single silk fibre *f*, which passes through the centre of inertia of the mirror and needle system *m* and is fixed at one end directly to the frame F and at the other end to a light spring *s.* The frame F is made thin enough to slide into the opening between the two bobbins, so that the mirror can be easily taken out for adjustment when necessary. So long as the suspending fibre passes through the centre of inertia of *m* it is clear that no motion of translation of F can produce rotation of the mirror. When the instrument requires to be highly sensitive, as for testing purposes, it is shielded from the action of the ship’s and the earth’s magnetism by enclosing it in a massive iron case. For signalling pur­poses the controlling magnet is arranged to produce at the needle a field so strong that the effect of variations of external mag­netism is inappreciable.

*Testing for Faults.—*Numerous methods have been proposed for the localization of faults in telegraph lines, some of a complex char­acter and adapted to the cases of faults of a kind which fortunately seldom, if ever, occur. We give here a brief outline of the tests for the cases of most common occurrence.

For the determination of the position of a complete rupture with the conductor insulated both the insulation and the capacity tests are theoretically applicable. The insulation of a line of uniform type and material is inversely as its length ; hence if a piece is broken off the insulation is increased. If I be the total insulation before rupture, I1 the insulation of one section after rupture, and *l* the total length of the line, the length of the section is I*l/*I1. Un­fortunately it is difficult to obtain the necessary accuracy in insula­tion testing on account of the great influence of earth-currents on the result ; but apart from this there is always some uncertainty, especially in cables, as to the insulation at the break. For cables a fairly reliable test can be obtained from the capacity even when the insulation at the fault is somewhat imperfect, if it be sufficient to hold the greater part of the charge for a few seconds, since the amount of loss in any short interval can be estimated by a separate test. The capacity of a uniform cable is inversely as its length ; hence, if C be the total capacity of the perfect cable and C1 the capacity of one section, the length of that section is *l*C1∕C. When— as is almost always the case—the cable is not quite uniform in electrical quality and in temperature, a table or a curve showing the wire resistance, the insulation, and the capacity up to any point from either end should be kept for reference.

It is not at all uncommon in cables for one side of a fracture to be partially insulated through the conductor not breaking exactly at the same point as the insulator. In this case, however, the other end will be in most cases almost perfectly earthed and the position of the fault can be very nearly determined by the wire­resistance test. When both ends are partially insulated it is very difficult to obtain a near approach to the position of the fault because of the uncertainty as to which side of the break offers the greatest resistance. A first approximation is obtained by finding the wire resistance from both ends and subtracting the total wire resistance of the cable from the sum of these. This gives the sum of the resistances at the fracture, and half of this, if it is not too great, subtracted from the resistance of either section gives an approxima­tion to the resistance of that section up to the break. If, however, the resistance at the fracture is comparable to the total wire re­sistance of the cable, this method is useless. An approach to the solution of the difficulty can be obtained from capacity tests, the cable being discharged through different resistances at the testing end. But the procedure is very uncertain and difficult, and a full discussion of it would take more space than can be afforded here. The resistance at a fault can sometimes be greatly diminished by repeated application alternately of the positive and negative poles of a powerful battery to the cable, but this should never be resorted to if it can possibly be avoided. The direct deflexion method of taking wire resistance is most suitable for these tests. The resist­ance seems to diminish gradually after the battery is applied until it reaches a minimum value, after which it again increases. This maximum deflexion should be taken as indicating most nearly the true wire resistance up to the fracture.

When the fault is a partial earth without fracture, and both ends of the cable are available—as in factory testing, or when a second well-insulated cable can be used—the most satisfactory method is the loop test. In this the two sections of the cable form two sides of the Wheatstone’s bridge ; one pole of the battery is put to the junction of the other two sides and the other pole to earth,—that is, practically to the fault. The ratio of the resist­ances in the bridge when balance is obtained gives the ratio of the resistances of the two sections of the cable, or the ratio of the resistance of one section to the resistance of the other section plus the resistance of the second cable. The total resistance of the

cable being known, it is easy to determine the position of the fault. When the fault has a high resistance it is necessary to make a cor­rection for the want of perfect insulation in the sound part of the cable. When both ends of the cable are not available, measure the potential at the testing end and the resistance between that end and the earth, and simultaneously measure, by means of a slide re­sistance and zero galvanometer or by means of a quadrant electro­meter, the potential at the distant end. Then, if V be the potential at the testing end, *v* the potential at the distant end, and R the re­sistance measured, the true resistance of the fault is R(l - *v*∕V). Another simple, although less perfect method, may be mentioned. Measure the resistance between both ends and the earth and subtract from the sum the true wire resistance of the cable ; the difference is twice the resistance of the fault. The imperfection of this method, and indeed of any which involves two observations not made simul­taneously, lies in the variable character of the resistance of a fault.

III. Modern Telegraphs.

The code of signals introduced by Morse is still employed in the United States and Canada, and the international code in vogue in Europe differs only slightly from it. Currents in one direction only are used, and different combinations of from one to four long and short contacts form the letters, while the numerals are represented by groups of five signals, and punctuation and other special signs by groups of six and sometimes more. The instruments used for land telegraphs on this system are of two types,—“ sounders,” which indicate by sound, and “recorders,” which record the signals.

(1) Recorders vary in details of construction, but all have the same object, namely, to record the intervals during which the current is applied to the line. In the earlier forms of instrument the record was made by embossing lines on a ribbon of paper by means of a sharp stile fixed to one end of a lever, which carried at the other end the armature of an electromagnet. This method of recording is still largely employed in America, and certainly has the advan­tage of simplicity. The form of instrument almost universally used in Europe makes the record in ink, and hence is sometimes called the “ ink-writer.” This method has the advantage of dis­tinctness, and so is less trying to the eyes of the operators. The action of the instrument will be understood from the annexed sketch (fig. 15). Sup­pose *s* to be a strip of paper which is being pull­ed towards the left by means of two rollers *r*1 and *r*2 moved by a train of mechanism. Underneath the roller *r*1 a small wheel *i* is kept turning by the same mechanism, and has its lower edge in contact with the surface of ink in the ink-well *w.* When a current is sent through the magnet *m,* the armature *a* is attracted and the lever *l* lifts the ink-wheel *i* into contact with the paper, against the surface of which it rolls until the current is broken, thus making a mark the length of which depends on the speed of the mechanism and the time the current flows. As the speed of the mechanism is nearly constant, the relative lengths of the marks depend only on the duration of the current. In this way the letters of the alphabet, or any other understood signs, are indicated by groups of long and short marks, commonly called “dashes” and “dots.”

(2) Operators who use the record- learn to read the message by the click against its stop, and as this is a less

ing instrument soon

of the armature fatiguing method of

reading, and leaves the hands and eyes free to write, the sound is usu­ally preferred. Thus, when it is not necessary to keep a copy, a much simpler instrument may be employed and the message read by sound. The earliest successful form was Bright’s bell sounder, which consisted of two bells of distinct tone or pitch, one of which was sounded when the current was sent in one direction and the other when it was reversed. This instru­ment was capable of giving very considerable speed, but it was more complicated than that now in use, which consists only of an electromagnet, with its armature lever arranged to stop