

THE DELANY SYNCHRONOUS-MULTIPLEX SYSTEM OF TELEGRAPHY.

By PROF. EDWIN J. HOUSTON.

In this day of remarkable advance in electrical science, it is necessary for an invention to possess very unusual practical applications, and to display uncommon ingenuity or genius on the part of the inventor, to attract any more than transient attention or admiration on the part of the general public.

The successful laying of the Atlantic Cable, the commercial applications of electric illumination, and the actual transmission of telephonic dispatches, have very properly given to their inventors or promoters a world-wide reputation. The rapidity with which these inventions have followed one another, has led many to believe that but little new could reasonably be expected in the near future.

There has been, however, during the past two or three years, another inventor at work, who has at last completed, even to many minor details, an invention which, if we are not mistaken, bids fair to rival in importance anything that has hitherto been accomplished in electrical science; we refer to the system of synchronous-multiplex telegraphy, of Mr. Patrick B. Delany, of the city of New York.

Like other great inventions, that belong rather to eras than to individuals, the growth of the synchronous-multiplex system has not been entirely the product of any single mind; though, in this particular instance, too much credit can scarcely be given to Mr. Delany, to whom the practical or working part of the system is almost wholly due. Indeed, since this gentleman has introduced into the system the numerous details and separate inventions, without which its commercial application would be impossible, we may correctly speak of it as the Delany system.

The Delany synchronous-multiplex system is founded on the Phonic Wheel of Mr. Poul La Cour, of Copenhagen, who patented his invention in Great Britain, under Letters Patent, No. 1,983, of 1878; and in the United States, as No. 202,423, of May 7, 1878.

Before proceeding to the description of the detailed apparatus of this remarkable invention, it will be best to first explain the nature of the work for which it is applicable, and to point out some of the more evident directions in which it may be practically employed.

The most evident commercial application of this system is its use for transmitting simultaneously, over a single wire, a great number of telegraphic dispatches, either in the same or in opposite directions.

Before the invention of the synchronous-multiplex system, the greatest number of messages that could be transmitted simultaneously over a single wire, as in the well-known quadruplex system, was four; and in this case, the four messages were, of necessity, sent in opposite directions; viz., two in one direction, and the remaining two in the opposite direction. In the synchronous-multiplex system, not only is the number of messages that can be transmitted greatly increased, but all such messages can be transmitted in one and the same direction; or any desired number sent in opposite directions. The great commercial importance of this feature of the invention will be at once recognized.

It may not be out of place to mention in this connection, as a confirmation of the importance of any system that will permit the simultaneous transmission of more than a single dispatch over the same wire, that it is a well-attested fact that the Western Union Telegraph Company has been enabled, to a very great extent, to practically control the telegraph business of the United States, by reason of its owning or controlling the only method heretofore known for successfully accomplishing this object.

Though we have mentioned the quadruplex as being the only system hitherto commercially employed for multiple transmission of dispatches, we have not forgotten the harmonic system of Mr. Gray. This, however, we believe, has not been commercially introduced to any considerable extent, owing to certain inherent difficulties attending its practical use.

Perhaps one of the most prominent features of the multiplex-synchronous system is its marked dissimilarity from either the quadruplex or the harmonic systems, already mentioned. The multiplex is a new departure in telegraphy, now practically realized for the first time.

As is well known to those acquainted with the principles of electro-magnetic telegraphy, the quadruplex system is based on

the balancing or differential method, whereby the instrument of the transmitting operator, being unaffected by the signals he transmits, is thus left open for the reception of signals sent from the distant end of the line.

The synchronous-multiplex system, on the contrary, is based on the synchronous rotation of two discs, placed one at each end of the line, by means of which a single wire, which constitutes the line, is simultaneously connected, at both of its ends, to corresponding operating instruments, and transferred from one set of instruments to another so rapidly that the operators, either sending or receiving, cannot realize that the line has been disconnected from their instruments and given to others, because each of them will always have the line ready for use, even at the highest rate of manipulation, and will, therefore, to all practical intents and purposes, have at his disposal a private wire between himself and the operator with whom he is in communication.

It will be seen, therefore, that in the synchronous-multiplex system, although more than one operator may be spoken of as simultaneously using the line at any given time, yet, in point of fact, no two operators are in reality absolutely using it at the same time; but that they follow one another at such short intervals, and the line is taken from one operator and transferred to another so rapidly, that none of them can at any time tell but that he has the line alone, and that therefore it is practically open for the use of every operator just as if he alone had control of it.

There will be practically established, by the use of a single line, as many private and separate lines as there are transferences of the line from the time it is taken from the first operator, and again given back to him.

This has, as we will hereafter point out, been extended in actual practice to as many as seventy-two distinct and separate circuits, maintained and operated on a single connecting wire.

