introduction.

THE fifth Reunion of the C.C.I.T. at Warsaw in October, 1936, marked the tenth anniversary of the existence of that body, the first Reunion having taken place in May, 1926, at Berlin. The succeeding conferences were held at Berlin, Berne and Prague in 1929, 1931 and 1934, respectively.

The history of the inception of the C.C.I.T. has been explained by F. E. A. Manning in Vol. 29, Part I, of this Journal, and the method of working of the C.C.I.T. is on very much the same lines as that described for the C.C.I.F. in the above-mentioned article.

The Warsaw Conference.

The Warsaw Conference was held in the building of the Institute of Engineers and was presided over by M. Krzyczkowski, Technical Director, Ministry of Posts and Telegraphs, Poland. More than twenty administrations were represented and their delegates, together with the representatives of some fifteen operating and manufacturing organizations, brought the number of participants to about one hundred and thirty. This number was greater than usual owing to the fact that the question of telegraph tariffs was under discussion, preparatory to the international telegraph conference to be held in Cairo in 1938. The British official delegation, seven in number, was headed by Mr. C. W. Phillips. C.M.G., Director of Telecommunications.

The work of the conference was dealt with by four commissions, *viz.,* Technical, Exploitation and Tariffs, Organization and Rédaction, and the following notes have reference to the work of the Technical Commission.

In the interval following the Prague conference the technical questions left for study by that conference had formed the subject matter of a large number of documents and the task facing the Technical Commission was the resolution of these questions into the form of " avis " or recommendations, due regard being paid to the opinions expressed in documents by the various administrations. To carry out this work effectively the Technical Commission functioned as four committees and, owing to the short time available, all four committees met concurrently. The first of these committees dealt with questions concerning definitions and relays; the second with questions of standardization, co-existence of telegraphs and telephones, and phototelegraphy; the third with questions of protection; and the fourth with symbols and vocabulary. In all, the conference issued twenty-nine separate " avis " or recommendations and accepted thirty questions for further study. The majority of the " avis " and new questions dealt with technical matters. It is a matter for congratulation that accord was reached upon all the subjects before the Technical Commission, although in documents widely differing view-points had been expressed by the various administrations concerned. Among the more important technical recommendations may be noted the following:

Voice Frequency Telegraphs.

The two systems at present most extensively used differ in that one utilizes current (tone) on the line during the repose condition whereas the other uses no tone during repose. Accord was reached that in all new systems the standard condition should be that of tone on the line during the repose condition which is the method of operation already in use in this country.

Maintenance of Telegraph Circuits. Development in telegraph practice has brought into being measuring equipment capable of giving direct readings which express quantitatively such things as, for instance, circuit distortion or machine margin, as defined by the C.C.I.T. It was recommended that on international circuits measurements made in connexion with maintenance should be made between the two terminals and by means of stroboscopic or other similar direct reading methods of measuring distortion.

Teleprinters. In order to give limits to the distortion which could reasonably be tolerated at the transmitter end of a teleprinter operated circuit, agreement was reached upon the question of the allowable variation from standard of the speed and the timing of the elementary signals corresponding to a letter.

Telex Service. The questions of the most suitable frequency for international telex working and of the allowable power input at the inter-urban exchange were the subject of investigation of a mixed commission of the C.C.I.T. and C.C.I.F. which met at the Hague in June, 1935. Its recommendations that the frequency should be 1,500 cycles per second and that the input power at an inter-urban exchange should not exceed 5 milli-watts were ratified by the C.C.I.F. at Copenhagen in June, 1936, and by the C.C.I.T. at Warsaw. As is known, the telex frequency in this country, which was formerly 300 cycles per second, has already been changed to the internationally agreed frequency.

Protection. Various modifications were made to the existing directives concerning protection of telegraph circuits and the forward step taken of recommending a fusion of the directives of the C.C.I.T. and C.C.I.F. dealing with protection.

Vocabulary. A vocabulary of terms exclusive to the telegraph art has been drawn up and will be presented to the Cairo conference for decision as to publication.

Avis of the C.C.I.T. The International Telegraph Conference of Madrid, held in 1932, recommended that the collection of avis of the C.C.I.T. should be issued under one cover. It was found impossible at Prague to give effect to this recommendation and the work was undertaken in the interval between Prague and Warsaw. As a result of this work and the decisions made at Warsaw, it will now be possible to issue the avis, numbered according to a rational plan, in a single series which will include all the avis issued at Warsaw.

F.E.N.

Carrier System No. 4

1 + 4 Channel System for Cables

R. J. HALSEY, B.Sc., A.C.G.I., D.I.C.
and D. P. M. MILLAR, M.Sc. A.C.G.I., D.I.C.

In this article, which is continued from the October issue of the Journal, the authors describe a carrier telephone system which has been developed to give the maximum number of carrier circuits on existing cables. In this part the design and performance of the terminal equipment are discussed and future applications of the system suggested

5. Line Equalization.

THE terminal equipment and repeaters have been designed to give, as nearly as possible, a uniform gain/frequency response. It is therefore necessary to provide equalizing networks in association with the lines. These networks are of the constant impedance type (Zobel equalizers), and it is found that satisfactory equalization of either loaded or unloaded lines is practicable. By very careful design, lines can be equalized to within ± 0.1 db. per repeater section. This is only necessary on very long circuits, and for shorter circuits limits of ± 0.25 db. per repeater section have been provisionally fixed. The frequency characteristic of the repeater is allowed for in designing the equalizer. Each equalizer includes a non-reactive attenuator (multiple of 5 db.) to build out the section loss to between 35 and 43 db., the gain limits of the repeater.

For the principles and methods of design of Zobel equalizers, reference should be made to B.S.T.J., 1928, pp. 438-535, and to an article in the present issue of this Journal, entitled "Constant Impedance Networks for Line Equalization," by D. G. Tucker. In this latter article, the design and performance of equalizers for a specific application of Carrier System No. 4 are detailed.

6. Description of Terminal Equipment.

General Arrangement of System.

In other carrier systems used by the British Post Office the voice channel has been separated from the carrier channels by means of high-pass and low-pass line filters. It has thus been possible to operate the voice channel on a 2-wire basis by reproducing the low-pass filter (and a reactance network to simulate the high-pass filter) in the balance. In the present system this facility is not provided and the voice channel gives exactly the same facilities as the carrier channels. Fig. 9 shows the arrangement of a terminal station which is not provided with echo suppressors. On the transmitting side, each carrier channel is fed into the appropriate frequency changer. This panel consists of sending and receiving units supplied with the appropriate carrier frequency. The sending unit consists of

(a) a voltage limiter,
(b) a low-pass filter (f_C = 3,000 c.p.s.) which eliminates the higher frequencies of speech and prevents high frequencies leaking back from the modulator into the exchange line.
(c) a valveless modulator which suppresses both the carrier frequency and the voice frequency input.
(d) a 20 db. attenuator.

The input level to the modulator is about − 4 db. (i.e., termination loss) and the modulation loss is about 6 db; thus the output level of wanted sideband is − 30 db. and is suitable for direct application to the sending repeater. The voice channel is fed from the termination direct to the channel filter on which are located a limiter, a 1 : 1 transformer and a 27 db. attenuator which reduces the level of the voice channel to that of the carrier channels. From the frequency changers the carrier channels are fed into the appropriate band filters, which are commoned together at the input of the transmitting line repeater. The transmitting level is about + 5 db. for all channels.

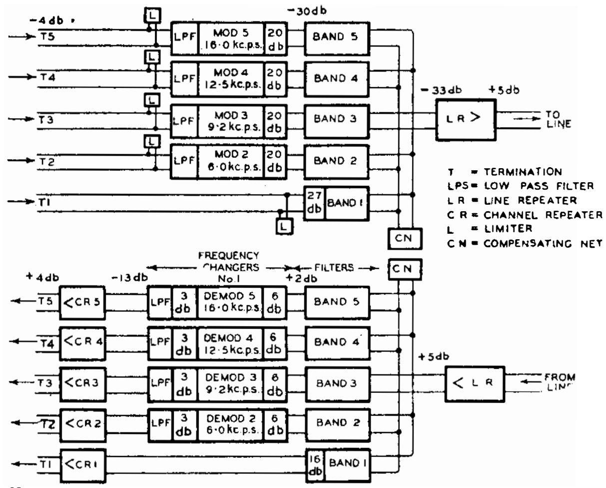


FIG. 9.—SCHEMATIC OF CARRIER TERMINAL WITHOUT ECHO-SUPPRESSORS.

On the receiving side of the equipment the output of the receiving line repeater is fed into the channel filters and thence for the carrier channels, into the receiving frequency changer. This consists of:—

(a) a 6 db. attenuator on the high frequency side of the demodulator,
(b) a valveless demodulator which suppresses both the carrier frequency and the sideband input,
(c) a 3 db. attenuator on the low frequency side of the demodulator,
(d) a low-pass filter, similar to that in the modulator.

In the voice channel, a 16 db. attenuator and a 1 : 1 transformer on the channel filter panel bring the level down to that of the carrier channels, i.e.— 13 db. In each channel the received signal is passed into a channel amplifier which is used to adjust the overall equivalent of the individual channel.

Where echo suppressors are fitted these are at one terminal and may be either

1. Echo Suppressor No. 3c (valveless) with appropriate repeater gains. This suppressor requires an input level of + 10 db.[11]
2. A new type of suppressor which is being developed for this and similar systems. This has networks similar to those of No. 3c and is

[11] *P.O.E.E.J.*, Vol. 26, Part 1.

inserted next to the termination. The amplifiers providing the switching currents are not included in the main transmission paths which are unaffected except by the networks themselves. (Suppressor No. 4A, mentioned in Section 3, has been abandoned for future work.)

Carrier Frequency Generation.

The carrier frequencies are generated by means of free oscillators (Nos. 16 A, B. C and D) designed to have a high degree of frequency stability when used in conjunction with temperature controlled ovens for the oscillatory circuits. These ovens are not necessary for the degree of frequency stability required for telephony, but must be used when multi-channel voice frequency telegraphs are operated over the carrier channels. Provision for these ovens is made in the lay-out of the equipment, but they were not used in the experimental terminals. Two oscillators will be provided for each frequency and each will normally carry half the load, with facilities for the transfer of the full load to either oscillator. U links are provided on the panels for this purpose.

Supply of Carrier Power.

The oscillators described are capable of feeding up to a maximum of 3 channels directly, except that when high stability is required and more than one channel is to be supplied, an amplifier is always recommended.

Amplifiers have been designed to supply up to about 18 channels and are known as Units, Amplifying Nos. 21 and 22 A, B, C and D.

The outputs of the two normal working amplifiers (No. 21) are wired through the U links of the spare amplifier (No. 22); except for these U links the amplifiers are identical. Either working amplifier may be replaced by the spare. By using two valves V.T.85 in parallel, an output of about 500 mW is obtained with 130 V. H.T.; the use of 200 V. H.T. is permissible when a greater output is required.

Frequency Changers.

Modulators and demodulators are both frequency changers, and the present unit incorporating the two directions of transmission is known as Frequency Changer No. 1 and occupies one side of a **7**-in. panel. Fig. **10** (a) gives a skeleton diagram of the circuit arrangement and shows how the carrier frequency is suppressed by being applied on a line of symmetry (i.e., similar to a phantom circuit). AA represents the signal input terminals, BB the output terminals and CC the carrier input terminals; (b) shows how the input signal is suppressed in the opposite diagonals of a balanced Wheatstone bridge. The operation of the frequency changer is best understood by considering that the carrier frequency causes the four rectifiers to switch suddenly, the carrier voltage being always in excess of the signal voltage and consequently the deciding factor in the switching action. Let (c) represent the input signal and let the vertical lines in (d) represent the switching intervals of the carrier. Over interval 1, suppose rectifiers R1 and R3 are conducting and R2 and R4 non-conducting, then corresponding to the input signal voltage, current will flow in the load in the direction of the arrow.

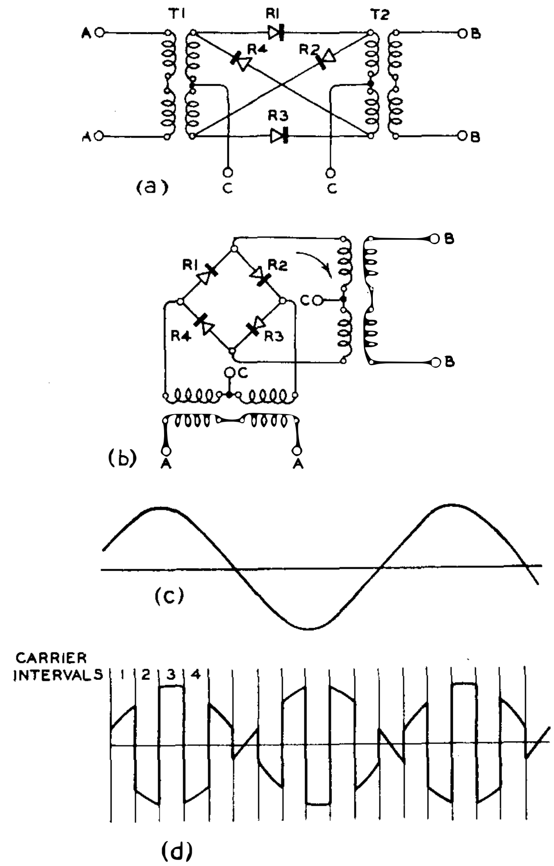


FIG. **10**.—EXPLANATORY DIAGRAM OF FREQUENCY CHANGER.

Over interval 2, the carrier biassing voltage on all rectifiers is reversed and the load current corresponding to the input signal voltage will maintain its magnitude, but will be reversed in sign. Interval 3 will repeat interval 1, 4 will repeat 2 and so on. The resultant output current wave will therefore be as in (d), and the effect of switching with a sinusoidal carrier current instead of a sudden change-over will be to round off the abrupt corners of the wave. Now this wave, either in the form shown or in practice, contains neither the carrier frequency nor the signal input frequency. Its primary components are frequencies (f_c+f_v) and (f_c-f_v) where f_c and f_v are the carrier and input frequencies respectively. Other products of modulation are present, but these will usually lie outside the wanted sideband range.

The argument above will only apply rigidly if the load impedance is the same to both the generated sideband frequencies. If this is not so, suppression still occurs as explained, but complications occur with input impedance and frequency response. The input impedance (at AA) of the frequency changer is determined by:

(a) the resistance and reactance of the input transformer T1 at the input frequency, plus

(b) the resistance and reactance of the rectifier system at the two output (sideband) frequencies, plus

(c) the resistance and reactance of the output transformer T2 at the two output frequencies, plus

(d) the load impedance at the two output frequencies.

Thus, the transformers T1 and T2 must be designed to operate at voice and sideband frequencies respectively. The impedance of T2 at the input frequencies is irrelevant but, since one of the output frequencies from the demodulator is $2f_C - f_V$, this must influence the design of T1. Both transformers have a 1 : 1 ratio, the rectifier windings being twin wound to reduce the leakage inductance in the carrier feed circuit. To minimize the leakage inductance in the signal transmission path, high permeability cores are used.

The loss/frequency characteristic of the unit is principally dependent upon the load impedances at the two sideband frequencies. In the present system it is necessary to suppress one sideband, hence the channel filter impedance will be substantially non-reactive (600 ohms) for the wanted sideband and reactive for the unwanted sideband. The result is that if the modulator is terminated with the channel filter the loss/frequency characteristic is irregular. To obviate this a 600 ohms non-reactive attenuator is inserted between the modulator and the channel filter. A similar argument applies to the demodulator.

The degree of carrier suppression will depend upon the balance of the rectifier bridge. In order to control this an auxiliary balancing network is provided in the modulator. It consists of a small fixed condenser, selected to balance the rectifier capacitances, and a resistance potentiometer in the centre point of the output transformer winding.

The principles underlying the design of the rectifier network to give an adequate power handling capacity are rather complex. In the first place, the unit is a current modulator, i.e., the resistance of each rectifier is determined by the instantaneous current which it carries. It is therefore necessary that the carrier current shall always be in excess of the signal current, but this condition alone is not sufficient. The direction in which a rectifier switches is determined by the impressed voltage. The carrier impedance is very low, being mainly due to the rectifiers; the impedance to the signal current is comparatively high, being mainly due to the load impedance. Thus, it is comparatively easy for a signal voltage to be impressed across the rectifier elements, of such a magnitude that the carrier voltage cannot perform the requisite switching. This results in overloading and the bridge design is mainly determined by consideration of this factor.

Rectifiers R2 and R3 (Fig. **10**) are identical and consist of 12 H-type elements in series, connexions being made at each three elements. In addition to passing specification tests for the individual elements the completed rectifier units must, for the modulator only, be sufficiently well matched to enable the carrier leak to be balanced out within the range of potentiometer P.

Voltage Limiters.

Voltage limiters are bridged across each sending 4-wire circuit and are located on the frequency changer panels. They are desirable for two reasons:

(a) the voltage peaks due to speech are cut off and this reduces the loading of the repeaters. Speech at R.T.P. has voltage peaks about 15 db. in excess of the peaks of 1 mW. of pure tone and, since these peaks are distortion products of the carbon microphones, they may be severely limited without deleterious effects.

(b) if one channel becomes unstable and " sings," the limiter will prevent the voltage from building up to the overload point of the repeater. If this occurred all channels would be unworkable.

The limiters employed are similar to those used on Carrier System No. 2,[12] except that the bias voltage is increased from 3 to 4 volts, thereby limiting at a level corresponding to about 8 db. above 1 mW. on the exchange line.

Filters.

The channel filters are identical at the sending and receiving ends and are designed to have an attenuation to adjacent channels of about 65 db., this being the worst signal/crosstalk ratio. They are designed in such a way that additional high frequency channels may be added as required. The ends of the filters remote from the line are terminated with derived sections to give a fairly flat terminal impedance (600 ohms). At the line ends this is not practicable, and in order to obtain the best frequency response a terminating resistance of 400 ohms is required. To avoid the complication of 400 ohms repeaters, this condition is met by including a 1,200 ohms shunt resistor in the compensating network. This gives an insertion loss of 2 db. at the middle of each band and thereby contributes the major part of the filter losses. Each filter is shunted by other filters which have impedances as follows:

Filters below the band under consideration,
+ve reactance.

Filters above the band under consideration,
−ve reactance.

These obviously tend to resonate and in the ideal condition will always do so in the middle of the band. To approximate to this condition, particularly for Band 5, a compensating condenser is fitted.

The circuit arrangement is given in Fig. **11** which also shows the types of coils and condensers. All end coils have low hysteresis cores to minimize intermodulation effects. Each filter is mounted on one side of a 5¼-in. panel.

The cut-off frequencies of the channel filters are as follows:

Channel	1	3	2	4	5
Lower cut-off	0	3,150	6,330	9,650	13,150
Upper cut-off	2,800	6,000	9,300	12,600	16,100

All channels present a constant-K mid-series impedance towards the line.

For the carrier channels no additional equipment is mounted on the filter panels. These filters are coded as Filters, Frequency Nos. 17A, B, C and D.

[12] I.P.O.E.E. Paper, No. 157. Page 20.

For the voice channel, however, a panel corresponding to the frequency changers is not fitted, the small amount of equipment necessary being mounted on the filter panels.

order to avoid earth currents, the unbalanced circuits are wired in screened pair cable, a rack earth connexion being made at one point only, the high frequency side of the frequency changer.

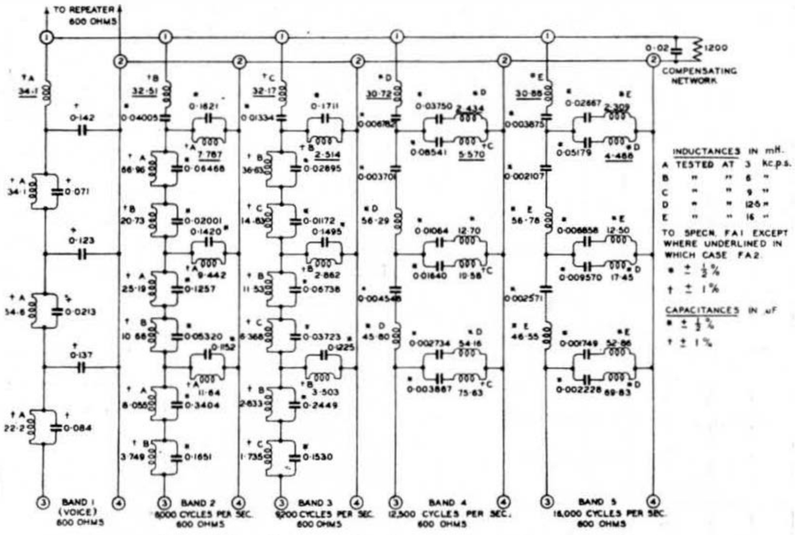


FIG. **11**.—SCHEMATIC DIAGRAM OF CHANNEL FILTERS.

Bay Wiring.

Owing to the relatively high frequencies employed and to the fact that the circuits are unbalanced (i.e., earthed on one wire) all bay wiring is screened. In

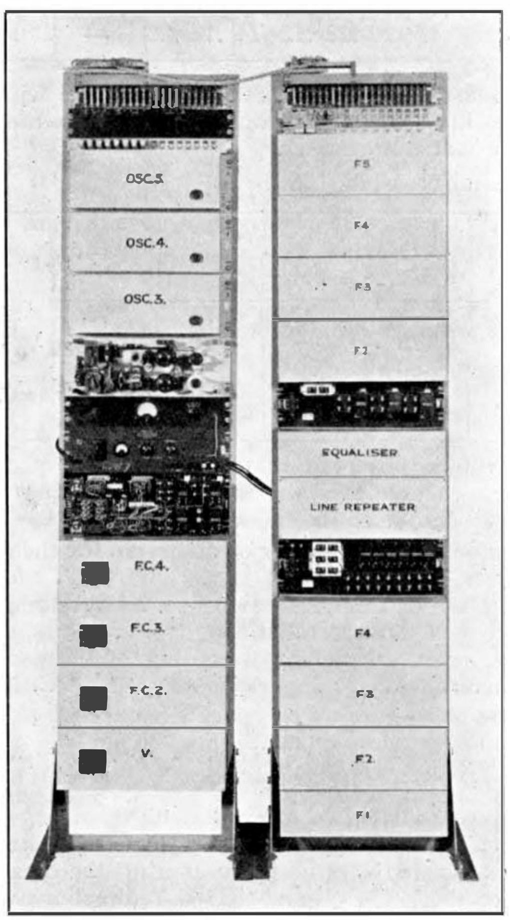


FIG. **12**.—EXPERIMENTAL TERMINAL EQUIPMENT.

Layout of Terminal Equipment.

The layout of the experimental equipment on the bays shown in Fig. **12** differs considerably from that of specified production equipment, which will be mounted on 10 ft. 6 in. bays.

7. PERFORMANCE OF TERMINAL EQUIPMENT.

Filter Characteristics.

The pass band characteristic of a typical channel filter is shown in Fig. **13**, taken with all filters in circuit. There is an improvement of about 0.5 db. at the ends of the bands due to the use of the 1,200-

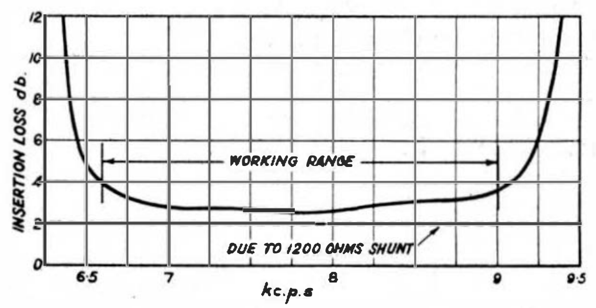


FIG. **13**.—PASS BAND CHARACTERISTIC OF TYPICAL CHANNEL.

ohm shunt resistance. The effect of the compensating condenser is to flatten the top band by about 0.5 db., with a smaller improvement on the lower bands.

Gain/Frequency Characteristics of Sending and Receiving Terminals.

The gain/frequency characteristics of a typical carrier channel are shown in Fig. **14**, relative to 800 cycles per sec.

(a) from the voice frequency (4-wire) input to the output of the sending line repeater,

(b) from the input of the receiving line repeater to the voice frequency (4-wire) output,

(c) from the voice frequency input to voice frequency output (4-wire to 4-wire).

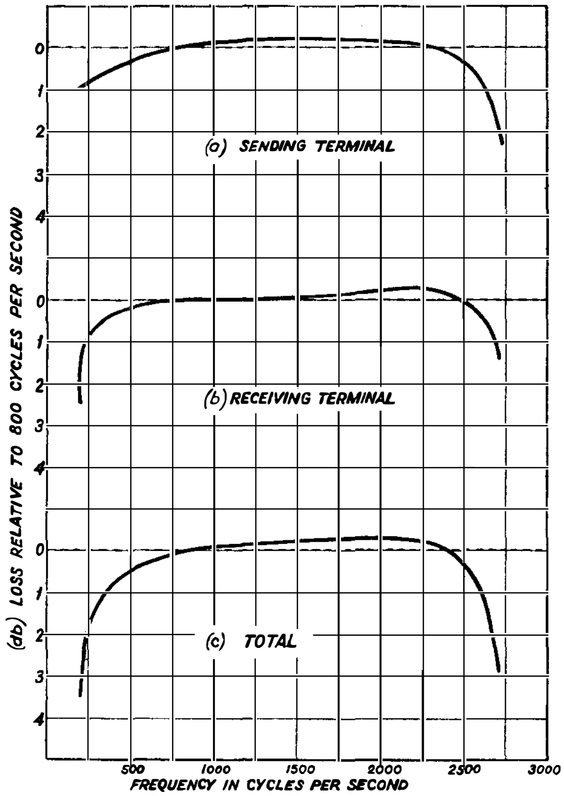


Fig. 14—Gain/Frequency Response of Terminal Equipment, Typical Channel.

Gain Stability of Frequency Changers.

The carrier feed voltage to the rectifier bridges has been standardized at 2V. ± 10%. The effect of variation within these limits is to alter the frequency changer loss by about ± 0.1 db.

The volume distortion at low input levels is such that the loss is always within 0.2 db. of the 1 mW. loss. Volume distortion for high input levels is shown in Fig. **5**.

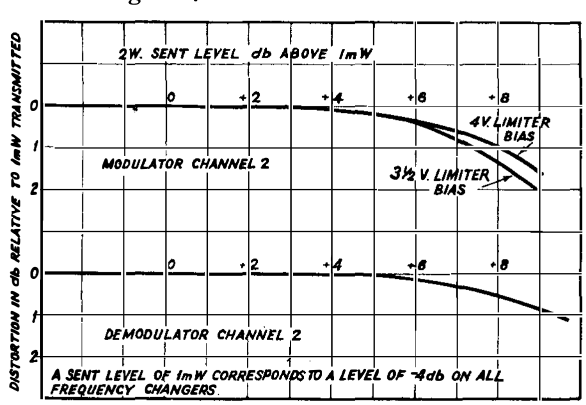


Fig. 15—Volume Distortion of Frequency Changer.

Frequency Changer Input Impedances.

The signal frequency impedance of a frequency changer network, without associated attenuator is about 750 ohms when closed with a load impedance of 600 ohms, the difference representing the series resistance of the rectifiers.

The carrier power supplied to the networks is determined by the impedance seen at the carrier feed terminals. For a single network, without its series 150 ohms decoupling resistance, this impedance amounts to about 120 ohms at the working current of 7.5 mA. Thus each complete panel will require about 15 mA. (i.e., 30 mW.) carrier feed.

Interchannel Interference due to Filters.

The channel to channel interference due to filters, measured on the sending and receiving terminals together, is given below. Two readings are given for the interference due to speech, measured at a zero level point.

(a) average peak and maximum peak voltage readings on a psophometer, weighted according to C.C.I.F. curves.
(b) an aural estimate, the average of several observers.

(a) Psophometer Peak Values (mV., P.D.).

Spk. / Meas.	1	2	3	4	5	All ccts. idle.
1	—	.16-.19	.12-.14	.11-.14	.11-.12	.09-.11
2	.14-.17	—	.16-.21	.10-.11	.09-.11	.08-.10
3	.11	.19-.21	—	.15-.17	.09-.11	.09-.11
4	.10	.10-.12	.17-.20	—	.19-.21	.08-.09
5	.12	.20-.22	.12-.14	.16-.20	—	.10-.12

The last column shows the circuit noise with all circuits idle. This noise was mainly due to the terminal channel amplifiers.

(b) Aural crosstalk (db.).

Spk. / List.	1	2	3	4	5
1	—	72	75	75	74
2	78	—	75	80	80
3	80	66	—	76	80
4	80	80	70	—	72
5	80	75	80	66	—

It will be observed that the aural and psophometric measurements are not in full agreement and this may be due to the following causes.

(a) an insufficient number of observers for the aural tests.
(b) the use of receivers having somewhat abnormal frequency characteristics.
(c) incorrect frequency weighting of the psophometer. (Weighting recommended by C.C.I.F. was used.)

Crosstalk between two channels operating at the same carrier frequency.

The crosstalk between two systems operating from common oscillators or amplifiers has been checked as > 84 db. (S/N ratio) by measuring the crosstalk between the " U-D " and " D-U " directions when dissociated from the terminations.

Stability of Rectifier Bridges in respect of Carrier Suppression.

By using a fine control potentiometer and condenser on the carrier bridge it is possible to balance out the carrier frequency completely in the output circuit. The resultant high degree of suppression is not, however, stable and for a number of units subjected to life test the minimum reliable " carrier leak " amounted to 38 db. below the sideband level corresponding to 1 mW. sent from the exchange line. With the additional suppression due to the filters this is more than adequate and a considerably greater leak is tolerable.

8. Field Trials between London and Canterbury.

Cable.

The circuits used for the field trials were in the London Canterbury No. 2 Cable (BXB) and consisted of unloaded 70 lb. conductors (multiple twin) in the outer layer. These pairs were deloaded for carrier tests.

Terminal equipment was located at London and Canterbury, with one intermediate repeater at Chatham, route mileages being as follows:

London-Chatham, 31.6 miles.
Chatham-Canterbury, 25.1 miles.

Arrangement of Equipment.

Each terminal was associated with a bay of five Amplifying Units No. 6, and Terminating Units, to complete the circuits. The voice frequency equipment and the oscillators were operated from the Repeater Station batteries, and the line repeaters from A.C. mains units supplying 4 volts A.C. for the heaters and 200 volts H.T.

Two equalization conditions were tested. In the first condition the equalizers occupied a normal position at the receiving end of each cable pair. In the second condition the equalizers preceded the repeaters and the output from each repeater was such that the frequency response at the distant end of the cable was uniform. This method has the advantage that the loading of the repeater is reduced.

Throughout the tests, speaking volumes were measured on calibrated volume indicators and unless otherwise stated, speech at R.T.P. is implied.

Gain/Frequency Response of System.

The overall gain/frequency response of the five channels is given in Fig. **16**. The low frequency response is, of course, partly due to the voice frequency equipment. All circuits were set up to approximately zero loss at 800 cycles per sec.

Interference from Mains.

When the system was set up with pre-equalization, considerable mains hum was experienced on Channel 1. This was due to the Chatham repeater and was severe, owing to the very low attenuation at 100 cycles per sec. between Chatham and the terminal stations (no equalizers in the receiving direction). It was reduced to negligible magnitude by keeping the mains transformer at least 3 ft. from the repeater. In these circumstances the psophometer reading at London was 0.2 mV. and this was almost completely eliminated when receiving equalizers were used.

Quality of Transmission.

The quality of transmission on the four carrier channels was good and was indistinguishable from that of the voice channel. Carrier leak was not observable on any channel. It was generally agreed that the carrier and voice circuits were of uniformly good quality.

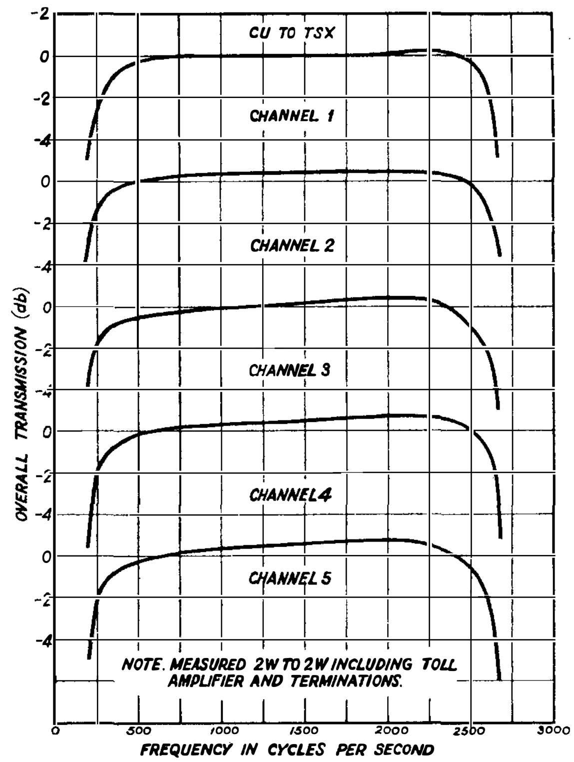


Fig. 16.—Overall Gain of 5 Channels.

Inter-channel Interference with Receiving Equalizers

(a) *One Speaker.*

The interference between channels is fundamentally observable at the distant end, being due to imperfections of the filters and repeaters. For one disturbing speaker, the interference ratio was independent of the output levels unless these were high. Thus, until the repeater loading is serious, the interference is independent of levels, battery voltages and limiters, being determined solely by the channel filters.

The maximum level at which interference is practically unaffected by repeater distortion will depend upon the anode voltage and the limiter bias; observed levels corresponding to a bias of 4 volts being as follows.

Repeaters 200V. H.T.	Repeaters 150V. H.T.	Output level
3	0	+14 db.
2	1	+10 db.
0	3	+10 db.

The interference due to both filters and repeaters is unintelligible and should strictly be classed as noise and not as crosstalk.

(b) *Two Speakers.*

Tests were next made with two channels busy, each with a speaker at R.T.P. Typical interference values are tabulated below, corresponding to output levels of + 5 db. with 200 volts on all repeaters and 4 volts bias on the limiters.

Aural Signal/Crosstalk Ratio. (db.).

Spk. \ List.	1	2	3	4	5
1 & 2	—	—	64	68	74
1 & 3	—	64	—	68	68
1 & 4	—	68	70	—	66
1 & 5	—	66	76	68	—
2 & 3	64	—	—	64	74
2 & 4	64	—	65	—	64
2 & 5	68	—	65	68	—
3 & 4	68	66	—	—	64
3 & 5	70	72	—	64	—
4 & 5	72	72	70	—	—

Psophometer Peak Values (mV., P.D.).

Spk. \ List.	1	2	3	4	5
1 & 2	—	—	.4 -.5	.3 -.39	.27-.33
1 & 3	—	.39-.51	—	20-.25	.39-.48
1 & 4	—	.18-.22	.33-.39	—	.22-.24
1 & 5	—	.17-.20	.11-.13	.33-.39	—
2 & 3	.3 -.39	—	—	.33-.42	.2 -.24
2 & 4	.36-.48	—	.4 -.5	—	.20-.24
2 & 5	.3 -.33	—	.4 -.5	.27-.33	—
3 & 4	.15-.18	.3 -.36	—	—	.33-.42
3 & 5	.30-.36	.30-.36	—	.33-.39	—
4 & 5	.14-.17	.11-.13	.16-.20	—	—

This interference is within the prescribed limits set out in Section 2, and may therefore be taken as satisfactory.

When the output levels are increased to + 10 db. for each channel, the interference is increased by about 3 db. to a worst value of 60 db. If the anode voltage on one repeater is then reduced to 150 volts there is a further degradation to a worst value of 56 db., which is just tolerable.

(c) *Four Speakers.*

Measurements were made of the interference caused on each channel when all four remaining channels are busy in the same direction with average speaker volumes (See Section 2). The following table shows the interference corresponding to maximum output levels of + 5 db. with 200 volts on all repeaters and 4 volts limiter bias.

Listen	Meter (mV.)	Aural (db.)
1	.17-.19	72
2	.14-.16	74
3	.15-.17	68
4	.17-.19	69
5	.15-.18	71

When the output levels are increased to + 10 db. for each channel, the interference is increased by about 2 db. to a worst value of 66 db. or 0.22 mV. maximum. If the anode voltage on one repeater is reduced to 150 volts there is a further degradation of about 2 db.

Inter-Channel Interference with Pre-equalizers.

Further tests were made using pre-equalizers so that the various channels are transmitted from each sending repeater at levels, such that the distant-end frequency characteristic is uniform on each cable section. This rearrangement does not affect the filter crosstalk, but there is a redistribution of repeater crosstalk owing to the new level conditions. The result is an increase in the interference on the lower channels and a decrease on the higher channels, as shown by the following typical tables for two speakers, the output levels at 16 kc.p.s. being + 5 db., and the repeater and limiter voltages being as before.

Psophometer Peak Values (mV., P.D.).

