CHAPTER XVIII.

Bells.

One of the ordinary forms of communication in a ship is by means of bells, with or without voice pipes and telephones. These bells can be either single stroke or trembler bells.

Single-stroke Bell.—The single-stroke bell is the simplest form. It is not much used, however, as it is not always sufficiently loud to attract attention, and its call is apt to be overlooked amongst other noises; engine-room reply gongs are of this type.

The wire is wound round a magnet, usually of horseshoe form, the two ends being secured to two terminals. The armature, carrying the hammer, faces the pole pieces. On passing a current through the coils the magnet becomes active and attracts the armature, thus causing the hammer to strike the gong; in this position the armature will remain until the battery circuit is broken by easing up the call push, when the spring will assert itself, and draw the armature back to its original position. The coils may be joined either in series or in parallel.

Trembler Bell.—In the trembling bell the wire from the terminal A after passing round the magnets is secured to their metal framework at B, and is thus electrically connected through the spring C to the armature itself D. The latter rests normally against the insulated stop E, which is connected to the other terminal F.

On passing a current through the bell, the armature flies forward and causes the hammer to strike the gong, but as in so doing it breaks the circuit at E, it is at once pulled back to its old position by the spring C; the circuit being now again completed, the action described will continue as long as the battery circuit is kept closed by pressing the push. The adjusting screw G regulates the distance of the armature from the pole pieces, giving considerable latitude in this respect; and, as these adjusting screws are liable to slack back with continual vibration, they require some attention, especially in watertight bells. The magnet coils are usually joined in parallel, in order to obtain the most powerful field. The two bells described above are shown in Plate XL.

Watertight Trembler Bell.—In the watertight trembling bell, Plate XLI., the legs of the magnets are screwed into the side of the watertight casing, the armature A making and breaking the circuit in the usual way; it does not, however, carry the hammer, which screws into another armature facing the pole pieces outside the case. This armature B is pivoted at C, and is adjustable by a screw. The coils and the electrical make-and-break are consequently watertight, whilst the hammer and armature B are not. These bells will often be found to ring better with their coils in series (*see* page 320). Each bobbin carries 2·8 ohms of 25 L.S.G. wire.

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SINGLE STROKE BELL

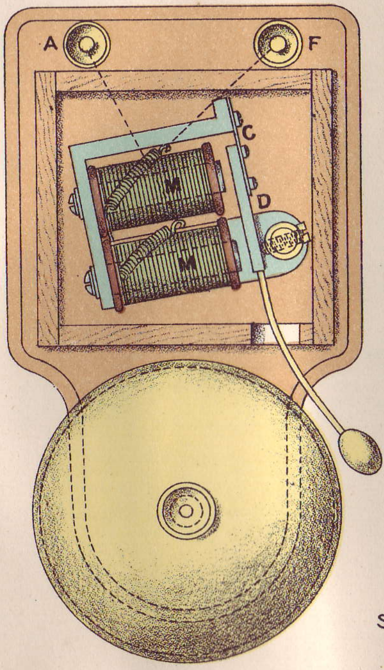

FIG. 1.

TREMBLER BELL
PATT. Nº 400

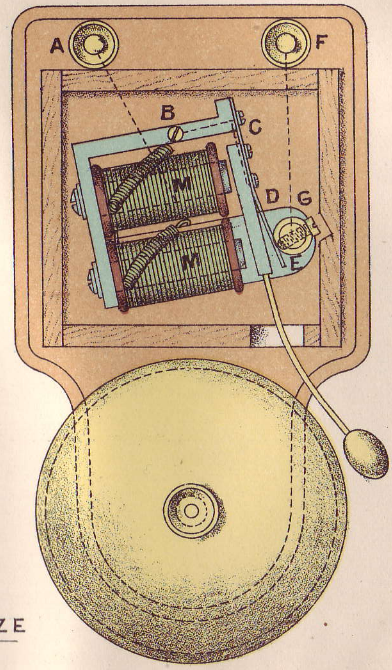

FIG. 2.

SCALE 3/8 FULL SIZE

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Alternate Current Bell.—One other form of bell is occasionally met with (*see* Plate XLIX.), viz., that for use with alternating currents. In this case two adjustable gongs are necessary, the hammer rocking between them. The magnet is wound in the usual way, but the armature, which carries the hammer, is pivoted between the pole pieces. It is so magnetised by permanent magnets that its extremities facing each pole piece of the electro-magnet are of the same polarity.

Faults.—The faults likely to be found in bells are:—

(1) Spindle carrying the hammer bent. This may jamb the hammer forward against the gong and so prevent the armature from moving, or throw the hammer out of line, with the result that it never strikes the gong. Under the second condition the armature will only rattle. The armature and spindle also stick occasionally in their metal covers (watertight bells).

(2) Make-and-break out of adjustment, contact dirty, or spring weak. If the spring is weak the defect can be temporarily rectified by placing the bell in such a position that the weight of the hammer at rest assists in keeping the armature spring against the adjusting screw.

(3) Armature touching the pole pieces and sticking to them by the pull of the residual magnetism. This can be cured by gumming a thin piece of paper to the pole pieces, and applies especially to the so-called relay. In some bells ivory stops are employed as a guard against this. It must be remembered that in bells, as in all other electrical instruments, absolute cleanliness of contacts is essential, and that there must be no loose contacts or bad mechanical fittings.

Shutters.—To avoid using a large number of bells, a shutter instrument, containing two or more shutters, is used, by means of which the station called is enabled to distinguish the caller.

Each shutter consists of a small electro-magnet, the wire wound round it being connected at one end to the calling line and at the other to the bell. The calling current, on arriving, passes through the shutter and bell in series, ringing the bell, and at the same time making the shutter magnet active; this pulls up a small armature in front of it and allows a shutter with a red disc painted on it to fall forward, the armature acting as a mechanical catch for the shutter. (*See* Plate XLII., Fig. 2.)

The shutters are placed two or more in a box, watertight or non-watertight, fitted with a glass front. There is also a rod projecting through the side of the box for mechanically replacing any shutters that may have fallen.

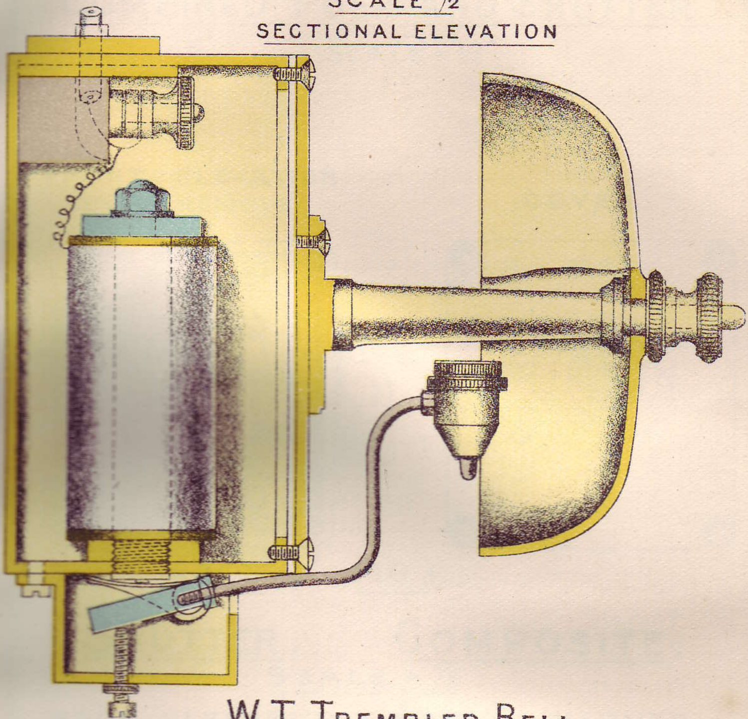
Each shutter offers a resistance of about 1 ohm. (25 L.S.G.).

Faults.—(1) The leads of all shutters are made "common" on one side by a bar, consequently an earth fault in one shutter will affect the whole group.

REPLY GONG (W. T.)

SCALE ½

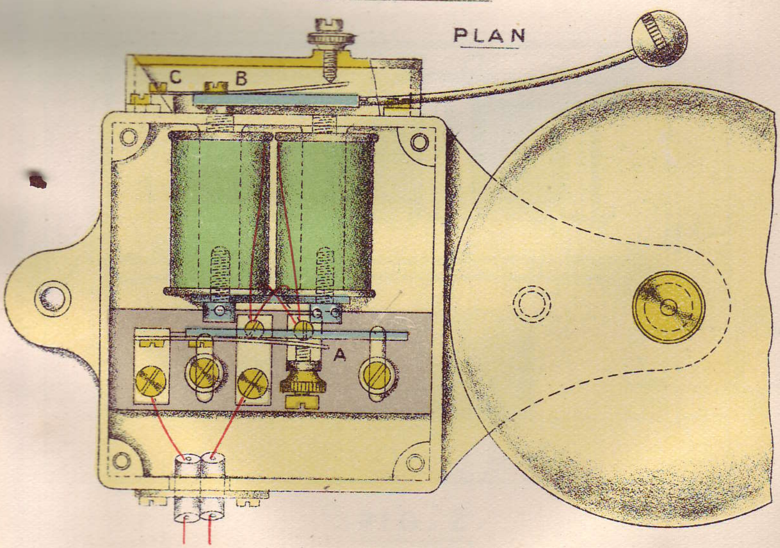
SECTIONAL ELEVATION



W. T. TREMBLER BELL

COVER REMOVED

PLAN



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Combined Push and Shutter

Scale = ½

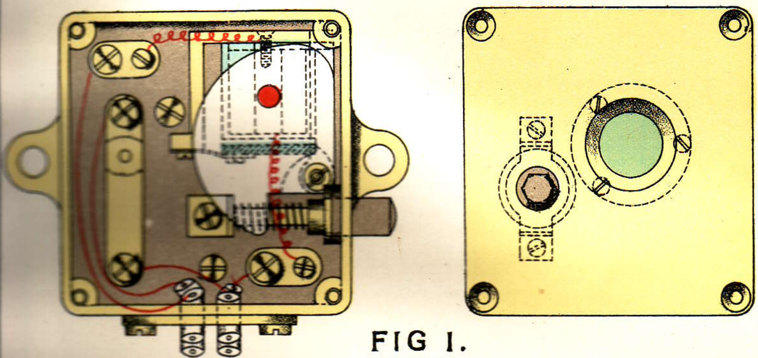

FIG. 1.

Shutter, Composite.

Scale = ½

BACK ELEVATION, BACK REMOVED.

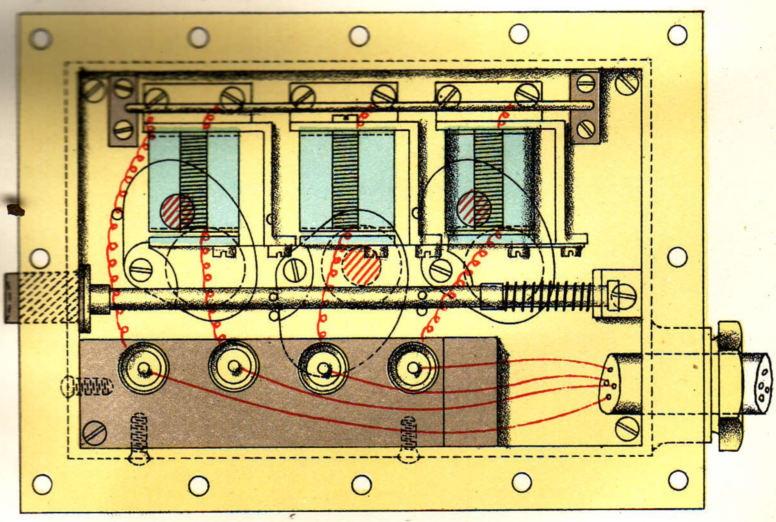

FIG. 2.

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FIG. 1.

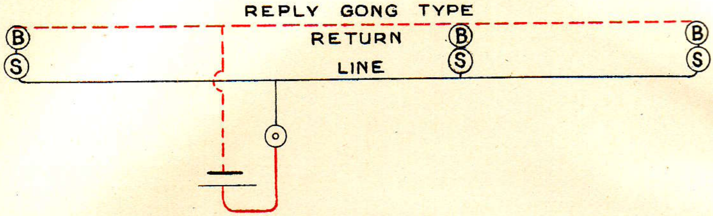


FIG. 2.

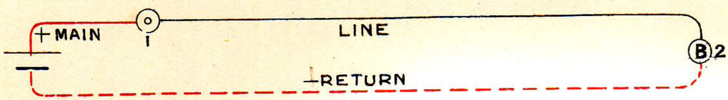


FIG. 3.

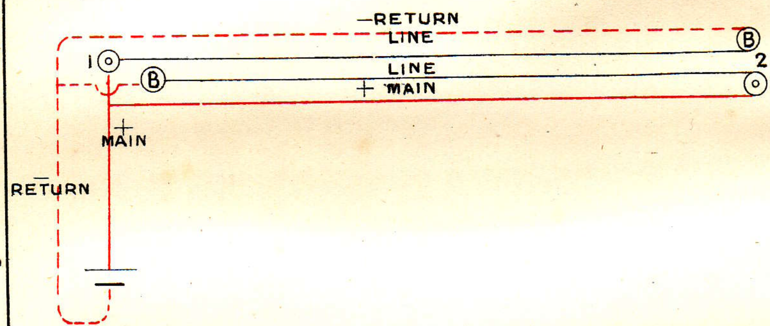
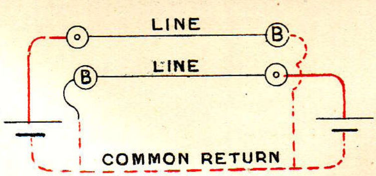


FIG. 4.



(B) = BELL
(S) = SWITCH
(⊙) = PUSH

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(2) The springs gradually become weak, allowing shutters to fall by concussion (without any passage of current), and no means are provided for adjusting the distance of the armature from the pole pieces.

Pushes.—The pushes for bell and reply gong systems are now usually made watertight, and it is important to remember that, if the covers are not properly screwed up, or if the glands are defective, the push will not make contact, or may short-circuit; they therefore require occasional attention.

Combined Single-push and Shutter.—A combined single-push and shutter, Fig. 1, Plate XLII., is employed in conjunction with the group system of bells.

Bell circuits can be joined up in several ways. (*See* Plate XLIII.)

Earth or a return wire can be used in each case, but earth returns are never used with bell circuits on board ship.

Fig. 1 shows three bells in fork off one push, with a switch fitted to each bell. (Reply gong type.)

Definition Terms.—Speaking generally, one *line wire* is required if one station is required to call another, and two if the latter is to call back. The $+^{ve}$ *pole* of the battery is connected to all the *pushes*, and the $-^{ve}$ *pole* to the *bells*, the latter wire being often called the *common return.* These two leads are called the *battery mains* or *charging leads.*

In Fig. 2 Station 1 calls Station 2 only, and if an alternative call position is required another push must be forked in between the line wire and the $+^{ve}$ main.

Should B wish to call back (Fig. 3) two line wires will be necessary, and both charging leads of the battery will be required at each station; or a battery employed at each station, wire being economised by using a common return (as shown in Fig. 4), if preferred.

Common Return System.—This system extended was employed in many ships, in conjunction with voice pipes, as the common return system, every station being able to send and receive calls. The stations are connected by line wires, laid up as two or four core cables, and several batteries are employed, all connected on the negative (return) side. It should be noted that in this system two line wires only will be required between two stations if they are fed off distant batteries, or by the same battery at two distant places, whilst two line wires and two charging leads will be required if the battery power of one is supplied from the other.

Group System.—The common return system is now obsolete, and will only be found in a few of the older ships. Its place has been taken by what is known as the Group System, each group having its own battery and return.

Plate XLIV., Fig. 2, shows an exchange group complete, and two extension boxes *x* and *y* have been put in to show how cable is sometimes still further economised. The connections of two stations of such a group system are filled in complete in Fig. 1, and the wires coloured to assist in tracing the circuits. The colours shown herein are not, however, those employed in the Service drawings supplied to ships, which show line wires in blue, + ve leads in red, and return in yellow. The two line wires between two stations were also frequently represented by one blue line in the older drawings.

The shutter return bar in the terminal boxes has been found necessary owing to the large number of stations calling by the same bell. The three bars are marked S R, P B, and B B, representing "shutter return," "push (battery positive)," and "bell (battery negative)," respectively. The line terminals at the top are connected by metal strips to the corresponding ones immediately beneath them. This avoids the inconvenience of placing two wires under one terminal, which was necessary in the older boxes, many of which still exist in the Service, fitted with terminals and two bars, or terminals only.

The new boxes are made of aluminium or gun-metal, and are supplied in three sizes. The base plates are made of vulcanised fibre, instead of slate, and are further insulated with mica and paraffin wax.

Reply Gongs.—Plate XLV. shows a complete set of reply gongs; as they require considerable current, and are fitted in fork, only those actually required should be kept switched on. They are usually kept distinct from the main bell circuits, and have a special battery of their own.

Faults.—Should a gong strike on switching on, examine the push, as, being in the engine room, it is apt to be short-circuited by damp. The springs also sometimes become rather weak, admitting of intermittent contacts, and the hammers are apt to slew round on their spindles. The coils are joined in series and offer 3·8 ohms resistance (20 L.S.G.).

Testing.—In testing bell circuits a little common sense will save a lot of trouble.

Do not be in a hurry to disconnect things, as the fault may be an incidental one.

Earth Leaks.—Should an earth leak be found to exist on the circuit, disconnect each lead in turn from the terminal box, and test with an earthed Menotti until the leaks are located in the direction of the bells, shutters, and line wires. It should be remembered that if an earth leak exists each side of a battery the battery will run down, a bell ring continuously, or a shutter persistently remain down.

Failures to ring.—Failures due to loose or disconnected leads, breaks, bad adjustment of bells, &c.

In the case of a bell failing to ring, the following list of questions will be found useful:—

(1) Has it a switch?
(2) Is there another bell in fork with it? If so, will either ring with the other switched off?
(3) Is there another push in fork?
(4) Will it ring with the push cover removed?

FIG. 1.

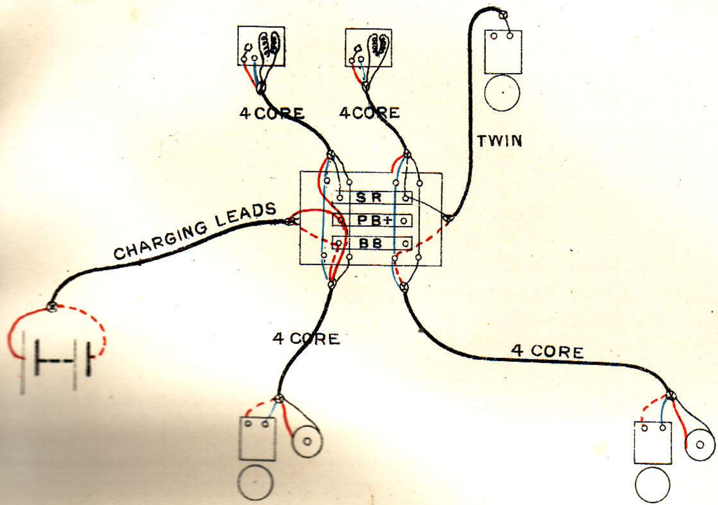
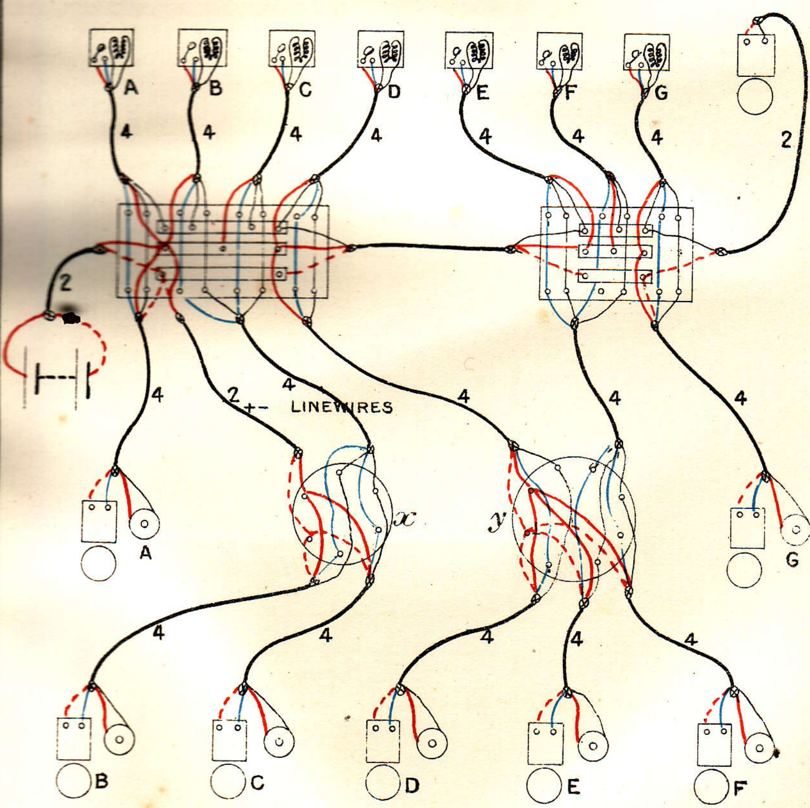


FIG. 2.



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Engine Room Reply Gongs

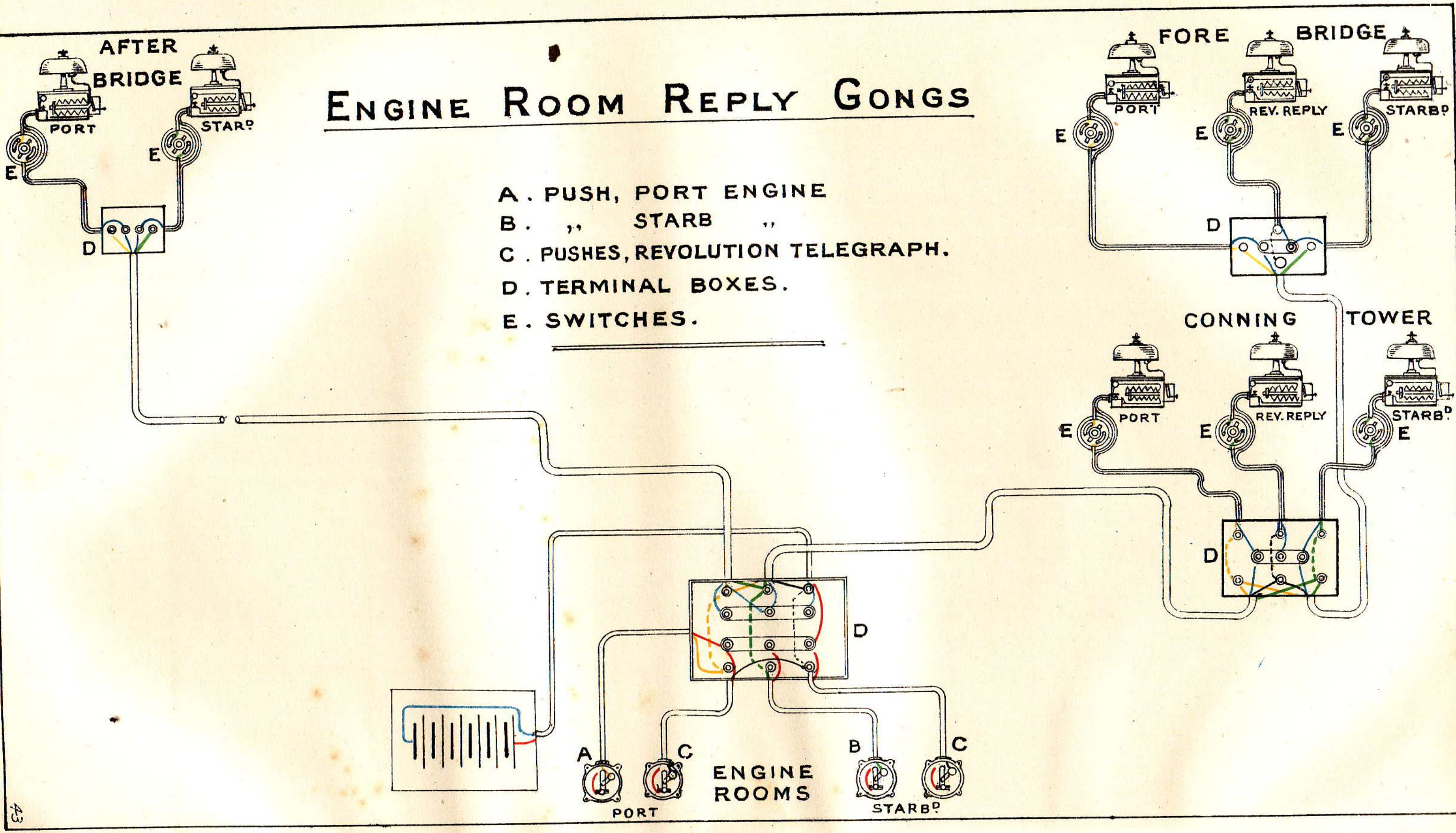


Plate XLV.

(5) If the bell is in connection with a shutter-box, can it be rung—

(*a*) by a distant push fed by the battery you ought to be able to ring with? If so, your battery, the bell, and the return connection between them are correct;

(*b*) through another of these shutters when called by a station fed by a different battery? If so, the bell and its connection to the common return are correct (as also the common return up to that battery and the various other leads used).

A few questions of this description will draw your attention to the part of the circuit in which the faults are, and these should then be located with a Menotti. It should be borne in mind that defective pushes, loose connections, and badly adjusted bells cannot always be avoided.

Group System. Obtaining Details.—Supposing a large group of bells on the new system to be unsatisfactory, and the drawings either wrong or mislaid.

The battery boxes are usually marked with the names of the places at which they feed pushes, the shutters are stamped with the names of the places which communicate with each other, and, in addition, the bells and terminal boxes are usually marked with the letter of the battery which feeds them; the connections also in the later pattern terminal boxes are marked. There should consequently be no difficulty in making out a list of what the communications ought to be. The number of bells at the exchange will give the number of systems employed there, unless two or more are common, and if the batteries are not properly marked the battery control can easily be verified by disconnecting the various batteries in turn until the right one is discovered.

Procedure.—First test, locate, and mark the battery wires, and see the poles of the battery joined to them, then, as it is useless to attempt to trace the four-core cables at an exchange, see all wires there at insulation; leave one hand at the exchange and go to any one outlying station. There, test the cores of the four-core cable to the exchange for insulation and for continuity (by earthing at the exchange), use the voice pipe for communicating, and tally the four-core cable at the exchange when identified. Having done this, join up the four cores at the distant station; this cannot be done wrong.

Now test with Menotti at the exchange. Two of these wires only will give continuity, viz., those connected to the bell; join either to the negative bar and the other to its proper line terminal. The other pair will give non-contact; join either to the positive bar and the other to its proper line terminal, verify the lead to, and join up the combined push and shutter at the exchange, temporarily join up the exchange battery and bell, and verify communication.

Proceed in the same manner with the other stations.

The only trouble likely to arise is where two batteries are made common by joining their negatives. Trace out this lead and see it disconnected at both ends until required.

Efficiency and Winding of Bells.—A bell will be at its best for ringing purposes when its resistance is equal to that of the line; consequently, you may find yourself with a bell which is quite unsuitable for the purpose to which you wish to apply it. This could generally be remedied by altering its winding. The field is proportional to the ampere turns, consequently, with a horseshoe magnet, the field can be largely increased by placing the coils in quantity if they were previously joined in series. Supposing each bobbin to carry N turns, and to offer a resistance of x ohms, the field with the coils in series will depend upon $\frac{E}{x + x} \times (N + N)$ or $\frac{E N}{x}$; and with the coils in quantity upon $\left(\frac{E}{x} \times N\right) \times 2$ or $\frac{2 E N}{x}$, and the resistance will change correspondingly from $2x$ to $\frac{x}{2}$. This change may be sufficient; if it is not, another bell must be obtained, or the bell can be re-wound provided the degree of saturation of the iron is allowed for.

This may be stated more plainly by saying that with a, low resistance circuit where the number of amperes is fairly large, the number of turns can be low; whilst with a high resistance circuit where the amperes are few, the turns must be more numerous, and therefore of finer wire, since the effect of coils whose distance from the core exceeds the diameter of the core itself may be neglected.

It is interesting in this respect to note the behaviour of the watertight bell (Patt. 1297): its coils offer a resistance of 2·8 ohms each, and are joined in parallel (Plate XLI., Fig. 2). The armature carrying the hammer is opposite two unlike poles screwed into the metal of the case, and will therefore always be attracted whenever a current is passed through the coils (provided it is properly adjusted), the strength of the blow depending, of course, upon the strength of the field; the other two unlike poles are joined by a thin yoke, and in their stray field lies the electrical make-and-break.

This works in the ordinary manner, but is very liable owing to the strength of the field to be pulled forward against the yoke and held there by the residual magnetism, in spite of the ivory stops and of the fact that the circuit is broken.

To adjust a Watertight Bell (*Patt.* 1297).

1. Take off the cover and disconnect the leads. Connect a Menotti in their place and test for continuity and insulation from metal of the box. Examine and clean connections if necessary;

see that armature spring is not bent or broken, and that the gong is firmly secured on its pedestal, and has a leather washer underneath it.

2. Secure the bell in a vertical position, gong downwards; take two tested cells (Patt. 1453) joined in series, and connect a lead from the free terminal of one cell to the upper terminal in bell, join another lead to the lower terminal of bell but do not connect it to battery yet. Ease back outside adjusting screw of armature, and unscrew capstan headed screw of make-and-break till it is well clear of the armature spring. Ease the two securing screws and shift ebonite base till ivory stops of armature are $\frac{1}{16}''$ from poles, then set taut, securing screws again.

3. Touch the short lead to the other battery terminal, screw up gradually on the capstan headed make-and-break adjusting screw, until armature always vibrates when the wire is touched to battery terminal, and comes to rest on breaking the circuit. Set the check nut well taut to prevent screw working back, and screw up the clapper adjusting screw till the bell rings loudest. When properly adjusted the bell should ring with any resistance from 0 to 8 ohms in circuit, a firing resistance coil or cell tester being placed in series with the two cells.

If it will not, probably part of the coils are short-circuited, and the bobbins should be balanced and if necessary rewound.

4. Replace the bell, connect up circuit, and try it in position.

NOTE.—All connections and screws should be carefully examined to see that there are no loose connections or dirty contacts. If all bells are carefully adjusted and kept properly watertight, they will remain in good condition for a considerable time under ordinary circumstances. If a bell goes wrong it should be repaired at once.

To adjust a Shutter (*Patt.* 1300).

If the bell rings and the shutter does not work, adjust the shutter as follows:—

1. Take off the cover with push attached and disconnect the line wires from the shutter terminal screws, work the shutter disc by hand, and look for mechanical faults in armature and shutter disc; if the shutter does not move freely it will probably be due to the following causes:—
   - (*a*) Pivot screw binding the shutter.
   - (*b*) Armature touching and preventing the shutter from falling when released.

To alter (*a*) take off the shutter by taking out pivot screw and countersink the hole a little more until the shutter works freely on the pivot screw when screwed hard up; to adjust (*b*) unscrew armature spring and move armature back a little (it may also be necessary to make the holes in the spring larger to give the armature a little lateral movement when screws are slack), or take a little off the front part of armature with a smooth file.

2. Join upper end of shutter coil to upper push terminal with a short piece of cut-out wire, join a tested cell (Patt. 1453) between lower push and lower shutter terminals; press the push, and the shutter should fall; if it does not, proceed as follows:—

   Take off shutter and examine armature spring; if this is too strong weaken it by bending upwards, press the push and see if the armature is attracted; if it is, continue the adjustment of the spring till it works correctly (putting in a new spring if necessary). If the armature is not attracted when the push is pressed and the continuity is correct, the shutter coil is probably short-circuited, and will require rewinding.

   If the armature is attracted and other adjustments are correct, put on the shutter disc and press the push; the shutter should now work correctly.

3. If the shutter disc will not remain up when the replacing rod is forced in, it may be due to the following causes:—
   (*a*) Armature not far enough back to catch projection on the disc.
   (*b*) Pin in replacing rod bent.

   Either of these can easily be repaired by bending or weakening the spring, or by straightening or shifting the pin of replacing rod till the toe of the armature catches the projection on the back of shutter disc and holds it correctly.

4. Disconnect the cell and the short piece of cut-out wire; join up the line wires, and work the shutter a few times.

NOTE.—If the shutter is properly adjusted to drop with one cell, it will work correctly through line and bell wires.

Electric Buzzer.

In the 12-inch shell rooms of the "King Edward VII." class, electric buzzers are fitted in place of call bells. The only difference from the ordinary type of bell is that the hammer is attached to the electrical make-and-break, and is consequently inside the brass cover of the buzzer, against which it strikes when a current is passed through the coils of the buzzer, the result being that a buzzing sound is emitted instead of the usual ringing of a bell. This buzzer is fitted on a round base.

High Voltage Bell.

On the introduction of dynamo firing into ships, it was found that although the ordinary type of W.T. trembler bell would ring with the higher voltage, the sparking at the contacts was excessive, and that these were soon worn out. It was therefore necessary to design a bell for the higher voltage. This bell is similar to Patt. 1297, but the coils have a resistance of 15 ohms. The engine-room reply gong for higher voltage has a resistance of 30 ohms.

In addition to the above there are other bells for use in connection with fire control.

Ringing Bells with an Alternator.—It is possible to ring the Service trembler bell by means of a small motor fitted with slip rings as an alternator. The make-and-break is screwed hard up, and the variations of the current cause the armature to be alternately attracted and released. This method has the advantage of doing away with the electrical make-and-break, which is the cause of most of the trouble with this type of bell.

CHAPTER XIX.

TELEPHONES.

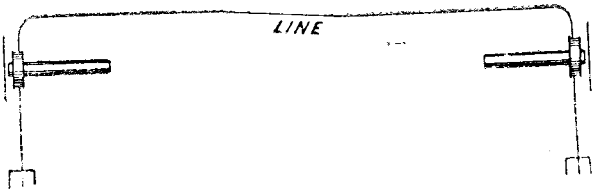
Telephones.—The instruments described in the last chapter are used for calling attention or conveying signals. In the telephone the actual words spoken into one instrument are reproduced in the other.

Transmitter and Receiver.—The simplest original form of telephone is the "Bell" (Plate XLVI.). It consists essentially of a permanent magnet in the form of a bar (single-pole type), or a horseshoe (double-pole type), the latter being more efficient.

Round one pole (or, in the case of a horseshoe, each pole) is wound a coil of insulated wire, mounted on a wooden sleeve. The magnet and coil are mounted in an ebonite frame, across the top of which is clamped a vibrating diaphragm of sheet iron. This acts partially as a keeper to the magnet, but serves principally to intensify the sounds produced.

The discs are tinned, or varnished, to prevent oxidation, and are clamped round their edges only.

FIG. 176.



Action.—Suppose two such instruments connected together by two lines, or one line and earth (Fig. 176). On speaking into one of them the iron disc is thrown into vibration by the sound waves formed by the voice; it therefore oscillates to and fro under their influence, and, whilst so doing, alternately approaches and recedes from the pole piece of the magnet. By so doing it alters the distribution of the magnetic field due to the magnet, and undulatory or periodic currents are consequently induced in the coil round the pole piece. These currents pass to line and so to the coil of the other instrument; here the field being altered by these currents in precisely the same manner as at the transmitting station, the disc, in conforming to the alterations, vibrates to and fro and, acting as an air beater, reproduces the sound waves.

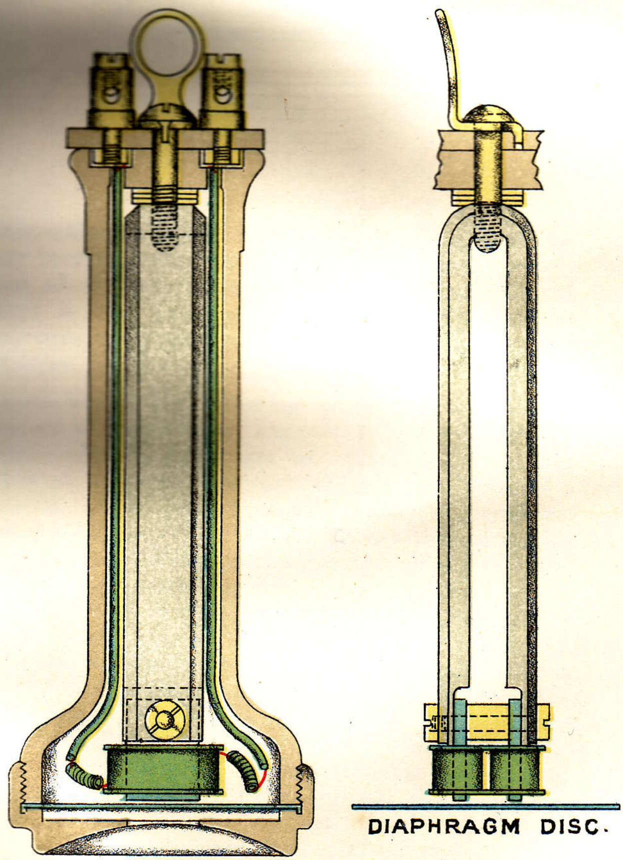
This may be looked on, broadly, as the action of a "Bell" telephone, but the actual phenomena are not really thoroughly understood. Musical sounds transmitted at one station can still

Double Pole Bell Receiver.

⅔ FULL SIZE

SECTION.

SIDE ELEVATION OF MAGNET.



DIAPHRAGM DISC.

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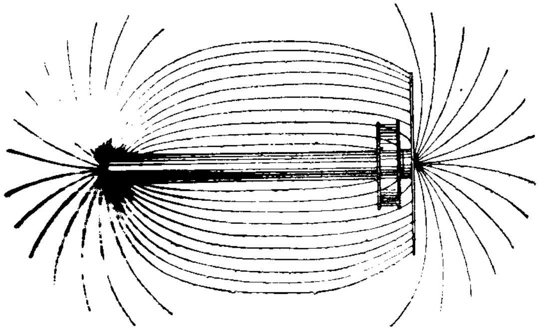
be heard at the other if the iron diaphragm is removed and the pole piece of the magnet held to the ear, whilst the mutual reactions of the various parts of the instruments are undoubtedly very complicated. The normal distribution of the magnetic field due to a single-pole magnet and diaphragm is shown in Fig. 177.

FIG. 177.



Limit.—Messages sent between two such instruments will obviously become weaker as the distance increases, owing to the resistance of the line wires, leakage faults, &c., and the Bell instrument is now only used as the receiver (or listener) of telephone circuits, its place as a transmitter being taken by more efficient types.

Adjustments. — The following points in connection with receivers are of importance, viz.:—(1) The stronger the field the thicker should the diaphragm be. (2) For a fixed thickness of diaphragm a certain diameter will give the greatest effect. (3) Since the action depends on two fields, the permanent and that induced by the coils, it might appear that increasing the permanent field should always increase the effect; this is not so, however, as not only does the disc lose its elasticity under strong magnetic attraction, but the variations due to the coils would cease to be appreciable if the permanent field was greatly in excess. The disc should be clamped as close as possible to the pole pieces, but should never touch them; the thickness of a sheet of writing paper will suffice; and paper or brass washers are often used under the edges of the disc to secure the necessary clearance. With continual use, however, the discs sometimes acquire a permanent set. If this occurs, the disc should be reversed. (4) The relative positions of the coils, discs, and magnets must be determined by the consideration that the greater the number of lines of force cutting the coil, and the greater the variation in these caused by the induced currents, the greater will be the movements of the disc and consequent effects.

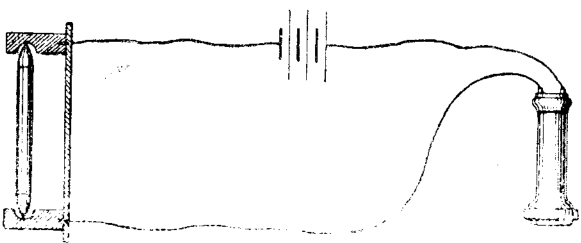
As the receiver shown in Plate XLVI. is rather large and clumsy for many purposes for which telephone receivers are required, a smaller pattern, known as the "watch pattern," has been introduced. Many varieties of this are used in the Service for different purposes, and one of them is shown in Plate XLVII. The long horseshoe magnet is replaced by one of small size, so that it will go into a case which is of about the same diameter as the diaphragm, and so shaped that its poles are in the centre, and the whole instrument is enclosed in a small case not much larger than a watch.

Microphone.—The "Bell" receiver as transmitter is now replaced by a *microphone*, which is essentially a loose contact in a circuit carrying a steady current. For this purpose carbon is employed, as it is practically infusible, inoxidisable, and a poor conductor. Its resistance, also, decreases as the temperature rises, and this serves to intensify the effect of the loose contact, since increased looseness of contact means higher resistance and therefore less current, *i.e.*, less heat and, consequently, a still further increase of resistance.

The carbon is usually employed in the form of carbon dust or granules between two carbon plates.

Simple Form of Microphone.—The simplest form is shown in Fig. 178, and consists merely of a carbon pencil resting between two carbon blocks attached to a sounding board. The circuit, battery, and receiver are joined up as shown.

FIG. 178.

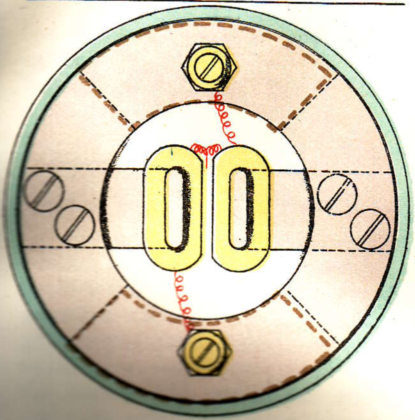


Action.—So long as the sounding board remains stationary the current in the circuit remains steady, but as soon as the sounding board is thrown into a state of vibration the contacts between the carbon rods and the blocks become variable, producing the so-called "phenomenon of loose contact," and causing alterations in the resistance of the transmitter. The corresponding alterations of current in the total circuit act on the receiver, causing the disc to reproduce as previously described, but with much greater effect. It is, in fact, a relay actuated by the voice, and is exceedingly sensitive, the slightest displacement of the carbon being audible in the receiver. Other systems of loose contacts will act as transmitters, but carbon is undoubtedly the most efficient, for the reasons stated above.

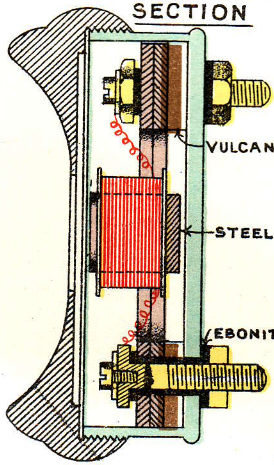
Limits.—The sensitiveness of such a transmitter depends on its range of contact and on the total resistance of the circuit.

"Watch Pattern" Telephone Receiver.