It will be readily understood that the rapidity of transmission of each telegraphic dispatch will be necessarily diminished as the number of messages that are simultaneously transmitted is increased. This decrease in the rate of transmission, however, is far less than might be supposed necessary, as actual experience has abundantly demonstrated. For example, with the simultaneous use of six Morse telegraphic circuits, the most rapid rate of transmission attainable by the most expert operators is practicable; and with twelve Morse circuits, a rate of transmission is

practicable as rapid as that generally employed by the ordinary operator; that is, by an operator whose rate of sending would be regarded as equal to that actually employed by the greatest number. It must not be supposed, however, that the use of the multiplex-synchronous system will be limited to the simultaneous transmission of twelve separate messages on one and the same wire, since certain contemplated improvements will, it is confidently believed, greatly increase both the rate of transmission and the extent of division of the line.

There have been actually applied to a single line, as we have already mentioned, as many as seventy-two separate and independent circuits. In this case, the Morse instruments have been replaced by the ordinary printing telegraphic instruments, so that the messages are received and recorded on paper slips, in the well-known manner as practiced in the stock printing instruments.

Although the rate of transmission is, in the above case, considerably decreased, yet the adoption of a printing instrument is attended with many advantages that go far towards removing the slight inconveniences that result in actual commercial use. A printing instrument, as is well known, requires no special skill on the part of the one who operates it. Any one who can spell can transmit a telegraphic dispatch, while no operator need be on hand for its reception, since the receiving instrument is entirely under the control of the person sending the dispatch. The necessity for skilled operators at each end of the line is, therefore, in a manner entirely done away with.

Three very considerable advantages are obtained by employing printing instruments, and thus doing away with the services of skilled operators for sending and receiving the dispatches, viz.: economy, secrecy, and an increase in the number of messages that can be sent during any given time.

The advantages on the score of economy and secrecy are manifest. Not only is the skill of an operator required at each end of a private line employing Morse instruments, but, since private messages are to be transmitted thereon, integrity, as well as skill, is a prime essential, and both of these requisites must be paid for. On private lines, maintained by the use of the synchronous-multiplex system and printing instruments, no publicity is necessary, the interested parties only, sending and receiving the dispatches.

The advantages on the score of rapidity, arising from no operator being needed at the receiving station, when printing instru-

ments are employed on a private line, lie in the fact that the line being a private one, no time is lost in waiting for some other party that may be using it, nor in calling the party for whom the dispatch is designed, nor in waiting for his return, during a temporary absence.

Taking all these facts into consideration, we think it will be found in actual practice, that the decrease in the rapidity of transmission, consequent on the simultaneous employment of seventy-two separate circuits on one and the same line, is not sufficiently great to interfere, to any marked degree, with its commercial applications. In point of fact, with the system as it is now actually used, the rate of transmission is quite sufficient to enable each of the seventy-two subscribers or users of the line to transmit, during, say, the six hours that elapse between 10 A. M. and 4 P. M., the business hours of the day, no less than one hundred telegraphic dispatches of the ordinary length, an amount generally in excess of actual requirements of ordinary business, and, as a rule, quite in excess of any rate of service that could be reasonably expected on the part of any of the telegraphic companies on which the general public are now dependent.

An advantage, however, of peculiar importance to the business public generally, that is possessed by the synchronous-multiplex system alone, is the readiness with which a single wire between any two subscribers connected therewith can be increased in its capacity to meet the growing needs for an increased extent of division, or to meet some unforeseen or unexpected emergency. Thus, suppose that one subscriber has a private line placed at his disposal between any two distant cities, and is furnished with what we may term one seventy-second of the line; should his business increase, it would be a matter of simple connection of the transmitting and receiving instruments at the ends of the line to give him increased facilities for communication by placing at his disposal the one thirty-sixth, or the one-eighteenth, and so increase his capacity for communication twice or four times, respectively. In other systems, as is well known, this would need the erection of extra lines, and would necessitate the expenditure of both time and money, so that sudden and unexpected calls for increased facilities for business, which are liable to occur in times of financial crises, or of other great public excitement, could not be met.

A peculiar feature of the synchronous-multiplex system, that is

not possessed by any other known telegraphic system, and that cannot fail to commend this system to the general public, is in its absolute secrecy. Unlike other systems, its lines cannot be secretly tapped and the messages intercepted, since an ordinary instrument placed in a break in the line would receive, in an utterly unintelligible form, not only all the signals being transmitted at the time, but also each of the separate makes and breaks in the continuity of the line circuit, while it is successively transferred from one operator to another, and these signals would be so transposed and altered, that even if the instrument could record them, they would be as devoid of intelligent connection as would the type correctly set for numerous messages, and afterwards dropped through successive sieves from a height to the ground. This feature of absolute secrecy of the synchronous-multiplex system will, it is believed, prove of almost inestimable advantage to a government for the secret transmission of dispatches during war, or, in fact, at any time.

