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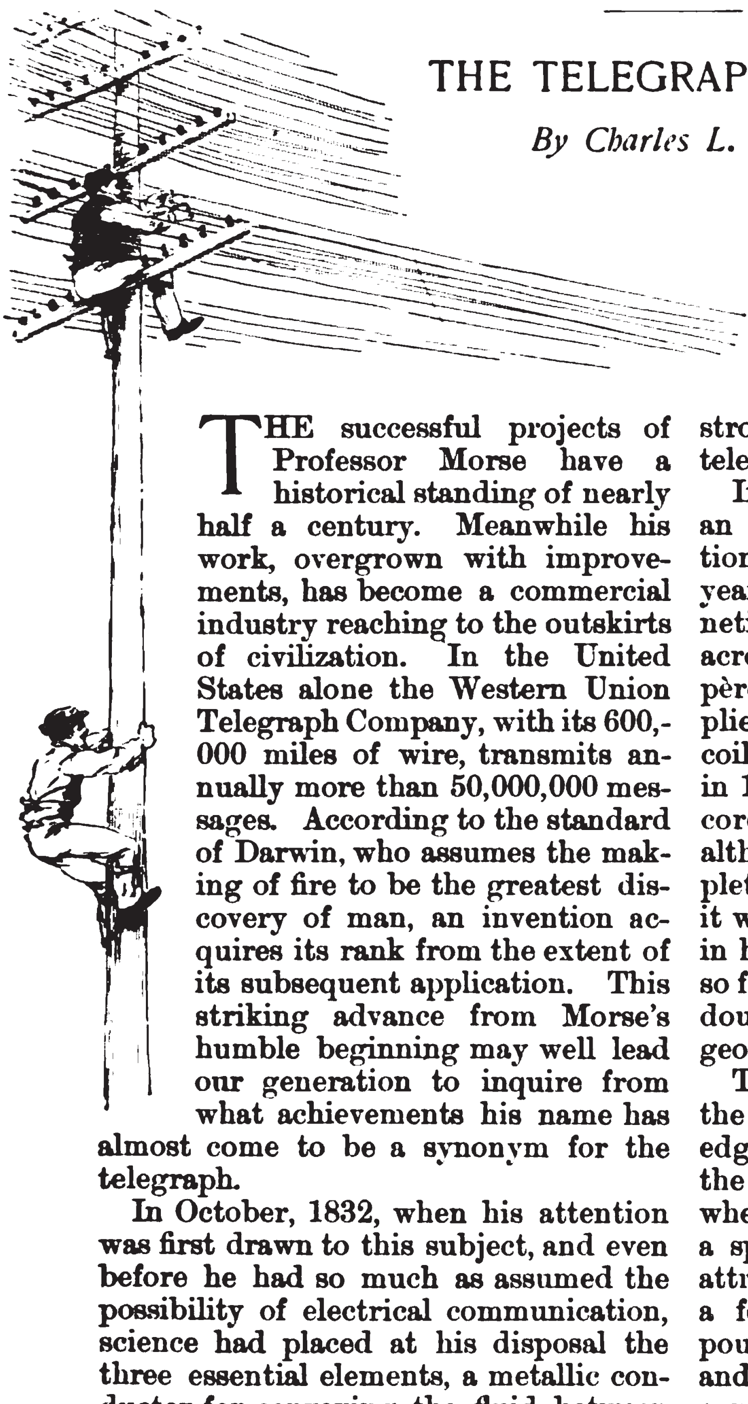

THE TELEGRAPH OF TO-DAY.

By Charles L. Buckingham.

THE successful projects of Professor Morse have a historical standing of nearly half a century. Meanwhile his work, overgrown with improvements, has become a commercial industry reaching to the outskirts of civilization. In the United States alone the Western Union Telegraph Company, with its 600,000 miles of wire, transmits annually more than 50,000,000 messages. According to the standard of Darwin, who assumes the making of fire to be the greatest discovery of man, an invention acquires its rank from the extent of its subsequent application. This striking advance from Morse's humble beginning may well lead our generation to inquire from what achievements his name has almost come to be a synonym for the telegraph.

In October, 1832, when his attention was first drawn to this subject, and even before he had so much as assumed the possibility of electrical communication, science had placed at his disposal the three essential elements, a metallic conductor for conveying the fluid between distant points, a galvanic battery affording an ample source of electricity, and an electro-magnet for translating electric currents into intelligible signals. Following the discovery of the voltaic pile in 1800, Davy, before 1810, had employed the combined action of two thousand battery cells in experimenting with the electric light, and had developed currents stronger than would operate the longest telegraph-circuit of the present day.

In 1819 Oersted had observed that an electric current caused the deflection of the compass-needle, and in the year following Arago succeeded in magnetizing a steel needle by placing it across a wire conveying a current. Ampère immediately perceived the multiplied effect that would be obtained by coiling the wire around the needle, and in 1825 Sturgeon substituted for steel a core of soft iron. The electro-magnet, although crude in form, was then complete as an invention. In 1828, however, it was taken up by Professor Henry, and in his hands, before 1831, was advanced so far from a laboratory experiment that doubtless it could have been advantageously used as a telegraph-receiver.

That Henry, during this period, placed the world in full possession of a knowledge of the character and properties of the electro-magnet cannot be doubted when we remember that he constructed a specimen, existing to-day, capable of attracting an armature to its poles with a force of more than two thousand pounds; and in 1831 he went farther and employed an electro-magnet in an experimental telegraph, which by vibrating a bell-hammer, audibly announced signals by the closing and breaking of the current. Whatever merit, there-

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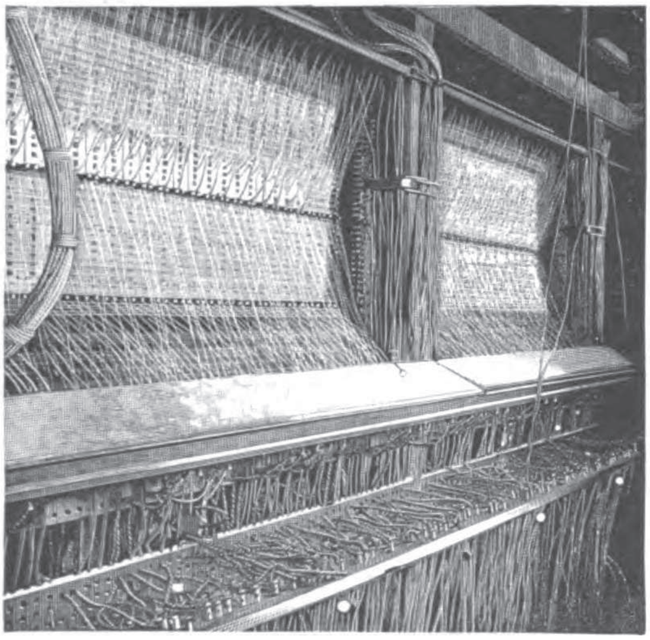

Underside of the Switchboard for 2,000 Wires; Western Union Building, New York.
(Above, the wires as seen in the room beneath the switchboard.)

fore, there may be in the claim advocated for Professor Henry that he invented the telegraph before Morse, there is little room for doubt that he brought the electro-magnet to a stage of development fitting it to many uses for which it has since been discovered to be suited.

If, in 1832, Morse had appreciated the possibility of manually closing and opening a circuit to effect transmission, and of reading sound-signals produced by the blows of an electro-magnet's armature, he might, with little trouble and expense, have organized a telegraph system from the galvanic battery and the Henry magnet. But instead of forming a system of those parts, he adopted them as a skeleton upon which he built, not thinking that one day his additions would become obsolete and that the system would be brought back to the simple elements with which he began. He assumed that an automatic mechanism must be employed to insure accuracy of transmission, and that messages must be permanently recorded upon paper or other fabric; and to meet these requirements, whether real or imaginary, consisted in large part the work of introducing the electric telegraph. The first telegraph contrived by Morse reveals complications which are entirely omitted in systems where signals are read by sound. The devices added by Morse contained designs requiring the most delicate workmanship, and every part of the mechanism became a source of difficulty, threatening the entire undertaking with failure. The possible electrical obstacles to its success seem almost to have been forgotten, for those of a purely mechanical character were much more serious. It was not merely a question whether, electrically, the system was possible, but chiefly whether a rather difficult electrical experiment could survive the encumbering intricacies of the apparatus. But Morse's early plans, involved as they were, contained the groundwork upon which the dot and dash alphabet was produced by a natural evolution; and, whether his system was the best or poorest of its kind, it brought the telegraph to the favorable notice of capitalists in a form which could not fail, even in the hands of unskilled operatives.