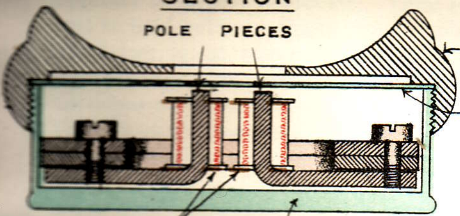
PLAN. EAR PIECE REMOVED.



SECTION

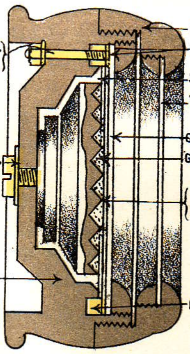


SECTION

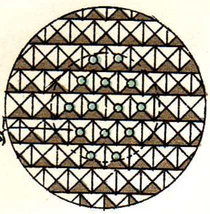


Hunnings-Cone Transmitter.

SECTION



CARBON PLATE



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Supposing the total circuit to offer a resistance of 10 ohms, and the transmitter to be varying 1 ohm each way, *i.e.*, through 2 ohms, the current will vary from $\frac{E}{9}$ to $\frac{E}{11}$; whereas if the resistance had been 100 ohms in the first place, the variation would only have been from $\frac{E}{99}$ to $\frac{E}{101}$; hence the advantage of keeping the circuit of low resistance.

Granular Transmitters.—The efficiency of the varying contact is very greatly improved by employing carbon dust in contact with a thin disc, usually made of carbon also. In these granular microphones greater efficiency is obtained owing to the greater number of carbon points of contact, but they are subject to the great disadvantage of being very susceptible to moisture, the carbon dust caking and collecting (*packing*) at the bottom, and very greatly reducing the sensitiveness.

Hunning's Cone Transmitters.—Of these the most efficient type is the Hunning's cone transmitter, in which the "packing" difficulty is largely overcome. (*See* Plate XLVII.) The carbon dust is held between the carbon diaphragm and the carbon plate. The latter is cut into a number of little pyramids, arranged alternately in rows, so that the dust in each partition is confined by the edges of those around it, and uniformity of contact is assured. The felt ring prevents damp penetrating, and gives the diaphragm an even bearing surface, and the centre cones, which are slightly truncated, have tufts of silk gummed to them to act as dampers to the diaphragm, and stamp out any persistent vibration.

The battery pressure used with this transmitter should not exceed three volts, otherwise hissing noises will commence, due probably to the formation of minute sparks and "arcing" at the carbon points of contact. This applies to all such transmitters, and its actual cause is not yet thoroughly understood.

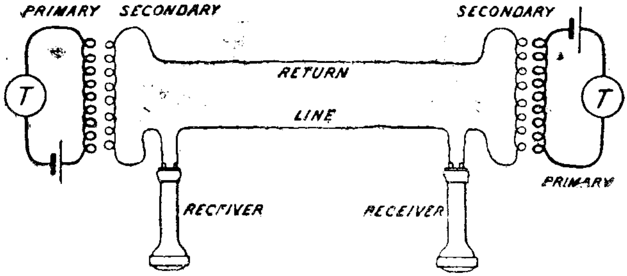
Range.—With a carbon transmitter, battery, and receiver in series, as the distance between the transmitter and receiver increases, an increase of battery power becomes necessary to overcome the resistance of the line. This, however, is limited, as not only does it tend to set up hissing in the microphone, but the increased line-resistance, faults, &c. tend to impair the sensitiveness of the whole system.

Induced Working.—To get over this difficulty induction coils are used, as shown in Fig. 179.

A primary coil of a few turns of wire of low resistance is joined in series with the microphone and battery (thus retaining a low resistance circuit, and consequently the greatest sensitiveness), whilst a secondary coil of many turns of fine wire is joined in series with the receivers and the line wires.

Action.—On speaking into the primary circuit at one end, variations in the current flowing in it are produced. The secondary coils and receivers at the two stations being all in series and forming a complete closed circuit, the variations of the primary are reproduced in the secondary coil at the speaking station, thus producing speech in the listeners at both stations. As the variations in the primary circuit are transformed from large current and low voltage in the primary coil to small current and high voltage in the secondary coil, these induced currents are carried over long and even faulty lines, the high voltage rendering the line resistance of small importance.

FIG. 179.



The receivers, however, must be so wound that these induced currents are capable of providing sufficient variations of field for their discs.

Speaking generally, for direct working, use low resistance receivers wound with medium gauge wire; and, for induced working, high resistance ones wound with fine gauge wire.

A bell is also required to call attention at either end.

Requirements.—The requirements for such a telephone are therefore as follows:—

(1) Primary (speaking) circuit broken when not in use.

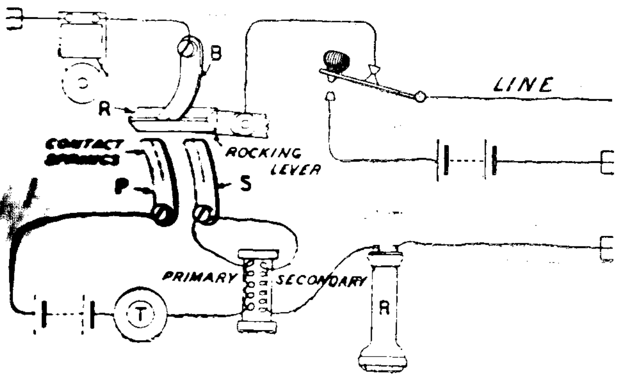
(2) Line wire joined normally to bell, but transferred to secondary coil and receiver during conversation.

(3) A ringing key and battery, capable of sending ringing currents direct to line clear of your own bell, listeners, &c.

Automatic Switch.—These can be met in a variety of ways. An automatic switch (*see* Fig. 180) is usually employed, on which the receiver is hooked when not in use; its weight hanging on the switch bar keeps the line wire on the contact connected to the bell circuit, and, on unhooking it, a spring asserts itself, causing the lever to rise; this joins the line wire to the contact connected to the secondary coil and receiver, and at the same time establishes the microphone circuit. It is not necessary that the microphone circuit should be entirely insulated from the secondary, that is to say, they may have one common point of contact, *e.g.*, S.

In Fig. 180 the line wire is connected to the heel of the ringing key, and the centre of the latter makes contact with the rocking lever R on which the receiver hangs, its weight keeping the lever R against the spring B, which is connected to the bell and so to earth. On unhooking the receiver a spring (not shown) draws R down, causing it to bridge across the two springs P and S, thus establishing the microphone circuit, and at the same time connecting the line to the receivers and secondary coil.

Fig. 180.



The telephones used in the Service may be divided into two **broad classes :—**

(1) Those which are used for communication in the ship.
(2) Those used for work away from the ship, such as mining, **and also for** use at ranges.

Class (1) are of the Graham's loud-speaking type, in which **the transmitter and receiver** are placed in series with the battery.

Class (2) is represented by the Wentworth and Bisley telephones, in which an induction coil is employed to enable communication to be carried on at considerable distances, and also over faulty line wires.

Mining Telephone (Patt. 1684) *or Wentworth Telephone.*

Mining Telephone.—This telephone is contained in a brass-clamped wooden box divided into three compartments. The front compartment is closed by a lid and spring clip, and contains—

(1) Transmitter of Hunning's cone, Deckert type (Post Office pattern), a description of which is given on page 327.
(2) A double-pole Bell's receiver. (*See* page 324 and Plate XLVI.)
(3) Rocking switch for completing the primary circuit, actuated by the weight of the receiver on the hook.
(4) Signalling key, arranged so that when pressed it short-circuits transmitter and rocking switch and works the vibrator.

The large back compartment contains three Delafon or Transport cells, forming the battery; the smaller one contains the induction coil and a "tommy" for adjusting it. This coil consists of a horseshoe magnet and make-and-break similar to that in an electric bell, and is wound with a primary and a secondary coil having resistances of 1 and 25 ohms respectively.

Fig. 181.

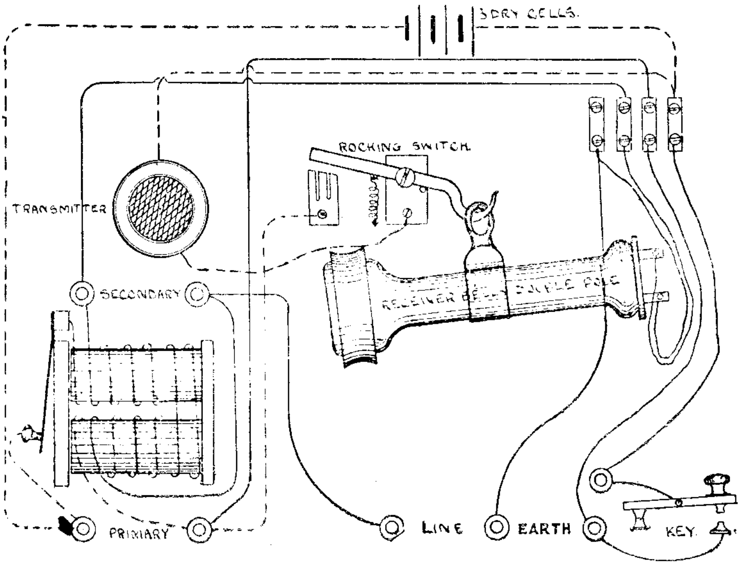


Fig. 181 shows the circuit. To call up, the key is pressed and the current then flows from the positive of the battery through the key, through the primary of the induction coil back to negative of battery.

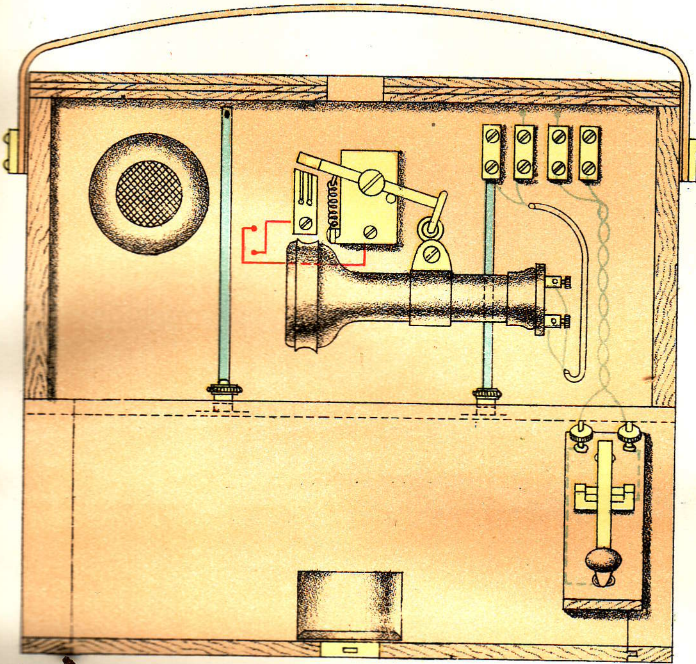
This causes the make-and-break to vibrate rapidly, producing an alternating current in the "secondary" which goes to line and away to the distant station's receiver and induction coil, and back by earth return to home station's receiver and secondary coil. This causes the receivers at both stations to "buzz" or "sing" loudly enough to be heard a considerable distance, and the fact of the buzzing being heard in your own receiver, when your own key is pressed, tests the "call up."

When speaking, the receiver being unhooked, the primary circuit is completed; and the current then flows from the positive pole of the battery, through the transmitter, through the rocking switch, and through the primary coil back to negative of battery. The current in this case will not be strong enough to work the vibrator, owing to the resistance of the transmitter. The variations in the primary coil cause corresponding variations in

NEW MINING TELEPHONE AND BUZZER.

FRONT ELEVATION

(VIEW SHOWS HINGED FRONT, OPEN.)



BACK ELEVATION.

(WITH BACK OF BOX REMOVED)

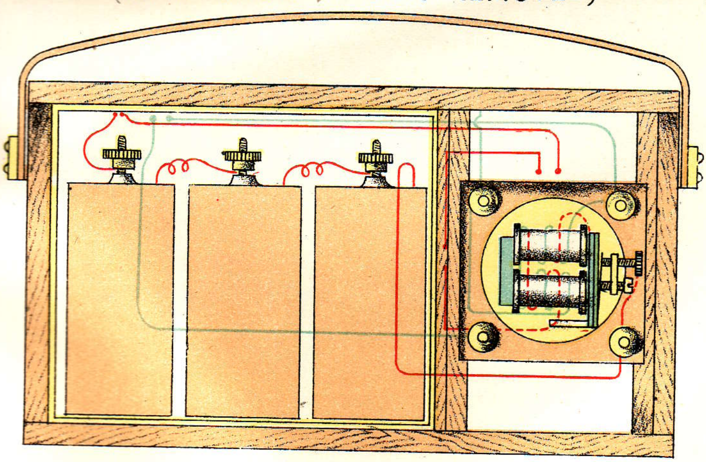


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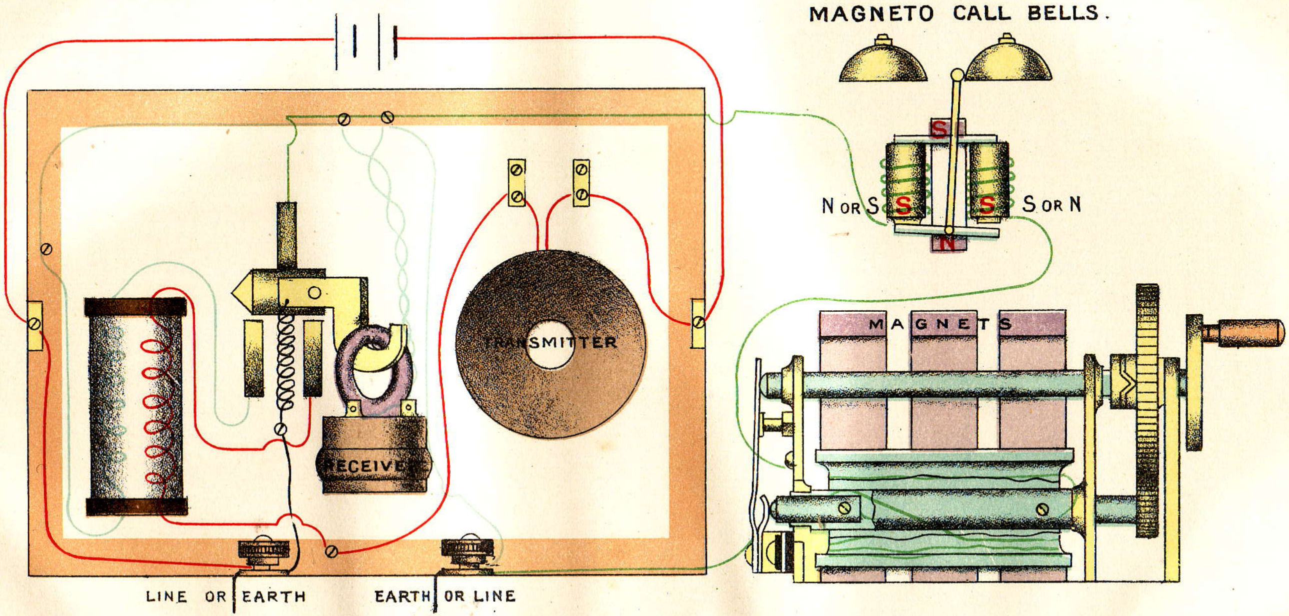
DIAGRAM OF CIRCUIT OF BISLEY TELEPHONE.



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the secondary of higher voltage, which go to line and so to the receiver of the distant station.

Plate XLVIII. shows the general arrangement.

Bisley Telephone.

Range Telephone.—The telephone employed for range purposes is called the "Bisley Telephone" (Plate XLIX.). It is fitted with a Hunning's cone transmitter, induction coil, and two dry cells in the primary circuit. The call-up is affected by a triple magneto generator. This consists of three strong permanent magnets with an H-shaped soft iron armature between their poles. One end of the wire wound round it is connected to an insulated contact on the spindle, and the other to the spindle itself. The armature of the generator is normally short-circuited, to enable the incoming currents to pass direct to bell. This short-circuit is mechanically broken by the first movement of the handle of the generator when calling up.

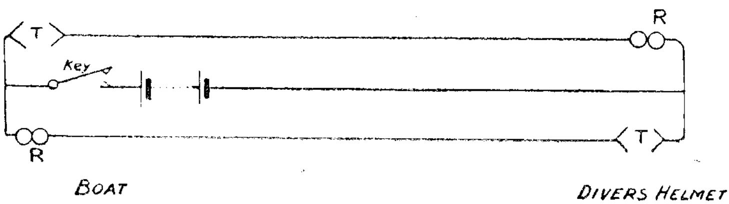
On revolving the handle, alternating currents are generated in the coil and sent to line, consequently an alternate current bell is employed, but it should not be forgotten that if the magneto instrument was fitted with a two-part commutator an ordinary bell could be used.

The receiver, which normally hangs on the automatic switch, is of the Ader type, and presents the special feature of a ring of soft iron, called the over-exciter, let into the cover and so lying directly over the pole pieces on the far side of the disc. This concentrates the field in which the disc lies, and the variations produced by the currents have consequently the maximum effect upon the disc.

On comparing the circuit with that shown on page 329, it will be seen that the rocking lever is connected to one line terminal. To the other terminal are connected in fork (1) the magneto, bell, and bell contact; (2) the receiver, secondary, and telephone contact.

Diver's Telephone.—This is a portable telephone, but as it has only to work over short distances, the induction coil is not necessary, and it is of the direct working type, the transmitter and receiver being in series with the battery. Fig. 182 shows a diagram of the

FIG. 182.



circuit, and Plate L. the instrument itself. The cable is three-core, and is laid up in the breast rope.

The transmitter and receiver are fixed in the helmet, the connections to the breast rope cable being made by a watertight gland, and the upper ends of the unarmoured cable connected to the gland nut on the battery box. The latter contains eight cells, Patt. 1451, or dry cells.

A spring switch is arranged in the handle, so that when the telephone is grasped by the hand the circuit through both transmitters and receivers is completed.

If the diver requires to call up the boat, he can do so by signalling on the breast rope.

New Diver's Telephone.—This is intended for the use of two divers at once. A switch in the box allows the boat to communicate with either or both divers, or one diver to communicate with the other.

Metaphone.

This instrument consists of a small transmitter and receiver in series with one another, fixed at the ends of a handle, so that the transmitter is near the mouth when the receiver is placed to the ear. It is intended to be used on any electric bell circuit which is worked off a battery, one metaphone being put in parallel with the push and another with the bell. It is fitted with a small switch attached to the lug by which it is hung up when not in use, which breaks the circuit when the weight of the instrument comes on the lug. The bell circuit is thus not interfered with until the instrument is unhooked for use.

It is not designed for use in conjunction with a generator, and so can only be used on a circuit fed from a battery.

Graham's Loud-Speaking Telephones.

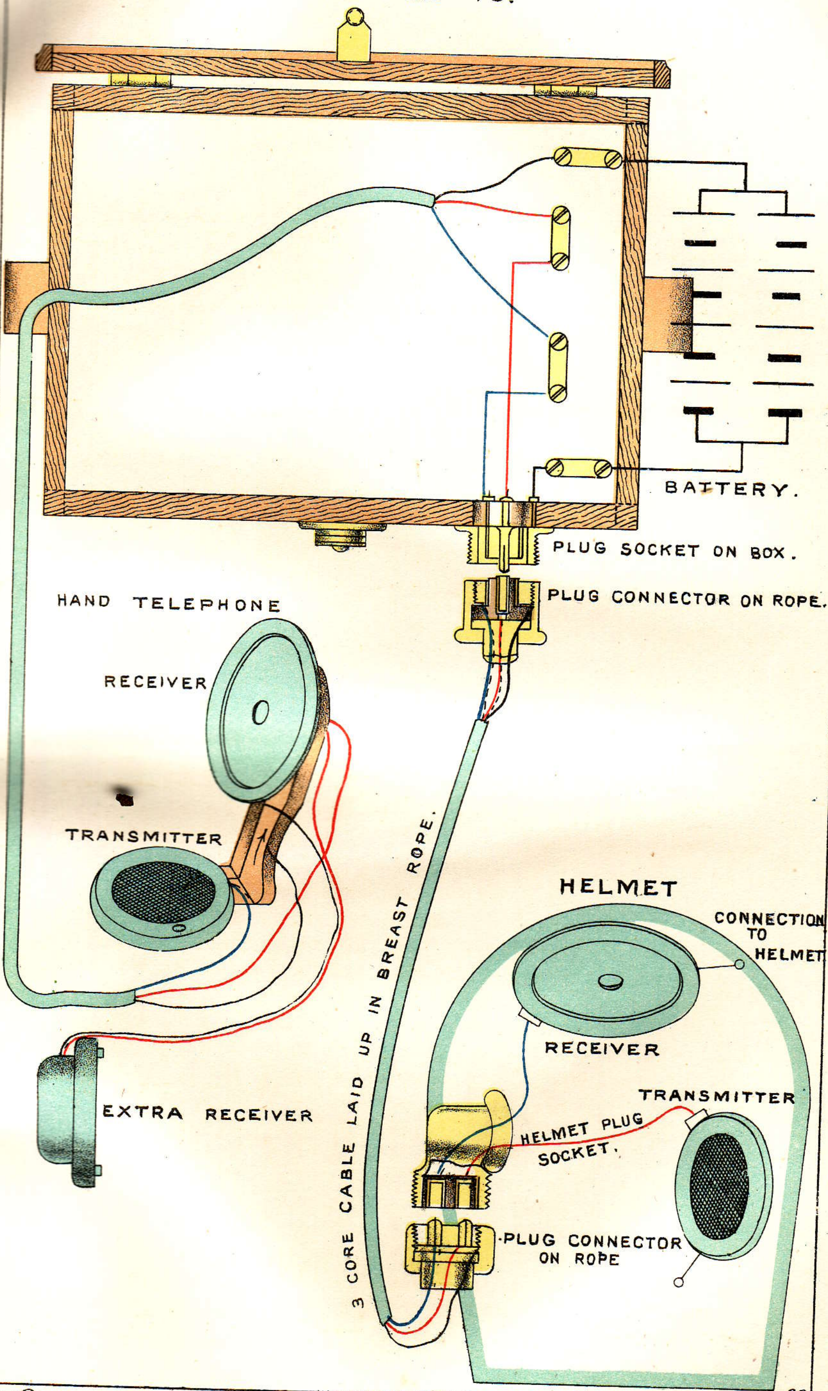
These telephones, as mentioned above, are used only for communication between different parts of the ship, and are all of the direct working type, the transmitter and receiver being in series with the battery. There are various different forms of them in use in the Service, which will be described in turn.

The earliest form now in use in the Service is the Patt. 1639, in which the transmitter and receiver are placed alongside one another in an oval gun-metal case, with an opening over each closed by a single shutter pivoted between them. When the shutter is closed the bell and push are connected each to their own line, and the transmitter and receiver disconnected. When the shutter is revolved to uncover the openings, the transmitter and receiver are each connected to their own lines, the bell cut out, and at the same time the transmitter is revolved by means of gearing, so as to shake up the carbon granules and ensure proper working.

The transmitter and receiver are both shown on Plate LI., as is also a diagram of the circuit. The transmitter and receiver are both made flat so that they take only a small space in the instrument, and leave room for the terminal blocks and switch gear.

DIVERS TELEPHONE.

SCALE 1/5.



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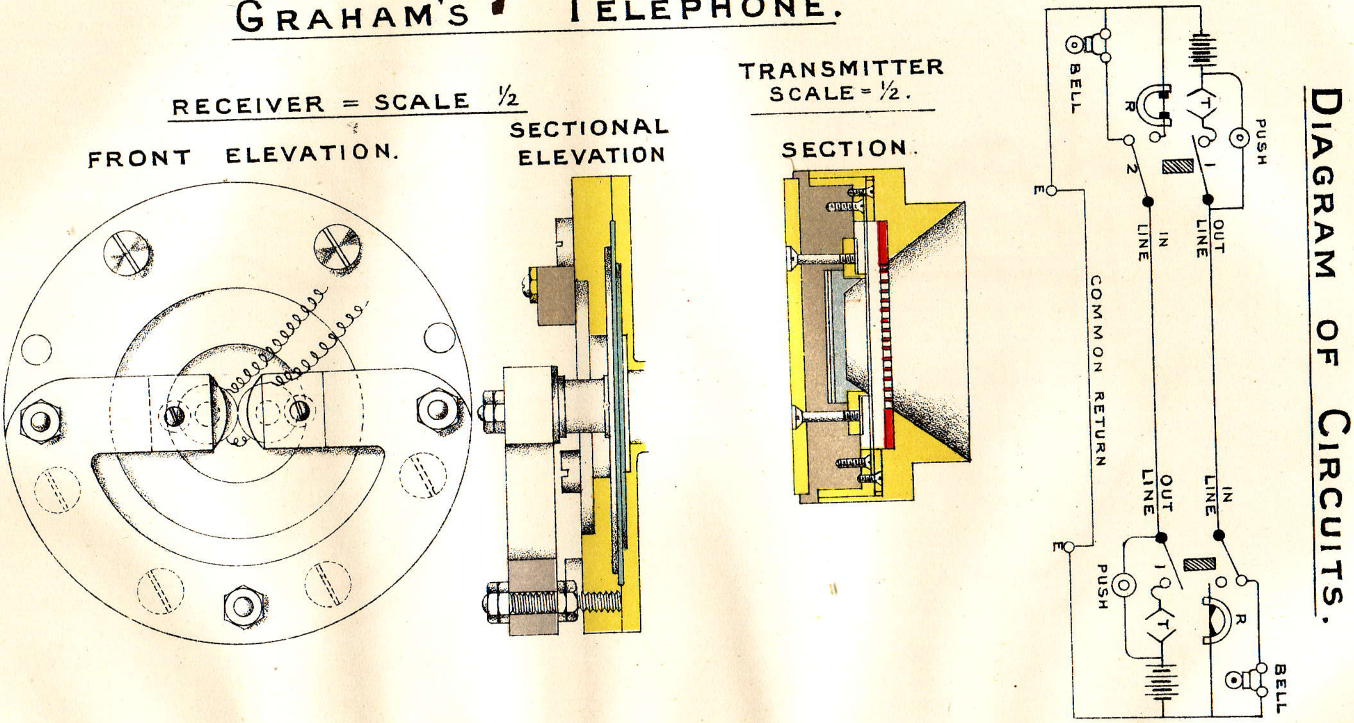
GRAHAM'S TELEPHONE.



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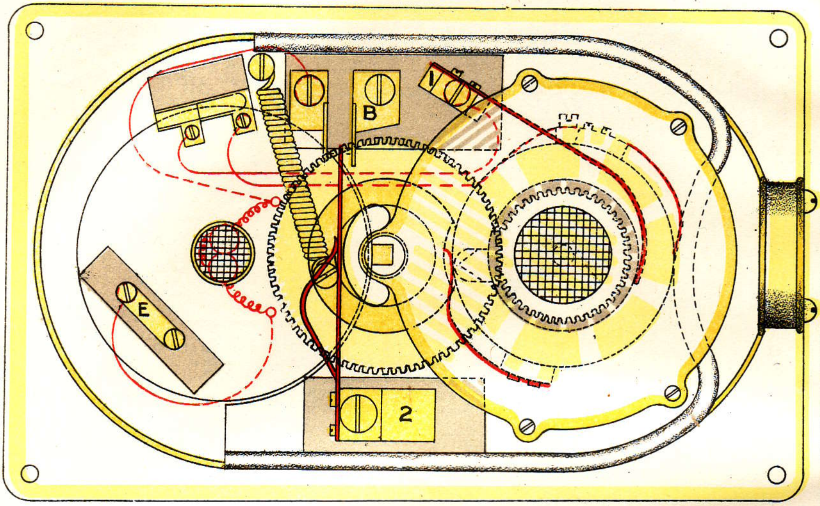
GRAHAM'S TELEPHONE. UPPER D^K TYPE (COVER REMOVED)

PATT. Nº 1639

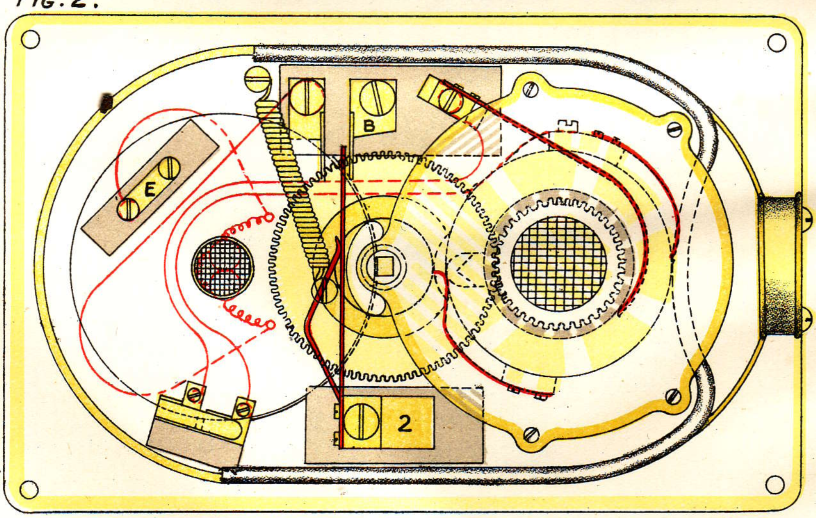
FIG. 1.



GRAHAM'S TELEPHONE. ENGINE R^M TYPE (COVER REMOVED)

PATT Nº 1643.

FIG. 2.



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The transmitter is of the granular carbon type, the carbon disc being protected by a mica disc placed in front of it and painted over so as to make the instrument watertight. In front of the mica disc is a grating of metal, usually fixed to the cover, of which the function is to protect the transmitter from damage.

The receiver consists of a large and powerfully magnetised horseshoe magnet, having soft iron pole pieces fixed into its ends and standing up at right angles, on which the coils are wound. There is generally some means of adjusting the distance of the diaphragm from the ends of the pole pieces, either by moving the diaphragm or by screwing the pole pieces in or out.

The transmitter and receiver shown in the plate are of the earliest type, but the later ones only differ from these in small constructional details, and these may be taken as the type of all Graham's instruments.

The diagram of the circuit shows two instruments joined up together for ordinary working with two batteries, one at each end. It is more usual nowadays, however, to use one battery only, and it is placed in the "common return" wire instead of the positions shown.

Plate LII. shows Patt. 1639 with the cover removed.

The "out line" is connected to the block marked 1 and the "in line" to the block marked 2, and the positive and negative leads from the battery, if two batteries are used to the "C" and "E" blocks respectively. If only one battery is used, "C" is joined to "E" and the battery put in the common return. The bell is joined in between the "B" and "E" blocks.

It will be seen that the 2 block is ordinarily connected to the bell by means of the spring extending across the instrument, but when the shutter is revolved a cam on its spindle presses this spring away from the "B" block and up against the block to which the receiver is connected. The transmitter is ordinarily disconnected, but when it is revolved a projection, which is shown dotted on the plate, comes into contact with the spring attached to the 1 block.

The "in line" of one instrument is, of course, connected to the "out line" of the other, and *vice versâ.*

Fig. 2 of Plate LII. shows Patt. 1643 telephone with the cover removed. It is the same as the Patt. 1639, except in the following details :—

The bell push is in a different position as shown.

The shutter, instead of covering both openings, only covers the transmitter, and the cover carries a projecting trumpet over the receiver, which has an india-rubber rim against which the ear can be pressed. There is also another similar ear piece on the end of a flexible tube coming out of the cover beside the receiver, which can be pressed against the other ear, so that all external noises can be excluded. This pattern of instrument is used in engine rooms and in gun positions of some earlier ships.

Navyphones.

All the Graham's telephones introduced into the Service since the Patt. 1643 have been of the type known as navyphones. In these instruments the receiver is placed at the back of the case, with its diaphragm facing the back of the instrument, and the transmitter is carried by the front of the instrument, which is removable, the connection to the circuit being made by two flat springs which press against contact pieces on the back of the transmitter when it is in place. There is a switch at the side, marked "Press whilst speaking," which performs the same duties as did revolving the shutter in the earlier patterns. A trumpet is fitted, starting from the back of the instrument opposite the centre of the receiver diaphragm, and having its mouth out at the side.

The transmitter is not revolved by gearing, but is fitted so that it can be revolved by hand, and is marked "Revolve before speaking." It is most important that this should always be done, as otherwise the carbon granules are liable to cake and the instruments will not work well.

The different pattern navyphones in the Service will now be described in turn.

Patt. 1855 *Navyphone.*—This was the first navyphone, and it is shown in Plate LIII.

The switch is on the right side, and this when pressed revolves a cylindrical ebonite shaft through an angle of about 45°; along the top of this shaft are two studs X and Y, Y being about 45° in advance of X. When this shaft is in its normal position the stud Y bridges the two contacts V, and thus makes the bell circuit; when speaking, the switch is pressed and the shaft revolved; this breaks the contact at V, and the stud X now bridges the two contacts T, thus breaking the bell circuit and making the receiver circuit; at the same time a strip on the lower part of the shaft bridges across two contacts K, thereby connecting the transmitter to line I. When the switch is released a spring brings the shaft back to its normal position.

There is an ordinary push on the left for calling up, which joins C to line I when pressed.

The transmitter is secured to the front by three screws, an I R washer making a watertight joint. The connections through the transmitter are made by two bent springs L, which bear against two concentric metal contacts at the back.

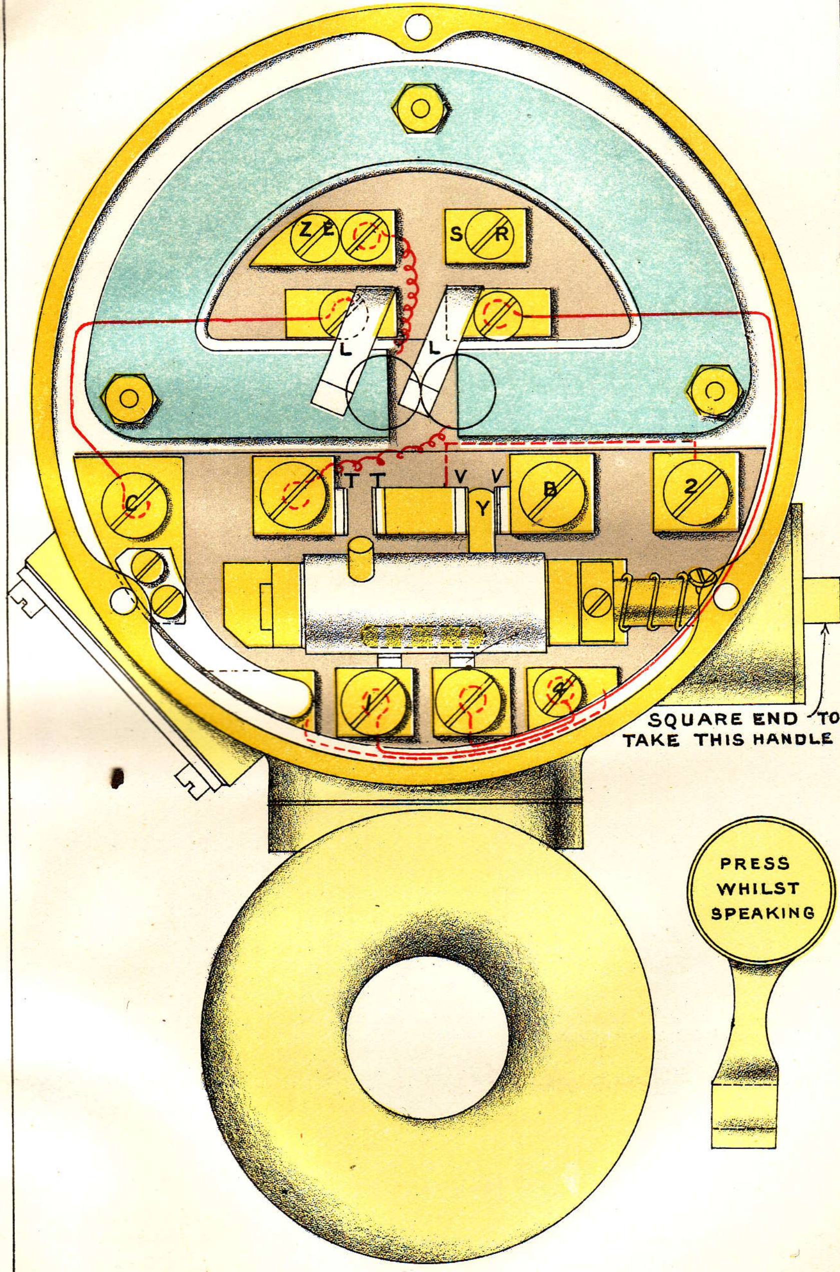
These instruments are joined up in pairs in the same way as the older pattern telephones, as shown in the diagram on Plate LI.

Patt. 1856 *Navyphone.*—This was introduced at the same time as the Patt. 1855 for use in engine rooms and other places where there is much noise. It is shown on Plate LV. It is exactly the same in principle as the Patt. 1855, but differs in the arrangement of the internal parts. Two rubber-rimmed ear pieces are fitted on the ends of tubes, which can be pressed

GRAHAM'S NAVYPHONE. PATT. 1855

WITH COVER AND TRANSMITTER REMOVED.

⅔ FULL SIZE



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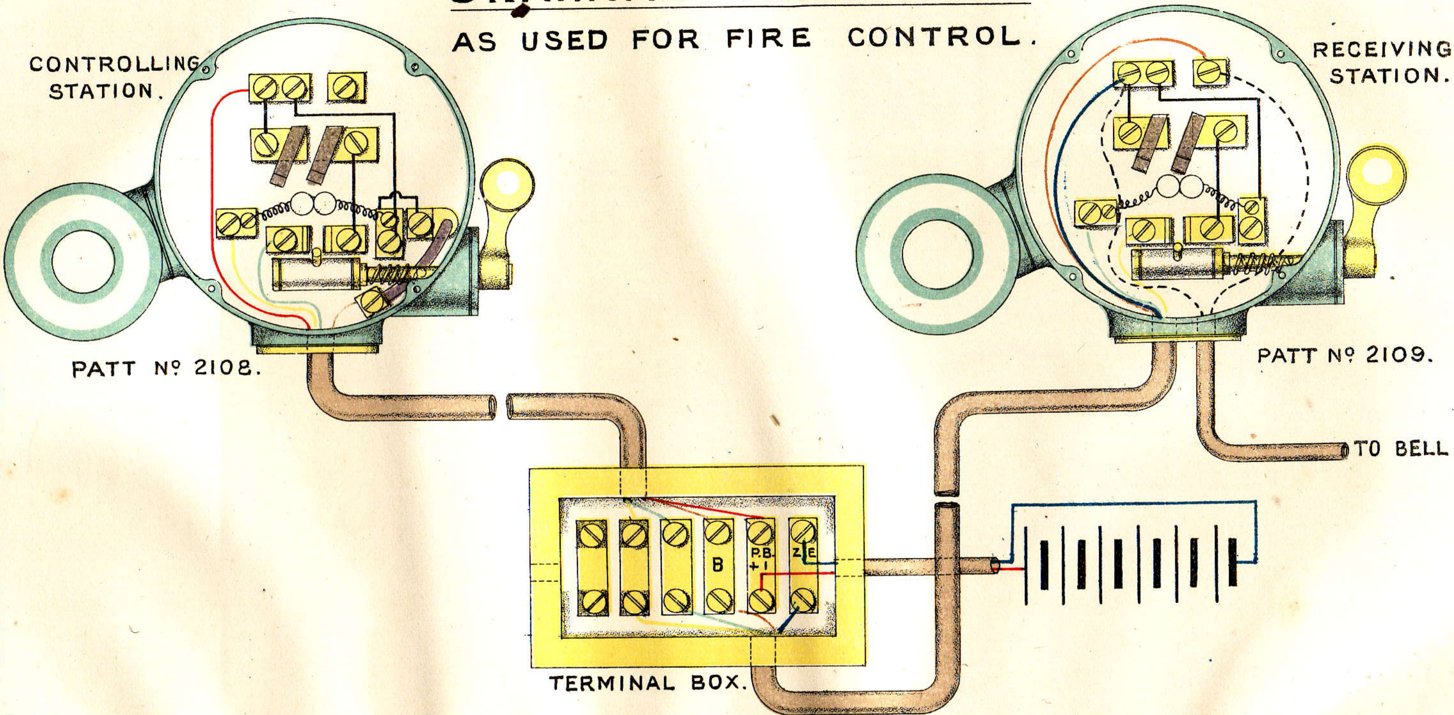
GRAHAM'S NAVYPHONE.

AS USED FOR FIRE CONTROL.



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to the ears to exclude noise. The tube at the left hand side is flexible, but that at the right is stiff, and when lifted to a horizontal position to place it to the ear, works the switch which puts the transmitter and receiver to line and cuts out the bell.

Navyphones for Fire Control.

When the system of controlling all the guns in a ship from a central station was introduced, it was found necessary to modify the existing navyphone for use in this connection. In order to avoid all risk of cross-talking, the instruments are all joined up in pairs, entirely separate from each other, one instrument in each pair being in the control position, and the other at the gun. Also the following conditions were laid down as having to be satisfied :—

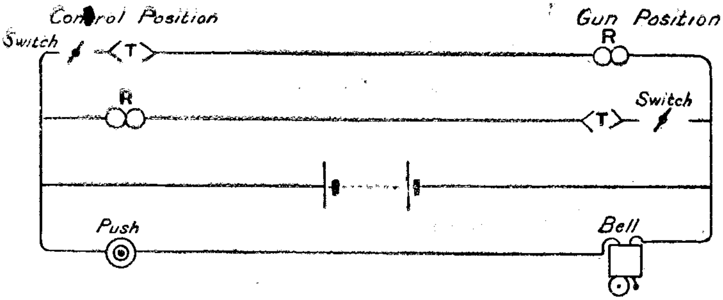
To avoid confusion, there must be no call-up bells in the central control station, but there must be a call-up bell at each gun position.

Each station must be able to call up the other by voice. The receivers, therefore, must be always connected to the incoming line, with no switch in the circuit.

To avoid running the battery down, there must be a switch in the circuit of the transmitter, which only completes this circuit when the instrument is being spoken into.

It will be seen that, to fulfil these conditions, a fourth wire is required; since the two lines are to be always joined to the receivers, an extra wire will be wanted for the bell. Fig. 183 shows a diagram of the circuit of a pair of navyphones joined up for fire control.

FIG. 183.



Patts. 2108 *and* 2109 *Navyphones.*—These patterns were introduced for use as fire control telephones only. Patt. 2108 is the telephone for the control station, and is fitted with a push but not with a bell. Patt. 2109 is the telephone for the gun position, and it is fitted with a bell but not with a push. In both telephones the change-over switch is abolished and replaced by a simple break switch in the circuit of the transmitter.

Plate LIV. shows a Patt. 2108 joined up to a Patt. 2109 for fire control purposes.

Patt. 2140 *Navyphone.*—This pattern was introduced as a universal navyphone which could be used for all purposes, either for ordinary working or for fire control. It is substantially the same as the Patt. 1855, except that it has the push on the right hand side instead of the left, and the transmitter and receiver are more efficient, being of later manufacture. Also, instead of having a flat contact on the lower side of the ebonite cylinder for closing the circuit of the transmitter, it has a brass spill similar to those on the upper side. It is shown on Plate LV. joined up to a Patt. 1856 navyphone.