The successful operation of the synchronous-multiplex system is dependent on the maintenance of the synchronous movements of the rotating discs placed at the ends of the line. We will now proceed to describe the details of the very ingenious and beautiful contrivances whereby Mr. Delany has practically created a new system of telegraphy.

Fig. 1 represents a diagrammatic plan of two distant stations, say, New York and Philadelphia, or Philadelphia and Chicago, represented by X and Y , respectively, electrically connected by the single line wire $Q Q$. The connections of the detailed apparatus required at both the transmitting and receiving stations are also shown in the figure.

In the following description the author has not hesitated to freely employ the language of the various patent specifications in all cases where he has deemed it advisable so to do.

An inspection of Fig. 1 will show that the apparatus at each end of the line, at the stations X and Y , is substantially identical. A steel fork a , at each station, is automatically and continuously vibrated by the action of the local battery $L B$ and the electro-magnet A . The circuit of the local battery is marked in the drawing a^1 . The cores of the magnet A , which may be called the vibrator magnet, are prolonged in the direction of the free ends of the vibrating fork by the regulable screws a^2 , of magnetic material, in the manner shown in the figure. The object of this

adjustment of the extended magnet poles is to enable the said poles to be approached towards, or withdrawn from, the tines of the vibrating fork, so as to regulate with great nicety the rate of their vibration.

Platinum contacts x x^1 , are placed on the inner faces of the tines of the fork, and make and break contact with delicate platinum contact springs y , y^1 supported by adjustable insulated arms or levers B , B^1 , pivoted on the bed-plate of the apparatus. The adjustment of these levers is secured by the thumb screws b , b^1 , against which they are drawn by the action of spiral springs. By these means the platinum contact-springs, y y^1 , are readily adjusted with great delicacy and firmness to the platinum contacts x , x^1 on the tines of the fork.

The circuit of the local battery L B , which is indicated in the drawing by the fine dotted lines, runs from the positive pole of the battery, through the coils of the vibrator magnet A , to the head of the fork, and through the contacts x^1 , y^1 to the insulated lever B^1 , from whence it passes back to the opposite pole of the battery. In order to prevent injurious sparking of the contacts x^1 and y^1 , a resistance coil R^1 is placed in a shunt circuit around them, extending from the point a^3 to the head of the fork, and to the insulated arm B^1 , as shown.

The fork being mechanically started into a vibratory motion, will automatically make and break its local circuit, and thus send impulses into the fork-magnet A that will continuously maintain the vibrations of the fork, in a well-known manner.

These movements, it will be observed, have been maintained solely by the making and breaking of the contacts x^1 and y^1 .

And now for the contacts x and y , which, as we have seen, are placed in connection with the opposite tine of the fork. The making and breaking of these contacts, consequent on the fork's vibration, opens and closes the circuit of another local battery, in which is placed an electro-magnet D , the function of which is to maintain the continuous rotation of the transmission apparatus C .

This circuit, which we will call the motor circuit, and which is indicated in the drawing by the larger dotted lines, passes from the positive pole of the motor battery D^1 to the lever B , through the platinum contacts y and x , to the tine of the fork, to its head or support A^1 , and thence through the wire d to the coils of the motor magnet D , and back to the opposite pole of

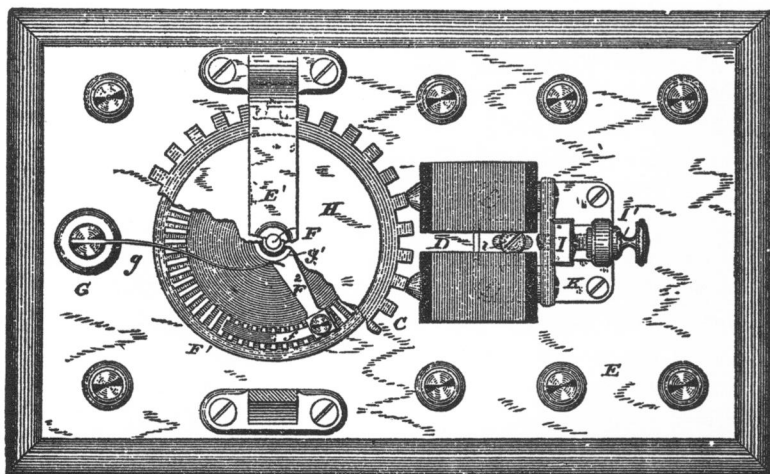
the battery. A resistance R , placed in a shunt between the head or support of the fork and the line of the lever B , prevents injurious sparking between the platinum contacts x and y .

