(No Model.) 15 Sheets—Sheet 1.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 1

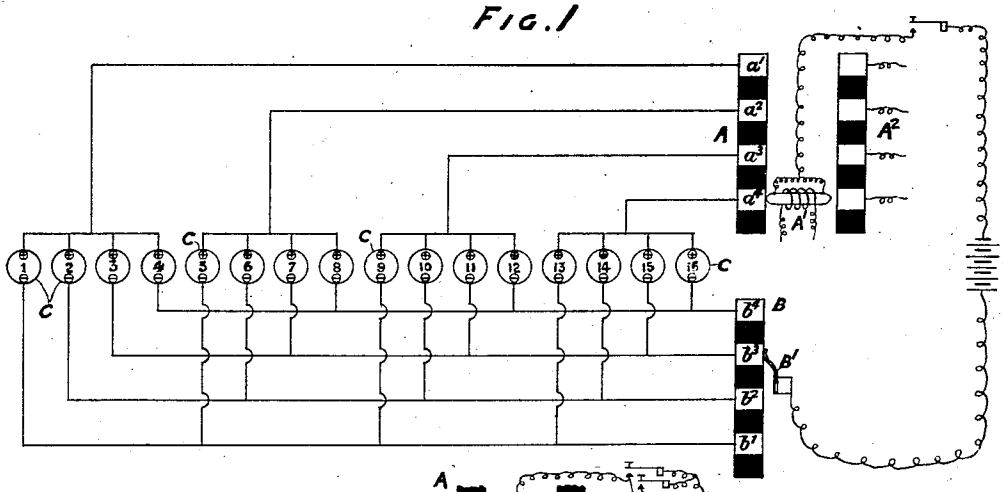
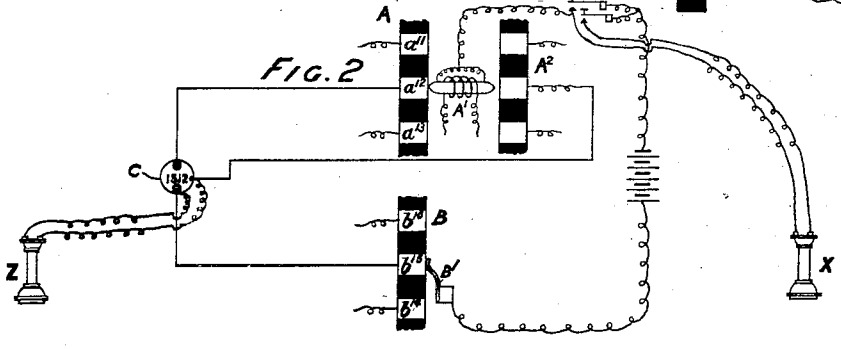


FIG. 2



Witnesses:

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Attorneys.

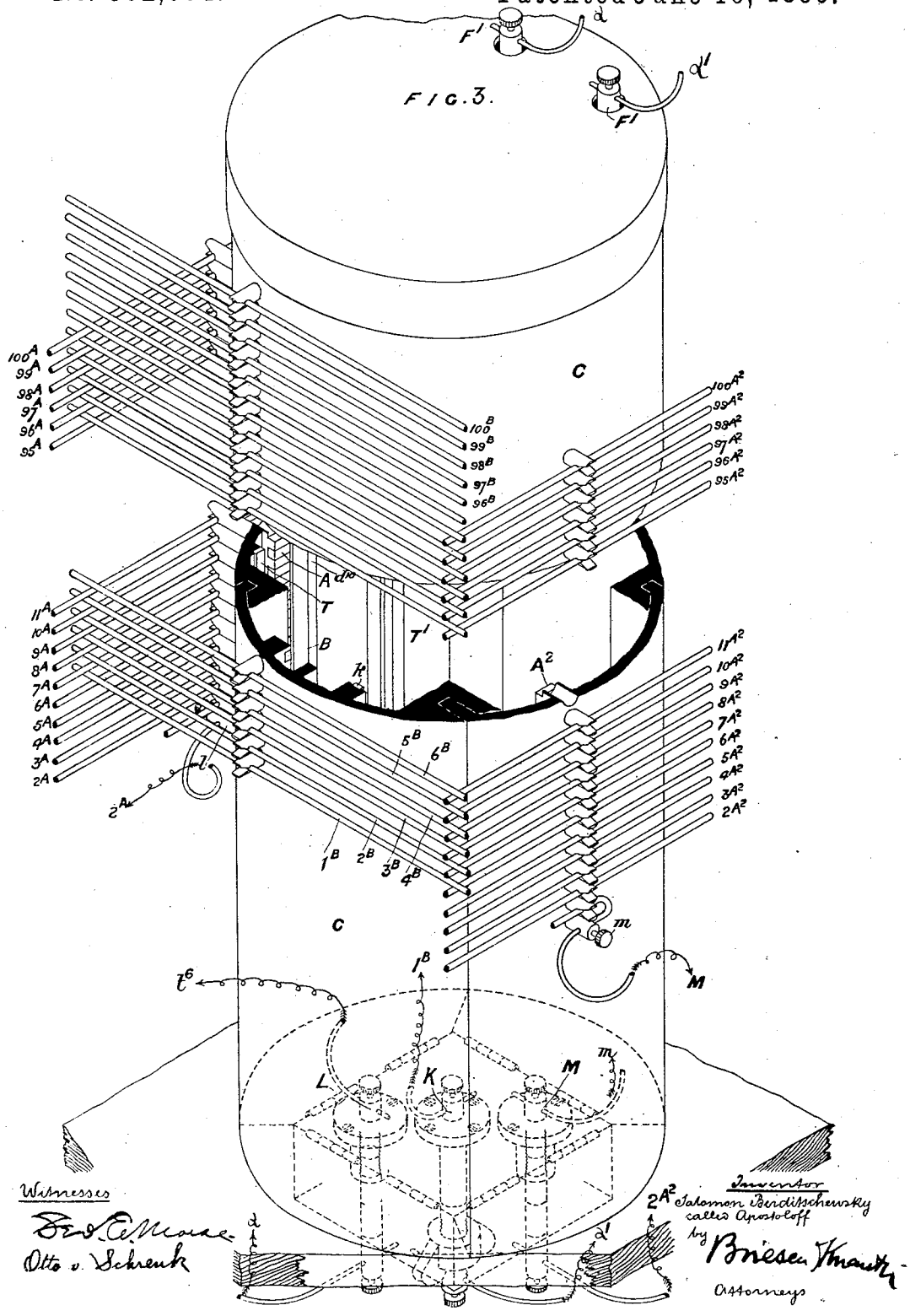
(No Model.) 15 Sheets—Sheet 2.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 3.



