(No Model.) 3 Sheets—Sheet 1.

T. N. VAIL.

TELEPHONE CIRCUIT AND APPARATUS.

No. 324,191. Patented Aug. 11, 1885.

Fig. 1.

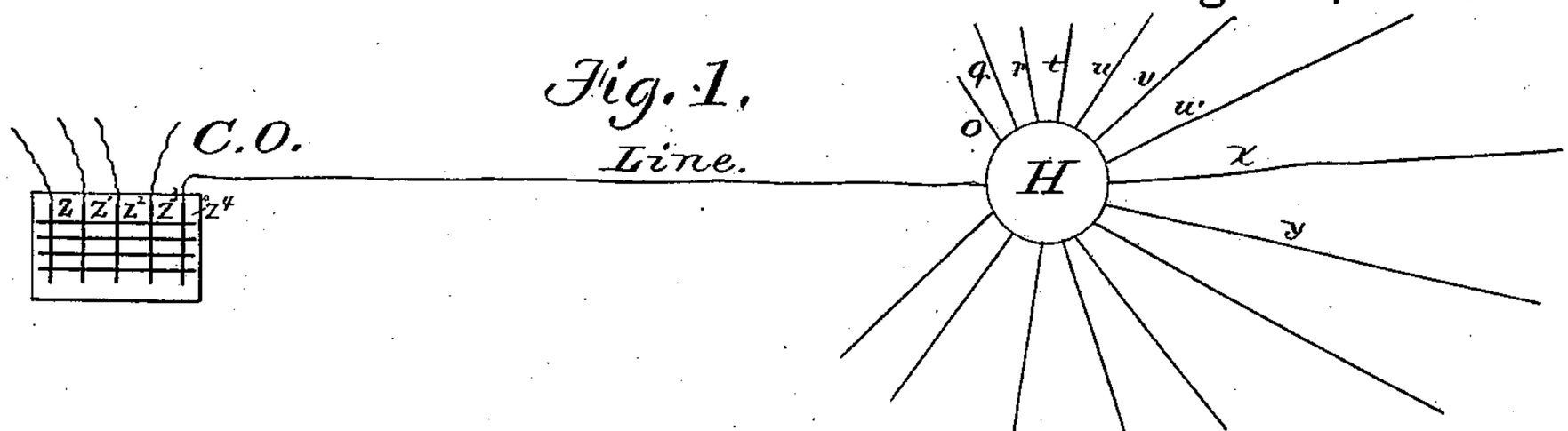


Fig. 2

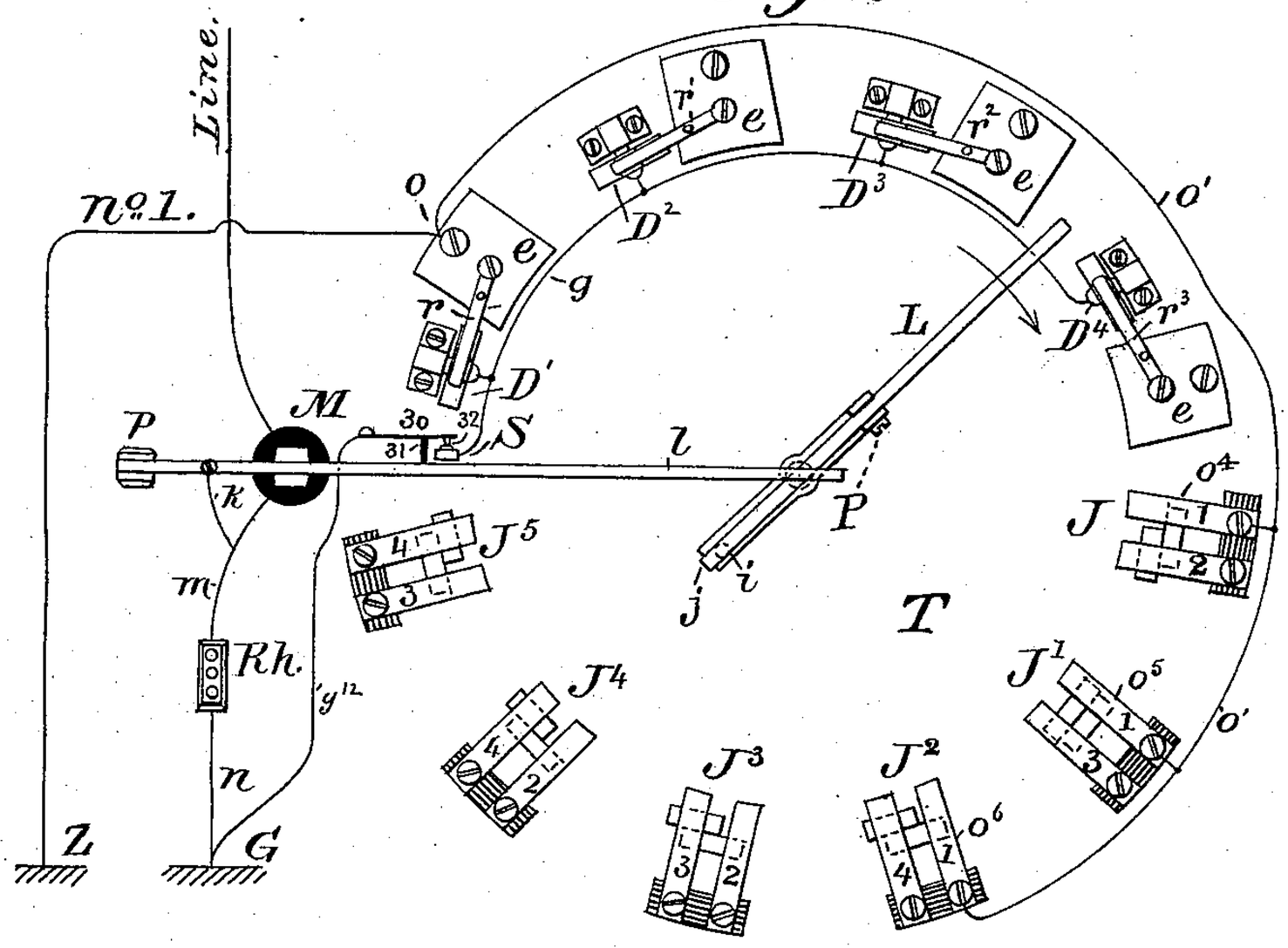
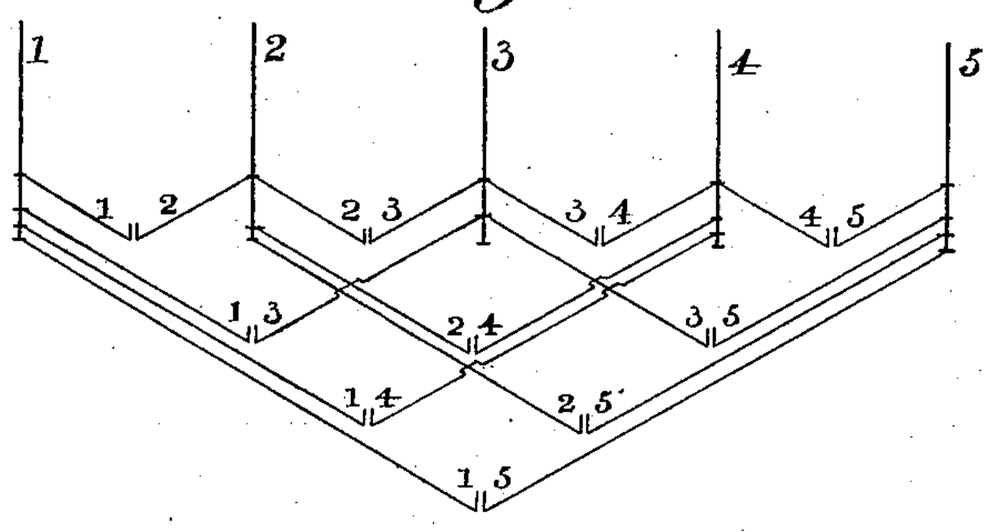


Fig. 3.