As the continuous vibration of the fork is automatically maintained by the local battery LB , as already explained, it will, at each vibration, make and break the contacts at x and y , and thereby make and break the motor circuit. The alternate magnetization and demagnetization of the cores of the motor magnet D causes the rotation of the transmission apparatus C . The cores of the magnet D have their faces shaped so as to conform to the circumference of the apparatus C , the teeth of which pass in close proximity to the faces of the curved magnet poles.

The motor magnet and transmission wheel, or disc, C , provided with projections c, c , is the invention of Poul La Cour, already referred to, and is styled by him "phonic wheel."

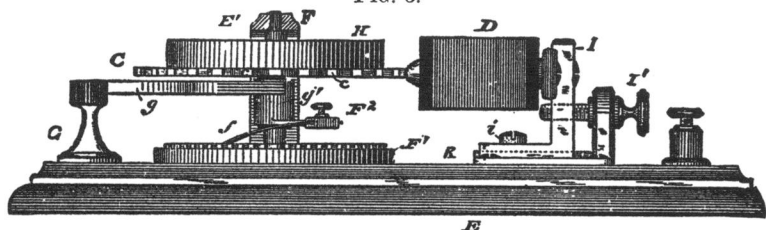
The transmission apparatus is illustrated in detail in Figs. 2 and 3. As we have already seen, it is an exact counterpart of

FIG. 2.



the receiving apparatus at the other end of the line. A base plate E , provided with binding posts for electrical connections, carries a vertical rotary shaft F , that has its lower bearing in the bed-plate, and its upper bearing in a suitably supported bridge E^1 . A circular table F^1 , provided with a series of insulated contacts, is arranged symmetrically around the axis of rotation of the shaft. A radial arm F^2 projects from the shaft F , and

FIG. 3.



carries at its outer extremity a socket and set screw, to which is attached a trailing contact finger f . As the disc C is rotated by the electro-magnet D , the trailing contact f sweeps around the circular table F^1 , and is brought successively into contact with the insulated contact pieces placed on the upper face of the table F^1 .

The main line $Q Q$ has one of its ends connected with the trailing finger f , through the radial arm F^2 , vertical shaft F , contact spring-arm g , and projecting post G . As the shaft F rotates, the line is, therefore, brought into successive electrical connection with the series of insulated contacts in the upper face of the table F^1 . The toothed armature, or phonic wheel, C is securely keyed to the vertical shaft, F just above the hub g^1 .

In order to equalize the speed of rotation of the apparatus, a cylindrical vase H , of wood, or other suitable material, filled with mercury, is attached to the face of the phonic wheel C , and rotates with it.

The cores of the motor magnet D , suitably supported by the standard I , can be readily adjusted towards, or from, the armature teeth on the phonic wheel C , by the motion of a screw I^1 , which moves the standard I in an elongated guide slot, through which passes the screw bolt i .

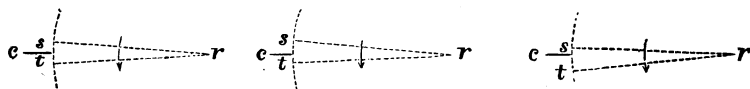
The cause of the synchronous rotation of the phonic wheel C is substantially as follows, viz.: Considering the action of a single pole of D when the wheel C is at rest, that one of its teeth, or projections, c that is nearest the pole of D will be attracted towards it, and maintained in position nearest it, by the influence of the magnetic attraction of the pole of D ; should, however, the phonic wheel be set into motion, with a velocity that shall cause a tooth c to pass the pole D for each intermittent impulse in the battery circuit traversing the coils of D , the wheel will be maintained in a rotation, the speed of which will be regulated and controlled by the frequency of intermissions of the

battery current through the coils of D . That is to say, the speed of rotation of the phonic wheel C , and consequently the rapidity with which the successive contacts are reached by the trailing arm F^1 , are regulated solely by the duration of the oscillation of the fork a .

FIG. 4.

FIG. 5.

FIG. 6.



The control which the intermission in the circuit traversing the coils of the electro-magnet D exercises on the regularity of rotation of the phonic wheel C , will be better understood from an inspection of Figs. 4, 5, and 6.

Suppose that the central or axial line of the pole of the magnet c is represented by the dash placed opposite c in the figure, and that r indicates the centre of the phonic wheel C , whose direction of rotation is indicated by the arrow. Now, if during one impulse, the central or axial line of one of the magnet teeth c on the phonic wheel is moved from the point s to t , it will be accelerated on its way from s to c , but retarded from c to t .

