of which is adjusted so as to be nearly equal to the magnetic attrac­tion. The current is sent in the proper direction to diminish the power of the magnet and allow the spring to preponderate. A very powerful action is thus obtained by means of a very small current, the actual work being done by motive-power in the instrument itself. After the letter is printed the mechanism short-circuits the magnet and replaces the armature automatically. The printing action is as follows. The type-wheel W is carried round continu­ously by the clockwork, to which it is attached through a friction sleeve which allows it to be stopped, and pushed backward or for­ward without stopping the mechanism. Another shaft carrying three cams is arranged so as to be locked into gear with the wheel­work when the armature leaves the poles of the magnet. The cams then come into action in rotation ; the first moves the adjustment lever, shown to the left of W in the figure, which pushes a wedge- shaped piece into the teeth of the type-wheel and adjusts it exactly to the proper position for printing ; the second cam presses the paper against the type ; the third moves forward the paper ; a fourth cam replaces the armature of the magnet and relieves the cam shaft, leaving the instrument ready to receive another letter. The whole of this operation occupies only a small fraction of a second. By means of the adjustment lever or “ corrector ” *l* every error in syn­chronism decidedly less than half the space from letter to letter is perfectly corrected each time an impression is made. Thus, during the time the receiving instrument at one station is in use, its type­wheel is kept in perfect agreement with the sending wheel at the other station ; and, if the electric action keeps time, a wrong letter cannot be printed unless the rate of the clockwork is at fault by some such amount as one or two per cent. If the two wheels are allowed to run a long time without the electric maintenance of agreement, they will be found more or less at variance, as the pieces of clockwork, however good, cannot be perfect. All that is necessary to bring them into agreement again is to strike several times the key corresponding to a prearranged adjustment signal— that corresponding to the dot type, for instance. The receiver knows (according to the regulated system of working) that it is adjustment, not message, that is being sent ; and he turns his type-wheel by hand till it prints dots. He then signals back “O.K.” (“All correct ! ”) and is ready to receive the message. If by any accident his type-wheel gets on a wrong letter in the course of a message, he disturbs the sender (who all the time sees the effect of his sending printed before his own eyes) by sending back a few currents on him ; he receives dots by way of acknowledgment, and resets his type-wheel to print correctly. This system of telegraphic printing has a great advantage over the step-by-step system in using con­tinuous instead of intermittent currents, and so avoiding the neces­sity for the rapidly acting electric escapement, which, however skil­fully planned and executed, is always liable to failure when worked too rapidly. In Hughes’s instrument almost perfect accuracy and certainty have been attained ; and in actual practice it has proved to be decidedly superior to all previous type-printing telegraphs, not only in speed and accuracy, but in less liability to mechanical derangement from wear and tear and from accident. It involves many novel features : the receiving electromagnet is of peculiar construction and remarkable efficiency ; the transmitting apparatus has a contrivance to prevent unintentional repetitions of a letter through the operator holding his finger too long on a key ; the type-wheel has a lock for each station, to be opened by its own key, one of the letter keys of any of the instruments in the circuit. This instrument was for some years extensively used in the United States, until superseded by G. Μ. Phelps’s modification of it, known as the “American combination printing telegraph,” because it embodied part of Hughes’s and part of House’s instruments. With this modified form somewhat greater speed was obtained, but it was found difficult to drive, requiring the use of steam or some such motive-power. In a subsequent modification introduced in 1875 an electromotor is applied to drive the printing mechanism. This allows a shorter train and stronger wheelwork to be used, secures more certain action, and involves less risk of derangement.

Hughes’s form was taken up by the French Government in 1860, and is still very largely in use in France.

Stock and private line telegraphs constitute an important class of instru­ments, of which Laws’s “gold indi­cator,” introduced in 1866, may be taken as the forerunner. A brief description of Calahan’s stock telegraph, introduced in 1867, will give a general idea of the action of this class of instruments. The printing mechanism consists of two type­wheels, on the edge of one of which are the letters of the alphabet and on the edge of the other the numerals from 1 to 9 and fractions by eighths up to unity. The type-wheels are placed side by side, but can be turned independently of each other. Beneath them a platen is carried on one end of a lever, whose other end is attached to the armature of an electro­magnet. Between the platen and the wheels a ribbon of paper broad enough to cover the edges of both wheels is passed. The instrument is worked by three lines of wire, one for driving each type-wheel and one for printing and feeding the paper forward. The movement of the type-wheel is accomplished by an escapement acted on by closing and opening the circuit of an electromagnet. For the convenience of the sender the transmitting instrument is made in the form of two dials, each resembling the dial of an ABC instrument, round the edge of one of which letters are printed, and round the other the numerals and fractions. Mechanism is provided for opening and closing the circuit, so that by turning a handle (fixed to an axis passing through the centre of the dial) until an index attached to it points to the letter which is to be printed, the type-wheel of the receiving instrument is in the proper position to print that letter, and this is accomplished by depressing a key and closing the third circuit. The printing magnet then raises the platen and presses the paper against the type. Suppose direct United States telegraph stock is to be reported and the price is 9⅜. The operator turns the index on the letter dial to D and presses the printing key ; he next turns the index to period and again presses the printing key ; he then turns in succession to U, to period, to S, to period, and prints these ; then he turns the index on the figure dial to 9 and prints it, lastly to ⅜ and to period, and prints them. The quotation then reads on the paper ribbon D. U. S. 9⅜.

Various modifications of this instrument have since been intro­duced. In one form, the “universal stock printer,” two lines of wire are required, and both type-wheels are driven by one wire, the printing magnet being made to change the action from one wheel to the other when the wheels are brought into a particular position. In another, “Phelps’s stock printer,” only one line of wire is required, a polarized armature being used for moving the type-wheels and an ordinary neutral armature for the printing. The rapid reversals which work the polarized armature do not last long enough to move the printing lever, but when a pause is made the printing mechanism is relieved and a letter printed. This instrument is similar in principle to the House apparatus and is capable of working at a considerable speed.@@1

Cowper’s writing telegraph is designed to record the message in written characters ; its arrangement is as follows :—Two lines of wire are connected, one with each of two small resistance slides, which are placed in such a way that the sliders move in the same plane but in directions at right angles to each other. A pen placed at the point of intersection of the lines of motion of the two sliders is connected with them in such a way that, when it is moved, as in the act of writing, each slider takes up that component of the motion which is in the direction in which it is free to move. The sliders thus vary the resistance in the line circuits by an amount proportional to the motion of the pen, and when a battery is kept joined in the circuit the current varies in the same way. The current is passed through the coils of two electromagnets at the receiving end, each capable of giving motion to a pencil in one line, at right angles to the direction of motion of the other. When the pen at the sending end is moved as in the act of writing a message

@@@1 For these and other type-printing instruments, see Prescott’s *Electricity and the Electric Telegraph.*