In order to use it for fire control, the internal connection must be altered so as to be like those of the Patts. 2108 and 2109, and it is then joined up in the same way as those patterns.

Batteries for Navyphones.—A pair of navyphones is worked off a battery of six Patt. 1453 cells placed in a Patt. 1704 battery box.

Working Navyphones off a Motor Generator.

Owing to the great number of telephones in later ships, and the large amount of space and weight occupied by their batteries, the question was mooted of replacing all the separate batteries by a single central motor-generator. Several difficulties, however, manifested themselves when this was first tried. In the first place, when a pair of telephones is fed from a generator instead of from a battery, the variations in the current produced by commutation cause such a buzzing noise in the receivers as almost entirely to drown the noise of speech. Various devices were tried for stopping this noise of commutation, consisting mostly of some sort of inductance placed in the circuit, but it was found that either they had no effect, or else, when they stopped the noise of commutation, they also stopped all speech.

Another difficulty that was experienced was that, when several pairs of telephones were fed from one source, any conversation in one pair was heard in all the other pairs as well. This phenomenon is known as "cross talking," and it was the fact that this difficulty was experienced, when more than one pair of telephones was fed off one battery, that led to navyphones being joined up in separate pairs, each with its own battery.

These difficulties have been surmounted in the latest patterns of Graham's navyphones as follows :—

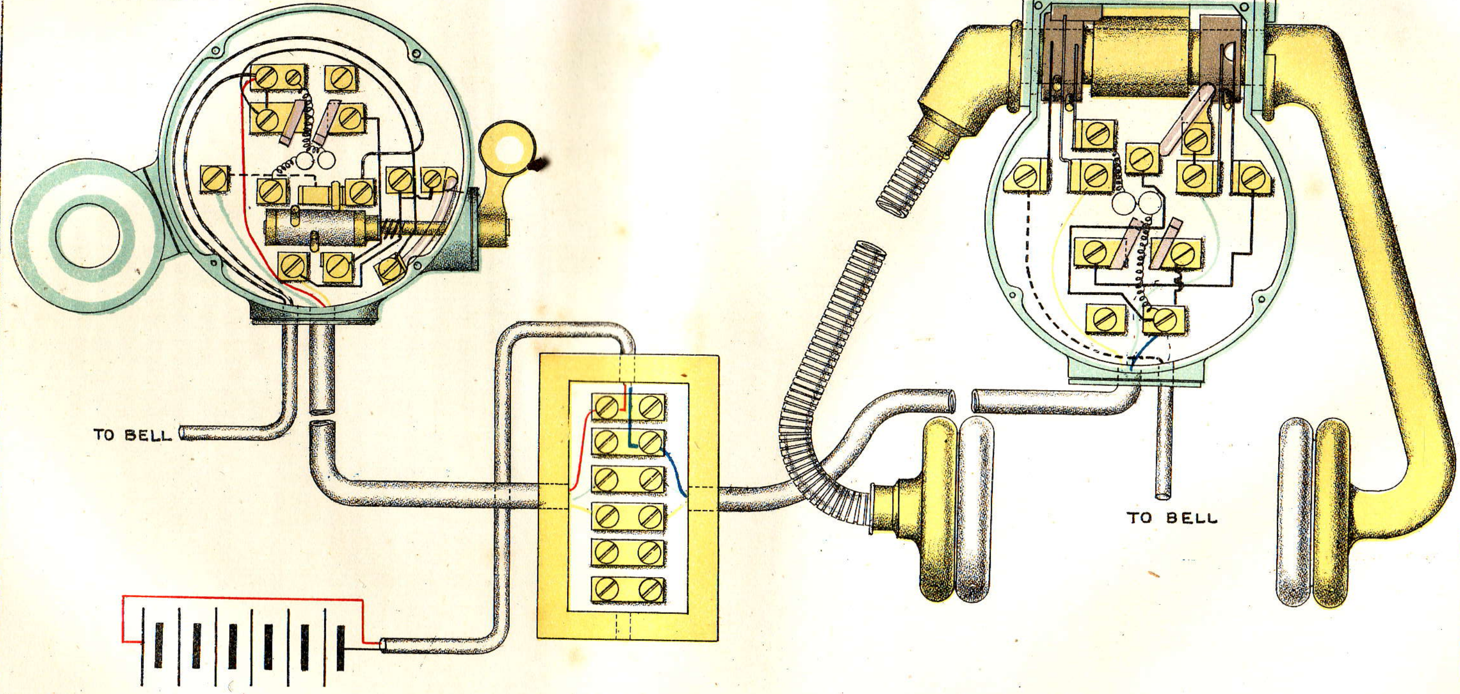
The noise of commutation has been reduced to a minimum by special construction of the generator, which, while only developing 20 volts, has 150 strips in the commutator, so that the fluctuation of voltage is very small indeed. The generator runs in ball bearings, which should never be oiled, as they are intended to run dry. It is shunt wound, and should be run at such a speed that it gives 20 volts. If it gives more the telephones will be heated, and if less, speech will not be clear.

To face page 336.

GRAHAMS NAVYPHONE.

PATT No. 2140.

ENGINE ROOM TYPE



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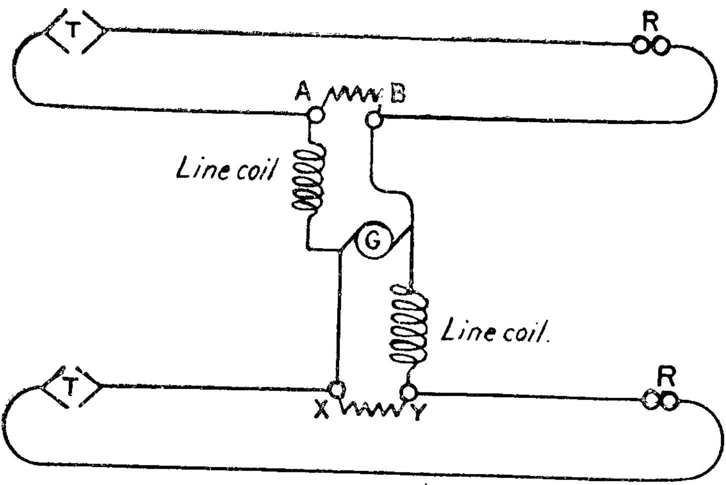
The difficulty of cross-talking is surmounted by putting a coil of large inductance in series with each circuit that is fed from the generator. The effect of this inductance is to damp down any variations in the current through it, so that these variations, which are intended to reproduce speech in the receiver, are not transmitted through the generator to the other circuits.

FIG. 184.



This inductance is known as the "line coil," and Fig. 184 shows two telephone circuits fed from the generator G, each with its own line coil. It will be seen that, since the line coil tends to prevent any variations in the current through it, it will stop not only cross-talking, but all speech, unless some other device is introduced. This other arrangement takes the shape of a non-inductive resistance joined between the points A and B and the points X and Y. The speech-producing variations of current can now take place in the circuit ABRT, while the current coming from the generator through the line coil remains practically constant.

This may be explained as follows :—The resistance of the shunt is practically equal to the resistance of the line, and consequently, under ordinary conditions, the same current is flowing in each. Let us suppose, for an example, that this current is 1 ampere. Now when the transmitter is spoken into, its resistance alters, and variations in the current are produced. Let us suppose that the resistance drops to such a value that $1\frac{1}{2}$ amperes flows instead of the 1 ampere that was flowing before. Now the effect of the inductance of the line coil is to resist any change in the strength of the current flowing through it, but this increase in the current through the telephone circuit can still take place if the current through the non-inductive shunt at the same time drops to $\frac{1}{2}$ an ampere. What is spoken into the transmitter will then be reproduced in the receiver, while the current supplied from the generator through the line coil will still be constant.

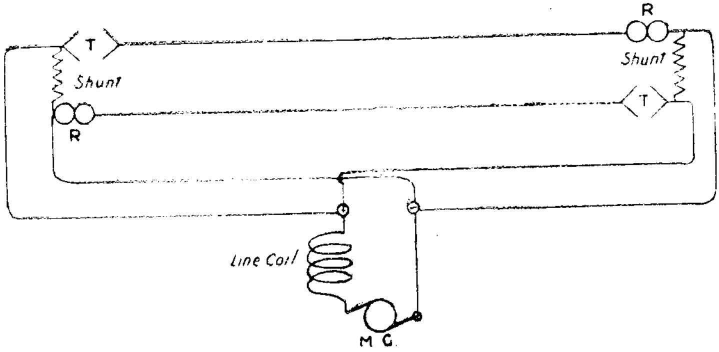
This explanation is not absolutely scientifically accurate, but it will help the student to understand the action of the line coil and non-inductive shunt.

The line coil, through primarily introduced for the purpose of preventing cross-talking, also has the effect of minimising the noise of commutation in the receiver. The resistance of the line coil is about 3·5 ohms.

Both these devices are embodied in the latest patterns of Graham's navyphones, which will now be described.

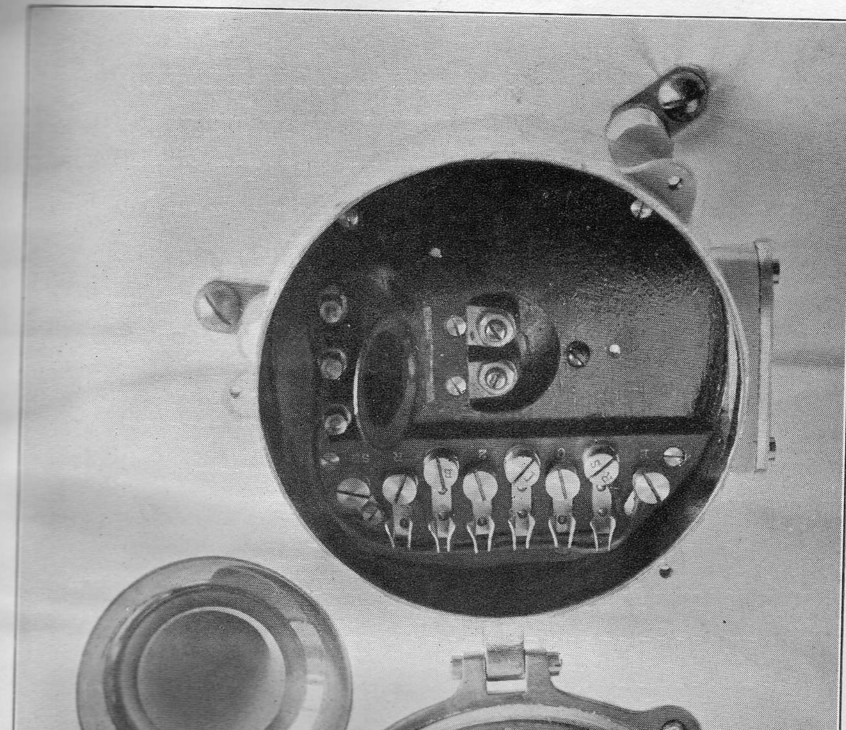
The actual arrangement of the circuit of two of these navyphones joined up together is as shown in Fig. 185.

Fig. 185.



A positive and a negative feeder is taken up to each telephone, and the non-inductive shunt is connected between them in the telephone, being switched on at the same time as the transmitter. One line coil is used for each pair of telephones.

Patt. 2140A *Navyphone.* — This navyphone, shown in Plate LVI., is for ordinary use only, not for fire control. Several improvements are embodied in it, besides the fittings necessary to enable it to be worked off a generator. The trumpet of the receiver is movable, and can be fixed at any angle that is convenient. The receiver is placed at the back of the case, and in front of it is a brass plate which has a shutter in the middle that can be opened to give access to the pole pieces of the receiver. These pole pieces are adjustable as to their distance from the diaphragm, and are fitted with lock nuts. All the rest of the gear is carried on the cover, which is hinged. When the cover is on, it is secured by three screws equally spaced round the circumference, and when these screws are taken out it can be swung open on its hinge. The screws are fitted with a collar so that they can not be entirely removed when unscrewed, but remain in their holes on the cover. The wires are brought in through a gland at the bottom of the case, and are secured to



Navyphone, Patt. No. 2140 A., with Cover Open.

To face page 338.

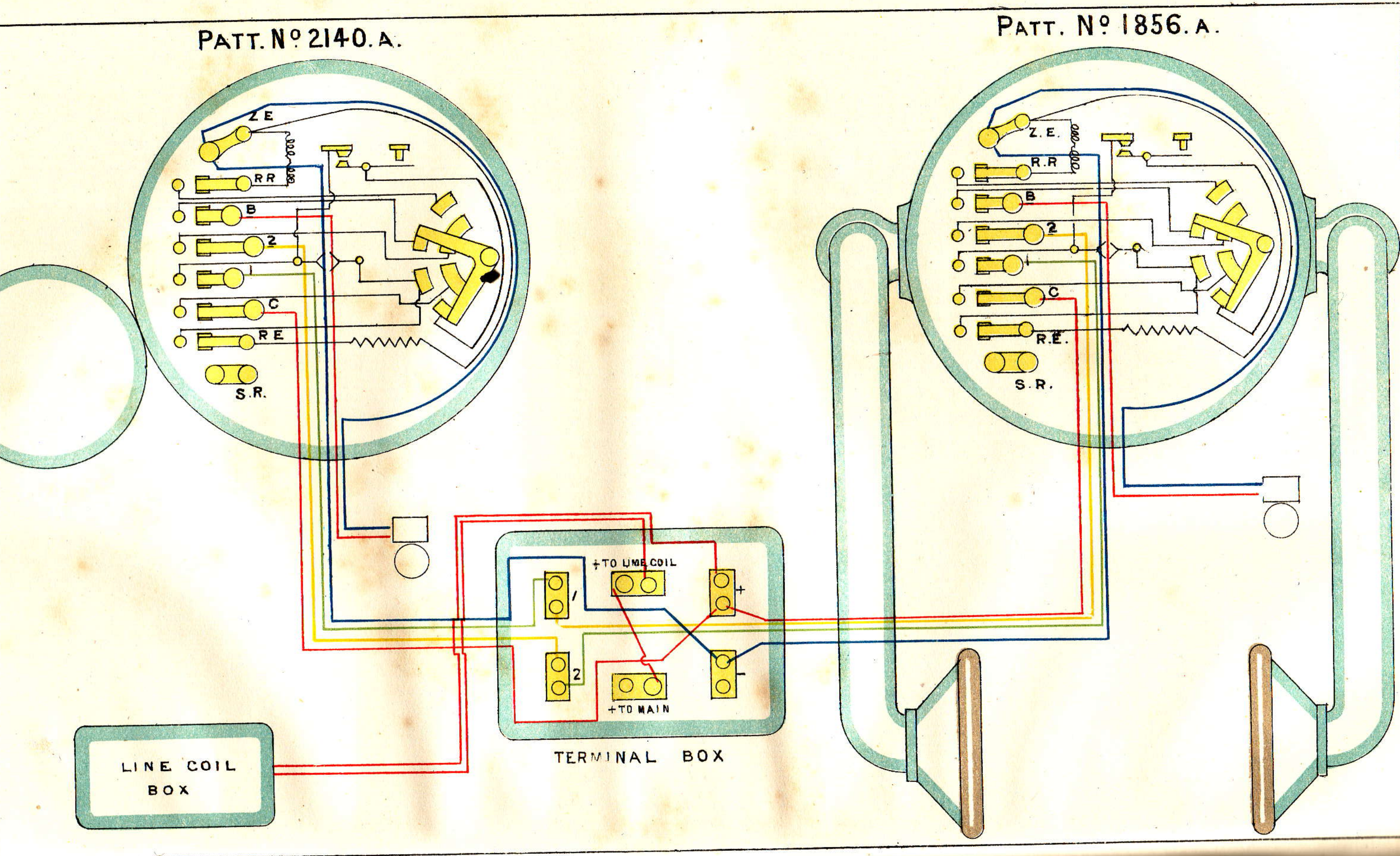

PATT. No. 2140. A.
Z E
R R
B
2
1
C
R E
S.R.
PATT. No. 1856. A.
Z. E.
R.R
B
2
C
R.E.
S.R.
+ TO LINE COIL
1
+
2
−
+ TO MAIN
TERMINAL BOX
LINE COIL
BOX

Plate LVII

insulated terminals fixed to the brass plate which covers the receiver. The connections to the gear on the cover are made by means of brass spills carried on the cover, which make contact with the terminals inside when the cover is secured in place. The lever that works the speaking switch, which is marked "Press whilst speaking," also revolves the transmitter by gearing when it is moved and so shakes up the carbon granules, as in the early forms of telephones. The non-inductive resistance shown in Fig. 185 is placed behind the brass plate that covers the receiver, round the outside of the case.

The transmitter is of a new pattern, being smaller than the older ones, and of higher resistance, about 45 ohms. The carbon granules, instead of being angular, as in the older telephones, are all rounded like pebbles, and the rear carbon plate is plain instead of being corrugated.

The front of the transmitter, as in the earlier patterns, is covered with a metal grating, but an opening is left at the bottom of the cover that carries this grating, in order to allow any water or dirt that gets through the grating to escape. There is also a small hole in the back of the case to allow any water that gets into the trumpet to escape. The receiver diaphragm is watertight, so that water that gets into the trumpet cannot get into the interior of the instrument.

The gear required for a pair of these telephones is as follows :—Two telephones, one line coil, and one terminal box.

The line coil is supplied in a brass box, and it has a watertight gland at the side for the wires.

The terminal box is that shown in Plate LVII. It contains six terminals, one in each corner and two in the middle, between which is a fusible cut-out, and has a watertight gland in each side. The two terminals in the left hand corners are marked 1 and 2 respectively, and those in the right hand corners are marked + and —.

The wires are joined up as in Plate LVII. Since the non-inductive shunt has to be joined between the positive and negative leads from the generator, it is necessary that both a positive and a negative lead should be taken into each instrument, and these, with the two line wires, make four wires for each pair of telephones, as against three for the older types of navyphones. The terminals are marked as shown, the non-inductive shunt being joined between the terminals marked Z E and E. The in-going line of one instrument is, of course, joined to the out-going line of the other, and *vice versâ*.

Patt. 1856A *Navyphone.*—This pattern is supplied for use in the engine room. It is exactly the same as the Patt. 2140A, except that it has rubber ear pieces on the end of hinged tubes instead of the ordinary trumpet. The speaking switch, instead of being actuated by a lever on the front of the instrument, is put over when the right hand tube is raised to a horizontal position. Plate LVII. shows a Patt. 2140A joined up to a Patt. 1856A for ordinary working.

Patts. 2108A and 2109A Navyphones for Fire Control.—Patt. 2140A cannot be used for fire control, as can Patt. 2140, without introducing an extra wire for the bell, and, as there are already four wires required for this pattern, this would be inconvenient, as all telephone cable in the Service is four-scored. Patts. 2108A and 2109A were therefore introduced. In these telephones the same line wire is used for ringing the bell that the gun station uses for talking to the control station, and the push at the control station is made into a two-way switch, like a morse key. Thus the gun station can always be called by the bell unless he is actually talking at the time and has his speaking switch pressed.

The receiver at the gun station is always to line, and that at the control station is also always to line unless the bell push is being pressed.

Plate LVIII. shows these two telephones joined up for fire control. The same line coil and terminal box is used for these as for the Patts. 2140A and 1856A. It will be seen that these patterns require fewer spills and terminals inside the telephone than do the Patts. 2140A and 1856A.

Table Navyphones.—These are fitted in some cabins in the "Dreadnought" and later ships. Each station consists of two parts, a wall fitting and a table fitting. The four-core cable from the other station is led into the wall fitting, which contains the bell, non-inductive resistance, and terminals, and is connected to the table fitting by a lead of six-core wire. The table fitting contains the receiver, bell push, and speaking switch, and the transmitter is connected to it by a length of twin-core wire. When the telephone is not in use the transmitter is placed face downwards on a rest provided for it on the table fitting. Its weight presses down this rest, and keeps the speaking switch in the position for ringing up. When it is removed for speaking, the speaking switch comes into action, and puts the transmitter and receiver to line. On the top of the table fitting, just over the receiver, is a short trumpet, which turns round on ball bearings, and can be turned to any position which is most convenient.

It is most important, when using these telephones, to hold the transmitter with its diaphragm *vertical* and close to the mouth when speaking, as otherwise they do not give good results.

The same line coil and terminal box are used with these as with the Patt. 2140A. Plate LIX. shows two of these table navyphones joined up together for working off a generator.

When any of the above telephones, which are designed for working off generators, are used in single pairs off a battery, it is only necessary to leave out the line coil, and disconnect one end of the non-inductive shunt.

Switches for use with Navyphones.

Two-way Switch.—In some ships in which a navyphone is fitted for communication between the bridge and engine room, a two-way switch is put in the circuit to connect the engine room

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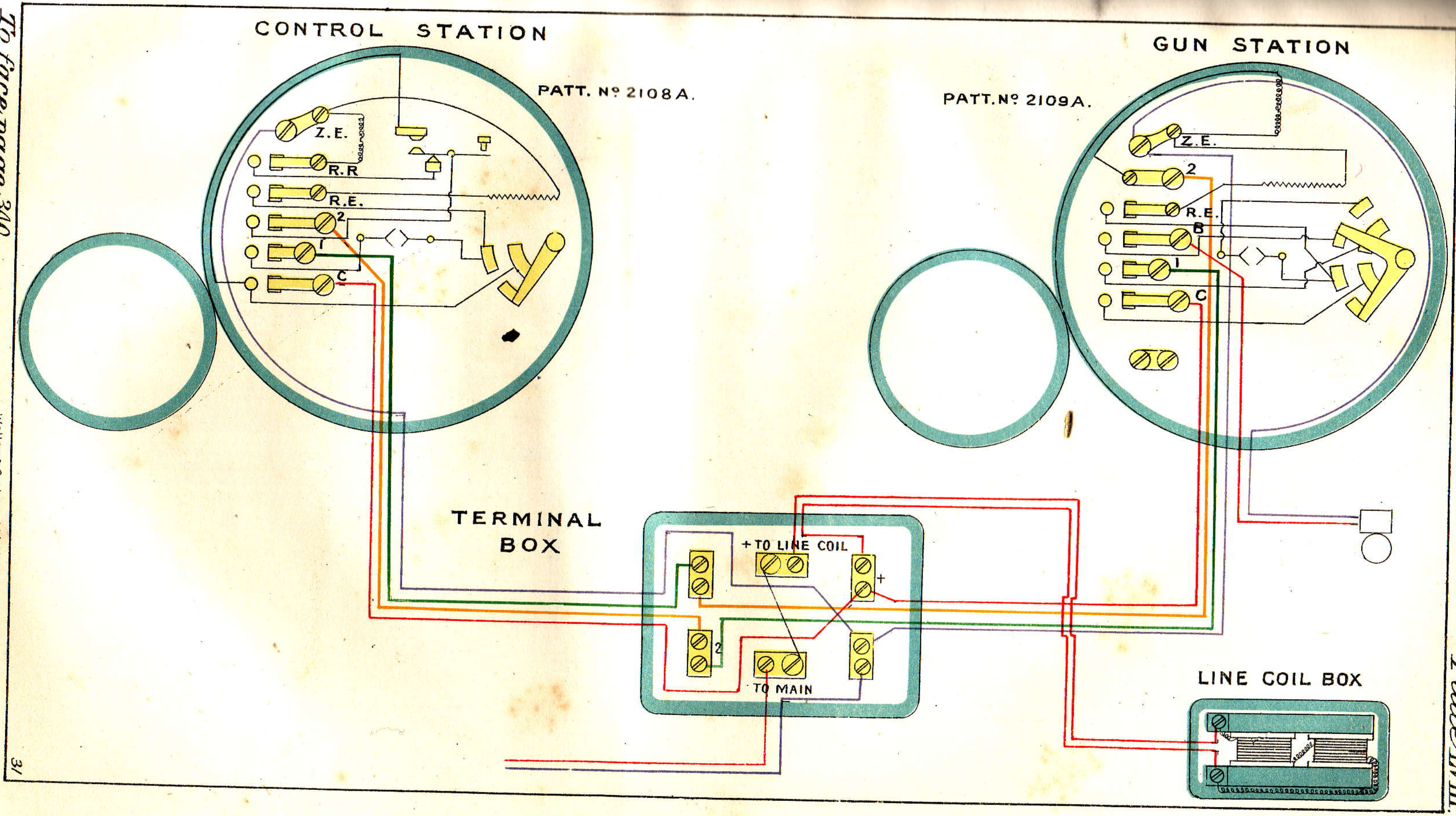

Plate LVIII.

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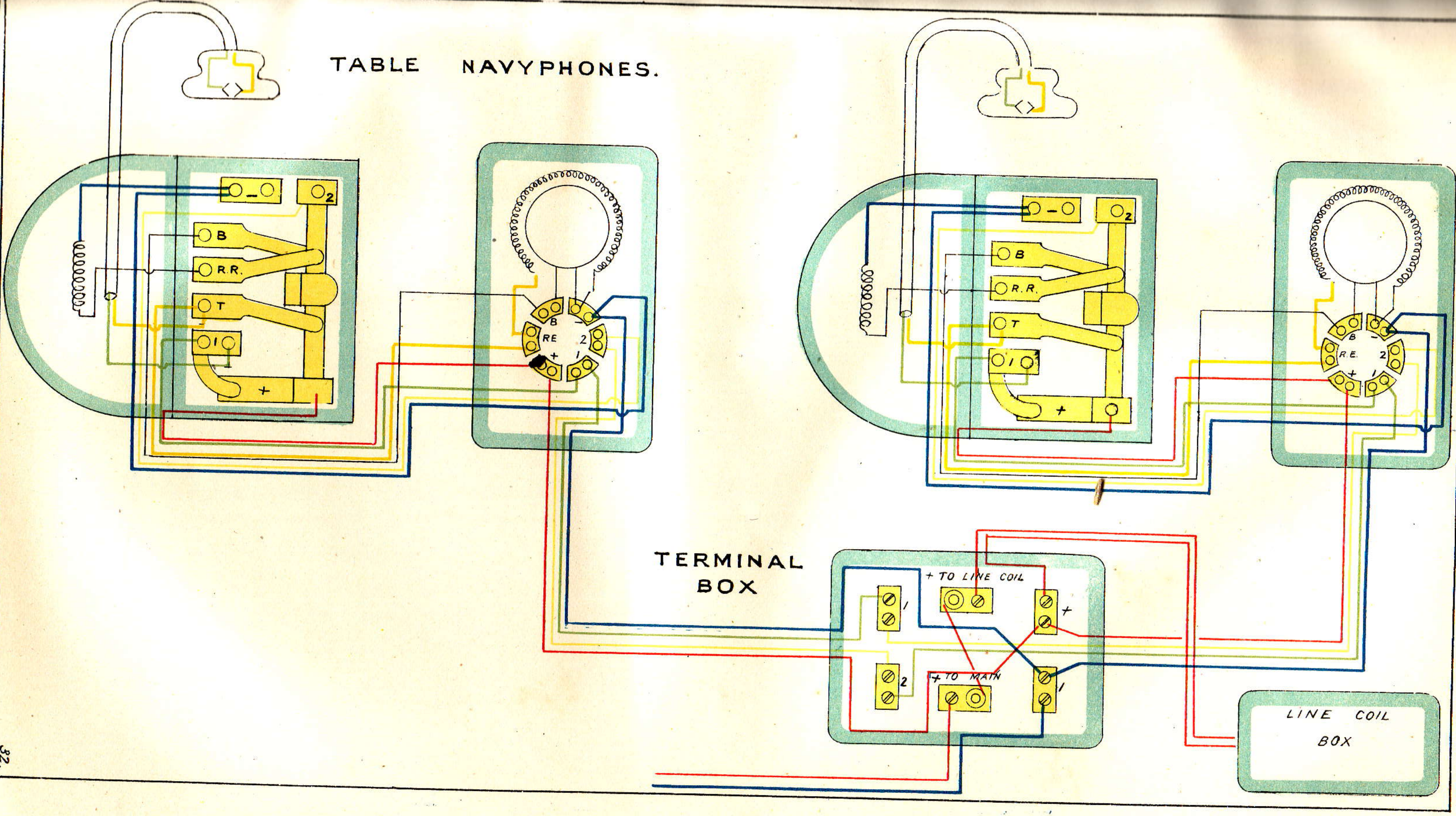
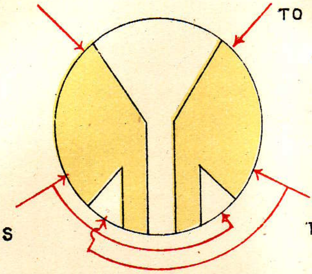


Plate LIX.

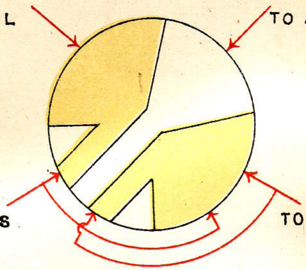
Weller & Graham Ltd Litho London

CHANGE OVER SWITCHES FOR NAVYPHONES.

FIG. 1.

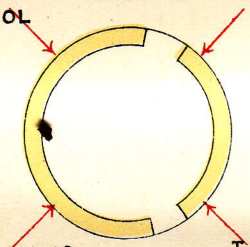


SEPARATE CONTROL

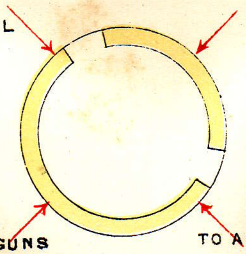


FORWARD CONTROL

FIG. 2.



SEPARATE CONTROL.



FORWARD CONTROL.

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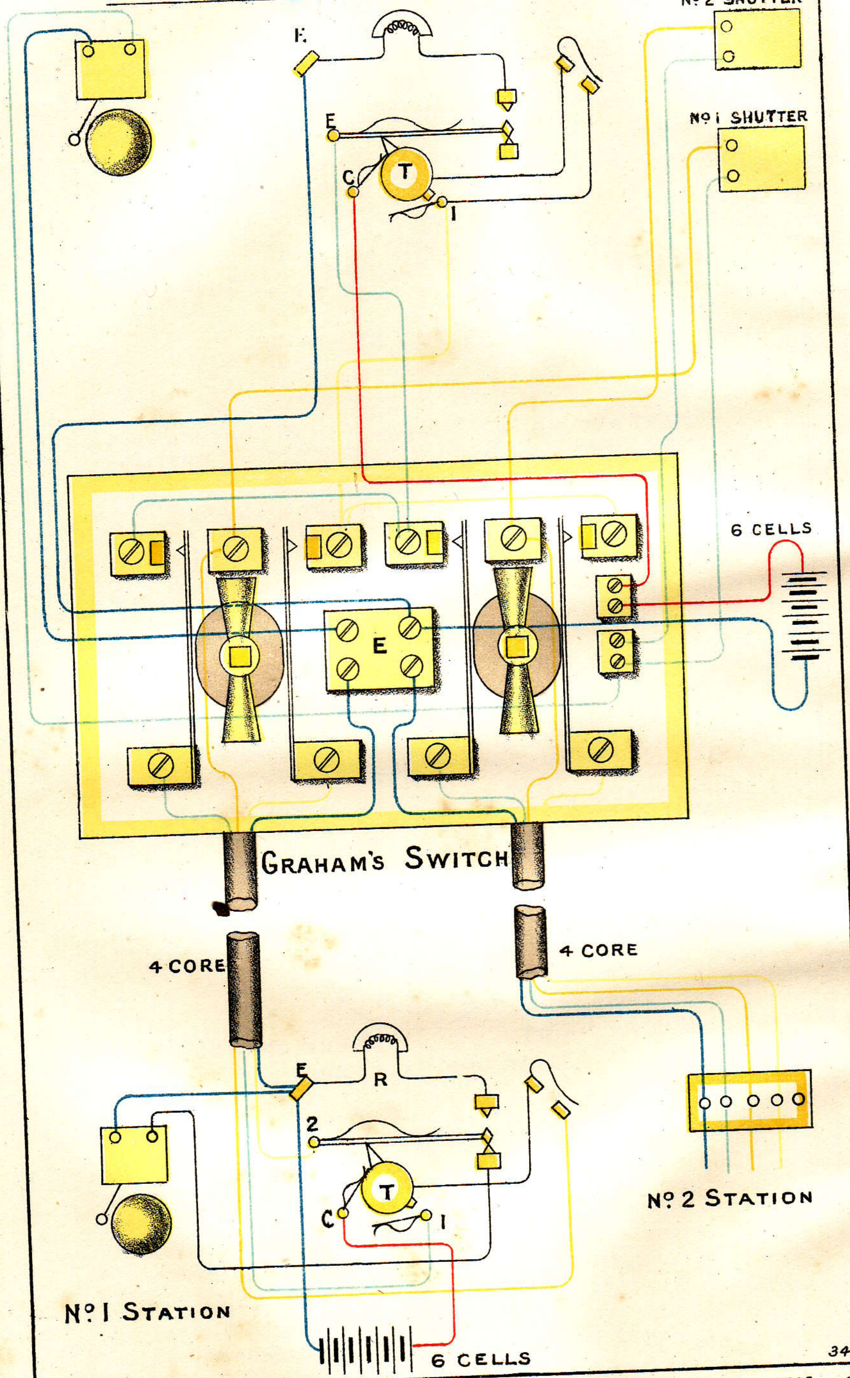
Graham Exchange Switch.



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either with the bridge or conning tower, according to which position is being used. It is an ordinary four-wire, two-way switch, and does not require any special description.

Change-over Switch for Fire Control Navyphones.—Most ships are fitted with two control positions, one forward and one aft, and this switch is required for the following purposes:—

(1) To put the forward guns in communication with the fore control position, and the after guns in communication with the after control position.

(2) To put all guns in communication with the fore control position, and insulate the after control position.

(3) To put all guns in communication with the after control position, and insulate the fore control position.

There are two patterns of switch for this purpose, and they are shown on Plate LX. The earlier pattern (Fig. 1) is only used in very few ships, most ships being fitted with the pattern shown in Fig. 2.

In the plate the contact piece for one wire only is shown, but of course there is one of these contacts for each wire, making four for each station. They are all fixed on one spindle, so as to form a [illegible] drum, and insulated from one another, and are all moved at once by a handle fixed on the spindle.

Exchange Switch.—This switch is used in some of the older ships which have still the Patts. 1639 and 1643 telephones. It is designed to enable a central station to communicate with any one or more of several outlying stations. Plate LXI. shows a central station joined up to an exchange switch for two outlying stations, but more than two can be joined up, if necessary, in the same way as these shown.

A double action switch for each outlying station is fitted so as, when switched to "on," to connect lines 1 and 2 of the exchange telephone to lines 2 to 1 of the particular outlying station with which communication is desired.

This switch when "off" breaks these connections. If both switches are "on," it will be seen that both the outlying telephones are joined up in fork with the exchange telephone.

If the exchange wishes to call up one or both of the outlying stations, one or both of the switches are put to "on," and the bell push of the exchange telephone used in the ordinary manner.

The ringing current from the outlying station passes from the outlying battery through the bell push to one of the other cores of the four-core cable, and so to its own shutter in the exchange, and the other wire from each shutter is connected to the "shutter return" block in the exchange switch, between which and the common return E the exchange bell is joined up.

Navyphone Exchange.

There are two forms of navyphone exchange in the Service—that fitted in the "Dreadnought," and that fitted in the "Lord Nelson," "Invincible," and "Bellerophon" classes of ships.

The "Dreadnought's" exchange, as it was fitted before navyphones that could be worked off generators were designed, was so arranged that the call-up bells were rung and the exchange lamps burnt by current derived from a generator, while a battery was used for the speaking circuits.

This necessitated two separate sources of electricity, and made the exchange very complicated. It is not proposed to describe this exchange here, as it is only fitted in one ship, but a full description and diagram of it will be found, if required, in the Annual Report of Torpedo School, 1906.

In the latter form navyphone exchange, the current for all operations—ringing, speaking, and lamps, is supplied from a motor generator of the form already described.

All the telephones in the ship, with the exception of those for fire control and a few other special pairs of instruments, are joined up to the exchange, so that any one station can communicate with any other.

The exchange with two stations joined up is shown in Plate LXII.

Beside the exchange there are one or more of the following, according to the number of outlying stations:—

21-way fuze box. This is fed from the positive of the generator, and from it are fed, through the fuzes, the line coils for the separate outlying stations, which are placed in a 21-way line coil box.

Testing terminal box. This contains three long blocks, marked +, —, and B, respectively, each having a number of terminals on it, which are joined to similarly marked terminals in the top of the exchange. The + and — blocks are fed from the generator, and the exchange bell is joined between the + and B blocks, and has a switch in its circuit.

The feeders to the testing terminal blocks pass through a two-way fuze box.

From each outlying station there are four wires to the exchange—positive and negative feeders and two line wires.

For each outlying station, there are in the exchange—

(1) Three terminals, marked +, 1, and 2.

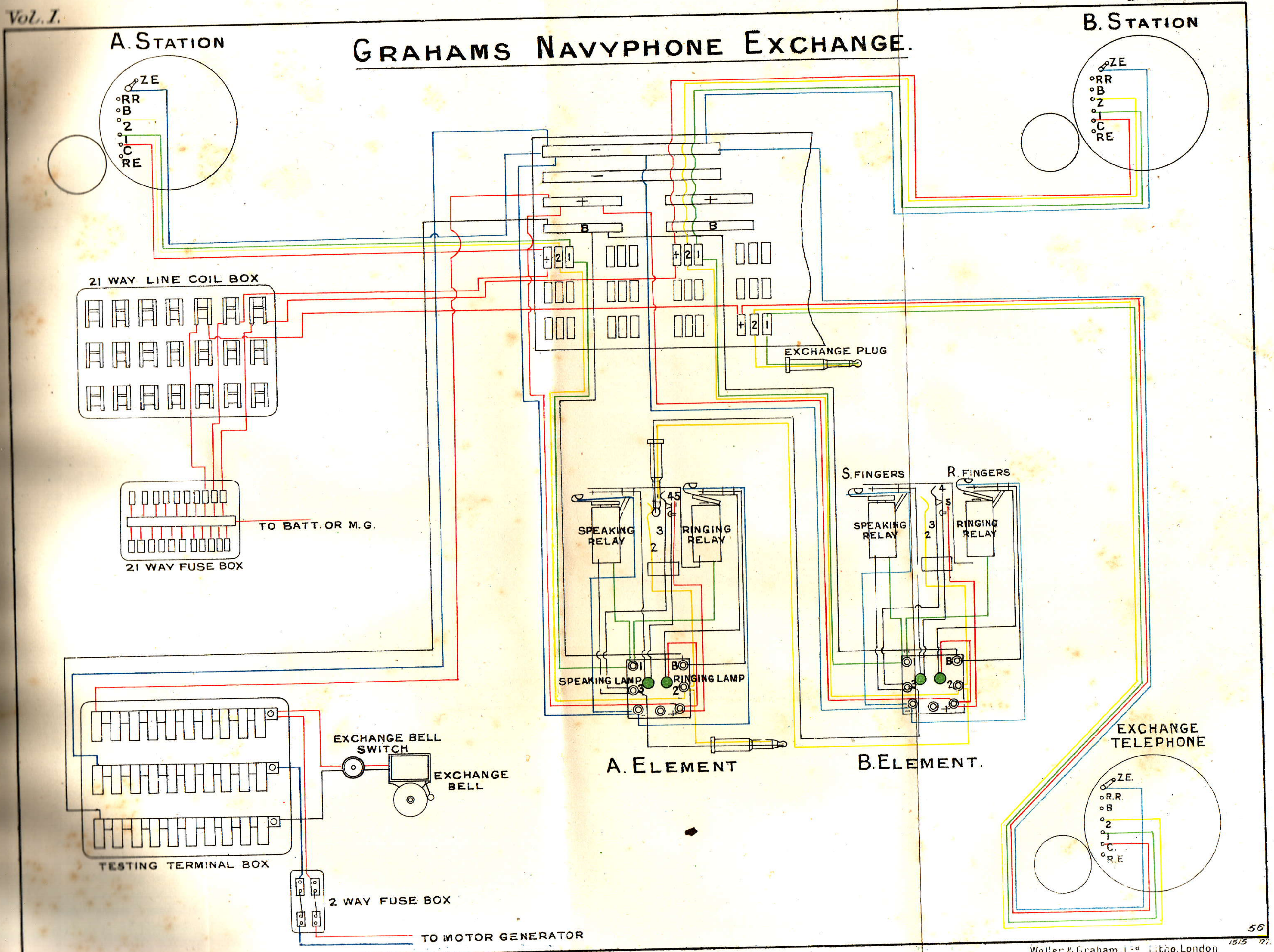
(2) An "element."

(3) A plug on the end of a wandering lead of twin wire.

There are also, in the upper part of the exchange, several terminal blocks each common to six stations. They are for (*a*) positive feeders for elements, (*b*) negative feeders, both for elements and telephones, (*c*) leads for ringing the exchange bell. The blocks for the negative feeders are twice the size of the other blocks, as they have to feed both elements and telephones, and so require twice the number of terminals.

Referring to (1).

The block marked + is fed from the generator through its own line coil, of which there is one for each station, and the positive feeder to the outlying telephone is joined to it.


GRAHAMS NAVYPHONE EXCHANGE.
A. STATION
ZE
RR
B
2
1
C
RE
B. STATION
ZE
RR
B
2
1
C
RE
21 WAY LINE COIL BOX
21 WAY FUSE BOX
TO BATT. OR M.G.
EXCHANGE PLUG
S. FINGERS
R. FINGERS
SPEAKING RELAY
RINGING RELAY
SPEAKING LAMP
RINGING LAMP
A. ELEMENT
B. ELEMENT.
EXCHANGE TELEPHONE
Z.E.
R.R.
B
2
1
C.
R.E
EXCHANGE BELL SWITCH
EXCHANGE BELL
TESTING TERMINAL BOX
2 WAY FUSE BOX
TO MOTOR GENERATOR
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The blocks marked 1 and 2 are joined to similarly marked blocks in the element, and also to lines 1 and 2 from the outlying station.

The negative feeder from the outlying station is joined to one of the negative blocks which are common to six stations, and these are all joined to the negative block in the testing terminal box.

Referring to (2).

Each element consists of—

(*a*) Six terminals marked respectively 1, 2, 3, +, −, B.

(*b*) Two relays, a "speaking relay" and a "ringing relay."

(*c*) Two glow lamps, a "speaking lamp" and a "ringing lamp."

(*d*) Four spring contact fingers which are moved when a plug is put into the element. The hole into which the plugs are put is between + and − terminals, and the spring contact fingers are behind it.

(*a*) The terminals 1, 2, +, −, and B are joined to the similarly marked terminals in the upper part of the exchange mentioned above, B being for the exchange bell.

(*b*) Each relay works three spring finger contacts. In the case of the "speaking relay" in the normal position of these three fingers, hereafter referred to as the S fingers, they are all making contact with one another, but when the relay is excited they are separated. In the case of the "ringing relay" in the normal position of the fingers, hereafter referred to as the R fingers, they are separate from one another, but when the relay is excited they all make contact with one another.