Witnesses.
Leo Willis Pierce
Thos D Lockwood

Inventor:
Theo Vail

(No Model.)

3 Sheets—Sheet 2.

T. N. VAIL.

TELEPHONE CIRCUIT AND APPARATUS.

No. 324,191. Patented Aug. 11, 1885.

Fig. 4.

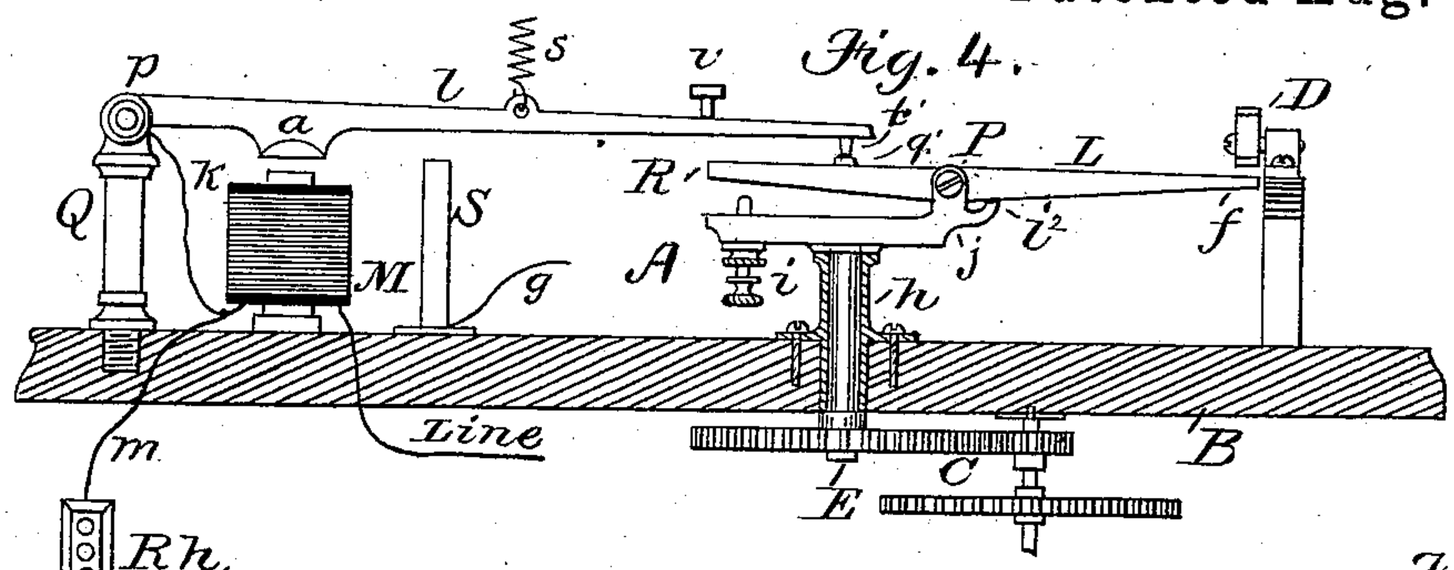


Fig. 5.

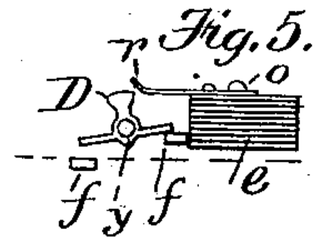


Fig. 6.

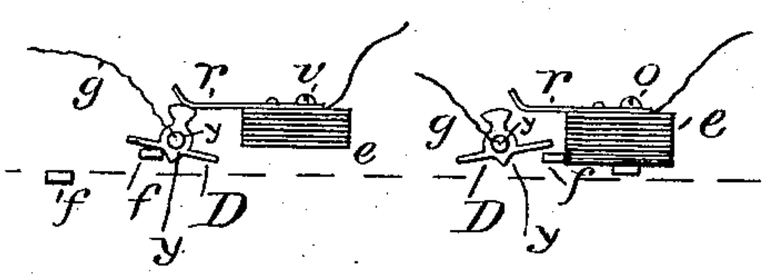


Fig. 7.

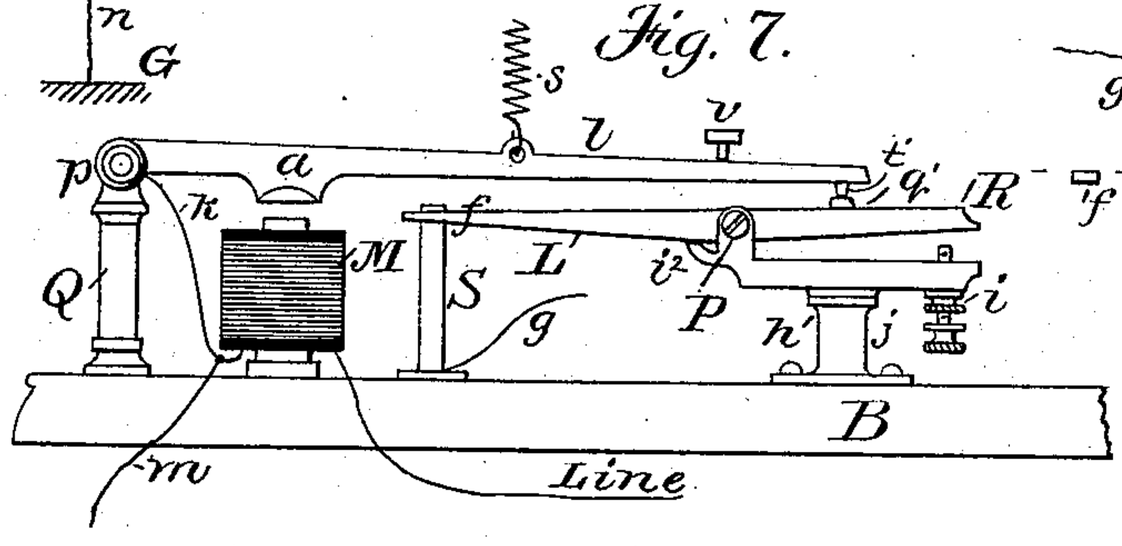


Fig. 8.

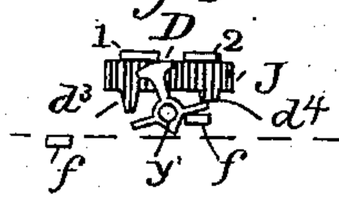


Fig. 9.

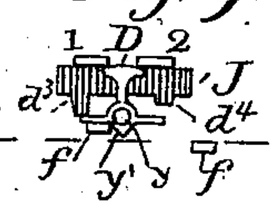


Fig. 10.

