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PICTURE TELEGRAPHY.

ALTHOUGH there are several methods of transmitting print and line drawings over telegraph wires, this article is limited to those systems which receive photographically.

The transmission of print and pictures over a telegraph line is not of recent origin, the first attempts actually dating from 1843, but the transmission of really good pictures is a modern achievement.

A photograph is considered critically sharp if the smallest element does not exceed the size of a dot one two-hundredth of an inch or, say, one-eighth of a millimetre in diameter. Systems which reproduce a picture coarser than this fall off in perfection proportionately, although they may be suitable for the purpose for which they are required.

All systems require a sending apparatus, a receiving apparatus, means for keeping the movements of the sending and receiving apparatus in synchronism and a line or medium for connecting the sending to the receiving apparatus.

The sending apparatus provides means for scanning the picture or print in closely spaced lines and converting the light and dark portions into an electric current whose strength is proportional to the light and shade on the picture. An alternating current is generally chosen for this purpose, as being more easily transmitted over a telephone line, its frequency being chosen to suit the line characteristics. The higher the carrier frequency the quicker can any given picture be sent for the same fineness of detail. It will at once be seen that radio offers advantages, since generally a higher carrier frequency can be used; in the case of line transmission the picture carrier is modulated in accordance with the light and shade of the picture, whilst for radio transmission this modulated picture carrier in turn modulates the radio waves.

The Sending Apparatus.—This consists of a source of light which can be focussed on the picture as a point. The picture is clamped to a drum which can be rotated and traversed as a nut along a screw thread. The point of light therefore scans the picture in the form of a spiral. In the case of the " Bell " system the picture is prepared in the form of a transparent film about seven inches by five inches and the light passes through the film and is concentrated by a lens on to a photo-cell, the amount of light passing being governed by the light and dark portions of the film. In the case of the " Belin " and " Siemens-Carolus " systems interrupted light is used, the number of interruptions per second being the carrier frequency. In the former system the light spot is of appreciable size on the picture, a point of the picture being taken and concentrated on to the photo-cell, whilst in the latter system the light falls as a point about two-tenths of a millimetre in diameter on the drum, the reflected light being caught in the photo-cell.

The photo-cell consists of an evacuated glass vessel on one wall of which is a deposit of potassium hydride; this deposit is connected to a lead passing through the glass and forms the cathode, the potassium emitting electrons in proportion to the amount of light falling on it. The anode consists of a metal plate or wire grid also with an external connection. A battery of suitable electromotive force and correct polarity converts the emitted electrons into a flow of current and by suitable coupling this current can be made to vary the grid potential of the first valve of a valve amplifier. Care must be taken not to use too high a priming voltage for the photo-cell as, if so, ionisation will occur and the electron emission will not be controlled by the light. In the case of the cell used in the "Siemens-Carolus" system, from 100 to about 150 volts, depending on the cell, will be found suitable; the votage is adjusted until ionisation occurs, and then reduced about 10 volts. The maximum current even for white light is very small, being of the order of 10^{-8} amperes. The cell behaves to coloured light much as an ordinary photographic plate does, red light corresponding to black, and blue and ultra violet to white.

In the Siemens system a four valve resistance-capacity coupled amplifier, fitted with potentiometers for controlling the amplification, amplifies the photo-cell current and puts it on the telephone line through an output transformer. A good adjustment is 0.3 volts for white light on an 800 ohm impedance line. Similar arrangements are used in the case of the Belin system. All leads and the amplifier must be carefully screened from interference.

In the case of the "Bell" system a two valve battery-coupled amplifier is used, the output voltage from the second valve being used to modulate an oscillator produced carrier current on the grid of a third and final valve which feeds the line through a transformer. In this system the voltage applied to the first valve from the photo-cell is of the order of 30 to 40 milli-volts.

In the Belin system the light is interrupted from 800 to 900 times a second. In the Siemens system an automobile headlight type of lamp, with its filament displaced from the centre so as not to produce two images and rated at 6 volts, is overrun at about 7 to 8 volts and controlled by a series resistance off a 12 volt battery. For normal telephone lines the light interruptions are 1300 per second.

A high pass filter cutting off below half the carrier frequency, in this case 650 cycles per second, is inserted between the output transformer and the line.

The carrier frequency can be changed from 1300 cycles per second to any reasonable value, by either changing the speed of the disc-driving

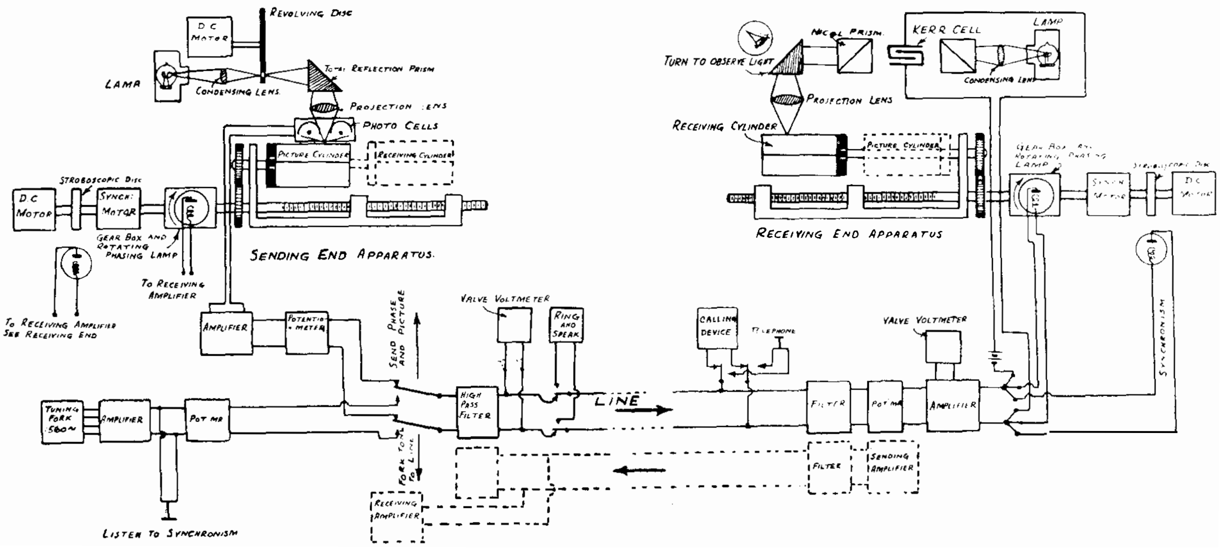

FIG. 1.—SIEMENS-CAROLUS SYSTEM: SCHEMATIC DIAGRAM.

motor by altering the series resistance, or another disc with a different number of holes can be used. The carrier frequency can be adjusted, either by observing a tachometer coupled to the interrupting disc or by listening to the carrier frequency in a telephone and also at the same time to a 1300 cycle tuning-fork.

The Receiving Apparatus.—The line is connected *via* a potentiometer which is used to control the incoming power to an amplifier which amplifies the line current to a value suitable for operating the receiving apparatus.

The picture is received on a photographic film, which is mounted on a drum and is rotated and traversed in a similar manner to the sending drum. The drum is of necessity enclosed in a light-tight case, a spot of light being projected on the drum by an optical system from a suitable source of light. The intensity of the light is controlled by the received current.

In the case of the Belin system, the carrier current is rectified and operates the mirror of a "Dubois" oscillograph; the tilting of the mirror throws more or less light through a special aperture and lens on to the film.

In the Bell system, the amplified current is passed through a narrow ribbon type conductor in a strong magnetic field; the ribbon is so arranged that it normally covers an aperture through which the light reaches the photographic film. The ribbon will vibrate in accordance with the frequency and amplitude of the received current; the greater the amplitude the greater the amount of light which will go through. In the case where the light aperture is focussed on the film, lines of constant intensity and varying width will be produced. In the second type of reception, diffused light falls on the film; in this case lines of constant width and varying intensity are formed. This latter type of reception is more suited to photographic manipulation, whilst in the first type if the lines are suitably spaced, say, 60 to the inch, the negative may be used to print directly on the zinc typographic plate. In the latter system a hundred lines to the inch are used and the usual screen is used for half-tone reproduction. The time of transmission of a 5 inch by 7 inch picture is about seven minutes.

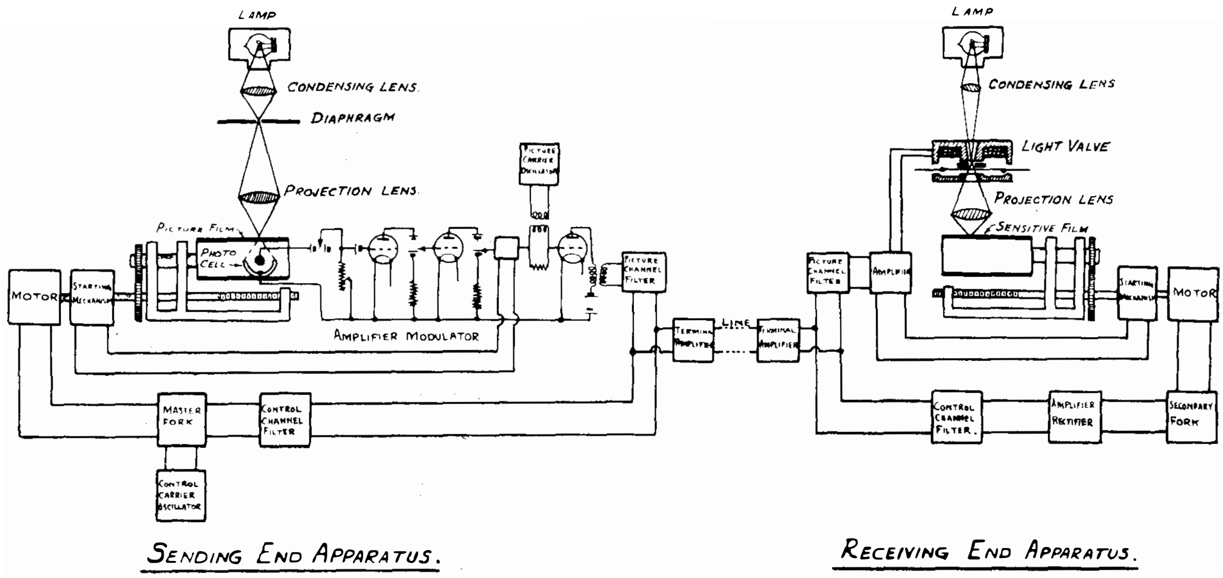

FIG. 2.—"BELL" SYSTEM: SCHEMATIC DIAGRAM.

In the Siemens-Carolus system a two valve amplifier transforms the line current to a voltage (for white light sent) of from 400 to 600 volts. This voltage is applied, together with a direct priming voltage of from 70 to 200 volts, to the electrodes of a Kerr or Carolus cell which consists of two brass terminals immersed in nitrobenzol in a glass vessel. In the earlier type of cell the electrode gap is adjustable and consists of one gap, whilst in the later type the electrodes are fixed and the gap is a multiple one like a multi-plate condenser. The adjustable type requires the higher voltages and the fixed type the lower voltages mentioned. The fixed type has the advantage that they may be constructed, filled and hermetically sealed in the works, whilst the adjustable type has to be cleaned and filled *in situ*.

Light from a source similar to that used at the transmitting end is passed through lenses and two Nicol prisms, between which the Kerr cell is placed, further lenses and prisms focus the light as a spot on the film. The Nicol prisms are set so as to cut off all light from being transmitted, each prism being set to polarise the light at right angles to the other. When voltage is applied to the Kerr cell, the plane of polarisation of the light is twisted, thus allowing more light to get through. The Kerr cell thus acts as a light valve without inertia and can therefore work up to any required carrier frequency, such as might be possible with radio transmission. The law followed (light against voltage applied) is very similar to that of the anode current of a valve where anode current corresponds to light and grid volts to volts across the electrodes of the Kerr cell. In the Belin and Siemens systems the films are fixed to drums enclosed in light-tight cases in the dark room; they are then brought out into the operating room and attached to the picture apparatus as required.

Synchronisation.—It is essential not only that the drum at the sending and receiving ends should run at a uniform speed but also that these speeds should be identical. The following quotation is taken from the "Bell System Technical Journal," Vol. IV., No. 2, April, 1925: "Were it possible to have two forks at widely separated points running at exactly the same speed, the problem of synchronizing would be immediately solved. Actually this is not practical, since variations of speed with temperature and other causes prevent the two forks from operating closely enough together for this purpose." In the Siemens system this problem has been satisfactorily solved. At each end of the circuit is a valve-driven 1560 cycle per second tuning-fork in a heavy steel case placed in a water-jacketed can, the outside of which is surrounded with cotton wool and the whole placed in a large wooden box. The water jacket and cotton wool serve to keep the temperature of the fork constant or at any rate prevent any rapid changes of temperature. The valve driving the fork is of the bright emitter type, with means for adjusting its filament current to a known and prearranged value. The method of adjusting synchronism is to send fork tone on the line, amplify it at the receiving end so as to light a neon lamp which illuminates a stroboscopic disc attached to the motor driving shaft. The small speed adjustment required to keep the marks on the disc from changing in position over a period of three to five minutes is made in the following manner. The condenser coupling the grid and plate circuits of the fork is increased in value which increases the reaction and the amplitude swing of the fork. This slows the fork down a fraction of a cycle per second; decreasing the

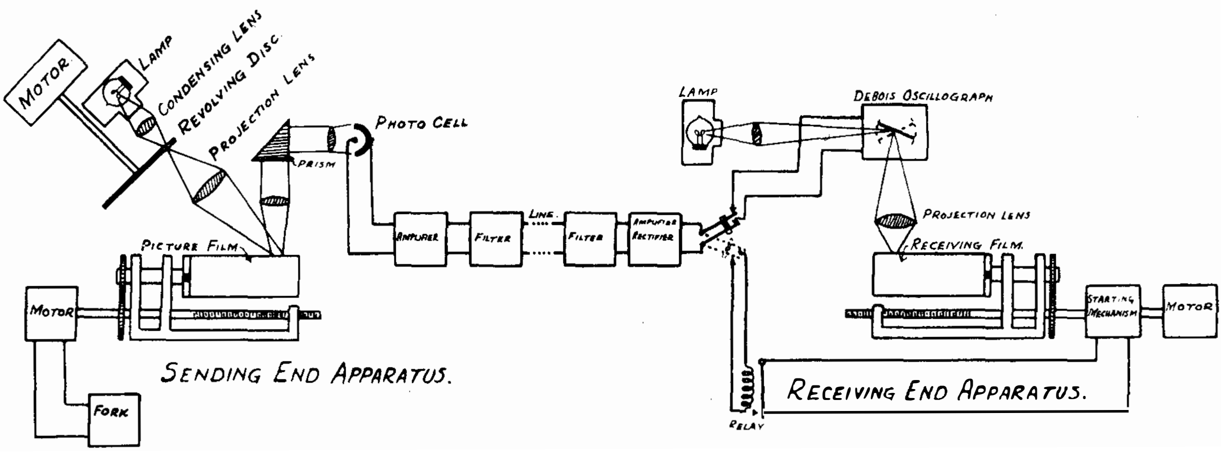

FIG. 3.—BELIN SYSTEM: SCHEMATIC DIAGRAM.

value of the capacity slightly increases the speed of the fork. Once set, the condenser adjustment requires little change, if any, from day to day. The fork tone is amplified two further stages, the last stage consisting of three power valves in parallel, the output of which is transformed into the stator of a synchronous motor or alternator which in turn is directly coupled to the direct current driving motor. Provided the fluctuations of voltage in the driving motor circuit are not excessive the synchronous motor will hold the speed constant. In the case of the "Bell" system, at the sending end a tuning fork, similar to those used for driving the phonic motor of the Baudot Telegraph, drives the picture apparatus in a similar manner but in addition is used to modulate a 400 cycle per second carrier wave, which is sent over the line to the receiving end where it is amplified and rectified and serves to hold a similar fork and phonic motor in perfect synchronism. The picture carrier and the fork carrier are separated by means of filters from interfering with one another at both the sending and receiving ends. If the two ends are not in synchronism the picture will be skewed, that is to say, instead of being a rectangle it will be a parallelogram.

Phasing.—In the Siemens system the driving apparatus is running continuously; the sending or receiving picture drums are arranged so that they can be coupled to the driving shaft by means of a magnetic clutch at one point only in the revolution. Providing the speed remains constant, no matter how often the sending or receiving end drums are started and stopped, they will always be in the same relative positions at the two ends. It is necessary therefore before starting the day's work to see that the joints in the picture at the sending end and the receiving end are in the same relative position. This is done as follows: on the picture clip at the sending end are two white lines, whilst the rest of the drum is black at this place; on rotating the drum without traversing it two rushes of picture carrier current close together once per revolution will be sent to line. At the receiving end, the amplifier is switched so as to light a small neon lamp which rotates at picture speed; if this lights opposite a certain mark nothing more has to be done; if, on the other hand, it does not, it is necessary to shift the phase until it does. This may be accomplished in two ways; for large displacements the driving motor resistance is changed so as to pull the motor out of synchronism either above or below synchronous speed, according as the phasing point has to be advanced or retarded; the resistance is restored to normal as soon as the correct point has been reached. The second method is generally used for small displacements, and for this the stator of the synchronous motor is rotated by means of a hand wheel suitably geared for the purpose.

In the Bell, and also in the case of the Belin systems, phasing is unnecessary, as a starting signal is sent on the line. In the case of the Belin system the picture drum is white, except where the clips are fixed. The carrier current is therefore interrupted at this point, as black sends no current from the photo-cell. At the receiving end, when the operator is told to start, a key is held down which connects an amplifier rectifier to a telegraph relay which releases as soon as the line current ceases and operates a clutch

FIG. 4.—PICTURE AS RECEIVED IN LONDON FROM BERLIN.

connecting the picture drum to the driving mechanism. The picture drum, being set at rest at the correct position, starts off at the right position.

Signalling and Speaking.—In the case of the Siemens system arrangements are provided for operating the set either over a two-wire telephone line or over a four-wire line; in the latter case a picture can be sent and received simultaneously at each end. At the receiving end, in the case of a four-wire connection, an amplifier rectifier and relay are permanently connected across the line and are operated by 500-cycle modulated by 25 cycles per second ringing current, so that in an emergency the distant end may be called even during the transmission of a picture, although this of course spoils the picture. Speaking is done on one line and listening on the other line for four-wire working, but, by throwing a key normal, two-wire working of the telephone is obtained, and in this case 17-cycle ringing may be sent and received. A thermionic voltmeter is also provided, which is suitable for measuring the sent and received picture voltages, as well as ammeters and voltmeters for measuring currents and voltages of the various batteries supplying the lamp and valve filaments, anodes, motors, etc.

Transmission Line Requirements. — The carrier current frequency chosen for picture transmission should be as high as possible, having due regard to the characteristics of the line. As one of the principal requirements of a picture is sharpness, that is, the transit from white to black in the shortest possible interval of time, one line requirement is that the carrier current be established or extinguished quickly. This can only be the case when all the frequencies transmitted for the picture arrive at the receiving end at the same time. A lump or coil-loaded line tends to have a longer time for transmission of the higher frequencies, until at the cut-off or critical frequency nothing is transmitted.

The following are also necessary conditions for good pictures:—

(1) The line must be free from momentary or other interruptions.
(2) The attenuation of the line must not vary appreciably throughout its transmission range.
(3) The attenuation must be constant and not vary from moment to moment.
(4) The line must be free from echoes and other irregularities.
(5) The line must be reasonably free from cross-talk, ringing induction, telegraph induction and noise.
(6) The telephone repeaters must not introduce spurious frequencies by modulating the carrier wave.
(7) The cut-off frequency should be as high as possible.

The carrier frequency should not exceed half the cut-off frequency, and high pass filters should be provided at the sending and receiving ends to cut off all below about half the carrier frequency.

The nominal time of transmission "t" seconds of a frequency $\frac{\omega}{2\pi}$ cycles per second is given approximately by the formula:—

$$t = \frac{2N}{\omega_c\sqrt{1-\frac{\omega^2}{\omega_c^2}}} = \frac{2l}{d\cdot\omega_c\sqrt{1-\frac{\omega^2}{\omega_c^2}}}$$

where N is the number of loading sections, $\frac{\omega_c}{2\pi}$ the critical frequency, "l" is the length of the line and "d" the coil spacing, both measured in the same units, for example, miles or, alternatively, kilometres.

Taking the Siemens system as an example (the same reasoning applies to other systems); the carrier frequency usually used is 1300 cycles per second. The drum, whose circumference is 22 centimetres, rotates once in 1.33 seconds; hence the movement is 0.165 millimetre in one millisecond, or 0.127 millimetres in one cycle of the carrier current. The traverse is 0.2 millimetres per revolution, if the same sharpness is to be obtained vertically and horizontally on the picture; then the building-up time of the carrier should not exceed 0.2/0.165 or about 1.2 milliseconds. This building-up time may be roughly reckoned as the difference in the time of transmission over the line of 650 cycles per second and the carrier frequency 1300 cycles per second and may be calculated by the above formula. Should this time be exceeded it is possible to insert special time correction networks in the line. These have been developed both in America and Germany. The calculated difference in time of 1300 cycles and 650 cycles on an experimental picture circuit set up between London and Berlin and about 1000 miles long was 1.39 milli-seconds, whilst the total time for 1300 cycles was about 50 milli-seconds.

The Photographic Requirements.—Whilst it is easy to transmit pictures on any of the three systems mentioned a certain amount of photographic skill and experience are necessary for the transmission and reproduction of good pictures. In the case of the "Bell" system, the correct density, etc., is necessary in the positive prepared for transmission. In the case of the Belin and the Siemens systems the following points require attention: the setting of the sent voltage for the light part of the picture at the sending end, and the setting of the light and amplification at the receiving end; the development, fixing, hardening and drying of the films. The printing of the films, either by contact or enlargement on a suitable grade of paper at the receiving end, and giving the correct exposure and development to these prints are matters which all require photographic skill and experience if the best results are to be obtained. If anything is worth doing, it is worth doing well!

A photograph is reckoned to be critically sharp if the smallest dot does not exceed a diameter of about 1/200 of an inch; in all picture transmission systems some sharpness must of necessity be lost. The Bell system scans at 100 lines to the inch and the Siemens at 127. A picture about 4 inches by 8 inches is transmitted in about 12 minutes on the Siemens system with a carrier of 1300 cycles, and a picture 7 inches by 5 inches in 7 minutes on the Bell system. The Belin system uses a carrier of 800 to 900 cycles and the pictures are transmitted about the same size and speed.

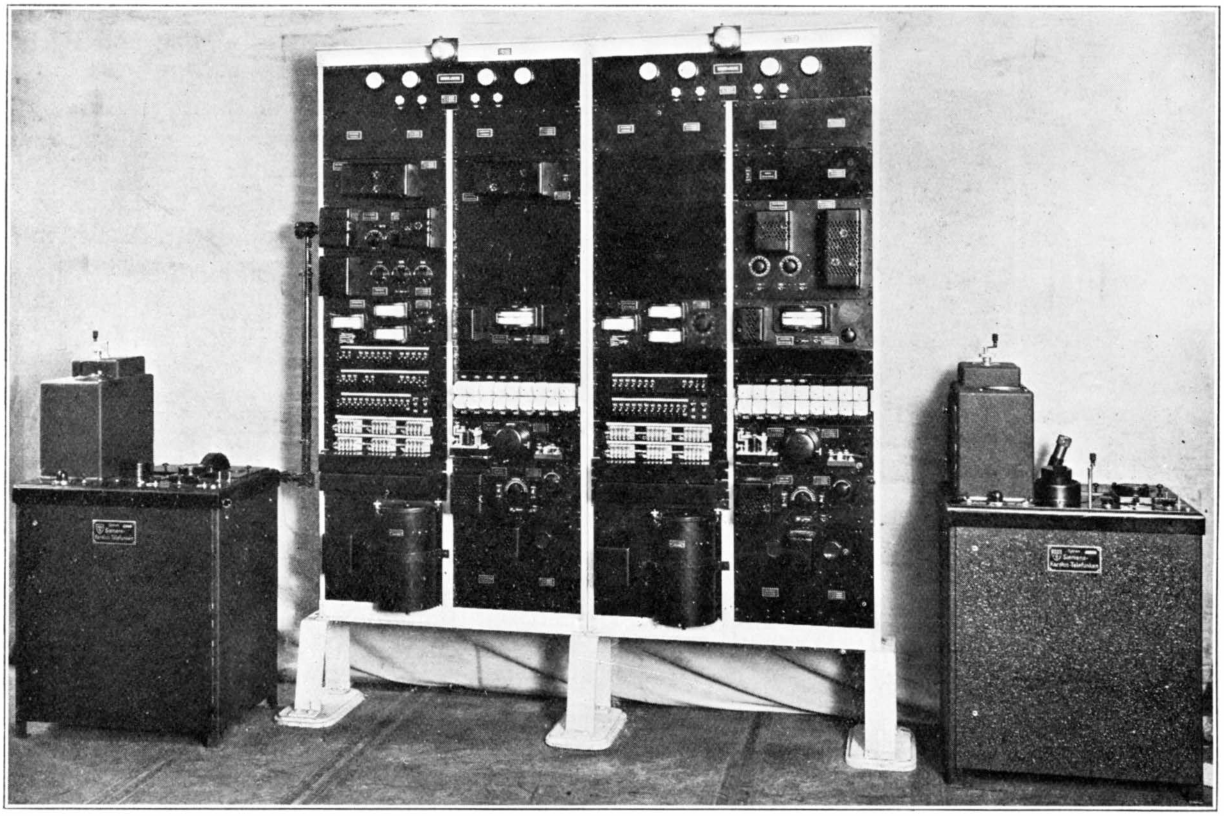

FIG. 5.—SIEMENS-CAROLUS SET (SENDING AND RECEIVING ENDS) AS RECENTLY SUPPLIED TO JAPAN. SIMILAR TO THOSE TO BE SUPPLIED TO CERTAIN ENGLISH NEWSPAPERS.

FIG. 6.—PICTURE TRANSMITTED FROM SENDING TO RECEIVING APPARATUS IN LONDON.

The right hand side through an artificial line and the left through the line, London to Berlin and back. The displacement is due to the propagation time of the signals over the line (104 milli-seconds) and the extra blurring effect to the distortion produced by the line.

There are systems in course of development which are not mentioned here. Several are designed to transmit relatively rough diagrams for reception in the home by radio on relatively cheap and inexpensive apparatus, using such methods as the decomposition of a chemical to give the light and shade of the picture instead of the photographic methods described. There are other systems primarily designed to transmit black and white print over the radio at high speed, but space and time prevent a description of them.

The Author appreciates the fact that owing to the quick rate of development in the different systems the descriptions given here are not up to date; at any rate, he is aware of improvements in important details in at least two of the systems described which will go some way to facilitate operating.

The Author has been engaged in trials on the Siemens system between London and Berlin on a line about 1000 miles in length. A few of the troubles met with may be of interest in showing that at any rate some of the troubles are not in the picture apparatus itself.

(1) It was found difficult to hold synchronism with the driving motor supposed to be running off the 120-volt telegraph battery during the daytime, though in the evening it ran satisfactorily. The motor was changed over to the lighting system and ran well. It was found afterwards that during the day the supply came from motor-generators and not from the telegraph battery and there were considerable fluctuations in the voltage.

(2) Ringing induction from harmonics in 17-cycle ringing current caused interference on the pictures occasionally. This induction originated between Canterbury and London and came from the side circuits, the picture circuit being the phantom. The trouble was removed by changing to other pairs.

(3) Circuit frequently interrupted for short intervals. Cause found in the plugs and cords used to cut out the 4-wire termination on the repeater; one plug fitted the jack badly.

(4) Wires run to cut out the cords. A peculiar overshoot in going from black to white was noticed. It was eventually traced to cross-talk between the input and the output of the repeater in these wires. Trouble removed when cause discovered.

(5) A fifty cycle per second modulation of the picture carrier wave was experienced frequently, particularly during the daytime. This was traced to the anode current supply at two repeater stations. When a certain rotary converter supplied the anode current the effect took place, but when supplied by a motor-generator

off the filament battery it did not take place. The offending repeater stations were discovered by a process of elimination, by looping back the line at each in turn and receiving a picture at the same end as the sending end. When good at one repeater station and faulty at the next, the last station brought in was located as the cause of the trouble. The trouble was removed by using the anode supply which did not cause trouble when pictures were being transmitted.

(6) Excessive voltage priming the photo-cell causes streaks like shadows across the picture.

(7) Failure to synchronise the ends causes the picture to be a parallelogram instead of a rectangle.

(8) Failure to phase will cause the joint in the transmitted picture to come in the received picture instead of at the joint. One day Berlin was in a hurry and London chanced the phase being correct. Actually, just the edge of the clip showed; this, of course, was luck.

(9) At first, run-down filament batteries was a source of trouble; changing to larger cells removed the cause.

Thanks are due to Messrs. Belin and to Messrs. Siemens and Halske for the information furnished in this article, and also to Col. Shreeve, the representative of the Bell Telephone Companies in this country, for the particulars of the Bell system.

E.S.R.

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SOME NOTES ON ARRIVAL CURVES AND THEORETICAL TELEGRAPH SPEEDS.

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SYNOPSIS.—The following describes a method for defining the theoretical maximum speed of a circuit which employs a rectangular impressed voltage wave for the signal elements and discusses the effect of the terminal conditions on this speed. Some examples of actual circuits having different characteristics are treated and experimentally obtained arrival curves are given as illustrations. Formulæ are deduced including leakance and inductance factors which will enable the theoretical maximum telegraphic speed to be determined in any particular case. The introduction of the "Permalloy" loaded cable has presented the possibility of telegraphic transmission limited only by the effects of irregular causes.

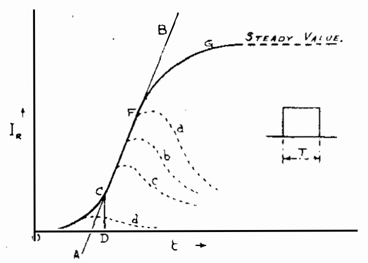
The maximum theoretical speed of signalling in a telegraph system is limited by the maximum allowable departure of the shape of the received signal from that of the transmitted signal. The factors causing the distortion of the signals can be divided into two classes:—

(*a*) Distortion due to the line itself.

(*b*) Distortion due to irregular causes, such as variation of battery voltage, chattering of relays, interference from external sources, etc.

It is thus seen that the development of any mathematical expression for the maximum speed of signalling when the effects of both (*a*) and (*b*) are present would involve an exact knowledge of the behaviour of all these separate factors. A reference to the work already done in this direction shows the difficulty of this problem. The limitation of speed imposed by (*a*) alone may be regarded as the maximum theoretical speed possible on any given line. With regard to the effects mentioned in (*b*) experimental methods can be developed for any particular case to enable some of the separate factors to be determined with a certain degree of accuracy. Empirical formulæ can then be formed to allow for the effects of (*b*) on the maximum theoretical speed. In the following paragraphs a simple method is shown by which the reduction of speed due to the combined effects of (*b*) in any given case, can be obtained.

Consider the case of a very long circuit, such as that of an unloaded ocean cable, the deciding factors in limiting the speed of signalling are



a, b, c and d represent elementary arrival dot signals

FIG. 1.

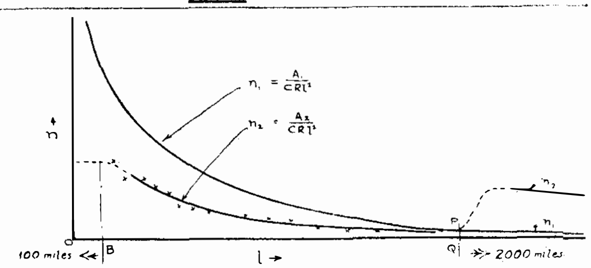


FIG. 2.

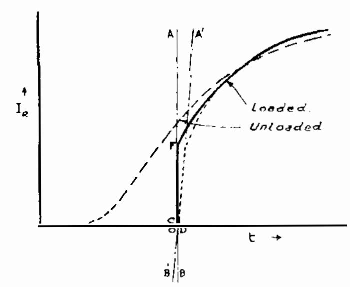


FIG. 4

those mentioned in (*a*). For very short lines, less than 50 miles, say, the limitation of speed is chiefly fixed by the effects of (*b*); but the majority of cases fall between these two extremes, and the actual speed obtainable is limited partly by (*a*) and partly by (*b*).

Consider Fig. **1**. The full curve OCFG is a typical example of the way in which the current grows at the receiving end of a line, whatever its length, or terminal apparatus in use, when a sudden steady e.m.f. V is applied at the sending end. (See Appendix I.).

The line of greatest slope AB can be easily drawn and it will be found to coincide with a portion CF of the curve. From C, the point at which AB leaves the curve, the ordinate CD is drawn and it can be seen that for times of contact greater than OD the elementary signals *a*, *b*, etc., are similar in shape, but for times smaller than OD the elementary signals tend to flatten rapidly and successive signals will thus overlap. OD can be taken as a measure of the smallest time of contact for a current impulse permissible if good legible signals are to be received, and assuming the receiving apparatus to have the necessary sensitivity. (See Appendix II.). If the number of signal elements per letter required by the particular code used be known, then from the length of time represented by OD the maximum theoretical speed in letters per minute, *n*, can be calculated. Further, it will be found that the maximum speeds calculated by this method for different lengths of unloaded cable, having the same electrical constants, obey a law of the form

$$n_1 = \frac{A_1}{CRl^2} \qquad (1)$$

where A_1 is a constant, C = capacity per unit length, R = resistance per unit length and l = total length of cable.

Having found n_1 from Fig. **1** as explained, the value of A_1 is readily calculated by equation (1). Now, if the actual working speeds, n_2, obtained on different lengths of the same type of cable using similar terminal apparatus be plotted and the mean curve drawn through them, this curve is found to be also of the form

$$n_2 = \frac{A_2}{CRl^2} \qquad (2)$$

and A_2 is obtained from points on the curve. See Fig. **2**, where the crosses represent experimentally obtained points and the dotted portions are possible continuations not verified by experiment.

Thus the *total reduction of speed* produced by the combined effects of (*b*)—and considered for lengths less than that represented by OQ in

Fig. **2**—appears to follow a similar law to that of the famous " KR " law and is given by

$$n_1 - n_2 = \frac{A_3}{CRl^2} \quad \dots\dots (3)$$

where $A_3 = A_1 - A_2$.

