THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

VOL. 15
PART 1

APRIL 1922

Price 2/- net.

ADVERTISEMENT INDEX
see page xii.

The Post Office Electrical Engineers' Journal.

A QUARTERLY JOURNAL.

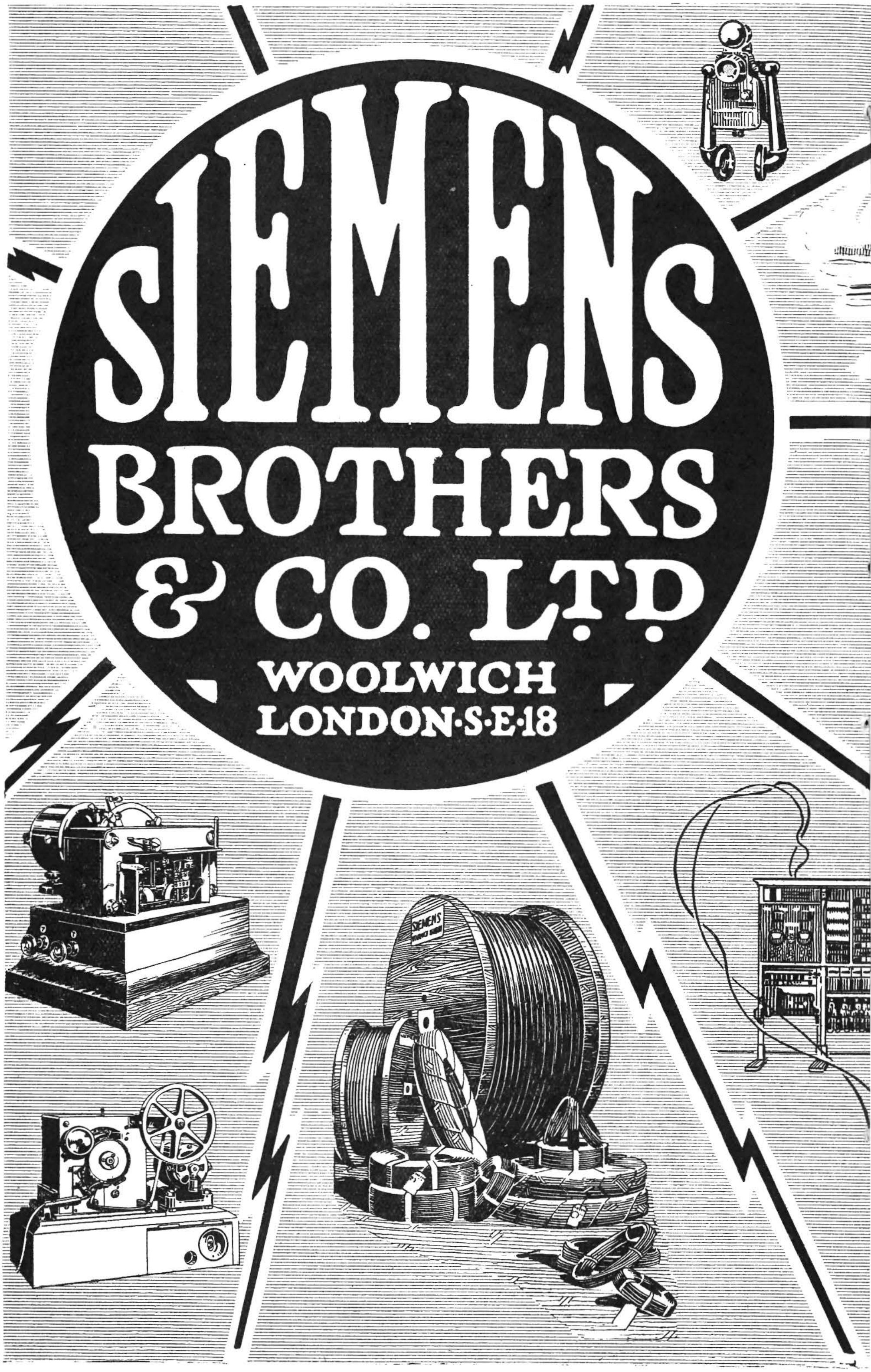
CONTENTS FOR APRIL, 1922.

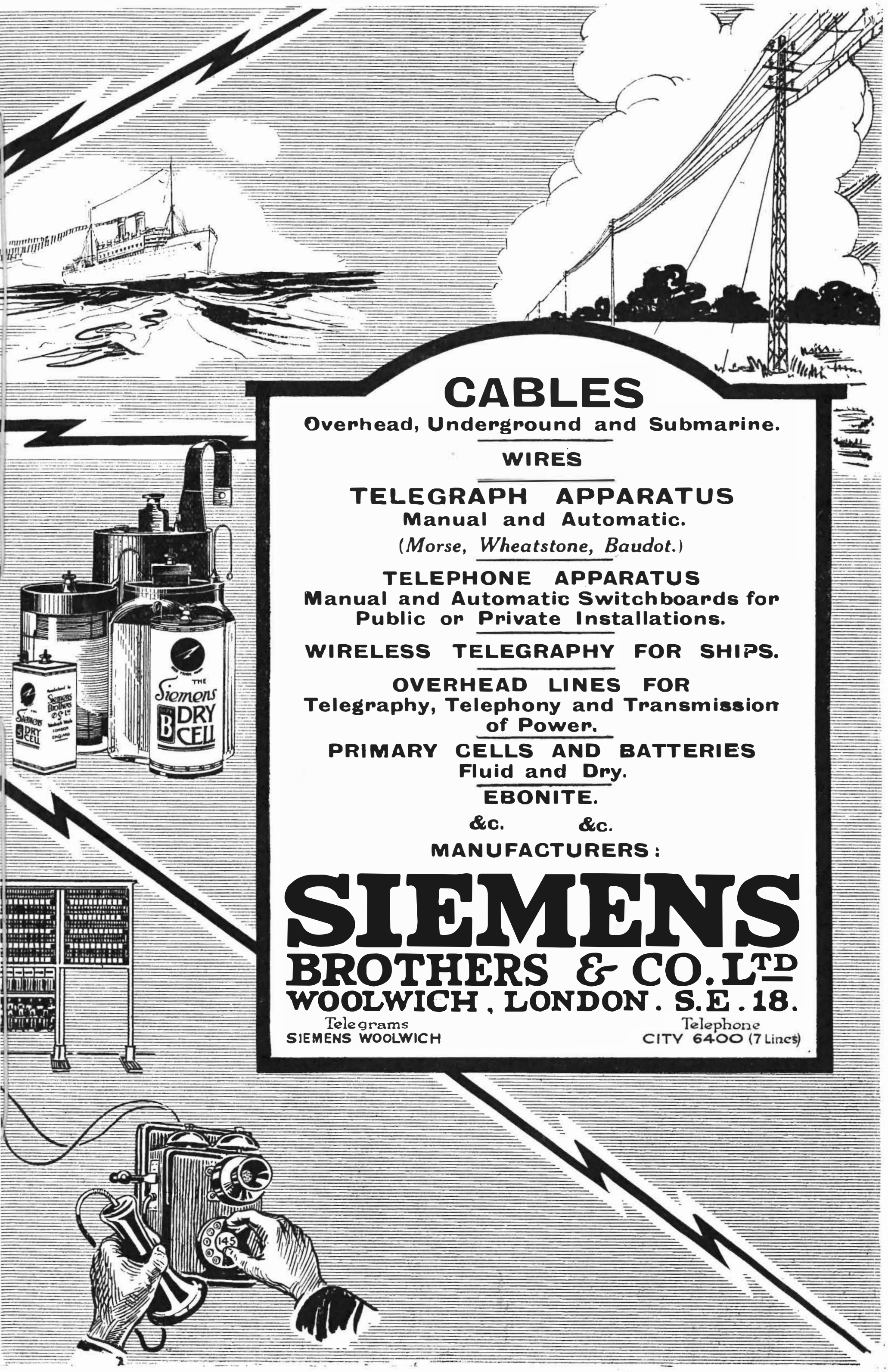
PUBLISHERS:

THE ELECTRICAL REVIEW, LTD., 4, LUDGATE HILL, E.C.

Price 2/- net, post free, 2/3. | Annual Subscription, postage inclusive, 9/-, payable in advance.

Editorial Communications see page 104.


SIEMENS
BROTHERS
& CO. LTD
WOOLWICH
LONDON·S·E·18


CABLES
Overhead, Underground and Submarine.
WIRES
TELEGRAPH APPARATUS
Manual and Automatic.
(Morse, Wheatstone, Baudot.)
TELEPHONE APPARATUS
Manual and Automatic Switchboards for Public or Private Installations.
WIRELESS TELEGRAPHY FOR SHIPS.
OVERHEAD LINES FOR
Telegraphy, Telephony and Transmission of Power.
PRIMARY CELLS AND BATTERIES
Fluid and Dry.
EBONITE.
&c. &c.
MANUFACTURERS:
SIEMENS
BROTHERS & CO. LTD
WOOLWICH, LONDON. S.E. 18.
Telegrams
SIEMENS WOOLWICH
Telephone
CITY 6400 (7 Lines)
THE
Siemens
DRY
B
CELL

"RELAY" AUTOMATIC TELEPHONE SYSTEM

SPEEDY SECRET SIMPLE INFALLIBLE

"Relay" Apparatus.

The apparatus used in the "Relay" System consists of relays of a type well known in manual practice, modified to make the coils and spring banks removable, thus minimising the stock of spare parts necessary for maintenance purposes. The coil tabs are of novel construction, very robust and cannot become loose due to heating whilst being soldered.

All fibre has been eliminated, mica being generally used for insulation the "Relay" System being thus eminently suited for trying climatic conditions.

Although the current values used in the "Relay" System are naturally much less than those used in Switch Systems and therefore sparking at the contacts is also less, yet each relay is wound so that the excitation is sufficient to permit of contacts—whether making or breaking—having a pressure of at least 1¼ ozs. (35 grammes).

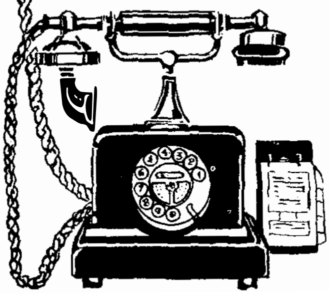
Attention has been paid to the circuit arrangements so that the operations are cyclic and function with certainty and rapidity.

All operations equivalent to hunting, impulse stepping, etc., are performed much more quickly than is possible with mechanical switching gear, as relays have no perceptible mechanical inertia.

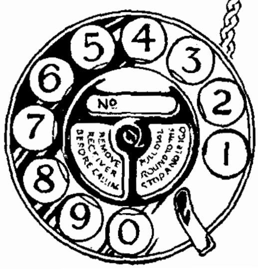
Send for Booklet No. 11.

We shall be pleased to arrange appointments for Telephone Engineers to inspect the "Relay" System in operation at Marconi House.

THE RELAY AUTOMATIC TELEPHONE CO., LTD.



MARCONI HOUSE,
STRAND,
LONDON,
W. C. 2.



THE
Post Office Electrical Engineers' Journal

COMPOSITE TELEGRAPHY AND TELEPHONY.

By J. H. BELL,
Western Electric Company (at one time Secretary I.P.O.E.E.)

A BRIEF description of the "composite" method of operating telegraph and telephone circuits as used on open wires and large gauge cables in the United States may be of interest to readers of the "Post Office Electrical Engineers' Journal."

Two telegraph circuits and one telephone circuit are obtained over one pair of wires by the use of a "composite set" at each end of the pair, which separates the comparatively low frequencies of the telegraph from the higher frequencies of the telephone. Such a circuit is termed a "composite circuit."

Composite Set.

A "composite set" is in effect two frequency filters and comprises inductance coils and condensers as shown in Fig. **1**.

The inductance coils A and B act as choke coils to the telephone frequencies and prevent the telegraph sets and condensers C and D from becoming shunt circuits across the telephone circuit. These inductances A and B together with their associated condensers C and D act as filter circuits for the outgoing telegraph signals, permitting frequencies from zero to about 80 cycles per second to pass to line, and suppressing higher frequencies. With the simple type of network forming the "composite set" it is of course impossible to effect a very sharp cut-off. If a curve were plotted to show the relation between frequency and attenuation it would be found that the knee of the curve occurs at about 80 cycle frequency.

The condensers E and F act as high impedances to the low frequency telegraph impulses. Enfeebled telegraph impulses which pass through these condensers are drained off to ground through condensers G and H and inductances J and K. Consequently, the " composite set " protects the telephone from interfer-

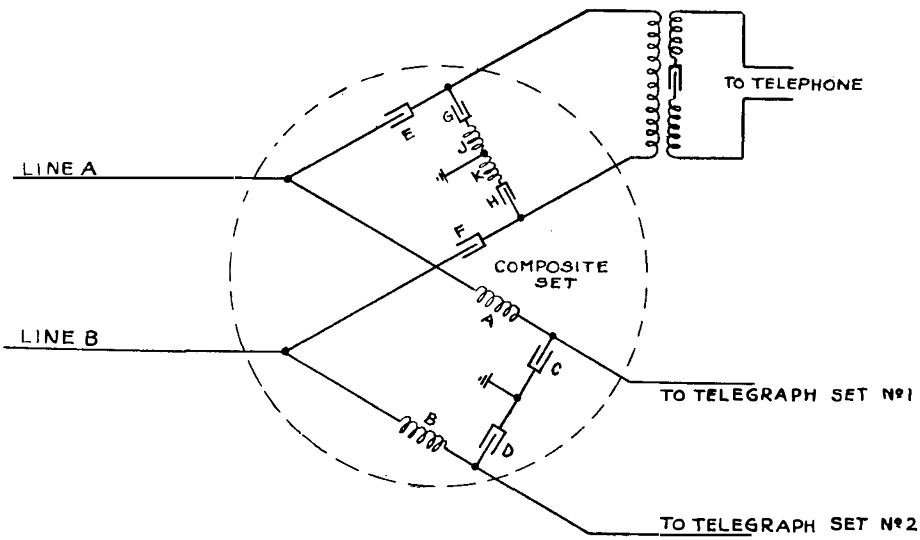


FIG. 1.

ence by the telegraph impulses, first by shutting out practically all the telegraph impulses, second, by providing a drainage path for that portion of the telegraph impulses not so suppressed.

Telegraph Signals.

The ideal wave shape for telegraph signals is that shown in Fig. **2**, in which an initial surge is provided to actuate the relay,

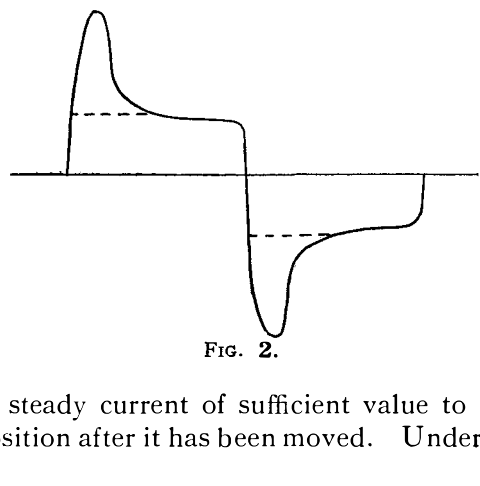


FIG. **2**.

followed by a steady current of sufficient value to hold the relay armature in position after it has been moved. Under certain circuit conditions means can be provided at the receiving end of a circuit to modify the wave shape of the signals to simulate this formation.

Without the initial surge, this formation is termed a "square wave." A square wave is built up of a sine wave and its third, fifth, seventh, ninth, eleventh, etc., harmonics. Fig. **3** shows a fundamental sine wave, its third, fifth, seventh, and ninth harmonics; also a sine wave plus third and fifth harmonics and a sine wave plus third, fifth, seventh, and ninth harmonics. As the number of harmonics of a wave is increased the more nearly does its shape approach square formation. If transmission takes place at the rate of 15 cycles per second, which is the frequency of fast hand sending by the Morse system, and coils and condensers are inserted in the circuit to suppress frequencies above 80 cycles per second, the shape of the wave will be that of a sine

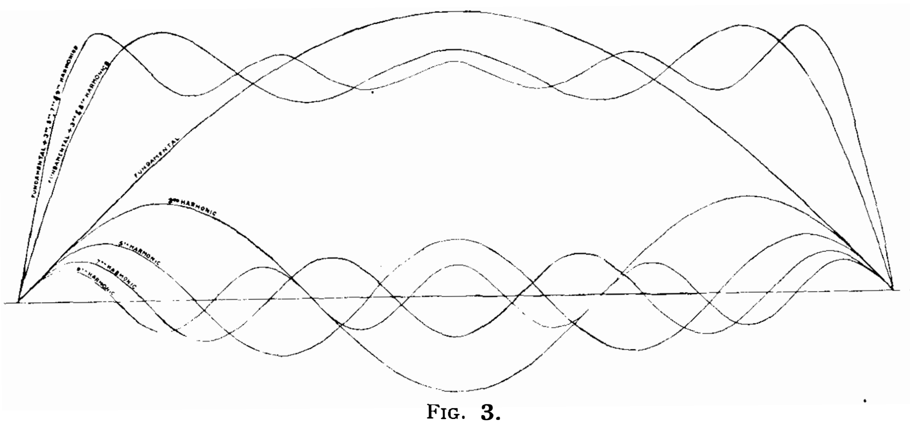


FIG. **3.**

wave plus its third and fifth harmonics (45 cycles and 75 cycles), assuming it is not modified by factors of the circuit other than the composite set.

If the speed of working be increased to 25 cycles per second the wave shape at the receiving station will be that of a sine wave plus its third harmonic only. If the speed of transmission be reduced to 10 cycles per second the third, fifth and seventh harmonics will pass to the line and the wave shape at the receiving relay will be improved.

Types of Telegraph Systems.

Either the "closed circuit" or the "double current" system may be used on "composite" telegraph circuits. "Open circuit" working is not practicable because of the condenser discharge which takes place at both sending and receiving ends when the key is raised and the line is connected to ground.

In "closed circuit" working with 120 volt battery the neutral relay used is one having a resistance of not less than 100 ohms, and two such relays or their equivalent are required to modify the wave shape by suppressing the higher harmonics, before the signals reach the composite set, Fig. 4.

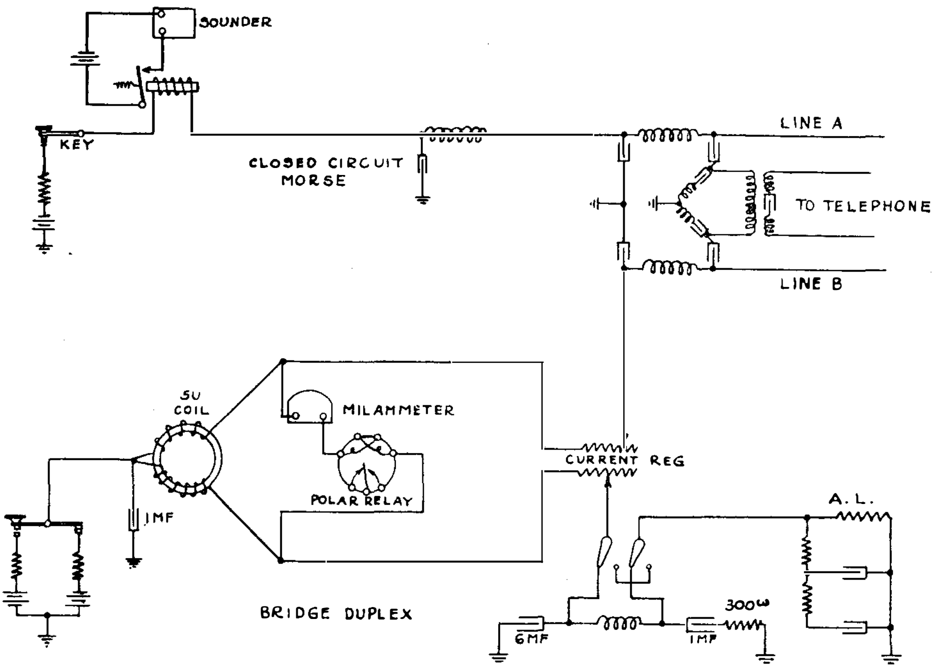


FIG. 4.

In bridge duplex working, modification of the wave shape is effected by a special coil (5-U) used as the bridge arms, Fig. 4. The magnetic leakage between the two arms of the coil introduces a small inductance to outgoing signals. In the differential duplex system the relay winding impedance is so small that a coil, and a condenser tapped to ground are inserted between the transmitter and the apex as shown in Fig. 5.

To obtain a duplex balance on a composited telegraph circuit it is necessary to place ahead of the artificial line a coil and two condensers tapped to the ground, one on either side of the coil to balance the coil and condensers in the "composite set." If provision be made for switching this coil and condensers into and out of the circuit, as shown in Fig. 4 and Fig. 5, the set is made more flexible because it can be used on a composited or a non-composited line.

Telegraph Line Currents.

For satisfactory operation of open wires the line current is limited to 70 milliamperes for duplex and 60 milliamperes for closed circuit Morse when the batteries at the terminal stations are aiding. Line current not to exceed 50 or 55 milliamperes is recommended for land line cable circuits. For loaded lines it is particularly desirable that these current values be not exceeded and that a specific type of loading coil be used, otherwise " Morse flutter " is produced in the telephone circuit. " Morse flutter " is the term applied to a condition in which the volume and quality of the telephonic transmission varies at each impulse of the telegraph, and it is produced by variations in the effective resistance of the loading coils resulting from the flow of current from the telegraph.

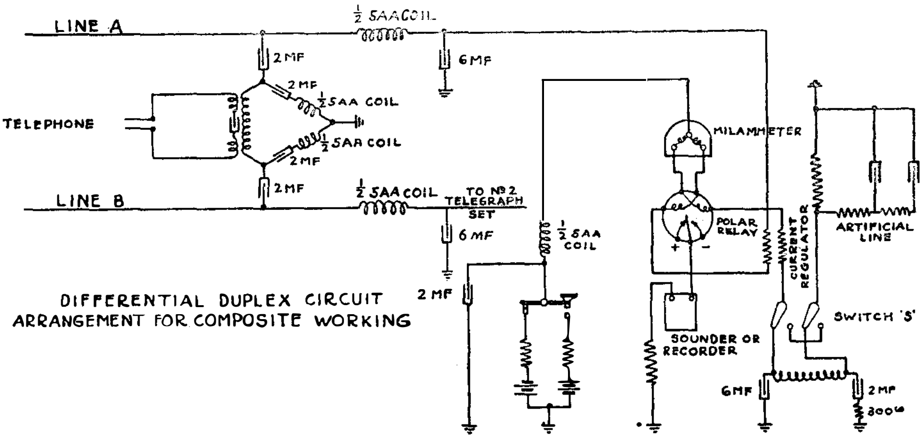


Fig. **5**.

To prevent permanent injury to the best type of loading coils provision should be made to limit the line currents under all conditions to a maximum of 200 milliamperes.

At offices where storage batteries are used as a source of supply for line current, and only two or three voltages are available, the strength of the line current may be kept within the limits specified above by inserting adjustable resistances of equal value in the line and artificial line circuits, as shown in Fig. **4** and Fig. **5**.

Possible Speed of Transmission over Composited Telegraph Circuits.

With a " composite " set designed to suppress all frequencies above 80 cycles an operating speed of about 40 cycles per second could probably be obtained with polar simplex apparatus on a comparatively short line, provided the line is not subject to heavy leakage or inductive interference. This method of operation, however, is not used in America. Under duplex conditions the rounded shape of the received signals introduces a brief interval at the moment of current reversal when little or no incoming current is passing through the line relay, leaving it free to be influenced by inductive disturbances or by any inequality existing between the current passing out to the line and current passing to the artificial line, that is, to a condition of duplex unbalance.

Fig. 6 shows how this interval varies with the wave formation. Assume the lines X and Y represent the values of positive and negative current required to actuate a polar relay. Obviously

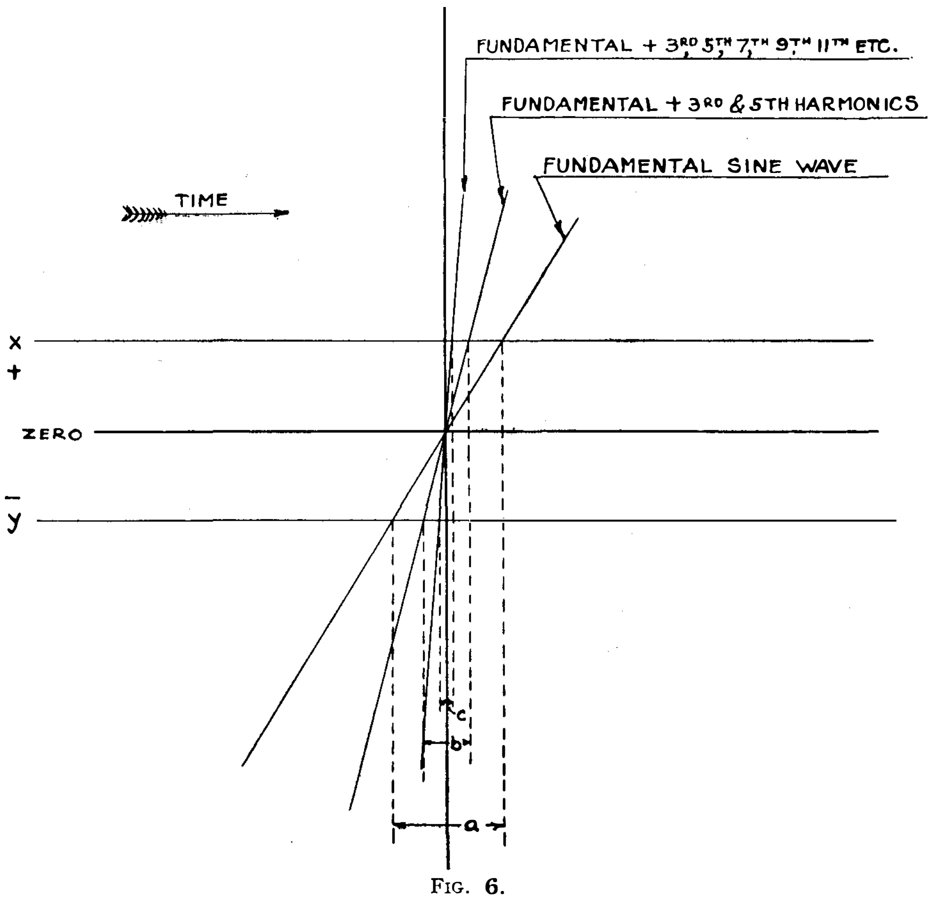


FIG. 6.

whilst the current is passing from X to Y or Y to X, only a slight increase or reduction in its strength, due to inductive interference or to duplex unbalance, will change the point where the current wave crosses lines X or Y. Consequently, actuation of the relay will take place ahead of time or will be delayed, with the result that the space impulse is made longer and the marking impulse is made shorter, or *vice versa*. The figure shows that with impulses approaching sine wave formation the time during which such distortion can take place, as at *a*, is much greater than when the wave approximates square formation, as at *b* and *c*. It has been shown that, as the speed of transmission is reduced, the number of harmonics is increased and the wave front becomes more abrupt, so that the relay is susceptible to inductive interference for a shorter interval. Further, a reduction in speed means that each dot impulse occupies more time, with the result that the distortion which has already been reduced by improved wave formation becomes a still smaller percentage of a dot impulse.

Although a satisfactory duplex balance may be obtained at the start of a day's work, it must be recognised that aerial lines are subject to variations in ohmic resistance due to temperature and insulation changes, and in a less degree to variations in electro-static capacity due to insulation changes. Consequently, it is inadvisable to spend much time in obtaining an accurate balance which may be upset by a change in weather conditions within an hour or two. With the approximate balances used in every day service, speeds of about 20 cycles per second in each direction can be maintained over duplex composited telegraph circuits.

Telephone Signalling over Composited Circuits.

When a telephone circuit is equipped with "composite sets" the usual $16\frac{2}{3}$ cycles ringing current must be substituted by ringing current of a higher frequency, which will not interfere with the telegraph signals. A frequency of 135 cycles has been chosen.

Where only one or two telephone circuits in an office are composited some form of "howler" may be used, but if a number of circuits are to be composited it is preferable to use composite ringer sets. These sets are adapted to connect with the $16\frac{2}{3}$ cycles ringing current circuit without change at the telephone switchboard.

Howler Signalling. Fig. 7.

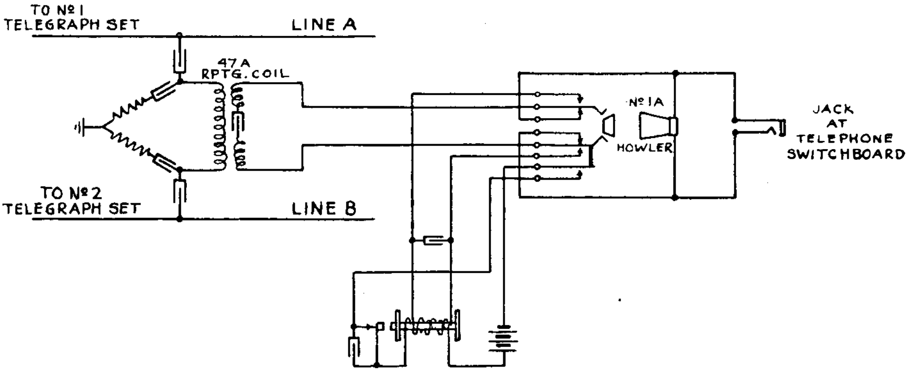
The "howler" consists of a high resistance telephone receiver equipped with a horn which gives audible signalling. For transmitting a #5 induction coil with interrupter is used with an 8 volt battery. This combination sets up signals at a frequency of about 150 cycles per second when the special #92-A key is depressed. At the same time the circuit to the "howler" and the telephone at the home station is disconnected. The signals pass through two windings of the #47-A repeating coil which acts as a transformer, the other two windings being connected to the line.

At the other end of the line the howler impulses pass through the line windings of the #47-A coil, which repeats them to the "howler."

Composite Ringer Signalling.

A composite ringer set comprises a #100-B interrupter which sets up reversals at a frequency of 135 cycles per second, a #150-B relay which is tuned to this frequency, and a group of switching relays, as shown in Fig **8**.

The composite ringer is connected to terminals 2 and 5 of the #47-A repeating coil. When the plug is inserted in the jack at the telephone switchboard and the 16⅔ cycle ringing key is actuated a path is provided for this ringing current as follows:—Tip of jack at switchboard, upper armature and back contact of #178-R relay, winding 1-2 of #68-C retard coil, #33-C condenser, relay #118 B.F. (specially designed for 16⅔ cycles), winding 3-4 of #68-C



Nº 5 INDUCTION COIL
WITH INTERRUPTER ATTACHED

FIG. **7**.

retard coil, back contact and lower armature of #178-R relay, to sleeve spring of jack at switchboard. Actuation of the #118 B.F. relay puts a ground connection on one side of relays #178-S and #178-T, both of which are energised. The left armature of the #178-T relay puts ground on one side of the input circuit of the #100-B interrupter, which sends out 135 cycles. The two armatures of the #178-S relay connect two terminals of the output side of the interrupter to the #47-A repeating coil, which repeats the 135 cycle ringing current over the line.

Relay #149-T is normally energised, the circuit through its winding being completed by the ground connection on the armature of the #150-B relay. Although the circuit through the #150-B is tuned to 135 cycles there is a possibility of this relay opening the ground connection of the relay #149-T by being momentarily actuated by the $16\frac{2}{3}$ cycle current. As safeguard against this ground connection being broken, and relay #419-T becoming de-energised, the right armature of the #178-T relay, when actuated, provides an alternative ground path.

The incoming 135 cycles current is repeated by the #47-A repeating coil, and it finds a path from terminal 5 *via* the upper armature and back contact of the #178-S relay, winding 1-2 of the #68-C retard coil, the #150-B relay, causing it to be actuated,

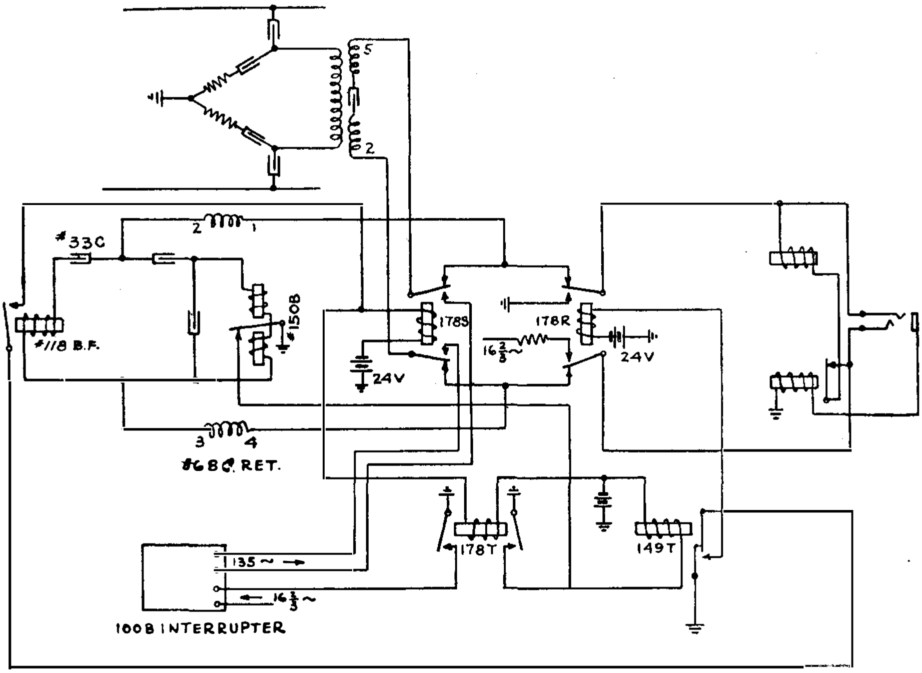


FIG. 8.

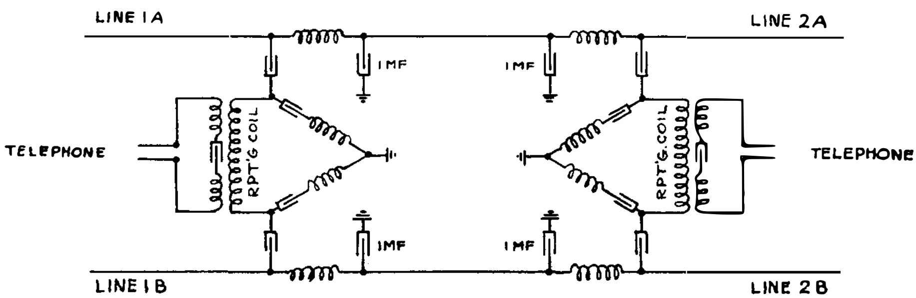
winding 3-4 of the #68-C retard coil, back contact and lower armature of the #178-S relay, to terminal 2 of the #47-A repeating coil. Actuation of #150-B relay removes the ground from the circuit through relay #149-T which becomes de-energised. When the armature of this relay falls back it connects a ground to the circuit of relay #178-R, which becomes energised. When the armatures of this relay are pulled up they connect ground to one side of the telephone circuit, and $16\frac{2}{3}$ cycle to the other, so that the usual $16\frac{2}{3}$ cycle signalling apparatus is actuated.