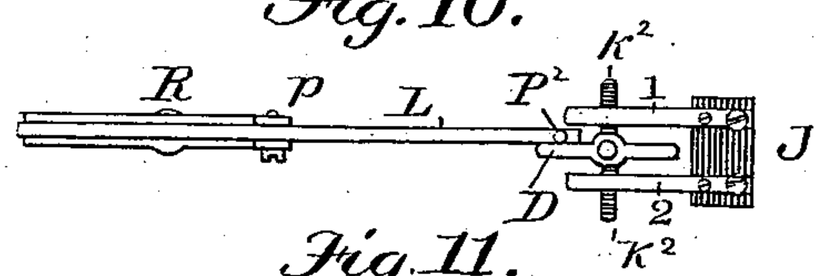
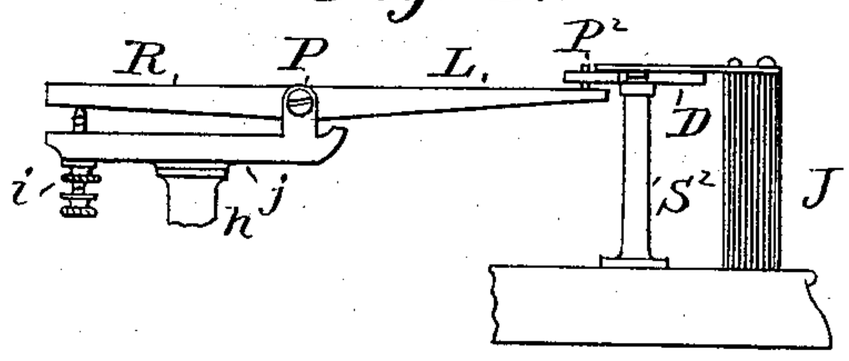


Fig. 11.



Witnesses.
Geo. Willis Pierce
Thos. D. Lockwood

Inventor.

(No Model.)

3 Sheets—Sheet 3.

T. N. VAIL.

TELEPHONE CIRCUIT AND APPARATUS.

No. 324,191. Patented Aug. 11, 1885.

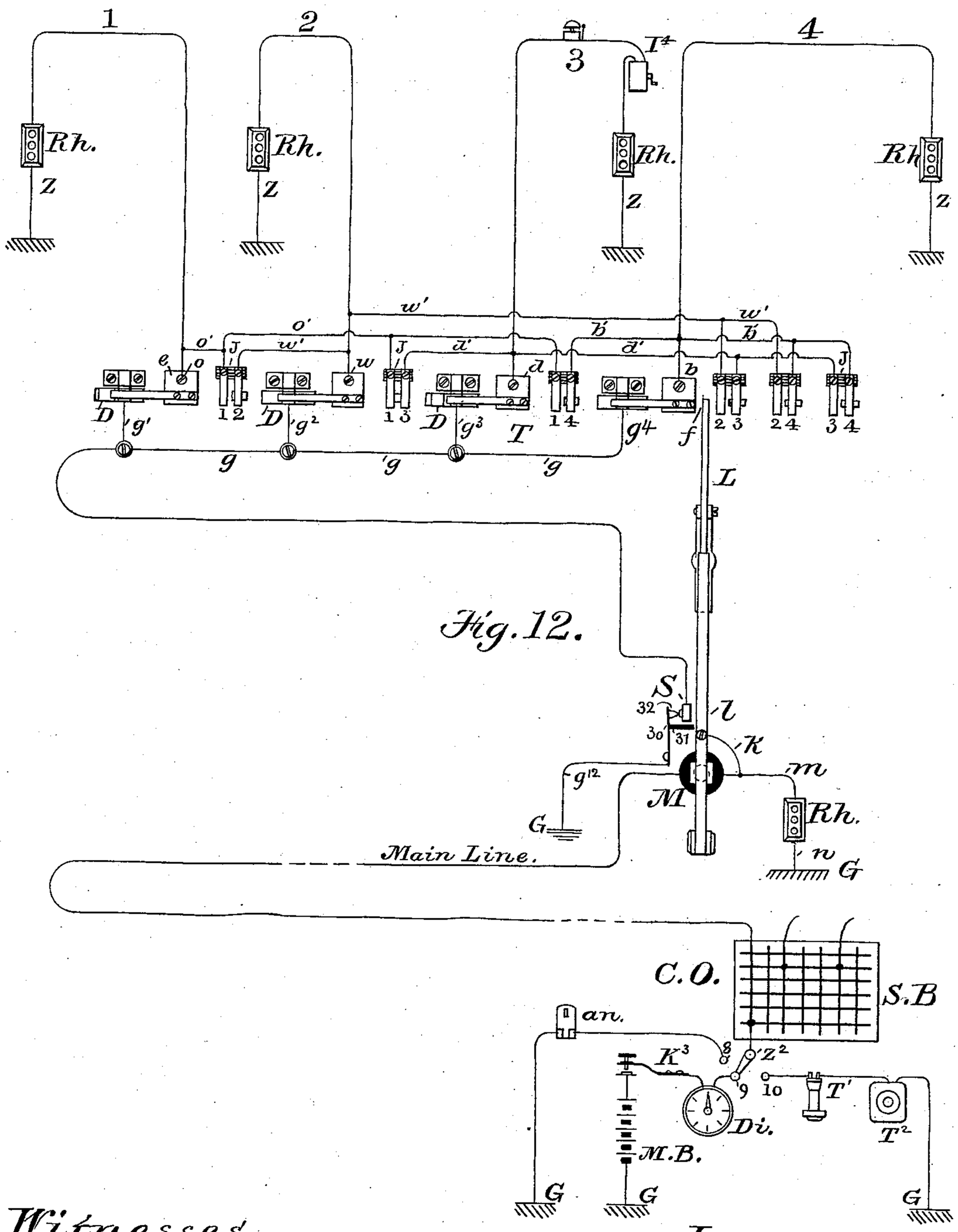


Fig. 12.

Witnesses.
Geo Willis Pierce
Thos D Lockwood

Inventor
Theo Vail

UNITED STATES PATENT OFFICE.

THEODORE N. VAIL, OF BOSTON, MASSACHUSETTS.

TELEPHONE CIRCUIT AND APPARATUS.

SPECIFICATION forming part of Letters Patent No. 324,191, dated August 11, 1885.

Application filed May 7, 1885. (No model.)

To all whom it may concern:

Be it known that I, THEO. N. VAIL, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented certain Improvements in Telephone Circuits and Apparatus, of which the following is a specification.

My invention relates to a system of electro-telephonic intercommunication, wherein separate line-wires, each leading from one or more sub-stations, converge to a central station, where any two of the said line-wires may be placed in electric connection with one another, so that the station or stations connected normally in circuit with one of the said two wires may communicate with the stations on the other wire of the pair, every other line-wire in the system being temporarily excluded from interfering in any way with the said union. Such organizations are known as "telephone-exchange systems."

Experience has fully demonstrated that as a matter of commercial economy it is not practicable to operate such systems as ordinarily constructed and arranged with any degree of financial success in very small towns and villages or other sparsely-populated localities, as it is rare that a sufficient number of subscribers willing or able to pay a remunerative rental can be obtained. Moreover, as the value of an exchange-telephone is in geometric ratio to the number of stations with which direct communication is obtainable, it is not often that sufficient inducement in that direction can be offered to persons in such small centers of population to make it worth their while to rent a telephone; yet the expenses of office-rental and manipulation are substantially as great in an exchange of twenty sub-stations as they would be in an exchange of one hundred. Reflection upon these considerations has led me to devise for such towns as are unable to sustain the expense of a regular exchange, or for auxiliary central points, a system of village intercommunication in which the several sub-station lines converge to a definite point, where I locate a special organization of instrumentalities or automatic circuit-changing devices, by means of which each of the functions of a regular telephone-exchange system can be perfectly controlled by the operator at a distant central station over a single independent line-wire extending between the said distant central office and the point of convergence of the several sub-station lines, hereinbefore referred to. I shall hereinafter, for convenience, refer to the said point of convergence as the "auxiliary" or "extension" exchange, to the connecting-line as the "trunk-line," and to the distant central station as the "main station" or "office."

My present invention is based upon the patent issued to George L. Anders, October 14, 1884, No. 306,457, and constitutes a practical exemplification and extension of the principles therein contained.