It is said that Morse was chagrined that operators, as they became skilful, could read messages by sound without the aid of his permanent recorder; but, with respect to the credit due him, it matters not whether his devices had their uses for a year or for a century,

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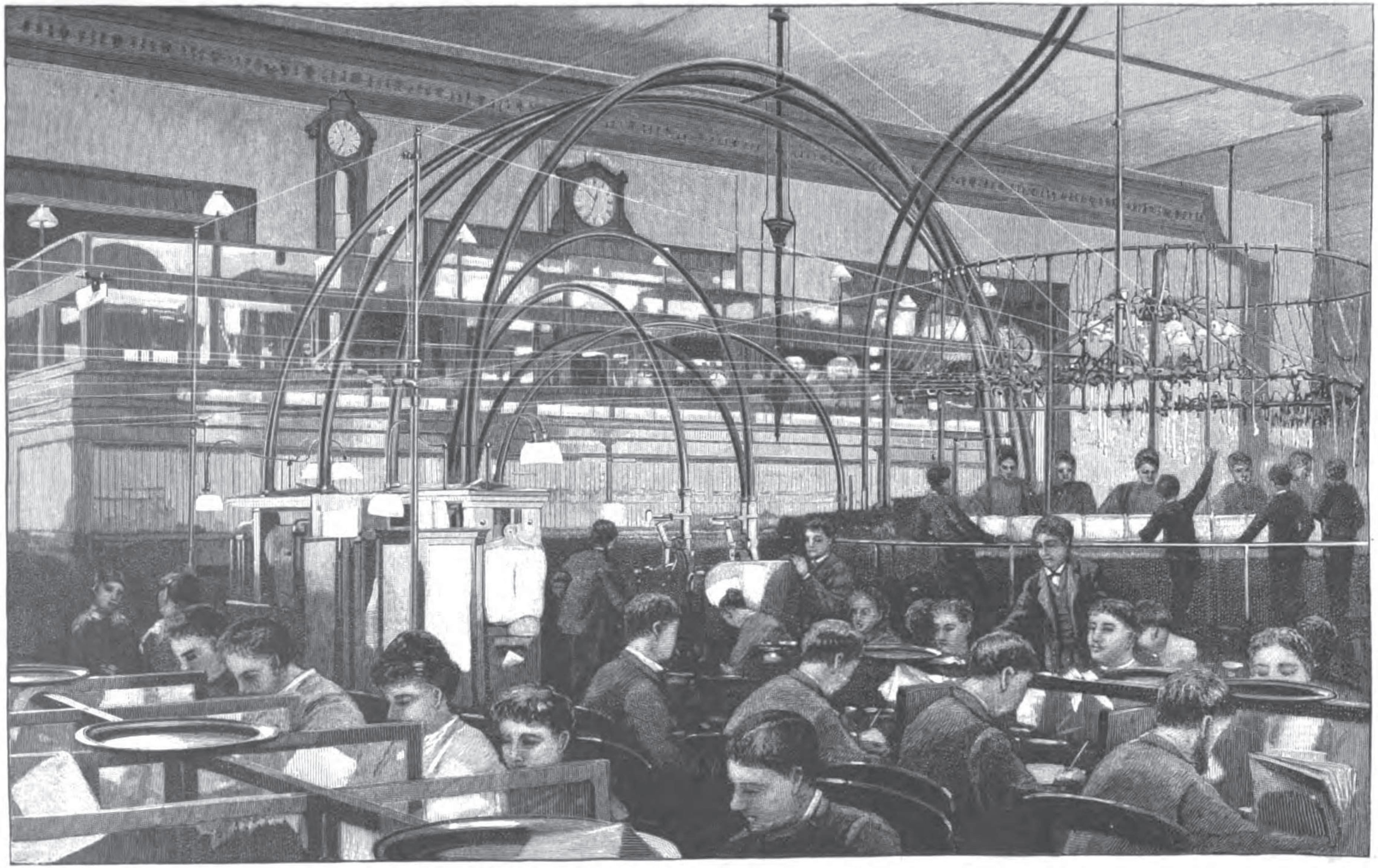

Main Operating-room of the Western Union, New York.

(Showing front view of switchboard; the pneumatic system for transmitting messages to and from city stations; and the mechanical system for collecting from and distributing to the 600 operators in the room.)

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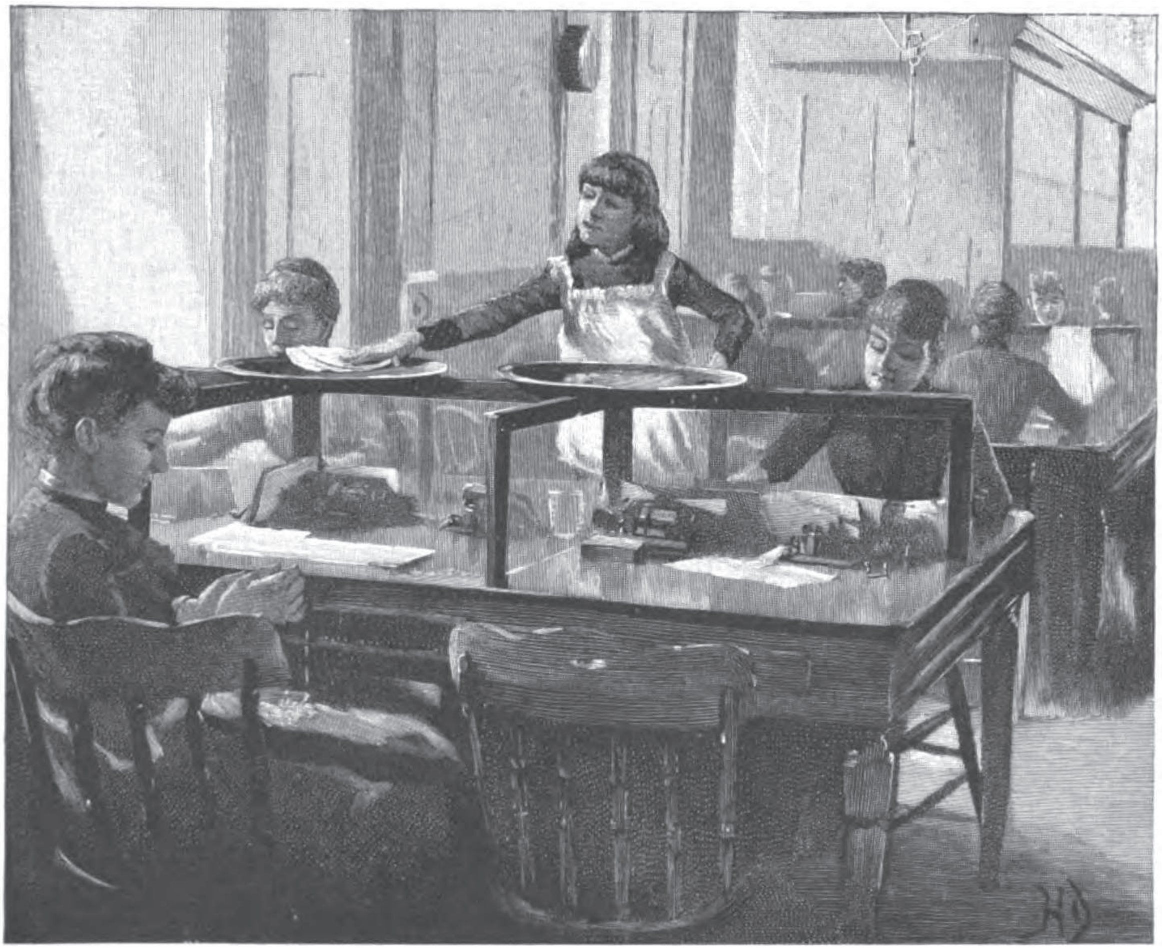


Check-girls who Collect and Distribute Messages.—Western Union Main Operating Room, New York.

they served their purpose and gave the telegraph an introduction to the world, which otherwise it might not have received for a generation.

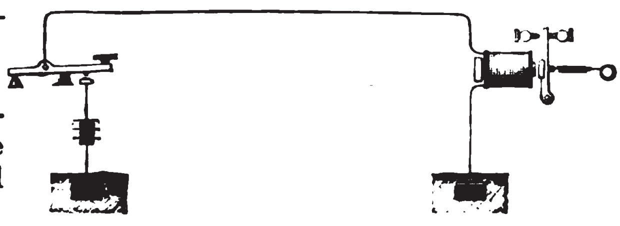
If the struggles of Morse and his associates in securing public recognition of their undertaking could be forgotten, it certainly would now seem anomalous that he should be honored by having his name metonymically represent the modern electro-magnetic telegraph ; consisting as it does of a circuit, a circuit-breaker, a battery, and an electro-magnet—for these are the elements which were old, and to which he had recourse when he first assumed the rôle of inventor.

Others before him had devised systems of great merit, while many of his contemporaries, of higher scientific attainments, were diligently working in the same direction ; nevertheless, his success in adapting the telegraph to the ignorance of the age rightfully placed him beyond competition.

Doubtless Morse derived valuable assistance from Henry and Vail, but the telegraph of to-day bears the marks of his genius in features, from the smallest detail to things of indispensable importance.

The world has lost nothing, nor is it less to his credit if parts of the invention which he esteemed most have, like the false works of an arch, been removed. When they became an encumbrance their absence was doubtless as important as had been their presence, to give the structure its original shape and strength.

No sooner had Morse and Vail demonstrated the feasibility of the telegraph than it became important to



The Modern Morse Telegraph.

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increase the carrying capacity of the wires. In 1846 Bain proposed to employ perforated strips of paper to effect automatic transmission in connection with an electro-chemical process for recording, in which marks upon a moving band of paper are made by discoloration attending the passage through it of signalling currents. But up to 1852 no one appears to have conceived the possibility of a system by which two or more operators might simultaneously use a wire to transmit independent messages.

