his first patent in 1867. Within the three succeeding years great improvements were effected on it, and the instrument has since that date been exclusively employed in working most of the more important submarine cables of the world,—indeed all except those on which the mirror galvanometer method is in use. In the siphon recorder (see fig. 30) the indicator consists of a light rectangular signal coil of fine wire, suspended be­tween the poles of two powerful elec­tromagnets Μ, M so as to be free to move about its longer axis, which is verti­cal, and so joined that the electric signal currents through the cable pass through it. A fine glass siphon tube is suspended with freedom to move in only one degree, and is con­nected with the sig­nal-coil and moves with it. The short leg of the siphon tube dips into an in­sulated ink-bottle, so that the ink it contains becomes electrified, while the long leg has its open end at a very small distance from a brass table, placed with its surface parallel to the plane in which the mouth of the leg moves, and over which a slip of paper may be passed at a uniform rate, as in the spark recorder. The ink is electrified by a small induction electrical machine E placed on the top of the instrument ; this causes it to fall in very minute drops from the open end of the siphon tube upon the brass table or the paper slip passing over it. When therefore the signal-coil moves in obedience to the electric signal currents passed through it, the motion communicated to the siphon is recorded on the moving slip of paper by a wavy line of ink-marks very close together. The interpretation of the signals is according to the Morse code,—the dot and dash being represented by deflexions of the line of dots to one side or other of the centre line of the paper. A very much simpler form of siphon recorder has been de­vised and brought into use within the last few years. Instead of the electromagnets, two bundles of long bar­magnets of square sec­tion and made up of square bars of glass- hard steel are used. They are supported vertically on a cast- iron socket, and on the upper end of each is fitted a soft iron shoe, shaped to concentrate the lines of force and thus produce a strong magnetic field in the space within which the signal-coil is suspended.

Instruments of this

kind have been made to work both with and without electrifi­cation of the ink. Without electrifi­cation the instrument (see fig. 31) is very simple and compact, and capable of doing good work on cables 500 or 600 miles long. When constructed for electrification of the ink they are available for much greater lengths, but for cables such as the Atlantic the original form is still used. The strongest magnetic field hitherto obtained by permanent magnets (of glass-hard steel) is about 3000 C.G.S. With the electromagnets used in the original form of siphon recorder a magnetic field of about or over 5000 C.G.S. is easily obtained. Fig. 32 shows a facsimile of part of a message received and recorded by a siphon recorder, such as that of fig. 30, from one of the Eastern Telegraph Company’s cables about 830 miles long.

(4) The automatic curb sender was designed by Sir W. Thomson Auto- for the purpose of diminishing the effect of inductive embarrass- matic ment in long cables. In ordinary hand-sending the end of the curb cable is put to one or the other pole of the battery and to earth sender. alternately, the relative time during which it is to battery and to earth depending to a great extent on the operator. By the auto­

matic curb sender the cable is put to one or the other pole of the battery and then to the reverse pole for definite proportionate times during each signal. The cable is thus charged first positively and then negatively, or *vice versa,* for each signal. This method not only facilitates the discharge of the cable, and so accelerates the return of the index of the receiving instrument to zero, but provides the means of sending positive and negative currents into the cable at the proper times and for the proper intervals. The action of the instrument is regulated, like that of Wheatstone’s automatic transmitter, by a perforated slip of paper. The arrange­ment of the perforations and the method of using the paper slip are, however, quite different. The paper is fed forward by a central row of holes, which are therefore continuous. The dots and dashes of the message are represented by the side rows of holes ; but the two currents required for a dot are produced wholly by one hole on one side and those for a dash by one hole on the other side. The perforated slip is exactly similar to the message written by the siphon recorder, the side holes occupying the same relative positions as the loops to one side or other of the central line in the record. As the side holes reach a certain point in their passage through the instru­ment they allow the end of one or the other of two levers to fall ; the other end of the lever lifts a light contact spring, forming one lever of a reversing key, and makes electrical connexion between the battery and another set of springs, which also form the levers of a reversing key. The spring is held up, by a flange on the edge of a revolving wheel passing under it, during the time required by the paper to advance through the distance between two central holes. During this interval the current is reversed at the proper time by a pair of adjustable cams fixed to the same spindle as the flanged wheel. This method of transmission has been found quite successful, though it has not been brought into use, as hand­sending has hitherto proved sufficient for the work required.

*Speed of Signalling.—*The mathematical theory of the speed of telegraphic signalling was given in a paper on “ The Theory of the Electric Telegraph” communicated by Sir W. Thomson@@1 to the Royal Society in 1855. He shows that, if *k* be the wire resistance, *c* the capacity per unit length, and *l* the total length of the line, the current at the receiving end at any time *t* after the application of the battery at the sending end is given by the equation

Ct = C{l — 2(ε - ε4 + ε9 - εl6 + &c.)},

where C is the maximum current which the battery is capable of

maintaining through the line, and ε is equal to (¾)*t*/*a* when *a* is equal to *kcl*2 loge (4/3)/π2. The number 4/3 is quite arbitrary ; it is chosen because it makes *a* nearly equal to the time required for the current to become sensible at one end of the line after the battery has been applied to the other end. The number 101/10, which is more con­venient for calculation and which does not differ greatly from 4/3, was subsequently adopted by Sir W. Thomson, and also by Professor Jenkin.@@2 The equation may be written

C*t =* C {1 - 2 (*e*-π2*t*/*kcl - e-*4*πt/kcl +* *e-*9π2*t/kcl -* &c*.* )},which shows plainly how the current is affected by the length, the resistance, and the capacity of the line.

It is evident from this equation that a finite time is required after the battery has been applied at the sending end for the current to become sensible at the receiving end, the interval being practi­cally equal to *a,* and also that for similar actions the intervals be­tween operations for one line must be to the corresponding intervals for another line directly as the values of *a* or of *kcl*2 for the two lines. We see, therefore, that for lines of the same type, worked in the same manner, the speed of working will be inversely as the square of the length of the line, or, if the type varies, inversely as the product KQ, where K is the total resistance and Q the total capacity

@@@1 See his *Mathematical and Physical Papers,* vol. ii. p. 61.

@@@2 See Jenkin, *Electricity and Magnetism,* p. 331.