Losses in Telephone Transmission Efficiency due to "Compositing."

The addition of "composite" sets results in a slight loss in the transmission efficiency of a telephone circuit, the exact amount of the loss being dependent upon the type of circuit. On a non-loaded pair the loss resulting from the addition of terminal composite sets of the type described should be about one mile of standard #19 B and S gauge cable.

If the two non-loaded telephone pairs used to provide a phantom telephone circuit are composited the loss in the phantom circuit due to the "composite" sets will be about 1.5 miles of standard cable and on the physical pairs about one mile on each. On loaded circuits the transmission efficiency loss is considerably less than in non-loaded circuits and may be as low as one-tenth of one mile of standard cable.

The use of composite ringers and howlers also results in loss in the transmission efficiency of the telephone circuit. The composite ringer set causes a loss of approximately one-tenth of one mile of standard cable, and the howler about one half to one mile of standard cable.



INTERMEDIATE "COMPOSITE SETS" PROVIDING FOR "THRU" TELEGRAPH CIRCUITS BY MEANS OF TWO SEPARATE TELEPHONE CIRCUITS.

Fig. 9.

Intermediate Composite Sets.

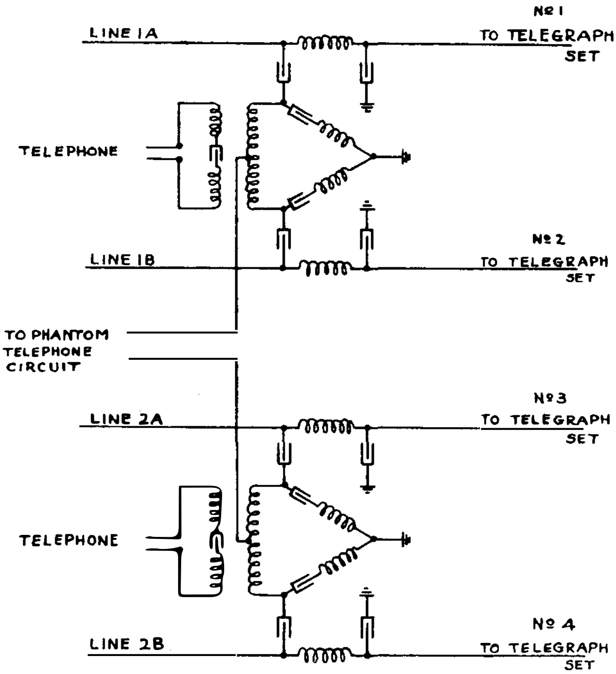
It is possible to provide telegraph circuits by linking together two or more telephone circuits through the low frequency filters of intermediate composite sets, as shown in Fig. 9. The intermediate composite set is identical with the terminal composite set except that 1 mf. condensers instead of 6 mf. condensers are used as taps to ground on the telegraph branches.

To maintain an electrical balance between the A and B wires of a composited telephone pair it is essential that the condensers teed to ground on the telegraph branches shall be of the same value. Consequently, both telegraph circuits connected to the intermediate composite set must be "through" circuits.

The inductive resistances in the telegraph branches effectively separate the telephone circuits so that there is no mutual interference between them.

Phantom Telephone Circuits.

Composite sets do not interfere with the operation of phantom telephone circuits. The arrangement is shown in Fig. **10**. To prevent an unbalanced condition of the phantom circuit it is necessary to equip both the physical circuits with composite sets although only one circuit may be required for telegraph purposes. Further, to maintain a balance between the two physical circuits, the



COMBINED COMPOSITE & PHANTOM CIRCUITS

FIG. 10.

condensers in the telephone branches are specially selected to avoid wide variations in their capacity, and the two windings of each 5-AA coil are distributed about the core so as to provide as nearly as practicable an electrically balanced coil. The possible tendency to unbalance the circuit by differences in impedance between the telegraph circuits which may be connected to the telegraph branches is overcome by the grounded condensers connected to these branches. These condensers serve to maintain the impedance of the telegraph branches to the telephone currents at practically a constant value, regardless of differences in the condition of the telegraph circuits which may be connected to the two branches.

Methods of Mounting Composite Sets and Composite Ringers.

In offices where a number of circuits are composited the most economical arrangement is to mount the various condensers, coil and relays forming composite sets and composite ringers on racks, connections being made by means of suitable cabling through a distributing frame to the switchboard. Composite sets and composite ringers can then be readily transferred at the distributing frame from one circuit to another. For small or temporary installations portable sets are provided. Each portable set is equipped with marked terminals so that it may be connected in a circuit in little time.

It will be seen that "compositing" is a method of utilizing the lower frequencies for telegraph purposes and the higher frequencies for telephone signalling and telephone speech over the same pair of wires, and that by changing the electrical characteristics of the "composite set," so as to change the frequency range allotted to each system, transmission by telegraph can be improved at the cost of greater loss in the telephone or telephone transmission can be improved at the cost of reduced speed of telegraph transmission. The present "composite set" has been found to provide the most satisfactory compromise between the two systems.

Number and Mileage of Composited Circuits.

There are at the present time about 700,000 miles of telegraph circuits in use by the Bell Telephone System. Approximately 90 per cent. of these circuits are derived from telephone circuits by the composite method described. The remaining 10 per cent. are derived from telephone circuits by superimposed and special composite methods. Most telegraph circuits have a number of offices or stations in circuit. Altogether there are about 1000 circuits and 4500 stations, giving an average of 4.5 stations per circuit. The average length per circuit is 700 miles. Many circuits, particularly those used for "news" distribution service extend over a wide territory, the various sections being interlinked by means of straight and forked repeaters. The greatest mileage in one circuit is 4100. There are 17 repeaters in this circuit. The largest number of repeaters in one circuit is 22 The mileage of this circuit is 3440. The greatest geographical distance between the terminals of any one circuit is approximately 3200 miles.

BAUDOT DISTRIBUTOR.

Correction of Speed by Control of Vibrating Reed.

A. E. STONE, A.R.C.Sc. AND E. A. LAKEY, A.M.I.E.E.

A METHOD of maintaining unison between two multiplex distributors is referred to in an article entitled, "Automatic signalling over superposed, relayed, and long distance cables," by Messrs. King and Barnes, in Vol. 14, Part I. (April, 1921) of this Journal.

The arrangement described therein has been modified to meet the requirements for Baudot working. The system has been in service for some months on several Duplex Baudot circuits in the Central Telegraph Office; and, as the results have proved satisfactory, its use is being extended.

The distributor used is of the phonic wheel type, in which the brush arms are caused to rotate by the magnetic action of currents passed alternately through two electro-magnets so placed that their pole-pieces act on the teeth of a mild steel wheel fitted on the axle carrying the brush arms. The circuits of these currents are alternately completed by means of a vibrating reed, see Fig. **1**, which shows the Standard connections for the Phonic Wheel Distributor and Vibrator adopted by the Post Office.

The speed of the phonic wheel depends solely on the rate of vibration of the reed; and if the latter be constant, the phonic wheel will rotate uniformly, the construction of the wheel being such as to damp out any tendency towards small fluctuations of speed. The rate of vibration of the reed is adjusted by altering the position of weights fixed on the reed by clamping screws.

Fig. **2** shows the method of correction by control of the driving reed at the corrected station. A small electro-magnet is placed near the free end of the reed of the vibrator in such a position that when the electro-magnet is energised by current the effect of the magnetic field set up causes a slight increase in the rate of vibration of the reed.

The correction as applied simply consists in the making and breaking of the circuit of the current through this controlling electro-magnet, with the result that when current is passing through the electro-magnet the speed of rotation of the brush arms is slightly increased.

The correcting contact on the receiving ring consists of two segments, and the connections from these to the Correcting Relay are so arranged that the correcting currents from the line relay will pass through the Correcting Relay, either in a " spacing " or a " marking " direction, depending on the segment of the correcting

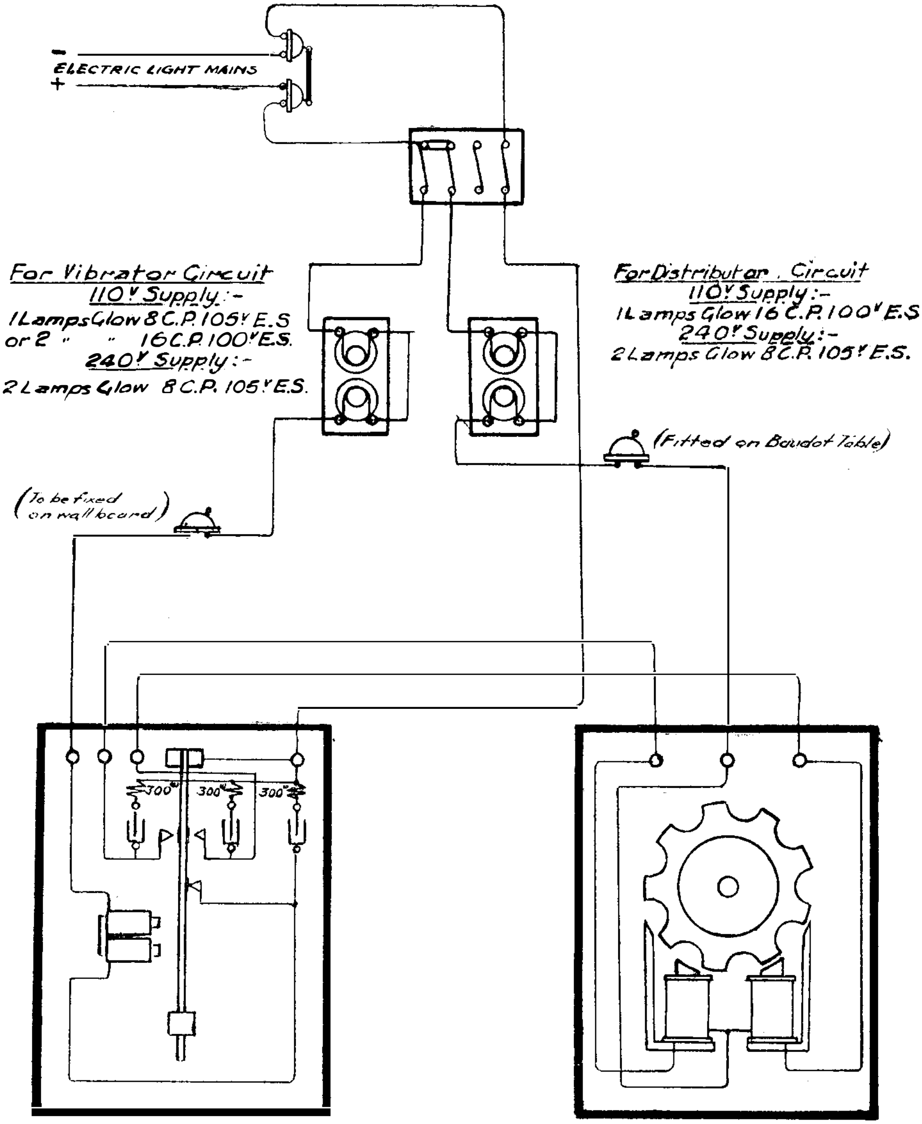


FIG. 1.

contact over which the receiving brush is passing at the moment. The Correcting Relay is adjusted with the contacts fairly wide, so that the tongue will remain firmly on either the " spacing " or the " marking " contact according to the direction of the current actuating the relay. The speed at the correcting station is first adjusted so that when no current is passing through the controlling

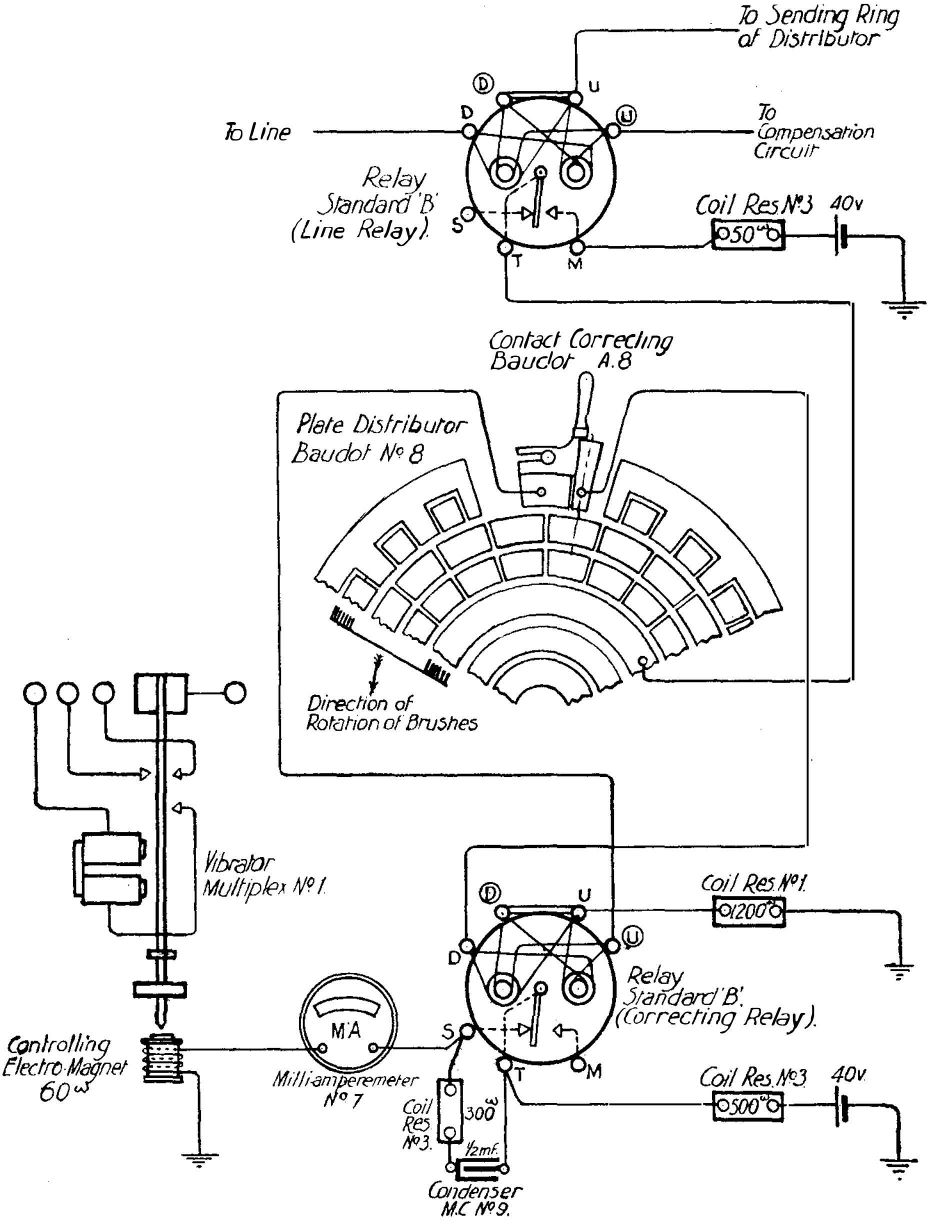


Fig. 2.

electro-magnet the speed is " slow " compared with that of the correcting station, but when the controlling electro-magnet is energised the relative speed is " fast."

As long as the phase of the brushes at the corrected station is behind that of the brushes of the correcting station the correction currents will pass in a spacing direction through the Correcting Relay, with the result that the path of the current through the controlling electro-magnet is completed, and the speed of rotation of the brush arms is therefore increased. The position of the correcting contact is such that, immediately the correcting current is picked up by the receiving brush in advance of the "point de repère," the correcting current passes through the Correcting Relay in a marking direction, the tongue of which therefore passes to the marking contact. The circuit through the controlling electro-magnet is disconnected immediately the tongue leaves the spacing contact, and the cessation of the accelerating force on the reed results in a slight reduction of the speed of rotation of the brush arms. A phase relationship suitable for working purposes is thus secured between the brushes of the two distributors. Indication of correction is given by the movements of the pointer of a milliammeter which is placed in the circuit of the controlling electro-magnet.

This method of control simplifies the construction of the distributor as the epicyclic gearing required for the original Baudot method of correction is dispensed with.

Other methods of correction have been tried with a certain measure of success; as, for instance, the introduction of resistance as a shunt on the driving coil of the vibrator by means of the correcting relay; in that case, however, it becomes necessary to use buffers to act on the reed in order to obtain a definite change of speed.

DIALLING-IN OVER LONG SUPERPOSED CABLES.

WITHIN the past few years the task of the engineer responsible for signalling facilities on long-distance telephone circuits has been growing a difficult one, and bids fair before long to enter the region of still greater difficulty, assuming no change in existing methods.

The reasons for this will be well known to all concerned with the art. The conducting channel is, in fact, becoming impassable to continuous battery currents, owing to decrease in copper weight, superposing, the necessity for avoiding earth connections on finely balanced multiple core cables, and probably also, in the immediate future, to the virtual discontinuity in the circuit brought about by the introduction of the speech repeater. It would therefore appear that new methods of signalling will have to be devised, and it has been the opinion of the writer for some time past that the employment of alternating currents lying somewhere within the speech frequency range may ultimately be a solution to the problem. Such currents can obviously be transmitted over the same channels as speech, and will obey the same laws. If therefore their magnitude can be kept within the transmission capabilities of the circuit, and suitable sources of A.C. supply, and receiving apparatus found, the difficulties inherent to battery signalling over phantomed and repeatered cables should disappear.

The present article deals with some laboratory experiments made with the special object in view of enabling dial signals to be transmitted over a circuit of the character indicated above to a distant automatic exchange. Similar methods are of course applicable to ordinary manual signalling, and a system of this kind has already been developed by the Bell Company of America in connection with transmitting ringing generator currents. The requirements for dialling are, however, more exacting.

Choice of Frequency.

In selecting an A.C. frequency for signalling purposes it is clear that the important speech range of say 500-1600 ∼ should be avoided, both from the point of view of inductive disturbance, and the liability of the A.C. receiving device being affected by strong voice currents. On the other hand, the lowest frequencies are not efficiently transmitted by the amplifier stations. From 150 ∼ to 300 ∼ probably include the most suitable values. In the particular case of the dialling-in line under consideration, two frequencies are required within this range (so far as the matter has gone at present), one being used for the dial impulses and the other for releasing the connection. Both should be of reasonably good wave shape to minimise inductive trouble from upper harmonics.

Receiving Relay.

A very sensitive, rapid, and clean acting A.C. relay, comparable as regards cost and size with its battery operating counterpart in telephone exchanges, does not seem to be obtainable yet. It is true that several highly sensitive relays of the reed or " harmonic "

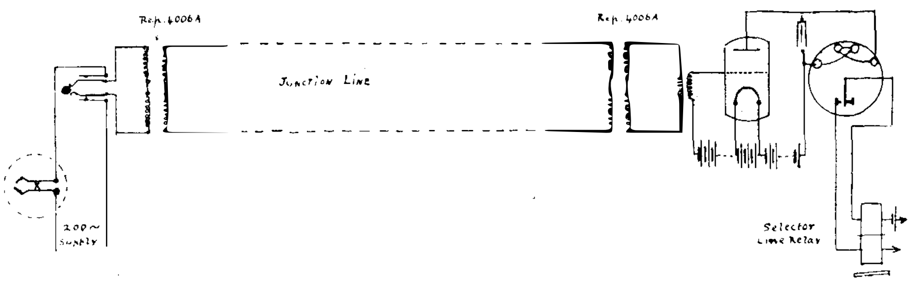


FIG. 1.

type are on the market, and it was actually found possible to correctly control a selector switch with one of these over a long length of 20 lbs. cable; but the stability of such a device for this purpose is doubtful. The only satisfactory arrangement was a telegraph relay (standard B) in combination with a thermionic rectifier (see Fig. 1). The valve, which may be of the ordinary " hard " pattern used for telephonic repeaters, is worked from the bottom of its characteristic curve, a rather large constant negative potential of about 30 v. being maintained on the grid. With a sending-end P.D. of 10 volts at 200 ∼, the simple receiving circuit shown was operative up to 60 m. of standard cable; also over about 80 miles of loaded 40 lbs. cable with an intermediate repeater station, and 40 miles of unloaded 20 lbs. in addition.

Practical Circuit Arrangements.

The next step was to adapt the principles indicated in Fig. 1 to commercial circuit conditions. Here a good many difficulties cropped up. It was quickly seen that the nature of the receiving apparatus excluded it from any direct association with the automatic switches, owing to the strong inductive reaction of the latter when in operation. Some scheme therefore had to be devised to switch over from the dialling to the speaking condition at the conclusion of the selective signals; also to restore to normal again at the end of the call. Fig. 2* shows a circuit that has been developed for this

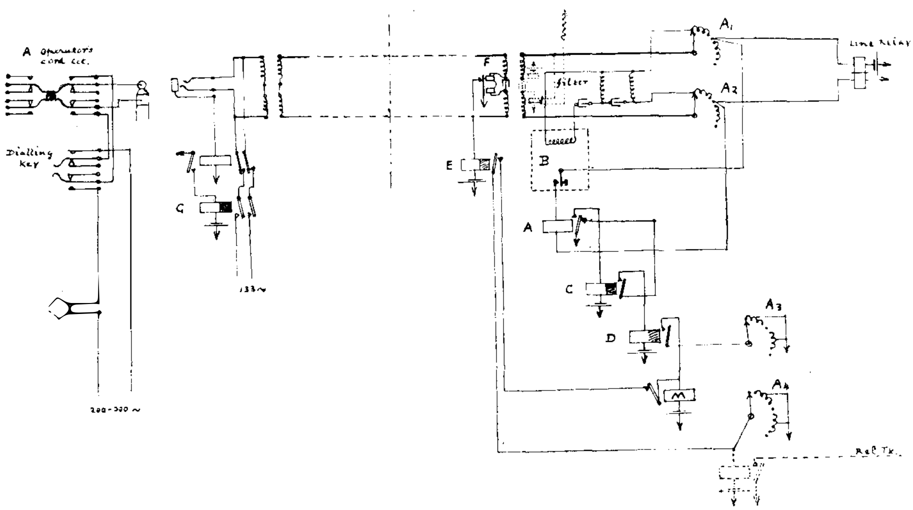


FIG. 2.

purpose. It involves the use of a 4-arc rotary line-switch between the incoming line and 1st selector, and the operation is as follows:

(1) Operator inserts plug at distant manual exchange, throws dialling key, etc; A.C. applied to primary side of terminal repeating coil; A.C. passes over trunk line to input transformer of valve relay B; selector held; A and C operated.

(2) Four digits then dialled. At each series D is operated once and when released at end of series, magnet M steps rotary switch on one.

(3) 5th contacts reached and speaking circuit then completed *viâ* connector circuit to required subscriber.

(4) At conclusion, operator withdraws plug. Sleeve relay and slow release relay G then gives a short impulse of another

* NOTE:—The apparatus enclosed by dotted square is the transformer, valve, and relay of Fig. 1.

frequency—133 ∿ was employed on these experiments—actuating harmonic relay F which responds only to that frequency; this releases E for an instant and steps the switch M on to position 1 for a new call. Should the plug be withdrawn at some intermediate stage of dialling, the switch M will step on automatically until it lands on a starting position again.

A filter to tune out the clearing current is inserted in the impulse relay circuit so that the A.C. relay B may not operate again at the conclusion of the call. Arc A3 prevents a step being taken when dialling current is cut off at 5th position. Relay E is of high resistance as it is normally kept energised, and slow release so that single impulses from any cause, such as reversal of battery at the connector line relay, shall not give a false clear. For this reason the relay G must be slower still, or two slow release relays used in tandem.

The above circuit was found to function quite well, but has one obvious objection. All calls are limited to a certain number of digits, and there is consequently no provision for dialling special services. An alternative scheme free from this particular defect is

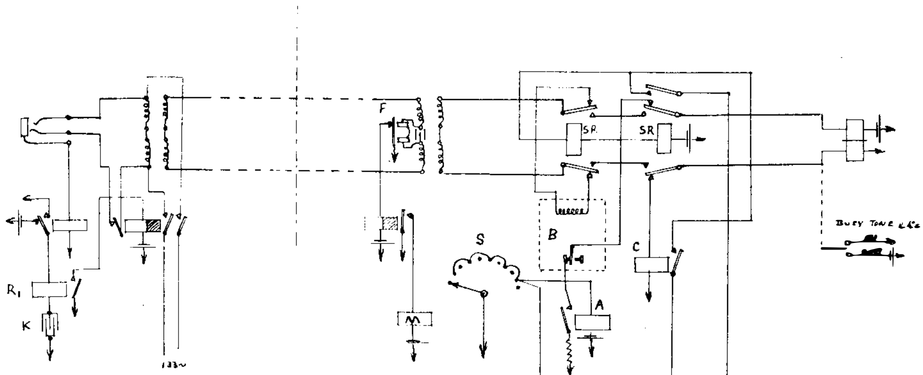


Fig. 3.

shown in Fig. **3**. This operates in a somewhat different manner in that alternating current is applied only during the *intervals* corresponding to the interruptions of the sending dial, which can be arranged quite easily by means of an impulse repeating relay at the calling end, or perhaps by the use of a special dial with a conducting cam. Another distinctive feature is that the switch-over is entirely controlled by the automatic exchange.

The sequence of operations is as follows:—

(1) Operator plugs in jack; sleeve relay operates and condenser K discharges through relay R_1, giving a short calling impulse. F operated momentarily and switch S takes a step. S may either be a simple form of rotary switch, or a reciprocating device oscillating between 2 contacts only. Contact of the A.C. relay B is normally closed, and the effect of the preliminary calling impulse is thus to complete the selector circuit over the negative line to earth at relay A.

(2) Operator dials any number. At end of dialling, it is assumed that one of two events will occur; either (*a*) the connector battery will reverse, or (*b*) the busy signal (flash) will be applied to the + line; in either event—

(3) Relay C will be operated; switching relays (or relay) S.R. then energised and locked by earth on S.

(4) Operator withdraws plug at end of call; relay R_1 again operated for a short time by condenser charge; impulse sent over line and switch S returned to a normal position

C must be of the highest resistance possible, consistent with its operation by 48 V battery, in order that its effect on the line relay movement may be negligible. If from any cause the switch S should get out of step with the operations of the calling exchange, it would of course be impossible for the operator to obtain anything, but this would probably be quickly found out and rectified.

This circuit also gave promising results and is less complicated than 2. The filter shown in the latter diagram may be omitted if the stepping switch be of the type shifting its wiper on release of the magnet.

Neither 2 or 3 are arranged to take advantage of the switching property of the later type of A.T.M. Co.'s connector. This, however, can be effected in the case of 2 by the modification shown in dotted lines in Fig. **2**, and may possibly be regarded as an improvement.

Another point that should be mentioned is that the engaged signal in this system of signalling is restricted to the ordinary busy tone, which is not very effective when the cable equivalent of the circuit is over 20 miles. It might be necessary therefore to augment the busy tone to some extent for long distance service.

Future Progress.

No attempt has yet been made to design special apparatus for A.C. working, and it is evident that here there is plenty of room for research. It may be found possible to construct a commercial electro-magnetic relay capable of replacing the thermionic valve, etc., used on these experiments. It is believed also that the " harmonic " type relay is capable of considerable improvement. Telephonic signalling on the lines indicated above appears to offer an attractive field for inventors.

In conclusion, the writer desires to express his thanks to Mr. H. W. Dipple, of the Automatic Group of the Telephone Section, and to Mr. A. L. Long, of the Research Section, for useful suggestions and assistance.

G. M. B. SHEPHERD.

CALCULATION OF BLOCKING FACTORS OF AUTOMATIC EXCHANGES.

By RAGNAR HOLM.

1. *Introduction. Normal Dispersion.*

THE term *blocking factor* for a time of observation T will be used below to denote the ratio of the number of calls not being effectuated, owing to all switches being engaged, to the total number of calls occurring during the time T. The loss of calls in question is a consequence of the variations of the traffic intensity about its average value. These variations can be mathematically defined, and therefore the blocking factor can be calculated.

Consider the calls to a part of a telephone exchange during a long (eventually non-coherent) time T. We presume that on the whole n calls are distributed over the m Time units of observation. $u = \frac{n}{m}$ is the *mean frequency* of the calls. We seek the probability of the frequency x at a certain time point. It is found in the calculus of probability that, if the calls are distributed by hazard, *i.e.*, if they have independent causes not preferring any part of T, most of the possible distributions show certain similarities mutually. Therefore we can speak of a *normal* distribution or *dispersion*. In the case of the normal dispersion the probability of the frequence x is[1]

$$w(u, x) = \frac{e^{-u}u^x}{x!}$$

In practice such instances are mostly realised which occur in predominating numbers among the possible ones. The more independent the active causes of the calls are mutually and of the

[1] S. D. Poisson, Recherches sur la probabilité des jugements, Paris 1837, No. 81, p. 205.

L. v. Bortkewitsch, Das Gesetz der kleinen Zahlen, Leipzig, 1898.

time, the larger will be the number of the distributions possible to hazard which are also possible in reality, and the more exactly the real dispersion will probably equal the normal dispersion.

The number of simultaneous conversations in a telephonic exchange or in a division thereof at a particular moment is, just as the calling rate, a mass phenomenon depending on several independent causes. Thus, it is to be expected that it is also normally dispersed if the dispersion of the calling rate is normal. It is easily proved that this is really the case.[1] Thus, if y be the average number of conversations going on simultaneously, the probability $s(y, x)$ of there being x simultaneous conversations at a particular moment is

$$s(y, x) = w(y, x).$$

Proposition (*1a*): If the time elements, for which the call distribution is calculated, are supposed to equal the average length L of a conversation, then $y = u$ and the probability of there being x calls in a time element as well as the probability of there being x simultaneous conversations is given by

$$w(y, x) = \frac{e^{-y} y^x}{x!}$$

For practical purposes it is mostly allowed to calculate with (1*a*).[2]

2. *A Main Problem. The functions $B(y, x)$ and $p(y, x)$.*

Problem (2*a*): A telephone traffic having on an average y simultaneous conversations (thus the average frequency y) is to be dealt with by means of connecting devices numbered 1, 2, 3. . . . . Upon a call the connecting devices are tested automatically in numerical order as to whether they are disengaged. The device which is first found to be free takes the call. We seek the probability $B(y, x)$ of the connecting device No. x being engaged at a certain moment.

If during the time of observation T the xth connecting device in question has been engaged for the total time T_x, we have:

$$B(y, x) = \lim_{T=\infty} \frac{T_x}{T} \qquad (2b)$$

Supposing the calls have a certain dispersion, then $B(y, x)$ is exactly defined. The exact calculation thereof should, however, lead to unperspicuous, impractical formulæ. I calculate $B(y, x)$ only approximately, but on the other hand in a very simple manner. The calculation will be made by means of a function $p(y, x)$ giving the probability of the connecting device No. x being the highest

[1] See R. Holm, Archiv für Elektrotechnik, Vol. 8, p. 413, 1920.

[2] Compare measurements accounted for in Sec. 7.

numbered one among the engaged connecting devices. It is to be noticed that, at a moment when the device No. x is engaged, one or more devices having lower numbers may have been disengaged. Certain pauses, *calling pauses,* may thus exist for some connecting devices, while devices having higher numbers are engaged. Thus, for sufficiently large x, we have

$$p(y, x) > w(y, x).$$

We will find, however, that the p and w functions are nearly equal. For not too small y and $\frac{y}{x}$ values the following holds true:

$$\left.\begin{array}{l} p(y, x) = w(\eta, x) \\ \text{where } \eta = y + \frac{1}{2} \end{array}\right\} \qquad (2c)$$

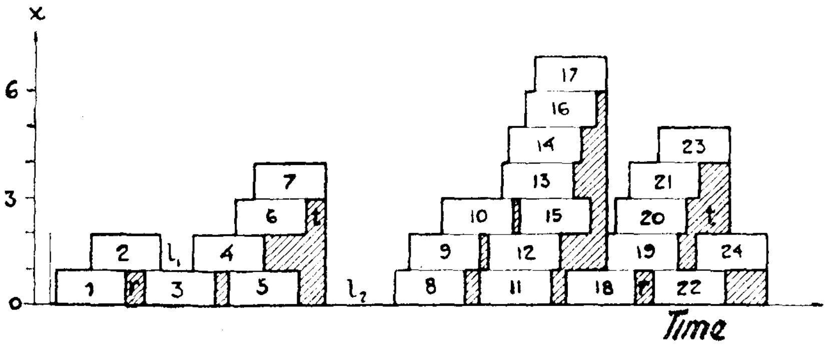


Fig. 1.

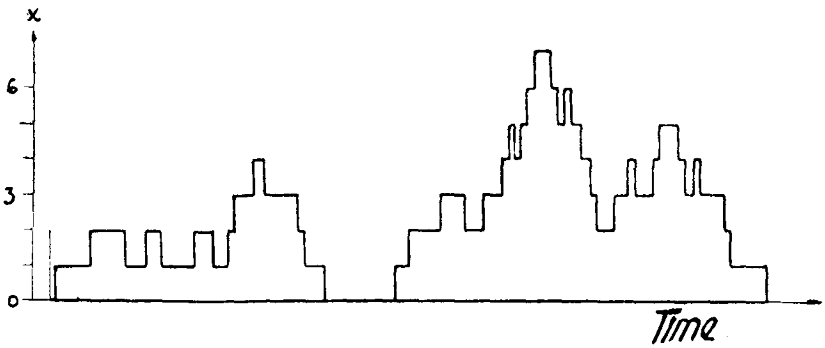


Fig. 2.

The functions $p(y, x)$ and $B(y, x)$ are illustrated by the Figures **1** and **2**. In Fig. **1** each conversation is represented by a rectangle, the length of which represents the length of the conversation. For the sake of simplicity all conversations are here assumed to be of equal length L. The rectangles are piled up above one another, when new calls occur. Each rectangle will thereby reach the height x that indicates the number of the engaged device in question. The shadowed spaces are calling pauses. Fig. **2** is constructed from Fig. **1**. It has in every moment an ordinate equal to the part of the ordinate of Fig. **1** that falls within the rectangles of conversations. Thus, it is seen that, if Figs. **1** and **2** are supposed to be carried out for a long time, the ratio of the total length of the steps corresponding to the heights x in Fig. **1** to the whole time just indicates our $p(y, x)$, the average height in Fig. **2** being y, as this average height is the average number of simultaneous conversations during the time of observation.