In a separate application for Letters Patent filed contemporaneously herewith, I have described another system adapted to perform the same functions, in which each sub-station line passes successively through a series of contact-springs, each spring being placed in juxtaposition to one spring of one other circuit, whereby by bringing such springs into contact with one another, and simultaneously removing their normal connections, the two lines belonging to the springs so united may be connected together. Furthermore, each line, after passing its complete series of contacts, ends in an electro-magnetic circuit-changing instrument, by operating which the sub-station on such line may connect its line direct to the trunk-line leading to the main station, and simultaneously remove the normal ground terminal from both, and likewise lock out the remaining sub-station lines from interfering with the new compound circuit so constituted.

The invention described in this specification provides that the several contact-springs, whereby any or all of the two lines may be connected in pairs instead of being actually included in and forming a part of the circuit, are in normally open branches thereof, whereby the number of necessary contacts is diminished.

My invention, briefly described, comprises the following circuit arrangements and instrumentalities, all of which will be dealt with hereinafter in detail. An auxiliary or subsidiary station is established at a suitable point adjacent to the sub-stations to be served, and

constitutes an intermediate station between the said sub-stations and the main station, which would ordinarily be at a considerable distance from the sub-station district, and located at the nearest large town. From this subsidiary central office electric-circuit lines radiate to any number of sub-stations, where the usual outfit of telephonic instruments are placed for the use of the subscribers. Trunk lines also extend from the auxiliary exchange to the main station. An automatic circuit-changing instrument is also placed there, which is capable of being rotated by clock-work, and which is controlled by an electro-magnet and lever-detent operated thereby, the electro-magnet being in the circuit of the trunk line, and controlled by the electric impulses which may traverse the same. After passing through the helices of the said electro-magnet the circuit of the trunk line passes through a suitable resistance to earth, and a branch circuit is led from it at a point between the electro-magnet and the resistance to the armature-lever. The common earth-terminal of the radiating lines is led to an abutment at which the clock-work is brought to rest after every single revolution, and as the retaining-lever of the clock-work is at all times in contact with the armature-lever the several lines are thus normally connected through the branch line to earth. When, by the action of the main-office operator, the lever-detent at the auxiliary station releases the clock-work, permitting it to rotate, the said lever is not allowed to escape beyond the control of the electro-magnet, and the operator at his will may actuate it to remove any one or more of the ground-terminals from the sub-station lines to send call-signals of the said lines or to connect any number of pairs of the said lines together. Each of the said lines may, moreover, communicate with the central station direct, inasmuch as the resistance in the intermediate ground will prevent more than a definite portion of the electricity from escaping there.

In the drawings which illustrate this invention, Figure 1 is a diagram denoting the nature of the object to be attained. Fig. 2 is a diagram of the arrangement of the trunk and local circuits at the auxiliary exchange tracing the course of but one of the local or sub-line circuits. Fig. 3 is a diagram explanatory of the several combinations which may be made of a definite number of lines. Fig. 4 is an elevation of the controlling electro-magnet and clock-driven lever-arm, showing the circuit-connections of the former. Figs. 5 and 6 illustrate the form of ground-connection which I prefer and the methods of removing and restoring the same. Fig. 7 is an elevation of the same apparatus shown in Fig. 4, but representing the same when at rest or unison. Figs. 8 and 9 illustrate the mechanism and mode required to connect any two circuits together, or, *per contra*, to disconnect them from one another. Figs. 10 and 11 show an alternative connecting device, and Fig. 12 is a diagram representing the complete system arranged in accordance with my invention.

To the end that my invention shall be more clearly understood, I will recite the separate operations which are required to be performed. It is required that the sub-stations upon each local line shall have the power to signal and communicate with the central station through the intermediate station, and to be connected through both auxiliary and main station with a separate line extending outward from the latter. It is also requisite that the main station should have the power to lock out during such connection the remaining sub-station lines, so that they shall be unable to interfere until such communication is discontinued and the normal condition of circuits resumed. It is also required that the main station shall be able to operate the instrument at the auxiliary exchange in such manner that it may pick out any line, disconnect its normal ground-terminal, send call-signals over that line, connect any two lines together, and disconnect the same when a communication is completed, restoring the original connections.

I establish an auxiliary central station, (see H, Fig. 1,) from which I radiate the several sub-station lines *o q r t*, &c., each of which has one or more sub-stations connected therewith in a manner well understood, each of the said sub-stations being provided with telephones and call receiving and sending devices, the former usually being an electric bell, while the latter may, according to circumstances, be either a magneto-generator or a battery and key.

Extending between the subsidiary station H and a main station, C O, which may be a considerable distance away is a trunk-line which preferably terminates in a switch-board at the station C O, by means of which it may at the will of the attendant be connected with any other line entering the said station C O for through communication, or may be connected with the office call receiving and transmitting devices or with the central-station telephones, as hereinafter indicated. At the subsidiary station H the trunk-line circuit is continued to the electro-magnet M, thence passing to the wire *m*, rheostat or resistance R*h*, and wire *n* to ground at G. The resistance R*h* may be adjustable. An electric current transmitted from C O over the said line must, it is evident, pass through the electro-magnet M, energizing the same. In addition to the electro-magnet M, I provide a line selecting and connecting apparatus, all of which may, if desired, be placed upon a common base-board, B. The said apparatus comprises a rotatable shaft, E, actuated by a clock-train, C, and held in place by being supported in a tube or sleeve, *h*, which sleeve may be secured or otherwise supported on the base-board, and aids the shaft E in sustaining a bar, *j*, upon which, pivoted at P, is a lever, the arm L whereof is slightly

heavier than the opposite arm, R, causing the lever to be normally tilted, so that the said arm L is lower than the arm R when the apparatus is unaffected by the action of the electro-magnet. When this condition prevails, the depressed arm L rests upon the limit-stop i^2, which may, as shown, be in one piece with the bar j, or may be otherwise fixed in any desired way.

Instead of effecting the normal depression of the arm L by gravity it may be done in any other convenient way—for example, by a retracting-spring attached thereto and united to some fixed point upon the revolving mechanism. The lever l of the armature a is fulcrumed at the pivot-screws p, and is held, when at rest, by means of the springs s against the limit-stop v. The end of the armature-lever is provided with a contact-point, t', which at all times presses upon the complementary point q' of the swinging lever, and while the latter is thus mechanically controlled by the former the points are also adapted to serve as an electrical connection between the two levers. It will be observed that the points q' and t' are in the same vertical line as the center of the upright shaft E, and that in consequence of such a construction the said points are always together, the swinging lever being thus uniformly controlled by the armature-lever irrespective of the position of the former in its orbit of rotation. When the apparatus is at rest, the long arm L bears against the metal post S, to which is attached a wire, g, forming the common terminal of a series of branch or local sub-station lines hereinafter to be described. The post S thus performs the double function of a unison or stop for the clock mechanism, and an electric link in the chain of conductors, by which the sub-station lines are united to their terminal ground and to the trunk line. When the arm L is brought up against the post S, as in Fig. 7, it serves as a detent for the clock-train, which is thus brought to rest at the conclusion of each revolution of the shaft E and the swinging arm. It may at any time be released from the said stop by the action of the central-station operator in sending over the main line an electric current, which, energizing the electro-magnet M, draws down the armature a against the counter force of the spring s. This movement of the armature is of course participated in by the lever l of the same, and is thereby transferred to the swinging lever by means of increased force exerted upon the point q'. Since this point is about the middle of the shorter arm R, the first result of such increased pressure is to rock the lever on its pivot P, pressing the shorter arm R thereof down onto the limit-screw i, which is preferably adjustable. A second result is that the end of the lever f being thus uplifted higher than the top of the stop-post S, is freed from the said stop and impelled by the clock-motor C, passes onward, and with the shaft E as a center, describes a circle, as indicated in Fig. 2, passing successively a series of circuit-changers belonging to the several circuits of the system, which, by the accomplishment of certain specific operations at certain times, may be actuated by the arm L of the swinging lever with the ultimate result of changing their relations to one another. I may here state that so long as the current continues to pass through the electro-magnet M, so long is the depression of the arm maintained; but when the current ceases to flow and the electro-magnet becomes again neutral, the arm L, by virtue of its superior weight, is again depressed. It follows, then, that by repeated impulses and intermissions of the magnetizing current, the end L of the swinging lever may be caused to rise and fall at will, and that though it may be raised by the first impulse of electricity to free it from the stop S, it may be at once lowered, by removing the battery from the line, until it arrives in its rotation opposite or immediately below the circuit-changer to be operated, when it may be again elevated to achieve the said operation, and then again allowed to fall until it arrives at another such point, and so on *ad libitum*. Further, the clock train or motor C exercises a constant power upon the revolving lever, which is only completely annulled when the long arm L impinges against the stop-post, but which may be checked or lessened in degree by any friction against or work done by the arm L. In the first place then, if, after passing all the circuit-changers, the electro-magnet is again energized, instead of striking the stop-post it will pass over the same and commence another revolution, and in the second place, whenever the end f of the arm L is opposite a circuit-changer and is at that time elevated by the sudden energization of the magnet, it will be pressed up against the said circuit-changer, and will thus be mechanically retarded.