Spk. \ List.	1	2	3	4	5
1 & 2	—	—	.3 -.4	.14-.18	.14-.18
1 & 3	—	.35-.4	—	.2 -.25	.15-.23
1 & 4	—	.15-.18	.2 -.23	—	.25-.4
1 & 5	—	.15-.23	.11-.13	.15-.25	—
2 & 3	.4 -.45	—	—	.15-.25	.15-.2
2 & 4	.4 -.45	—	.2 -.4	—	.3 -.33
2 & 5	.3 -.4	—	.3 -.4	.2 -.22	—
3 & 4	.25-.35	.3 -.5	—	—	.3 -.5
3 & 5	.4 -.45	.2 -.5	—	.3 -.4	—
4 & 5	.3 -.4	.15-.2	.3 -.4	—	—

For four average volume speakers in the same conditions the following table applies.

Listen	Meter (mV.)	Aural (db.)
1	.2 -.25+	68
2	.1 -.12	74
3	.1 -.15	68
4	.14-.17	68
5	.12-.15	72

+ Mains Hum.

Choice of Equalizer Arrangements.

It will be seen that the results obtained with both equalizer arrangements are satisfactory. The argument in favour of pre-equalization is that the lower frequency channels, which are subject to low line attenuations, do not contribute seriously to the loading of the repeaters. For a large number of channels this reasoning is probably sound, but in the present case, where the worst crosstalk conditions are set by two speakers at R.T.P. and not by a large number of average speakers, no sensible advantage accrues. On the other hand, owing to the low level of the first channels (particularly Channel 1), the noise on these is increased. Thus, the generation of (A—B) products in any band causes crosstalk into Channel 1, in the frequency range of which these products must necessarily fall.

There are other important advantages of receiving equalization as follows:—

1. the terminal equalizers have the same impedance as the intermediate equalizers, whereas for pre-equalization special 400-ohm networks have to be made for the sending terminal.
2. lining-up of circuits is facilitated if the output level from the repeaters is the same for all channels.
3. Channel 1 is not so susceptible to mains hum from intermediate repeaters if these are operated from A.C.
4. Channel 1 is not so susceptible to crosstalk from voice circuits in other groups in the cable. If these are screening groups the circuits will probably be operating at output levels of + 10 db.

As a result of these considerations it has been decided that receiving equalizers shall be used in conjunction with this system.

Consideration of Longer Circuits.

Although tests were made over a circuit involving only three repeaters, it is probable that other circuits may involve ten or fifteen repeaters. In such circuits the interference due to the terminal equipment (mainly filters) will be exactly as in the present case and, as long as the repeater interference is negligible, the total noise level will be unaffected. Thus, to ensure that the system is suitable for longer distances it is necessary to choose operating conditions which involve repeater interference of low magnitude. For example, with receiving equalizers, output levels of + 10 db. with 200 V. on the repeaters gives interference which is adequate, being 0.8 mV. in the worst case. Since, however, this worst value has been increased from about 0.4 mV. at lower output levels, most of the interference is due to the repeaters, and an increase in the number will mean an increase in the interference to approximately the following magnitudes:—

(Present case)	3 repeaters	0.8 mV.
	6 ,,	1.1 ,,
	12 ,,	1.4 ,,
	24 ,,	2.0 ,,

Since a satisfactory limit for this type of noise is about 1 mV., it will be seen that this output level is not reasonable for long circuits, although it would be suitable for the London-Canterbury cable. For the general application of the system it has been decided to operate with transmission levels of + 5 db. for each channel from each repeater, and under these conditions it is felt that the new system will enable sound and economical additions to be made to the communication network. It is considered that the laboratory tests and field trials indicate the suitability of the system for inclusion in telephone channels of any length, internal or international.

8. Future Application of the System.

Although the system has been designed for use on existing land cables after deloading (and in certain cases reloading to a suitable cut-off frequency) other possibilities of its use have already become apparent. In the first place, the new Anglo-Dutch (1937) cables, which have been designed for operation up to about 64 kc.p.s., will be equipped with this system to cover the lower frequency range. The higher range (16-64 kc.p.s.) will be covered by a 12 channel system of the Bristol-Plymouth[13] type (Carrier System No. 5) with a modified frequency range. Thus the two single cored cables will carry 17 4-wire channels.

The new London-Oxford cables, also designed for 12-channel working, will also be equipped with 15 of these systems in the first place, as this is adequate for immediate development. The Anglo-Dutch scheme suggests that the same arrangement might be employed on the London-Oxford and similar land cables, instead of wasting the frequency range 0-8 or 0-12 kc.p.s. This arrangement has other advantages besides an increase in the number of channels provided, viz.:—

(a) equalization for the 12 channel systems is simplified by working to a lowest frequency of 16 kc.p.s., from which point the loss-frequency characteristic is almost linear.
(b) if the upper frequency limit of the cables is extended to (say) 100 kc.p.s., the repeater design will be less difficult when the lower frequency limit is raised.
(c) the use of a separate low frequency system facilitates the working of short distance circuits in the long distance cables. Terminal equipment for System No. 4 may be located at intermediate points along the route, without disturbing the high frequency system.

As a further possible development, it may be found practicable to group modulate the whole band 200-16,000 c.p.s. and thereby provide additional high frequency channels by a simple extension of the existing system. Thus, by modulating a carrier frequency of 32 kc.p.s. with the entire output of the new system it may be practicable to locate five more channels in the range 16-32 kc.p.s. This arrangement has not yet been properly tested, however, and may prove to be impracticable.

[13] *P.O.E.E.J.*, Vol. 29. Part 3.

Constant Impedance Networks for Line Equalization

D. G. TUCKER, B.Sc.(Eng.)

In multi-channel carrier systems it is necessary to use four-terminal networks for purposes of equalization. This article deals with the elementary theory of such structures, and shows how they may be designed.

Introduction.

IT has always been the practice hitherto to arrange for equalization in a repeatered transmission system by means of tuning elements in the input circuits of the repeaters. This method is satisfactory for audio or single channel carrier systems, where the range of frequencies is not great, and where the amount of equalization required is small. For the 1+4 channel and multi-channel carrier systems, however, the equalization must cover a wide band of frequencies, and the amount of equalization required is considerable, due to the shape of the attenuation characteristic of the unloaded, or lightly loaded, cable used. It is therefore necessary to use equalizers of the four-terminal type. These are inserted between the line and the repeater, and cause an insertion loss such that overall attenuation of line plus network is constant over the range of frequencies considered. Repeaters with a flat gain characteristic can then be used; this is an advantage in that all repeaters are readily interchangeable, and also, in that internal equalization in negative feedback repeaters, which are generally used for multi-channel carrier systems, is a matter of difficulty owing to the phase shift inherent in equalizers.

The four-terminal networks used have a constant resistive characteristic impedance at all frequencies. They can therefore be inserted between a line and its repeater without causing reflexion. Also several networks can be connected in tandem if desired. This feature is obtained by making the shunt impedance arm inverse to the series arm. The subject of constant impedance equalizing networks has been dealt with in great detail by Otto J. Zobel, the inventor, in the Bell System Technical Journal, July, 1928. Methods are given there for design by calculation, but in most cases they are rather long and involved, and do not always yield a satisfactory solution at the first attempt. The present article is intended to set out simply the fundamental properties of the networks, and to indicate an easy practical method of design.

Impedance and Attenuation of the General Ladder Network.

The general ladder inverse network is as shown in Fig. 1. Z_1 and Z_2 are impedance such that $Z_1Z_2 = R^2$, where R is the characteristic impedance of the system.

If terminals 3 and 4 are closed with a resistance R, then the impedance measured at the terminals 1 and 2 is shown to be also R thus:—

The impedance of the series arm is $\dfrac{RZ_1}{R+Z_1}$

The impedance of the shunt arm with the resistance R across terminals 3 and 4 is $\dfrac{RZ_2}{R+Z_2}$

Therefore the impedance measured between terminals 1 and 2 is

$$\frac{RZ_1}{R+Z_1}+\frac{RZ_2}{R+Z_2}$$

$$=\frac{RZ_1}{R+Z_1}+\frac{R\times\dfrac{R^2}{Z_1}}{R+\dfrac{R^2}{Z_1}} \text{ because } Z_2=\frac{R^2}{Z_1}$$

$$=\frac{RZ_1}{R+Z_1}+\frac{R^2}{R+Z_1}$$

$$=\frac{R(R+Z_1)}{R+Z_1}=\underline{R}$$

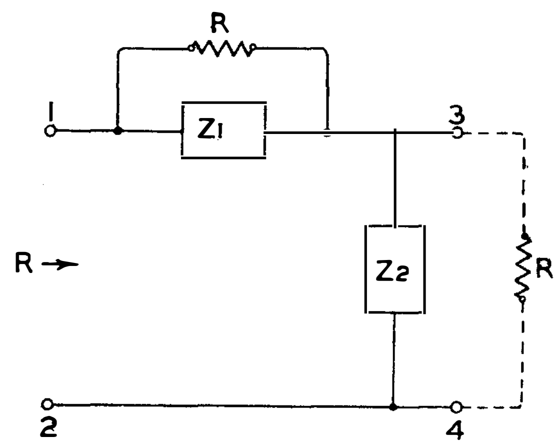


Fig. 1.—General Ladder Network.

The attenuation of the network is found by considering it as a potentiometer. The ratio

$$\frac{\text{Volts input (on 1, 2)}}{\text{Volts output (on 3, 4)}}=\frac{\text{impedance between 1 and 2}}{\text{impedance between 3 and 4}}$$

$$=\frac{R}{\dfrac{RZ_2}{R+Z_2}}$$

$$=\frac{R+Z_2}{Z_2}$$

$$=\frac{R+\dfrac{R^2}{Z_1}}{\dfrac{R^2}{Z_1}}$$

$$=\frac{R+Z_1}{R}$$

so that the attenuation in decibels

$$=20\log_{10}\left|\frac{R+Z_1}{R}\right| \quad\text{.................(1)}$$

This equation forms the basis of design.

Other Network Arrangements.

There are several types of network that can be used in place of the ladder type. Normally, the ladder type is the most economical, however, and should therefore be used.

Only two other types of network will be dealt with here—the Bridged-T and the Lattice types. The general form of these is shown in Figs. **2** and **3** respectively.

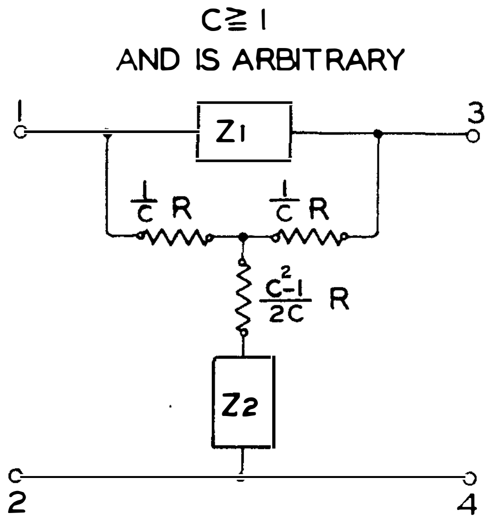


FIG. 2 —BRIDGED T NETWORK.

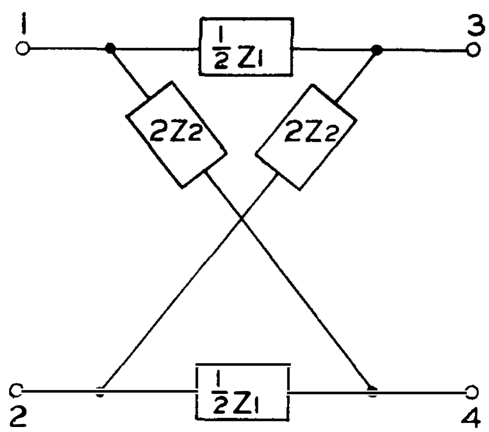


FIG. 3.—LATTICE NETWORK.

It should be pointed out that whereas the ladder and the bridged-T types can be either unbalanced or balanced (in the latter case, the series impedance is merely put half in each leg), the lattice type can only be balanced.

The ladder network can be used only in one direction, since it is not symmetrical, whereas the other networks can be used in either direction; but this point is generally of no importance.

Conversion from one type to another can generally be made. The impedances Z_1 and Z_2 are, of course, different for the different types of network (although always $Z_1Z_2 = R^2$), but they differ only by the resistance values. Conversion is made by adding parallel resistance to Z_1 and series resistance to Z_2. Since having once determined Z_1 we can determine Z_2 by inverse rules, the following conversion table deals only with Z_1.

It will be observed that in some cases the resistance to be added in parallel is negative. It will only be physically possible to make the conversion, therefore, if the resultant parallel resistance component of Z_1 is still positive after conversion.

Conversion.	Resistance to be added in parallel with Z_1
Ladder to Bridged-T	$-2R/(C-1)$
Ladder to Lattice	$2R$
Bridged-T to Ladder	$2R/(C-1)$
Bridged-T to Lattice	$2R/C$
Lattice to Ladder	$-2R$
Lattice to Bridged-T	$-2R/C$

The Formation of the Inverse Impedances Z_1 and Z_2.

If the arrangement and values of the components in either of the impedances Z_1 or Z_2 are given, those of the other can be readily determined. Any component that is in series in one impedance must be in parallel in the other, and *vice versa*, and every condenser in one must correspond to an inductor in the other, and *vice versa*. If R is the characteristic impedance, R_1, L_1 and C_1 any components of the series arm, and R_2, C_2 and L_2 the corresponding components of the shunt arm, then

$$R_1R_2 = \frac{L_1}{C_2} = \frac{L_2}{C_1} = R^2 \quad \text{.................................(2)}$$

The networks type 1 to 6, given later, illustrate the formation of the inverse impedance arms.

The Characteristics of Specific Ladder Networks.

Six arrangements of ladder networks are shown, together with typical attenuation characteristics, in Figs. **4** to **15**. These represent the useful simple networks. Resistances shown dotted can generally be omitted, but are occasionally useful to modify the characteristic, as shown by the dotted curves.

For all curves, the frequency scale is linear.

Phase Shift in Network.

The full statement of equation (1) is

$$e^{\gamma} = \frac{R+Z_1}{R} = \left|\frac{R+Z_1}{R}\right| . e^{j\phi}$$
$$= M.e^{j\phi}$$

where γ = propagation constant
$= \beta + j\alpha$

and M = the modulus $\left|\frac{R+Z_1}{R}\right|$

$\therefore e^{\beta+j\alpha} = M.e^{j\phi}$

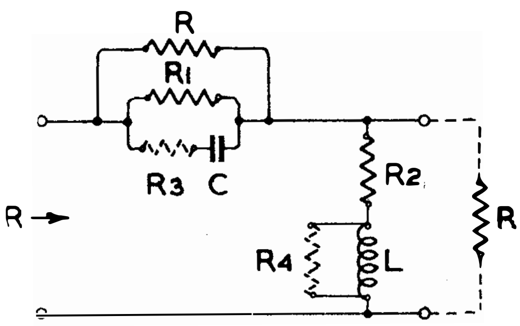
$\therefore e^{\beta} = M$ which is another form of equation (1) and $\alpha = \phi$ which shows that the phase shift in the network is given by the angle of the impedance $R+Z_1$.

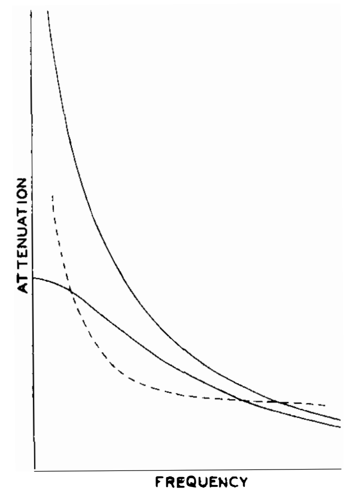
In all normal equalization problems we need not be concerned with phase shift, but in special cases it is of importance, and the final equalizer must have a given phase shift characteristic. This complicates the choice of network arrangements, and it may be necessary also to use special non-attenuating phase networks. This aspect of equalization, however, is beyond the scope of this article.

Methods of Design.

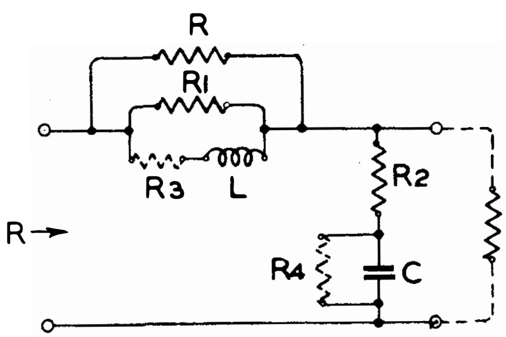
The problem usually met with is to design a network, the attenuation characteristic of which is exactly inverse to that of the line. It is not often that a single section is sufficient, but as a rule two will be satisfactory, one perhaps to equalize at the

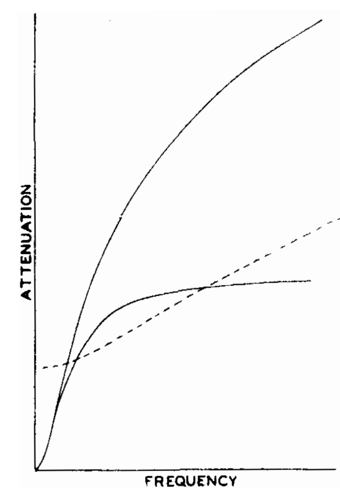
NETWORK **ATTENUATION CHARACTERISTIC**



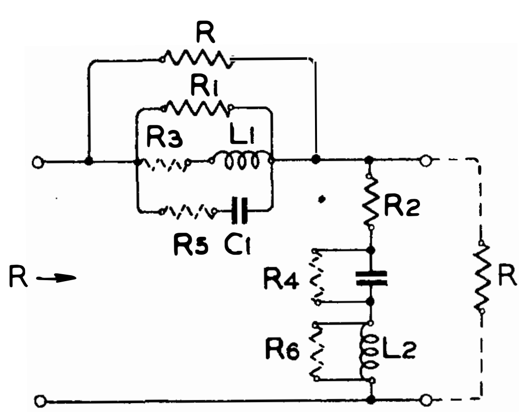


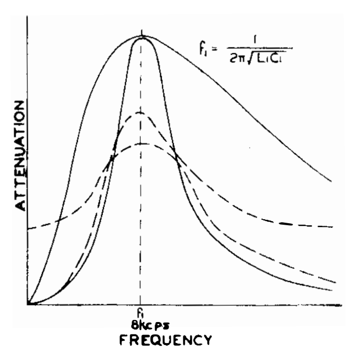
FIGS. 4 AND 5.—NETWORK TYPE 1.





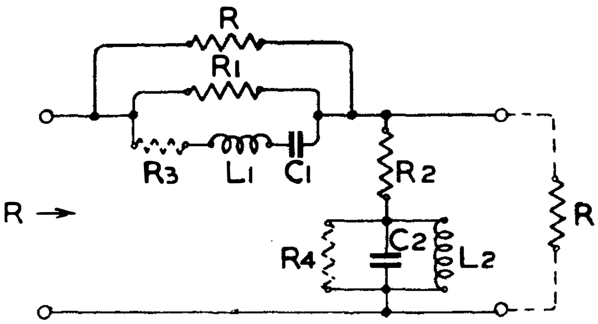
FIGS. 6 AND 7.—NETWORK TYPE 2.

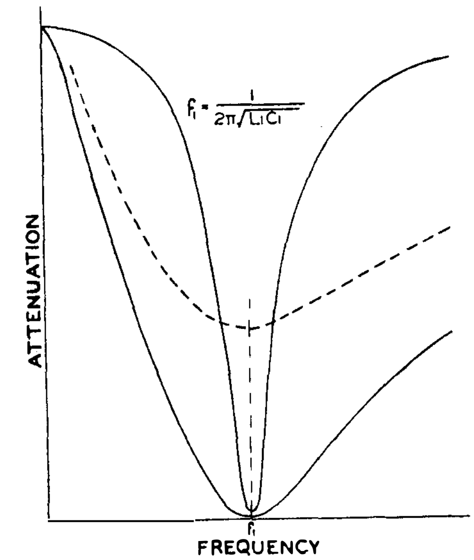




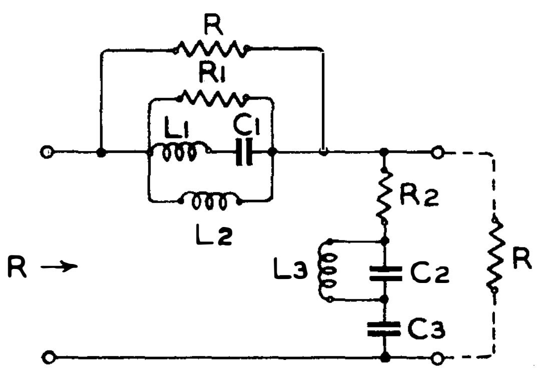
FIGS. 8 AND 9.—NETWORK TYPE 3.

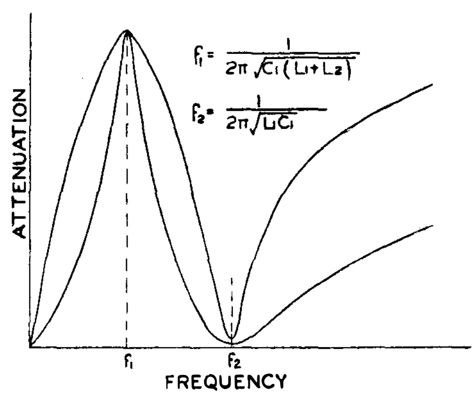
NETWORK	ATTENUATION CHARACTERISTIC



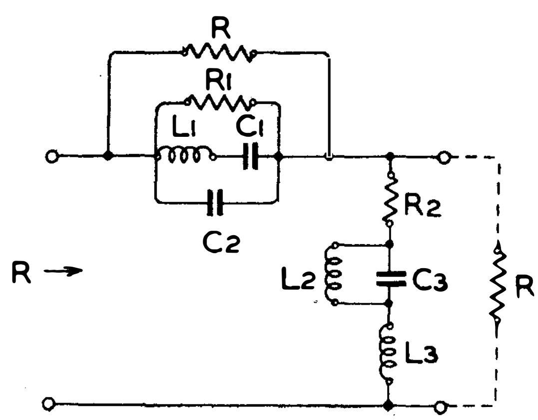


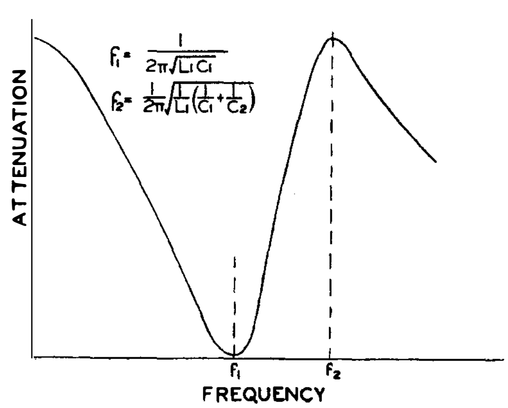
FIGS. **10** AND **11**.—NETWORK TYPE 4.





FIGS. **12** AND **13**.—NETWORK TYPE 5.





FIGS. **14** AND **15**.—NETWORK TYPE 6.

high frequency end, and the other to make a final correction at the low frequency end. The examples given later indicate how the number and type of sections are chosen.

For most networks the simplest method of design is the practical one described below, but with networks type 1 and 2, if the resistances R_3 and R_4 are omitted, Zobel's equations form a straightforward means of design. This method is given first, but only for network type 1, since type 2 has little practical application at present.

Zobel's Method for Network Type 1.

Since a knowledge of only two components (i.e., R_1 and C) enables us to determine the network and its characteristics, it is evident that any attentuation equation can involve only two unknowns. If we make an attenuation equation involving the values of the components, however, we have a rather cumbersome quadratic expression to deal with, i.e.,

$$F = \frac{\left(1+\frac{R}{R_1}\right)^2 + \omega^2 C^2 R^2}{\left(\frac{R}{R_1}\right)^2 + \omega^2 C^2 R^2} \quad \ldots\ldots\ldots\ldots \text{(3a)}$$

where $10 \log_{10} F$ = decibels.

Zobel's Method is to replace this by a linear equation,

$$F = \frac{P+f^2}{Q+f^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3b)}$$

where P and Q are " attenuation coefficients " and f is the frequency.

The design of an equalizer of this type is now quite simple, and is carried out as follows :—

The two attenuation coefficients, P and Q, are first determined from the shape of the attenuation curve required. It is easy to show from equation (3b) that if two frequencies f_1 and f_2 are taken at suitable points in the range, and if the attenuation required at these frequencies is expressed at F_1 and F_2, then

$$\left.\begin{aligned} Q &= \frac{f_2^2 (F_2-1) - f_1^2 (F_1-1)}{F_1-F_2} \\ \text{and} \quad P &= f_1^2 (F_1-1)+F_1 Q \end{aligned}\right\} \ldots\ldots\ldots\ldots \text{(4)}$$

The attenuation of the network is then calculated at other frequencies by using equation (3b). Should the attenuation characteristic not be quite as required, small modifications can be made to P and Q to make the shape correct. Then comparing equations (3a) and (3b) the network components can be shown to be:

$$\left.\begin{aligned} R_1 &= \frac{R\,(\sqrt{P}-\sqrt{Q})}{\sqrt{Q}} \\ C &= 1/(2\pi R_1 \sqrt{Q}) \\ R_2 &= \frac{R^2}{R_1}\ ;\ L = CR^2 \end{aligned}\right\} \ldots\ldots\ldots\ldots \text{(5)}$$

If the network is to be physically realized, $P \geq Q \geq O$

Practical, or " Modulus," Method.

From equation (1) we see that the attenuation characteristic of a network is determined by the frequency characteristic of the modulus $|R+Z_1|$. If, therefore, we derive from our required attenuation curve a curve of modulus plotted against frequency, we have only to design a two-terminal network the impedance of which fits the curve. This can be done practically by means of the circuit shown in Fig. **16**.

M=VALVE VOLTMETER.

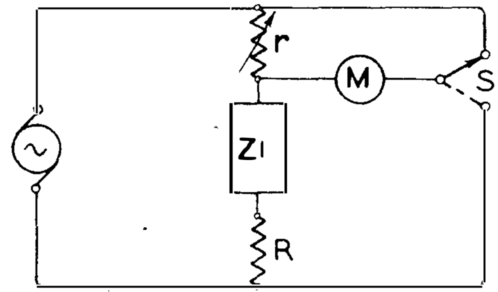


Fig. **16**.

If, by changing over the switch S, the variable resistance "r" is adjusted until the voltmeter reads the same voltage across it as across $|R+Z_1|$, then "r" equals the modulus $|R+Z_1|$ The network Z_1 can therefore be altered until the required modulus curve is obtained. The whole equalizer can then be calculated by the inverse rules of equation (2).

This method is, of course, an empirical one, but by making one or two trials over a wide range of values of components, at two or three frequencies only, a good idea of the actual values required can be obtained. The final adjustments can then be made. Variable components are essential, of course.

The derivation of the impedance values from attenuation is most easily made by using a graph of equation (1).

Example I. Calculation by Zobel's Equations.

Chatham-Canterbury 70 *lb. unloaded pairs.* (*BXB Cable*).—The insertion loss of a pair in this section of cable is shown in Fig. **17**, and in column (1) in Table 2. The frequency range considered is that

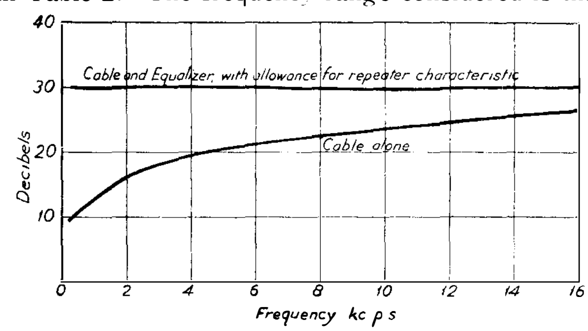


Fig. **17**.—Attenuation of 70 lb. unloaded pair in BXB cable, with and without equalizer.

for the 1+4 channel carrier system, described elsewhere in this Journal.[1] The allowance to be made for the frequency characteristic of the repeater used is shown in column (2). Thus the required equalizer must have a characteristic shaped as in column (3). This assumes zero attenuation at 16 kc.p.s. Generally it is desirable to keep the attenuation at the highest frequency as low as possible by using a tuned equalizer, since it is an undesirable loss that must be overcome by the repeater gain. In this particular case, however, there is ample gain to spare, so that a considerable loss at 16 kc.p.s. is allowable. This allows us to use network type 1, which is not tuned, and so effects a saving in components. As it is required to obtain a fairly straight characteristic at the high frequency end, it will not be possible to

[1] Carrier System No. 4. *P.O.E.E.J.* Vol. 29, Pts. 3 and 4.

TABLE 2.

Freq. kc.p.s.	Cable Attenuation. db. (1)	Allowance for Repeater. db. (2)	Required Equalizer Shape. db. (3)	H.F. Network. db. (4)	Still Required. db. (5)	L.F. Network. db. (6)	Error. db. (7)	New L.F. Network. db. (8)	Error. db. (9)
.25	9.7	+0.4	15.9	11.1	8.8	9.2	+0.4	9.0	+0.2
.5	10.6	+0.1	15.3	11.1	8.2	8.2	0	8.2	0
1	12.8	0	13.2	11.05	6.15	5.85	−0.3	6.15	0
2	16.05	0	10.0	10.75	3.25	2.9	−0.35	3.3	+0.05
3	18.0	0	8.0	10.3	1.7	1.6	−0.1	1.9	+0.2
4	19.3	0	6.7	9.7	1.0	1.0	0	1.2	+0.2
6	21.0	0	5.0	8.5	0.5	0.5	0	0.6	+0.1
8	22.4	−0.1	3.7	7.3	0.4	0.3	−0.1	0.35	−0.05
10	23.5	−0.1	2.6	6.25	0.35	0.2	−0.15	0.25	−0.1
12	24.7	−0.2	1.5	5.4	0.1	0.15	+0.05	0.15	+0.05
14	25.6	−0.3	0.7	4.65	0.05	0.1	+0.05	0.1	+0.05
16	26.35	−0.3	0	4.0	0	0.05	+0.05	0.05	+0.05

equalize with one equalizer section only. Let us therefore first obtain a network which equalizes the high frequency end. Using Zobel's method for the case where R_3 and R_4 are omitted, consider two frequencies.

$$f_1 = 6 \text{ kc.p.s.}$$
$$f_2 = 16 \text{ kc.p.s.}$$

Assume an attenuation at 16 kc.p.s. of 4.0 db. Then the attentuation at 6 kc.p.s. should be 9.0 db.; but as we must allow for the attenuation of the low frequency network at this frequency, assume an attenuation at 6 kc.p.s. of 8.5 db.

Then $F_1 = 7.08$ and $F_2 = 2.51$.

Substituting in equation (4),

$$Q = \frac{256 \times 10^6 \times 1.51 - 36 \times 10^6 \times 6.08}{4.57}$$
$$= 36.7 \times 10^6$$
$$P = 36 \times 10^6 \times 6.08 + 7.08 \times 36.7 \times 10^6$$
$$= 479 \times 10^6$$

Substituting these values in equation (3b), we obtain the characteristic of the network having these P and Q values, as given in column (4). If now we add 4.0 db. to all the figures in column (3), we obtain our actual required characteristic. Column (5) shows the amount of equalization still required.

For the low frequency network, therefore, take $f_1 = 0.5$ kc.p.s. and $f_2 = 4$ kc.p.s. Corresponding to the attenuations required at these frequencies we have

$$F_1 = 6.60 \qquad F_2 = 1.26$$
$$\therefore Q = \frac{16 \times 10^6 \times 0.26 - 0.25 \times 10^6 \times 5.6}{5.34}$$
$$= 0.517 \times 10^6$$
$$P = 0.25 \times 10^6 \times 5.6 + 6.6 \times 0.517 \times 10^6$$
$$= 4.8 \times 10^6$$

Substituting in equation (3b), we obtain the characteristic of the network, as given in column (6). It will be seen that the error is about ± 0.4 db., which is in this case too great. If, however, we assume the attenuation at 4 kc.p.s. to be 1.2 db., *i.e.*, $F_2 = 1.32$, then we obtain $Q = 0.705 \times 10^6$ and $P = 6.05 \times 10^6$. The characteristic of this network is given in column (8). The total error is now only ± 0.15 db., which is satisfactory.

Thus for the final equalizer we want two networks, one with $P = 479 \times 10^6$ and $Q = 36.7 \times 10^6$, and the other with $P = 6.05 \times 10^6$ and $Q = 0.705 \times 10^6$. The

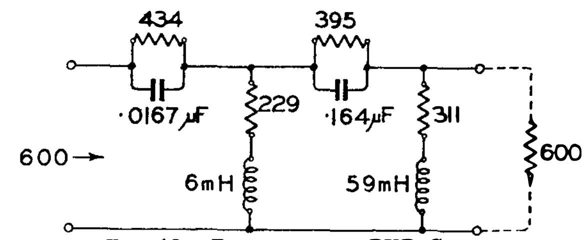


FIG. 18.—EQUALIZER FOR BXB CABLE.

network components are calculated from equation (5), and work out to be (assuming R = 600 ohms).

High end network.
- R_1 = 1570 ohms
- C = .0167 μF.
- R_2 = 229 ohms
- L = 6.0 mH.

Low end network.
- R_1 = 1157 ohms
- C = .164 μF.
- R_2 = 311 ohms
- L = 59.0mH

and therefore the complete equalizer is as shown in Fig. **18**.

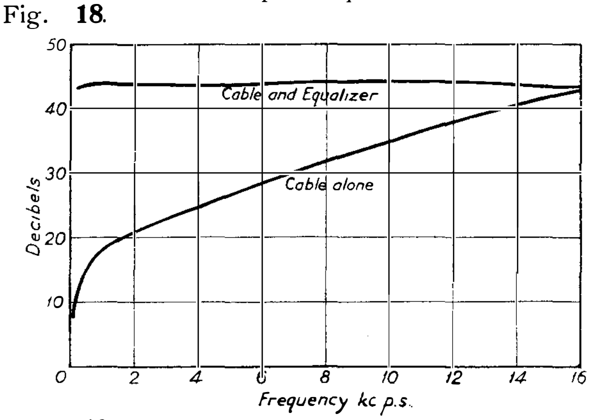


FIG. **19**.—ATTENUATION CHARACTERISTIC OF SUBMARINE CABLE, WITH AND WITHOUT EQUALIZER.

Example 2. *Determination by Modulus Method.*

Suppose we have to equalize up to 16 kc.p.s. a 79 naut length of co-axial paragutta submarine cable, such as will be used for the Anglo-Dutch (1937) cable. The attenuation characteristic is given in Fig. **19** and in column (1) of table 3, the characteristic of the equalizer required is therefore as shown in column (2). In this case, owing to the high attenuation of the cable, it is necessary to minimize the attenuation in the equalizer at 16 kc.p.s. and consequently a tuned network is essential. Network type 4 will evidently give a characteristic of the right shape over most of the range, though an additional section (probably type 1) will be required for the low frequency end. In the network type 4, we must obviously omit R_3 and R_4, and the resonant frequency f_1 should be a little higher than 16 kc.p.s., since we wish to avoid the reverse curvature of the characteristic near resonance. Take $f_1 = 17$ kc.p.s. The product of L_1 in millihenrys and C_1 in microfarads is 0.087 for resonance at this frequency.

The practical method of determination is applied as previously described. The network impedance Z_1 here consists of R_1, L_1 and C_1. L_1 and C_1 can be varied to give the right shape of curve, but their product must always be 0.087. The ratio of L_1 in millihenrys to C_1 in microfarads is generally between 1,500 and 5,000 for ordinary cable sections so it is fairly easy to obtain the correct values by trial. Only about three frequencies need be considered at this stage. The attenuation at 16 kc.p.s. must first be determined, of course, and then added to the figures in column (2). The resistance R_1 determines the attenuation at low frequencies, and should be adjusted at the same time as L_1 and C_1 to give the correct attenuation (as represented by the modulus measurement) at, say, 2 kc.p.s. It is found that when $R_1 = 10{,}000$ ohms, $L_1 = 13.1$ mH and $C_1 = .0066\ \mu F$, the attenuation is approximately correct at 2, 6 and 16 kc.p.s. Measurements are therefore made at more frequent intervals, and the results obtained are given in column (3). The intermediate step of converting from measured impedance to attenuation is not shown, as this is quite straightforward.

The amount of equalization still required is shown in column (4). A network type 1 with R_3 and R_4 omitted should be suitable for the subsidiary equalizer. The same method of determination is used, the impedance Z_1 being now R_1 and C in parallel. These two components are varied so that the correct attenuation is obtained at two frequencies, say, 0.4 and 1 kc.p.s. The attenuation is then determined for the whole range. The values of R_1 and C thus determined are 1,260 ohms and 0.65 μF respectively, and the attenuation characteristic is given in column (5). The remaining error is shown in column (6). If we except the error at 200 c.p.s., the error does not exceed ± 0.4 db. Since we are concerned with a carrier system with only the one cable section, this accuracy of equalization is sufficient. The final equalizer can then be calculated by the inverse rules, and works out as shown in Fig. **20**.

The network type 4 can also be determined by calculation. From equation (1) or from first principles we can readily derive the following equation:

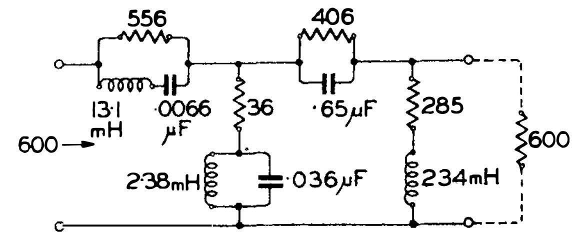


FIG. 20.—EQUALIZER FOR SUBMARINE CABLE.