In that year, however, Moses G. Farmer, of Salem, Mass., devised a synchronous-multiple telegraph, in which he proposed to employ two rotating switches, one at each end of the line, to successively and simultaneously join the several operators at one station with those at another. For illustration, it may be assumed that at each end of the line an equal number of short wires is connected from the earth with a circular series of stationary electrical contacts arranged like the hour-marks of a clock-dial, over which a rotating arm, like the hand of a clock, rapidly draws a spring or trailing conductor. The rotating arms are connected with the main line, one at each end, while each of the short wires is provided with a set of Morse instruments, and thus it is that each operator may send a signal to, or receive one from, the operator upon a corresponding branch at the distant station. It is now seen that if the two arms are rotated together, having been started from the same angular position, the main line will simultaneously join the No. 1 branches at each station, and all the several branches at one end will, in rapid succession, be connected with corresponding branches at the other. When two branches are thus joined, a momentary electrical connection is made between the operator at one station and his correspondent at the distant end. But not so if one arm is running faster or slower than the other, for then branch 2, at one station, might be joined either with 1 or 3 at the other.

Only an intermittent current, however, is sent over the circuit of each pair of operators; nevertheless, the pulses succeed each other with such rapidity that a practically continuous magnetic effect will be produced upon the relay in making a signal, provided the time required for an electro-magnet to part with its magnetism, upon the cessation of current, be longer than the interval between pulses.

The multiple-synchronous system, from a historical standpoint, is worthy of notice, not because of demonstrated superiority over other methods, but rather from the fact that it was the first multiple system invented. Moreover, it is important because of its promise of a capacity for a larger number of transmissions than it was supposed could otherwise be obtained. The public is occasionally startled with an announcement that someone has invented a telegraph by which a wire may be utilized for twenty or perhaps forty transmissions; but usually it is the old wanderer in a new garb. Speed by this method, however, is limited far within the bounds of these statements. It might seem that it would only be necessary to multiply the number of contacts and to increase the velocity of the rotating arms; but the limit in this direction is soon reached, for only a certain number of impulses can be transmitted over a line within a certain period with force

The Door-keeper, Western Union Operating Room.

(In the service of various Telegraph Companies for over forty years.)

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Sending Coffee Quotations over Ticker Circuit.

sufficient to produce signals. Many valuable improvements have been made in recent years in this class of telegraphy, but, large as the art has grown, the great object of all has been to obtain more perfect synchronism—that is to say, to cause two mechanically independent arms to rotate at the same speed.

The reduction of the duplex to practical form, in 1872, marked the most important advance in the art of telegraphy since 1844. For not only did it practically double the capacity of a wire by utilizing it for two simultaneous transmissions—one in each direction—but its development led to a careful investigation and a full understanding of the phenomenon of static induction on telegraph-lines. [For further effects of static induction, see pp. 16, 18, 22.]

In 1853 Dr. Wilhelm Gintl, of Austria, invented a duplex system which, in the following year, was so far improved by Carl Frischen, of Hanover, that it lacked only one essential element—means to balance the effects of static induction upon the relays—to bring it to its present perfection. This important addition was supplied by Joseph B. Stearns, of Boston, Mass., in the early part of 1872, and by its application the duplex became a successful means of doubling the telegraphic capacity of the longest circuits. From that moment messages were simultaneously transmitted between New York and Chicago,

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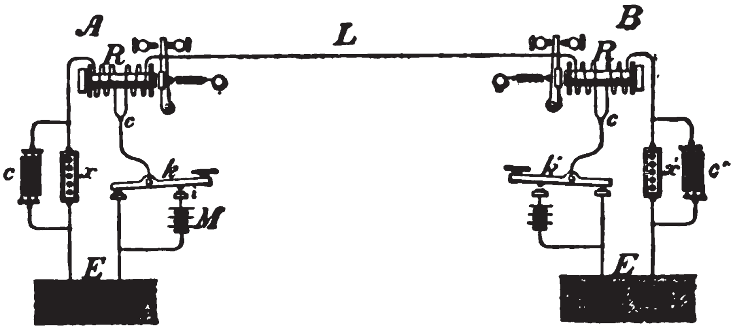
and upon lines of even greater length. Yet before this improvement the duplex was of no greater utility than had been the systems which had preceded Morse.

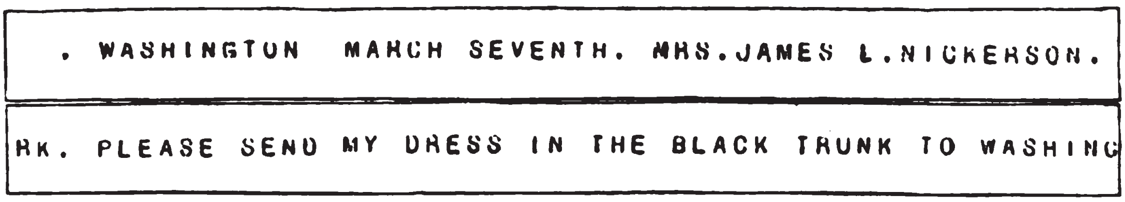


The Duplex System, for Simultaneously sending two messages, one in each direction on a single wire.

In the accompanying diagram, showing the essential parts of Frischen's method as improved by Stearns, *A* and *B* are the respective stations at the opposite ends of the line. At *A* the artificial line is split from the main circuit *L* at a point *c*. and is made to include a second relay coil and an artificial resistance, *X*, and from the latter continues to the ground at *E*. Each coil has an equal number of turns around the relay core, but the one is wound in opposition to the other, so that currents of electricity passing simultaneously through them will create neutralizing effects. The resistance of the artificial line is made equal to that of the main line *L*, extending from point *c* of station *A* to earth, *E*, at station *B*, by adding resistance-coils *X*. If, now, key *K* be depressed upon its front stop, *I*, battery *M*, whose pole is connected with *E*, will be connected with the line, and the current issuing from the battery *M* will be divided at *c*, one-half flowing over the main line to produce a signal upon relay *R* at station *B*, while the other half passes through the artificial line, and thus acts upon the core of the differential relay *R*, to neutralize the magnetic effect produced by the main-line flow. A current in passing along a wire coiled around the iron core of a relay makes the core magnetic, and produces a signal through the attraction and consequent vibration of a movable iron bar, or armature, which is normally held in a back position by means of a spring.

It is said that if Morse had failed in 1844, someone would have succeeded within a few years. It, however, required eighteen years to supply one step, or, more properly, to discover one fault in the duplex, at a time when its value was as certain as the fact that two telegraph-lines cost more than one.

The principal characteristic of the duplex is, that a signal which is sent to a distant station for reproduction shall produce no effect upon the home receiving-instrument. In transmitting a signal, Frischen split the outgoing current into equal parts, and used one-half on the main line to produce a signal at a distant station, and the remainder upon an artificial line, beginning and terminating in the same office, to prevent signals at the home station. But, that the division of the current between the main and artificial lines may be equal, the resistance to the electrical flow in one must be made equal to that of the other. The use, however, of great lengths of wire for the artificial line is avoided, by employing a German-silver conductor of such small calibre that only a foot of its length may have the resistance of a mile of telegraph-line; and by this expedient an artificial line which will balance a long telegraph-circuit may be reduced to the compass of a small box weighing only a few pounds.

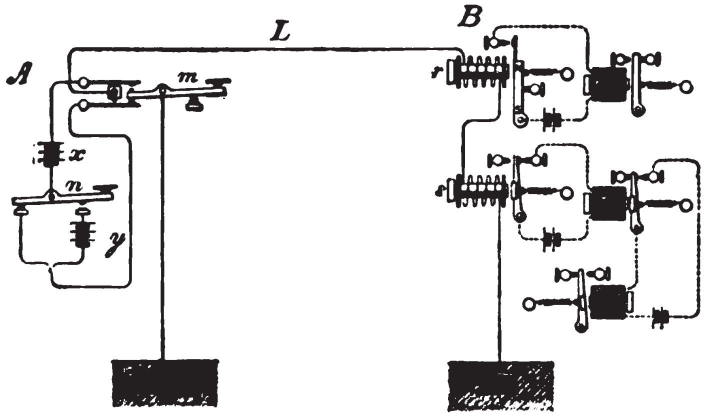


Telegram as Received by the Phelps Motor Printer.

If, with the batteries arranged, as shown in the diagram above, both keys were depressed at once, no current would flow over the main line, because one battery would oppose the other. Still, signals would be made at both stations, notwithstanding an absence of main-line current, for the relay cores would be made magnetic by currents in the artificial-line coils. If, however, the battery at one end were changed about, with its negative pole to line, its positive being connected with the earth, one battery would not neutralize the other upon the depression of both keys. On the contrary, the main line current would be of double strength. As before, signals would be simultaneously made at both stations, but from a different cause. In this instance the double current in the main-line coils of the relays overbalances the single strength flowing in each artificial line.

When a telegraph-line is connected with a battery in sending a signal, it is charged, or filled from point to point, as is the bed of a river with an unlimited supply of water flowing from its source. A current would not begin at any point until the bayous and lagoons above had been partly or wholly filled, for they would serve as reservoirs, temporarily, to exhaust the supply; and as time is required for a flood to set in from the source to the mouth, so there must intervene an appreciable period before an electrical current of normal strength will be established throughout the length of a telegraph-line. While a line is becoming charged, a variable current, starting at great strength at the battery end is set up, because the electric flow in the beginning encounters only the resistance of a short length of line; and after the removal of the battery, if the line is connected with earth, a momentary return-current will occur. Thus it is seen that, accompanying each signal transmitted, an abnormally strong current will flow from the battery at the first instant, while at its termination there will be a strong return-discharge.