Witnesses
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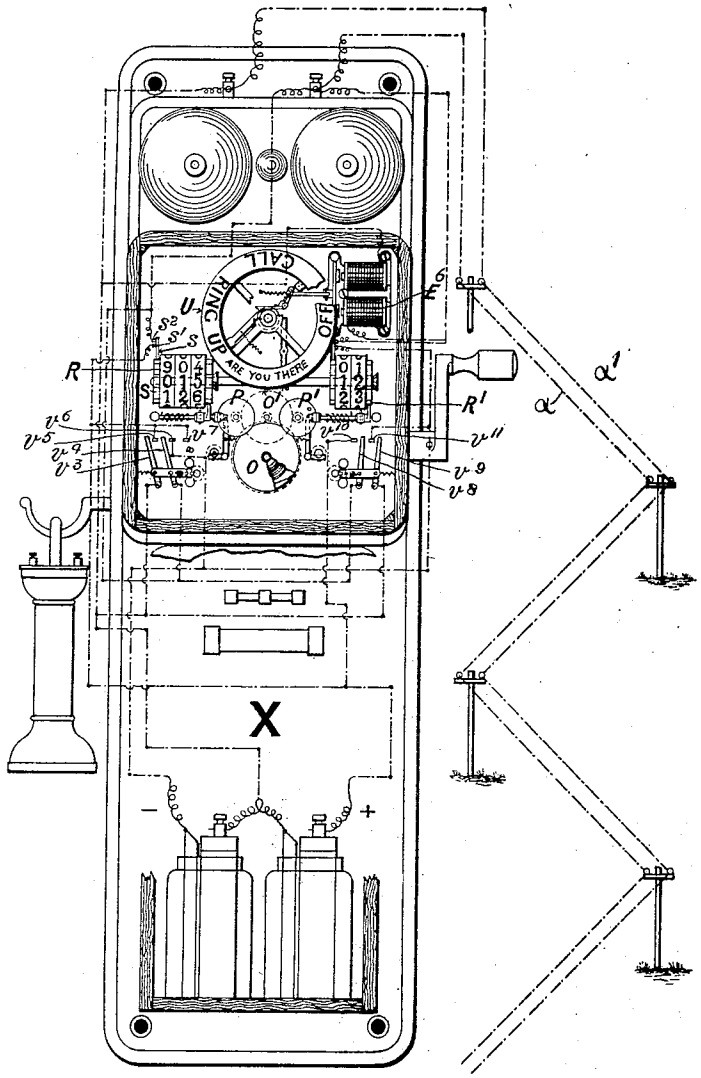
(No Model.) 15 Sheets—Sheet 3.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 4X



Witnesses:

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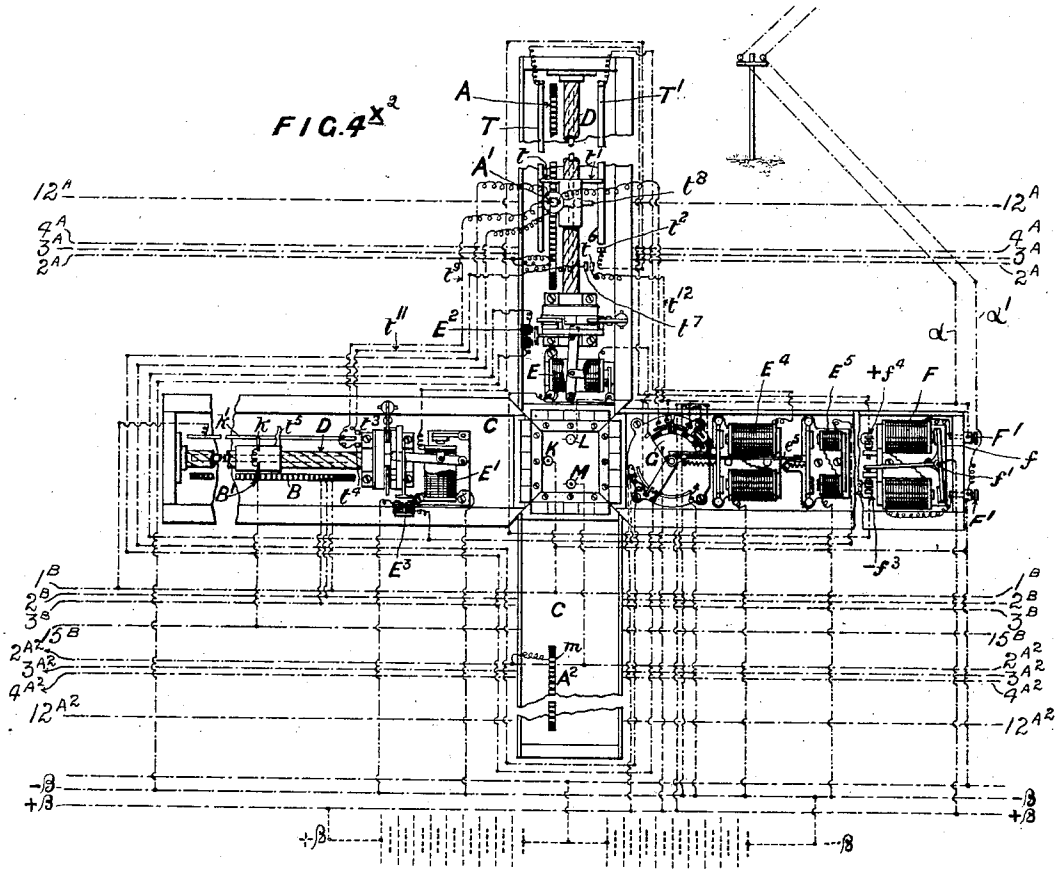
(No Model.) 15 Sheets—Sheet 4.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 4



Witnesses:

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(No Model.) 15 Sheets—Sheet 5.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

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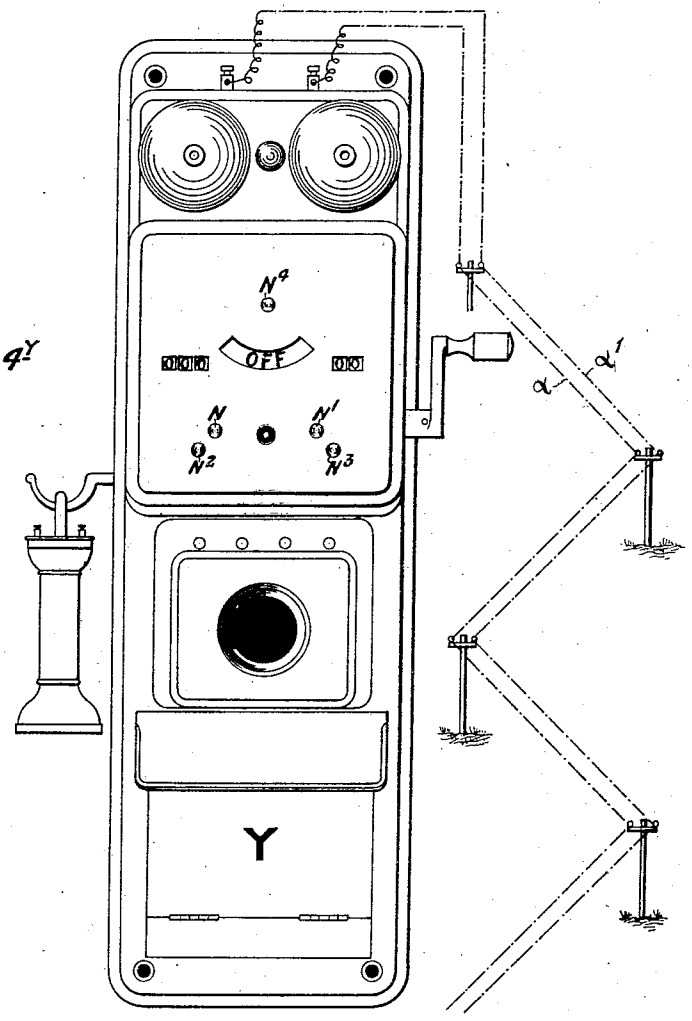
FIG. 4Y