Attenuation in decibels

$$= 10\log_{10}\frac{(R_1+R)^2(1-\omega^2L_1C_1)^2+\omega^2C_1^2R_1^2R^2}{R^2(1-\omega^2L_1C_1)^2+\omega^2C_1^2R_1^2R^2}$$

where R = characteristic impedance.

Now the product L_1C_1 is easily determined as already explained. The value of R_1 can be estimated from the expected attenuation at low frequencies:—
Maximum attenuation (at zero frequency)

$$= 10\ \log_{10}\frac{R + R_1}{R}$$

If these values are substituted in the equation above, and also the required attenuation at some intermediate frequency, an equation is obtained which can be solved to give the value of C_1. The values of the other components are then easily computed. The attenuation characteristic can be calculated over the frequency range, and the remaining equalization then taken up by a network type 1 calculated as in Example No. 1.

Conclusions.

The design of constant impedance equalizers, which must inevitably find an increasing field of application in telephone transmission, may be carried out with considerable precision, although the networks lack much of the flexibility commonly associated with the tuned input circuits used on voice frequency repeaters. The practical method of design outlined in this article gives results which are sufficiently accurate for line equalization, and avoids the tedious calculations associated with Zobel's original methods.

TABLE 3.

Freq. kc.p.s.	Cable Attenuation. db. (1)	Required Equalizer. db. (2)	H.F. Section db. (3)	Still to be equalized. db. (4)	L.F. Section. db. (5)	Error. db. (6)
.2	11.1	32.1	24.9	7.7	7.1	−0.6
.4	14.6	28.6	24.8	4.3	4.3	0
.6	16.5	26.7	24.7	2.5	2.7	+0.2
.8	17.7	25.5	24.6	1.4	1.8	+0.4
1	18.6	24.6	24.4	0.7	1.2	+0.5
2	21.0	22.2	22.6	0.1	0.3	+0.2
4	24.9	18.3	18.7	0.1	0.2	+0.1
6	28.7	14.5	15.2	−0.2	0.1	+0.3
8	32.2	11.0	12.1	−0.6	0.1	+0.7
10	35.4	7.8	9.1	−0.8	0	+0.8
12	38.2	5.0	6.1	−0.6	0	+0.6
14	40.8	2.4	2.9	0	0	0
16	43.2	0	0.5	0	0	0

Impact Testing

GEO. F. TANNER, M.I.E.E.

The present article deals with one aspect of the control of material, that of impact testing. The application of modern methods is described.

Introduction.

PRIMITIVE man, when he sallied forth from his limestone cave armed with a crude club which he had torn from a tree, intuitively realized the value of the impact test when he wielded the weapon over his shoulder to deliver a percussive blow to the nearest tree trunk. He had to protect himself in a world filled with fierce creatures of the wild and had already had unhappy experience of the club that had fractured over the head of his antagonist, leaving in his hand a useless short end for the purpose of defence. Thousands of years later his highly developed progeny discover in less arduous circumstances that although tensile, compression and hardness testing machines are extremely valuable for ascertaining the dead load resistance of materials, they will not necessarily indicate the shock stress resistance, and that this very important information must be obtained from an impact test.

It is still necessary, as of yore, that materials subject to sudden shock should be tested to ascertain their fitness, but to-day, those materials are used, maybe, for the moulded composition of the telephone which is so liable to shock when it is accidentally, or otherwise, dropped, for the railway carriage coupling and drawbar that may be so violently wrenched, or for the airplane that may be subject to shocks of extraordinary severity.

Various machines have been developed for making impact tests, the most well known being the Charpy, Izod, Frémont, Amsler and Guillery. All these machines employ the same principle, *i.e.*, a test piece of the material is fractured by a single blow of a falling tup or pendulum or revolving flywheel. The work expended in fracture is measured by the difference of the striking energy before and after impact.

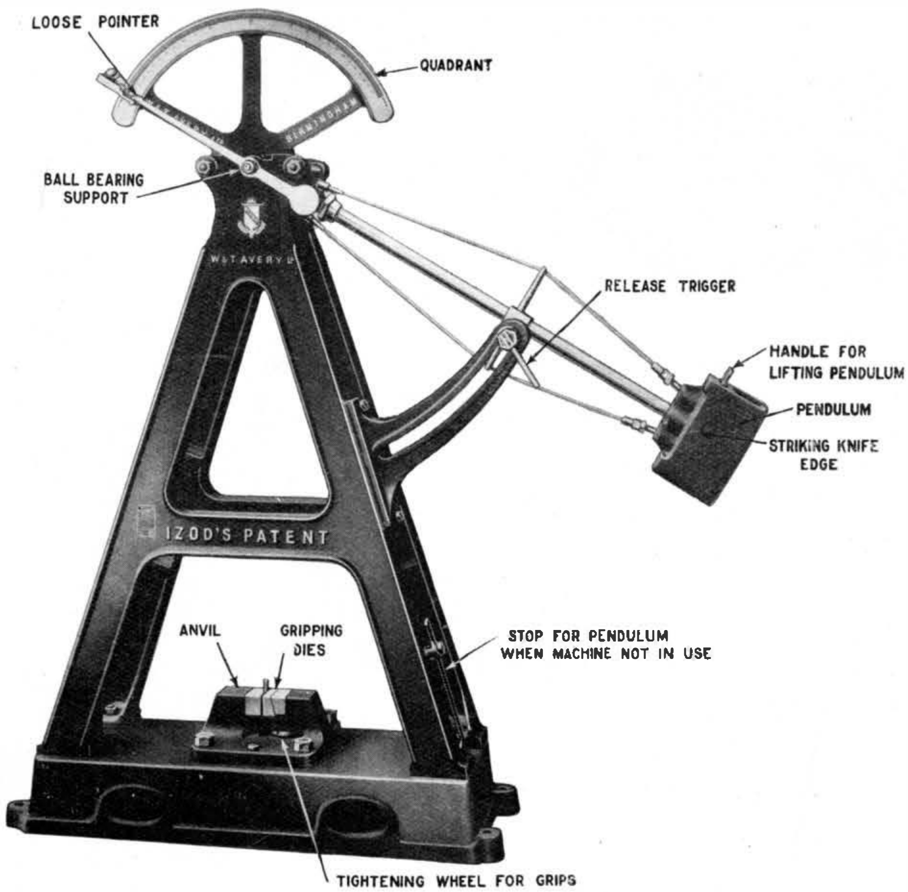


FIG. 1.—STANDARD 120 FT.-LB. (17 KG-METRES) IMPACT TESTING MACHINE.

THE IZOD MACHINE.

Of these machines the Izod is probably the most generally used to-day, the "Izod Test," as it is now called, being specified by government departments, testing institutions, and engineers the world over. A form of this machine is shown in Fig. 1.

The form of test universally adopted is that of a single blow applied to a specimen of the material it is desired to test, the specimen being of cantilever form and definite section. The specimen is notched to ensure that the force of the blow is concentrated at a definite position relative to the point of impact and the blow is delivered by a pendulum, which has a fixed potential energy due to its effective weight and height of fall.

Description of Machine.

The machine consists of a substantial base casting upon which are erected two rigid "A" frames between the apex of which is swung a pendulum mounted upon ball bearings. (See Fig. 1.) A vice, provided with suitable grips for holding the specimen, is also secured to the base casting. The pendulum is fitted with a special hardened steel knife-edge which strikes the specimen at a fixed distance above the gripping dies. A graduated quadrant is secured to the "A" frames and the impact value of the specimen is indicated upon this quadrant by means of a loose pointer which is carried forward by the pendulum.

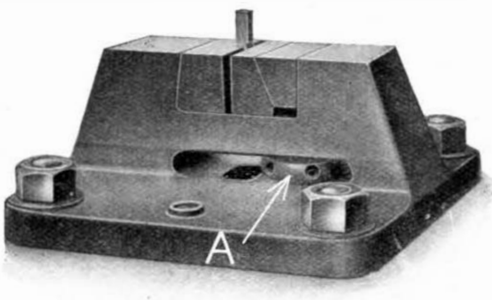


FIG. 2.—VICE FOR GRIPPING SPECIMEN UNDER TEST.

Method of Making the Test.

To make the test the specimen is positioned in the vice as shown in Fig. 2. The pendulum is raised to its maximum position, is then released by means of a trigger, and on its downward swing breaks the specimen. The residual energy in the pendulum causes it to continue its arc, the extent of its travel (which is also a measure of the residual energy) being indicated on the quadrant by means of the loose pointer.

While the specimen is being removed, the pendulum may be rested against the stop on the frames; this stop falls away when the pendulum is raised.

After fracture the specimen is examined as certain qualities of a material may be judged from the appearance of the fracture. This point is referred to again later.

The Quadrant.

The quadrant is graduated on both sides from zero to maximum capacity. The impact value of the specimen under test is indicated on the right-hand side of the quadrant, and the left-hand side is graduated to enable the pendulum to be adjusted to various capacities (it will be realized that if the height of fall of the pendulum is altered, the striking velocity is also altered). The standard graduation for the quadrant is 120 ft.lbs., but it may be graduated in metric standard to 17 kilogram metres, or in both English and Metric units.

The graduations on the quadrant are fixed by the vertical fall of the pendulum, the position of the pendulum at the various heights being measured by standard gauges. The quadrant is depicted in Fig. 3.

Pendulum.

The pendulum consists of a tube, to one end of which is secured a hammer fitted with a specially formed striking knife-edge. The unit is rigidly braced by tie rods and the whole mounted in ball bearings carried in the "A" frames. The striking velocity conforms with the requirements of the British Standards Institution.

Vice.

The vice which is shown in detail in Fig. 2 receives the gripping dies for the specimen. These dies are adjusted by a wedge arrangement, controlled by an adjusting hand wheel A (Fig. 2), which is operated by a tommy bar. This ensures that the specimen is securely gripped, and provides a convenient and rapid method for inserting or removing the test pieces. The illustration shows the specimen in position ready for test. The specimen may be either round or square.

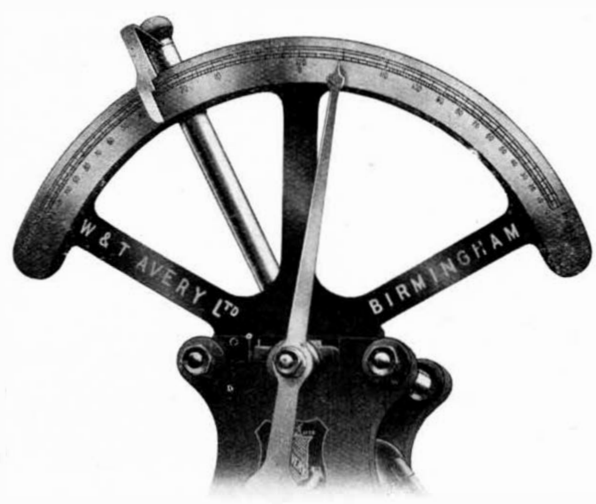


FIG. 3.—QUADRANT WITH LOOSE POINTER.

British Standard Notched Bar.

The standard notched bar test piece (see B.S.S. 131) is 10 mm. × 10 mm. in cross section, the form and depth of notch being as illustrated in Fig. 4. A round section test piece is shown in Fig. 5. This form of test piece has been adopted by the British Air Board (see B.S.S. 2 A 4).

The specimen is positioned in the vice by means of a positioning gauge, thus ensuring that the blow shall be struck at the requisite height above the notch (22 mm. for 120 ft.lb. machine).

It is usual for at least three tests to be made of a material and the average result taken. For this purpose specimens are often prepared in lengths having three notches, which are so arranged that the second test can be carried out in an opposite direction to the first and last. (See Figs. **4** and **5**.)

Gauges for Specimens.

A set of gauges, consisting of a notch gauge, a caliper gauge and a positioning gauge, are usually supplied with each machine. The notch gauge is provided for checking the profile of the notch, the caliper gauge for checking the depth of material behind the notch in the specimen, and the positioning gauge for setting the specimen in the vice at the correct height. A separate set of gauges is required for round specimens.

Milling Cutters.

These cutters are of a special type for preparing the standard notch in either the round or square type of specimens and can be supplied with the machine, if desired.

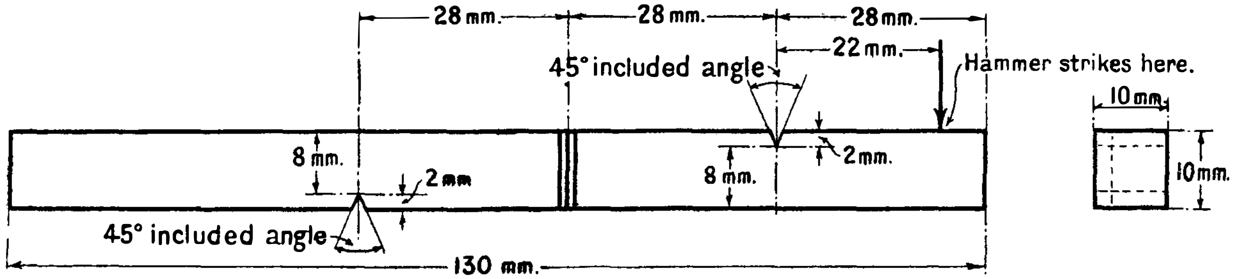


FIG. **4**.—THREE NOTCH BRITISH STANDARD TEST PIECE, CANTILEVER TYPE.

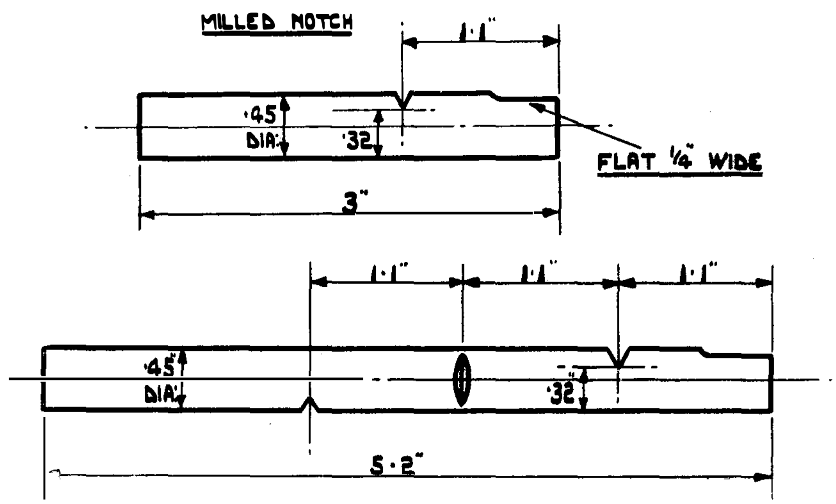


FIG. **5**.—ROUND SECTION ADOPTED BY BRITISH AIR BOARD.

Variable Capacity.

In the machine shown in Fig. **1** the capacity may be varied, if desired, and for this purpose the bracket which carries the trigger for supporting and releasing the pendulum is slotted to permit the necessary adjustment in the height of fall of the pendulum, but as the striking velocity of the pendulum is altered when its height of fall is reduced, tests made at the reduced capacities are not comparable with tests made at standard capacity. When small capacity tests are made it is necessary to make a deduction (being the difference between the full and set capacities of the machine) from the actual indicated values.

Foundation.

The machine should always be fixed on a concrete foundation and, when correctly levelled, grouted in position. The machine should not be operated while insecurely fixed as, besides the liability to incorrect results, there is the possibility of fracture of one of the frame members.

Supplementary Tests.

The machine can be arranged so that impact tension tests or impact transmission tests may be undertaken, special accessories being required to enable these to be carried out. The impact tension test is frequently used to test small chains.

Special Machines.

The machine depicted in Fig. **6** is designed on the same principle as the standard 120 ft.lb. machine, but has a capacity of only 10 in.lb., the scale being graduated by divisions of 0.1 in.lb. The machine is provided with dies for gripping a specimen 15 mm. square, with a notch machined on one face, this notch being 5 mm. deep and having a radius at the bottom of 1 mm. It is suitable for testing samples of bakelite, porcelain and glass. A large impulse testing machine used for testing railway couplings and drawbars, is shown in Fig. **7**.

Another special machine is designed to test clear specimens of timber. (See B.S.S. 373.)

The Izod test is of great value in the testing of metals, particularly in the case of alloys, and Izod values are taken in all steel works in order to assess the value of the product. The fracture of a metal varies with its purity, and the heat treatment to which it has been subjected and, on that account, the test is particularly useful for determining the effect of tempering or annealing on various compositions.

FIG. **6**.—SPECIAL MACHINE FOR TESTING BAKELITE, PORCELAIN, OR GLASS.

Fracture.

The appearance of metals and other substances after fracture is of great use and from this alone a great deal of information may be gathered by the expert.

Fractures may be classified as:—

Crystalline. Metals presenting this appearance are weak. Rupture occurs by separation of the adherent facets. Antimony offers a good example. Iron containing phosphorous breaks with **a** crystalline fracture.

Granular. The structure of sandstone. The uniformity of the mass is greater than when crystalline and the metal is consequently stronger and more readily worked. Cast iron is a good example.

Fibrous. This structure is well known. It is developed to a great degree in wrought iron, by the elongation and welding together of the particles during rolling. The toughness and strength is great.

Silky. This is a fairly fibrous structure of a brilliant silky lustre. It is seen in copper and steel. Metals which possess it are usually strong, tough and malleable.

Conchoidal. This appearance is common with the harder varieties of steel. The metal breaks with a convex or concave surface with divergent markings resembling a shell. Metals possessing this fracture are usually hard, highly resilient and brittle.

Columnar. This structure is manifested by the tendency of metals to separate in long fingers, the pieces resembling lump starch. In tin it may be obtained by heating the metal nearly to its melting point and then either allowing it to fall to the ground, or by striking it with a wooden mallet while hot. It is a very unsatisfactory fracture.

Standardization of Tests.

The following is an excerpt from the report of the Committee approved by the British Standards Institution: " In view of the large use of notched bar tests and the diversity in the dimensions of the test pieces at present used, it has been considered desirable that the test should be standardized and this Report (see B.S.S. 131) gives the standard dimensions of the test pieces and the form of notch recommended." Among the recommendations of that Committee are the following:—

The results in some materials depend upon the striking velocity which should not in any case be less than 3 metres per second.

The following table gives the striking velocities of representative machines:—

Machine.	Striking Energy kg.m.	Striking Velocity m. per second.
Charpy, pendulum	30	5.3
Izod, pendulum	16.6	3.5
Fremont, falling tup	20 or 60	8.85
Amsler, pendulum	30	4.95
Guillery, rotary flywheel	60	8.85

The weight of the anvil block and its foundation should be at least 40 times the weight of the tup or pendulum.

Effect of the form of notch.

Various forms of notch have been employed by different engineers, and the work of fracture is different according to the type used. It is certain that the indication of brittleness, marked by a low value of the work of fracture, is more definite the smaller the angle of the notch and the radius of curvature at the bottom of the notch. After much investigation the B.S.I. Committee decided that the standard notch should be a Vee notch of **45°** angle with a quarter millimetre radius at the bottom of the notch. The standard cantilever type of test piece is shown in Fig. 4.

Size of test piece.

A trustworthy relationship, between the work of fracture in test pieces of different sizes has not yet been found, but there is evidence that it is probably different in different materials. Test pieces of 15 mm. × 15 mm. × 80 mm. and 30 mm. × 30 mm. × 160 mm. have been used by various engineers. Considering the cases in which the notch bar test is most likely to be useful, and the difficulties in obtaining pieces of so large a size, the B.S.I. Committee decided that a smaller test piece is more practical.

Units employed.

It is recommended that all dimensions should be expressed in metric units, the dimensions of the test piece in millimetres, the striking velocity (which should be stated) in metres per second, and the work of fracture in kilogrammetres. For the purpose of conversion it may be taken that one kg.m. = 7,233 ft. lbs. and that one ft. lb. = 0.138 kg.m. Only results taken on test pieces of identical dimensions should be compared and at least three tests of one material should be made and the average result taken.

Conclusion.

The subject is one about which much might be written, and in this brief summary it has only been possible to outline the salient points of a very interesting test by which the quality of many different classes of material is controlled. The test is a routine one in all large foundries and in the production of our own moulded telephone the quality of the composition is largely controlled by this test.

The writer desires to acknowledge the courtesy of Messrs. W. and T. Avery, Ltd., Soho Foundry, Birmingham, in supplying certain blocks for illustrating the article.

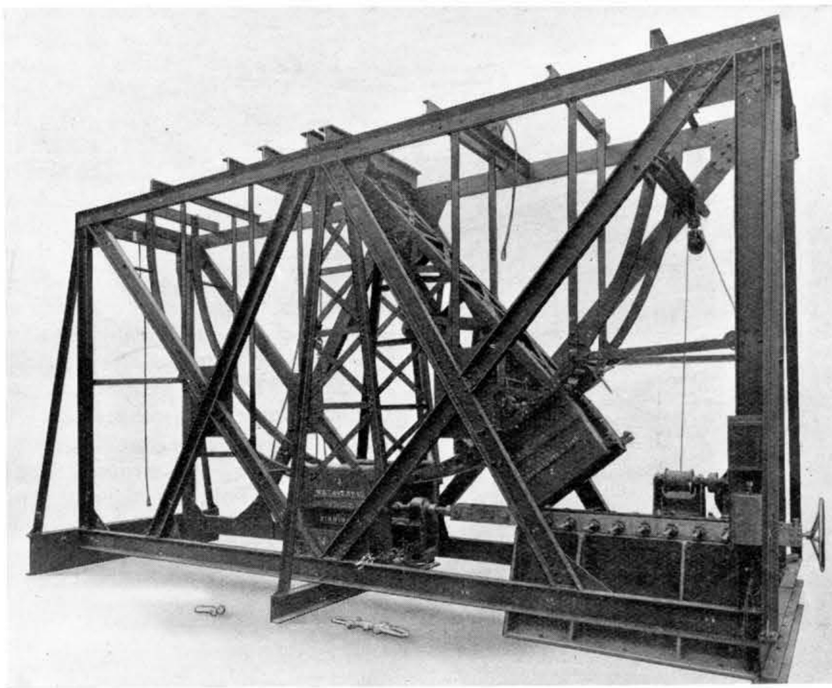


FIG. 7.—A LARGE IMPACT TESTING MACHINE FOR TESTING RAILWAY COUPLINGS AND DRAWBARS.

Birmingham Trunk and Toll Exchange

E. F. W. ALLSUP and
T. A. HANDY

A description is given of the new Trunk and Toll equipment installed at Birmingham.

Introduction.

BIRMINGHAM'S geographical position renders it particularly suitable as a telephone switching centre, in fact it may be said that what London is to the telephone world, Birmingham is to England. The enormous increase in trunk and toll traffic, due mainly to the reduction of fees and the "on demand" method of handling trunk calls, has therefore affected Birmingham extensively and, coupled with lack of accommodation in the existing buildings, led to the decision to combine the trunk and toll exchanges in one building.

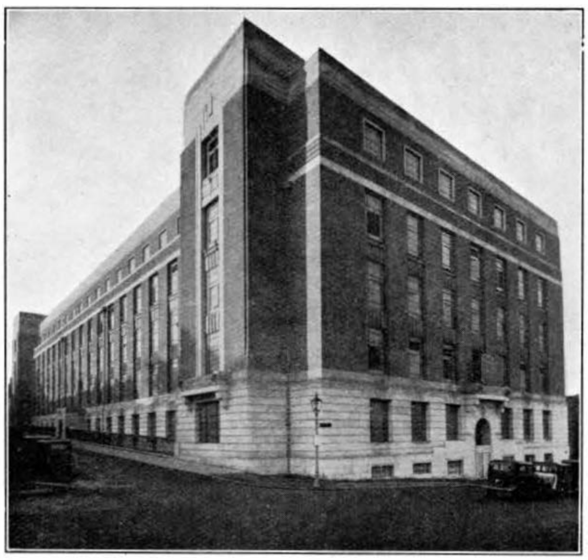


Fig. 1.—Telephone House, Birmingham.

Early in 1934 preparations were made to carry this decision into effect. A site was obtained and one of Birmingham's finest buildings erected. The building, known as Telephone House (Fig. 1), is at the junction of Lionel Street and Newhall Street, and has frontages of approximately 100 and 45 yards. In addition to the trunk and toll exchanges accommodation is provided for the Central automatic exchange, a new repeater station and a sub-post office.

Telephone House Layout.

The five floors are laid out as follows:—

Basement.—Separate batteries and associated charging plants for the telephone exchange and repeater station equipments, main distribution frames and test tablets for the termination of external cables, together with test racks for testing trunk and junction circuits. The sub-post office is also situated on this floor. The entrance is at street level, due to the sloping nature of the ground.

Ground Floor.—Accommodation for the automatic switching equipment of Central exchange and offices for the engineering staff.

First Floor.—Repeater station equipment and offices for the engineering staff.

Second Floor.—Apparatus room for trunk and toll exchange and offices for District Manager's staff.

Third Floor.—Auxiliary apparatus rooms for Trunk and Toll, dining club and telephonists' welfare accommodation.

Fourth Floor.—Switch room, Exchange Superintendent's offices and a sick bay.

Trunk and Toll Exchange Switchroom.

The switchroom houses both trunk and toll exchanges and accommodates 367 operators' positions, 6 supervisors' desks, trunk and directory inquiry tables, information card positions, a pneumatic distribution position and ticket filing position and 4 keysender positions. The switchboards are standard 3 position, 7 panel sections, 6 ft. 4 in. high

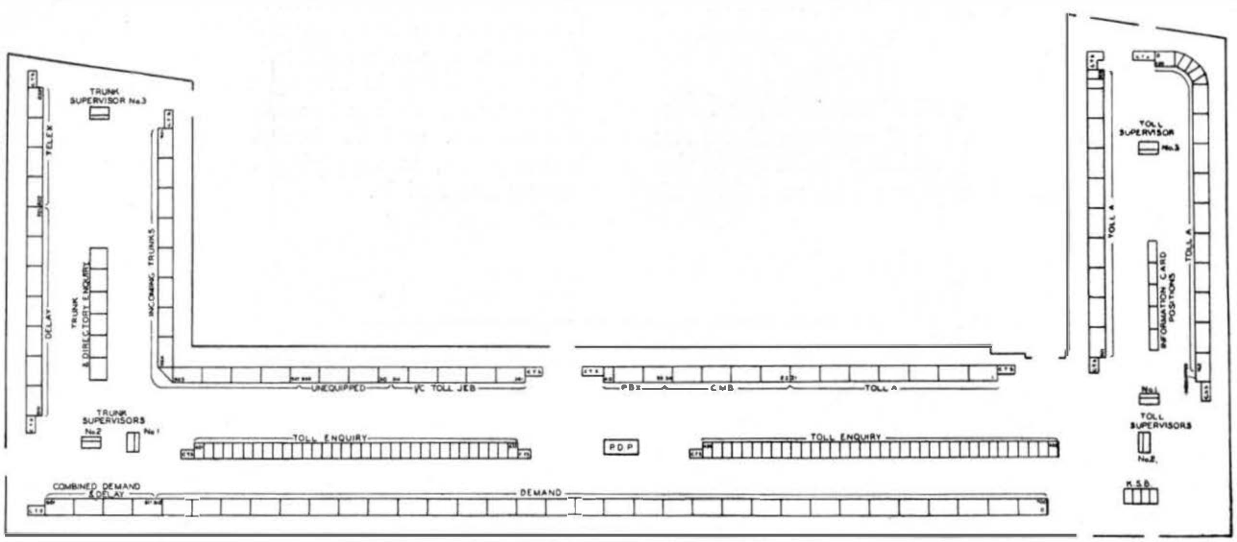


Fig. 2.—Switchroom Layout.

with the exception of the island suite which is 4 ft. 8½ in. high.

The layout is shown in Fig. 2 and comprises the demand and delay suite (Fig. 3), of 102 positions in one unbroken line (reputed to be the longest line of operators' positions in Europe) of which ten are delay positions;
the delay and telex suite of 33 positions of which twenty are used for delay working;
the incoming trunk suite of 60 positions;
the toll A and jack ended B suite of 102 positions in two portions;
the toll inquiry suite (island suite) of 69 positions, the pneumatic distribution and ticket filing positions dividing the inquiry suite in two portions of 33 and 36 positions respectively;
six trunk and directory inquiry tables (Fig. 4), each fitted with a double sided panel and seating four operators per table; and
an information card table comprising 10 operators' positions.

FIG. 3.—VIEW OF SWITCHROOM.

It was decided, as a temporary measure and to reduce costs, to retain keysender working in order to keep at a minimum the number of jack-ended toll positions. Four keysender positions have therefore been provided to replace those at the old toll exchange, a special feature of the arrangement being that the junction relay sets, senders and associated equipment remain in the old apparatus room approximately 1 mile away.

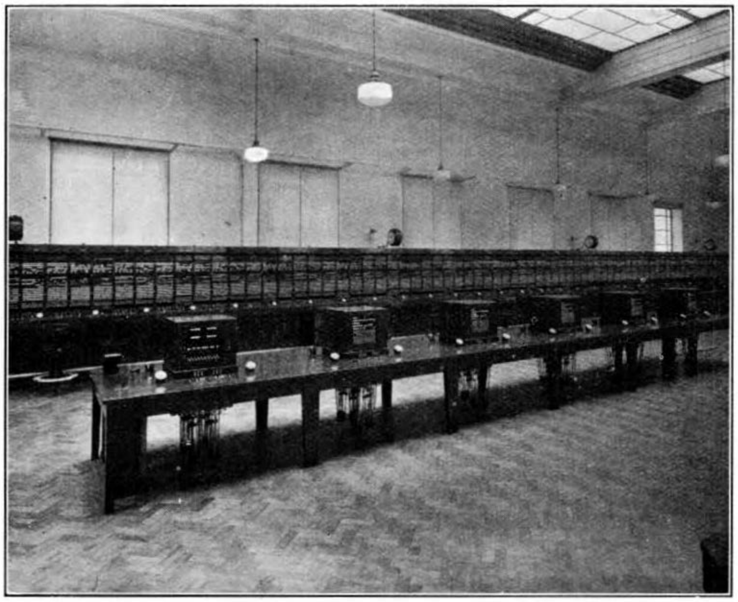


FIG. 4.—TRUNK AND DIRECTORY INQUIRY TABLES.

Switchboard Equipment.—Standard sleeve control circuits have been provided on the trunk and toll positions, thus allowing uniformity in operation.

Multiples.—The outgoing junction multiple on the trunk positions is arranged as follows:—

Outgoing junctions without free line signalling.	720 circuits per 5 panel repetition.
Outgoing junctions with free line signalling.	560 circuits per 5 panel repetition.
Outgoing junctions with free line signalling (long distance).	700 circuits per 5 panel repetition.

In addition a special multiple of 100 circuits is provided for a mechanical toll exchange, and when this is developed it will provide the trunk and toll operators access to toll exchanges on a full dialling basis.

The answering multiple is provided on a 12 panel repetition basis and consists of 600 circuits for the trunk demand and telex suites and 620 circuits for the incoming trunk suite.

The outgoing junction multiple on the toll A and jack-ended " B " portion is arranged as follows:—

Outgoing junctions without free line signalling	340 circuits per 5 panel repetition.
Outgoing junctions with free line signalling.	1,100 circuits per 5 panel repetition.

The answering multiple, as in the trunk portion, is on a 12 panel repetition basis, and comprises 1,020 circuits, which are divided between the two suites, i.e., 680 circuits on one and 340 on the other. During slack periods arrangements have been made to concentrate the 1,020 circuits on 10 fully staffed positions.

The outgoing junction multiple for the toll inquiry suite is as follows:—

Outgoing junctions without free line signalling.	160 circuits per 5 panel repetition.
Outgoing junctions with free line signalling.	340 circuits per 5 panel repetition.

The answering multiple is also arranged on a 12 panel repetition basis and comprises 400 circuits, 200 on each of the two suites. Arrangements to concentrate the circuits on fully staffed positions during slack periods have also been made.

Delay Indicator Panel.—A delay indicator panel and associated cord (TL 1531) is provided on the trunk portion, this facility replacing the delay posting boards formerly in use. Keys are pressed on the indicator panel according to the amount of delay on a group of junctions. This causes the delay lamp associated with the group to glow. To ascertain the extent of the delay the operator places the delay cord into the delay jack associated with the group and a visual indication is given by means of lamps in the keyboard.

At Birmingham the following code is used:—

When no keyboard lamp glows the delay = 20 mins.

When white keyboard lamp glows the delay = 40 mins.

When red keyboard lamp glows the delay = 60 mins.

When white and red keyboard lamps glow the delay = indefinite.

Information Positions.—Owing to the large number of information cards that would be required for the Birmingham area inquiries and the impracticability of accommodating these cards on the individual positions, ten information card positions have been provided. These positions are obtainable from the toll inquiry multiple, the card operators being selected in cyclic order. During slack periods, when the information table is not staffed, arrangements are made to transfer inquiries to a position on the toll inquiry suite, access to the operator controlling the cards being provided by means of a special jack in the multiple.

Auxiliary Apparatus Rooms (Fig. 5).

The auxiliary apparatus rooms contain the lamp relays and associated equipment and are situated as near the switchboard as possible in order to reduce to

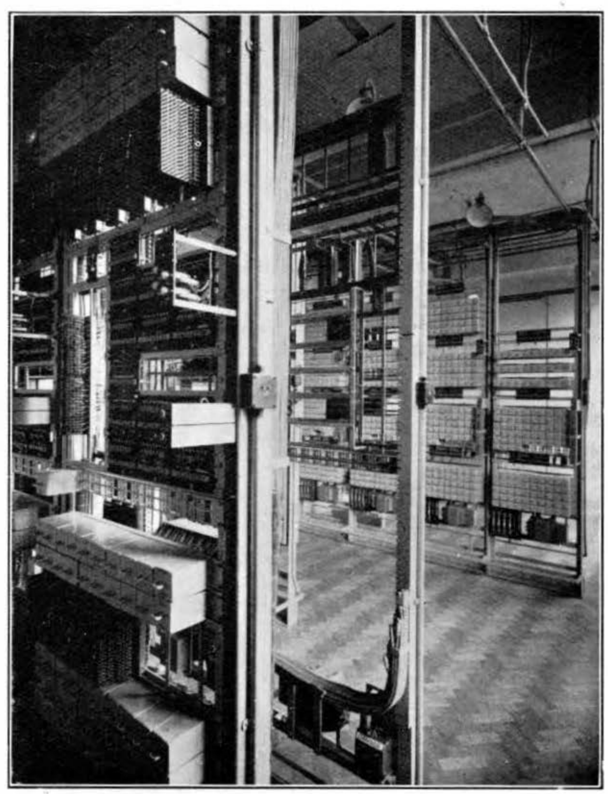


Fig. 5.—A.C. Lamp Racks.

a minimum the P.D. in the lamp feeds. The length of the feeds is governed by the number of lamp appearances, the longest feed for the trunk suite being approximately 80 yards.

Provision has been made to operate the answering lamps from the A.C. supply via transformers (mounted on the lamp racks), which step the supply voltage down to 13 volts, the lamps being wired on a 3-wire system giving 6½ volts on each leg. In the event of a failure on the public supply a change-over relay switches over to the 6 volt supply from the telephone battery.

The Apparatus Room.

Accommodation is provided in the main apparatus room for the following:—

79 relay set racks.
18 chargeable time indicator racks.
7 busy relay racks.
7 multiple answering lamp racks.
4 bays of special apparatus.
2 intermediate distribution frames.
1 fuse panel.

The intermediate distribution frames have 60 verticals each, and in order to reduce the length of jumpers it was decided to allocate a frame for each exchange, i.e., one for trunk and one for toll. The relay sets are standard circuits and are suitable in most cases for working to each exchange. They are therefore divided equally where possible over the two frames. Tie cabling is provided between the two frames to ensure flexibility in the arrangement.

The cabling from the intermediate distribution frame to the switchroom is run via cable chutes in the wall of the dining-room and along the main corridor of the third floor to the various suites. The corridor, which is approximately 80 yards in length, has a removable false ceiling constructed in five feet sections above which the cable runway is situated. Cabling is also carried to the basement and terminated on the main distribution frame.

The main distribution frame (Fig. 6) is in two

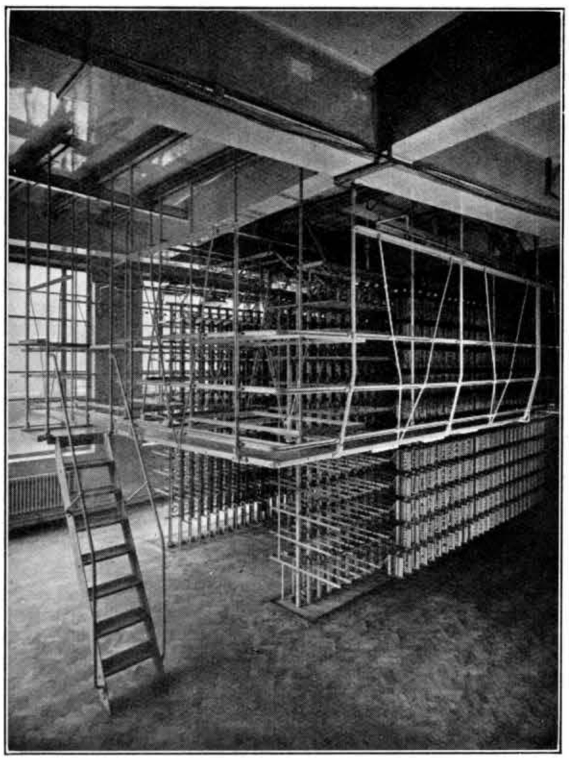


FIG. 6.—M.D.F. SHOWING MEZZANINE PLATFORM.

portions, each having 97 verticals, with the exchange or protector sides facing. A mezzanine platform is supported from subsidiary girders. The platform is constructed on a new principle and is very rigid, a clear height of 6 ft. 3 in. is given above and below the platform. A cross connexion field is provided overhead to allow jumpering between the two frames. In order that each jumper ring of the cross connexion field may be directly opposite its corresponding vertical, the leading-in pipes for one of the frames are staggered $10\frac{3}{4}$ in. with respect to those of the other frame.

