resistances, when zinc and copper were respectively to the line, will give nearly the true resistance. Since the deflexions are reproduced by substituting resistances for the line, the galvano­meter zero may be off the scale to one side, and hence the total deflexion, and therefore the sensi­bility, may be made very considerable. In this case the reversing key K is re­quired for keeping the de­flexion in the same direc­tion. With a perfectly insulated battery this can be accomplished by putting the galvanometer between the battery and the key K ; but the arrangement shown is safer. The most suitable galvano­meter for these tests is a dead-beat mirror galvanometer with a long enough suspension to prevent error from the viscosity of the fibre. Such an instrument is much to be preferred to the astatic form, especially when variable earth-currents are present.

1. A highly sensitive modification of method (2) is obtained by the use of a differential galvanometer, one coil of which is joined in circuit with the standard resistances and the other coil with the line. The resistances are then adjusted to balance, or to give no permanent deflexion when the battery circuit is closed. Several balances with positive and negative currents must be taken and the results combined as indicated above.
2. When an electrometer is employed for testing insulation, as described below, it may be used for the wire resistance also either by substituting it for the galvanometer in Wheatstone’s bridge method (fig. 8, G) or by that shown in fig. 10. One pole of the battery B is joined to the line through the reversing key K and the resistance R, the other pole being to the earth. The electrometer *El* is then applied to the two ends of R and to the end of *l* and the earth alternately and the relative deflexion noted. The deflexions should be as nearly as possible equal ; that is, R should be as nearly as possible equal to *l.* The form of re­versing key shown at K1 is convenient for this test, as it allows the comparisons to be made quickly ; and, as the readings can be always taken to the same side of zero, the whole length of the scale is available for each deflexion. The key consists of two ordinary front and back stop single lever keys fixed together by an insulat­ing piece *i* at such a distance apart that the contact stops *a, b* and *c*, *d* are at the corners of a square. Suppose one pole of the battery put to the line and the resistance R adjusted until no change of deflexion is obtained by depressing K1 ; then R is equal to *l* if there is no earth disturbance. Then put the other pole of the battery to the line ; turn the levers of K through 90o round the pivot *p ;* and repeat the adjustment of R for a second determination of *l.* Repeat these measurements several times and combine the results in the manner described in method (2). If R is not made equal to *l*, the resistances are in the ratio of the corresponding deflexions.

*Measurement of Insulator Resistance.—*(1) In the direct deflexion method the connexions are the same as those shown in fig. 9, except that the distant end of the line is insulated. Very great care must be taken that the galvanometer and all the connexions between it and the end of the line are so well insulated that no sensible part of the observed deflexion is due to leakage through them. In making the test, first earth the line for five minutes ; then, with the galvanometer short-circuited, apply the zinc pole of the battery to the line ; at the end of from thirty seconds to a minute, depend­ing on the length and capacity of the line, remove the short-circuit plug ; and record the deflexion at the end of every ten or fifteen seconds during the whole time (usually from ten to twenty minutes) the test is continued. Again earth the line for an interval equal to that during which the battery was applied ; then apply the copper pole of the battery and repeat the readings as before. Using the deflexions as ordinates and the corresponding times as abscissæ, construct a smooth curve for both the zinc and the copper test. The galvanometer constant divided by the mean ordinate of these curves at any time gives the insulation at that time. To deter­mine the galvanometer constant, substitute a high resistance R, say one megohm, for the line, and shunt the galvanometer with a shunt *s.* If the deflexion under these circumstances is *d* and G is the galvanometer resistance, the constant is

C=R*d*{(G+s)/s}

s

(2) The electrometer method is only applicable to lines of con­siderable inductive capacity, but is particularly well suited for cable testing. The battery B (fig. 11) is connected through a re­versing key K1 to the ends of the resistance slide *ab,* one end of which is put to earth. The slide generally consists either of 10 or 100 equal resistances, amounting in the aggregate to from 10,000 to 100,000 ohms. The cable can be connected by means of the reversing key K to either pair of quadrants of the electrometer *El,* the slider *s* being at the same time put to the other pair.

To determine the constant of the electrometer, con­nect the earth wire *w* with the cable terminal and the slider with contact 1, and observe the deflexion ; this should be the same for both directions of the current through the slide ; its value multiplied by 10, when the slide is made up of ten coils, gives the value in scale divisions of the full difference of potential between the ends of the slide. This number added to the zero reading of the electrometer is called the *inferred zero.* To find the insulation of the cable, remove the wire *w,* put in the short circuit plug *p*, move the slider to contact 10, and, the distant end of the cable being insulated, apply by means of K1 the zinc pole of the battery to the cable and the copper pole to the earth. Allow sufficient time for the cable to charge—say one minute for a cable of 2000 knots—then remove the short-cir­cuit plug and take readings every fifteen or thirty seconds. The difference of these readings from zero gives the fall of potential of the cable due to discharge through the insulating coat. Next earth the cable at both ends for a time equal to the duration of the last test, and after reversing K put the copper pole of the battery to the cable and the zinc pole to the earth and take another series of readings. Subtract these readings from the inferred zero, and, using the differences as ordinates and the corresponding times as abscissæ, draw two curves. To find the insulation of the cable at any interval *t* after the battery was applied, draw a tangent to the curve at the point corresponding to that time and produce it to cut the axis of the ordinates. Let D1 be the ordinate to the point of intersection, and D the ordinate at the time *t* ; then, if C be the capacity of the cable in microfarads and I its insulation in megohms,

I = (*t*D)/(C)(D1-D)

If the difference between the reading and the inferred zero at the times *t* and *t*1 be D and D1, the insulation is given by the equation

I = (4343)(*t*1-*t*)/(ClogD/D1)

when *t*1 - *t* is reckoned in seconds. This latter is the formula com­monly used ; it gives the insulation at some time in the interval between the two observations ; the exact time depends on the rate of “ absorption ” of the cable.

The advantages of the electrometer method of testing cables are the comparative steadiness of the needle during earth-current dis­turbances, its high sensibility for the detection of small intermittent faults, and the fact that simultaneous tests can be taken from both ends of the cable. In order to test from both ends simultaneously one or other of the following methods may be adopted. Call the ends of the cable A and B, and suppose the operator at A is to be­gin the test. The operator at B joins the copper pole to the earth and the zinc pole to the line, and leaves the slider of his slide re­sistance at the earth end of the slide. Then, at a time previously arranged, he watches until he sees the electrometer begin to indi­cate a charge in the cable, and moves the slider along the slide so as to keep the electrometer near zero. As soon as the electrometer ceases to indicate increase of charge he ceases to move the slider and begins to record the deflexions at regular intervals, the first reading being taken as zero. The other method is to leave the slider permanently to earth and keep the electrometer so insensitive that the deflexion is always within the limits of the scale. Ob­serve the time at which the electrometer begins to be deflected, and from that time onward take readings every thirty seconds during the time of the test. The mean of the readings taken at both ends, reduced to the same sensibility, should be used for calculating the insulation. This method not only eliminates the effects of earth­current disturbance but also throws light on the nature and dis­tribution of such disturbances.

When an electrometer is not available and the line is too much disturbed for good tests to be obtained by the galvanometer method, the following procedure may be adopted. Join the battery and the galvanometer in series with the cable as for the direct deflexion test. Short-circuit the galvanometer and charge the cable for one minute. Insulate the cable for fifteen seconds ; then break the short circuit of the galvanometer; again apply the battery, and take the deflexion produced by the charge. Keep the battery on the cable for fifteen seconds, and during that time take if possible the direct deflexion reading two or three times. Again insulate for