Referring now to Fig. 2, it will be seen that the several circuit-changers of the different sub-station lines are ranged round the circle described by the end f of the arm L and are adapted to be struck by the same when the said arm is passing round in the direction of the arrow, provided that when passing below any given circuit-changer it is elevated by the action of the electro-magnet. The instrumentalities so arranged comprise for each line a single ground-switch and a series of connecting-switches in number equal to the total number of centering lines less one. In the present instance I have shown but four sub-station lines, although it may readily be imagined that any reasonable number may be grouped in like manner. In the majority of cases, ten or twelve lines would be a maximum number. Each line is represented by one of the ground-terminal switches, D, and by three connecting-switches, J. This may be clearly elucidated by reference to the diagram, Fig. 3, in which it is assumed that five lines center at a given station. I have numbered these lines from 1 to 5, and it is

evident that a subscriber stationed upon any one of these lines may desire to communicate with stations upon any of the other lines. Ten combinations of lines are requisite to make such an arrangement. I accomplish it by running from each of the lines a series of normally-open branch lines equal in number to the sum of all the remaining lines, and by bringing each branch near to one of the branches of each other line. For example, from line No. 1 I run four branches—one to a co-ordinate branch from No. 2, a second to a similar branch from No. 3, a third to No. 4, and a fourth to No. 5. In like manner branches are led from each line. As shown, the several pairs are not united but merely brought near to one another, so that when required a union may easily be effected. No. 2, for instance, may readily be connected with No. 3 by first removing the terminal grounds of both lines and then bringing the two points 2 and 3 together. Such is the principle which is embodied in my invention.

I will now trace the path of a single sub-station line through the apparatus, after which I will describe the form of circuit-changers which may be adopted. The line No. 1 extends between the sub-station Z, where it is of course connected with any preferred style of telephone apparatus (not shown) and the subsidiary central station, T. Entering the said station T it connects directly at the screw *o* with the metal base plate or block *e*, where it normally terminates as a circuit by means of the flat spring *r* which bears upon the top of the rocking ground-plate D, this plate being in electrical connection with the common ground-wire *g* leading to the stop-post S. Through this post all of the sub-station wires find earth, when the system is at rest, *via* the lever-arm L, contact-points q' and t', armature-lever *l*, fulcrum-post *p*, connecting-wires *k* and *m*, resistance R*h*, and wire *n*. A normally open or incomplete branch extends, however, from the line-wire to a series of extra contact-springs equal in number to all of the remaining wires of the system.

As indicated in the drawings, the wire o' leaves the line-wire at a point before reaching the ground-spring. It is convenient to attach the branch wire o', as shown, to the screw *o*. From that point it is led successively to each of a series of non-conducting blocks, J J′ J^2, where it branches to contact-springs o^4, o^5, and o^6, and, in fact, to as many additional springs as there are additional wires. Thus at the block J the spring o^4 is in close juxtaposition to a similar spring similarly branched from No. 2 wire, and I have consequently marked the two springs 1 and 2 at the block J′ in like manner. The spring o^5 is brought into close communion with a spring branched from circuit 3, the two springs being marked 1 and 3. At the block J^2 the spring o^6 is placed close to the spring connected with circuit 4, and the two are marked 1 and 4. The other blocks, J^3, J^4, and J^5, which I have shown, each carry similar springs, and each consequently constitute points of connection—at J^3, between circuits 2 and 3; at J^4, between 2 and 4; and at J^5, between 3 and 4. It is quite obvious, moreover, that this principle of arrangement may be carried out irrespective of the number of circuits, all circuits in the system being arranged precisely in the same manner that I have described—that is, each circuit terminates normally in a removable ground-plate connecting with the common ground-wire, and has, also, a normally-open branch extending to a series of connecting-springs, each of the said springs being in close proximity to a similar spring of one of the other circuits. It must now be evident that to connect any of the pairs of circuits together for through communication it is only necessary to trip off the ground-connections of the two circuits concerned, and then to bring the two contiguous springs of such circuits into metallic connection. By my invention I not only accomplish this in the case of a single pair, but I am able to connect the total number of circuits in the system in pairs, if so required, and, furthermore, to disconnect the two wires of any pair from one another and replace their ground-connections without interfering with the connection of any other wires which are paired. So far as I am aware, this has never been accomplished in a subsidiary exchange operated from a central exchange at a distance, prior to my invention.

Figs. 5 and 6 show one form of the appliance which I use as a ground-plate, and illustrates the mode in which it may be removed and replaced. It consists of a metal rocking-plate, D, pivoted at the point *y*, and adapted, when tilted in one direction, as shown in the left-hand view, Fig. 6, to pass under the free end of the circuit-spring *r* and to make electrical contact therewith. The wire *g* leading to the ground is attached to the rocking piece, and thus the line is terminated, as hereinbefore described, when the spring rests on the plate D. When tilted in the other direction, as indicated in the right-hand view of Fig. 6, and in Fig. 5, the ground-connection is removed from the circuit.

In Fig. 5 the act of tilting the ground-plate is indicated. In the right-hand view of Fig. 6 the removal is completed, and the end *f* of the moving lever is indicated in two successive positions—first, in contact with the end of the metal block *e*, the progress of the rotating arm being thereby arrested, and, second, as being released from the said block and as passing onward in the continuance of its revolution. It can be maintained in the first position as long as may be required by simply keeping the battery-current on the main line, and while so held the telephones at the central station may be introduced. I avail myself of this construction when two lines have already been connected and it is desired to ascertain whether the conversation is or is not concluded; as by causing the lever to make contact with the block

e of either of the two connected lines, as described, the operator may readily listen to the conversation which is passing thereon. In the left-hand view, Fig. 6, the act of replacement is indicated.

In Figs. 8 and 9 I show one form of connector. The two springs 1 and 2 are shown affixed to a non-conducting block, J, as in the diagram Fig. 2. Centered below them, on a pivot, *y'*, is a connecting rock-plate, D, identical in form with the ground-plate. The moving power, which in practice is the end *f* of the arm L of the revolving lever, is shown in Fig. 8 as having just struck up the end of the rocking plate, and as having thereby disconnected the two springs, 1 and 2, and consequently the lines 1 and 2 from one another.

In Fig. 9 the two springs 1 and 2 are represented as being in contact through the metal substance of the plate D, which, to form such connection, has just been struck up. In practice suitable limiting-screws, as d^3 d^4, will of course be required to prevent the plates from swinging too far on either side.

