fifteen seconds and repeat the above readings ; and continue the same cycle of operations for the whole time of the test. After earthing the cable for the proper interval repeat the above test with the other pole of the battery to the cable. To reduce the charge readings to absolute measure, find the deflexion of the gal­vanometer needle due to the charge of a condenser of *n* microfarads capacity by the testing battery ; let *d* be this deflexion. Then the deflexion that would be obtaiued by charging the whole cable would be C*d*/*n,* and, if D be any one of the deflexions during the test, D*n∣*C*d* is the fraction of the whole charge which has been lost in the fifteen seconds immediately preceding this charge ; thus

τ ∙4343 ×15

C2rf2 ' cl°δC2<i2-n2D

The method just described takes advantage in a somewhat imper­fect manner of both the direct deflexion and the electrometer test ; but the galvanometer should have such a long period that the whole of the charge can take place before the needle is sensibly moved from its zero position, and that the vibration of the needle must not be damped to any great extent,—a condition which renders the instrument unsuitable for direct deflexion testing.

The points with regard to the cable which should be particularly attended to when testing for insulation are—the continuity of the insulation all through the test, that is, there should be no sign of a breakdown for ever so short a time ; the rate of polarization with positive and negative current is always the same in a perfect cable, but is seldom so when a fault exists ; the absolute insulation with both currents should also be the same if the cable is perfect, but is never so for any length of time when a fault exists. If the insula­tions show any sign of being defective great care must be taken not to apply a powerful battery to the cable, unless the object is to increase or “ break down ” the fault. The resistance of a fault is generally diminished by applying the zinc pole of the battery to the cable and increased by applying the copper pole ; but if the fault is small it sometimes happens that both currents increase the resistance. Even a very powerful battery may in such a case fail to increase the fault.

*Capacity Tests.—*The arrangement of the connexions for Thom­son’s capacity test are shown in fig. 12. A well-insulated battery B is connected through a reversing key K1 to the slide resistance *ab,* and by means of a key K *a* can be put to a standard condenser C and *b* to the cable, or the condenser and the cable can be con­nected together and then both put to earth through the galvanometer G by closing the key K2. Any point in the re­sistance *ab* can be put to earth by means of the slider *s.* Suppose the middle point put to the earth, then C and L will be charged to equal potentials but of opposite sign. If the connexions to the slide are broken and C is joined to L, the resulting charge will be zero when the capacity C is equal to the capacity L, and when K2 is closed no current will flow through G. Similarly, if *as* is to *sb* as L is to C the resulting charge is zero. Hence when, after join­ing C to L, no deflexion is shown on G when K2 is closed—

L = C(*as*/*sb*)

*sb*

A modification of this test has been suggested by Mr John Gott. The condenser C is joined in series with the cable and one end of the slide is put to earth. The galvanometer G is joined from the end of the cable to the slider s and the position of the latter, which gives no deflexion, is found by successive trials, the cable being discharged and recharged between the trials. A small con­denser in the galvanometer circuit is an advantage, as it allows several adjustments to be made without discharging the cable. The most suitable instrument, however, is an electrometer, as it allows the adjustment to be made at once.

The capacities of condensers may be compared by charging or discharging them through a galvanometer and comparing the deflexions, or, as in De Sauty’s method, by substituting them for two sides of a Wheatstone’s bridge and finding the ratio of the resistances in the other two sides ; then, with the galvanometer circuit closed, the battery circuit can be closed without producing any deflexion. The galvanometer circuit must join the condensers at the same points as the bridge resistances. These methods are quite unsuited for telegraph-line testing because of the resistance and the inductive retardation of the line.

*Tests of a Submerged Cable.—*During the submergence of a cable it is necessary to provide the means of knowing at every instant whether it continues in perfect electrical condition, so that should any fault develop it can be at once detected and further paying out stopped until it is removed. It is also of great importance that the ship aud shore should be in telegraphic communication with each other. The arrangements made for these purposes by different electricians vary considerably ; but the general principle will be gathered from fig. 13, which includes all that is absolutely necessary for the purpose. The principal testing sta­tion is always on board the ship, and from it all the testing operations both on board and on shore are regulated. Referring first to the arrangements on board, B is the testing battery, K the testing key, and G the testing galvano­meter ; B1 is the sig­nalling or “ speaking ” battery, K1 the key, and G1 the galvanometer ; R is a resistance box and E the earth-plate—the ship’s side in this case. The battery B is connected through the key K, the resistance R, and the galvano­meter G to the cable, as for direct deflexion testing. The shore end of the cable is at the same time connected to one set of plates of a highly insulated condenser C1 and (although this may be omitted) to one pair of quadrants of an electrometer *El.* The other pair of plates of the condenser are put to earth through the signalling key K1. It is convenient also to have a second condenser C, on shore, the capacity of which can be readily varied, so arranged that its capacity can be added to that of C1 by depressing the key K, and again discharged through a galvanometer G by releasing the key. The operations are then conducted as follows. The insulation is measured on board ship, alternately with positive and negative currents of from ten to fifteen minutes’ duration, by observing the deflexion on the galvanometer G ; and the reading at the end of each minute, or oftener, is recorded in a diary. The continuity of the conductor is tested at short intervals—say every five minutes— by the observer on shore depressing the key K and thus adding the capacity of C to the cable. This gives a sudden deflexion on the galvanometer G on board, and at the same time shows that the conductor is continuous and that the observer on shore is attending to his duties. When the shore key K is released, the discharge through G is indicated by a throw deflexion, the amount of which is recorded in the diary and shows the potential to which the shore end of the cable is kept charged. When the electrometer *El* is used, a continuous test of the potential at the shore end is obtained, and the development of a fault in the cable is at once indicated. It is convenient for this purpose to dispense with the charge in the electrometer jar and needle and connect the needle to the pair of quadrants which are joined to the cable. The deflexion is then proportional to the square of the potential and is always to one side of zero, so that the whole range of the scale is available for the de­flexion. The tests for wire-resistance and capacity are practically the same as those already described. They are in ordinary circum­stances of much less importance than the insulation tests. The wire-resistance test is of great value, however, for giving a close estimate of the temperature of the submerged cable, and hence for giving the means of comparing the tests of the submerged cable with those of the cable previous to submersion. In laying short lengths of cable the shore station may be dispensed with and capacity tests relied on for continuity. Communication between ship and shore is carried on by means of the keys K1, K1, the galvanometer G1, and the batteries B1, B1. The signalling key on board the ship adds or subtracts the electromotive force of the battery B1 from the testing battery, and hence varies the potential of the cable. This is shown on shore by the partial charge or discharge of C1 passing through the galvanometer G1 and is interpreted in accordance with the single needle alphabet in the ordinary way. In a similar manner the signalling key on shore varies the charge of C1, and so causes slight variations of the testing-current on board the ship, which are read on the galvanometer G1 and interpreted in the same way. The testing is usually suspended during the signalling ; but if the message is long an insulation reading is taken every few minutes according to pre-arrangement.

The galvanometers used at sea require to be constructed so that the rolling of the ship does not deflect the needle, either on account of its inertia and the action of gravity, or of the relative changes in the position of the ship’s magnetism. The best form of marine galvanometer consists of two short bobbins of fine silk-covered wire placed end to end, about an eighth of an inch apart, and having their axes in the same line, with a very light mirror, carrying ce­mented to its back one or more small magnets suspended between the two bobbins in such a way that the centre of the mirror is in their common axis. The mirror and magnet system weighs from one-half to one grain. It is suspended as shown in fig. 14 by a