Witnesses:
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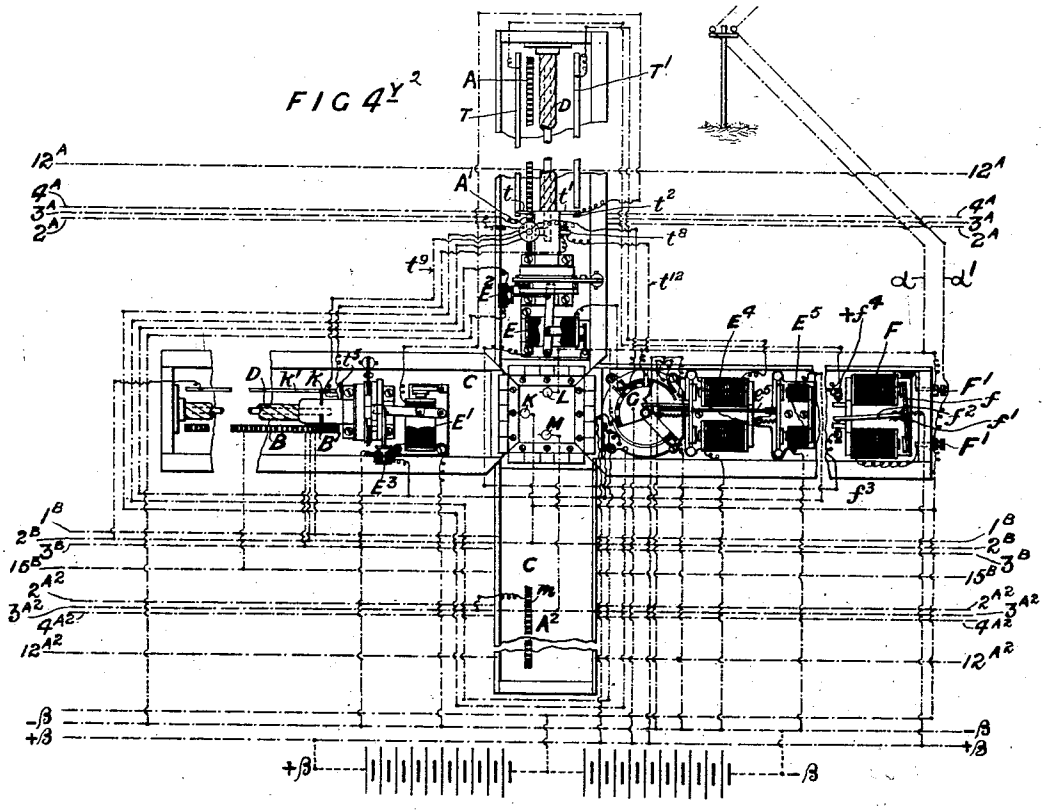
(No Model.) 15 Sheets—Sheet 6.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG 4



Witnesses:

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(No Model.) 15 Sheets—Sheet 7.

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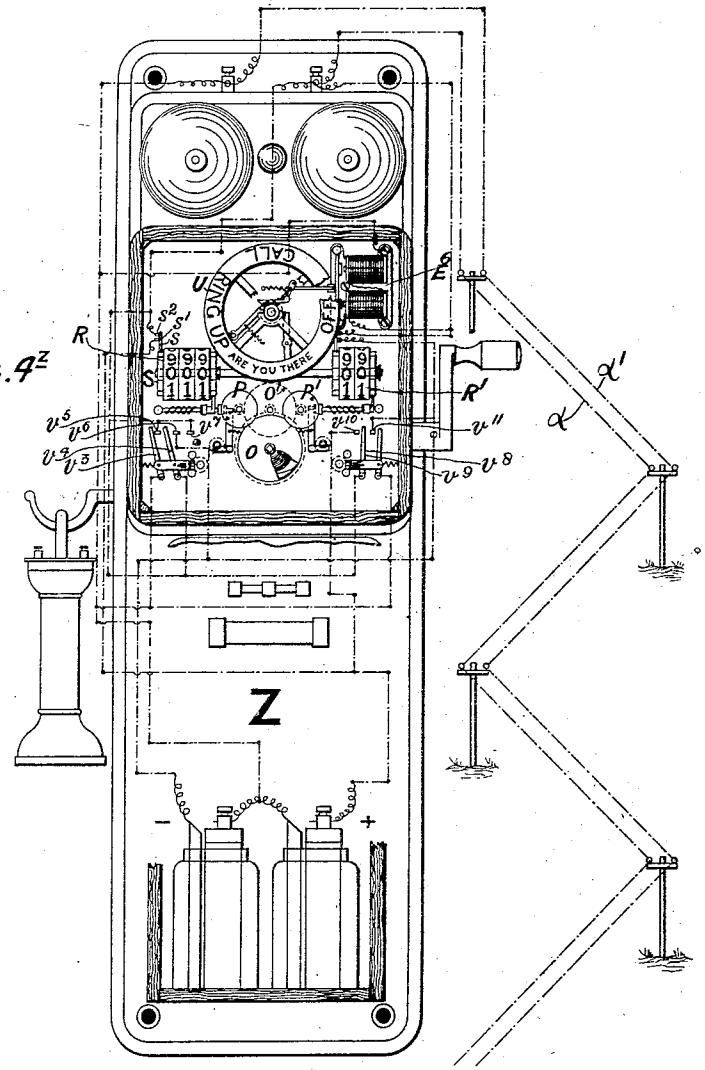
SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 4z



Witnesses:

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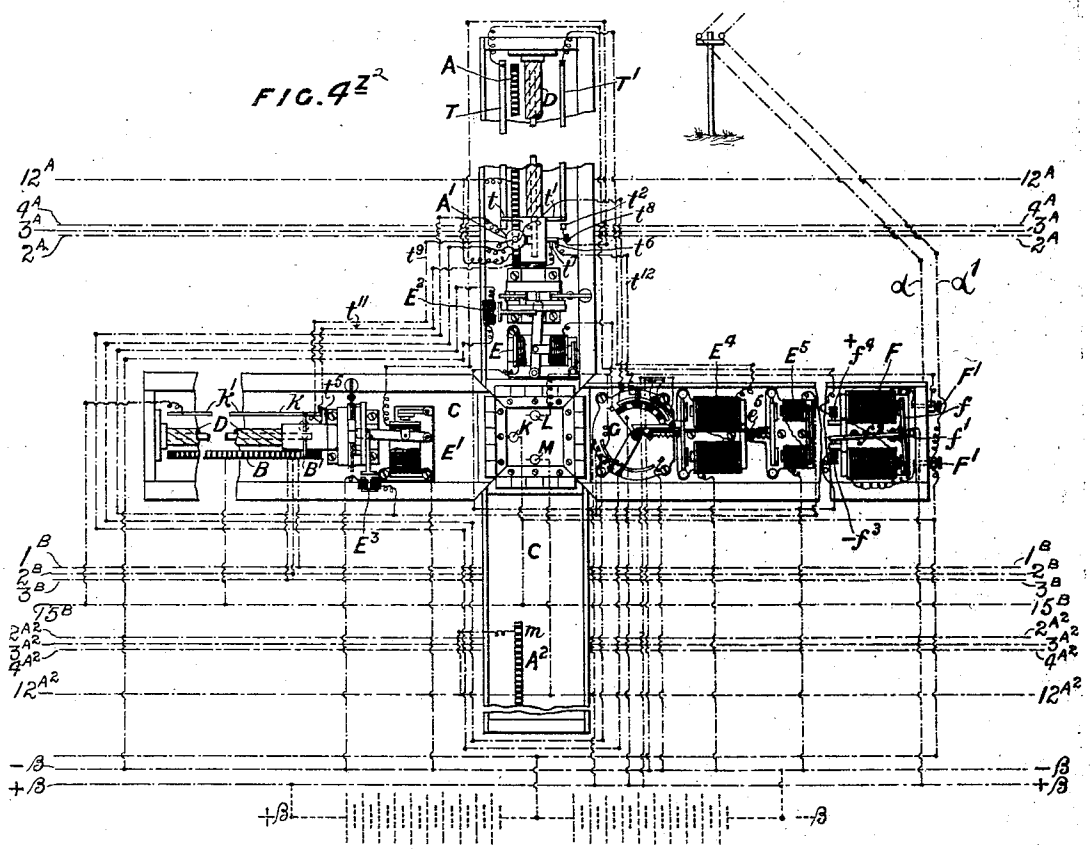
(No Model.) 15 Sheets—Sheet 8.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 42



Witnesses:

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(No Model.) 15 Sheets—Sheet 9.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 5.

