circuit according to any law which might be required to prevent the receiving instrument being affected by the outgoing current. Four years later Varley patented his artificial cable, which was the first near approach to a successful solution of the duplex problem on the principle now adopted. It was not, however, a sufficiently perfect representation of a laid cable to serve for duplexing cables of more than a few hundred miles in length. By a mollification of the bridge method, applied with excellent results by Dr Muirhead to submarine work, condensers are substituted for *a* and *b,* one being also placed in the circuit between P and Q. In this case no current flows from the battery through the line or instruments, the whole action being inductive. As we have already stated, the distri­bution of the capacity along the resistance R must in submarine cable work be made to correspond very accurately with the distri­bution of the capacity along the resistance of the cable. This is accomplished by Dr Muirhead in the following manner. One side of a sheet of paraffined paper is covered with a sheet of conducting substance, say tinfoil, and over the other side narrow strips of the same substance arc arranged gridironwise to form a continuous circuit along the strip. The breadth and thickness of the strip and the thickness of the paraffined paper are adjusted so that the relative resistance and capacity of this arrangement arc the same as those of the cable with which it is intended to be used. A large number of such sheets are prepared and placed together, one over the other, the end of the strip of the first sheet being connected with the beginning of the strip of the second, and so on to the last sheet, the whole representing the conductor of the cable. In the same way all the conducting sheets on the other side of the paper are connected together and form the earth-plate of this artificial cable, thus representing the sea. The leakage through the insulator of the cable is compensated for by connecting high resistances be­tween different points of the strip conductor and the earth coating. Faults or any other irregularity in the cable may be represented by putting resistances of the proper kind into the artificial line. This system of duplexing cables has proved remarkably successful.

Quadruplex telegraphy consists in the simultaneous trans­mission of two messages from each end of the line. The only new problem introduced is the simultaneous transmission of two messages in the same direction; this is sometimes called “ diplex transmission." The solution of this problem was attempted by Dr J. B. Stark of Vienna in 1855, and during the next ten years it was worked at by Bosscha, Kramer, Maron, Schaak, Schreder, Wartmann and others. The first to attain practical success was Edison, and his method with some modifications is still the one in most general use.

The arrangement is shown in fig. 25, and indicates the general principle involved. K1 and Kι are two transmitting keys; the former reverses the direction of the line current, the latter increases the strength irrespective of direction, by joining on another battery when the key is depressed. R1 and R2 are relays for receiving the currents; the former is polarized and responds to reversals of current, while the latter is non-polarizcd and responds only to the increased current from K2 irrespective of the direction of that current. This arrangement can be duplexed in the way already explained, by providing differential relays and arranging for the outgoing currents to divide differentially through the two relays at each end.

The “ multiplex ” system devised by Patrick B. Delany (which was adopted to a limited extent in Great Britain, but has now been entirely discarded) had for its object the working of a num­ber of instruments simultaneously on one wire. The general principle of the arrangement of the apparatus is shown by fig. 26. Arms *a* and *b*, one at each station A and B, are connected to the line wire, and are made to rotate simultaneously over metallic segments, 1, 2, 3, 4, and l', 2', 3', 4', at the two stations, so that when the arm *a* is on segment 1 at A, then *b* is on segment 1' at B, and so on. At each station sets of telegraph apparatus are connected to the segments, so that when the arms are kept rotating the set connected to 1 becomes periodically con­nected to the set connected to 1', the set connected to 2 to the set connected to 2', and so on. In practice the number of segments actually employed is much greater than that indicated on the figure, and the segments are arranged in a number of groups, as shown by fig. 27, all the segments 1 being connected together, all the segments 2, all the segments 3, and all the segments 4. To each group is connected a set of apparatus; hence during a complete revolution of the arms a pair of instruments (at station A and station B) will be in communication four times, and the intervals during which any particular set of instruments at the two stations are not in connexion with each other become much smaller than in the case of fig. 26. In practice this subdivision of the segments is so far extended that the intervals of disconnexion become extremely small, and each set of apparatus works as if it were alone connected to the line. As many as 162 segments in eight groups arc practi­cally used. The arm which moves round over the segments rotates at the rate of three revolutions per second, and is kept in motion by means of an iron toothed wheel, the rim of which is set in close proximity to the poles of an electromagnet. Through this electro­magnet pass impulses of current regulated in frequency by a tuning­fork contact breaker; these impulses, acting on the teeth of the iron wheel, by a series of pulls keep it in uniform rotation. If the rates of vibration of the two tuning-forks at the two stations could be maintained precisely the same, the two arms would rotate in synchronism, but as this uniform vibration cannot be exactly

preserved for any length of time, a means is provided whereby the rate of vibration of either of the forks can be slowed down, so as to retard the rate of rotation of one or other of the arms. This is effected by means of “ correcting ” segments, of which there are six sets containing three each. Should the rotating arms fail to pass over these correcting segments at their synchronous positions, correcting currents pass to a relay which cuts off momentarily the current actuating the tuning-fork, thereby altering the rate of vibration of the latter until the arms once more run together uni­formly. The actual number of sets of apparatus it was possible to work multiplex depended upon the length of the line, for if the latter were long, retardation effects modified the working conditions. Thus between London and Manchester only four sets of apparatus could be worked, but between London and Birmingham, a shorter distance, six sets (the maximum for which the system is adapted) were used.

*Chemical Telegraphs.—*A method of recording signals in the Morse code, formerly used to a considerable extent, was to use a chemically prepared ribbon of paper. Suppose, for instance, the paper ribbon to be soaked in a solution of iodide of potassium and a light contact spring made to press con­tinuously on its surface as it is pulled forward by the mechanism. Then, if a current is sent from the spring to the roller through the paper, a brown mark will be made by the spring due to the liberation of iodine. This was the principle of the chemical telegraph proposed by Edward Davy in 1838 and of that proposed by Bain in 1846. Several ingenious applications of his method were proposed and practically worked, as, for example, the copying telegraph of Bakewell and of Cros, by means of which a telegram may be transmitted in the sender’s own handwriting; the pantelegraph of Caselli; the auto­graphic telegraphs of Meyer, Lenoir, Sawyer and others; and the autographic typo-telegraph of Bonelli; all forms of the apparatus have, however, fallen into disuse.

*Automatic Telegraphs.—*It was found impossible to make the Morse ink writer so sensitive that it could record signals sent over land lines of several hundred miles in length, if the speed of transmission was very much faster than that which could be effected by hand, and this led to the adoption of automatic methods of transmission. One was proposed by Bain as early as 1846, but it did not come into use. That now employed is, however, practically a development of his