If, then, as shown in Fig. 4, the acceleration and retardation are equal, the velocity of the wheel is unaffected by the impetus of the electro-magnet; but, should the wheel move slower, that is, lose in its motion, as shown in Fig. 5, then the acceleration s, c will increase, and the retardation c, t will decrease. Consequently, the electro-magnet D will increase the velocity of the wheel in the same ratio that the wheel slows, or loses time.

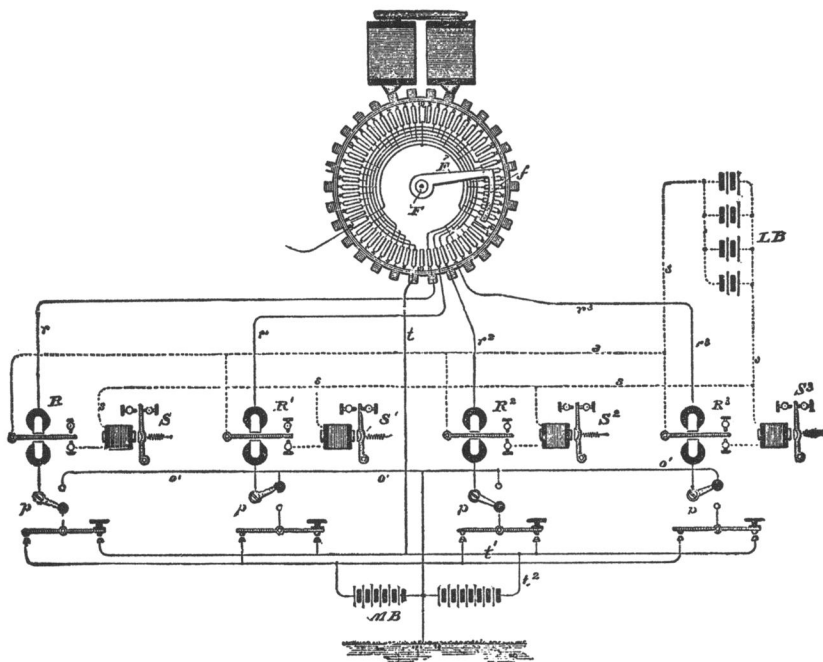
If, however, the wheel gains or increases in speed, as shown in Fig. 6, the acceleration s, c will be decreased, and the retardation c, t increased, so that the electro-magnet will have the opposite effect, and retard the wheel, in the same ratio that it tends to increase or go faster.

In the apparatus for transmission and reception, shown in connection with Fig. 1, which is substantially the same as that just described, the table of contacts F^1 is, for convenience of illustration, shown as placed above the armature disc C . In starting the disc C , an impulse of rotation is given to it somewhat in excess of the speed at which it will be maintained by the motor magnet, when, as the speed of rotation decreases, the armature teeth will come into proper relation with the poles of the magnet,

and into the periods at which the makes and breaks occur in the circuit traversing its coils, when the disc will be continuously driven by the motor magnet. A suitable thumb-piece, placed on the vertical axis F^1 , serves to start the apparatus, an operation that is readily accomplished after very little practice.

Any suitable number of insulated contacts may be placed on the circular table F^1 ; sixty are shown in the figure. In practice these contacts are connected in accordance with the special number of circuits which it is desired to simultaneously maintain on the same wire. In the special case shown in connection with Fig. 7, it is arranged so that four separate circuits shall be established on the same line wire. The sixty contacts are placed in six independent series, numbered from 1 to 10, consecutively. In the arrangement here shown, two of the contact pieces in each series of ten are connected in the same circuit, and as there are six series, each of the circuits so connected will have twelve contacts for each rotation of the disc. An inspection of Fig. 7 will show that the 1's and the 5's in each series are all connected in one and the same circuit; the 2's and the 6's in another circuit; the 3's and the 7's in another circuit; and the 4's and the 8's in another

FIG. 7.



circuit—thus providing four separate circuits, in all. The contacts, therefore, from one to eight in each series, are apportioned among the four independent circuits, each of which will receive, for each revolution of the trailing finger, twelve contacts and twelve electrical impulses, as will be afterwards described.

The detailed mechanism, by means of which the separate and independent circuits so obtained are utilized for the transmission and reception of messages, is shown in connection with Fig. 7. R , R^1 , R^2 , and R^3 are polarized relays, the function of which will be afterwards explained. S , S^1 , S^2 , and S^3 are ordinary Morse sounders, although in the practice of this invention some improvement has been introduced in connection with the instrument. The connections with the main and local batteries $M B$ and $L B$ are clearly shown in the figure.