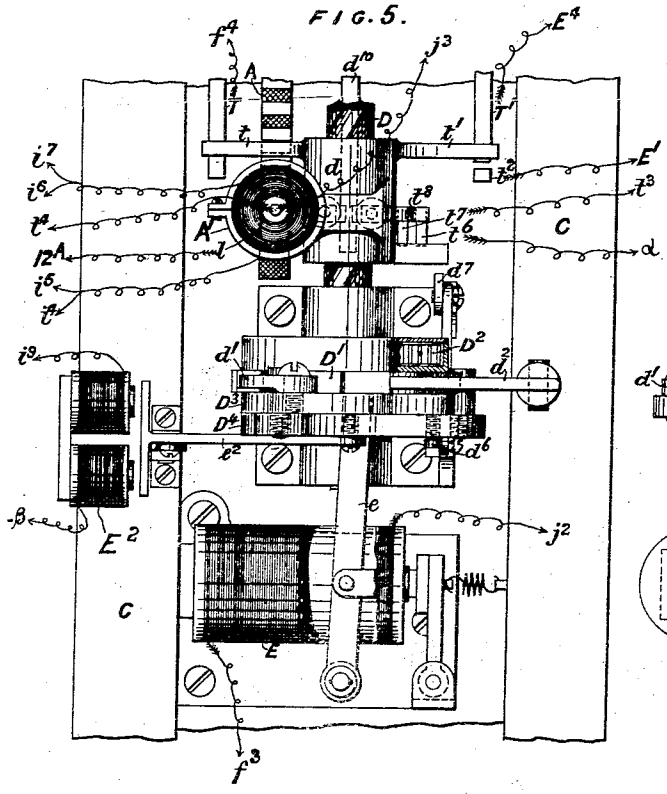
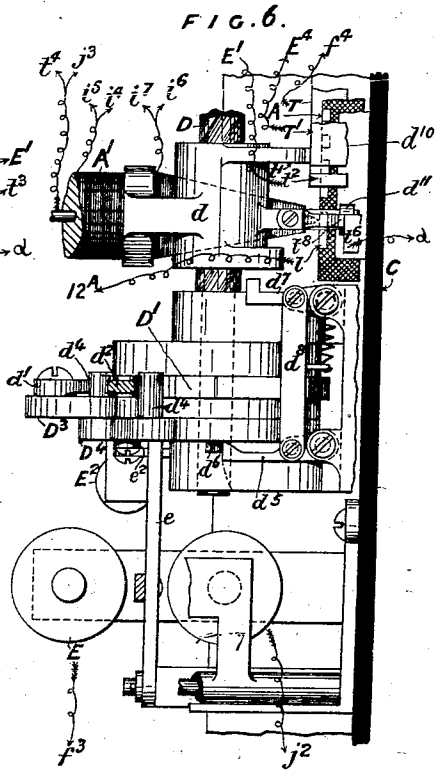


FIG. 6.



Witnesses
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Attorneys.

(No Model.) 15 Sheets—Sheet 10.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 22.

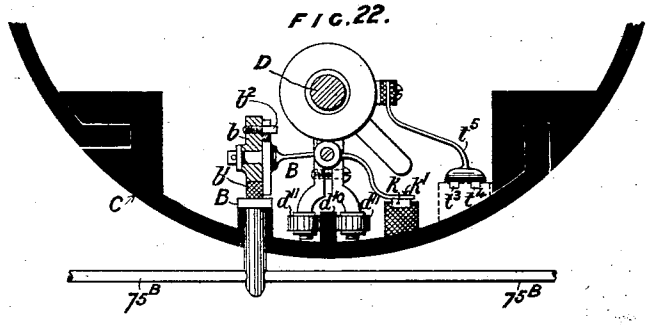


FIG. 7.

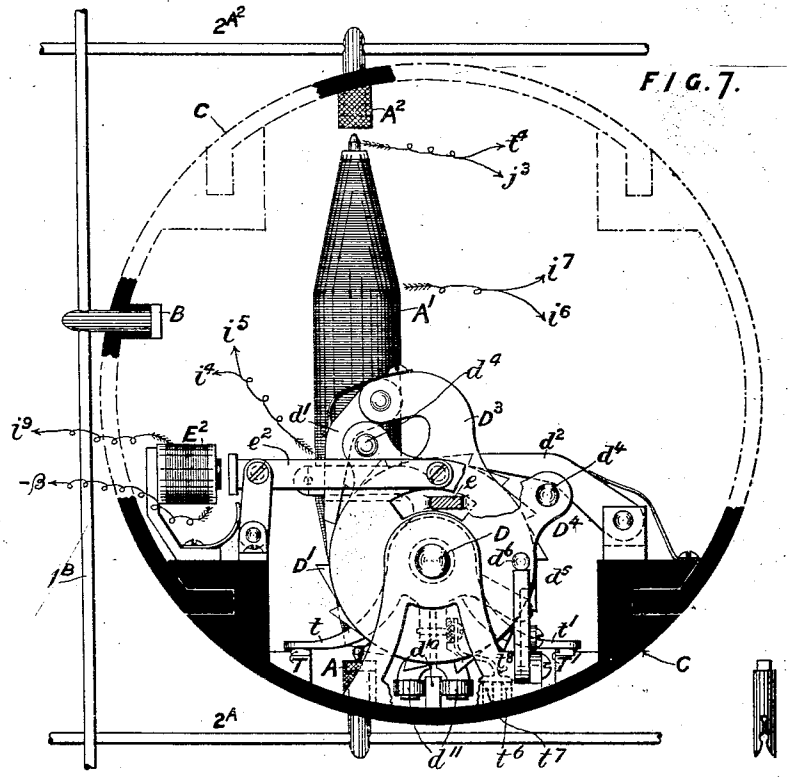
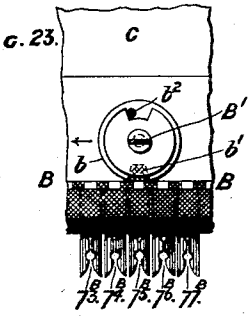


FIG. 23.



Witnesses:

Fred. A. Mann.

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(No Model.) 15 Sheets—Sheet 11.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 9