These currents were the source of difficulty in Frischen's duplex, for they were not balanced upon the differential relay, because there were no similar currents in the artificial line. A circuit made up of a short, thin wire, like Frischen's artificial line, however great its resistance to the electric flow, has no considerable metallic surface and no appreciable electrostatic capacity.



The Diplex System, for simultaneously sending two messages in the same direction on a single wire

In the diagram of the diplex, two transmitting keys, *m* and *n* are shown at station *A*, and two receiving-instruments, *r* and *s*, at station *B*. Receiving-instrument *r* is a polarized relay—or, for convenience of illustration, an electro-magnet having an armature consisting of a permanent magnet, responsive only to the backward and forward flow of current in the line, commonly known as reversals; while receiver *s* is neutral, its armature being of soft iron and therefore being actuated only by increasing the current-strength. By the depression of key *m* the current normally flowing to line from battery *x* is reversed, and by the depression of *n* battery *y* is added to *x*; while, if both keys are simultaneously operated, not only is *y* added to *x* but both are inverted and a strong reverse current is sent to line. A normal current of minor strength, sent to line when both keys are underpressed, magnetizes the polar relay in such manner as to force its armature to a back or non-signalling position. If, however, key *n* alone is depressed, a full current of normal direction will be transmitted which will serve to press the armature of the polar relay more firmly to its back position. If the direction of current normally flowing develops a north magnetism in the right end of the relay core, the upper or vibrating end of the armature being north, one mutually repels the other; if, however, the current is reversed, the resulting south magnetism of the iron core and the north magnetism of the armature become mutually attractive. An increased current, therefore, will not actuate the polar relay to produce a signal, but it will serve to magnetize the core of the neutral relay sufficiently to overcome the strong retracting spring of its armature, and thus to produce a signal. The neutral relay is equally influenced by positive and negative currents, the armature being of soft iron and equally attracted by either north or south magnetism, and hence it is that the reversal of a minor current which is capable of moving the polar relay will have no effect upon its armature. If, therefore, the latter be in its back position, it will not be actuated by the reversal of a minor current. Likewise, if the armature of the neutral relay be attracted, a subsequent reversal should not cause its movement. In practice, however, it is found upon long lines that during reversal there is a tendency for the armature of the neutral relay, if attracted, to be drawn back by its spring and thus to mutilate its signals. In other words, the period of static charge and discharge during a reversal is so long that the neutral relay, which should be wholly governed by changes in current-strength, has the fault of responding to reversals and to signals sent by the wrong operator. This is the great difficulty encountered in operating the quadruplex system. Otherwise it would be as perfect in its operation as the single Morse system.

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Stearns gave the artificial line an electrostatic capacity, and thereby, at the beginning of a signal, the abnormally strong current flowing to the main line was balanced by an approximately equal one passing into the artificial line. Likewise at its termination the discharge from the main line was balanced by an equal return-current from the artificial line. And this Stearns accomplished by connecting the opposite plates of a Leyden jar, or condenser, one above and one below the resistance *X*.

In the diplex, forming a part of the quadruplex of the Western Union, two messages are simultaneously sent over a wire in the same direction, one by current-reversals and the other by changes in current-strength ; and although both signals are electrically effected they are, nevertheless, as independent as would be two messages, if one were sent along a metal rod by the blows of a hammer, and the other electrically by the Morse method. [See Diagram and Explanation, pg. 10.]

Doubtless many methods of illustrating double transmission will suggest themselves to the reader. A long rod might be moved backward and forward along its axis by one operator to ring a gong, while at the same time a second operator could rotate the rod about its axis to move a flag or to turn the hand of a dial. Two transmissions could also be effected by the action of water in a single pipe. If a section of the pipe were of glass, a valve placed within could be made visibly to move to and fro, and by the backward and forward flow, thus caused, to indicate signals of one message, while signals of a second message could independently and simultaneously be indicated by increased pressure, shown by the height of fluid in a vertical pressure-gauge.

It has now been shown that two messages may simultaneously be transmitted in opposite directions, and also that two messages may simultaneously be sent in the same direction. It will readily be understood, by referring to the illustration, that the quadruplex, by which two messages are simultaneously sent in each direction, is formed by placing at each end of the duplex two transmitters and two receivers such as are shown in the diplex. In this arrangement the artificial line of the duplex is made to include a neutralizing coil on each of the two relays, thus preventing the receiving-instruments at the home station from responding to outgoing signals, while the reversing and current-changing keys independently serve to bring into action the polar and neutral relays at the distant station.

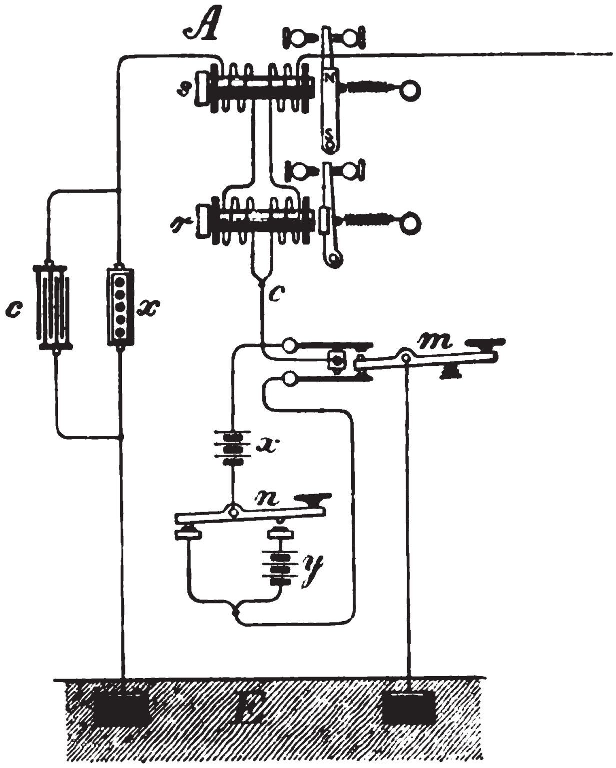

Diagram of the Quadruplex Telegraph, for sending four messages, two in each direction, at the same time on a single wire.

Instead of transmitting two messages in the same direction, one by reversals and the other by changes in current-strength, both transmissions may be effected by employing three different strengths of current, all in one direction ; and, in fact, this principle has been adopted in using the quadruplex as a foundation for a sextuplex—a system for three simultaneous transmissions in each direction.

In the multiple-harmonic system, by which many messages may be transmitted in one direction, or in opposite directions, each operator, by depressing a Morse key, puts in action a vibratory circuit-breaker, and thus causes a series of electrical pulses to flow over the main

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line and through several receiving electro-magnets, which are provided with vibrating armatures formed of reeds or steel ribbons so proportioned that their different rates of vibration may be made equal to those of the transmitters. If the elastic reed or ribbon of a receiving-instrument is not tuned to vibrate in unison with the transmitter it will not be brought into action, but will remain quiescent, as would a pendulum if forces were applied on both sides without regard to its period of vibration and direction of movement. The several receivers are thus made responsive to the corresponding transmitters, while each is silent to all but its own pulsations; and although a composite tone will be transmitted when all the sending keys are simultaneously depressed, no interference between the several transmissions will ensue; for each receiver, under the action of the resultant series of pulses, is vibrated, as though only an intermittent current from its own transmitter were sent to line. The several receivers act to analyze the composite series of pulses, each taking up a component series equal in number to the vibrations derived from its transmitter. If the several transmitters were tuned to the notes of a musical scale, a tune could be played and reproduced by the several receivers if placed in the same room; but each receiver would produce only its characteristic note, as is found by placing them in separate apartments. Thus an independent message may be transmitted by each of the several keys, and it will be reproduced only upon the corresponding receiver.

The efficiency of this system, however, is seriously impaired by inductive disturbances from other wires on the same poles, and probably this defect, more than any other, has prevented its adoption. Experiments, however, at moderate distances, with only one wire on a line of poles, seem to have been very successful.

Morse originally proposed to employ type-blocks, which, placed in forms, were mechanically moved under the arm of a circuit-breaker, to automatically transmit signals. In 1832 he suggested also the electro-chemical process of discoloring a strip of paper for making a permanent record. But neither idea was practically applied by him. The modern chemical automatic was first put into experimental form by Bain before 1850, but with little success. Bain, as is now done, transmitted messages by drawing a perforated strip of paper between the points of a key and a metallic surface, the holes in the paper permitting the two to come in contact, and thus to transmit a signal. Morse did not suggest the automatic for the sake of great speed—he only sought mathematical accuracy in transmission. Whatever Bain hoped to accomplish in the direction of greater capacity, his primary object was to make a telegraph that he could use notwithstanding Morse's patents. In 1869, however, the electro-chemical automatic was brought to public notice as a system possessing rare qualities of speed. But in its several competitive trials with the Morse it has proved a remarkable failure, although, perhaps, more than a moderate degree of success might have been expected. Many believed that it would give a wire at least thirty times the capacity of a Morse circuit; and perhaps not without reason, for President Grant's annual message of 1876 was sent over the wires of the Atlantic & Pacific Telegraph Company, from Washington to New York, at a rate which apparently justified this estimate. But, notwithstanding the theoretical advantages of the system, it has failed in the hands of companies having the strongest financial support, and, in fact, it has ruined every organization which has persisted in using it in competition with the Morse. And so conspicuous have been the failures that their history may have some interest for the general reader.

