the pencil at the receiving end moves in a corresponding manner on account of the variations of the current, and in this way it writes the message on a slip of paper moving beneath its point.

*Methods of Working Telegraph Circuits.—*(1) The arrangement on the open circuit system for single-current working is shown in fig. 20, in which L1 represents the line, G a simple form of galvanoscope, used simply to show that the currents are going to line when the message is being transmitted, K the transmitting key, B the battery, *I* the re­ceiving instrument, and E the earth­plate. The complete circuit is from the plate E through the instrument I, the key K, and the galvano­scope G to the line L1, then through the corresponding instru­ments to the earth-plate E at the other end, and back through the earth to the plate E. The earth is always, except for some special reason, used as a return, because it offers little resist­ance and saves the expense and the risk of failure of the return wire. The earth-plate E ought to be buried in moist earth or in water. In towns the water and gas pipe systems form excellent earth-plates. It will be observed that the circuit is not in this case actually *open* ; the meaning of the expression “open circuit” is “no battery to line.” Under normal circumstances the instru­ments at both ends are ready to receive, both ends of the line being to earth through the receiving instruments. A signal is sent by depressing the key K, and so changing the contact from *a* to *b,* and thus putting the battery to line. On circuits where the traffic is small it is usual to make one wire serve several stations. The connexions at an intermediate or wayside station are shown at W. S is a switch, consisting of three blocks of brass fixed to an insulat­ing base. W may be made the terminal station of L1 by inserting plug 3, and of L2 by inserting plug 2, or the instruments may be cut out of circuit by inserting plug 1. In ordinary circumstances the messages from all stations are sent through the whole line, and thus the operator at any station may transmit, if the line is free, by manipulating his key. The greatest inconvenience of this system arises from the varying strength and resistance of the batteries used at the different stations. As, however, delicate recording instruments are seldom required on such circuits little difficulty is experienced.

1. The connexions for positive and negative current or single­needle working on open circuit are shown in fig. 21, in which all the letters have the same meanings as before. But N is a single needle instru­ment, and K is a reversing key. The levers 1 and 2 press against the stops *a* when the line is free ; hence the line is to earth at both ends. But, if lever 1 is depressed, one pole of the battery is put to line ; if 2 is depressed, the other pole is put to the line. In this way the needles of the receiving instrument may be made to turn to either left or right ; and, if we call a motion to the left a dot and a motion to the right a dash, the Morse alphabet may be read from these motions. The connexions for wayside stations are illustrated at W, and will be readily understood from the descrip­tion given under single-current working above.
2. When the line consists in whole or in part of underground or submarine cable the capacity causes a very considerable diminu­tion in the speed of working. This is to some extent got over by putting the earth con­nexion in the middle of the bat­tery and us­ing double the number of cells, as shown in fig. 22. The stop *a* of the key K is connected through a switch S with one pole of the battery B, and the stop *b* in the usual way with the other pole. Suppose the arm c of the switch S to be in contact with 2; then when the key is mani­pulated it sends alternately positive and negative currents into the line. If the positive is called the signalling current, the line will be charged positively each time a signal is sent ; but as soon as the signal is completed a negative charge is communicated to the line, thus hastening the discharge and the return of the relay lever to its insulated stop. This method of working has been already referred to in connexion with Wheatstone’s automatic system.

The connexions for single-current working on this system are illustrated in fig. 23. It differs from the open circuit in only requir­ing one battery (although, as in the figure, half of it is often placed at each end), in having the receiving instrument be­tween the line and the key, and in having the battery con­tinuously to the line. The battery is kept to the line by the bar *c*, which short-circuits the keys. When signals are to be sent from either station the operator turns the bar *c* out of contact with the stop *b,* and then operates precisely as in open cir­cuit sending. This system is more expensive than the open circuit system, as the battery is always at work ; but it offers some ad­vantages on circuits where there are a number of intermediate stations, as the circuit is under a constant electromotive force and has the same resistance no matter which station is sending or receiving. The arrangement at a wayside station is shown at W. When the circuit is long and contains a large number of stations, the sending battery is sometimes divided among them in order to give greater uniformity of current along the line. When only one battery is used the current at the distant end may be considerably affected by the leakage to earth along the line.

In working long circuits with ordinary instruments inconven­iently high battery power is required in order to send sufficient current to produce the signals. In such cases it is usual to employ a local battery to produce the signals and to close the local battery circuit by means of a delicate circuit-closing apparatus called a *relay,* which is a very delicate electromagnetic key having its lever attached to the armature of the magnet. The arrangement at a station worked by relay is shown in fig. 24, where L is the line of wire, joined through the key K to one end of the coil of the relay magnet R, the other end of which is put to earth. When a current passes through R the armature A is attracted and the local circuit is closed through the armature at *b.* The local battery B1 then sends a current through the instrument I and records the signal. In the form of relay indicated in the figure the armature is held against the stop *a* by a spring S. In some cases—as, for example, in Siemens’s polarized relay, shown in fig. 25—the armature *a* is put in contact through the pivot *h* with one pole N of a permanent magnet *m,* the other pole *s* of which is fixed to the yolk *y* of a horse-shoe electromag­net Μ. The armature is placed between the poles of the electromagnet, a little nearer one pole than the other, so that the magnetic attraction holds the con­tact lever against the insulated stop without the aid of a spring. This form of relay only answers to currents in one direction, but it is capable of giving great sensibility, and for some pur­poses—for instance, in some methods of quadruplex working—its directional character is an advantage.

*Translation.—*In a precisely similar manner a relay may be made to re-transmit automatically the message over another line, or, what is the same thing, over a continuation of the same line when the whole length is too great for direct working. It is not usual in practice to employ the delicate receiving relay for re-transmitting the message, but it is made to work a coarser instrument, which takes the place of the sounder, or, it may be, the sounder itself, in the local circuit. It is clear that one receiving relay may be used to work a number of re-transmitting keys in the same local circuit, and hence to distribute a message simultaneously over a num ber of branch lines from a central station.

*Duplex, Quadrupler, and Multiple Telegraphy.—*Duplex tele­graphy consists in the simultaneous transmission of two messages,