As examples of the application of the foregoing consider the following cases:—

(1) *Single U/G Conductor*, having

$C = 0.11\ \mu F.$ per mile
$R = 12.5$ ohms ,, ,,

Taking l at intervals of 100 miles the upper

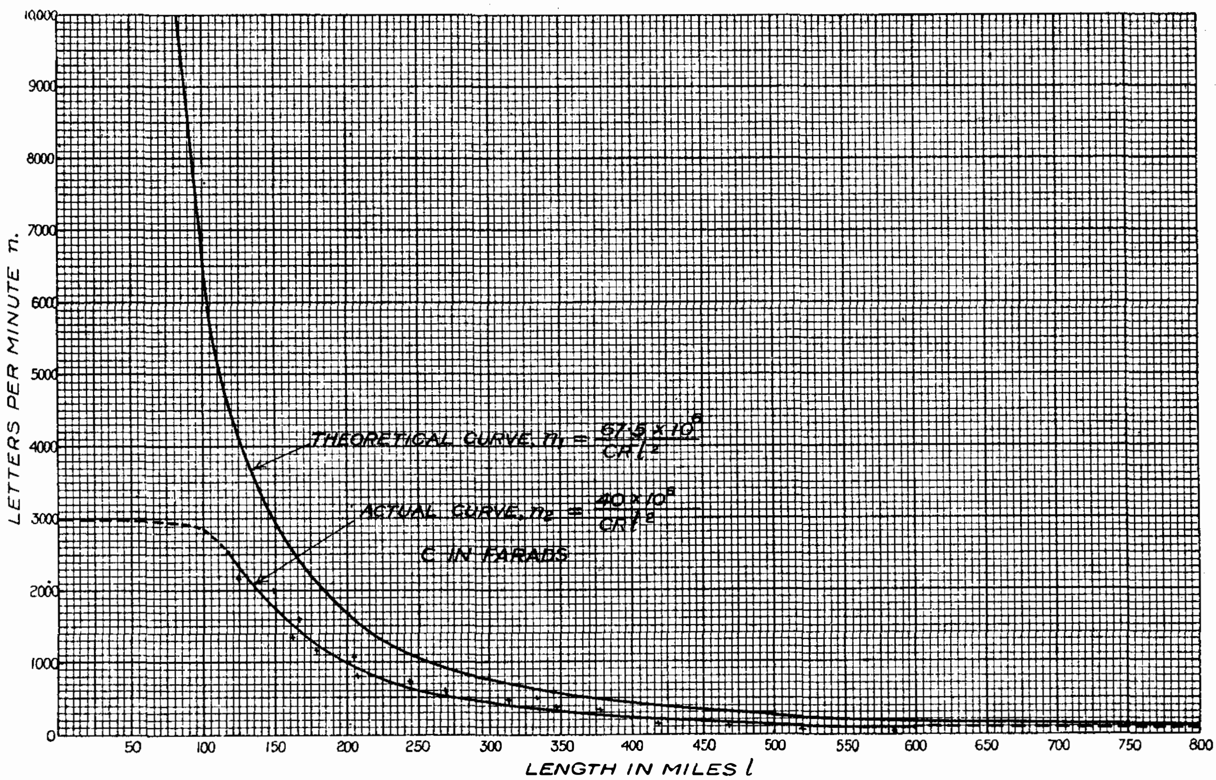


FIG. **3**.—CURVES SHOWING THEORETICAL MAXIMUM SPEED AND ACTUAL SPEED.

curve shown in Fig. **3** has been constructed by using equation (1), the value of $A_1 = 67.5$ in that equation, being obtained by the method previously described. The lower curve in this figure is one obtained from observed values of maximum speeds obtained on a single wire circuit (between London and Glasgow) with approximately the above electrical constants and gives by equation (2) $A_2 = 40$, (taking five letters one word on the average). Hence the reduction of speed in letters per minute produced by the irregular causes for any length l of this circuit is represented by

$$\frac{67.5 - 40}{CRl^2} = \frac{27.5}{CRl^2} = \frac{20 \times 10^6}{l^2}$$

if C is expressed in microfarads. Thus whilst for 600 miles we get only a total reduction of 56 letters per minute from the theoretically possible speed, we find that for a length of 100 miles the reduction is 2,000 letters per minute, or 36 times as much.

(2) *Long Ocean Cable*, having

$C = 0.409\ \mu F.$ per naut.
$R = 2.578$ ohms per naut.

Such cables are usually more than 1000 nauts in length and the elementary curve in Fig. **1** rises very slowly, so that the time OD is comparatively long. By means of large condensers at the ends of the cable and other terminal devices the curve can be made a little steeper though less in amplitude and the time OD decreased, thus increasing the theoretical speed of the cable. The Imperial No. 2 cable has for the major part of its length—2108 nauts—approximately the constants given above. Then *neglecting the effect of terminal arrangements* used for decreasing the time OD we get by equation (1) a theoretical speed of working in letters per minute imposed by the cable itself of only

$$n_1 = \frac{97}{CRl^2}$$

Malcolm has shown, by means of Heaviside's Expansion Theorem how to construct the curve shown in Fig. **1** when the effects of the signalling condensers are included. Such a curve drawn for the cable just considered gives by equation (1)

$$n_1 \doteqdot \frac{500}{CRl^2}$$

which represents an *increase* of about 500% over the limit imposed by (*a*) and accounts for the crossing of the curves at the point P in Fig. **2** for large values of *l*.

By increasing the sensitivity of the receiving apparatus and by use of shaping networks the value of $\Lambda_1 = 500$ can be slightly increased, and the actual working curve for n_2 will be raised a little above that shown in the figure. It has not been possible to make a sufficient number of experiments to obtain for such long cables the information corresponding to that given in Fig. **3**.

(3) *"Encroachment" or "Margin" and Loaded Telegraph Cables.* (See Appendix III.).

The separate factors mentioned in (*b*) have been studied by M. Collet,* H. Salinger,† and Messrs. Nyquist, Shanck and Cory‡ and the term "encroachment" or "margin" has been used to denote the amount by which parasitic or interfering currents modulate the received signal. The greater the slope of the tangent AB, shown in Fig. **1**, the more will the effect of "encroachment" be diminished. In the limit if the tangent AB is made vertical, the "encroachment" can be made negligible by sufficient amplification of the received signal. Now, in long cables such as those considered in (2), no very great increase in speed of working has been possible by further terminal improvements and it would appear necessary to increase the slope of AB by altering the cable constants. Recent investigations have led to the development of long ocean cables having artificially increased inductance by means of uniform wrappings of "permalloy"—a material which is capable of adding more than 100 milli-henries per naut to the natural inductance of the cable. The added inductance alters the shape of the arrival curve shown in Fig. **1** to the type shown in Fig. **4** and it will be seen that the current is now propagated with a vertical head FO; the shorter the length of cable considered the greater is the height FO, and AB is, theoretically, a vertical line.

In practice AB is not quite vertical, but slopes like A^1B^1 due to variation of the electrical constants with frequency and current.

By reference to Fig. **4** it is quite clear that the time OD is not easily determined by this method. This time, however, will be extremely small and the theoretical speed is enormously higher than the actual speed obtained in any given case, due to the limitations imposed by the irregular causes (*b*).

* *Ann des Postes Tél. et Tel. 16 p. 1. 1927.*

† *Documents of the first reunion of the C.C.I. of the Telegraphic Communications at Berlin. Berne, 1927. Vol. 2, p. 3.*

‡ *Journal A.I.E.E., p. 231. 1927.*

APPENDIX I.

ARRIVAL CURVES.

Finite Line.

The full line curve in Fig. **1** can be calculated from the Kelvin formula,

$$I_R = \frac{V}{Rl}\left\{1 + 2\sum_{m=1}^{m=\infty} e^{-\frac{m^2\pi^2 t}{CRl^2}} \cos m\pi\right\} \quad \ldots\ldots(1)$$

where

I_R = received current when both ends of the line are put to earth.

t = time in seconds after application of a steady e.m.f. V volts at the sending end.

l = length of line.
R = conductor resistance in ohms per unit length.
C = capacity in farads per unit length.

For the part of the curve which governs the slope AB in Fig. 1 a sufficiently accurate expression may be derived from (1) by means of the identity,

$$q \sum_{n=-\infty}^{n=+\infty} e^{-\pi(p+nq)^2} = 1 + 2 \sum_{m=1}^{m=\infty} e^{-\pi\left(\frac{m}{q}\right)^2} \cos \frac{2m\pi p}{q}$$

where,

$$p = \frac{q}{2} \text{ and } q^2 = \frac{CRl^2}{\pi t}$$

and hence (1) becomes

$$I_R = 2V\sqrt{\frac{C}{\pi R}} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{t}} \quad \text{.......................(2)}$$

where $\phi = CRl^2$

This expression becomes less accurate as the values of time t taken approach the time at which the current becomes a maximum.

Infinite Line.

It will be noticed that (2) can be derived from a study of the infinite line as follows:—

Consider a smooth line with distributed resistance R and capacity C per unit length. If I denote the current at distance l from the transmitting end and V the corresponding potential, the differential equations are:—

$$\left.\begin{aligned} -\frac{dV}{dl} &= IR \\ -\frac{dI}{dl} &= C\frac{dV}{dt} \end{aligned}\right\} \quad \text{................................(3)}$$

From (3) we obtain

$$\frac{d^2I}{dl^2} = CR\frac{dI}{dt} \quad \text{....................................(4)}$$

Put $p = \frac{d}{dt}$ and $D = \frac{d}{dl}$.

Then,

$$D = \pm\sqrt{pCR}$$

Hence,

$$I = Ae^{\pm l\sqrt{pCR}} \quad \text{where } A = \frac{V}{Z_0}$$

Assuming that a unit e.m.f. is applied to the line terminals, and that the reflected wave is suppressed, we obtain the operational equation for the current, namely,

$$I = \sqrt{\frac{C}{R}} \cdot \sqrt{p} \cdot e^{-\sqrt{\phi p}} \quad \text{..................(5)}$$

where $\phi = CRl^2$.

Now,

$$\sqrt{\frac{C}{R}} \cdot \sqrt{p} \cdot e^{-2\sqrt{\lambda p}}$$

$$= \sqrt{\frac{C}{R}} \cdot p \cdot \int_0^\infty e^{-pt} \cdot \frac{e^{-\frac{\lambda}{t}}}{\sqrt{\pi t}} \cdot dt \quad \text{...........(6)}$$

where λ is any positive real parameter.

In equation (6) put $\lambda = \frac{\phi}{4}$ and obtain,

$$\sqrt{\frac{C}{R}} \cdot \sqrt{p} \cdot e^{-\sqrt{\phi p}}$$

$$= \sqrt{\frac{C}{R}} \cdot p \cdot \int_0^\infty e^{-pt} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{\pi t}} \cdot dt$$

Hence,

$$I_R = \sqrt{\frac{C}{\pi R}} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{t}} \quad \text{..........................(7)}$$

If the cable is earthed, or is terminated with a comparatively low resistance, we can assume that the reflection is total and equation (7) must be corrected by the factor 2, therefore, this equation can now be written,

$$I_R = 2V\sqrt{\frac{C}{\pi R}} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{t}}$$

which is the same as equation (2).

Suppose that in addition to the distributed resistance R and capacity C, the cable also has distributed leakance G per unit length. The differential equations are now,

$$\left.\begin{aligned} -\frac{dV}{dl} &= IR \\ -\frac{dI}{dl} &= (G+pC)V \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Therefore replacing pC by $(pC+G)$ in equation (5) we obtain the operational equation for the current when the leakance is included,

$$I=\sqrt{\frac{C}{R}}\cdot\sqrt{p+\delta}\cdot e^{-\sqrt{\phi p+\psi}} \quad \ldots\ldots\ldots\ldots(9)$$

where $\delta=\dfrac{G}{C}$

and $\psi=GRl^2$

Write equation (5) as

$$I_o=\sqrt{\frac{C}{R}}\cdot\sqrt{p}\cdot e^{\sqrt{-\phi p}}$$

$$\therefore\ I_o e^{-\Gamma t}=\sqrt{\frac{C}{R}}\cdot\frac{p}{p+\Gamma}\cdot\sqrt{p+\Gamma}\cdot e^{-\sqrt{\phi(p+\Gamma)}}$$

where Γ is any positive real parameter.

Now write equation (9) as

$$I_g=\sqrt{\frac{C}{R}}\cdot\frac{p+\Gamma}{p}\cdot\frac{p}{p+\Gamma}\cdot\sqrt{p+\delta}\cdot e^{-\sqrt{\phi p+\psi}}$$

$$=\sqrt{\frac{C}{R}}\cdot\left(1+\frac{\Gamma}{p}\right)\cdot\frac{p}{p+\Gamma}\cdot\sqrt{p+\delta}\cdot e^{-\sqrt{\phi p+\psi}}$$

Hence,

$$I_g=\left(1+\Gamma\int_o^t dt\right)I_o e^{-\Gamma t}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Provided

$$\Gamma=\delta=\frac{G}{C}$$

and $\phi\Gamma=\psi=GRl^2$

The value of I_o can be obtained from equation (7), hence, equation (10) can be rewritten

$$I_g=\sqrt{\frac{C}{\pi R}}\cdot e^{-\frac{\phi}{4t}}\cdot\left(\frac{e^{-\Gamma t}}{\sqrt{t}}+\Gamma\int_o^t\frac{e^{-\Gamma t}}{\sqrt{t}}\cdot dt\right)\ \ldots\ldots(11)$$

The integral term in equation (11) can be evaluated by repeated integration by parts, thus,

$$\int_o^t\frac{e^{-\Gamma t}}{\sqrt{t}}\cdot dt=2\sqrt{t}\,e^{-\Gamma t}\left\{1+\frac{2\Gamma t}{3}+\frac{4\Gamma^2t^2}{15}+\ldots\right\}$$

For purposes of calculation equation (11) can now be written,

$$I_g=\sqrt{\frac{C}{\pi R}}\cdot e^{-\frac{\phi}{4t}}\left(\frac{e^{-\Gamma t}}{\sqrt{t}}+2\sqrt{t}\cdot\Gamma e^{-\Gamma t}\left\{1+\frac{2\Gamma t}{3}+\frac{(2\Gamma t)^2}{15}+\ldots\right\}\right)\ \ldots\ldots\ldots(12)$$

In equation (7) put $\gamma=\dfrac{4t}{CRl^2}$, then this equation can now be rewritten as

$$I=\frac{2}{Rl\sqrt{\pi}}\cdot\frac{e^{-\frac{1}{\gamma}}}{\sqrt{\gamma}}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

From this equation a curve can be easily drawn to depict the current wave at any distance from the cable terminals. The current, while finite, is negligibly small until γ reaches the value 0.2. In the neighbourhood of this point it begins to build up rapidly, reaching at $\gamma=2$ its maximum value. From equation (12) the effect of the leakance can be easily calculated and interpreted, and it can be seen that the leakance attenuates the wave by the factor $e^{-\frac{G}{C}\cdot t}$ and at the same time adds a progressive integral of the attenuated wave.

APPENDIX II.

Similar Signal Shapes.

If the series representing I_R in equation (1) of Appendix I. be written in functional form as

I(t), then an elementary signal of time duration T can be expressed in the form

$$D = I(t) - I(t-T) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Expanding this by Taylor's Theorem we get

$$D = T \cdot \frac{dI}{dt} - \frac{T^2}{\lfloor 2} \cdot \frac{d^2 I}{dt^2} + \frac{T^3}{\lfloor 3} \cdot \frac{d^3 I}{dt^3} - \ldots (2)$$

which becomes, for relatively small values of T,

$$D = T \cdot \frac{dI}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

corresponds to the time represented by OD in Fig. 1.

For times less than OD the series expansion of (2) does not converge rapidly and (3) cannot be used with a good degree of approximation.

APPENDIX III.

Loaded Telegraph Cable.

A. Uniform Cable.

The signalling speed will always be limited by

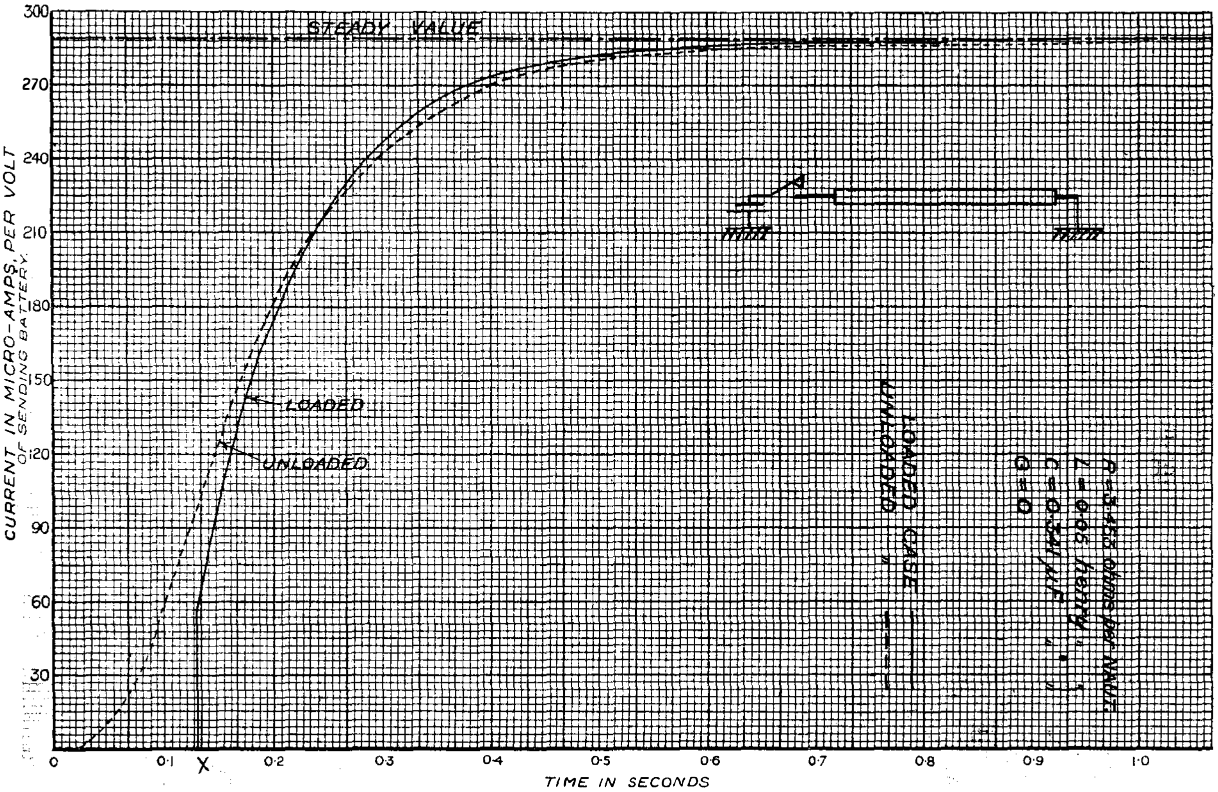


Fig. 6.—Calculated Curves of Arrival for 1,000 Nauts. of Uniform Cable.

It will be found that $\frac{dI}{dt}$ reaches a maximum when $t = 0.09\ \varphi$ where $\phi = CRl^2$, but that from $t = 0.083\ \phi$ to $t = 0.10\ \phi$ the value of $\frac{dI}{dt}$ is relatively constant. Therefore by examination of (3) from the value $t = 0.083\ \phi$ to $t = 0.10\ \phi$ the elementary signal shapes will be essentially similar, having amplitudes proportional to the duration time T and further the value $t = 0.083\ \varphi$ the fact that the signals are formed exclusively by the initial "slope" of the arriving current wave, but the addition of effective inductance to the line, by giving to the current wave an initial steep "head" reduces the importance of this factor.

If I denotes the current and V the voltage at any point l on the line, then, neglecting leakance, the differential equations of the problem are:—

$$\left.\begin{aligned} -\frac{dV}{dl} &= L\frac{dI}{dt} + IR \\ -\frac{dI}{dl} &= C\frac{dV}{dt} \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

From (1) we obtain the fundamental differential equation for the current wave, viz.,

$$\frac{d^2I}{dl^2} = LC\frac{d^2I}{dt^2} + RC\frac{dI}{dt} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

This equation introduces the phenomenon of true propagation with finite velocity, instead of the diffusion phenomenon of the unloaded line and is more difficult to solve.

In equation (2) put $p = \frac{d}{dt}$ and $D = \frac{d}{dl}$, then

$$D - \pm\sqrt{pC\,(pL + R)} = \pm\gamma$$

Hence,

$$I = Ae^{\pm\gamma l} \text{ where } A = \frac{E}{Z_0}$$

Assuming that a unit e.m.f. is applied to the line terminals and that the reflected wave is suppressed, we have,

$$I = \frac{pC}{\gamma}\,e^{-\gamma l} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\text{where } \gamma = \frac{1}{a}\sqrt{p^2 + 2\phi p}$$

$$a^2 = \frac{1}{LC}$$

$$\phi = \frac{R}{2L}$$

Hence,

$$I = \sqrt{\frac{C}{L}} \cdot p \cdot \frac{e^{-\frac{l}{a}\sqrt{p^2+2\phi p}}}{\sqrt{p^2 + 2\phi p}}$$

$$= \sqrt{\frac{C}{L}} \cdot p \cdot \int_0^\infty e^{-pt} \cdot F(t)\,dt \qquad \ldots\ldots\ldots\ldots(4)$$

The problem is thus reduced to evaluating the functions $F(t)$ from the operational equation.

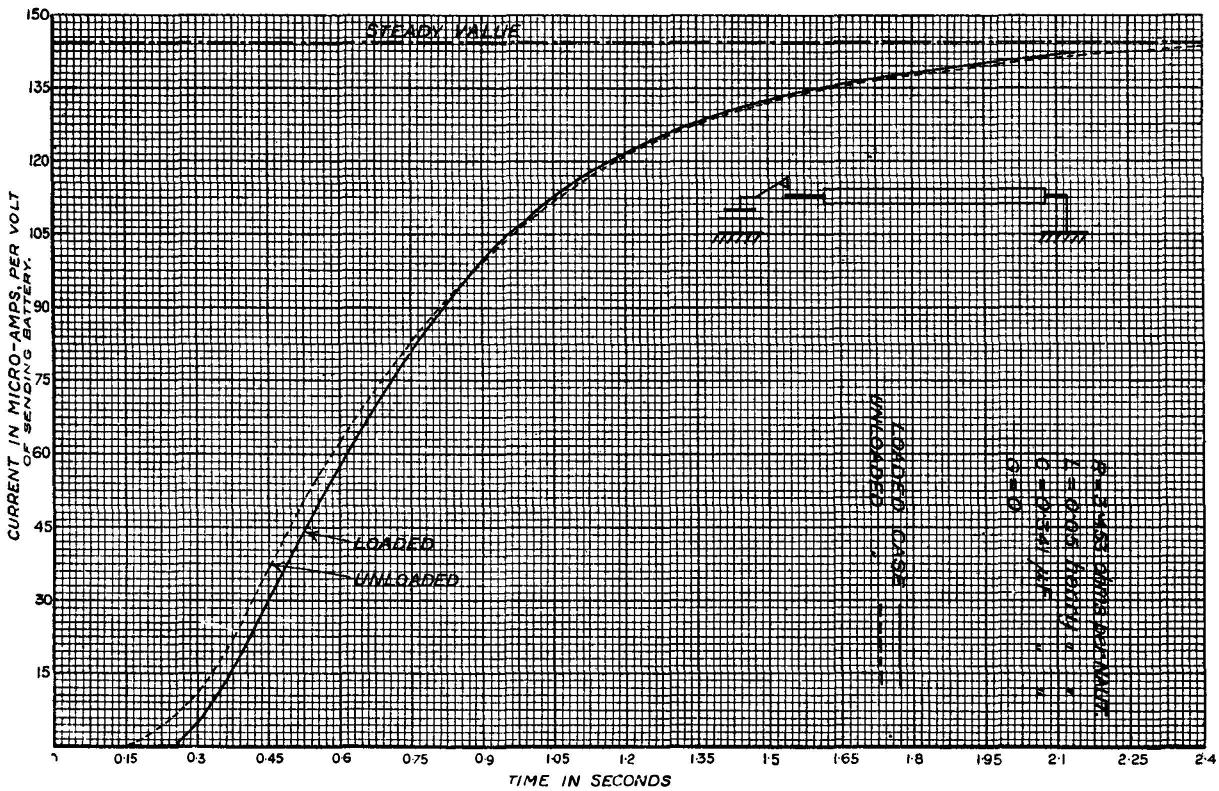


FIG. 7.—CALCULATED CURVES OF ARRIVAL FOR 2,000 NAUTS. OF UNIFORM CABLE.

Assume $\lambda = \frac{l}{a} = 2\phi p$, then equation (4) can be written as,

$$I = \sqrt{\frac{C}{L}} \cdot \frac{e^{-\sqrt{p^2+\lambda^2}}}{\sqrt{p^2+\lambda^2}}$$

$$= \sqrt{\frac{C}{L}} \int_{\lambda}^{\infty} e^{-pt} J_o(\lambda\sqrt{t^2-1})dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where the R.H.S. of this equation defines a function which is zero for $t < \lambda$ and has the value $J_o(\sqrt{t^2-\lambda^2})$ for $t > \lambda$, where J_o represents the Bessel function of order zero.

Where h_1 and λ_1 are arbitrary parameters restricted to positive values,

$$\text{here} \quad \lambda_1 = \frac{a}{l} \cdot \lambda$$

$$\text{and} \quad h_1 = \frac{a}{l} \cdot h$$

Now comparing equation (6) with the operational equation (4) we see that they can be made identical provided we set,

$$h_1 = \phi$$

$$\text{and} \quad \lambda_1 = j\phi \quad \text{where } j = \sqrt{-1}$$

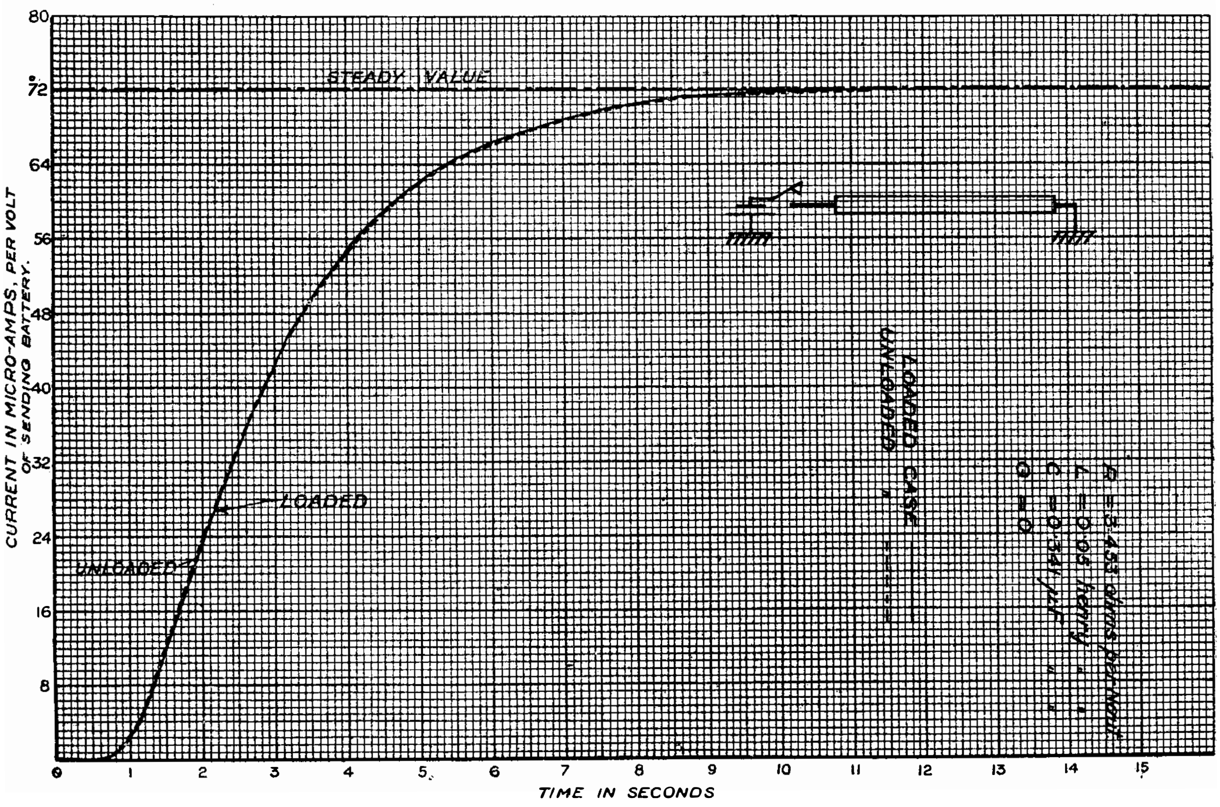


FIG. 8.—CALCULATED CURVES OF ARRIVAL FOR 4,000 NAUTS. OF UNIFORM CABLE.

Now assume that p increases by a value h, equation (5) can now be rewritten as

$$\sqrt{\frac{C}{L}} \cdot \frac{e^{-\frac{l}{a}\sqrt{(p+h_1)^2+\lambda_1^2}}}{\sqrt{(p+h_1)^2+\lambda_1^2}}$$

$$= \sqrt{\frac{C}{L}} \int_{\frac{l}{a}}^{\infty} e^{-pt-h_1 t} J_o\left(\lambda_1 \sqrt{t^2 - \frac{l^2}{a^2}}\right)dt \qquad \ldots\ldots(6)$$

Thus equation (4) now becomes

$$\sqrt{\frac{C}{L}} \cdot \frac{e^{-\frac{l}{a}\sqrt{p^2+2\phi p}}}{\sqrt{p^2+2\phi p}}$$

$$= \sqrt{\frac{C}{L}} \int_{\frac{l}{a}}^{\infty} e^{-pt-\phi t} \; I_o\left(\phi\sqrt{t^2 - \frac{l^2}{a^2}}\right) dt \qquad \ldots\ldots\ldots(7)$$

Hence,

$$I = \sqrt{\frac{C}{L}} \cdot e^{-\phi t} \cdot I_0\left(\phi\sqrt{t^2 - \frac{l^2}{a^2}}\right) \quad \ldots\ldots\ldots(8)$$

where $I_0 = J_0(jx)$ is a Bessel function of imaginary argument, the value of which can be obtained from tables.

Effect of Leakance.

In order to obtain the operational equation for the current when the distributed leakance G is included, replace pC by $(pC+G)$ in equation (3) and obtain,

$$I = \frac{(pC+G)}{\gamma}\, e^{-\gamma l} \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where

$$\gamma^2 = (Lp+R)\,(Cp+G)$$

$$= \frac{1}{a^2}\left[(p+\phi_1)^2 - \phi_2{}^2\right]$$

where $a^2 = \dfrac{1}{LC}$

$$\phi_1 = \frac{R}{2L} + \frac{G}{2C}$$

$$\phi_2 = \frac{R}{2L} - \frac{G}{2C}$$

Hence,

$$I = a\left(C + \frac{G}{p}\right) \cdot p \cdot \frac{e^{-\frac{l}{a}\sqrt{(p+\phi_1)^2 - \phi^2_2}}}{\sqrt{(p+\phi_1)^2 - \phi_2{}^2}}$$

$$= \sqrt{\frac{C}{L}} \cdot F_1(t) + \frac{G}{\sqrt{LC}}\int_0^t F_1(t)\,dt \quad \ldots\ldots(10)$$

To evaluate the function $F_1(t)$, use equation (6) and put

$$h_1 = \phi_1$$

$$\text{and} \quad \lambda_1 = \phi_2$$

Then equation (10) can be rewritten as

$$I = \sqrt{\frac{C}{L}} \cdot e^{-\phi_1 t}\, I_0\left(\phi_2\sqrt{t^2 - \frac{l^2}{a^2}}\right)$$

$$+ \frac{G}{\sqrt{LC}}\int_{\frac{l}{a}}^{t} e^{-\phi_1 t}\, I_0\left(\phi_2\sqrt{t^2 - \frac{l^2}{a^2}}\right) dt \quad \ldots\ldots(11)$$

$$\text{for } t > \frac{l}{a}$$

Equation (11) is an exact formula for the current wave in terms of Bessel functions and in order to evaluate the definite integral it is necessary to expand the Bessel function as a power series, integrate term by term and rearrange. Thus it is a matter of considerable labour to determine the effect of the leakance for any particular case.

Consider a point l on the cable, the current is zero until $\quad l = at,$
at which time it jumps suddenly to the value,

$$I_c = \sqrt{\frac{C}{L}} \cdot e^{-\frac{\phi_1 l}{a}}.$$

After this initial jump the current may attain a maximum value which is large compared with the " head " of the wave, and the resulting curve given by equation (11) is of the type indicated in Fig. **4.**

Equation (3) is based on the assumption that the reflected wave is suppressed, but if the impedance of the terminal apparatus is very small the reflection may be regarded as total, *i.e.*, the current is doubled and consequently equation (3) must be corrected by the factor 2. As the length l is increased, or the value of the added L is decreased, the " head " of the wave becomes smaller and if l be increased beyond a certain limit (or the value of L added is too small to be effective) then the resulting curve approaches coincidence with the dotted unloaded curve shown in Fig. **4.** See Figs. **9, 10** and **11.**

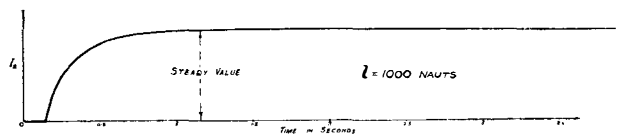


Fig 9

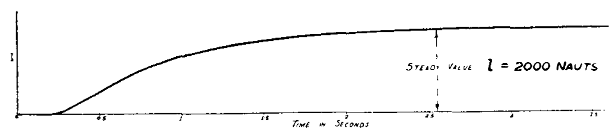


Fig. 10.

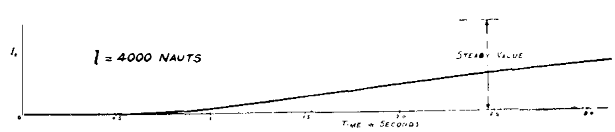


Fig. 11.

B. Artificial Network with Loading.

To study the effect of inductance on the arrival curve the cable can be replaced by a meshwork and the number of meshes increased until it behaves practically as a cable having the same total values of L, R and C uniformly distributed throughout its length. Such an artificial cable has been constructed at the laboratories at Dollis Hill and contains 1,050 meshes. These meshes have the values shown in Fig. 5 and is such that when all the meshes are in series it represents an actual cable having a length of 4,000 nauts. with the following constants:—

$R = 3.45$ ohms per naut.
$C = 0.34\ \mu F$. ,, ,,
$L = 0.05$ henry ,, ,,

By the use of Heaviside's Expansion Theorem the series given in equation (1), Appendix I., can be deduced by calculating the arrival current for the nth section of an artificial network and passing to the actual case of a cable by putting $n = \infty$. Following this procedure Dr. Malcolm proves that when inductance is added to the cable equation (1), Appendix I., can be replaced without serious error by:—

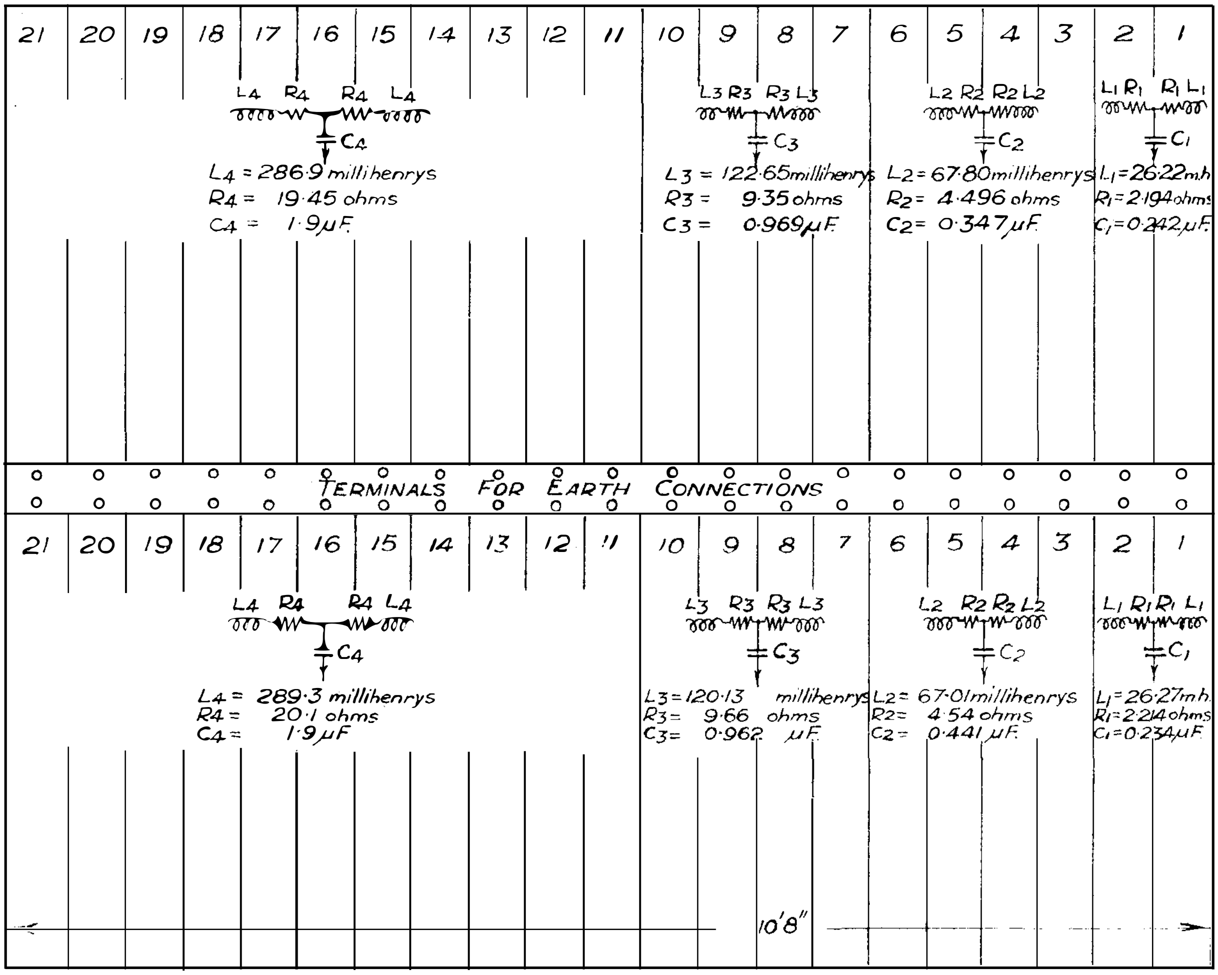


FIG. 5.—ARTIFICIAL SUBMARINE LOADED CABLE INSTALLED AT DOLLIS HILL.

$$I_R = \frac{E}{Rl}\left[1 + 4e^{-\frac{Rt}{2L}} \sum_{1}^{\infty} \frac{\cos m\pi \sinh \frac{Rt}{2L}\sqrt{1 - \frac{4m^2\pi^2 L}{CRl^2 \cdot R}}}{\sqrt{1 - \frac{4m^2\pi^2 L}{CRl^2 \cdot R}}}\right] \qquad \ldots\ldots\ldots\ldots(12)$$

and this applies after the time t_c seconds where

$$t_c = l\sqrt{LC} \quad \text{.......................................} (13)$$

Before this time the current $I_R = 0$ and at t_c jumps suddenly to the height of the ordinate given by

$$I_c = \frac{2E}{Z_0} \times e^{-\beta l} \doteqdot 2E\sqrt{\frac{C}{L}} \cdot e^{-\frac{Rl}{2}\sqrt{\frac{C}{L}}} \quad \text{........} (14)$$

where Z_0 = the characteristic impedance, β = attenuation constant.