The ratio of the total length of the rectangles reaching the height x to the whole time is just our $B(y, x)$, while the ratio of the sum of lengths which are parallel with the time axis and which, upon a height immediately below x, fall within the outline of Fig. **1**, to the whole time is indicated by $B(y, x)+S(y, x)$, where $S(y, x)$ represents the probability of shadows immediately below the height x. It is then understood, that

$$B(y, x)+S(y, x)=\sum_{v=x}^{\infty} p(y, v) \; . \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2d)$$

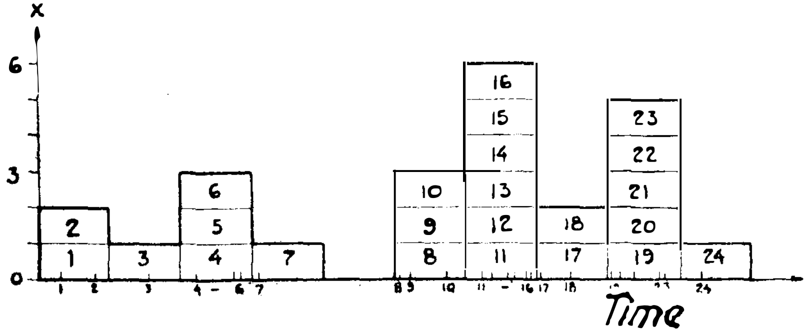


Fig. 3.

Now consider Fig. **3** for a moment. This figure is obtained from Fig. **1** by dividing the time into elements of the length L, and by piling within each element a number of rectangles equal to the number of calls within the same element according to Fig. **1**. Thus, the ordinate in Fig. **3** indicates the number of calls in the corresponding time element. According to what has been stated in Prop. (1a) the probability for the ordinate to reach the height x will be the same in the case of Fig. **3** as in that of Fig. **2**. We see that Fig. **1** can be thought to be formed nearly in the same way as Fig. **3**, if only each rectangle is lengthened by a certain shadowed space. Thus, if we make the supposition that the mean length of the adjoined shadowed spaces is independent of x, the probability

$p(y, x)$ of the ordinate x of the outline in Fig. 1 would be like $w(y, x)$, where, owing to the lengthening of the rectangles by the shadows, η would be somewhat longer than y. Now, this supposition does not hold strictly, but it can be shown[1] that for

$$y > 2 \text{ and } \frac{y}{x} > \text{about } \frac{1}{3} \quad \text{.........} (2e)$$

we can with practically sufficient accuracy put the mean length, s, of a shadowed space independent of x and equal to the average time between the end of a conversation and the following call. As y ends and y calls occur on an average during the average length L of a conversation, s must be like $\frac{L}{2y}$. Thus, Fig. 1 can be considered as built up by rectangles of the mean length $L\left(1 + \frac{1}{2y}\right)$ and we can, if $(2e)$ holds, approximately put:

$$\left.\begin{array}{l} p(y, x) = w(\eta, x) \\ \text{where } \eta = y\left(1 + \frac{1}{2y}\right) = y + \frac{1}{2}; \end{array}\right\} \quad \text{.........} (2f)$$

and further, according to $(2d)$:

$$B(y, x) + S(y, x) = B(y, x)\left(1 + \frac{1}{2y}\right) = \sum_{v=x}^{\infty} w(\eta, v) \quad \text{.........} (2g)$$

Figs. 4 *and* 5 illustrate some calculations of $B(y, x)$ according to $(2g)$. The $B(y, x)$ values are represented by the ordinates of the steps and are also indicated by numerals. It is seen that the first connecting devices will be the better utilised, the larger y is.

3. *The blocking factor* $V(y, x)$.

There may be z connecting devices to deal with a traffic of frequency y dispersed in the manner defined by the function of $w(y, x)$. Then the blocking factor is equal to the ratio of the total time of conversations of a normal mean length corresponding to lost calls, to the total time of conversations corresponding to all the given calls. In Fig. 1 the rectangles belonging to $x \leqq z$ correspond to calls getting through and rectangles belonging to $x > z$ correspond to lost calls. Thus, the mentioned ratio $V(y, z)$ is equal to

$$\frac{\sum_{x=z+1}^{\infty} B(y, x)}{\sum_{x=1}^{\infty} B(y, x)} = \frac{\left(1 + \frac{1}{2y}\right) \sum_{x=z+1}^{\infty} B(y, x)}{\left(1 + \frac{1}{2y}\right) \sum_{x=1}^{\infty} B(y, x)} = \frac{\sum_{x=z+1}^{\infty} \sum_{v=x}^{\infty} w(\eta, v)}{\sum_{x=1}^{\infty} \sum_{v=x}^{\infty} w(\eta, v)} \quad \text{.....} (3a)$$

[1] See R. Holm, loc. cit.

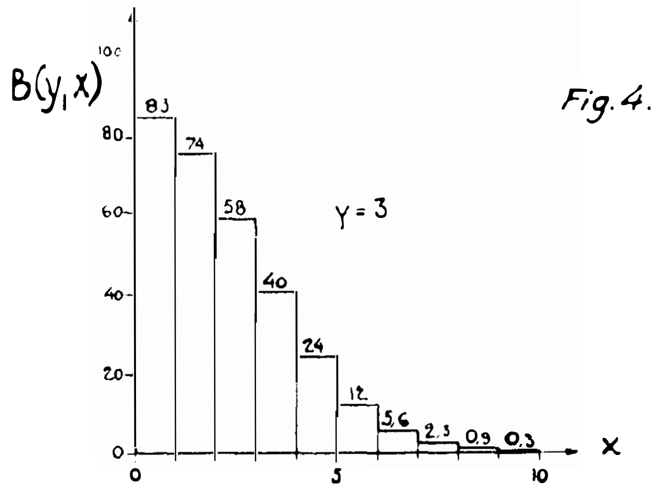


Fig. 4.

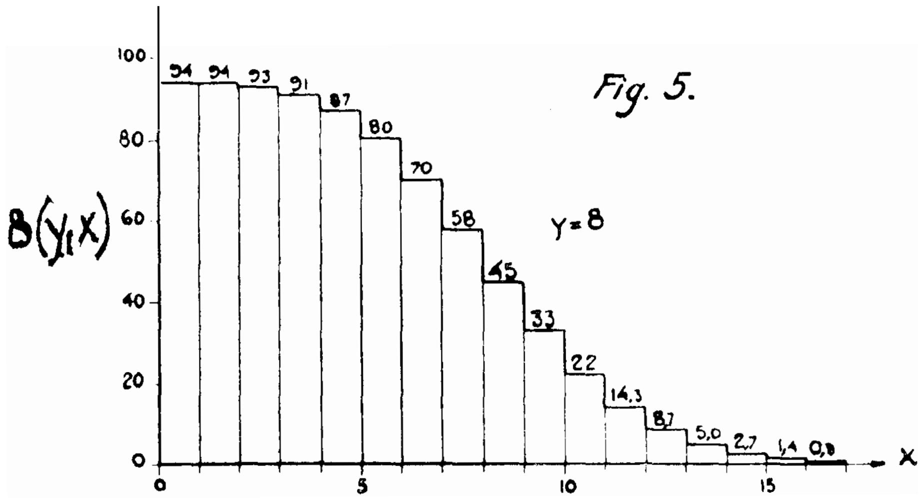


Fig. 5.

After converting the last sums and observing that as a consequence of the definition of the mean value:

$$\sum_{x=1}^{\infty} x \cdot w(y,\, x) = y \qquad \text{.......... (3b)}$$

we find

$$\left.\begin{aligned} V(y,\, z) &= \frac{1}{\eta} \sum_{\xi=1}^{\infty} \xi \cdot w(\eta,\, z+\xi) \\ \text{where } \eta &= y + \tfrac{1}{2} \end{aligned}\right\} \qquad \text{.......... (3c)}$$

It may be noticed that (3*c*) holds good even if w is substituted by a function somewhat different from the w-function of (1*a*), that is, it holds for somewhat abnormal dispersions.

Remark (3*d*): I have proved, *loc. cit.*, that $V(y, z)$ is independent of in which way disengaged devices are searched for, and dependent only on the dispersion, y and z.

I have pointed out that the formula (2*f*) used for the function p does not hold good for small y or $\frac{y}{x}$ values. This, of course, also applies to the V function. For *very* small y or $\frac{y}{x}$ and yet not to large V values, for instance, for $y < \cdot 3$, it is more correct to calculate V in a manner stated by A. K. Erlang. One may then argue in the following manner: The probability of all z lines being engaged cannot be altered to any considerable extent, if—for the purpose of reducing the losses—some lines are added to the z ones. It will therefore be given approximately by $w(y, z)$. The incoming calls will, consequently, occur with the probability $w(y, z)$ during periods of time when all z lines are engaged. This, however, means that the portion $w(y, z)$ of the incoming calls will not be effectuated. Hence, for *sufficiently small values of y*, we may put

$$V(y, z) = w(y, z) \qquad (3e)$$

It should be observed that Mr. Erlang believed that this formula had greater applicability, particularly if the function $w(y, z)$ was altered to a small extent. His conclusions in this respect are, however, wrong, as I have shown *loc. cit.*

4. *Interconnecting.*[1]

On the basis of the theories stated above I have also worked out a theory for calculating the losses of calls in interconnected trunking schemes. Some points of this theory may be considered in brief.

In the calculation of ***graded*** schemes it is wrong to assume that those lines which are common to a plurality of groups of switches receive a traffic of normal dispersion. Said lines will receive a traffic of a highly over-normal dispersion which, however, may be calculated with a satisfactory approximation by means of complex probabilities $P(y, z, x)$ of the form:—

[1] For defining the terms graded and staggered trunking it may be sufficient to refer to Fig. 6. Each vertical row of small circles designate the contacts $K_1, K_2 \ldots$ of a selector switch which, upon a call, are tested successively from the top downward. The lines drawn in full are the wires connecting the contacts. The arrows indicate outgoing wires leading f.i. to the switches of the next stage. We call

a a square-shaped group of contacts having a clean outgoing bundle;
b a *graded* connection of two square groups of contacts; the outgoing bundle is divided into first-choice and second-choice (over-flow) lines;
c and *d* *staggering* over a single square group and over two square groups of contacts respectively; the outgoing bundle is called a staggered bundle.

$$P(y, z, x) = \sum_{\Sigma\xi_v = x} p(y, z+\xi_1) \cdot p(y, z+\xi_2) \ldots\ldots p(y, z+\xi_n) \quad \ldots\ldots\ldots\ldots (4a)$$

when $P(y, z, 0)$ is put $= \sum_{x=0}^{z} p(y, x)$ and when z is the number of first-choice, not shared lines of each of the n connecting groups.

When $P(y, z, x)$ and the appertaining values $B(y, z, x) + S(y, z, x) = \sum_{v=x}^{\infty} P(y, z, v)$ have been calculated for a sort of overflow lines, the probabilities $B(y, z, x)$ of the said lines being engaged are obtained from

$$B(y, z, x) = \frac{1}{1+q} \sum_{v=x}^{\infty} P(y, z, x) \quad \ldots\ldots\ldots\ldots (4b)$$

wherein q is determined so as to make $\sum_{x=1}^{\infty} B(y, z, x)$ equal to the

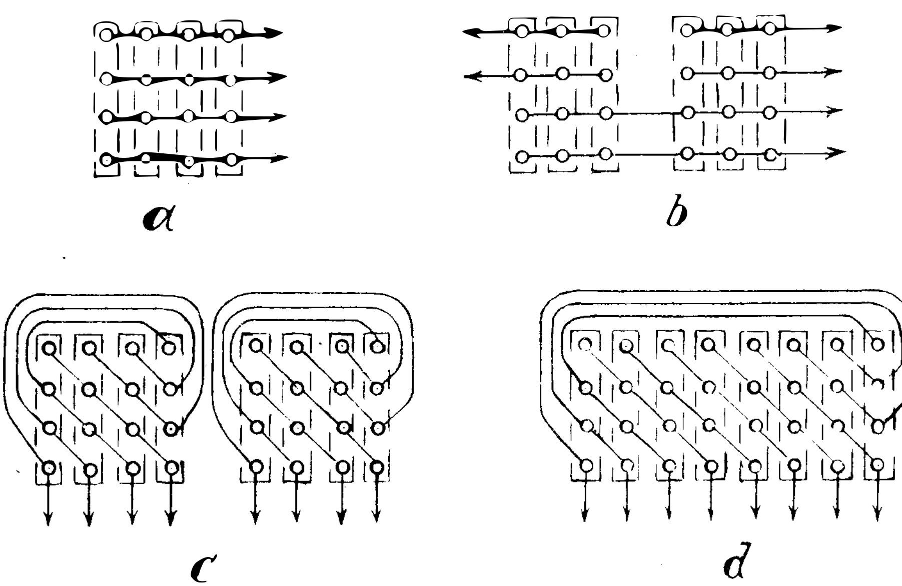


FIG. 6.

average intensity of the traffic reaching the overflow lines in question. At last the blocking factor is calculated according to the principle used for (3*a*).

The *staggered* connection is suitable for attaining a uniform utilization of the bank contacts of the switches. A reduction of the losses can only be obtained by extending the staggering over several groups so that connecting groups having *different average loads* are thereby joined together. The staggered trunking may particularly have a levelling effect on the distribution to the advantage of the subscribers of a heavily loaded 100-group, thereby improving the distribution aimed at in the main distributor.

5. *The probability of a Subscriber being engaged when called.*

We suppose that the average rate of calls to and from the subscriber in question is y. As y is small, the probability of the subscriber being engaged at a certain moment will approximately equal y. The calls to him are therefore likely to find him engaged during the fraction y of the time of observation, *i.e.*, the fraction y of the calls will receive the answer "busy." *The blocking factor will be* y.

6. *Congestions in Switching Systems according to Fig. 7.*

In a Swedish article[1] I have calculated blocking factors for some special arrangements. The main arrangement in question is shown

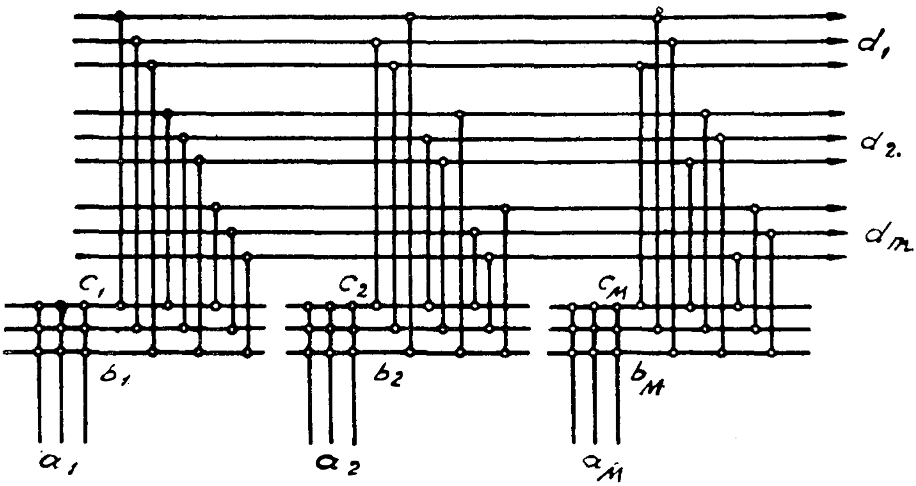


FIG. 7.

by Fig. 7. $a_1, a_2, \ldots a_M$ are incoming, $d_1, d_2 \ldots d_m$ outgoing lines.

As far as a connection can be traced in Fig. 7 from an a-line over b- and c-lines to a d-line in such a manner that such connection between two crossing lines is effected by a contact marked by a circle, this will form a connection that can really be established if none of the lines included is being used in another connection.

Every a_v-bundle may be loaded with the same average rate u (dispersion unimportant). The d_v-bundle ($d_v = 1, 2 \ldots m$) may be

[1] R. Holm, Teknisk bilaga Till K. telegrafstyrelsens cirkulär, Aug. 1919.

searched for by calls of the frequency y_v with normal dispersion. Then

$$M \cdot u = y_1 + y_2 + \ldots + y_m \qquad \ldots\ldots(6a)$$

Congestions may occur partly by the outgoing bundles being fully engaged so that they are unable to receive more conversations, partly by what we call *internal congestions*, *i.e.*, congestions on the way between the a- and d-bundles. Congestions of the kind last-mentioned may be described as follows:—

Suppose that a call occurs in the bundle a_1 wanting the bundle d_1. Some lines in d_1 may be free but those lines in b_1 which can be connected with them, may be engaged by conversations in the directions of d_2, d_3 . . . d_m. Then the said call cannot obtain connection with d_1 in spite of d_1 as well as b_1 having free lines. The calculation of the internal blocking factor F is worked out in the said Swedish article in the following way. The probability p_1 of any particular one of the n b_1-lines being engaged in a direction d_2, . . . d_m a moment when only few b_1-lines are free is approximately (see below):

$$p_1 = \frac{u}{n} \cdot \frac{y_2 + y_3 + \ldots + y_m}{y_1 + y_2 + \ldots + y_m} \qquad \ldots\ldots(6b)$$

The corresponding probability of two engaged b_1-lines is p_1^2 and so on. The probability of there being x free lines in d_1 is approximately $w(y_1, n-x)$, if there are n lines in every d_v-bundle. Thus the probability of x lines being free in d_1 while the corresponding b_1-lines are engaged in the directions d_2, d_3 . . . d_m, is $p_1^x \cdot w(y_1, n-x)$. Such quantities, evidently, show which fraction of the calls from a_1 to d_1 will find the way blocked up, while there are x free lines in d_1. On the whole the fraction

$$\left.\begin{array}{l} F_v = p_v \cdot w(y_v, n-1) + p_v^2 \cdot w(y_v, n-2) + p_v^3 \cdot w(y_v, n-3) + \ldots \\ \text{where } p_v = \dfrac{u}{n} \cdot \dfrac{\Sigma y - y_v}{\Sigma y} \end{array}\right\} \ldots(6c)$$

of the calls from an a-bundle to the d_v-bundle must find the way blocked up in the corresponding b-bundle. *The internal blocking factor* F_1 for the whole line arrangement will be a mean of the expressions (6*c*), *i.e.*,

$$F_1 = \frac{y_1 F_1 + y_2 F_2 + \ldots + y_m F_m}{y_1 + y_2 + \ldots + y_m} \qquad \ldots\ldots(6d)$$

Now the expression p_v according to (6*b*) is not quite correct. In the said Swedish article I show that, if we are not content with the approximations in (6*b*) and (6*d*), we can calculate correcter with

$$F = 0.8 \cdot F_1 \qquad \ldots\ldots(6e)$$

As for *losses owing to a d-bundle being fully engaged* we must consider that the traffic reaching the d-bundles has got its crests reduced. The fraction p_v of the conversations seeking the d_v-bundle, while $n-1$ of its lines are engaged, will not reach d_v owing to internal congestion. This means partly that the probability of there being n engaged d_v lines will be diminished by the factor $(1-p_v)$, partly that the 'numerousness' of new conversations during the time unit of the condition, when n lines are engaged, will be diminished by the same factor. As a consequence, the number of conversations seeking to the d_v-bundle, while its n lines are engaged,

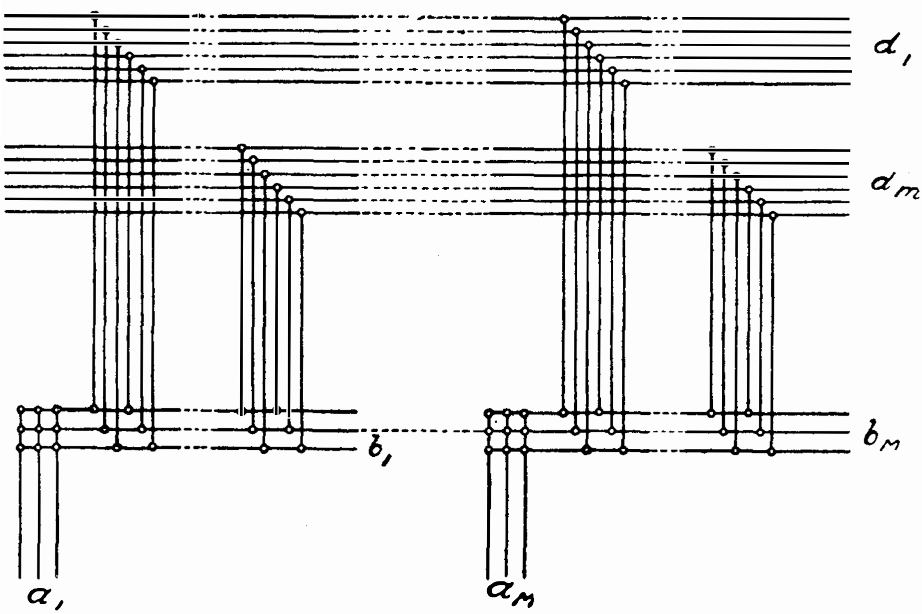


FIG. 8.

will be diminished by the factor $(1-p_v)^2$. Hence, the blocking factor for fully-engaged losses in d_v will be approximately

$$\varphi_v = (1-p_v)^2 V(y_v, n) \quad \ldots\ldots (6f)$$

Thus the *total blocking factor* according to the system of Fig. 7 is—

$$F + \frac{\Sigma y_v \varphi_v}{\Sigma y_v} \quad \ldots\ldots (6g)$$

7. *Measurements.*

In this paragraph I give an extract of the equally designed paragraph of my above-mentioned Swedish article. At first I will show an example of dispersion-measurements on a group of 100 subscribers of an Amsterdam exchange. $w_{obs.}$ are values calculated from register-curves corresponding to Fig. **2**. $w_{calc.}$ are values resulting from the function $w(y, x)$.

(7a)

$x =$	0	1	2	3	4	5	6	7	8	9	10	11	12
$w_{obs.} =$	·013	·045	·125	·185	·187	·186	·126	·071	·036	·018	·005	·002	·001
$w_{calc.} =$	·013	·058	·125	·179	·193	·166	·120	·074	·039	·019	·008	·003	·001

The dispersion measured has been very nearly normal.

In the Telegraph Office of Stockholm I have carried out other tests. Two telegraph slips I. and II. were divided into 400 elements of equal length. On each element there were drawn at irregular distances a number, x, of transverse lines. The x-values were decided (by drawing lots) so as to provide a nearly normal dispersion of the 2000 lines. By means of these slips the function $V(y, z)$ was proved in the following way:—

The slip in question was moved along on a table past two fixed lines. When a line on the slip passed the first fixed line, an operator engaged a switch. When a line passed the second fixed line, another operator released some one of the switches thus engaged. It was noted how often there was no free switch for a passing line. The line corresponding to a lost call was marked so as not to allow it to cause the release of a switch. The distance between the fixed lines was chosen larger than the element of the slip. The results are given in the table (7*b*). It is seen that the formula (3*c*) gives a good agreement with the measurements, while Erlang's formula gives far too high values.

Table (7*b*).

BLOCKING FACTORS.

	Measured by means of the slip.		Calculated	
	I.	II.	According to (3*c*)	According to Erlang.
V(5, 5; 10)	—	.012	.0129	.0285
V(7; 10)	.0425	.053	.0402	.0710
V(10; 14)	.0235	.032	.0253	.0521

Also the formula (6*g*) was proved by means of particular slips. The test was made with a Betulander line arrangement according to Fig. **7**. The result (see table (7*c*)) was a splendid verification of the formula (6*g*).

Table (7c).

BLOCKING FACTORS.

	Internal.	Owing to fully eng. bundle.
1. Observation	.0441	.0032
2 ,,	.0474	.0038
Calculated from (6g)	F = .048	$\frac{\Sigma y_v \varphi_v}{\Sigma y_v} = .0037$

8. *Tables for w(y, x) and V(y, z).*

The *table W* of the appendix gives values of the function $w(y, z)$ according to $(1a)$.

The *table V* gives blocking factors which are calculated for $y>3$ according to the formula $(3c)$. For $y<0,6$ and $z\leqq 3$ calculations have been made by means of $(3e)$. For y- and z-values in the intermediate range a geometrical interpolation has been used.

I estimate the accuracy of the table for this intermediate range, which is not yet theoretically covered, to at least 20% of the V-values. Within the other part of the table the faults will hardly exceed 5 to 10% of the V-values by more than one figure in the numerator of the decimal fraction, provided the calls are normally dispersed and conversations are of normally varying lengths.

LIST OF EARLIER LITERATURE.

W. L. Campbell: A.I.E.E., 29-6-1908.

W. H. Grinsted: Post Office Electrical Engineers' Journal, Vol. 8, p. 33, 1915, written 1907.

Fr. Johannsen: Post Office Electrical Engineers' Journal, Oct. 1910 and Jan. 1911.

P. V. Christensen: E.T.Z., Vol. 34, p. 1314, 1913.

F. Spiecker: Dissertation, Berlin, 1913.

F. Lubberger: Dissertation, Karlsruhe, 1914.

H. Milon: La Telephonie Automatique, Paris, 1914.

A. K. Erlang: E.T.Z., Vol. 39, p. 504, 1918.

T. Engset: E.T.Z., Vol. 39, p. 304, 1918

U. P. Lely: Dissertation, Delft, 1918.

R Holm: Archiv für Elektrotechnik, Vol. 8, p. 413, 1920.

R. Holm: Bilaga till telegrafstyrelsens circulär, 1919, p. 57.

G. F. O'Dell: Post Office Electrical Engineers' Journal, Vol. 13, p. 209, 1920

F. Lubberger: Zeitscher für Fernmeldetechn, Vol. 2, p. 21, 1921.

Table V.

z =	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
y =																			
0.4	.050	.007	.0006																
0.5	—	.0123	.0014																
0.6	—	.0187	.0027																
0.7	—	.0266	.0044	.0005															
0.8	—	.0351	.0069	.0010															
0.9	—	.0445	.0100	.0019															
1.0	—	—	.0138	.0030															
1.1	—	—	.0180	.0044	.0008														
1.2	—	—	.0230	.0061	.0013	.0002													
1.3	—	—	.0282	.0080	.0019	.0003													
1.4	—	—	.0340	.0103	.0026	.0006													
1.5	—	—	.0405	.0128	.0035	.0008	.0002												
1.6	—	—	.0458	.0154	.0044	.0012	.0003												
1.7	—	—	—	.0184	.0054	.0015	.0004												
1.8	—	—	—	.0214	.0066	.0020	.0005												
1.9	—	—	—	.0250	.0080	.0024	.0006												
2.0	—	—	—	.0292	.0098	.0030	.0007	.0002											
2.2	—	—	—	.0365	.0132	.0041	.0012	.0003											
2.4	—	—	—	0447	.0173	.0057	.0017	.0005											
2.6	—	—	—	.0525	.0221	.0075	.0024	.0007	.0002										
2.8	—	—	—	—	.0275	.0098	.0033	.0009	.0004										
3.0	—	—	—	—	.0330	.0123	.0045	.0014	.0005	.0002									
3.5	—	—	—	—	.0489	.0212	.0084	.0031	.0010	.0004									
4.0	—	—	—	—	—	.0343	.0150	.0061	.0022	.0008	.0003								
4.5	—	—	—	—	—	.0611	.0244	.0108	.0044	.0017	.0006	.0002							
5.0	—	—	—	—	—	—	.0369	.0176	.0079	.0033	.0013	.0006	.0002						
5.5	—	—	—	—	—	—	.0523	.0269	.0129	.0058	.0024	.0010	.0004	.0001					
6.0	—	—	—	—	—	—	—	.0387	.0198	.0095	.0043	.0017	.0007	.0003					
6.5	—	—	—	—	—	—	—	.0530	.0288	.0147	.0071	.0032	.0014	.0006	.0002				
7.0	—	—	—	—	—	—	—	—	.0399	.0216	.0110	.0053	.0024	.0010	.0004	.0001			
7.5	—	—	—	—	—	—	—	—	.0632	.0302	.0162	.0083	.0040	.0018	.0008	.0003			

z =	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
y =																				
8.0	.0408	.0230	.0128	.0062	.0030	.0014	.0006	.0002												
8.5	.0533	.0314	.0180	.0093	.0047	.0023	.0011	.0004	.0001											
9.0	—	.0414	.0242	.0135	.0071	.0036	.0017	.0008	.0004	.0001										
9.5	—	.0512	.0322	.0187	.0106	.0055	.0027	.0013	.0006	.0003	.0001									
10	—	—	.042	.0253	.0150	.0077	.0041	.0021	.0010	.0004	.0001									
11	—	—	—	.042	.0260	.0152	.0086	.0046	.0024	.0012	.0006	.0001								
12	—	—	—	—	.043	.0269	.0167	.0099	.0053	.0030	.0016	.0008	.0002							
13	—	—	—	—	—	.043	.0275	.0175	.0105	.0060	.0034	.0020	.0010	.0005	.0001					
14	—	—	—	—	—	—	.043	.0274	.0174	.0105	.0064	.0038	.0021	.0013	.0006	.0002				
15	—	—	—	—	—	—	—	.043	.0275	.0176	.0111	.0069	.0041	.0026	.0014	.0006	.0003	.0001		
16	—	—	—	—	—	—	—	—	.044	.0289	.0188	.0125	.0077	.0046	.0028	.0015	.0008	.0004	.0001	
17	—	—	—	—	—	—	—	—	—	.042	0.282	.0194	.0130	.0080	.0049	.0028	.0017	.0010	.0004	.0001

z =	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
y =																				
18	.043	.0286	.0200	.0131	.0082	.0051	.0032	.0020	.0010	.0004	.0001									
19	—	.043	.0300	.0206	.0136	.0088	.0058	.0036	.0022	.0011	.0004	.0001								
20	—	—	.042	.0284	.0200	.0133	.0091	.0060	.0036	.0022	.0008	.0002								
22	—	—	—	.055	.042	.030	.0209	.0146	.0097	.0065	.0027	.0010	.0003							
24	—	—	—	—	—	.062	.041	.030	.0208	.0147	.0070	.0030	.0012	.0003						
26	—	—	—	—	—	—	—	.053	.041	.030	.0151	.0076	.0034	.0013	.0004	.0001				
28	—	—	—	—	—	—	—	—	—	.053	.030	.0157	.0081	.0037	.0016	.0006	.0002			
30	—	—	—	—	—	—	—	—	—	—	.060	.029	.0164	.0085	.0042	.0017	.0007	.0002		

z =	38	40	42	44	46	48	50	52	54	56	58	60	65	70	75	80	85	90	95	100
y =																				
35	.040	.023	.0132	.0071	.0036	.0016	.0006	.0002												
40	—	—	.046	.029	.0171	.0100	.0052	.0026	.0013	.0006	.0002									
45	—	—	—	—	.062	.036	.0218	.0134	.0080	.0048	.0027	.0015	.0001							
50	—	—	—	—	—	—	—	.042	.029	.0182	.0114	.0071	.0016	.0002						
55	—	—	—	—	—	—	—	—	—	.048	.034	.022	.0069	.0017	.0002					
60	—	—	—	—	—	—	—	—	—	—	—	.053	.023	.0080	.0022	.0004				
65	—	—	—	—	—	—	—	—	—	—	—	—	.051	.023	.0083	.0021	.0006			
70	—	—	—	—	—	—	—	—	—	—	—	—	—	.050	.022	.0084	.0022	.0006		
75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.049	.022	.0083	.0028	.0009	.0001

z =	80	85	90	95	100	105	110	115	120	125
y =										
80	.049	.022	.0090	.0032	.0007	.0001				
85	—	.045	.022	.0095	.0028	.0010	.0001			
90	—	—	.044	.022	.0090	.0031	.0009	.0002		
95	—	—	—	.042	.022	.0094	.0031	.0010	.0002	
100	—	—	—	—	.041	.0214	.0097	.0036	.0014	.0004

Table W.