It will be noticed that the relay R is connected by the wire r with the contacts 1 and 5; R^1 is connected by r^1 with the contacts 2 and 6; R^2 by the wire r^2 with the contacts 3 and 7; and R^3 by the wire r^3 with the contacts 4 and 8. Similar instruments and circuits are placed at each end of the line.

Without further describing the operation of the instruments shown in Fig. 7, it need only now be borne in mind that the corresponding relays at the distant stations are connected with the correspondingly numbered contacts. When, therefore, the trailing contact finger at each station simultaneously touches the contacts bearing the same number, the corresponding instruments connected with these contacts at each station will be placed in communication over the main line, the trailing contact finger f completing the connection of the main line with the contact arm in the manner already described.

If, then, the trailing fingers f at each station are maintained in synchronous rotation, they will pass regularly and simultaneously to the next contact, and successively over the similar contacts at each station.

During the time that the trailing contact fingers are on the correspondingly numbered contact pieces at each station, a complete and independent circuit, that has no connection whatever with the other circuits, is established between these stations.

Under the arrangement shown in Fig. 7, each of the four separate circuits will be placed in independent electrical connection with the main line, twelve times for each rotation of the distributing wheel C . Assuming the normal rate of vibration of

the fork at eighty-five vibrations per second, and that the distributing wheel *C* is furnished with thirty armature teeth, or polar projections, the armature discs and trailing fingers will be rotated at the rate of two and five-sixths times per second, so that the corresponding instruments at the two stations will be placed in independent electrical communication with the main line, thirty-four times each second. This number of contacts per second will give to each set of operators a practically unbroken circuit, so that the operators at any two connected stations may communicate with each other, in either direction, as if they had a separate and independent line devoted entirely to their exclusive use.

We will now describe, in greater detail, the method adopted for transmitting and receiving the messages over any, or all, of the four circuits so provided. An inspection of Fig. 7 shows the relays *R*, *R*¹, *R*², and *R*³ connected with the series of contacts, as described, and the circuit completed from each relay, either to the ground through the line *o*¹, when the switches *p* are placed as at *R*¹ and *R*³, on their upper contacts, when the line is ready for receiving; or in connection with their lower contacts, as at *R* and *R*², when the line is ready for transmitting.

The main battery *M B*, preferably split and grounded in the middle, has its positive pole connected with the back stops of the keys, and its negative pole with their front stops. The action of transmitting, therefore, sends into the line impulses of opposite polarity, and therefore permits the employment of the polarized relays. The local battery *L B* is connected in multiple arc, in the manner clearly shown in the drawing.

Since each operator's circuit is made up of numerous rapid contacts with the main line, at the rate of thirty-four contacts per second, each of the ordinary Morse characters sent into the main line is made up of more than a single contact, proportioned in number to the length of the character, the ordinary Morse relay could not be employed for the reception of these characters, since the numerous breaks comprised in each character would be recorded by the armature of the relay. In order to avoid this confusion, and to make the relays respond not to mere pulsations caused by the successive makes and breaks, but only to the reversals in polarity, caused by the connection of the split battery *M B* with the transmitting keys, the polarized relays *R*, *R*¹, *R*², and *R*³ have been used in place of ordinary relays, so that

the armatures of the polarized relays remain in the position that the last current has placed them, until reversal of the current changes their position, notwithstanding that the finer vibrations comprised in these reversals are continuously passing through the magnet of the polarized relay, but are not manifested on the armature. This feature of the invention is due to Mr. E. A. Calahan, the inventor of the gold and stock printing telegraph, and also the inventor of the American District Telegraph System, and who has been associated with Mr. Delany from the commencement of his investigations on the subject, and whose ability and great mechanical skill have very materially aided the full development of the system.

The prime essential for the successful application of the preceding system is undoubtedly the maintenance of the synchronous movements of the trailing arms over the contact pieces on the table F^1 . This Mr. Delany has effected by an invention of marvelous beauty and ingenuity, which is entirely automatic in its operation, and is so successful in practice that the synchronism can be perfectly maintained for days continuously without one instrument varying from the other the six-hundredth part of a second during that time. We will now proceed to an explanation of the comparatively simple means by which this practically absolute synchronism is maintained.

It has been shown, in connection with the description of the operation of the transmitting wheel, that its rate of motion is absolutely controlled by the rate of vibration of the fork, by means of which the successive impulses of the battery current through the motor magnet are regulated.

Now, it has been tried, but unsuccessfully, to obtain this synchronism by the mere mechanical adjustments of two forks, one at each end of the line; the forks being delicately tuned to exact unison with one another.

The many circumstances which produce slight variations in the rate of vibrations of a fork, have rendered it impossible to maintain, even in the same room, synchronism between two forks for more than a few minutes at a time, and this has only been possible by the most careful attention to the adjustment of the same. At distant stations, where the mere differences of temperature alone would, of necessity, produce sensible variations in the rates of motion of the two forks, the maintenance of even approximate synchronism would be practically impossible.