We may obtain an idea of the enthusiasm aroused in behalf of this system from the annual report of Postmaster-General Cresswell, of November 14, 1873:

"For years past the attention of inventors and scientists has been attracted to the necessity for a more rapid and less expensive mode of transmission than the Morse, which requires the messages to be spelled out by a slow and tedious process, at about the speed of an ordinary writer. One of the results of their investigations is the automatic or fast system now in operation between New York and Washington.

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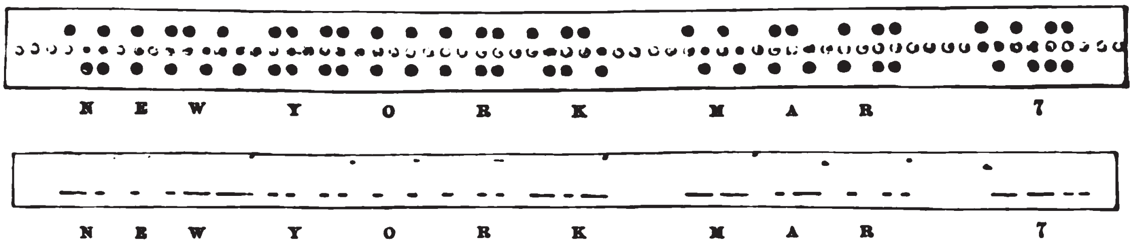
This system is capable of a speed of from five hundred to eight hundred words per minute. The average of an expert Morse operator is not over twenty-five words per minute. Therefore it is evident that if the automatic method can be made to accomplish what its advocates con-

Perforating Messages to be Sent by the Wheatstone System.

fidently predict for it, the capacity of a single wire for business will be increased nearly or quite thirty times. . . . There can be no doubt of the ultimate success of the automatic principle. Its battle with an incredulous public is almost won. As soon as it shall be thoroughly developed and applied in practice the problem of cheap telegraphy will be definitively solved."

The Postmaster-General assumed that the time had come for the formation by the Government of a postal telegraph



Specimen of Perforated Slip for Sending Message by the Wheatstone ; same message as received.

system. Failing, however, to induce Congress to build lines, the owners of the automatic system, in 1874, secured a purchaser in the Atlantic & Pacific, a corporation owning many thousand miles of wire, which was then in opposition to the Western Union. Notwithstanding the fact that the Western Union had recently doubled the capacity of its wires by using the duplex, it was naturally assumed that, with the assistance of the chemical automatic, the Atlantic & Pacific could operate its lines at a profit after reducing Western Union rates by one-half, for it had been confidently represented that a wire thus equipped was capable of at least thirty Morse transmissions. President Grant's message in 1876 had been telegraphed two hundred and fifty miles at the rate of several hundred words a minute ; but notwithstanding this, and other apparently successful tests, the system, after a use of about two years, was discarded. The failure was made conspicuous by the fact that the Atlantic & Pacific was able to give the undertaking all necessary support. This, therefore, is not an instance of a meritorious invention permitted to perish

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for want of nourishment in infancy. It was not abandoned until it had proved an expensive experiment; and in the end its worthlessness was so thoroughly demonstrated that the Atlantic & Pacific having only an imperfect system of double transmission was for the most part reduced to the use of single Morse instruments, while its rival enjoyed the advantage of the Stearns Duplex.

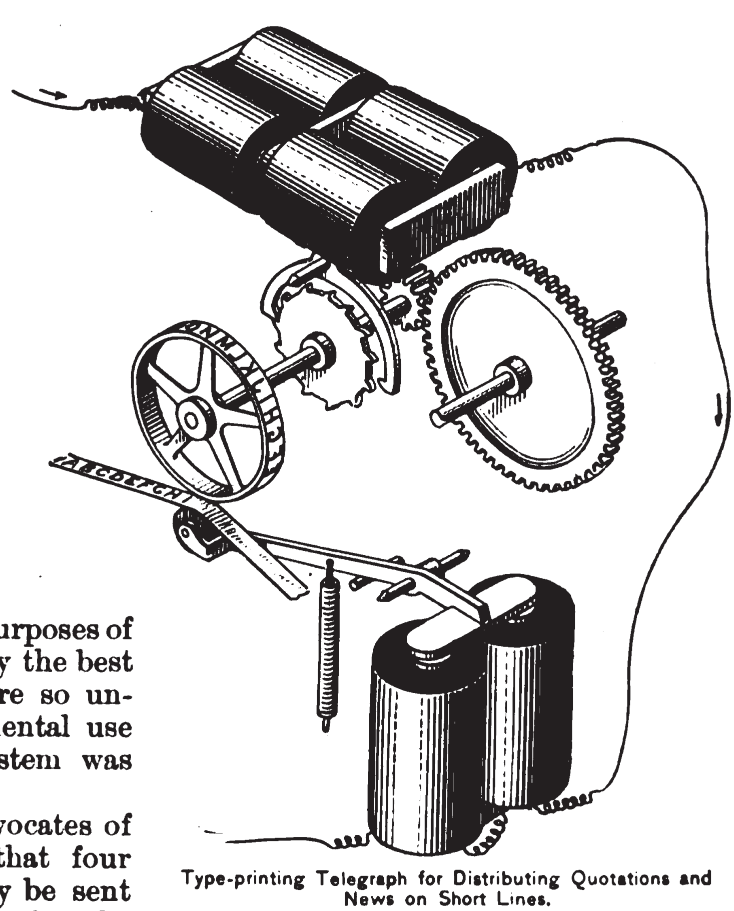
Again, in 1879, an automatic system containing many valuable improvements was taken up by the American Rapid Telegraph Company, a corporation of large means, whose lines were built to remedy certain defects said to have contributed largely to the Atlantic & Pacific failure. But after a trial of nearly five years the automatic was again abandoned. The American Rapid began with a system which, of its class, will probably never be excelled, and for which it was promised that two thousand words a minute, instead of one thousand, could be sent over a wire; but at one speed or another, with good wires or bad, the automatic system seemed equally potent to break down any company attempting to use it to the exclusion of other methods.

In 1883 an effort was made by the Postal Telegraph Company to introduce the automatic system of Leggo, upon a large wire of low resistance, between New York and Chicago; and although, for the purposes of an automatic, this was probably the best line ever built, the results were so unsatisfactory that after experimental use for about three years the system was finally abandoned.

It is now maintained by advocates of this method of telegraphy, that four thousand words a minute may be sent over a single wire; but, considering the signal failures at one thousand and two thousand, these assertions only lead to the conclusion that the great speed of the system is of no avail, and that it is the *ignis fatuus* of the telegraph world.

New men will from time to time be induced to take up this chimera as a means of revolutionizing telegraphy, but a company could now wish a competitor no greater harm than the use of an electro-chemical system as its principal method of transmission. The automatic is doubtless a valuable auxiliary to a telegraph system, but it cannot be exclusively used to advantage.

The Wheatstone telegraph is a system which has long been used with a high degree of success in Great Britain, and has in late years proved a valuable adjunct to the Morse in the Western Union service, particularly where large volumes of business must pass over few wires. In this system messages are automatically transmitted by a strip of perforated paper, while their reception is effected by an ink-marker which, under the action of a receiving electro-



Type-printing Telegraph for Distributing Quotations and News on Short Lines.

The diagram indicates the principal parts of a step-by-step printer which, in various modifications, has been very generally used for reporting quotations and news upon short lines in cities. The type-wheel is rotated in this case by a clock-motor, and its step-by-step action is limited by reverse currents sent over the circuit. If a short pulse, of one polarity or the other, is prolonged, a neutral magnet in the same circuit is actuated to press a paper strip against the wheel to effect printing. To print a particular character, therefore, it is only necessary to transmit a number of reversals; to turn the wheel from the position which it last occupied, so bringing the character over the press-pad, then to prolong the last current transmitted, to effect an impression.

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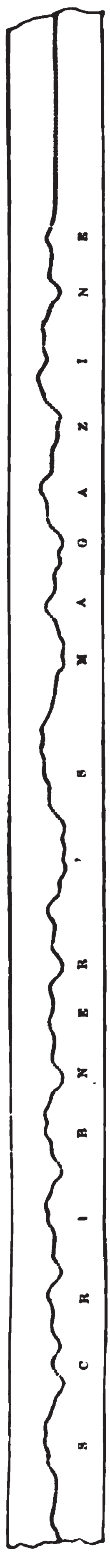

Cable Message as Received by a Siphon Recorder.

magnet, makes Morse dots and dashes upon a moving band of paper. Although the use of an electro-magnetic receiver makes impossible the high speed which may be obtained by the electro-chemical method, the one possesses advantages over the other which are indispensable to a successful system. In the Wheatstone, repeaters which serve to convey transmissions from one circuit to another without manual aid may be employed, as is done at four points on a line twenty-six hundred miles long, from Chicago to San Francisco, while in the electro-chemical system this is impossible; and for this reason alone it is not practicable upon lines of the greatest length, where it would be most useful. Moreover, the record, when made in ink-marks, is far more reliable than when formed by electro-chemical discolorations on moistened paper, for in the latter case, at great speed, the tendency for dots and dashes to become blended into a continuous line is marked. The Western Union has long controlled the electro-chemical systems with which the Atlantic & Pacific and the American Rapid Companies failed; but it has not attempted to utilize either, and most of the apparatus has long since found its way to the junk-dealer.