The main frame is floodlit and strip lighting is provided underneath the platform to illuminate the lower portion.

Test Racks (Fig. 7).

These are similar in design to those in use at Leeds,[1] the only departure being the adoption of

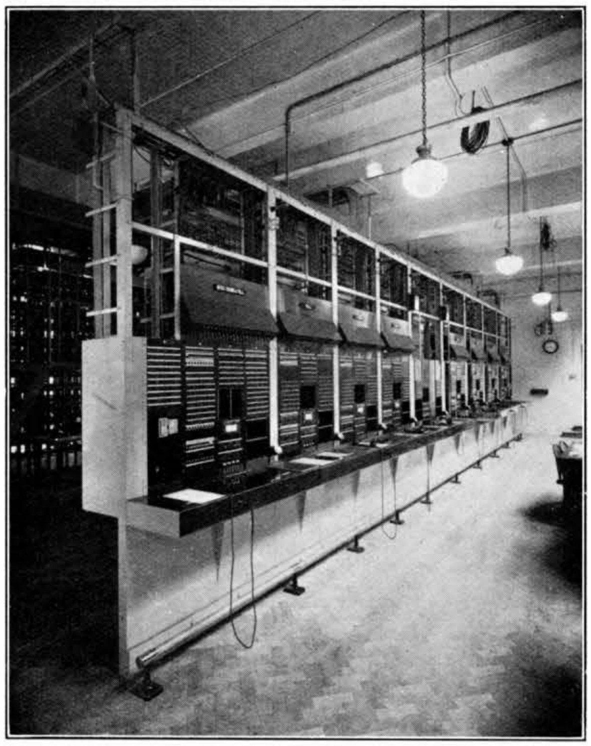


FIG. 7.—TRUNK TEST RACKS.

various sizes comprising single, three and four panel units.

Ten units have been installed, made up as follows:—

6 four panel units,
3 three panel units, and
1 single panel unit.

The suite is arranged in the following order:—

1 miscellaneous position.
3 toll testing positions.
1 fault and record position.
4 trunk test positions.

A special feature of this rack is the busying circuit (Fig. 8). This facility has been provided in order that faulty junctions can be put "out of service" by

[1] P.O.E.E.J., Vol. 26, p. 56.

the engineering staff, thus making the provision of " plugging-up " arrangements on the manual board by the traffic staff unnecessary.

When a circuit is required for test or is faulty the test clerk presses the busy key associated with the junction and relay BR operates and at BR1 operates the free line signal in the outgoing junction multiple. At BR2 it disconnects the sleeve circuit from the relay set and connects engaged test conditions to the outgoing junction multiple.

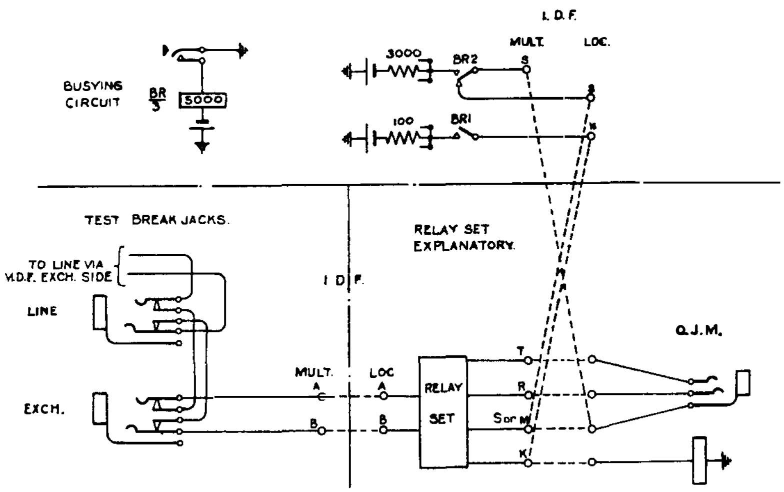


Fig. 8.—Busying Circuit.

Two mains operated bridge meggers of a special design have been incorporated in the testing equipment, one for trunk and the other for toll testing. To bring a megger into service a switch is depressed and a mercury contact relay connects the public supply to the rectifier, and this provides the necessary 250 volts D.C. for testing purposes.

Power Plant.

The power plant provided will eventually supply the needs of the new Central exchange as well as the trunk and toll exchanges. It consists of the following:—

2 motor-generators. The motors are of the auto-synchronous induction type and the generators have an output of 1,600 amperes at 57 volts.

2 main batteries, each having a capacity of 10,000 ampere hours.

2 ringing machines, one operated from the public supply and the other from the main battery, an automatic changeover system effecting the change.

Cable Chamber.

The cable chamber is approximately 65 yards long and 5 yards wide in the widest portion. The main and local junction cables are led in from each end of the chamber.

It may be of interest to record that owing to the sandy nature of the subsoil on which the building is erected it was impossible to find suitable conditions for an effective earth plate even at a depth of 20 ft., and to overcome this difficulty rather a novel scheme was evolved. Advantage was taken during the laying of the new duct lines in Fleet Street and Lionel Street, to lay down edgewise a strip of 8 lb. lead 4 in. wide, in the bottom and on the outside of the duct run. The strips were then taken into the cable chamber through a self-aligning duct and the end of the duct was afterwards sealed. The lead strip was reduced to 2 in. and sweated to the main earth leads.

Installation.

Some idea of the amount of work involved can be gathered from the following summary:—

Line terminations, approximately 24,000.

Jumper wire used, approximately 150 miles.

Switchboard lamps, various used, approximately 225,000.

Lamp jacks in multiple, approximately 11,000.

Jacks in multiple, approximately 15,000.

Cable used in multiple, approximately 51 miles.

Cable and wire used to connect switchboards, approximately 188 miles.

The number of soldered joints in multiple, approximately $1\frac{1}{2}$ million.

The number of relay sets provided is over 6,500, and there are approximately 1,200 C.T.I. circuits.

The number of relays fitted is approximately 71,000, and 5,900 plugs and cords, including 10 miles of flexible cordage, have been used.

It is of interest to note that in the batteries there are $10\frac{1}{2}$ miles of glass tube separators and that each cell weighs $2\frac{3}{4}$ tons complete with acid.

Transfer.

The exchanges have now been brought into service, the transfer of the two exchanges taking place at an interval of about three months. The trunk portion was transferred on August 2, 1936, advantage being taken of the slack period during the August Bank Holiday, and the toll portion on November 28, 1936. In both cases the equipment is working satisfactorily.

The equipment was manufactured and installed by Messrs. Siemens Bros. to whom thanks is due for the use of various photographs.

A Note on Differential Condensers and Resistors

A. ROSEN, Ph.D., A.M.I.E.E.
(Siemens Bros. & Co., Ltd.)

The author describes a simple means of altering the range of differential condensers and resistors and gives examples of their use for the measurement of capacitance and resistance unbalances in telephone cables

Differential Condensers.

THE differential condenser is used chiefly in alternating-current bridges of a symmetrical form, and is arranged so that by its means the capacitance of one arm of the bridge can be augmented while that of an adjacent arm is diminished. For small capacitances, a convenient form consists of an air condenser having one set of movable plates and two sets of fixed plates. The movable plates are in the shape of a semi-circle and are pivoted to rotate about their centre; in doing so, their capacitance to one set of fixed plates is increased while the capacitance to the other set is decreased. If the condenser is accurately constructed, these two changes in capacitance will be equal to each other, and, in effect, as the movable plates are rotated, capacitance is transferred from one arm of the bridge to the other, the total capacitance remaining constant.

This type of condenser finds considerable application in the measurement of the unbalance capacitance in telephone cables, and for this purpose, a usual form is one having a scale reading of about 600 picofarads on either side of a central zero. (One picofarad is 10^{-12} farad.) The scale is marked every 5 pF, and it is possible with care to estimate to 1 pF. For the measurement of small unbalance capacitances of the order of a few picofarads, this form of condenser is too large, and it becomes necessary to employ one having fewer plates with a scale range of, say, 100 pF.

The writer has found that it is possible to adapt a differential condenser with a high scale range to give any desired smaller range by a simple modification.

Fig. **1**a shows a bridge employing a differential condenser in the usual manner for measuring the unbalance capacitances between the terminals AC

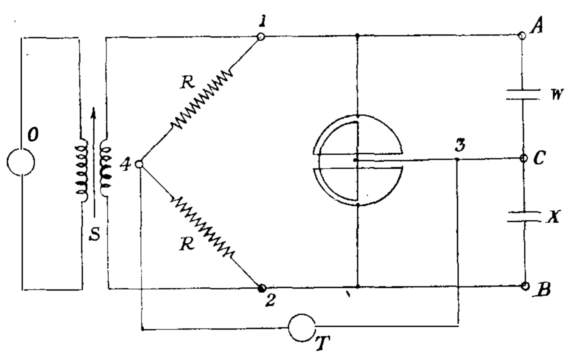


FIG. **1***a*.

and BC. The supply is introduced through the screened and balanced transformer S across the equal ratio arms R R, the detector T being joined between the junction of the ratio arms and the moving plates of the differential condenser; the terminals A and B are connected to the fixed plates and C to the moving plates. The equivalent capacitances are shown in Fig. **1**b. When balance is obtained,

$$K_1+W=K_2+X,$$
$$\text{i.e., } W-X=K_2-K_1 \quad \ldots\ldots(1)$$

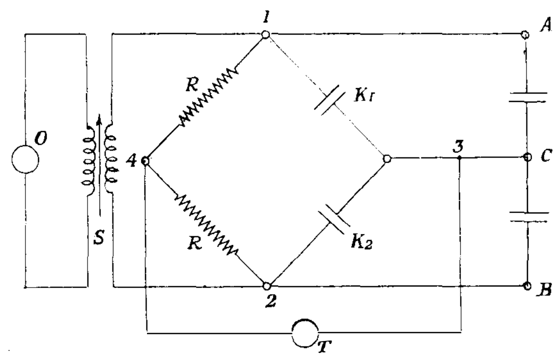


FIG. **1** *b*

The condenser is calibrated to read K_2-K_1 directly.

In the modification introduced by the writer,[1] the connexion between the moving plates and the point 3 is broken, and a series condenser of capitance K_e is inserted (Fig. **2**a). When the bridge is balanced, let the new capacitances of the differential condenser be K'_1 and K'_2. Using the star-mesh transformation theorem,[2] the star 01, 02, 03 is converted into the

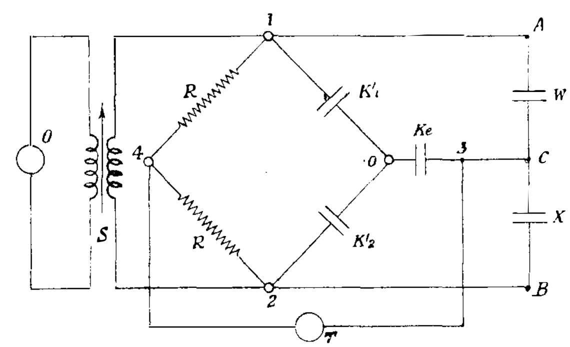


FIG. **2** *a*.

corresponding mesh, and the network shown in Fig. **2**b is obtained. The equivalent capacitance between 1 and 3 is $K'_1\,K_e/(K_e+K'_1+K'_2)$ and between 2 and 3 is $K'_2K_e/(K_e+K'_1+K'_2)$. The capacitance $K'_1\,K'_2/(K_e+K'_1+K'_2)$ introduced across 1 and 2 acts as a shunt to the supply and does not affect the bridge balance. The condition for balance is

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[1] Patent No. 317,228.

[2] A. E. Kennelly, " Electrical World," 1899, Vol. 34, p. 413. A. Rosen, J.I.E.E., 1924, Vol. 62, p. 916.

$$\frac{K'_1 \, K_e}{K_e + K'_1 + K'_2} + W = \frac{K'_2 \, K_e}{K_e + K'_1 + K'_2} + X,$$

i.e., $W - X = (K'_2 - K'_1) \dfrac{K_e}{K_e + K'_1 + K'_2}$ .... (2)

Now the sum of the capacitances in a differential condenser is constant,

i.e., $K_1 + K_2 = K'_1 + K'_2 = K$, where K is a constant.

Thus, $K'_2 - K'_1 = (K_2 - K_1)\ (K + K_e)/K_e$ ....(3)

Hence by the introduction of the series condenser K_e the original reading $K_2 - K_1$ has been multiplied by the factor $(K + K_e)/K_e$; this factor is independent of the position of the moving vanes, and can be made

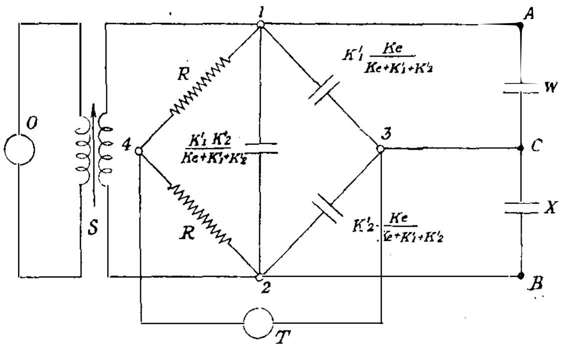

FIG. 2b.

to have any convenient value by the suitable choice of K_e. For example, for a factor of 10 with K=600 pF, K_e would be 66.7 pF.

The series condenser K_e may conveniently be a small good quality mica condenser and can be incorporated with the differential condenser; in fact, two or three auxiliary condensers can be provided, so that by means of a switch the choice of several ranges is available.

In the differential condenser provided in a test set for trunk telephone cables, there are two ranges of ± 600 and ± 180 pF, divided every 5 and 2 pF respectively. The lower range is obtained by means of a switch operated by a cam attached to the lower end of the condenser spindle. The higher range is effective over 180° movement of the vanes, during which the blades of the switch are in contact and the series condenser is short-circuited; by continuing to rotate the spindle, the switch is opened and the series condenser is brought into the circuit, giving the low range which occupies the second half revolution. Connexion is made to the moving vanes by means of a brush, so that no stops are necessary, and the change of range can be made at either end of the scale. The two scales are engraved on a dial attached to the spindle, and the appropriate one is brought into view through a window in the panel.

During the process of testing, the point 3 is sometimes connected to earth. It is therefore essential that the moving vanes shall not possess any direct capacitance to earth, which would alter the value of the series condenser, and thus affect the calibration of the lower range in the earth tests. This difficulty is overcome by completely screening the variable air condenser and enclosing the series condenser inside the metal case, which is connected permanently to 3. There is thus no direct capacitance between the moving vanes and anything outside the screen. The case has of course to be insulated from the earthed metal panel on which it is mounted.

Differential Resistors.

It does not appear to be widely known that the scale of a differential resistor can be opened out by putting another resistor in parallel with it. The method is an inversion of the arrangement described above for condensers; on inversion, admittances (capacitances) become impedances (resistances), and a star network become a mesh. Fig **3**a represents as an example a differential resistor

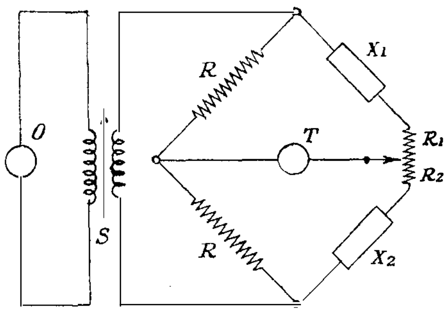

FIG. 3a.

used in a common form of resistance bridge. R R are equal ratio arms, and X_1, X_2 the resistors being compared. (The arms X_1, X_2 may be reactive, in which case only the resistance components are considered, it being understood that the reactive components are balanced by other means.) If R_1 and R_2 are the values of the parts of the differential resistor, then

$$X_1 + R_1 = X_2 + R_2$$

i.e., $X_1 - X_2 = R_2 - R_1$ .... (4)

In Fig. **3**b a resistor R_e is placed as a shunt across the differential resistor, and the bridge re-balanced.

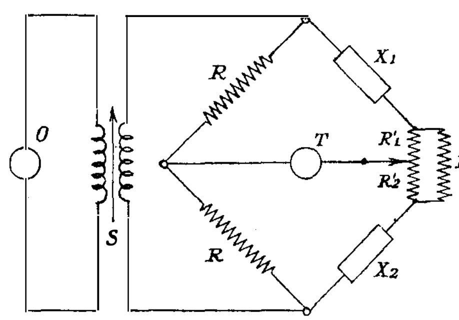

FIG. 3b.

The effect can be seen by replacing the mesh R_e, R'_1, R'_2 by the equivalent star,[3] Fig. **3**c. The new condition for balance is

$$X_1 + R'_1 \, R_e/(R'_1 + R'_2 + R_e) = X_2 + R'_2 R_e/(R'_1 + R'_2 + R_e)$$

i.e., $X_1 - X_2 = (R'_2 - R'_1) R_e/(R'_1 + R'_2 + R_e)$ ..... (5)

Hence $R'_2 - R'_1 = (R_2 - R_1)\ (R'_1 + R'_2 + R_e)/R_e$ ... (6)

Now $R'_1 + R'_2$ is constant and thus the factor $(R'_1 + R'_2 + R_e)/R_e$ is constant and independent of the position of the slider; by a suitable choice of the

[3] A. E. Kennelly, *loc. cit.*

shunting resistor R_e this factor can be given any convenient value. It will be noticed that a resistance $R'_1\, R'/(R'_1+R'_2+R_e)$ is introduced into the moving arm, but as this is in series with the detector, it does not affect the condition for balance.

This method of opening out the scale for lower readings of a differential resistor by shunting it applies to the more complicated Kelvin-Varley

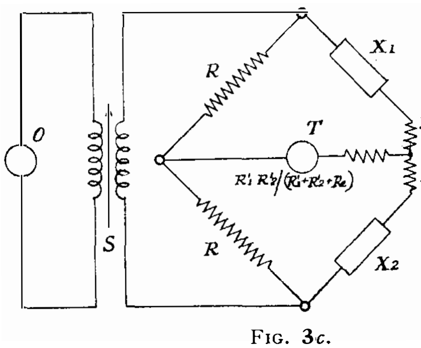

FIG. 3c.

potentiometer as well as to the simple slide wire.

The trunk test set mentioned above has a slide resistor which is used for measuring the unbalance resistance between the wires forming a pair. Referring to Fig. **4,** the variable ratio arms consist of a potentiometer of 1,000 ohms between two 9,500-ohm resistors. The pair to be measured, A B, is joined across the ratio arms, and the two other wires of the quad are used for the return to the bridge, all four being joined at the far end.

If r is the resistance between the slider and the mid-point of the potentiometer,

$$\text{then } \frac{r+10{,}000}{r-10{,}000} = \frac{R_a}{R_b},$$

$$\text{i.e., } \frac{R_a - R_b}{R_a + R_b} = \frac{r}{10{,}000}$$

The dial of the potentiometer can thus be calibrated to read the out-of-balance resistance directly

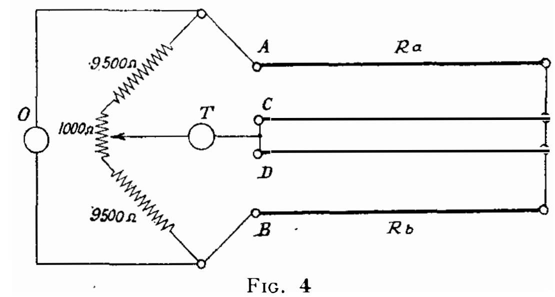

FIG. 4

as a percentage of the loop resistance. By shunting the potentiometer with a resistor of 1/9 of its value, the scale is opened out 10 times. As actually arranged, the shunt is connected in the normal position of a key-switch, and the dial is calibrated for the low range of ± 0.5 per cent., which is most frequently used. On throwing the switch, the high range of ± 5 per cent. is obtained, and the readings have to be multiplied by 10.

Post Office Telecommunications Convention 1937

WE are pleased to announce that the second Telecommunications Convention is to be held this year during the period June 12—June 19. Again, the venue is to be " The Hayes," Swanwick.

Sir Thomas and Lady Gardiner have kindly consented to open the Convention on the evening of Saturday, June 12.

The arrangements are in the hands of a small Committee under the Chairmanship of Mr. B. O. Anson, Assistant Engineer-in-Chief.

The field to be covered is extensive and the Committee fear that there may be some who through inadvertence fail to receive invitations. Any member who is interested and who has failed to receive an invitation by the end of the first week in February is asked to make application to the Hon. Secretary, Mr. C. W. Gerrard, L.T.S., Union House, E.C.1.

Intending visitors are asked to signify their intention to be present at the earliest possible date, as the accommodation is unfortunately limited to about 300 persons.

Recent years have seen considerable development of the Post Office services and there seems every prospect of continued development. Changes in organization are in progress. These conditions have brought about a much closer association between the various branches of the Post Office. As time goes on the need for co-operation on the part of individual members of the service will increase. Co-operation can be most effective if based on friendly relationships between individuals. The Convention will provide a unique opportunity for members of all branches to meet socially and to cultivate these personal relationships.

We take this opportunity of wishing the organizers of the scheme full success in this, its second venture.

An Outline of the Principles of Atomic Physics

IV.—The Positron and the Neutrino

F. C. MEAD, B.Sc., A.R.C.S.

The fourth and concluding article of this series deals with the theoretical conception of the positron and its subsequent experimental discovery. The discussion of quantization and spin leads to a discussion of the neutrino hypothesis and some general concluding remarks

The Positron.

In the second article of this series we noted the fact that the lightest particle carrying a positive charge which is to be found in a conducting gas is the proton. This particle was identified with the nucleus of the lightest atom, that of hydrogen. We shall now proceed to be introduced to a much lighter particle carrying a positive charge. This particle is in many respects the positive counterpart of the negative electron. Its charge and mass are known to approximate very closely to that of the negative electron, experimental measurements showing that the value of q/m_0 for this positive particle is within 5 per cent. of the corresponding value for the negative electron. It may be that the values are exactly equal, but the possibility of experimental error in the measurement so far made does not allow us to state this as a known fact at the present time. The two particles have many properties in common and the positive particle has accordingly been known as the " positive electron." In the U.S.A. this term is still often used. Recent work has, however, led to the belief that there may be important differences in properties and we shall therefore adopt the nomenclature now usually followed in this country which assigns the name " positron " to the positive particle, reserving the term "electron " for the negative particle.

Like some of the other elementary particles, the existence of the positron was postulated by theory before its existence was shown to be consistent with experimental observation. In order to explain the known experimental laws of atomic physics in a quantitative manner, Dirac had developed a mathematical theory culminating in what is known as the Dirac Electron Equation. Like many other mathematical theories, any attempt to express it in physical terms involves somewhat fantastic ideas. This, however, must be tolerated, remembering that the general lines of the theory are consistent with many known facts but that the theory itself is by no means final as it is not yet fully developed. According to Dirac's theory what is generally known as free space, i.e., space empty of matter and fields of force, consists of a closely packed mass of negative electrons. He postulates further that these electrons can exist in states of positive or negative energy. In a positive energy state the existence of the electron is detectable by experiment, while in a negative energy state the existence is not detectable. In the mathematical discussion the mass becomes negative and the charge does not obey the usual laws of electromagnetism or electrostatics.

The closely packed mass of negative electrons which constitutes free space is assumed to be in a negative energy state. Under certain conditions, say, by the application of an electromagnetic field, one of these electrons may pass into a positive energy state. It then appears as an ordinary electron and is detectable experimentally. In leaving the state of negative energy, however, it leaves what can best be described as a " hole " in the closely packed mass of electrons with negative energy. Dirac's equations indicate that this "hole" will manifest itself relative to the surrounding space as an electron with positive charge and positive mass, and hence positive energy. To be consistent with the rest of his theory the occurrence of these "holes" will be rare and will have a maximum duration of the order of 10^{-6} second. These " holes " are evidently Dirac's picture for the particle which has since been experimentally detected and called the positron.

Further, the existence of the positron for such a short time and its disappearance are accounted for on an energy basis provided it can be assumed that a positron and a negative electron will coalesce on mutual contact and suffer complete annihilation as far as their masses and charges are concerned. The mass of matter disappearing is assumed to be replaced by the energy of two photons which are created by the coalescence. The necessity for assuming the creation of two photons rather than one arises in order to preserve the conservation of momentum. If the positron and the electron are at rest, or moving with only small speeds, the recoil due to the emission of one photon must be balanced by that due to the emission of a second photon in the opposite direction. This remarkable prediction of the annihilation of matter and its replacement by radiant energy has since been experimentally observed to occur in some circumstances which we will examine later.

The positron was first detected by Andersson in 1932, that is about two years after the publication of Dirai's theory, as a result of an investigation into the nature of cosmic rays. We have already had occasion to mention these rays in connexion with the description of the Geiger counter in the previous article. Andersson was using a Wilson cloud chamber to study the tracks caused by cosmic rays and was attempting to measure the energies of any charged particles in the rays by observing the radius of curvature of the track when a magnetic field was applied. This method is basically similar to that explained in the first article of this series when a magnetic field was used to deflect a stream of charged particles for the determination of q/m for cathode rays.

It was there shown, in deriving equation (4), that if a particle of mass m grams and charge of q coulombs is moving with a velocity of v cms. per second in a magnetic field of H c.g.s. units, it is bent into a circular path of radius r cms. in accordance with the equation

$$H\,q\,v \times 10^7 = \frac{mv^2}{r}$$

whence $q/m = \frac{v}{Hr.\ 10^7}$ .... (10)

We have already described in the second article of the series how, in a Wilson cloud chamber, the nature of the track enables an observer to recognize at once whether the particle causing the track is a heavy one such as a proton or a light one such as an electron. In other words since the charges of the proton and the electron are equal but their masses differ by a factor of 1840, their q/m values also differ by a factor of 1840, and the nature of the Wilson cloud track enables the observer to decide which value of q/m he must use in equation (10). Inserting this value in equation (10) he can accordingly calculate the speed v of the particle by observing the values of H and r. Knowing the speed and again deciding from the nature of the cloud track whether the particle is a proton or an electron, he can assume the relevant mass and calculate the energy of the particle. Prior to Andersson's experiments no deviation of the tracks of cosmic rays had been observed in a magnetic field and it had accordingly been assumed that the tracks were either those of photons which would show no deviation, or that if they were the tracks of charged particles, the energies were so high that the deviations were too small to observe in the magnetic fields employed. The magnetic fields used would have detected particles with energies of the order of 10^7 equivalent electron volts. Andersson's apparatus was capable of producing a magnetic field of 24,000 c.g.s. units and this would produce a measurable curvature on the path of a charged particle with an energy of 10^9 equivalent electron volts.

On August 2, 1932, Andersson obtained a photograph of a single particle which by the curvature of its path and its direction of motion must have been positively charged, and whose cloud track indicated a small mass of the same order as that of the electron. In addition, the particle was capable of penetrating a lead plate 6 mm. thick which had been placed in its path and still emerged from the lead plate with an energy of 23 million equivalent electron volts. The curvature of the track before it passed through the lead plate corresponded to an energy of 63 million equivalent electron volts. This amount of energy is so large that it has been asserted that no apparatus ever built by man could impart this energy to an electron or any other elementary particle. The fact that a lead plate was in the path of the particle was a fortunate one. It enabled the direction of the motion of the particle to be confirmed without doubt. Since energy would inevitably be lost in traversing the lead plate, the path on emergence is more curved because it must have been traversed at a lower speed. This evidence together with that of the direction of curvature of the path confirms without any doubt the positive charge of the particle causing the cloud track. The experimental evidence was confirmed in March, 1933, by Blackett and Occhialini at Cambridge, and since that date positrons have been observed to be ejected in certain nuclear transformations which confirms their existence apart from cosmic ray phenomena. The existence of the positron having been confirmed, the interest of Dirac was aroused, who foresaw the immediate possibility of the appeal to experiment to confirm his further prediction of the formation of a pair of photons from the coalescing and annihilation of a positron and an electron. We have seen in the second article of this series in discussing the equivalence of mass and energy that, in accordance with equation (7), the mass of an electron represents a quantity of energy equal to 511,000 equivalent electron volts; if, therefore, a positron and an electron coalesce, the available energy is about 10^6 equivalent electron volts. Experiment shows that during the scattering of gamma rays by atoms, in addition to the normal Compton effect (Article II, page 107) photons are emitted with an energy of about 500,000 equivalent electron volts. In 1934, Klemperer found by experiment that when positrons are absorbed by a sheet of metal, a pair of photons is emitted in opposite directions, each with an energy of 500,000 equivalent volts. This is in striking accordance with Dirac's theory and helps to justify the rather fantastic ideas which we have previously seen to be involved.

A further important fact which stresses a requirement of the principle of the conservation of momentum is brought out by the conditions which experiment indicates are required for the converse of the above phenomenon, namely, the conversion of radiant energy in the form of photons into matter. In this case, in order exactly to reverse the process of the previous phenomenon, we should need to have two photons proceeding in opposite directions in the same straight line so as to effect a head on collision. The probability of such a collision is naturally extremely small, so small in fact that it is for practical purposes impossible. It has already been mentioned that positrons have been observed outside of cosmic ray phenomena. Some of these cases include the bombardment of certain metals such as beryllium and aluminium with high energy alpha particles and are thus independent of formation by photons. Other cases include the bombardment of some of the heavier elements such as thorium and polonium with high frequency photons in the form of gamma rays, and experiment shows that the emission of positrons is dependent upon the energy of the photons. If the energy of the photons is less than 10^6 equivalent electron volts, no positrons are emitted. This seems to suggest that each photon probably gives rise to a pair of particles, one positron and one electron. When the energy of the photons exceeds 10^6 equivalent electron volts, we should expect the energy difference to appear as kinetic energy in the electron and the positron. Pairs of particles are in fact observed and the sum of the kinetic energies is never greater than the difference between the actual energy of the photon and 10^6 equivalent electron volts.

The experimental facts are accordingly observed to be consistent with the principle of the conservation of energy. We meet a difficulty, however, in accounting for conservation of momentum for the momenta of the two generated particles cannot possibly be equal to that of the generating photon. This is seen to be the case by an examination of the energy and momentum equations. If the two equations are both assumed to hold, the original assumptions are contradicted and we appear to have a case of *reductio ad absurdum*.

This state of affairs is, however, very fortunate indeed, for it draws our attention very forcibly to an important condition for the transmutation of photons into matter. In no case have photons been experimentally observed to give rise to positrons and electrons in free space. The phenomenon has only been observed when the photons impinge on matter containing very heavy nuclei. Under these conditions the heavy nucleus may be said to act as a catalyst, and while not being effected appreciably as far as energy is concerned, its relatively heavy mass enables it to absorb a large amount of the momentum of the photon, and the recoil thus produced in the nucleus makes the transformation consistent with the classical principle of the conservation of momentum. Actually by discussing the matter on the lines of quantum mechanics one would very likely find that the conversion of a photon into a positron and electron in free space is not an actual impossibility but a very small probability, so nearly approaching zero as to be extremely rare, but not entirely to be ruled out. The author does not know at the time of writing whether any of the theorists have as yet tackled the problem, which is a very difficult one, but in any case it will only be a matter of time before the solution is obtained.

Before leaving the positron, attention must be drawn to a very important phenomenon in which a fundamental difference between its properties and that of the electron is stressed. So many writers seem to draw a close analogy between the properties of these two particles that an impression is given that they are as it were identical twins, differing only in the sign of their charge. This impression must be avoided. In the author's article on Wave Mechanics[1] a description was given of the diffraction of electrons. When a stream of electrons passes through a thin film of metal it is diffracted just as if the electrons were X-rays, a photograph of the diffracted beam showing a series of concentric rings. According to Rupp the positron does not exhibit this effect, the photographs of the positron beam showing random scattering instead of regular diffraction. These experiments have not been repeated by other observers as far as the author is aware at the time of writing, and therefore the result should not be taken as conclusive. It is interesting, however, to note that the result appears to be consistent with a theory of the nature of electricity propounded by J. J. Thomson as early as 1928 before the existence of the positron had even been postulated. According to Thomson the " atoms " of positive and negative electricity will differ in certain fundamental properties. The positron indeed has some of the character of the photon, it has not yet been isolated at rest. While it has kinetic energy it is observable but in the short space of time in which this energy is dissipated by ionization (approximately 10^{-6} second), like the photon it disappears and apparently coalesces with the first electron that comes near to it. This short duration, corresponding to a path in air of about 500 cm. at the speeds at which it is usually observed, effectively prevents the positron from taking any part in the mechanism of electrical conduction in either gases, solids or liquids. The electrons which act as carriers of the current in electric discharges all move at comparatively low speeds, and it is this which accounts for the fact that the positron has not been observed in discharge tube phenomena.

[1] *P.O.E.E.J.* Vol. 27, Pt. 1.

Quantization and Spin.

We have already had occasion to discuss the quantum theory of radiation, and it has been seen how radiation takes place in small units or quanta hf, where h is a universal constant and f is the frequency of radiation. Now the radiating body which emits these quanta of energy is the atom and in view of the observed fact that different sorts of atoms radiate energy at different frequencies, but that different atoms of the same sort always radiate energy at the same frequencies, it is clear that the character of the radiation is closely bound up with the structure of the radiating atom. As a matter of fact most theories of atomic structure have had their origin in attempting to account systematically for the spectra of emitted radiations. One of the fundamental experimental facts is that all atoms of the same element emit radiations in series of frequencies, and thus give rise to a regular pattern or series of lines in their spectra.

These facts lead to the general conclusion that the atom can exist in any one of a number of definite states of energy, the energy values assigned to these states depending on its structure, and that when the atom is suitably excited its energy passes from one state to another in a series of jumps; at each jump, a quantum of energy is emitted equal to the difference between the energy of the two states. Thus, if we observe spectral lines with frequencies f_1, f_2, f_3, f_4, ... we assume that the atom is capable of existing in a series of energy states, the energies in each state being in increasing order of magnitude, w_0, w_1, w_2, w_3, and so on,

such that
$$hf_1 = w_1 - w_0$$
$$hf_2 = w_2 - w_0$$
$$hf_3 = w_3 - w_0$$
and so on.

This is equivalent to asserting that each spectral line, that is each frequency of radiation, may be regarded as a beat frequency between two other frequencies, each of which is associated with a particular energy state of the radiating atom.

It appears that the atom is only capable of existing in one or other of this series of energy states and accordingly the values of the energies are known as " permitted values." These "permitted values" can be accounted for, by assuming that the electrons in the atom are revolving round the nucleus in certain " permitted " orbits, each orbit being characterized by a value of angular momentum which is an integral multiple of a certain minimum value. This leads us to a definition of the term " quantization." A certain variable is said to be quantized when it is confined to any one of a series of permitted values, each one of which is an integral multiple of a particular unit.

We have seen above that the theory of series of lines in spectra requires the quantization of angular momentum for the orbital electrons in an atom. We shall shortly encounter other properties of the electron and the other elementary particles which appear to be quantized if experimental facts are to be accounted for.

Spectrum analysis also reveals that with certain elements, notably the alkali metals, e.g., sodium, potassium, the lines in the principal series are double. The well-known sodium D line in the orange part of the spectrum is a notable example. The only feasible method of explaining these " doublets " in terms of atomic theory is to assume that the electron and the other elementary particles are spinning, and in fact possess angular momentum about their axis of rotation. The consequence of a spinning electric charge, which is equivalent to a series of circular currents round the axis of rotation, is inevitably a magnetic field, and in consequence the electron on this hypothesis will possess a magnetic moment. The requirements of the quantum theory involve the " quantization " of the angular momentum and also of its direction. That is, there are certain " permitted " values of angular momentum and certain " permitted " directions for the axis of rotation. We have not the space to enter into this discussion in any detail but must pass to a consideration of the consequences of spin in nuclear reactions, for we must now seek to justify conservation of angular momentum in addition to linear momentum in discussing the mechanics of collisions between the elementary particles and atomic nuclei. For convenience the value of spin is always expressed in units equal to $h/2\pi$, since quantum requirements involve all known spins in being a simple multiple of this unit.

The Neutrino Hypothesis.