(*c*) The glow lamps show through two holes just above the hole into which the plug is put. The "ringing lamp" glows when the outlying station is ringing up the exchange. The "speaking lamp" glows when, a plug being in position in the element, the outlying station has finished speaking.

(*d*) Of the four spring contact fingers, two are used for making contact with any plug that is put into the element. One is longer than the other, the long one making contact with the body of the plug, and the short one with the point of the plug. When no plug is in they make no contact with anything. The long finger is joined to No. 3 terminal, and the short one to No. 2, and will be referred to by these numbers.

The other two spring fingers are normally separate from one another, but when Nos. 2 and 3 fingers are forced apart by a plug being put into the element, an ebonite cam on No. 3 finger presses them together, and they make contact with one another. They are included in the circuit of the + feeder to the "speaking lamp," and will be referred to as Nos. 4 and 5 fingers.

Referring to (3).

The plug is in two parts, which are insulated from one another, the "point" and the "body." The point is connected, through one core of the wandering lead, to No. 3 terminal in the element, and the body, through the other core to No. 2 terminal.

The connections in the element are as follows:—

The "speaking relay" is connected between Nos. 1 and 3 terminals.

The "ringing relay" is connected between No. 1 terminal and one of the S fingers.

The "speaking lamp" is joined up between No. 4 finger and one of the S fingers.

The "ringing lamp" is joined up between the + terminal and one of the R fingers.

No. 5 finger is joined to the + terminal.

The S fingers are joined to the "speaking lamp," the "ringing relay," and the — terminal, respectively.

The R fingers are joined to the "ringing lamp," the B terminal, and the — terminal, respectively.

The exchange has a telephone, whose lines 1 and 2 are connected to a plug, line 1 to the point, and line 2 to the body.

The action of the exchange is as follows:—The stand by position is, of course, with all the plugs out. It will be noticed that, as the "speaking relay" is joined up between Nos. 1 and 3 terminals, it cannot be excited unless either a plug is in its element, or its own plug is in some other element, as otherwise No. 3 terminal is insulated.

Suppose A outlying station to ring up the exchange. When the ringing push is pressed at A, the positive feeder is connected to No. 1 line wire, which is connected to No. 1 terminal in A's element.

From No. 1 terminal there is no circuit through the "speaking relay," but there is a circuit through the "ringing relay," through the S fingers, to the — terminal. So the "ringing relay" will be excited when A rings up. This presses the R fingers all together, and so joins the — terminal to the "ringing lamp" and the B terminal. The effect of this will be to light up A's "ringing lamp" and ring the exchange bell.

The operator then puts the exchange plug into A's element, and so connects the lines 1 and 2 of the exchange telephone to A's lines 2 and 1. He can then ring up A and talk to him in the usual way.

If A asks to be connected to B, the operator can either put A's plug into B's element, or he can put B's plug into A's element. Let us suppose he does the former. This will connect A's Nos. 2 and 3 terminals to B's No. 3 and 2, and will make contact between Nos. 4 and 5 fingers in B's element.

If A now presses his ringing push, there is a circuit from his No. 1 line, through his "speaking relay" to his No. 3, through the point of his plug to B's No. 2, and so through B's bell to the negative.

This rings B's bell and excites A's "speaking relay," thus breaking the contact between A's S fingers. Since this contact is broken, A's "ringing relay" is not excited, and the exchange bell is not rung.

Similarly B can ring A's bell without ringing the exchange bell.

While conversation is going on between A and B, both "speaking relays" are excited, as each is in series with one of the line wires.

As soon as they have finished, the speaking relays are demagnetised, and the S fingers all make contact again. The effect of this is that the "speaking lamp" in B's element lights up, since its circuit is already completed as far as the S fingers by Nos. 4 and 5 fingers making contact together.

This shows the operator that conversation is finished, and he can then remove A's plug from B's element.

Should the telephone motor generator break down, the line coil box can be fed from a battery, while the testing terminal box, which supplies current for the exchange bell and lamps only, can be fed from one of the ordinary motor generators that supply the bells and fire control instruments.

In this case, however, provision will have to be made for joining the negative pole of the battery to the exchange terminal board.

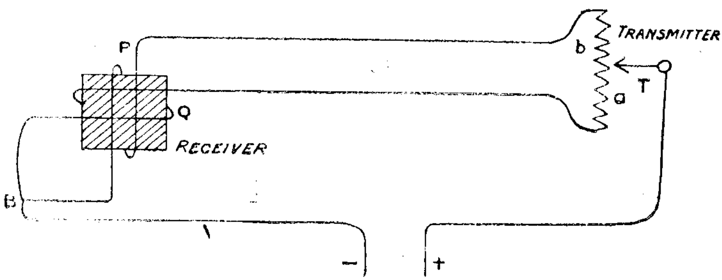
CHAPTER XX.

Dial Instruments.

It is proposed to describe in this chapter such dial instruments as are in use in the Service for purposes other than fire control.

Evershed's Electric Helm Indicator. Old Pattern.—This instrument is of the type known as "ratio coil" instruments The principle of it is as follows :—

Fig. 186.

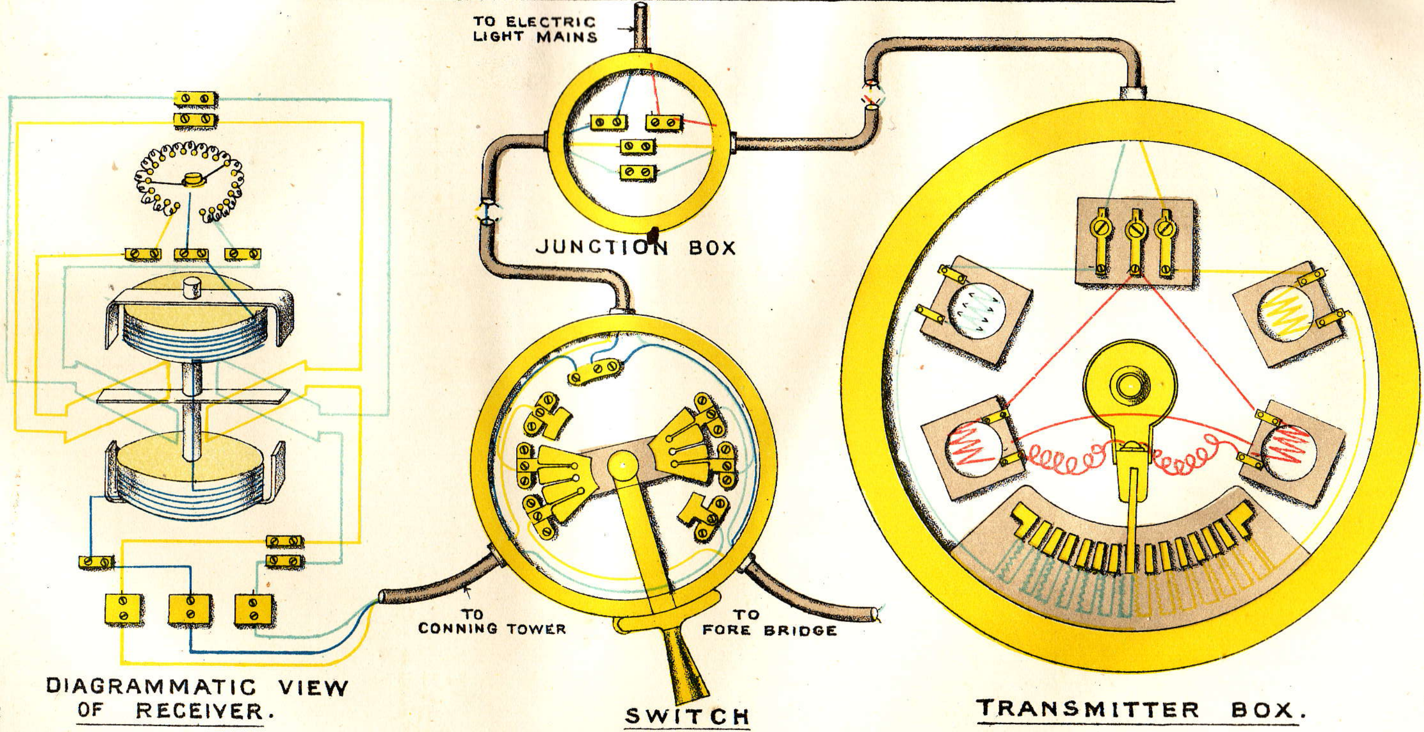


The transmitter has a contact piece, represented by the arrow head in Fig. 186, which can sweep over a number of contacts which have resistance coils between them, thereby cutting out resistance from one side of a divided circuit and adding it to the other. From each end of the resistance in the transmitter is led a wire which is joined to a coil in the receiver. These coils, P and Q, are placed at right angles to one another, as shown in the figure, and the wires from their other ends are joined together. One lead from the source of electricity is connected to the contact piece of the transmitter, and the other to the junction of the coils in the receiver.

When the circuit is completed, if the contact piece in the transmitter is central, the resistances in the two circuit T a Q B and T b P B are equal. The current will consequently be the same in each, and the strengths of the magnetic fields produced by the two coils P and Q will be equal. The direction of the resultant field in the receiver will therefore be half-way between the directions of the fields of the two coils.

Now, suppose the contact piece in the transmitter to be moved over half-way to the right, so that there is three times as much resistance in the circuit T a Q B as in the circuit T b P B. The current of the coil Q, and consequently the magnetic field produced by Q, will now be much stronger than the current and magnetic field of P. The resultant field will then be much nearer the direction of the field due to Q than to the direction of the

Evershed's Electric Helm Indicator.



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Evershed's Helm Indicator

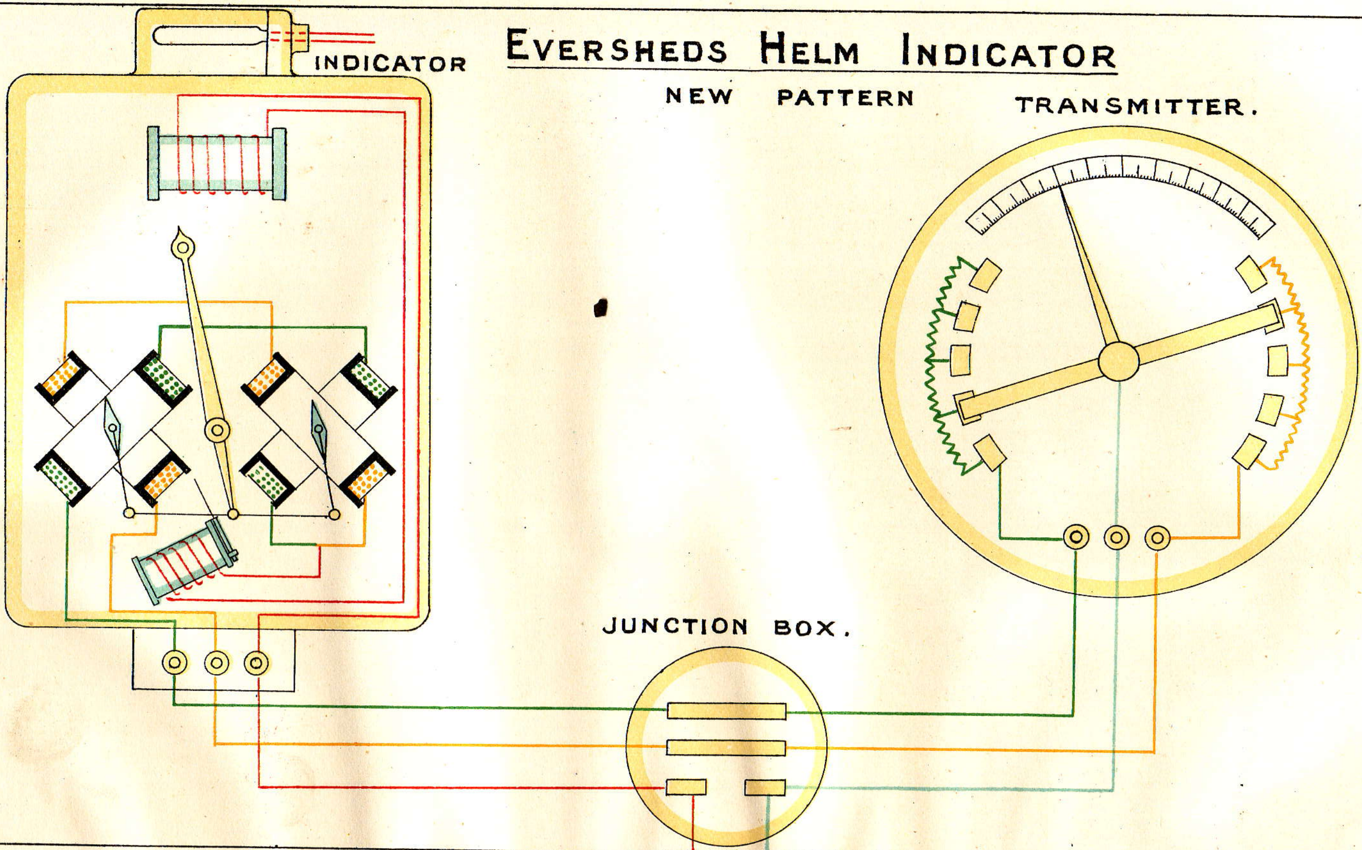

Plate LXIV.

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field due to P. So we see that, as the contact piece in the transmitter is moved over its contacts, the resultant magnetic field in the receiver alters its direction, moving round through a certain angle.

If, now, a magnet is pivoted in the centre of the two coils P and Q, it will always take up the position of the resultant field, and will so reproduce the motions of the transmitter.

In the old pattern helm indicator, shown in Plate LXIII., one of the feeder wires is taken into the transmitter and connected, through two resistances in parallel, to the contact arm. The resistance contacts are arranged on the arc of a circle, and the contact arm turns on a pivot in the middle which is worked off the rudder head by some sort of gearing.

The two line wires from the ends of the resistance are taken each through an extra resistance coil, to the ratio coils in the receiver. There are two pairs of ratio coils, one of which acts on each end of the swinging magnet, and the corresponding coils in each pair are in series. The return wires from the ratio coils are joined together through an adjustable resistance, and the common return goes round the exciting coils of the moving magnet, and so back to the other feeder. The swinging magnet is of the shape shown, and it carries a brass ring with teeth on it, which gear into the spindle of a pointer working over a dial on the face of the instrument.

A two-way switch is fitted as shown, as there is generally one receiver on the bridge and one on the conning tower. The instruments are worked off the lighting mains.

If the instrument gets out of adjustment either through leaks, bad contacts, or distortion of its several parts, it can be regulated by taking off a small brass cap on top of the receiver and turning the two switch arms either to the right or left as necessary, and so switching out resistances on that side till the receiver shows the same as transmitter. The instrument should be kept switched off when not in use. When first switched on (and frequently when in use) the indications of transmitter and receiver should be compared, and corrected if necessary.

Evershed's Helm Indicator, New Pattern.—This instrument embodies the same electrical principle as the old one, but the ratio of the two currents is altered in a different manner, and the arrangement of the receiver is also different. It will be seen (Plate LXIV.) that the transmitter has two contact pieces, one at each end of an arm that is pivoted in the middle, each moving over its own set of resistance steps, and the two line wires are taken away from the ends of these two resistances. In the receiver, the two pairs of ratio coils are set upright, and pivoted in the middle of each is a small soft iron bar. These two bars are connected together by a link, which is also connected to the pointer, so that the bars and pointer are always parallel to one another.

The common return is taken first round a small compass correcting coil which is designed to neutralise any stray external field from the ratio coils, and then round the magnet of a locking device. This locking arrangement keeps the pointer out of sight when the magnet is not energised, but frees it when the current is on.

The corresponding ratio coils on opposite sides of the instrument are in series, as in the old pattern, but the current flows round them in opposite directions, so as to produce as little external field as possible, but any stray field that there is is neutralised by the compass corrector.

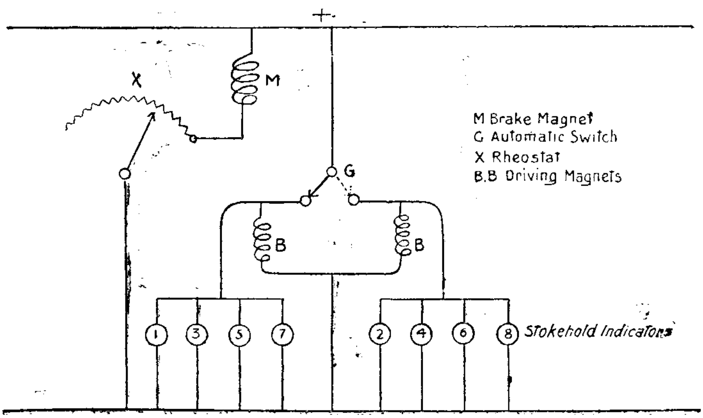
Only few resistance steps are shown in the diagram on each side of the transmitter, but there are, of course, as many on each side as there are indications on the dial of the receiver. There is no adjusting arrangement, as it is not needed.

Kilroy's Stoking Indicator.—This is an instrument for facilitating the uniform firing of boiler furnaces. Each of the boiler furnace doors is given a number, and a stoking indicator is provided in each stokehold which signals these numbers in rotation at regular intervals, ringing a loud gong to call attention to each change of signal. The length of the interval between successive signals is controlled from the engine room by means of a regulator placed there, and both regulator and indicators are worked off the lighting circuits.

The regulator, or timing apparatus, consists of a special switch mechanism, which, at uniformly recurring intervals of time, closes electrical circuits which actuate the stokehold indicators.

A diagrammatic view of the circuit of the whole system is shown in Fig. 187, while Plates LXV. and LXVI. give views of the instrument itself and the actual arrangements of the circuit respectively.

FIG. 187.



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KILROY'S STOKING INDICATOR.

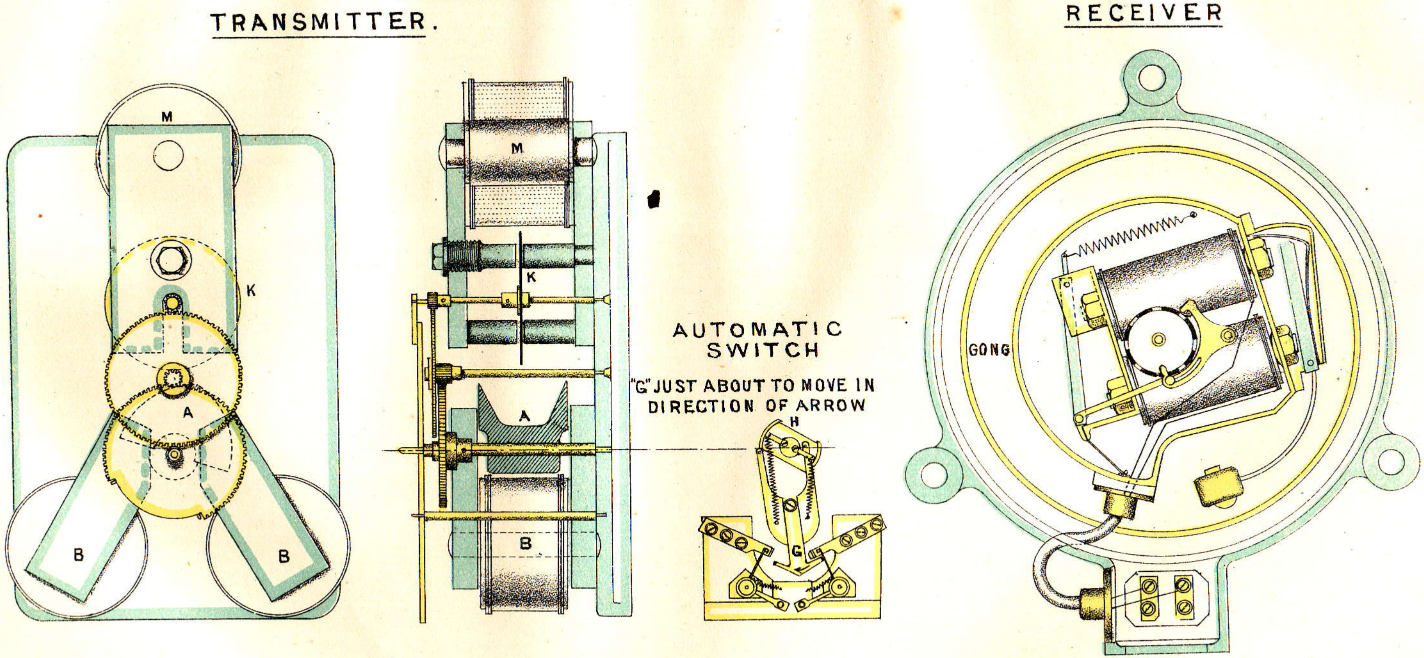

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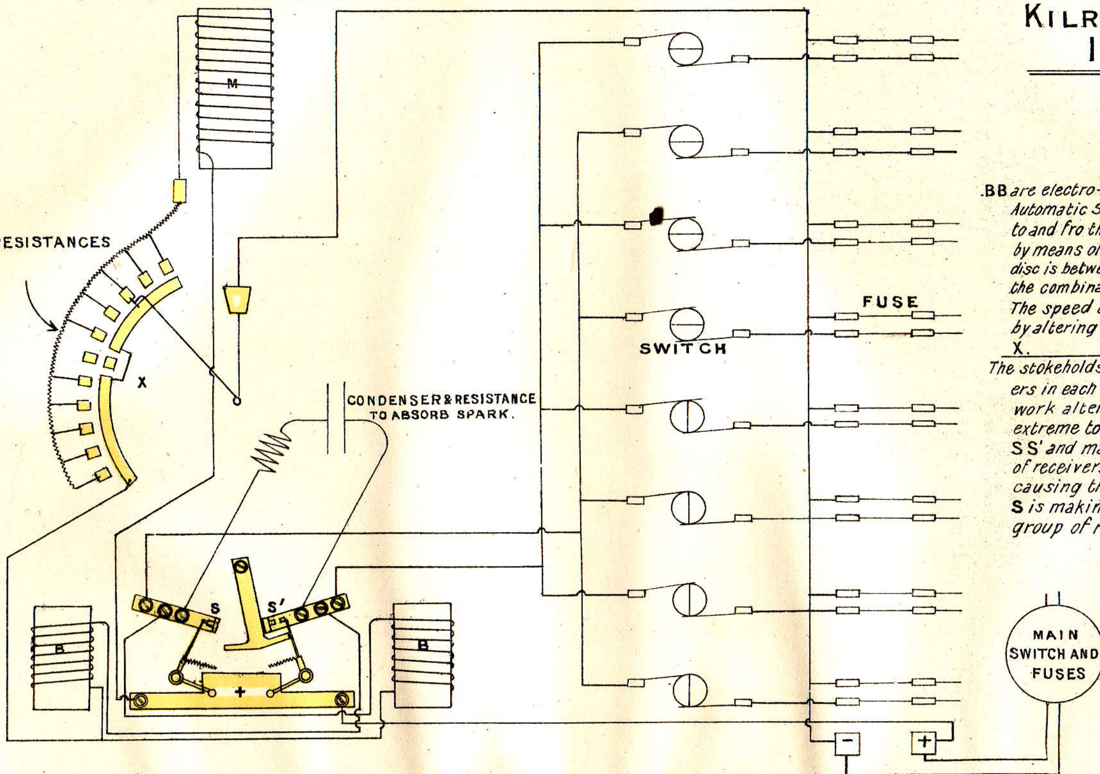
DIAGRAM OF CONNECTIONS OF (REGULATOR) TRANSMITTER



KILROY'S STOKING INDICATOR.

REFERENCE

BB are electro-magnets which act alternately (due to Automatic Switch) on soft iron armature A rocking it to and fro the motion of the armature is transmitted by means of a train of wheels to copper disc K. This disc is between the poles of the electro-magnet M and the combination of K & M forms an eddy current brake. The speed of rotation of the disc may be altered by altering the excitation of M. This is done by switch X.

The stokeholds are divided into two groups, the receivers in each group are in parallel, and the groups work alternately. Every time C moves from one extreme to the other, it breaks one of the switches S S' and makes the other, thus allowing one group of receivers to get into stand-by position, and causing the other group to work. As long as switch S is making the current will flow though the group of receivers it governs.

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Referring to the Plates LXV. and LXVI., the path of the current is, firstly, from the positive terminal of the regulator to the block marked + which carries the two small switches S and S[1]. One of these switches is always made, and the other broken, and the current goes through the one that is made to the driving magnet B on the opposite side, and so to the negative through the contact X. These driving magnets act on a pivoted soft iron armature A, which works a train of gear wheels. An automatic switch G is worked by the armature A, and is so arranged that, when A gets right over to one side, the circuit of the driving magnet on that side is broken, and the other magnet energised, so that the armature starts to swing back again. The same thing happens at the other end of A's travel, and so A goes on swinging backwards and forwards as long as the current is switched on.

The speed at which A swings is regulated as follows:—At the end of the train of gear wheels driven by A is a copper disc K, which revolves between the poles of an electro-magnet M, and so acts as an eddy current brake, as explained in Chapter III. The amount of the breaking effect, and consequently the speed of the disc and train of gearing, depends on the strength of the magnet M, and the amount of current flowing through its coil can be regulated by the adjustable resistance X. If there is little resistance in the circuit M will be strong, and the disc K, and consequently the armature A, will move slowly. If more resistance is put in by moving the regulating switch M will be weaker, and the mechanism will move faster. It will be seen that M is fed direct from the positive block at the bottom, and the return goes through the adjustable resistance to the negative.

The two small switches S and S[1], besides directing the current alternately to the driving magnets, also switch off and on the stoking indicator circuits, half of which are fed from one and half from the other. S and S[1] are actuated by the automatic switch G, which is always right over one way or the other. In Plate LXV. it is shown with its lower end over to the right, thus breaking the contact at S[1], while the contact at S is kept made by a spring. Since S is made, the right hand driving magnet will be energised, and the armature A will be moving over to the right. Fixed to the spindle of A, and moving with it, is a small metal plate H, which has circular ends with raised edges, and carries two springs, one at each side, the other ends of which are secured to the corresponding sides of G. As A swings over to the right, the left hand spring is tightened, and tends to pull G over, but G cannot move until A gets to the end of its travel, as it has a pin on the horn at its upper end which is held outside the raised end of H until H has revolved far enough to clear it. As soon as it does clear, G flies over, breaking the contact at S and allowing that of S[1] to be made, und the armature A begins to swing in the other direction. This begins to tighten the right hand spring between G and H, but H is kept in the extreme position for the whole of the travel of A by the pin on its other horn, which is caught outside the raised edge at the right hand end of H.

A condenser and resistance are connected in series between the two blocks on which S and S^1 make contact, to prevent sparking when the contacts are broken.

The receivers, which are in two groups in parallel with one another, the groups working alternately, consist simply of instruments with single stroke gongs, with a window in the face of each, through which a different number is shown every time the gong is struck. The numbers correspond to the numbers assigned to the boiler furnace doors.

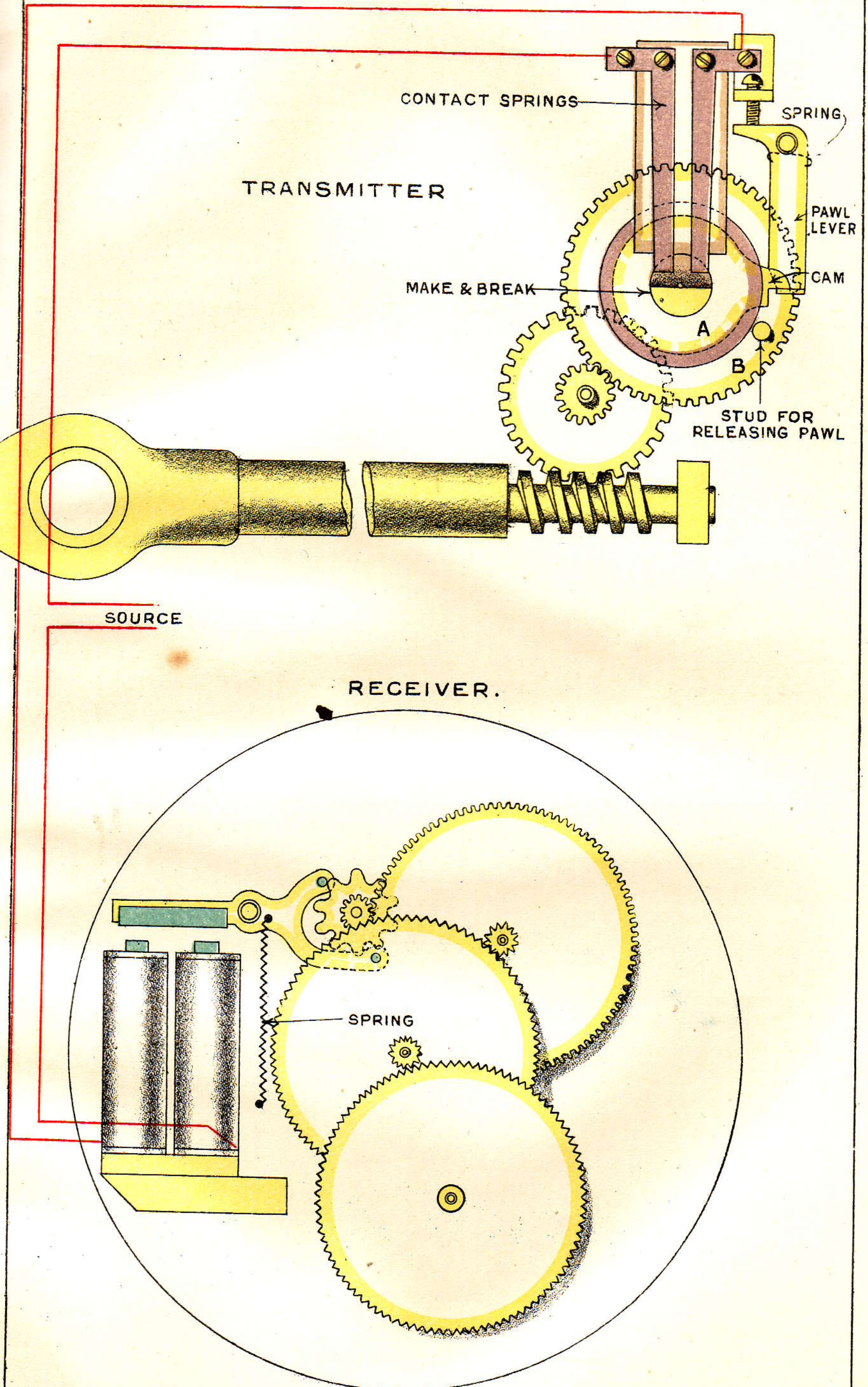
The electrical part of the instrument is enclosed in a watertight brass case which is placed inside the gong. It consists of two soft iron cores fixed in one side of the brass case, each with one end protruding through the side of the case, and wound in series with one another, the resistance of each coil being about 50 ohms. Across the ends that are outside the case is the armature that carries the hammer for striking the gong, and across the other ends, inside the case, is another armature which revolves the disc on which the numbers are printed. This second armature, when it is attracted by the magnet being excited, revolves the disc through one step so that a different number is shown through the window, by means of a link and specially shaped pawl. When the circuit is broken, the armature is returned to its former position by a spring, while the disc is held stationary by the pawl, and it is then ready to perform the same operation again. The disc and the gear that works it are inside the watertight case, and the circuit is led in through a gland.

The whole instrument requires very little attention. It should always be kept switched off when not in use, and care should be taken that larger cut-out wire than that supplied is never used.

Electric Ship Log.

This is an instrument by means of which the indications of the Cherub log on the quarter are reproduced on a dial placed in the chart house. The mechanism is shown in Plate LXVII. The action of the transmitter is as follows :—The gear wheel B, which is part of the recording mechanism, carries a spring box A on its spindle. A contains a coiled spring, one end of which is secured to itself and the other to B, and this spring keeps the cam on A pressing up against the stud on B. As B revolves in the direction of the arrow, the cam on A is caught by the pawl, and A is held stationary while B goes on revolving and coiling up the spring still further. When B has made nearly a complete revolution, the stud comes up against the pawl and pushes it out, thus releasing A, which flies round under the influence of the spring until it is brought up by the cam coming up against the stud. As A flies round, a contact piece on its spindle makes a momentary contact between two German silver fingers which are included in the electrical circuit. The same succession of events takes place on each revolution of B, so that the electrical circuit is momentarily completed once in each revolution of B.

Electric Ship Log and Chart Room Register.



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The resistances a, b, c, and d are those that are acted on by the heat of the glow lamp in the transmitter, and they are arranged as shown in the upper diagram.

The receiver (Plates LXIX. and LXX.) consists of a circular electro-magnet with poles projecting towards the centre. Between the poles is pivoted an armature, which is similar to that in a moving coil voltmeter, except that it carries two coils at right angles to one another. The spindle of the armature carries a card at the top which has the points of the compass marked on it. The ends of the wires of the two coils are brought out to spiral connections on the spindle just below the card.

In order that the armature may be able to make complete revolutions without becoming jammed by winding up the spiral connections, these latter are secured, not to the standing part of the instrument, but to a part which can be revolved by means of a handle at the side. From this the connections are made to the line wires from the transmitter by four brushes bearing on fixed contact rings. This revolving part must be kept in such a position, by means of the handle, that the card does not get jammed by winding up the spiral connections.

The working of the instrument is as follows:—Suppose current to be flowing in the bolometer, but the glow lamp to be switched off, so that the resistances a, b, c, and d are all at the same temperature. The adjustable resistances in series with e and g are then altered until there is no current in either coil of the receiver. The instrument is then in adjustment and ready for use.

Now suppose the compass card to be in such a position that the window in it is over the resistance a of the bolometer, while b, c, and d are shielded by the tin foil. If now the glow lamp is switched on, the resistance a will be heated, while b, c, and d remain at the same temperature as before. The effect of this will be that the resistance of a will increase, and consequently the balance of the left hand bridge will be disturbed and a current will flow from A to B through one coil of the receiver. There will be no current in the other coil of the receiver, since the balance of the right-hand bridge is not disturbed.

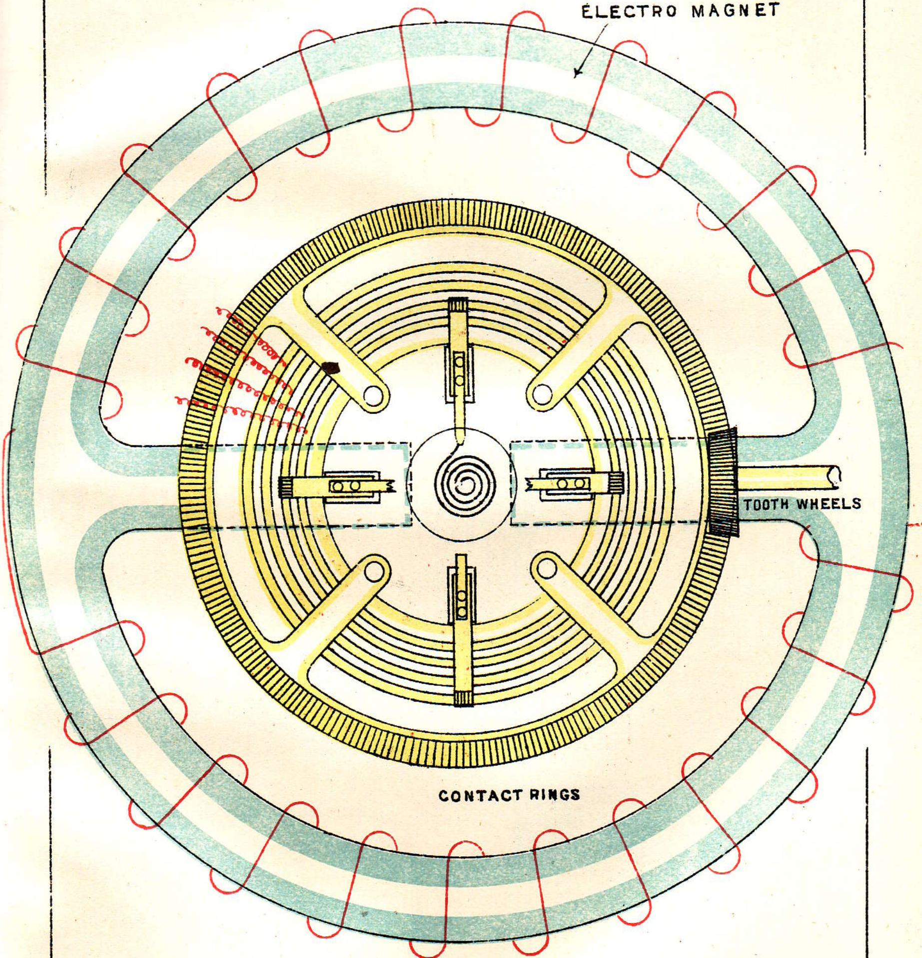
The effect of this will be that the armature of the receiver will turn round until the magnetic field of the A B coil coincides with that of the fixed electro-magnet.

Now suppose the compass card to turn through 45° with regard to the bolometer, so that the window is now half over a and half over c. Since only one half of a is now heated by the lamp, the disturbance of the left hand bridge will be only half of what it was before, and the current from A to B will only be half as great as it was. But at the same time, since one half of c is heated, the balance of the right hand bridge will be disturbed to the same extent, and there will be the same current from C to D as from A to B.

There will therefore be the same current in each coil of the receiver, and the direction of resultant field due to the two coils will be 45° from the direction of the field due to the A B coil

Electrically Controlled Compass.

Receiver Plan.



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RECEIVER.

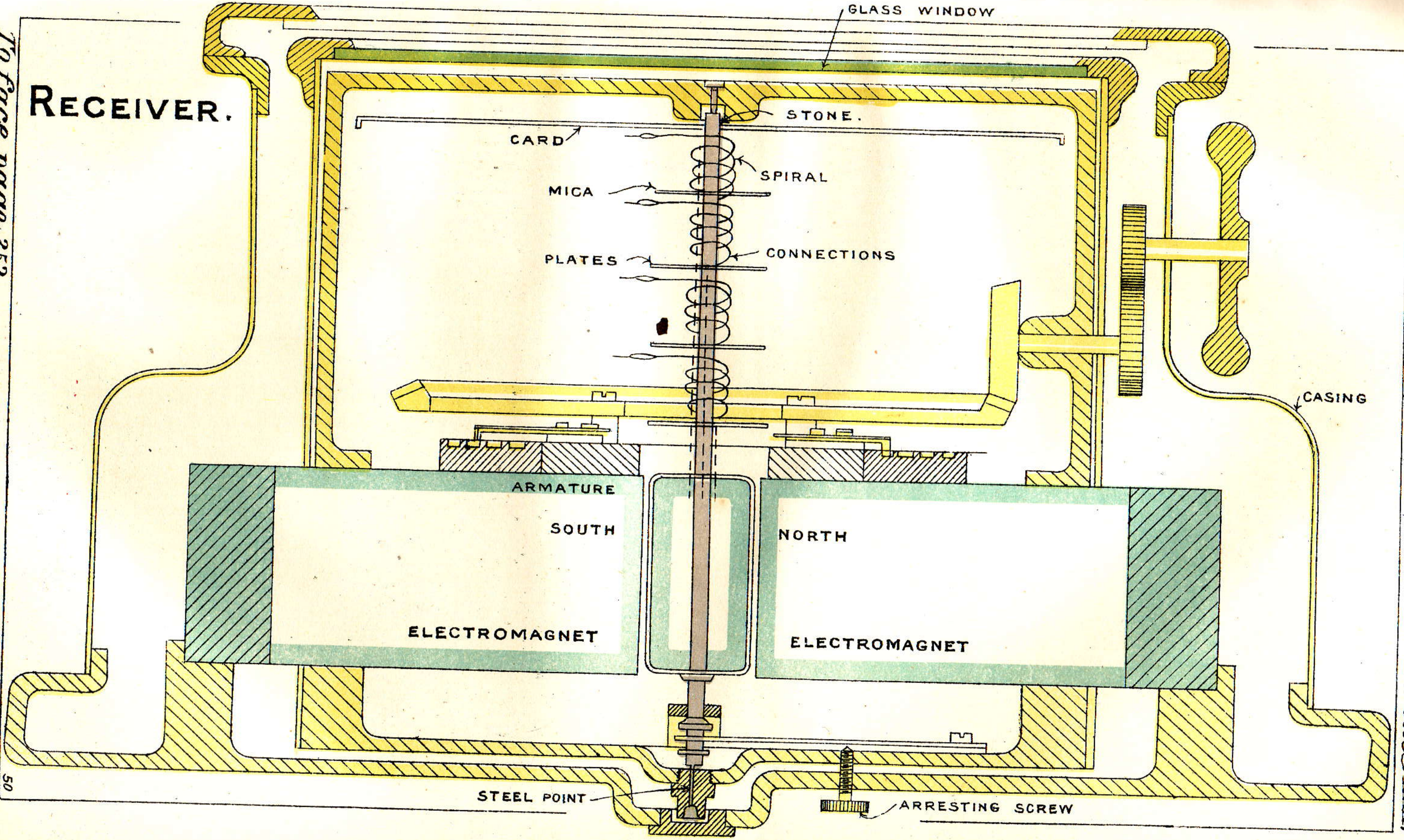
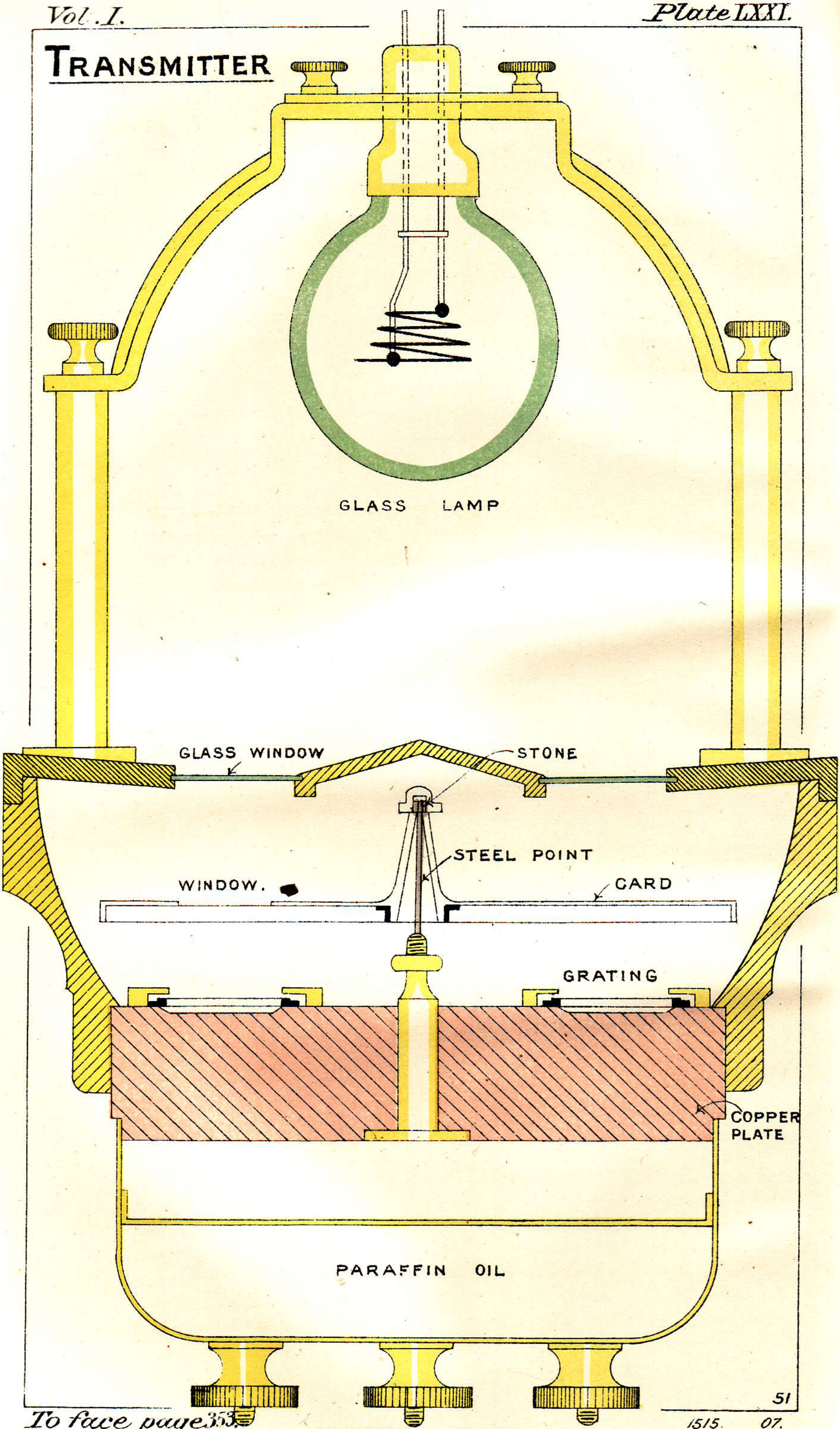


Plate LXX.



