transmit a separate series of positive and negative currents in diffe­rent combinations; these are distributed, by suitably arranged distributors and relays at the receiving end of the line, into their respective receivers. The function of the “ combiner ” in each receiving instrument is so to group the received combination of positive and negative currents that they operate polarized relays in such a manner that the position of the tongues corresponds with the operation of the levers on the transmitter. Since each letter is represented by a specific combination of positive and negative currents, it is possible, by means of the combinations, to close a local circuit at any given interval, and so cause the paper to be pressed against the periphery of the type-wheel at the time when the letter required is opposite. The paper is also caused to ad­vance automatically for each letter, start a fresh line, and also to commence a fresh form at the completion of each message.

*Telautograph.—*Instruments such as the telautograph and telewriter are apparatus for transmitting a facsimile of hand­writing inscribed on a paper at one end of a line, the reproduc­tion being made automatically at the other end of the line at the same time that the message is being written.

A successful apparatus for effecting this was devised by Cowper and was known as the writing telegraph. The telautograph is on a similar principle to the Cowper apparatus, the motion of the transmitting pencil or stylus used in writing being resolved by a system of levers into two component rectilinear motions, which are used to control and vary the currents in two distinct electrical circuits. By the action of the two variable currents on the electro­magnetic mechanism in the receiver, the two component motions are reproduced and by their combined action on a second system of levers the receiving pen is caused to duplicate the motions of the transmitting pencil. The motion communicated to rollers by the pencil serves to cut resistance in or out of the two line circuits which are connected to the rollers, and thus two independent variable line currents are obtained. In the receiver there is a strong electromagnet, excited by a local current, which has in its circuit two annular air gaps, across which the magnetic field is practically uniform and constant. In these annular spaces there are suspended by springs two light coils of fine copper wire, capable of being moved vertically, and connected in such a manner as to be traversed by the two variable line currents from the transmitter. These coils are drawn down, by the magnetic action of the field on the currents in the coils, into the annular spaces, against the pull of the springs, more or less strongly, according to the strengths of the two line currents. Each coil is attached to a shaft by a bell crank arrangement, and to these shafts there is secured a system . of levers similar to that at the transmitter carrying the receiving pencil at the junction. The shafts are turned by the pull of the magnet upon the coils, and the motions of the transmitting pencil are thus reproduced.

The Korn telephotographic apparatus is based on the principle of an apparatus devised by Shelford Bidwell in 1881 for the electrical transmission of pictures to a distance, in which use was made of the change in electrical resistance which selenium undergoes when acted upon by light. In the Korn apparatus the light from a Nernst electric lamp is concentrated to a point by means of a lens on the original picture, which is wound on a glass cylinder in the shape of a trans­parent photographic film. A totally reflecting prism placed inside the glass cylinder projects the light which penetrates the film upon a selenium cell situated at the end of the cylinder. An illumination of variable intensity (according to the deeper or lighter shades of the portion of the picture on which the light falls) thus takes place on the selenium cell. As the glass cylinder, driven by a motor, revolves upon its axis while also advancing (by means of a screw thread on the axis), all portions of the picture are successively brought under the beam or pencil of light and cause a beam of varying intensity to fall on the selenium cell. Owing to the variable illumination of the selenium thus produced, the resistance of the latter, and therefore the intensity of the current sent through the line to the receiving station by the battery, will be altered accord­ingly. At the receiving station a cylinder—which revolves syn­chronously with the transmitting cylinder—is covered with a photographic film or paper, upon a point of which a pencil of light from a Nernst lamp is concentrated. Before reaching the paper the light passes through perforations in two iron plates which are, in fact, the pole pieces of a strong electromagnet ; between these is an aluminium shutter which is attached to two parallel wires or thin strips. When there is no current the shutter covers the per­forations and no light passes, but when a current traverses the wires they are depressed by electromagnetic action, carrying the shutter with them, and a quantity of light proportional to the current strength is admitted through the perforations. By means of this “ light-relay ” the intensity of the light acting at any moment upon the sensitized paper is made proportional to the illumination of the selenium in the transmitter. To eliminate the sluggish action of the selenium transmitter a selenium cell similar to that at the transmitting station is arranged at the receiving apparatus, and exposed to precisely similar variations of light, the arrangement being such that the lag of this cell counteracts the lag of the trans­mitting cell. The synchronous revolutions of the transmitting cylinders are effected by making one cylinder revolve slightly faster than the other; after each revolution the cylinder which is acceler­ated is arrested for a moment by means of a special relay until the difference of speed is accurately compensated for. This device was originally adopted in the d'Arlincourt copying telegraph.