y=	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
x = 0	.606528	.367880	.223131	.135335	.082084	.049787	.030197	.018315	.011109
1	.303264	.367880	.334696	.270670	.205211	.149362	.105690	.073262	.049991
2	.075816	.183940	.251022	.270670	.256514	.224043	.184957	.146524	.112480
3	.012636	.061313	.125511	.180447	.213762	.224043	.215783	.195365	.168720
4	.001579	.015328	.047067	.090223	.133601	.168032	.188810	.195365	.189810
5	.000158	.003066	.014120	.036089	.066800	.100819	.132167	.156292	.170829
6	.000013	.000511	.003530	.012030	.027833	.050409	.077097	.104195	.128122
7	.000001	.000073	.000756	.003437	.009940	.021604	.038548	.059540	.082364
8	.000000	.000009	.000142	.000859	.003106	.008101	.016865	.029770	.046330
9	—	.000001	.000024	.000191	.000863	.002700	.006559	.013231	.023165
10	—	.000000	.000004	.000038	.000216	.000810	.002296	.005292	.010424
11	—	—	.000000	.000007	.000049	.000221	.000731	.001924	.004264
12	—	—		.000001	.000010	.000055	.000213	.000641	.001599
13	—	—	—	.000000	.000002	.000013	.000057	.000197	.000553
14	—	—	—	—	.000000	.000003	.000014	.000056	.000178
15	—	—	—	—	—	.000001	.000003	.000015	.000053
16	—	—	—	—	—	.000000	.000001	.000004	.000015
17	—	—	—	—	—	—	.000000	.000001	.000004
18	—	—	—	—	—	—	—	.000000	.000001
19	—	—	—	—	—	—	—	—	.000000

y=	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
x = 0	.006738	.004087	.002479	.001503	.000912	.000553	.000336	.000203	.000123
1	.033690	.022477	.014572	.009772	.006383	.004148	.002684	.001729	.001111
2	.084225	.061813	.044617	.031760	.022341	.015556	.010735	.007350	.004998
3	.140375	.113323	.089235	.068813	.052130	.038889	.028626	.020826	.014994
4	.175469	.155819	.133853	.111821	.091228	.072916	.057252	.044255	.033737
5	.175469	.171401	.160624	.145368	.127719	.109374	.091603	.075233	.060727
6	.146224	.157118	.160624	.157482	.149003	.136718	.122137	.106580	.091090
7	.104446	.123450	.137678	.146233	.149005	.146484	.139585	.129419	.117116
8	.065279	.084872	.103258	.118814	.130379	.137329	.139585	.137508	.131756
9	.036266	.051866	.068839	.085810	.101406	.114441	.124076	.129869	.131756
10	.018133	.028526	.041303	.055776	.070984	.085831	.099261	.110389	.118580
11	.008242	.014263	.022530	.032959	.045172	.053521	.072190	.085301	.097020
12	.003434	.006537	.011265	.017853	.026350	.036576	.048127	.060422	.072767
13	.001321	.002766	.005199	.008926	.014188	.021102	.029617	.039507	.050376
14	.000472	.001087	.002228	.004144	.007094	.011305	.016924	.023986	.032385
15	.000157	.000399	.000891	.001796	.003310	.005652	.009026	.013592	.019431
16	.000049	.000137	.000334	.000730	.001448	.002649	.004513	.007221	.010930
17	.000014	.000044	.000118	.000101	.000596	.001169	.002124	.003610	.005786
18	.000004	.000013	.000039	.000034	.000232	.000487	.000944	.001705	.002893
19	.000001	.000004	.000012	.000011	.000085	.000192	.000397	.000763	.001370
20	.000000	.000001	.000004	.000003	.000030	.000072	.000159	.000324	.000616
21	—	.000000	.000001	.000001	.000010	.000026	.000061	.000131	.000264
22	—	—	.000000	.000000	.000003	.000009	.000022	.000051	.000108
23	—	—	—	—	.000001	.000003	.000008	.000019	.000042
24	—	—	—	—	.000000	.000001	.000002	.000007	.000016
25	—	—	—	—	—	.000000	.000001	.000002	.000006
26	—	—	—	—	—	—	.000000	.000001	.000002
27	—	—	—	—	—	—	—	.000000	.000001
28	—	—	—	—	—	—	—	—	.000000

y=	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
x = 0	.000075	.000045	.000028	.000017	.000010	.000006	.000004	.000002	.000001
1	.000711	.000454	.000289	.000184	.000117	.000074	.000047	.000029	.000019
2	.003378	.002270	.001518	.001010	.000670	.000442	.000291	.000191	.000125
3	.010696	.007566	.005312	.003705	.002568	.001769	.001213	.000828	.000562
4	.025403	.018916	.013944	.010189	.007382	.005308	.003791	.002690	.001897
5	.048266	.037833	.029283	.022415	.016979	.012740	.009477	.006994	.005123
6	.076421	.063055	.051246	.041094	.032544	.025481	.019744	.015153	.011526
7	.103714	.090079	.076869	.064577	.053465	.043682	.035258	.028142	.022229
8	.123160	.112599	.100891	.088794	.076856	.065523	.055090	.045730	.037512
9	.130002	.125110	.117707	.108526	.098205	.087364	.076514	.066054	.056268
10	.123502	.125110	.123603	.119378	.112936	.104837	.095643	.085870	.075962
11	.106661	.113736	.117985	.119378	.118069	.114368	.108685	.101483	.093226
12	.084440	.094780	.103237	.109430	.113149	.114368	.113214	.109940	.104879
13	.061706	.072908	.083384	.092595	.100093	.105570	.108860	.109940	.108913
14	.041872	.052077	.062538	.072753	.082219	.090489	.097196	.102087	.105023
15	.026519	.034718	.043777	.053352	.063035	.072391	.080997	.088475	.094521
16	.015746	.021699	.028729	.036679	.045306	.054293	.063279	.071886	.079762
17	.008799	.012764	.017744	.023733	.030748	.038324	.046529	.054972	.063332
18	.004644	.007091	.010351	.014503	.019581	.025549	.032312	.039702	.047499
19	.002322	.003732	.005720	.083965	.011852	.016136	.021258	.027165	.033749
20	.001103	.001866	.003003	.046181	.006815	.009682	.013286	.017657	.022781
21	.000499	.000889	.001501	.002419	.003732	.005533	.007908	.010931	.014645
22	.000215	.000404	.000716	.001209	.001951	.003018	.004493	.006459	.008987
23	.000089	.000176	.000327	.000578	.000976	.001575	.002442	.003651	.005275
24	.000035	.000073	.000143	.000265	.000467	.000787	.001272	.001978	.002967
25	.000013	.000029	.000060	.000117	.000215	.000378	.000636	.001029	.001602
26	.000005	.000011	.000024	.000049	.000095	.000174	.000306	.000514	.000832
27	.000002	.000004	.000009	.000020	.000040	.000077	.000142	.000247	.000416
28	.000001	.000002	.000003	.000004	.000016	.000033	.000063	.000115	.000201
29	.000000	.000001	.000001	.000002	.000006	.000014	.000027	.000052	.000094
30	—	.000000	.000000	.000001	.000002	.000006	.000011	.000023	.000042
31	—	—	—	.000000	.000001	.000002	.000004	.000010	.000018
32	—	—	—	—	.000000	.000001	.000002	.000004	.000008
33	—	—	—	—	—	.000000	.000001	.000002	.000003
34	—	—	—	—	—	—	.000000	.000001	.000001
35	—	—	—	—	—	—	—	.000000	.000000

y=	14.0	14.5	15.0	17.0	20.0	22.0	26.0	27.0	30.0
x = 0	.000001	.000000	.000000	.000000	—	—	—	—	—
1	.000012	.000007	.000005	.000001	—	—	—	—	—
2	.000081	.000053	.000034	.000006	.000000	.000000	—	—	—
3	.000380	.000256	.000172	.000034	.000003	.000001	—	—	—
4	.001331	.000929	.000645	.000144	.000014	.000003	.000000	—	—
5	.003727	.002694	.001935	.000490	.000055	.000012	.000001	.000000	—
6	.008696	.006510	.004837	.001388	.000183	.000044	.000005	.000001	—
7	.017391	.013486	.010364	.003370	.000524	.000138	.000017	.000004	.000000
8	.030435	.024443	.019432	.007162	.001309	.000380	.000053	.000013	.000001
9	.047344	.039381	.032387	.013529	.002908	.000928	.000146	.000040	.000005
10	.066281	.057102	.048580	.023000	.005816	.002041	.000365	.000107	.000015
11	.084358	.075271	.066245	.035545	.010575	.004083	.000829	.000262	.000042
12	.098418	.090052	.082860	.050355	.017625	.007486	.001728	.000589	.000104
13	.105989	.101446	.095608	.065849	.027116	.012669	.003324	.001223	.000239
14	.105989	.105069	.102437	.079960	.038737	.019908	.005935	.002359	.000513
15	.098923	.101567	.102437	.090621	.051650	.029199	.009891	.004247	.001027
16	.086558	.092045	.096035	.096285	.064562	.040148	.015455	.007166	.001925
17	.071283	.078509	.084737	.096285	.075955	.051956	.022728	.011381	.003398
18	.055442	.063243	.070614	.090936	.084394	.063502	.031566	.017071	.006663
19	.040852	.048264	.055748	.081364	.088836	.073528	.041534	.024259	.008941

Table W—continued.

y=	14.0	14.5	16.0	17.0	20.0	22.0	26.0	27.0	30.0
x = 20	.028596	.034991	.041811	.069159	.088836	.080881	.051918	.032749	.013411
21	.019064	.024160	.029865	.055986	.084606	.084732	.061807	.042106	.019159
22	.012132	.015924	.020362	.043262	.076915	.084732	.070235	.051675	.026126
23	.007385	.010039	.013280	.031976	.066883	.081048	.076342	.060662	.034078
24	.004308	.006065	.008300	022650	.055736	.074294	.079523	.068245	.042597
25	.002412	.003518	.004980	.015402	.044589	.065378	.079523	.073705	.051116
26	.001299	.001962	.002873	.010070	.034299	.055320	.076464	.076540	.058980
27	.000674	.001054	.001596	.006341	.025407	.045076	.070800	.076540	.065533
28	.000337	.000546	.000855	.003850	.018148	.035416	.063214	.073806	.070214
29	.000163	.000273	.000442	.002257	.012516	.026868	.054495	.068716	.072635
30	.000076	.000132	.000221	.001279	.008344	.019703	045413	.061844	.072635
31	.000034	.000062	.000107	.000701	.005383	.013983	.036623	.053864	.070292
32	.000015	.000028	.000050	.000373	.003364	.009613	.028612	.045448	.065899
33	.000006	.000012	.000023	.000192	.002039	.006409	.021676	.037185	.059908
34	.000002	.000005	.000010	.000096	.001199	.004147	.015938	029529	.052860
35	.000001	.000002	.000004	.000047	.000685	.002607	.011384	.022780	045309
36	.000000	.000001	.000002	.000022	.000381	.001593	.007906	.017085	037757
37	—	.000000	.000001	.000010	.000206	.000947	.005342	012467	.030614
38	—	—	.000000	.000004	.000108	.000548	.003514	008858	.024169
39	—	—	—	.000002	.000055	.000309	.002253	.006132	.018592
40	—	—	—	.000001	.000028	.000170	.001408	.004139	.013944
41	—	—	—	.000000	.000011	.000091	.000859	.002726	.010203
42	—	—	—	—	.000005	.000048	.000511	.001752	.007288
43	—	—	—	—	.000002	.000024	.000297	.001100	.005085
44	—	—	—	—	.000001	.000012	.000169	.000675	.003467
45	—	—	—	—	.000000	.000006	.000094	.000405	.002311
46	—	—	—	—	—	.000003	.000051	.000238	.001507
47	—	—	—	—	—	.000001	.000027	.000137	.000962
48	—	—	—	—	—	.000001	.000014	.000077	.000601
49	—	—	—	—	—	.000000	.000007	.000042	.000368
50	—	—	—	—	—	—	.000004	.000023	.000221
51	—	—	—	—	—	—	.000002	.000012	.000130
52	—	—	—	—	—	—	.000001	.000006	.000075
53	—	—	—	—	—	—	.000000	.000003	.000042
54	—	—	—	—	—	—	—	.000002	.000024
55	—	—	—	—	—	—	—	.000001	.000013
56	—	—	—	—	—	—	—	.000000	.000007
57	—	—	—	—	—	—	—	—	.000004
58	—	—	—	—	—	—	—	—	.000002
59	—	—	—	—	—	—	—	—	.000001
60	—	—	—	—	—	—	—	—	.000000

Table W—continued.

y =	32.0	35.0	38.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	80.0	90.0	100.0
x = 8	.000000	—	—	—	—	—	—	—	—	—	—	—	—
9	.000001	—	—	—	—	—	—	—	—	—	—	—	—
10	.000004	.000000	—	—	—	—	—	—	—	—	—	—	—
11	.000011	.000001	.000000	—	—	—	—	—	—	—	—	—	—
12	.000030	.000004	.000001	—	—	—	—	—	—	—	—	—	—
13	.000075	.000012	.000002	.000000	—	—	—	—	—	—	—	—	—
14	.000172	.000030	.000005	.000001	—	—	—	—	—	—	—	—	—
15	.000366	.000070	.000012	.000004	.000000	—	—	—	—	—	—	—	—
16	.000732	.000153	.000028	.000009	.000001	—	—	—	—	—	—	—	—
17	.001377	.000315	.000063	.000021	.000003	—	—	—	—	—	—	—	—
18	.002449	.000612	.000134	.000046	.000008	—	—	—	—	—	—	—	—
19	.004124	.001127	.000268	.000096	.000019	.000000	—	—	—	—	—	—	—
20	.006599	.001972	.000509	.000192	.000041	.000001	—	—	—	—	—	—	—
21	.010055	.003287	.000921	.000366	.000083	.000002	—	—	—	—	—	—	—
22	.014625	.005229	.001590	.000665	.000163	.000004	—	—	—	—	—	—	—
23	.020348	.007957	.002627	.001156	.000304	.000009	.000000	—	—	—	—	—	—
24	.027131	.011604	.004159	.001927	.000544	.000018	.000001	—	—	—	—	—	—
25	.034728	.016246	.006321	.003084	.000936	.000037	.000003	—	—	—	—	—	—
26	.042742	.021870	.009238	.004744	.001548	.000071	.000006	.000000	—	—	—	—	—
27	.050657	.028350	.013002	.007028	.002466	.000132	.000012	.000001	—	—	—	—	—
28	.057894	.035438	.017645	.010040	.003787	.000236	.000023	.000002	—	—	—	—	—
29	.063883	.042770	.023121	.013849	.005615	.000407	.000043	.000004	—	—	—	—	—
30	.068142	.049898	.029286	.018465	.008048	.000678	.000079	.000007	.000000	—	—	—	—
31	.070340	.056336	.035899	.023826	.011164	.001093	.000141	.000014	.000001	—	—	—	—
32	.070340	.061617	.042630	.029783	.015002	.001707	.000243	.000026	.000002	—	—	—	—
33	.068209	.065351	.049089	.036101	.019548	.002586	.000405	.000048	.000005	.000000	—	—	—
34	.064197	.067273	.054864	.042472	.024723	.003803	.000655	.000085	.000009	.000001	—	—	—
35	.058694	.067273	.059567	.048539	.030374	.005432	.001029	.000146	.000016	.000001	—	—	—
36	.052172	.065404	.062876	.053932	.036280	.007545	.001572	.000243	.000029	.000003	—	—	—
37	.045122	.061869	.064575	.058305	.042163	.010196	.002337	.000394	.000051	.000005	—	—	—
38	.037997	.056985	.064575	.061373	.047711	.013416	.003382	.000622	.000088	.000010	—	—	—
39	.031177	.051140	.062919	.062947	.052605	.017200	.004769	.000956	.000146	.000018	—	—	—
40	.024942	.044747	.059773	.062947	.056550	.021500	.006557	.001434	.000238	.000031	.000000	—	—
41	.019467	.038199	.055399	.061412	.059309	.026219	.008796	.002099	.000377	.000053	.000001	—	—
42	.014832	.031832	.050123	.058488	.060721	.031213	.011518	.002999	.000583	.000088	.000001	—	—
43	.011038	.025910	.044295	.054407	.060721	.036294	.014732	.004185	.000881	.000143	.000002	—	—
44	.008028	.020610	.038255	.049461	.059341	.041243	.018415	.005707	.001302	.000228	.000003	—	—
45	.005709	.016030	.032304	.043965	.056704	.045826	.022507	.007609	.001880	.000355	.000006	—	—
46	.003971	.012197	.026686	.038230	.053006	.049811	.026910	.009925	.002657	.000541	.000011	—	—
47	.002704	.009083	.021576	.032536	.048495	.052990	.031491	.012670	.003674	.000806	.000019	—	—
48	.001803	.006623	.017081	.027114	.043443	.055198	.036083	.015837	.004975	.001175	.000032	.000000	—
49	.001177	.004731	.013246	.022134	.038123	.056325	.040501	.019392	.006599	.001679	.000053	.000001	—
50	.000753	.003312	.010067	.017707	.032786	.056325	.044551	.023271	.008579	.002351	.000085	.000001	—
51	.000472	.002273	.007501	.013888	.027643	.055221	.048045	.027378	.010934	.003227	.000133	.000002	—
52	.000290	.001530	.005481	.010683	.022859	.053097	.050817	.031590	.013668	.004344	.000204	.000004	—
53	.000175	.001010	.003930	.008062	.018546	.050091	.052735	.035762	.016762	.005737	.000308	.000007	—
54	.000104	.000655	.002766	.005972	.014768	.046381	.053712	.039736	.020177	.007437	.000457	.000012	—
55	.000061	.000417	.001911	.004343	.011546	.042165	.053712	.043348	.023846	.009465	.000665	.000020	.000000
56	.000035	.000260	.001297	.003102	.008866	.037647	.052753	.046444	.027678	.011831	.000950	.000032	.000001
57	.000020	.000160	.000865	.002177	.006688	.033024	.050902	.048889	.031563	.014529	.001333	.000050	.000001
58	.000011	.000096	.000567	.001501	.004958	.028469	.048269	.050575	.035372	.017535	.001839	.000077	.000001
59	.000006	.000057	.000365	.001018	.003614	.024126	.044997	.051432	.038969	.020804	.002493	.000118	.000002
60	.000003	.000033	.000231	.000679	.002590	.020105	.041247	.051432	.042217	.024271	.003324	.000177	.000004
61	.000002	.000019	.000144	.000445	.001826	.016480	.037190	.050589	.044985	.027852	.004359	.000261	.000007
62	.000001	.000011	.000088	.000287	.001266	.013290	.032991	.048957	.047162	.031446	.005625	.000379	.000012
63	.000000	.000006	.000053	.000182	.000864	.010548	.028802	.046626	.048659	.034940	.007143	.000541	.000019
64	—	.000003	.000031	.000116	.000581	.008240	.024752	.043712	.049420	.038216	.008929	.000761	.000029
65	—	.000002	.000018	.000071	.000384	.006339	.020944	.040350	.049420	.041156	.010989	.001054	.000045
66	—	.000001	.000010	.000043	.000250	.004802	.017453	.036682	.048671	.043650	.013320	.001437	.000068
67	—	.000000	.000006	.000026	.000161	.003584	.014327	.032849	.047218	.045604	.015904	.001930	.000102
68	—	—	.000003	.000015	.000102	.002635	.011588	.028985	.045135	.046945	.018711	.002555	.000150
69	—	—	.000002	.000009	.000063	.001909	.009237	.025204	.042518	.047626	.021694	.003333	.000217
70	—	—	.000001	.000005	.000039	.001364	.007258	.021603	.039481	.047626	.024793	.004286	.000310
71	—	—	.000001	.000003	.000024	.000960	.005622	.018256	.036145	.046955	.027936	.005433	.000437
72	—	—	.000000	.000002	.000014	.000667	.004295	.015214	.032631	.045651	.031040	.006791	.000607
73	—	—	—	.000001	.000008	.000457	.003236	.012504	.029055	.043775	.034016	.008372	.000832
74	—	—	—	.000000	.000005	.000309	.002405	.010139	.025521	.041409	.036774	.010183	.001124
75	—	—	—	—	.000003	.000206	.001763	.008111	.022118	.038648	.039226	.012220	.001499
76	—	—	—	—	.000002	.000135	.001276	.006403	.018917	.035597	.041291	.014471	.001973
77	—	—	—	—	.000001	.000088	.000912	.004990	.015969	.032361	.042900	.016914	.002562
78	—	—	—	—	.000000	.000056	.000643	.003838	.013307	.029042	.044000	.019516	.003285
79	—	—	—	—	—	.000036	.000447	.002915	.010949	.025733	.044557	.022234	.004158
80	—	—	—	—	—	.000022	.000308	.002186	.008896	.022516	.044557	.025013	.005198
81	—	—	—	—	—	.000014	.000209	.001619	.007139	.019459	.044007	.027792	.006417
82	—	—	—	—	—	.000008	.000140	.001185	.005659	.016611	.042934	.030503	.007826
83	—	—	—	—	—	.000005	.000093	.000857	.004432	.014009	.041382	.033076	.009429
84	—	—	—	—	—	.000003	.000061	.000612	.003429	.011674	.039411	.035439	.011225
85	—	—	—	—	—	.000002	.000039	.000432	.002622	.009614	.037093	.037524	.013206
86	—	—	—	—	—	.000001	.000025	.000301	.001982	.007825	.034505	.039269	.015356
87	—	—	—	—	—	.000001	.000016	.000208	.001481	.006296	.031729	.040623	.017650
88	—	—	—	—	—	.000000	.000010	.000142	.001094	.005008	.028845	.041546	.020057
89	—	—	—	—	—	—	.000006	.000095	.000799	.003939	.025928	.042013	.022535
90	—	—	—	—	—	—	.000004	.000064	.000577	.003064	.023047	.042013	.025039
91	—	—	—	—	—	—	.000002	.000042	.000412	.002357	.020261	.041551	.027515
92	—	—	—	—	—	—	.000001	.000027	.000291	.001793	.017618	.040648	.029908
93	—	—	—	—	—	—	.000001	.000018	.000203	.001350	.015155	.039327	.032159
94	—	—	—	—	—	—	.000000	.000011	.000141	.001005	.012898	.037663	.034212
95	—	—	—	—	—	—	—	.000007	.000096	.000741	.010861	.035681	.036013
96	—	—	—	—	—	—	—	.000004	.000065	.000540	.009051	.033451	.037513
97	—	—	—	—	—	—	—	.000003	.000044	.000390	.007465	.031037	.038673
98	—	—	—	—	—	—	—	.000002	.000029	.000278	.006094	.028503	.039462
99	—	—	—	—	—	—	—	.000001	.000019	.000197	.004924	.025912	.039861
100	—	—	—	—	—	—	—	.000001	.000012	.000138	.003939	.023321	.039861
101	—	—	—	—	—	—	—	.000000	.000008	.000095	.003120	.020781	.039466
102	—	—	—	—	—	—	—	—	.000005	.000065	.002447	.018336	.038692
103	—	—	—	—	—	—	—	—	.000003	.000044	.001901	.016022	.037566
104	—	—	—	—	—	—	—	—	.000002	.000030	.001462	.013865	.036121
105	—	—	—	—	—	—	—	—	.000001	.000020	.001114	.011884	.034401
106	—	—	—	—	—	—	—	—	.000001	.000013	.000841	.010090	.032454
107	—	—	—	—	—	—	—	—	.000000	.000009	.000629	.008487	.030331
108	—	—	—	—	—	—	—	—	—	.000006	.000466	.007073	.028084
109	—	—	—	—	—	—	—	—	—	.000004	.000342	.005840	.025765
110	—	—	—	—	—	—	—	—	—	.000002	.000249	.004778	.023423
111	—	—	—	—	—	—	—	—	—	.000001	.000179	.003874	.021200
112	—	—	—	—	—	—	—	—	—	.000001	.000128	.003113	.018839
113	—	—	—	—	—	—	—	—	—	.000001	.000090	.002479	.016672
114	—	—	—	—	—	—	—	—	—	.000000	.000063	.001957	.014625
115	—	—	—	—	—	—	—	—	—	—	.000044	.001532	.012717
116	—	—	—	—	—	—	—	—	—	—	.000030	.001189	.010963
117	—	—	—	—	—	—	—	—	—	—	.000021	.000915	.009370
118	—	—	—	—	—	—	—	—	—	—	.000014	.000698	.007941
119	—	—	—	—	—	—	—	—	—	—	.000009	.000528	.006673
120	—	—	—	—	—	—	—	—	—	—	.000006	.000396	.005561
121	—	—	—	—	—	—	—	—	—	—	.000004	.000294	.004596
122	—	—	—	—	—	—	—	—	—	—	.000003	.000217	.003767
123	—	—	—	—	—	—	—	—	—	—	.000002	.000159	.003063
124	—	—	—	—	—	—	—	—	—	—	.000001	.000115	.002470
125	—	—	—	—	—	—	—	—	—	—	.000001	.000083	.001976
126	—	—	—	—	—	—	—	—	—	—	.000000	.000059	.001568
127	—	—	—	—	—	—	—	—	—	—	—	.000042	.001235

EFFECTS OF AURORA ON TELEGRAPHS, TELEPHONES AND WIRELESS.

MR. A. GIBBS, M.I.E.E., Deputy Chief Telegraph Engineer of the Dominion of New Zealand, has sent us a pamphlet on the above subject, which he contributed to the New Zealand Journal of Science and Technology, Vol. IV., No. 4, 1921.

After discussing the effects produced by auroral phenomenon generally, Mr. Gibbs deals with interferences experienced during an exceptionally brilliant display in May last year, and states that those interferences were of greater magnitude and more far-reaching in their effects than any of which the New Zealand Department has record. It is the first time, also, that the effect of the aurora upon wireless communications in this, or probably any other country, has been so noticeable.

Land Telegraph Lines.

During the auroral period the land telegraph lines throughout New Zealand were subject to abnormal disturbances due to what are technically known as "earth currents." The Morse lines all over New Zealand were affected, but not necessarily at the same time nor to the same degree. In general the interference manifested itself in the form of violent fluctuations of current in the telegraph lines and instruments, but in many cases the variations in the direction of the foreign currents were slow and gradual, although far from uniform in their movements. In some cases the foreign voltages were found to be of the order of 60 volts, and were of sufficient magnitude to render Morse working by the usual means impossible. At the principal centres it was frequently observed that lines running east and west were more seriously affected than those running north and south, but the experience cannot be said to have been either general or uniform. The main effects were first noticed at all stations upon opening for business at 8 a.m. on the 14th. Practically all Morse lines, and especially the longer ones, were badly affected by earth currents, and during the 14th, 15th, and 16th the longer-distance lines had during the greater part of this period to be worked upon the metallic-circuit principle, by which means all connection with the earth was removed and a conducting wire substituted for the earth-return circuit.

As an indication that earth currents were not entirely responsible for these circumstances, it should be mentioned that on the longer lines even the metallic-circuit arrangement did not remove all causes of trouble. The atmospheric electrical charges which accompanied the aurora continued to induce in the metallic Morse wires electrical potentials which, although not sufficient to interrupt Morse signalling, rendered the adjustment of these circuits difficult and sensitive.

As in the case of the wireless signals, there were brief periods during which little interference was experienced, and the whole phenomena were erratic in the extreme both as regards intensity, duration, and direction of disturbances.

Telephone Lines.

A rather unusual interference was experienced at certain telephone exchanges, such as Nelson, Palmerston North, Featherston, and Pahiatua, where there are a number of long-distance earth-working telephone lines. These lines were subject to disturbances similar to those described in connection with the Morse telegraph lines, but the greatest degree of interference appears to have occurred at Pahiatua late on the afternoon of the 15th. At this station the call indicators on earthed lines were operated by the induced voltages for as long a period as two minutes; and here, as at some of the other stations mentioned, lightning-protectors on all lines were operated in much the same manner as if the lines had been struck by mild lightning-discharges.

Although Morse circuits operated upon the metallic or loop principle were not entirely immune from interference, the speech on metallic telephone circuits was unaffected. This, however, was not due to the absence therein of foreign voltages, but to the fact that these telephone circuits are balanced and are operated upon such a principle that the voltages induced in the two wires of the circuit are rendered mutually compensating and produce no effect upon the telephones connected therewith.

Radio Coast Stations.

The effects of the aurora upon wireless reception were felt by all the New Zealand wireless coast stations—viz., Awanui, Auckland, Wellington, Awarua, and Chatham Islands. The Auckland Radio Station records that unusual variations in the signal strength were noticed, beginning on the 9th May, accompanied by what are known as "hissing" statics. At other stations the principal effects were noticed on the 14th and 15th May, tapering off on the 16th, and returning to practically normal conditions late on the 17th.

At 1 p.m. on the 14th Awarua observed that the long-wave signals from the Awanui Station were very much above normal strength, and by 4 p.m. a decided variation in the strength of wireless signals had been observed at all stations. At 5 p.m. Awarua (near the Bluff—lat. 46° 36′ S.) noticed the first visible evidence of the aurora, and this was accompanied for a short period by a remarkably quiescent interval during which statics and wireless signals disappeared altogether. Shortly afterwards the signals emitted by the Wellington and Chatham Island stations became very weak and variable in strength, although signals from Auckland and the Australian stations were very little affected. Such conditions may be said to have prevailed generally until the evening of the 17th, when signals resumed their normal characteristics, but atmospheric disturbances continued for some time to be heavy and numerous. During the 14th, 15th, and 16th signals at all radio stations were very erratic, both in intensity and uniformity. A rather interesting phenomenon was that, while signals from New Zealand and Australian stations were subject to great variation, the signals from long-wave European stations did not appear to suffer any variation either in intensity or uniformity. This is corroborated by Rarotonga (Cook Islands), which at times experienced variation in New Zealand signals but no variation in signals from northwards. Apart from the variations in the New Zealand radio signals, the only effect observable at Rarotonga was the prevalence of strong atmospherics during the auroral period. At Apia (Samoa) the auroral display was visible at 6.45 p.m. (Samoan time) on the 15th, and simultaneously the signals from Awanui on 2,000-metres wave-length were considerably augmented in strength, and for a short period were the strongest that had ever been received from that station. While stations in the North Island of New Zealand were fading and weak to South Island stations, they were of usual strength to Apia. Apart from these circumstances nothing unusual was observed by Apia.

An interesting experiment was performed at Awarua, where during the height of the disturbance an insulated counterpoise (or network of insulated wires) was substituted for the usual earth connection. In effect, the wireless receiving-system was entirely disconnected form the earth, and therefore not subject to direct interference from electrical charges circulating therein. This removal of the earth connection did not in any way affect the prevailing variations of the signals, which continued to be as erratic as ever. During the period referred to there were brief intervals at all New Zealand stations when signals returned to normal and nothing unusual was noticed.

The effects at New Zealand stations may be summarised as follows: (1) Great and sudden variations in signal-strength from maximum to minimum; (2) signals from different directions not simultaneously affected; (3) dead periods when neither signals nor statics were heard; (4) period of abnormal intensity of signals and statics; (5) signals from European long-wave stations unaffected during the whole period.

All of the New Zealand stations are connected by land telegraph lines with the telegraph centres, and it was noticed at times that great variations in radio signals were simultaneously accompanied by earth currents in the land telegraph lines of sufficient intensity to render the Morse circuits inoperative.

INSULATOR WASHING.

By T. KENYON.

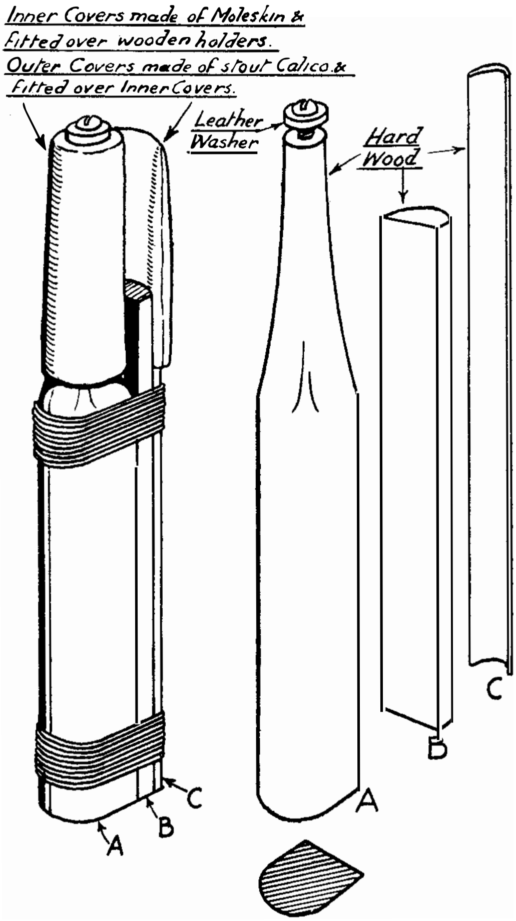
CONSIDERABLE attention has been given to methods of Insulator Washing in the Manchester District recently, and it is thought readers of the Journal may be interested in the results of a number of successful experiments which were carried out.

The first experiment was made in a Suburban Stores Yard, where no gas or steam was available for heating purposes. In devising suitable methods it was necessary to bear in mind the fact that the materials should be easily mobile for use either in stores or out on line. The kit decided upon and found very successful was made up as follows:—

- 2 Zinc washing baths (one with cover), capacity 8 gallons.
- 1 Bucket.
- 2 Strong wire baskets (to fit inside baths).
- 1 Fire Devil (burning coal and coke).
- 1 Washing tool (as designed), see drawing.
- 1 Washing glove.

The washing tool of wood was designed to fit inside the sheds of a No. 6 Insulator, but the dimensions could be varied to fit any other class of insulator. The centre piece and outside curved piece were covered with materials such as calico, flannel, moleskin, etc., a supply of spare covers being always on hand ready for replacements. The insulator being washed was placed on the tool held in the right hand, and revolved with left hand covered with the flannel glove, which was simultaneously cleaning the outside whilst the tool was cleaning the inside sheds, time being thus saved by reducing what had previously been three separate operations.

One of the baths was filled with a solution of soda ash and water (approximately five gallons) sufficient to cover 30 insulators No. 6 or 50 No. 12, placed in a wire basket. The bath, oval in shape, was 2′ 4″ long, 1′ 8″ wide, and 9″ deep. The wire basket of the same shape measured 2′ 3″ × 1′ 7½″ × 8¾″. This bath containing insulators was placed on the fire devil, and it was found that with a good fire the water would boil in half an hour. After 10 minutes continuous boiling from this stage, the wire basket in the bath on the fire was raised, allowed to drain, and transferred with its contents to the second bath, which was filled with clean water. Immediately this operation was completed a second wire basket containing a similar number of insulators was placed in the first bath of boiling solution and the man proceeded with the washing operation.



INSULATOR WASHING TOOL.

The insulators in the bath on the fire were allowed to boil, the whole of the time that the washer was occupied in disposing of the first consignment, the sequence of operations being continued throughout the day. As a result of this method, it was found that one man could wash 600 insulators No. 6 during an ordinary working day.

The next step was to try the foregoing arrangement under conditions obtaining with an insulator washing gang on a trunk line, and to ascertain how many men changing insulators up the poles could be kept going by one man washing 600 insulators per day. It was found that this one man could keep going three wiremen each taking a pole, constantly changing. The most suitable gang for the work was found to consist of five men made up of one Foreman, three Skilled men and one labourer.

The following procedure was adopted :—

First of all it was necessary to have sufficient clean insulators available to allow the men on the poles to make an immediate start, and to provide for replacement of cracked and broken insulators. Three men then ascended poles at one time, each being equipped with a sash line and tool bass. Whilst the men were putting themselves in position between the two top arms and adjusting their belts, etc., the foreman proceeded to fill the tool bass at the foot of each with 8 clean insulators. The next operation of the men up the poles was to ease with their pliers all the eight binders on the two arms on which they were working. The next step was to haul up the tool bass containing clean insulators by means of the sash line, undo each binder in turn, unscrew the dirty insulator, replace by clean one from bass, and tack in temporarily again with the binder, until all the eight insulators comprising the first set were changed. The dirty insulators were next let down, and whilst the wireman was completing the binding in and changing his position to the next two arms, the Foreman on the ground was changing the dirty insulators for clean ones, this operation being repeated until the pole was finished. The whole series of operations were fitted in so as to avoid all losses due to dead time. Defective binders and cracked and broken insulators were, of course, changed as occasion required.

An interesting point was noticed at this stage. It was found that although the three wiremen were of equal ability, and apparently working with the same effort, one was finishing his pole with the same number of changes 5 or 6 minutes before the second man, and 8 or 10 minutes before the third man. After close investigation on the lines of a " time and motion " study, it was found this was accounted for by the fact that the first man eased all 8 binders in succession with his pliers, before returning the pliers to his " frog." He then untwisted and eased the end of each binder in succession with his fingers, changed the insulators, tacking each one in with the binder, and then proceeded with the rebinding operations in the reverse order, finally tightening up the eight binders in succession with his pliers, having recourse to his " frog " only twice for the eight insulators, *i.e.*, once for unbinding and once for rebinding in.

The second man eased one binder only with his pliers, returned the pliers to the frog, and completed the unbinding with his fingers. This operation was repeated in the case of eight insulators. He then changed the whole of the insulators, rebound one only with his fingers, and completed with the pliers, repeating this operation eight times. The third man eased one binder only and returned the pliers to his frog. He then changed the insulator, rebound the wire with his fingers, and completed the operation with his pliers. It will therefore be seen that in changing eight insulators, the second and third men withdrew their pliers and returned them to their frogs sixteen times, as against twice in the case of the first man.

Travelling time and other "ineffective" time charged to the work was found to have reached approximately 25 per cent. The cost per insulator including the cleaning of terminal insulators in situ which was found to slightly slow down the rate of progress worked out at .07 man-hours per insulator. The trunk lines followed routes through smoky manufacturing districts and chemical areas, including overhouse sections from the suburbs right through the City to the standard on the H.P.O., and the insulators had not previously been washed for at least 8 years. With further practice the gang in question ultimately reached an average of .065 man-hours per insulator.