The *fac-simile* telegraph, by which manuscript, maps, or pictures may be transmitted, is a species of the automatic method already described, in which the receiver is actuated synchronously with its transmitter. By Lenoir's method a picture or map is outlined with insulating ink upon the cylindrical surface of a rotating drum, which revolves under a point having a slow movement along the axis of the cylinder, and thus the conducting point goes over the cylindrical surface in a spiral path. The electrical circuit will be broken by every ink-mark on the cylinder which is in this path, and thereby corresponding marks are made in a spiral line by an ink-marker upon a drum at the receiving end. To produce these outlines it is only necessary that the two drums be rotated in unison. This system is of little utility, there being no apparent demand for fac-simile transmission, particularly at so great an expense of speed, for it will be seen that instead of making a character of the alphabet by a very few separate pulses, as is done by Morse, the number must be greatly increased. Many dots become necessary to show the outlines of the more complex characters.

The pantelegraph is an interesting type of the fac-simile method. In this form the movements of a pen in the writer's hand produce corresponding movements of a pen at the distant station, and thereby a fac-simile record.

In the many forms of type-printing telegraphs which have come into use there has been employed a rotating type-wheel carrying the necessary characters, as shown in the illustration on page 14.

Printers in which the type-wheel is rotated step by step were, in the earlier days of telegraphy, employed upon comparatively long lines, and very considerable speed was obtained, but because of the number of pulses required to bring the type-wheel into position for an impression, such printers are not well adapted to the longest lines, the speed at which one pulse may be made to follow another being limited.

In the Phelps motor printer, which is used to a limited extent by the Western Union Telegraph Company, only one pulse transmitted over the main line is required to print each letter. This is accomplished by the synchronous principle, a transmitter at one station and a type-wheel at the other being rotated

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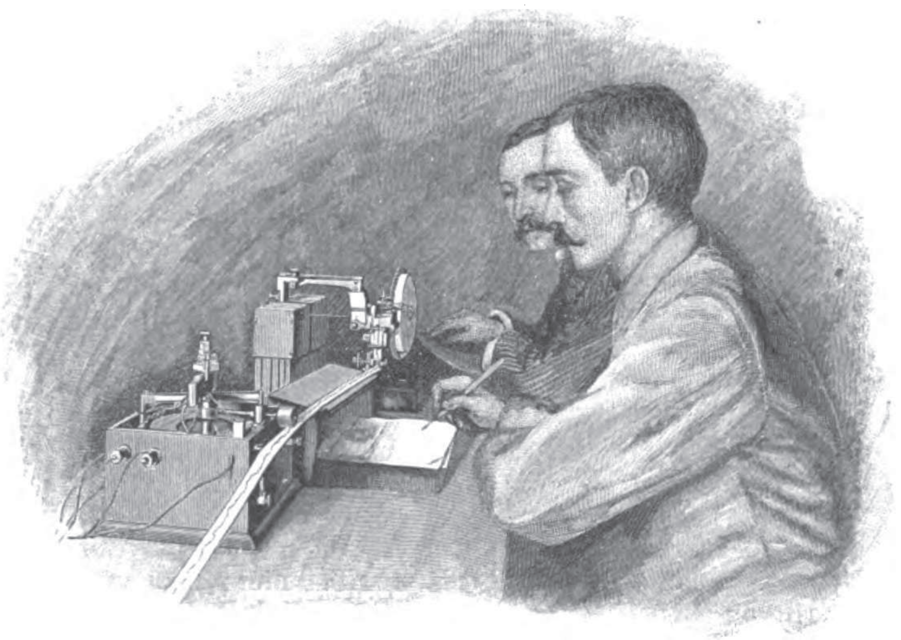
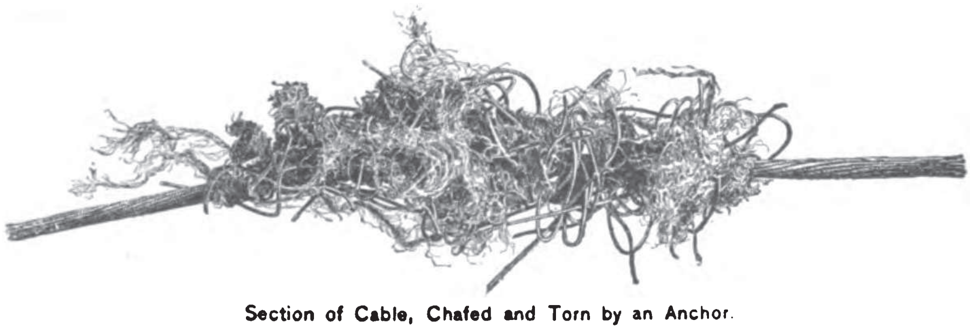
by suitable motors at exactly the same speed. In the rotation of the transmitter, upon depressing a key, a current is sent to line just when the character on the type-wheel corresponding with the key depressed is brought opposite the press-pad.



The Siphon Recorder for Receiving Cable Messages—Office of the Commercial Cable Company, 1 Broad Street, New York.

Only the feeblest currents should be used on submarine lines, since heavy pulses which could be employed with impunity on land lines, if they did not soon destroy the cable-covering would, at least, tend to develop faults which otherwise might long remain latent. Defects in cable-covering that otherwise may not lead to harm admit moisture, and hence, under the action of a strong current, oxides are quickly formed, destroying insulation. The necessary use, in ocean telegraphy, of the lightest currents has led to the development of a class of recording instruments remarkable for delicacy of action—notably the Siphon Recorder, which indicates the electric impulses by a wavy ink-line on a tape, and the Reflecting Galvanometer, which causes a spot of light to move from right to left in a darkened room. With these recorders and thirty cells of battery, messages sent across the Atlantic are telegraphically reproduced in ink at the rate of from twenty to twenty-five words a minute, each way, the cable being duplexed. But for electrostatic induction a single cell of battery would suffice for transmission from the earth to the moon, if those bodies could be connected by a wire of the size used in ocean cables. Indeed, under such conditions, if there were only the resistance of the wire, with the larger batteries now used in working the quadruplex on land lines five or six hundred miles long, messages might be sent from the earth to the sun, ór from one planet of the solar system to another. The impediment of static induction in telegraphy is strikingly exemplified in the ocean telegraph. If there were no such phenomenon a single battery cell could operate around the globe better than do thirty cells across the Atlantic. Upon land lines there is usually found not



Section of Cable, Chafed and Torn by an Anchor.

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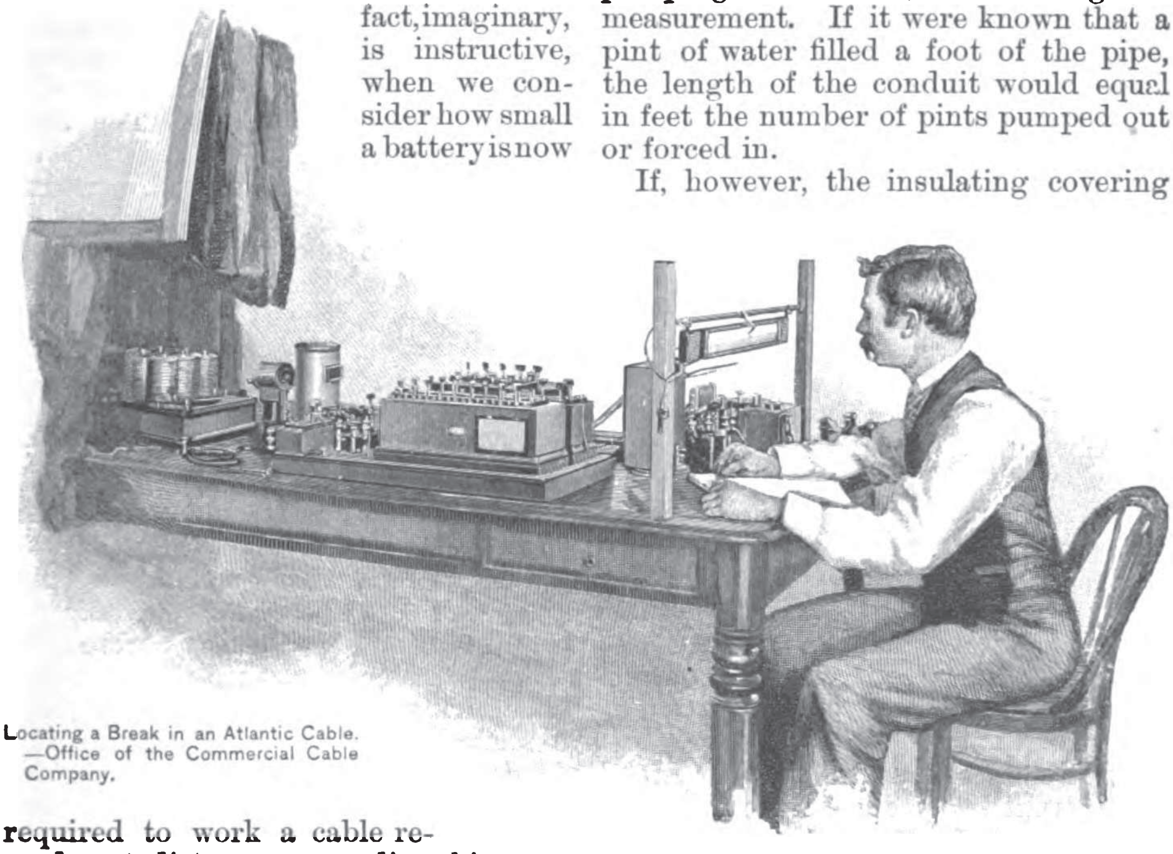
more than one-fiftieth of the opposition encountered from this cause on ocean cables; yet, even here, the amount of current absorbed along the line by static induction is far greater than the portion employed in making signals.