Mr. Delany has completely overcome this hitherto insuperable obstacle to the successful adoption of any synchronous-multiplex system, by the happy invention of correcting impulses, that are automatically sent over the main line from one instrument to another, at such times only as the distant instrument is slightly in advance or behind the other instrument. These correcting impulses, that are thrown into the line only when needed, and of the necessity for which the instruments themselves, so to speak, are constituted the judges, are utilized for the purpose of slightly increasing or decreasing the rate of vibration of the distant fork, and, consequently, the rate of rotation for the trailing arm at the distant station.

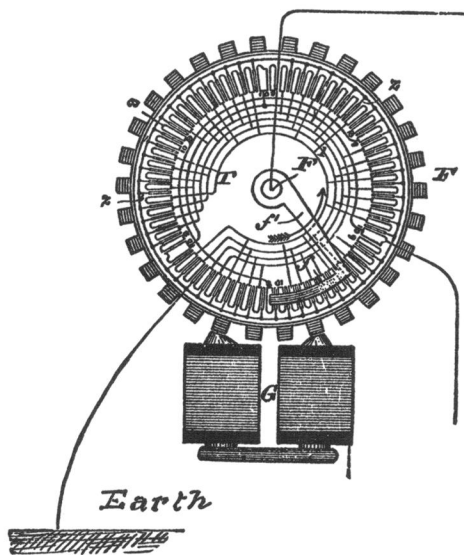
The manner in which these impulses are obtained when needed is as follows: It was probably remarked by the reader, that in speaking of the contacts in the plate F^1 , no mention was made of the 9's and the 10's in any of the series, as having connection with any of the telegraphic instruments or circuits. It is the function of these contacts to maintain the synchronism of the apparatus.

Referring again to Fig. 1, it will be noticed that at one of the stations, as X , three of the 9's, that are the furthest removed from one another, that is, three that are 120° distant from each other, are connected together, and to a battery K , one pole of which is connected to the ground; and that three of the 10's, that are likewise furthest removed from one another, are connected together and to a line l , leading to the correcting and regulating devices, which we will afterwards describe. The remaining three intermediate 9's and 10's are left open, that is, are not connected with any circuit.

At the other station, Y , the 9's, corresponding with those connected with the battery at X , are left unconnected, or open, while the alternate 9's are connected with the battery K^2 , one end of which is grounded, while the 10's, at Y , which are connected with one another, and with the connecting devices through the line l^1 , correspond with those which are unconnected with the station X , the remaining 10's, at Y , being unconnected at both stations; the three 10's, which are connected with the correcting devices through the lines l and l^1 , respectively, are extended or built out towards the adjoining 9's, that are unconnected with any circuit.

In order to provide room on the table F^1 for the expanded

FIG. 8.



or extended 10's, without disturbing the symmetrical arrangement of the remaining contacts, the plates or contacts provided for the static discharge of the line, and which an inspection of Fig. 8 will show, as located between each of the successive contacts of the circular table F^1 , are omitted, and their place occupied by the extension of the expanded 10's, so that the space between the expanded 10's and the 9's which precede them is the same as the spaces between the remaining contacts. Since the 9's preceding the extended 10's, and corresponding in position to the battery-connected 9's, are open or disconnected, and since the static discharge plate between the 9's and the 10's at the distant end is retained, no bad results are experienced.

As long as the trailing contact fingers are moving synchronously at both stations, that is, as long as they rest on correspondingly numbered contacts at the same moment, no occasion will exist for the correction of either apparatus; should, however, the instrument at Y run a trifle faster than that at X , the trailing finger f , at station Y , will touch the extended side of a 10 contact, while the finger at X is still on a battery-connected 9. An electrical impulse, consequently, will flow from the battery K , at station X , over the main line, and through the contact 10, at Y , and the line, l , to the connecting device at that station.

A similar operation occurs if the apparatus at X moves a trifle faster than that at Y .

As thus arranged, the correcting impulses are retarding ones, since they are called into action only when the instrument at one or the other end of the line gains in speed slightly on the other. The inventor causes them to act as retarding impulses by employing them to cut a resistance out of the circuit of the vibrator battery. The effect of this is to increase the strength of the current traversing the coils of the electro-magnet *A*, and consequently its magnetic attraction for the tines of the fork. There thus results an increased amplitude of the fork's vibration, and a consequent lowering, or decrease, in the rapidity of its vibration. This retardation will, of course, affect the speed with which the transmission wheel is rotated, and consequently retard the rotation of the trailing finger.