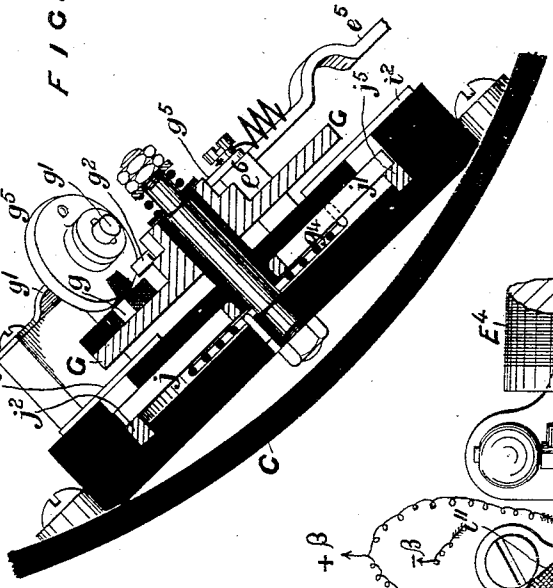


FIG. 9a

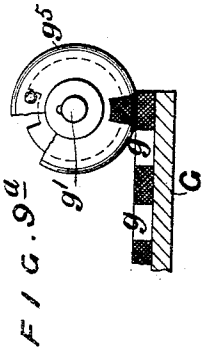
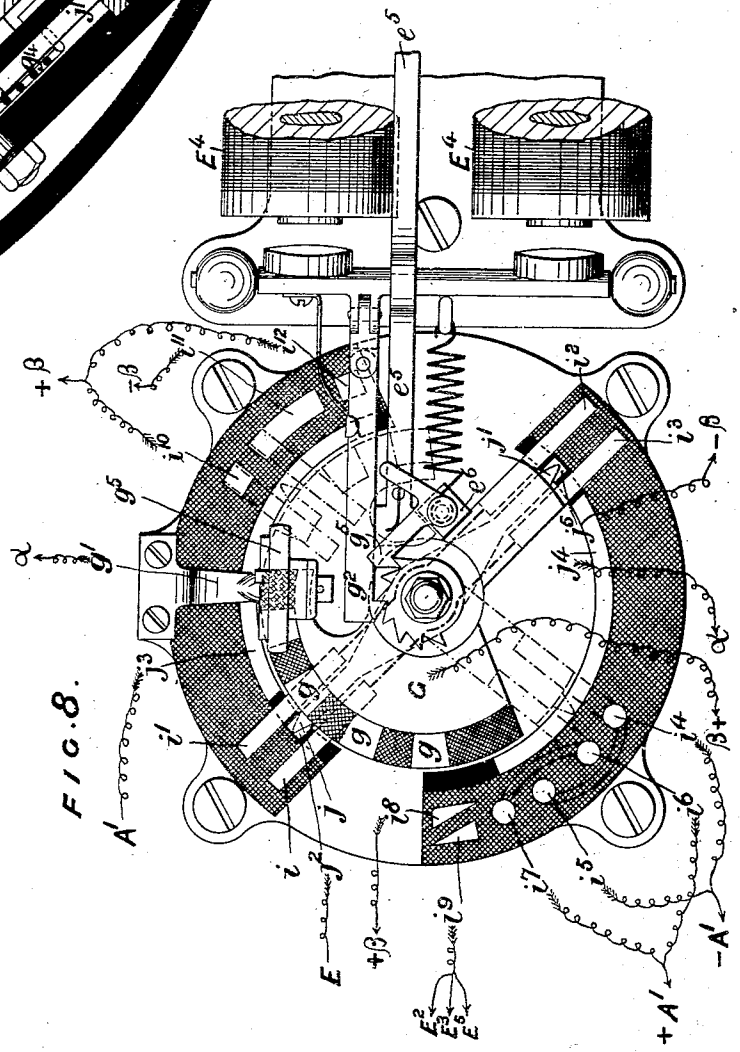


FIG. 8.



Witnesses:

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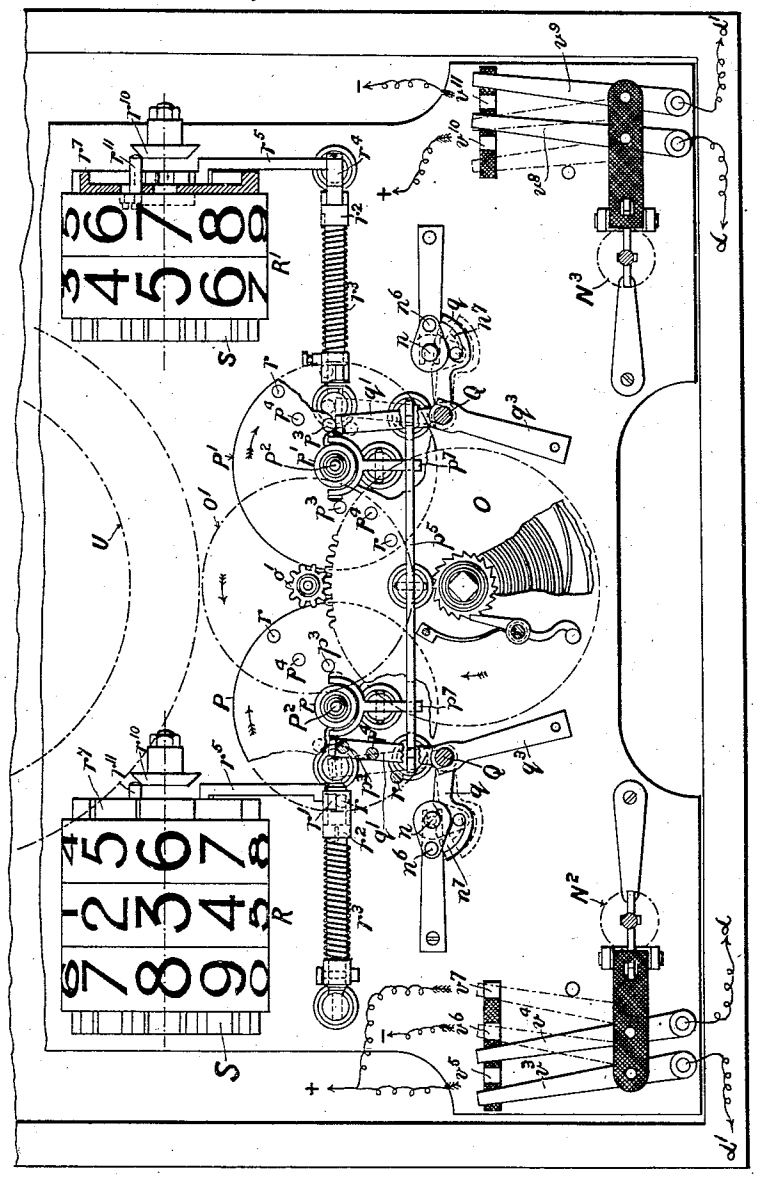
(No Model.) 15 Sheets—Sheet 12.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 10.



Witnesses:

Fr. A. Mosse.

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(No Model.) 15 Sheets—Sheet 13.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

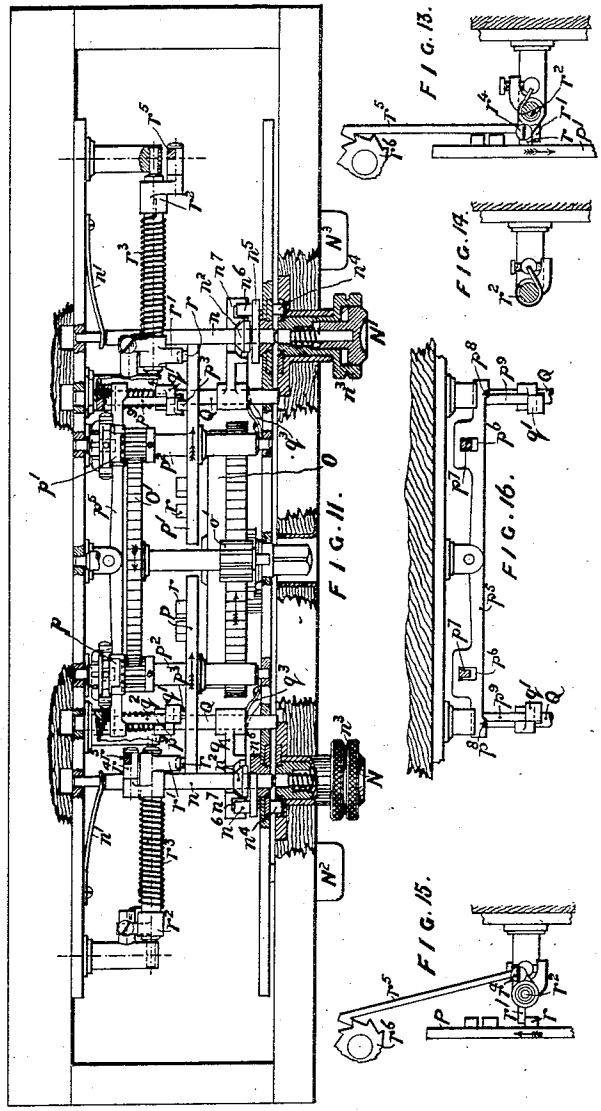

FIG. 11.