ADJUSTING WEIGHTS

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alone. The armature of the receiver will turn so that its resultant field coincides with the field of the electro-magnet, that is to say, it will turn through 45°.

If now the compass card turns through another 45°, *c* only will be heated, so that there will be a current from C to D, but none in the A B coil. The receiver will therefore turn through another 45°, until the field of the C D coil coincides with that of the field magnet.

Another 45° of revolution of the compass card will expose half *c* and half *b* to the lamp, so that the currents will flow from C to D and from B to A.

So far we have only instanced the turning of the card through 45°, but it will easily be seen that any smaller motion of the card is, in the same way, reproduced in the receiver.

In order that the receiver may follow the motions of the transmitter at once without sluggishness, the resistances *a*, *b*, *c*, and *d* are made of very thin tin foil, and are mounted on, though insulated from, a thick slab of copper, so that, when the lamp is not shining on them, their heat is all conducted away at once, and they immediately return to their original temperature. The coils in the receiver are wound on metal frames, as are those in moving coil voltmeters, so that the receivers are absolutely dead-beat.

A special switchboard is supplied for this apparatus and only the receiver actually in use is switched on, the others all being kept switched off.

CHAPTER XXI.

TELEGRAPHY.

In this chapter it is proposed to describe the telegraph instruments supplied to ships and the methods of joining them up, and also to give a few hints as to the working of military and land telegraphs, and their maintenance and repair.

The subject of wireless telegraphy is dealt with in the Manual of Wireless Telegraphy.

Morse System.

The instruments supplied to the Service for telegraphy are intended for sending messages on the well-known Morse system, in which the letters of the alphabet, numerals, and other signals are made by combinations of long and short signs, or dashes and dots. For this purpose, when working at short distances, two instruments are required at each station.

A *Morse key* to send the signals, and a *Morse sounder* to receive them; these instruments will now be described, together with the method of using them.

Morse Key.—Plate LXXII., Fig. 1, shows the Morse key. It consists of a metal lever with an ebonite handle at one end, and pivoted near the centre of its length.

The movement in either direction is arrested by stops or contacts F and B, usually known as the *front* and *back* contacts. Three terminals are fitted—F connected to the front contact, B to the back contact, and P to the pivot. A spring T holds the lever when in its normal condition, so that it makes contact with the stop at B.

When the knob is pressed, contact will be broken at B, and made at F; the tension of the spring and the "travel" of the key being regulated by the screws G and H as required.

The contact pieces which project from the lever and from the corresponding points on the base are terminated with short pieces cut from stout platinum wire, the lower contact being hammered flat so as to give a good surface for the upper ones to strike upon. This is necessary on account of the great oxidising property of the spark, caused by self-induction when the circuit is broken.

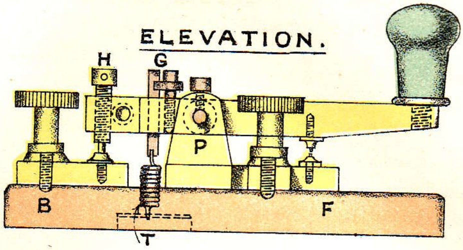
Morse Sounder.—Plate LXXII., Fig. 2, shows the Morse sounder. It consists of a horse-shoe shaped electro-magnet M, wound with two bobbins, each having a resistance of 10 ohms.

A shunt coil having a resistance of 500 ohms is placed between the two terminals of the instrument.

A bell crank lever L is pivoted at Z, and the horizontal part of its length is capable of a small motion up or down between the adjustable stop screws S and T. To this is fixed a soft iron

Key for Morse Sounder.

Elevation.



Plan

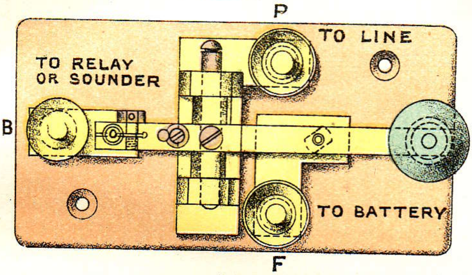


Fig I.

Scale 3/8 full size

Morse Sounder.

Sectional Elevation.

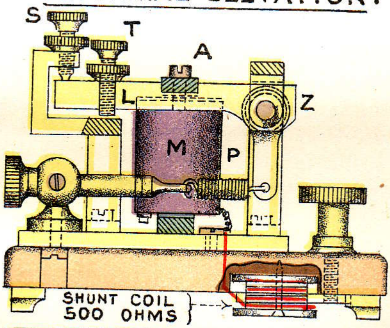
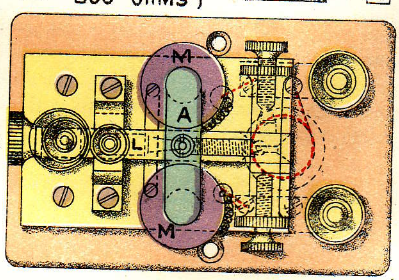


Fig. 2.



Plan

armature A, which is pulled downwards by the magnet M whenever a current is sent through the coils. When the current ceases, the spring P causes the lever to rise, drawing the armature away from the magnet.

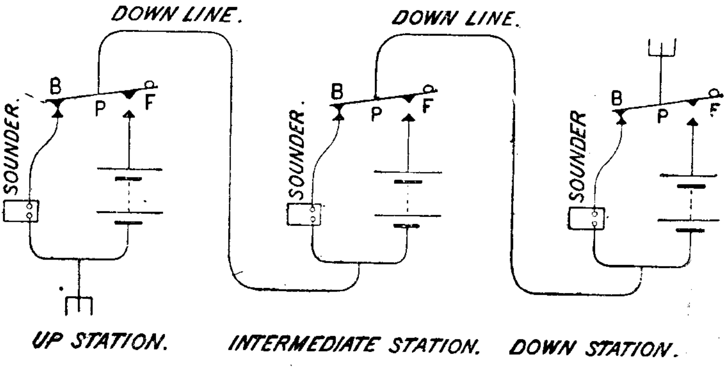
The tension of P can be regulated by the screw R.

The motions of the lever L give rise to a series of sharp "clicks," on the current being made and broken, by means of the Morse key at the sending station; and the time intervals between these clicks form the "longs" and "shorts" of the code. Hence the name, Morse sounder.

The stop T should be adjusted so that daylight is just visible between the poles and the armature. If the latter be too close to the poles it has a tendency to stick, and will not rise on the current being broken. The stop S regulates the distance of travel of the lever; the longer the distance the greater the blow, and, therefore, the louder the sound and the slower the rate of working.

Direct Working.—The method of joining up, say, three stations with these instruments, is shown in Fig. 188.

Fig. 188. Direct Working.



Telegraph Battery.—The battery is supplied in a wooden box, described in Chapter IV. It will be seen that if the operator at the up station presses his key, he will send the current from the $+^{ve}$ pole of his battery, along the line, to the intermediate and down stations, the current finally going to earth at the end down station, and so back to the $-^{ve}$ pole of the sending battery.

This method of joining up is termed *direct working.* Evidently with this system only one station can signal at a time, and the distance is limited by the resistance of the line and the battery power used.

Relay Working. — Hence on long circuits *local currents,* actuated by *relays,* are made use of. This principle is briefly as follows :—A small current is used to work a delicately pivoted magnet, which current would be quite unable to move the armature of a sounder. This small magnet is arranged by its motion to "make" or "break" a *local* circuit, in which a local battery and sounder are joined.

FIG. 189. RELAY WORKING.

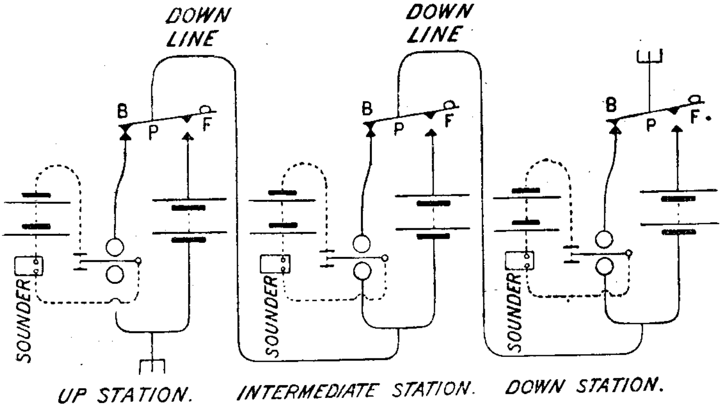


Fig. 189 shows such a circuit, which will be seen only to differ from Fig. 188 in that the relay is inserted in the place of the sounder, and from the relay an entirely different circuit is put in with the local battery and sounder, their circuit remaining open at the relay with no current running in the line wire.

Battery Power required.—Three of the cells of the telegraph battery are generally used for working the local circuit, the remaining cells forming the main battery.

If now up-station depresses his key, the current flows from the battery, through F, and down line to the intermediate and down stations, passing through their relays so long as their keys are not pressed. The current passing through the relays completes the local circuits and works the sounders. In a similar manner it may be seen that any station will work all the relays and sounders on the line, whenever signals are made with its key.

Intermittent and Continuous Current Systems.—The method which has been described is called the *intermittent current system*, because the current is only flowing along the line when the key is pressed for long or short signals. Evidently a converse system to the above may be used, in which the current is always kept flowing, and is interrupted for long or short periods, as necessary to make dashes and dots. This is termed the *continuous current system.* The advantages claimed for this method are that—(i) Any break in the line is at once notified to all stations; (ii) more stations can be worked on a single line; (iii) there is no necessity for a battery at every station.

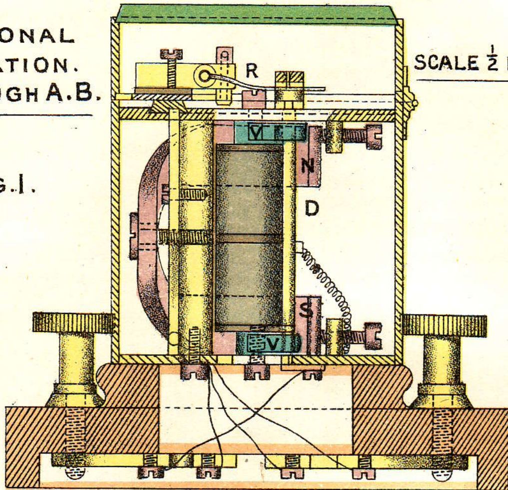
The disadvantages of the continuous current system are as follows:—(i) It more quickly exhausts the batteries; (ii) the long continuance of the current in one direction intensifies the residual magnetism in the magnets; (iii) it is injurious to sub-

POST OFFICE RELAY

SECTIONAL ELEVATION. THROUGH A.B.

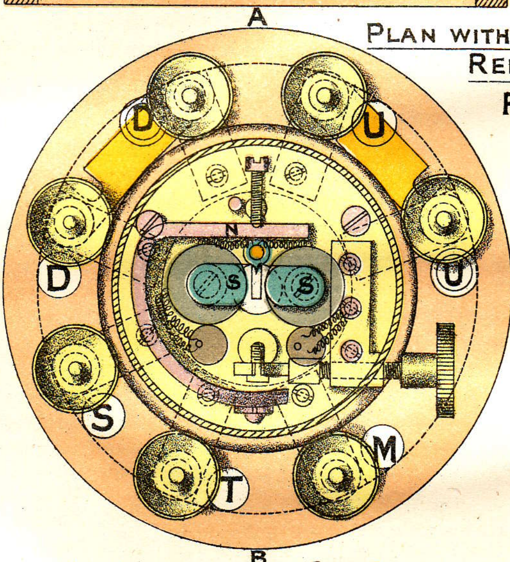
SCALE ½ FULL SIZE.

FIG. I.



PLAN WITH TOP PLATE REMOVED

FIG. 2.



PLAN OF TOP PLATE

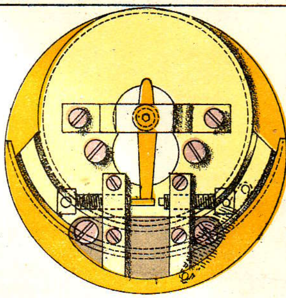


FIG. 3

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marine cables, owing to the increased length of time during which electrolytic action takes place.

The former method, that of using intermittent currents, is the one always used in the Navy. The latter is sometimes employed by the Royal Engineers.

Post Office Relay.

P.O. Relay.—The relay supplied to the Service for use with the Morse sounder is the Post Office standard relay shown on Plate LXXIII.

It consists of a curved steel horse-shoe *permanent magnet*, near the poles of which are mounted two vertical *electro-magnets.* Between the poles of the latter are placed two soft iron vanes VV mounted on a spindle D. A tongue R is mounted on the same spindle as the vanes. Supposing that the upper portion of the steel magnet shown in Fig. 2 is a north pole, south magnetism will be induced in the upper ends of both electro-magnets. In the upper vane, south polarity will be induced in the end nearest to the permanent magnet, and therefore north in the moving end, which lies between the poles of the electro-magnets.

In the lower vane and poles, the reverse will take place.

Each pole therefore exerts an attractive force on the vane; consequently, whichever side of the line midway between the pole pieces the vane happens to be, that pole piece will exert a superior attraction on the vane, and will keep the tongue R over to the contact (F or K) on that side. These two contacts are in connection with the terminals M (marking) and S (spacing), whilst the tongue is in connection with the terminal T. (*See* Fig. 190.)

By turning the screw B, the two stops F and K can be moved so that the vanes can be approached to either pole piece; and adjusting screws are fitted to regulate the travel of the tongue. The coils of the electro-magnet each consist of two separate coils, one pair running between the terminals D and U, and the other pair between the terminals (D) and (U), each pair having a resistance of 100 ohms.

FIG. 190. P.O. RELAY.

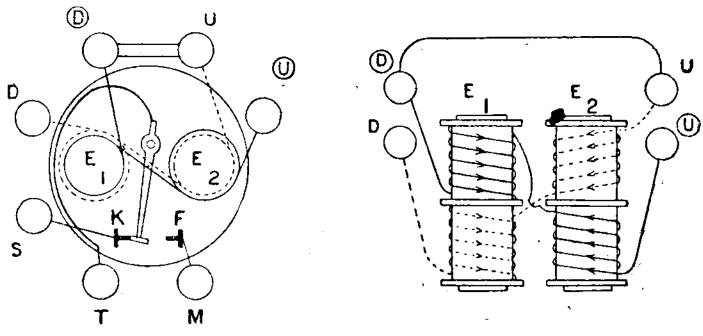


DIAGRAM OF CIRCUIT | WINDING OF MAGNETS.

As shown in Fig. 190, half of each is wound in opposite directions, on each magnet leg. Hence if a $+^{ve}$ current enters at U and leaves at D, it reduces the south magnetism in the pole piece E_1, and increases the south magnetism in the pole piece E_2. Let us suppose that the screw B has been so adjusted that the armature rests against the stop K, then the tongue will be repelled and driven over against the stop F, thus completing the local circuit; it will remain there so long as the current flows.

When the current ceases, it will return to its former position against the stop K, breaking the local circuit, the ends of the local circuit being joined to M and T.

Similarly if a $+^{ve}$ current be sent from (U) to (D) the same action takes place. Hence by joining the terminals D (D), U (U) by the copper straps as shown in Fig. 2 Plate LXI., the two coils are put in parallel, the resistance is halved, and the magnetising effect doubled, provided the current is the same in each coil as it was in one. If, instead of joining D (D), U (U), both straps are turned round so as to join (D) U as shown in Fig. 190, the two coils are joined in series and a positive current entering at (U) will pass by (D) to U, and so through the second coil to D, doubling the effect of a single coil, but also doubling the resistance. On short lines the coils should be placed in parallel so as to keep the resistance low; in long lines, however, where the instrument resistance is unimportant, the coils should be placed in series, giving the same effect with half the current in the main wire that would be obtained with the coils in parallel.

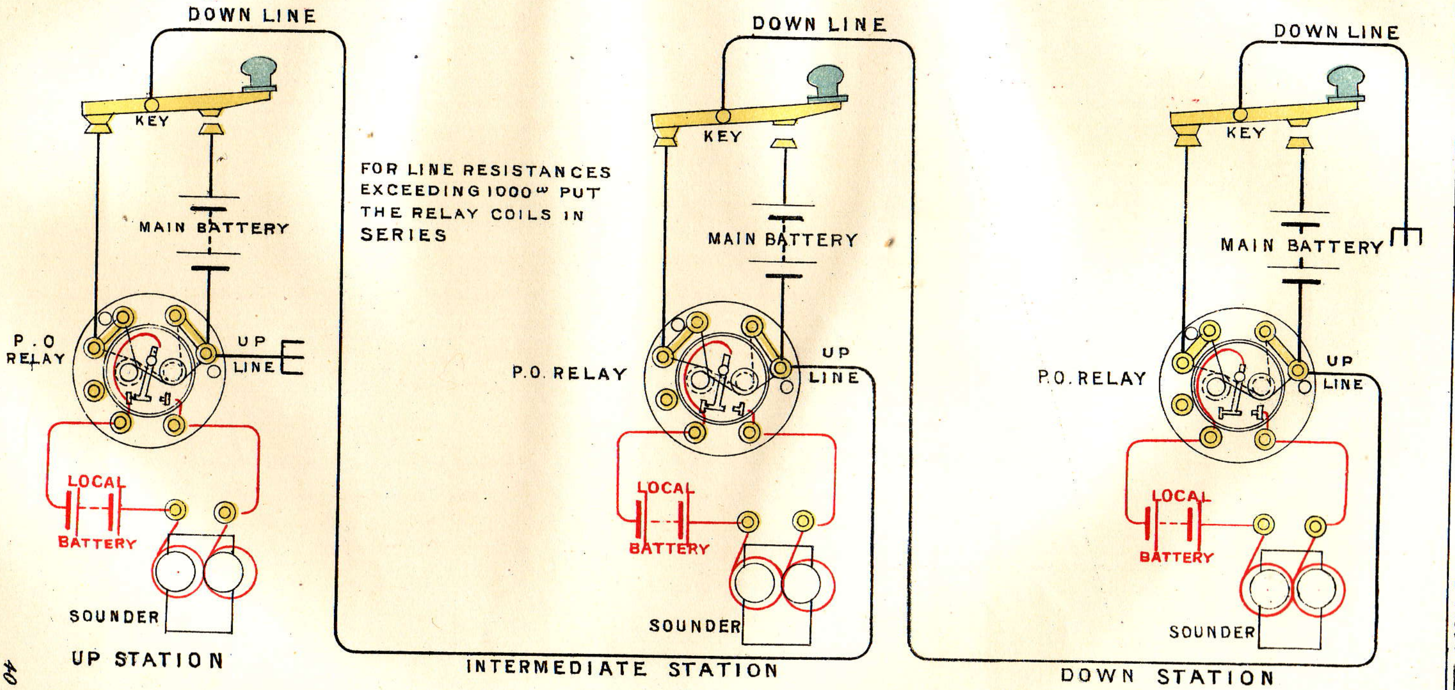
Adjusting the Relay.—The stops F and K should be screwed up equally till they just touch the platinum contact tongue and then each eased up about one turn, and finally clamped by the set screws in the standards through which they pass. If it is desired that the tongue should rest against or have a bias towards S, turn the milled head B until the tongue rests against M, and then reverse the motion till the tongue just reverts to S. When once the stops F and K are adjusted, all further adjustments should be made by means of B.

Local Relay Working.—Plate LXXIV. shows three stations joined up for working relays on this plan. It will be noticed that each station is joined up in exactly the same way, and that all are connected *in series.* One end station is called the *Up station,* and (U) is put to earth; the other end station is called the *Down station;* and there, the pivot of the key is put to earth.

A switch and a 20-ohm galvanometer may be placed at any station, between (U) on the relay and the contact B of the key

To face page 358.

Stations Joined up for Local Working



FOR LINE RESISTANCES EXCEEDING 1000 ω PUT THE RELAY COILS IN SERIES

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Relays used as Buzzers.

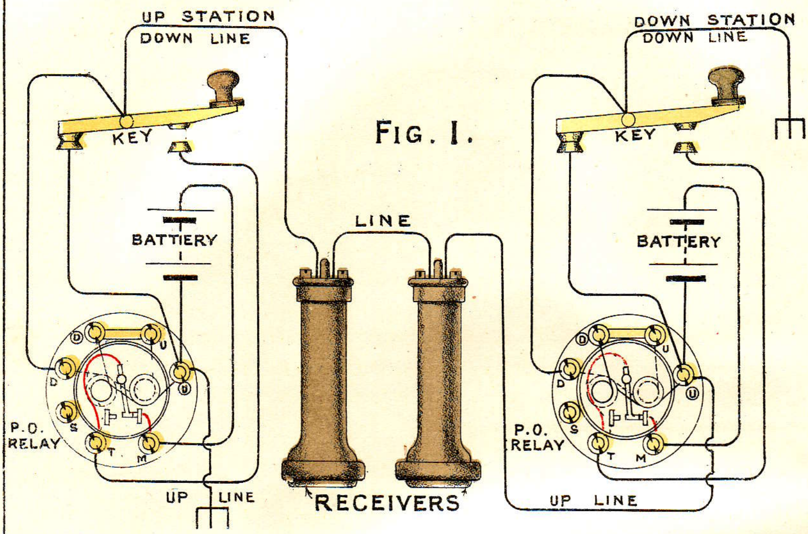

Fig. I.

NOTE, IN RELAY ADJUST TONGUE TO M

Stations Joined up for Duplex Working.

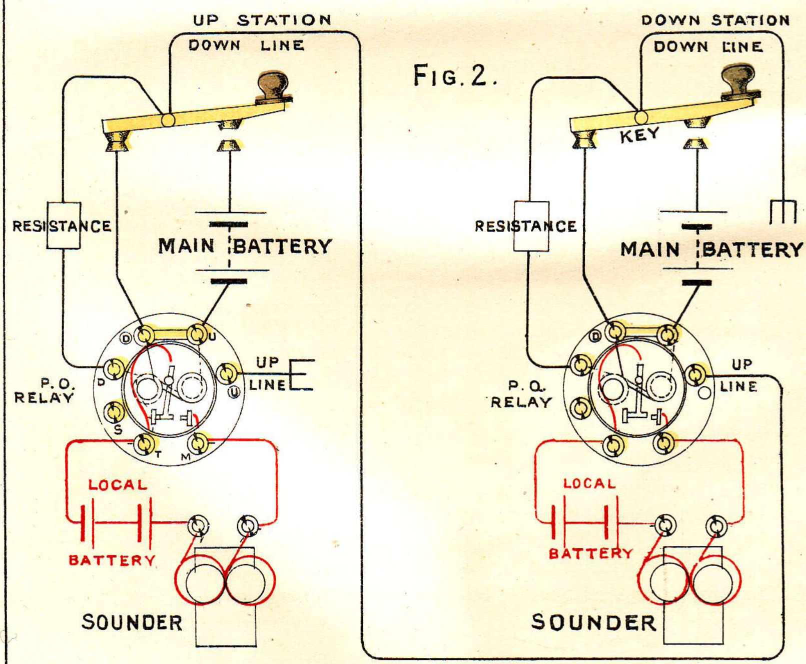

Fig. 2.

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1515. 07.

so that if any signal does not concern the station, that station can be cut out by the switch, the galvanometer showing when the signal is finished.

When the line resistance exceeds 1,000 ohms (or the line is over 50 miles long), the relay coils should be put in series; if below 1,000 ohms they should be put in parallel, by shifting the copper straps between the terminals of the relay.

Duplex Working.—When only two stations are used and quick working is required, it is sometimes desirable to send messages from both ends at the same time. Plate LXXV., Fig. 1, shows the method of connecting up that should be used for this purpose.

In *duplex working*, as this is called, the relay coils *must be in series.* The back of the key is connected to D, and an extra lead joined between the key pivot and D, having in it an adjustable resistance (Wheatstone's bridge). It will be seen on reference to Plate LXXV. that if a current enters at (D) it will divide, part will circulate through one coil to (U), and the other part will traverse the other coil in the reverse direction, to D. If the current be equally divided, the relay will be unaffected; if, on the contrary, one current is stronger than the other, the relay will work as usual. Suppose the key at "Down" station to be depressed. The positive current from that main battery divides at the pivot of the key, one portion flows through the compensating resistance, and through the coil D U, binding the tongue against the stop S; the other portion passes to earth, through the instruments at "Up" station, back by the line wire, and through the coils (U) (D) at "Down" station.

If the compensating resistance has been properly adjusted, the two currents at "Down" station being equal and opposite, the down relay will not respond to its own key.

The positive current, arriving at the "Up" station by earth, will find the key in one of three positions as follows:—

(*a*) *Key up.*—The current arriving at (U) passes from (U) to (D) and back by the "Down" line. This attracts the tongue over to M.

(*b*) *Key in intermediate position.*—The current passes through the coils in series from (U) to (D) attracting the tongue to M, through the compensating resistance, and so back by "Down" line.

(*c*) *Key down.*—The positive current after passing through the coil (U) (D) is reinforced by the main battery at "Up" station, through which it passes on the way to "Down" line ; the compensating circuit at "Up" station is at the same time established as already described for "Down" station.

Under the last conditions, the keys at both stations being depressed, both main batteries are in series through the line wire and the two coils (U) (D).

Consequently, the compensation of each is destroyed, and each will receive a signal.

Adjustment for Duplex Working.

Adjustment for Duplex Working.—After joining up in the manner described, the resistance (Wheatstone's bridge) should be adjusted by each station in turn, as follows:—A large resistance must be unplugged in the box, and then gradually decreased until the relay at the adjusting station ceases to respond to its own key.

The resistance unplugged at each station will be equal to the resistance of the line added to the resistance of one pair of coils of a relay (100 ohms). Duplex working necessitates about two and a half times the battery power used for single working.

Instruments joined up on a Board.—On Plate LXXVI. is shown a convenient and compact way of mounting and joining up sets of Service telegraph instruments, so that by merely following the directions stamped on the tallies, communication can rapidly and with certainty be established between two stations, by anyone with the most elementary knowledge of wiring.

The keys are made portable, so that for duplex working they can be removed to a little distance from the sounder.

In ships that are supplied with the Patt. 1870 telegraph battery box, the instruments are already secured in place inside the lid of the box.

Buzzers.

Buzzers.—By joining up two relays and telephone receivers, as shown in Fig. 1, Plate LXXV., signals can be made by causing the sending relay to "make" and "break" the circuit very rapidly, so that a musical note or *buzz* can be heard in a telephone receiver at the receiving station.

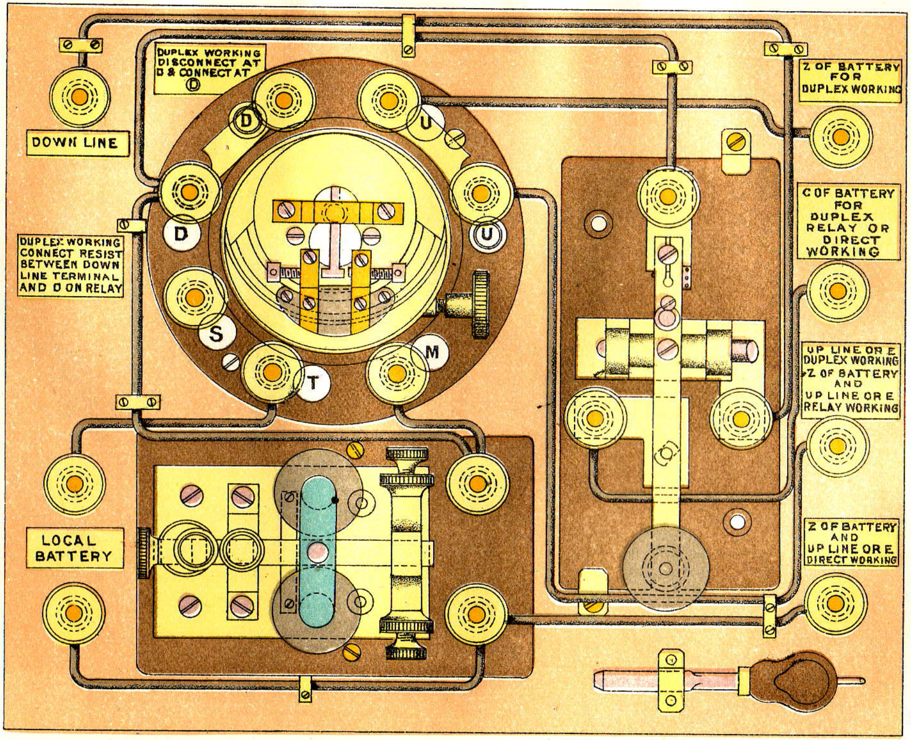
The signals are made by long and short contacts of sending key, causing long and short buzzes in both receivers, and the relays are adjusted with the tongues leaning against the M stops.

The advantages of this system for mining and field work may be summed up as follows:—

(i) No local or relay battery is required.

(ii) The extreme sensitiveness of the receivers enables the system to be used, and communication maintained, through faulty and badly insulated wires laid on the bare ground.

METHOD OF PERMANENT CONNECTIONS OF TELEGRAPH INSTRUMENTS ON A BOARD.



SCALE 3/8TH FULL SIZE.

Plate LXXVI.

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(iii) A great saving of battery power; further, the current being intermittent, the battery does not polarise so rapidly.

(iv) The receiving telephones rarely require adjustment, and signals are easily read.

Practical Limits.—The disadvantage of this system is that signals on one circuit are liable to become confused (by induction) with those on neighbouring circuits, owing to the great sensitiveness of the telephone.

The system is, therefore, most suitable for isolated lines, especially where (as in advanced military lines), owing to difficulties of transport or great haste in erection, the insulation is defective.

The system has worked well through 27 miles of bare wire laid on the ground in the Soudan, where the ground was, of course, dry, and through 17 miles similarly laid in very wet weather in England.

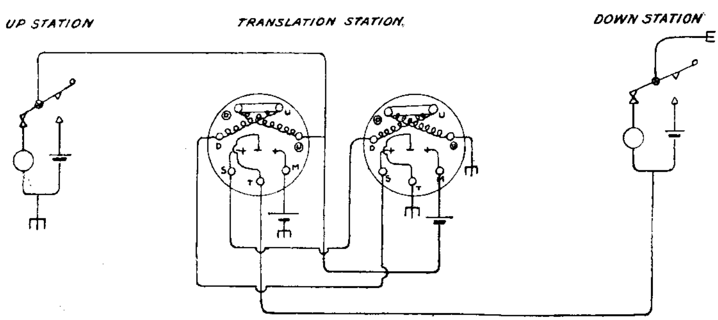
Translation.

In very long or imperfectly insulated lines, to get a sufficient current at a distant station to work a relay with certainty, would necessitate the use of a very large battery.

This difficulty can be obviated by dividing the line up into sections, and transmitting by hand from one section to the next. Such transmission by hand involves time, labour, and inaccuracy; and so it is usual to cause the relay on one section to automatically work the sending apparatus of the next station. It would be impracticable to make the relay work the Morse key, and consequently the device is adopted of converting the local sounders into automatic keys, by insulating the stops which limit the play of the armature lever, and connecting them up as the back and front contacts of the key.

A simpler way, however, is to use two relays and two batteries only at the translation station, the tongue of each relay, working between the M and S stops, being used as the Morse key.

Fig. 191.



A diagram of a translation station joined up in this way is given in Fig. 191.

The relay coils are shown in series, as this method would only be used on high resistance lines. The relays must be adjusted with the tongues resting against the S stops.

The Printer.

The Printer.—This instrument consists of an electro-magnet worked in exactly the same way as that of the ordinary sounder, but instead of the signals having to be interpreted by sound, the armature causes an inking wheel to press on a travelling strip of paper, and by the length of its contact to register dots or dashes. Plate LXXVII. shows a view of the instrument; a wheel I, revolved by clockwork, is attached to one end of a lever I G F, whose pivot is at O. To the other end the armature F is fixed. The magnet is able to attract the armature against the spring S, and pull the lever down as far as the stop B will allow it to travel. On the stoppage of current the spring S pulls the lever back against the stop A. This motion of the lever causes the wheel I to rise and to be pressed against the travelling strip of paper P, and then to fall back away from contact with it. The clockwork not only revolves this inking roller, but also causes the paper to be dragged by the friction rollers R, R^1 past it. This clockwork is regulated by an air beater, which is capable of adjustment, so as to get an increase or decrease of speed if required. The lever L presses against the beater, and so stops the clockwork when the printer is not being used. The clockwork is wound up by the key K.

An ink-well W and reservoir V are fitted. The ink roller revolving in the well keeps its edge always covered with ink. The electro-magnets are capable of being raised or lowered by the screw D, so that the pole pieces are brought nearer to or further from the armature.

The paper is slightly coloured, and is about half an inch wide. The ink used is printer's ink, of good quality, diluted with olive oil, from which the stearine has been removed by freezing. It is supplied ready for use.

Adjustment of the Printer.—This instrument has three adjustments:—

(1) Screws A and B, which regulate the play up and down of the armature F, and therefore of the inker.

(2) Screw C, which regulates the tension of the spring S.

(3) Screw D, which regulates the distance between the poles of the electro-magnet and the armature F, by raising and lowering the former so as to increase or diminish its attractive force.

It is regulated for working as follows:—

I.—(*a*) The screw B is first adjusted so that disc I gently touches the paper without pressing too hard when the brass stop F is placed in contact with the stud B.

If the disc presses the paper too hard, it makes thick and indistinct signals; if it presses too lightly, it causes the disc to jump and signals to split; thus ▬▬ may become ▪ ▬ or ▬ ▪.

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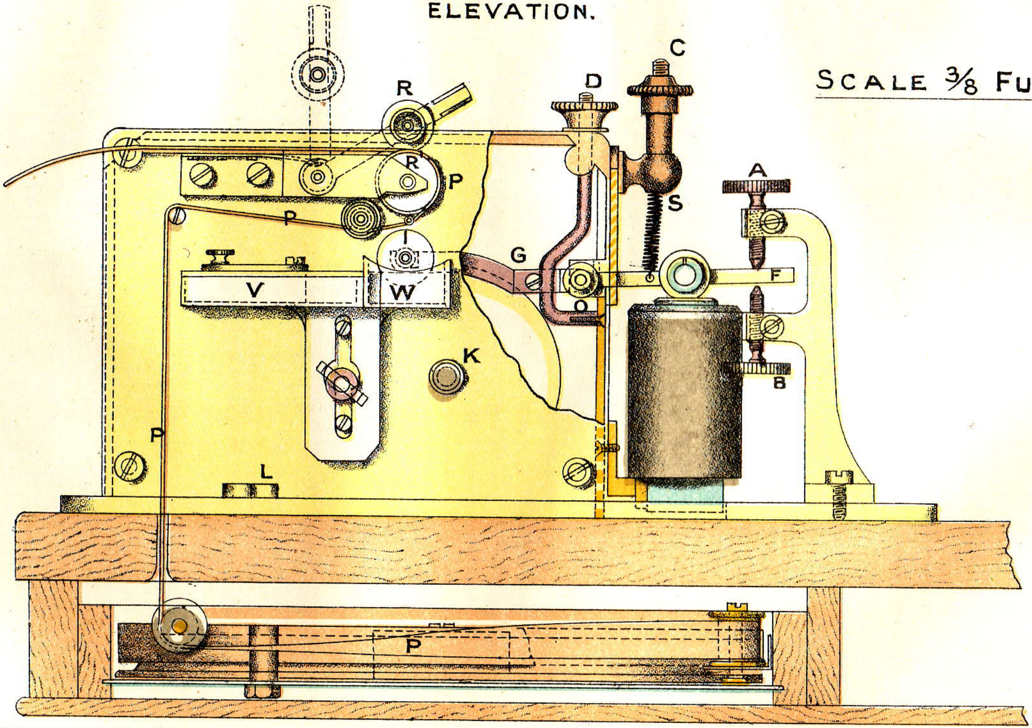
THE PRINTER.

ELEVATION.

SCALE 3/8 FULL SIZE



Weller & Graham, Ltd Litho. London 1515 07

(*b*) The electro-magnet is then raised by turning the screw D to the right, so that when the brass lever F rests upon the already adjusted stud B the poles *just* clear the armature without actually touching it.

A thin streak of light should be seen between the armature and the poles of the electro-magnet.

(*c*) The screw A is next adjusted so that the brass lever F is allowed to move through a space of about $\frac{1}{10}$th of an inch; A and B, together, so regulate the play of the inker that, while it just dips into the ink-well, it also *gently* presses against the paper so as to mark it clearly.

II. The screw C is now adjusted so that the tension of the spiral spring is just sufficient to bring back the armature to its upper position of rest, when the current ceases to act, and also to overcome the effects of residual magnetism, if any exists. The amount of tension required varies with every instrument. The letter V generally should be sent by the distant station, using very low power, and the spring gently tightened until the marks are clear and distinct. The ear is usually the best judge in this adjustment.

The instrument is thus regulated to work with the most delicate currents.

III. The electro-magnet is lowered by means of the screw D until a space of $\frac{1}{8}$th of an inch separates the armature from its poles; the nearest station should then send V's with full power, the electro-magnet being raised until the marks on the paper tape are distinct and clear.

The instrument is thus placed in a position to work with every current sent, viz., the strongest current from the nearest station, and the weakest current from the most distant station, supposing there are more than two stations upon the same wire.

IV. The intermediate adjustments are made by the screw D, and as the currents vary, so must the distance between the armature and electro-magnet be varied; hence the only adjustment necessary to meet currents of different strengths from different stations, or from the same station during different states of the atmosphere, when once the instrument has been placed in working order, is that effected by the screw D.

(*a*) If, when a station is working, a continuous mark is made upon the paper, or signals run into each other, thus ——— (usually the result of a powerful current), the electro-magnet should be lowered by means of D until the marks are clear and distinct.

If marks should still run together when the coils are as low as they can be, the spring S must be tightened up.

(*b*) If marks fail (dots are lost and letters become illegible, faults arising from some weakness in the currents), the electro-magnet should be raised until the signals become distinct.

If this should fail to obtain the desired result, then the spring S must be weakened; as a rule the screw D is found sufficient to meet all the requirements of adjustment; and when once A, B, and C have been fixed, they rarely require alteration.

D, however, requires to be frequently altered, and where several stations exist on the same circuit, a different adjustment is often required for each.

V.—(*a*) The ink reservoir should never be too full, otherwise the apparatus is apt to become clogged with ink.

(*b*) The communication between the ink reservoir and well becomes frequently choked with coagulated ink after disuse. This should be cleared with a piece of wire.

(*c*) The ink reservoir must be frequently cleaned out and the ink never left in for any length of time. When the day's work is over the paper should be taken out, and the instrument should be allowed to run down to prevent the weakening of the main spring.

Double Current Working.

Double Current Working.—We have, hitherto, only considered circuits in which the current is sent in one direction; the cessation of the current releasing the armature of the receiver and allowing the spring in the case of the sounder or printer to pull it into the position of rest; or in the case of relays, to allow the armature to return to the nearer pole piece.

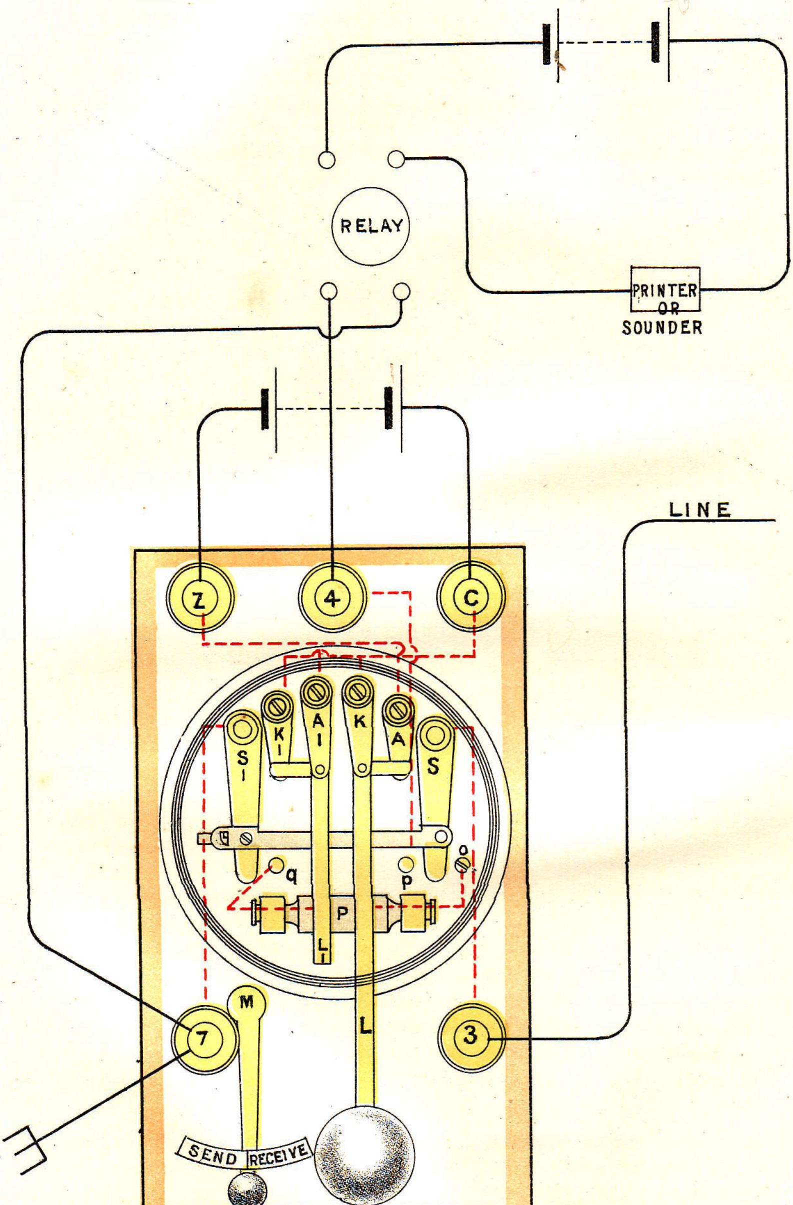
When working long lines, especially if using insulated cables, the speed of working is greatly diminished, since the cable has a tendency to collect a certain portion of the current on its surface. The current must, therefore, be kept running sufficiently long to allow this charging effect to take place and the current to reach the magnet coils of the relay at the far end. On breaking the circuit the exact reverse takes place and the cable has to discharge itself through the receiving instrument, which prolongs the time of stopping the current. If, then, we work with any of the methods already described on long lines, the pauses on make and break will have to be increased to prevent the signals from overlapping at the far end.