We now come to a hypothesis according to which there should exist yet another elementary particle, and it arises in connexion with the attempt to explain the phenomenon of β-decay or the emission of electrons by radioactive nuclei. The electrons emitted by a given nucleus do not all have the same energy, neither are the energies quantized. The values appear to be uniformly distributed over a range of energies from zero to a definite maximum value. This observed fact is difficult to reconcile with a second observed fact, namely, that the parent nucleus before and after the emission of an electron has exactly determined quantized energies. There appear to be two, and only two, ways of accounting for the state of affairs. Either the principle of the conservation of energy does not hold for this phenomenon, or another uncharged particle is emitted with the electron. The energy could then be divided between this particle and the electron in order to account for the experimental observations. This new hypothetical particle is known as the neutrino, and so far all we know about its properties is that it must have energy and no charge. In view of the fact that the spin of the emitted electron is $\frac{1}{2}$ and that of the nucleus remains unchanged, we must also assume that the spin of the neutrino is $\frac{1}{2}$. This latter requirement is a piece of additional evidence in favour of the existence of the neutrino, if it is ignored the principle of the conservation of angular momentum is violated. All this evidence, however, is hypothetical and merely an attempt to explain facts; before the neutrino can be accepted as an additional elementary particle, some more direct evidence of its separate existence must be sought.

The experimental detection of such a particle as the neutrino is very difficult. It must have a very small mass compared with the electron, and the fact that it is neutral precludes its causing any detectable ionization. The only possibility of detecting it seems to be the measurement of the recoil in the nucleus due to the momentum of the emitted neutrino. Careful measurements of this have been made without result, and in the opinion of many authorities the physical existence of the neutrino has now been shown to be mythical. What is probably the best point of view to adopt is that the necessity of the existence of the neutrino has been established, but that the required physical properties prevent its detection. This puts the neutrino in the same philosophical position as the ether. It is a convenient hypothesis, but its existence cannot be proved or disproved. Philosophically then, it has no real existence, because it is an axiom of scientific thought that real existence is dependent upon such properties as are capable of detection and measurement. The hypothesis is, however, valuable in enabling us to complete our mental picture of β-decay. In the words of Professor Andrade, " It (the neutrino) is, as it were, a bag in which we can put all the troubles together, although it may have no more material existence than the troubles. Whether we say that it accounts for the failure of the conservation laws, or is just a way of expressing the failure of these laws, is a matter of taste."

Before leaving the neutrino, we must mention that the consequences of assuming the physical existence of the neutrino would lead us to yet another particle, which has been called the " antineutrino." It is possible to construct an equation exactly analogous to Dirac's Electron Equation to account for the properties of the neutrino. In consequence of the existence of this equation, the solution of which involves positive and negative states of energy, just as the transition of an electron from a negative to a positive state left a "hole" with the properties of a positron, so the transition of a neutrino from a negative to a positive state leaves a "hole" with the properties of an "antineutrino." Since the neutrino has no charge, the antineutrino will not be physically distinguishable from the neutrino, the only feasible difference being associated with such details as the duration of its existence and its wave properties.

Recently the question has been raised by the theorists of the possibility of the existence of a negative counterpart of the proton, which has been called the "negatron," that is a particle with a mass of the same order as the proton but carrying a negative charge. So far, however, there appears to be no theoretical necessity for the existence of such a particle. The postulation of its existence does not help to clear up any outstanding difficulties and little or no interest has been shown in the matter of the possibility of its experimental detection.

Conclusion.

It is hoped that this outline of the principles involved in theoretical and experimental atomic physics will have made clear the type of evidence upon which the modern theory of the constitution of matter is based. An attempt has been made in these articles to make a clear distinction between two types of theoretical conception.

(1) That of such particles as the electron.

(2) That of such particles as the neutrino.

On the one hand, the electron and similar particles can be shown by direct experimental observation to have real independent existences at least in so far as they are carriers of electric charge and mechanical energy We must avoid picturing their physical existence too vividly in terms of the properties of such material particles as are capable of direct observation by optical vision. In particular the idea of mass and volume must be restricted. From the fact that they have momentum and carry mechanical energy we can certainly associate a value of mass with them, but the phenomenon of the diffraction of electrons just as if they were waves should remind us that they are not just pieces of matter of a definite density equal to the ratio of their mass to their volume. On the other hand, we have the neutrino, which appears to be quite hypothetical and probably has no real existence in the sense that **it is** detectable as a separate entity by experimental observation. Both types of particle, however, have their uses in helping us to systematize our knowledge of the physical world, and to make use of that knowledge for the benefit of mankind, which is our business as engineers.

Mobile Exchange

The development is being considered of a mobile automatic exchange for use mainly when the requisite number of prospective subscribers for a new U.A.X. has been obtained, but where some considerable period must elapse during which a site must be acquired, a building erected and the exchange equipment installed. Also cases arise where for various reasons discontinuance of a small manual exchange becomes imperative and the rapid replacement of the exchange by a U.A.X. is the most practicable solution.

The Mobile Exchange visualized would comprise a standard U.A.X. equipment housed in a weatherproof body mounted on a trailer chassis. It is probable that this chassis would be equipped with independent torsion bar springing, the use of which would ensure the minimum of strain on both bodywork and contents when transported over rough ground.

The size and design of the trailer would have to be such that it could readily be handled by railway companies so that when required it could be moved from site to site by a combination of rail and road transport.

Such a mobile exchange would need to be self-contained and should require for its installation little labour other than temporary connexions to permanent line plant.

The exchange equipment would probably be of the Unit Auto. No. 12 type and would comprise an "A" unit, a "B" unit and an Auxiliary Unit. Such equipment would enable service to be given to a maximum of 45 subscribers who would then enjoy the same facilities as are provided on a standard U.A.X. of the No. 12 type.

The mobile exchange would need to house its own power plant. The batteries would be of the traction type and would be charged by means of a generator driven by a petrol or heavy oil engine. For cases where a public electricity supply is available a rectifier unit would probably be included.

The New Telegraph Terminal at Bangor

S. G. LEWIS, A.M.I.E.E.

A brief description is given of the combined VF Telegraph terminal and repeater equipment installed in the Bangor H.P.O. which replaces the Llanfair Repeater Station

Introduction.

ON May 1st last, an eighteen-channel voice-frequency telegraph[1] link was opened for service between Liverpool and Bangor. In itself, this is commonplace enough, but the occurrence was memorable in that it allowed a further step to be taken in the improvement of telegraphic communication between this country and Ireland, and the closing of Llanfair Repeater Station.

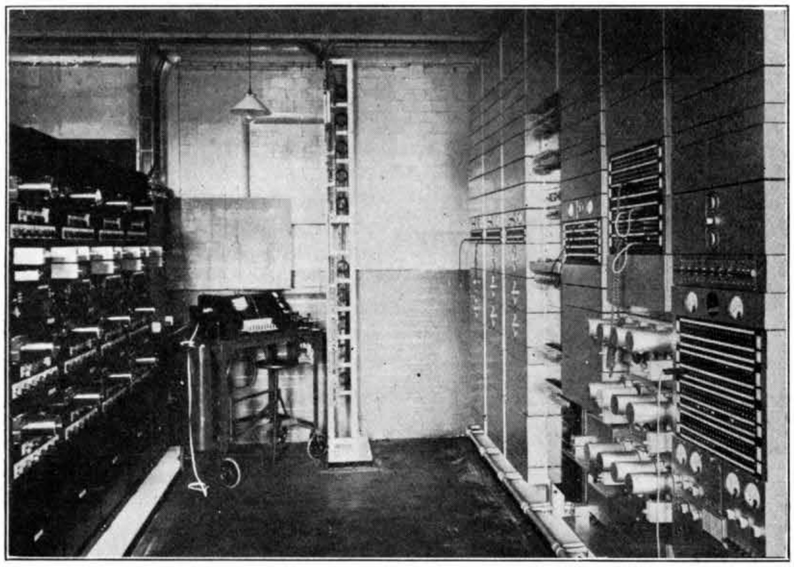

FIG. 1.—BANGOR TELEGRAPH TERMINAL.

FIG. 2.—OLD REPEATERS AT THE LLANFAIR STATION.

The Llanfair Station was brought into service in 1902 as a result of the introduction of the Wheatstone automatic system of working on the Irish circuits, and to meet the requirements of this method of working eleven high speed simplex/duplex repeaters were installed.

In 1934 the Anglo-Irish Free State circuits were converted to Teleprinter working and the repeaters previously arranged to provide for "up station" or "down station" working as required were modified for universal working, whereby signalling battery arrangements were standardized whatever be the condition.

The circuits feeding Llanfair were routed overhead from Liverpool along the North Wales coast, and, in consequence of the exposed situation were subject to interruption, particularly during the winter months.

The New Equipment.

The extension of the underground cables from Liverpool to Bangor provided an opportunity for the introduction of voice-frequency working between these cities and led to the decision to instal a new repeater station at the voice-frequency terminal at Bangor. At the same time it was decided to provide repeater equipment more in keeping with the voice-frequency apparatus. Thus the duplex telegraph apparatus is panel mounted on standard racks, each rack carrying complete equipment for three circuits. The radical change which has been effected is illustrated by Figs. **1** and **2**. The new form of the repeaters at Bangor is shown on the left of the picture of Fig. **1** and a general view of the old repeaters at the Llanfair Station is given in Fig. **2**.

In the latter station each repeater board accommodated apparatus to provide simplex or duplex

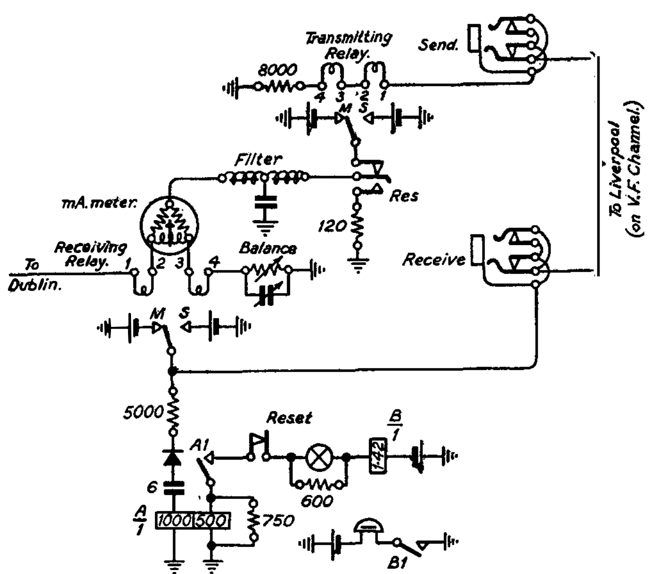

FIG. 3.—CIRCUIT ARRANGEMENT.

working for both the landline and submarine cable sides of the circuit, together with repeater alarms and leak circuits for testing, balancing and observation purposes. With the introduction of VF working on the landline side of the repeater station, the circuits are, with the exception of part-time newspaper circuits, now worked on a two-way basis, and since at Bangor it was necessary to provide for duplex working on the submarine side only, the opportunity was taken to simplify the circuit arrangements as shown in the schematic diagram (Fig. **3**).

It was considered desirable to introduce a transmitting relay between the VF receive relay and the submarine cable to eliminate variations in the duplex balance at Dublin when testing or observing on the circuit at Bangor. The repeater alarm circuit is a departure from what has hitherto been recognized as the standard, but is operated in a similar manner, *i.e.*, by the distant station applying a positive battery to line for a period of 12-15 seconds. The cable receive relay tongue is held on the spacing contact during that period and the 6 μF. condenser is slowly charged through the rectifiers in the reverse direction. On the restoration of the relay tongue at the end of the period the discharge current from the condenser flowing through the rectifiers operates the alarm relay A. This relay is held in the operated position by its locking coil until restored by the operation of the reset key.

Facilities are provided on the repeater racks for the use of a common testing and observation set using a portable teleprinter (shown in Fig. **1**) which can be connected as desired through the agency of the testing jacks and plugs and cords. The cable duplex balancing is carried out by means of a portable centre-zero voltmeter connected across the relay coils and an adapter unit comprising a morse-key and sounder plugged into circuit in place of the testing teleprinter.

A rack adjacent to the repeater racks accommodates the fuses and battery feed resistances for the transmitting and receiving relays, and for the repeater alarm circuits. Signalling voltages are supplied from an 80 + 80 volt generator.

Facing the repeater racks in Fig. **1** are the racks accommodating the eighteen-channel voice-frequency equipment. Eleven of the channels are used for Anglo Irish communications and four are allocated to provide teleprinter circuits between Liverpool and Bangor, Carnarvon, Holyhead and Pwllheli.

In order to provide simplex working on newspaper circuits, arrangements are made by means of switches controlled from the London end of the circuits to connect the cable to either the send or receive VF channel according to the direction of the traffic.

The actual conversion from Llanfair to Bangor was made on Sunday, May 24, 1936.

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[1]Voice Frequency Telegraphy. Green Paper, No. 26.

A V.F. Multi-Channel Telegraph System. P.O.E.E.J Vol. 21, p. 243.

Carrier Telephony IV

G. J. S. LITTLE, B.Sc., A.M.I.E.E.

In the last article in this series on Carrier Telephony, the author discusses wide band carrier systems with co-axial line conductors

The Economics of Carrier Circuit Provision.

THE last article in this series gave some indication of the principles involved in the 12-channel underground cable carrier systems which, one may expect, will form an important part of the trunk network of this country. It is possible to deal here only in a general way with the economics of circuit provision, but some reference to this aspect of the matter is desirable.

Modern methods of providing long telephone circuits over land, apart from radio, may be considered as being based upon a uniform system of conductors (such as an open wire line, loaded cable, etc.) connecting the terminal points of the circuit, with amplification at regular intervals. Broadly, if the circuit is long enough to include several amplifying points, the capital cost of providing a circuit apart from the cost of equipment at the terminals can be regarded as being proportional to the length of the circuit. That is, the cost per circuit mile, apart from terminal equipment, is constant for a particular system. This generalization, although convenient, is only approximately true, and should be understood as applying only to groups of circuits of a given size. (Thus the cost of a cable to provide 20 circuits will be much more than 1/5 of the cost cost of a cable to provide 100 circuits). The cost of terminal equipment will be independent of the length of circuit but will vary according to the system employed.

In the 12-channel carrier system the cost per mile of circuit has been reduced at the expense of a considerable increase in the cost of terminal equipment. In general the 12-channel system is suitable for long distance circuits hitherto provided by 4-wire audio circuits for which the cost of terminal equipment is relatively small. The terminal equipment of a 4-wire circuit consists of (a) differential 4-wire termination, (b) signalling equipment, and (c) terminal 4-wire repeaters. Of these (a) and (b) are common also to the 12-channel equipment and of the terminal repeaters under (c) the charge proportional to the circuit length will include the repeaters at one terminal. Excluding equipment common to the two systems one can say broadly that the cost of circuit provision on an audio basis is proportional to circuit length. In the 12-channel case there is a (smaller) charge proportional to circuit length and in addition a fixed charge for terminal equipment which for short distance circuits becomes the dominant factor.

The principal factors affecting the cost per circuit mile of a 12-channel system (apart from terminal equipment) as compared with audio 4-wire circuits are summarized below:—

(a) Those tending to reduce the cost per mile.

1. Twelve channels on each pair instead of one.
2. Twelve channels are amplified in each repeater.
3. Cost of loading coils and loading coil manholes is avoided.
4. Fewer pairs to balance and smaller overall drawing-in and jointing costs.

(b) Those tending to increase the cost per mile.

1. Heavier gauge conductors (40 lb. instead of 20 or 25 lb.) Pairs occupy more space than in normal cables with 40 lb. pairs.
2. The cost per pair of manufacture of cables with a small number of pairs is higher than that of large cables. This is accentuated by providing separate cables for " go " and " return."
3. Repeaters are required at intervals of about 20 miles instead of about 50 miles.
4. Repeaters are more costly than repeaters of normal type.

The considerable reduction in the cost of circuits, apart from the cost of terminal equipment, makes the 12-channel system one which is essentially suitable for long circuits. In determining the minimum length of circuit for which the 12-channel system will be economical, cost of maintenance of equipment at the terminal and intermediate stations is highly important. While, owing to the uncertainty of this and other factors, no final conclusion is possible at the present time several 12-channel schemes of the order of 100 miles in length are now in hand.

The transmission of 12 channels over underground cable pairs is a noteworthy application of carrier principles but the ideas underlying the 12-channel system, carried to their logical conclusion, lead to a system of transmission in which the separate cables for the two directions of transmission are replaced by two specially constructed pairs of conductors capable of carrying as many channels as may be required.

Wideband Carrier Systems.

If we take 4 kc.p.s., as in the 12-channel system, as a bandwidth likely to be adequate for each speech channel, the minimum total band width required for the transmission of 200 channels would be 800 kc.p.s. Reasons which led to the omission of frequencies from 0 to 12 kc.p.s. in the 12-channel system would also be operative here and possibly an allowance of 200 kc.p.s. would be reasonable in a 200-channel system. The transmission of frequencies up to at least 1,000 kc.p.s. (i.e., 1,000,000 c.p.s. or 1 megacycle per sec.) would need to be envisaged for the transmission of 200 circuits. The system would be operating at frequencies extending to the middle of the medium wave radio broadcasting band. Transmission systems of this type have been aptly referred to as wideband systems.

One form of construction which has been adopted for lines for wideband transmission is that of a wire surrounded by a metallic cylinder, used as the return path. This concentric arrangement, shown diagrammatically in Fig. **1**, was thoroughly investigated mathematically many years ago, but it is only within comparatively recent years that its advantages for transmission of high frequency currents have come to be realized. Although it is not clear to what extent the design of submarine cables has influenced the selection of this type of construction for use on

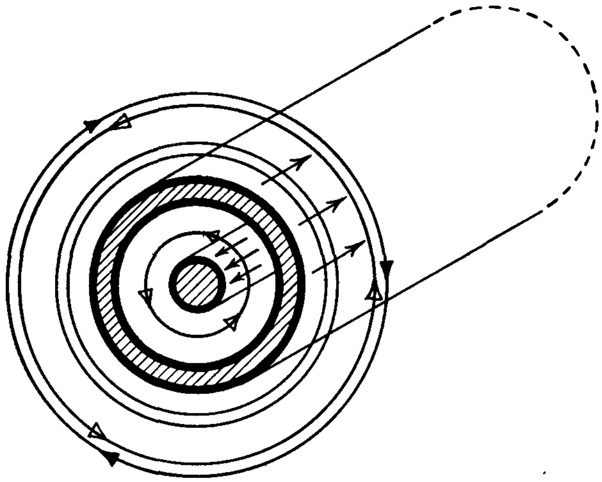


Fig. **1**.—Diagrammatic Representation of Co-axial Line showing Lines of Force in a Plane at Right Angles to the Axis.

land it is convenient to approach the matter from this aspect.

The early submarine cables, used for telegraphy, consisted of a single conductor insulated by gutta percha, the water being used as the return path. Telephone circuits, with occasionally a carrier circuit as well, have been obtained from cables of this type, but the resistance of the return path rises rapidly as the frequency of currents transmitted is increased. In comparatively shallow waters such as, for example, the Straits of Dover, submarine cables with paper insulated conductors are usual and are normally operated as links in the land cable system, with audio repeaters. In deep waters, however, cables of this type are unsuitable and cables with solid dielectric, such as gutta percha, balata, etc., are essential. In cables of the single core type, specially designed for carrier working, the resistance of the return path in the water at high frequencies has been avoided by adding an outer conductor formed of copper tapes applied side by side in a long spiral to form a cylinder around the dielectric. Improved solid dielectrics such as Paragutta are available of which the dielectric losses are very small even at frequencies as high as 100 kc.p.s. Fig. **2** is a cross section of the type of cable laid between Key West and Havana in 1930, a distance of 108 nautical miles on which three carrier circuits were provided initially. Cables of the same design have recently been brought into use to link Australia and Tasmania. This involved two sections each about 80 nauts in length. Two similar cables will be laid in 1937 between Aldeburgh and Domburg for the provision of circuits be-

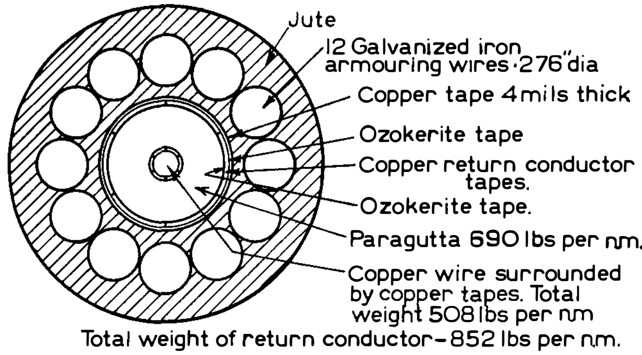


Fig. **2**.—Cross Section of Paragutta Insulated Co-axial Submarine Cable. (Anglo-Dutch and Anglo-Irish Free State 1937 Cables).

tween England and Holland, and a cable across the Irish Sea (Nevin-Howth) for circuits between England and Dublin will be laid shortly afterwards. The attenuation-frequency characteristic of this design of cable is shown in Fig. **3**. The number of channels obtainable will depend upon the length (Anglo-Dutch 82 nauts, Anglo-Irish Free State 65 nauts). It will probably be economical to provide equipment that can deal with attenuations up to 80 db. or more, though the initial installations will not use frequencies above 60 kc.p.s. The heavy cost of submarine cable links makes it economical to operate the audio and lower carrier channels as a subsidiary system below equipment similar in type to that of the 12-channel system. The loss of potential channels below 12 kc.p.s. as in the 12-channel system cannot be justified. Should a similar type of cable be used in a situation requiring a length as short as 20 nauts it is not improbable that frequencies as high as 300 kc.p.s. might be transmitted. The modern concentric submarine cable when used for comparatively short distances is thus a medium of transmission suitable for a wide-band system.

Lines of concentric construction have been in use for some years as feeders for short-wave radio transmitters and in the London-Birmingham co-axial cable this type of construction has been employed to provide lines for a wide-band transmission system. Land lines not having to resist the pressures to which submarine cables are subjected, effort has been directed to supporting the inner conductor in its correct position relative to the outer conductor with the minimum of solid material so as to approach the ideal condition in which the dielectric between the inner and outer conductors is (dry) air.

Transmission over a Co-axial Pair.

Some consideration will now be given to the theoretical aspects of transmission over a concentric or co-axial pair. A direct current flowing in the central wire gives rise to lines of force which are a series of concentric circles. A current returning in the surrounding tube may be assumed to be evenly distributed throughout the cross section of the conductor. The return current also gives rise to a concentric system of lines of force and if the inner conductor is

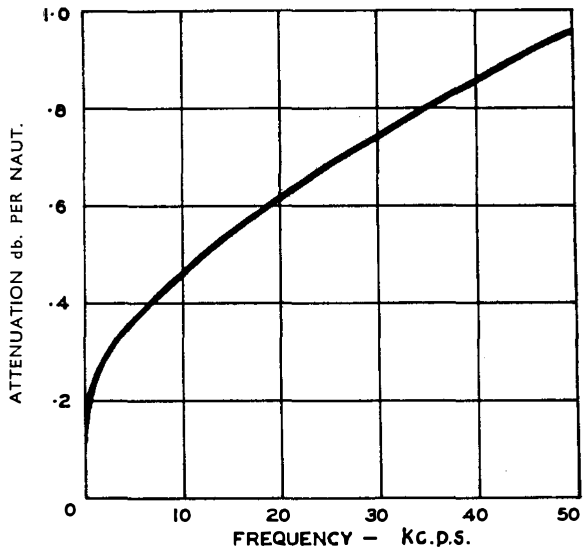


Fig. 3.—Attenuation per Naut. Anglo-Dutch and Anglo-Irish Free State Paragutta Submarine Cables.

accurately centred within the surrounding tube then outside the tubular conductor the two systems of lines of force will cancel out. This is illustrated in Fig. 1. When used to transmit alternating currents of very low frequency, say, 50 c.p.s., substantially the same conditions will apply, but as the frequency is increased, eddy currents in the conductors become more and more pronounced. The effect of interaction of these currents with the currents being transmitted is to increase the density of current near the outer surface of the central wire and near the inner surface of the outer cylinder. At high frequencies, say, above 50 or 100 kc.p.s., this " skin effect " becomes so pronounced that the current can be regarded as almost completely concentrated at the surfaces of the two conductors nearest to each other. In a similar way the currents in the outer conductor due to an external disturbing voltage of high frequency do not effectively penetrate more than a small distance into the outer conductor. The outer conductor thus acts as a shield against disturbing voltages and the shielding becomes more and and more complete as the frequency is raised. To such an extent is this effective that co-axial lines used for opposite directions of transmission can be satisfactorily operated with the outer conductors in contact with each other and uninsulated from earth.

At first sight, since the transmission of direct current in the theoretical case gives rise to no external field one might expect that a concentric system would be fundamentally free from external disturbance. If the effect of eddy currents could be neglected a *uniformly distributed* alternating magnetic field would have no effect on the system as a whole in the ideal case. In addition to physical departures from the ideal in respect of symmetry of shape and relative position of the two conductors the effect of eddy currents is to reduce voltages induced in the inner conductor. Further, in practice, disturbing magnetic alternating fields, due to flow of current in neighbouring conductors, are not uniformly distributed. The degree to which external interference and crosstalk are present is dependent upon the effectiveness of the shielding due to the outer conductor. The shielding, due to the small effective penetration of high frequency currents into the thickness of the outer conductor, can be augmented by a layer of another metal as by a lead sheath or a wrapping of iron or steel tape.

Speaking generally, at frequencies above 100 kc.p.s. the current density in the conductors of a co-axial line falls off so rapidly as the thickness of the metal is penetrated that the thicknesses required for mechanical strength are sufficiently great for the attenuation of the line to be independent of the actual thicknesses. Thus at 100 kc.p.s. the outer conductor would have to be reduced to less than 10 mils to affect the attenuation appreciably. Assuming a greater thickness than this for the outer conductor the attenuation per mile in the ideal case would depend only upon.

1. The inside diameter D of the outer conductor and the diameter d of the inner conductor (see Fig. 4).

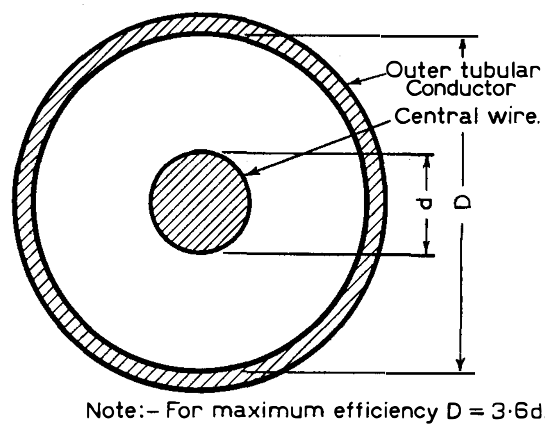


Fig. 4.—Cross Section of Co-axial Line.

2. The conductivity of the materials of which the inner and outer conductors are constructed.
3. The specific inductive capacitance of the dielectric between the inner and outer conductors.

(Note: it is assumed that the conductors are non-magnetic.)

If both conductors are of copper, for a given value of D the attenuation per mile will be least if $d = D/3.6$. Assuming this ratio in the ideal case of air only between the inner and outer conductors the attenuation per mile of a $\frac{1}{2}$-inch co-axial line ($D = \frac{1}{2}$ inch) at 1 megacycle per second (1,000 kc.p.s.) would be 3.0 db. The high-frequency resistance of the conductors is entirely controlled by eddy-current effects with the result that the attenuation is proportional to the square root of the frequency. The theoretical attenuation of a $\frac{1}{2}$ inch co-axial line

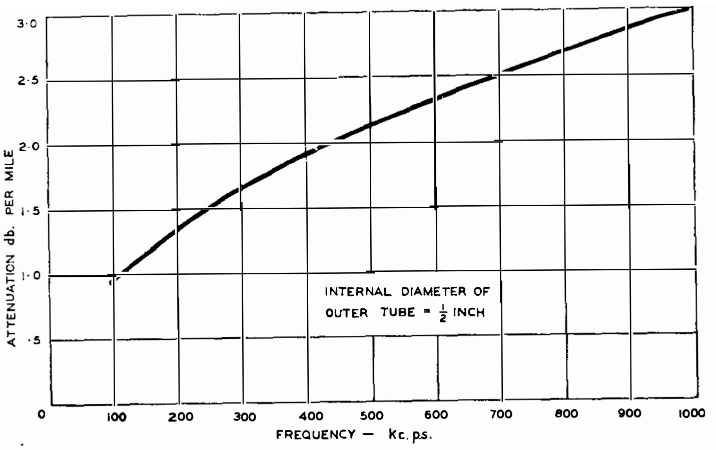


FIG. **5**.—ATTENUATION OF IDEAL CO-AXIAL LINE.

is shown in Fig. **5** . The attenuations of other sizes would be inversely proportional to the diameter of the line (i.e., the internal diameter of the outer conductor).

In an actual line the attenuation will be greater than the ideal, since in order to support the central conductor solid material must be present, increasing capacitance and introducing dielectric loss (leakance). Leakance adds a component of attenuation which is roughly proportional to frequency. The effect of increased capacitance is to increase the attenuation above the ideal in proportion to the square root of the ratio in which the capacitance has been increased.

The Construction of a Co-axial Line.

The construction of a co-axial line, that will approach the ideal, is attended by a number of difficulties and the following may be perhaps regarded as controlling factors.

1. If transport and installation is to be carried out at reasonable cost the co-axial structure must be flexible so that it can be coiled on to drums.
2. The central conductor must be supported without introducing serious dielectric losses and without serious increase of capacitance.
3. To avoid high costs the process of manufacture should be a continuous one.

The following comments refer to known types of practical co-axial cable structures. Flexibility has been obtained by forming the tubular conductor of a number of copper ribbons which may overlap or interlock in some way. In this form of construction a binding to hold the ribbons in place may be necessary. Another method is to form the outer conductor as an extruded lead sheath. This has the disadvantage that a greater overall diameter is necessary due to the lower conductivity of lead compared with copper.

Fortunately it is not necessary for the centre conductor to be absolutely accurately positioned. Probably the method of support which would introduce least loss and least increase in capacitance is some form of disc threaded on the centre wire at intervals, but this can make the even formation of ribbon into a tube somewhat difficult. A continuous method of manufacture is more readily devized if the support is in the form of a spiral of insulating material around the centre wire. Another method of support relies upon kinks in the centre conductor at regular intervals.

The ineffectiveness of screening against external low frequency disturbances and crosstalk is not a serious disadvantage where telephony is concerned as the design of wideband amplifiers with very low harmonic output presents serious difficulties if low frequencies as well as high frequencies have to be transmitted. The frequencies necessary for the transmission of high definition television, however, range from zero up to at least 1 megacycle per second. For present standards $1\frac{1}{2}$ megacycles per second appears to be the approximate requirement. If such signals are to be transmitted over a co-axial system, the signal frequencies require to be raised by a modulation process into the normal transmission band of the co-axial system. If it is desirable to avoid this modulation process (which, of course, has its own difficulties) a balanced form of shielded line construction must be adopted. This can be regarded as an extension of the principle of screened pairs in underground cables provided for music circuits. The general principles of construction described for co-axial cables can be employed, but with two wires inside the tube instead of one. Transmission takes place over the wires, the outer cylinder acting only as a shield. The twisting of the wires around each other can be made use of, as in the pairs of a normal underground cable, to minimize external interference and crosstalk.

Advantages of Group Modulation.

Equipment to deal with the large number of telephone channels which a wideband system is capable of transmitting, can be regarded as conforming in principle with the block schematic of a 12-channel carrier system, which was given as Fig. **4** in the last article in this series.[1] The frequency allocation of the 12-channel system is shown contrasted with that of a possible wideband allocation in Fig. **6** .

As will be seen from the radio broadcasting stations indicated on the base of an assumed attenuation frequency curve for a typical repeater section in the same figure, the range of frequencies transmitted lies in the radio range. The repeaters have to deal with frequencies throughout this wideband with equal efficiency. Valve capacitances may be a difficulty in radio receivers receiving a narrow band, and in the design of a repeater for such a system as is being considered, the effects of inter-electrode capacitance constitute one of the principal controlling factors.

The narrowness of the transmitting bands of

[1] Carrier Telephony III, October, 1936.

the filters of a 12-channel system, or more accurately the smallness of the ratio between bandwidth and mid-band frequency, is sufficient to cause some difficulty in the design of the filters for the higher channels. In a wideband system using frequencies from 200 to 1,000 kc.p.s., filters constructed with coils and condensers, are inadequate for placing channels in adjacent bands 4 kc.p.s. wide. In a wideband system such as is under discussion, it is advantageous to form groups of channels, such, for example, as are transmitted over each pair of a 12-channel system. Each group of channels can be modulated with the appropriate carrier frequency to bring the channels comprised in the group to their assigned position in the frequency spectrum. Fig. **7** is a block diagram to illustrate the assembly of channels and groups, for transmission in the " go " direction, and the reverse demodulatory process in the " return " direction. The diagram has been drawn as an isometric view in which all channels but the first have been omitted from all groups except the first group. (Equalizers and channel receiving amplifiers have been omitted for simplicity.) It would be possible for the groups to be formed in the same frequency range as the 12-channel system, but the modulation of a group of channels extending from 12-60 kc.p.s. is attended by difficulties due to the fact that certain unwanted modulation products are liable to cause interference between the channels comprising the group. This is avoided if the channels are assembled, say, between 60 and 108 kc.p.s. (The topmost frequency being in this case less than twice the lowest frequency.) Raising the frequency to avoid modulation difficulties increases the difficulty of constructing satisfactory filters, but use is now being made of plates of quartz crystal as impedance elements in filters. High frequency currents, through the piezo-electric coupling which is inherent in crystals of quartz, set the plates into mechanical vibration and electrically the crystals behave as resonant circuits with extremely low losses. The development of crystal filters has made possible the construction of band filters in the range above 60 kc.p.s., having remarkably good characteristics.

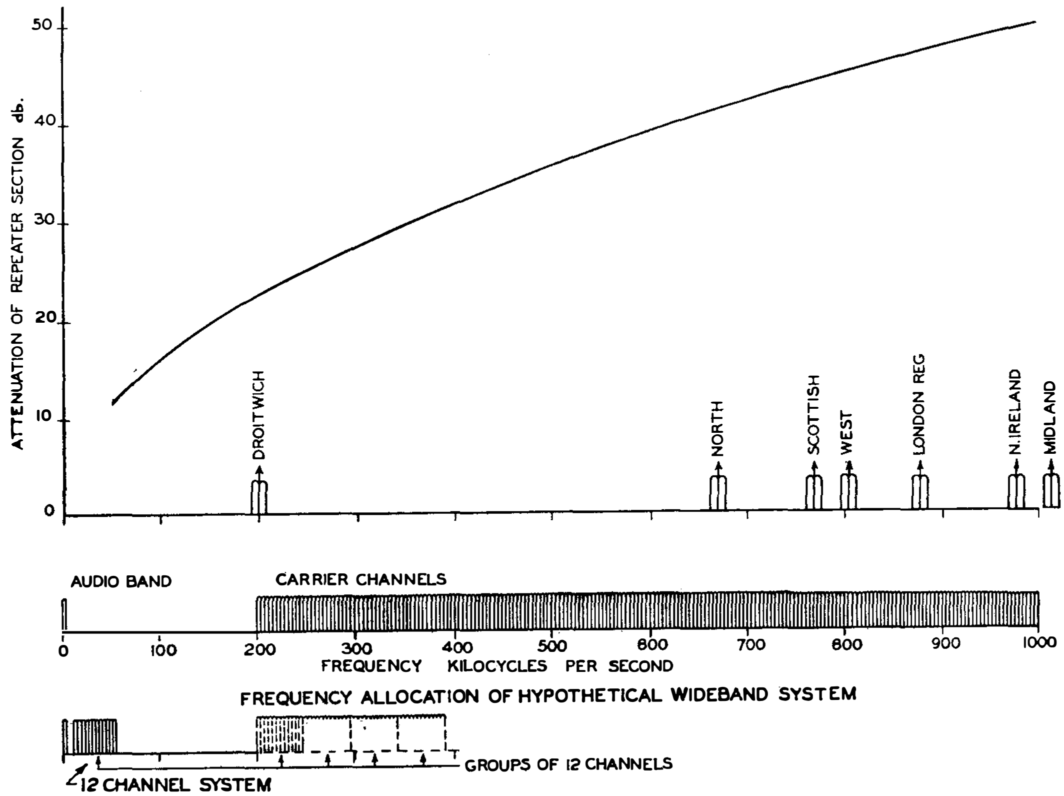


FIG. 6.

There is a constructional advantage from the use of group modulation which should be mentioned. If each channel were placed in its final position in the frequency scale in the range from 200 to 1,000 kc.p.s. by a single modulation there would be 200 different types of filters required, for the filters for each channel would have to be different. When group modulation is used, the channel filters of each group will be identical and the number of separate carrier frequencies which have to be generated is greatly lessened. Group filters will be required to combine the groups at the points of connexion to the common transmitting and receiving repeaters, but these can be more readily constructed with normal components than the channel filters. The group modulators may be of the balanced valve type.

Probably the most surprising feature of a wideband system is the transmission of so many channels through one repeater. Higher anode voltage than the normal 130 volts of existing repeater stations would be used, but it does not appear to be necessary to go to voltages higher than are to be met with in broadcast radio receivers. The use of negative feedback enables practically the full power of the output valves to be used effectively, and with so many channels passing through the same repeater the total power handling capacity required comes to depend on average power rather than on peak voltages. It is probable that the actual power required to transmit a large number of carrier channels simultaneously is not yet known and, until a wideband system has been brought into service and observations have been made, it will remain to some extent a matter of conjecture. Factors tending to a low average power per channel are:—

(a) During a conversation, on the average, speech is passing in, say, the " go " direction for only 50 per cent. of the time.

