indicating whether a station is calling, in case the relay sticks or is out of adjustment. The key K (shown in general plan), when worked, sends reversed currents from the battery B. In cases where “ universal battery" working, *i.e.* the working of several instru­ments from one set of batteries or accumulators, is adopted, the positive and negative currents have to be sent from independent batteries, as shown by 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 tongue to its insulated stop.

When a local instrument such as a sounder (fig. 15) is worked from a relay, the dying away of the magnetism in the iron cores of the electromagnet, when the relay tongue moves from the marking to the spacing side, *i.e.* when the local battery is cut off, sets up an induced current of high tension, which causes a spark to jump across the contact points of the relay, and by oxidizing them makes it necessary for them to be frequently cleaned. In order to avoid this sparking, every local instrument in the British Postal Telegraph Department has a “ spark ” coil connected across the terminals of the electromagnet. The spark coil has a resistance about ten times as great as that of the electro­magnet it shunts, and the wire of which it is composed is double wound so as to have no retarding effect on the induced current, which circulates through the spark coil instead of jumping in the form of a spark across the contact points. The device is a most effectual one.

On long circuits worked by the Wheatstone fast-speed apparatus, and especially on those in which a submarine cable is included, it is found necessary to introduce “ repeaters ” half-way, in order to enable a high speed to be maintained. The speed at which a circuit can be worked depends upon what is known as the “ KR ” of the line, *i.e.* the product of the total capacity and the total resistance, both the capacity and the resistance having a retarding effect on the signals. By dividing a line into two halves the working speed will be dependent upon the KR of the longest half, and as *both* K and R are directly proportional to the length of the line, the KR product for the half of a circuit is but one quarter that of the whole length of the circuit, and the retardation is correspondingly small. Thus the speed on a line at which the repeater is situated exactly midway will be four times that of the line worked direct. Repeaters (or translators, as they are some­times termed) are in Great Britain only used on fast-speed circuits; they are in no case found necessary on circuits worked by hand, or at “ key speed ” as it is called.

Duplex telegraphy consists in the simultaneous transmission of two messages, one in each direction, over the same wire. The solution of this problem was attempted by J. W. Gintl of Vienna in 1853 and in the following year by Frischen and by Siemens and Halske. Within a few years several methods had been proposed by different inventors, but none was at first very successful, not from any fault in the principle, but because the effect of electrostatic capacity of the line was left out of account in the early arrangements. The first to introduce a really good practical system of duplex telegraphy, in which this difficulty was sufficiently overcome for land line purposes, was J. B. Steams of Boston (Mass.). In order that the line between two stations may be worked on the duplex system it is essential that the receiving instru­ment shall not be acted on by the outgoing currents, but shall respond to incoming currents. The two methods most commonly employed are the differential and bridge methods.

In fig. 23, representing the “ differential" method, B is the sending battery, B1 a resistance equal to that of the battery, R a rheostat and *C* an adjustable condenser. Suppose the key to be depressed, then a current flows through one winding of the differential relay to line and through the other winding and rheostat to earth. Now if the values of the rheostat and condenser are adjusted so as to make the rise and fall of the outgoing current through both windings of the relay exactly equal, then no effect is produced on the armature of the relay, as the two currents neutralize each other’s magnetizing effect.

Incoming currents pass from line through one coil of the relay, the key, and either the battery or battery resistance, according as whether the key is raised or depressed. The result is that the arma­ture of the relay is attracted, and currents are sent through the sounder from the local battery, producing the signals from the distant station. When the key is in the middle position, that is, not making connexion with either the front or back contacts, the received currents pass through both coils of the relay and the rheostat; no interference is, however, felt from this extra resistance because, although the current is halved, it has double the effect on the relay, because it passes through two coils instead of one.

In the “ bridge ” method (fig. 24), instead of sending the currents through the two coils of a differentially wound relay or receiving instrument as in Frischen’s method, two resistances *a* and *b* are inserted, and the receiving instrument is joined between P and Q. The currents thus divide at the point D, and it is clear that if the difference of potential be­tween P and Q is unaffected by closing the sending key, then no change of current will take place in the instrument circuit. The relative potential of P and Q is not affected by the manipulation of the sending key if the resistance of *a* bears the same proportion to that of *b* as the resistance of the line does to that of the resistance R; hence that is the arrangement used. One very great advantage in this method is that the instrument used between P and Q may be of any ordinary form, *i.e.* relay, Hughes, siphon re­corder, &c.

Most important cables, such as. those of the Eastern Telegraph Company and the various Atlantic cables, are worked duplex on Muirnead’s plan. What may be called a mechanical method of duplexing a cable was described by Lord Kelvin in a patent taken out by him in 1858. In this, as in the ordinary methods, a differentially wound receiving instrument was used, one coil being connected with the cable and the other with the earth ; but it differed from other methods in requiring no “ artificial ” or balancing cable. The compensation was to be obtained by working a slide resistance included in the circuit of the compensating coil, either by the sending key or by clockwork released by the key, so as to vary the resistance in that