To minimise this evil the system of double current working is introduced, by which the current is reversed in direction, instead of being merely stopped; this not only tends quickly to destroy the lingering effects of the previous current, but it allows of a more sensitive adjustment of the relay.

Plate LXXVIII. shows the double current key used in England. L and L_1 are levers connected on the same pivot P, but insulated from one another. When the key is pressed they rest respectively on the contacts K and A_1; when the key is released they leave these and rest against A and K_1. K and K_1 are connected to the terminal C, which is in connection with the $+^{ve}$ of battery, and

Double Current Key (P.O. Pattern)

Joined up with Relay and Sounder.



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A_1 and A are connected to the negative of the battery by the terminal Z. Hence, when the key is released L is in connection with the $-^{ve}$ pole and L_1 with the $+^{ve}$ pole of the battery, and *vice versâ*. If, therefore, L and L_1 be connected to line and earth, the *up* and *down* positions of the key will send *positive* and *negative* currents to line respectively, or in other words, the motion of the key will reverse the direction of the current in the circuit.

L and L_1, however, cannot be directly connected to line and earth, as the key must be used for either sending or receiving. To effect this a small switch M with two positions, "send" and "receive," is fitted to the same base plate. When to "send" S and S_1 are switched over by this switch M, so as to be in contact with *o* and *q* respectively, *o* is connected to L and *q* to L_1. S is connected to (3) terminal; and S_1 to (7) terminal, which latter is joined to the relay and to earth. With key "up" and switch to "send" the current runs from zinc to A, to L, to *o*, to S, to 3, to line, through the far instrument to earth, to 7 terminal on home key, to S^1, to *q*, to L_1, to K_1, to C, to battery. If the key be depressed the carbon of the battery is put to line and the zinc to earth.

If the small switch is put to "receive," S is switched over to *p*, and S_1 away from *q*. The current then enters at 3, to S. to *p*, to 4 terminal, to relay, to 7, to earth, and back to far battery.

The objection advanced against this system is that a message cannot be interrupted and the attention of the sending operator attracted while transmitting. Sometimes a galvanometer is used, wound with two separate wires, one in the sending the other in the receiving circuit. In sending, the receiving coil is out of circuit, but the sending coil is affected by outgoing and incoming signals, and the breaks of the receiving station are readily felt. Practically the objection mentioned is very slight.

In addition to the above, there are two other methods of telegraphy, but as they require special keys and relays, it is not proposed to describe them here.

The first of these is known as "Diplex," and by it two messages in the same direction can be sent simultaneously over the same line wire.

The other is known as "Quadruplex," and is a combination of Duplex and Diplex. By this method four messages, two in each direction, can be sent simultaneously over the same line.

Battery Power.—The current required for working the different forms of instruments in milliamperes (thousandths of an ampere) is given below :—

Needle - - - -	15 milliamperes.
Direct printer - - -	20 ,,
Direct sounder - - -	35 ,,
Relays - - - -	7 to 10 ,,

hence the number of cells required to work a line is determined from the necessary current and the resistance of the line.

The approximate resistances of the different instruments used in the Service are—

Needle	200 ohms.	
Printer	300 „	
Sounder	20 „	
Post Office standard relay	100 „	each coil.

Single Needle Instruments.

Receiving Instruments.—In these instruments Morse signals are made by small movements of a vertical indicator needle to the

FIG. 192.

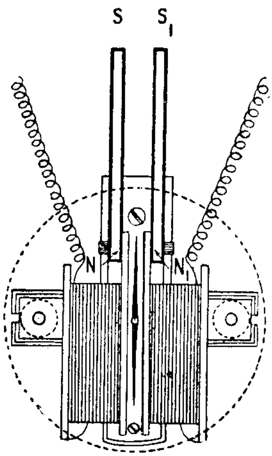
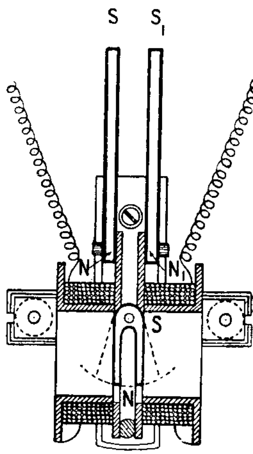


FIG. 193.



right or left, against ivory stops on a dial. Movements to the right correspond to "longs," and those to the left to "shorts." The principle and construction of these instruments in their earlier form was the same as that of a 20-ohm galvanometer, whose needle swings either to the right or left according to the direction of the current passing through its coils.

The dial itself is capable of being turned, to compensate for earth currents in the coils altering the zero of the needle.

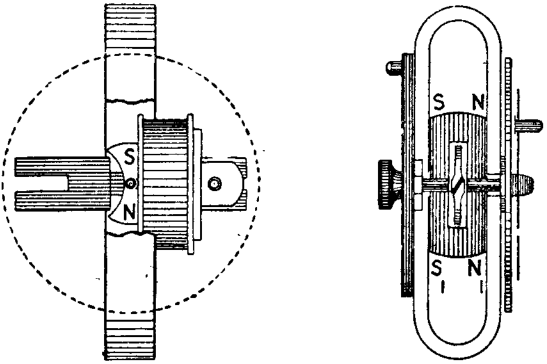
Permanent magnets were first employed, but owing to their small size they were frequently demagnetised, or even reversed, during thunderstorms, owing to the passage of strong currents through the coils. Consequently it has been found better to attach a small soft iron magnet to the spindle of the indicator needle, and to induce magnetism in it by means of strong permanent magnets fixed in the vicinity.

Varley Instruments.—In the Varley instrument, Figs. 192 and 193, two large vertical steel magnets are fixed with their *north* poles downward; the moving needle is of soft iron, horseshoe shaped, and pivoted at the bend; thus *south* polarity will be induced at the bend, and *north* in both legs.

On a current being sent through the bobbins, the horseshoe magnet will be deflected to the right or left (according to the direction of the current), carrying with it the indicator needle. At the same time the effect of a lightning current on the permanent magnets will be insufficient to destroy their magnetism, partly owing to their large size, and also to their not being inside the bobbins.

Spagnoletti's Instrument.—In Spagnoletti's instrument, two permanent magnets of horseshoe form are used, one placed above and the other below the spindle on which the needle is mounted, with their like poles adjacent (*see* Fig. 194).

FIG. 194.



The moveable soft iron magnet is in two sections of the form shown, separated magnetically from each other by being brazed together diagonally with a layer of spelter between them. The axle on which they are mounted is also in two parts, the front part being joined to the lower end of the needle and the back part to the upper end.

It will be seen from the figure that the upper end of the central needle will be induced with south polarity.

The coils are wound as shown in the diagram, and the action of the current is the same as in the Varley instrument.

This form of induced needle gives a rather firmer impact of the needle than the Varley with the same strength of current.

Reading by Sound.—In recent instruments two tin drums take the place of the ivory stops, each giving a distinct note, and thus enabling the operator to read signals by sound.

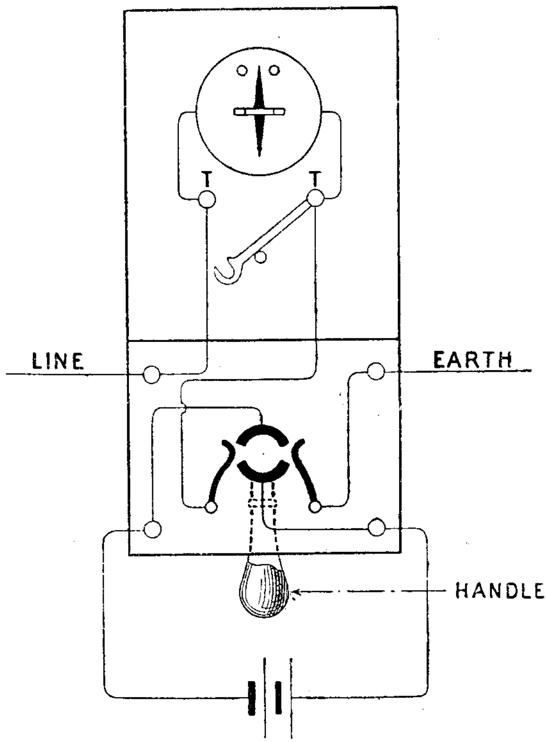
Sending Keys.—There are two forms of key in common use, one called the *drop handle*, and the other the *pedal key*.

Drop Handle Key.—The former consists of a handle projecting downwards, mounted on a shaft having on it contact strips with springs (in connection with terminals) bearing against them. These are so arranged that a positive or negative current from the battery will be sent to "line" according as the handle is moved to the left or right. When the handle is central the contact springs are short-circuited, so as to receive signals.

Fig. 195 shows the connections diagrammatically. The key is mounted on the base of the receiving instrument, the whole being contained in a wooden box with a desk in front, on which messages received can be written.

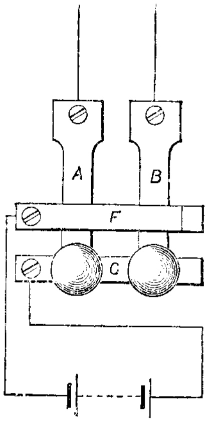
A metal bar is supplied, which when bridged across between the terminals T T in the figure, cuts the receiving instrument out of the circuit.

Fig. 195.



Pedal Key.—The other, or *pedal key* type, consists of two flat wooden keys side by side, the various connections being made by means of metal spring contacts. Fig. 196 shows the action of the key diagrammatically. A and B represent the two keys which, in their normal position, rest with their upper surfaces bearing against the strip F in connection with the $-^{ve}$ pole of the battery, and clear of the lower strip G attached to the $+^{ve}$. In this position, therefore, the $+^{ve}$ of the battery is totally disconnected from the circuit, and no current can flow, and the line and earth are connected together; but if either key is depressed it is brought in contact with G, while the other remains touching F; by this means either earth or line are brought into connection with the positive and negative poles of the battery at

FIG. 196.



will, and a current passed in either direction through the coils of the instruments in the circuit.

Lightning Guard.—The earlier instruments were protected from lightning by having the two wires leading to the bobbins of the receiver wound together with several turns round a wooden reel; this was found insufficient, as it only protected the receiver. Instruments are now always guarded by a lightning protector in the line wire (*see* page 374), which is placed outside the office or house.

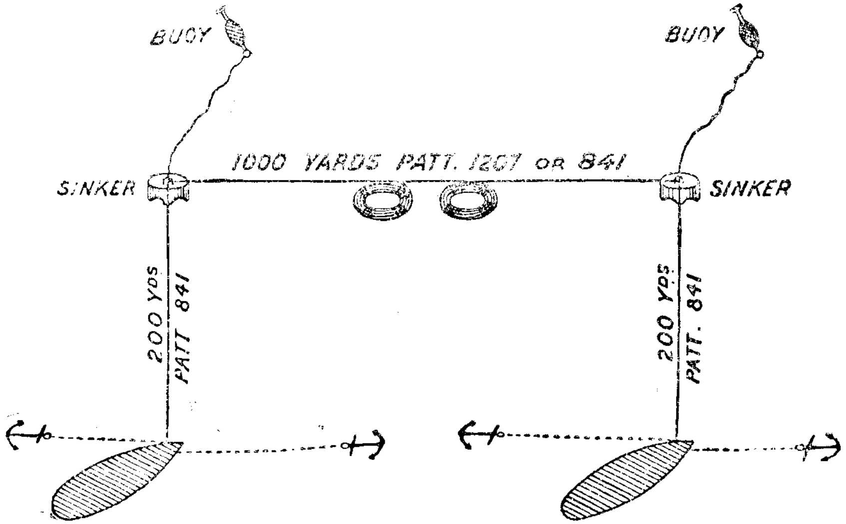
Naval Submarine Lines.

The naval submarine telegraph cable, Patt. 1207, is supplied in reels of 1,000 yards to all ships carrying telegraph instruments, but Patt. 841, if available, is preferable.

It is possible, and may be very convenient, to join a ship of the squadron to the Post Office or other station on shore. When it is desired to establish communication between the ships of the Fleet, the best method of joining up the ships necessarily depends on the formation in which they are anchored.

Connecting Ships of a Squadron by Telegraph Cable.—If in single line, it may be convenient to join the flagship to the centre of the line, or to the repeating ship if one is so stationed. With ships moored in two or more lines, it is better to join up as follows:—Each ship should run her cable to her next ahead, thus forming a complete line through each division. The divisional leaders should then be joined by separate lines and instruments. When a number of ships are joined up in this manner it will be found necessary (i) to lay down a special time daily for breaking connection and clearing the lines; (ii) to arrange for special signals to indicate the position of a break; and (iii) for the "earthing" of the instruments at either side of the break.

Fig. 197.



For the "ship end" a 200-yards length of Patt. 841 is taken and laid out taut in the direction of open hawse. (*See* Fig. 197.)

It is joined to the end of the Patt. 1207 or 841 through a straight junction box which is secured to a $1\frac{3}{4}$-cwt. sinker, and buoyed.

Where distances are short the surplus length of Patt. 1207 should be carefully stopped up in coils, as shown in figure, to prevent fouls, which are very likely to occur with a slack cable in a tideway.

Whenever the ship swings completely round, the "ship end" must, of course, be cleared. For ease in clearing, the inboard end of the Patt. 841 is secured to the foremost awning stanchion, the circuit being led aft by securing a twin lead of Patt. 600 to a light wire jackstay.

Land Lines.

Torpedo depots and torpedo depot ships are each supplied with 10,000 yards of cable, Patt. 1049. This is a very light armoured cable, having a core of three No. 27 L.S.G. wires. It weighs 50 lbs. per 1,000 yards. (*See* table in Appendix.)

It is intended to be used with the Morse instruments supplied to ships for telegraph work on shore. Should this wire not be obtainable, Patt. 600 unarmoured cable may be used.

These wires can be laid along the ground, as their insulation is good, or they may be buried, or attached to poles if available.

R.E. Telegraph Lines.

R.E. Method of Quick Laying.—For quick laying, the Royal Engineers are provided with two-wheeled carts, each carrying eight miles of lightly-insulated steel cable. This wire is paid out from a drum as the cart advances, and a few poles and insulators are carried to lift the cable over roads, &c. where necessary.

A winding arrangement is fitted by which the cable can be quickly reeled up again, and telegraph instruments of the "buzzer" type are carried, so that communication can always be maintained. With "fast drill" a cable can be laid up, to the rate of about eight miles an hour in a good country.

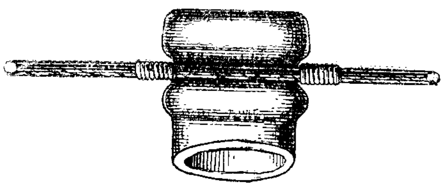
More permanent *air lines* are laid from waggons carrying about seven miles of cable and the necessary number of poles and insulators, the speed of laying greatly depending on the nature of the country traversed.

Hints on Land Lines.

Hints on extemporised Land Lines.—As occasions may arise in the Service where a line has to be erected with the ship's appliances, a few hints on the subject are included in this chapter.

Insulators.—Any iron, steel, or copper wire may be used for running a telegraph line and should be supported well above the ground and out of harm's way on poles, the wire itself being attached to an insulator which, in its turn, is attached to the pole. Extemporary insulators may be made out of the necks of bottles mounted on a spike, driven into the pole or other support, the line wire being secured into the groove in the neck by a binding of wire; but on no account should the line wire be bent or

Fig. 198.



kinked at the insulators on account of the increased tendency to produce breaks. The method of binding on a wire is shown in Fig. 198.

Junctions.—The best wire for binding purposes is No. 16 or 18 L.S.G., iron binding wire being used for iron lines, and copper wire for copper lines. The best method of jointing iron wires is shown below in Fig. 199. Clean the wires for about $2\frac{1}{2}$ inches;

Fig. 199.

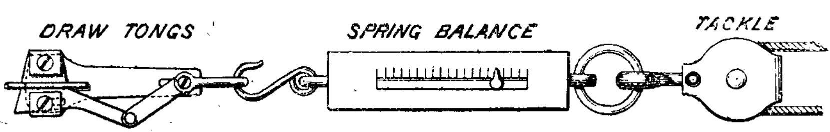
then, about $2\frac{1}{4}$ inches from the end of one, take 6 turns of binding wire, next bring the two parts together and bind them as shown, finishing off with 6 turns round the second wire. Finally, the joint should be soldered, using candle as a flux. In the case of copper wire use a Britannia junction.

The following table gives the wires most often met with, and from it the tension for each span may be obtained, which will be a guide in stretching the wires. The maximum strain put on a wire should not exceed $\frac{1}{4}$ its breaking strain, consequently, in erecting a line in hot weather, considerably less strain is put on the wire than the maximum allowed, to provide for the increase when the wire contracts from cold:—

Weight per Mile.	Diameter.	Resistance per Mile.	Breaking Strength.	L.S.G.	Stress on each Span at Maximum Temperature.	Remarks.
Lbs.	Mils.	Ohms.	Lbs.		Lbs.	
800	242	6·75	2,500	$3\frac{1}{2}$	625	Seldom used.
600	209	9·0	1,860	$5\frac{1}{2}$	465	Iron wire.
400	171	13·50	1,240	$7\frac{1}{2}$	310	
200	121	27·00	620	$10\frac{1}{2}$	155	
400	158	2·27	1,500	$8\frac{1}{2}$	325	
200	112	4·53	650	$11\frac{1}{2}$	160	
150	97	6·05	490	13	120	Copper wire.
100	79	9·10	330	$14\frac{1}{2}$	80	
50	53	—	170	$17\frac{1}{2}$	40	

The wires can be stretched by means of draw-tongs and a small handy-billy, a spring balance being joined in as shown in Fig. 200, to give the strain.

Fig. 200.

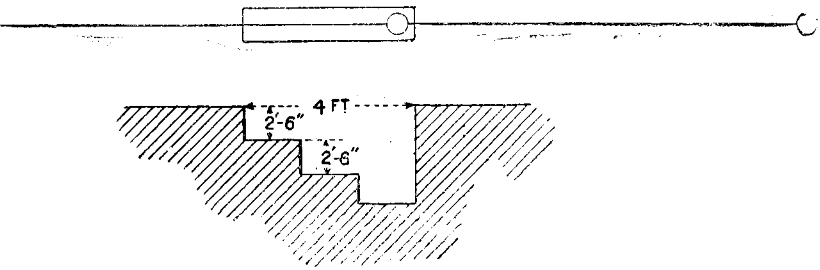


The ends of the line should be secured to the last insulator, and small flexible leads of insulated wire led from there to the instruments.

Poles.

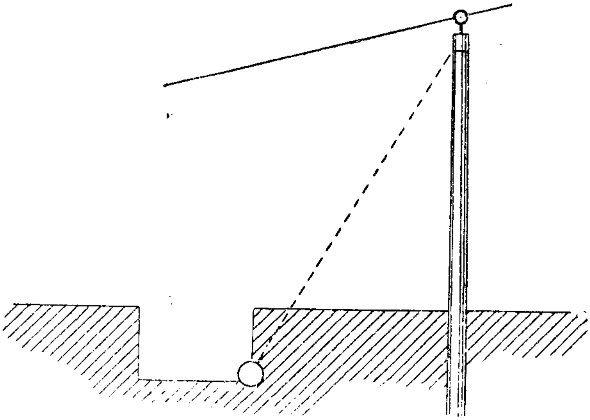
Erecting Telegraph Poles.—In erecting the line, good stout poles should be employed, and the hole in which the pole is set should be dug as shown below, in order that it may have solid ground on either side of it (Fig. 201).

Fig. 201.



The depth of the hole should be from 4 to 8 feet, according to the size of the pole. Whenever poles have to bear any lateral stress they should be inclined, in the first place, slightly against their work, and it will then be found by the time the line wire is attached, the pole will be upright. Poles at the angles or end of sections should be stayed with a wire stay secured as shown

Fig. 202.



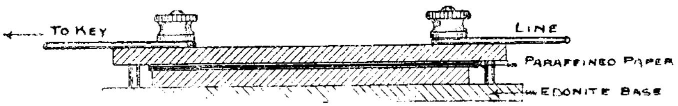
to the pole and the other end to a log of wood about 3 feet long buried in the ground, the hole being undercut to take the log (*see*

Fig. 202). In some cases it may be more convenient to employ a strut to support the pole. At every 300 or 400 yards a pole should be stayed on both sides in the direction of the line—this prevents poles being pulled down should the line wire break. Spans should be 60 to 80 yards, according to the country and the wire used.

Lightning Protectors.

Wherever the line wire is led into a building a lightning protector or guard should be inserted; this can easily be made of two sheets of brass about 6 inches by 4, separated by a piece of thin mica or paraffined paper, the line wire being secured to the upper plate as shown (Fig. 203); the lower plate should be well

Fig. 203.



earthed. Both plates should be clamped on to an ebonite base, care being taken that no connection is established between the two. It is also well in countries subjected to thunderstorms to connect the spindle of the insulator *on each pole* to earth, as this forms a lightning conductor, and also avoids disturbances in the line due to electric storms, &c.

Earth Plates.

Earth Plates.—Earth plates are generally made of galvanised iron about 3 feet square, and are, if possible, buried vertically at a sufficient depth to ensure the soil being always moist. An insulated wire should be soldered to the earth plate, the joint being well covered with varnish.

Water and gas pipes of iron, or a coil of wire, will also form good earth plates.

For temporary lines, an iron pipe with a solid pointed end is useful; the pipe should have holes drilled through it, and should be forced into the ground. If the soil is dry, water poured into the pipe will lower the resistance of the "earth."

Submarine Telegraphy.

A special slide used to be supplied with Sullivan's galvanometer for use in connection with submarine telegraphy, the idea being that a ship that wished to get into communication with a shore cable station should grapple the cable at sea, weigh and cut it, dropping it again when she had sent her message. It is considered, however, that in view of the development of wireless telegraphy, it would never be worth while to spend time over this, and the gear is consequently no longer supplied.

CHAPTER XXII.

Electrical Measurements.

The following chapter deals with the theory of a few of the practical measurements which are likely to be of use on board ship.

To perform the different operations, a knowledge of manipulating and joining up electrical circuits is required, which can only be learned from practice.

Since in most of such determinations the Wheatstone bridge is used, and nearly all deal with currents that divide through two or more circuits joined in parallel, it will be advisable to call attention to some simple laws, commonly known as Kirchoff's laws.

Kirchoff's Laws.

(1) states that if a current divides at a point, the algebraic sum of the two resulting currents is equal in amount to the original current.

The truth of this is obvious.

(2) states that when there are several E.M.F.'s acting at different points of a circuit, the total E.M.F. round the whole circuit is equal to the sum of the resistances of its separate parts multiplied each into the strength of the current that flows through it.

This is merely another way of stating that Ohm's Law can be applied to any part of a circuit that has current flowing in it, and that the total E.M.F. in a circuit is equal to the sum of the E.M.F.'s in the separate parts that are in series with one another.

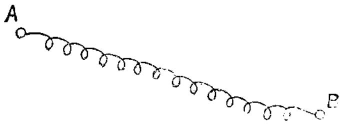
We have in previous chapters spoken of the actual measurement of current, voltage, and resistance, but have not hitherto shown how this is done, except is cases where instruments such as the ammeter and voltmeter could be employed. We will now proceed to describe a few methods by means of which such measurements can be made on board ship. Generally speaking, there are two broad classes of measurement, viz., absolute and by comparison. Absolute measurements, or those from which values of a current or voltage may be obtained from fundamental properties of matter and carefully calibrated instruments, are not practicable in sea-going ships, being more fitly undertaken in laboratories, but methods of comparison, although not so accurate, since they admit of errors in the comparing standard, are quite accurate enough for practical work, and are often exceedingly useful. These may be classed under three heads, viz., measurement of resistance, of current, and of voltage.

(I.) *The Measurement of Resistance.*

Principle of Wheatstone's Bridge.—Resistances of between $\frac{1}{10}$th of an ohm and 100,000 ohms may be conveniently measured by means of Wheatstone's bridge, a means of comparing an unknown resistance with a resistance of known value.

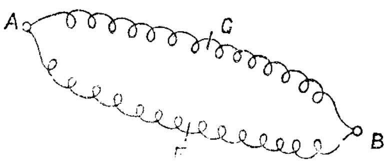
Suppose two points A, B, at different potentials, be joined by a wire offering a resistance, a current will flow in the wire,

FIG. 204.



and there will be a gradual fall of potential all along the wire between A and B. Now suppose A and B joined by two wires A F B and A G B:—

FIG. 205.



There is a certain D.P. between A and B, and therefore a gradual fall of potential along each wire, in each case equal in amount to the total D.P. between A and B.

Suppose now we fix upon some point F in A F B. Between A and F there will be a certain fall of potential due to the resistance A F. Suppose the fall to be 2 volts. Now there must be some point G in A G B where the fall of potential between A and G is also 2 volts, due to the resistance of A G.

Now if the fall from A to F is 2 volts and from A to G 2 volts, then F and G must be at the same potential, and a wire joining F and G will have no current flowing in it, since there is no D.P. between its two ends.

If F and G be at the same potential, a very convenient relation exists between the resistances of the wires A G; A F; G B; F B; namely, that—

$$\frac{\text{resistance of A G}}{\text{resistance of A F}} = \frac{\text{resistance of G B}}{\text{resistance of F B}}.$$

Proof of Theory of Wheatstone's Bridge.—This we will proceed to prove.

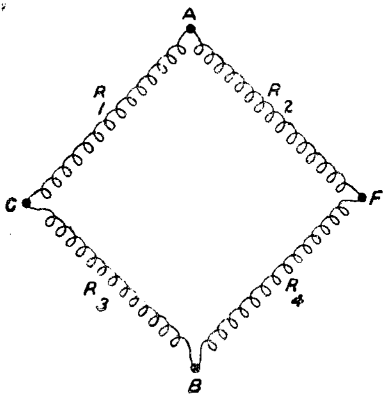
Suppose the fall of potential in A F and in A G to be E_1.

" " " F B and in G B to be E_2.

Let the resistances of A G, A F, G B, F B be R_1, R_2, R_3, and R_4 respectively.

Let C_1 be the current flowing in the wires A F and F B, and C_2 the current flowing in A G and G B.

FIG. 206.



Then by Ohm's Law the following is true—

$$\frac{E_1}{R_2} = C \text{ and } \frac{E_2}{R_4} = C_1.$$

Also

$$\frac{E_1}{R_1} = C_2 \text{ and } \frac{E_2}{R_3} = C_2.$$

Hence

$$\frac{E_1}{E_2} = \frac{R_2}{R_4} \text{ and } \frac{E_1}{E_2} = \frac{R_1}{R_3}$$

$$\text{or } \frac{R_2}{R_4} = \frac{R_1}{R_3} \text{ or } \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

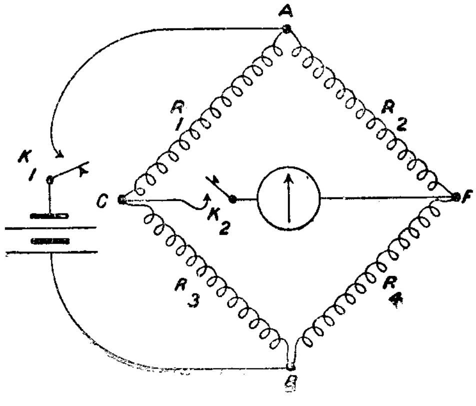
which is as before stated—

$$\frac{\text{resistance of A G}}{\text{resistance of A F}} = \frac{\text{resistance of G B}}{\text{resistance of F B}}.$$

Now from the above, if we know three of these resistances, we can easily calculate the fourth.

Wheatstone's Bridge.—Wheatstone's bridge consists of three resistances R_1, R_2, and R_3, arranged as shown in Fig. 207; the

FIG. 207.



points F and G are joined by a galvanometer and contact key, and the points A and B to the terminals of a battery and key.

Now suppose R_1, R_2, and R_3 to be known resistances, and R_4 to be unknown; then we may keep R_1 and R_2 constant, and alter R_3 until no current passes through the galvanometer when both the keys are pressed. When this is the case R_4 can be calculated from the formula $\frac{R_4}{R_3} = \frac{R_2}{R_1}$.

Arms of the Bridge.—In instruments used for balancing on this principle, it is customary to make the "arms of the bridge," as A F and A G are called, adjustable in multiples of 10; so that either A G or A F can be of 10, 100, or 1,000 ohms resistance.

Obtaining a Balance.—Now suppose that A F and A G are equal, that is to say, each 10, each 100, or each 1,000; then if we adjust R_3 until a "balance" is obtained, that is until the galvanometer needle ceases to deflect when the key is pressed, R_4 will be equal to R_3. If, however, we use "unequal arms," the value of R_3 when the balance is obtained will have to be multiplied or divided by 10 or 100 as the case may be.

A galvanometer is an especially suitable instrument for use in the wire G F, since it not only shows the presence of the current but indicates by the direction of its swing whether the current is flowing from G to F or from F to G. So that we can tell whether to increase or reduce the adjustable resistance R_3 accordingly.

If R is 10 or 100 times R_2 we must divide R_3 by 10 or 100 to obtain R_4; on the other hand, if R_2 is 10 or 100 times R_1, R_3 must be multiplied by 10 or 100 to obtain R_4.

The numbers 10, 100, and 1,000 are specially chosen for the arms because they are easy to multiply or divide by. Usually the resistance R_3 can be adjusted to any value between 1 ohm and 10,000 ohms, so that by using unequal arms a total range is obtained from one hundredth of an ohm to one million ohms.

Post Office Bridge.—Plate LXXIX. shows the two forms of bridge at present used in the Service.

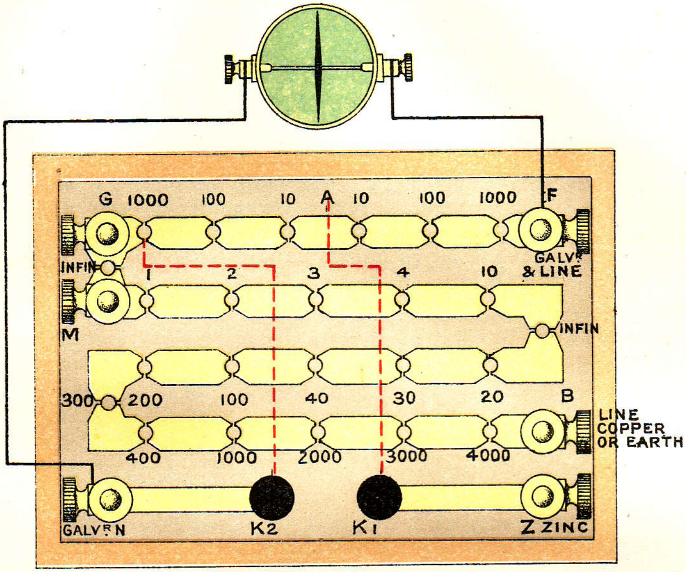
The Post Office bridge, which is now obsolescent, will be described first.

The plate shows the arrangement of the resistances and keys. A G, A F are the arms of the bridge, each capable of adjustment to 10, 100, or 1,000 ohms. From the junction of these two arms A, a permanent lead is taken to the key K_1, which is in connection with the terminal Z. The end of the left-hand arm is in connection with the resistance box by means of the plug L, which can be taken out and an extra resistance inserted between G and M should it be necessary; from G a permanent lead goes to the key K_2 in connection with the terminal N.

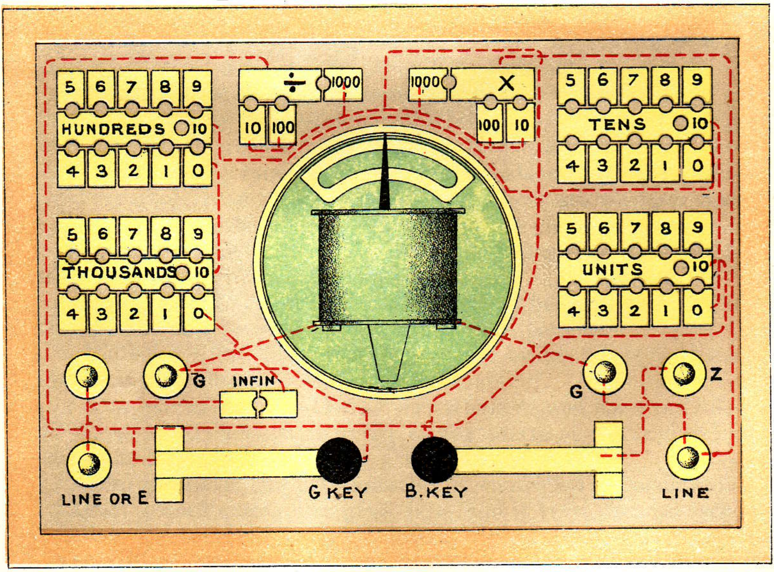
The end of the adjustable resistance has a terminal B, and the end of the right-hand arm a terminal F. The adjustable resistance is broken at the point I, the two parts being connected by a plug known as the "infinity plug."

Wheatstone's Post Office Bridge.

Scale 4" = 1 Foot.



Dial Bridge.



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All the resistance coils are wound "on the bight" as shown in Fig. 35, page 52, this prevents them from affecting the galvanometer needle by induction.

Referring to Fig. 207, it will be easy to see how to make the connection for balancing a resistance.

Insert the battery between the terminals Z and B, and the galvanometer between F and N, and the resistance to be balanced between F and B.

To commence to balance, take out equal resistances in the two arms A G, A F; these resistances should be as nearly as possible equal to the resistance that is being balanced. It is not always possible to arrange this at first, since the resistance being measured may be totally unknown, but as the balancing proceeds, the arms should be altered to get the best effect.

Noting the direction of Unplug.—Key 1 should be pressed, then Key 2, and the needle will be found to swing. Note the direction of swing, and call this the direction of *unplug*, for since none of the adjustable resistance has yet been unplugged the resistance under measurement must be greater than the adjustable resistance. Now take out the infinity plug. The needle should swing in the opposite direction, because the adjustable resistance is now infinity, and therefore nothing short of a very high resistance in the object being measured can produce a balance. Judging by the larger of the two "swings" in the previous cases, take out a trial resistance and see which way the needle swings, and plug up or unplug accordingly until a balance is obtained. When this is done adjust the arms to the most sensitive amount and obtain a close balance.

If no swing is obtained with the infinity plug out the resistance under measurement is very large or its circuit is broken. The connection of the leads, &c., may be verified by joining F B by a piece of wire, when a swing should be obtained.

If the needle swings the same way with the infinity plug out and also with no resistance out, the bridge is at fault; the plugs are not making good contact with the blocks, and in reality there is a resistance greater than that being balanced in the surface contact of plugs and blocks, or the connections are wrongly made. If the former is the case, carefully clean the plugs and plug holes with rouge. The brass blocks holding the plugs are undercut for this purpose.

Dial Bridge.—Siemens Dial Bridge.—This form of balancing bridge has now been adopted as the Service pattern.

Plate LXXIX. shows this form of dial bridge. It is so shaped as to be easily fitted in the naval test table.

The galvanometer, which is very sensitive, and has a resistance of about 1,000 ohms, is mounted on the centre of the bridge, and connected up as shown.

The needle of this galvanometer is controlled by means of a magnet placed across the glass face, and it may also be locked during transport by a special catch. When using the galvanometer it is necessary that the box should be level, and turned until the needle is at zero.

The dial is graduated to 40° on either side of zero, and a mirror placed under the needle assists the observer to greater accuracy in reading.

Advantage over the Post Office Bridge.—The resistances are put in by "plugging up" *one* hole in each set of blocks, thus doing away with the large number of plugs necessary in the old bridge, and so greatly minimising the chance of errors due to bad contacts in the plug holes.

Balancing with Sullivan's Galvanometer.

Connect the galvanometer and shunt, in place of the 1,000-ohm galvanometer. Insert the plug $\frac{1}{1000}$ first, to prevent too large a current passing through the instrument. If using a large battery insert a disconnector fuze in the battery lead as well. Then balance. If the mirror swings very violently alter the arms to make them less sensitive, and when an approximate balance has been obtained, make them again sensitive. As successive balances are obtained increase the current through the galvanometer by plugging successively the $\frac{1}{100}$, the $\frac{1}{10}$, and finally the $\frac{1}{1}$ plugs.

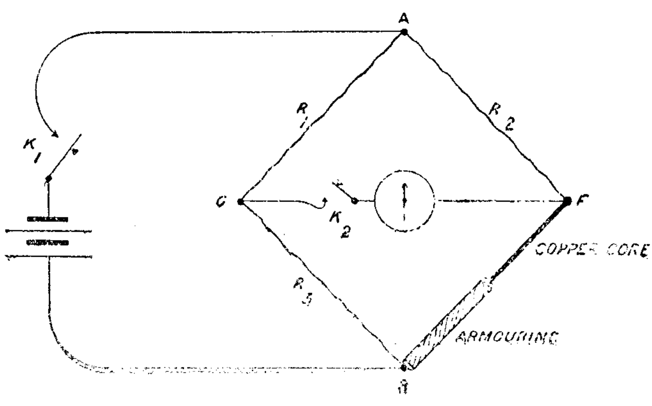
When the unknown resistance is very high the battery power may be increased, care being taken not to pass an excessive current through any of the coils. The resistances that can be measured with a single bridge lie between ·01 and 1,110,000 ohms. Should a lower resistance be required, join a firing resistance coil between G and M, unplug L, and vary the known resistance by the $\frac{1}{20}$ ohm coils of the firing resistance coil.

K_1 pressed before K_2.—The reason K_1 should be pressed before K_2 is to obviate the effects of self-induction in the circuits, which would give a spurious deflection of the galvanometer needle.

Balancing with a Sea Cell.

Sea Cell.—The *sea cell* is a term usually applied to the D.P. set up in the unknown resistance (R_4), when it consists of two different metals. In the case of a cable, these two metals are copper (in the core), and iron (the steel armouring), which, when acted upon by salt water, caused a current to flow from iron to copper inside the cell and from copper to iron outside the cell :—

Fig. 208.



The figure shows diagrammatically an armoured cable, joined up for balancing to a Wheatstone's bridge.

If K_2, the galvanometer key, is pressed, the current due to the "sea cell" will flow from F to G, or in the direction we should call "unplug" when balancing.

False zero.—This current, and consequently the swing of the needle, will gradually decrease owing to polarisation; and, in addition, the *false zero*—as the position of the needle with K_2 only pressed is termed—will alter with every adjustment of the resistance R_3.

If the battery is put on with zinc to *line* and copper to *earth* in the usual way, hydrogen will be evolved on the core and oxygen on the iron armouring, the former tending to keep the leak clean. This will lower the resistance of the cable (R_4) so long as the hydrogen can escape.

If, on the other hand, a positive current were sent to line instead, then salts of copper oxide would be formed on the copper, raising the resistance largely, and perhaps making a high resistance type of "fault," which it would be difficult to break down afterwards with the negative current. For this reason the Wheatstone's bridge is so arranged that negative is put to *line* and positive to *earth* when joined up as marked. In practice K_2 should be pressed first, and kept pressed whilst the galvanometer is allowed to steady itself to rest; if the deflection is large it may be reduced by means of a magnet. "Snap" contacts should then be made with K_1, and R_3 altered until the needle just "kicks" towards *plug*, and then swings back towards *unplug*. This will give the lowest reading, and consequently the true resistance of R_4.

"Salting up" a Leak.—When a very accurate result is required a reversing key may be connected to the battery terminals, and whilst balancing, the positive current occasionally put to *line* for at most a couple of seconds, to free the copper from the hydrogen collected on it, and yet not to allow time for the formation of a sufficient deposit of salts to "seal" the leak. The "balance," however, should be obtained with the negative current to *line* as marked on the bridge.

Measurement of Small Resistances.

Small resistances cannot be conveniently measured with a Post Office bridge, since small errors due to resistance of leads, contacts, plugs, &c., all tend to reduce the accuracy of the result. In such cases, where anything below $\frac{1}{10}$ ohm is to be balanced, and which at the same time will stand a fair sized current, the following method is advised. It is especially useful for balancing the armatures or series coils of dynamos and motors, or large earth plates.

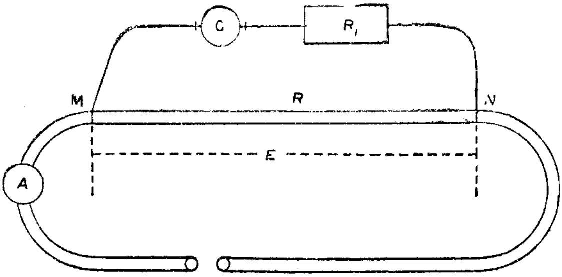
Any current C flowing through a resistance R produces a loss in D.P. of

$$E = C\,R \text{ volts.}$$

If, therefore, we can measure E and C, R may be calculated.

If a sufficiently delicate ammeter and voltmeter are available, the thing is simple; but if not, a galvanometer and resistance coil will have to be used in lieu. This may be done as follows (Fig. 209):—

FIG. 209.



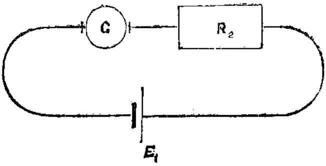
Suppose M R N the resistance to be measured. Pass a current of C amperes through it from a dynamo or some other source of D.P.; the current should be such as to produce a fall of roughly 2 volts in D.P. between M and N; adjust R_1 so that the needle of the 1,000-ohm galvanometer G deflects to 40°.

We then know that if C_1 be the current in the galvanometer circuit—

$$C_1 = \frac{E}{R_1 + G} \quad - \quad - \quad (1)$$

Now take away M R N and substitute a Menotti-Daniell cell; readjust R_1 till the deflection of 40° is again obtained; let this resistance be R_2. (*See* Fig. 210.) The current will now be the same as before.