Equations (12), (13) and (14) just given can be used to replace equation (8) for calculation purposes. Curves in Figs. **6**, **7** and **8** have been so calculated for the lengths of cable indicated, whilst in Figs. **9**, **10** and **11** are reproduced the actual corresponding arrival curves. The agreement between the actual curves and the calculated curves is very good and the wavefront for l = 1000 nauts. departs from the vertical slightly due to the variation of the inductance and resistance units of the network with frequency and current.

From the foregoing results, as the length l is increased, it can be clearly seen how the effective value of the inductance decreases until at l = 4000 nauts. the arrival curve is practically coincident with the unloaded curve, although the actual value of inductance (0.05 henry per naut.) is much greater than the natural inductances of such a cable.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH JUNE, 1928.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
588,706	537	4,036	51,577	170	London	24,198	68,040	2,251,365	106,942
75,696	2,169	21,547	64,814	1,575	S. East	3,989	46,411	189,535	33,902
79,079	4,538	30,737	55,228	2,913	S. West	20,359	11,651	143,156	60,387
61,864	6,077	37,508	58,556	5,030	Eastern	23,167	37,176	108,340	71,609
76,861	8,586	44,919	58,146	3,895	N. Mid.	27,896	53,288	241,400	115,817
95,371	4,682	29,491	70,982	4,577	S. Mid.	12,008	22,671	179,874	88,481
57,373	4,385	29,606	51,806	3,136	S. Wales	6,277	26,084	118,322	71,934
102,443	8,185	26,237	49,262	4,213	N. Wales	13,393	41,104	267,926	61,004
156,403	1,495	16,450	43,186	2,439	S. Lancs.	13,149	78,189	464,817	48,912
91,836	6,164	30,746	46,755	3,144	N. East	11,609	45,487	220,456	66,535
63,392	4,105	24,762	37,641	2,408	N. West	8.053	33,116	161,300	36,834
46,614	2,511	16,135	25,009	2,542	Northern	4,697	14,915	107,194	50,866
21,107	4,564	8,343	13,905	554	Ireland N.	131	2,322	38,190	1,579
64,591	5,441	25,567	37,222	1,467	Scot. East	3,776	12,851	147,923	47,556
86,762	7,329	24,243	42,972	888	Scot. West	12,133	24,549	219,857	34,673
1,668,098	70,768	370,327	707,061	38,951	Total	184,835	517,854	4,859,655	897,031
1,639,837	70,599	368,939	697,790	36,915	Figures as 31st March, 1928.	180,552	507,932	4,719,708	880,678

MEASUREMENT OF IMPULSE RATIO AND FREQUENCY IN AUTOMATIC NETWORKS.

C. L. HOSKING and R. M. BADENACH, B.Sc.

(Postmaster-General's Department, Australia.)

TO ensure reliable operation of an automatic exchange, it is essential that the characteristics of all the impulses delivered into that exchange, either from subscribers' lines or over junction lines from other automatic exchanges, shall be such that correct operation of the switches will result. In a network where the majority of impulses are generated by a dial at the subscribers' premises, the features in which the impulse is most likely to be unstandard are (1) ratio and (2) frequency, the former being the more important.

Frequency errors can only arise at the dial, but the factors causing distortion of impulse ratio are legion. In a multi-office network, such as Melbourne or Sydney where the conversion to automatic working was commenced in 1913 and is still proceeding, these factors may be summarised as follows :—

(*a*) Variations in the dials in use due to manufacturing differences and standards and to incorrect adjustment. In addition to the dials supplied in 1913 there are in use numerous other types supplied by various manufacturers since that date.

(*b*) Varying dialling circuits in substation equipment. The earlier substation sets are of the series receiver type and the dial is not shunted whilst impulsing, but later types are fitted with induction coils and the condenser is introduced into the dialling circuit. These types again vary in the actual circuit conditions during dialling. Further variations occur due to P.B.X., extension, parallel sets and other special services.

(*c*) Varying lines conditions. Nominally the networks extend for a radial distance of 10 miles from the central exchanges of the areas but in practice there are suburban exchanges beyond this limit. In addition, several exchanges on the limits of the areas are comparatively large, so the distortion of impulses due to long junction lines is obvious. It might be mentioned here in passing that it has been noticed that the insulation resistance of a line that tests satisfactorily on the test desk voltmeter fails apparently under the stress of dialling voltages and so distorts the impulses by having a shunting effect on the impulsing relay.

(*d*) Repeating impulses between exchanges. A call from one branch exchange to another branch may pass through three repeaters.

(*e*) Variations in the resistance and mechanical and electrical adjustment of impulsing relays. There are at least four types in use, the equipment containing the relays having either been supplied by different manufacturers or at various periods by one manufacturer.

(*f*) The standard of switch adjustment for any particular exchange is the interrupter or varying machine, and manufacturers for complete exchange installations have from time to time supplied machines the characteristics of which differ. It would appear, however, that these alterations compensate to some extent for the variations mentioned in (*e*).

(*g*) Unstandard frequency of impulses. The ratio of " make " to " break " of an " A " relay in the train of switches depends upon the frequency at which it is impulsing.

Although the factors mentioned above individually may not cause switch failure, the cumulative effect is sufficiently great to cause considerable trouble, and experience has shown the necessity of having some simple and reliable means of effecting any necessary corrections.

As mentioned under (*f*) above, the group and final selectors in any automatic exchange are subjected to frequent routines by means of an interrupter or varying machine. This machine delivers impulses of a definite ratio and speed under conditions which represent two extreme conditions of dialling. These conditions are:—

(*a*) With a maximum resistance in series with the impulsing relay under test. In this case the impulsing spring of " A " relays on selectors remains on the back contact for a comparatively long period, resulting in a " heavy impulse " being transmitted to the operating magnets. The switch would in such circumstances tend to fail due to the relapse of the " B " relay;

(*b*) With a minimum resistance shunted across the impulsing relay. Under this test the " A " relay tends to remain energised and consequently a " light impulse " is transmitted, the switch tending to fail on account of the operating magnets being insufficiently energised or the relapse of the " C " relay.

It is considered that all impulses received in a particular exchange should fall within these limits. The problem is, however, to obtain a means of defining these limits in such a manner that any impulse can be checked readily. The natural location for checking the condition of a subscriber's service is the test desk, and the instrument that naturally suggests itself for use is the ordinary test deck voltmeter. It was keeping these factors in mind that the test circuit indicated in Fig. 1 was developed.

The operation is as follows:—By throwing test key K^1 the circuit under test is connected to relay " A " which is energised. On the first break of the dial impulse springs the short-circuit is removed from " C," which operates and remains operated during the train of impulses, owing to the slugging effect due to its winding being short-circuited. " B " is adjusted to remain energised for more than 0.9 seconds but for less than 1 second. Contacts B^1 and C^1 being closed, the impulsing of A^1 is transmitted to the low scale winding of the voltmeter.

It will be noted that the negative terminal of the voltmeter is permanently connected to the junction of resistances X and Y and that the other terminal is alternately at a higher and lower potential compared with the negative terminal depending upon the impulsing of A^1.

Owing to the inertia of the moving system of the voltmeter, the needle takes up a position depending upon the proportion of impulse time that the impulsing contact of relay " A " is making on the front or back contact. This reading is therefore in essence a measure of impulse ratio.

Relay " A " should be the same type of impulse relay as used in the selector switches in the exchange, and should be adjusted to the manufacturer's standard. Relay " B " serves to disconnect the voltmeter just prior to the completion of a train of impulses, and so prevents an unnecessarily long final deflection due to the slow release of " C." Relay " C " controls " B," and contact C1 prevents deflections when " B " is operated prior to the reception of dialling impulses or between trains of impulses.

To calibrate the test circuit the exchange interrupter machine is carefully adjusted to give 10 impulses per second and is connected to the test circuit so as to cause relay " A " to impulse continuously. Relay " B " of the test circuit is permanently wedged up so that the continuous train of impulses is indicated on the voltmeter. The " loop " key on the interrupter machine is operated and the voltmeter should be so connected and the resistance of X and Y so adjusted that under these conditions the needle takes up a position approximately 7 divisions on the right of the zero. On the operation of the "shunt" key the needle moves to the left of zero. These tests are repeated until a deflection of 7 divisions is obtained on either side of zero. A higher reading than the figure mentioned is not advisable, otherwise during testing the instrument pointer will take too long to reach a final position.

The voltmeter scale is permanently amended as indicated in Fig. **2**. Here only five divisions are shown on either side of zero. The instrument is calibrated for a deflection of 7 divisions as explained earlier, but in order to obtain a margin of safety all impulsing devices are adjusted so that the reading falls within 5 divisions in either direction from zero. Impulses which show beyond the limit in the direction of the normal scale of the voltmeter are called "heavy," and the impulsing springs of the dial under test are suitably adjusted to bring the reading within the limits. Readings beyond the limit below zero are termed "light," and here again in most cases suitable adjustment can be obtained by slightly altering the spacing of the dial impulsing springs. Care is exercised, however, to ensure that these adjustments are not carried beyond the limits of safe mechanical operation. Provided a dial is adjusted to the correct ratio before installation, tests taken recently indicate that on new services it should only be for special circuits such as extension working, parallel services, P.B.X. circuits, etc., that an adjustment for impulse ratio is necessary. The test, however, should be applied as a matter of routine whenever a subscriber's service is being inspected by the maintenance force.

The test circuit has been used to great advantage for repeater adjustment between exchanges, but to date the limits of its usefulness in this direction have not been fully exploited.

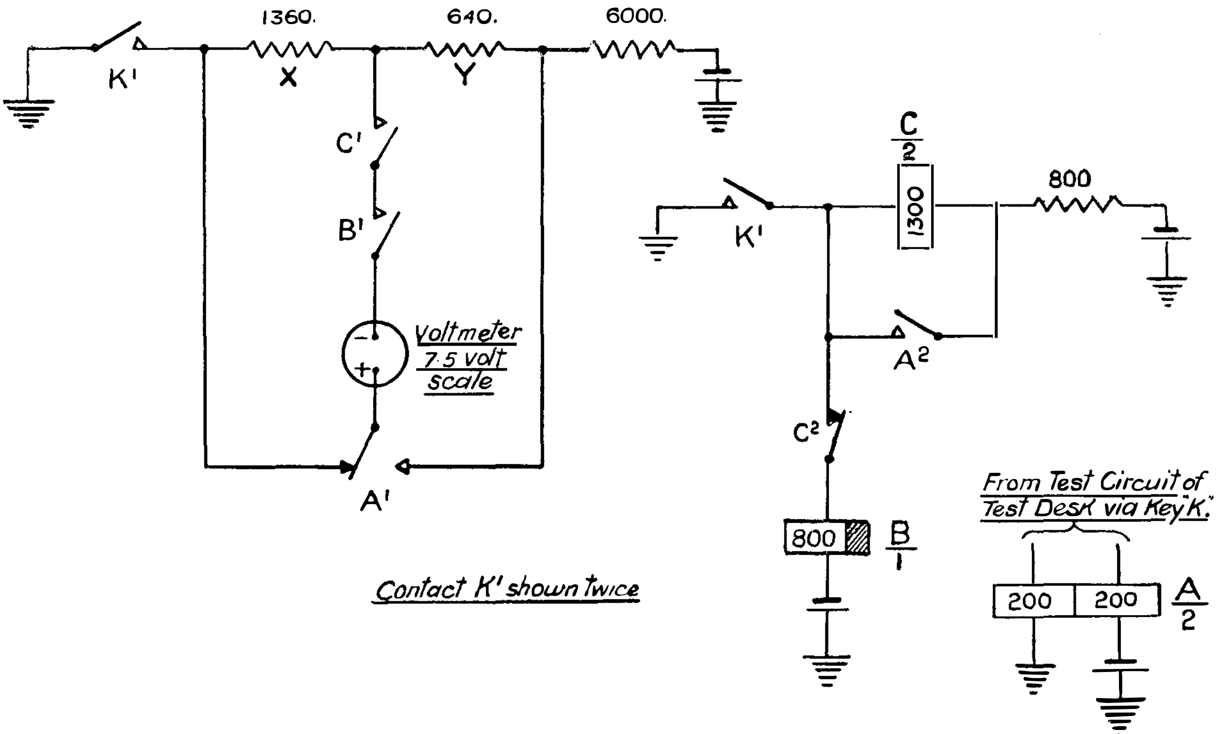


Fig. **1**.—Circuit for Measuring Ratio of Impulse.

It is realised that the circuit is not perfect. Tests are being conducted at present to improve the method of calibration, particularly in the direction of defining the limits and the margin of safety to be allowed. Errors also arise due to the "lost time" of contact of a dialling relay and to variation of exchange voltage. It is considered, however, the accuracy obtained is well within the limits procurable for any electrical measurement on an exchange test desk. The circuit is installed in several exchanges and its

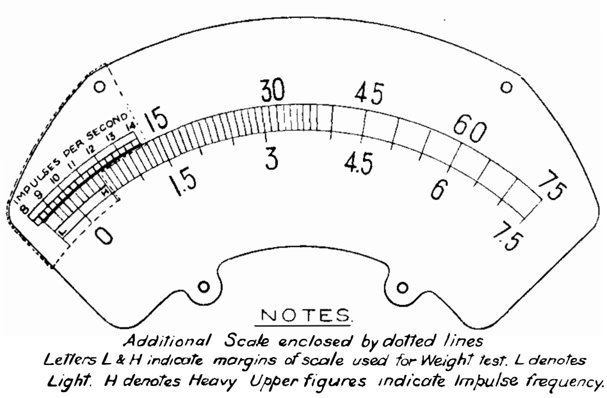


FIG. 2.—VOLTMETER SCALE MODIFIED F●R TESTING IMPULSE FREQUENCIES AND WEIGHT.

usefulness and accuracy has been well proved. The circuit shown in Fig. 1 is schematic only and does not show all the details necessary for connecting the apparatus in the desk test circuit.

An electrical method employing the test desk voltmeter for the measurement of impulse frequency has also been developed, the elements of the circuit being indicated in Fig. 3. The impulsing and voltmeter control relays have not been shown, but this part of the circuit is similar to the corresponding part of Fig. 1, relays AA′, BA′ and CA′ corresponding respectively with relays A, B and C. The test key KA′ is inserted in the regular test circuit on the test desk and, on being thrown, relay AA′ is operated from the subscriber's service under test. The mechanic at the subscriber's premises pulls O on the dial, thus causing relay AA′ to impulse. The impulsing of contact AA′ causes the charge and discharge of the two microfarad condensers, the discharge being dissipated in the closed circuit provided, the charge being obtained through the bridge combination.

The bridge is arranged so that when impulses are being delivered at the rate of 10 per second there is no average potential difference across the terminals of the voltmeter. For frequencies other than 10, an unbalanced condition is set up, a deflection in one direction being obtained on the instrument for frequencies above 1● and in the opposite direction for frequencies below 10.

Owing to the time of charge and discharge of the condensers being small compared with the time of contact of the relay for ordinary impulse frequencies and ratios, the average charging current taken over the time of one impulse train is practically proportional to the frequency of impulsing. Owing to the damping of the voltmeter movement, the pointer takes up an almost stationary position proportional to the average current passing through it, and the instrument may therefore be calibrated to measure frequency.

The frequency is indicated in the manner shown in the top auxiliary scale in Fig. 2. It will be noted that standard speed corresponds with zero deflection. As a dial in standard adjustment takes but one second to deliver its impulses, it is essential that the voltmeter needle move as little distance as possible. Incidentally, it may be mentioned that the sensitivity of the apparatus is such that variations of frequency during a train of 10 impulses are indicated.

To calibrate the circuit, connect the interrupter machine on zero loop to relay AA′. By running the machine alternately at 10 and 14 impulses per second and adjusting resistance *a*, and perhaps *b*, the correct frequency indication can be obtained on the voltmeter. The resistance values shown in Fig. 3 are typical only. Other frequencies should be indicated correctly, but should be checked.

As stated earlier, the keys for connecting both the frequency and ratio test circuits are placed in the ordinary test desk circuit. This arrangement gives a very convenient and rapid method of carrying out the tests, with the added advantage of utilising standard test desk equipment.

Our thanks are due to the Chief Electrical Engineer for permission to use the information gained from various tests.

[*Note.—In the B.P.O. Administration, maintenance men do not adjust faulty dials, but change them on instructions from the Test Clerk. Adjustment of the dials is done by skilled staff at the exchange as a bench job.*—EDS., *P.O.E.E.J.*]

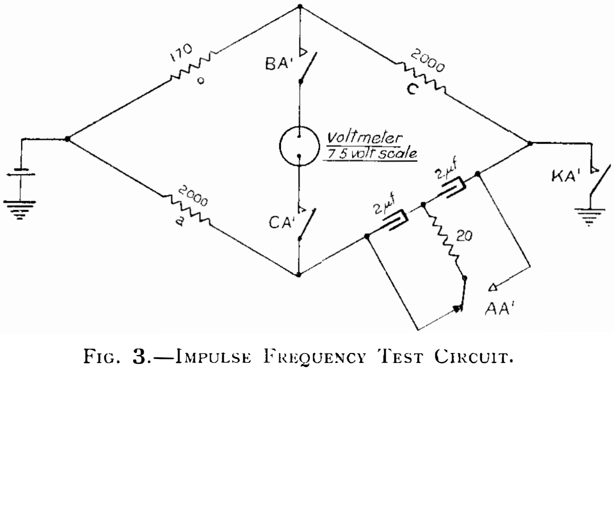


FIG. 3.—IMPULSE FREQUENCY TEST CIRCUIT.

AUSTRALIAN CARRIER SYSTEMS.

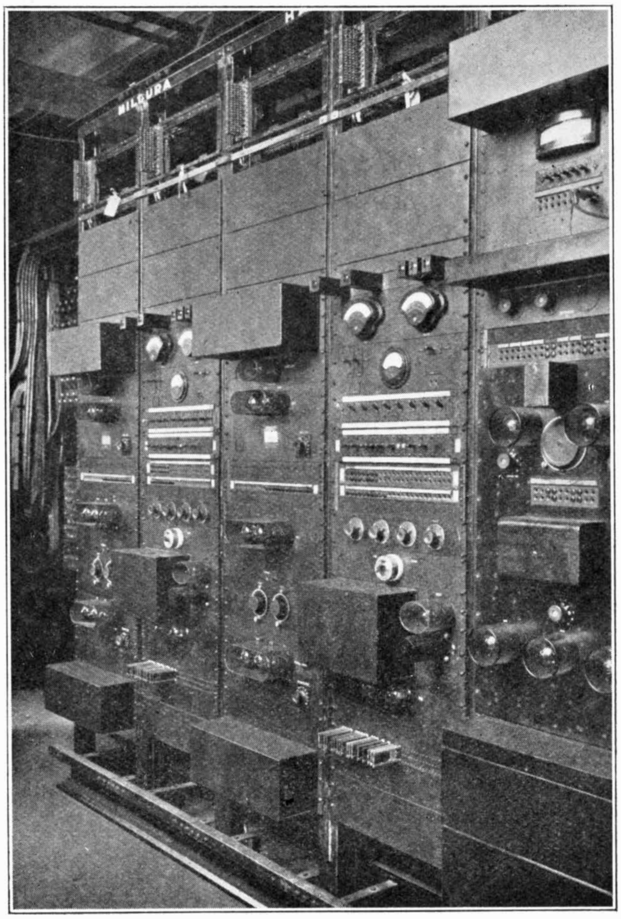
INSTALLATION OF SINGLE CHANNEL CARRIER SYSTEM CONNECTING MELBOURNE TO HAMILTON AND MILDURA.

[*From the general data communicated by the Standard Telephones and Cables Company Limited, the officers of the Engineering Branch of the Postmaster-General's Department proposed a scheme whereby the new type of carrier apparatus which had just emerged from laboratory tests should be put into commercial practice. As this equipment is the first of its kind to be installed, it is considered that a brief outline of the system will be of general interest.*]

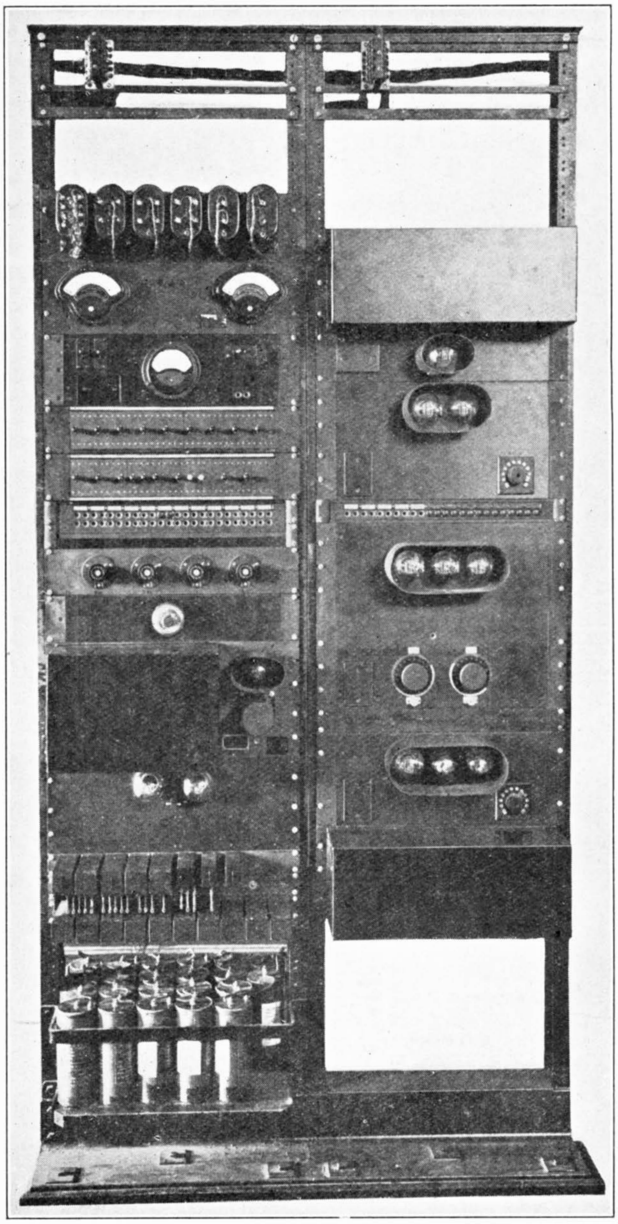
R. N. Partington, M.I.E. (*Aust.*),

Superintending Engineer, Postmaster-General's Department, for the State of Victoria, Australia.

TYPE C2,F. carrier telephone system was recently developed by the Laboratories of the Standard Telephones and Cables Company Limited, in order to provide economically for a one 2-way telephone channel over a pair of open wire aerial conductors without disturbing any existing facility, either telephone or telegraph.



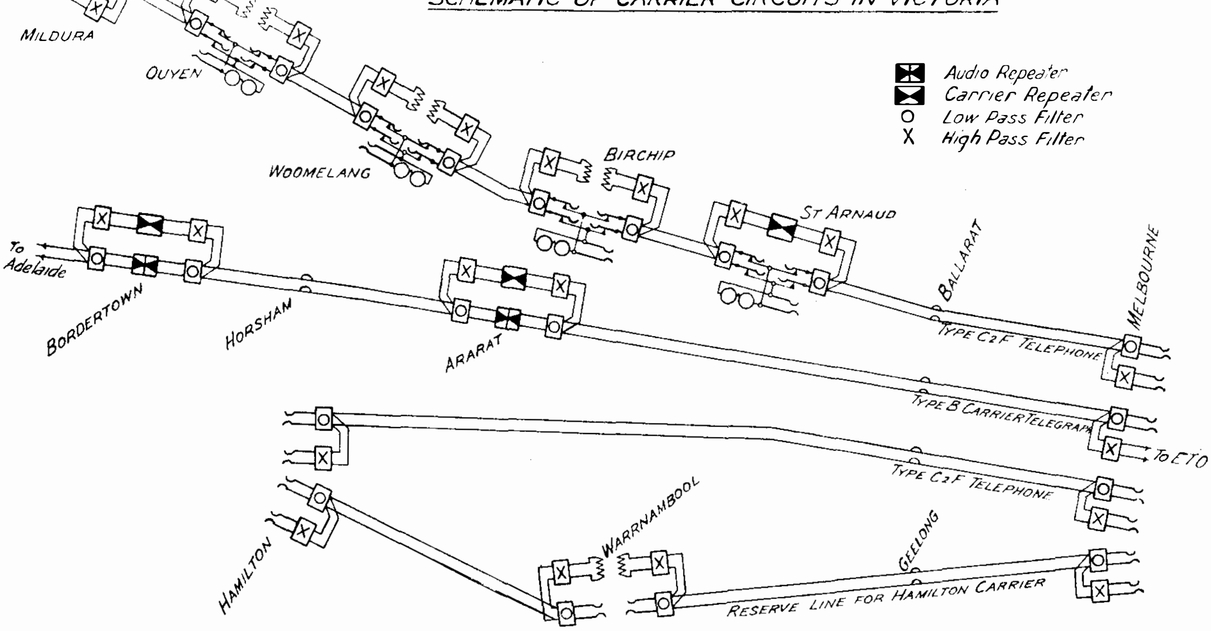
Carrier Systems: Melbourne Panels.



Carrier System: Hamilton Panel.

FIG 1

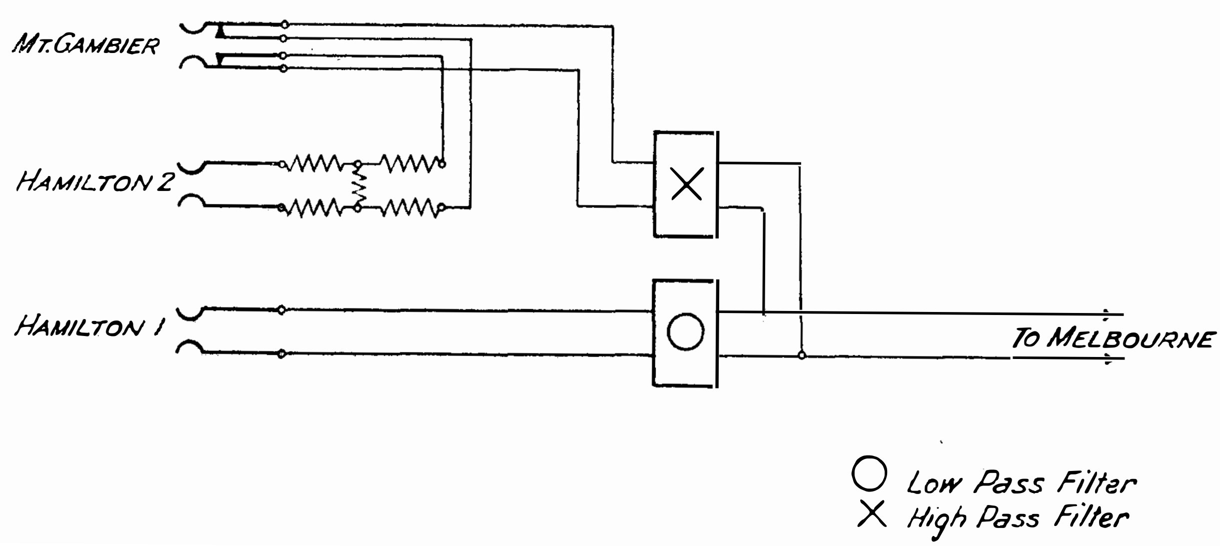
SCHEMATIC OF CARRIER CIRCUITS IN VICTORIA



The system is essentially long haul and is applied in Victoria to connect important country towns separated by a distance between 150 and 800 miles over the route either where relatively few wires exist, or else where congestion would necessitate expenditure on new pole routes. For moderate distances terminal apparatus only is required, but over long ranges it is necessary to have a carrier repeater to compensate for the line losses.

FIG 2

SWITCHING ARRANGEMENTS HAMILTON



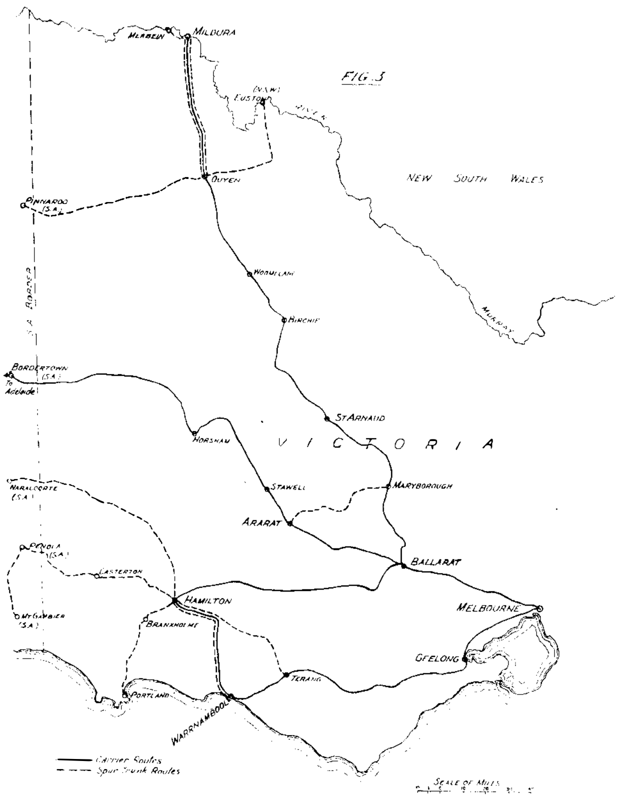


Fig. 3.

The positions of various components of the terminal apparatus are shown in Fig. **4**. On the left is a 4-wire terminating circuit, with which is associated the ringer equipment. Under present practices this is now 16 cycles, but provision has been made to utilise the 1000 cycle ringer. The terminating equipment comprises a hybrid coil and the line balancing network, which function to separate the incoming from the outgoing speech currents. On the extreme right is the carrier line filter group, comprising a high pass filter having a characteristic such that it suppresses currents of frequencies below 3000 cycles, and a low pass filter which suppresses frequencies above 3000 cycles. This group is essential to the derivation of the carrier circuit. The remaining components are shown in greater detail in Fig. **5**.

The current from the carrier oscillator, together with the speech currents from the 4-wire terminating circuit, are together impressed upon the grid of the modulator in such a manner that the modulated carrier current consisting mainly of two side bands and the original speech currents pass through the equaliser which attenuates the lower frequencies of side band more than the upper, so compensating for the unequal propagation in the line and incidentally suppressing the speech current. The transmitting filter, one of two band pass filters connected in parallel across the line, functions to suppress the unwanted modulation component and to transmit the wanted side band, after its power level has been raised to +15 TU by the transmitting amplifier. At Melbourne this filter transmits the lower side band over the carrier line to the receiving filter at the distance

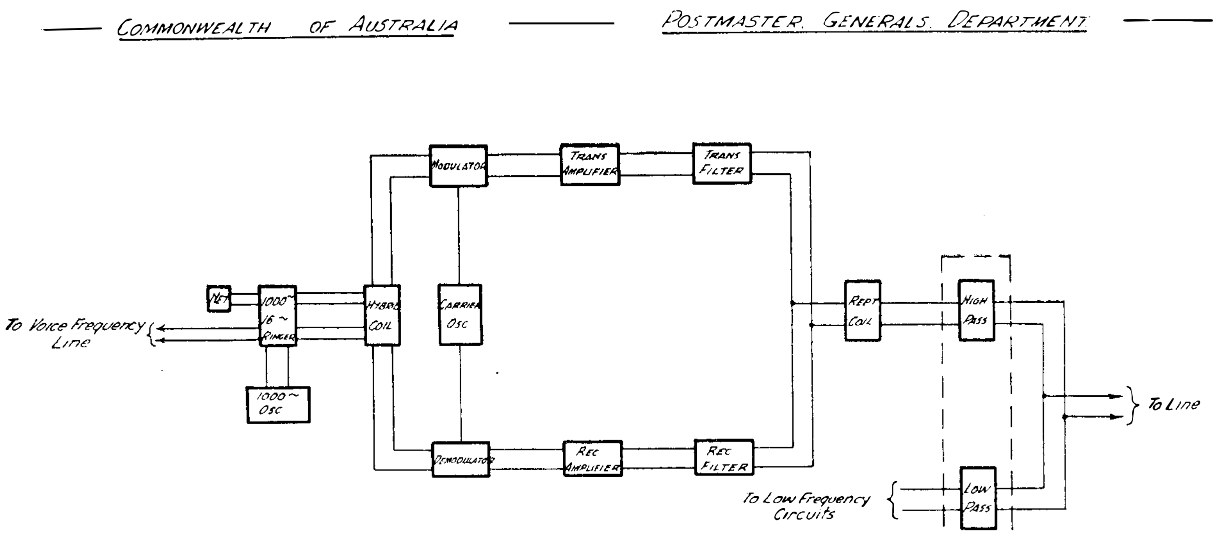


FIG 4

terminal. This attenuated band passes through the receiving amplifier, where its level is raised 12 TU, then to the demodulator which is supplied by the same carrier current as the modulator. Resultant speech currents only are transmitted through the low pass filter to the hybrid coil and thence on to the switchboard.

The Engineering Department of the Australian Post Office has completed recently the installation of a single channel carrier system between Mebourne and Hamilton in order to improve the transmission over an omnibus circuit between Mt. Gambier and equivalent of approximately 12 TU. In consequence of this voice frequency loss, any feeder line switched at Hamilton over this circuit would have an equivalent in excess of that which the Transmission Section regards as the limit for the propagation of commercial speech. The longest of these spur lines was 100 miles in length and served the famous tourist resort, Mt. Gambier.