FIG. 13.

FIG. 14.

FIG. 16.

FIG. 15.

Witnesses:

Otto v. Schrenk

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15 Sheets—Sheet 14.

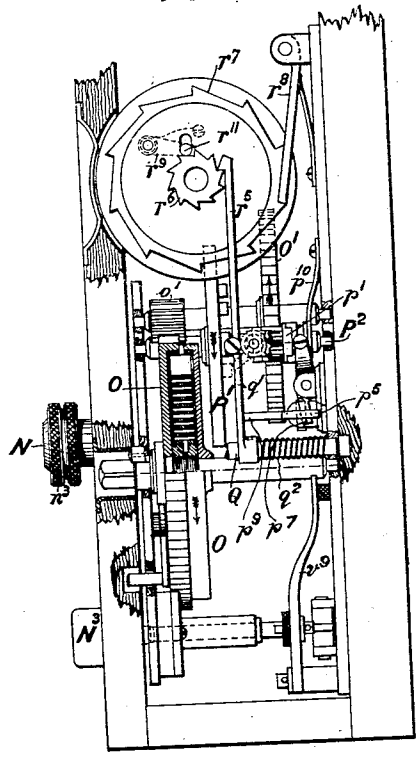
(No Model.)

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

FIG. 12.



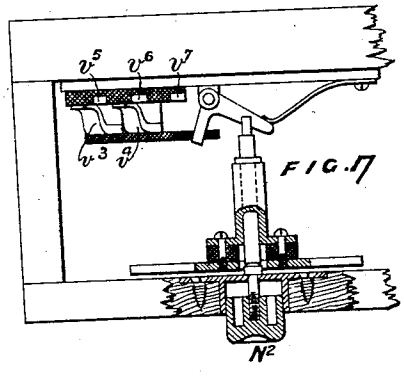


FIG. 17

Witnesses:

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(No Model.) 15 Sheets—Sheet 15.

S. BERDITSCHEWSKY CALLED APOSTOLOFF.

SYSTEM OF TELEPHONIC EXCHANGE.

No. 562,064. Patented June 16, 1896.

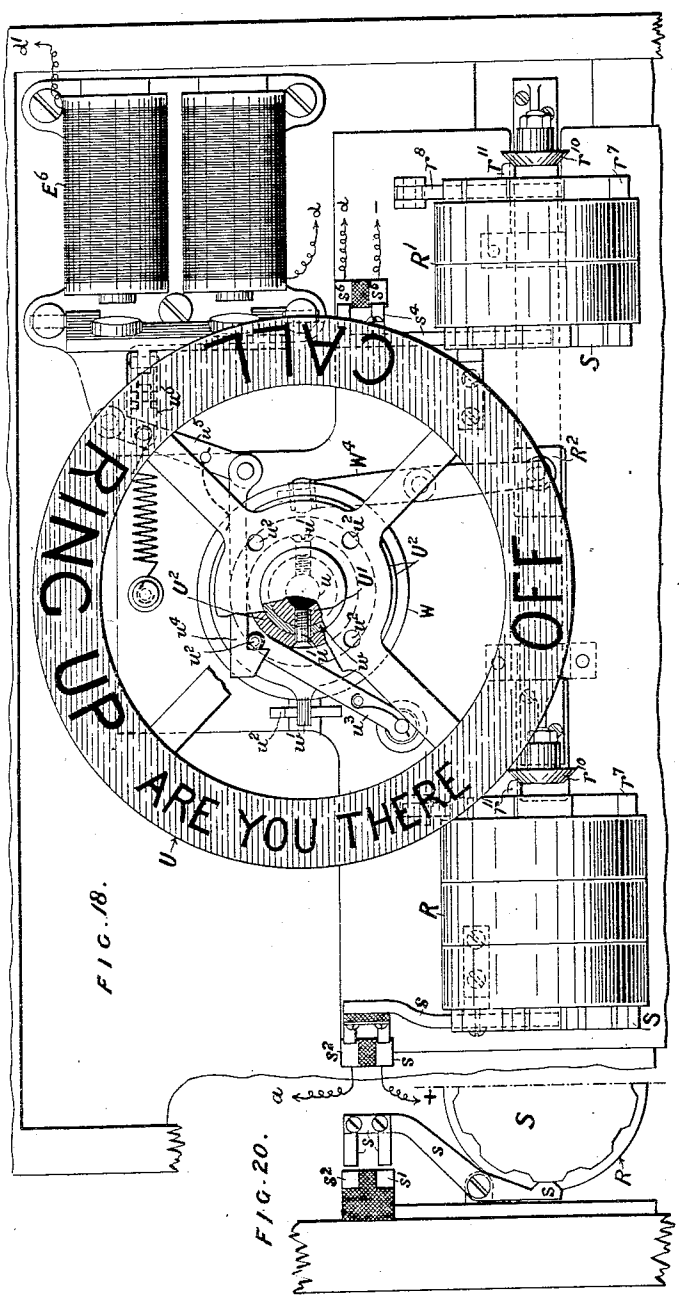

FIG. 18.

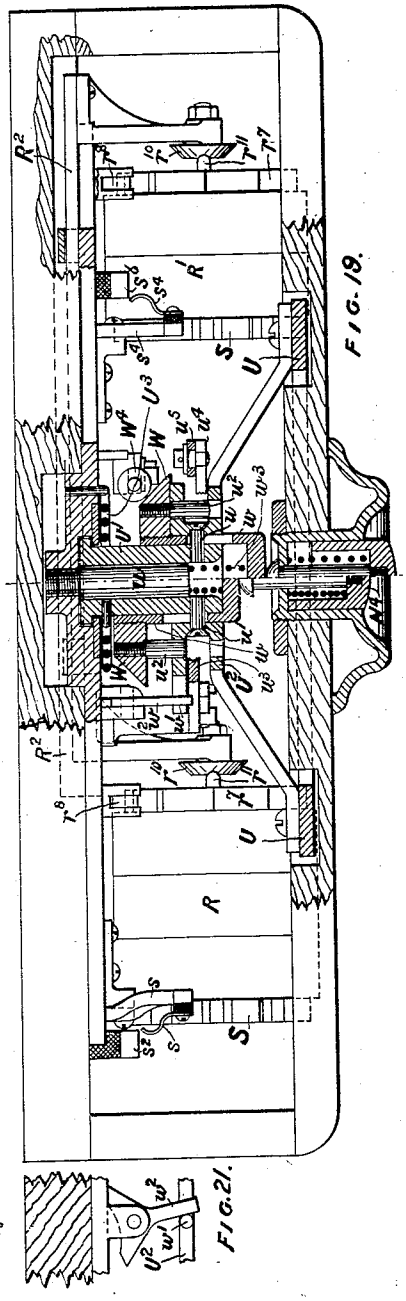

FIG. 19.

FIG. 20.

FIG. 21.

Witnesses:
Fred. C. Moore
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Attorneys.

UNITED STATES PATENT OFFICE.

SALOMON BERDITSCHEWSKY CALLED APOSTOLOFF, OF LONDON, ENGLAND, ASSIGNOR TO THE APOSTOLOFF AUTOMATIC TELEPHONE PARENT SYNDICATE, LIMITED, OF SAME PLACE.

SYSTEM OF TELEPHONIC EXCHANGE.