FIG. 210.



$$\text{Then } C_1 = \frac{E_1}{G + R_2} \quad - \quad - \quad (2)$$

$$\text{From (1) and (2) we have } \frac{E}{R_1 + G} = \frac{E_1}{R_2 + G}$$

$$\text{or } E = E_1 \times \frac{R_1 + G}{R_2 + G}$$

The D.P. of the Daniell may be taken as 1 volt; R_1, G, and R_2 are all known; therefore E may be calculated. The original current C_1 in M R N can be read from the ammeter, and the unknown resistance R found from the equation—

$$R = \frac{E}{C}.$$

It is best to get the result (2) with more than one source of D.P., such as a Daniell, Menotti, or Grove cell; or any other source of low D.P., taking the mean of the results.

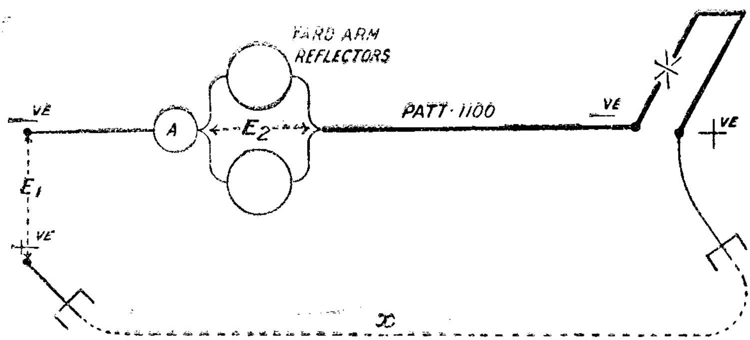
The larger the current employed the less will be the error due to a small mistake in the voltage.

It is well, therefore, to employ as large a current as the conductor to be balanced will stand, provided sufficient resistance is available for R_1 and R_2. The Sullivan galvanometer having a high resistance is especially suitable for this work, provided it can be suitably fixed up. The resistance in the galvanometer circuit is so large that resistances of leads, &c. may be neglected.

Measuring the Resistance of Searchlight Earth Plates.

(*See* Fig. 211.)

FIG. 211.



An accurate voltmeter is required. Join up the ammeter an two yardarm groups as shown in Fig. 211, and close the carbons of the projector, and put the switch to "on."

First, measure with a voltmeter the total D.P. E_1 between the mains when current C is flowing.

Second, measure the D.P. E_2 between the terminals of the yardarm group with the same current C flowing. Then the total D.P. E_1 must be equal to the sum of all the D.P.'s in the various parts of the circuit. That is, $E_1 = E_2 + (C \times \cdot 36) + x$. Where x is the D.P. of the earth return, and ·36 is the resistance of the searchlight cable in ohms.

Hence, $x = E_1 - E_2 - (C \times \cdot 36)$.

Measuring the Internal Resistance of Cells or Batteries.

If no cell tester is available a useful practical method is by fusing platinum silver wire.

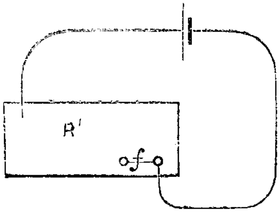
The method is based on the assumption that a definite length of P S wire requires a certain current to fuse it, in which case two parts will require double this current to fuse them, hence the P S wire takes the place of the galvanometer, and gives us a method of ascertaining when once, twice, three times, &c., a certain current is flowing in the circuit.

A "firing resistance coil" is required. This consists of a number of resistance coils in a box, connected to blocks as in the Post Office bridge. At one end of the row of blocks is a pair of clips between which one or more parts of P S wire can be held, and there are terminals so that the resistances and P S wire can be connected to an outside circuit. The resistances are normally short-circuited by plugs between the blocks, but can be put into the circuit by removing the plugs. There is a key between the P S wire and the end of the resistances.

Join up the battery to the firing resistance coil and insert one piece of P S wire, unplug a resistance, and gradually increase it till the wire just fuses. Call the final resistance through which the wire just fused R_1.

Then referring to Fig. 212.

FIG. 212.



If f be the resistance of the P S wire, r the internal resistance of the battery, E its D.P., and C the current, we get

$$C = \frac{E}{R_1 + r + f} \quad - \quad - \quad - \quad (1).$$

Now insert *two* pieces of P S wire and work as before, let R_2 be the resistance taken out so that they just fuse. The resistance of the two parts of P S wire will now be $\frac{f}{2}$, and since both parts have fused the current will be 2 C; we therefore get

$$2\,C = \frac{E}{R_2 + r + \frac{f}{2}} \quad - \quad - \quad - \quad (2)$$

or

$$\frac{2\,E}{R_1 + r + f} = \frac{E}{R_2 + r + \frac{f}{2}}$$

or

$$2\,R_2 + 2\,r + f = R_1 + r + f$$

or

$$r = R_1 - 2\,R_2$$

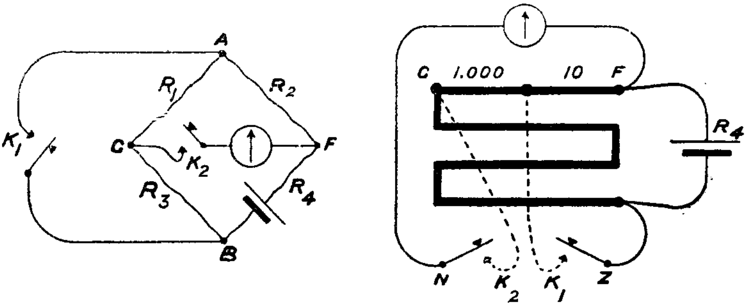
from which r can easily be calculated. The result shows that the trial resistance to be taken out for fusing two parts should be less than half the fusing resistance of one part when the internal resistance being measured is small.

Mance's Method.

This may be of use in finding the internal resistance of a constant cell, and is in fact a case of the problem of balancing a resistance containing a D.P., or in other words balancing a sea cell.

To join up to balance by this method, connect the cell to be balanced where the unknown resistance (x) is usually placed, remove the test battery and keep the key in circuit. Press key 2, bring the deflection of the galvanometer to 40°, and adjust the known resistance until pressing key 1 makes no difference in the galvanometer deflection.

FIG. 213.



Exactly the same ratio holds good as in ordinary balancing with a test battery in as well as the key, supposing 1,000 to 100 "arms" of the balance to be used, as in Fig. 213; if R_3 be the resistance unplugged and R_4 the internal resistance of the cell, then—

$$R_4 = \frac{R_3}{100}.$$

When this particular balance is obtained the galvanometer is unaffected by the test battery, so that the ratio still holds good if a test battery be inserted in the key circuit as well as a source of D.P. in the unknown resistance. The ordinary method of balancing a sea cell therefore holds good.

If preferred, the galvanometer may be inserted between B and Z, and a short lead joined between G and F, thus necessitating the use of K_1 only.

Cell Tester Method.—Much the quickest and easiest method of finding the internal resistance of a cell is, however, by means of a cell tester and low-reading voltmeter.

First take the voltage of the cell on open circuit, and call this E_1.

Then, keeping the voltmeter joined up across the terminals of the cell, join up the cell to a cell tester, and adjust the rheostat so that any convenient current C flows on pressing the key. Read the voltage when this current is flowing, and call this second voltage E_2.

The difference between these two readings, $E_1 - E_2$, will be the drop of voltage in the cell when the current C is flowing. This drop, by Ohm's Law, is equal to the current multiplied by the resistance of the cell.

If then R is the internal resistance of the cell, we have the equation $E_1 - E_2 = C\,R$, from which the value of R may be calculated.

Internal Resistance of Secondary Batteries.

As the internal resistance (x) of secondary batteries is very low and the D.P. very high, the best method is to determine the internal resistance by means of a voltmeter and an ammeter.

The method is similar to that described above.

Whilst Discharging.—Join up a suitable resistance, such as two yard-arm groups in parallel, and a switch to the cells; and connect a voltmeter between their terminals.

(i) Take readings of the voltmeter and ammeter when the current is flowing through this resistance, and call these readings E_1 and C respectively.

(ii) Switch off the current and take a fresh reading of the voltmeter; call this reading E.

Then $(E - E_1)$ will be the D.P. required to force the current C through the internal resistance (x) of the battery.

Therefore—

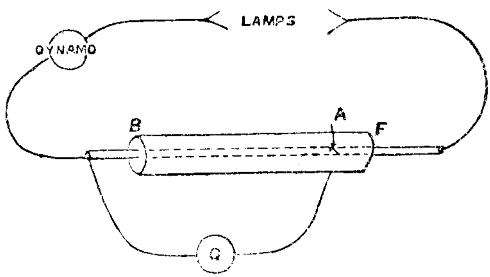
$$E - E_1 = Cx$$

$$\text{or, } x = \frac{E - E_1}{C}$$

Whilst Charging.—The internal resistance whilst charging may be similarly measured, since in this case an extra D.P. will be required at the battery terminals to force the current C through the cells.

To find the Place of Contact between Core and Lead Covering of a Cable with Reflecting Galvanometer.

FIG. 214.



Earth between Core and Sheathing of Lead-covered Cable.—Let A be position of contact, B and F the ends of the cable, G the reflecting galvanometer. Join lamps in circuit with wire and dynamo so as to get a current (*c*) up to the full capacity of the wire.

Join one wire from the galvanometer anywhere to the lead covering, which will be the same as if joined to A, since the resistance of the lead is small compared to that of the galvanometer.

Let r_1 = resistance, and E_1 = D.P. of core between A and B.
„ r_2 = „ „ E_2 = „ „ „ A „ F.

Then—

$$\frac{E_1}{E_2} = \frac{r_1}{r_2} = \frac{\text{length A B}}{\text{length A F}}.$$

Let D_1 be the deflection of galvanometer when joined between the lead covering and the core at B, and D_2 the deflection when joined between the lead covering and the core at F.

We have—

$$\frac{D_1}{D_2} = \frac{\text{length A B}}{\text{length A F}}.$$

Hence we can find the position of the leak.

Testing Cables for High Insulation.

High Insulation Testing.—All armoured mining, electric lighting, and telegraph cables in store should, at the annual inspection, be balanced for continuity and tested for high insulation, and a record kept in order that the best cables may be known, any failing detected, and, at foreign depôts, an indication as to the cables to be sent home obtained.

When cables are in good order the insulation of moderate lengths should be several hundred megohms.

The specified insulation resistance of Pattern 841 when new is 2,000 megohms per 1,000 yards at a pressure of 500 volts. This is too high a resistance to be balanced by the ordinary Post Office bridge and reflecting galvanometer when joined up as a Wheatstone's bridge, but resistances up to about 2,500 megohms may be measured, reading to one degree of scale, by the following method, if a supply of 100 volts is available:—

Set up the Sullivan's galvanometer and its shunt as described in Chapter V. Connect the source of electricity to the reversing key. Join up the bridge as shown (Fig. 215), connecting B to the galvanometer shunt and K_1 to the reversing key. K_2 is connected to the end of the cable in the cable tank.

The shunt is also joined to the reversing key through a No. 19 disconnector to prevent injury to the galvanometer through a wrong connection being made.

To take the test:—Put down one bar of reversing key—

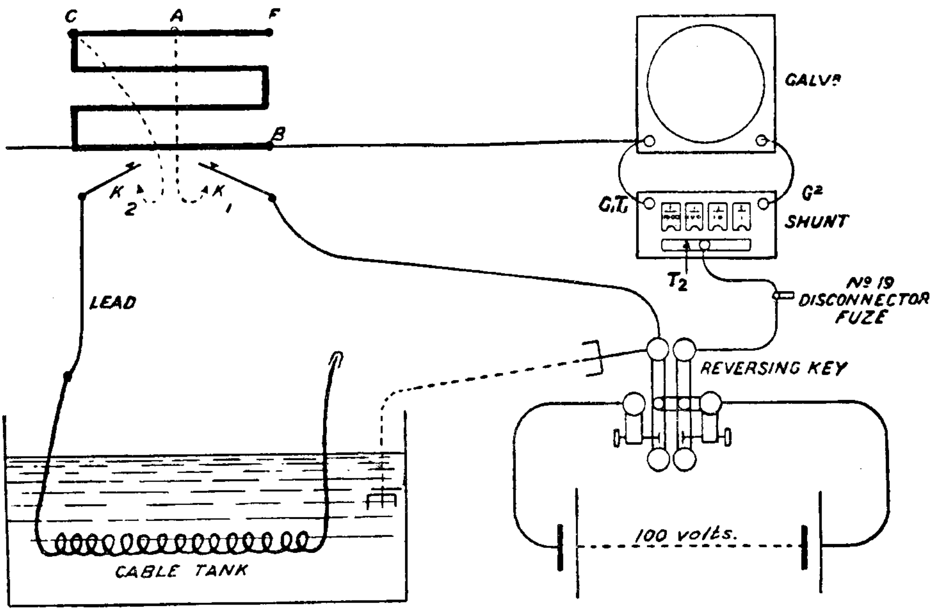
1st. Unplug 12,000 ohms in the body and left arm of the bridge. Plug the $\frac{1}{1000}$ shunt and press K_1. Note the deflection. Ease up K_1, and disconnect the lead from K_1 and join it to an earth plate in the cable tank. Otherwise if K_1 were accidentally pressed during the next operation, the excessive current would fire the disconnector fuze.

2nd. Plug up the 12,000 ohms in the bridge and press K_2. Note the deflection. If the deflection is too small, increase it by plugging the $\frac{1}{100}$, $\frac{1}{10}$, or $\frac{1}{1}$ shunt until a suitable deflection is obtained.

Reverse battery and repeat test. Take the means—

Then, if D_1 is the deflection with K_1 pressed,
D_2 ,, ,, ,, K_2 ,,
S ,, multiplying power of the shunt with K_2 pressed.

FIG. 215.



The insulation resistance of the cable $= \frac{12000 \times 1000 \times D_1}{D_2 \times S}$.

If it is desired to express the insulation resistance *per* 1,000 *yards* at 60° Fahrenheit, the expression becomes

$$\frac{12000 \times 1000 \times D_1 \times Y \times T}{D_2 \times S},$$

where Y is the length in thousands of yards, and T is the temperature coefficient taken from the following table:—

Temperature Coefficient.

Temperature in Degrees Fahrenheit.	Coefficient.	Temperature in Degrees Fahrenheit.	Coefficient.
°		°	
30	·4629	65	1·137
35	·5263	70	1·293
40	·5984	75	1·470
45	·6802	80	1·671
50	·7733	85	1·900
55	·8795	90	2·160
60	1·000		

The readings should always be taken when the key has been pressed for *one minute*, and with a sensitive galvanometer such as a Sullivan's, it will be found advantageous to arrange a key so that the galvanometer can be short-circuited until the cable is charged, as otherwise a violent swing may be experienced on K_2 being pressed, owing to the sudden rush of electricity through the galvanometer to charge the cable.

In the later pattern universal shunt a "short-circuit" block and plug is introduced for this purpose.

Precautions when Testing for High Insulation.—It is *most important* that the lead to the cable tank should be perfect for insulation; and that the ends of the cable should be thoroughly dry, clean, and well insulated, as the slightest damp will cause a leak and make the cable appear bad for insulation.

Before the lead is joined to the cable it is necessary that it should be tested for leakage. The lead being in place and the end cleaned a deflection is taken which should be deducted from the deflection D_2 taken when lead and cable are in circuit.

The ends of the cables should be triced up at least 2 feet above the surface of the water and always kept well insulated with paraffin wax or tape and solution; as otherwise moisture will condense on the ends and gradually creep along the conductor, seriously impairing the insulation resistance and causing the core to corrode and perish.

Examples.—Example I. With a Sullivan's galvanometer and a D.P. of 100 volts, on pressing K_1, the deflection D_1 with $\frac{1}{1000}$ shunt plugged, was 250 divisions. On pressing Key 2 and reducing the shunt to $\frac{1}{1}$ the deflection D_2 was two divisions.

$$\text{Insulation resistance of cable} = \frac{12000 \times 1000 \times 250}{2 \times 1}$$
$$= 6000 \times 1000 \times 250$$
$$= 1500000000 \text{ ohms.}$$
$$= 1500 \text{ megohms.}$$

Example II. D_1 was, as before, 250 divisions with the $\frac{1}{1000}$ plugged; D_2, with $\frac{1}{10}$ shunt plugged, was 50 divisions.

$$\text{Insulation resistance of cable} = \frac{12000 \times 1000 \times 250}{50 \times 10}$$
$$= 12000 \times 100 \times 5$$
$$= 6000000 \text{ ohms.}$$
$$= 6 \text{ megohms.}$$

Example III. In this case D_1 was 250 divisions with the $\frac{1}{1000}$ shunt plugged as before; and D_2, with the $\frac{1}{1000}$ shunt plugged, was 300 divisions.

$$\text{Insulation resistance of the cable} = \frac{12000 \times 1000 \times 250}{300 \times 1000}$$
$$= 40 \times 250$$
$$= 10000 \text{ ohms.}$$

When using the dial bridge the connections should be made as shown in Fig. 216, connecting terminal C to galvanometer shunt and Z to reversing key. See infinity plug in.

To take the test :—Clamp down one bar of reversing key.

1st. Plug up 12,000 ohms in the body and left arm of the bridge. Plug the $\frac{1}{1000}$ shunt and press B. key. Note deflection. Ease up B. key.

2nd. Disconnect the lead from terminal Z and join it to an earth plate in the cable tank, or if stowed dry to the armouring. Connect one end of the balancing lead to terminal G, see the lead carefully laid along and the other end well cleaned and insulated. Remove the plug from the left arm of the bridge, plug blocks marked O. Plug block of shunt marked "short-circuit" and press G. key (this charges the lead short of the galvanometer and the charge should be continued for one minute). After 15 or 20 seconds, remove the plug from the "short-circuit" block, and, moving the other plug into a suitable shunt, note the deflection at the end of one minute's electrification, and ease up G. key at the same instant.

Discharge the lead for two minutes. Reverse the battery and repeat the test. Take a mean of the two readings and this should be deducted from D_2 obtained when the lead and cable are in circuit.

3rd. Discharge the lead for two minutes and join the outer end to the cable to be tested, carefully insulating the junction. Repeat the previous operation with lead and cable in the circuit, being careful the cable is discharged before reversing the current to line.

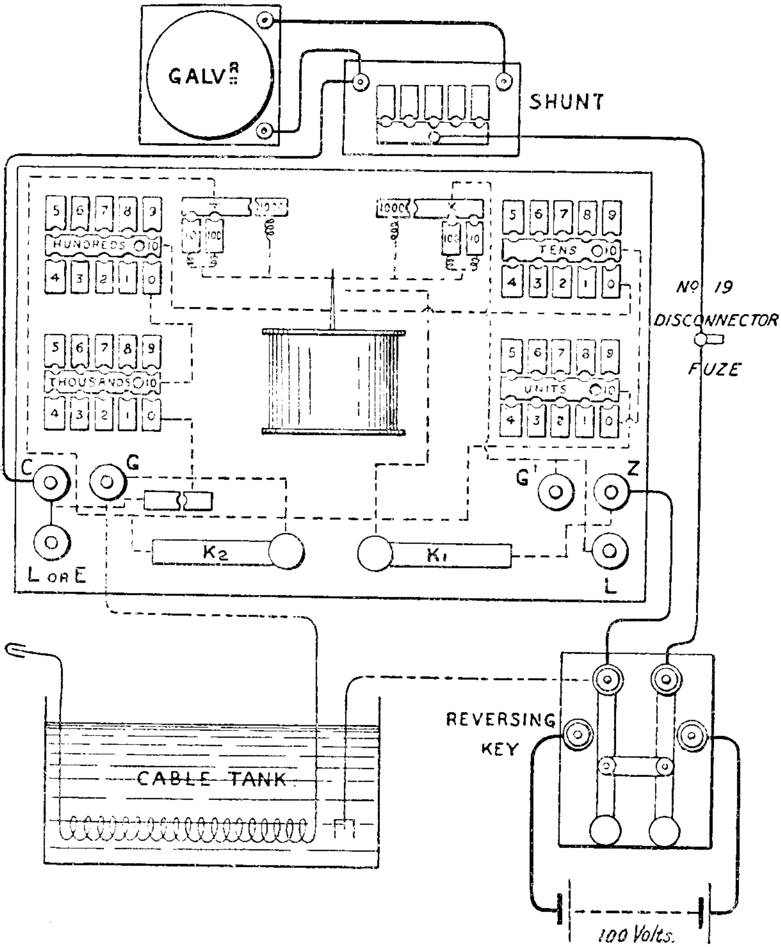
The final equation.

$$\text{Insulation resistance of cable} = \frac{12000 \times 1000 \times D_1}{D_2 \times S}$$ remains the same.

NOTE.—In taking deflections with — and + to line, they should be within 5 per cent. of each other if everything is correct.

Both plugs should not be out of the shunt at the same time.

FIG. 216.



Guard Wires.—It is of great importance when testing for insulation to prevent any leakage that will affect the galvanometer readings, and is not due to the state of the cable. The places at which this is most likely to occur are :—

(1) The testing leads.

(2) The instruments, such as keys, galvanometers, shunts, &c.

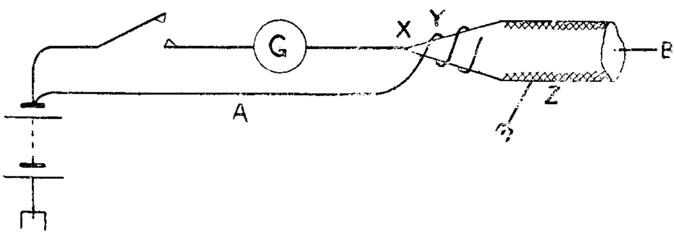
(3) The end of the cable laid bare for testing.

These errors can be eliminated by the use of "guard wires."

In Fig. 217, the bare copper wire A is the guard wire, the end of which is wound round the tapered portion of the insulation C, and clear of the core B of the cable under test. If X is the point where the insulation commences, Y the point where the guard wire is placed, and Z earthed, Y will always be at the same potential as the battery, Z being earthed there will probably be a certain amount of leakage between Y and Z. This current does not pass through the galvanometer, and is too small to affect the battery voltage. On the key being pressed to take the galvanometer readings, the point X is raised to practically the same potential as the point Y, therefore there is no tendency for leakage between X and Y. Thus the current passing through the galvanometer is a true measure of the insulation resistance between the core B and earth, all leakage current passing to earth through the guard wire A.

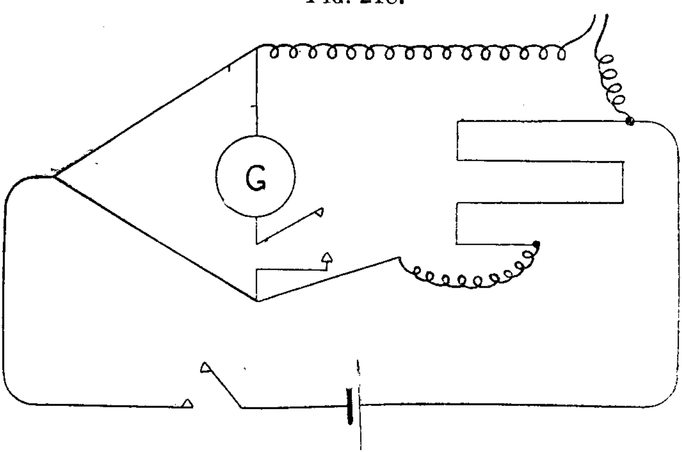
In practice the guard wire is taken from the battery, wound round the ebonite stands of all the instruments, and finally round the tapered portion of the insulation of the cable, thus preventing leakage from the instruments and the exposed end of the insulation.

FIG. 217.



Balancing for Continuity Resistance.—When it is required to balance more than one cable for continuity resistance, it is usually convenient to use the same leads. Much time will be saved by using the following method of eliminating the resistance of the leads. *See* Fig. 218.

FIG. 218.



Join the testing leads together, to the bridge. Plug up R to zero, and balance the leads by means of the F R coil. When testing the cable, leave the F R coil in the circuit as shown, and the actual resistance of the cable is obtained from R. It is obvious that the arms of the bridge must be the same when balancing the leads as when testing the cable.

Variation in Length of Core of Multiple Cable.—When balancing the continuity resistance of 7 and 4 core cables, it must be remembered that, with the exception of the centre core of the 7 core, the length of the cores is 1,015 yards to every 1,000 yards of cable. The continuity resistance now shown on the labels attached to the cable when passed into the Service are for the actual lengths of core on the drums, corrected to 60° F., and the insulation resistances are for the actual lengths on the drums at 60° F., after one minute's electrification with $-^{ve}$ to line. With multiple cables the mean continuity and insulation resistance of the number of cores is shown.

Statical Charge developed in Cables.—It has been found that cables coiled on drums, although unused for long periods, develop a statical charge. Before testing, therefore, the core and armouring should be joined together, or the core earthed for a few seconds.

Precautions to be observed in Testing for High Insulation.—(i) The voltage used in testing for high insulation is to be 100 volts, and the batteries used for testing are not to be used for any other purpose.

(ii) The readings are to be taken after one minute of electrification; *i.e.*, when K_2 has been pressed for one minute.

(iii) The galvanometer should always be short-circuited until the cable is charged (about 15 to 20 seconds), as otherwise a violent swing is experienced on K_2 being pressed.

(iv) Should the cable be put in water for testing, it should remain immersed for at least 24 hours before the test is taken.

(v) All cables with a lower resistance than 100,000 ohms should be balanced by Wheatstone's bridge in the ordinary way.

(vi) The $+^{ve}$ and $-^{ve}$ current should both be sent to line in turn, and the mean of the two deflections taken.

Before applying the $+^{ve}$ current, it is most important to ensure the dis-electrification of the cable. For this purpose the core of the cable should be earthed for at least two minutes before a current of the opposite sign to that used in the first test is applied.

It should be clearly understood that for complete dis-electrification a period of forty-five minutes should be allowed, but this is unnecessarily long for practical purposes. In high insulation testing, when it is necessary to discharge either leads or cable a period of two minutes is allowed.

(vii) All instruments and batteries used should stand on india-rubber sheathing, the outer covering of the leads should be stripped back for 6 inches and all tape carefully removed from the insulation.

The guard wire described on previous page should be used.

(viii) The cable ends should have their armouring turned back about one foot, all tape removed from the insulation, and the core then cut back for about 3 inches to ensure any moisture which might have crept along the conductor being removed.

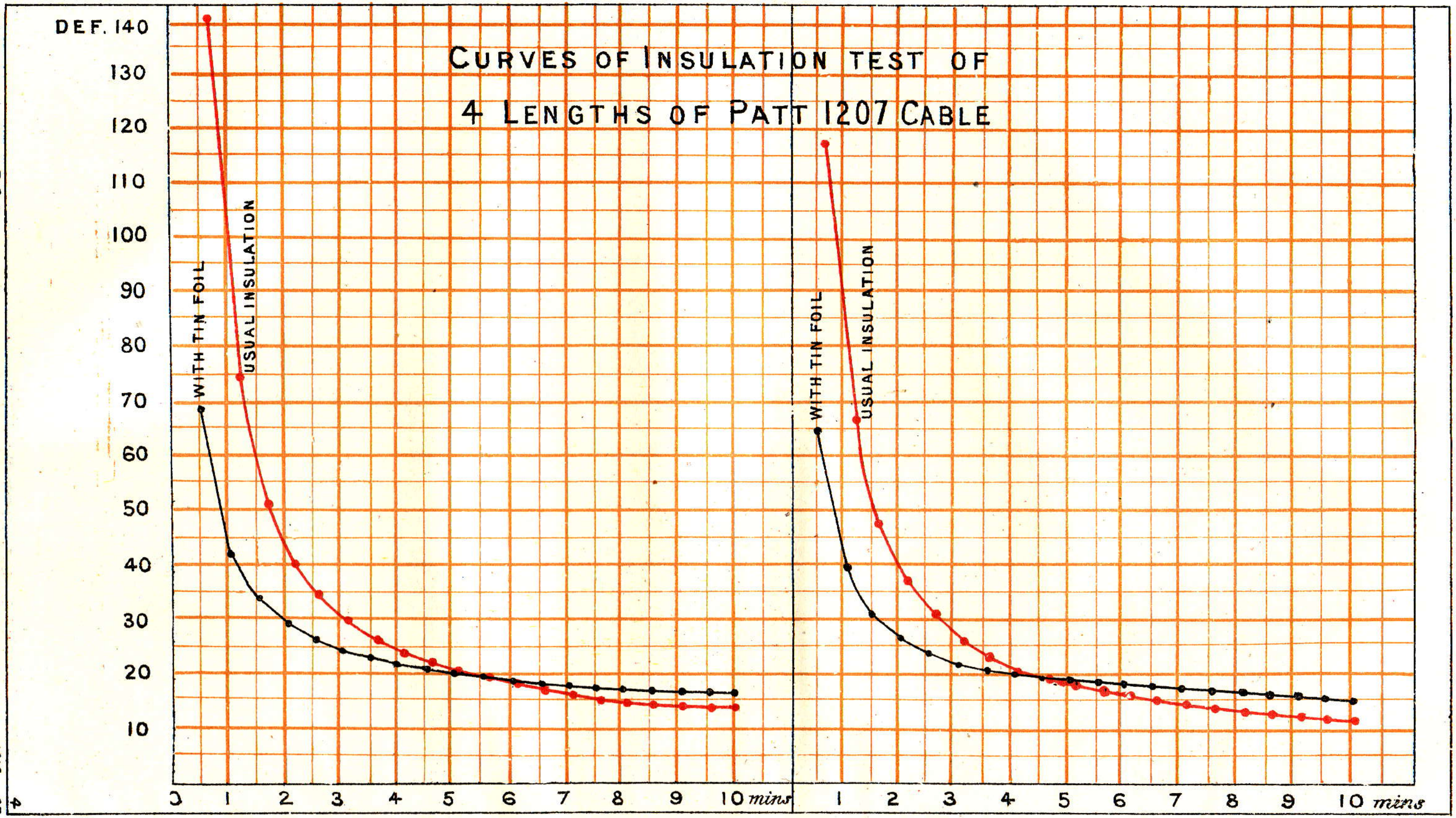
(ix) The spot of light will sometimes "creep" on the scale on plugging the $\frac{1}{1}$ shunt before K_2 is pressed. If this should happen remove the cover of the galvanometer and carefully wipe the ebonite stand. If the instruments are not insulated, *see* (vii); this creeping of the spot will frequently occur.

The foregoing instructions are to be observed at all annual inspections of electrical stores, and the report made out as shown on the form:—

REPORT OF EXAMINATION AND TEST OF ARMOURED CABLES AT:

Pattern No.	Quantity.	No. of Drum.	Manufactured by	C.P. and Date of Contract.	Resistance.		Voltage used at Test.	Temperature.	Electrification.	Condition of			How stored. Wet or Dry.	Date received.	Date tested.	Remarks.
					Continuity.	Insulation.				Core.	Armouring.	Outer Covering.				

To face page 395.



Weller & Graham, Ltd Litho, London 1515 07.

The curves given on Plate LXXX. show the necessity, firstly, for an appreciable time being given for electrification; and, secondly, the necessity for always taking the galvanometer readings after exactly the same interval has elapsed when testing by the comparison method.

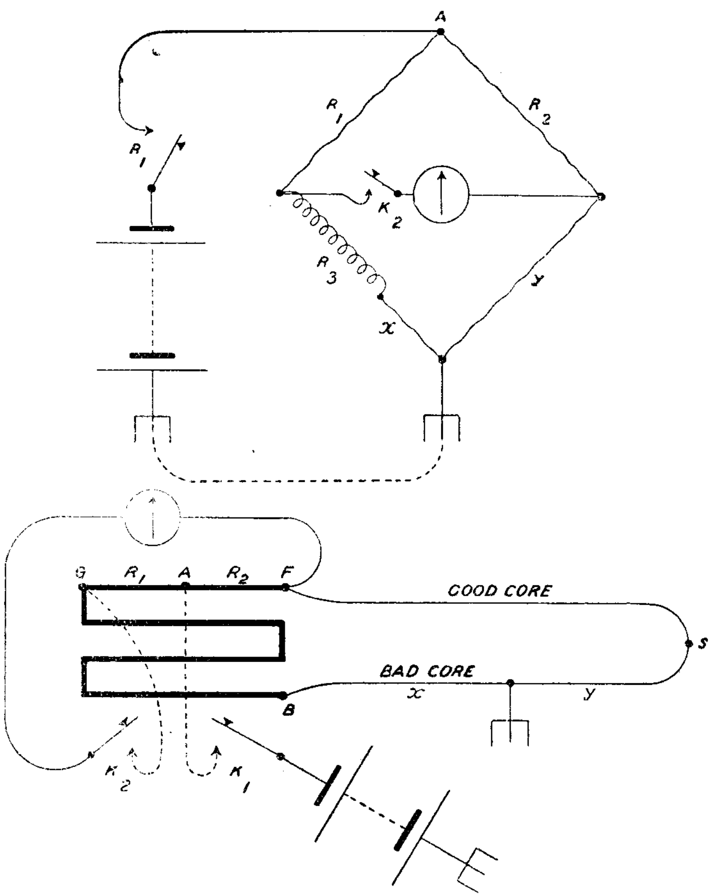
The curves are taken from the tests of four lengths of Pattern 1207 cable, two being of the usual type, and the other two being an experimental cable with a layer of tinfoil underneath the tape.

The galvanometer deflections are plotted for every half minute during the ten minutes' electrification, and it will be seen that the curves are still falling slowly at the end of the ten minutes, showing that electrification is not complete even after this interval.

Locating Faults in Cables.

Varley's Loop Test.—This test can be used to locate a fault in a cable either by bringing both its ends, if practicable, to one

FIG. 219.



testing station ; or, if the cable is laid out, it can be used, if there is another sound core or cable available, to join to the far end of the faulty cable.

In the first case the two cable ends would be joined respectively to F and B of the bridge.

Fig. 219 shows an example of the second case, F S being the good core and B S the bad one, whose leak it is required to locate, the far ends of the two cores being joined together at S.

Let x be the continuity resistance from B to the fault.

" y " " " F "

" L " " of the whole loop. Found by previous balancing if unknown.

Adjust R_3 until a balance is obtained :

Then, $\frac{R_1}{R_2} = \frac{R_3 + x}{y} = \frac{R_3 + x}{L - x}$.

Hence x can be found, which locates the fault in the cable.

An earth fault of high resistance requires strong battery power, since the leak forms part of the battery circuit.

Remember that a positive current seals the leak and raises its resistance by the deposit of copper oxides. A negative current cleans the leak, and then afterwards begins to increase its resistance by polarisation, due to hydrogen being occluded on the copper. Therefore when balancing, a positive current should be first put to line for about 2 seconds, to free the leak of hydrogen, and then the current should be reversed, and the true result obtained just before the resistance begins to increase, due to polarisation.

Earth Overlap.—Supposing both ends of a faulty cable can be balanced, this method will locate the fault. It is important that the same testing conditions, *i.e.*, battery power, proportion of "arms" of the bridge, &c., should be used at each end.

Balance from A with B "earthed."

$$r_1 = x + \frac{y z}{y + z} \qquad \text{(i)}$$

Balance from B with A "earthed."

$$r_2 = y + \frac{x z}{x + z} \qquad \text{(ii)}$$

Let L be the resistance of the line.

$$\text{Hence : } x = \frac{r_1 (L - r_2)}{r_1 - r_2} \times \left(1 - \sqrt{\frac{r_2 (L - r_1)}{r_1 (L - r_2)}}\right) \qquad (\alpha)$$

$$\text{Similarly } y = \frac{r_2 (L - r_1)}{r_2 - r_1} \times \left(1 - \sqrt{\frac{r_1 (L - r_2)}{r_2 (L - r_1)}}\right) \qquad (\beta)$$

The readings r_1 and r_2 will probably differ considerably ; the end nearest the fault giving the lowest reading.

At this end add a resistance r_3 equal to the difference between r_1 and r_2, and balance from both ends again.

The readings r_1 and r_2 will be nearer but perhaps still unequal. Increase or decrease the added resistance r_3 by the difference of the two second readings, and repeat this process until, when balancing, r_1 and r_2 become equal. The additional resistance r_3 has placed the fault electrically in the centre of the line.

Call this final resistance R, and suppose it added at A we have:

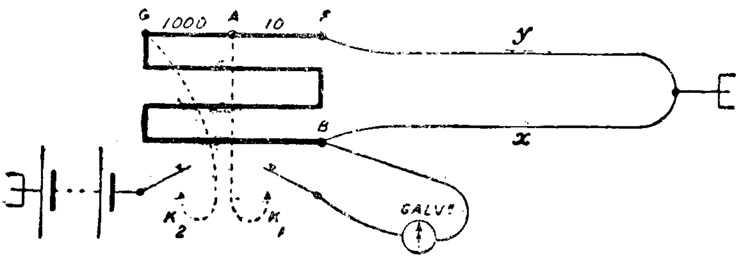
$$R + x = y = L - x;$$

$$\text{or } x = \frac{L - R}{2}.$$

This saves working out the long equations α and β.

For finding high-resistance faults in short lengths of cable, the following method of joining up will be found useful:—

Fig. 220.



Let r_1, r_2, r_3 be the resistances unplugged when a balance is obtained in the three following cases respectively:—

First: When joined up as in figure we have—

$$\frac{x}{10 + y} = \frac{r_1}{1000} \quad - \quad - \quad \text{(i)}$$

Second: Reverse the ends of the cable at B and F, and balance again, we get—

$$\frac{y}{10 + x} = \frac{r_2}{1000} \quad - \quad - \quad \text{(ii)}$$

Third: Disconnect the battery from earth, and join its positive pole to F, we get—

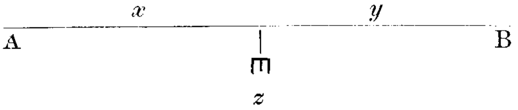
$$\frac{x + y}{10} = \frac{r_3}{1000} \quad - \quad - \quad \text{(iii)}$$

From (i) and (ii) the position of the earth may be located, and (iii) may be used to check the result.

Blavier's Test.—Suppose only one end of the cable is accessible and no loop line is available, and that signals can be made as to what is to be done with the distant end.

Suppose A B in figure 221 represents the cable, and E the leak :—

FIG. 221.



Let x = continuity resistance of A E.
y = ,, ,, E B.
z = resistance of the leak.

Join up a bridge and galvanometer to A, and let r_1 and r_2 be the resistances unplugged in the two following cases, when a balance is obtained :—

First.—Balance with B insulated, $r_1 = x + z$.

Second.—Balance with B to earth, $r_2 = x + \frac{y z}{y + z}$.

Let the resistance of the line be $L = x + y$.

Then $x = r_2 - \sqrt{(r_1 - r_2)(L - r_2)}$

and $z = r_1 - r_2 + \sqrt{(r_1 - r_2)(L - r_2)}$.

From which x and z can be calculated.

This method is not of much value with short lines and high resistance earth leaks, but it is used for long telegraph cables.

The Bridge-Megger.

An instrument known as the bridge-megger has been supplied to ships lately completed in place of the dial bridge, six-cell test battery, and Sullivan's galvanometer. It can be used either as a megger, for measuring directly resistances between 1,000 ohms and 20 megohms, or, in conjunction with a resistance box, for all operations in which a Wheatstone's bridge was formerly used for balancing.

The galvanometer is of special construction, and consists of an astatic needle pivoted in the middle of two coils wound at right angles to one another. One of these coils is called the "pressure coil" and the other the "current coil," for reasons that will appear later.

The instrument contains two small direct-current generators, driven by gearing from a handle at the side of the box.

On the front of the box are two terminals, called the megger terminals, and marked "line" and "earth" respectively. On the end, opposite to that where the handle for driving the generator is, are four terminals, called the bridge terminals, two of which are marked "To resistance box," while the other two are marked "To resistance under test."

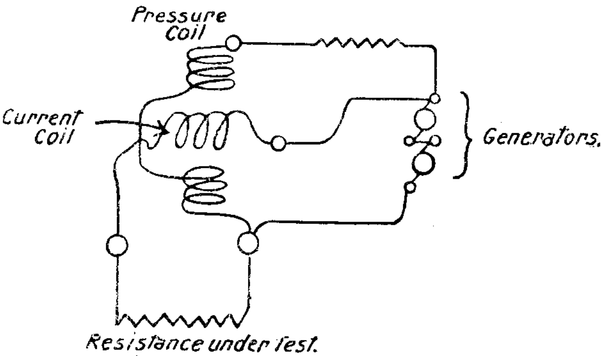
On the top of the box, besides the window through which the pointer of the galvanometer is seen, are two switches, called the "change-over" switch and the "ratio" switch. The change-over switch has two positions, one marked "megger" and the other marked "bridge." The ratio switch is marked on the handle "X = R ÷ " and has three positions, marked 1, 10, and 100 respectively.

The resistance box supplied with the bridge-megger contains two terminals and four switches. The switches are marked "thousands," "hundreds," "tens," and "units" respectively, and each has ten positions. In each position of each switch a number, from 0 to 9, shows through a hole beside the switch.

To use the instrument as a megger, for measuring high resistances, the change-over switch is put to "megger," and the resistance to be measured is joined up between the "megger" terminals.

With the change-over switch at "megger," the generators are put in series, and the internal connections are as shown in Fig. 222.

Fig. 222.



For the sake of clearness, the pressure coil is shown in two halves, one on each side of the current coil.

It will be seen that the pressure coil is connected directly across the generators, in series with a resistance inside the box, while the current coil is connected in series with the unknown resistance across the generators. The resistance in series with the pressure coil is merely to prevent too much current from passing through it.

If now the resistance under test is infinity, when the generators are hove round by the handle there will be no current in the current coil, but there will be a current in the pressure coil. The needle will consequently set itself in line with the axis of the pressure coil, and in this position the pointer will be at the end of the scale marked "infinity."

If the resistance under test is under 1,000 ohms, there will be so much current in the current coil that the needle will set itself in line with the axis of the current coil, and in that position the pointer will be at the other end of the scale.

If the value of the resistance under test is somewhere between these two, the needle will take up an intermediate position, and the value of the unknown resistance can be read directly from the position of the pointer on the dial.

In order that the generators may give a constant voltage, the handle is arranged to drive them through a friction clutch. This clutch slips when the generators are revolving at a speed that corresponds to 100 revolutions per minute of the handle, so that they cannot be driven above this speed. In order to get a constant voltage, therefore, it is only necessary to increase the speed of the handle until the clutch is felt to slip, and at anything over this speed the speed of the generators will be constant.

If it is required to measure resistance under 10,000 ohms with greater accuracy than is possible with the instrument when used as a megger, it must be used as a bridge.