Subsequently experiments were tried with a solution of quebracho extract and caustic soda, the use of which was described in the "Electrical Review," of June, 1917. It was claimed for this process that after boiling in a solution of quebracho and caustic soda, from 10 to 15 minutes, the dirt could generally be rinsed off the insulators in clean water without rubbing or the use of abrasive material.

The same appliances were used as in the previous trials, and highly satisfactory results were obtained with a solution of 2 lbs. of quebracho and 1 lb. of caustic soda to 5 gallons of water. In only a small proportion of cases was it necessary to use the special tool or cleaning cloth, and one man, working alone, in the Suburban Stores was able to clean 150 insulators in one hour. From this result it is calculated one man could regularly wash approximately 1,000 insulators in a day of 8 hours.

Quebracho is a boiler composition obtained from Argentina.

The process of insulator washing on a large scale is comparable with the principle of "mass production" in the manufacturing world. The secret of success lies in the use of proper appliances, the adoption of proper methods and the drilling of each member of the gang into the details of his own particular job.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

MILEAGES AND TELEPHONE STATIONS FOR EACH ENGINEERING DISTRICT AS AT 31ST DECEMBER, 1921.

Telephone Stations.	Overhead Wires: Mileages.				Engineering District.	Underground Wires: Mileages.				Submarine (Land miles).
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.	
318,018	565	2,214	51,807	177	London	17,154	17,276	1,174,716	20,321	
48,987	2,762	15,498	41,699	2,579	S.E.	2,191	8,963	148,564	15,975	
40,408	4,775	19,728	35,815	1,518	S.W.	12,288	1,782	77,488	1,324	
33,595	9,676	26,017	33,439	4,156	E.	15,594	21,908	43,759	14,657	
55,454	9,684	36,840	39,602	2,535	N. Mid.	7,880	13,538	95,702	64,306	
44,476	5,470	24,667	45,050	4,433	S. Mid.	6,592	8,094	111,309	82,892	
38,080	5,494	24,018	35,767	3,101	S. Wales	4,854	9 819	61,849	18,339	
52,186	9,439	21,107	34,801	5,481	N. Wales	11,732	16,748	95,159	9,957	
95,626	3,220	16,075	44,074	3,301	S. Lancs.	9,517	32,143	232,152	30,151	
47,373	6,755	24,472	34,714	1,856	N.E.	4,536	12,199	104,529	23,640	
47,661	4,353	26,142	38,877	2,739	N.W.	9,455	15,635	100,500	13,982	
31,236	3,009	14,013	21,412	2,151	N.	2,592	4,955	51,805	5,692	
32,826	22,889	11,155	26,055	893	Ireland	838	100	53,149	489	
41,044	6,010	18,991	28,093	2,057	Scot. E.	1,383	4,984	75,382	3,433	
61,514	7,433	21,093	39,202	450	Scot. W.	11,444	11,955	168,432	19,002	
988,484	101,534	302,030	550,407	37,427	**Total.**	118,050	180,099	2,594,495	324,160	
972,578	101,653	301,042	549,218	39,033	Figures on 30th Sept. **1921.**	118,275	177,949	2,590,267	320,677	

POST OFFICE WAR SIGNALS DESIGNS.

THE review, elsewhere in this number, of the book published by the Institution of Royal Engineers, describing the work of the Corps of Signals in the Great War, suggests that our readers might be interested in knowing something of the special military signals apparatus devised and supplied by the Post Office.

Out of about 200 special designs produced during the war, the following items are selected:—

P.O. FULLERPHONES.

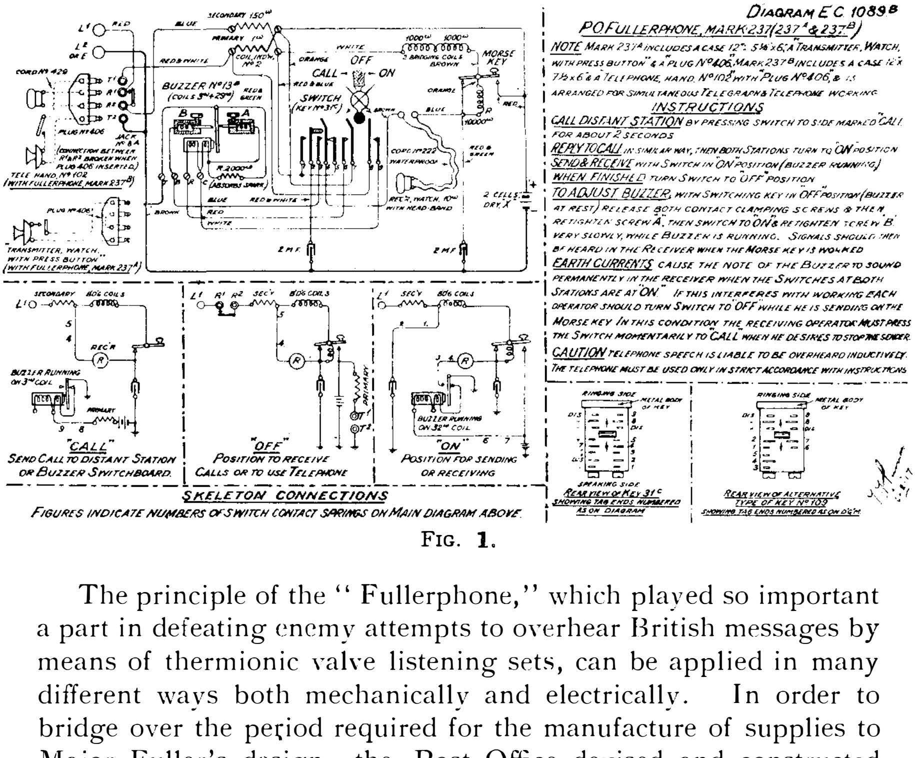
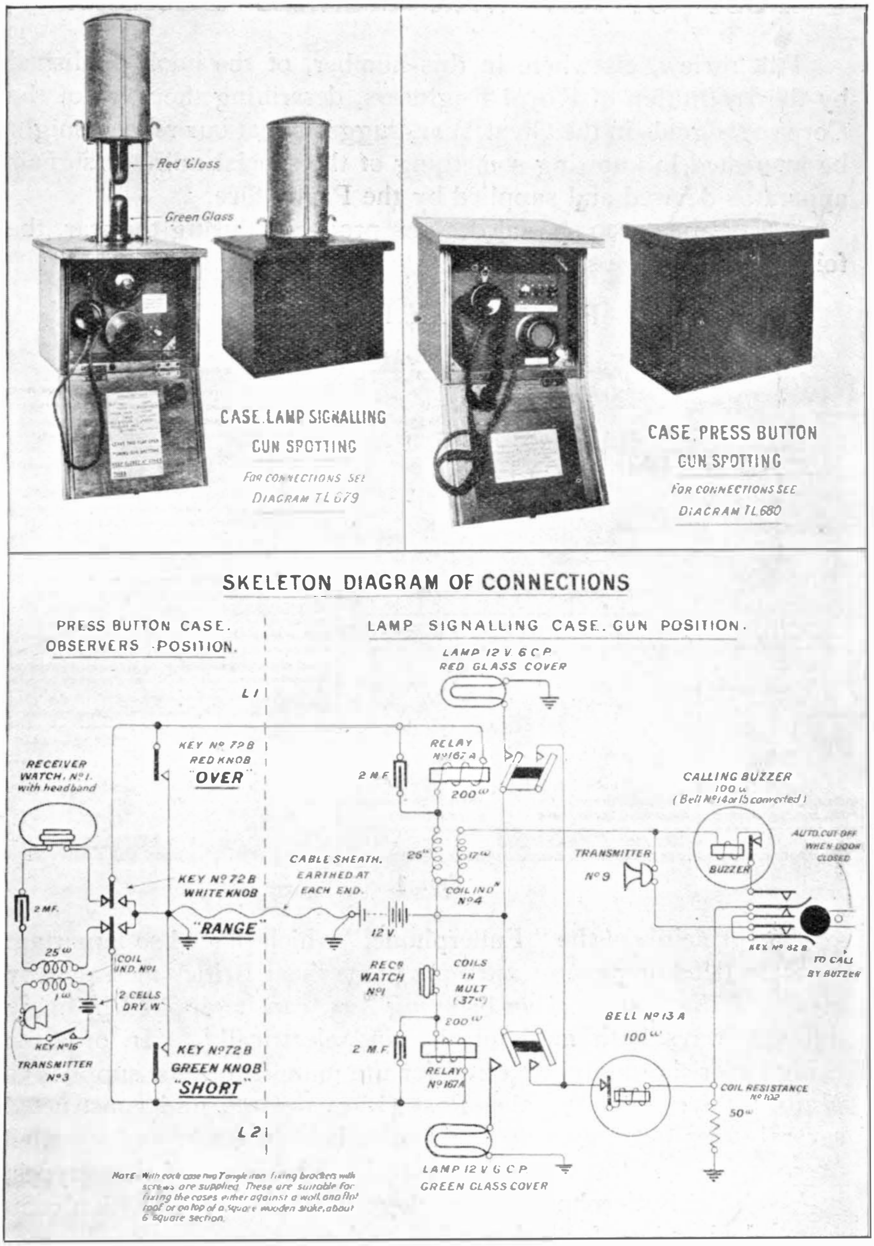


FIG. 1.

The principle of the "Fullerphone," which played so important a part in defeating enemy attempts to overhear British messages by means of thermionic valve listening sets, can be applied in many different ways both mechanically and electrically. In order to bridge over the period required for the manufacture of supplies to Major Fuller's design, the Post Office devised and constructed several types from apparatus and parts held in stock, and supplied about 3,650 sets to the armies abroad. The latest of these types, in which the Fullerphone secret telegraph is associated with a complete telephone set for independent and non-secret communication, is shown in Diagram E.C. 1089 B.

ANTI-AIRCRAFT FIRE OBSERVATION SYSTEM.

Diagram T.L. 623 shows lamp signalling and press button apparatus designed to communicate the results of anti-aircraft gun fire to the gunners. Two observers were stationed about a mile



T.L. 623.

from the guns in such positions that one or both could always secure flank observation and report whether shells were bursting beyond, or short of, the hostile target. Each observer wore a headband receiver in which he could hear the discharge of the gun. His set included three press buttons; No. 1—green lamp—indicated to the gunner that the shot was short; No. 2—red lamp—that the shot had passed over the target; and No. 3—red and green lamps together—that the range was correct. 1000 complete sets of this equipment were provided and were in general use until the system of aiming and correcting individual shots was superseded by group and barrage firing.

TRENCH TELEPHONES.

Over 42,000 trench telephones, designed and manufactured by the Post Office, were supplied to the armies. They are self-contained magneto-ringing instruments of protected type, capable of withstanding exposure and rough usage, and transportable without packing cases. The latest type, known as "Telephone No. 110," is now the War Office standard. In appearance it is identical with "Telephone 110 B," shown on page 50. Its connections are similar to those of "Telephone 110 A," shown on Diagram E.C. 1166, with the exception that the latter, which was used in the anti-

CONNECTIONS OF TELEPHONE No. 110A (MARK 234)

DIAGRAM No. E.C. 1166
File ref. War. 1101/17 (2)

Fitted with Jack No. 8 so that Headgear set with Plug No. 406 may be connected when desired in place of Hand-Telephone

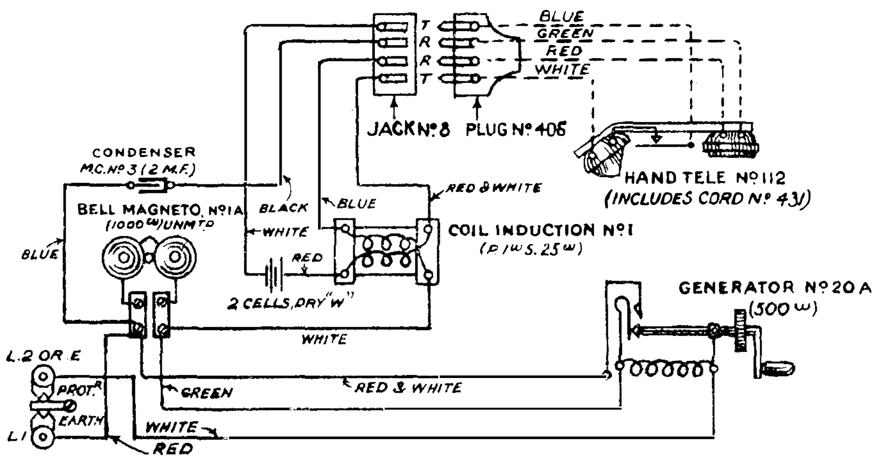


FIG. 3.

aircraft service, is provided with a jack and plug by which the hand micro telephone can, when desired, be replaced by a breastplate and headgear set. It will be seen that the instrument does not include a receiver switchhook; the bell and the generator (normally short-circuited) are connected directly across the line, in shunt with the talking circuit, which comprises a condenser in series with the receiver and the secondary winding of the induction coil.

TRENCH SWITCHBOARDS.

The first types of trench switchboards made by the Post Office, to replace many diverse patterns improvised by the armies in the field, were known as "Switch Units, buzzer 4+3," and "Switch Units, magneto, 5-line." In these the watch receivers used to detect buzzer calls, and the drop indicators for magnetic signals, were connected permanently to the line jacks. There were no switching keys and all connections were made by loose pairs of plugs and cords. In some cases sets of triple plugs were used in order to provide for listening in by the operator, but special plugs having the rear end adapted to serve as a listening in jack were also supplied. At a later stage in the war these switch-units were superseded by 10-line types of the same size and external construction, but with provision for rapid operating with full supervision, for bunched connections, and for coupling adjacent switch-units under the control of one operator. The photo shows the appear-

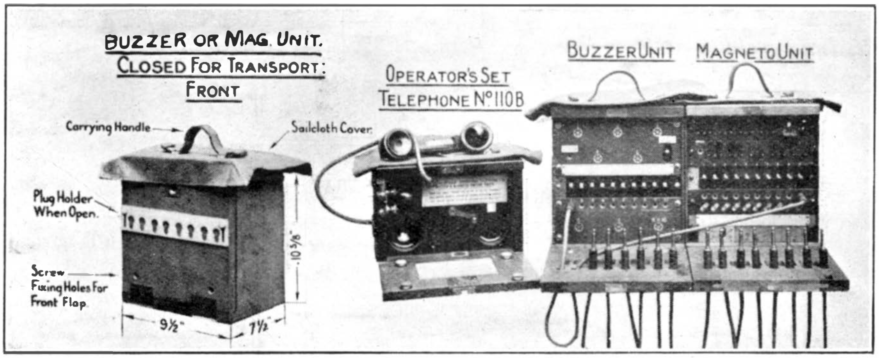
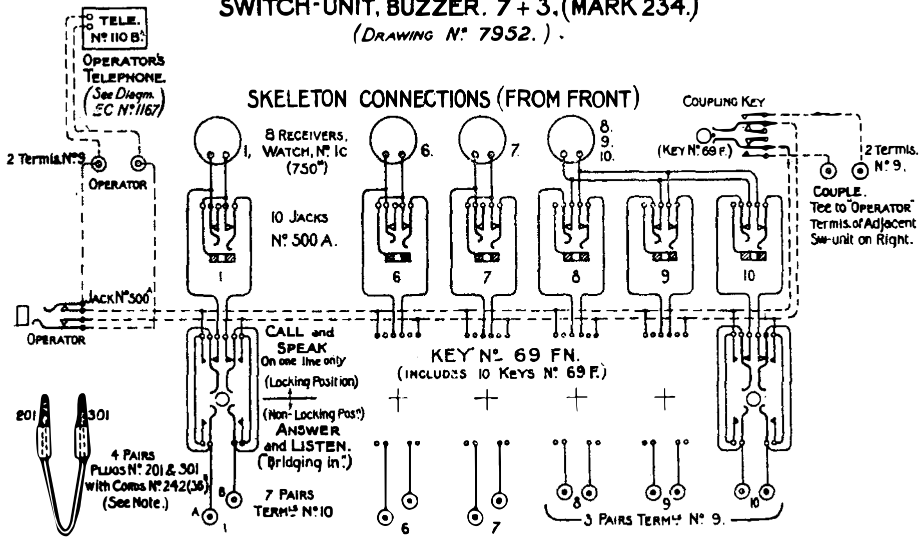


FIG. 4.

ance of these portable switchboards, which have now been adopted as standard by the War Office, and indicates how they can be lined up in groups for the equipment of exchanges in dugouts and advanced positions. Diagrams E.C. 1161 and 1165 show their electrical connections, and Diagram E.C. 1167A shows the connections of the operator's telephone (No. 110B), which is adapted for use on either buzzer or magnetic circuits. The stations connected to buzzer switch-units were usually equipped with the War Office "D 3" buzzer telephone, or with Fullerphones, and those connected to magneto switch-units had trench telephones (No. 100 or No. 110). About 36,000 buzzer units and 5,000 magneto units were

CONNECTIONS OF SWITCH-UNIT, BUZZER, 7 + 3, (MARK 234.)

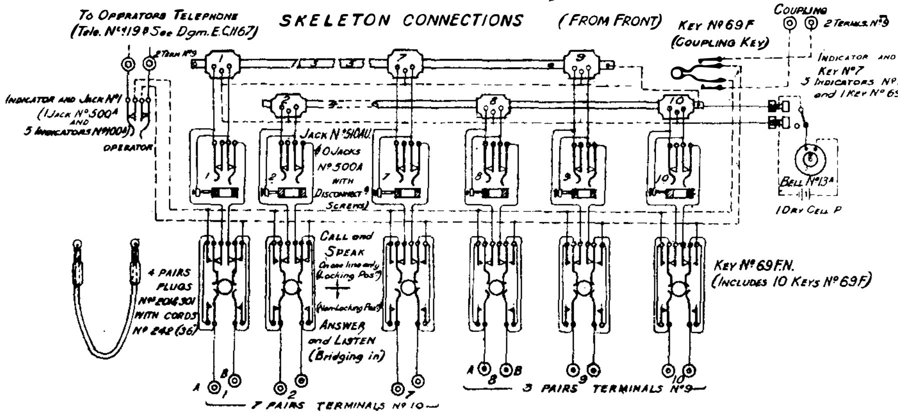
(DRAWING Nº 7952.)



E.C. 1161

CONNECTIONS OF "SWITCH-UNIT MAGNETO 10-LINE (MARK 234)"

(DRAWING Nº 7953)



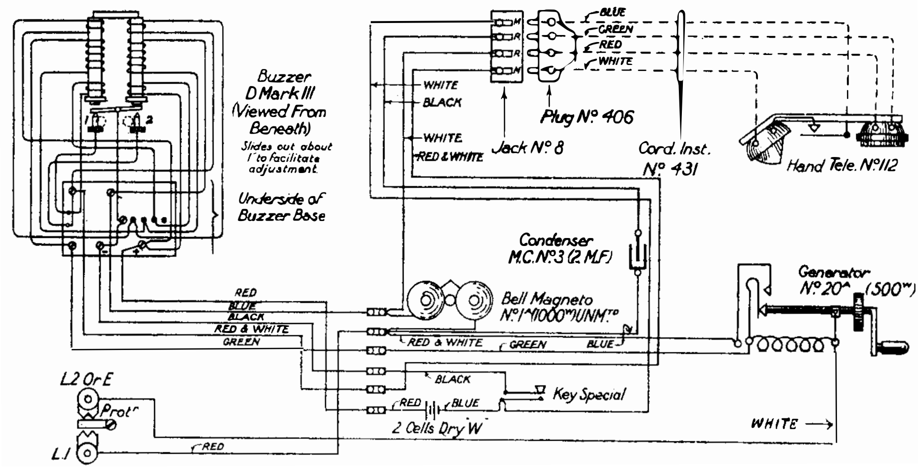
E.C. 1165.

supplied to the armies. Other forms of buzzer switch-units fitted with visual indicators responsive to buzzer signals were also devised and about 1300 were supplied, but these have not been adopted as post-war standards.

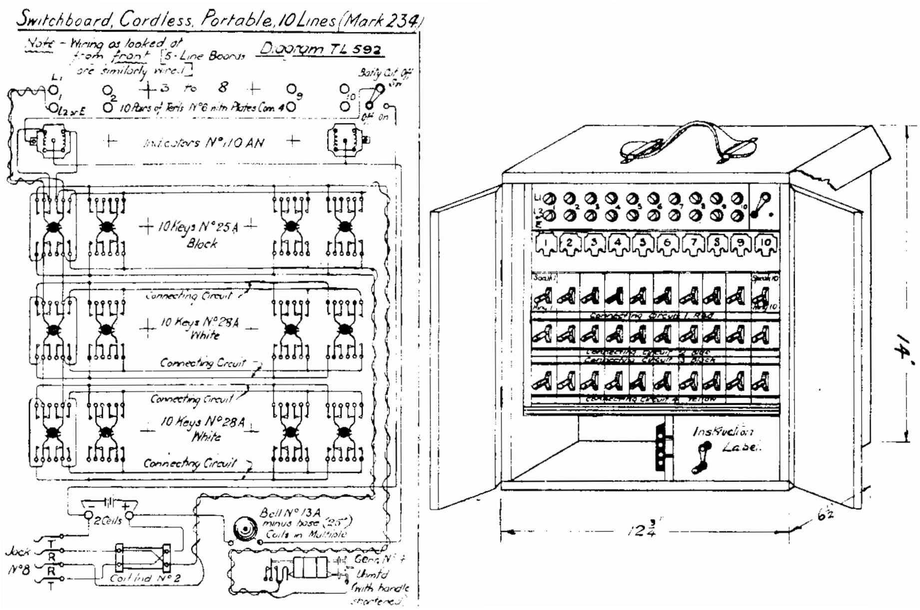
CORDLESS TRENCH SWITCHBOARDS.

The 10-line portable cordless magneto switchboards shown in Diagram T.L. 592, were introduced at an early stage in the war,

CONNECTIONS OF TELEPHONE Nº 110 B (MARK 234)



E.C. 1167A.



T.L. 592.

and were extensively used at artillery and brigade headquarters. They are of robust construction, self-contained and self-packing. About 5,000 were issued.

PORTABLE MAGNETO SWITCHBOARDS—20-LINE.

In the earlier stages of the war, great numbers of wall switchboards, 20-line and 30-line, of ordinary Post Office type, were mounted in combined stands and packing cases, for use by the larger formations—divisional and corps headquarters. When supplies of these became exhausted, special portable 20-line switchboards were designed. One of these, closed for transport, is shown by Fig. **9**. The carcase of the switchboard revolves on a trunnion

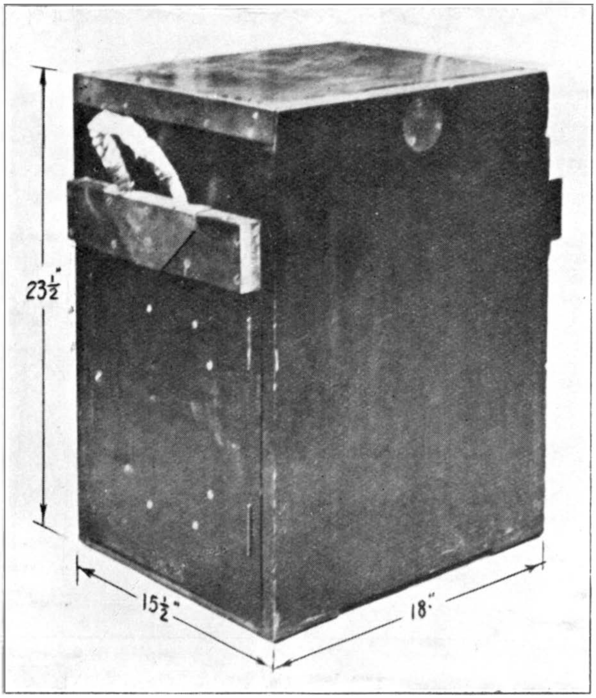


FIG. **9**.

and can be swung up into the working position shown by Fig. **10**. A cord-box flap hangs behind the cords and pulleys in the working position and forms the lid of the package when collapsed for transportation. Fig. **10** also shows a 10-line magneto switch-unit secured to the top of the 20-line switchboard, increasing its capacity to 30 lines when required, and providing for the make-up of exchanges of 20, 30, 40, 50 or 60 lines. Modifications of capacity can thus be readily secured to suit the requirements of different formations which may have to occupy a positionn successively when armies are advancing or retiring. The line terminals of the 20-line switchboard are so arranged that the cables carrying the external lines can be permanently wired to 10-pair connectors, which can be passed through holes in the roof of the switchboard and secured in position under the terminals in a few minutes.

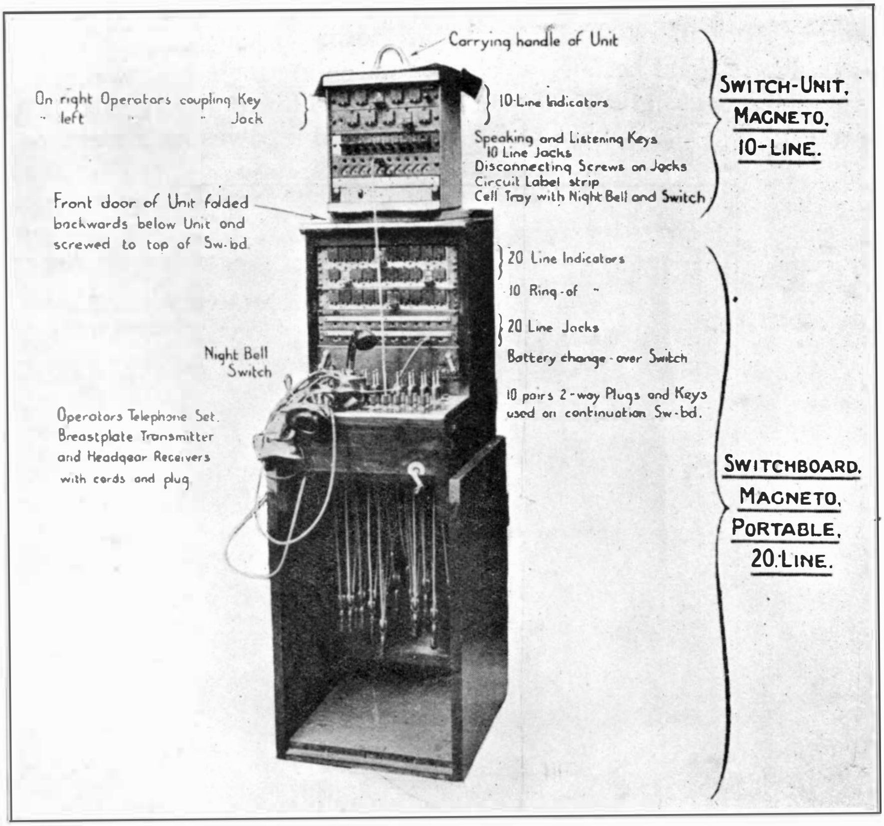


FIG. 10.

40-LINE PORTABLE SWITCHBOARDS.

These items—Figs. **11** and **12**—are made up on the same collapsible and self-packing principle as the 20-line switchboards. They are fitted with self-restoring bull's-eye indicators, a pedal form of generator, and very complete arrangements for rapid installation and rapid operating. Two such switchboards side by side provide an 80-line exchange for a corps headquarters office.

PORTABLE MULTIPLE EXCHANGES.

The above 40-line switchboards are also designed for use as sections of a portable multiple exchange, which can be installed to serve as many as 320 lines at an army headquarters. For this purpose multiple jack-boxes are provided. These have a 4-point break-

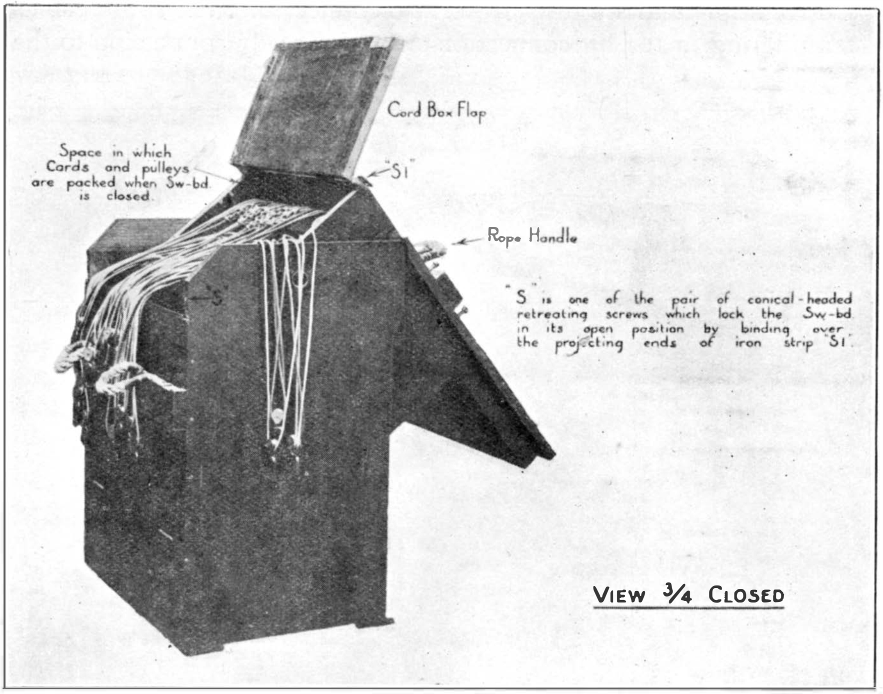

Cord Box Flap
Space in which Cords and pulleys are packed when Sw-bd is closed.
"S1"
Rope Handle
"S"
"S" is one of the pair of conical-headed retreating screws which lock the Sw-bd in its open position by binding over the projecting ends of iron strip "S1".
VIEW 3/4 CLOSED

FIG. 11.