While Morse in planning his telegraph apprehended that the fluid might not act upon a circuit with sufficient force to effect transmission over great distances, he was confident of his ability to accomplish this, if a line could be worked ten miles, by employing a series of circuits joined by relays. His assumption of only one prime difficulty, which was, in fact, imaginary, is instructive, when we consider how small a battery is now required to work a cable recorder at distances exceeding his most sanguine speculation.



Locating a Break in an Atlantic Cable. —Office of the Commercial Cable Company.

Simple as are the methods of locating mid-ocean breaks in cables, so that a vessel may sail to the point of rupture, they are, perhaps, not popularly understood. If the metallic conductor were broken, the surrounding insulation remaining perfect, the electrostatic charge of the cable, or the amount of electricity which it absorbs in becoming charged, is electrically weighed by building up an artificial line until the current flows equally into the cable and such artificial line. This equal division of the current might be indicated by a differential instrument resembling the duplex relays, shown on page 9. If the currents are equal, the armature of the differential instrument remains quiescent during their passage through its coils, for one balances the other. Each element of the artificial line having the static capacity of a known length of cable, an inventory of the elements used in making the artificial line would obviously give the length of the cable. This process is no more abstruse than would be the determination of the distance to a water-tight obstruction in a pipe, by forcing in or pumping out water, and taking its measurement. If it were known that a pint of water filled a foot of the pipe, the length of the conduit would equal in feet the number of pints pumped out or forced in.

If, however, the insulating covering of the wire is broken, the current will flow freely from the conductor to the surrounding water, and its strength, if the power of the battery is known, definitely measures the electrical resistance and consequently the length of the conductor. [See Ohm's law, p. 648, June.] In other words, the battery-power, divided by the indicated current-strength, gives the line's resistance, and therefore its length. In the same manner, if we know the head of a water-supply, we may easily determine the length of a pipe by noting the velocity of the flow.

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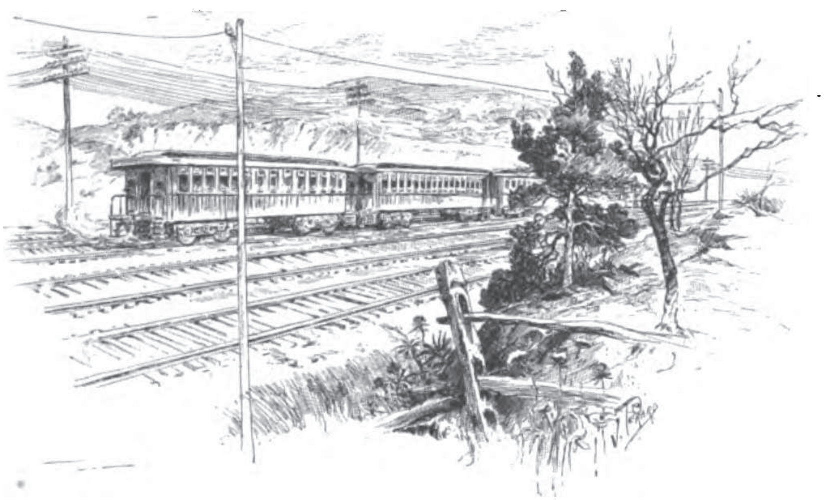
Few discoveries have added more to the fund of electrical science than the recent determination of the fact that feeble telegraphic currents may inductively be conveyed across an air-space of one hundred feet or more.



Train Telegraph—the message transmitted by induction from the moving train to the single wire.

The idea of telegraphing to moving trains had its inception as early as 1853; but of the many forms suggested all were impracticable in that they involved a mechanical contact between the train and the stationary conductor. Obviously, it is not feasible to make a circuit, either through a sliding arm projecting from a car, or by so modifying the track of a railroad that its rails may be utilized as electric conductors. But that this may be done by induction there can be no doubt, for its feasibility has been shown in daily practice upon the lines of the Lehigh Valley Railroad for the past two years. A moving train may now receive messages passing along a neighboring wire almost as readily as New York communicates with Philadelphia by ordinary methods. Nor does the great speed of the train interfere with successful communication. If it could attain the velocity of a meteor, signals upon the wire would fly across the intervening space, inductively impressing themselves upon the metal roofs of the cars, with the same certainty as if the cars were motionless upon a side track; and it is not even essential that the train and the line be separated by a clear air-space, for non-conducting or non-magnetic substances may be interposed without impeding transmission. During the memorable blizzard of March, 1888, the capacity of the system, in this particular, was subjected to an instructive test on the Lehigh Road.

On the afternoon of March 14th, the second day of the storm, an effort was made to clear the road by forcing a train of four locomotives and two tool cars, carrying two hundred workmen, through a long cut near Three Bridges Station. The snow had filled the cut upon the north side high above the train and the telegraph-wire, but the south side was nearly empty. As a consequence of the great resistance offered by the snow on one side, the three locomotives in the lead were forced off the rails to the right, and were badly wrecked. No sooner had the train operator recovered from the shock than he sent a message advising the division superintendent of the accident, and requesting aid for the killed and injured. For a long distance, at this point, snow and ice covered the wire to a depth of more than ten feet, yet during the following three days, in clearing the wreck, about six hundred messages were sent between the car on the south track and the wire running along the north side of the road. Notwithstanding the intervention of snow, communication remained as clear as before.

When an electric current passes over a telegraph-line, objects along its length, although at a considerable distance, are electrostatically charged, and thereby secondary currents are made to flow between these objects and the earth, both at the beginning and at the end of the electrical signal. Thus, if at the beginning of a signalling pulse a secondary current flows over an electrical conductor from a car-roof to the earth, at its termination a return-discharge will

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be established from the earth to the roof. But the currents between the roof and the earth are only momentary, and they will not be lengthened by prolonging the flow upon the main line. For this reason it is necessary to send many pulses over the main line, in making either a dot or a dash of the Morse alphabet, in order that a continuous effect may be produced upon the instruments in the car. If fifty short currents, following each other in rapid succession, should pass over the main line during the depression of a key to make a Morse dot, or one hundred to make a dash, double the number of induced pulses in the train-circuit would be developed, and tones like the buzzing of a wasp, of varying duration, representing dots and dashes, would follow in the receiving-telephone, which in this case replaces the Morse sounder. These signals are taken up by the cars all along the line, whether upon one track or the other of the road, and when running in either direction.

The accompanying diagram illustrates the arrangement of the apparatus used in a car. As here shown, an intermittent current is inductively thrown upon the line during the depression of key *K*. When the key is closed, primary circuits 6, 7, 8, 9 of an induction coil, including battery *B*, is first closed,

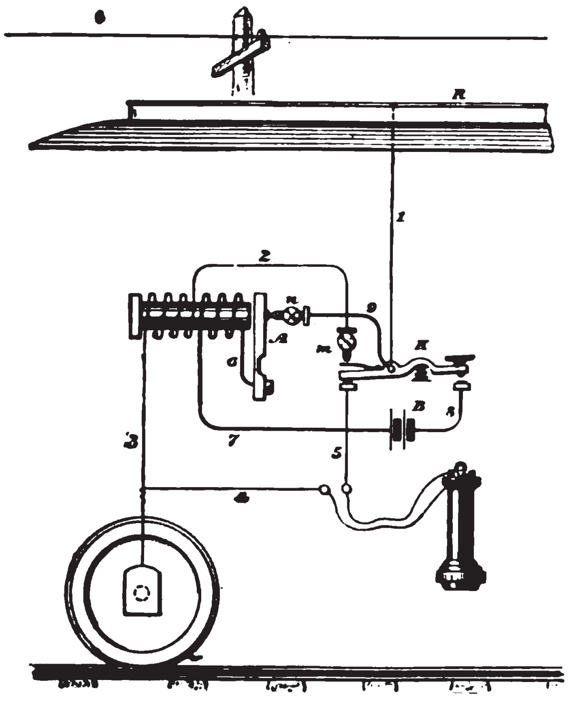

Diagram showing the Method of Telegraphing from a Moving Train by Induction.

and thereupon is rapidly opened and closed by an automatic vibrator, consisting in part of an armature, *A*, which normally rests against back contact *n*. The armature is first attracted, breaking the circuit; the iron core of the induction coil is then demagnetized, permitting the armature to return to contact *n*, and again to close the primary circuit. In this manner the forward and backward movement of armature *A* is effected. The secondary circuit of the induction coil, which is wound upon the same core and insulated from the primary, is shown by wires 1, 2, 3, and, although normally open, is closed upon the depression of the key at contact *m*, and is made to connect the car-roof *R* with the earth through wheel *W* and rail *M*. An induced current is set up within the secondary coil at each opening and each closing of the automatic vibrator, and as a result the car-roof is electrified, first above and then below the potential of the earth with which it is connected, and in each case its condition is impressed by induction upon the wire at the roadside. In this manner intermittent currents are thrown upon the line and are received upon a telephone at a distant station by "buzzing sounds," as in the car. When signals are not being sent from the car the transmitting key is not depressed, or is in its back position, and a receiving-telephone in the car is placed in circuit between the roof and the earth. At stations on the line the transmitting apparatus is not unlike that already described, except that the secondary circuit of the induction coil is made a part of the main line, while the telephone receiver is placed in the primary circuit of the induction coil.