The local circuit of the vibrator is shown in Fig. 1 as working generally through the adjustable resistances *S*. When, however, the apparatus at one station runs slightly in advance of that at the other station, and a correcting impulse is consequently received through the main line and the line *l*, or *l'*, the relay *U*, placed in that line, is energized, and its armature drawn from its back stop, thus breaking the local circuit *u*, and permitting the armature of a second electro-magnet *V* to rapidly pass to its back stop, and thus complete a shunt circuit *v* around the resistance *S*, so as to cut it out of the vibrator circuit. The consequent increase in the current strength of the vibrator circuit that is thus momentarily produced, retards the rate of vibration of the fork, and consequently slows the rotation of the trailing finger, and causes it to drop back on its proper contact. The operation is the same at both stations.

Whenever the operator at either station hears the stroke of the relay *V*, he knows that a correcting impulse has been received. By placing a relay and sounder *W* in the circuit of the correcting battery, at each station, between the 9 contacts and the ground, he can also tell when a correcting impulse has been sent out. No difficulty will be experienced, therefore, in ascertaining which of the instruments is slightly in advance of the other, but as long as any ticks or sounds are heard on the instruments on the correcting circuits, the instruments will be found to be in synchronism, since the variations possible are confined to a limit not exceeding one-fifth of the width of any regular segment.

The apparatus is readily started by starting the fork and rotating the vertical shaft *F*, and the adjustment of the two apparatuses

is completed at the other station *Y*. At that station the operator also starts his apparatus and closes the switches at *M* and *N*. By the means already described the operator at *Y* can tell which apparatus is running the faster, and he then proceeds to adjust his own apparatus, until he is aware of the synchronism of the two, by the tell-tale strokes at *V* and *W*. It is found convenient in practice to make the resistance at *S* in the shape of a box of resistances, so as to readily vary the amount of resistance normally included in the local circuit.

A very important and beautiful feature of this invention is found in the manner in which the correcting impulses are rendered effective when the relay *U* leaves its back stop, as the corrections are thereby rendered practically instantaneous; whereas, if they were not made effective until the armature of the relay had been drawn to its front stop, the action of the correcting device would be sluggish. The adjustment of the armature of the relay *U* is very delicate, and it therefore responds immediately to any correcting impulse; so, too, the spring of the relay *V* is of sufficiently high tension to enable its armature to move almost instantaneously to its back stop.

Should the trailing arm at one station be moving more rapidly than that at the other station, it must soon overtake the trailing arm at the other station and bring them both into such relation to the battery connected 9's, and the extended correcting 10's, that the correcting impulses will thereafter maintain them in practical synchronism.

Should the main line between the two stations be accidentally broken, the synchronism would of course be destroyed; but on connecting it again, the instruments would of themselves, within two or three minutes at the most, again come into synchronism without the intervention of the operators.

The correcting impulses we have described are retarding ones, and are only called into play when one instrument runs faster than the other. Mr. Delany has slightly modified his apparatus, so as to make the correcting impulses accelerating ones, that are only called into play when one instrument runs slower than the other.

In this connection it may be well to state that numerous devices by means of which synchronism can be obtained, in connection with substantially the apparatus before described, have been discovered by Mr. Delany, and are fully protected.

We have described four sets of independent circuits simultaneously established on the same line. It is evident, however, that by increasing the speed of rotation, fewer contacts during a single rotation will suffice for the practical operation of the ordinary Morse circuits, or by increasing the number of contacts in the circle, a much greater number of circuits may be obtained, so that the subdivision of the line into a greater number of circuits may be effected, without diminishing the speed of working.

An essential feature of the invention, without which it cannot be practically operated for long distances, consists in separate contacts, as shown in Fig. 8, placed between the contacts on the table F^1 , at each station, and connected together to the ground, so that the line, being put to the ground before each completion of the circuits, will be freed from the greater or less static charge, which is very apt to be present in all lines of any considerable length.

Though the synchronous-multiplex system, as we have seen, is somewhat complicated in its apparatus, it is far simpler in its operation, and requires far less delicate adjustments than are essential in the quadruplex system. The difference between the two in this respect will better appear, when it is known that in the quadruplex system a change of electrical condition, equivalent to an increase in the length of the circuit of ten miles, is sufficient to throw it out of balance, and thus stop all communication; while in the synchronous-multiplex system, a change equivalent to five hundred miles may be instantly thrown on the synchronously operated wire without destroying the synchronous rotation of the trailing arms, or interrupting the various circuits.

The possibilities that suggest themselves as naturally resulting from the solution that Mr. Delany has made of the problem of obtaining and maintaining, at distant stations, practically absolute synchronism, are indeed, bewildering, and justly entitle this gentleman to a place among the world's great inventors.