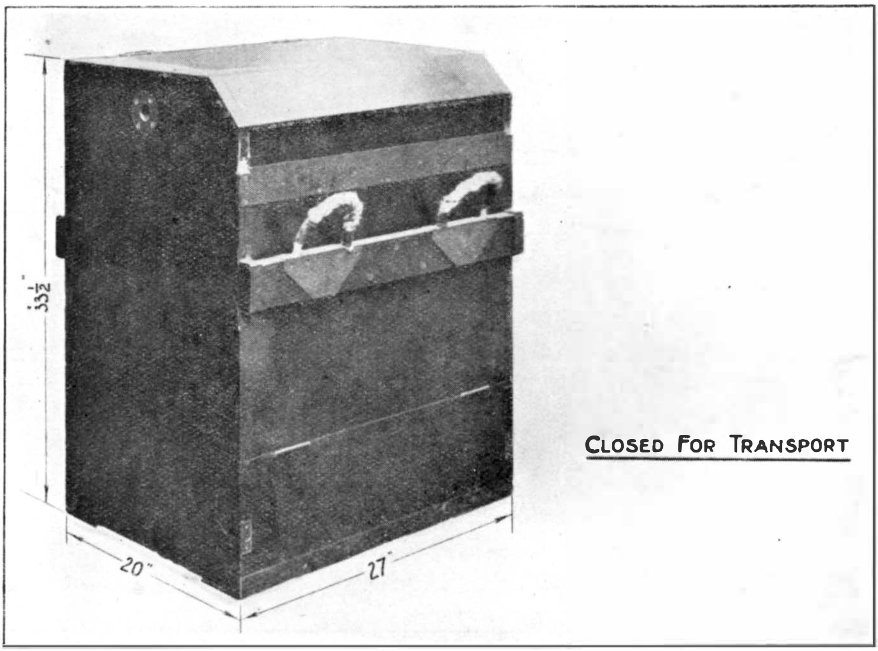

33½"
20"
27"
CLOSED FOR TRANSPORT

FIG 12

jack multiple and are fully wired and connected to extension cables terminating in 10-pair connection strips for ready connection to the

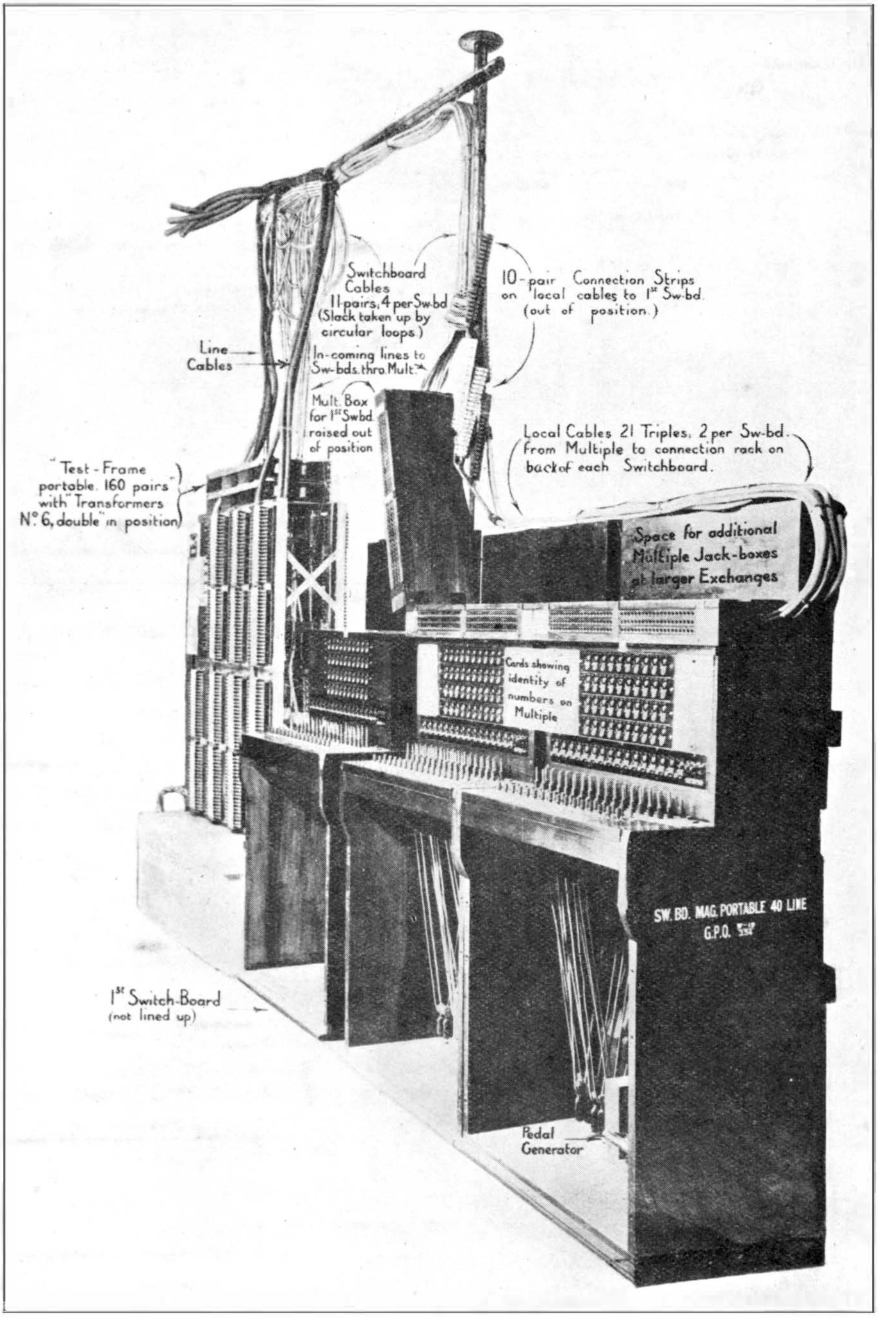


FIG. 13

answering positions of the switchboards at one end and to the test frames at the other. The sections of the multiple jack box are so hinged together that the whole can be folded up concertina fashion into a rectangular block, and transported, with its extension cables, in a special packing case. Fig. 13 shows a multiple exchange of

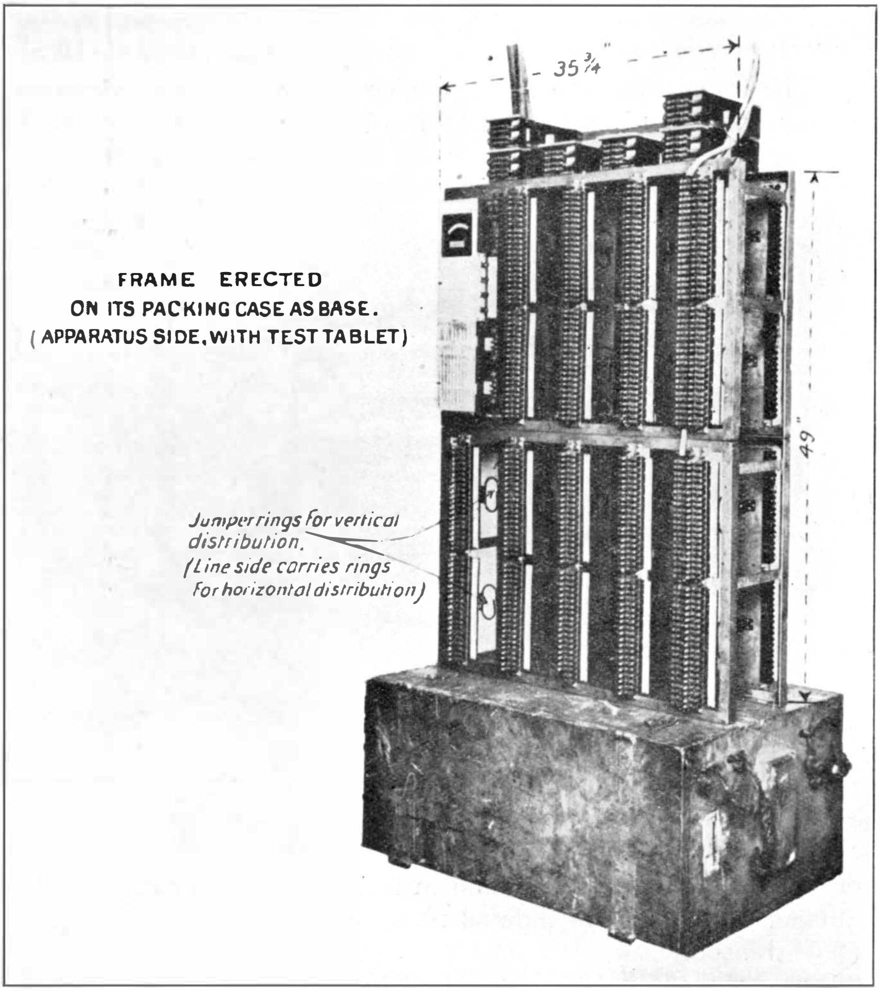
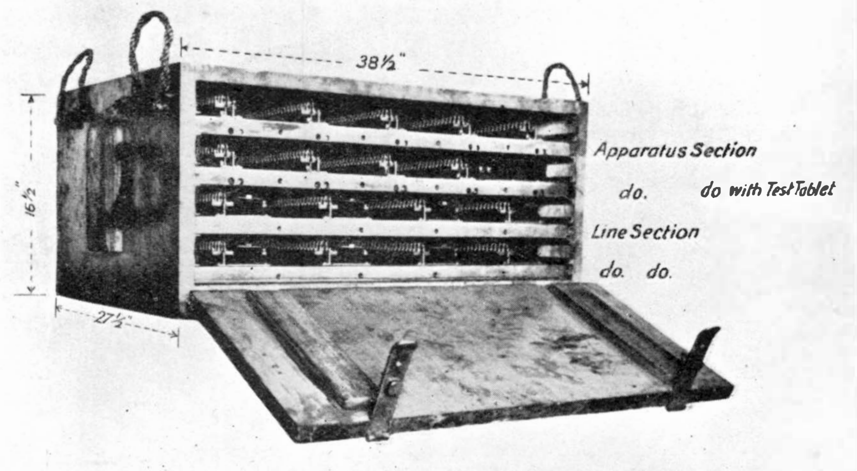


FIG. 14.

three sections in course of erection. It will be seen that the multiple jack boxes lie on top of the 40-line switchboards and can be stacked, one above the other, to the required capacity. A complete multiple is provided in front of each operator. It may be mentioned that 40 lines generally represents a maximum load for an operator under field conditions. The lines are generally very busy, the holding time is long, and the operators have to do much tracing. 16 pairs of plugs and cords are provided on each 40-line switchboard. By the use of these switchboards and the portable test frames referred to later, a complete multiple exchange for 320 lines can be carried about, and can be set up, or dismantled and placed intact on transport, in about an hour.

TEST FRAMES, PORTABLE, 160 PAIRS (AND 80 PAIRS).

The 80-pair test frame was provided for divisional headquarter offices and the 160-pair frame for corps and army headquarters.



FRAME DIVIDED IN FOUR SECTIONS & PLACED IN CASE FOR TRANSPORTATION. WEIGHT ABOUT 2 CWTS.

FIG. 15.

Two or more frames can stand in line and be inter-connected by jumper wires. Fig. **14** shows a 160-pair frame erected, and Fig. **15** in its transport case. It will be noticed that the transport case forms the base of the frame when in use. The sections of the frame can be withdrawn from the case and fixed in situ in a few minutes without the use of any tools. Fig. **13** shows one of the frames erected as part of a multiple exchange. The strips on the line side carry fuses, lightning protectors, and U links; those on the exchange side carry duplicate lightning protectors and U links. The terminals are all arranged for wiring by means of cables ready connected to the 10-pair connection strips shown in Fig. **13**. Transformers specially mounted in pairs can be stacked to any required extent on top of the frames while in situ and can be connected, either temporarily by plugs and cords or more permanently by jumper wires, for the purpose of making up superposed circuits. One section of each frame is fitted with a "Detector No. 2" provided with four 3-position testing keys by means of which any required test may be applied automatically to a line plugged through to the testing terminals. Tables showing the resistance and insulation values corresponding to the various readings on the scale of the detector are engraved on the metal front of the test tablet.

TEST PANELS.

These were introduced in 1916 and provide mobile testing and protective equipment for all classes of the smaller formations; until the introduction of Portable Test Frames they had even been used

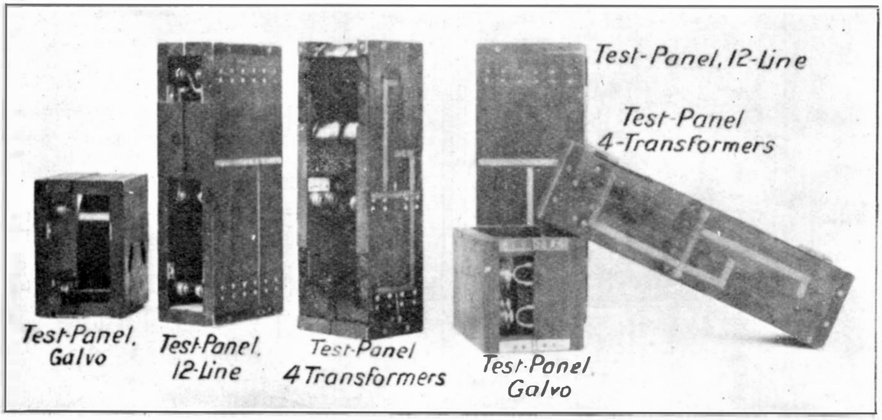


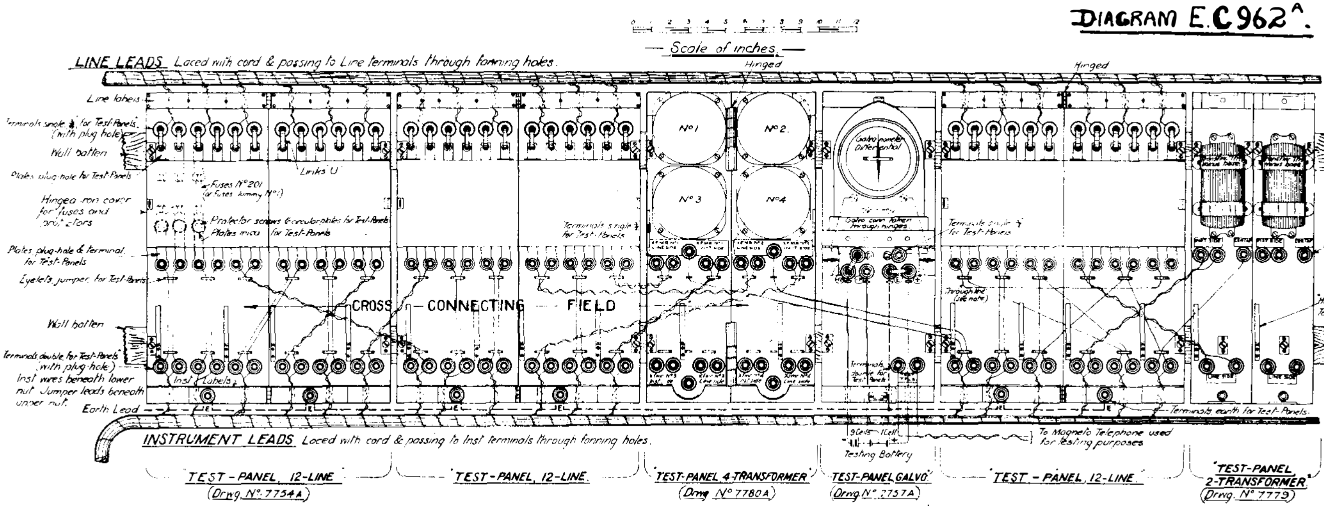
FIG. **16.**

at some corps headquarters. The line test panels provide U links, fuses, lightning protectors and cross connecting facilities. Other types of panel provide a testing galvanometer and transformers for superposing. All types are hinged and self-packing and all can be assembled *en suite* on a wall. Fig. **16** shows a group of test panels shut up for transportation, and Diagram E.C. 962 A shows how they are assembled side by side in a military office. Over 11,000 of these test panels were supplied.

GENERAL.

Among interesting items, which want of space prevents us from describing, are the special thermophone transmitters used by the sound ranging section of the R.E., by means of which the location of enemy guns at distances of several miles could be determined

DIAGRAM E.C.962^A.



TEST-PANEL, 12-LINE – In two sections, hinged to fold inwards horizontally with spring catch for transportation.

Comprises – 12 Terminals, single ¾" for Test-Panels
12 " double " " "
2 " earth " " "
12 Plates plug-hole " "
12 " " and terminal for (Test-Panels
12 Protector screws and circular plates (for Test-Panels
12 Plates, mica for Test-Panels
12 Eyelets, jumper " "
4 Hooks " " "
2 Labels line " " "
2 " inst. " " "
12 Links 'U'
12 Fuses Nº 201 (or Fuses dummy Nº1)

TEST-PANEL GALVO – In two parts, hinged horizontally to fold together with spring catch (When mounting the Panel a small supporting batten should be fixed on wall behind hinges).

Comprises – 6 Terminals, single ¾" for Test-Panels
2 " double " " "
2 Links 'U'
1 Galvanometer, differential (coils in series)

Positions of Links etc.:–

Left hand group of 3

To connect 10-cell battery (12 volts): for insulation tests

To connect 1-cell battery; for local continuity tests.

Right hand group of 3.

Insulation test; positive pole to line plug & cord connection to line

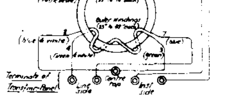
Insulation test. negative pole to line. plug & cord connection to line

[illegible] insulation test. plug & cord connection to A line
" " to B do

TEST-PANEL 4-TRANSFORMER – In two sections hinged to fold inwards horizontally with spring catch for transportation.

Comprises – 20 Terminals single ¾" for Test-Panels
8 Eyelets, jumper " " "
2 Hooks " " "
4 Coils repeating Nº 4006 A, minus (bases
1 Set of Labels for Test-Panel (4-Transformer

Connections of Coils to Terminals.

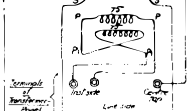


The coil end numbers & colours indicated correspond to those of ordinary Repeating Coils 4006A

TEST-PANEL, 2-TRANSFORMER. – Consists of "Test-Panels 1-Transformer" fixed together for transportation by thumb-screw fastenings. Each 1-Transformer Panel comprises –

5 Terminals single ¾" for Test-Panels
1 Hook jumper " " "
1 Transformer 7 terminal minus base.
1 Set labels for Test-Panel 1-Transfmr

Connections of Coils to Terminals.



Letters refer to corresponding terminals of ordinary "Transformers 7 terminal."

GENERAL NOTES. – The above mentioned fittings provide mobile equipment on the unit principle for lines in Military Offices. The Panels will be fitted side by side in such numbers as may be necessary on horizontal wall-battens provided locally. The "Cross Connecting Field" is continuous across all the Panels and jumper connections are made thereon by means of switchboard wire which is supplied in bundles known as "WIRE, SWITCH-BOARD, BUNDLES," each containing four 15-yard lengths of twin wire of different colours. Jumper wires should be drawn taut but without strain. Circuit codes should be written in pencil on the labels and washed out when alteration required. All terminals are constructed with central plug-holes, as well as with ringnuts, and pairs of plugs and cords are provided for making temporary or emergency connections, 2 Sets "PLUGS Nº 103 PAIRS, WITH 72 INCH D1 CORD" are required for each "Test-Panel, 12-line." Longer cords may be made locally of D1 Field Cable. If "through" circuits are numerous the sides towards forward offices may be connected to "Instrument" terminals (lowest row on Test-Panels) in order to avoid taking up two sets of fuses and protectors. Panels may be fitted in two rows one above the other, if wall space is not otherwise available, in such cases supporting hooks or pins, for jumper wires between the two rows, should be arranged at the ends or at intermediate gaps left for the purpose. If floor space is plentiful suites of Panels may be fitted back to back on a simple wooden rack made locally, gaps 3 or 4 inches wide being left at suitable intervals in order that jumper wires may be passed from one side to the other.

Fig. 17.

with a margin of error of only a few yards. These were made and supplied by the Post Office, together with the special resonating air containers, microphone holders, protective devices, testboards, line balancing equipment, graphical ranging instruments, and other items used for sound ranging purposes.

Another important section of the R.E. dealt with the location of enemy guns by observed cross-bearings on the flash. Switchboards and signalling devices of various types were designed and supplied for controlling and co-relating the reports of different observers.

Portable testing sets, common battery telegraph sets, silent patrol telegraph sets, concentration and intercommunication telegraph switchboards, cross-connecting cases, etc., were made up and supplied in large numbers. Large multiple exchanges were provided for installation at the main coastal bases and at general headquarters. Thermionic valve telephone repeaters were supplied towards the end of the war and gave excellent service. A great many types of special trench and aerial cables were designed and shipped in enormous quantities to the armies in the field, as well as line stores of all descriptions.

CORRESPONDENCE.

THE SHUNTED CONDENSER.

The Editor, THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL.

DEAR SIR,—A. F. has given us some interesting information. I hope he will give us more and the deductions drawn from the Report. On page 231, it is said that the best results are given by the high resistance and small capacity. This suggests to me that four curves showing the current shape with

(1) High resistance and small capacity;
(2) Low resistance and large capacity;
(3) Condenser only (work by condenser impulses);
(4) High resistance, without condenser, in series with the Wheatstone receiver

might be given. The values used should be those to emphasize the peculiarities of the system employed—not to try to approximate results—so that we may see clearly what the main characteristics of the different arrangements are.

(1) and (3) could, of course, be made similar by increasing the resistance unduly in (1). In (2) the very low resistance would no doubt make the condenser almost ineffective.

(4) The resistance can be made to smother the inductance.

Yours faithfully,
E. V. SMART.

THE INSULATION OF A LINE.

The Editor, THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL.

DEAR SIR,—With reference to Mr. J. G. Hill's article on the "Insulation of a Line," which appeared in the January issue, the writer would like to take the opportunity of pointing out that formula (8), *viz.*, $Z = \frac{Rl}{2} + \frac{R_2}{l}$ does not contain the inaccuracy indicated if it is put in the form and used in the same sense shown in the writer's articles on Circuits efficiency and on the Leakage Conductance Theory, which appeared in this Journal some years ago. For the purpose of obtaining a limiting distance in miles the formula was given in the following form:—

$$R_1 = \frac{r_0}{L} + \frac{R_a}{2}$$

Where R_1 is the reading obtained by making an insulation resistance test; R_a is the conductor resistance of the wire obtained by multiplying the conductor resistance per mile by the length in miles (L). From the derivation of the formula it may be written

$$R_1 = \frac{C \times L}{L} + \frac{L \times r}{2}$$

where C is derived as follows:—

Let R_1 be defined as above; R_c be the observed reading obtained by taking a conductivity test when the apparent insulation resistance is equal to R_1.

Then the Circuit condition will be represented as in Fig. (1).

In order to arrive at an equivalent Circuit on the basis of the readings R_1 and R_c it is assumed that $a = b$ (Fig. 1), and it is required to find a value for C which will satisfy the two conditions represented by the observed readings R_1 and R_c.

This is an ordinary algebraic problem and for the moment we may exclude all questions involved in the definition of the Standard known as "Insulation resistance per mile."

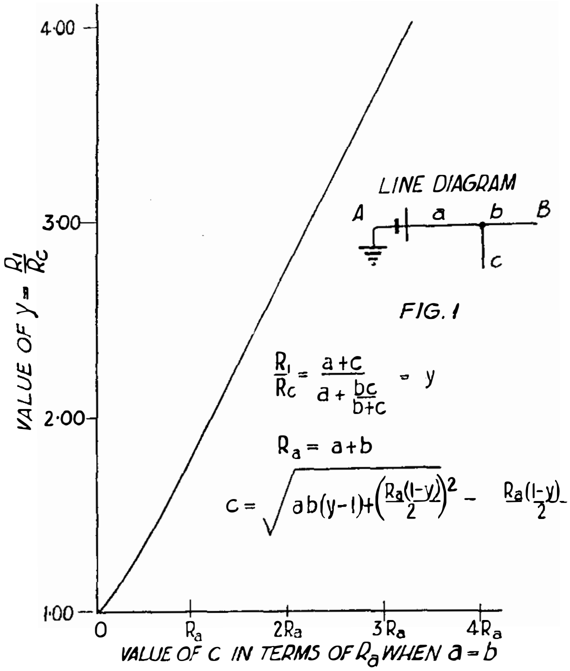


FIG. 2

FIGS. 1 AND 2.

From Fig. I A is the testing station and

with $a=b$ and B disconnected: $R_1 = a+c$

with B earthed $R_c = A + \dfrac{bc}{b+c}$

call the ratio $\dfrac{R_1}{R_c} = \dfrac{a+c}{a+\dfrac{bc}{b+c}} = y$

Working out the quadratic for C

$$\text{gives } C = \sqrt{ab(y-1)+\left(\frac{R_a(1-y)}{2}\right)^2} - \frac{R_a(1-y)}{2}$$

Values of C for different values of y are shown in Fig. **2**, and these values are confirmed by applying the relevant formulæ given by Kennelly in his " Application of hyperbolic functions to electrical engineering problems," *viz.*,

equivalent value of $a=b=R_1\left(1-\sqrt{1-\dfrac{R_c}{R_1}}\right)$

equivalent value of $C = R_1\sqrt{1-\dfrac{R_c}{R_1}}$

The use of the formula $R_1 = \frac{r_o}{L} + \frac{R_a}{2}$ in connection with leakage conductance problems will therefore give true values for the mileage (L) provided the factor r_o (equal to $C \times L$) is derived from the readings representing the true "apparent insulation resistance" (R_1) and the true "apparent conductivity" (R_c).

It will be clear that the use of these observed values in the form of a ratio has obviated the need for dragging in the very arbitrary standard known as the insulation resistance per mile.

It is of course recognised that one of the main points of Mr. Hill's article is to indicate the extent to which the "Sending end resistance Z" (which is a derivation from the characteristic $R_o = \sqrt{\frac{R}{G}}$) varies from the true insulation resistance, represented by the observed readings (R_1), as the length of the line is increased and the graph shown in Fig. 1 of Mr. Hill's article will doubtless be of great assistance to those who wish to translate the terms of one system of computation into those of another.

Yours faithfully,

J. L. TAYLOR.

January 18th, 1922.

[MR. HILL'S REPLY.—I am glad to have had the opportunity of seeing Mr. Taylor's letter. Before dealing with the point raised in it, however, may I point out that my article deals with the *calculation* of sending end resistance, etc., from known constants, whereas Mr. Taylor first makes two *measurements* and then calculates his value, etc. This is not quite the same case as the one I dealt with, but still I think, so far as my casual examination goes, that the value now given for C is correct. Mr. Taylor, however, then forms a further equation

$$R_1 = \frac{C \times L}{L} + \frac{R_a}{2}$$

and this is of the same form as used in his previous articles. I will now show that this cannot be even approximately correct for very long circuits.

It is known that the correct sending end resistance Z_0 of a line which is electrically very long, and with the distant end open is

$$Z_0 = \sqrt{\frac{R}{G}}$$

where R is the conductor resistance and G the leakance per mile respectively. In order to test the accuracy of Mr. Taylor's formula I will compare the results obtained from the two formulæ, based on data taken from Mr. Taylor's previous articles. In the P.O.E.E. Journal for July, 1917, pages 82—83, we learn that the limiting distance for double-current Morse working on a 150lbs. overhead circuit is 414 miles, based on an insulation resistance of 60,000 ohms per mile. This circuit is therefore a possible commercial circuit. Take the conductor resistance of a 150lbs. circuit as 6 ohms per mile and let the circuit length be 400 miles. Comparing the values of Z_0 and R_1 we have

$$Z_0 = \sqrt{\frac{R}{G}} = \sqrt{\frac{6}{\frac{1}{60,000}}} = 600 \text{ ohms.}$$

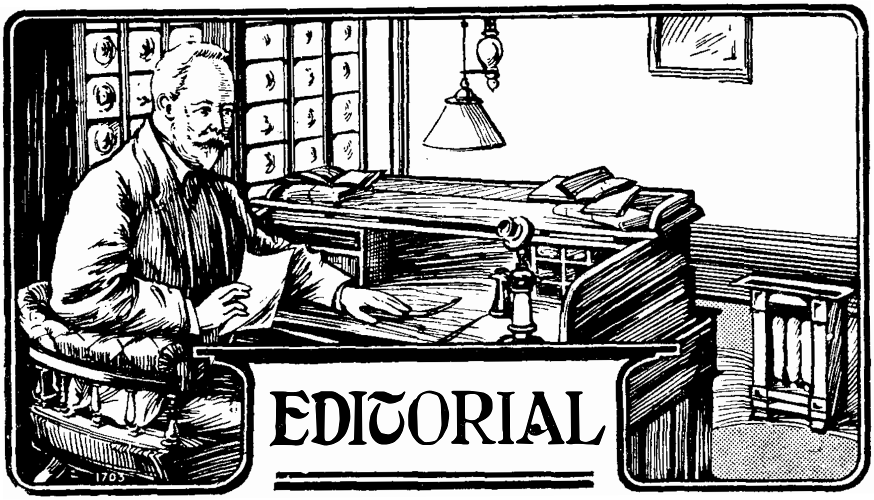
$$R_1 = \frac{C \times L}{L} + \frac{400 \times 6}{2} = C + 1200 \text{ ohms.}$$

No matter what value is given to C (it cannot be less than zero) the error in this case cannot be less than 100%, and there is no need to pursue the calculation further in order to show that the formula for R_1 is, in such a case, very far from correct.

I may point out that the correct formula in this case for the sending end and resistance is $Z = Z_0 \coth \theta$, as previously defined in my article. When, however, the line is very long, as in this case, the formula reduces to $Z = Z_0$, and I have used this.

Yours faithfully,

J. G. HILL.]



EDITORIAL NOTES AND COMMENTS.

THE Engineering Department of the Post Office waited with equanimity the publication of the Third and Final Report of the Geddes Committee. If any fear was expressed at all, it was that the Committee, in its keen desire to reach the £100,000,000 reduction in expenditure at which it was aiming, might be tempted to make a cut in the capital sum scheduled for new construction and equipment work during the next financial year. Such a policy, no doubt, would have been hailed with acclamation by a certain section of the press, but if carried out it would have had serious effects upon the development of the telephone service in this country, and would have considerably hampered the business community in its struggle towards better times. Prices are falling, and with the reduction in the Bank Rate the Government ought to be able to obtain money on cheaper terms than it has done for the past seven years. We can construct now on a sound economic basis—in the last six months of the year wages will be lower still—and the present offers an excellent opportunity for wiping out arrears and bringing down the waiting list to extinction point. In this part of its report at any rate the Committee has done the correct thing and has justified completely the policy of the Department.

We think we might be pardoned if we congratulated ourselves a little on the entire findings of the Committee on Post Office Engineering. The " five men of good will " examined very carefully the various methods employed to secure a satisfactory output of work from each workman and had no fault to find.

"The Engineer-in-Chief keeps in close touch with the cost of maintenance in each of his districts and is able to compare the results obtained in the various districts; progress reports enable him to ascertain the cost under each item of construction work. The results are circulated, so that a laudable spirit of rivalry is encouraged. In this Department there is a systematic compilation of results and circulation of information."

Just as we go to press, the Report of the Select Committee on the Telephone Service has been issued. A 10% reduction in rates, salaries and overhead charges for construction work and renewals to be debited to capital, a reduction in the amount set aside for depreciation, the extra mileage rate to be reduced to £5 a mile, and certain re-arrangements of doubtful efficacy in administration constitute the findings. The mountain has been in travail again with the traditional result!

In our Review pages we have pleasure in publishing details regarding our French contemporary "Les Annales des Postes, Télégraphés et Téléphones." The magazine is now appearing every two months instead of quarterly as formerly. It may be of interest to students of sociology to mark the difference between the methods of the two races in even such a small matter as the running of a semi-official magazine. In this country the Journal is the organ of the I.P.O.E.E. which receives a grant from the Department, but is conducted by a popularly elected Council free to follow its own policy, to appoint its own editing committees and to publish what these committees think fit and proper. Across the Channel the State appoints the editing committee and thus exercises control over the production and its contents. We are afraid our "guid conceit o' oorsels" would be impaired seriously if we attempted a strict comparison of the relative values of the two journals. The editing committee of "Les Annales" does its work exceedingly well, and we strongly recommend the magazine to the notice of our readers.

HEADQUARTERS NOTES.

THE TELEPHONE TRUNK LINE SYSTEM OF THE UNITED KINGDOM.

CONSIDERABLE progress has been made during the year with the Post Office programme for constructing a complete underground network of Main Telephone Cables in the United Kingdom. The programme was formulated as far back as 1913 and was actually commenced in that year.

Previous to the advent of the thermionic valve amplifier, Telephone Engineers had regarded a distance of about 450 miles as the practicable limit for commercial speech through an underground cable. The original scheme for the network of the United Kingdom was designed on this basis and provided cable communication between all the largest towns. The present day aspect, however, due entirely to the Telephone Relay, is that underground communication is practicable over any distance overland, and we are within sight of the time when it will be possible to speak from London, Manchester or Glasgow to any large town on the Continent. It is safe to say that there are no insuperable engineering difficulties. The question is one of finance and policy only.

Although construction work on the main cable system was practically at a standstill during the war, progress on the new scheme has been so rapid since that 1,880 miles of ducts and 1,055 miles of main cable, representing a wire mileage of 320,000 miles, were laid up to the end of 1921. In the course of a few weeks the first section of the new network between London and Manchester will be put into commercial service, and spur cables to Liverpool, Leeds, Birmingham, Sheffield, Nottingham and Leicester will be connected. Construction of the main cable to Bristol and South Wales is also well advanced and the South Coast is provided for by new cables from London to Brighton, Southampton and Portsmouth, which are now nearing completion.

The cable scheme includes the provision of a number of Telephone Relay Stations which are spaced at intervals of about 60 miles along the cable route. For instance, on the route between London and Glasgow, Relay Stations will be in operation at Fenny Stratford, Derby, Leeds, Darlington, Jedburgh and Edinburgh.

For communications with the Continent there will be Relay Stations in the London Trunk Exchange and also at Dover and Ipswich.

Birmingham is virtually the hub of the internal cable network and a large Relay Station is to be provided at that point. Between London and the West Coast, Maidenhead, Marlborough, Bristol, Gloucester and Newport will be relaying points.

A Telephone Relay Station on the main cable routes involves an installation of machinery, batteries and special apparatus on a scale equal to the plant in the largest Telephone Exchanges. In most cases special buildings are required, and as some of them are necessarily located outside the areas of public electricity power supply, independent power plants will be installed. The daily power consumption at a Station on the main Northern route will be at the rate of about 350 kilowatt hours for each cable, exclusive of lighting. The main power units will be direct-coupled oil-engine sets, the dynamos having an output of 40 kilowatts.

High-frequency Carrier Current Telephony is the generally accepted nomenclature of the most recent innovation in the art of long distance communications. Primarily it is an adaptation of the principles of wireless telephony to wire circuits—hence the description "wired wireless" by which it has been popularly known. The system has many attractive features, especially in the direction of multiplex working, that is, the operation of several channels over one physical circuit.

Up to the present time its practical application is limited to wire circuits which are entirely on overhead lines. The difficulties of maintaining such lines in this Country over any considerable distance necessarily restrict the use of the system until it can be applied to underground or submarine cables. This involves many difficult problems. The subject is now receiving special investigation and considerable success has already been achieved. A paper dealing with "Some experiments on Carrier Current Telephony" was read by Mr. C. A. Taylor on the 8th ult. before the London Centre of the I.P.O.E.E. Further details will be published in due course.

EXCHANGE DEVELOPMENTS.

Orders have been placed for the following new Exchanges:—

Exchange.	Type.	No. of Lines.
Buxton	Manual C.B.	620
Dundee	Automatic	3340
Ramsgate	Manual C.B.	500
Rossendale	Manual C.B.	560
Windsor	Manual C.B.	700

Orders have been placed for extending the equipment at the following existing Exchanges:—

Exchange.	Type.	No. of Lines.
Leeds Trunk	Manual C.B.	17 Additional Positions.
Park 2nd Extension ..	Manual C.B.	1460

In the list furnished last quarter Birmingham-Victoria was quoted as a new Exchange; it should have been given as an Extension to existing exchange.

LONDON DISTRICT NOTES.

DURING the thirteen weeks ended December 27th, 1922, 5,548 exchange lines, 4,762 internal extensions and 525 external extensions were provided; in the same period 2,275 exchange lines, 2,903 internal extensions and 315 external extensions were recovered, making nett increases of 3,273 exchange lines, 1,859 internal extensions and 210 external extensions.

INTERNAL CONSTRUCTION.

New Exchanges.

Bishopsgate Temporary Exchange.—This C.B. No. 1 switchboard which was in use formerly for Clerkenwell Temporary Exchange has a capacity of 1500 lines and was opened on March 4th with 727 subscribers and 576 junctions. The lines were transferred from London Wall, Central and Avenue. A further transfer of 501 lines will be effected before the end of March.

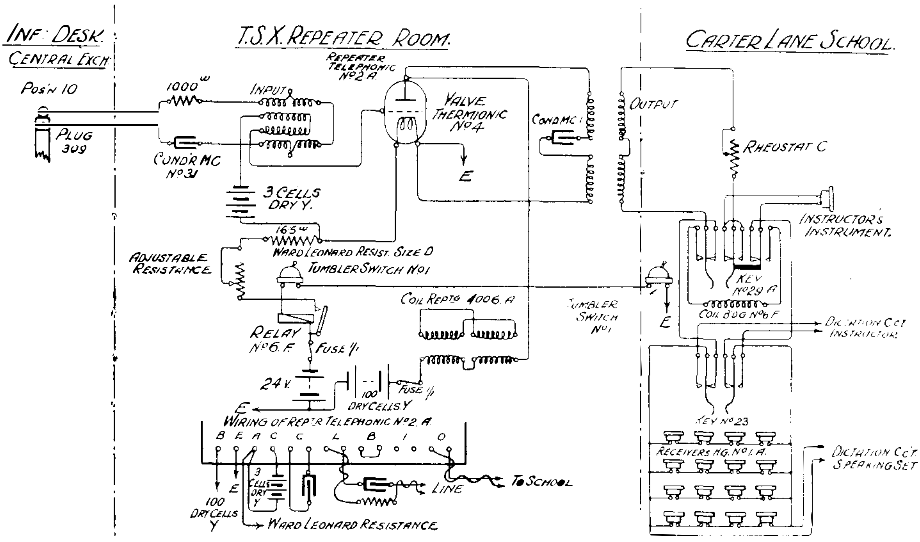
Maryland Exchange, formerly known as new Stratford, is rapidly approaching completion. It is a C.B. No. 1 board comprising 16A, 11B, 1 Testing and 1 electrophone positions, and will be equipped with 1920 locals and a multiple of 2000 lines. It will absorb the old Stratford Magneto Exchange and the temporary exchange installed in an Army hut on the same site as the new exchange and known as Broadway.

Kilburn Temporary Exchange is in course of construction. The equipment is being installed by the L.E.D. staff in the old Kilburn Fire Brigade Station, one of the buildings relinquished by the London Fire Brigade as the result of motor vehicles being brought into general use by the brigade.

Electrophone Exchange.—The capacity of the Electrophone Exchange has been increased by the addition of two new music positions, thereby accommodating 294 more subscribers and making the total capacity 2,205.

The repeater equipment at the Electrophone Exchange referred to in the London Engineering District notes of the last issue of the Journal, was brought into use early in February. The amplification of transmission on the music circuits has allowed of a substantial number of theatre transmitters and lines being scheduled for recovery.