The necessity for an improved service with Melbourne caused the Commonwealth Post Office Administration to consider the erection of a direct circuit which would provide good

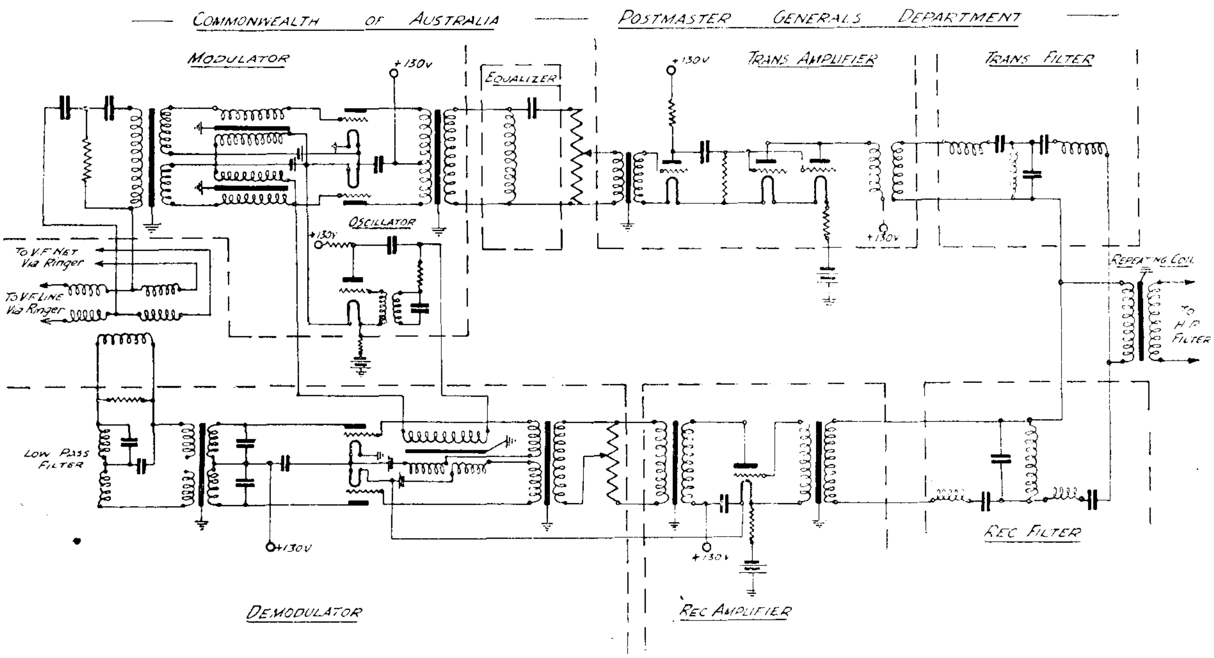


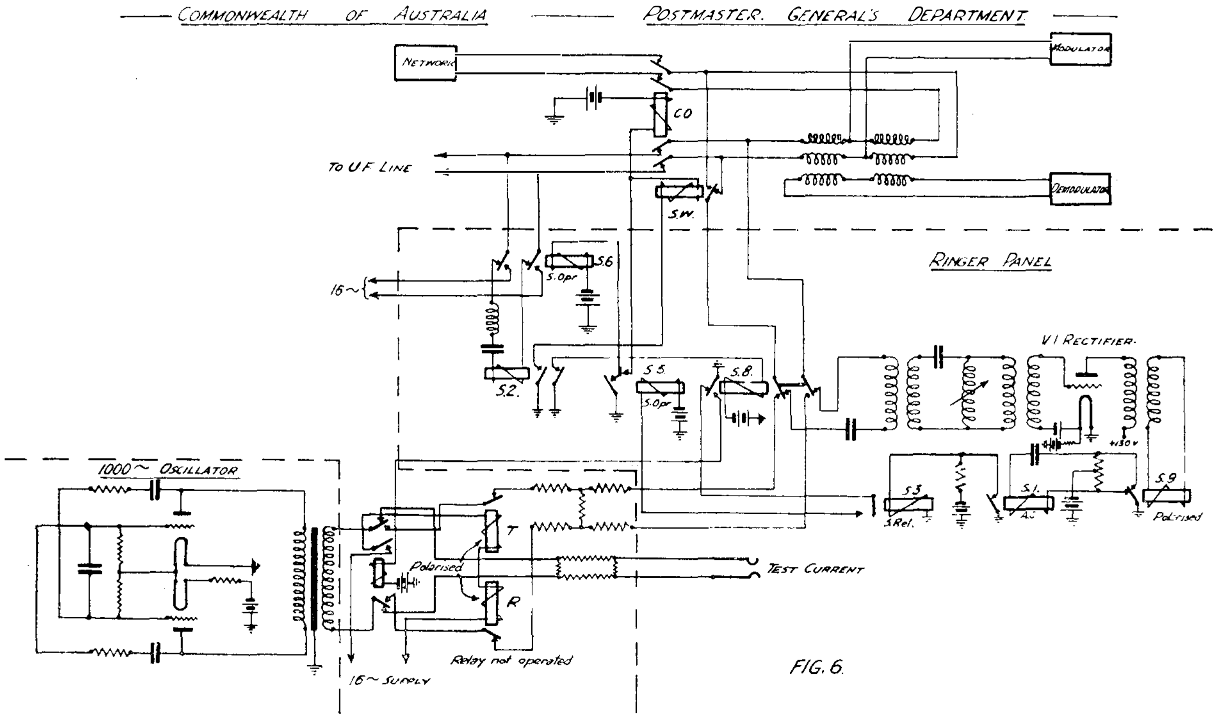
FIG. 5
TERMINAL EQUIPMENT.

Hamilton. In the western portion of Victoria and the south-eastern portion of South Australia there exists a tremendous farming district having a large community of interest with Melbourne, the capital city of Victoria. Hamilton, a prosperous country town with a population of about 5,000, is situated in the centre of this area and is the logical traffic centre of the telephone and telegraph communication of this district with Melbourne. Prior to the carrier installation, the only means of communication consisted of one 200 lb. H.D.C. non-repeatered open wire line between Melbourne and Hamilton, 168 miles in length, giving an transmission between Mt. Gambier and Melbourne. Both from an economic and transmission standpoint it was decided to instal type C2,F. carrier system between Melbourne and Hamilton, using the existing omnibus line to Mt. Gambier as voice frequency link. To ensure continuity of service a reserve carrier line was obtained on a different pole route by installing carrier transfer filters at Warrnambool.

Fig. 1 is a schematic layout of the carrier lines within that portion of the Commonwealth controlled by the Superintending Engineer for Victoria. The original proposal for the

Melborne-Hamilton circuit required the carrier to operate with a zero equivalent between terminal test boards in order that Mt. Gambier could obtain a 12 TU service. By special engineering devices it was found possible to operate the system at a 4 TU gain on the carrier line and this, together with the 12 TU loss between Hamilton and Mt. Gambier, gave a net equivalent of 8 TU between Melbourne and Mt. Gambier, and, by using one channel of the Melbourne-Sydney system having a 3 TU equivalent, the Administration is able to offer to the telephone public a facility between Mt. work because the nearest office on the voice frequency line between Hamilton and Mt. Gambier was but 2 TU distant. At the Melbourne terminal, only 50 ft. separates the trunk switchboard from the carrier unit and to obtain better balance characteristics a 10 TU pad was inserted permanently in the voice frequency line. This has reduced the possibility of end-to-end sing and undoubtedly the result has made possible the 4 TU gain.

Fig. 3 will enable the reader to picture the area served by these various spur lines and will show that Hamilton is able to switch 4 spur



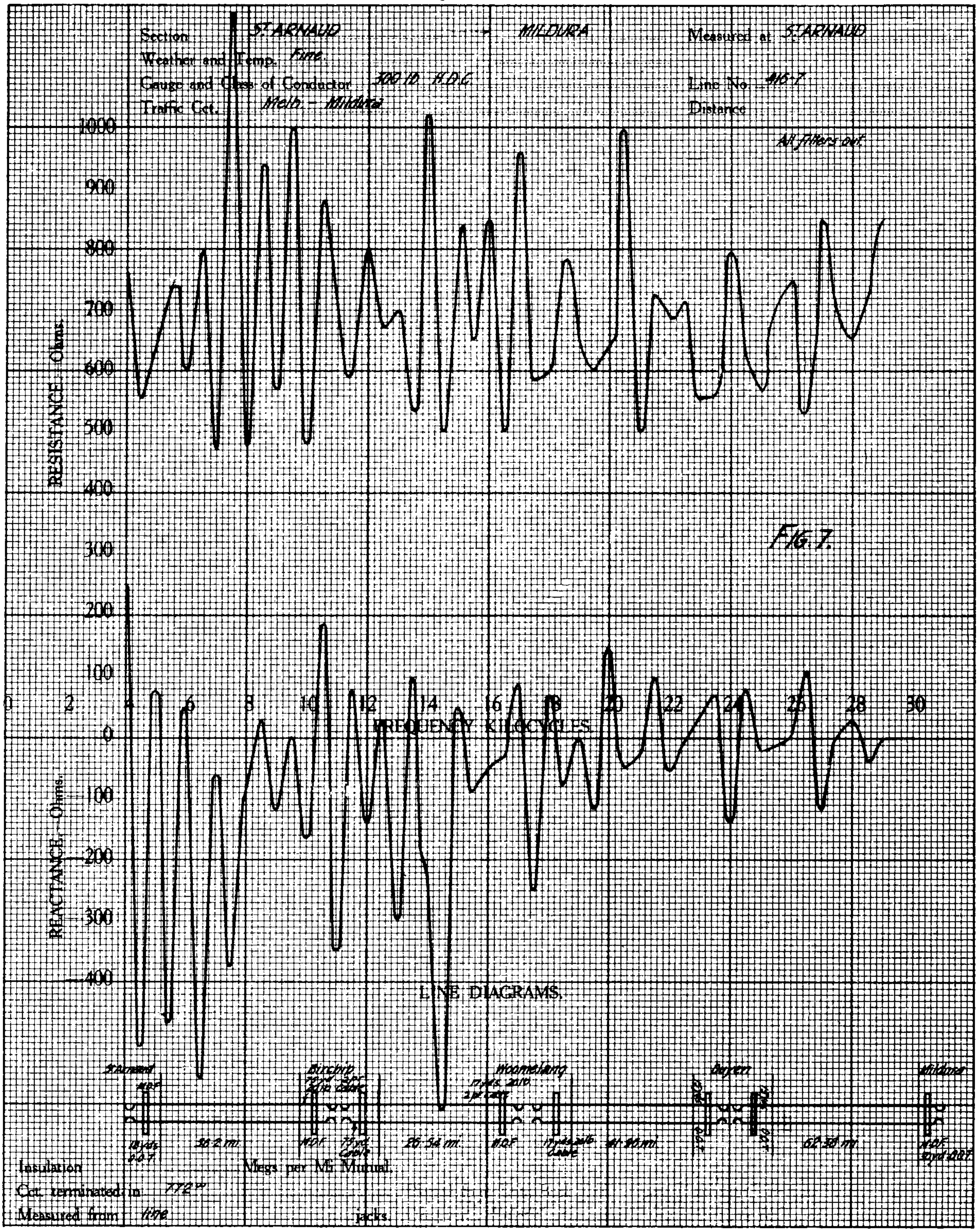
1000 Cycle Ringer.

Gambier and Sydney, a distance of approximately 1,000 miles, having a voice frequency equivalent of 11 TU. To ensure the carrier system being used to its full advantage, a parallel jack arrangement was installed in the switchboard at Hamilton as shown in Fig. 2. The 8 TU pad in the voice frequency circuit prevents overloading of the transmitting amplifier, when Hamilton and 4 short spur lines are switched over the system. This pad is automatically cut out when the system is switched through to Mt. Gambier. Considerable trouble was experienced in the provision of a balance net-

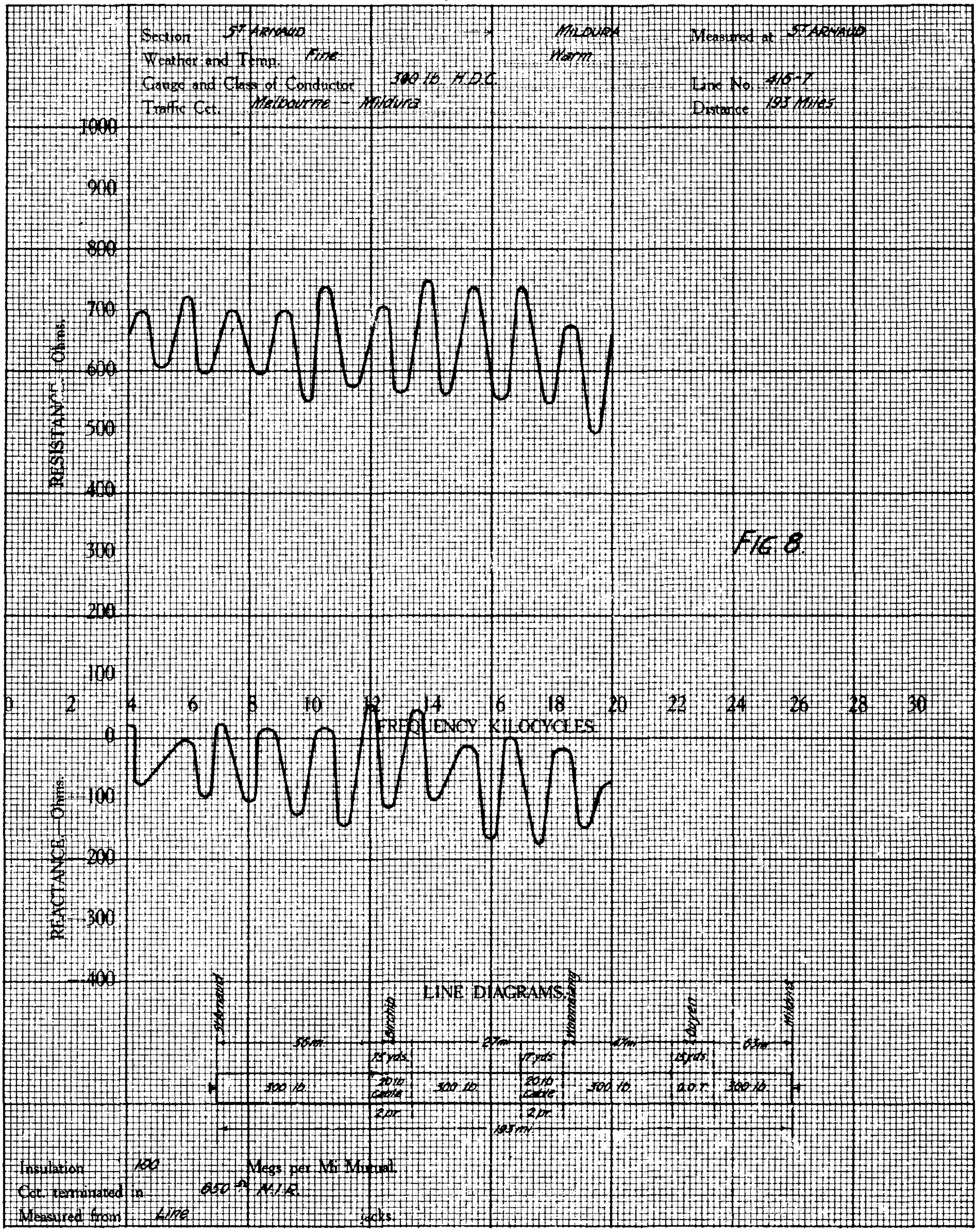
lines extending to Terang Warrnambool, Portland, Mt. Gambier and Narracoorte.

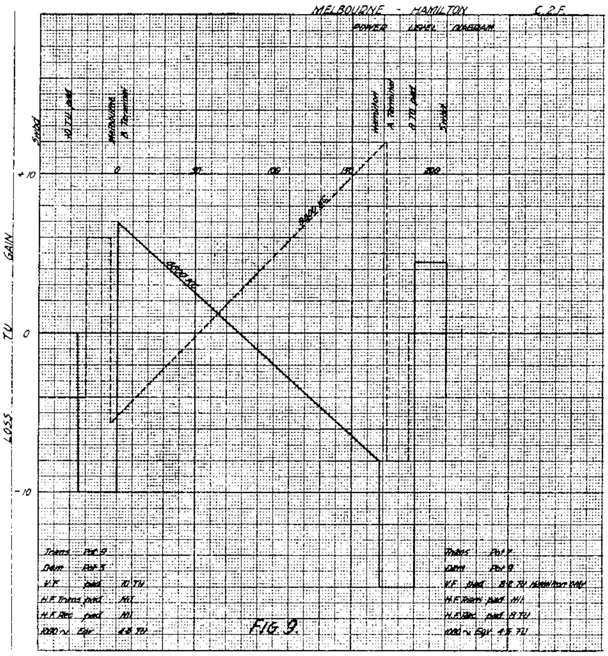
The problem of providing a high grade transmission circuit between Melbourne and Mildura was solved also by the use of a type C2,F. system, together with the installation of an intermediate repeater at St. Arnaud, approximately the half-way point of the line. Mildura is the commercial centre for a district made wealthy and fertile by the successful application of agricultural science to farming problems. It is the centre of a wonderful fruit-growing area, stimulated in recent years

IMPEDANCE v. FREQUENCY CHARACTERISTIC. **T.R.M. 10.**



IMPEDANCE v. FREQUENCY CHARACTERISTIC. **T.R.M. 10.**





POWER LEVEL DIAGRAM, MELBOURNE-HAMILTON.

by the assignment of land to returned soldiers, and the town must progress by virtue of its position on the banks of the river Murray. This telephone traffic centre was connected to Melbourne by a 300 lb. copper non-repeatered aerial trunk line serving the intermediate stations St. Arnaud, Birchip, Woomelang and Ouyen. To relieve traffic congestion and to provide a high grade transmission circuit to Mildura and the outlying areas, a carrier system was superimposed on this circuit, the carrier current being by-passed at the intermediate offices by means of carrier transfer filter sets.

With the installation of the carrier channel the trunk line was permanently divided at Birchip and arranged so that Birchip and St. Arnaud were given direct access to Melbourne on one half of the physical circuit. The other half was used for local traffic between the intermediate stations and for conversations extending through Mildura to Melbourne. In effect, then, a Melbourne subscriber calling Birchip can be switched over one of two circuits,

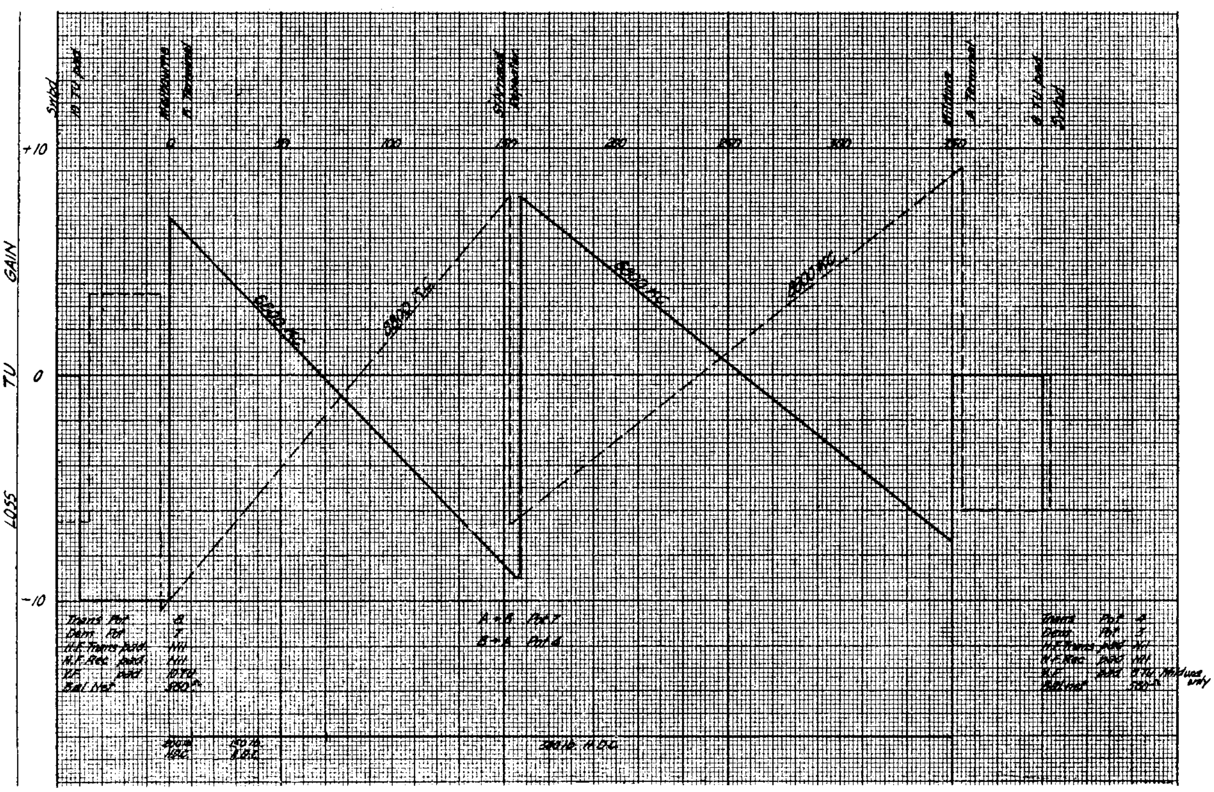


FIG. 10.—POWER LEVEL DIAGRAM, MELBOURNE-MILDURA.

the one by the physical trunk having 1000 cycle equivalent 12 TU and the other over carrier to Mildura and thence back *via* physical to Birchip, having an equivalent of approximately 7 TU. The transmission equivalent of the original circuit at 1000 cycles was 16 TU. This included the loss in the transfer filter sets.

To ensure that the line was free from irregularities other than the unavoidable lengths of trunk entrance cable, impedance and attenuation measurements were taken over the range 4000 to 30,000 cycles. The line was by no means free from irregularities and a study of the graph in Fig. 7 revealed the existence of unknown irregularities, the majority of which lay between St. Arnaud and Birchip. The special line party detailed to make a thorough examination of the trunk located all of these, and the satisfactory state of the line after the examination is revealed by the graph in Fig. 8. The 10% variation in the mean characteristic impedance was due entirely to the presence of a length of trunk entrance cable used to lead the trunks under the railway line and into the office.

This system can be used to give a 6 TU conversation when used for Mildura subscribers by the switching in of a 6 TU pad in the voice frequency circuit operated by a relay connected to the spring contacts of the local jack. The circuit will also give a 2 TU conversation when used for Ouyen subscribers, and as Ouyen is the switching centre for Euston in New South Wales and Pineroo in South Australia we are able to carry out a conversation with Melbourne over 500 route miles with an equivalent not greater than 9 TU. As in the case also of the Hamilton installation, we are able to extend this system to Sydney, Adelaide, and within a very short space of time to Brisbane. This last connection will be made possible by the completion of the multi-channel system between Sydney and Brisbane. Conversation from Pineroo to Brisbane will then be approximately 2,000 route miles, and the equivalent will not be greater than 15 TU.

THE USE OF A WENTE CONDENSER TRANSMITTER TO MEASURE SOUND PRESSURES IN ABSOLUTE TERMS.

A. J. ALDRIDGE, A.C.G.I., A.M.I.E.E.

WENTE Condenser Transmitters have now been in use for some ten years or more, both as practically distortionless transmitters for speech and broadcasting and as a means of measuring sound pressures. It is probably not generally known that their use, without suitable corrections, may involve certain errors which it is proposed to indicate here. These errors have been referred to by Mr. E. J. Barnes in the discussion on Captain Cohen's I.E.E. paper (read 17.11.27).

So far as is known, no calibration curves have been published other than those supplied by the makers. It is not suggested that these are inaccurate, but the calibrations are carried out in a certain manner and are not, in many cases, applicable to the conditions in which the instruments are used.

As is probably well known, the calibration is carried out by means of a thermophone. This consists of two slips of gold foil mounted upon a plate which is caused to fit airtight in the recess in front of the transmitter. A known direct current is passed through these strips and superimposed upon this current is a known alternating current of any desired frequency. The small space between the transmitter diaphragm and the thermophone mounting plate is kept filled with hydrogen gas under atmospheric pressure. Knowing the dimensions of the foils, and of the chamber in which they are, it is possible to calculate the alternating sound pressure developed by the passage of the alternating current through the foils. The calibration curve is the ratio of the E.M.F. developed by the transmitter to this sound pressure in dynes per square centimetre.

Assuming the various constants are accurately known, and the computation is accurate, this gives a perfectly definite calibration, but it is at once evident that the transmitter will seldom, if ever, be used in the condition in which it is calibrated, and unless corrections are applied errors will be introduced. The following appear to be the chief sources of possible error.

(1) The calibration is made in hydrogen.

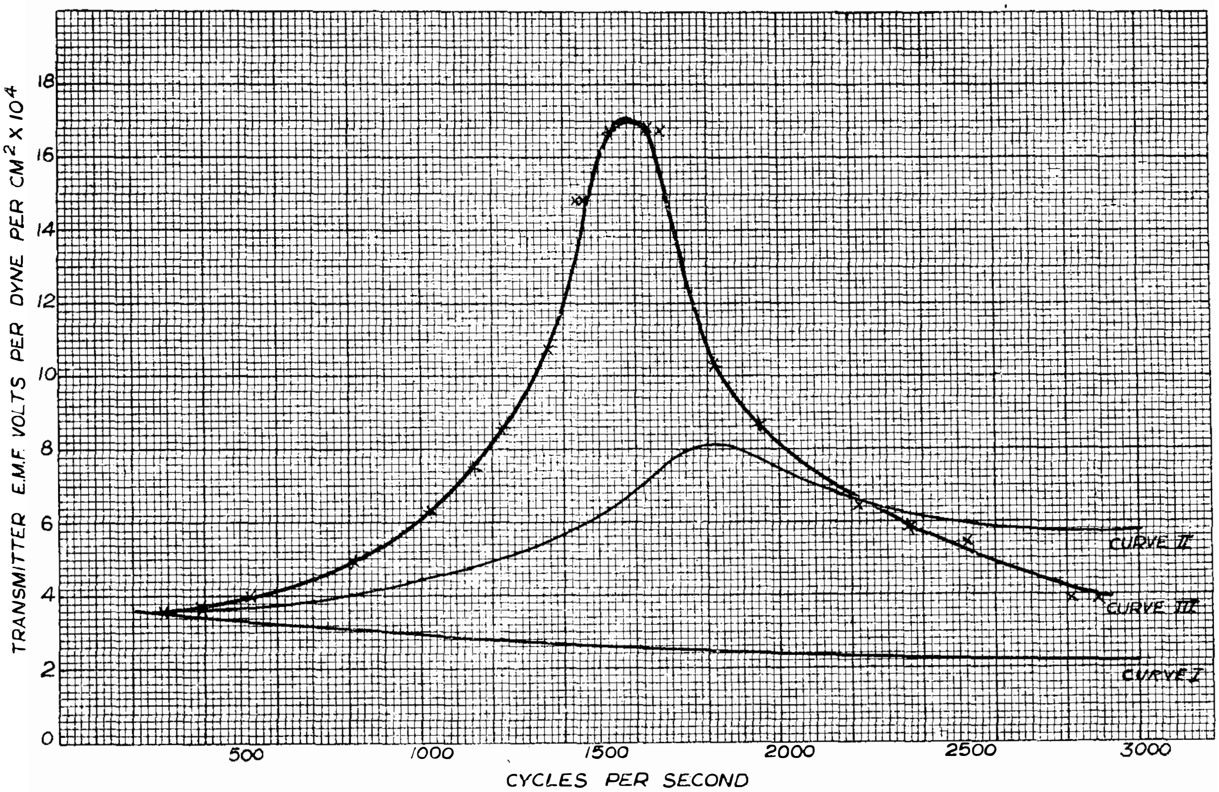
(2) The front of the transmitter is sealed with a small hydrogen-filled cavity, whereas in use it will usually be open to the air.

(3) The air pressures in terms of which the calibration is given are the actual sound pressures actuating the diaphragm. In use the transmitter by its mere presence in a sound field will distort this field and cause the pressure at the position of the diaphragm to be greater than it was before the insertion of the transmitter.

Considering these in turn :—

(1) The effect of the hydrogen is probably negligible. It will slightly alter the damping on the diaphragm, but as by far the greatest damping is produced by the very small enclosed space between the diaphragm and the back electrode the other may be neglected.

(2) The enclosure of the front of the transmitter has three effects. The restoring force in the diaphragm will be somewhat increased, tending to raise the natural frequency; the additional load on the diaphragm due to the air which must be moved when the transmitter is is used in the open is absent, and this will also raise the natural frequency. Neither of these effects is likely to be serious except at resonance, and as this is usually outside the range of frequency over which the transmitter



Condenser Transmitter No. 111 Type 370W. Frequency Characteristics.

is used, the effects may probably be neglected. The third effect is, however, important. The diaphragm is set in the case about 1.5 cm. below the front, and hence there is left, when the transmitter is used in the open, a shallow tubular resonator. The effect of this is shewn in the curves in the figure based on tests carried out in the P.O. Research Laboratory by Mr. West on a 370W type transmitter. Curve I gives the calibration in terms of the actual pressure on the diaphragm and corresponds to the calibration supplied by the makers. Curve II gives the calibration in terms of the pressure at the position of the diaphragm in the sound field, before the introduction of the transmitter. It will be seen there is a pronounced resonance present, masked, to some extent, by an effect referred to under (3). Curve III is taken under conditions similar to those for Curve II, except that the recess has been artificially doubled in depth without altering the diameter.

Considering the space as a tubular resonator, and allowing for the end correction, the calculated resonance frequencies for the two conditions are 2600∽ and 1800∽ which indicate that the effects obtained experimentally shew the right order of resonant frequency.

(3) A sound wave striking any obstacle in its path will be partially reflected. The greater the ratio of the diameter of the obstacle to the wave length the more complete will be the reflection, until at high frequencies complete reflection will occur. The reflected pressure adds to the incident pressure, with the result that the actual pressure on the diaphragm is greater than that of the original sound field at the position of the diaphragm. If the transmitter is being used to measure sound pressures using the published calibration the effects of (2) and (3) will be to indicate pressures considerably greater than they really are.

It will be seen that at 1800∽ the pressure indicated is 3.1 times the true pressure.

With an ordinary Wente transmitter the reflection effect referred to causes an increase of pressure of about 50% at 1500∽

The effects of an obstacle in a sound field are being more fully dealt with by Mr. W. West in an article which will shortly appear.

The preceding remarks are of importance in connection with the C.C.I. Master Reference System.

A Wente condenser transmitter, having a somewhat smaller recess in front, has now been installed as part of the Master Reference Telephone Standard at the C.C.I. Laboratory in Paris, with thermophones for calibration. As previously stated, this gives a perfectly definite calibration and can be used to ensure that no change has occurred in the efficiency of the system. It must be remembered, however, that the calibration will not give the efficiency in absolute terms for the conditions of actual use, and this may give rise to misconception if comparative tests are made using transmitters of different shapes and sizes, or calibrated or used in other ways.

ROTTERDAM MUNICIPAL TELEPHONE SERVICE.

WE have received the official report on the Rotterdam Municipal Telephone Service for the year 1927. It contains some interesting information as to the development of the Ericsson Automatic system in a large commercial centre on the continent where the Municipality is distinguished for its progressive and enterprising attitude.

During the year reviewed, the third of the three main exchanges which provide the Municipal Service was converted to automatic working. With the completion of this work at Botersloot, which involved the transfer of the semi-automatic equipment from the Vlaggemans Street Exchange, automatic working is now installed throughout the Municipal area. At the end of the year 1927, the total number of subscribers' circuits was 20,804 (as compared with 19,752 at the end of the year 1926) of which 12,509 were connected to the Botersloot Exchange, 4,691 to the Korenaar Street Exchange and 3,544 to the Vlaggemans Street Exchange. So far as the Korenaar Street Exchange is concerned, 3,770 circuits, out of the 4,691, are now being worked wholly automatic, and all of the 3,544 circuits conected to the Vlaggemans Street Exchange.

The automatic plant fulfils all expectations and, as in the past, no serious interference with working occurred.

The increase in local traffic, compared with 1926, amounted to 4.2 million calls (the increase in 1926 over 1925 was 6.5 millions). The figures for the international traffic are interesting. While the number of calls with England diminished from 57,544 in 1926 to 53,829 in 1927, the calls with Germany increased from 280,940 in 1926 to 345,941 in 1927—an increase of 23.6%. The calls with Belgium fell from 125,115 in 1926 to 115,710 in 1927. The calls to France increased from 3,963 to 10,002 in 1927. Calls to Denmark, Czecho Slovakia and Switzerland also increased very substantially—there were nearly seven times as many calls to Czecho Slovakia, for example, in 1927 as in 1926, and nearly five times as many calls to Switzerland. New circuits to Austria, Dantzic, Italy and Hungary resulted in considerable traffic with these countries. The trunk calls from and to Rotterdam during the year 1927, were 3,408,450, an increase of 204,298 or approximately 9.5% compared with the previous year.

Appreciable increases also took place in the time and fire alarm services, but a reduction occurred in the number of telegrams forwarded over telephone circuits, the number of telegrams falling from 446,983 in 1926 to 408,617 in 1927; on the other hand, the number of telegrams delivered to telephone subscribers over their telephone circuits rose from 94,687 in 1926 to 103,913 in 1927.

The daily total of faults fell from 123.1 to 118.1 in 1926.

The profit on the whole undertaking amounted to 989,141 Dutch florins in 1927, compared with 955,352 florins in 1926.

THE STANDARDISATION OF STATIONARY SECONDARY CELLS IN THE BRITISH POST OFFICE.

H. C. JONES, B.Sc., Eng. Hons.

TELEPHONE apparatus designed and installed during recent years has generally required considerably more power for its operation than had been the case previously, and it is not surprising, therefore, that the capacity of batteries in use in the British Post Office has increased enormously as a result. In 1919 the total capacity of batteries in use in the Post Office was 5,000 kilowatt hours. To-day it is approximately 30,000 kilowatt hours and by 1936 it is estimated it will have increased to 100,000 kilowatt hours. In one building alone there are now batteries working having 2,000 K.W. hours capacity, *i.e.*, 40% of the capacity of all the batteries in Post Office use in the country in 1919, whilst there are installations under consideration which may require batteries of double this size. The development is not confined, however, to large installations, for with the extended use of automatic apparatus and lamp signalling manual equipment, it is now necessary to work many small exchanges of 50 lines and less from secondary cells. During 1927, over 20,000 secondary cells of less than 300 Amp. hrs. capacity were installed by the Department's staff, making an estimated number 70,000 cells of these sizes in Post Office use at the present time.

It will be appreciated from the foregoing that the standardisation of all sizes of secondary cells has become an absolute necessity, as otherwise undue difficulties would be experienced when repairs are required. Non-standardisation would necessitate each repair being treated as a special job and would entail excessive time and labour. Detailed standardisation results in each plate renewal being a comparatively simple matter of routine.

Some four or five years ago the Department standardised in detail 11 sizes of stationary cells varying from 8 Amp. hrs. to 300 Amp. hrs. capacity, and consequently the installation of many small power plants that were required shortly afterwards was made a very simple matter. Probably about 95% of the small secondary cells in use at present are of these standard types. The stardardisation of large secondary cells up to the largest sizes was a matter which could not be dealt with rapidly, but it was appreciated that if the large new exchanges then under consideration were fitted with non-standard plates considerable difficulty would result in future when repairs were required. In 1925, therefore, five standard plates were agreed upon by the Department in conjunction with the Accumulator manufacturers, and it was arranged that all new batteries of above 300 Amp. hrs. capacity supplied to the Department should be fitted with plates of one of the agreed dimensions. This scheme standardised cells, as regards plate dimensions, from 8 Amp. hrs. to those of the largest sizes and ensured that future repairs on all batteries could be carried out economically.

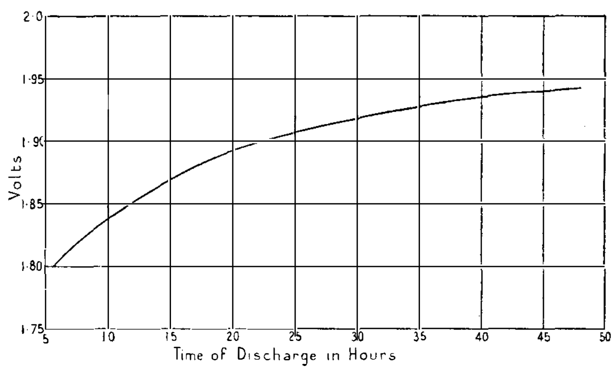


FIG. 1.—VOLTAGE OF CELL AT END OF DISCHARGE.

