movements of small pieces of paper marked with the letters of the alphabet and placed under the ends of the wires. A very interesting modification was also proposed in the same letter, viz. to attach to the end of each wire a small light ball which when charged would be attracted towards an adjacent bell and strike it. Some twenty years later G. L. Le Sage proposed a similar method, in which each conductor was to be attached to a pith ball electroscope. An important advance on this was proposed in 1797 by Lomond,@@1 who used only one line of wire and an alphabet of motions. Besides these we have in the same period the spark telegraph of Reiser, of Don Silva, and of Cavallo, the pith ball telegraph of Francis Ronalds (a model of which is in the collection of telegraph apparatus in the Victoria and Albert Museum), and several others.

Next came the discovery of Galvani and of Volta, and as a consequence a fresh set of proposals, in which voltaic electricity was to be used. The discovery by Nicholson and Carlisle of the decomposition of water, and the subsequent researches of Sir II. Davy on the decomposition of the solutions of salts by the voltaic current were turned to account in the water volta­meter telegraph of Sömmering and the modification of it pro­posed by Schweigger, and in a similar method proposed by Coxe, in which a solution of salts was substituted for water. Then came the discovery by G. C. Romagnosi and by H. C. Oersted, of the action of the galvanic current on a magnet. The application of this to telegraphic purposes was suggested by Laplace and taken up by Ampere, and afterwards by Tri- boaillet and by Schilling, whose work forms the foundation of much of modern telegraphy. Faraday’s discovery of the induced current produced by passing a magnet through a helix of wire forming part of a closed circuit was laid hold of in the telegraph of Gauss and Weber, and this application was at the request of Gauss taken up by Steinheil, who brought it to considerable perfection. Steinheil communicated to the Göttingen Academy of Sciences in September 1838 an account of his telegraph, which had been constructed about the middle of the preceding year. The currents were produced by a magneto-electric machine resembling that of Clarke. The receiving apparatus consisted of a multiplier, in the centre of which were pivoted one or two magnetic needles, which either indicated the message by the movement of an index or by striking two bells of different tone, or recorded it by making ink dots on a ribbon of paper.

Steinheil appears to have been anticipated in the matter of a recording telegraph by Morse of America, who in 1835 con­structed a rude working model of an instrument; this within a few years was so perfected that with some modification in detail it has been largely used ever since (see below). In 1836 Cooke, to whom the idea appears to have been suggested by Schilling’s method, invented a telegraph in which an alphabet was worked out by the single and combined movement of three needles. Subsequently, in conjunction with Wheatstone, he introduced another form, in which five vertical index needles, each worked by a separate multiplier, were made to point out the letters on a dial. Two needles (for some letters, one only) were acted upon at the same time, and the letter at the point of intersection of the direction of the indexes was read. This telegraph required six wires, and was shortly afterwards dis­placed by the single-needle system, still to a large extent used on railway and other less important circuits. The single­needle instrument is a vertical needle galvanoscope worked by a battery and reversing handle, or two “ tapper ” keys, the motions to right and left of one end of the index corre­sponding to the dashes and dots of the Morse alphabet. To increase the speed of working, two single-needle instruments were sometimes used (double-needle telegraph). This system required two line wires, and, although a remarkably serviceable apparatus and in use for many years, is no longer employed. Similar instruments to the single and double needle apparatus of Cooke and Wheatstone were about the same time invented by the Rev. II. Highton and his brother Edward Highton, and

were used for a considerable time on some of the railway lines in England. Another series of instruments, introduced by Cooke and Wheatstone in 1840, and generally known as “ Wheat­stone’s step-by-step letter-showing ” or “ ABC instruments,” were worked out with great ingenuity of detail by Wheat3tone in Great Britain and by Bréguet and others in France. The Wheatstone instrument in the form devised by Stroh is still largely used in the British Postal Telegraph Department. Wheatstone also described and to some extent worked out an interesting modification of his step-by-step instrument, the object of which was to produce a letter-printing telegraph. But it never came into use; some years later, however, an instrument embodying the same principle, although differing greatly in mechanical detail, was brought into use by Royal E. House, of Vermont, U.S., and was very successfully worked on some of the American telegraph lines till i860, after which it was gradually displaced by other forms. Various modifications of the instrument are still employed for stock telegraph purposes.

*Construction of Telegraph Circuits.—*The first requisite for electro-telegraphic communication between two localities is an insulated conductor extending from one to the other. This, with proper apparatus for originating electric currents at one end and for discovering the effects produced by them at the other end, constitutes an electric telegraph. Faraday’s term “ electrode,” literally “ a way (δδos) for electricity to travel along,” might be well applied to designate the insulated con­ductor along which the electric messenger is despatched. It is, however, more commonly and familiarly called “ the wire ” or “ the line.” The apparatus for generating the electric action at one end is commonly called the *transmitting apparatus* or *instrument,* or the *sending apparatus* or *instrument, or* some­times simply the *transmitter* or *sender.* The apparatus used at the other end of the line to render the effects of this action perceptible to the eye or ear, is called the *receiving apparatus* or *instrument.*

In the aerial or overground system of land telegraphs the use of copper wire has become very general. The advantage of the high conducting power which copper possesses is of especial value in moist climates (like that of the United Kingdom), since the effect of leakage over the surface of the damp insulators is much less notice­able when the conducting power of the wire is high than when it is low, especially when the line is a long one. Copper is not yet universally employed, price being the governing factor in its employment; moreover, the conducting quality of the iron used for telegraphic purposes has of late years been very greatly improved.

In the British Postal Telegraph system five sizes of iron wire are in general use, weighing respectively 200, 400, 450, 600 and 800 lb per statute mile, and having electrical resistances (at 60° F.) of 26∙64, 13∙32, 11∙84, 8∙88 and 6∙66 standard ohms per statute mile respectively. The sizes of copper wire employed have weights of 100, 150, 200 and 400 lb per statute mile, and have electrical resistances (at 60° F.) of 8∙782, 5∙855, 4∙391 and 2·195 standard ohms respectively. Copper wire weighing 600 and 800 lb per mile has also been used to some extent. The copper is "hard drawn,” and has a breaking strain as high as 28 tons per sq. in.; the test strain required for the iron wire is about 22½ tons. The particular sizes and descriptions of wires used are dependent upon the character of the “ circuits ” the longer and more important circuits requiring the heavier wire.

The lines are carried on poles, at a sufficient height above the ground, by means of insulators. These vary in form, but essentially they consist of a stem of porcelain, coarse earthen­ware, glass or other non-conducting substance, protected by an overhanging roof or screen. The form in general use on the British postal lines is the “ Cordeaux screw,” but the “ Varley double cup ” is still employed, especially by the railway companies.

The latter form consists (fig. 1) of two distinct cups (c, C), which are moulded and fired separately, and afterwards cemented together. The double cup gives great security against loss of insulation due to cracks extending through the insulator, and also gives a high surface insulation. An iron bolt (*b*) cemented into the centre of the inner cup is used for fixing the insulator to the pole or bracket.

@@@1 See Arthur Young, *Travels in France,* p. 3.