Telephonists' School, G.P.O. South.—A thermionic valve has been installed in the Telephonists' School at G.P.O. South. This will enable a number of learners to listen simultaneously on working positions in the Exchanges without reducing appreciably the transmission efficiency of the working position. The accompanying diagram shows the arrangement, and it will be seen that the keys



AMPLIFIER CIRCUIT FOR OPERATORS' SCHOOL. G.P.O. SOUTH.

are wired so that the Supervisor is enabled to connect the class and herself or herself alone to a working circuit on the Information Desk. An ordinary dictation circuit is also provided.

Conversion of Signal Junctions to Automatic working.—Arrangements are being made to convert to automatic signalling the signal junctions in the London area over which it is still necessary to ring.

Pneumatic Tube Services.—An experimental ejector has been placed on trial at the Billingsgate B.O. to replace the old type of receiving box. A forked exhaust near the termination of the pressure tube has been provided so that along the last two yards of the tube a carrier travels with a reduced power and forces open a balanced stopper which automatically closes when the carriers fall into a tray on the table.

To enable a tube to be divided into two sections for day working, an intermediate switch has been modified so that the "up" and "down" sections of the tube at the intermediate station can be extended by means of short additional lengths to two receiving boxes.

A considerable re-arrangement of the house tubes on the Second Floor of the C.T.O. has just been completed. A 5″ service pipe has been run from the principal vacuum main to which has been fitted a connection box with service cocks for 12 tubes, 10 of which have been brought into use in connection with the diversion. The entire work was carried through by the Department's officers, and during the change-over no tube was stopped for more than half an hour. The original installation was provided under contract.

A modified " Stopper, brass " for pneumatic tube tests, designed by a C.T.O. Inspector, has been approved by the Engineer-in-Chief. The difference between the new item and that at present in use, as illustrated in Technical Instruction X is the replacement of the rubber washer and flat compression plates by a stout rubber ball between two cup-shaped pieces.

External Construction.

During the three months ended 31st January, 1922, the following changes have taken place in the single wire mileages:—

Telegraphs.—Nett increases of 1 mile open wire and 19 miles underground.

Telephones (Exchange).—Nett decreases of 24 miles open wire, 517 miles in aerial cable and 1553 miles in underground.

Telephones (Trunks).—Nett increases of 20 miles open and 112 miles underground.

Pole Line.—Nett increase of 44 miles, the total now being 2982 miles.

Pipe Line.—Nett increase of 2 miles, the total now being 3984 miles.

There was a nett decrease of 34 miles of underground cable, the total now being 7903 miles.

The total single wire mileages, exclusive of wires on Railways maintained by Companies, at the end of the period under review were:—

Telegraphs	17,719
Telephones (Exchange)	1,228,258
Telephones (Trunks)	19,491
Spare Wires	20,660

Improved Results in London Telephone Service.

Comparative statistics of efficiency for the first half year of 1920, compared with July-November, 1921, show improvement, which is still growing, as follows:—

Percentage Cut-Offs.

Percentage for 1920.	.45 = one in 222 calls.
July-November, 1921.	.41 = one in 244 calls.

An improvement of about 9 per cent.

Percentage Wrong Numbers.

Percentage for 1920. 4.1 = one in 24 calls.
July-November, 1921. 3.5 = one in 29 calls.
An improvement of about 7 per cent.

Percentage Double Connections.

Percentage for 1920. .47 = one in 213 calls.
July-November, 1921. .35 = one in 286 calls.
An improvement of about 26 per cent.

Percentage "No Replies."

Percentage for 1920. 3.8 = one in 26 calls.
July-November, 1921. 3.0 = one in 33 calls.
An improvement of about 21 per cent.

Percentage Completed Calls.

The expression "completed calls" means calls which are completed satisfactorily on the subscriber's first demand.

Percentage for 1920. 73
July-November, 1921. 80.2
An improvement of about 10 per cent.

Average Time of Answer.

1920. 7.4 seconds.
July-November, 1921. 5.3 seconds.
An improvement of approximately 28 per cent.

Percentage of Calls Answered in 10 Seconds or Less.

Percentage for 1920. 82.8
July-November, 1921. 89.7
An improvement of about 8 per cent.

Average Time to Disconnect.

1920. 5.7 seconds.
July-November, 1921. 5.3 seconds.
An improvement of about 7 per cent.

Percentage "Number Engaged."

Percentage for 1920. 18.0
July-November, 1921. 13.7
An improvement of 23.9 per cent.

Summary.

It will be seen from the foregoing particulars that the latest available service results for the last months of the present year show a substantial improvement on those of the first six months of 1920.

During the War period some 5,000 telephonists—including a high proportion of the most experienced—left the service for more distinctively War work and their places had to be filled by new staff. The resulting decrease in the corporate efficiency of the staff as a whole caused marked deterioration of service during the later War and earlier Reconstruction periods. The proportion of skilled telephonists, however, is now normal and the service at the present time is slightly better than it was before the War, although much short of the point it would have reached had it not been for the War.

"LIVERPOOL COURIER" AUTOMATIC PRIVATE BRANCH EXCHANGE.

AN automatic P.B.X. installed in the offices of the *Liverpool Courier* was brought into service on the 16th January, 1921.

The equipment was supplied by the Relay Automatic Telephone Co., of Marconi House, Strand, under contract with the Department.

The installation comprises an automatic equipment for 50 extensions with an ultimate capacity for 80 extensions, together with a manual switchboard, distributing frame and power plant, with the usual traffic and engineering facilities, including busy tone, dialling tone, interrupted ringing signal and alarm signals.

The extension lines are multiplied on the manual board and the general scheme of operating is as follows:—

Originated exchange calls. A predetermined digit is dialled from the extension telephone. The call arrives at the manual board on a multiple jack and lamp associated with the line of the calling extension and, immediately the call arrives, the automatic switching equipment is released for other calls. The telephonist answers the call on the multiple jack and completes the connection in the usual manner.

Incoming exchange calls. The telephonist answers the call on the incoming exchange line jack and completes the call in the usual manner, by inserting the calling plug into the multiple jack associated with the line of the required extension.

Local calls, *i.e.*, calls between extensions, are completed automatically.

The provision of a multiple of the extension lines on the manual board effects a considerable economy in automatic switching plant.

The circuit arrangements are such that the telephonist can plug into the multiple jack of an engaged extension without breaking down the connection on the automatic equipment for the purpose of offering an exchange call.

Facilities for carrying out routine tests of the equipment are also provided and arrangements are made for the extension of any exchange line to any extension line during night or any other desired periods when the telephonist is not in attendance at the manual board.

Sir William Noble opened the new exchange and took the opportunity, both at the opening ceremony and at the luncheon which followed, of making a spirited defence of the service against unreasonable press attacks.

The opening ceremony took place in the Board Room in the presence of a large company, the Municipality and Dock Board, banking, shipping and commercial interests, the three Liverpool morning newspapers and the two evening papers all being represented, with many others. Mr. A. Burchill, J.P. (managing editor of the *Liverpool Courier* and *Express*), presided. He paid a whole-hearted tribute to the Liverpool P.O. Engineers, who during the installation had been most assiduous and unremitting in their attention, and specially mentioned the invaluable co-operation of Mr. Cornfoot, the sectional engineer.

In conclusion, he invited Sir William Noble to accept a handsome silver inkstand, the centre of which consists of an automatic dial with which Sir William made the first call on the new system. On the stand is the inscription, " Presented to Sir William Noble, M.I.E.E., Engineer-in-Chief to the British Post Office, on the opening of the *Liverpool Courier* and *Express* relay automatic branch exchange, Liverpool, January 16, 1922." After the ceremony the guests were entertained to luncheon at the Midland Adelphi Hotel.

ANNUAL DINNER OF THE POST OFFICE ENGINEERING DEPARTMENT.

THE Annual Dinner of the Engineering Department was held on the 17th February, in the Connaught Rooms. A very large gathering assembled under the chairmanship of the Engineer-in-Chief, and the function was a highly successful one. All the superintending engineers were present, and also many representatives from other Departments of the Post Office. Among the guests were the following:—Sir Westcott Abell, K.B.E.; W. Aitken; W. H. Allen; L. B. Atkinson; Lt.-Col. T. M. Banks, D.S.O., M.C.; J. Y. Bell; Sir Robert Bruce, C.B.; Sir H. Bunbury, K.C.B; Sir Tom Calendar, K.B.E.; M. S. Connor; R. A. Dalzell; F. Gill, O.B.E.; H. P. Gisborne; J. S. Highfield, President

I.E.E.; H. Hirst; H. R. Kempe; A. R. Kidner; J. E. Kingsbury; P. P. Kipping; W. W. Lackie; J. Lee; W. T. Leech; F. A. B. Lord, C.C.; J. L. Macquarrie; G. F. Mansbridge; Lt.-Col. A. Matheson; Sir Wm. Lane Mitchell, M.P.; A. Moir, O.B.E.; G. Morgan, C.B.E.; Sir Evelyn Murray, K.C.B.; G. H. Nash, C.B.E.; Sir Wm. J. Noble, Bart.; Col. Sir Andrew Ogilvie, K.B.E.; C. C. Paterson; Rt. Hon. H. Pike Pease, M.P.; H. M. Pease; G. F. Preston, C.B.E.; E. Raven, C.B.; Sir Alex Richardson, M.P.; Sir Arthur Roberts, K.B.E.; C. C. Sanderson, A. M. Sillar; L. G. Sloan, J.P.; Sir John Snell; Sir John Stewart, Bart.; A. J. Stubbs; Sir Edward Troup, K.C.B.; H. C. Turner; Lt. Col. W. B. Vince, D.S.O., M.C.; Dr. R. Mullineux Walmsley; D. Weston; W. Will; C. H. Wordingham, C.B.E.

In the unavoidable absence of the Postmaster General, the toast of the Engineering Department was proposed by the Rt. Hon. H. Pike Pease. In an interesting speech Mr. Pike Pease expressed regret that Mr. Kellaway was not able to be present as he probably would have dealt with the question of Post Office charges generally. Cheap communications were vital to industry and any move in that direction would be of enormous advantage. The Civil Service is said to dam initiative, but he thought Sir William Noble was a proof of what can be done by a Civil Servant. During the last twelve months great strides have been made and he believed the general public realised the efficiency of the work. Mr. Pike Pease then summarised the progress made during the year, both in telephones and telegraphs. He congratulated the service on the work done, and concluded by an appeal to the staff in the following terms:—

"I do not believe there really is any patent device for good government and though good laws may perhaps mitigate in certain directions, still, as a whole we are dependent upon the nation itself and our character, and just as our character brought us through in the war—that pertinacity so exemplified in France—so I believe that the day may come when the same characteristics will be able to drive away the clouds that beset us. Everybody who has any capacity should show it and should put forth his best endeavour. Many of us think we do our best and I believe we try hard, but at the same time concentration is one of the great gifts of God and I believe that if the nation as a whole put forth a supreme effort it would mean that in the future we should see on the industrial horizon a streak of light which meant prosperity for our country.

"Of course there are a great many critics in regard to the Service. Many of them are asking for the impossible. Some of those critics have little or no real reason for the views they hold.

"I think this little ditty rather applies to the Engineers:—

Got any rivers you say are uncrossable,
Got any mountains you can't tunnel through,
We specialise in the wholly impossible,
Doing the things that no man can do.

"I now ask you to drink the health of the Department coupled with the name of Sir William Noble." (Applause.)

In reply the CHAIRMAN said: Mr. Pike Pease and Gentlemen,— On behalf of the Engineering Department I have to thank you, Sir, for filling the breach caused by the absence of Mr. Kellaway and undertaking the duty for which he was to be responsible. I have to thank you, Sir, for proposing the toast in the way in which you have done, and you, gentlemen, who are visitors, for the way in which you have received it. Perhaps I wont be considered ungracious or ungrateful to Mr. Pike Pease if I say that we are sorry that Mr. Kellaway is not here to-night. I am emboldened to do so because Mr. Pike Pease has already said it himself. There are one or two reasons why we should have liked Mr. Kellaway here to-night. One is that he has never yet been present at an Engineering dinner. It is very useful for the political chief of a big Department to get to know as many of his staff as possible. Conversely, it is useful and interesting for as many of the staff as possible to see and to hear the chief and to hear what he thinks of them.

Last year Mr. Kellaway was engaged in a political contest and therefore was absent from our dinner. Some little time ago we feared that that might be a reason for his not being present to-night, but that has blown over.

We are rather disappointed that Mr. Whitley, who was the Chairman of the Whitley Committee which gave us Whitleyism, has transgressed one of the tenets of Whitleyism! You know that Government Departments nowadays are pretty largely run by Whitley Councils and Whitley Committees and anything which will affect the staff must be put by the Official side before the Staff side. Now on this occasion Mr. Whitley has arranged for a dinner and levee to-night, to which he has invited Mr. Kellaway, on the same evening as our dinner without consulting the Engineering Staff. It is just possible that this may result in a protest to the National Whitley Council in order that a similar occurrence may not again take place. (Laughter.) We can only hope that circumstances over which Mr. Kellaway will have control will still admit of his being present at an annual dinner of the Engineering Department.

It is very difficult on such an occasion as this to know what to say and perhaps you would prefer that I should say nothing more than I have. I would like, however, to mention one or two points to which I referred last year. One of the things which I mentioned was this: that shortly before our dinner took place in 1921 a Parliamentary Committee had been appointed to inquire into the telephone service. Little did I think that this year I would not be able to give you my opinion of the report of the Committee, but Parliamentary Committees move slowly as a rule. This particular Committee must have found its task very much more difficult than a certain other Committee which was appointed at a much later date and which covered the whole field of Government Departments, took evidence from all these Departments, have issued two voluminous interim reports, and will furnish a final report by the end of this month. There is a rumour that comparing the speed with which this extra Parliamentary Committee of business men have conducted the operations, that the Government have decided that where there is a matter which they wish to shelve for a long period, they will appoint a Parliamentary Committee, which committee will consist of a ratio of Scotsmen to other nationalities of not more than one to four; but when there is any work of an urgent character they will appoint an outside committee in which the ratio of Scotsmen to gentlemen of other nationalities must not be less than four to one! (Loud laughter.)

One other matter that I referred to last year was the conditions in regard to telephone work. I stated that there was a great shortage of material; that prices were high; and that contractors were giving long dates for delivery and even these dates they did not keep to. I am glad to say that in these respects things are now much better. There is more raw material; prices have fallen; and dates for contracts are very much shorter. Unfortunately, however, work has fallen off. We know that good trade and good telephone business go hand in hand. There has been a great slump in trade and it has had its effect on the telephone work. This is shown in our Department by this fact; that last year at this time we had a staff of over 26,000: this year it is about 24,000, a falling off of over 2,000. This is very regrettable at such a time of unemployment. We are only hopeful that trade will revive and the telephone business will revive along with it.

One other matter; you know that there is an economy campaign. I have referred to a Committee which has been dealing with the subject. They may save the millions from Departments which are not revenue earning departments if they will only keep their hands off the revenue earning departments. We have never had a chance to bring the telephone plant up to date so that we could meet every demand promptly. This is an excellent opportunity when trade is not good, and telephone business has, as I have said, fallen off, to bring our local and trunk systems right up to date so that when trade revives no business man will have to wait for weeks for his telephone. I hope, therefore, there will be no cutting down of our programme for next year.

One or two words with regard to the press campaign which has been waged against the telephones as managed by the Department. Sir Evelyn Murray last year stated that newspapers must have a ramp to fill their columns when there is not too much other news. Fortunately for us there is some other ramp such as the General Election rumours and the Geddes Committee; at any rate, they are leaving us alone at the present time. It is encouraging when they are reducing their comments to short paragraphs and even being humorous! A short paragraph the other day said this: "There is not a single letter wrong in what appeared in an evening paper the other night which said 'We should advise Mr. Kellaway, before he speaks again, to go to——Hull!'" (Loud laughter.)

In conclusion I would like to say that no matter what the press may say or the public may say, the Engineering Department will continue working quietly but energetically in its endeavour to bring its plant up to the highest mark so that we shall have one of the most efficient services in the world. ("Hear, hear" and loud applause.)

MAJOR PURVES proposed the toast of "The Visitors." He said. Mr. Chairman and Gentlemen,—My duty is the light and pleasant one of giving you the toast of our visitors. In bygone days, when a man who had to propose the toast of the King was expected to make a speech about it, he very often opened by saying, in the tone of a new and original remark, that the toast was one which required no words of his to recommend it. I feel that I might take a certain amount of cover behind the same idea now. Good wine needs no bush; good toast needs no butter; and this is a good toast. (Cheers.)

There are still some things about which the Engineering Department of the Post Office feels it has a right to be proud—quand même—and one of them is the character and the calibre of the friends who honour us with their presence on an occasion of this kind. We like to think that they enjoy themselves and the best we can hope in that way is that their pleasure may correspond in some degree with the heartiness and the sincerity of their welcome.

I am sure we are all very sorry that the Postmaster General has been prevented, by an urgent cabinet call, from being with us, but we greatly appreciate the presence of the Assistant Postmaster-

General, Mr. Pike Pease, who has willingly and worthily taken his place this evening, as he is so well accustomed to doing on all kinds of occasions—pleasant and otherwise!

We know that Mr. Kellaway greatly regrets the fact that he has not yet been able to attend one of our engineering dinners and that he has every desire to help us to establish and consolidate the tradition that the Postmaster General is our regular guest of the evening. Last year when, in Sir William Noble's absence in America, I wrote and asked Mr. Kellaway to come I ventured to tell him that that tradition was already a fully settled one, but unfortunately last year also he was up against a position which brooked no argument. As Sir William Noble has told you, his contest for re-election to Parliament was due to take place at Bedford on the following day. Not even for the sake of attending the Engineering dinner could we have wished him to turn his back upon the battle ground at so fateful a moment.

I am afraid Mr. Kellaway's first twelve months at the Post Office has been rather a hectic time and so far as I have been able to observe he seems to have enjoyed it thoroughly. I have heard him describe himself as the lightning conductor of the Department, and he has certainly had to stand among the thunder pretty well all the time. I think that, if he had been here, we should all have liked to congratulate him on having shown that he can not only conduct sparks harmlessly away but that he is able to emit them very effectively himself.

We are also honoured by the presence of the Secretary, Sir Evelyn Murray, which, I am happy to say, represents an unbroken tradition since the first combined Engineering dinner, nearly twenty years ago, when Sir John Gavey was Chief of the Department.

Another tradition which our dinner committee seems determined to set up in connection with Sir Evelyn Murray is apparently that year after year he should propose the health of the Engineer-in-Chief. I hope it is not becoming a little embarrassing to the Engineer-in-Chief. I don't suggest that it is the least little bit in the world embarrassing to the Secretary. If I had to epitomise my impression of Sir Evelyn Murray, I think I should put it in four words—" Equal to the occasion." Those of you who know the kinds of occasion which the Secretary to the Post Office has to face, from time to time, will realise that there are not many men about whom, in such a position, that could be truly said.

No annual dinner of the Post Office Engineering Department would be complete without the presence of the President of the Institution of Electrical Engineers, and we have great pleasure in welcoming Mr. Highfield, whose distinguished services to electrical engineering have this year appropriately brought him to that premier position. (Hear, hear.) We have also past presidents in the persons of Mr. L. B. Atkinson—who last year spoke so appreciatively of the telephone service—of Mr. Wordingham, and of Sir John Snell, an old friend and associate who has helped us on many occasions and with whose name I have much pleasure in coupling this toast.

This is the first comprehensive social gathering of Post Office Engineers since the Institution obtained the Royal Charter which now adorns it, and I should like to take the opportunity of congratulating the President, and the other gentlemen I have named, upon that notable achievement, and of thanking them for the strenuous personal efforts on their part which have thus succeeded in securing to electrical engineers the cachet of professional status which has long been their due.

In that matter I am sure I am speaking for you all, and I should like to remind Mr. Highfield that the Post Office Engineering Department justly regards itself as one of the pillars of his Institution, not only for the historical reason that the Institution started as the Society of Telegraph Engineers, but because we have in the ranks of the Engineering Department, more than 70 full members, and nearly 300 associate members, of the I.E.E. I am not sure whether any other single engineering organisation in the country can beat these figures, but I should think it very unlikely. (Cheers.)

We have also here this evening many other prominent representatives of the electrical engineering profession, and we have unofficial representatives of Parliament, and of engineering, in the worthy persons of Sir William Lane Mitchell and Sir Alexander Richardson, both of whom hail from North of the Tweed and both of whom, for some strange reason, have elected to represent London Conservative Constituencies. (Laughter.)

We welcome also Sir John Stewart and Sir Westcott Abell and Sir Edward Troup, and I must not forget Sir Arthur Roberts, who has recently been bringing his keen sense and experience of finance to bear upon an examination of the principles of the Post Office system of cost accounting and assessing charges for service, with the result, I am happy to say, that we have his blessing.

I think it was at the famous battle of Bosworth that Richard the Third thought he saw two Richmonds in the field—or was it six? At any rate, without any suspicion of departure from strict sobriety, we can see two Sir William Nobles in this room to-night, and we are very pleased to have Sir William J. Noble here.

A week or two ago I dined, in company with both Sir William Nobles, at a gathering which was out to celebrate in an appropriate manner the birthday of Robert Burns; naturally a very quiet and circumspect gathering (laughter), as Mr. Kellaway could have corroborated, for he was there too. Our Sir William Noble referred to cases of mistaken identity which had arisen, and confessed that he had received quite undeserved congratulations on having written many excellent articles on the industrial and international situation, while, on the other hand, he had been severely taken to task as a civil servant for having dared to appear prominently on coalition platforms. Sir William J. Noble, when his turn came to speak, rather more than got his own back by explaining that he, for his part, had frequently been taken to task for the disgraceful state of the telephones. (Laughter.)

Last year we had with us Dr. Jewett, one of the leading engineers of the great Bell Telephone organisation of the United States—the only telephone engineering organisation in the world, I may say, to which the Post Office Engineering Department admits that it plays second fiddle,—and to-night by a stroke of luck we are able to have another of that race of telephone supermen, Mr. McQuarrie, whose name has been for many years a household word to me and to many others in this room. We are pleased that these gentlemen think it worth their while to come over here to visit us and to see what we have to show them. I hear that Mr. McQuarrie a few days ago, after having a conversation on one of our high frequency carrier wave channels between London and Bristol, expressed the opinion that the transmission of speech was uncommonly good. I don't know that he actually said it was much better than anything of the kind he had heard in America, but it was rather inferred, from the excited expression on his face and the trembling of his hands, that that was so. (Hear, hear.)

Our Department has recently been a target for many ill balanced attacks on account of the backwardness of British telephone development as compared with that of the United States, and we are aware that the manner of these attacks has made our good friends at the head of the American Bell organisation both sorry and indignant. We know that there is nothing more irritating to a well disposed man than to have his perfections and accomplishments used, ignorantly and malevolently, as a rod to be laid on the back of his friends. Mr. McQuarrie is sailing for home to-morrow and I would ask him to assure our friends in the States that in that matter they have our sincere and affectionate sympathy.

We have also here to-night many friends from outside the Department who are associated with us in the telegraph and telephone industry. We have Sir Tom Calendar, who does not care a button whether he receives any Post Office Contracts or not; we have Mr. Hirst, who doesn't need to care much either, and many others, some of whom perhaps do care a little.

And we have with us also a large and very fine selection of the ruling princes and captains of the Post Office, our colleagues in other Branches. There is Mr. Raven, there is Sir Henry Bunbury, there is Mr. Kidner beside me here, who should surely, as the head of the administrative side of the telephones, be one of the most popular men in the country. (A laugh.) But all their names, and all their faces are so well known to us in everyday intercourse that it would really be a slight upon them to go into particulars.

And last but not least we have old Post Office colleagues whose term of official activity has run out, and who have left us for, I hope, more leisured walks of life—Sir Andrew Ogilvie, Sir Robert Bruce, Morgan, Kempe, Stubbs, Moir and others. It warms our hearts to have them among us again and I can assure them that it is only the good hope of seeing them occasionally at gatherings such as this that enables us, when they depart, to say goodbye with a fair amount of equanimity. (Hear, hear.)

Perhaps I might be allowed a specially personal word of welcome to Dr. Walmsley who, long ago at the Heriot Watt College in Edinburgh—well over 30 years ago—was the first man who tried to hammer into me some of the elements of electrical science.

Gentlemen of the Engineering Department, I ask you to rise and honour right heartily the toast of our visitors, coupled with the name of Sir John Snell. (Loud and prolonged applause.)

Sir JOHN SNELL, on behalf of the guests, replied to the toast: Major Purves, Sir William Noble and Gentlemen,—I am afraid I must begin by apologising for my voice as I have only just recovered from the prevalent 'flu and a slight touch of pneumonia, and my voice may not be able to carry into the far ends of this big room.

I certainly cannot emulate the humorous speech of the proposer of this toast, I only wish that I could. It is very happy for me to be one of your visitors to-night, because that I feel that I am among friends. Many years ago—I hardly like to remember how many—I met your old friend Mr. Moir, who was then in the North East of England, and together we carried out some rather important experiments in the effect of falling telephone wires on "live" tramway wires. That was my first connection with the Post Office—I was going to say actual physical connection, because I think I touched one of the wires. Since then I have been brought into touch with your Engineering Department in many ways. When I look back to 1911 and 1912, to the great fight we had then with the National Telephone Company, I am not sure whether the engineer of the Post Office will look upon me with friendly or with unfriendly eyes, because with so many of the officers of the Engineering Department I was partly responsible for the transfer or, at any rate, the terms of the transfer of the telephones to this great Department. I was a mere instrument because it is only fair to say that the great bulk of the work was done by the Engineering Officers themselves.

I have only to think of my friend, Mr. Delattre; of Mr. Morgan; of Mr. Sparkes; of my dear old friend Sir Andrew Ogilvie, to remember the enormous amount of help I received from them during those very strenuous times. When we had accomplished that work the Post Office, apparently, was still not sick of me, because they asked me to assist them with their Post Office Tube. Therefore, in association with Major Gunton and with other officers of the Department, again I had much to do with this Engineering Department of the Post Office. Even later, in a very humble way I admit, as a member of the Imperial Wireless Telegraphy Committee I met another of your friends—Mr. Brown—who was of so much assistance to us on the Committee, so that I say one may feel that one is really among friends in coming to this Engineering Department dinner. (Hear, hear.)

I should like to take the opportunity which is afforded me of making some reference to the telephone position. I have often thought in reading of the complaints in the Press against this Department for what is termed inefficient telephone service, how little the Public and the Press really know of the true position. Without in any way attacking the National Telephone Company or my old and trusted friend Mr. Gill, it was the sheer force of circumstances prior to 1912, namely the purchase, the impending purchase of the Company's system which not unnaturally caused those who were directing their affairs to spend as little money as possible on the expansion of the system. And it naturally fell to this Department and the Post Office, when the telephones were transferred, to have to buckle to and make up the lee-way in order to bring the system up to a most efficient position. I venture to say, without fear of contradiction, that had it not been that some 18 months later we were met by the circumstances of the Great War, this Department would by now and for several years past, have overtaken the arrears of work and put the telephone system in as high and efficient a position as any engineering work of that kind could possibly be.

I feel that, although, I suppose, a semi-Government officer to-day, I can speak with a bold impartiality and fairness as to the position of the telephone Department in the Post Office. I say that but for the circumstances of the war you would have overtaken the arrears of work and to-day there would be no complaints such as one occasionally hears.

It seems to me that the knowledge of the Engineer-in-Chief of a great Department like this and of the principal engineering officers must be almost encyclopædic because not only have they to deal with vast telegraph systems; not only land but marine; with wireless telegraphy on a big scale, but even with great engineering problems which, if anyone will only visit such a place as Mount Pleasant or some of the other big distribution centres of the Post Office Engineering Department, he will see for himself the mechanical devices and time saving devices indicative of engineering skill of the very highest character. The public, I am perfectly convinced, do not in the least appreciate the real and immense engineering knowledge which is necessary to the staff conducting this great work. In the problem with which we were faced in the Post Office Tube, a work which for the time being is not completed but will be completed some time or other, the engineering problems—electrical and otherwise—with which the engineers were confronted were really of a most interesting character, but also requiring a very high degree of engineering skill. (Cheers.)

In my work as Electricity Commissioner I believe that my colleagues and myself will continue to be brought into touch frequently with the work of the Post Office. It has been said that His Majesty's Postmaster General thinks that he possesses the earth and also the air, but I hope he will give to the purveyors of electrical energy a little room under the pavements and a little space in the air in which to run their overhead transmission lines, because I think the Rt. Hon. Gentleman who spoke just now—or it may have been the Engineer-in-Chief—made reference to the requirements of this Department of supplies of power in rural districts and it is to the electrical undertakers of this country that you will have to look for the supplies of power which will be auxiliary to many of your engineering developments.

I do not profess to be a telephone expert, but one does think of the developments which are taking place and are yet to take place, and personally I am rather inclined to think that instead of developing automatic telephones in our big centres you are going to get more assistance from them in your rural and outlying districts where we have occasionally to complain of some of the operators. It may be a heresy to say what I have said, but I believe that you will derive more benefit and more economy from the use of automatics in the isolated and rural districts than you are likely to get from their concentration in denser districts.

The P.O. has, however, occasional lapses and I will close with one little incident which happened to me and which I hope my wife will forgive me for repeating. Just before the war I had a chauffeur whose name was Twiner and I received a telegram from my wife on one occasion which said—" 12.50 train. Arriving with twins." (Laughter.)

I wish to thank you on behalf of my fellow visitors for the kind hospitality extended to us; for the felicitous terms in which Major Purves has proposed our health, and I thank the Engineering Department most heartily for their kind welcome to-night. (Cheers.)

Sir EVELYN MURRAY, K.C.B., proposed the toast of "The Chairman."

Gentlemen,—It is quite true, as Major Purves has said, that this is the third year in which I have had the honour to propose the toast of our Chairman. I do not suggest that that period is excessive, or even adequate, to exhaust his virtues. Sir William Noble has held the responsible position of Engineer-in-Chief to the Post Office for close upon three years, I suppose three of the most difficult years which the Department has had to pass through. He came, as I understand, with the reputation of being a man who got things done and he has fully realised that reputation. I can assure him that I should not dream of recommending his inclusion in any committtee which was intended for shelving an inconvenient question.

The imposing catalogue of your achievements which Mr. Pike Pease has given us to-night is a record of three years strenuous work on the part of the Engineer-in-Chief and his staff, and I think it is right that, as the engineers bear the main responsibility for providing the plant of the telegraph and telephone services, they also should get the credit for the very notable results they have achieved in the face of great difficulties. Those of us who are identified with other Departments of the Post Office can say, I hope, that we have done nothing to obstruct and have done everything we can to assist the great and difficult work with which the Engineering Department has been charged.

I personally have the highest respect and admiration and some feelings of awe for engineers in general. They provide us with many services that are useful and indeed necessary. We do not ask how they work or what happens to them. We say a great deal when, by some mischance, they occasionally fail to function. I have especially a feeling of awe because I know perfectly that if by any chance you corner them in a discussion, they can always relapse into a technical jargon, which to me is equivalent to an unknown tongue. I have specially an affection for Sir William Noble because, in the many discussions which he and I have from day to day, he has always refrained from using his natural advantages in that respect. If I had any complaint it would be this—the pertinacity and vigour with which he presses what he considers the legitimate claims of his staff, but I appreciate that in this assembly that quality is not regarded as a defect. (Hear, hear, and cheers.)

The toast was received with musical honours.

Sir WILLIAM NOBLE replied as follows: Sir Evelyn Murray and Gentlemen,—I was rather sorry for Sir Evelyn that he should be asked to propose this toast again, but the Committee said that he was certainly the best qualified to propose the toast of the Chairman. I have no fault to find with the Committee and I have certainly no reason to complain of the terms in which Sir Evelyn has proposed the toast.

In regard to one of the remarks which he made; that he does not obstruct the Engineering Department, I should like to endorse that heartily. There are some people who say that you cannot get successful telegraph and telephone business with the management in the hands of the Secretariat. It is entirely wrong. Every business must have a General Manager and there is no business in which a General Manager interferes less with the technical work than does the Secretariat. On practically every occasion we get our own way. And why? Simply because we do not put forward any mad-cap schemes. We think well over every scheme we put forward and give good reasons for putting them forward, and never once have we been in the slightest degree obstructed by the Secretary or any of his staff. They simply act as administrators of the Department and, in my opinion, have done so successfully.

I am indebted to Sir Evelyn for proposing the toast in the way in which he has done, but I should like it to be considered as embracing my colleagues as well as myself. In a big Department like ours it is impossible for an Engineer-in-Chief, who is to be successful in the position, to meddle with the details of the work. He has to find the round pegs to put in the round holes and the square pegs to put in the square holes. That is what I have endeavoured to do—to select the most suitable men for particular jobs and then to see that the work is done. I have been most ably supported by the whole of the staff. Any success I may have as Engineer-in-Chief to the Post Office will be largely due to the hard work and the loyalty of my staff.

On behalf of myself and my staff I thank Sir Evelyn for the toast and you gentlemen for the way in which you have received it. (Applause.)

The CHAIRMAN proposed a hearty vote of thanks to the Committee who, he thought, had carried out their duties in a very satisfactory manner.

Lieut.-Col. BOOTH replied on behalf of the Committee. He thanked the company for the manner in which they had responded to the request for a vote of thanks. The hard work had been done really by a sub-committee and he would like to mention specially the names of Mr. H. S. Thompson, secretary, and Messrs. M. F. G. Boddington, musical director, and H. J. Loney, who had arranged the seating accommodation. The Committee had been rewarded by the undoubted success of the gathering.

An enjoyable musical programme was submitted during the evening.

LOCAL CENTRE NOTES.

SCOTLAND WEST CENTRE.

An ordinary General Meeting of the Scotland West Centre was held on 28th November, at which a lecture on "The limits of resistance for subscribers' lines in Scotland West District," was given by Mr. T. Hetherington.

The position, he said, in Glasgow differed from that in the remaining parts of the District inasmuch as the normal 300 ohm loop for exchange lines did not apply to exchange areas in the centre of the city. Ten exchange areas had limits ranging from 350 to 450 ohms, and some difficulty had been experienced in dealing with extension circuits in these areas. The aim of the lecture was to explain the factors which came into the process of calculating the resistance of these circuits.

The lecturer then outlined the manner in which the Transmission Curve (Diagram CV No. 9) was obtained, and the points on the curve relating to the limits for all cases in the District were noted. Current supply loss was then dealt with, and examples and a curve were given to emphasise its effect on transmission on long lines; and further its combination with the receiving allowance curve to form the original curve was explained.

The second portion of the lecture was devoted to examples to illustrate the application of Curve CV No. 9 to the determination of the resistance of circuits in the various exchange areas.

Interest in the lecture was sustained throughout, and the subsequent discussion was taken part in by Capt. Cameron, Mr. Witherby, Mr. Cunningham, Mr. Scott, Mr. Barclay and Mr.

Robertson, and the points raised were dealt with by Mr. Hetherington.