(b) Even in the busy hour there are pauses in conversation and periods between calls when no speech is passing.

(c) The few calls with particularly high volume which have to be allowed for when only a few channels are concerned, do not much affect the average volume of calls over a period.

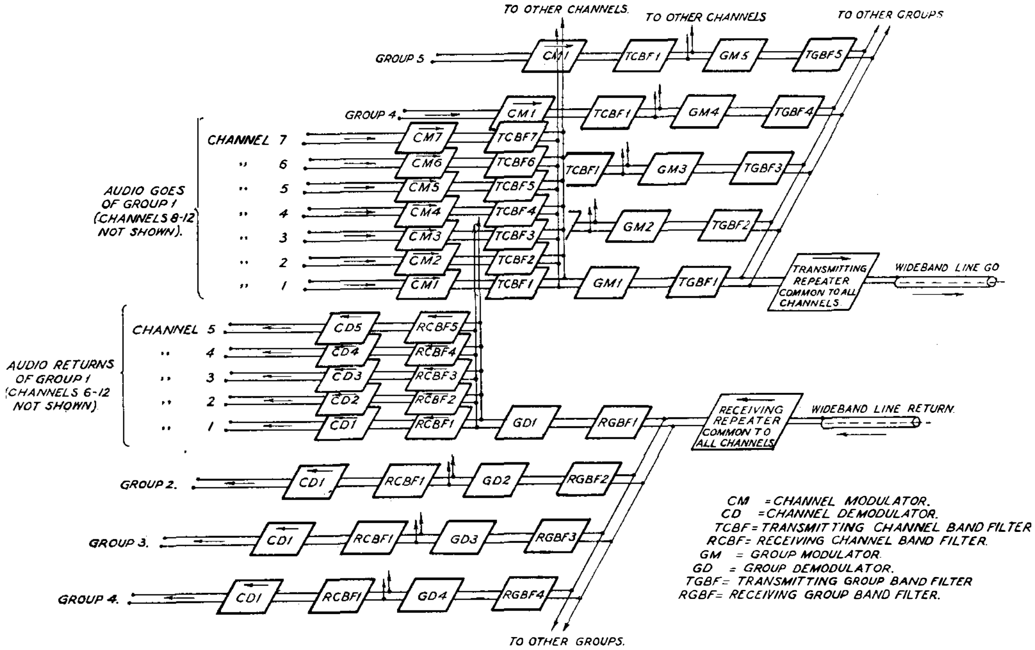


FIG. 7.—BLOCK SCHEMATIC OF WIDE-BAND SYSTEM TERMINAL.

The references in this article to some underlying principles of wideband systems will, it is hoped, be useful as an introduction to papers which will be given, within a few months, on the subject of the London-Birmingham co-axial cable, and the equipment which has been designed to operate it.

Emergency Telephone Call Service

It is intended to introduce an " Emergency Telephone Call Service " which will provide for special attention to be given to emergency calls originated by subscribers or call office users in automatic exchange areas, for Fire Brigade, Police, Ambulance, etc. All calls will be routed to the auto-manual board by dialling the code " 999." On the auto-manual board, the calling equipments will be specially marked and associated with a distinctive visual and audible alarm in order to secure immediate attention. The alarm will comprise a lamp and a buzzer independent of the regular night alarm system and there will be no means of disconnecting this alarm during the day. Where possible, operators will be given direct access to fire station and other emergency lines for completion of the calls via the switchboard multiple without dialling. The "999" circuits will utilize relay sets of the "0" level type appropriate to the exchange concerned, and arrangements are in hand to introduce the service in the London area early in 1937 to be followed by the remainder of the country at a later date.

Transmitter Inset No. 13

C. A. R. PEARCE, M.Sc. (Eng.) D.I.C., A.C.G.I.

The article describes some developments in the design of the standard transmitter inset.

Introduction.

THE developments which have recently occurred in the design of the standard transmitter inset are not concerned with the acoustic and electrical properties of the inset but are directed towards securing an increase in its useful life.

Transmitter Inset No. 10 was first introduced in 1929 and since that date it has become the Department's standard and has done good service. Nevertheless, the design suffers from certain fundamental weaknesses which become particularly apparent when it is subjected to the exacting conditions encountered in call offices, and it was to eliminate these that the Engineer-in-Chief's Office, working in conjunction with Messrs. Siemens, Bros., developed the Transmitter Inset No. 13.

The primary causes of degraded transmission from the No. 10 Inset are associated with the oiled silk

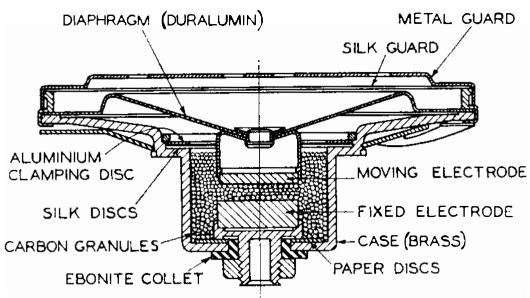


FIG. 1.—TRANSMITTER INSET NO. 10.

membrane which protects the duralumin diaphragm (see Fig. 1), and the faults are of two classes:

(1) the adhesion of the oiled silk to the front metal guard, and

(2) the collection of moisture between the oiled silk membrane and the metal grid where it is held by surface tension.

The first of these occurs when the inset is warmed by the passage of the electric current and the resultant rise in air pressure brought about in the case forces the silk forward against the guard, with the result that should the silk happen to be already "tacky" due to the warmth and moisture of the speaker's breath, it remains firmly fixed to the guard, even after the inset has cooled. Where the silk does not form a complete seal moisture is often sucked into the inset during the period when it is cooling.

The second type of fault, which is of a more temporary nature, is only encountered where the inset is subjected to very heavy usage. Either of these faults is liable to cause a loss in transmission of at least 5 db.

Elimination of the Oiled Silk Membrane.

Although an intermediate step was taken when a " non-sticking " bituminized silk was used in Transmitter Inset No. 12, it was clear that one of the first considerations in any re-design should be the elimination of the protecting silk membrane. To effect this it was necessary to devise another form of protection to prevent the corrosion of the diaphragm due, not only to the normal electrolytic action which occurs between dissimilar metals in the presence of moisture, but also to that which is liable to be set up by the contents of certain speakers' breaths. Extreme cases have been known where, despite the oiled silk, a large portion of the diaphragm has been corroded completely away.

The protection in the No. 13 transmitter is afforded by enamelling the diaphragm. Considerable care was necessary in selecting this enamel, since with certain classes which were tried it was found that excessive " fry " occurred in the inset. " Fry " is a term covering the energy which the inset generates due to numerous minute changes in its condition; it is heard as a hiss and is very often associated with the condition of the carbon granules, but in this instance it was probably due to different co-efficients of expansion between the enamel and the diaphragm.

The enamel finally selected was found to be free from " fry " and also capable of being satisfactorily sprayed free from pin holes and flaws.

Corrosion of the diaphragm at the point at which it meets the dissimilar metals of the case and clamp-

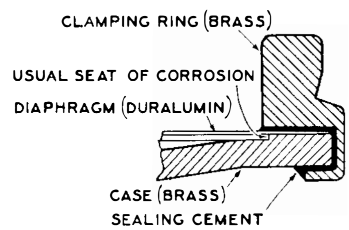


FIG. 2.—METHOD OF SEALING DIAPHRAGM.

ing ring is prevented by protecting the junction with a sealing cement (see Fig. 2). Various other expedients were tried to eliminate corrosion in the front and at the clamping surfaces of the diaphragm, such as substituting aluminium for brass for the material of the clamping ring in order to reduce the electro-chemical E.M.F. between adjacent surfaces, but the net result was only to shift the seat of the corrosion.

It should be mentioned that although the omission of the oiled silk and the enamelling of the diaphragm bring about a change in the shape of the frequency response curve for the inset, the effect on the measured articulation and volume efficiency is negligible.

Location of the Breathing Hole.

Following the removal of the oiled silk it was deemed to be expedient to transfer the breathing hole from the diaphragm to a less exposed position at the rear of the inset, so as to reduce the likelihood of moisture penetrating to the interior, with the result that it became necessary to re-design the mounting for the back electrode, this being chosen as the most suitable position for the breathing hole. Fig. **3** shows a section of the new back electrode. It will be seen that ventilation is effected by the leakage of air

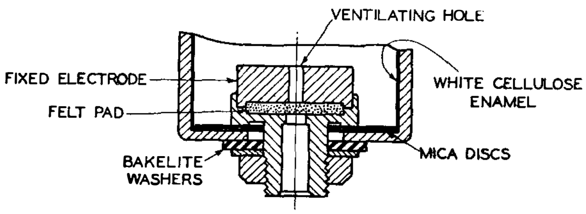


FIG. 3.—NEW BACK ELECTRODE.

past and through the felt disc which effectively prevents the egress of granules.

In the Inset No. 10 the insulation of the rear electrode is effected by two paper discs in the front and an ebonite collet in the rear with the result that in the course of time the shrinkage of these materials brings about a loosening of the back electrode. The re-design, therefore included the substitution of mica discs for the interior insulation (these also serve to locate the electrode centrally and maintain it clear of the metal case), while bakelite is substituted as the material for the exterior insulator. These materials are, of course, more stable than those previously used, so that all trouble at this point should be eliminated.

Granule Leakage.

One further source of fault, viz., granule leakage, is eliminated by the stiffening of the silk washers around the front electrode, which serve to seal the granule chamber, by the use of stiff mica washers at the front and rear of the silk discs. The effect of using " dished " silk washers was also tried, but the improvement was insufficient to warrant the increased manufacturing difficulties. In the Inset No. 10 an aluminium washer is used which serves only to clamp the silk and in no way stiffen it.

Summary.

To summarize the changes in the new inset, they are:—

(1) The oiled silk protecting membrane has been omitted and the diaphragm protected by a coating of enamel.
(2) Corrosion of the diaphragm is prevented by sealing it completely, so as to prevent the ingress of moisture to the points at which dissimilar metals come into contact.
(3) The breathing hole for the inset is transferred from the duralumin diaphragm to the centre of the rear electrode.
(4) The fixing for the back electrode has been changed to obviate any loosening.
(5) The silk washers have been stiffened to eliminate granule leakage.

The field trials and laboratory tests on the new inset have shown it to be a definite improvement, and it will shortly be introduced as the standard for call office instruments in order that a more complete trial may be made before standardizing the inset for all subscribers' installations.

Telephone Interference

Predetermination of the dangerous voltage which may be induced from earth-fault currents in power and traction systems, or of the noise disturbance which may be caused by harmonic currents in such systems, depends on a knowledge of the mutual impedance between two circuits with earth return. Theoretical formulæ, which have been confirmed by field experiments, are available for its calculation when the earth can be considered homogeneous and of uniform conductivity. In practice, however, this condition is not always fulfilled, and calculation of the mutual impedance has consequently been exceedingly difficult. At the request of the C.C.I.F., curves have been prepared which will make the calculation easy for conditions where the earth may be considered to consist of two horizontal layers of different conductivity. The assumption corresponds to a common arrangement of glacial drift or other overburden on older rocks and, in view of the topographical irregularities which invariably occur in practice, gives all the accuracy practicable for calculations connected with telephone interference. The curves will eventually be included in the C.C.I. directives.

An article dealing with the interference experienced on telephone circuits from power lines will appear in the next issue of this Journal.

Notes and Comments

London's Millionth Telephone Installed

THE Postmaster-General, Major G. C. Tryon, on October 16th presented the millionth telephone to be installed in the London area to the Lord Mayor, Sir Percy Vincent. The gold coloured instrument had an inscribed plaque replacing the dial and was immediatly used by the Lord Mayor to call the Mayor of London, Ontario, Canada, to exchange greetings. The Postmaster-General, in making the presentation, said that London then had 254 exchanges, of which 102 were automatic.

Erratum

It is regretted that a mis-statement occurred in the article " Portable Petrol Driven Rock Drills and Concrete Breaking Machines " in the October issue, page 199. In the fourth paragraph from the end, line 2, the existing wording " of less than 1 h.p. rating " should read " just over 1 h.p. rating."

Mr. Amberg

The many friends of Mr. Amberg will be interested to learn that he has been appointed Managing Director of The Express Lift Company, Limited. The General Electric Company enlisted the services of Mr. Amberg in 1920 to advise them on the manufacture of automatic telephone exchange equipment, which they were then commencing, and Mr. Amberg has been mainly concerned with their telephone interests since. He is known to telephone men in many countries having been twice round the world upon the Company's interests. While his appointment on the board of The Express Lift Company, Limited will mean practically whole time work he remains a G.E.C. man since the G.E.C. owns the entire capital of The Express Lift Company. It would seem that he also will not entirely lose touch with telephone practice since The Express Lift Company use telephone type relays in their controlling mechanism, as described in an article in this issue of the Journal.

Book Reviews

" Accumulator Charging, Maintenance and Repair." W. S. Ibbetson, B.Sc., A.M.I.E.E., etc. 151 pp. 41 ill Pitmans. 3/6.

This book appears in its fifth edition with the addition of a chapter dealing with country house and emergency battery installations and an appendix giving the syllabus of the City and Guilds examination for Motor Vehicle Electricians.

Much of the space is taken up with descriptions of charging equipment suitable for D.C. mains and very little mention is made of plant suitable for connecting to the now almost universal A.C. supplies. Numerous small inaccuracies also occur, *e.g.*, in the calculation of a series limiting resistance for charging from D.C. mains the E.M.F. of the battery to be charged is neglected despite the author's statement in the same paragraph that it may be up to one quarter of the supply voltage; Fig. 7 shows a lead accumulator when charged as having an electrolyte of strong H_2SO_4; the use of tap water is condemned unconditionally; in Fig. 28 the arrangement shown would continue to syphon acid out of the carboy when the air pressure was released, etc. Despite these blemishes the book contains much sound advice on the upkeep of secondary cells and should be of considerable value to the layman who takes an interest in the welfare of his car, radio or house lighting battery, and especially to the garage proprietor or wireless dealer who undertakes the charging and maintenance of secondary cells. H.L.

" Vibration and Sound." P. M. Morse. 343 pp. 91 ill. McGraw-Hill. 24/-.

The rapid expansion of physical studies has left to the science of sound a relatively small but by no means unimportant place in modern physics. In the collection of works under the name " International Series in Physics," that place is now filled by Prof. Morse's book.

In its general arrangement the book follows the excellent example of the older classical literature; thus, after a brief introduction concerned mostly with " a little mathematics," there follow in succession chapters on oscillations of bodies with concentrated mass, flexible strings, bars, membranes and plates, plane waves of sound, radiation and, finally, stationary waves of sound. At the end are appended a list of symbols used in the text, some of the less common mathematical tables of interest in acoustics, and an adequate index. Where the book differs from the older texts is chiefly in the different emphasis placed on parts of the subject which have relatively gained or lost in importance in recent years, and in the method of mathematical treatment. Practical examples illustrating applications of the method are included not only in the text but also by problems at the conclusion of each chapter; the majority of students would require some tutorial aid for solving many of those problems.

The chapter on strings, introducing wave motion in a simple manner, is the longest chapter. Various forms of displacement are particularly well illustrated in the treatment of vibrations of strings, bars, membranes and plates. The diaphragm of the condenser microphone is considered, in some detail, as an example of the membrane, though no corresponding mention is made of the diaphragm of the telephone receiver as an example of the plate; actually, theory is more readily applicable in the latter case because there is no localised powerful reaction on the diaphragm due to the close proximity of a back electrode.

While the chapters on aerial vibrations deal mainly with idealized sound sources, resonators, etc., such as are amenable to exact theoretical study, mention is also made of applications to loud-speakers and microphones and of speech and hearing. The concluding chapter has particular reference to acoustics of rooms, it gives a neat and concise account of the very complicated system of vibrations of the air in an enclosed space.

This is essentially a physical text book, written with an understanding of many of the practical problems encountered in engineering applications of acoustics. W.W.

District Notes

Scottish Region.

STORM DAMAGE.

A gale swept over Britain on the night of 26th October, and on the following day the resultant havoc caused to the telecommunications services in Scotland showed that a major breakdown had occurred. The Paisley Observatory recorded a maximum gust of 95 m.p.h., a pressure which has not been exceeded since 28th January, 1927, when gusts of 102 m.p.h. were recorded. The wind velocity recorded at the Royal Observatory at Blackford Hill, Edinburgh, was 71 m.p.h.

Extensive damage was experienced mainly in the Scotland West and Edinburgh Areas, nearly 500 large trees being brought down, causing broken lines. In the Scottish Region 208 exchanges were isolated, 672 telegraphs, trunks and junctions were interrupted and 10,350 subscribers' lines stopped.

The West Highlands main trunk route—which runs through Helensburgh and Arrochar thence to Inveraray whence one branch running south down the Mull of Kintyre, to Lochgilphead and Campeltown, and the other running Northwards to Dalmally, to Connel, Oban and Fort William—was broken down by falling trees at over 40 points. Some of these breaks, for instance that near Inveraray, extended for nearly half a mile. A difficulty which arises in the remote territories of the West Highlands at such a time is keeping in touch with isolated groups of men for control purposes. This was overcome in the case of Islay, an island off the Mull of Kintyre, by specially chartering an aeroplane to carry instructions to the men there.

Normal conditions were restored on the 3rd of November, but the work was much hampered by the blocked road conditions.

It was found practicable to effect all temporary restoration of services by the Regional staff, assistance being rendered mainly from the Aberdeen and Dundee Areas after attaining normal working.

MAIN UNDERGROUND CABLE EXTENSION.

The work of excavating and laying the Dumfries-Stranraer cable referred to in the Journal (July, 1936), is now about to commence. The size of the main cable is 122 pr/25 P.C.Q.T. with branches to Castle Douglas, New Galloway, Kirkcudbright and Newton Stewart. The cable length will be 95 miles, approximately, of which 82 miles is armoured. It is anticipated that the cable will be ready for service in May, 1937. Two repeater stations are to be built in connexion with the south going circuits from Stranraer, one on the Stranraer side of Dumfries, at Castle Douglas, the other on the south side of Dumfries near Carrutherstown.

ENOCH HILL (PORTPATRICK) ULTRA SHORT-WAVE STATION.

Two further channels in the ST and C 9 channel system, were brought into service early in November, making a total of 7 channels. Inclusive of the 6-channel equipment installed by the Department, there are now 13 radio links working between Scotland and Ireland.

The 6-channel equipment has no provision against breakdown of power supply other than that of a standby secondary cell battery. By way of contrast, the 9-channel equipment has a diesel-electric alternator set which is automatically brought into operation on the failure of the mains and is cut out of operation on the restoration of the power supply. It is intended to extend this facility to the 6-channel equipment.

LAYING OF SUBMARINE CABLE ACROSS THE TAY ESTUARY.

The first submarine cables provided for 12-channel carrier working were laid in the Tay Estuary on October 29th and 30th, 1936. Each cable is of the paper core, star quad, carrier type, having twelve quads of 40 lb. conductors, double lead-antimony alloy sheathed, and armoured with single wire armouring of No. 4 s.w.g. galvanized iron wires. Each cable is appproximately 1.87 miles in length.

To provide for a minimum of handling of the cable prior to laying, it was desirable that the vessel to be engaged for the work should also be suitable for bringing the cable up from the works of the manufacturers, Messrs. Standard Telephones and Cables, at Woolwich. The Dundee, Perth and London Shipping Co. were approached and suggested their M.V. "Glamis" as being the most suitable. This vessel was built at Dundee by the Caledon Shipbuilding Co., and had only been in commission about six weeks She is intended for the coastal trade and, having a draught of six feet and being flat-bottomed, was admirably suited for the purpose.

The "Glamis" loaded the cable at Woolwich, together with some 200 drums of cable for the land portion, and arrived in Dundee on the evening of October 27th. The following day, the land cable was off-loaded, and the courses for the two cables were buoyed by craft supplied by the Dundee Harbour Trust.

FIG. 1. PAYING OUT CABLE NO. 2 IN DEEP CHANNEL.

As the courses lay across a sand bank that dries out at low water, the laying operation had to be timed to take place about high water. On the morning of the 29th October, the "Glamis," having been rigged with rollers and sheaves, set out on her novel expedition. By reason of her shallow draught, the vessel could be worked quite close in shore.

At this time, the tide was flowing at 4-5 knots, and the "Glamis" was held steady during the operation by occassional use of her own engines and also by using the motor launch to hold her head to the tide.

The arrangement of the roller and side sheave is seen in Fig. 1, which shows the cable being paid out in mid-stream. The journey across the river was accomplished in half an hour.

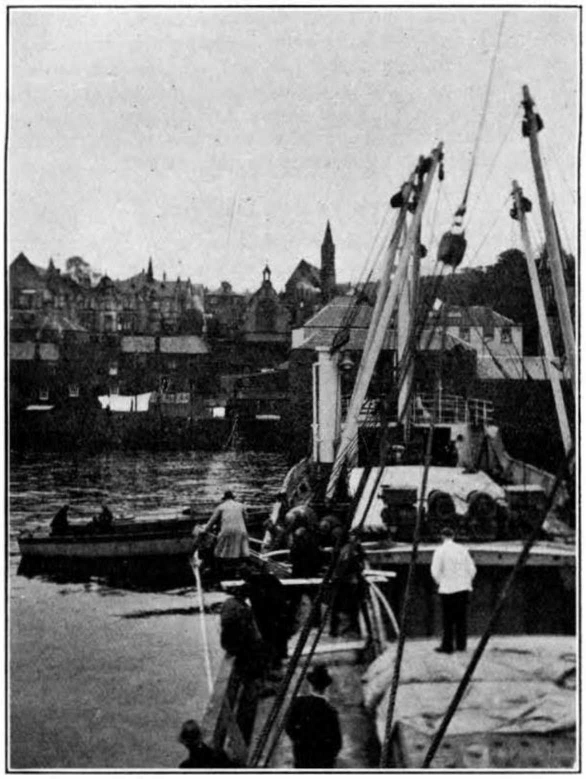


FIG. 2. PULLING THE SHORE-END OUT OF THE HOLD.

At the Newport side, there is deep water right up to the river wall. The "Glamis" was able to get close in, and was moored by head and stern ropes while the cable was cut and the end pulled ashore. Fig. 2 shows the shore end of No. 2 cable, laid on the following day, being pulled out of the hold.

London District

LARGE RECONSTRUCTION WORKS.

Finchley Road Station Reconstruction.—The abandonment of the existing duct tracks and manholes, and the construction of a new route of 54 steel pipes for a distance of 400 yards, involving the construction of several very large manholes and the replacement of twenty-six trunks, junction and subscribers' cables is involved in this reconstruction work.

Post Office Station Reconstruction.—The construction of an underground Booking Hall caused the abandonment of the existing conduits, and the laying of sixty-eight new steel pipes over the new passenger subway. Forty-one existing trunk, junctions and subscribers' cables had to be diverted to a new route. A number of other cases involving smaller alterations to the Department's underground plant has been carried out as the result of the L.P.T.B. reconstruction programme.

An extensive programme of road reconstruction works is also being carried out, involving in most cases alterations to the Department's plant, Overhead and Underground.

The rebuilding of Waterloo Bridge is proceeding, and in order to commence the shore end of the north side, it was necessary to lift the end section of the temporary bridge. This section, weighing 1,000 tons, was lifted 5½ feet by means of hydraulic jacks. Extensive alterations to the Department's plant on the north approach to the temporary bridge was necessary before this operation could be carried out.

The rebuilding of Chelsea Bridge is proceeding, and provision for twelve conduits in the footways of the bridge is being made. The existing cables on the old bridge had previously been diverted to the temporary bridge.

TRUNK AND JUNCTION CABLES THAT HAVE BEEN COMPLETED OR UNDER CONSTRUCTION DURING 1936.

Total mileage of trunk and junction cables involved is 517 miles, consisting of 108 junction cables with a total of 253 miles, and twenty-two trunk cables with aggregate mileage of 263 miles. These cables include the provision of a co-axial cable between Faraday Building and Alexandra Palace for television service, also the L.E.D. section of the London-Birmingham co-axial cable.

ALTERATIONS AT OLYMPIA.

In connexion with the improvements which have been carried out at the Olympia, new suites of telephone call office cabinets have been installed in the Addison Road entrance hall, under the new escalators in the Empire Hall and at the entrance to the Princes Rooms in the first floor. All the cabinets have been constructed to the special design of the Olympia architect, and are faced in teak and walnut.

TELEPRINTER ANCILLARY SYSTEM.

The second Teleprinter Ancillary System for twenty-three London Postal Service circuits installed on the fourth floor C.T.O., was handed over for service on the 27th July, 1936. For traffic distribution purposes the first and second systems, totalling fifty-seven stations, are connected to an Ancillary Filtration Board, standard concentrator facilities being provided on both systems.

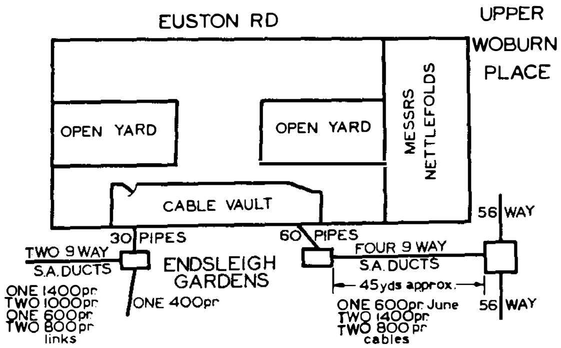
The third Teleprinter Ancillary System for twenty-eight provincial offices is installed in the Inland Gallery, third floor C.T.O., and was handed over for traffic on the 30th November, 1936.

The fourth system will be commenced very shortly.

EUSTON EXCHANGE.

Euston (Physical) Exchange opened on September 19th with the transfer of 1,202 Museum lines and 1,160 from Euston (Hypothetical Exchange.

The building is in the form of an H facing Euston Road, the rear running parallel to Endsleigh Gardens, on which side is the M.D.F. and the cable vault. Two exchange manholes were constructed when the building was erected, one at either end of the cable vault. The leading-in conduits comprise a nest of sixty steel pipes at the eastern end and thirty at the western end. These pipes are recessed in the wall about 6 in., a brick arch forming the top of the cavity. Covering the face of the leading-in pipes, standard lead



grids have been provided, made up of two sheets of 8 lb. lead for each grid.

A development layout was prepared in conjunction with the transfer. The entire work comprised a main duct and cable scheme, three distribution, and a transfer scheme.

Duct Work.—The duct work consisted of four 9-way S.A. ducts from the east manhole to Upper Woburn Place, where a 56-way route running at right angles, was intercepted, and a concrete manhole 12 ft. by 8 ft. by 8 ft. with central entrance was constructed, the thickness of the walls varying from 8 in. at the ends to 10 in. at the centre.

From the west manhole, two 9-ways were provided to Gower Street, thence tailing off to a single way.

Cable Work.—Four cables were provided westwards C.1,400 pr., D.1,000 pr., E.1,000 pr. and F. 1,000 pr. to cater for Museum subscribers, in addition to which an existing Museum subscribers' cable was extended to the new exchange, while a Museum-Welbeck junction cable was also intercepted and extended to Euston. These two latter cables furnished links between Euston and Museum and also Euston and Welbeck. In jointing the first cable Silica Gel was used, but no drying adopted. In the subsequent cables both methods were used. It was, however, found necessary to apply CO_2 in order to bring all the cables up to the requisite insulation standard.

Two cables were provided in an easterly direction, *viz.,* A.1,400 pr. and B.1,400 pr., and owing to the relatively short distance between the vault and Upper Woburn Place manhole, joints in the exchange manhole were eliminated by a process of fleeting. At several of the auxiliary jointing points the new type of mechanical joint was fixed, *viz.,* Victaulic and Bromford joints. These are similar to the Cable Union of years ago. In the Victaulic joint the meeting point is covered by a thick wide rubber ring slipped over afterwards and held rigidly in position by a hinged iron band. In the Bromford joint, the rubber band is internal, the two sections being provided with an external flange, secured by three bolts. The object of the rubber washer in both cases is to exclude moisture.

Two Euston (Hypothetical) 800 pr. cables served the area to be catered for by the new A and B cables. These were "cut into" Euston, the circuits being cross-connected on the new M.D.F. and taken out on the new cables immediately after the transfer. The two 800 pr. cables will thus be available for junction purposes. The jointing of the E.S. and W. quad cables was effected with the new flat type of plug. It is believed that this was the first occasion upon which the 7-way plug catering for a 1,400 pr. cable had been used. The plugs were made upon the site, from a 6 in. soil pipe.

Transfer.—As previously mentioned in the areas served by the A and B Cables the circuits were taken *via* the new M.D.F., thus simplifying the transfer. In the western area, the new F cable has been made to intercept the Museum plant, the circuits in this area also being diverted through the new M.D.F. and taken back to the old exchange on " linked " cables. The old plant made spare by the interception was used for another part of the scheme. In the case of the E cable, as the direction of feed is reversed, " teeing " had to be resorted to at various points along the street.

The C and D areas were " teed " at the manhole in Tottenham Court Road. By effecting an additional 850 exchange diversions it was found possible to complete the " tees " in three separate bags. The alternative to this would have been to make all joints in one large bag. Owing to the position of the old cables it will be necessary to remake the joints after cutting away the " tees." This operation cannot be effected until later as only those Museum subscribers affecting the L-Z directory were transferred initially.

North Wales District

ANNUAL STAFF DINNER.

The social activities of the North Wales Engineering District would not be complete without the Annual Staff Dinner, and the seventh of its kind was held at Morris's Cafe, Shrewsbury, on November 4th, 1936. The Superintending Engineer, Mr. H. Faulkner, presided over a company of 130, representative of retired colleagues and of many Departments of the Post Office, and on this occasion we were privileged to entertain as the principal guest Mr. B. O. Anson, M.I.E.E., Assistant Engineer-in-Chief.

After the loyal toast and the toast of " His Majesty's Postmaster-General " had been honoured, Mr. J. L. Parry, District Manager, Birmingham, proposed "The Post Office Engineering Department." Mr. Anson, in returning thanks, referred to recent development in the spheres of science and organization, and to the successful scheme of vocational training which had been built up in the Engineering Department.

The toast of " The Visitors " was proposed by Mr. C. G. A. McDonald, Executive Engineer, Power Section, and responded to by Mr. A. Morris, Superintending Engineer, South Lancashire District, and Mr. H. A. Thomas, Senior Staff Officer, Stores Department, Birmingham.

Mr. W. H. Ferguson, Higher Clerical Officer, spoke in complimentary terms of the popularity of " The Chairman," whose health was accorded musical honours. Mr. Faulkner, in reply, expressed his appreciation of the loyal support he had received from all sections of the staff.

An excellent entertainment of magic, mirth and music was interspersed between the speeches, and it is a tribute to the skill of the Toastmaster—Mr. A. C. Smith, late Staff Officer, and to the organizing ability of the Dinner Committee that the proceedings went along at a steady tempo until "Auld Lang Syne" was sung at 11.30 p.m. Altogether it was a thoroughly enjoyable function.

LLANFAIR REPEATER STATION.

An 18-channel V.F. terminal equipment was brought into use at Bangor Post Office on the 24th May. This takes the Irish telegraph circuits formerly working through Llanfair p.g. Repeater Station, which has been closed down.

Associated with the V.F. terminal are telegraph apparatus racks with equipment enabling the two-wire simplex extensions of the V.F. to work to single-wire duplex circuits to Ireland. The particular apparatus used is the first of its kind.

The closing down of the old repeater station at Llanfair p.g. (the village famous for its name which spelt in full has 59 letters) closes a page of history. The first Irish cable which contained seven wires, was laid in 1871. Wheatstone transmitters were used with bichromate batteries and the linemen at the time when cleaning the cells emptied the waste into the ground adjacent. This is evident by many traces of mercury in the soil. Following Wheatstone working came Baudot transmitters and then teleprinters. The repeaters had to be modified to meet any condition which might arise, and they became very complex pieces of apparatus, but their performance was of high order.

AN "AERIAL" DUCT LINE.

An unusual accident to the Birmingham-Kidderminster cables that occurred recently may, it is thought, be of interest.

Between four and six o'clock, on November 4th, two large trees on the Birmingham-Kidderminster road were blown down. A two-way duct line carrying two trunk cables was caught in their extensive root system and lifted clear out of the groud for a distance of thirty yards. Only twelve ducts were broken, and the cables were found to be undamaged, although they had been stretched three yards by the upheaval of the track.

The damage was repaired by relaying the unbroken ducts, and completing the track with split ducts. A manhole was built on the track and the cables were finally cut and rejointed to take up the slack due to stretching.

PRESENTATION TO MR. J. A. ROBINSON.

Mr. J. A. Robinson, inspector, Colwyn Bay, has been presented with the Imperial Service Medal, awarded by the King, for "over twenty-five years in the service with unblemished record and meritorious services." The presentation was made by Mr. H. G. S. Peck, Assistant Superintending Engineer.

Mr. Robinson entered the service in 1900 as a labourer, and in 1912 he was made an inspector. He retired in August this year, after 36 years' service. In 1911 he was complimented and thanked for the arrangements he made in connexion with the investiture of the Prince of Wales at Caernarvon, whilst in 1929 he was thanked by the Engineer-in-Chief for the work done in connexion with the fire at the Llandudno Exchange, and the restoration of the automatic working at the exchange after the fire.

North Eastern Region

In common with other parts of the country the Region is feeling the effects of the increased volume of business, in the form of general pressure of work, and considerable attention is having to be given to recruitment and training. An extensive programme is in hand, but as most items are on standard lines or are mainly of local interest, there is little to justify inclusion in these notes.

The unusual weather conditions experienced between the 20th and the 26th November accounted for a good deal of trouble throughout the Region. In one case, however, the conditions appear to have been really exceptional. A new U.A.X. was opened on the 23rd instant at North Cave, some 16 miles from Hull, the parent exchange. Prior to the fog the junctions had been thoroughly tested and the normal insulation was of the order of 5 megohm. With the advent of the fog the insulation grew steadily worse and at the time of the opening certain of the relays at the U.A.X. had to be very critically adjusted. The insulation became lower and lower until the relays refused to function, and continuous attention had to be given in order that they could be operated manually. It was hoped at first that this necessity would be of short duration, but instead the insulation continued to get worse. Finally, as there was no sign of an improvement in the weather it was found necessary as an emergency measure to divert the circuits into a main cable passing near the exchange.

The insulation actually decreased to less than a thousand ohms. According to reports the rime was three-quarters of an inch thick on the wires, and in the worst parts was bridging the gap between the insulators and the arms.

It is unfortunate that the circumstances precluded any possibility of obtaining photographs.

South Lancs District

CENTRAL AUTOMATIC EXCHANGE.

The conversion of Central Exchange, Manchester to automatic working, on Saturday, 17th October, was effected in the presence of 50 guests headed by the Lord Mayor of Manchester, Alderman T. S. Williams, J.P.

The hall and reception room were attractively decorated with masses of flowers and evergreen shrubs and presented a colourful contrast to the typically gloomy Manchester weather outside. A cordial welcome was extended to the guests by the Postmaster Surveyor, Mr. Kenny, and the Superintending Engineer, Mr. Morris, and Sir William Noble spoke on behalf of the equipment contractors, the General Electric Company.

There were present those who had assisted at the opening of the manual exchange in 1917, which was also installed by the General Electric Co., and they felt a sentimental regret as the time for the transfer to automatic working approached. A nearly faultless transfer took place soon after one o'clock, having been delayed a few minutes in order to allow a fire-call to be completed. This was the largest exchange transfer yet effected in this district, involving over 5,000 direct exchange lines. No less than 895 private branch exchanges are connected to the exchange and the total number of telephones affected is nearly 14,000. A total of 1,500 new junction circuits to 68 different exchanges had also to be provided. Extensive underground rearrangements were involved, and the opportunity was taken of cleaning up the layout of the cables in the cable chamber, a difficult task which entailed breaking away a large tapering nest of ducts in concrete and providing suitable racking in its place.

At the conclusion of the ceremony, the guests adjourned to the dining room, and the Lord Mayor made the first call on the new exchange, using a handsome white telephone with an inscribed gold mounted dial, by making a personal call to the Postmaster-General in London. Loud speakers and amplifying equipment made the conversation audible to the assembled guests, and at the conclusion Sir William Noble presented the telephone to the Lord Mayor, and a bouquet of carnations was presented to the Lady Mayoress.

BIRMINGHAM-MANCHESTER CO-AXIAL CABLE.

Two of the intermediate repeater stations on the new Birmingham-Manchester co-axial cable are situated in this District. The site for the one at Adlington has been acquired and building is to commence at an early date, but as the one at Stockport is in a built-up area it was not possible to find a suitable site and arrangements are in hand for the purchase of a vacant property to house the equipment.

RETIREMENT OF MR. A. KEMP, A.M.I.E.E.

On Friday, November 27th, despite thick fog, some 140 members of the Post Office attended a Hot-Pot Supper at the Waldorf Hotel, Manchester, in honour of, and to mark the occasion of the retirement of "Alf." Kemp. The gathering was representative of all Departments and all grades of the Service, and many retired members were also present. Some had travelled from as far afield as Preston, Lancaster, Leicester and London, and it may be judged that the event was most successful.