SPECIFICATION forming part of Letters Patent No. 562,064, dated June 16, 1896.

Application filed March 23, 1896. Serial No. 584,468. (No model.)

To all whom it may concern:

Be it known that I, SALOMON BERDITSCHEWSKY CALLED APOSTOLOFF, electrical engineer, a subject of the Emperor of Russia, residing at 139 Warwick Street, Eccleston Square, London, England, have invented a new and useful Improved System of Telephonic Exchange, of which the following is a full, clear, and exact description.

This invention relates to an improved system of automatic telephone-exchange whereby telephonic communication may be established between any two subscribers in connection with the system without the intervention of any attendant at the central station and without increasing the number of wires (connecting the subscribers with the central station) beyond the double wire ordinarily used for a metallic circuit. One of the means which has been proposed to accomplish this result comprises as many similar pairs of switchboards at the central station as there are subscribers' lines in connection with the exchange, each of the said pairs of switchboards corresponding to a different subscriber and each switchboard of each pair comprising as many insulated contacts as there are subscribers' lines to be connected thereto, so that each subscriber was represented (in each of the pairs of switchboards corresponding to the other subscribers) by a contact specially appropriated to him. These contacts were proposed to be arranged upon each of the switchboards at the points of intersection of coördinate lines, the contacts which correspond to the same subscriber in all the switchboards being consequently connected electrically together by twice as many wires as there are subscribers. Each apparatus also comprised the mechanisms necessary to enable each subscriber to put his telephonic line in telephonic communication with that of any other subscriber through the medium of the corresponding contacts and connections. It would follow, therefore, with such a system that if the number of subscribers in connection with the same exchange were ten thousand the central station would require to be provided with ten thousand identically similar apparatus, each provided with twice ten thousand contacts, the grouping together of which, as above mentioned, would involve the employment of twice one hundred million connections between the contacts—that is to say, twice the square of the number of subscribers—so that such a system is obviously impracticable by reason of its mere bulk and the number of connections to be made where the number of subscribers in connection with the system approaches in any degree to that of the subscribers to existing telephonic systems in great cities.

The object of my present invention is to enable this great number of contacts and their connections to be so far diminished as to be brought within practicable limits. The extent of the diminution will be readily appreciated when it is understood that instead of employing a number of contacts equal to twice the square of the whole number of subscribers I am enabled to attain the same end with a number of contacts equal only to three times the square root of the same number of subscribers, since it will be seen that by the present invention each contact represents not merely one subscriber, but a whole group of, say, one hundred subscribers, or more. Consequently the number of wires connecting the terminals of the groups in the several subscribers' apparatus at the central station is equal not to the whole number of subscribers, but only to three times the square root of the number of subscribers. This result is attained by a special system of grouping at the central station the positive and negative members of the subscribers' circuits, and consequently the apparatus in which they terminate. Each group comprises a number of elements equal to the square root of the whole number of subscribers, the groups of the same sign (+, for example) being respectively connected, each group with its own contact, in a row of insulated contacts, while the groups of the other sign are respectively connected, each to its own contact, in another row of insulated contacts, so that in each subscriber's apparatus at the central station there are two rows of insulated contacts each equal in number to the square root of the number of subscribers, the corresponding contacts of all of the

rows appropriated to the same sign being connected together; but the system of grouping the positive elements differs from that of grouping the negative elements in such manner that the coupling together of any one contact of the positive row with any one contact of the negative row will complete one particular circuit and no other, each possible combination between the contacts of the two rows therefore corresponding to a different subscriber's circuit. This cardinal point of the invention will be more readily understood by reference to the accompanying drawings, wherein—

Figure 1 is a diagram illustrating such a system of grouping as one example of the many possible combinations of groupings which might be adopted to carry the invention into effect, it being supposed for purposes of explanation that there are sixteen subscribers in connection with the exchange. The numbers 1, 2, 3, 4, &c., to 16, represent as many cells C as there are subscribers' circuits entering the central station.

The signs + and − indicate the terminal points or couples corresponding to the several subscribers' circuits. The positive elements of these couples are grouped together in four groups, each group comprising a number equal to the $\sqrt{16}$—that is to say, four—and the said groups being respectively connected to the respective metallic contacts a' a^2 a^3 a^4, while the negative elements are grouped also in groups of four, which groups are respectively connected to the respective contacts b' b^2 b^3 b^4, the positive elements being taken in consecutive order, while the negative elements are taken in such other order of progression that the positive elements of a group correspond, respectively, to different negative groups and conversely.

Figs. 1 and 2 of the drawings are explanatory diagrams.

A′ is a traveling switch movable along the row A and connected through a key with one pole of a battery, while B′ is another traveling switch movable along the row B and connected with the other pole of the battery. Then by placing the switch A′ on any one of the positive contacts (a^4, for example) and the switch B′ on any one of the negative contacts (b^3, for example) the circuit will be completed only through the couple corresponding to that combination of contacts, (No. 15 in the example illustrated,) and so on for any other combination of contacts.

If there were ten thousand subscribers' circuits, distinguished by consecutive numbers 1 to 10,000, they would be divided into groups of one hundred. Then if the positive elements (numbered consecutively) be grouped together in one hundred groups of one hundred each and each group be connected to its corresponding contact, then the negative elements would be grouped together also in one hundred groups of one hundred each, but in such manner that the negative elements of any one of those groups correspond to as many different groups of positive elements and conversely. In other words, if the positive elements, consecutively numbered 1, 2, 3, 4, &c., up to 100, be grouped together and connected to the first contact of the positive row of contacts, then the negative elements, numbered 1, 101, 201, 301, 401, &c., up to 9,901, would be grouped together and connected to the first contact of the negative row of contacts. Similarly, if the positive elements, consecutively numbered from 101 to 200, be grouped together and connected to the second contact of the positive row of contacts, then the negative elements, numbered 2, 102, 202, 302, 402, &c., up to 9,902, would be grouped together and connected to the second contact of the negative row of contacts, and so on, for all the other groups of positive and negative elements.

It is to be observed that in the case of a subscriber's serial number which is higher than 100 the juxtaposition of the figures denoting the numbers of the positive and negative elements thus conjugated forms a figure which corresponds to the serial number of the subscriber. Thus in the diagram Fig. 2 the conjugation of the contacts b^{15} and a^{12} closes the circuit through No. 1,512, or, in telephonic parlance, "fifteen twelve."

Reference is now to be had to the other figures of the accompanying drawings, which illustrate an example of the practical embodiment of my invention, wherein—

Fig. 3 is an external perspective view, partly broken away, of one of the cells at the central station, showing the external wires connecting the corresponding contacts of different cells. Figs. 4^x, 4^y, and 4^z represent three stations or subscribers. Figs. 4^{x2}, 4^{y2}, and 4^{z2} represent three of the central-station cells developed or opened out in the plat to show the mechanism and accessories contained therein (each segment of the cell being partly broken away) and showing the mechanism applied to the corresponding transmitters, these six views, Figs. 4^x, 4^y, 4^z, 4^{x2}, 4^{y2}, and 4^{z2}, together constituting one general diagram illustrating the positions corresponding to the establishment of communication between Figs. 4^{x2} and 4^{z2}, assuming X to be the subscriber calling and Z the subscriber called, while Fig. 4^{y2} shows the normal position of the mechanism. Figs. 5, 6, and 7 show detail views of the switch-propelment mechanism. Figs. 8, 9, and 9^a show details of the bridge-switch hereinafter referred to, the looped arrows which point to reference-letters indicating the connections of the various parts from which the arrows lead, with the parts of the mechanism shown in the other figures. Figs. 10 to 17 show details of the numerator-operating mechanism and of the current-commutating mechanisms of the transmitter for bringing about the operation of the bridge-switch of the cell. Figs. 18 to 21 show details of the indicator mechanism and of the mechanism for send-

ing current impulses from the transmitter to the corresponding cell at the central station for bringing about the operation of the traveling-switch-propelment mechanisms. Figs. 22 and 23 show details of the contact-roller of one of these switches.