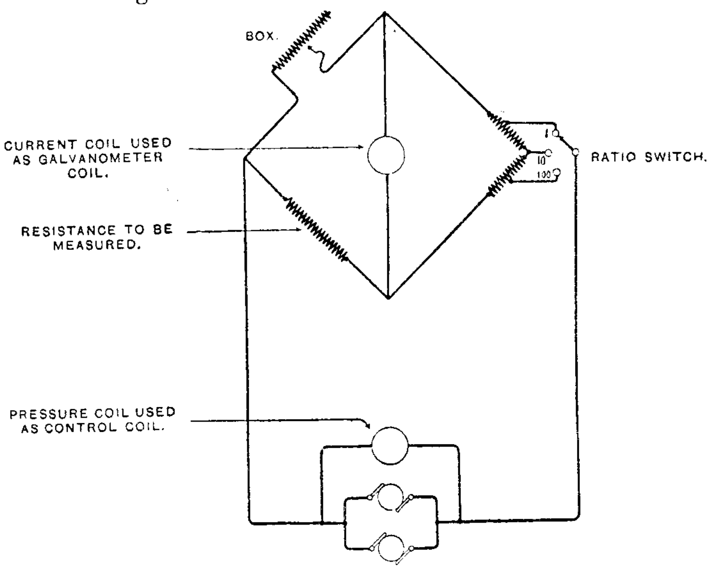
To do this, turn the change-over switch to "bridge," and connect the resistance box and unknown resistance to the terminals marked for them.

When the change-over switch is put to "bridge," the generators are put in parallel, and the internal connections are altered so that the generators take the place of the battery in a Wheatstone's bridge, while the current coil is joined up in the galvanometer position. The pressure coil still remains connected directly across the generators, while the resistance box and unknown resistance take the places of R_3 and R_4.

Fig. 223 shows this, and also the position of the ratio switch, which, it will be seen, alters R_1 and R_2.

FIG. 223.

Diagram of Circuits as used in Bridge Testing.



The pressure coil becomes the control coil, and, when a balance has been obtained and there is no current in the current coil, the needle will be in line with the axis of the pressure coil, and the pointer will be at the "infinity" end of the scale. This point is marked G.

If the resistance in the box is too large for a balance, the current in the current coil will be in one direction, while if it is too small, the current will be in the opposite direction. The pointer will therefore swing to one side or the other of G, according as the resistance in the box requires to be increased or decreased. On one side of the line G, therefore, is printed "Increase R," and on the other, "Decrease R."

The procedure in bridge testing is as follows:—

Set the ratio switch to 1, and all the resistance box dials to zero. Turn the generator handle slowly clockwise, so as not to send too much current through the current coil before a balance is obtained.

The needle will take up a position off the scale, and on the side of the line G, marked "Increase R."

While turning slowly with the right hand, with the left hand turn the "thousands" dial in the resistance box step by step until the needle crosses the line G and points to "Decrease R." Then turn the thousands dial back one step, and do the same with the hundreds dial.

Thus if the unknown resistance is between 3,000 and 4,000 ohms, the pointer will show "Increase R" when the dial is at 3,000, and "Decrease R" when it is at 4,000. The thousands dial is therefore put to 3, and the same procedure followed with the other dials in succession, until an exact balance is obtained.

When the pointer rests accurately on the line G, increase the generator to full speed, to secure maximum sensibility. The value of the unknown resistance is then read off directly from the figures in the resistance box.

If the resistance is found to be under 1,000 ohms, the ratio switch may be turned to 10, and the same operations gone through. The value of the unknown resistance is then the resistance read off from the box divided by 10.

The same thing can be done with the ratio switch at 100, and a still more accurate value obtained.

If it is required to measure a large resistance, over 10,000 ohms, by the bridge method, it may be done as follows:—

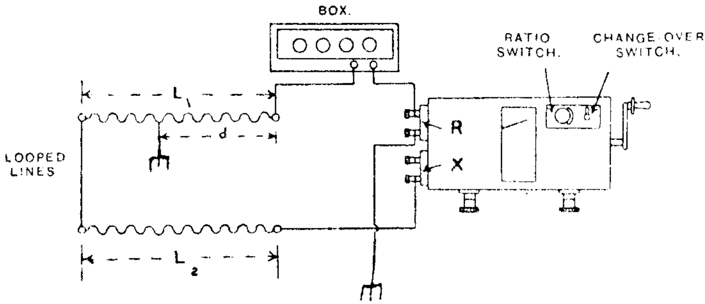
Change the positions of the unknown resistance and the box, joining each up to the terminals marked for the other.

The resistance of the unknown, when a balance is obtained, will then be equal to that shown in the resistance box multiplied by the number to which the ratio switch is pointing, instead of divided by it.

When measuring the resistance of field coils of dynamos and motors, and other circuits of large inductance, the generator must be driven at above the speed at which the clutch slips, in order to obtain a steady current.

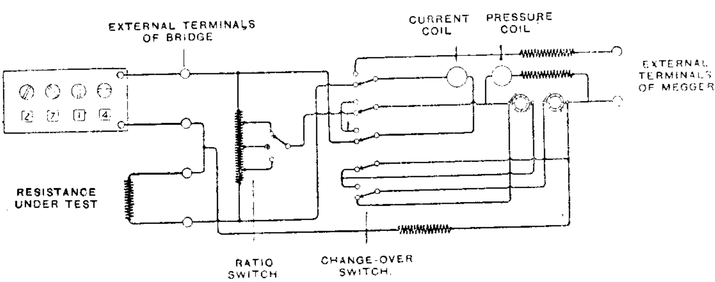
It will be seen that any balancing operation that can be carried out with a Wheatstone's bridge can also be done with a megger. A diagram of Varley's Loop Test with the megger is here given, in Fig. 224.

Fig. 224.



A diagram of the internal connections of the bridge-megger is given in Fig. 225. The change-over switch works five small two-way switches, which are here shown in the "bridge" position.

Fig. 225.



The instruments are supplied sealed by the makers, Messrs. Evershed and Vignoles, and, if the seals are unbroken, they undertake to make good, free of charge, any defect of workmanship or material discovered within five years from the date of purchase of the instruments.

It is as well, therefore, not to part the instruments if it can be avoided.

To find the Resistance of a Lightning Conductor and its Earth.

Gear required:—10-*cell battery*; *lead*, Pattern 600 (of sufficient length to go from deck to truck spindle): *two large earth plates* (with leads reaching from deck to the water); and a cell tester.

Let:—

r = internal resistance of the 10-cell battery.
L = resistance of long lead.
x = ,, ,, lightning conductor and its earth.
P = ,, ,, one large earth plate.
Q = ,, ,, the other large earth plate.

It is evident that, provided the same battery is used, whenever the ammeter of the cell tester shows the same current the total resistance in the circuit will always be the same.

Let R_1, R_2, R_3, and R_4, be the resistances respectively inserted in the rheostat of the cell tester to obtain the same reading on the ammeter in the four following cases:—

1st. Join battery and lead to cell tester:

Total resistance $= r + L + R_1$ - - (i)

2nd. Join battery, lead, cell tester, and both earth plates:

Total resistance $= r + L + R_2 + P + Q$ - (ii)

3rd. Join battery, lead, cell tester, lightning conductor, and P:

Total resistance $= r + L + R_3 + x + P$ - (iii)

4th. Join battery, lead, cell tester, lightning conductor, and Q:

Total resistance $= r + L + R_4 + x + Q$ - (iv)

The *total resistance* being the same in each case:—

$$\text{(i)} + \text{(ii)} = \text{(iii)} + \text{(iv)},$$

$$\text{or, } R_1 + R_2 = R_3 + R_4 + 2x.$$

Hence,—

$$x = \tfrac{1}{2}(R_1 + R_2 - R_3 - R_4).$$

In the 3rd and 4th cases, to join the long lead to the lightning conductor, one of the ends of the former will have to be taken up to the truck and a good connection made there with the metal spindle. Care must be taken not to polarise the battery.

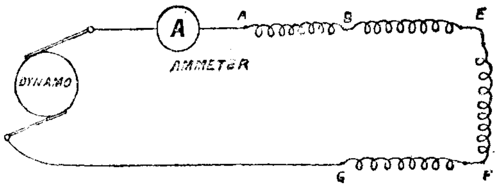
(II.) *The Measurement of Voltage or D.P.*

Measurement of D.P.—For large D.P.'s use the voltmeter as being by far the most accurate, as small inaccuracies in estimation of the D.P. of a standard cell form a considerable error when used to measure 80 or 100 volts. For instance, suppose the D.P. of the standard cell to be estimated ·1 volt wrong, and supposing by any comparison method the D.P. to be measured is found to be 80 times the D.P. of the cell. The D.P. to be measured will be wrongly estimated by 80 × ·1 or 8 volts. Unless a very accurate cell, such as a standard Clark cell, is available, the ordinary voltmeter is far preferable.

Cases, however, may arise in practice when the voltmeter itself after repair may require recalibrating. In such an event, it is necessary to have a ready and practical method of re-marking it which is sufficiently accurate for ordinary work, without resorting to laboratory refinements.

Recalibration of Voltmeters. — The dynamo on board run at its proper number of revolutions will, on open circuit, be a very good standard. If not exactly 80 volts it will be well known what the voltmeter under such circumstances used to show, and this can be used as the starting point for recalibrating. To get other readings, join up resistances in series with the machine as shown, Fig. 226. Four search light resistances will answer the purpose. Each having a resistance of ·2, the total will be ·8, and therefore a current of 100 amperes will be obtained. If only two are available split them so as to get two resistances of ·8 each, in which case $\frac{80}{1 \cdot 6}$ or 50 amperes will flow through them.

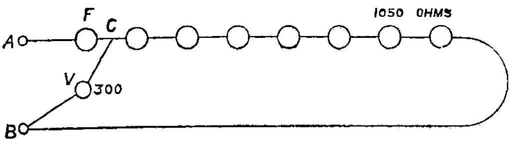
FIG. 226.



This gives 5 points, namely, A, B, E, F, and G, joined by equal resistances. The loss of voltage in each resistance is $100 \times \cdot 2 = 20$ volts. Join the voltmeter in succession between A B; B E; E F; F G; and mark the mean position of the needle 20 volts. Then join between A E; E G; and B F; and mark the mean position 40 volts. Then between A and F, B and G, and mark the mean position 60 volts, and graduate the intermediate position by measurement. A voltmeter, so calibrated, will be sufficiently accurate for all practical purposes. The resistances used should be very small compared to that of the voltmeter, otherwise the current flowing through the latter would render the results obtained untrue.

Fig. 227 shows a case in point. Eight 16 c.p. 80-volt lamps are joined between the terminals of a dynamo giving 80 volts. The resistance of each lamp will be about 150 ohms, and the D.P. in each lamp 10 volts.

FIG. 227.



When the voltmeter V, having, say, 300 ohms resistance, is joined up as shown in the figure, the fall of voltage in the lamp F will be altered.

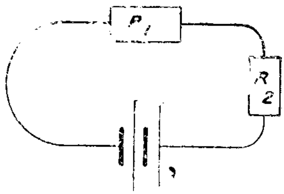
For the joint resistance between C and B will now be 233 ohms, and, therefore, the D.P. in F will be $\frac{150}{150+233} \times 80 = 31 \cdot 3$ volts.

Hence, we see that the resistance of the voltmeter must be large in comparison to the resistance used in the circuit, so as not appreciably to alter the current through F.

Poggendorf's Method.

To compare the D.P. of an inconstant cell with that of a constant one, Poggendorf's method is most suitable, since when near a balance no current flows through the inconstant cell, and therefore it does not polarise. The principle of the method is as follows. If a circuit be taken and resistances inserted, there will be a fall of potential from one pole of the battery to the other. Suppose Fig. 228 such a circuit, and the D.P. of the two constant cells at A to be E.

FIG. 228.

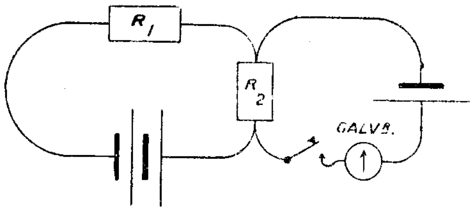


The relative value of the two resistances R_1 and R_2 can be adjusted so as to make the D.P. in R_2 of any value from E to zero.

Suppose E_1 to be the unknown D.P. of an inconstant cell.

Then, if we join up, as shown in Fig. 229, and adjust R_1 until the D.P. caused by E in R_2 is equal to the D.P. E_1.

FIG. 229.

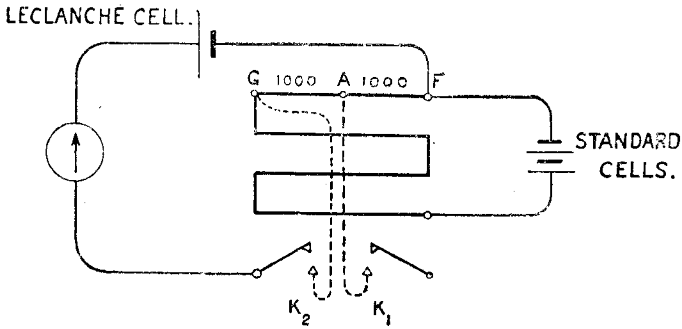


When this is the case no current will flow through the galvanometer G. Since the current C is flowing through the main circuit R_1, R_2 we have $E_1 = C \times R_2$.

Also that $$C = \frac{E}{R_1 + R_2},$$
since r, the internal resistance of the two constant cells, is so small compared with R_1 and R_2 that it may be neglected: hence,
$$E_1 = \frac{E}{R_1 + R_2} \times R_2.$$

Fig. 230 shows the post office bridge joined up to compare the D.P. of a Leclanché cell with that of two Daniells cells.

FIG. 230.



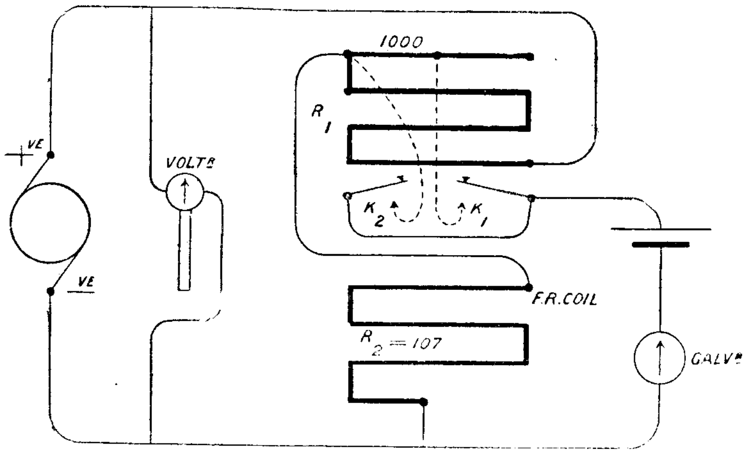
The two 1,000-ohm plugs in the arms are taken out to form the resistance R_2. A large resistance in the main body of the bridge should then also be taken out to form R_1, and reduced until a balance is obtained when key 2 is pressed.

Another Method of calibrating a Voltmeter.

An application of Poggendorf's method of comparing cells may be used for calibrating or checking a voltmeter.

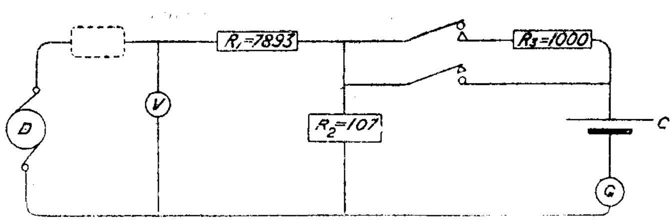
Join up the circuit as shown in Fig. 231.

FIG. 231.



The following is a diagrammatic view of the same circuit, and is clearer to follow :—

FIG. 232.



D is the dynamo. C is a standard cell. G is the galvanometer V the voltmeter to be calibrated. R_2 a resistance equal to 100 times the D.P. of the standard cell, in volts. R^1 a resistance arranged so that $R_1 + R_2$ is 100 times the voltage which the voltmeter is required to show. R_3 a resistance of 1,000 ohms as a precaution against sending an excessive current through the galvanometer circuit.

Suppose the standard cell in use to be a Standard Daniell, having a D.P. of 1·07 volts : and that it is required to mark the voltmeter for 80 volts :—

Unplug 107 ohms in R_2.
7,893 „ R_1.
1,000 „ R_3.

Alter the D.P. at the terminals of the voltmeter until there is no swing of the galvanometer needle, K_1 being pressed first, and K_2 when the needle is nearly steady.

The D.P. can be altered either by increasing or decreasing the revolutions of the dynamo, or by inserting a firing-resistance coil (or two in series, if available) next to the terminal of the dynamo (as shown by dotted line in Fig. 232), and unplugging resistances as necessary.

When the needle is steady there will be no current in the galvanometer circuit, and it is evident that the fall in potential in the main circuit, due to R_2, must be equal to the D.P. of the cell (1·07), that is to say, in the main circuit there is a fall of 1 volt for every 100 ohms, and therefore, at the terminals of the voltmeter there is a fall of 80 volts. The reading on the voltmeter may, therefore, be marked as 80 volts.

Proceed in a similar manner for 70, 60, &c., or any other reading, by altering R_1 to 6,893, 5,893, &c.

A good 1,000-ohm galvanometer is accurate, but a Sullivan galvanometer is more suitable, if available.

This method depends on the D.P. of the standard cell being accurately known. Any error in the computed D.P. of the cell will cause an error in the calibration of the voltmeter, in the same proportion as the D.P. of the cell is to the D.P. at the terminals of the voltmeter. Thus in the case quoted above, an error of ·05 in the D.P. of standard Daniell would produce an error of $\frac{80}{1 \cdot 07} \times \cdot 05$ or 3·7 volts in the reading of the voltmeter.

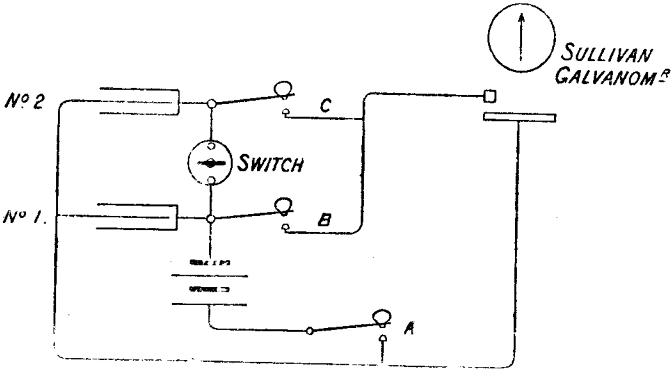
(III.) *The Measurement of Current.*

The ammeter is the only practical method of measuring a large current on board ship. Should it be required to recalibrate an ammeter, or rather to readjust it after repair, the best method is by comparison with another similar instrument. If none are available, then it may be roughly adjusted by placing it in series with fixed resistances of known value, such as search light resistances, and measuring the D.P. at the ends of the circuit; but owing to such resistances heating and altering their resistance, this method can only be looked on as approximate.

Small currents may be measured by means of a reflecting galvanometer. The deflection of this galvanometer will be proportional to the current flowing through it when the scale is at the proper distance from the mirror; and therefore if the "constant" of the galvanometer is known, the strength of the current will be obtained from the number of degrees of deflection and the multiplying power of the shunt used.

Comparing the Capacities of two Condensers.

FIG. 233.



Join up a Sullivan's galvanometer, a battery of three cells, three keys, one switch, and the two condensers whose capacity it is desired to compare, as shown in Fig. 233.

Switch on the switch S, press key A to charge both condensers, for a few seconds, then release key A and switch off S.

(1st.) Press key B and note deflection of Sullivan D^1.

(2nd.) „ C „ „ D.

Then—

$$\frac{\text{capacity of No. 1}}{\text{capacity of No. 2}} = \frac{D_1}{D_2}.$$

APPENDIX I.

VARIOUS INSULATORS AND THEIR USES.

Ambroin - -	Non-absorbent and not affected by heat, very tough; cannot be machined, must be moulded or pressed.
Asbestos - -	Absorbent, but useful where heating is likely to occur. Used for washers in inclined hand lamps.
Ebonite - - -	Neither pliable nor elastic, but brittle. Useful where it is unlikely to be subjected to strain. Used for the bushes of lamp fittings, and the base plates of instruments.
Glass - -	A good insulator, but brittle. Used for Leyden jars.
Glazeboard - -	Somewhat absorbent. Used for insulating the conductors in armature slots.
India-rubber -	Pliable and elastic, but will not stand much heat, and is therefore never used in dynamos. Largely used for cables.
India-rubber solution	Used in conjunction with india-rubber tape for making junctions. Should not be employed anywhere where heat is generated.
Linen - - -	Saturated with varnish, is used between the layers of the shunt windings of dynamos.
Mica - - -	In thin sheets is pliable and elastic; and will also stand compression and is non-absorbent. Used between commutator strips, under the binding bands of armatures, and in many other places where thin durable insulation is required.
Micanite - - -	Consists of thin sheets of mica stuck together with shellac, so as to form a fairly thick slab. If heated until the shellac softens, it can be bent into any desired form. Non-absorbent, and stands compression. It is used for insulating commutators of dynamos and motors. Its use is being largely extended in the Service, and it is now used in all places, such as section boxes, switches, &c, where it is suitable.
Oil - - -	Used in condensers, choking coils, transformers, and other Wireless Telegraphy instruments.

Parchment tape -	Strong but absorbent. Sometimes used as a covering for ring armature cores before winding.
Paraffin wax -	A very good insulator but easily melted. Soaked into sheets of paper, it is used to insulate the tin foil plates in condensers; also in many electrical instruments.
Porcelain - -	Non-absorbent but brittle. Used on shore in switches, &c., and also for the insulators of land telegraph wires. Used in the Service in the artifical resistances for searchlights.
Press-pahn - -	Very similar to glazeboard and is used in the same places; is somewhat absorbent.
Shellac - -	Used as a varnish on cotton covered wire or linen, which will not be subjected to friction.
Slate - - -	Easily worked but liable to split. Used for the bases of switch-boards, and in the older pattern section and distributor boxes.
Tape (cotton) -	Is absorbent. Used for junctions in electric light cables, and for insulating armature bars and end connections. It should always be well varnished.
Tape (silk) - -	The same as cotton tape, is more expensive but occupies less space.
Thread (cotton or silk).	Used for insulating the wires of magnet coils where fine insultation is required. The latter is lighter but more expensive.
Vulcanite - -	Similar to ebonite but not brittle, and is slightly absorbent. Used for the bases of contact blocks in dynamos, and the insulating flanges of magnets.
Vulcanised fibre - -	Pliable but not elastic, is slightly absorbent. Used for the bases and some other parts of the later pattern section and distributor boxes.
Willesden paper -	Is absorbent; used for coverings of armature cores or the insulation flanges of magnets. Should be well varnished over.
Wood - -	Can be used temporarily for the same purposes as slate or vulcanite when the latter are not procurable. Should be boiled in paraffin wax, or well varnished over, to prevent the absorption of moisture.

APPENDIX II.

Constants and Electrical Properties of various Substances.

Substance.	Specific Gravity.	Specific Resistance. Microhms at 0° C. per Cubic Centimetre.	Per Cent. Increase of Resistance per Degree C.
Silver, pure, annealed -	10·5	1·47	·400
Copper, pure, annealed -	8·91	1·56	·428
Gold, 99·9 per cent. pure -	19·3	2·04	·388
Aluminium, 99 per cent. pure.	2·6	2·56	·423
Aluminium, commercial, 97·5 per cent. pure.	2·6	2·67	·435
Cast copper - - -	—	4·65	—
Zinc, pure - - -	7·1	5·75	·406
„ compressed - -	7·1	5·8	·365
Platinum, annealed - -	21·2	8·98	·247
Iron, pure - - -	7·8	9·07	·625
Platinum, pure - -	21·2	11·0	·35
Nickel - - -	8·9	12·3	·62
Tin, pure - - -	7·3	13·1	·44
Wrought iron - -	7·8	13·8	—
Lead, pure - -	11·4	20·4	·411
Mercury - - -	13·6	94·3	·072
Manganin (Cu. 80·5 per cent., Mn. 16·5 per cent., Ni. 3 per cent.).	8·9	49·0	0
Distilled water (ordinary) -	—	7×10^{18}	—
Mica - - -	—	4×10^{18}	—
Glass (ordinary) - -	—	9×10^{18}	—
Paraffin wax, solid -	—	3000×10^{18}	—
Shellac - - -	—	1500×10^{18}	-
Vulcanised fibre, red -	—	10×10^{18}	—
Ebonite - - -	—	4000×10^{18}	—
Micanite - - -	—	2490×10^{18}	—
Wood (ordinary) - -	—	50×10^{18}	—
„ (paraffined) -	—	300×10^{18}	—
India-rubber - -	—	800×10^{18}	—
„ (high insulation).	—	1400×10^{18}	—
Asbestos (very variable) -	—	16×10^{16}	—
Press-pahn - -	—	11×10^{15}	—
Air - - - -	—	Practically infinite.	—

APPENDIX III.

Approximate Fuzing Currents of Wires.

Current in Ampères.	Tin Wire. Approximate L.S.G.	Lead Wire. Approximate L.S.G.	Copper Wire. Approximate L.S.G.	Iron Wire. Approximate L.S.G.
1	36	35	47	40
2	31	30	43	36
3	28	27	41	33
4	26	25	39	31
5	25	23	38	29
10	21	20	33	24
15	19	18	30	22
20	17	17	28	20·5
25	16	15	26	19
30	15	14	25	18·5
35	14·5	13·5	24	18
40	13·5	13	23	17
45	13	12	22	16·5
50	12·5	11·5	22	16
60	11	10	21	15
70	10	9·5	20	14
80	9·5	8·5	19	13·5
90	9	8	18·5	13
100	8·5	7	18	12
120	7	6	17·5	11
140	6	5	17	10
160	5	4	16	9·5
180	4	3	16	9
200	3·5	2	15	8
250	1·5	0	13·5	6·5

APPENDIX IV.

Wire Gauges.

There are three wire gauges in general use, to wit:—

(1) The Legal Standard Wire Gauge, impartially referred to as L.S.W.G., S.W.G., or L.S.G., the last named being the most usual denomination.

(2) The Birmingham Wire Gauge, referred to as B.W.G.

(3) Whitworth's Decimal Gauge, referred to as W.D.G.

The following table gives these three gauges side by side with the diameter in inches, area of cross section, and weight and resistance of a yard of copper wire of each size.

In the Whitworth Decimal Gauge each wire is called by a number that represents its diameter in thousandths of an inch, so that the size of a W.D.G. wire is immediately apparent from its denomination. Only those W.D.G. wires that correspond exactly to a wire in one of the other gauges have been inserted in the table, though several intermediate sizes exist.

The proper denomination of the first wire given in the table is 0000000 L.S.G., but, for the sake of brevity, this has been written 7/0. This applies also to all the wires of the Legal and Birmingham Gauges above size 0 B.W.G.

WIRE GAUGES.

L.S.G.	B.W.G.	W.D.G.	Diameter.	Area of Cross Section.	Per Yard of Copper Wire. Weight.	Per Yard of Copper Wire. Resistance.
			Inches.	Square Inches.	Lbs.	Ohms.
7/0	—	500	·5	·1963	2·27	·0001225
6/0	—	464	·464	·1691	1·955	·0001422
—	4/0	—	·454	·1619	1·872	·0001485
5/0	—	432	·432	·1466	1·695	·000164
—	3/0	425	·425	·1419	1·641	·0001694
4/0	—	400	·4	·1257	1·453	·0001913
—	2/0	—	·38	·1134	1·311	·000212
3/0	—	372	·372	·1087	1·257	·0002212
2/0	—	348	·348	·09511	1·099	·0002528
—	0	—	·34	·09079	1·05	·000265
0	—	324	·324	·08245	·9534	·0002917
1	1	300	·3	·07069	·8176	·0003402
—	2	—	·284	·06335	·7324	·0003795
2	—	276	·276	·05983	·6921	·0004019
—	3	—	·259	·05269	·6091	·0004563
3	—	252	·252	·04988	·5767	·0004821
—	4	—	·238	·04449	·5144	·0005403
4	—	232	·232	·04227	·4888	·0005688
—	5	220	·22	·03801	·4395	·0006325
5	—	212	·212	·0353	·4082	·0006813
—	6	—	·203	·03237	·3743	·0007427
6	—	192	·192	·02895	·3347	·0008307
—	7	180	·18	·02545	·2943	·0009446
7	—	176	·176	·02433	·2813	·0009881
—	8	165	·165	·02138	·2472	·001124
8	—	160	·16	·02011	·2325	·001195
—	9	—	·148	·0172	·1989	·001398
9	—	144	·144	·01629	·1884	·001476
—	10	—	·134	·0141	·163	·001705
10	—	128	·128	·01287	·1488	·001868
—	11	120	·12	·01131	·1308	·002126
11	—	116	·116	·01057	·1222	·002275
—	12	—	·109	·009331	·1079	·002576
12	—	104	·104	·008495	·09824	·002831
—	13	95	·095	·007088	·08193	·003392
13	—	92	·092	·006648	·07688	·003617
—	14	—	·083	·005411	·06256	·004443
14	—	80	·08	·005027	·05813	·004784
15	15	72	·072	·004072	·04709	·005904
—	16	65	·065	·003318	·03836	·007245
16	—	64	·064	·003217	·0372	·007478
—	17	—	·058	·002642	·03055	·009099
17	—	56	·056	·002462	·02848	·009762
—	18	—	·049	·001886	·0218	·01275
18	—	48	·048	·001810	·02093	·01328

L.S.G.	B.W.G.	W.D.G.	Diameter.	Area of Cross Section.	Per Yard of Copper Wire.	
					Weight.	Resistance.
			Inches.	Square Inches.	Lbs.	Ohms.
—	19	—	·042	001385	·01601	·01736
19	—	40	·04	·001257	·01453	·01913
20	—	36	·036	·001018	·01177	·02362
—	20	—	·035	·0009621	·01113	·02499
21	21	32	·032	·0008042	·009301	·0299
22	22	28	·028	·0006158	·00712	·03905
—	23	—	·025	·0004909	·005676	·04897
23	—	24	·024	·0004524	·005231	·05316
24	24	22	·022	·0003801	·004395	·06324
25	25	20	·02	·0003142	·003633	·07654
26	26	18	·018	·0002545	·002943	·09449
27	—	—	·0164	·0002112	·002442	·1139
—	27	16	·016	·0002011	·002325	·1195
28	—	—	·0148	·000172	·001989	·1398
—	28	14	·014	·0001539	·00178	·1562
29	—	—	·0136	·0001453	·00168	·1655
—	29	13	·013	·0001327	·001534	·1812
30	—	—	·0124	·0001208	·001397	·199
—	30	12	·012	·0001131	·001308	·2126
31	—	—	·0116	·0001057	·301222	·2275
32	—	—	·0108	·00009161	·001059	·2625
33	31	10	·01	·00007854	·000908	·3061
34	—	—	0092	·00006648	·0007688	·3617
—	32	9	·009	·00006362	·000735	·3878
35	—	—	·0084	·00005542	·0006409	·4339
—	33	8	·008	·00005027	·000581	·4775
36	—	—	·0076	·00004536	·0005245	·5301
—	34	7	·007	·00003848	·000445	·6245
37	—	—	·0068	·00003632	·00042	·662
38	—	6	·006	·00002827	·0003269	·8506
39	—	—	·0052	·00002124	·0002456	1·132
—	35	5	·005	·00001963	·000227	1·223
40	—	—	·0048	·0000181	·0002093	1·328
41	—	—	·0044	·00001521	·0001759	1·581
42	36	4	·004	·00001257	·0001453	1·913
43	—	—	·0036	·00001018	·0001177	2·362
44	—	—	·0032	·000008042	·00009301	2·99
45	—	—	·0028	·000006158	·0000712	3·905
46	—	—	·0024	·000004524	·00005231	5·316
47	—	2	·002	·000003141	·00003632	7·654
48	—	—	·0016	·000002011	·00002325	11·95
49	—	—	·0012	·000001131	·00001308	21·26
50	—	1	·001	·0000007854	·00000908	30·61

APPENDIX V.

Details Relating to Electric Light and Telegraph Cables.

A.—Lead-Covered Cables.

Pattern No.	No. of Wires.	Size of Wire, L.S.G.	Resistance per 1,000 Yards.	Service Current Capacity.	Insulation, Covering, &c.	Use and Remarks.
816A	114	14	·042	476	One layer pure rubber, one layer mixed rubber, waterproof tape, ozokerite compound, lead tube.	Power and lighting.
1746	91	14	·058	345	Ditto - - - - - -	
817A	75	14	·065	308	Ditto - - - - - - -	
818A	52	14	·094	213	Ditto - - - - - - -	
819A	48	16	·156	128	Ditto - - - - - -	
820A	80	20	·296	67	Ditto - - - - - - -	
821A	60	20	·394	51	Ditto - - - - - - -	
822A	30	20	·79	25	Ditto - - - - - - -	
823A	15	20	1·57	12·7	Ditto - - - - - - -	
824A	11	20	2·15	9·3	Ditto - - - - - - -	
825A	7	20	3·38	6	Ditto - - - - - -	
848A	7	22	5·57	3·6	Ditto - - - - - - -	
798A	1	16	7·48	2·7	Ditto - - - - - - -	
799A	1	19	19·1	1·05	Ditto - - - - - - -	
786A	1	16	7·48	2·7	Ditto - - - - - -	Twin core } Bells, telephones and dial instruments.
1334	1	16	7·48	2·7	Ditto - - - - - - -	3 core
785A	1	16	7·48	2·7	Ditto - - - - - - -	4 core

		Diam. Ins.				
241	127	·101	·0248	808	Ditto - - - - - - -	
242	91	·098	·0368	544	Ditto - - - - - - -	
243	61	·101	·0517	388	Ditto - - - - - - -	
244	37	·11	·0718	280	Ditto - - - - - - -	
245	37	·092	·1027	195	Ditto - - - - - - -	
246	37	·082	·1292	155	Ditto - - - - - - -	
		L.S.G.				
247	37	16	·1676	120	Ditto - - - - - - -	
248	19	14	·2642	76	Ditto - - - - - - -	Power and lighting.
249	19	16	·4129	48	Ditto - - - - - - -	
250	19	17	·5391	37	Ditto - - - - - - -	
251	19	20	1·035	15·5	Ditto - - - - - -	
252	7	18	1·99	10	Ditto - - - - - - -	
253	3	18	4·65	4·3	Ditto - - - - - - -	
254	1	17	10·05	2	Ditto - - - - - - -	
255	1	18	13·32	1·5	Ditto - - - - - - -	

B.—*Other Electric Light Cables.*

Pattern No.	No. of Wires.	Size of Wire, L.S.C.	Resistance per 1,000 Yards.	Service Current Capacity.	Insulation, Covering, &c.	Use and Remarks.
			Ohms.	Ampères.		
1,100	37	18	0·35	100	One coating of tin foil, one layer pure and two layers mixed rubber, coating of tin foil, waterproof tape, paraffin wax, jute serving, 30 strands steel wire, hemp braiding.	Burning searchlight away from ship.
1,296	450	25	0·17	118	One layer pure and two layers mixed rubber, waterproof tape, ozokerite compound, and hemp braiding.	Brush leads of dynamos.
1,200	150	25	0·51	39	Ditto - - - - - - -	Flexible leads to searchlights.
736	7	18	1·9	10·5	One layer pure and one layer mixed rubber, waterproof tape, ozokerite, and flax braiding.	Lighting.
600	36	30	5·6	*12	Same as Pattern 1,296 - - - - -	Illuminating ship.
104	1	16	7·48	2·7	Do. 736 - - - - -	Lighting.
733	1	19	19·1	1·05	Do. - - - - - - - -	Ditto.
546	19	22	2	10	Same as Pattern 1,296 - - - - -	Twin wire for yard-arm groups.
902	7	27	16·5	1·2	Do. - - - - - - - -	Twin wire for diver's lamp.
726	40	40	35	·57	Layer of cotton, layer of mixed rubber, waterproof tape, glazed cotton braiding.	Twin wire cabin lamps.
1,478	23	38	38	·53	Layer of cotton, one layer pure and two layers mixed rubber, waterproof tape, phosphor bronze braiding.	Compass lamp and examining internal parts of torpedoes.
1,680	100	38	8·8	2·3	Ditto - - - - - - -	Portable lamps.
342	40	40	35	·53	Ditto - - - - - - -	Same as 1,478.

* This is the maximum current that that Pattern 600 will carry without damage to the insulation. All the other current capacities are calculated on a basis of 2 volts drop per 100 yards run, except in the case of Pattern 1100, in which a larger drop is allowed.

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C.—*Telegraph Cables.*

Pattern No.	No. of Wires.	Size of Wire, L.S.C.	Resistance per 1,000 Yards.	Service Current Capacity.	Insulation, Covering, &c.	Use and Remarks.
841	19	30	5	—	Same as Pattern 1100, except that armouring is 12 stranded steel wires.	Telegraph, submarine.
1,207	7	24	8·4	—	Ditto - - - - - - -	Ditto.
1,049	3	27	36	—	Ditto - - - - -	Shore telegraph lines.
991	100	38	8·5	—	Same as Pattern 736 - - - -	Twin wire for telegraph work in ships.

APPENDIX VI.

Units.

Fundamental Units.

Unit of	English System.	C.G.S. System.	Connection.
1.—Length.	The foot.	Centimetre (cm.).	1 foot = 30·4797 cm.
2.—Time.	The second.	Second.	
3.—Mass.	Pound avoirdupois.	Gramme (gm.).	1 lb. av. = 453·59 gm.

Derived Units.

A.—From Length.

Unit of	English System.	C.G.S. System.	Connection.
1.—Area.	Square foot.	Square centimetre.	1 square foot = 929·01 sq. cm.
2.—Volume.	Cubic foot.	Cubic centimetre.	1 cubic foot = 28315·65 cu. cm.

B.—From Length and Time.

Unit of	English System.	C.G.S. System.	Connection.
1.—Velocity.	1 foot in 1 second.	1 cm. in 1 second.	1 foot per second = 30·4797 cm. per second.
2.—Acceleration.	Change of velocity of 1 foot per second in 1 second.	Change of velocity 1 cm. per second in 1 second.	Acceleration due to gravity in England 32·2 feet per second per second = 981 cm. per second per second.

C.—From Length, Time, and Mass.

Unit of	English System.	C.G.S. System.	Connection.
1.—Force.	The force acting for 1 second on 1 lb., giving it a velocity of 1 foot per second.	The force acting for 1 second on 1 gramme, giving it a velocity of 1 cm. per second, called the dyne.	1 lb. av. = $4{\cdot}45 \times 10^5$ dynes.
2.—Work.	The work done in overcoming 1 lb. weight through 1 foot, called the foot-lb.	The work done in overcoming one dyne through 1 c.m., called the erg.	1 foot lb. = $1{\cdot}356 \times 10^7$ ergs.
3.—Energy.	(Same as Work.)	Joule = 10^7 ergs.	(Same as Work.)
4.—Power = rate of doing work.	H.P. = 33,000 foot-lbs. per minute.	Watt = 10^7 ergs per second = 1 joule per second.	1 H.P. = 746 watts. Force de cheval = 736 watts. 1 H.P. = $1{\cdot}01385$ force de cheval.

Kinetic energy is the work a body can do in virtue of its motion.
Potential energy is the work a body can do in virtue of its position.

Electrical Units.

There are two separate systems of electrical units, both derived from the C.G.S. system, one set based on the force exerted between two quantities of electricity at rest, called the electro-static system, and the other based on the force exerted between two magnetic poles, called the electro-magnetic system. The practical units that are used in ordinary work are derived from the electro-magnetic units. For the connection between the two systems, the student is referred to any of the more advanced text-books of electricity.

Electrostatic Units (absolute).

Quantity.—Unit quantity of electricity is that quantity which, when placed at a distance of one centimetre in air from a similar and equal quantity, repels it with a force of one dyne.

Potential.—Potential is measured by the amount of *work* done against electric force. A point is said to be at unit potential when it requires an expenditure of one erg to move a unit quantity of electricity from an infinite distance up to that point.

Unit difference of potential is said to exist between two points when it requires an expenditure of one erg to move a unit quantity of electricity from one point to the other.

Electric field.—Unit electric field is said to exist at a point when a unit quantity of electricity placed at that point is acted upon with a force of one dyne.

Capacity.—Unit capacity is the capacity of a body which requires a charge of one unit of electricity to bring it up to unit potential.

Electro-Magnetic Units (absolute).

Magnetic pole.—A unit magnetic pole is such that, when placed at a distance of one centimetre in air from a similar and equal magnetic pole, it repels it with a force of one dyne.

Magnetic field.—**The strength of a magnetic field is measured by the force that it exerts on a magnetic pole.**

Unit magnetic field is said to exist at a point when a unit magnetic pole placed at that point is acted upon with a force of one dyne. Unit magnetic field therefore exists at a distance of one centimetre from a unit magnetic pole, as will be seen from the first definition.

Flux density is another name for the strength of a magnetic field, and the flux density in a unit magnetic field is said to be one line of force per square centimetre.

Magnetic flux.—The magnetic flux over an area is the flux density multiplied by the area. The unit of flux is the line of force. If an area of one square centimetre is taken in a unit magnetic field, the total flux over that area will be one line of force.

Current.—A current has unit strength when one centimetre length of its circuit bent into a circular arc of one centimetre radius exerts a force of one dyne on a unit magnetic pole placed at the centre of the arc.

Quantity.—The unit quantity of electricity is the quantity that passes when unit current flows for one second.

Potential.—Two points are said to be at unit difference of potential when it requires an expenditure of one erg to move a unit quantity of electricity from one point to the other.

Resistance.—The unit of resistance is that resistance through which unit difference of potential will cause unit current to flow.

Capacity.—A body has unit capacity when it requires a unit quantity of electricity to charge it to unit potential.

Inductance.—A circuit is said to have unit inductance when, if the current in it is changing at the rate of one unit per second, a difference of potential of one unit is produced at its ends.

Power.—Since potential is measured by the work done in moving unit quantity of electricity, and current by the rate of movement of electricity, therefore if the current in a circuit is multiplied by the difference of potential at its ends, the result will be the rate of doing work, that is, the power exerted.

The unit of power is therefore the power exerted by the unit of current moved by unit difference of potential, and this is one erg per second.

Practical Units.

Current.—The ampere = $\frac{1}{10}$ of an absolute unit.

Quantity.—The coulomb = $\frac{1}{10}$ of an absolute unit.

Potential.—The volt = 10^8 absolute units.

Power.—The watt = 10^7 absolute units.

Resistance.—The ohm = 10^9 absolute units.

Capacity.—The farad = 10^{-9} absolute unit. The microfarad, which is one millionth of a farad, is more generally used.

Inductance.—The henry = 10^9 absolute units.

These practical units are all related to one another in the same way that the absolute units are. That is to say, a volt produces a current of one ampère through one ohm, a farad is the capacity that requires a coulomb to charge it to a potential of one volt, and so on.

Heat Units.

The calorie is the amount of heat that is required to raise one gramme of water from 0° C. to 1° C.

The British Thermal Unit is the amount of heat that is required to raise one pound of water from 60° F. to 61° F.

1 B.T.U. = 9,968 calories.

Joule's Equivalent is the amount of energy equivalent to a heat unit.
1 calorie = 4·2 joules.
1 B.T.U. = 778 foot-pounds.

Light Units.

The British *Candle power* is the light of a spermaceti candle $\frac{7}{8}$ inch in diameter, burning 120 grains per hour.

The French unit, the *Bec Carcel*, is the light of a carcel lamp burning 42 grammes of pure colza oil per hour with a flame 40 mm. high under fixed conditions.

Connection.—Bec Carcel = 9·5 British standard candle-power.

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