Mr. Morris, the Superintending Engineer, presided, and after several eulogistic speeches from friends and colleagues of Mr. Kemp, presented him, on behalf of the Staff, with a radiogram, an easy chair and an electric fire—ideal presents for one who is determined to enjoy his retirement.

Mr. Kemp, who retired on November 30th, had, apart from a period of 2½ years in South Africa during the Boer War, been in the Post Office Engineering Department for 39 years, and only the first year was spent outside Manchester. He entered the Service on October 4th, 1897 as a Labourer in a heavy construction gang at Bolton, and was transferred to Manchester in 1898. In 1900 he went to South Africa and returned to Manchester in September, 1902, and subsequently had extensive experience of all classes of work, both internal and external.

His progress to the rank of Sectional Engineer was as follows:—Inspector 1909, Senior Inspector 1912, Chief Inspector 1919, Assistant Engineer 1927, Sectional Engineer 1934.

Mr. Kemp has, of course, seen the telegraph and telephone services completely revolutionized during his career in the service, and it was a fitting climax to his career, when a civic ceremony was held at the transfer of Central Exchange to automatic working on October 17th—the largest single transfer which has taken place in Manchester.

The social and sporting side of official life was not neglected by Mr. Kemp, and he will long be remembered in connexion with his introduction of the "Johnnie Walker" Bowling Cup Competition. It is to be hoped that he will be present at many of the future competitions, during a long and happy retirement.

South Wales District

VISIT of H.M. KING EDWARD.

The visit of H.M. The King to South Wales on the 18th and 19th November, 1936, called for the provision of a number of special circuits.

During the night of the 18th/19th the Royal Train remained at Usk Railway Station, and it was necessary to provide circuits from the train to Buckingham Palace. This involved the erection of 5 miles of interruption cable, in order to connect the train with the main underground trunk network. Two 4-wire circuits were set up via the Newport-Abergavenny cable to Newport Repeater Station, thence via Gloucester and Oxford to London. Arrangements were made for a frequent testing of the underground cable and for patrol of the interruption cable.

The installation and recovery of the telephones on the train were carried out while the train was being cleaned at Cardiff Sidings.

In addition to the above, twenty-one special telephone circuits for the use of the Press were installed at various points on the King's route, and four circuits for the transmission of pictures were set up between Cardiff and London.

The King's tour was carried out in fine weather, which contrasted with the continuous rain and wind which occurred during the erection of the interruption cable. In spite of the bad weather all the circuits were provided on time and the whole of the telephonic arrangements were carried through without a hitch.

EVESHAM EXCHANGE.

The conversion of the Evesham exchange to automatic working was successfully effected at 2 p.m. on Saturday, October 3rd, 1936. A public opening was staged on the following Wednesday, and was attended by His Worship the Mayor of Evesham and other public dignitaries, together with the Surveyor, and Superintending Engineer of the South Wales district, the Gloucester Sectional Engineer, and other prominent officials of the Post Office.

At this function a telephone conversation took place between the Engineer-in-Chief in London and the Mayor and was amplified in the exchange so that all present could listen-in.

The exchange, which is situated in the beautiful vale of Evesham, is the nerve centre of an important fruit-growing industry, and, in consequence, has one of the busiest trunk calling sales in Great Britain. This accounts for the fact that there is at present one trunk circuit to approximately every 3.75 subscribers; or 125 trunks and junctions to 468 direct exchange lines. The ultimate capacity is 2,000 subscribers.

The exchange building is undoubtedly a fine example of present-day Post Office architecture; and its appearance is enhanced by its delightful situation near the banks of the well-known river Avon.

Tribute is due to many for the work done in connexion with this transfer, but it is felt that special mention should be made of the untiring efforts of the Engineering staff responsible, who carried out the programme in spite of the many difficulties encountered.

South Western District

BRISTOL MAINTENANCE EXPERIMENT.

The following notes are intended to amplify the brief description which was given in the District Notes in Volume 28 of the Journal of this experiment, which has now been running for about twelve months.

The experiment was designed to investigate the possibility of considerably reducing the fault liability on all classes of telephone plant. A stage in the experiment has now been reached when a concentrated drive is about to be undertaken on the plant which has the greatest fault liability.

1. *Fault Analyses.*

Analyses have been taken of the fault incidence on all types of exchange equipment, subscribers' apparatus and line plant and the analyses have enabled conclusions to be drawn as to the items of plant causing most trouble.

During the analysis stage it has been found necessary to undertake additional analyses to those previously mentioned, such as:—

Analysis of Exchange F.O.K.'s and Sub-Apparatus and line F.O.K.'s.

Analysis of Dial Faults (kept at Dial Repair Centre).

Analysis of Relay and Lamp Faults in respect of Auto-Manual Boards.

Analysis of Routine and Non-Routine Faults on Manual and Auto-Manual Boards.

2. *Incidence of Faults and Proposed Action.*

(a) *Exchange Equipment Auto.*

Considerable difficulty has been revealed on the "B" and "C" relays and as an experiment certain remedial measures using carbon tetrachloride are being tried out.

(b) *Auto-Manual and Manual Boards.*

Cords, relays, keys, lamps and plugs give most trouble, and various experiments are in progress with a view to reducing the fault liability; mention may be made of the use of lubricants for the prevention of key sticking faults, and a re-design of switchboard plugs recently completed.

(c) *Subscribers' Apparatus.*

The analyses reveal that the fault liability is highest on bells, transmitters, primary cells, dials and protectors.

Special instructions regarding proposed preventative measures have been issued to all maintenance and construction officers, while in regard to kiosk apparatus, arrangements have been made for periodic special maintenance attention based upon the degree of usage of the kiosks as revealed by the District Manager's returns.

Experiments are in progress to overcome faults due to dampness in call office and kiosk transmitters.

(d) *External Plant.*

The summary of line faults reveals that the majority of the faults occur in the last span to the subscriber's premises and that existing flat and quarter twist drops are mostly to blame. Faults on D.P.'s are a serious contributory cause of the high liability.

Maintenance gangs are now being formed and a systematic survey is being made in specially selected exchange areas where there is adequate spare plant and no likelihood of immediate rearrangements of plant. As a preliminary step attention will be concentrated upon the replacement of flat and quarter twist drops by either bare vertical or covered drops.

3. *Staff.*

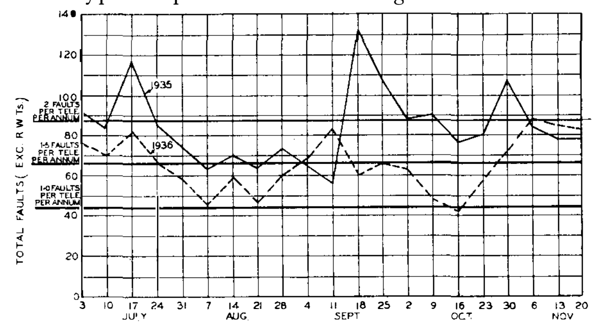
It is unfortunate that the period of the experiment has coincided with a time of greatest recruitment in the Bristol Section. Intensive training has been undertaken at the Regional School with a view to raising the standard of workmanship of the maintenance, fitting and external construction staffs, but it has been difficult to meet the exceptional requirements following the rapid promotions during the period.

The experiment is now being controlled by a staff of one Probationary Assistant Engineer and three Inspectors.

4. *Results of the Experiment.*

It is too early yet to be able to demonstrate clearly the results which have so far been achieved as they are masked by the effects of rapid staff and work fluctuations over the period.

Curves showing the total faults on each type of plant, plotted weekly, are being maintained, such as the one below, which indicates the improvement in total faults on all types of plant in M.2 exchange areas in the area



of the experiment. The results will be more clearly apparent after a period of concentrated attention upon the items of plant now known to be responsible for the present high fault liability.

G.P.O. FILM DISPLAY AT EXETER.

A G.P.O. Film Display at the Congregational Church Hall, Exeter, was accorded a civic send-off when the Lord Mayor performed the opening ceremony on Wednesday, November 4th. Previously the hall had been converted by the District Engineering Staff, in conjunction with the Film Unit Staff and the Office of Works, into a cinema seating 260 persons.

At the two performances given daily until November 28th, an interesting programme of Post Office Films was given, including "Fairy of the Phone" (one of the latest "all talkie" productions), "Colour Box," and "Weather Forecasting." The shows were much appreciated by large audiences at all performances and the general opinion is illustrated by the following extracts from the *Exeter Express and Echo.*

"There is no irksome waiting between the films . . ."

"There is nothing amateurish about these films nor can they be criticised as being too technical for general entertainment."

The display was very successful from a technical point of view and proved the reliability of the apparatus provided by the Department for such work.

TROWBRIDGE HEAD POST OFFICE.

Modern tendencies in regard to heating and lighting of public offices are well illustrated by recent improvements carried out at Trowbridge. The office has been reconstructed on modern lines and the heating and lighting of the Public Office has been designed and arranged by the Department in harmony with the architectural features.

The lighting units comprise a series of 12″ square prismatic panels in line formation parallel to the counter, there being six-panel units and one four-panel unit. The prismatic reflectors fitted in the units are designed to reflect the upward emitted light back through the lamp centres.

An advantage of this type of fitting is that adjustment of the lamp filament position relative to the panel controls the angle over which the light is distributed, so that account can be taken of the varying mounting heights, position of fixtures, etc. The maximum concentration which can be obtained is approximately 10 times the bare lamp candle power over an angle of 20° varying down to 3 times over an angle of 80°.

The heating installation comprises a series of wall pattern heating panels partially recessed into the walnut panelling of the walls.

This type of heating panel is very effective and enables the complete concealment of all pipework.

North Western District

REPEATER AND AMPLIFIER STATIONS.

New stations have been opened at Carlisle, Kendal and Lancaster.

EXCHANGE TRANSFERS and EXTENSIONS.

Chorley was transferred from magneto to automatic working in July last. The approximate number of lines concerned was 640, the fitted multiple being 800. The system employed is line finder with partial secondary working.

A similar magneto exchange at Cleveleys was transferred to automatic U.A.X. No. 7 working on October 17th last, 625 subscribers with a 700 multiple being concerned. Conversion to U.A.X. No. 7 working also took place at Ramsbottom in October last. In this case 320 subscribers were concerned with a multiple of 400 capacity.

Extensions of equipment are in hand in various exchanges, the most important being at Blackpool and Carlisle.

SMALL U.A.X.'s.

There are now working in the District 11 U.A.X.'s of the No. 12 type, some of which are conversions from No. 5 type to meet new dialling requirements, the remainder replacing manual exchanges under the general scheme of automatization. It is anticipated that a number of U.A.X.'s of the No. 13 type will be opened early in 1937.

TELEGRAPHS.

Arrangements are well advanced in connexion with out-office modifications required for the introduction of ancillary working to Manchester, Glasgow and Newcastle.

MAIN LINES.

Relief cables have been provided betwween Rossendale-Bacup; Preston-Blackburn; Bolton-Blackburn; and Bolton-Chorley. A new cable route has been provided between Carlisle, Workington and Whitehaven and duct laying is in progress, in extension of this cable, to Egremont and Gosforth. Further new cable routes in hand are Penrith-Temple Sowerby, and Lancaster-Caton-Hornby.

ADDITIONAL LOADING WORKS.

The London-Liverpool-Glasgow cable (of which 113 miles pass through this District) has been additionally loaded in various circuit groups with 22 mH. coils at 2,000-yard spacing, thus allowing the use of one quad for one audio plus one carrier circuit. Certain quads of the same cable have been loaded with six mH. coils at 1,000-yard spacing designed to accommodate one audio plus four carrier circuits per quad.

To meet traffic growth, the remaining unloaded pairs of the Carlisle-Newcastle cable, laid within the last two years, have now been loaded.

The Burnley-Nelson-Colne 1 and 2 cables originally loaded at 2.6 mile intervals, have now been modified to 1.3 mile loading to improve transmission over this route.

STORMS.

The past fourteen months have been particularly productive of stormy periods, giving rise to much repair work by staff already pressed heavily in other directions. The Lancaster Section has suffered most.

POLES in ROCK.

As can be expected, rock is frequently encountered in this district, but one recent U.A.X. work at Bardsea in the Lancaster Section proved unique, two to three blasting operations per pole hole being required for approximately 400 pole positions.

I.P.O.E.E.

The technical interest of the staff is well maintained, the Senior Section creating a record for this district in the number of papers being given by the local staff. The Junior Sections' activities are at their usual high standards.

GROWTH OF WORK AND STAFF.

Since October, 1934, the number of men employed has increased by 28 per cent. and the number of gangs by 53 per cent. A large programme of work is ahead. A study of telephone growth over the period October, 1934, to date reveals abnormal features in many areas, indicating the need of extensive line plant additions at early dates.

FUNCTIONS.

Blackpool. The usual heavy seasonal work experienced in this town was added to this year by the British Association Meetings taking place here. A unique feature was the opening of the Blackpool Illumination Season by Sir Josiah Stamp from a railway carriage stationed 36 miles crow fly from Blackpool. (A detailed description is given in the Post Office Magazine for November last.)

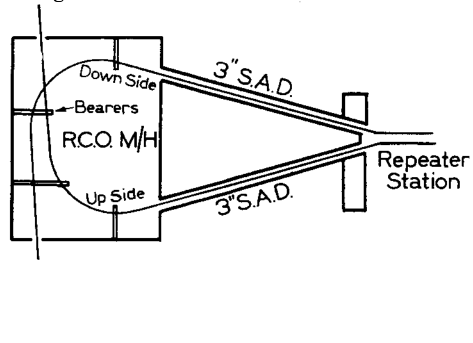
Blackburn.—An interesting event took place recently when an exhibition of work by the unemployed was opened by the Postmaster-General at the Post Office Savings Bank, London. By means of loudspeakers and microphones, several of the Blackburn Social Services, meeting together at Community House, Blackburn, were able to listen to the Post Office Savings Bank ceremony and reply to the messages of cheer and goodwill received from the London end.

F.S.H.

Eastern District

LONDON-BIRMINGHAM CO-AXIAL CABLE.

Approximately 24 miles of this cable pass through the District, the whole of the length being in the St. Albans Section. The track extends from the district boundary at Warrington Toll Bar on the north side to the London Engineering District boundary at Kinsbourne Green on the south side. There are five repeater points in the Section at approximately 8-mile intervals. One has been accommodated in the existing exchange building at Bedford. The remaining four are as near as possible to the sites originally selected. The buildings are similar to U.A.X. B type buildings, but the dimensions are 14 ft. by 20 ft., and the trench is modified to meet the requirements of the co-axial cable. Owing to the make-up of the cable (described in the January issue under N.Wa. Notes) it was not possible to turn the cable in a radius less than $22\frac{1}{2}$ in. The cable trench had therefore to be deepened and the turning into the repeater station negotiated by special manholes, in no case of less size than an R.C.O. Where the turn was made in ducts the limiting radius was 45 in.



Considerable difficulty was experienced in obtaining land for the repeater station sites; in one case the whole village was owned by two persons only, and the amenities of the district became a prime factor. This difficulty was overcome, and the site obtained, large enough to accommodate a U.A.X., in addition to the repeater station. In another case, by shifting the proposed site a few yards, the department was saved the cost of the land by negotiation with the Forestry Commission, apart from the saving of approximately £50 on cabling costs.

The cabling and jointing proceeded at a fairly fast rate and was completed ready for testing in this district in August. The actual operations and difficulties met, would require too much space to describe in District Notes.

South Midland District

MAIN UNDERGROUND PROGRAMME.

The geographical position of this district naturally results in its participation in meeting the demands for a large number of through circuits, in addition to what might be described as local circuits. This is reflected in the large M.U. programme which is current in this district.

Of the 1936-7 programme, approximately £150,000 is still outstanding, and the value of next year's programme in this district is about £300,000. On a mileage basis this represents about 650 miles of cable, or 90,000 miles of circuit.

An interesting feature of this programme is the provision of the following carrier cables:—

> *Guildford—Portsmouth—Southampton,* which is likely to be extended to London in next year's programme. This is a Standard Telephones and Cables, Ltd., 12 channel system.
>
> *London—Oxford,* which is to be extended to Gloucester next year. This is a 4 channel, plus audio system, which was described in the October issue of the Journal, and is being installed by Messrs. Siemens Bros.

In addition, co-operation will be afforded in the provision of a London-Salisbury 12 channel carrier cable, 16 miles of which will pass through this district.

Such a programme gives full opportunity for the personal touch between the officers of this and adjacent districts, and it is, therefore, pleasing to record that full advantage is taken of these circumstances.

SOCIAL EVENTS.

October 31 was a notable day in the South Midland district owing to the number of social events which took place. At Guildford at Sectional Engineer's staff held a very successful tea, social and dance, which was attended by 300 members of the staff and friends. Mr. T. Cornfoot, Superintending Engineer, and several members of the district office staff were present.

Mr. E. S. Francis, Assistant Superintending Engineer, represented the district office at a well attended Oxford Section Staff Dinner, at which the Postmaster, Oxford, and the District Manager, Reading, were also present.

At Windsor the presentation of the "Safety First" medals to drivers of official vehicles was made the occasion for a smoking concert at the Victoria Hotel, preceded by a football match in the afternoon between teams representing Reading and Windsor, which was won by Windsor with a score of 3—0. Mr. Moffatt, Sectional Engineer, Reading, was present, and the medals were presented by Mrs. Moffatt.

North Midland District

RUGBY AUTOMATIC TELEPHONE EXCHANGE.

Rugby new automatic telephone exchange was opened on October 17. The automatic equipment, provided and installed by Messrs. Automatic Telephone and Electric Company, is of the standard step-by-step type, featuring the 2,000 type mechanism. Equipped for an initial capacity of 1,300 subscribers' lines, provision is made for an ultimate capacity of 2,200 lines; 1,000 subscribers are already connected.

At the public opening, on October 21, a civic ceremony took place at which, in the presence of a representative gathering of prominent local visitors, his Worship the Mayor of Rugby, officiated and declared the new exchange open. The guests were entertained to afternoon tea and a pleasant function terminated when, on the invitation of the Superintending Engineer, Mr. A. Wright, a tour of inspection of the new exchange was carried out.

BOSTON AUTOMATIC TELEPHONE EXCHANGE

The automatic telephone exchange at Boston, which was opened on October 31 is provided with standard step-by-step equipment, manufactured and installed by Messrs. Automatic Telephone and Electric Company, Liverpool. The exchange is designed for an ultimate capacity of 1,700 subscribers' lines, with initial capacity of 900 lines.

A ceremony in connexion with the public opening on November 6 took place in the automatic apparatus room, when Sir Walter J. Womersley, M.P., J.P., the Assistant Postmaster-General, declared the new exchange open and cut the last wires connecting the old to the new exchange. Prior to the ceremony the Superintending Engineer, Mr. A. Wright, demonstrated by loud speaker the time signal which was specially relayed from London.

Afternoon tea was taken in the old magneto exchange switchroom, which had been partially cleared for the purpose. Amongst the prominent guests and officials present were his Worship the Mayor of Boston, Sir Walter J. Womersley, M.P., J.P., Assistant Postmaster-General, Mr. B. O. Anson, M.I.E.E., the Assistant Engineer-in-Chief, Mr. W. R. Storr, Post Office Surveyor, Mr. A. Wright, M.I.E.E., Superintending Engineer, Mr. T. Beck, District Manager, Mr. N. C. Anderson, the Head Postmaster, Mr. J. McOwen, M.I.E.E., Sectional Engineer.

Boston possesses in the spire of its Parish Church a famous landmark familiarly known as the "Stump." Mr. Storr stated in a brief introductory address that serious difficulty in securing foundations for the new exchange building had only been overcome by the extensive use of piles, some of which are 36' in length, and commented that the stability of the "Stump" was remarkable in view of the nature of the foundations to be found in Boston. In this connexion it may be of interest to note that the foundations for this ancient spire were built upon bales of wool donated by the old staplers of the then flourishing wool industry.

The Assistant Postmaster-General, in a happy speech covering the Postal Services generally, congratulated the Mayor and the town of Boston on the manner in which the town had kept to the front as a trading centre.

Book Reviews

" The Alternating Current Circuit." P. Kemp, M.Sc., M.I.E.E., etc. 104 pp. 57 ill. Pitmans. 2/6.

In this small volume the author has packed all the essential facts and formulæ relating to the alternating current circuit. In quick succession he deals with the generation of alternating currents, average and R.M.S. values, the effect of inductance and capacitance, phase difference, series and parallel circuits, resonance, power, mutual inductance and polyphase circuits.

The treatment is elementary, rigid proofs are not attempted and the use of mathematics is restricted as far as possible. Liberal use is made of vector diagrams, and the newcomer to alternating current theory, provided he is familiar with elementary trigonometrical identities, should have no difficulty in following the whole of the field covered.

The book appears admirably suited to the needs of mechanical and civil engineering students who wish to know only the elementary facts of the electric circuit, but the electrical engineering student will find he has to cover the ground in greater detail than is possible in a book of this size. H.L.

" Telecommunications, Economics and Regulation." By James M. Herring, Ph.D., and Gerald C. Gross. 544 pp. McGraw-Hill Book Company, Inc., New York and London. 30/-.

This book presents a comprehensive history of the introduction, development and control of telecommunication services in the United States of America. It is concerned more with economics and regulation than with technical matters, and its appeal is naturally greatest in that country. It seeks to show telecommunications as something of more than local interest or national utility, and of international importance in industry, commerce and social life. Many of the difficulties encountered are common ground in both Great Britain and the United States, and although there is the fundamental difference of private ownership and commercial competition in the States as against the monopoly of the Postmaster General in Great Britain, a study of these problems and their ultimate solution cannot fail to offer the greatest interest and much food for thought to those interested in telecommunications.

The first four chapters sketch the growth of the main services, *i.e.,* telegraphs, telephones, cable and radio communications and these are followed by several chapters dealing with expenditures, revenues and the fixation of rates. The book is generously provided with tables of comparative statistics covering all phases of costs, income, plant development, traffic distribution, capitalized values, etc., from year to year.

A third section of the book covers aspects of legislation and jurisdiction which have no counterpart in this country. This shows how the commercial nature of the various enterprises has led to the introduction of measures to provide against overcharging and against the fusion of competing interests such as cables and radio in order to avoid monopolistic conditions. All services are subject both to Federal regulation and to the jurisdiction of the State Department of Justice. The special position of broadcasting in America is very clearly explained.

Among the appendixes is the text of the Communications Act of 1934 which is the most recent effort to provide for the regulation of inter-state and international communication by wire or radio and for other purposes. S.J.H.

" Heaviside's Operational Calculus." By E. J. Berg, Sc.D. Second Edition. 256 pp. 93 ill. McGraw Hill Publishing Company. 18/-.

Modern electrical problems are becoming more difficult to solve and the introduction of the Heaviside operational calculus is not merely a matter of elegance, but is essential if the power of engineering analysis is to keep pace with the growing difficulty of its technical problems. In this book, Professor Berg presents the elements of the Heaviside calculus in a manner suitable for electrical students approaching the subject for the first time. Recognizing that too much attention can be paid to questions of mathematical rigour, the author explains the first principles of the operational calculus in a plausible and simple manner without recourse to contour integration in the complex plane and the calculus of residues. The manner of applying the Heaviside calculus to practical problems is illustrated by a wide variety of applications to electrical and other problems. These illustrations bring home to the reader in a compelling manner the power of the Heaviside method and its peculiar utility for physical problems in which the initial conditions are assigned.

The second edition of Professor Berg's book contains a number of appendixes dealing with additional problems, but the reason why Heaviside was forced to invent his calculus is not made clear. Heaviside was a self-taught mathematician with an excellent knowledge of standard mathematical processes. In his early writings, however, his attitude was that of the engineer and not that of the mathematician. He had certain engineering problems before him and he wanted to get at the best possible solution with the mathematical processes available. He found that the ordinary standard methods of analysis presented formidable mathematical difficulties and in many important cases broke down completely : it was at this point that he parted with academic methods and invented that part of the operational calculus which is the subject of Professor Berg's book. In his later writings, however, Heaviside dealt almost exclusively with electromagnetic wave theory and continued to invent mathematical procedure of a radical and powerful kind. This later aspect of Heaviside's work has not been discussed by Professor Berg; a partial discussion may be possible to the mathematician but hardly to the engineer. Much of Heaviside's electromagnetic theory as well as his analysis is not understood even to-day. Only a very few persons indeed, even in future generations, will be qualified to understand and appreciate at its true value the whole of Heaviside's work.

Several schemes put forward by Heaviside as a result of his mathematical researches were, to put it mildly, regarded as ridiculous by some eminent authorities, though they proved an immediate success when tested practically by engineers in other countries. To some extent this treatment embittered him and he sought seclusion at Torquay where he lived alone. His principal contact with the world was through a local policeman who bought and delivered his supplies. One of his few personal friends was Professor Berg. In his book Professor Berg gives a personal sketch of Heaviside in his declining years. Whilst working on a fourth volume of his " Electromagnetic Theory " the war came, and with it much hardship and suffering for the old scholar. Lack of proper food and heat undermined his health. The light went out.

H.J.J.

Junior Section Notes

Wolverhampton Centre

The Fourth Annual General Meeting of the Wolverhampton and District Junior Section was held on September 30, 1936.

At the opening of the meeting cordial messages from the President and from Mr. H. Faulkner, A.M.I.E.E., Superintending Engineer of North Wales Section, were read.

The Secretary, Mr. P. S. Coss, reported upon the work of the Centre during the preceding session. A satisfactory programme had been carried out—and several very interesting places visited.

The following officers were elected for the ensuing year:—

Chairman—J. T. Davis.
Secretary—P. S. Coss.
Treasurer—B. O. Roberts.
Committee—I. Snow, J. Costello, T. Genner, E. Wakefield, E. Venmore.
Auditors—H. Jarratt and J. Shelley.

The Secretary reported that the schedule of papers, and visits to interesting places was nearly complete, and included papers on "Thermionic Valves," by Mr. H. Faulkner, A.M.I.E.E.; "Routine Testing," by Mr. H. Bishop, of Shrewsbury; "Office Routine," by Mr. H. A. Bishop, of Dudley; "Overhead Construction," by Mr. B. O. Roberts, of Wolverhampton.

The room was filled with members and friends on Wednesday, October 28th, to hear Mr. Faulkner. The paper proved to be very interesting, and at the termination Mr. Faulkner received a hearty vote of thanks from the members. We sincerely hope that our Superintending Engineer will pay us another visit at an early date.

P.S.C.

Blackpool Centre

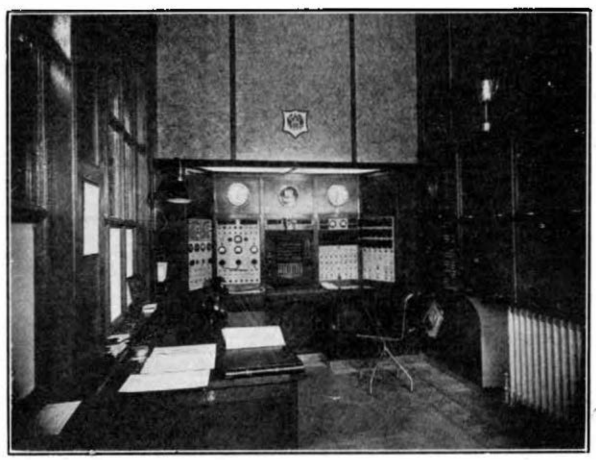
The officers connected with the Blackpool Junior Section of the I.P.O.E.E. are encouraged by the knowledge that the membership is 100 per cent. greater than other sections in the district. A well attended meeting listened intently to a lecture by Mr. Varley, the Superintendent of the Blackpool Fire Brigade.

The lecturer gave a resumé of the early history of fire brigades, and stated that insurance companies originally had their own brigades. To distinguish the buildings insured by a particular company, metal plates were fixed in a prominent position.

The "Parish Fire Engines Acts" was one of the earliest Acts for the constitution of fire brigades. The Parish Beagles and Overseers were generally responsible for the setting-up of such brigades. Mr. Varley enumerated the various types of brigades in existence at the present time, mentioning that Blackpool was a professional brigade, the most common in use in this country. This particular brigade included several tradesmen, such as electrician, plumber, bricklayer, joiner, skilled engineer, etc. All of these dealt with their particular trade, which was essential for the efficient maintenance of the plant, as well as proving invaluable during the actual calling of their duty.

Other types of brigades mentioned were police, retained, volunteer, and private, but Mr. Varley considered the professional brigade the most efficient, as the work was becoming more complicated due to the type of buildings being erected at the present time, and to the fact that various chemicals of an highly inflammable nature had to be dealt with, besides oils, petrol and spirits which are now so commonly used, necessitating specialists at the work. The Blackpool Fire Brigade are drilled daily and every opportunity is taken to drill at large buildings in the town under conditions similar to those likely to be experienced at actual fires. Lectures are given weekly on engineering matters and general education. The headquarters were becoming a training centre for members of other brigades, and close attention is given to the technique of fire brigade work.

During the recent reorganization at Blackpool, modern equipment was purchased, including a turntable ladder extending to a height of 150 feet. The watch-room had been re-designed and constructed by the members of the brigade. All operations are grouped to one switch which automatically turns on the lights, starts the fire engines, rings the alarm bells, stops the hour clock, and allows a special record clock to indicate the time taken for the brigade to turn out (which is about 15 seconds during the day and 35 seconds at night) and brings into circuit a microphone to enable the operator to instruct the firemen as to the situation, etc., of the fire. If any of the multiple of operations should fail, each point could be operated individually and each signal is supplemented by a pilot light. Mr. Varley mentioned that the local Post Office Engineering Department had given invaluable assistance in the layout of the switchboard, in the centre of which is a 50-line P.B.X. (Fig. 1).



Switchboard in the Watch Room.

The lecturer went on to give his opinion on the merits and demerits of the fire alarm systems and the Post Office Telephone Service. He mentioned that the closed circuit alarm system was in existence in the borough, but owing to the system being obsolete it had been modernized locally, although it was still unsatisfactory owing to the orginating call being merely a signal. Part of the borough is now served with the modern Post Office pillar alarm system, the principle of which Mr. Varley greatly favoured by virtue of a verbal message being received. It was of very great importance to have the actual location and extent of the fire, thus enabling the brigade to turn out with the requisite equipment and personnel, whereas with the closed circuit signalling system every call had to be treated as one of equal gravity.

In connexion with the pillar alarm system, Mr. Varley was not in favour of the public side of the pillar going direct to the police station, as the call had to be handled twice before it reached the fire station. He suggested that there should be separate emergency call systems for police matters and calls intended for the fire brigade or ambulance.

Mr. Varley advocated the use of direct telephone lines between large buildings in the town and the fire station. Twenty-two such lines were already installed and several others were contemplated in the near future.

He was of the opinion that the operation of the existing telephone system should be speeded up, as he had personally experienced delays of five or six minutes, and considered that the automatic system was a decided improvement on the manual system in this respect.

Mr. Varley gave an interesting demonstration of the three common types of fire-fighting aparatus, including the soda acid, the foam, and C.T.C., describing the operation of various extinguishers and the purpose for which they are used. Mr. Varley also very ably demonstrated the method of dealing with a person whose clothing had become ignited, and gave several hints as to the best method of dealing with fires in the initial stage during the period the brigade was travelling from headquarters to the fire.

An interesting discussion followed, in which Mr. J. Thompson proposed a vote of thanks to Mr. Varley, seconded by Mr. F. Walton. Mr. Varley thanked the members and extended an invitation to attend the fire station at a convenient date.

The photograph is by permission of the *Blackpool Gazette and Herald.*

Manchester Centre

Since the commencement of the current session, the Centre has had the misfortune to lose, owing to promotion, the services of both the Chairman and the Vice-Chairman. The two offices have been filled by Mr. J. H. Watson and Mr. J. Pratt, respectively.

The session has so far been very successful, and while it is gratifying to note that the membership has increased by 100 per cent. to its present figure of 200, the attendance at meetings has, unfortunately, not increased by a similar amount.

One of the papers read before the Centre last session, " A general outline of the Voice Frequency Telegraph System," by Mr. J. Bickerton, has gained an award in the National Competition for papers read by Junior Section members before meetings of Centres during the session. The local essay competition, closing on September 30th last, was won by Mr. A. Jones with his essay " The working of the Central Normal Stock and Replacement Depot Scheme." The awards for both these papers were presented to the authors b ythe Superintending Engineer, Mr. Morris, at the meeting on November 23rd last.

The number of meetings and visits this session has been considerably increased, eleven meetings and nine visits having been arranged.

The programme for the first half of the session is as follows :—

Oct. 3rd.—Visit to Manchester Docks.
Oct. 8th.—" Materials and Methods of Construction." W. H. Brent, A.M.I.E.E.
Oct. 24th.—Visit to Miners' Rescue Station, Boothstown.
Oct. 26th.—" Scientific Management and Industrial Psychology." A. Whiteley.
Nov. 12th.—" News." E. W. Cheadle, Publicity Manager, Allied Newspapers.
Nov. 14th.—Visit to Allied Newspapers.
Nov. 23rd.—" Teleprinter Private Wires." Rr. G. Cowen.
Dec. 5th.—Visit to Manchester Corporation Gas Works.
Dec. 17th.—" Any Questions Night."

The committee would like to than the Superintending Engineer and Sectional Engineers for their assistance in the recruitment of new members, and particularly in the stimulation of interest in the Junior Section among external staffs.

Edinburgh Centre

The 1936-37 session was inaugurated by a visit to the Edinburgh Central Automatic, Manual and Trunk Demand Exchange on September 7, 1936. A large number of the younger members of the staff who have not had automatic experience participated in the visit.

At the October meeting Mr. E. B. Spence read a paper on " Public Health," in the course of which the importance of bacteriology in the every day health of the community was stressed. This departure from the usual type of paper was enjoyed.

At the November meeting Mr. D. G. Buchanan read a paper on " The Bypath Automatic Exchange." The lecture was illustrated by lantern slides and was informative, as few of our members are familiar with this type of exchange. Mr. Buchanan read a paper last session on " Petrol from Coal," and that paper has been voted the best paper for the 1935/36 session.

Arrangements have been made for Mr. F. A. Hough to deliver his paper on " Maintenance " to the Edinburgh Centre in January next.

There has been a slight fall in the membership this session, but we are hopeful that further enrolments will take place at an early date.

Aldershot Centre

The following is the programme for the 1936/37 session.

October.—" A Few Thoughts on Transmission." V. Smith.
November.—" The General Lay-out of Line Plant." A. G. Robins.
December.—" The Unit Amplifier (with lantern slides). S. Allen.
January.—" Multi-office Auto Schemes." R. W. Haywood.
February.—" Secondary Cells." J. E. Porter.
March.—" A Visit to Ash Vale Auto Exchange." R. H. Silvester.

In addition, endeavours will be made to visit Croydon Air-port, Brighton Post Office, Johnson and Phillips Cable Works.

Portsmouth Centre

A General Meeting of the Portsmouth Branch of the Junior Section of the I.P.O.E.E., was held in the Linesmen's Room, H.P.O., Portsmouth, on Thursday, October 29th. The Vice-Chairman, Mr. A. A. Axton, officiated, in the unavoidable absence of the Chairman, Mr. G. G. H. Ogburn. Mr. W. Bell, of Reading, Secretary of the South Midland Centre, gave a talk on the need for, and work of, the Junior Sections, and his remarks and well wishes for a successful session were warmly appreciated.

To the members :—The greatest assistance you can give in assuring a successful session is to be present at the meetings. The library facilities are at your disposal, as also are the Institute Printed Papers—See the Secretary!

Guildford Centre

The first meeting of the 1936/37 session was held on October 21st, 1936. Mr. F. Lock, M.I.E.E (sectional engineer), who was in the chair, congratulated the Centre and its officers on the excellent programme arranged. He stressed the advantages and benefit to be derived from membership of the Institution and hoped that a good attendance would be maintained throughout the session.

Dr. R. R. Jenkins, B.Sc., A.R.C.Sc., Ph.D., D.I.C., then gave a most interesting lecture entitled: " Mainly Electrons." After a reference to atomic theory, explaining how evidence supported the theory of the existence of a nucleus surrounded by moving electrons, Dr. Jenkins dealt with free electrons and the methods of electronic emission:

(1) Thermionic emission.
(2) Secondary emission.
(3) Photo-electric emission.

The rest of the lecture was taken up with applications of the harnessed electron.

(1) The cathode-ray tube—theory—its uses, was made very interesting with a demonstration using a tube.
(2) The electron microscope, with interesting projected photographs of emitting surfaces.
(3) Electron diffraction—again projected photographs showing atomic alignment in crystals.
(4) The " electric eye " (with demonstration) for use in radio receivers with automatic volume control to show when the set is in tune with the carrier.

A hearty vote of thanks was accorded Dr. Jenkins for his interesting and informative lecture.

Forthcoming lectures are:—

January 6th.—" The Timing of Trunk Calls." R. J. W. Myerson.
February 3rd.—" The Inland Trunk and Junction System." A. E. Higgins, B.Sc.
March 3rd.—" Underground Cable Corrosion." E. C. Sawyer.

London Centre

We are now well embarked on the 1936/37 session and hope to see our efforts meet with the success deserved in increased membership. Many new ventures have been attempted, and it remains for your assistance to make them successful. The most important is the incorporation of the programme in a diary for the coming year. This innovation, although delaying the programme slightly, will indicate that every effort is being made to maintain the previous high standard of the Centre.