Figs. 10 and 11 illustrate a modification in the connecting device which show it as moving in a horizontal plane on the turnstile principle. The connector is a four-rayed star adapted to turn horizontally on the pivot S^2. Two of its rays, k^2, opposite to one another, are of non-conducting material, and these normally are in position under the circuit-springs 1 and 2, which, as in the former apparatus, are affixed to the block J. When, however, the turnstile is caused to rotate a quarter of a revolution, the conducting-arms D are brought into contact with the springs 1 and 2, which are thus united through the metal of the said arms.

I operate the turnstile mechanism by placing an upwardly-projecting pin, p^2, on the L end of the lever-arm L, which pin, when the lever end in its rotation reaches the connecting device and is struck upward, by the electro-magnet, bears against the projecting ray of said device and carries it forward bringing the next into position. It will thus be seen that connections and disconnections are effected in the same way. I am, of course, not restricted to a four-ray connector, as it may frequently occur that a greater number will be preferable; and to that end I reserve the right to employ any number I see fit.

Fig. 12 is a diagram of the complete system, and is intended to facilitate the explanation of the method of operation. It shows a number of sub-station circuits, 1, 2, 3, and 4, centering at a subsidiary exchange, T, which in turn is connected by a single line with the central station C O.

Although in practice the several circuit changers and connectors D and J are ranged round the periphery of a circle in the orbit of the rotating lever, I have, for purposes of illustration, delineated them in this diagram upon the projection of Mercator, in a straight line, and have placed the actuating mechanism in a position on one side apart from the same. Each circuit, at its sub-station or at some convenient point between the ground-plate D and the sub-station, is provided with a high resistance, R*h*. It has also the regular sub-station apparatus of telephones, signal-bell, and calling apparatus, as shown in detail in one instance at I^4, circuit 3. The line passes from the sub-station direct to the conducting-block *e* at the subsidiary exchange, and thence to ground, as hereinbefore explained. The normally-open branch of each line passes to the non-conducting-blocks J, where it connects with contact-springs, these springs being placed near to others belonging to the other circuits of the system. Two of these circuits, No. 1 and No. 3, are shown in Fig. 12 as being connected to one another, the ground-plates being tilted to one side, and the springs 1 and 3 being united by the upright position of the connecting-plate. The ground-plates are connected by branch wires *g'*, g^2, g^3, and g^4 with a common ground-wire, *g*, leading to the post S. Against this post normally rests the long arm L of a balanced lever, which is adapted to be rotated by clock-work, so that its end *f* passes successively under the several tilting circuit-changing plates D, these being, as before described, arranged in a circle of which the central shaft of the rotating lever is a center. When the lever-arm rests against the said post S, the lines 1 2 3 4, &c., find earth-terminal thereby *via* the said lever, the armature-lever *l*, the wires *k* and *m*, the resistance R*h*, and the wire *n*, also by wire *k*, electro-magnet M, and over the main line and *via* the annunciator *an* at the central station. When the lever arm leaves the post S, the lines need not be deprived of a ground-terminal, for, as shown in Figs. 2 and 12, I may, where required, provide a simple attachment, whereby as soon as the lever moves away from the said post a secondary ground-terminal is established. This comprises a spring, 30, furnished with a contact-point, 32, which is adapted to make contact with the post S. It is, however, normally prevented from making contact therewith by a pin of non-conducting material, 31, which is pressed against by the lever-arm when the said arm is at unison, whereby the said spring 30 is held away from the post; but when the lever is released the spring 30 by its own resiliency is brought into contact with the post, and since it is attached to a ground-wire, *g*, a ground-terminal is thus at once provided for the several sub-station lines, so that stations on the same line can call one another.

S B is a switch-board at the central station through which the main line may be connected with any line centering there. The said main or trunk line, after passing through the switch-board, may be connected through a small switch, z^2, or an equivalent device, with the stud 8, leading to earth through an ordinary annunciator. This would be its normal position, so as to receive calls. The small switch z^2 may also be placed on either of the other two studs,

9 or 10. When placed on the stud 9, it is in position to operate the rotary lever at the subsidiary station and to transmit signals, and the circuit includes an indicating device, D*i*, a key, k^3, and a main battery, MB. When placed on the stud 10, the telephones T′ and T^2 are brought into circuit and conversation may be carried on. When the line is to be connected through the switch-board S B with any other line, the switch z^2 may be thrown off altogether, or the circuit-terminal otherwise removed, and the trunk line may then be connected with any other by means of the switch cross-bars, in a manner well understood.

I do not restrict myself to the use of manual transmitting devices for operating the rotary arm, and for sending calls, since it is obvious that automatic transmitters—such, for example, as that described in the patent of Thos. D. Lockwood, No. 296,588, of April 8, 1884—may be advantageously employed in connection therewith.

Operation: I will now describe the operation of my invention as briefly as may be, so that the relations of the several instrumentalities may be more clearly perceived. When any one of the sub-stations Z desires to communicate with the central station, the generator is operated, or a battery-call is sent in the usual manner. The electricity so transmitted passes over the sub-station line, and, arriving at the subsidiary exchange, there divides, traversing the several paths open to it in inverse proportion to their several resistances. The remainder of the sub-station lines together constitutes one of the said routes, the subsidiary station-ground forms a second, and the line to the central station diverging from the second at the junction of the wires *k* and *m* is the third. The object of the resistances R*h* in each of the lines and in the intermediate ground, is to prevent a large proportion of the current from passing over the first and second routes to the detriment of the calling-current. These resistances are accordingly made sufficiently high to subserve that function, and when a call is sent in, the annunciator *an* at the central station becomes energized and announces the said call. I so adjust the electro-magnet M that it responds only to a current much stronger than any generated at the sub-stations. It therefore remains unaffected by the action of the sub-station in calling. In like manner conversation may be carried on between the sub-station and the central station without any other alteration of circuits than that of changing the little switch z^2 from stud 8 to 10 to bring the telephones into circuit. When it becomes necessary for the central station to select any given one of the sub-station-lines, and send call-signals over the same, this is done by turning the small switch to the stud 9, as shown, and sending a single pulsation of electricity to line from the battery MB. This passes over the line and through the magnet M, energizing the same, and causing the armature *a* to be attracted. The result is that the lever-arm L is released from the post S, and the clock-motor C is permitted to revolve the said arm, which thereupon travels round the circle of circuit-changers. Let it be required now to call over No. 3. When it is seen by the dial D*i*, which rotates synchronously with the rotating lever, that the lever end *f* is below the right-hand end of the tilting ground-plate D of line 3, as in Fig. 6, (the dotted line in that figure, as also in Figs. 8 and 9, representing the normal plane of rotation,) a second impulse of electricity is given by pressing the key. The electro-magnet again attracts the armature, which presses down the arm R of the balanced lever. The other arm, L, consequently flies up, and its end *f* strikes the end of the ground-plate, tilting it away from the spring *r*, and thus removing the ground-terminal from the circuit. As soon as the key is released, the rotating arm falls to its ordinary plane, but as it passes below the metal plate *e* it is again forced up, and may be, by repeated strokes of the key at the central station, caused, while passing the said plate, to strike upward a distinct number of times corresponding to the number of times the key is pressed. Since the end *f* of the lever is in direct electrical communication with the main line, it follows that every time it makes contact with the lower surface of the metal block *e* a pulsation of electricity is transferred over the sub-station line and gives the signal. The length of the blocks *e* may be regulated as desired. To connect any two of the sub-station lines together at the subsidiary exchange—say No. 1 and No. 3—the central station will cause the mechanism to revolve, and will successively remove the ground tilting plates D from the said circuits. The traveling arm will then pass on until it reaches the point where the contact-springs of 1 and 3 adjoin one another on the same base-block, and as it passes that point the tilting lever there will be tilted in the required direction to make the contact, the proper time for action by the central-station operator being in all cases known by the synchronic action of the indicating-dial D *i*. Disconnections are effected in substantially the same way, care being taken in all cases to strike the reverse end of the tilting lever, listening, prior to disconnection, being effected in the manner hereinbefore indicated. When it is desired to connect one of the sub-station lines through the subsidiary and central exchanges with a line centering at the latter point, the central-station attendant will, to prevent interference from other lines, pass the rotating arm once round and remove the grounds of all lines except the one with which connection is required. Communication will then readily be maintained. As an alternative mode of accomplishing the above, instead of tripping all the ground-plates I may simply trip the ground of the line with which connection is desired, and then cause the end *f* of the lever to be held

against the metal block *e* as in the "listening-off" operation. It will be necessary, if this mode is adopted, to keep sufficient battery on the line to sustain the elevation of the lever-arm. I prefer, however, the former mode of procedure.