The scheme has now been completed in detail by the recent issue of "Specification for Cells, Secondary Stationary, Nos. 12/N to 16/N," in which every component required for the construction of any cells from 400 Amp. hrs. to 13,800 Amp. hrs. capacity has been definitely specified.

The following is a brief resumé of the chief points encountered in the work of standardisation. In the first place it was necessary to decide on a basis for the comparison of cells of various types and manufacture, and in order to do this the voltage at which a cell was to be considered discharged had to be decided. As a result of experiments, the curve shown in Fig. 1, in which the voltage of a cell at the end of discharge is plotted against the rate of discharge, was produced and was agreed by the accumulator manufacturers. In passing, it will be noticed that it is from this curve, that the now familiar figure of 1.83 volts, which represents the P.D. of a cell at the end of a discharge at the 9 hour rate, is obtained.

A second problem was to define in what way the Amp. hour capacity of a cell was related to the dimensions of the plates. It was fairly obvious that the capacity was proportional to the superficial area, but it was not clear how it was affected by the thickness. As the result of tests on a large number and variety of cells, it was found that the capacity of plates, both positive and negative, as manufactured by the various reputable Accumulator firms, varied with the plate thickness as indicated by the curve shown in Fig. 2 and could be expressed by the formula : 1.03 area $\sqrt[5]{\text{thickness}^2}$ Amp. hours, the dimensions being in inches.

It should be noted that this formula does not hold good for all types of cells. Portable batteries, in which weight must be kept to a minimum, have a much higher capacity than is indicated by the above expression, but as a basis for comparing stationary cells, where weight and space are not vital considerations, but where long life is required, the formula has been found to be very accurate.

It was now possible to proceed with the actual design of the cells (we are considering for the moment those up to 300 Amp. hrs. capacity). At the outset three sizes of plates were decided upon as follows :—

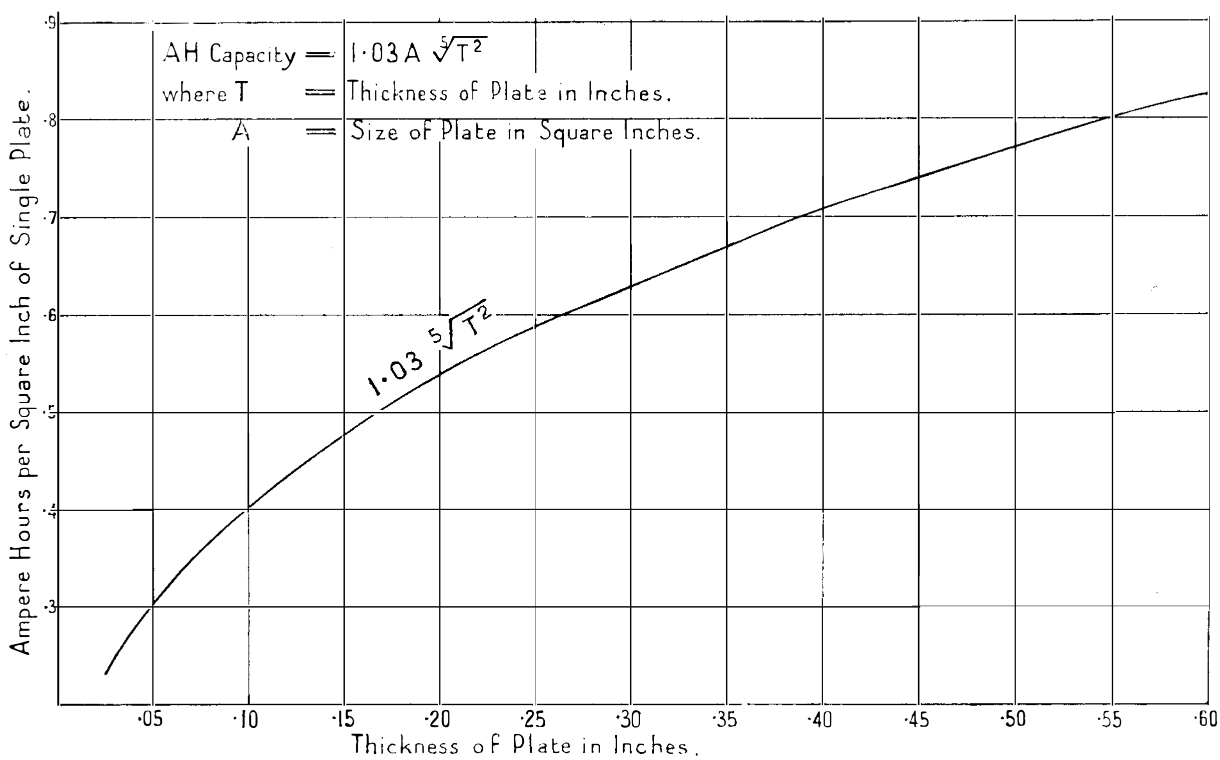


FIG. 2.

Positive Plates.			Negative Plates.			Capacity of Positive Plates.
Width.	Height.	Thickness.	Width.	Height.	Thickness.	Amp. Hrs.
4″	4″	.2″	4″	4″	.15″	8
5″	6½″	12 mm.	5″	6½″	8 mm.	24
7″	9¾″	12 mm.	7″	9¾″	8 mm.	50

and it was arranged that these should be burnt up into sections containing 1 to 5 8-Amp. hour positive plates; 3, 4 or 5 24-Amp. hour positive plates, and 4, 5 or 6 50-Amp. hour positive plates. The negative sections contained one more plate than the corresponding positive sections.

Provision was made on each of the sections for bolted connections so that batteries could be erected by bolting together adjacent cells, no lead burning being, therefore, necessary. Eleven sizes of glass boxes suitable for containing the various sizes of sections and the other necessary components for building up batteries were also designed and standardised. By this means a comprehensive series of 11 sizes of secondary cells having capacities of 8, 16, 24, 32, 40, 72, 96, 120, 200, 250 and 300 Amp. hours was built up, the cells being styled "Cells, Secondary, Stationary Nos. 1-11." Arrangements were made for the Stores Department to hold stocks of these cells, both complete and in their separate components.

As no lead burning whatever is necessary, the erection and repair of batteries composed of these cells can be conveniently carried out by staff which is not specially experienced in battery work.

Now as regards the larger cells. The details of the five standard plates which have already been referred to are shown below:—

Nominal Capacity.	Positive Plates.			Negative Plates.		
Amps. Hrs.	Width.	Height.	Thickness.	Width.	Height.	Thickness.
100	10″	13″	12 mm.	10″	13½″	8 mm.
150	14″	14″	12 mm.	14″	14½″	8 mm.
200	14″	20″	10.4 mm.	14″	20½″	8 mm.
300	14″	30″	10.4 mm.	14″	30″	8 mm.
430	20⅝″	29″	10.4 mm.	20⅝″	29″	8 mm.

The standard plate pitch is 1¾″.

The standardisation of these plates was a big step forward. Hitherto each battery maker had supplied cells of his own special size and design, which frequently entailed difficulty as regards effective competition when plate renewals were required. Standardised plate dimensions obviated this feature. Previously the space allowed in the design of new buildings for battery equipment had to be on generous lines as, although the necessary Amp. hour capacity could be determined fairly accurately, the linear dimensions of the batteries were not definitely known. The standardisation of plate dimensions, however, permitted the necessary accommodation being accurately determined from a simple formula.

Following the agreement regarding plate dimensions the standardisation of the large batteries was proceeded with in detail. It was decided to adopt a somewhat unique scheme in which the plates were burnt together in convenient sections containing 2, 3 or 4 plates, arrangements for the inter-cell connections being made by bolting together adjacent positive and negative sections.

The positive plates were arranged to be made up into 2 or 3 plate sections and negative plates into 2, 3 or 4 plate sections. It is obvious that

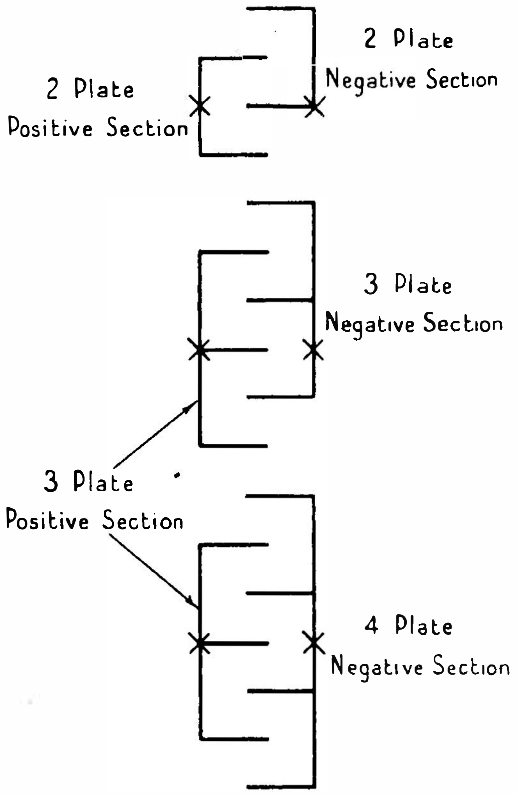


FIG. 3.

by a suitable arrangement of these sections a cell could be constructed containing any number of positive plates more than 2. The negative plate sections were arranged to be connected to positive sections containing the same number of plates, except at one end of the cell where the negative section contained one more plate than the corresponding positive section. This will be made clear from Fig. **3**, which shows diagrammatically the construction of a cell containing 8 positive plates. Fig. **4** shows clearly the construction of the plate sections and the method by which adjacent positive and negative sections are bolted together. This system of grouping plates in small sections of bolted connections obviates lead burning in exchanges and renders possible the ready removal of plates by the local staff for inspection, the straightening where necessary of buckled plates, the removal of short-circuits and enables replacements to be made with facility. It permits, where necessary, the use of deeper plates in existing boxes, seeing that by the removal of one or two sections a gap can be made for the removal of sediment. Moreover, any repairs or replacements may be carried out piecemeal whilst the battery is working. Additional

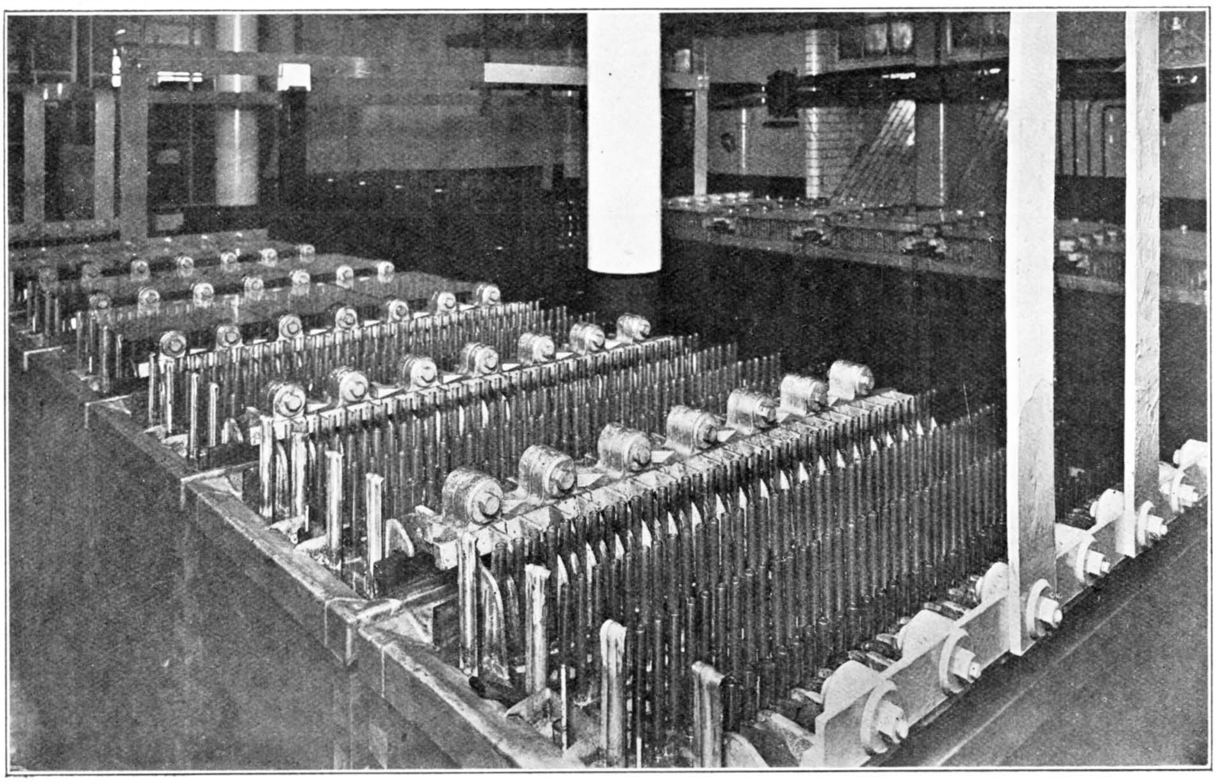


FIG. **4**.—VIEW OF CELLS SHOWING BOLTED CONNECTIONS.

sections can easily be fitted to partially equipped batteries, either by adding previously charged sections to each cell if the existing plates are in good condition, or by re-distributing existing sections over fewer boxes and fitting the remaining boxes with new sections. The usefulness of the scheme will be appreciated from the following example. It was recently necessary to examine a battery where some slight buckling had occurred. A buckled plate having been located, the section concerned was removed from the cell, the plate straightened and the section replaced in the cell and bolted up again in five minutes.

In the new specification 113 sizes of cells have been specified in detail to cover a range of from 400 Amp. hours, using 100 Amp. hour plates to 13,800 Amp. hrs., in which cells 430 Amp. hr. plates are used. The following schedules give extracts from the tables in which the components required for the construction of these cells are specified in detail, and Fig. **5** shows in detail the construction of the cells and scheme of cell connections:—

PARTICULARS OF CELLS CONTAINING PLATES OF 299 AH. CAPACITY PER PLATE AT 9 HR. RATE.

ll lary iary	(b) Minimum Ah. Capacity at 9 hr. rate.	(c) No. and Type of Sections. Positive 15/2	Positive 15/3	Negative 15/2	Negative 15/3	Negative 15/4	(d) Dimension of Box Wood No 15/n. (See Drawing 8795.) A	B	C	D	E	F	G	H	(e) Slabs, Glass, ⅜″ Thickness. Length	Depth	No. per cell.	(f) Separators Secondary Cell No. 7 44½ × 12.55 mm. 110 per cell.	(g) Bolts Connection No. 6 per cell.	(h) Insulators Battery No. 5 per cell.	(k) Springs Secondary Cell No. 6 per cell	(m) Spray Arrestors Width—16″. Length	No. per cell.	(n) Insulator Battery No. 6 No. per cell	(o) Galls. of Acid Sulphuric No. 3 required per cell Sp.G. 1.215.
800	1790	—	2	—	1	1	13″	$16\frac{3}{8}''$	$40\frac{11}{16}$	½″	1½″	6″	1¾″	21¼″	12½″	$41\frac{15}{16}$	2	56	2	4	4	11¼″	1	—	24.5
100	2090	2	1	1	2	—	14¾″	$16\frac{3}{8}''$	$40\frac{11}{16}$	½″	1½″	6″	1¾″	21¼″	14¼″	$41\frac{15}{16}$	2	64	3	4	4	13″	1	—	27.7
400	2390	1	2	1	1	1	16½″	$16\frac{3}{8}''$	$40\frac{11}{16}$	½″	1½″	6″	1¾″	21¼″	16″	$41\frac{15}{16}$	2	72	3	4	4	14¾″	1	—	31.0
700	2690	—	3	—	2	1	18¼″	$16\frac{3}{8}''$	$40\frac{11}{16}$	½″	1½″	6″	1¾″	21¼″	17¾″	$41\frac{15}{16}$	2	80	3	4	4	9″	2	—	34.2
000	2960	2	2	2	1	1	20″	$16\frac{3}{8}''$	$40\frac{11}{16}$	½″	1½″	6″	1¾″	21⅓″	19½″	$41\frac{15}{16}$	2	88	4	6	4	10″	2	—	37.4

Fig. **6** shows a general view of two 11 cell batteries of 5650 Amp. hr. capacity constructed of 300 Amp. hr. plates. It shows clearly the construction of the battery stands, the supporting insulators, the method of supporting end cells, the interconnecting of the plate sections at the positive and negative ends of the battery, all of which points are covered in the specification.

It will have been noticed from an examination of Figs. **4** and **6** that except at the positive and negative ends of the battery, individual cell positive or negative sections are not interconnected. Theoretically this particular disposition of plate sections results in a transfer of current on charge and discharge diagonally across the battery and consequent unequal working of the plates. This is confirmed to some extent in practice by slightly uneven voltage readings, certain sections showing a tendency to attain a high voltage on charge and a lower voltage on discharge than other sections. This has led to a certain amount of difficulty in making the acceptance tests, as it has not been possible to determine by voltage readings exactly when a cell was discharged. It has, therefore, been decided to fit connection bars in the form of

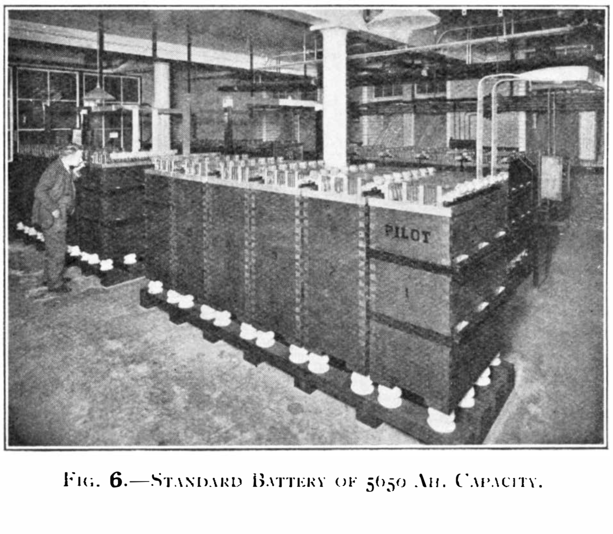


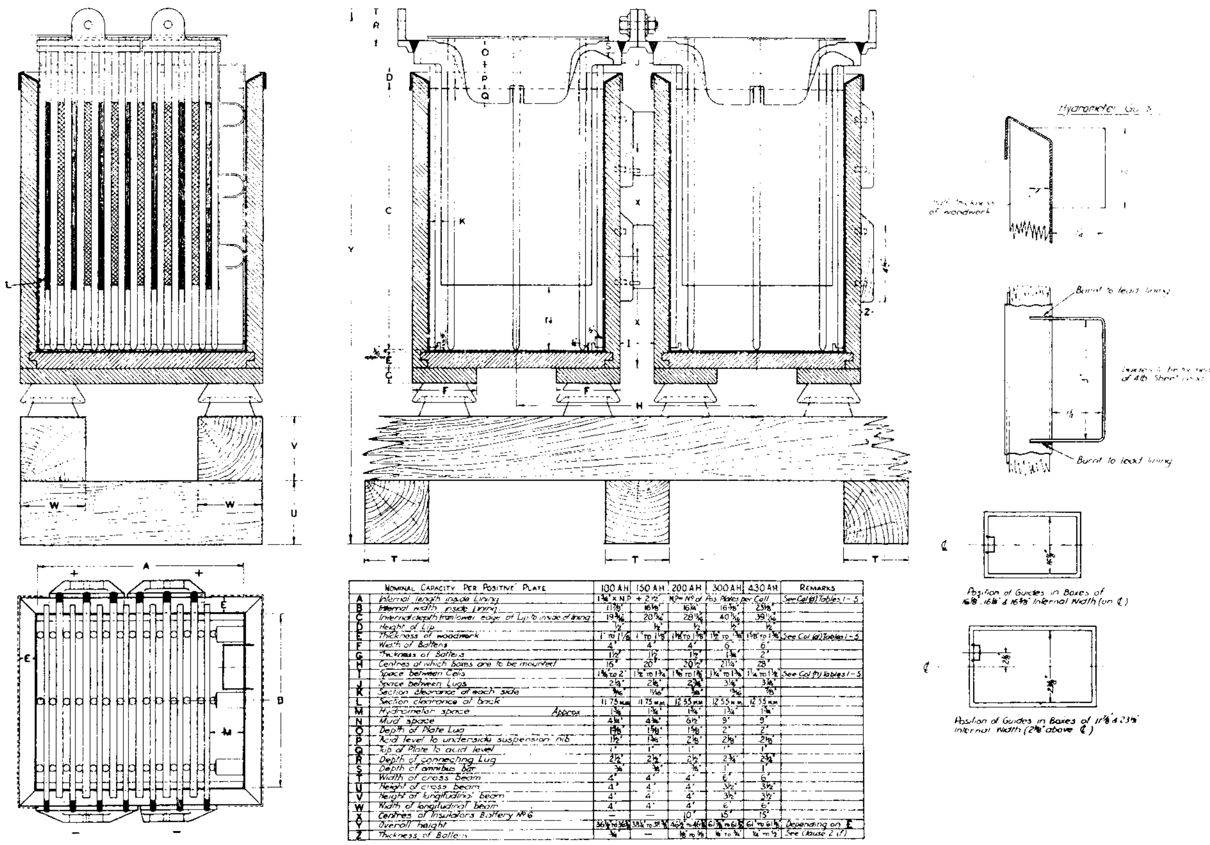
FIG. **6**.—STANDARD BATTERY OF 5650 AH. CAPACITY.

leadised copper strips so as to common the adjacent sections of individual cells. These will not interfere with the particular advantages of the bolted connection system previously enumerated, and will also nullify the possibility of any trouble which might have resulted from the unequal distribution of the current on charge and discharge.

There has been in the past a certain amount of controversy regarding the testing of secondary cells. All the relevant P.O. specifications, however, definitely stipulate what tests are to be applied and have clarified the position as far as the battery contractors and the Department are concerned. It is thought that particulars of the tests may prove of interest and the tests made in respect of the large cells are therefore given in some detail below.

In the first place, when tendering, the contractor is required to state the number of Amp. hours required for the initial charge of the batteries. The Department supplies this amount of power free of cost and also the power required for the test charge, provided this does not exceed 1/9th more than the guaranteed capacity of the batteries. Any excess power used is chargeable to the contractor at a rate of 3d. per B.O.T. unit.

The initial charge and preliminary or emptying discharge are given prior to the tests so as to get the cells into a cyclic condition. The preliminary discharge is continued for 9 hours at the 9 hour discharge rate, or alternatively at the 9 hour rate until the voltage of the battery falls to $1.83 \times N$, where N is the number of cells in the battery. The test charge is then immediately given at a rate which is determined by the contractor, but must not be less than the 8 hour discharge rate. The charge is continued at this rate until not less than 70% of the total charge has been given, when the current may be reduced to a rate not less than half of what it was previously and continued until the cells are



	Nominal Capacity per Positive Plate	100 AH	150 AH	200 AH	300 AH	430 AH	Remarks
A	Internal length inside Lining	1¾" × N.P + 2½". N.P = No. of Pos Plates per Cell					See Col (d) Tables 1–5
B	Internal width inside Lining	11⅞"	16⅛"	16¼"	16⅜"	23⅛"	
C	Internal depth from lower edge of Lip to inside of lining	19 3/16"	20 11/32"	28 11/16"	40 7/16"	39 11/16"	
D	Height of Lip	½"	½"	½"	½"	½"	
E	Thickness of woodwork	1" to 1⅛"	1" to 1⅛"	1⅛" to 1⅝"	1½" to [illegible]	1⅝" to [illegible]	See Col (d) Tables 1–5
F	Width of Battens	4"	4"	4"	6"	6"	
G	Thickness of Battens	1½"	1½"	1½"	1¾"	2"	
H	Centres at which Boxes are to be mounted	16"	20"	20½"	21¼"	28"	
I	Space between Cells	1⅜" to 2"	1½" to 1¾"	1⅜" to 1⅝"	1¼" to 1⅜"	1¼" to 1½"	See Col (h) Tables 1–5
J	Space between Lugs	2¼"	2⅛"	2¾"	3¼"	3⅛"	
K	Section clearance at each side	9/16"	11/16"	⅝"	13/16"	⅞"	
L	Section clearance at back	11.75 mm	11.75 mm	12.55 mm	12.55 mm	12.55 mm	
M	Hydrometer space Approx	1¾"	1¾"	1¾"	1¾"	1¾"	
N	Mud space	4¼"	4¾"	6½"	9"	9"	
O	Depth of Plate Lug	1⅝"	1⅝"	1⅝"	2"	2"	
P	Acid level to underside suspension rib	1½"	1⅜"	2⅛"	2⅛"	2⅛"	
Q	Top of Plate to acid level	1"	1"	1"	1"	1"	
R	Depth of connecting Lug	2½"	2½"	2½"	2¾"	2¾"	
S	Depth of omnibus bar	⅜"	⅜"	⅜"	1"	1"	
T	Width of cross beam	4"	4"	4"	6"	6"	
U	Height of cross beam	4"	4"	4"	3½"	3½"	
V	Height of longitudinal beam	4"	4"	4"	3½"	3½"	
W	Width of longitudinal beam	4"	4"	4"	6"	6"	
X	Centres of Insulators Battery No. 6	—	—	10"	15"	15"	
Y	Overall height	36½" to 36[illegible]	38¼" to 38[illegible]	46½" to 46[illegible]	61⅜" to 61[illegible]	61" to 61⅜"	Depending on E
Z	Thickness of Battens	⅜"	—	⅜" to ⅝"	⅛" to ¼"	¼" to ½"	See Clause 2 (f)

FIG. 5.—STANDARD CELLS. DETAILS OF CONSTRUCTION.

charged to the contractor's satisfaction. After three hours, and before 12 hours have elapsed after the test charge, the test discharge from which the capacity of the battery is determined is commenced. The discharge is made at the 9 hour discharge rate and is continued until the voltage across the battery falls to 1.83 × N, N being the number of cells in the battery. The ampere-hour and watt-hour efficiencies are determined from the test charge and discharge. In the event of the guaranteed Amp. hour capacity being discharged before the battery voltage falls to the above limit, the amp.-hour and watt-hour efficiencies are determined from the readings taken down to the point at which the guaranteed Amp. hour capacity had been discharged.

During the tests, hourly readings are taken on each cell of specific gravity, the temperature of electrolyte and the voltage, but towards the end of the test discharge, $\frac{1}{4}$ hourly readings are required, not less than five $\frac{1}{4}$ hourly readings being necessary. All specific gravity readings are corrected for temperature to 60°F., by adding .001 to the hydrometer readings for each 3°F. by which the temperature exceeds 60°F., or by deducting .001 for each 3°F. by which the temperature is less than 60°F. The ampere-hour capacity obtained on the test discharge is also corrected for temperature, by deducting .5% of the ampere-hour output obtained on test for each degree Fahrenheit by which the temperature of the electrolyte exceeds 60°F., or by increasing the capacity by .5% for each degree Fahrenheit by which the temperature of the electrolyte is less than 60°F. The temperature on which this correction is based is the mean of the average temperature readings of the electrolyte of all the cells taken during the last 15 minutes of the test discharge.

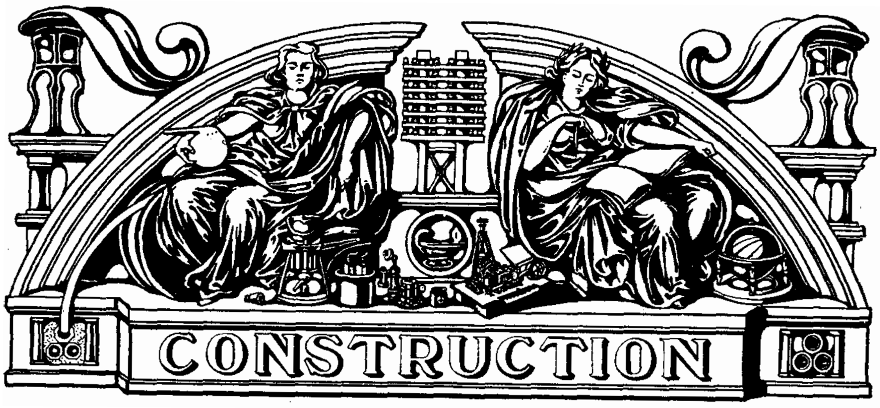
In addition to the cells themselves, instructions and apparatus for their maintenance have also been definitely standardised. The Secondary Cell Log Book, which was introduced in 1919, lays down the necessary regulations as regards day-to-day maintenance. As the maintenance is carried out on the specific gravity method, suitable hydrometers with specially long scales to facilitate accurate measurement have been designed and three types cover the whole range of cells. Hydrometers No. 9 are used with Cells, Secondary, Stationary, Nos. 1 to 8; Hydrometers No. 8 complete with a float, which enables the scale to be read about 1″ above the surface of the acid for Cells Secondary Nos. 9 to 11; and Hydrometers No. 12, which are to be used in the near future for all cells above 300 Amp. hrs. capacity.

Thermometer No. 1, a special floating type instrument, has been standardised for the determination of the temperature of the electrolyte.

A convenient instrument known as the Electrode Cadmium has been designed so as to enable Cadmium readings, which is a well-known method of isolating trouble in secondary cells, to be taken.

In conclusion, the anti-spray oil film which is used on all stationary cells in the British Post Office should be mentioned. The oil used is very pure petroleum and is standardised under the title of Oil, Insulating, No. 3. By its use, the spray of acid into the atmosphere has been prevented and the installation of batteries in the same room as the charging plant and exchange apparatus has been made possible. It has also resulted in a considerable diminution in the consumption of distilled water.

It is hoped that the foregoing, although not by any means a complete account of the standardisation of secondary cells, will serve in some small measure as an indication of the work which is being done in this growing branch of the Department's activities.



CONCRETE CONSTRUCTION.

By Lieut.-Colonel C. H. Fox, O.B.E., B.Sc. (Fellow).

[Extracted from a Paper read before the Yorkshire Branch of The Surveyors' Institution at Leeds on the 24th March, 1927, and reprinted from the Journal of the Surveyors' Institution with the permission of the Council.]

SUPERIORITY OVER OTHER MATERIALS.—No doubt the following are some of the reasons for the rapidly increasing adoption of this material in place of older established building materials. It is strong, impermeable to moisture, resists fire well, and does not harbour vermin. It does not deteriorate with age, but actually grows stronger as has been proved by tests over many years, and therefore costs very little in upkeep. It will thus be seen to have many advantages over other building materials. It has greater strength than stone, bricks, or timber, and these, together with steel, all deteriorate with age and require a varying amount expending on upkeep. Steel rusts and needs constant applications of paint or other preservative. Timber and steel do not resist fire, the former burns while the latter expands, twists and buckles. Stone also splinters and cracks under extreme heat.

Reinforced concrete is a scientifically designed material utilising the best properties of the component parts. Concrete is relatively cheap, strong in compression, resists absorption of water, and is one of the best preservatives of steel. Steel is relatively dear, needs protection from the atmosphere, but is very strong in tension; so in reinforced concrete just sufficient steel is provided to take up the tensile and shear stresses in the combined member, and this is placed in the correct position for this purpose. The concrete supplies the main bulk, protects the steel, and resists the compressive stresses. Stone and timber are both relatively wasteful as structural members, for they are both stronger in compression than tension, and so have to be used in larger sections on account of this tensile weakness than would be the case if they were used like concrete to resist the type of stress they are best fitted for.

Freedom in Design.—Stone, bricks and timber all cramp design as there is obviously a limit to the size in which these can be obtained, and to the parts they can play in a structure, although these limiting conditions have led in the past to great ingenuity in design. Concrete, however, has no such restrictions, and almost any kind or style of building can be designed.

Materials easily available.—Another consideration in favour of concrete is that the main bulk of the materials of which it is formed, namely, stone and sand, can be found in practically all parts of the country, and only the cement (and in the case of reinforced work the steel) needs transporting from a distance, thus heavy transport expense is avoided and materials on the spot can be utilised. The stone needed is of such a small size that quarry waste and material that could only otherwise be used for filling can be utilised. In many parts of the country great tips of stone for which no use could be found are now being broken and crushed and sold as aggregate for concrete. Stone for masonry needs skilled workmen both to get and work it, and to fix it in position, Concrete can be largely made with semi-skilled labour under the supervision of a few skilled men.

Plasticity.—Stone is very expensive if worked to any but the simplest shapes, and the labour has to be repeated on each piece however many there may be alike. Concrete can be moulded or cast to any shape, and once a mould is made it can be used several times, thus reducing the cost. In this way artificial stone (or concrete) competes very well with stone if there is any quantity of repetition work. This is the real test of economy in concrete.

Generally.—Concrete is composed of a mixture of certain substances such as broken stone or brick, sand, and cement. The broken stone is usually known as the aggregate, and this forms the bulk of the concrete, while the sand and cement fills the voids between the particles and set and bind the whole mass together.

Voids, &c.—To obtain a concrete strong and impermeable it is necessary that the proportions of the aggregate sand and cement should be so arranged that all the voids in the coarser material are completely filled by the finer stuff. An ideal aggregate is one which contains all sizes of particles from the largest to the lowest limits so that the particles may pack well together leaving the minimum amount of voids. The sand again should vary in size so that this may fill all the voids in the aggregate. The cement then has to fill any voids in the sand and coat over the whole mass. Economy in concrete construction is obtained by making the concrete as strong as possible at the least expense, which usually means using the minimum amount of cement to form a dense compact mass. When once all the voids are filled and the cement is adhering to all the sand and aggregate, the maximum strength is obtained for the materials used. The addition of more cement will increase the strength but also the cost.

In plain mass concrete in its simplest form the percentage costs are as follows for a good average mix:—

Aggregate ...	...	25 to 30 per cent
Sand ...	...	20 to 15 ,,
Cement ...	...	40 per cent.
Labour ...	...	15 ,,

It will be seen that the cement accounts for over one-third of the cost.

A correctly graded aggregate can effect a saving of 10 per cent. over the cost of a badly graded one, so this point is most important.

Cleanliness.—All the substances used in concrete, *i.e.*, aggregate sand and water, must be clean and free from impurities such as sulphur, loam, earthly and vegetable matter, and if not in that state the aggregate and sand must be washed before use. Salt is an impurity cement and causes efflorescence and permanent to be avoided, as it retards the setting of dampness in the finished concrete.

Aggregate.—The aggregate must consist of some clean, hard, sharp and preferably angular material such as coke breeze, shingle, broken stone or brick, or crushed granite, and as to which is selected depends on what the concrete is required for, and which aggregate is most easily available. In making this selection for any particular work, regard must be paid to the grading of the material in addition to its toughness, hardness, and cost.

(A) *Coke Breeze.*—The advantages of coke breeze are that it is cheap, and forms a concrete light in weight and fairly fire-resisting; but against these must be set the disadvantages that it is porous, and has very little strength in compression. It is therefore no use for reinforced concrete, as its porosity allows damp to penetrate to the steel reinforcement, and so sets up corrosion. Other similar but inferior substances are confused with coke breeze, such as pan breeze, ashes and clinker, and these must be avoided, as they usually contain dust, unburnt or partially burnt coal and coke, and dangerous elements such as sulphur, which set up expansion in the concrete during setting.

Coke breeze is mainly used for such purposes as partitions, or inside linings to hollow walls or blocks, or for filling between steel joists in floors, or any position where lightness is essential and the porosity is an advantage rather than a disadvantage. Nails can be easily driven into coke breeze concrete and obtain a firm grip.

(B) *Shingle.*—Shingle obtained from river beds or pits, or even the seashore if efflorescence is of no importance, form a concrete of great strength. River or sea shingles are usually free from loam or clay, whereas that from pits is usually coated with these. If loam or clay are present, the particles of these prevent the cement adhering to the aggregate, and so interfere with the binding together of the mass, and reduce the compressive strength. Thus pit sand must be well washed before use. An angular aggregate usually makes a stronger concrete than a smooth one, so crushed shingle is to be preferred to smooth water-worn stones. Similarly when used in fire-resisting construction shingle should be crushed so as not to exceed $\frac{3}{4}$ inch, as it is apt to splinter at a high temperature when exposed to fire unless broken to a small size.