*Submarine Telegraphy.—*For working long submarine cables the apparatus ordinarily employed on land lines cannot be used, as the retarding effect of the electrostatic capacity of the cable is so marked that signals fail to be recorded except at a very slow speed of working. The transmitted signals or electric impulses, which on a land line are sharply defined when re­ceived, become attenuated and prolonged in the case of a long cable, and are unable to actuate the comparatively heavy moving parts of which the land line instruments are formed. Other patterns of apparatus are therefore necessary.

The arrangement of the apparatus for working some of the most recent cables is shown in Fig. 30. The cable is supposed to be worked duplex; but, if S, C1, C2, and AC are removed and the key connected directly with C3, the arrangement for simplex working is obtained. The apparatus consists of a sending battery B, a reversing transmitting key K, a. slide of small resistance S, three condensers C1, C2, C3, an artificial cable AC, the receiving instru­ments I and G, and one or more resistances R for adjusting the leakage current. The peculiar construction of AC has been already referred to. The conductor of the cable is practically insulated, as the condensers in the bridge have a very high resistance; hence no appreciable current ever flows into or out of the line. Two re­ceiving instruments, a. siphon recorder and a mirror galvanometer, are shown; one only is absolutely necessary, but it is convenient to have the galvanometer ready, so that in case of accident to the recorder it may be at once switched into circuit by the switch *s*. When one of the levers of K is depressed, the condenser C1 and the cable, and the condenser C2 and the artificial cable, are simultane­ously charged in series; but, if the capacity of C1 bears the same proportion to the capacity of the cable as the capacity of C2 bears to the capacity of the artificial cable, and if the other adjustments are properly made, no charge will be communicated to C3. After a very short interval of time, the length of which depends on the inductive retardation of the cable, the condensers corresponding to C1 and C3 at the other end begin to be charged from the cable, and since the charge of C3 passes through the receiving instrument I or G. the signal is recorded. The charging of C3 at the receiving end will take place, no matter what is the absolute potential of the condensers, consequently the incoming signals are not affected by those which are being transmitted from that end. In actual prac­tice the receiving instrument is so sensitive that the difference of potential between the two coatings of the condenser C3 produced by the incoming signal is only a very’ small fraction of the potential of the battery B. When the key is released the condensers and cables at once begin to return to zero potential, and if the key is depressed and released several times in rapid succession the cable is divided into sections of varying potential, which travel rapidly towards the receiving end, and indicate their arrival there by pro­ducing corresponding fluctuations in the charge of the condenser C3. All cables of any great length are worked by reverse currents. A modification (known as the cable code) of the ordinary single needle alphabet is used; that is to say, currents in one direction indicate dots and in the other direction dashes.

The general principle on which the instruments for working long submarine cables are based is that of making the moving parts very light and perfectly free to follow the comparatively slow rise and fall of the electric impulses or waves. The simplest form of re­ceiving instrument (formerly much used) is known as the "mirror.” In this instrument a small and very light mirror, about ⅜ in. in diameter, attached to a stretched fibre and having a small magnetic needle fixed to its back, is arranged within a galvanometer coil so that the influence of the latter causes the mirror (through the action of the magnetic needle) to be turned through a. small angle in one direction or the other according to the direction of the current through the coil. A ray of light from a lamp is thrown on the mirror, whence it is reflected upon a white