I may, without departing from the spirit of my invention, employ at the central station a magneto-generator adapted to send straight currents, in lieu of a battery, such a sub-station being one which would readily suggest itself to one skilled in the art. Furthermore, I do not restrict myself to the precise form of circuit changing and connecting pieces shown, since I have herein shown one modification of the same. Others are mere matters of detail.

Having now fully described my invention, I claim—

1. A telephone-exchange system comprising a main central station, a subsidiary or auxiliary central station, a series of sub-station lines converging to the latter, a trunk line extending between the main and auxiliary central stations, a double series of circuit-changers for the lines terminating at the subsidiary station, one of the said series being arranged to effect the removal and replacement of the ground-terminals of the several lines, and the other providing for the connection of any of the two lines together, a rotating lever operated by a suitable clock-motor and adapted to select and actuate any of the said circuit-changers, and an electro-magnet in the trunk-line circuit provided with an armature-lever controlling the said rotating lever and its clock-motor, substantially as described.

2. In a subsidiary telephone-exchange system, the combination, substantially as hereinbefore described, of a trunk-line circuit extending to a distant station, an electro-magnet included in the said circuit and provided with an armature and lever therefor, a pivoted lever adapted to be rotated by clock-work, but at all times in contact with and connected by the said armature, a series of sub-station lines converging to a common terminal wire, and suitable connections, through both of the said levers, whereby the several sub-station lines are by their common terminal-wire connected normally to earth, and whereby they are disconnected from earth when the pivoted lever is in the act of rotation, for the purposes specified.

3. In an auxiliary telephone-exchange, a series of sub-station line-circuits provided with removable earth-connections, and with normally-open extensions branched from a point on said lines external to said ground-connections, and each extension leading by sub-branches to a series of connecting points or springs, each of the said connecting points or springs being adjacent to a similar point or spring of one other of the series of line-circuits, combined with movable connection-pieces, whereby any two adjacent springs representing any two circuits may be connected together to constitute a compound circuit for the purpose of inter-communication, substantially as hereinbefore specified.

4. The combination, substantially as hereinbefore described, in an auxiliary telephone central-office system, of a series of lines converging to said stations, a series of circuit-changers therefor arranged in a circle, each sub-station line being represented in the said series by a single earth-terminal circuit-changer, and also by a series of separate connecting circuit-changers, one for every line in the system, a trunk line extending from a distant central station, an automatic selecting and connecting apparatus located at the auxiliary station, fixed at the center of the circuit-changer circle and consisting of a rotating arm actuated by a clock-train motor, and adapted to traverse the edge of the said circle within range of the several circuit-changers, a stop or unison adapted to arrest the motion of the rotating arm and clock-motor at the end of each revolution, and an electro-magnet provided with an armature and armature-lever, and included in a separate main-line circuit extending from a distant station, the said electro-magnet being adapted, as herein shown and described, to control at all times the rotating arm for the purposes specified.

5. The combination, in an auxiliary telephone-exchange system, of two or more sub-station lines converging to a central point, each provided at its sub-stations with telephones and signaling apparatus, and each having in branch circuit at the said central point a mechanical ground-switch and a series of mechanical connecting-switches equal in number to the total number of converging sub-station lines less one, with a trunk line connecting said point of convergence with a distant central station, an electro-magnet included in the said trunk-line circuit, and apparatus comprising a revolving arm, a motor to revolve the same, and a lever actuated by the electro-magnet to control the said arm, whereby the ground-switch of any sub-station line may be automatically operated, and whereby any pair or number of pairs may be automatically connected together at the will of the operator at the distant central station.

6. The combination, with a lever adapted to be rotated in a horizontal plane and to rock on a pivot in a vertical plane, an electro-magnet, an armature, and an armature-lever controlling the vertical rocking movement of the said rotatable lever by a bearing thereon at a point immediately above the center of rotation, of a series of mechanical circuit-changers or switches arranged in circular series in the orbit of revolution of the said rotatable lever and within range of the longer arm thereof, the said arm being brought alternately into juxtaposition with each circuit-changer by its rotation, and being caused to operate any desired one in passing by its rocking movement

under the actuation of the controlling-lever and electro-magnet, substantially as hereinbefore described.

7. The combination, in an auxiliary central station, of a main or trunk line, a series of sub-station lines, a ground-terminal including a high resistance permanently connected with the main line, and normally serving the sub-station lines also, and means, as indicated, actuated by an electro-magnet included in the main line-circuit for disconnecting the several sub-station lines from the said ground-terminal, substantially as described.

8. The combination, in a subsidiary telephone-exchange, of a lever supported on a vertical rotatable shaft, so as to be rotated by a suitable motor in a horizontal plane and hung on pivots at a point nearer to one end than the other, so that the longer arm is normally depressed, and so that it may rock on the said pivots in a vertical plane, a stop or unison post against which the said longer arm rests to normally arrest the rotary motion thereof, the said post being electrically connected with the common terminal wire of a number of circuits, a controlling-lever furnished with an armature and operated by an electro-magnet in a main circuit, the said lever at its free end resting lightly upon the rocking lever at a point in the same vertical plane as its center of rotation, and a ground-wire, including a rheostat or other suitable resistance, attached to the said controlling-lever, whereby the several circuits connected by the common terminal-wire with the said unison-post are completed to the earth through the said rheostat when the apparatus is at rest through the conducting substance of the said post, the two levers, the ground-wire, and resistances, whereby the said circuits may be disconnected from the said earth-terminal, and reconnected to earth direct by releasing the rotating lever from the said post, substantially as herein specified.

9. The combination of a series of mechanical switches or circuit changers arranged round the circumference of a circle, each consisting of contact-springs suitably mounted upon base-blocks, and of metal plates mounted on arbors or pivots, so that when turned in one direction they may be caused to make contact with the said springs, and when turned in the other direction they may be freed from such contact, with a traveling arm supported upon a vertical shaft actuated by a suitable motor to pass round the circle of circuit-changers within range thereof and passing each successively, and actuated by an armature-lever, and an electro-magnet in an independent circuit to fly upward and strike when passing any desired circuit-changer to operate the same, as specified.

10. The combination of a selecting mechanism at a subsidiary exchange, with a series of ground-switches, each representing a separate sub-station circuit, and each comprising a contact-spring mounted on a metal block, and a tilting ground-plate therefor, a trunk line, and an electro-magnet included therein, controlling the said selecting mechanism, the said trunk line extending between the subsidiary exchange and a central station, a source of electric energy located at the said central station, and a key or other circuit-closer, whereby the current from such source may be directed momentarily to the line to set in motion the selecting mechanism, and again when the selecting mechanism arrives at the desired circuit to throw the ground-connection from the said circuit, and to signal the same by repeated contacts with the metal base-block of the ground-switch, substantially as specified.