NORTHERN CENTRE.

On the 14th December, Mr. J. Peel read a paper entitled "Construction—Economy Suggestions" which was well received and freely discussed.

Mr. Peel's suggestions respecting transport organisation, lodgings, stores matters, contractors' works, etc., are backed by a wide and varied experience. The description of the experiments made with the Simplex Pole Lifting and Straightening Jack was very interesting and Mr. Peel's outline of the proposal to remove *en bloc* laterally 35 H poles carrying over 60 wires a distance varying from 6ft. to 18ft. by the use of two of these jacks, has attracted more than local attention.

On the 11th January, a paper on "Clerical Organisation" was read by Mr. Jas. A. Motyer, who was complimented by subsequent speakers upon his treatment of the subject with which he has an intimate knowledge. The ideals to be aimed at were carefully portrayed and the paper was illustrated by slides. The discussion on the paper was spirited and of a high standard.

On the 8th February, Mr. T. Fewster read a paper on "Unit Costing" which was illustrated by slides and was well received. The subject was topical and attractive and a well-sustained, well-informed and interesting discussion was terminated by the Chairman applying the closure with regret. Mr. Fewster, whose paper has evoked interest throughout the country, is to be complimented upon his treatment of the subject.

On the 20th February, three Western Electric Co's. Films entitled "The Audion," "Telephone Inventors of To-day," and "Electricity in the Home," were shown at the Scala Picture Theatre, Newcastle. The pictures were very clear and were enjoyed and applauded by an audience of about 200, including representatives from the Institution of Electrical Engineers, The North East Coast Engineers and Shipbuilders, The North of England Mining Institute, etc.

Arrangements have been made for the Centre to visit the Lemington Glass Works on the 29th March.

SOUTH MIDLAND CENTRE.

No notes have appeared under this heading for some considerable time, but we learn that, since the resumption of meetings after the armistice in January, 1919, twenty meetings have been held, each one being well attended and papers of a high order being presented. It is evident that Reading is a very lively centre of the Institution.

The programme for the current session was:—

Speaker.	*Subject.*
Mr. H. Macpherson.	Balancing Main Cables.
Mr. J. E. Taylor.	Wireless. Some notes on Transmitters and Receivers.
Mr. B. J. Beasley.	Ferro Concrete, construction.
Mr. A. C. Smith.	Co-ordination.
Mr. H. A. Mc.Innes.	The C.B.S. Multiple System.
Mr. B. W. Beaumont.	Long-distance Cable Testing.

which covers a range of interesting and instructive subjects.

The Centre is somewhat favoured in being afforded assistance in the matter of accommodation by Reading University College, the authorities of which have placed their Physics Lecture Theatre at the Institution's disposal when required. This hall is almost exactly a half-scale replica of the familiar lecture room at the "Northampton," and as it is fitted with current and appliances is a great asset.

Another symptom of the keen interest taken is the fact that more offers of papers are received than can be accepted and the committee have had to make a selection from those put forward. This is, of course, as it should be and it helps greatly in the smooth working of the Centre.

It is hoped that notes from Reading will be received more frequently in future.

SOUTH LANCASHIRE CENTRE.

The Fourth and Fifth meetings of the Session were held on the 4th January and 27th February respectively.

On the former occasion Mr. G. Batho read a paper on "The Payment of Wages." The Lecturer dealt with the principles involved in a comprehensive manner. He pointed out the important effect which a satisfactory system of payment had in the relations between the employer and employed, and laid stress on the need for accuracy in calculating workmen's wages in the first instance. Practical difficulties of payment in the case of an organisation like the Post Office Engineering Department, where small numbers of men were scattered over large areas, were touched upon, and some suggestions were made for facilitating payment.

The last paper to date was read by Mr. A. A. Hignett on "Building Construction." The magnitude of the subject required that certain portions should only be considered briefly, but many points of interest were brought under notice, especially with regard to the Department's Underground Construction methods. Certain suggestions for modifications of the latter were made.

The attendance was good on each occasion. The papers were well received, and evoked a good discussion.

NORTH WALES CENTRE.

A meeting of the Centre was held in the Technical School, Shrewsbury, on 10th January, 1922, in order to listen to a paper read by Mr. F. P. Gresswell, on "Teaching of the Post Office Workmen." Mr. T. Plummer occupied the Chair.

Mr. Gresswell, who has lectured to P.O. Workmen at the Hanley Technical School for some years, dealt with the type of men generally engaged by the Department, and the work which he is called upon to perform. He also expressed his views on the qualities requisite in the teacher. He referred to the instincts and psychology of the workman, his mode of expression, his attitude to mistakes, and his apprehension of difficulty. The lecturer expressed the opinion that a teacher required above all things patience, sympathy, and tact, and that it was necessary that he should show real enthusiasm in his work if good results were to ensue. He commented upon the character of the work which students were subsequently called upon to perform—faulting, testing, construction, etc., and referred to the questions of apprenticeship and training and the desirability of creating pride in craftsmanship.

The subsequent speeches indicated that the subject was considered of great importance and that for the creation of a thoroughly efficient staff adequate theoretical and practical training was essential.

The February meeting was held at Birmingham on 8th February, 1922, under the chairmanship of Mr. T. Plummer. Mr. F. A. Coxon read a paper on "The maintenance of Motor Vehicles in use by the Department."

The subject was dealt with from the point of view of an officer who has to maintain the vehicles in repair. The lecturer was critical of the methods of the average driver in carrying out running repairs, and in the handling of vehicles. He considered that if efficient and economical maintenance is to be arranged it is necessary that a system of Running Reports kept by drivers should be instituted for recording the character of defects and the dates on which they are observed. He urged strict attention to the organisation of the various services to prevent overlapping or loss due to idle vehicles.

Captain N. F. Cave-Brown-Cave presented statistics showing the relative value of the services given by the different types of vehicles. He favoured the employment of 30cwt. lorries in place of 3-ton lorries. He was also of opinion that in many cases motor cycle combinations could be replaced by light cars adapted to carry stores.

Mr. C. G. McDonald, referring to the Returns which are prepared, drew attention to the excessive cost of putting second-hand vehicles on the road. He doubted whether motor cycles were always allocated to the officers best qualified to handle them.

Other members also took part in the discussion.

The Chairman in winding up the discussion commented on the variety of the views expressed and the instructive character of the meeting. He expressed his approval of the suggested Running Report which would be of utility to the officer effecting repairs.

Mr. Coxon repeated the paper before other members, etc., of the Centre at Shrewsbury on 7th March, 1922.

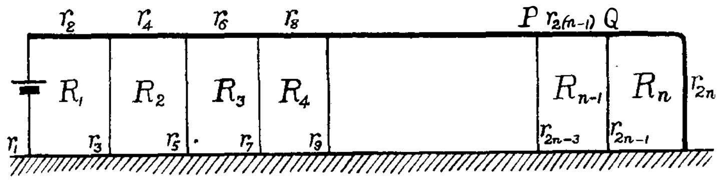
A visit from Mr. J. G. Hill, of the Engineer-in-Chief's Office, is expected in April, when he will read a paper on "Phantom Telephone Circuits, and combined Telegraph and Telephone Circuits, worked at audio frequencies."

A.J.W.D.

A RULE FOR WRITING DOWN FROM INSPECTION THE SENDING-END RESISTANCE OF A SINGLE CONDUCTOR HAVING ANY NUMBER OF LEAKS.

By HERBERT P. FEW.

PROBABLY the method most commonly employed for finding the sending-end resistance of the leak system, shown in the figure, is



that which leads to a continued fraction. Thus, working backwards from the last mesh, the resistance from the junction Q to earth is the joint resistance of r_{2n-1} and r_{2n}, *i.e.*,

$$\frac{1}{\frac{1}{r_{2n-1}} + \frac{1}{r_{2n}}}$$

and adding the section of line PQ, we have

$$r_{2(n-1)} + \cfrac{1}{\cfrac{1}{r_{2n-1}} + \cfrac{1}{r_{2n}}}$$

The joint resistance from the junction P is—

$$\cfrac{1}{\cfrac{1}{r_{2n-3}} + \cfrac{1}{r_{2(n-1)} + \cfrac{1}{\cfrac{1}{r_{2(n-1)}} + \cfrac{1}{r_{2n}}}}}$$

and so on until the leading mesh is reached. The continued fraction for the whole circuit can be written down in the form—

$$r_1 + r_2 + \frac{1}{r_3^{-1}} + \frac{1}{r_4} + \ldots\ldots\ldots \frac{1}{r_{2(n-1)}} + \frac{1}{r^{-1}_{2n-1}} + \frac{1}{r_{2n}}.$$

This expression is easily evaluated, but the work is exceedingly tiresome. The rule given below for writing down from inspection the sending-end resistance is a particular case of a general rule* given by Professor J. A. Fleming for writing down the equivalent resistance of any network of resistances (Handbook for the Electrical Laboratory and Testing Room, Vol. I., page 204).

Professor Fleming's rule states:—*Join the two points of the network between which the resistance is required by a conductor whose resistance is assumed to be zero, calling the mesh thus formed the added mesh; for the numerator of the joint resistance write down a determinant whose dexter diagonal consists of the sum of the resistances bounding each mesh; beginning with the added mesh; the other constituents common to any row and column being the resistances separating the two meshes proper to the row and column, such constituents being zero for any row and column proper to any two meshes which are non-adjacent.*

In the figure, let R_1, R_2, R_3,......R_n be the mesh resistances, *i.e.*, $R_1 = r_1 + r_2 + r_3$; $R_2 = r_3 + r_4 + r_5$, etc., then, in accordance with Professor Fleming's rule, we write down the sending-end resistance of the leak system—

$$R_s = \frac{\begin{vmatrix} R_1 & -r_3 & 0 & 0 & \cdot & 0 & 0 \\ -r_3 & R_2 & -r_5 & 0 & \cdot & 0 & 0 \\ 0 & -r_5 & R_3 & -r_7 & \cdot & 0 & 0 \\ 0 & 0 & -r_7 & R_4 & \cdot & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & -r_{2n-3} & 0 \\ 0 & 0 & 0 & 0 & -r_{2n-3} & R_{n-1} & -r_{2n-1} \\ 0 & 0 & 0 & 0 & 0 & -r_{2n-1} & R_n \end{vmatrix}}{D}$$

* Problems on the Distribution of Electric Currents in Networks of Conductors treated by the method of Maxwell; J. A. Fleming, Philosophical Magazine, September, 1885.

where R_s denotes the sending-end resistance, and D is the denominator determinant formed from the numerator determinant by deleting the first column and first row. This expression is axi-symmetric, and in its present form is somewhat inconvenient to deal with. Dividing the top row of the numerator by r_3 and multiplying the first column by r_3; similarly dividing the second row by r_5 and multiplying the second column by r_5; and so on, we get the following equivalent expression—

$$R_s = \frac{\begin{vmatrix} R_1 & -1 & 0 & 0 & \cdot & 0 & 0 \\ -r_3^2 & R_2 & -1 & 0 & \cdot & 0 & 0 \\ 0 & -r_5^2 & R_3 & -1 & \cdot & 0 & 0 \\ 0 & 0 & -r_7^2 & R_4 & \cdot & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & -1 & 0 \\ 0 & 0 & 0 & 0 & -r_{2n-3}^2 & R_{n-1} & -1 \\ 0 & 0 & 0 & 0 & 0 & -r_{2n-1}^2 & R_n \end{vmatrix}}{D} \quad \text{.........(1)}$$

A determinant of this form is called a *Continuant*, and it can be evaluated from inspection. Thus the numerator of (1) may be written in the special notation—

$$N = (R_1, -r_3^2, R_2, -r_5^2, R_3, -r_7^2, \ldots\ldots R_{n-1}, \ -r_{2n-1}^2, R_n) \quad \text{...............(2)}$$

and it can be developed or expanded from the leading elements as follows—

$$N = R_1(R_2, -r_5^2, R_3, \ldots\ldots\ldots\ldots\ldots R_{n-1}, -r_{2n-1}^2, R_n)$$
$$-r_3^2(R_3, -r_7^2, R_4, \ldots\ldots\ldots\ldots\ldots R_{n-1}, -r_{2n-1}^2, R_n).$$

This expression can again be expanded to—

$$N = R_1\{R_2(R_3, -r_7^2, \ldots\ldots R_n) - r_5^2(R_4, -r_9^2, \ldots\ldots R_n)\}$$
$$-r_3^2\{R_3(R_4, -r_9^2, \ldots\ldots R_n) - r_7^2(R_5, -r_{11}^2, \ldots\ldots R_n)\},$$

and so on.

If we develop (2) backwards from the rear elements we should get—

$$N = R_n(R_1, -r_3^2, R_2, -r_5^2, \ldots R_{n-1}) - r_{2n-1}^2(R_1, -r_3^2, R_2, \ldots R_{n-2})$$

and so on.

Similarly the denominator of the continuant (1) may be developed. In practice it is easier to develop continuants backwards.

As a concrete case, let us find the sending-end resistance of the four-mesh circuit R_1 to R_4. Then

$$R_s = \frac{(R_1, -r_3^2, R_2, -r_5^2, R_3, -r_7^2, R_4)}{(R_2, -r_5^2, R_3, -r_7^2, R_4)}$$

Taking the numerator first and developing it backwards as indicated above, we have

$$R_1(R_1, -r_3^2, R_2, -r_5^2, R_3) - r_7^2(R_1, -r_3^2, R_2)$$
$$= R_4R_3(R_1, -r_3^2, R_2) - r_5^2R_1R_4 - r_7^2(R_1, -r_3^2, R_2).$$
$$= R_1R_2R_3R_4 - r_3^2 R_3R_4 - r_5^2 R_1R_4 - r_7^2 R_1R_2 + r_3^2r_7^2.$$

The value of the denominator is, of course, included in the expansion of the numerator, but we shall show how to develop it in a slightly different way. Thus:—

$$(R_3, -r_7^2, R_4) = R_3R_4 - r_7^2$$
$$(R_2, -r_5^2, R_3, -r_7^2, R_4) = R_2(R_3R_4 - r_7^2) - r_5^2R_4$$
$$= R_2R_3R_4 - r_7^2 R_2 - r_5^2R_4$$

$$\therefore R_s = \frac{R_1R_2R_3R_4 - r_3^2 R_3R_4 - r_5^2 R_1R_4 - r_7^2 R_1R_2 + r_3^2r_7^2}{R_2R_3R_4 - r_7^2 R_2 - r_5^2 R_4} \quad \ldots\ldots\ldots(3)$$

and inserting the values $R_1 = r_1 + r_2 + r_3$; $R_2 = r_3 + r_4 + r_5$, etc., we have the full expression for the sending-end resistance.

Similarly for the five-mesh circuit R_1 to R_5, we write down—

$$R_s = \frac{[R_1R_2R_3R_4R_5 - r_9^2 R_1R_2R_3 - r_7^2R_1R_2R_5 - r_5^2 R_1R_4R_5 - r_3^2 R_3R_4R_5 + r_5^2r_9^2 R_1 + r_3^2r_9^2 R_3 + r_3^2r_7^2 R_5]}{R_2R_3R_4R_5 - r_9^2 R_2R_3 - r_7^2 R_2R_5 - r_5^2 R_4R_5 + r_5^2r_9^2}$$

and substituting the component resistances for R_1, R_2, R_3, etc., we have the full expression for the sending-end resistance. The value of the sending-end *current* can then be written down, for

$$I_s = \frac{E}{R_s}.$$

Thus, in the case of the four-mesh leak circuit, we have from (3) above—

$$I_s = \frac{E(R_2R_3R_4 - r_7^2 R_2 - r_5^2 R_4)}{R_1R_2R_3R_4 - r_3^2 R_3R_4 - r_5^2 R_1R_4 - r_7^2 R_1R_2 + r_3^2r_7^2}$$

We are, accordingly, led to formulate the rule:—*Write down in order, beginning at the sending end, the symbols representing the mesh resistances and the leak resistance to the desired number of meshes; prefix the negative sign to, and square, each of the leak resistances; enclose the whole expression in brackets. Expand this expression into the algebraic sum of two bracketed expressions, the first of the latter expressions consisting of the original expression with the last two elements omitted, multiplied by the last element; the second expression consisting of the original bracketed expression with the last four elements omitted, multiplied by the last element but one, taking care to prefix the negative sign. Expand each of the two latter expressions into the algebraic sum of two other expressions in the same way; and so on until the original expression is evaluated*

This expression represents the numerator. The denominator is obtained from the derived numerator by omitting the expansion relating to the leading mesh.

The rule for writing down the value of the *sending-end current* is:—(ii.) *The sending-end current is equal to the reciprocal of the sending-end resistance multiplied by the impressed electromotive force.*

The rule for writing down the value of the *received current* is:—(iii.) *The received current is equal to the product of the resistances of all the leaks of the system multiplied by the impressed electromotive force divided by the numerator of the sending-end resistance.* Thus

$$I_r = \frac{cr_3 r_5 r_7 \ldots\ldots r_{2n-1}}{(R_1, -r_3^2, R_2, -r_5^2 \ldots\ldots -r_{2n-1}^2, R_n)}$$

or in the particular case of four meshes—

$$I_r = \frac{er_3 r_5 r_7}{R_1R_2R_3R_4 - r_3^2\, R_3R_4 - r_5^2\, R_1R_4 - r_7^2\, R_1R_2 + r_3^2 r_7^2}$$

The rule for finding the sending-end resistance is somewhat lengthy, but with a little practice its value can be written down mechanically. When the number of meshes exceeds two or three much time and fatigue is saved by its use. The rule can be modified or extended to apply to impedances; and to pairs of conductors, uniform or non-uniform. (See Professor Fleming's paper aforementioned and Malcolm: Theory of the Submarine Telegraph and Telephone Cable, Chapter 16).

BOOK REVIEWS.

"Work of the R.E. in the European War 1914-19. The Signal Service (France)." Published by the Secretary, The Institution of Royal Engineers, Chatham. Price 12*s*. 6*d*.; post free.

This volume, compiled by Major R. E. Priestley, M.C., B.A., of Christ's College, Cambridge, is the official history of the work of the Signal Service in the Great War. It is a comprehensive story extending to more than 350 pages and illustrated with 25 plates and photographs. Major Priestley has obviously had full access to the service narrative prepared at Signals Headquarters in France, as well as to many more or less unofficial war diaries. In spite of occasional patchiness and some repetition due to the diverse sources drawn upon, he has succeeded in producing a volume of almost epic character, and one which will interest even the general reader as a revelation of a little known but vital factor in the wonderful military effort of the nation. The cumulative effect of its quietly told story illustrates in the most vivid way the determined self-reliance and capacity for improvisation, which in nearly every feature of the war made initial faults and blunders serve as stepping stones to ultimate success. Among the many thousands of the Post Office Engineering Staff who served as Officers and men in the Signal Service throughout the war the book will be hailed as an indispensable memento of unforgetable experiences, and many will find in it the explanation of much that had been obscure both in policy and practice.

The book represents a sustained endeavour to present, as clearly as possible, an understandable picture of the evolution of signal policy, organisation, and practice, during the war period. It deals almost entirely with the operations in France, and a companion volume is now under consideration which will outline the salient features of signals evolution in other theatres of war, where the conditions of campaigning were such as to call for radically different methods and developments. So far as the technique of inter-communication is concerned the present volume discusses the evolution of all the arts of signalling to which the unprecedented conditions of the war successively gave birth. During the five fateful years from 1914 onwards the signal service developed, from the position of little more than a supernumerary, until it almost assumed the rôle of a dictator of strategy. Division, Corps, and Army Headquarters had to adapt their movements to the signalling possibilities of the situation. The Signal Service multiplied itself nearly a hundred fold, and it moved with the times. Such compelling causes as the modern artillery barrage, on the one hand, and the development of enemy over-hearing devices, on the other, left it only two alternatives,—invent or perish.

Its story is too big for even the most inclusive volume and the present book necessarily omits much detail well worthy of record. It does, perhaps, less than justice to the amount of inventive ingenuity which was displayed by signal officers and men in the construction of extemporised technical equipment, out of the most unpromising materials, in the actual field of war. In the early part of 1916, before the resources of home production had got effectively to work in the design and manufacture of equipment based on war experiences, each signal formation was carrying about with it a collection of home-made telephone switchboards, test boards, maintenance testing sets, and other useful and entirely practical electrical "gadgets," which was truly remarkable. The history makes a generous reference to the assistance which the Post Office was able to render in that connection. "In the Post Office," it states, "there was a skilled staff, a good reserve supply of standard parts of instruments, and a great eagerness to help in every way possible. All that was required to enable this help to be as well directed as it was skilled in execution was a knowledge of the active service conditions under which the apparatus was destined to be used. This was achieved by periodical visits to France by a G.P.O. representative, when typical Signal Offices of all degrees of magnitude were visited, and personal contact was established with the D.D. Signals of Armies, the A.D. Signals of Corps, and O's. C.Divisional Signal Companies." As is well known the Post Office continued to provide, up to the end of the war, enormous quantities of telegraph, telephone and special apparatus, trench cables, etc., specially designed for war purposes, and constructed either in its own factories or by its specialised contractors.

"The Emission of Electricity from Hot Bodies." By Prof. O. W. Richardson, F.R.S. (2nd Edition. Longmans, Green & Co. pp. 315. 8 vo. Price 16*s*.)

There have been of recent years many publications dealing with the technical applications of thermionics to wireless telegraphy, telephony, and to carrier wave systems. Prof. Richardson's book on the other hand deals with the subject from the purely scientific point of view. It appears to be written mainly for physicists, but should also prove of great value to those engaged in technical developments in which a fundamental knowledge of thermionics is required. In the development of the theory of thermionic emission somewhat advanced mathematics are employed. The conclusions arrived at are, however, clearly stated and experimental confirmation is given. No attempt has been made to deal with the technical developments of the subject since these have, during the last few years, grown beyond the scope of a book of this size.

The book opens with a short historical summary of early experimental work leading up to the foundation of the theory of emission of electricity from hot bodies. A description of experimental methods is given, including the production of high vacuum. The main part of the book is taken up with the development of the theory of emission of electrons and positive ions from hot bodies and its experimental verification. The effects of the pressure of gasses is also dealt with. Since it is in certain cases difficult to differentiate between purely thermionic effects and those due to chemical action a chapter dealing with the latter has been added.

Full references are given to other publications dealing with the subject. Indications are also given of the directions in which further research is required.

In reading the book one is struck with the large share which British scientists have had in the development of this branch of physics which is without doubt one of the most important recent additions to our knowledge both from the scientific and commercial points of view.

"A Catalogue of British Scientific and Technical Books." Compiled by a Committee of the British Science Guild, 6, John Street, Adelphi, London, W.C.2. Agents A. & F. Denny, Strand, London, W.C. 2. Price 10*s*. net. 376 pages.

This catalogue gives a list of British books purchaseable at the date of compilation, Summer, 1921; and also includes editions which were in preparation or being printed. It should be in the hands of all librarians and others who are purchasing scientific and technical books for institutions, societies, research departments, and educational authorities, so that they may easily see what books are available on any subject. It is also valuable to ordinary engineers who want to find out what books they might read on any particular scientific subject.

No attempt is made to indicate the relative merit of books. The catalogue purports to be "a complete record of scientific and technical books other than those intended for primary schools and elementary volumes of like nature in the current lists of publishers in the United Kingdom and obtainable through booksellers in the usual way."

Approximately 6,000 titles are classified into 50 main headings and about 500 smaller classes, so that under any one heading or sub-division of a subject one has only to read about a column on half-a-page to find what books exist. This is incomparably better than the list published in 1918, where the books on Chemistry were all together on about 6 pages without sub-division. The classification is the most difficult part of the compilation. Sir John Snell's "Power House Design" comes under "Mechanical Engineering; Power Transmission and Gearing" and not under Electrical Engineering Power Plant, where the other books on Central Stations are found. Such cases of classification can easily be amended in the next edition, if it is found that a better classification exists.

The type of classification is very good; an alphabetical subject and name index is provided so that books can readily be found if only either the author or the subject is known. Besides the ordinary engineering subjects, which are all included, books are classified under the following headings:—Science and biographies, Philosophy including Logic, Physchology, all medical subjects, Chemistry, Geology and its allied sciences, Forestry and Agriculture, Textiles, Printing, Photography, Scientific Management, Dictionaries.

The book should be useful to engineers who are interested in learning from books as well as from experience.

"The Practical Electrician's Pocket Book and Diary, 1922." (S. Rentell & Co., Ltd. 3*s*. net).

This well-known reference book has been revised, and new chapters have been added, without increasing the size of the Volume, owing to the use of thinner paper. The book now contains 557 pages, in addition to a diary. The Volume comprises a condensed mass of useful information at a very modest price.

"Annales des Postes, Télégraphes et Téléphones."

The Administration of the French Posts, Telegraphs and Telephones has been publishing since 1910 a quarterly technical journal entitled the "Annales des Postes, Télégraphes et Téléphones," which is being received with ever increasing favour by the public. In addition to profound studies on automatic telephony and wireless, telephone relays, important telegraph apparatus both French and foreign, and radio-telegraphy there will be found also articles on the not-less important subjects of anti-induction devices, the electrification of railways, the use of aluminium in the construction of electric lines and the employment of mechanical apparatus in large post offices.

The review publishes a resumé of the work carried out under the heading of Service Studies and Research by the Technical Committee of the Posts and Telegraph Administration, and gives an analysis of the subject matter of current periodicals in French and translations of selected articles in foreign magazines; it sums up also the working practice and the most recent progress achieved abroad from the technical point of view.

The Annales brings regularly to the technicians of the industry as well as to those of the State generally a complete representation of the work in progress in foreign laboratories.

The publication is carried out by means of a Commission appointed by the Minister of Posts and Telegraphs, which, presided over by M. Dennery, Inspector General, vice-president of the Technical Committee of Posts and Telegraphs, includes also among its members such well-known personalities as Messieurs Blondel (Member of the Institute) and Milon, Director of Telephone Development, General Ferrie and Professors Henri Abraham and Gutton.

"Practical Engineer," Electrical Pocket Book and Diary, 1922. (Technical Publishing Company, Ltd. Cloth, 2*s*. net).

This is the twenty-third issue of this hardy and popular annual.

The whole of the subject matter has been revised and brought up to date, but the principal additions have been made to the sections dealing with Electric Traction, Wireless Telegraphy, and Synchronisers and Power Factor Indicators. A few of the blocks have become so worn that the lettering is hardly decipherable, *e.g.*, the figures on pages 177, 178 and 184, and we suggest that this be put right in the next issue. The pocket book contains over 600 pages of useful information, in addition to a diary, and it is a marvel of cheap production as prices of books rule at the present time.

"Motor and Dynamo Control, Theory and Practice." By W. S. Ibbetson, B.Sc., A.M.I.E.E. pp. 487, viii. (Messrs. E. & F. N. Spon, Ltd., London. 21*s*. net).

This work is described as having been specially written for the purpose of providing the knowledge requisite for the efficient control, care and operation of all kinds of electrical machinery. It is a book suited to the switchboard and machine attendant and is non-mathematical in its treatment of the subject.

The matter is divided into thirteen chapters, of which the first is devoted to first principles.

The second chapter deals with D.C. dynamos, boosters, balancers, alternators, converters and static transformers in an elementary and descriptive manner. Chapter III. is concerned with direct current motors.

The two succeeding chapters deal with alternating current measurements and alternating current motors.

The procedure necessary in the erection and testing of D.C. dynamos is next described and a chapter on private plants follows. Many useful and practical hints are contained in this section.

Succeeding chapters deal with the parallel operation of alternators and the operation of converting plant. In this section methods of synchronising are clearly explained and the various methods employed for starting rotary converters are fully described, the actual operations necessary being detailed in each case. In this section a number of pages are devoted to the La Cour Converter.

The localisation of faults is very fully dealt with in the following chapters. A description of secondary cells follows. Their manufacture and first charging is described and particulars are given of various methods of regulating their charge and discharge. Explanations are here given of the Highfield and Entz automatic reversible boosters.

A short final chapter contains some useful notes on lubricants and a few hints on mechanical devices.

A good feature of the book is the comprehensive index which is provided.

There are 178 illustrations and diagrams. The diagrams are clearly drawn and well reproduced, but the paper used is not so suitable for half tones and several of them are obscure.

With regard to the subject matter of this volume, the author has in many places presented his statements in a very loose style. In addition to this looseness of style there are many actual errors. For example a student would understand from perusal of the second page that the action of a secondary cell depended on the deposition of copper in a solution of copper sulphate and that this effect is known as electrolysis. On page ten, example (*b*) contains an arithmetical error; the result being given as 32.03 K.W. instead of 3.9 K.W. Again on pages 18 and 19 the formulæ given for reluctance and total flux are incorrect when inch units are used. On pages 25, 72, and 159 single-phase and di-phase waveforms are shown as semicircles, while on page 76 the curves on a three-phase E.M.F. diagram are of approximately sinusoidal form. From these curves a student would reasonably infer that an essential difference exists between the wave shapes of three-phase and single or di-phase currents.

In dealing with battery boosters the machine is spoken of as a dynamo, and the fact that the booster acts as a motor when opposing the flow of current is not mentioned although its use in this manner is explained.

There are numerous other slips in this work, as for example the statement that the voltage drop due to ohmic resistance of an alternator armature is greatest on non-inductive loads. Also we are informed that a full steam supply would be necessary to drive an alternator when delivering less than full load on a low power factor.

In descriptions of synchronising gear the author frequently insists on the necessity for the indicating lamps used being suitable for double the bus bar voltage, overlooking the fact that since lamps are shown in each circuit between the incoming machine and the bus bars the voltage across each lamp or group of lamps in a particular circuit will not exceed the voltage of the bus bars.

In spite of these rather obvious defects the book contains much useful practical information and many of the operations necessary in alternator and rotary converter control are very fully described. The section devoted to faults is very comprehensive, and for the class of reader whose duties involve the control and maintenance of small and medium sized electrical machines the work may be regarded as useful and instructive.

A. J. GILL.

"Electrical Installation Rules and Tables." By W. S. Ibbetson, B.Sc., A.M.I.E.E. (Messrs. E. & F. N. Spon, Ltd., London). pp. 60. 1*s*. 6*d*. net.

This little booklet is of handy size suitable for the waistcoat pocket and contains a large number of useful tables required in estimating and laying out wiring installations for lighting or power. All values are given in the new standard sizes of wire and cable, while the nearest old standard size is quoted for reference in all cases. Extracts are given from the more important Wiring Rules of the I.E.E. The tables given include dimensions of cables, sizes requred for given numbers of lamps at all voltages, working and fusing currents of fuses, power rating of cables, sizes and capacity of casing and conduit insulation tests and many other particulars. A complete index is included. This little volume should prove a convenient time saver to engineers, wiremen and contractors.

A. J. GILL.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to.	Office.	Date.
Hill, G. A. D. ..	Chief Inspector	Asst. Engineer	E.-in-C.O. (Equipment).	4 : 3 : 22

RETIREMENTS,

Name.	Grade.	District.	Date.
Parkinson, F. S. ...	Assist. Suptg. Eng.	South Lancs.	25 : 2 : 22
Cooke, A. E.	Principal Clerk	London	27 : 2 : 22
Sheldon, J.	Executive Engr.	South Western	28 : 2 : 22
Park, J.	Asst. Engineer	Do.	21 : 2 : 22

TRANSFERS, ETC.

Name.	Grade.	Transferred. From.	Transferred. To.	Date, Etc.
Wise, F. H. ...	Executive Eng.	Eastern	South Western	1 : 3 : 22
Jones, T. V. .	Asst. Engineer	Eastern	London	1 : 1 : 22
Sharpley, A. J. ...	Do.	London	E.-in-C.O. (Construction)	1 : 1 : 22

COMMUNICATIONS.

DEATH.

Name.	Grade.	District.	Date.
Hook, R. M.	Executive Engineer	E.-in-C.O. (Lines).	31 : 12 : 21

BOARD OF EDITORS.

COMMUNICATIONS.

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

Binding covers and copies of the Contents Index for Vol. 3 to 14 are available, and may be obtained from the local agents for 1*s*. 6*d*. and 3*d*. respectively. Subscribers can have their copies of Vol. 14 bound, with index included, at a cost of 3*s*. by sending the JOURNALS to the local agents. Orders should indicate whether the original binding with black lettering, or the later pattern in gold, are required.

The Council of the Institution of Post Office Electrical Engineers has decided to raise the price of the JOURNAL to 2*s*. (2*s*. 3*d*. post free) per copy. This price applies also to annual subscribers, the subscription being 9*s*. per annum, post free. The price to P.O. subscribers is 1*s*. 6*d*. per number. All back numbers 2*s*. each. The Board of Editors is anxious to repurchase copies of the following parts: Vol. 1, Part 1; Vol. 5, Part 2; Vol. 6, Part 1; Vol. 7, Part 1; Vol. 9, Part 2; Vol. 12, all Parts; Vol. 14, Parts 1 and 2. Two shillings each part will be paid for clean copies in good condition.

INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

CENTRAL LIBRARY.

The following books have recently been added, and are available to members on application to the Librarian, Room 50A, G.P.O. West:—

No.	Title	Author
396.	Ideas of Einstein's Theory ...	J. H. Thirring.
397.	Wiring for Light and Power ...	Terrell Croft.
398.	Real Mathematics ...	E. G. Beck.
399.	Radio Engineering Principles ...	H. Lauer and H. L. Brown.
694.	Continuous Wave Wireless Telegraphy ...	B. E. G. Mittell.
695.	Directive Wireless Telegraphy ...	L. H. Walter.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year:

Colonial Members ...	£1	10 0
Foreign ,, ...	£2	0 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P O.E. Engineers,
Room 50A,
G.P.O. West, E.C. 1.

INDEX TO ADVERTISERS.


Radio Valves—
The chain is no stronger than its weakest link. The life of a valve is no longer than that of the filament—unless the filament is renewable. This unique patented feature of Mullard Power Valves means cutting in half the annual cost of valves at your wireless station. The renewal of your filament is an inexpensive operation, and when the valve is re-pumped, it is as good as new,
In Mullard Power and Power Rectifying Valves, in glass up to 500 watts and in fused silica for greater outputs, the patented construction permits filament renewal. You cannot do better than use them—they will save you money.
Trade terms are liberal and will be quoted on request.
Mullard
Radio Valve Co. Ltd.
Claybrook Road.
Hammersmith. W.6.
Telephone: Hammersmith 312.
Codes: ABC (5th Ed)
Telegrams: Radiovalve, Hammer, London
Contractors to H.M. Admiralty.
War Office, Royal Air Force & Post Office
Trade Mark
Radio Mullard Valve
MULLARD RADIO VALVE CO. LTD.
BRITISH MADE
250 WATTS TRANSMITTING VALVE IN GLASS
PATENT No. 158720/21.

Printed by Birch & Whittington, Epsom, and
Published by The Electrical Review Limited at 4 Ludgate Hill London E.C.