The programme for the session again presents many varied and instructive subjects, sections of which should cover the interests of every phase of our membership. A synopsis of the programme is as follows:—

" City and Guilds Examinations, Pitfalls and Pointers." A. S. A. Johnson, M.I.E.E.
" Post Office Publicity." W. J. Bentlett (E-in-C's Office).
" Television." G. Carr (E-in-C's Office).
" Cinematograph Technique with the Lid Off." D. M. Robson (P.O. Film Unit).
" A Review of American Electrical Practice of To-day." (Illustrated by a colour film). R. Borelasse Mathews, Wh.Ex., A.M.Inst.C.E.
" An Hour with Camera and Print." H. G. Kraushaar.
" Preselectors v. Line-Finders." J. Spinks.
" Efficiency." A. D. Harmden, A. W. Whitaker, and G. E. Smith.
" The 2,000 Type Selector." L. Chant.
" The Installation and Maintenance of Secondary Cells." H. E. Barnett (E-in-C's Office).
" The Post Office Talkie Clock." J. R. L. Burchell and G. Goymer.
" Remote Control Apparatus." F. R. Moody.
" The Contribution of Radio to the Safety of Ships at Sea." R. G. Smith.
" Carrier Current Telephony." J. A. Stretton.

You will agree that the preparation of these talks entails much hard work and time, and in order to show the lecturers that their efforts are being appreciated, we ask you to endeavour to attend these meetings whenever possible.

The Committee would be pleased to receive suggestions and offers of paper for the next session and would like to remind members that, in addition to the awards given by the senior section, the London Centre offer two prizes for papers read before the Junior Section, London Centre. These prizes take the form of cheques, the first being for £1 1s., and the second for 10s. 6d.

Our congratulations are offered to Mr. Sharp for his success in obtaining a Certificate of Merit for his paper, which was given last session.

Finally, our visits to the works and places of interest are meeting with remarkable success, the most recent being:—

The Tunnel Cement Works, at Essex, and

The Southern Railway Remote Control Railway Signalling Apparatus at Three Bridges and Brighton.

Others are being arranged, and if you have any suggestions to offer to the committee on this matter, your representative will be pleased to act as liaison officer.

J.A.S.

Staff Changes

PROMOTIONS.

Name.	From.	To.	Date.
Hines, R. J.	Exec. Engr. S. Western	A.S.E., N.E. Reg.	30-9-36
	A.S.E., N.E. Reg.	Regional Engr., N.E. Reg.	21-1-37
Morgan, C. E.	A.S.E., N.E. Reg.	Regional Engr., N.E. Reg.	30-9-36
Ashdowne, H. A.	Exec. Engr., S. Midland	Regional Engr. Scot. Reg.	10-11-36
Judd, F. J.	Actg. Exec. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	29-7-36
Turner, H. M.	Actg. Exec. Engr., London	Exec. Engr., London	29-7-36
Chew, W. G. N.	Actg. Exec. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	30-9-36
Macwhirter, R.	Actg. Area Engr., Scot. Reg.	Area Engr. Scot. Reg.	29-8-36
Smith, H. G.	Asst. Engr., Eastern	Actg. Exec. Engr., S. Western	—
Thorn, B. K.	Chief Insp., London	Asst. Engr., E.-in-C.O.	1-1-37
Bentley, F. E.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Freestone, A. G.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-1-37
Bird, F. T.	Chief Insp., N. Midland	Asst. Engr., E.-in-C.O.	1-1-37
Young, J. S.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Clibbon, H. A.	Chief Insp., E.-in-C.O.	Asst. Engr., S. Lancs.	25-9-36
Wright, C.	Chief Insp., N. Ireland	Asst. Engr., N. Ireland	7-10-36
Ranner, E. W.	Chief Insp., E.-in-C.O.	Asst. Engr., E.-in-C.O.	16-11-36
Delahunty, T. P. J.	Insp., London	Chief Insp., London	1-9-36
Ellis, F. G.	Insp., London	Chief Insp., London	1-12-36
Iliffe, G. E.	Insp., N. Wales	Chief Insp., N. Wales	14-5-36
Thornley, H. G.	Insp., N. Western	Chief Insp., N. Western	1-1-37
Stevens, F. W.	Insp., S. Western	Chief Insp., S. Western	9-7-36
Lewis, C. H.	Insp., S. Western	Chief Insp., S. Western	24-5-36
Brown, R. C. C.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	1-6-36
Thraves, J. J.	Insp., London	Chief Insp., London	10-8-36
Johnstone, W. S.	Insp., Cupar Radio Stn.	Chief Insp., Cupar Radio Stn.	29-6-36
Verney, J. P. S.	Insp., S. Wales	Chief Insp., S. Wales	31-6-36
Joliffe, A. P.	Insp., S. Eastern	Chief Insp., S. Eastern	11-8-36
Miles, A.	Insp., S. Eastern	Chief Insp., S. Eastern	30-8-36
Britton, G. A. C. R.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	31-7-36
Allies, H. J.	Insp., N. Western	Chief Insp., N. Western	24-5-36
Skeoch, W.	Insp., Scot. Region	Chief Insp., Scot. Region	1-10-36
Morgan, C. A.	Insp., London	Chief Insp., London	15-9-36
Porter, E. R. C.	Insp., S. Midland	Chief Insp., S. Midland	26-6-36
Hills, J. A. E.	Insp., London	Chief Insp., London	13-7-36
Lee, A.	Insp., Test Section	Chief Insp., Test Section	24-5-36
McDougald, F. M.	Insp., N. Midland	Chief Insp., N. Midland	30-8-36
Stewart, A. D.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	1-9-36
Osborne, W. V.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	22-7-35
Purvis, C.	Insp., Eastern	Chief Insp., Eastern	13-10-36
Davis, A. T.	Insp., N. Wales	Chief Insp., N. Wales	3-10-36
Thomas, H. C.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	29-8-36
Cottrell, H. E.	Insp., Test Section	Chief Insp., Test Section	To be fixed later.
Latimer, E. D.	Insp., Test Section	Chief Insp., Test Section	24-5-36
Voss, L. C.	Insp., Test Section	Chief Insp., Test Section	24-5-36
Marks, R.	Area M.T.O., Birmingham	Regional M.T.O. London	23-11-36
Whitehurst, J. F.	Tech. Asst., Exeter	M.T.O. Cl. III., E.-in-C.O.	23-11-36
Williams, A. J. F.	Mech.-in-Charge, Grade I.	Tech. Asst.	14-11-36
Dring, G. S.	Mech.-in-Charge, Grade I.	Tech. Asst.	11-11-36
Sharp, H. N.	S.W.I., N. Wales	Insp., N. Wales	15-5-36
Webb, C. W.	S.W.I., N. Western	Insp., N. Western	1-10-36
Thornley, R. B.	S.W.I., N. Western	Insp., N. Western	1-10-36
Aitchison, A.	S.W.I., Scot. Region	Insp., Scot. Region	23-3-36
Malcolm, H.	S.W.I., Scot. Region	Insp., Scot. Region	3-10-36
Menzies, W. C. K.	S.W.I., Scot. Region	Insp., Scot. Region	31-8-36
Graham, J.	S.W.I., Scot. Region	Insp., Scot. Region	27-9-36
Massey, G. O.	S.W.I., Scot. Region	Insp., Scot. Region	22-9-35
Malley, J.	S.W.I., Scot. Region	Insp., Scot. Region	1-9-36
Cameron, J. W.	S.W.I., Scot. Region	Insp., Scot. Region	3-10-36
Baxter, W. S.	S.W.I., Scot. Region	Insp., Scot. Region	6-2-36
Miller, P.	S.W.I., Scot. Region	Insp., Scot. Region	23-3-36
Johnston, T. D.	S.W.I., Scot. Region	Insp., Scot. Region	2-7-36
Hastie, T.	S.W.I., Scot. Region	Insp., Scot. Region	24-2-36
Montgomery, D.	S.W.I., Scot. Region	Insp., Scot. Region	24-2-36
Gibson, J.	S.W.I., Scot. Region	Insp., Scot. Region	1-10-36
Duncan, N.	S.W.I., Scot. Region	Insp., Scot. Region	6-10-36
Bettelley, F. H.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Budgen, A. H.	S.W.I., S. Eastern	Insp., S. Eastern	15-10-36
Budgen, F. B.	S.W.I., S. Eastern	Insp., S. Eastern	24-10-36
Casemore, F. H.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Chapman, E. A.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Davis, P. J.	S.W.I., S. Eastern	Insp., S. Eastern	25-10-36

Name.	From.	To.	Date.
Giles, F. R.	S.W.I., S. Eastern	Insp., S. Eastern	25-10-36
Goodwin, W. O. L.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Hewett, C. H.	S.W.I., S. Eastern	Insp., S. Eastern	23-8-36
Heyburn, L. G.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Hickmott, R. S.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Hutchins, H.	S.W.I., S. Eastern	Insp., S. Eastern	30-8-36
Jarvis, H. W.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Laws, A. R. J.	S.W.I., S. Eastern	Insp., S. Eastern	25-10-36
Lucas, V. F.	S.W.I., S. Eastern	Insp., S. Eastern	13-7-36
Malyon, J.	S.W.I., S. Eastern	Insp., S. Eastern	14-10-36
Norris, H. E.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-36
Polhill, C. F.	S.W.I., S. Eastern	Insp., S. Eastern	25-10-36
Quinnell, C.	S.W.I., S. Eastern	Insp., S. Eastern	1-11-36
Scutt, R. S.	S.W.I., S. Eastern	Insp., S. Eastern	25-10-36
Tulley, J.	S.W.I., S. Eastern	Insp., S. Eastern	1-11-36
Wheeler, A.	S.W.I., S. Eastern	Insp., S. Eastern	25-10-36
Whitehead, E. H.	S.W.I., S. Eastern	Insp., S. Eastern	23-8-36
Carter, R. E.	S.W.I., Test Section, London	Insp., Test Section, London	3-7-36
Clark, E. N.	S.W.I., Eastern	Insp., Eastern	28-6-36
Coe. W. D.	S.W.I., Eastern	Insp., Eastern	10-5-36
Hamblett, R.	S.W.I., Eastern	Insp., Eastern	26-1-36
Huke, C. J.	S.W.I., Eastern	Insp., Eastern	28-6-36
Kitteridge, H.	S.W.I., Eastern	Insp., Eastern	8-10-35
Miller, E. W.	S.W.I., Eastern	Insp., Eastern	8-10-35
Pickering, E.	S.W.I., Eastern	Insp., Eastern	16-8-36
Plumstead, E. F.	S.W.I., Eastern	Insp., Eastern	20-10-35
Smith, S. C.	S.W.I., Eastern	Insp., Eastern	1-7-36
Titmarsh, G.	S.W.I., Eastern	Insp., Eastern	20-10-35
Whitman, W. F.	S.W.I., Eastern	Insp., Eastern	11-8-36
Colburn, J. T.	S.W.I., N. Midland	Insp., N. Midland	8-10-35
Came, A. G. W.	S.W.I., S. Western	Insp., S. Western	29-3-36
Came, C. H.	S.W.I., S. Western	Insp., S. Western	8-11-36
Carter, R.	S.W.I., S. Western	Insp. S. Western	20-9-36
Collett, W. H.	S.W.I., S. Western	Insp., S. Western	24-9-36
Harris, C.	S.W.I., S. Western	Insp., S. Western	27-8-36
McMullin, J. G.	S.W.I., S. Western	Insp., S. Western	22-11-36
Smith, B. W.	S.W.I., S. Western	Insp., S. Western	15-9-36
Trott, S. L.	S.W.I., S. Western	Insp., S. Western	1-8-36
Winckworth, S. E.	S.W.I., S. Western	Insp., S. Western	9-8-36
Hillard, E. F.	S.W.I., S. Midland	Insp., S. Midland	20-10-36
Holt, W. R.	S.W.I., S. Midland	Insp., S. Midland	25-10-36
Horne, W. J.	S.W.I., S. Midland	Insp., S. Midland	1-11-36
Callon, E.	S.W.I., N.E. Region	Insp., N.E. Region	20-4-36
Wallis, I. H.	S.W.I., Eastern	Insp., Eastern	28-6-36
Kain, J. S.	S.W.I., N. Ireland	Insp., N. Ireland	10-9-36
O'Doherty, J. S.	S.W.I., N. Ireland	Insp., N. Ireland	7-11-36
Kelly, F. M.	S.W.I., Scot. Region	Insp., Scot. Region	2-2-36
Mackenzie, W. H.	S.W.I., Scot. Region	Insp., Scot. Region	27-1-36
Crighton, R. D.	S.W.I., Scot. Region	Insp., Scot. Region	26-2-36
McGaw, P.	S.W.I., Scot. Region	Insp., Scot. Region	29-2-36
McEwan, A.	S.W.I., Scot. Region	Insp., Scot. Region	2-5-36
McWalter, W. V.	S.W.I., Scot. Region	Insp., Scot. Region	1-1-36
McKendrick, W.	S.W.I., Scot. Region	Insp., Scot. Region	15-12-35
Paterson, W. O.	S.W.I., Scot. Region	Insp., Scot. Region	2-8-36
Crowe, F.	S.W.I., Scot. Region	Insp., Scot. Region	23-8-36
Halligan, M.	S.W.I., Scot. Region	Insp., Scot. Region	25-2-36
Young, A.	S.W.I., Scot. Region	Insp., Scot. Region	25-2-36
Dunbar, W. E.	S.W.I., Scot. Region	Insp., Scot. Region	26-2-36
Griffith, M.	S.W.I., Scot. Region	Insp., Scot. Region	24-2-36
Yeats, J. A.	S.W.I., Scot. Region	Insp., Scot. Region	26-2-36
Kinnear, D. J.	S.W.I., Scot. Region	Insp., Scot. Region	23-3-36
Donaldson, J.	S.W.I., Scot. Region	Insp., Scot. Region	24-3-36
Kilgour, C. E.	S.W.I., Scot. Region	Insp., Scot. Region	9-8-36
Horner, W.	S.W.I., N.E. Region	Insp., N.E. Region	1-11-36
Crew, S. A.	S.W.I., N.E. Region	Insp., N.E. Region	25-10-36
Wright, G. W. P.	S.W.I., N.E. Region	Insp., N.E. Region	31-7-36
Jackson, W. H.	S.W.I., N.E. Region	Insp., N.E. Region	31-7-36
Bulfin, A.	S.W.I., N.E. Region	Insp., N.E. Region	1-2-36
Bell, W. M.	S.W.I., N.E. Region	Insp., N.E. Region	1-5-36
Kitcheman, E.	S.W.I., N.E. Region	Insp., N.E. Region	31-7-36
Stafford, R. F.	S.W.I., N.E. Region	Insp., N.E. Region	25-10-36
Buckley, W.	S.W.I., N.E. Region	Insp., N.E. Region	25-10-36
Green, D.	S.W.I., N.E. Region	Insp., N.E. Region	1-4-36
Bull, W. H.	Draughtsman II., N.E. Region	Insp., N.E. Region	19-10-36
Hilton, H.	Draughtsman II., N.E. Region	Insp., N.E. Region	31-7-36
Shaw, H.	S.W.I., S. Lancs.	Insp., S. Lancs.	22-11-36

PROMOTIONS—continued.

Name.	From.	To.	Date.
Thomas, A. S.	S.W.I., S. Western	Insp., S. Western	28-10-36
Rolls, H. R.	S.W.I., S. Western	Insp., S. Western	24-8-36
Jones, G. A. H.	S.W.I., S. Eastern	Insp., S. Eastern	13-11-36
Bishop, H. H.	S.W.I., S. Eastern	Insp., S. Eastern	12-11-36
Fowler, L.	S.W.I., N. Midland	Insp., N. Midland	2-5-36
Lewis, F. L.	S.W.I., S. Western	Insp., S. Western	26-7-36
Abbott, R. W. O.	S.W.I., London	Insp., London	To be fixed later.
Appleford, L. E.	S.W.I., London	Insp., London	,,
Barron, D. F. J.	S.W.I., London	Insp., London	,,
Benham, A. D.	S.W.I., London	Insp., London	,,
Brackenborough, L. W. E.	S.W.I., London	Insp., London	,,
Gardener, S. A.	S.W.I., London	Insp., London	,,
Gosling, A. H.	S.W.I., London	Insp., London	,,
Hannah, H. W. G.	S.W.I., London	Insp., London	,,
Kennedy, D.	S.W.II., London	Insp., London	,,
Kerrison, A. V.	S.W.I., London	Insp., London	,,
Pearce, H. S.	S.W.I., London	Insp., London	,,
Prince, C. J.	S.W.I., London	Insp., London	,,
Stephens, H. R.	S.W.I., London	Insp., London	,,
Honeybone, A. J.	S.W.I., Test Section, London	Insp., Test Section, London	,,
Willson, A. H.	S.W.I., Test Section, B'ham.	Insp., Test Section, London	,,
Adair, W. H.	S.W.I., N. Ireland	Insp., N. Ireland	,,
Brooks, W.	S.W.I., N. Ireland	Insp., N. Ireland	,,
Dooley, T.	S.W.I., N. Ireland	Insp., N. Ireland	,,
Greaves, H.	S.W.I., N. Ireland	Insp., N. Ireland	,,
Mearns, E. R.	S.W.I., N. Ireland	Insp., N. Ireland	,,
Pearcey, J. F. H.	S.W.I., N. Ireland	Insp., N. Ireland	,,
Price, V. C.	S.W.I., N. Ireland	Insp., N. Ireland	,,
Bartlett, D. L. G.	S.W.I., S. Wales	Insp., S. Wales	,,
Chiswell, J. A.	S.W.I., S. Wales	Insp., S. Wales	,,
Coles, W. H. A.	S.W.I., S. Wales	Insp., S. Wales	,,
Dukes, H. B.	S.W.I., S. Wales	Insp., S. Wales	,,
Fox, G.	S.W.I., S. Wales	Insp., S. Wales	,,
Jones, O. H.	S.W.I., S. Wales	Insp., S. Wales	,,
Watkins, H. W.	S.W.I., S. Wales	Insp., S. Wales	,,
Warwick, A.	S.W.I., N. Midland	Insp., N. Midland	,,
Tennant, T. M.	Draughtsman II. (Unstd.), E.-in-C.O.	Draughtsman I. (Unstd.), E.-in-C.O.	28-7-36
Morris, A. J.	Draughtsman II., E.-in-C.O.	Draughtsman I., E.-in-C.O.	28-7-36
Aris, F. C.	Draughtsman II., E.-in-C.O.	Draughtsman I., E.-in-C.O.	28-7-36
Winterborne, A. C.	Draughtsman II., E.-in-C.O.	Draughtsman I., E.-in-C.O.	31-10-36
Waldegrave, R. F.	Draughtsman II., E.-in-C.O.	Draughtsman I., E.-in-C.O.	1-11-36
Fuse, R. D.	Draughtsman II., S. Wales	Draughtsman I., N. Midland	20-9-36
Thistlethwaite, H.	Draughtsman II., N. Wales	Draughtsman I., N. Wales	23-8-36
Dadswell, J. H.	Draughtsman II., London	Draughtsman I., E.-in-C.O.	12-10-36

APPOINTMENTS.

Name.	From.	To.	Date.
Coleman, W. L. A.	Proby. Asst. Engr., S. Western	Asst. Engr., S. Western	1-10-36
Seaman, E. C. H.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Smith, D.	Proby. Asst. Engr., N.E. Region	Asst. Engr. N.E. Region	1-10-36
Turner, C.	Proby. Asst. Engr., S. Lancs.	Asst. Engr. S. Lancs.	1-10-36
Turner, H. A.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr. E.-in-C.O.	1-10-36
Reed, R. E.	Proby. Asst. Engr., N.E. Region	Asst. Engr., N.E. Region	1-10-36
Nicholls, C. A. L.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr. E.-in-C.O.	1-10-36
Wilcockson, H. E.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Combridge, J. H.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Maddison, W. H.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Blackburn, E.	Proby. Asst. Engr., S. Lancs.	Asst. Engr., S. Lancs.	1-10-36
Millar, D. P. M.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Parker, J. D.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Bray, W. J.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Pearce, C. A. R.	Proby. Asst. Engr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	1-10-36
Thompson, J. O.	New Entrant	Proby. Asst. Engr., E.-in-C.O.	21-9-36
Welch, S.	New Entrant	Proby. Asst. Engr., E.-in-C.O.	12-10-36
Prescott, J.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	22-9-36
Chapman, E.	M.T.O. III., E.-in-C.O.	Asst. Reg. M.T.O., London	28-10-36

TRANSFERS.

Name.	Rank.	From.	To.	Date.
Gregory, H. J.	Asst. Staff Engr.	E.-in-C.O.	S. Eastern	1-10-36
Ingram, C. P.	Asst. Engr.	E.-in-C.O.	S. Western	15-11-36
Towle, E. H. N.	Chief Insp.	London	E.-in-C.O.	25-9-36
Wright, F. V.	Area M.T.O.	London	Birmingham	23-11-36
Rhodes, W.	Insp.	Baldock, R. S.	E.-in-C.O.	26-10-36
Gerrard, J.	Insp.	S. Lancs.	E.-in-C.O.	1-11-36
Newson, W.	Insp.	London	E.-in-C.O.	20-11-36

RETIREMENTS.

Name.	Rank.	District.	Date.
Gravill, W. E.	Asst. Suptg. Engr.	S. Eastern	30-9-36
Martin, P. C.	Exec. Engr.	London	31-10-36
Gill, L. P.	Asst. Engr.	N. Ireland	30-9-36
McIntyre, J.	Asst. Engr.	Scot. Region	19-9-36
Sinclair, J.	Chief Insp.	Scot. Region	31-7-36
McAllan, J. N.	Chief Insp.	Scot. Region	30-9-36
Downing, D. R. J.	Chief Insp.	Eastern	12-10-36
Ward, D. V.	Chief Insp.	S. Eastern	31-10-36
James, E.	Chief Insp.	London	30-11-36
Morris, H.	Chief Insp.	N. Eastern	30-11-36
Braund, T. C.	Insp.	N. Midland	22-9-36
Gayfer, R. A. C.	Insp.	London	30-9-36
Donovan, A. E.	Insp.	London	30-9-36
Tansley, W.	Insp.	S. Lancs.	14-10-36
Darkin, J.	Insp.	Eastern	1-11-36
Hulton, H. H.	Insp.	S. Western	31-10-36
Sleath, E. E.	Insp.	S. Wales	10-12-36

DEATHS.

Name.	Rank.	District.	Date.
Bucklitsch, A. A. K. F.	Chief Insp.	S. Western	12-10-36
Gilbert, J.	Chief Insp.	London	28-10-36
Beveridge, W.	Chief Insp.	London	30-10-36

CLERICAL GRADES.

PROMOTIONS.

Name.	From.	To.	Date.
Frewin, W. D.	H.C.O., London	Staff Officer, London	1-10-36
Hunt, H. H.	C.O., London	Actg. H.C.O., London	29-8-36
Poole, R. R.	C.O., London	Actg. H.C.O., London	1-10-36
Wright, G. H.	C.O., London	Actg. H.C.O., London	1-12-36
Hanbury, H. D.	C.O., London	Actg. H.C.O., London	1-1-37
Bate, E.	C.O., S. Lancs	Actg. H.C.O., N. Wales	1-1-37
Gladman, J. A.	C.O., S. Eastern	Actg. H.C.O., N. Wales	10-10-36
Hadfield, W. H.	C.O., S. Lancs.	Actg. H.C.O., N.E. Region	30-10-36
Sault, F. S.	C.O., N. Midland	Actg. H.C.O., N. Midland	22-9-36
Thurslby, E.	C.O., N. Midland	H.C.O., N.E. Region	22-11-36
Mosdell, J. V. B.	C.O., S. Midland	Actg. H.C.O., Eastern	1-12-36
Martin, H. G.	C.O., S. Eastern	Actg. H.C.O., N. Wales	6-12-36

RETIREMENTS.

Name.	Rank.	District.	Date.
Pither, L. D.	E.O.	London	30-11-36
French, J. J.	H.C.O.	London	31-12-36
Lane, J.	H.C.O.	N.E. Region	29-10-36
Clarke, A. H.	H.C.O.	N. Wales	9-10-36
Bartlett, A. H.	H.C.O.	S. Eastern	9-11-36
Deacon, S. H.	H.C.O.	Eastern	30-11-36
Read, A. M.	H.C.O.	N. Wales	31-12-36

TRANSFERS.

Name.	Rank.	From.	To.	Date.
Jenkins, L. T.	E.O.	A.G.D.	E.-in-C.O.	27-9-36

DEATHS.

Name.	Rank.	District.	Date.
West, H. J.	Clerical Officer	E.-in-C.O.	1-9-36

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Post Office Electrical Engineers' Journal

Volume XXIX April 1936—March 1937

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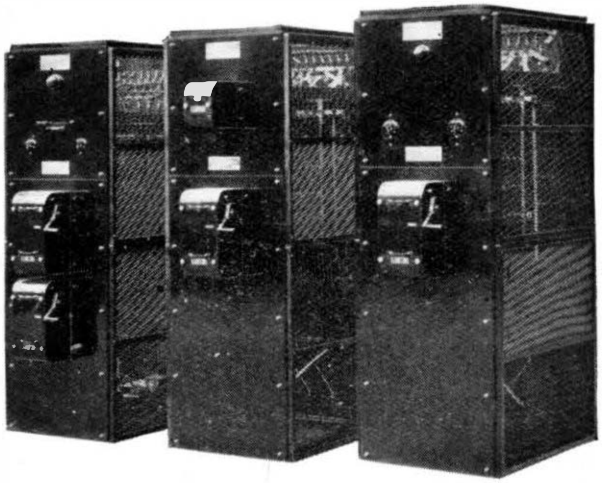
Power Supply for Transmitters



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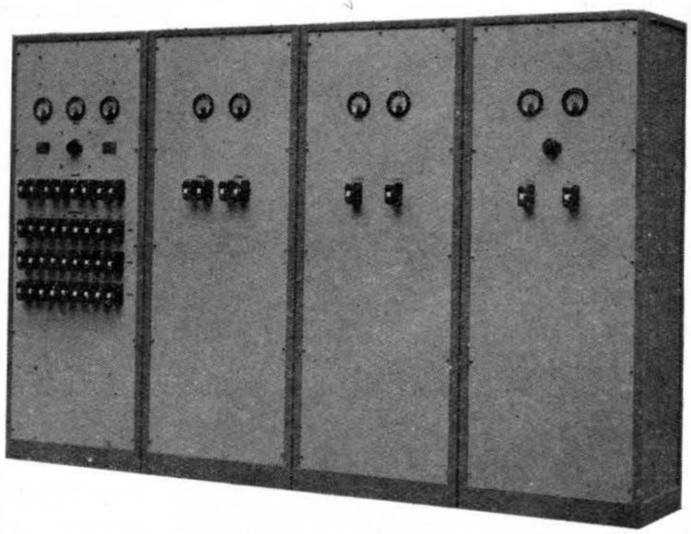

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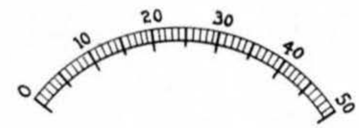

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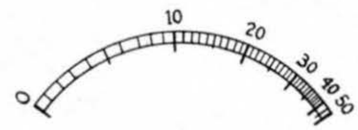

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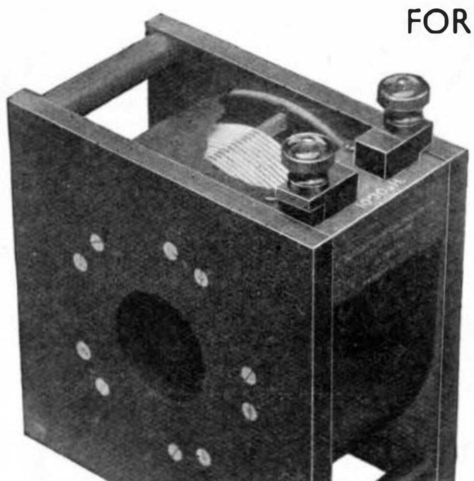

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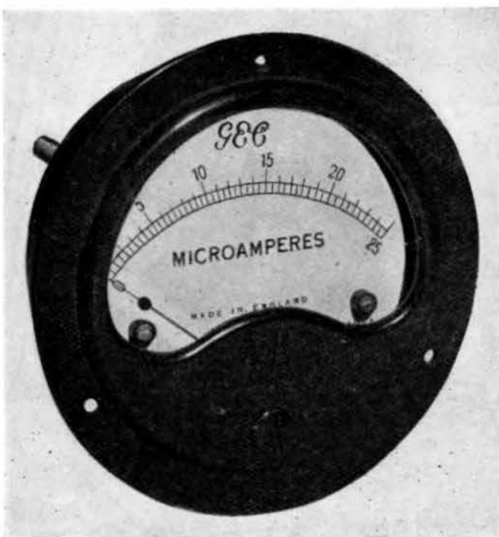

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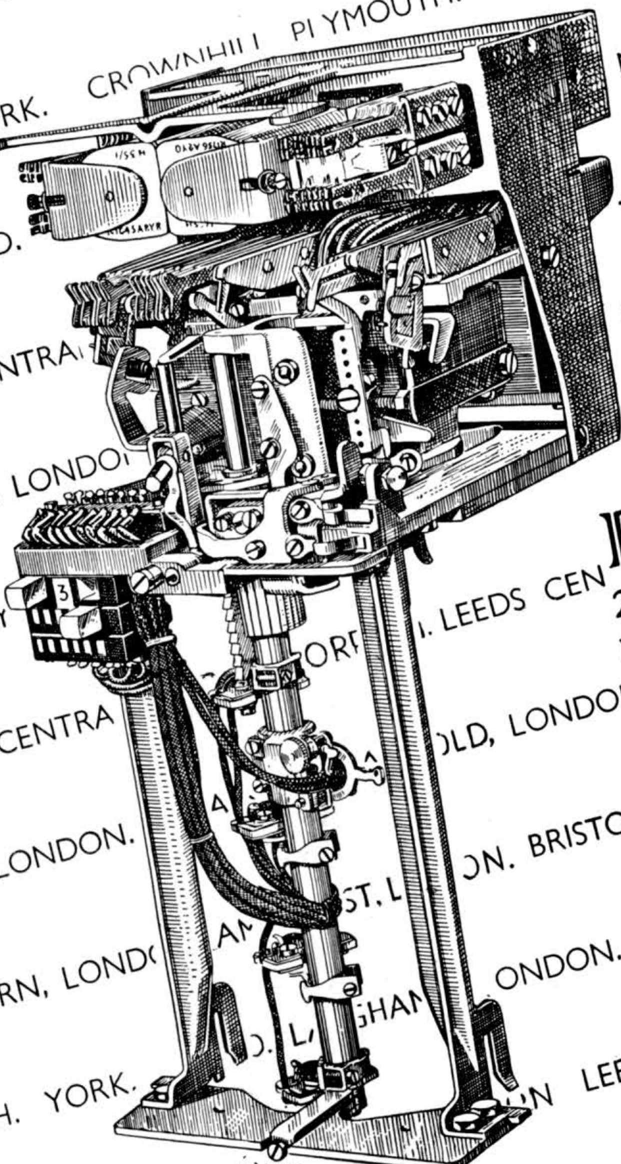

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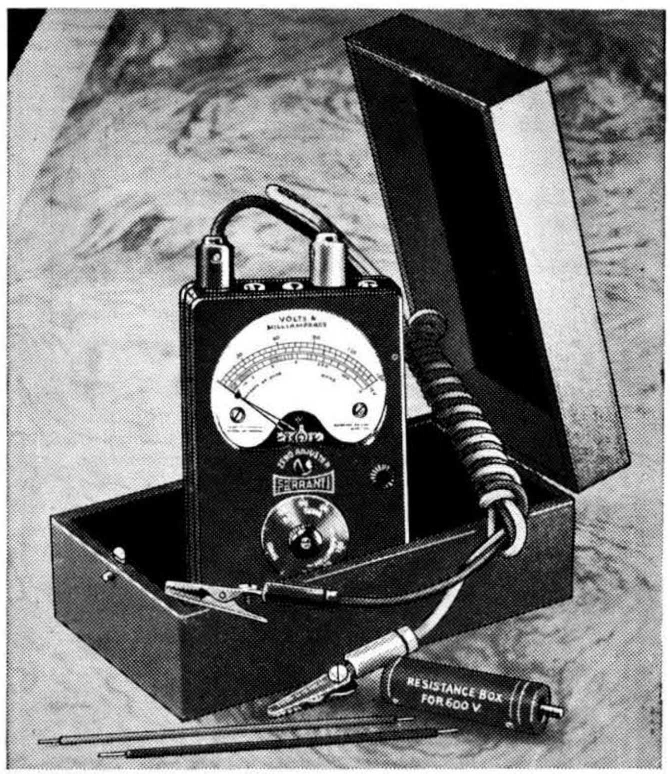

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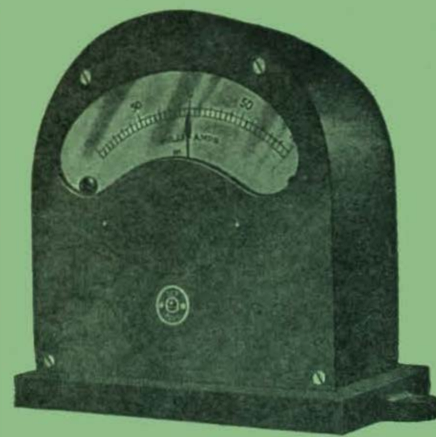

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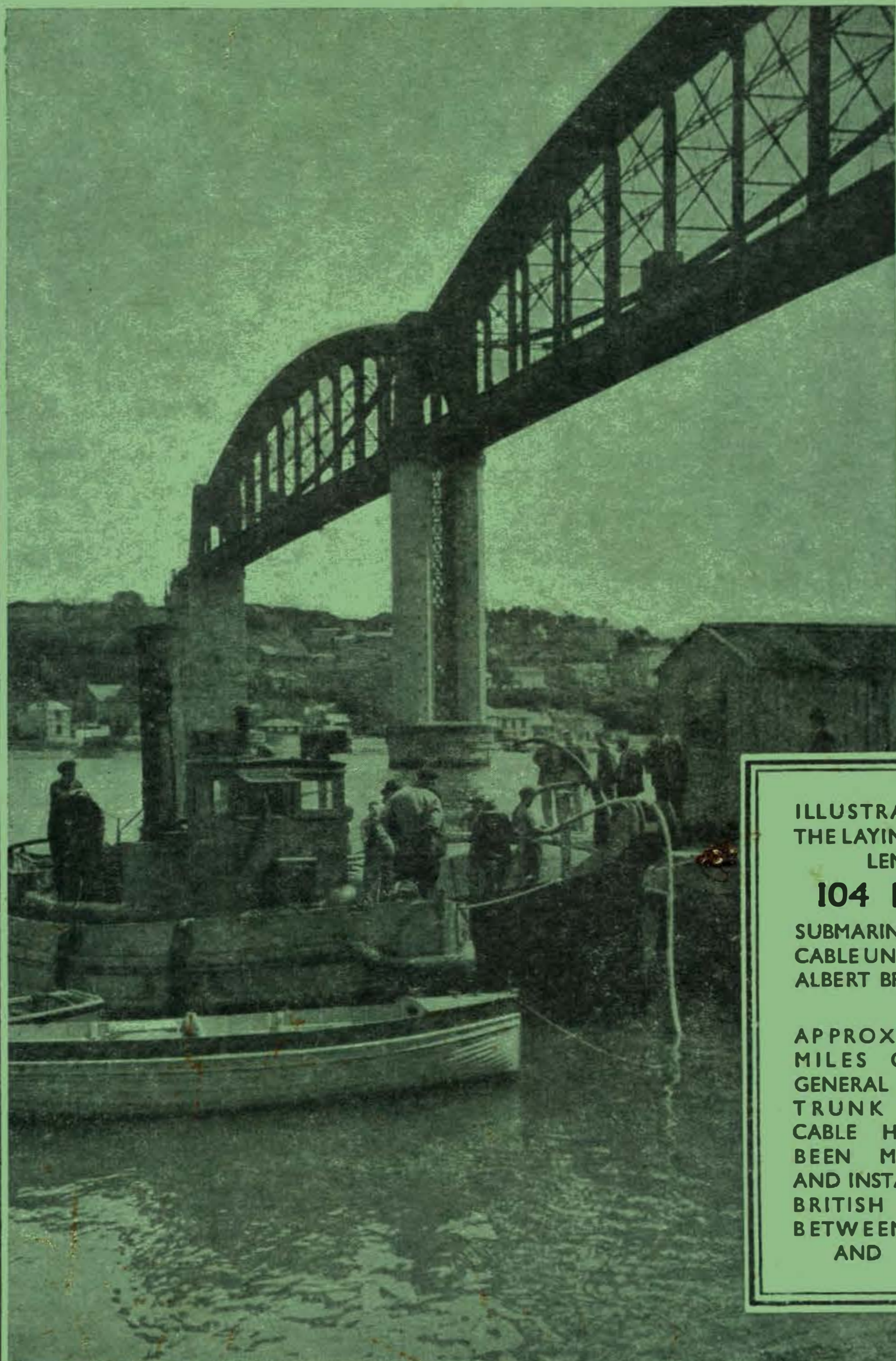

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