(C) *Limestone and Sandstone.* — Broken stones, such as limestone, sandstones and various crystalline rocks that occur geologically between the former and the igneous rocks like granite, are used for aggregate. Hard limestones, such as Portland stone, form a very strong concrete, but are apt to be disintegrated when exposed to fire. Sandstones, such as our local stones, form a good aggregate for concrete, subject to the same limitations as limestones, but must be carefully graded and washed. Angular, sharp and roughly square pieces should be used in preference to long thin or flaky ones.

(D) *Granite.*—Granite forms a strong hard-wearing concrete, and is much used for floor finishes, but it does not behave too well when exposed to fire.

(E) *Broken Brick.*—Broken brick forms one of the best concretes where resistance to fire is required. As old bricks are usually used for this purpose, they must be well cleaned of all dust, mortar, paper, &c. Some bricks contain some sulphur and unslaked lime, which cause expansion and cracking of the concrete. Fletton bricks should be avoided, as these have been proved to be responsible for unsound concrete.

Sand.—The sand, like the aggregate, must also consist of some clean hard and sharp material well graded in size in order that it may completely fill all the voids between the aggregate. Sand is frequently obtained from the process of crushing the aggregate from large blocks of stone, and all the small stuff that will pass a 3/16 in. mesh is usually classed as sand. The bulk of the sand grains should be between 1/16 in. and $\frac{1}{8}$ in. in size with a small proportion of larger and smaller stuff. Sand is also frequently found in natural deposits. The sand should always be graded and measured separately to the aggregate, as otherwise there is no guarantee that they are in the correct proportions, and probably different batches of concrete will vary considerably in composition. If sufficient sand be used to fill up the voids between the aggregate, and just enough cement added to fill up the interstices in the sand, a much smaller amount of cement is needed than if the sand be omitted, and a stronger and more impervious concrete is obtained. Old mortar reground should never be used as sand for concrete, as it may contain impurities and even a small amount of unslaked lime which will blow and cause expansion and cracking. Old bricks ground up for sand are similarly unreliable, due to the risk of having old mortar still adhering to them.

Portland Cement.—In the early part of the 19th century a great demand arose for a reliable hydraulic cement due to the amount of engineering work in hand then. Several people in this country experimented to make an artificial mixture of limestone and clay, and the person usually credited with the invention of Portland cement just over 100 years ago is Joseph Aspden of Leeds.

Chemical Composition. The chemical composition of Portland cement may vary between narrow limits due to the nature of the raw materials used, but the following ranges cover all cases: Lime, 60 to 67 per cent.; silica, 19 to 27 per cent.; alumina and ferricoxide, 7 to 14 per cent.; and average figures would be lime, 65 per cent.; silica, $21\frac{1}{2}$ per cent.; alumina and ferricoxide, $9\frac{1}{2}$ per cent.; water, impurities, insoluble matter, &c., 4 per cent.

The writer has said nothing about the manufacture of Portland cement, but wishes to emphasise that it is a very scientifically manufactured material, and nowadays is so carefully watched and frequently tested at all stages of its manufacture by highly skilled chemists that the resulting product is of the highest uniform quality. In the last few years other cements than Portland have been put on the market for special purposes, such as white cement, rapid-hardening Portland cement, and aluminous cements.

White Cement.—White cement differs from Portland cement mainly in the fact that the ferric-oxide has been removed, thus eliminating the characteristics grey colour of Portland cement. This, unfortunately, is an expensive process, and at present is not done in this country, so "white" cement has to be imported. This material is used for surface work, as in artificial stone, rough-cast, &c., as it enables any colour of finish to be obtained by the addition of appropriate colouring matter. Portland cement can be coloured, but the result is much deader than when " white " cement is used. With white cement any natural stone colour can be obtained.

Rapid-hardening Portland Cement.—Rapid-hardening Portland cement is a true Portland cement of practically the same analysis, but it is ground very much finer, and this process adds slightly to the cost, say about 15 per cent. The only difference in the chemical analysis is a slight decrease in the silica content and a corresponding increase in the alumina, and a typical analysis of a rapid-hardening Portland cement would be: Lime, 65 per cent.; silica, 20 per cent.; alumina and ferric-oxide, 11 per cent.; water impurities and insoluble matter, 4 per cent. In a Portland cement the aluminates of calcium (*i.e.,* alumina and lime compounds) produce the early hardening, while the silicates of calcium (*i.e.,* silica and lime compounds) produce the steadily increasing strength. It can thus be seen why rapid-hardening Portland cement, with its slightly greater alumina contents, hardens more rapidly.

Aluminous Cement.—Aluminous cement, as its name indicates, goes much further in making use of this property. It is not a Portland cement at all, but is made from limestone and bauxite, an aluminous mineral. The chemical proportions are altogether different to Portland cement. The lime is now about 39 per cent. instead of 65 per cent., silica 8 per cent. instead of 21½ per cent., alumina and ferric-oxide 51 per cent. instead of 9½ per cent., and remaining items 2 per cent. instead of 4 per cent. Aluminous cement, as may be expected from a consideration of its composition, hardens very rapidly, more so than rapid-hardening Portland cement, but does not increase in strength so quickly afterwards. Aluminous cement is relatively expensive, almost twice the cost of Portland cement, because very little bauxite is obtained in England, and this has to be imported, mainly from France. The name adopted almost universally in England for rapid-hardening Portland cement is " Ferrocrete," whilst the best known aluminous cement is " Ciment Fondu," the name given to it in France, whilst the best known English brand is " Lightning " brand.

Advantages of Rapid-hardening Cements.—These newer cements therefore overcome what has been one of the principal disadvantages of Portland cement concrete, namely, the long period of waiting for the concrete to set sufficiently hard, and the consequent tieing up of expensive formwork and scaffolding. These newer cements effect a considerable saving of time and money in freeing the formwork much more quickly, so that it can be taken down, re-erected and used again more frequently. Where Portland cement concrete takes 28 days to mature before full loads can be applied, Ferrocrete takes only three days and aluminous cement one day. In addition Ferrocrete or aluminous cements give a permanent strength at least 50 per cent. higher than Portland cement. It is possible, therefore, to use less of these cements to obtain an equal strength without losing any of the rapid-hardening properties. Without doubt Ferrocrete will displace Portland cement more and more for almost all work, but aluminous cement is hardly likely to be used except for special cases on account of the extra expense. There is one point against the latter cement, and that is that it must be kept entirely apart from Portland cement and never used along with it, as Portland cement dilutes the former and removes from it all its rapid-

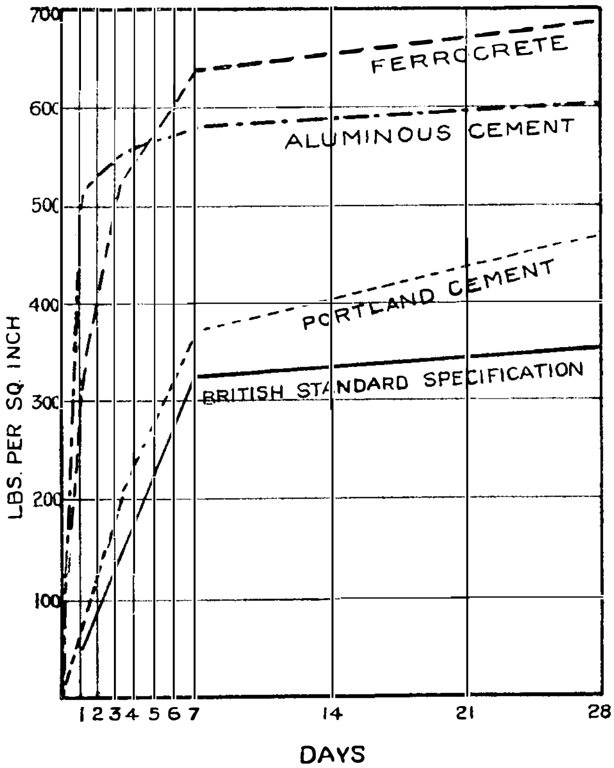


FIG. 1.—TENSILE TESTS. CEMENT AND SAND 1 TO 3.

hardening qualities. On the other hand, Ferrocrete is not affected by Portland cement, in fact, it is merely Portland cement of superior make. Aluminous cement is darker in colour and makes a darker concrete. Figs. **1** and **2** show the strength comparisons of the three cements with sand (tensile), and 1-2-4 concrete in comparison with Portland and Ferrocrete.

There is a further point in favour of both Ferrocrete and aluminous cements, and that is that concrete made of these is much less affected by frost: (1) The concrete hardens so quickly that frost cannot affect its initial set; (2) the setting of these cements is accompanied by a rise of temperature which resists the frost. These cements resist the action of sea-water and acids.

Size of Aggregate.—Having considered the types of aggregate sand and cement which, together with clean water, constitutes the components of concrete, the next thing to consider is the size of the aggregate and the relative proportions of the aggregate sand and cement for the concrete required. In ordinary mass concrete for foundations, stones up to 3 inches diameter can be used; but for walls, floors, columns and reinforced work generally, nothing exceeding $\frac{3}{4}$ inch should be used.

Proportions to eliminate Voids. — It is desirable to test the voids in the aggregate and sand it is decided to use before settling the relative proportions. A simple way of doing this is to take the watertight vessel of known capacity and fill it flush to the surface with the selected aggregate, and then fill up with water. The water added represents the volume of sand required to fill the voids in the aggregate. The sand can be tested in a similar way; but it should be noted that both the aggregate and sand should be well wetted before the test is made, or some of the water will be absorbed. In practice the average percentage of voids in the aggregate is found to be about 40 per cent., and about 10 per cent. excess sand is usually added, making 50 per cent. in all. Similary the voids in the sand are found to be 40 per cent. in average cases, and adding 10 per cent. excess cement we again get 50 per cent. Thus the well-known proportion of

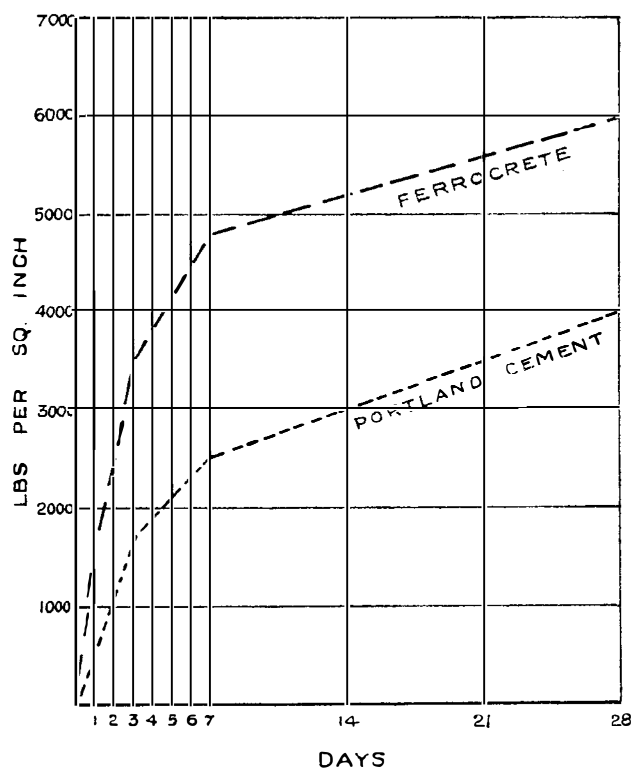


FIG. 2.—COMPRESSION TESTS. CONCRETE 1-2-4.

4-2-1 is arrived at, *i.e.*, 4 parts (by volume) aggregate and 2 parts sand to 1 part cement, and this in average cases gives a good compact concrete. However, if the aggregate contains a greater percentage of voids, it is necessary to add more sand and cement to obtain a compact concrete. A perfectly graded concrete may easily be stronger at 6-3-1 than a badly graded one made. 4-2-1. Thus it pays to test the voids. It should be pointed out that 4 parts of aggregate, 2 of sand and 1 of cement, do not give 7 parts of concrete, but only about 15 per cent. to 20 per cent. greater bulk than the aggregate alone, as the sand and cement are practically lost in filling voids.

Water.—One of the most important points affecting the final strength of the concrete is that of the correct amount of water used in the mix. The golden rule is to use as little water as possible consistent with providing sufficient to wet all the cement, and permit it to be thoroughly mixed with the other materials. The result of too much water is to slow the setting action and reduce the ultimate strength, besides giving rise to other troubles. The excess water ultimately evaporates and is replaced by air, thus forcing air voids. Too much water helps to cause contraction cracks. Sufficient water, however, must be provided to give perfect hydration of all the cement, and to permit the concrete to be placed into its position in the formwork. Thus the more elaborate the formwork and the more complicated the steel reinforcement the wetter must be the mix, and the wetter the mix the more rodding and tamping will the concrete require to consolidate it and force out all air bubbles, &c. Fig. **3** shows the loss of strength due to excess water.

Mixing. — Mixing, then, must be very thorough, and can be done either by machinery or by hand. If the former, a batch and not a continuous mixer should be used. The materials are measured by volume, placed in the mixer, which rotates, and the correct amount of water added. These machines give very uniform results, but the cost is justified only when there is a large amount of concreting to be done. The common method for small jobs is hand-mixing. In this the materials are measured on a mixing board or impervious surface, such as flags or concrete—never on the natural ground. The materials must be well mixed in a dry state by turning over the heap twice, then add water through a rose, and turn over the mass at least twice in a wet state until the concrete has assumed a uniform grey colour. The concrete should be mixed as close as possible to its final position and laid at once. It must be in position before any setting takes place, *i.e.*, within thirty minutes of the water being added.

Slump Test.—A modern and quite useful test for ensuring uniformity of mix is known as the slump test, and this is worth describing in detail, as this matter is much too important to be left to the personal whims of either the

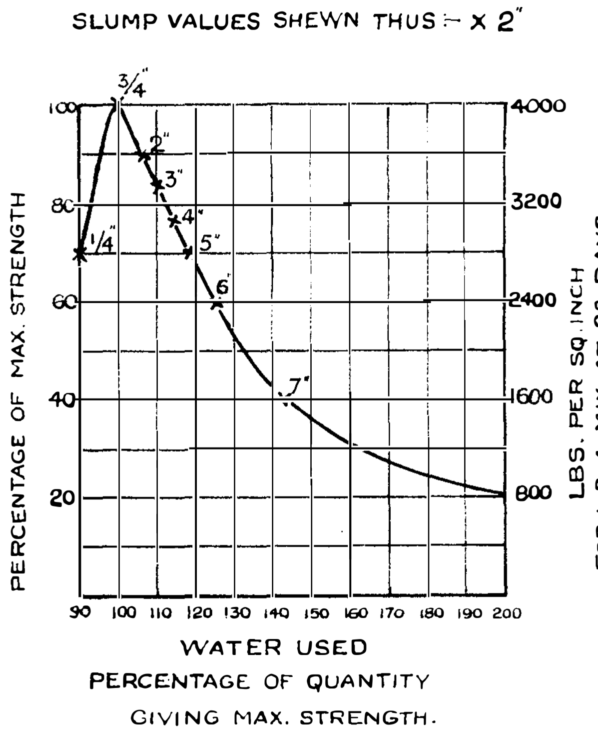


FIG. 3.—RELATION BETWEEN STRENGTH OF CONCRETE AND WATER CONTENT.

foreman or men mixing the concrete. When a person designs any building he assumes the materials will have a certain strength, and on that assumption provides a certain cross-section for each member. In the case of steel, timber, &c., he can rely more or less on certain strengths, but in the case of concrete he is at the mercy of those who make it on the job, and herein lies the chief difference between concrete and other materials. The apparatus required for the slump test is very simple, and consists of a sheet-metal truncated cone with open ends, 12 inches high, tapering from 8 inches diameter at the base to 4 inches diameter at the top, and fitted with two handles at the sides. To make the test, concrete is taken from any mix on the board and filled into the metal box 4 inches at a time, and rammed at each stage twenty-five times with a rod $\frac{1}{4}$ inch in diameter. After the box is filled the top surface is struck off level and the box lifted carefully away from the board. The concrete that was enclosed then settles down to an extent depending on its wetness. The wetter the mix the further it slumps (*i.e.,* settles down). The amount the concrete has settled is measured, and this is called the slump. A dry mix will only settle $\frac{1}{2}$ inch to 1 inch, but a sloppy mix may settle as much as 10 inches. For mass concrete, or in sections easy to lay, a slump of 2 inches should be adopted. In more complicated work and thin vertical sections as great a slump as 6 inches may be required, but 3 inches or 4 inches is a good average. In any case the designer can settle what slump he intends to work to, and this test enables the workmen to check the mix at frequent intervals, preferably with each batch. If one batch is too wet the next can have less water, and so on.

Depositing in Position. — Concrete when mixed must be carefully placed in position, not tipped from a height, as this causes the cement and aggregate to become separated. It must be well tamped or rammed to consolidate it, and worked well into position and round any reinforcement.

Fire Resistance.—From the point of view of fire resistance concrete is an excellent material, provided a suitable aggregate is used and a sufficient thickness of cover provided to all embedded steel. Concrete of which the aggregate is coke breeze or broken brick resists fire best; limestone is not good, sandstone and gravel are a little better, but the gravel should be crushed; granite does not act well and is apt to splinter. A small aggregate is better than a large one for fire resistance..

Reinforcement. — The general principles of reinforced concrete, *i.e.,* the reason for embedding steel in concrete have been stated earlier. The principal material used for reinforcement is mild steel in plain round rods. This is steel with an ultimate strength of, say 28 to 32 tons per square inch. Other steels of higher tensile strengths such as medium carbon steel, cold twisted steel, and drawn steel wire, are also used, and are usually calcuated to resist stresses about 25 to 50 per cent. higher than mild steel. Drawn-steel wire is usually used in the form of a built-up fabric such as B.R.C., &c. Before it is used in concrete the metal must be clean and free from scale or loose rust, and must not be tarred, oiled, or painted, as oil or paint, &c., reduce the adhesion between steel and concrete.

The greatest care must be exercised to see that all reinforcement is placed exactly in the position indicated by the designer, and that it is not disturbed during concreting. If it is not in the form of built-up fabric it must all be tied together and carefully checked before concreting is commenced.

Description of Various Uses.

Some of the uses to which concrete is put will be briefly described with suggestions as to the best average proportions of the materials and the most suitable consistency under the slump test. Only average proportions are suggested as each aggregate should be tested to find the best grading, but for some uses a richer cement content is needed than for others. Similarly the values for slump are governed by the main rule that for strength the mix should be as dry as possible; but the rule has to be waived sufficiently to obtain a mix wet enough to flow into its position. Thus plain mass work can be very dry, but thin confined sections must be wettest.

In building work one of the first uses of concrete is in the construction of *foundations* and *walls.* Every wall should rest on a foundation of greater width than itself in order to spread the weight over as great an area as is required by the carrying power of the earth. The greater the weight the wider must be the foundations. In simple cases on good ground a plain mass foundation about 12 inches wider than the wall is sufficient, but if the ground is so weak as to need a much greater spread, the advantage of concrete is that the foundation can be increased and reinforced to stand the bending stress on the projections. In brickwork or masonry this would necessitate gradually spreading footings on top of the foundation. With a concrete foundation the wall can rest directly on it, thus economising in walling. If the ground is very weak, sometimes the best solution is to build the bottom floor as a *reinforced concrete raft,* so distributing the weight over the whole site. In other cases *piles* driven well into the ground can be used and the building erected on these. Slump for plain foundations, 2 inches; reinforced, 3 inches; proportions of aggregate sand and cement 6-3-1, or 8-4-1 if plain, but 4-2-1 if reinforced.

Walls.—Concrete walls can be used for buildings and for enclosing ground. Solid walls are usually adopted for boundary or retaining walls, dams, &c., whereas hollow walls are more usually adopted in buildings on account of the greater resistance of hollow walls to weather and temperature changes. Concrete walls are stronger than brick walls of the same thickness. Concrete walls can be built of pre-cast blocks walled like brickwork or be cast *in situ.* Much ingenuity—some of it wasted—has been devoted to the design of concrete blocks, especially in connection with housing, but the principal aims have been to provide a block with the following properties: (1) The block to be hollow with as large a cavity as possible, to save material and weight in handling; (2) the outer face to be impervious to the penetration of wet, and the inner face to be sufficiently porous to absorb condensation like plaster. Inner face often of coke breeze, into which nails can be driven; the outer face is often moulded to represent stone. There are numerous machines for block-making.

For *dam walls* concrete is almost invariably in mass form similar to masonry, though sometimes it is used as a core and faced with stone.

For walls to *retain earth,* however, it is more economical to use thin reinforced sections with a broad base or foundation projecting back under the earth. The earth resisting on this then helps to prevent the wall being pushed outwards and overturning. Counterforts at intervals connect the base to the front wall. This construction is only possible in concrete.

Slump for blocks, 1 inch to 2 inches; mass walls, 2 inches thin reinforced walls, 6 inches. Proportions, 6-3-1 for mass walls, 4-2-1 for reinforced work or blocks. Boundary walls can be left with surface rough to enable creepers, &c., to cling to them, and so improve the appearance. Corrugated iron as centering will give a flutted appearance to relieve the monotony of long unbroken surfaces.

Floors.—These can be laid either on the solid ground or suspended like wooden floors, and the suspended floors can be solid or hollow. In all suspended floors reinforcement must be used and so disposed as to take up the tenstile stresses. Roughly it may be stated that reinforcement must be placed at the bottom of all beams and slabs except over supports, where it must be on the top. In beams steel must be provided to resist shear stresses, but this is not necessary in slabs. Even floors on the solid are better reinforced, preferably with a light built-up fabric reinforcement, and this need not increase the cost. A 4-inch floor reinforced with a light fabric is as cheap as a 6-inch plain floor, and much less likely to crack.

Suspended floors in this country are usually of the beam and slab type, but in America the flat slab, or mushroom type, is more generally used. The reinforcement of this is much more complicated, but the resulting flat ceiling is of great benefit as regards lighting and resistance to fire. Hollow floors can be of many types, principally consisting of reinforced beams at close intervals, supporting hollow blocks of tile or concrete. Slump, 2 inches to 3 inches in slabs, 3 inches to 4 inches in beams. Proportions, 4-2-1 or 3-1½-1.

Flat Roofs.—Flat roofs formed similarly to floors, and usually water-proofed with rock asphalt or something similar. In factories the flat roof is sometimes used as a water tank.

Pitched Roofs.—The whole of the roof can be of concrete. Trusses, purlins, &c., can either be pre-cast and hoisted to position or cast *in situ.* The roof slabbing can be cast *in situ,* but pitches steeper than 25 degrees entail double shuttering, *i.e.*, top as well as bottom, to prevent the concrete slipping, and then cease to be economical. Roofing slabs or tiles, however, can be pre-cast at a very economical figure. Ceilings can be flat or curved. Slump for trusses, &c., 5 inches or 6 inches; slabs, 2 inches or 3 inches. Proportions, 4-2-1 or 3-1½-1. Tiles, &c., 3 sand to 1 cement.

Stairs.—Stairs can be made of concrete, either pre-cast or *in situ,* and reinforced. These are usually provided with non-slip treads. Slump, 3 inches. Proportions, 4-2-1.

Roads, Paths, and Pavings.—These can be constructed entirely of concrete. In the case of roads in towns concrete is frequently used for the foundation even where the actual surface is composed of other materials such as setts, asphalt, tarred macadam, wood blocks, &c., but there is no reason why the surface itself should not be of concrete. In America thousands of miles of concrete roads are in use. The following are the requirements of a good road: (1) It must be hard, firm and have a long life; (2) it must offer low resistance to wheel traffic; (3) it must be dustless and easy to clean; (4) the surface must be even but not slippery; (5) it must not be affected by climatic conditions; (6) the first cost must be reasonable and the maintenance low. Concrete most nearly satisfies these conditions. The usual construction is (1) a layer of balder or broken stone; (2) 8 inches to 12 inches of concrete plain or reinforced according to the nature of the ground. The road should be laid in short sections with elastic joints in order to avoid cracks that would occur if laid in long continuous lengths. 4-2-1 is a suitable proportion, and 2-inch slump is wet enough. Paths and pavings are built similarly, but with less depth of concrete, say 3 inches or 4 inches. A finishing coat of 1-3 Portland cement and sand, 1 inch thick laid on top before the first coat has set. This is important, as, if the foundation is allowed to set before the top coat is applied, there may be a poor bond between the two. When laid the surface must be protected from the sun or wind and left damp for some days to assist hardening. Very little camber is needed. Concrete curbs and channels can be used in substitution for stone on any kind of road.

Farm and Estate Work.—Farm and estate work offer and provide many opportunities for the use of concrete. Apart from the floors, walls, and roofs of buildings, and road, &c., already dealt with, concrete can be used with advantage for the following: Water tanks and cisterns, water troughs, feeding mangers, stall divisions, piggeries, fencing posts, and many other things. One reason for the wider adoption of the material is that much of it can be done without specially skilled labour; thus any surplus labour on the farm can be employed to make concrete blocks, fencing posts, &c.

Sewers, Water Mains, &c.—These can be made of concrete, and can either be laid *in situ* or pre-cast. Many firms specialise in making concrete pipes of all sizes, both round and egg-shaped. Up to 18 inches diameter, no doubt, concrete drains are more expensive than earthenware, but are stronger. They can be laid with unbroken joints inside. Mix needs to be fairly rich, and slump 6 inches or 7 inches.

Reservoirs, Water Tanks, &c.—Concrete is useful for the storage of water in reservoirs and swimming baths, and also in elevated tanks. Floors and walls can be quite thin, but need reinforcing. Fine materials, such as 1, 2 or 3 Portland cement and sand or fine gravel graded to form a dense concrete. Concrete can be made waterproof or lined with asphalt, &c.

Silos and Coal Bunkers. — Silos and coal bunkers, for storage of grain and coal, &c., are made of concrete. Same rules as for elevated water tanks.

Chimneys.—Same rules as for elevated water tanks.

Bridges.—Arched, solid, or latticed girder have been made up to 300 feet or 400-feet spans, although the latter are somewhat rare. The upkeep expense is practically nil.

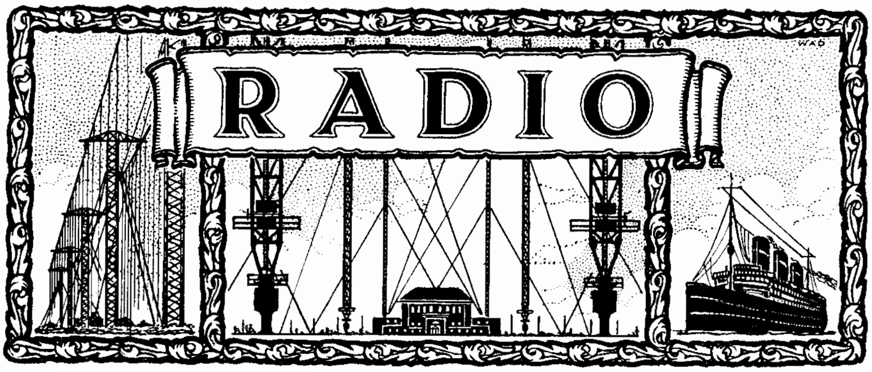
Harbour Work.—Wharves, piers, breakwaters, sea walls, floating docks, ships, &c. (latter up to 7,000 or 8,000 tons).

Railways.—For fencing posts, telegraph and signal posts sleepers, and even for bodies of trucks abroad.

Mines.—Used for sealing shafts, &c., and other uses.

Conclusion.

In conclusion, it is hoped the Paper may have proved of some interest by indicating the value of concrete as a building material for surveyors, as well as architects and engineers. It is equally suitable for use in small jobs as in large engineering works, and its possibilities have not yet been fully explored.



PORTISHEAD RADIO STATION.

THE completion of the new Portishead Radio Station in February, 1928, marked the passing of the first Post Office Radio Station equipped with a continuous wave transmitter, namely, at Devizes.

The Devizes Radio Station, which was originally intended as a receiving station in the England-Egypt link of the Imperial Chain (the masts only had been erected when the scheme was dropped) was equipped in 1919 with a Marconi 6 K.W. continuous wave valve transmitter for long distance ship and shore traffic mainly in the Atlantic. The plant comprising engines, batteries, transmitter and receiver were housed in existing Army huts.

In 1924 the Burnham Receiving Station was completed and in 1925 a second transmitter was installed at Devizes. Burnham then became the

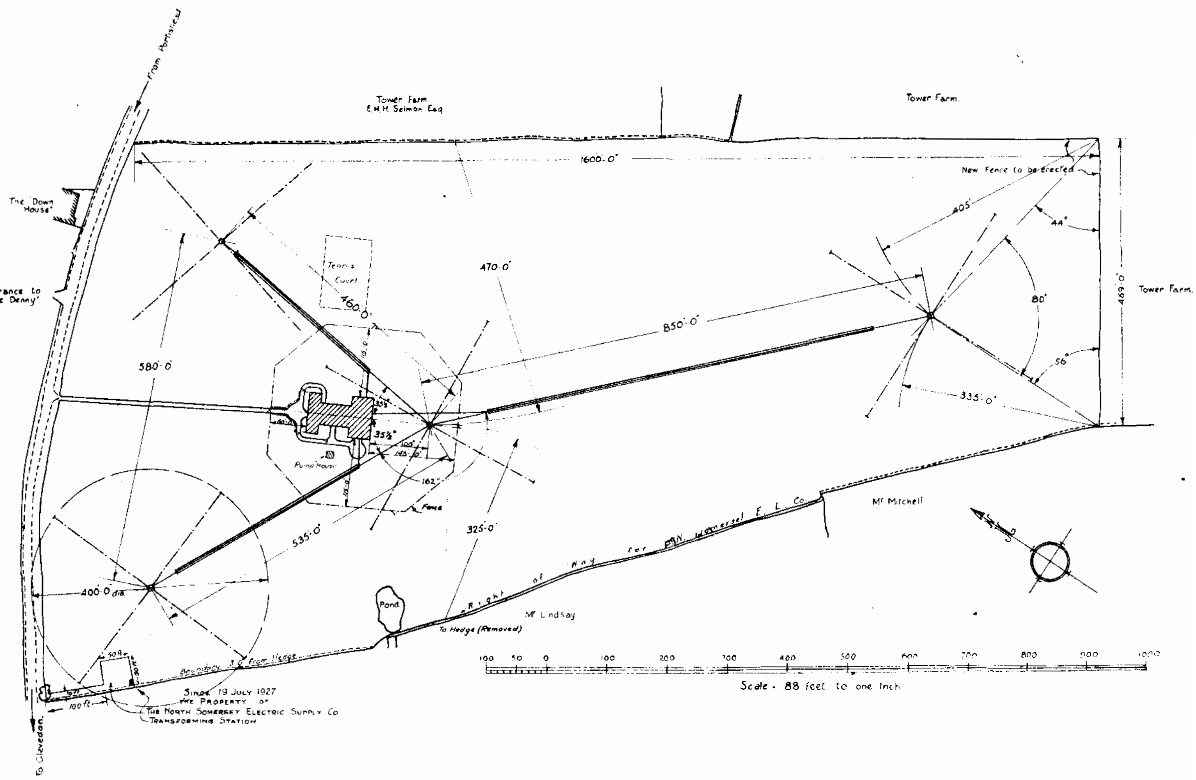


FIG. 1.—PORTISHEAD RADIO STATION. SITE PLAN.

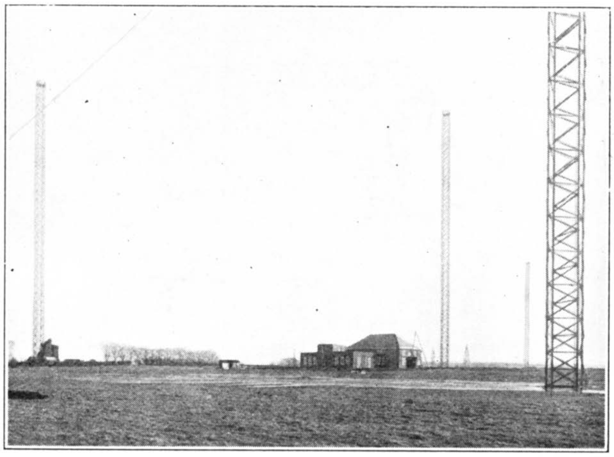


Fig. 2.—Aerial System.

receiving station and Devizes the transmitting station, control of the latter being carried out from Burnham. In 1926 the erection of a new transmitting station at Portishead near Bristol was authorised. As far as possible the design and installation of the plant was carried out by Post Office Engineers. The masts, power plant and transmitting plant were supplied by various contractors to P.O. design or specification, whilst the aerial and earth systems and all internal wireless plant were designed and installed by P.O. staff.

The plant at the new station consists of three tuning fork controlled transmitters fitted with coupled circuits, one taking 25 K.W. input (to the main transformer) and the other two, 6 K.W. input as compared with two 6 K.W. sets at Devizes. The sets were designed to give daylight ranges over sea of 1500-2000 miles, with increased ranges at night, but in practice these ranges are frequently exceeded and a regular schedule of working is maintained at night with ships just leaving New York harbour.

Site.—Burnham Radio Station, the receiving station for C.W. ship and shore traffic, is situated twenty-five miles south west of Bristol and it was desirable therefore that the transmitting station replacing Devizes should be located near Bristol, but not less than 20 miles from Burnham. Portishead fulfils these conditions and since it overlooks the Bristol Channel it is ideally situated for its purpose.

The station which is located one mile from Portishead and about nine miles from Bristol on a main road and telegraph route from Portishead to Clevedon, Weston-super-Mare and Burnham, stands on a stretch of down land 360 feet above sea level.

Masts, Aerials, etc.—A site plan is shown in Fig. 1 indicating the lay-out of the masts, buildings, etc. The design of three aerial systems in close proximity and excited on frequencies only a few kilocycles removed from each other necessitated a careful lay-out of masts and aerial systems in order to avoid interference and a reduction in efficiency. This has been done by, firstly, removing the 25 K.W. aerial as far as possible from the two 6 K.W. aerials and by disposing the last two approximately at right angles, and, secondly, by keeping each lead down as far apart as possible, the connections from the lead down to the building being disposed so as to reduce the coupling between them as far as possible.

The three aerial systems are supported from four 300′ masts of semi self-supporting type equipped with only one set of stays. They are of lattice steel construction, the cross section

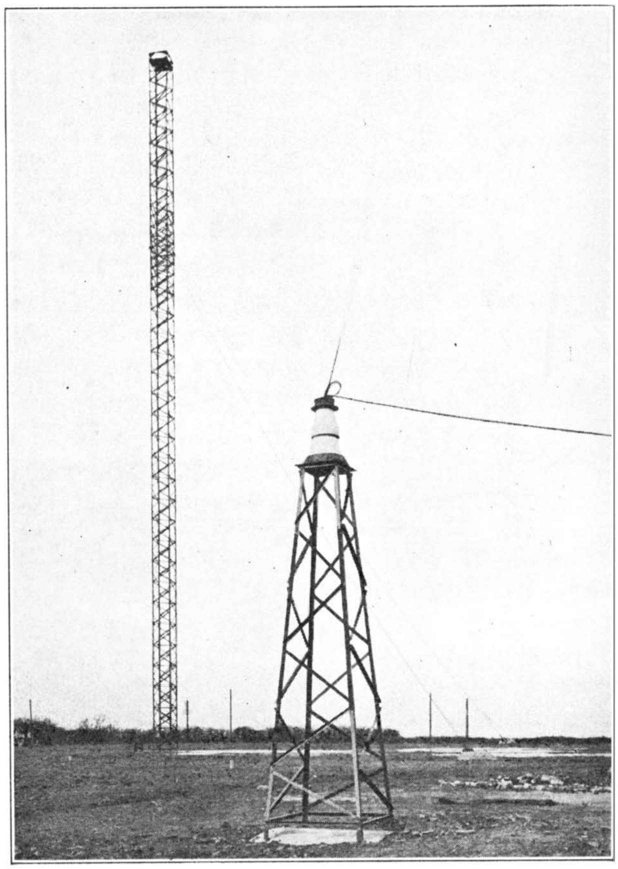


Fig. 3.—Aerial System.

being eight feet square, and are designed for a horizontal pull of four tons. They were manufactured by the Horsley Bridge Engineering Co., Ltd., and were erected on site by Messrs. C. F. Elwell. A good idea of the lay-out and construction is given in Figs. **2** and **3**.