11. The combination of a ground-switch, a metal supporting and signaling block, a connecting-switch, a revolving arm, a motor to actuate the same past the said block and switch, and a separate lever operated by an electro-magnet to start the motor and to bring the revolving arm in contact with the said instrumentalities as it passes them all at an auxiliary exchange, with a trunk line from said auxiliary exchange to a distant central station, and a source of electric energy, a circuit-closing key, and an indicator adapted to rotate synchronously with the said revolving arm all at a main station, whereby the current from such source may be directed to line momentarily, to start the motor and revolving arm again, when the desired circuit is reached, to throw off the ground-plate; a third time, to send signals to the sub-station by striking the rotating arm any number of times against the call-block as it passes the same; and, finally, to operate the connecting-switch and connect the two lines together, substantially as hereinbefore described.

12. A mechanical switch or circuit-changer consisting, substantially as hereinbefore described, of a non-conducting base-block or support, two contact-springs affixed thereto and supported thereon, each of the said springs constituting a separate circuit-connection, and a conducting block or plate having a broad upper surface, the said plate being balanced on a pivot so as to tilt in either direction, in combination with a movable actuating-arm, whereby, when erect, said plate may be caused to impinge upon both circuit-springs and unite the same electrically, and when tilted in either direction by said arm it may be disconnected from the said springs, opening the circuit between them.

13. A mechanical switch or circuit-changer, consisting, substantially as herein shown and described, of a contact-spring attached to a metal base and connected by wire with one part of the circuit, and a conducting block or plate connected by wire with the other part of the circuit, and pivoted at its center so as to be tilted in either direction, in combination with a movable actuating-arm, whereby said plate is adapted, when tilted in one di-

rection, to impinge upon the said contact-spring and to make frictional contact therewith and close the circuit, and when tilted in the other direction by said arm to be freed from such contact, opening the circuit.

14. The combination, in an auxiliary central station, of a main or trunk line extending from a distant central station, a series of sub-station lines, each provided at the point of convergence of all the lines with two branches, one of the said branches terminating in a ground-connection and the other extending to a series of normally-open sub-branches, each of which ends in a connecting-spring placed in close contiguity to a spring representing some other circuit, the said ground-connections and connecting-springs being all arranged in circular form, a common ground-terminal for main and sub station lines, an electro-magnet included in the main line, and means, consisting, substantially as described, of a clock-rotated lever revolving within the circle of ground-connections, and line-connectors controlled by the said electro-magnet, and operated over the trunk line from the distant station, whereby the ground-connection may be removed from any one or more of the sub-station lines, and whereby one or more pairs of the sub-station lines may be connected together, substantially as hereinbefore described.

15. The combination, in an auxiliary exchange system, substantially as hereinbefore described, of a main or trunk line circuit connecting with a distant central station, an electro-magnet included therein, and a ground-terminal wire therefor, including a suitable resistance, with a rotatable rocking lever, a clock-motor therefor, a stop or unison post, against which the rotatable lever normally rests, a controlling-lever attached to an armature governed by the said electro-magnet, and resting at its free end upon the rotatable lever at a point in the same vertical plane with its center of rotation, whereby the said controlling-lever is enabled to control at any time the rocking movement of the said rotatable lever, a connecting-wire from the said controlling-lever to a point on the main-circuit ground-wire between the electro-magnet and the resistance, and a series of sub-station circuits, converging to a common terminal wire leading to the stop-post, whereby, when the apparatus is at rest, the several sub-station lines and the main or trunk line are provided with a common ground-terminal and resistance, and whereby the said sub-station lines may be disconnected from the same when the rotatable lever is by the depression of the controlling-lever released from the stop-post, for the purposes described.

16. The combination, in an auxiliary central station, of a main or trunk line, a series of sub-station lines, each having in circuit a suitable resistance, a ground-terminal, likewise including a resistance, the said ground-terminal being permanently connected with the main line, and normally serving as the common ground-terminal of the several sub-station lines also, and means, as indicated, actuated by an electro-magnet included in the main-line circuit for disconnecting the several sub-station lines from the said ground-terminal when desired, substantially as specified.

17. The combination, in an auxiliary telephone-exchange, with a series of ground-switches of the character herein described, each representing the terminal of a sub-station line, and a series of metallic base or call plates to which such ground-switches are attached, the whole being arranged round the segment of a circle, of a trunk line extending between the station where the said appliances are located and a distant central-station, signal-sending apparatus at said distant station, and a rotating line-selecting arm operated by an electro-magnet included in the trunk-line circuit, the said arm also being in a branch circuit from the said trunk line and adapted to pass the several ground-switches and call-plates successively, and to be brought into contact with the same when desired, whereby the call-signals transmitted from the said central station may be directed by means of the said arm and call-plate to the desired sub-station, and whereby the trunk line may be temporarily united with any of the said sub-station lines for listening purposes or for telephonic communications, substantially as herein described.

18. The combination of a series of sub-station lines converging to a subsidiary exchange, a series of sub-stations, one or more located on each line and provided with call signal-transmitting devices, a central station and call-receiving instruments located thereat, a trunk line extending between the central and subsidiary exchanges, and a series of resistances included in the trunk line and sub-station circuits, the said sub-station circuits being normally connected as a joint or compound branch circuit of the said trunk line, whereby call-signals transmitted from any of the sub-stations are prevented from being dissipated over the other sub-station lines, and may be caused to operate the call-receiving instruments at the central station.

19. The combination, substantially as hereinbefore described, of a series of sub-station lines converging to a subsidiary central station, a trunk line connecting said subsidiary station to a main central station, a selecting and connecting mechanism located at the said subsidiary exchange and comprising an electro-magnet in the trunk-line circuit, and rotating lever and controlling-lever in a branch circuit of said trunk line, whereby the action of the main station said rotating lever may connect itself with one of the sub-station lines, opening each of the others, a battery, key, and indicating-dial at said central station, whereby the selecting device may be operated

by means of the electro-magnet, and a switch-board also at the central station, whereby the trunk line and through it the line united thereto at the subsidiary exchange, may be connected with any other line entering the said central station, for the purposes specified.

20. The combination, substantially as hereinbefore described, of a lever placed on a vertical shaft and actuated by a clock-train motor to rotate in a horizontal plane, but fixed unequally on pivots, so as to rock in a vertical plane, a stop or unison post with which the longer arm of said lever is normally in contact, and which by such normal contact maintains the quiescence of the said motor, a controlling-lever furnished with an armature, and normally being in light contact with the rocking lever at a point in the same vertical plane as the center of rotation thereof, so that the rocking movement of the rotating lever is at all times under the control of the said controlling-lever irrespective of the position of the former in its orbit of horizontal rotation, and an electro-magnet in a main circuit, adapted, when energized, to attract the said armature, and to depress thereby the free end of said controlling-lever, whereby the rotating lever may be released from its stop, the motor permitted to move and to rotate the said rotating lever, and also whereby the short arm of the rotating lever may be depressed and the longer arm correspondingly elevated at any desired point in the sphere of its revolution, for the purposes specified.

21. The combination, in an auxiliary central station, of a main or trunk line, a series of sub-station lines, a ground-terminal including a high resistance permanently connected with the main line, and normally serving the sub-station lines also, a separate and direct ground-terminal, means, as indicated, actuated by an electro-magnet included in the main-line circuit for disconnecting the several sub-station lines from the said first ground terminal, and other means, as described, for thereupon connecting them automatically to the direct ground, substantially as described.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 4th day of April, 1885.

THEO N. VAIL.

Witnesses:
GEO. WILLIS PIERCE,
THOS. D. LOCKWOOD.