The train system of the Lehigh Valley Railroad is provided with a single wire suspended upon a line of poles about sixteen feet above the rails and some ten feet from the double roadway, and hence about eight feet from the cars on one track, and twenty feet from those of the other; and so perfectly does the system act, at varying distances, that communication is quite possible even to a fourth track from the wire. While any one of the large collection of wires usually built along a railroad may be

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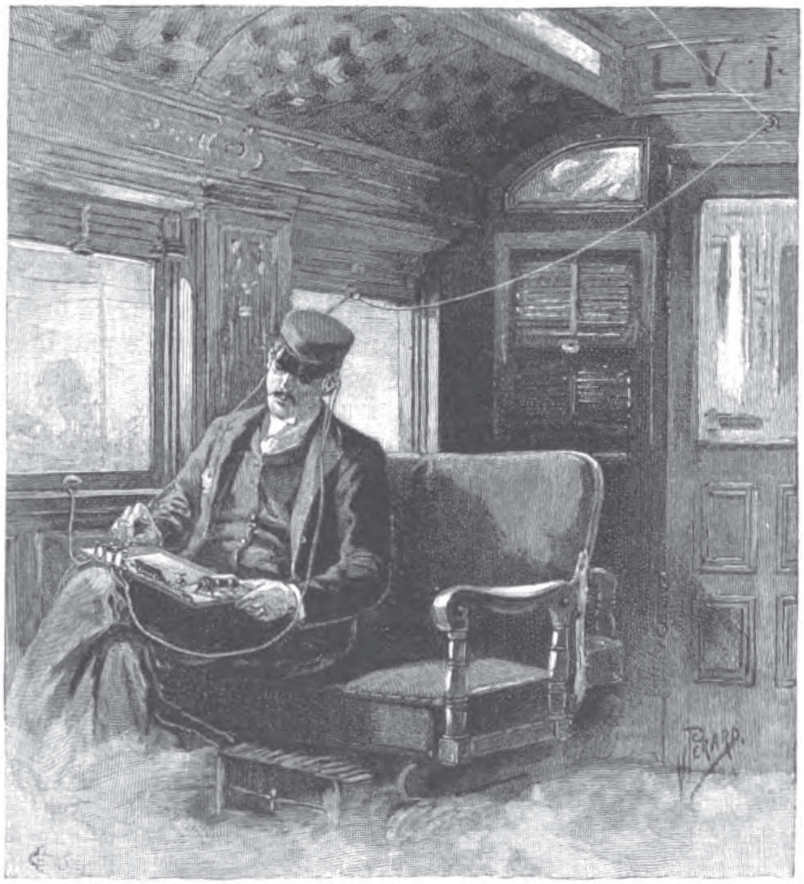
used, it is preferable, as is done by the Lehigh Valley Company, to employ a wire isolated from the others and carried by a separate pole line. The line, however, need not be wholly given over to train telegraphing, for messages may simultaneously be transmitted by the Morse system, thus duplexing the wire.

with tin, the only necessary outlay is a few cents for clips wherewith to attach the wire to the roof and to the truck.

In 1881 William Wiley Smith, of Indiana, proposed to communicate between moving cars and a stationary wire by induction; but he appears to have thought this practicable only at small



Interior of a Car on the Lehigh Valley Railroad, showing the Method of Operating the Train Telegraph.

distances. The remarkable possibilities of long-distance transmission by induction seem to have been discovered by T. A. Edison and L. J. Phelps, who, aided by others, have added improvements adapting it to every requirement of a commercially successful telegraph system.

The outfit of an office upon a train consists essentially of a telegraph-key, with an induction coil mounted upon a small board, which the operator holds in his lap; a telephone carried at his ear, and a hand-case containing a few small cells of battery. To equip a car, therefore, is only the work of a moment. One wire is passed through the bell-cord-opening above the door and is attached by a clip to the end of the metal roof, while a second is passed out of the window and fixed to a metal part of the car-truck. The instruments are then properly arranged in circuit between the roof and the earth, and the operator is prepared to send or receive messages. As all passenger cars have long been roofed

The train-telegraph of the Consolidated Railway Telegraph Company, which has just been described, is now used upon more than two hundred miles of the Lehigh Valley Railroad, and although it has not found wider use, it deserves, as a scientific achievement, a high place among electrical improvements of the last ten years. It certainly would seem to be of great value in oper-

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ating trains, for it offers a means whereby a despatcher may instantly communicate with every train under his supervision.

Stock Quotations as Received on the Scott Instrument.

Specimen from the Edison Stock Printer.

The inductive method of transmission employed in train-telegraphy has already been suggested as one way of telegraphing over considerable distances without the aid of a wire. It is said that Edison has succeeded in obtaining intelligible signals between apparatus placed upon masts five hundred and forty feet apart, and it is now confidently asserted that messages may be telegraphed from a wire along the Hudson River to steamers plying between New York and Albany. It is claimed by Mr. L. J. Phelps that by employing a receiving-coil consisting of a wire wound several times around the steamer, one of the early forms employed in the train-telegraph, no difficulty would be experienced in communicating with boats running within five hundred feet of the shore; and that such communication would be possible even over a distance of two thousand feet. Obviously, by this method, ships not far apart may be placed in communication.

Telegraphing between points not connected by a line is also accomplished by diffusion. If an electrical current is sent over a telegraph-line connected with the earth at both extremities, it will return through the earth from one extremity to the other. In returning, the current will not follow a narrow straight line, but will be diffused; and although the larger part will return by the easiest and shortest path, enough to actuate a telegraphic apparatus may flow back by way of a distant parallel wire. Two wires, one along the shore of the Isle of Wight, and the other along the shore of the channel, in Hampshire, were thus employed; and although the width of the channel is six miles at one end, and one and one-fourth mile at the other, harmonic signals like those used in the train-telegraph, sent on one wire, were distinctly reproduced upon the other, telegraphic communication across the channel being thereby established. Professor A. G. Bell succeeded in telegraphing in this manner more than a mile between boats on the Potomac River.

Respecting the action of diffusion, it should be noted that the battery in a telegraph-line, when the latter is closed, tends at one end of the line to raise the electrical potential of the earth, and at the other to lower it. If an engine in a long tunnel were pumping air through the tunnel, bringing it in at one end, and forcing it out at the other, a barometer would show higher pressure at the point of egress than at the point of entrance, and, as a consequence, currents of air would tend to flow back to the entrance through the outer atmosphere, covering in their return a wide tract of country. If such an operation should be carried on in a tunnel extending from New York to Chicago, it is not

Kiernan's News Tape.

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to be presumed that windmills in Kentucky would be much disturbed, although in theory such a tendency would exist.

Had the promoters of the telegraph foreseen the extent of its subsequent improvement, they would then have considered its perfection as substantially assured. But the modern telegraph doubtless seems to us even further from perfection than did Morse's system appear to him when he had first succeeded in working from Washington to Baltimore. For the telegraph might now have almost unlimited speed if difficulties, which have become apparent in the course of its development, could be successfully removed.

The capacity of an Atlantic cable has been advanced from ten to fifty words a minute; but valuable as are the immediate results of this achievement, they have served the better purpose of making clear, that if the impediment of static induction could be eliminated, transmission of five hundred words a minute would be equally possible. Stearns's discovery doubled the capacity of every long line in the world, and made possible the quadruplex. Yet his improvement was more valuable in other ways; for when it had been widely adopted the phenomenon of static induction was brought under the daily observation and scrutiny of hundreds of intelligent men in a manner to insure its removal, if possible. From Stearns's invention it became a matter of common information that all along a line, with each signal transmitted, the electrical conditions of a thunder-cloud are feebly reproduced. For illustration, we may assume that from the wire hangs an invisible electrical cloud from which, if the tension of its charge were sufficiently increased, lightning flashes would burst forth through the air to the earth.

Perhaps static retardation, and the absorption of current in electrifying the surrounding air along the line is as inseparably connected with telegraphic transmission as is friction with machinery, and a solution of the problem may be an impossibility. But the expedients of raising the line on poles high above the earth, and of dividing a long circuit by repeaters, show at least two methods by which the difficulty may be modified, if it cannot be overcome, and encourage us to hope that better means may be found. It is certain that fame and fortune await him who shall solve the mystery.

Barnacles on a Cable.

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