Each aerial system is of sausage type and consists of six 7/14 silicon bronze wires on 6 ft. hexagonal spreaders. The spreaders are carried on a steel cable which takes the main strain on the aerial. The wires are bunched round 4″ diam. rings for the lead down, in order to reduce inductance variations and to reduce coupling between the three systems. The lead downs are anchored to short lead in towers and from these towers they are led into the transmitting building.

The earth system is common to all three transmitters and consists of wires buried over practically the full area of the site.

Power Supply.—Power supply is obtained from the North Somerset Power Supply Company at 400 volts 3 phase 50 cycles per second and is brought on to the main switchboard (installed by Messrs. Drake and Gorham Limited) shown in Fig. **4**, from which it is distributed to the transmitters and auxiliary machines. The main and filament transformers of each transmitter are fed direct from this supply and thus rotating machines are needed for auxiliary supplies only. To eliminate delays in starting and stopping the transmitters these auxiliaries are kept running continuously, and in order to maintain continuity of supply they are supplied in duplicate.

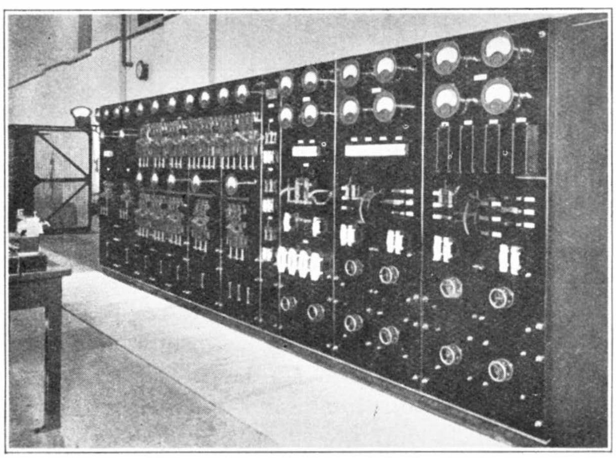


Fig. **4**.—Power Switchboard.

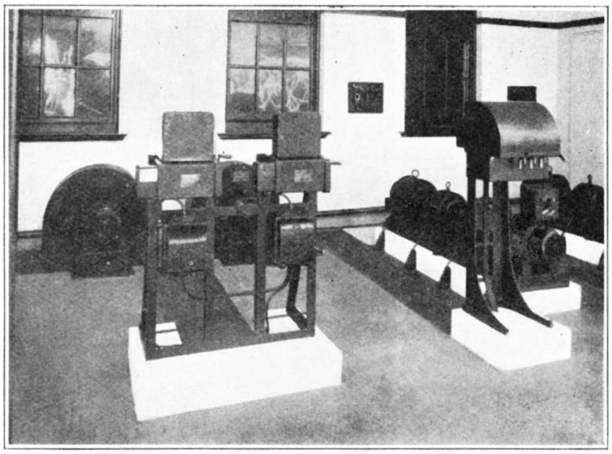


Fig. **5**.—Auxiliary Machines.

These auxiliaries consist of:—

(1) Motor-generator sets for the supplies to the Tuning-Fork Control Units, all four units being fed from one set. Each set consists of an induction motor and three D.C. generators, giving 6-10 volts for filament supply, 1200 volts for anode supply and 400 volts for grid bias on the main stages.

(2) A 3 H.P. Blower provides air blast for the silica valves of all three transmitters.

The small amount of running machinery is clearly brought out in Fig. **5**, which shows the auxiliary machine room.

Transmitting Plant.—The transmitting plant consists of three tuning-fork controlled transmitters, fitted with coupled circuits and capable of being adjusted to operate on frequencies between 100 and 150 kilocycles. The working frequencies are actually 121, 143 and 149 k.c. for the 25 K.W. and 6 K.W. sets respectively. Thus it will be seen that the frequency difference between the 6 K.W. sets is only 6 kilocycles or 4% of the actual frequency. Such a small difference in frequency necessitates a very careful design both of the transmitting plant and aerial systems, in order to avoid interference between the transmitters by either forced excitation or shock excitation due to keying. The experience gained on multiple station working at Northolt and Devizes enabled this to be accomplished satisfactorily with very little reduction in efficiency.

The general lay-out of the transmitting room

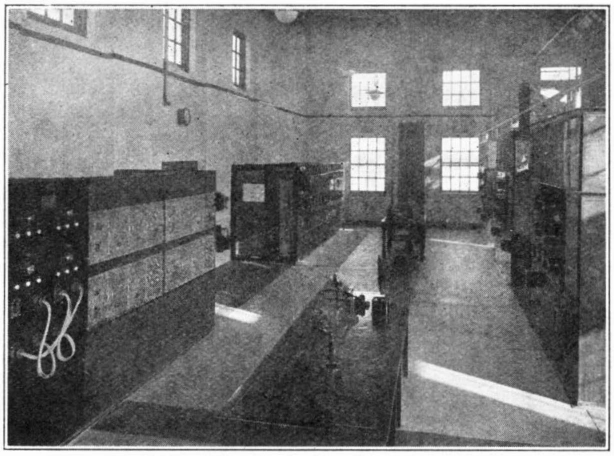


Fig. 6.—General Lay-out of Transmitter Room.

is illustrated in Fig. **6**, which shows the Tuning-Fork Units on the left front, the Power Switchboard beyond, the three transmitters on the right and the landline and control apparatus in the centre. The staff needed to handle such plant is small; each shift consists of two men, one at each table, and these men can easily handle the whole of the apparatus.

Tuning Fork Control Units.—The design of three transmitters working on frequencies very close together naturally made the interchangeability of portions of the high frequency plant a feasible proposition. It was decided therefore to separate the Tuning-Fork Control Units from the remainder of the transmitter and to mount them on a separate frame. The complete frame and distribution panel, Fig. **7**, are mounted at one end of the transmitting room and the output of these units, which provides the excitation to the power amplifiers, is distributed from a panel in the centre. Four T.F. Units are provided, one spare, and are so arranged that any one unit and its controls can be associated with any one transmitter. A description of the tuning-fork unit is contained in an article by Lt.-Col. A. G. Lee, O.B.E., M.C., in the *Electrician* for 1st May, 1925. The present units shown in Figs. **7** and **8** were designed and manufactured in the workshops of the Radio Section at Dollis Hill

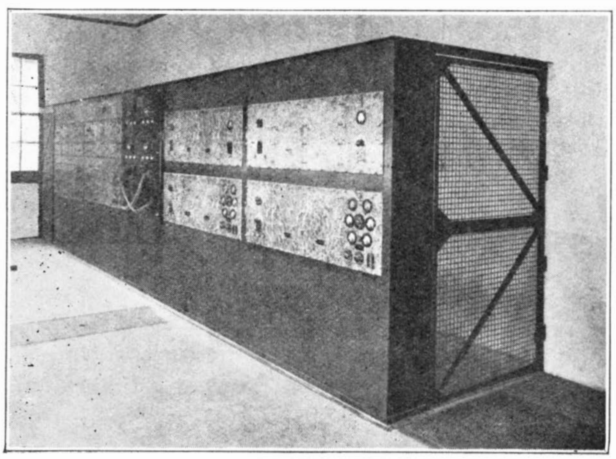


Fig. 7.—T.F. Enclosure.

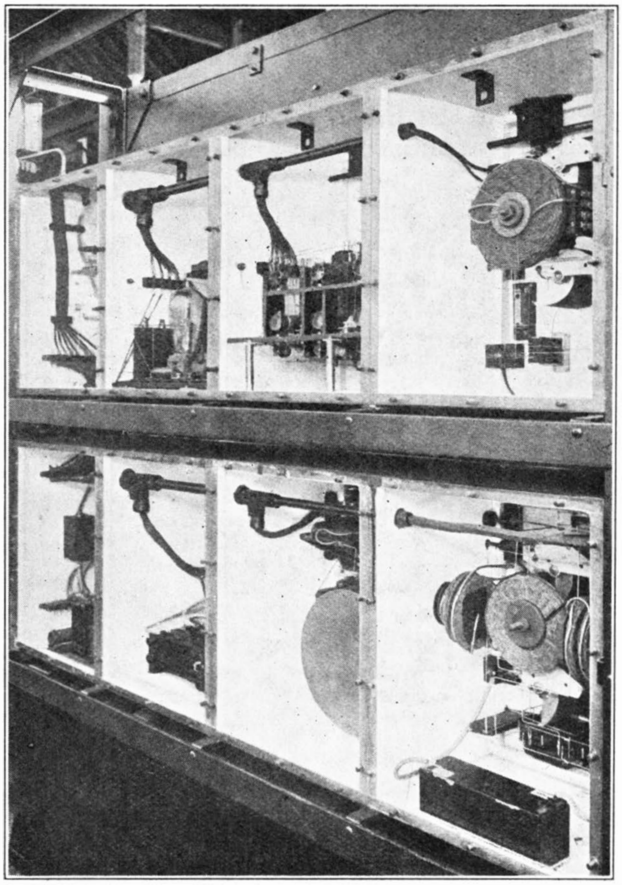


Fig. 8.—T.F. Unit. Rear View with Covers removed.

and represent a very considerable advance on the early models. Each unit consists of two copper screening boxes mounted one above the other, each box having four compartments which are completely screened from one another. The apparatus is mounted on the front panels, the connections between the stages in the various compartments being made by means of knife switch contacts mounted on the panels and boxes. Thus each stage can be easily removed for examination, testing and repair if necessary.

Mechanical interlocking arrangements are fitted so that (1) no panel can be removed unless the 1200 volt supply has been switched off, and (2) this supply cannot be switched on unless all panels are in place. The bottom right hand panel is an instrument panel for the reading of filament voltages and of the valves in the various stages, anode voltages and currents. The output circuit is fitted on the right hand top panel.

applied to the grid of the 1st power amplifier. Changes in frequency can be secured (*a*) by varying the frequency of the tuning fork itself by means of screws inserted in the prongs or (*b*) by selecting a different harmonic on either the 1st or 2nd multiplication. Except for one or two particular frequency changes, the frequency of a T.F. Control Unit is not varied in practice.

Power Amplifiers.—The arrangement of the power amplifiers is shown in Figs. **6** and **10**.

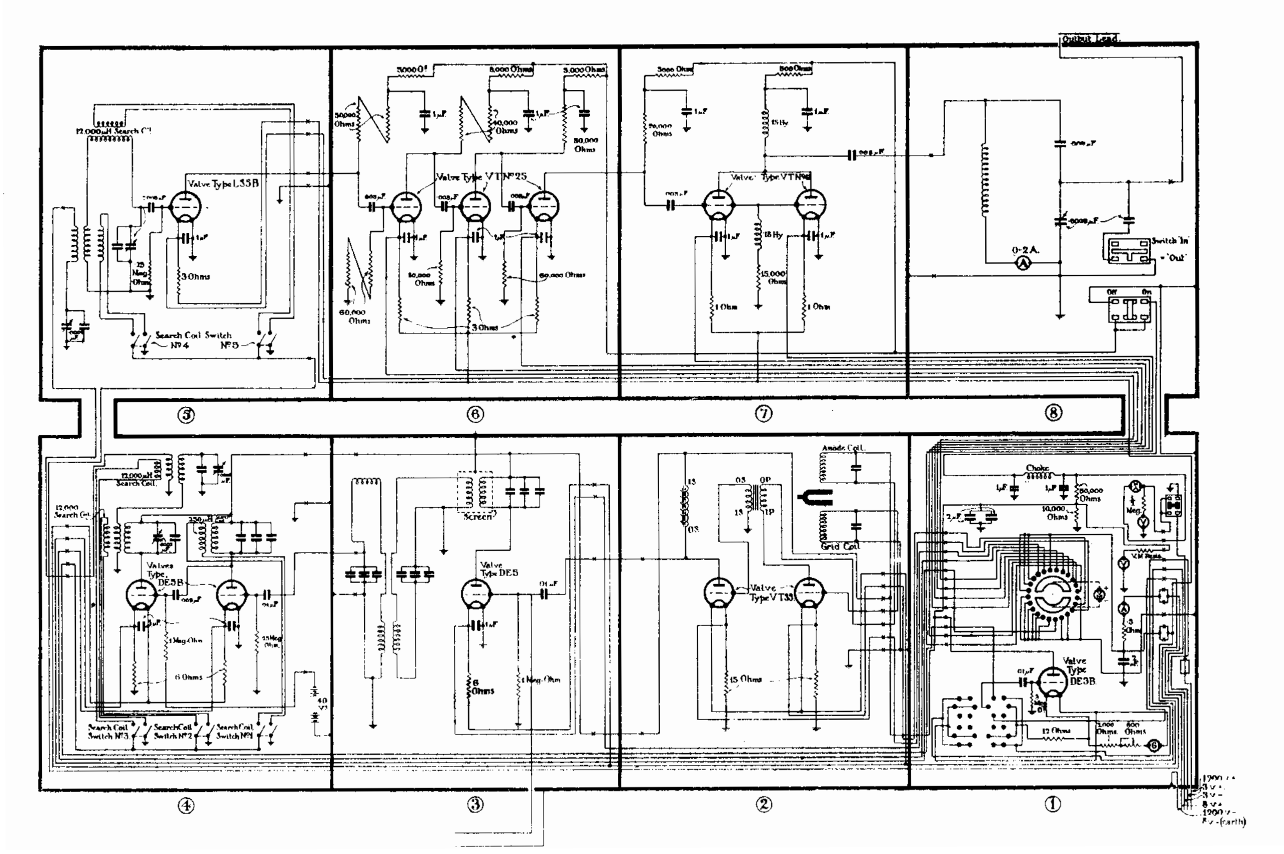


FIG. **9**.—WIRING OF T.F. UNIT.

The wiring of a tuning fork unit is shown in Fig. **9**. There is a double multiplication of frequency in each set; for example, one tuning-fork controlled oscillator operates on 1833 cycles and after the wave form of this oscillation has been distorted by rectification, the 6th harmonic (11,000 cycles) is selected and amplified. This oscillation is then distorted and the 11th or 13th harmonic (121 or 143 kilocycles) selected and amplified. This amplified oscillation becomes the output of the tuning-fork unit and is then

The main transformer, rectifying valves and smoothing circuits are mounted at the back, the main amplifying valves on the left hand side and the 1st power amplifying valve on the right. An instrument panel fitted in the front centre gives readings of the currents, etc., in the various circuits. The tuned circuit of the 1st power amplifier is fitted behind this panel and the control handle for tuning this circuit is brought on to the instrument panel, as is also that of the aerial circuit variometer. Overload relays, in-

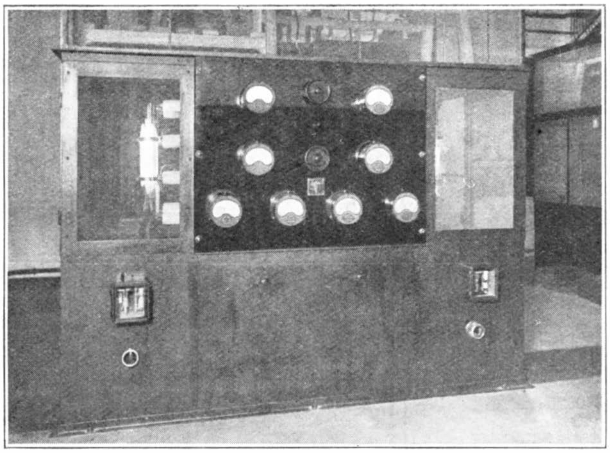


FIG. 10.—TRANSMITTER ENCLOSURE.

serted in the anode supplies to the power stages and arranged to cut off the supply in the event of sudden overloads, can be seen in Fig. **10** at the bottom corners of the enclosure.

The main tuned circuits are mounted over the amplifier enclosures in order to save floor space and to improve the lay-out. The primary and aerial coils of each transmitter are disposed at right angles, but the primary and aerial coils of all three sets are necessarily parallel to each other. The design of coil used by the Department is of pancake construction, and in consequence the magnetic field is not extensive along the axis of the coil but some distance removed from it, as would be the case if a long solenoid were used. In consequence the coupling between the coils of the various transmitters is negligible.

The wiring diagram of one transmitter is shown in Fig. **11**. The circuit employed has no special features, in fact, one might say that the main developments lie in the design of instruments, apparatus and lay-out rather than in the circuits.

The transmitters are equipped with glass and silica valves and give outputs as under:—

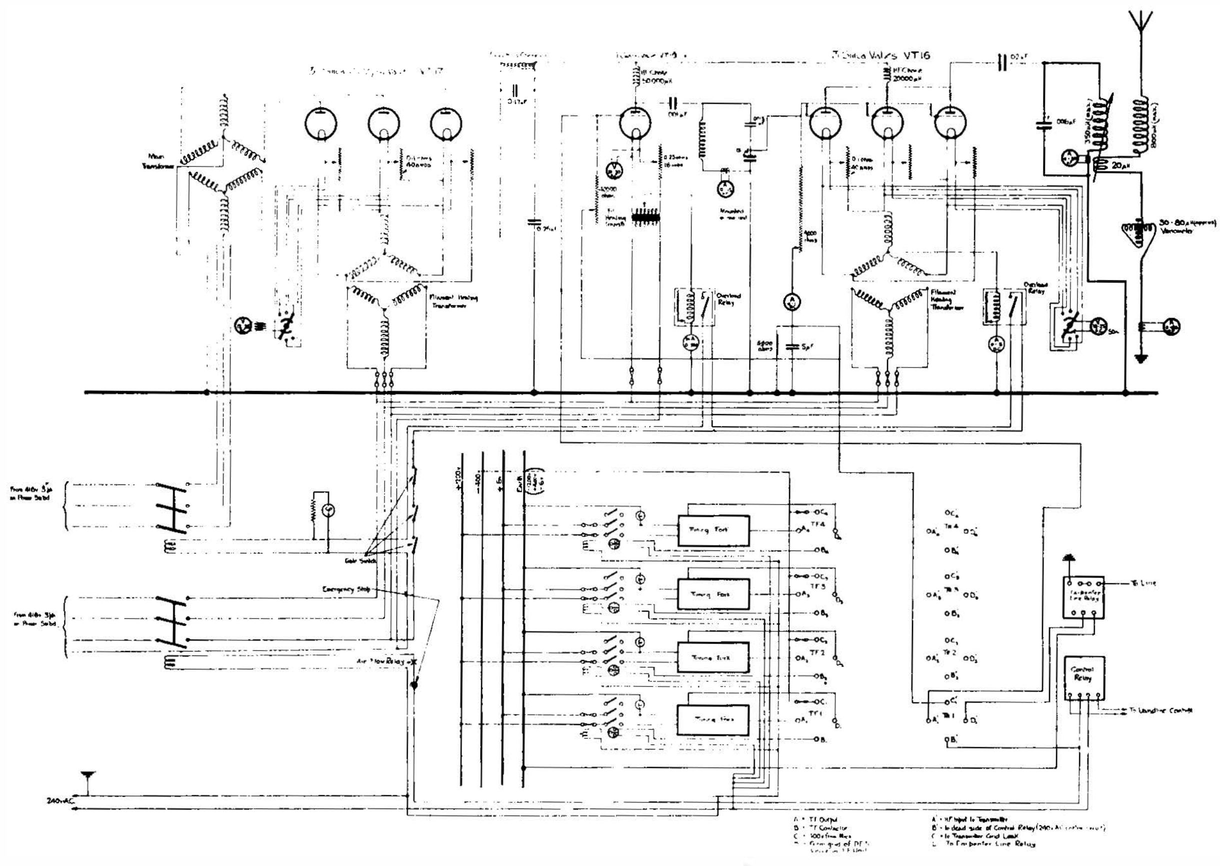


FIG. 11.—WIRING DIAGRAM OF ONE TRANSMITTER.

Transmitter.	No. 1.	No. 2.	No. 3.
Power imput	25 K.W.	6 K.W.	6 K.W.
Wave length	2479 metres	2013 metres	2100 metres
Rectifying Valves	3-2.5 K.W. silica Type V.T. 17	3-1.0 K.W. glass V.T. 21	3-1.0 K.W. glass V.T. 21
Main Amplifying Valves	3-2.5 K.W. silica Type V.T. 16	1-2.5 K.W. silica V.T. 16	1-2.5 K.W. silica V.T. 16
Aeriel Current	55-60 amps.	28-30 amps.	28-30 amps.

its controls and other auxiliaries to that particular transmitter.

Landline control of the transmitters is secured by means of diplex circuits, one channel being used for closing the transmitter control circuit and the other for keying. Simplex circuits only are used, communication with Burnham being maintained by means of a direct telephone line;

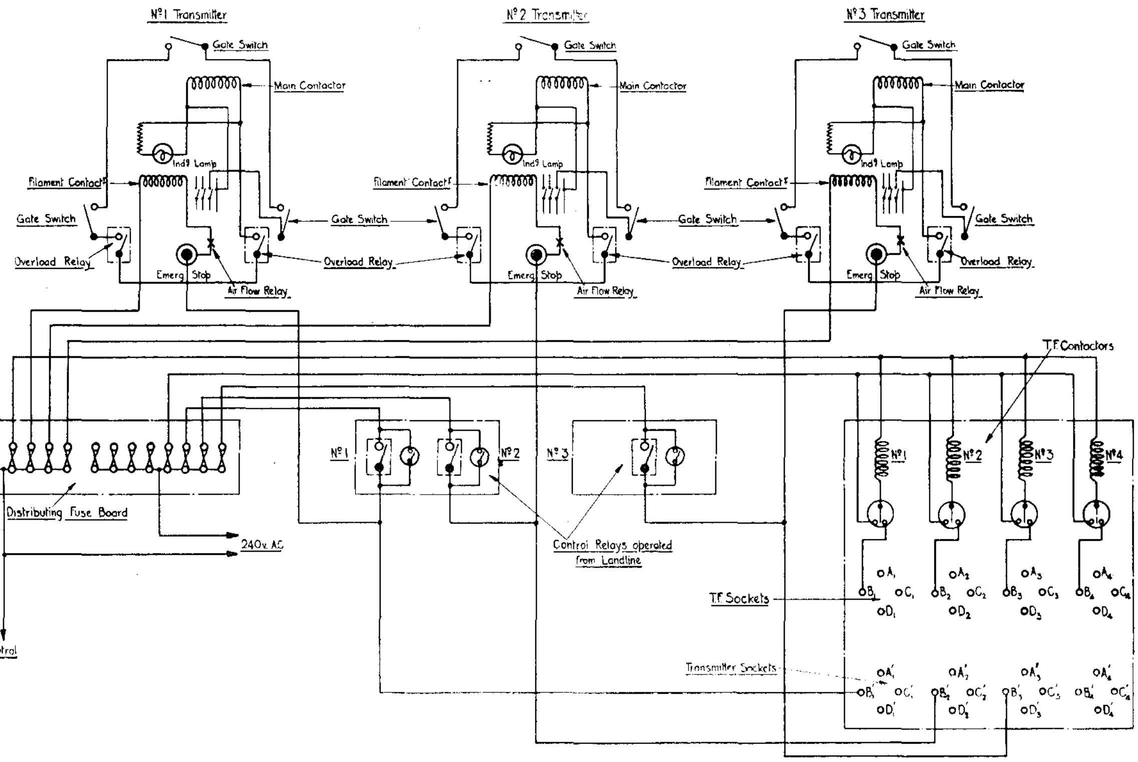


Fig. 12.—Transmitter Control Circuit.

Transmitter Control.—The transmitters may be controlled locally or by landline from Burnham through a series of control relays. The last of these relays closes a 240v. A. C. circuit and operates contactors which make the T.F. supply, main and filament supplies to the particular transmitter, provided that the local contacts on all protective devices are made. The control circuits in which these protective devices are inserted are shown in Fig. **12**. The sockets shown on the bottom right hand corner are fitted on the Tuning-Fork Control Panel (Fig. **7**) from which the output of the T.F. Units is distributed. The plugging-in of a particular T.F. Unit on to a transmitter automatically transfers this arrangement materially speeds up circuit changes, etc.

Keying is effected by means of a Creed line relay or Standard B, operated from a Standard B inserted in the line. This relay short circuits the output from the tuning fork controlled oscillator. See Fig. **9**.

It is pleasing to record that the results obtained at Portishead are considerably better than those obtainable at Devizes. The aerial current for a 6 K.W. transmitter has been increased by 50-100%, representing a three to four-fold increase in overall efficiency and the time lost in starting up a transmitter has been reduced from about 45 seconds to 10 seconds.

This saving in starting time appears small, but since a transmitter may be started up as many as a hundred times a day, the saving becomes a real one. Further, if the starting-up of a transmitter is a lengthy operation the tendency is for the receiving station to keep the transmitter running in the interval between messages in order to save delay when traffic comes to hand. The shortening of the starting-up period has reduced this tendency very considerably. Lastly, increased communication facilities between the transmitting and receiving stations have enabled the two stations to co-operate more effectively for the improvement of the service.

ANNUAL REPORT ON POSTS AND TELEGRAPHS, FEDERATED MALAY STATES FOR YEAR 1927.

TELEGRAPHS.—During the year 474,265 telegrams were despatched and 506,248 were delivered, being an increase of 8,749 in the telegrams despatched and a decrease of 3,274 in those delivered. The revenue derived from telegrams was $498,431, of which $305,958 is included in the stamp sales. The revenue shows an increase of $42,852 as compared with 1926. The value of telegrams sent free of charge for other Government departments was $59,554, an increase of $8,217.

Wheatstone high-speed telegraph apparatus was installed in the Kuala Lumpur and Ipoh Post Offices during the year and proved of great assistance in disposing of telegraph traffic between the Federated Malay States and the Straits Settlements.

Telephones.—The number of subscribers to the telephone system on the 31st December, 1927, was 4,003, an increase of 553 as compared with 1926. In addition there were 1,871 extension lines, extension bells, private circuits, private bell or alarm circuits and tell-tale clock circuits maintained by the department, as compared with 1,598 in 1926.

The revenue derived from telephones was $1,062,562, an increase of $158,051 over 1926. The trunk revenue amounted to $317,380, an increase of $40,127 as compared with the previous year.

Four new public telephone exchanges were opened in the course of the year, and on 31st December, 1927, there were 46 public exchanges in the Federated Malay States.

Public call boxes are available at 83 post offices.

On 31st December, 1927, there were 41 applicants awaiting connection to the telephone system; these were very recent applications.

The average number of originated calls per direct exchange line per day was 12.3, an increase of about 2.5 per cent. compared with 1926 (which should have been given as 12.0 not 12.3).

The average total numbers of originated calls per day throughout the Federated Malay States during the year were:—

Local calls	40,200
(increase over 1926, 10%)	
Junction calls	1,000
(increase over 1926, 39%)	
Trunk calls	4,500
(increase over 1926, 17.2%)	
Total originated calls per day ...	45,700
(increase over 1926, 17.6%)	

The approximate total originated telephone traffic during the year was as follows:—

Local calls	11,738,400
Junction calls	292,000
Trunk calls	1,314,000
Total originated traffic during 1927 ...	13,344,400

Development studies were made in a large proportion of the Federated Malay States Telephone Exchange areas during the year for the purpose of estimating equipment and plant requirements.

The preliminary traffic investigations in connection with the design of the new Kuala Lumpur Exchange building were completed during the year.

With regard to the question of "party line" working—referred to in para. 51 of my predecessor's report for 1926—arrangements were made during the year for the installation of a "Rural automatic unit." The equipment is not, however, expected to arrive before the middle of 1928.

Engineering.—On 31st December there were 2,602 miles of telegraph and telephone lines and 21,716 miles of overhead wire in the Federated Malay States, of which 18,483 miles were telephone wires. In addition there were 102 miles of underground cables containing 9,908 miles of wire single line. These figures do not include the poles and lines maintained by the Railway Department for their own use. The Posts and Telegraphs Department also owns and maintains 123 miles of line and 606 miles of wire in Johore. It also maintained in 1927 one and a half miles of pole line for Kedah, 847 miles of wire for Johore, and 24 miles of pole line in the Dindings.

The erection of trunk lines involved heavy work of construction in practically all parts of the country. The progress of new work in Pahang was heavily handicapped by the necessity for almost a complete reconstruction of the whole overhead system due to the damage done by the flood.

Underground cables were considerably extended during the year in all parts of the Federated Malay States, a total additional length of approximately 23 miles of cable, 2,134 miles of single wire, having been laid.

The proposed Malayan Trunk Telephone Cable Scheme was, however, abandoned on financial grounds both by the Federal and Colonial Governments. The rejection of a scheme on which the Engineering Branch had spent so much time and labour, and which was intended to meet trunk requirements for many years, has left the department with considerable leeway to make up as regards the provision of adequate trunk facilities between existing exchanges, so that the extension of the aerial lines to Singapore will not be practicable in the immediate future.

New exchange equipment either additional or replacement was installed at Banting, Bentong, Fraser's Hill, Ipoh, Klang, Kuala Lumpur, Kuala Lipis, Kuantan, Raub, Seremban, Taiping and Tanjong Malim.

At the request of the Governments of Kedah, Kelantan and Trengganu, reports were made by the Senior Engineer of the department on the telegraph and telephone systems in these countries. Following on the report furnished to Kedah, a detailed scheme for the reconstruction of the whole Kedah system was prepared.

Engineering work was somewhat hampered by the shortage of technically trained Asiatic staff. Every endeavour is being made to overcome this shortage by training suitable men in a Departmental Technical School.

Wireless.—Thirty-seven temporary licences for the use of wireless receiving apparatus were issued during the year and four experimental transmitting licences.

The British official news broadcast from the wireless station at Rugby in England, received at Penang Wireless Station and retransmitted from Penang by land line for delivery to the local newspapers on payment of a monthly fee, averaged about 20,000 words a month.

For the purpose of conducting short wave wireless experiments throughout Malaya, two ½ k.w. standard Marconi short wave—C.W. and I.C.W. sets were received in October, but owing to certain faults in the sets it was necessary to obtain various replacements, and these had not been received by the end of the year. It is intended to fit one of these sets on to a motor-lorry, and from this mobile station carry out experiments in various parts of the country. The development of wireless in Malaya will largely depend upon the results of these tests.

Workshop.—The activities of this branch of the department during the year were unprecedented. An outstanding feature of the work was the number of telephone switchboard sections made and installed. The on-costs remained practically the same as in the previous year.

Stores.—The number of different items stocked was 4,180, an increase of 688 as compared with 1926. The value of stores issued and received in 1927 was $2,657,390, compared with $2,183,773 in 1926. Work in the stores was greatly handicapped by inadequate accommodation. The need for more space and for the proposed new store was more strongly felt than ever.

Postal Franking Machines.—During the year postal franking machines were brought into use in the Federated Malay States for the first time, and revenue collected on this account, which would otherwise have been spent on postage stamps, amounted to $2,950.

Co-operative Society.—During the year the Federated Malay States Posts and Telegraphs Co-operative Thrift and Loan Society Limited continued to progress and by the end of the year had a membership of 1,091 as compared with 1,039 on 31st December, 1926, with a total subscribed capital of $246,165. A dividend of 7 per cent. was paid on the 30th June, 1927, as compared with 6 per cent. for the previous year.

Seven hundred and seventy-five loans totalling $198,227 were granted during the period under review, making the total loans granted since the inception of the society 2,567 in number and $617,290 in amount.

It is of interest to note that whilst the number of loans for liquidating debts is decreasing the number of loans for buying land and for building houses is increasing. During the year 119 loans for a total amount of $40,518 were granted for the purchase of land and for the building of houses.

That the society has proved a boon of great value to the members is shown by the fact that during the year 388 loans for a total amount of $71,466 were granted to members on the security of their own subscription credit; such savings would not, in the majority of cases, have been made but for the existence of the society.

Employment of Malays.—The policy of giving preference to Malays in all branches of the department where vacancies occurred was followed wherever possible.

Employment was given to 37 Malays as telephone operators and 31 Malays were engaged as postmen, messengers, peons, mail-runners, etc.

On the engineering side there were at the end of the year 11 Malay apprentice linesmen and nine Malay apprentice or probationer technical subordinates being trained at the Departmental Technical School.

Thirteen Malays with suitable educational qualifications were also engaged as probationer clerks.

Conclusory.—In its endeavour to give the best possible service the department is conscious enough that attainment lags behind the ideal, but postal shortcomings are not entirely departmental and the assistance of the public is earnestly sought in two directions. There is probably no other country in the world where the posting public is so careless about addresses as in Malaya; it is the exception rather than rule to inscribe on the envelope anything fuller than "Richard Doe, Esq., Kuala Lumpur." That may have been explicit enough twenty years ago, but to-day in a town of some hundred thousand inhabitants, and spread over some ninety miles of roads and streets, it is gravely insufficient. Secondly, it should be remembered that English not being the mother tongue of the majority of our telephone operators, wrong connections are as often as not the inevitable result of hurried or imperfect articulation on the part of the calling subscriber.

The following table indicates the growth of the system:—

TELEGRAPH AND TELEPHONE SYSTEM.

Year	Length of overhead line. Miles.	Length of overhead wire. Miles.	Length of underground cables. Miles.	Length of wire single line in cables. Miles.
1907	1,341	3,079		
1917	2,276	11,211	26	2,406
1927	2,602	21,716	102	9,908

NOTES & COMMENTS

THE most important happening in the world of communications during the past quarter is perhaps the report of the Imperial Wireless and Cable Conference, which was published on the 27th July. Sir John Gilmore, Secretary for Scotland, was Chairman of the Conference, and Mr. A. M. Samuel, Financial Secretary to the Treasury, was the other representative of this country. Canada, Australia, New Zealand, South Africa, the Irish Free State, India and the Crown Colonies and Protectorates were represented, and Sir Otto Niemeyer and Sir William McLintoch acted as financial advisers to the Conference. The Eastern Telegraph Coy. and its associated companies and Marconi's Wireless Telegraph Co. had declared their intention of forming a combined company on condition that the British Government, as owner of two Atlantic cables and the Beam Radio Stations, and co-partner in the Pacific Cable Board, should agree to merging their interests with those of the companies. After full evidence had been heard and communications duly considered the Conference recommended as follows:—

(1) A Merger Company to be formed to acquire as from April 1st, 1928, all the ordinary shares of the Eastern, Eastern Extension, and Western Telegraph Companies, and all the ordinary and preference shares and debentures (if any) of the Marconi's Wireless Telegraph Co., Ltd.

(2) A Communications Company to be also formed to which the Cable and Marconi Companies will sell as at April 1st, 1928, all their communication assets in exchange for shares. The Communications Company will, therefore, hold all the communication assets of the Cable and Marconi Companies, except in so far as they belong to the subsidiary companies in which the Cable and Marconi Companies' holdings are less than 100 per cent. The Communications Company will acquire the holdings of the Cable and Marconi Companies in those communications companies in which the Cable and Marconi Companies' holding is less than 100 per cent. The Communications Company will also acquire the Government cables and hold the lease of the Post Office beam radio stations. The capital of the Communications Company not to exceed at its inception £30,000,000.

(3) *Terms of transfer of the Government's cable and radio beam assets.*—The Communications Company to take over as from April 1st, 1928, the Pacific Cable Board's cables, the West Indian cable and wireless system worked by the Pacific Cable Board, the Imperial Atlantic cables and the lease of the Post Office beam services (including provision for the transfer to the Company of existing staffs) on terms to be arranged.

The beam services to be leased for 25 years at a rental of—

(*a*) a basic sum of £250,000 per annum;

(*b*) as from April 1st, 1931, an addition equivalent to 12 per cent. on any increase in the Company's profits (from communication services) above the standard revenue;

(*c*) a payment of £60,000 to be made in such manner as may be agreed.

The Communications Company to undertake

to meet the annual service of the outstanding debt on the Pacific Cable Board as on April 1st, 1928, and to pay in addition a capital sum of £517,000 for the Pacific cables, together with interest at 5 per cent. as from April 1st, 1928; to pay £300,000 for the West Indian cable and £450,000 for the Imperial cables.

The rental payable by the Communications Company and the service of the Pacific Cable Board debt will be guaranteed by the Merger Company.

(4) *Direction and management of the undertakings concerned.*—The Board of Directors of the Merger Company, the Communications Company, the Cable and Marconi Companies will be identical. Two of the directors, one of whom shall be chairman of the Communications Company, to be persons approved by His Majesty's Government on the suggestion of the Cable Companies.

(5) *Revenues of the Communications Company.*—A standard net revenue of £1,865,000 (exclusive of non-telegraph investment revenue) from the Communications Company services to be fixed to the purposes of the Company; all net revenue from communication service in excess of that sum to go as to 50 per cent. to the Company, and as to 50 per cent. to reduction of rates or such other purpose as the Advisory Committee (see recommendation 6) may approve. If additional capital expenditure is incurred by the Communications Company in relation to traffic, there shall be added to the above initial standard revenue an appropriate charge for interest at such rate as may later be agreed.

(6) *Control by the Governments concerned.*—The Communications Company to consult, with regard to questions of policy, including any alteration of rates, an Advisory Committee, which the Conference suggests should include representatives of the Governments participating in this Conference, to whom representatives of other parts of the Empire may be added as required from time to time with the approval of the Governments concerned. No increases of rates prevailing at the date of the formation of the Communications Company are to be made except with the assent of the Advisory Committee.

(7) *Additional safeguards and conditions.*—It is to be agreed: (*a*) that British control of all the Companies must be guaranteed; (*b*) that the Governments may assume control of the cable and wireless systems in time of war or other national emergency; (*c*) that the fighting services are entitled to build and work cable or wireless stations for their own purposes, but not for commercial purposes.

(8) *Telephone services.*—The Post Office in London will reserve the right to conduct the external telephone services of Great Britain, but will agree with the Company the terms on which it will have the right to use the Company's wireless stations, or portions thereof, for telephone purposes.

After an appreciatory comment on the value of the Journal to colonial subscribers, Mr. G. W. Heugh, of the engineering branch, Cape Town, gives an amusing account of the difficulties they are experiencing in erecting a line to a new very rich diamond field. Labour is very difficult to obtain for the erection of poles; the men all wish to dig certainly, but in the wrong places; even those who are persuaded to stick to the job carefully sift the soil and toss it in the air to see if they have any luck!

We commend the following letter to the attention of engineering firms who may be considering the extension of their advertising field and are still in doubt as to the best organ in which to extol the claims of their wares. Mr. Turner's advertisement was one dealing with combined voltmeter and milliampèremeter, which is known as the Detector, No. 4:—

Chiltern Works,
55/73, Totteridge Avenue,
High Wycombe, Bucks.
July 5th, 1928.

The Managing Editor,
Post Office Electrical Engineers' Journal,
Alder House, Aldersgate Street,
London, E.C.1.

Dear Sir,

It may interest you to know that my advertisement, which was inserted once in your Journal recently, brought more *orders* than any other advertisement I have had, and enquiries are still coming in from it.

Yours faithfully,
ERNEST TURNER,
per E. GOOD.

We have been asked by Lieut-Col. C. B. Clay to announce that it is proposed to hold a dinner of old National Telephone Company's staff, both active and retired, in London during December. Some sixty names have already been received and Col. Clay would be glad to hear from any men with the above qualifications who would care to attend. His address is Hurst, Sundridge Avenue, Bromley, Kent.

In the *Daily Express* of the 13th ult., the following statement appeared :—

The succession of fires due to defective Post Office cables has caused enormous inconvenience and loss to business firms, and there is widespread curiosity with regard to the real cause of the outbreaks. An electrical expert said to a *Daily Express* representative yesterday: "The fires are due to the antiquated equipment which the Post Office use for their cables.

"The outbreaks are caused by spontaneous combustion. During hot weather, such as we have had this summer, there is a constant danger of fires, which can only be overcome by installing modern equipment.

"The Post Office are afraid to spend the necessary money to bring the service up to date, though business men have lost thousands of pounds this week owing to the disorganised telephone service."

We wonder who the electrical expert is that comes forward with this ridiculous explanation. If there be any "sich person," he either does not know what he is talking about or he is deliberately deceiving the public. He belongs, we are afraid, to the second category of witnesses as defined by a well-known public man, who calls a spade a spade. The cables used by the British Post Office—and here we call the Cable Manufacturers to witness—are the finest and most up-to-date in the world.

We regret that owing to the absence in America on official business of Mr. A. E. Stone it is not possible to include a further article on Start-Stop Printing Telegraphs in the present number. It is hoped to continue this series of articles when Mr. Stone returns.

HEADQUARTER'S NOTES.

EXCHANGE DEVELOPMENTS.

The following works have been completed :—

Exchange.	Type.	No. of Lines.
Holborn	New Auto.	9400
Keighley	,,	1280
Lofthouse Gate	,,	100
Llandudno Junc.	,,	140
Old Colwyn	,,	500
Penrhynside	,,	180
Rochdale	,,	2000
Castleton	,,	165
Heywood	,,	365
Littleborough	,,	265
Milnrow	,,	80
Norden	,,	75
Shaw	,,	270
Whitworth	,,	80
Wilpshire	,,	270
Cosham	Auto Extn.	200
Fleetwood	,,	220
Southampton	,,	540
Batley	New Manual	800
Colne	,,	620
East Grinstead	,,	460
Haywards Heath	,,	540
Ealing	Manual Extns.	2050
Hatch End	,,	390
Kingston	,,	780
Liverpool Desk	,,	—
Margate	,,	820
Maryland	,,	1340
St. Albans	,,	440
Wavertree	,,	1040
Weybridge	,,	300
Worthing	,,	860
Armstrong Siddeley	P.A.B.X's	120
Atkinson & Co.	,,	20
Calico Printers	,,	30
Davenports	,,	30
Delta Metal Co.	,,	30
Dunlop Rubber Co.	,,	20
Huntley & Palmer	,,	170
Nairn & Co.	,,	30
Newcastle Elec. Light	,,	20
Rochdale Co-op.	,,	150
St. Helens Corporation	,,	80
Salford Corporation	,,	30
Shell Mex (Bristol)	,,	30
Southport Corporation	,,	100

Orders have been placed for the following works:—

Exchange.	Type.	No. of Lines.
Addiscombe	New Auto	2700
Crewe	,,	840
Hendon	,,	3100
Macaulay	,,	4500
Nantwich	,,	290
Brighton	Auto Extns.	Rearrangement.
Hove	,,	Rearrangement.
Kirkcaldy	,,	540
Portslade	,,	90
Preston	,,	350
Rottingdean	,,	80
Southwick	,,	110

Exchange.	Type.	No. of Lines.
Connah's Quay	New Manual	440
Parkstone	,,	1580
Stanmore	,,	560
Cambridge	Manual Extns.	1480
Ryde	,,	240
Smethwick	,,	580
Streatham	,,	660
Wednesbury	,,	440
West Bromwich	,,	420
Fleetwood Co-op.	P.A.B.X's	20
Martin Walter & Co.	,,	20
Morris Garages (Oxford) ...	,,	30
Newcastle Elec. Light ...	,,	20
Outram & Co.	,,	20
Reading Co.-op.	,,	20
Shell Mex (Bristol)	,,	30

LONDON DISTRICT NOTES.

Telephones.

The following figures show the changes in the number of exchange lines, extensions and stations during the three months ending, and the totals at 30th June, 1928:—

	Increase.	Total.
Exchange Lines ...	6,319	341,821
Extensions ...	6,823	287,655
Stations	11,987	573,731

External Plant.

During the same period the changes shown below have occurred in mileage:—

Telegraphs.—A nett decrease in open wire of 4 miles, and a nett increase in underground of 261 miles.

Telephones (Exchange).—A nett decrease in open wire (including Aerial Cable) of 242 miles, and a nett increase in underground of 68,424 miles.

Telephones (Trunk).—A nett decrease in open wire of 23 miles, and a nett increase in underground of 2,013 miles.

Pole Line.—A nett increase of 13 miles, the total to date being 5,868 miles.

Pipe Line.—A nett increase of 136 miles, the total to date being 9,761 miles.

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

Telegraphs	25,475
Telephones (Exchange) ...	2,303,718
Telephones (Trunk) ...	73,271
Spare	107,112

Exchange Works.

Beckenham Exchange (C.B. No. 10), capacity 8,000 lines, was opened for traffic on July 25th. Sloane and Bermondsey Auto. Exchanges were successfully opened on July 28th and September 1st respectively. Other Automatic Exchanges which are rapidly nearing completion and will be opened before the end of the year are Monument, Western, and Welbeck. The latter Exchange will relieve the Langham Area.

The installation of the following new Manual Exchanges is well in hand and will be completed within the next few months:—Pollards (in the Norbury Area), Chigwell, Rainham, Sutton, Molesey, Tudor (relieving the Mountview Area) and Valentine (for the relief of Ilford).

The opening of Sloane and Bermondsey Auto Exchanges on July 28th and September 1st respectively marks a further important step in the conversion of the London Telephone Area to automatic working.

The Sloane Exchange was opened with an initial capacity of 8,400 lines and the Bermondsey Exchange with 2,600 lines. Both Exchanges were equipped and installed by the Standard Telephone & Cables, Ltd.

The opening of these Exchanges was eminently satisfactory, the number of faults reported as the result in each case of the transfer being practically nil.

MR. A. B. HART.

MR. A. B. HART.

MR. HART who, on 1st November next, will succeed Mr. W. M. France as Staff Engineer in charge of the Lines Section of the Engineer-in-Chief's Office, entered the service of the Post Office at Cambridge on 1st June, 1893; was transferred to the Engineering Department at Cambridge on 1st December, 1896, and came to Headquarters as 3rd Class Clerk on 20th April, 1898. He was promoted 2nd Class Engineer in charge of the Merthyr Tydvil Section on 9th December, 1901. The period following was a strenuous one. There was keen competition with the National Telephone Company in the coal and steel areas, and active development of the telephone system in new territory in Brecknockshire and Herefordshire was in progress. The opening of new exchanges soon made it necessary to shift the headquarters to a more central position at Brecon. Under the general reorganisation of 1904. the section was further enlarged and the headquarters were again removed—this time to Hereford. Even during this busy period, when long hours had to be worked, Mr. Hart found time for fly fishing and golf, with occasional motoring as opportunity offered. The latter two recreations he still enjoys. On 26th September, 1908, Mr. Hart took charge of the Brighton Section as 1st Class Engineer and returned to Headquarters as Staff Engineer, 2nd Class, on 19th December, 1910. His task was to set up an organisation for dealing with the transmission efficiency aspect of line and exchange plant and with this work he has been associated from that time.

During the War, Mr. Hart was responsible for the circuit arrangements in connection with the Submarine Cable communications with France and the General Headquarters of the Expeditionary Forces and for other special cable arrangements, including those for the Grand Fleet. At the termination of the War he visited Cologne in company with the then Engineer-in-Chief, Sir William Slingo, in order to examine the developments which had taken place in Germany during hostilities, particularly in connection with the use of valves as telephone repeaters. In this way he was among the first to re-establish personal contact between the Administrations of the Allies and of Germany. Being peculiarly gifted with a tactful and conciliating personality and a never-failing fund of humour, which has since endeared him to his numerous friends on the Continent, he was particularly fitted for this delicate mission.

As head of the Transmission group, Mr. Hart has been responsible for the many schemes for loading underground cables, of which, as is well known, there has been an enormous development. Probably the outstanding work for which he will be remembered is the development of the long underground cable system, in association with the Telephone Repeater. While loading enabled underground cable conductors to be used for relatively long distances, as, for example, in the case of the London-Liverpool cable, the gauge of conductor had still to be heavy and the number of pairs which could be accommodated in a cable was limited, being only 52 in the case of the cable mentioned. The Telephone Repeater, however, has revolutionised the whole system. Cables containing over 200 pairs of light gauge conductors can be used and the limit of distance has not yet been reached. It is due to the energy and foresight of Mr. Hart that the development of the Repeater system has been pushed forward and has thus kept this Country abreast of the growth of similar systems on the Continent. It is fortunate that he will still be in control of this work, as the Transmission group has been transferred to the Lines Section. Other developments taking place under Mr. Hart's supervision are Carrier Current Telephony, Voice Frequency Telegraphy and the provision of circuits for Photo-Telegraphy.

Mention should also be made of Mr. Hart's work on the Comité Consultatif International des Communications téléphoniques à grande distance, to all the Conferences of which he has been an active and keenly interested delegate since the inception of the Comité in 1923.

MR. F. TANDY.

Mr. F. Tandy.

Mr. F. Tandy retired on the 31st July, 1928, after having held for 17 years the post of Superintending Engineer, South Eastern District.

His services in the Engineering Department commenced in 1891 at the East Dean Repeater Station on its transfer from the Submarine Cable Company to the Post Office. He also served at Llanfairpwllgwyngyll, Anglesey, the Irish Repeater Station. He was promoted, in 1894, 2nd Class Engineer in the Engineer-in-Chief's Office and became a member of the historical Room 90 staff, which included Messrs. W. Brown, J. Chapman, Eden, Hartnell, Kemp, Purves, Stubbs and Tremain. There he took up the investigation and development of new ideas in electrical communication, many of which betrayed marvellous ingenuity.

Among the earliest problems that made exacting demands on the newly-fledged engineer was Pollock's Multiplex Duplex. Another was the 4-wire Telautograph, a fascimile writing apparatus originally of extreme complexity. Although considerable simplification was effected, this apparatus did not attract the customers whose signatures to distant cheques, and documents, etc., it was designed to transmit. It was tried out between London and Paris.

He shared with Mr. J. Chapman the work which came to fruition in the duplexing of Hughes Typeprinting System. He was the initiator of experiments with the oscillograph and his demonstrations of its applicability to the analysis of telephone speech led to the subject being brought prominently before the I.E.E. by the late Sir John Gavey in his presidential address. Mr. Tandy worked on Poulsen's Telegraphone which had been brought to this country from the Paris Exhibition. The Telegraphone produced results similar to those produced by the Dictaphone. By the magnetisation of a steel wire travelling between the electro-magnets of a telephone receiver the speech currents that passed through the receiver were recorded. These currents were reproduced in the receiver—which in turn became the transmitter — when the magnetised wire was caused to retravel between the electromagnets.

He co-operated with Mr. W. Brown in the experiments on the first heavy gauge trunk lines. These wires, erected on the Midland Railway, provided the first long distance telephone service from London to Leeds, Glasgow, Belfast and Dublin. He was similarly associated in the tests over trunk lines between English provincial towns and the Continent.

When the first two C.B. Switchboards came from America they arrived in this country in a deplorable state of disrepair. One of them was taken by Mr. Tandy to Cork, restored and installed there for experimental trials between London and Cork over the new heavy gauge trunk lines *via* Belfast. Long distance C.B. working was thus proved to be practicable. He co-operated with Mr. Matthew Cooper in the trials of the earliest form of Air-spaced G.P. Cable for submarine telephony, which had been laid between the Isle of Wight and the Mainland. This cable consisted of a G.P. tube in the walls of which were embedded four equi-spaced wires. It may be mentioned that a similar cable laid across the Irish Sea had to be abandoned because the compression in deep sea caused displacement of the wires and consequent distortion of speech.

He took part in the tests and experiments which preceded the adoption of the Trunk Signalling method devised by Mr. Alexander Moir at Leeds. He was the headquarter's expert responsible for the construction and opening of the original trunk exchanges at Glasgow, Manchester, Birmingham and other places. He was engaged at Headquarters in developing Common Battery exchanges in London at Carter Lane, Western, Mayfair, etc., and in connection with the introduction of C.B.S. exchanges in the Thames Valley. He was employed in the experiments on the air-spaced cable between London and Elstree upon which the specifications for the London-Birmingham cable were based.

Mr. Tandy did pioneer work in Wireless. He assisted in Preece's magnetic induction experiments at Carnarvon and elsewhere. He assisted both Preece and Gavey in their public lectures at the British Association and the Society of Arts. He co-operated in the early development of the Marconi invention and in the wireless experiments across the Bristol Channel with Mr. J. E. Taylor.

During his 12 years at Headquarters he was promoted 1st Class Engineer (in 1898) and Technical Officer 2nd Class (in 1902). In 1906 he was transferred to the Metropolitan Central District as Assistant Superintending Engineer, and in 1911 was promoted Superintending Engineer at a time when the responsibilities of the P.O. Engineering Department were about to expand enormously. His district has been conspicuous for growth of plant and services, especially the Continental telegraph and telephone services.

On his last day of office the staff of the district presented to him, with many expressions of esteem and respect, a Rice-Kellogg Loud-speaker, a Phillips Mains H.T. Unit, and a walking stick. Next day a representative party called on Mrs. Tandy and presented to her a gold wristlet watch as a souvenir of the relationship which had existed between Mr. Tandy and the staff for so many years.

At the last Local Engineering Whitley Meeting over which Mr. Tandy presided the Vice-Chairman on behalf of the Staff regretted the imminent retirement of Mr. Tandy, and thanked him for all he had done to further the aims of Whitleyism in the S.E. District. It was also stated that the Staff Side fully appreciated Mr. Tandy's sympathetic attitude, the patience which he had shown in connection with all matters brought forward for discussion, and the invariably tactful manner in which he had presented the views of the Official Side and the Department's requirements.

H. L.

MR. JAMES SINCLAIR TERRAS, S.E. SOUTH WALES.

MR. JAMES SINCLAIR TERRAS.

MR. TERRAS was born and educated in Glasgow. He entered the service of the National Telephone Company in his native city in 1889 and speedily gained recognition, being appointed inspector in charge at Paisley in 1892. In the following year he was promoted District Manager at Galashiels and again in 1896 at Greenock. In 1904 Mr. Terras followed the example of many of his countrymen and crossed the border when he received the district managership at Reading. He was promoted to District Engineer, Birmingham, in 1909, and when the inventory work was started in connection with the transfer of the Company's plant to the P.O. he was placed in charge of one of the divisions. He came over to the Department in 1912 as Executive Engineer, Birmingham, but was promoted next year to Preston as Assistant Superintending Engineer of the North Western District. He has now succeeded Mr. H. Wilson at Cardiff in charge of the South Wales District.

Mr. Terras has had a wide and varied experience. In the early days at Greenock he designed and carried out the original underground system of that town which was one of the first municipalities to afford facilities for underground work in the streets. Since he went to Preston, he has been closely associated with the installation and maintenance of automatics in the areas of Accrington, Blackburn and Fleetwood. Throughout his career he has been keenly interested in the technical education and training of the staff, and has studied the economics of P.O. administration with a continual eye upon the reduction of costs. His recreations now are walking and music, but in his youth he was a keen oarsman. He goes to Cardiff with the best wishes of the staff at Preston and district.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

Provisional Programmes, 1928-9.

LONDON CENTRE.

1928.

9 Oct. W. J. BAILEY.
"Chairman's Address."

13 Nov. H. G. S. PECK, B.Sc.
"The Director Exchange in Practice."

11 Dec. E. J. WOODS.
"The Main Underground Trunk Cable System of the British Isles."

1929.

8 Jan. A. J. GILL.
"Telephonic Communication by means of Short Waves."

12 Feb. A. J. ALDRIDGE.
"Sound Measurement."

12 Mar. I. H. JENKINS.
"Circuit Design."

14 May W. G. RADLEY.
"X-Rays and the Structure of some Engineering Materials."

Reserves: Capt. TIMMIS.
"Carrier Current Telephony."
R. W. PALMER.
"The Measurement of Relay Times."

Informal Meetings.

1928.

25 Oct. P. J. RIDD.
"Chairman's Address."

27 Nov. J. COWIE.
"Staff: Character judging. Talk on Personal Characteristics."

1929.

22 Jan. H. E. MORRISH.
"Laying, Jointing and Testing of Cables."

26 Feb. W. DOLTON.
"Wireless. Inspection of Amateur Stations."

26 Mar. D. C. MADDOCKS.
"Tandem Exchange & C.C.I. Working."
H. T. BINES.
"Holborn Automatic Exchange."

23 Apl. B. LYNN.
"Ecclectic Junctions."

NORTHERN CENTRE.

1928.
9 Aug. Summer Outing.
17 Oct. J. R. Edwards.
"Output of the Worker and Methods of increasing it."
21 Nov. T. Pearson.
"Organisation of Advice Note Work."
12 Dec. Thos. Davidson.
"Underground Breakdown Organisation."
1929.
9 Jan. E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
20 Feb. C. E. Worthington.
"Underground Line Construction with suggestions for reducing Costs."
20 Mar. F. W. Gaskins.
"The Cabling of the Tyne Bridge."

NORTH EASTERN CENTRE.

1928.
9 Oct. A. S. Renshaw. *(E.-in-C.O.).*
"Some general considerations relating to Clerical Organisation of Engineering Department."
13 Nov. J. J. Edwards, B.Sc.(Eng.), A.C.G.I., D.I.C.
"Modern Electrical Illumination."
11 Dec. C. Wood.
"Secondary Cells as used in the P.O."
1929.
8 Jan. E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).*
"Main Underground Trunk Cable System of the British Isles."
12 Feb. R. G. DeWardt, A.M.I.E.E.
"Grimsby Beam Radio."
12 Mar. H. McLean.
"P.O. Engineering Inspectors."

NORTH WESTERN CENTRE.

W. S. Procter. *(Technical Section).*
"Cordless B Key-sending positions in Director and Non-Director Areas."
H. Horrocks. *(Rochdale).*
"Petrol Engines, with special reference to the Electrical Circuits."
C. Coward. *(Preston).*
"Unit Construction and Maintenance Costs (External) from fundamentals."
T. E. Tootell. *(Preston).*
"Some Notes on the Maintenance of Machine Telegraphs."
E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
F. G. C. Baldwin. *(Northern Centre).*
"The Early Development of Telephonic Switching."

SOUTH LANCS. CENTRE.

1928.
15 Oct. Chairman's Address.
Film—"Wires across the Sea."
12 Nov. H. P. Clyma.
"Automatic Telephony—Trunk and Grading."
10 Dec. H. M. Turner.
"Secondary Cells."
1929.
14 Jan. E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
11 Feb. R. G. DeWardt. *(N.E. Centre).*
"Wireless Beam System."
11 Mar. *To be decided later.*
8 Apl. A. J. Aldridge. *(E.-in-C.O.).*
"Sound Measurement."

NORTH MIDLAND CENTRE.

1928.
Oct. Mr. Thatcher.
"Auxiliary Power Plant Services; Sheffield Auto. Area."
Nov. J. Wyatt.
"Fundamental Lay-out Claims."
Dec. Capt. H. G. Tissington.
"Time Tests and Construction Costs."
1929.
Jan. E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
Feb. R. Towers.
"Skegness Radio Station."
Mar. Mr. Warrand.
"Main and Local Lines. Plans and Records."

SOUTH MIDLAND CENTRE.

1928.
3 Oct. J. E. Taylor, M.I.E.E.
"Chairman's Address."
7 Nov. H. W. Peck.
"Notes and Comments on Records."
5 Dec. F. D. Traviss.
"Secondary Cell Maintenance."
1929.
2 Jan. F. R. Luckham.
"The Training of Youths."
6 Feb. E. J. Woods, A.M.I.E.E. *(E.in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
6 Mar. P. J. Campbell.
"Four Wire Telephone Repeaters and associated Circuits."

NORTH WALES CENTRE.

1928.
10 Oct. Capt. J. Oxon, M.I.E.E
"Secondary Cells."
14 Nov. A. S. Renshaw. *(E.-in-C.O.).*
"Some general considerations relating to the Clerical Organisation of the Engineering Department."
11 Dec. Exhibition of Technical Films, including the film "Voices Across the Sea."
1929.
10 Jan. Capt. Cave-Browne-Cave.
"Modern Views as to the structure of Matter" (with visit to Fordrough Lane, Birmingham Testing Branch and Repair Factory).
6 Feb. E. J. Jarrett.
"Director Working."
27 Feb. E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
19 Mar. E. J. Prichard.
"Telephone Repeaters."

SOUTH WALES CENTRE.

1928.
8 Oct. E. H. Jaynes.
"Photo Telegraphy and Television."
12 Nov. E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
3 Dec. H. C. Gunton. *(E.-in-C.O.).*
"Recent Developments in Power Engineering in the Post Office."
1929.
14 Jan. G. E. J. Jacobs.
"Repeater Station Working."
11 Feb. E. S. Ritter. *(E.-in-C.O.).*
"Picture Telegraphy."
Mar. R. T. Robinson. *(E.-in-C.O.).*
"Motor Transport in the Engineering Department."

SOUTH WESTERN CENTRE.

1928.
9 Oct. Chairman's Address.
Cinematograph Film, "Voices across the Sea."
13 Nov. E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
11 Dec. Messrs. Came and Treglown.
"Automatic Exchange Maintenance."
1929.
9 Jan. I. H. Jenkins. *(E.-in-C.O.).*
"Circuit Design."
12 Feb. J. Radford. *(E.-in-C.O.).*
"Automatic Exchange Design."
12 Mar. R. F. Soper.
"Some Aspects of Trench Restoration with a view to the avoidance of claims for consequential damage."

EASTERN CENTRE.

1928.
11 Sept. Film, "Voices across the Sea," followed by certain slides on Submarine Cables about which Mr. J. F. Lamb will speak.
23 Oct. A. S. Renshaw. *(E.-in-C.O.).*
"Some General Considerations relating to the Organisation of the Engineering Department."
20 Nov. E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
Dec. *Being arranged.*
1929.
Jan. *Being arranged.*
R. J. Hines.
"Some Phases of Automatic Telephony."

Owing to want of space, Scotland East and West and North Ireland Centres have been held over until next issue.

SILVER MEDALISTS, 1926-27.

Mr. J. Innes, Edinburgh.
I.P.O.E.E. Senior Silver Medalist, 1926-27.

Mr. B. Millar, Newcastle-on-Tyne.
I.P.O.E.E. Junior Silver Medalist, 1926-7.

LOCAL CENTRE NOTES.

NORTH MIDLAND DISTRICT.

The promotion of Mr. Gomersall to Deputy Superintending Engineer, London, was made the occasion in the North Midland District of a presentation to him by the Staff of a gold watch, suitably engraved, to mark the appreciation in which he was held. In acknowledging the gift Mr. Gomersall stated that the nine years spent in the District were years of great activity and some difficulty and the success achieved had only been made possible by the zeal which was common to all grades and the friendly co-operation which was shown on all sides. He would always retain the warmest regard for the North Midland District from which he parted with great regret.

BOOK REVIEWS.

Pitman's Technical Dictionary. To be issued in about 36 Parts, each part containing about 64 pp., size $9\frac{3}{4}$ in. by $7\frac{1}{2}$ in.; price 2/6 net. Sir Isaac Pitman & Sons, Ltd., London, W.2.

The complete issue will contain nearly 2,000,000 words, covering engineering and industrial science terms in seven languages: English, French, Spanish, Italian, Portuguese, Russian and German. The dictionary is edited by Ernest Slater, M.I.E.E., M.I.Mech.E. The first part was issued at the end of April, the others to follow fortnightly.

The A.T.M. "Universal" Duplex Unit R 86. The A.T.M. Company has issued a bulletin describing the above unit, which has been designed for fitting on duplex telegraph circuits and provides a means of readily providing terminal apparatus ready for service on practically any length of line. The unit is enclosed in a wooden case, similar in make-up to many wireless cases now on the market, and is completely wired up with spring sets for relay fixing and is fitted with testing facilities for measuring the characteristic resistance, the conductor resistance and the insulation resistance of the line. The set can be used for either Up or Down Station working and two units, side by side, can be quickly utilised by cross-connecting as a duplex repeater.

Strowger Automatic Telephones (Automatic Telephones Co. Bulletin No. 300).

The Automatic Telephone Manufacturing Co. are to be congratulated on this production, which is handsomely bound and combines a delightful colour scheme with interesting reading matter. The Bulletin gives a general description of Strowger working including the Director system. The value of the Bulletin is enhanced by the inclusion of a list of some of the Public Exchanges throughout the world using Strowger equipment, and it is extremely informative.

The illustration of the Holborn Exchange equipment will be of immediate interest to readers of the Journal. It is interesting to note that there are over four million Strowger Automatic Telephones installed or under construction throughout the world.

We have received from the Weidmannsche Buckhandlung Co., of Berlin, the following:—

(*a*) "Zur Theorie des Fernsprechrerkehrs." By K. Frei.

(*b*) "Die Ausbreitung der Elektromagnetishen Wellen." By Dr. Alfred Sacklowski.

(*c*) "French-German Dictionary for Long Distance Telephone Traffic." By Albert Lang.

These are volumes I., II. and III. respectively of a series of short treatises on various phases of the electrical industry of which the general editor is F. Moench.

(*a*) This is a book on telephone traffic and treats the matter, of course, from a theoretical standpoint, and from this point of view goes back to first principle. Besides dealing with the theories most favoured in Germany, the author includes criticisms of workers of other countries. Besides the ordinary telephone traffic problems he includes chapters on waiting times as experienced with such systems as the Western Electric rotary and also with the distribution of call durations.

(*b*) This book is a review of existing literature on the propagation of electro magnetic waves.

At the end, a bibliography with 474 entries is given and many of these are referred to in the text.

(*c*) This dictionary being only in French and German is of comparatively little direct interest in this country. It does, however, appear to give very completely, both in French-German and German-French the main terms used in telephone transmission.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	Grade.	Promoted to	Date.
Terras, J. S.	Asst. Suptg. Engineer, N.W. Dist.	Suptg. Engineer, S. Wales District.	15-8-28
Bullock, A. H.	Executive Engineer, Leicester Section, N.Mid. District.	Assistant Suptg. Engineer, N. Mid. District.	19-8-28
Alexander, R.	Executive Engineer, Edinburgh Inner Section, Scot. E. Dist.	Assistant Suptg. Ennginecr, N.E. District.	30-8-28
Baxter, J.	Executive Engineer, Hereford Section, S. Wales District.	Assistant Suptg. Engineer, S.W. Dist.	4-9-28
Halton, R.	Executive Engineer, Technical Section, S. Mid. District.	Assistant Staff Engineer. Lines Section, E.-in-C.-O.	31-8-28
Pink, E. A.	Executive Engineer. Bristol Section, S.W. Dist.	Assistant Staff Engineer, Construction Section, E.-in-C.O.	To be fixed later.
Statters, J. E.	Executive Engineer, Lines Section, E-in-C.O.	Assistant Staff Engineer, Lines Section, E.-in-C.O.	1-11-28
Lucas, J. G.	Executive Engineer, Telephone Section, E-in-C.O.	Assistant Staff Engineer, Telephone Section, E.-in-C.O.	1-8-28
Reid, Capt. F., M.C.	Executive Engineer, Designs. Section, E-in-C.O.	Assistant Staff Engineer, Designs Section, E.-in-C.O.	1-12-28
Cruickshank, W.	Executive Engineer, Research Section, E-in-C.O.	Assistant Staff Engineer, Research Section, E.-in-C.O.	1-8-28
Hansford, R. V., D.Sc.	Executive Engineer, Radio Section, E-in-C.O.	Assistant Staff Engineer, Radio Section, E.-in-C.O.	1-8-28
Dolton, W.	Assistant Engineer, Technical Section, London District.	Executive Engineer, Technical Section, London District.	1-8-28
Ryder, W. V.	Assistant Engineer, Lincoln Section, N.E. District.	Executive Engineer, Headquarters to be fixed later.	26-8-28
Mitton, F. E.	Assistant Engineer, Centre External Section, London Dist.	Executive Engineer, North West External Section London District.	1-8-28
Pratt, A. J.	Assistant Engineer, Technical Section, S. Lancs. District.	Executive Engineer Technical Section, N. Wales District.	To be fixed later.
Dunthorne, H. R. J.	Assistant Engineer, Technical Section, N. District.	Executive Engineer, Hereford Sectn., S. Wales District.	To be fixed later.
Deane, W.	Assistant Engineer, City Internal Section, London District.	Executive Engineer, Leicester Section, N. Mid. District.	19-8-28
Peacock, C. T.	Assistant Engineer, Designs Section, E-in-C.O.	Executive Engineer, Designs Section, E.-in-C.O.	1-8-28
Harding, R. W.	Assistant Engineer, Lines Section, E-in-C.O.	Executive Engineer, Technical Section, S. Mid. District.	To be fixed later.
Plymen, H. S.	Assistant Engineer, Telephone Section, E-in-C.O.	Executive Engineer, Lines Section, E.-in-C.O.	1-11-28
Scott, W. D.	Assistant Engineer, Telephone Section, E.-in-C.O.	Executive Engineer, Telephone Section, E.-in-C..O	1-8-28
Carter, Major H.	Assist. Engineer, Construction Section, E-in-C.O.	Executive Engineer, Construction Section, E.-in-C.O.	1-8-28
Struthers, G. A.	Assistant Engineer, Radio Section, E-in-C.O.	Executive Engineer, Bodmin Radio.	18-8-28
Walmsley, T.	Assistant Engineer, Radio Section, E-in-C.O.	Executive Engineer, Radio Section, E.-in-C.O.	1-8-28
Smith, Albert	S.W.I., Testing Bch.	Inspector, Testing Bch.	6-4-28
Smith, Arthur, ...	S.W.I., Testing Bch.	Inspector, Testing Bch.	5-8-28
Noble, J.	S.W.I., Scotland West.	Inspector, Scot. West.	16-4-28
Burn, T.	S.W.I., Scotland West.	Inspector, Scot. West.	To be fixed later.
Thomson, J.	S.W.I., Scotland West.	Inspector, Scot. West.	25-8-28

RETIREMENTS.

Name.	Districts.	Grade.	Date.
Brien, J. G.	Executive Engineer.	E.-in-C.O.	30-6-28
Allen, F. J.	,,	E.-in-C.O.	30-6-28
Wood, A. H.	,,	E.-in-C.O.	30-7-28
Morris, A. C.	Assistant Engineer.	N. Mid. District.	1-6-28
Copeland, F. H.	,,	S. Wales District.	25-6-28
Broomhead, H. H.	,,	N. Ireland District.	20-8-28
Bradshaw, A. R.	Inspector.	N. Wales District (resgd.)	1-8-28
Folkard, G. F.	,,	Ldn. Engineering Dist. (resgd.)	8-8-28
Tandy, F.	Suptg. Engineer,	S.E. District.	31-7-28
Wilson, H.	,,	S. Wales District.	31-7-28

DEATHS.

Name.	District.	Grade.	Date.
Sunderland, M.	N.W. District.	Inspector.	9-8-28

TRANSFERS

Name.	Rank.	From	To	Date.
Mathew, K. R.	Inspector.	Scot. E. District.	Scot. West District.	3-6-28
Hall, H.	,,	,,	,,	3-6-28
Michaelsen, G. E. F.	,,	S. Lancs.	S. West District.	17-6-28

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	Rank.	Promoted to.	Date.
Hardham, H. A.	Staff Officer, E.-in-C.O.	Principal Clerk, E.-in-C.O.	1-7-28
Oldfield, G.	Acting Staff Officer, E.-in-C.O.	Staff Officer, E.-in-C.O.	17-7-28
Ramsay, J.	Executive Officer, E.-in-C.O.	Acting Staff Officer, E.-in-C.O.	17-7-28

OTHER CHANGES.

Name.	Grade.	Cause.	Date
Boddington, M.F.G.	Principal Clerk, E.-in-C.O.	Retirement.	30-6-28
Jelf, F. H.	Higher Clerical Officer, London.	Death.	13-6-28

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	(1) The Design of an Automatic Telephone System	H. A. Langley.
	(2) Ventilation and Humidity ...	C. A. Maggs.
	(3) Efficiency methods in relation to Emergencies	S. H. Johnson.
	(4) The Alternating Current Bridge	F. W. G. Dye.
	(5) The Cadmium Electrode ...	H. W. Satterthwaite
	(6) Coder Call Equipment in practice	A. J. Allison.
	(7) Automatic Dials and relevant details of Auto. Exchange Apparatus	R. N. Renton.
	(8) The Training of Youths ...	N. V. Knight.
	(9) The evolution of the Thermionic Valve and its application to modern Telephony	F. V. Padgham.
	(10) Development Studies	E. S. Davies.
	Electrical Safety Code	Bureau of Standards, U.S. Dept. of Commerce.
875	Textbook of Telegraphy	A. E. Stone.