The same reference letters and numerals indicate corresponding parts in all the figures.

In the practical embodiment of the principle set forth diagrammatically in Figs. 1 and 2 each subscriber is represented at the central station by the "couple" forming the terminals of his circuit, (the elements of the various couples being grouped as above described,) and also by a set of apparatus comprising the two rows of contacts A B, the traveling switches A' B', the mechanisms for moving the latter, a third row of contacts A^2 parallel with and opposite to row A, and other accessories which will be described later on. All these apparatus may be contained in a pigeon-hole or tubular cell C, made of insulating material, and which may, for convenience of mounting the apparatus therein, be constructed of four segments hinged to a common base so as to open out flat, as shown in Figs. 4^{x2}, 4^{y2}, and 4^{z2}, the segments fitting together tightly at the joints and the cell being hermetically closed to protect the mechanism from dust.

The construction and arrangement of the mechanism will, for convenience, be described in the first place with regard to Fig. 4^y, which shows the parts in their initial position, (it being understood that the same description applies also to all the other cells at the central station,) while the description of the working will apply more particularly to Figs. 4^x and 4^z.

A is the row of insulated contacts, to which are connected the respective groups of positive elements, and B is the row of insulated contacts, to which are connected the respective groups of negative elements of the several couples formed by the several subscribers' circuits.

A' is the traveling switch movable along the row A, B' the traveling switch movable along the row B, and A^2 the third row of contacts grouped similarly to row A. Each subscriber's line is in constant communication with the corresponding cell, as shown.

The means whereby the switches A' B' are caused to move along their respective rows of contacts A B are similar, and the description of the mechanism of one will be sufficient for both; but it is to be understood that the whole of the mechanical devices hereinafter described are given merely as one example of the various means which may be employed for producing the requisite movements and that the invention is in no way limited thereto or dependent thereon. This mechanism is shown in detail in Figs. 5, 6, and 7, Fig. 5 being an inside face view of as much of one side of the cell as is necessary to show the mechanism of the switch A'; Fig. 6, a side view, partly in section, of the propelment mechanism of the same switch; and Fig. 7 a sectional plan view of the cell, looking upward, the propelment mechanism of the other switch being omitted.

The traveling switch A' is carried by an arm fixed to a nut d, which being prevented from turning (by means of a guide-rail d^{10}, fixed to the side of the cell and straddled by a forked arm carrying two friction-rollers d^{11}) is caused to travel along a screw-spindle D, having a fast-pitched screw-thread. This screw-spindle is placed parallel to the row of contacts A, is journaled to revolve in bearings, and receives step-by-step rotary motion by means of a propelment mechanism consisting of a ratchet-wheel D', fixed on the screw-spindle D and engaged by a click d', carried by a disk D^3, loose on spindle D, and actuated through a lever e in the one direction by the armature of an electromagnet E and in the other direction by the antagonistic spring, the pitch of the screw D being such that by each advance of the ratchet-wheel to the extent of one tooth produced by each impulse in the electromagnet E the switch A' is moved from one metallic contact to the next of the row A.

In order to provide for a quick return motion of the traveling switch to its normal position, the advance motion of the mechanism is caused to wind up a coiled spring D^2, which gives the motive power for the return movement. The spring D^2 is contained in a barrel fast with the ratchet-wheel D', the one end of the spring D^2 being connected to the barrel and the other end being attached to a fixed point, so that as the screw-spindle D is turned to the right the spring D^2 is wound up. A detent d^2, engaging with the ratchet-wheel D', retains it after each step in advance, so that when the traveling switch A' has been moved to a certain position it there remains until the quick-return mechanism is allowed to come into action. This is effected by means of an electromagnet E^2, whose armature disengages the click d' and detent d^2 from the ratchet-wheel D', which wheel, being free, revolves quickly to the left under the force of the wound-up spring D^2. The armature of E^2 thus acts through the agency of a second disk D^4, carrying two studs d^4 d^4, respectively adapted to pass under the click d' and detent d^2 and so disengage them from the ratchet-wheel D' when the disk D^4 is pulled to the left by the armature of electromagnet E^2 acting through link e^2. The disk D^4 is retained in this position by a lever d^5, engaging with a stud d^6 on the disk, which lever remains so engaged until the return of the switch-carrier d to its initial position, whereupon the switch-carrier causes the withdrawal of the studs d^4 and allows the clicks d' d^2 to again engage with the ratchet-wheel D'. This is effected by the switch-carrier d striking against a lever d^7, connected by a link d^8 with the lever d^5, and so disengaging it from the stud d^6

thereby allowing the disk D^4 to be returned to its initial position by another spring. The mechanism for operating the switch B′ is similar and is mounted on the second side of the cell, the only difference being in the constitution and function of the switches themselves.

The switch A′ is formed by the magnetized core of a solenoid placed perpendicular to the row of contacts A, and as the latter are arranged vertically in the cell C the core of the solenoid is horizontal. It is guided within the solenoid-coil, within which it is free to slide to and fro when influenced by currents of different direction passed through the solenoid-coil for the purpose of causing the switch to be transferred from the contact of row A (to which it has been brought by the above-described propelment mechanism) to the corresponding contact of the row of contacts A^2, fixed to the third side of the cell C, opposite that to which the row of contacts A is fixed.

The switch B′ is, for the sake of clearness, shown in Figs. 4^x, 4^y, and 4^z as a simple spring-finger bearing upon the row of insulated contacts B; but the acting end of the finger is in fact a small metal roller *b*, Figs. 22 and 23, capable of making only a half-revolution about its journal, the roller having an insulating-segment *b′* in such relation to a stop b^2, which limits the rotation of the roller, that during the advance motion of the switch the roller will turn until its metal portion slides on the divisions B, while during its return motion it will turn back and bear by its insulating-segment on the divisions over which it passes.

To the fourth side of the cell are fixed, first, a polarized relay F, to whose terminals F′ are connected the two members *x x′* of the circuit or line wire of the subscriber to whom the particular cell under consideration corresponds, the function of this relay being to distribute to one or other of the electromagnets E, E′, or E^4 the currents from a local battery *β*, according to the direction of the currents received by the relay from the subscriber's transmitter, and, second, a movable bridge-switch G, actuated by the electromagnet E^4, and serving for a number of different purposes hereinafter described.

The relay F is of ordinary construction, its armature *f* being pivoted at *f″* to the one pole of a permanent magnet and provided with a tongue-switch f^2, which oscillates between the two contacts f^3 f^4 and serves to thus close the circuit of the local battery through the coils of one or other of the electromagnets E, E′, or E^4.

The bridge-switch G, which is shown separately in plan view in Fig. 8 and in section in Fig. 9, comprises, first, a number of divisions or contacts *g* in one with the quadrant-shaped body portion G, but separated from one another by insulating divisions. These divisions are shifted beneath a spring contact-finger *g′* to an extent equal to the distance of one division *g* to the next at each current impulse passing through the electromagnet E^4, the finger terminating in a metal roller g^5, (shown in Fig. 9^a,) having an insulating-segment and capable of limited rotation in the same way as the roller of the switch B′; second, a number of spring contact-bars i i' i^2 i^3, which (by the movement imparted to the switch by the electromagnet E^4) are moved over a number of fixed contacts i^4 i^5 i^6 i^7 i^8 i^9 i^{10} i^{11} i^{12}; third, a spring contact-bar *j j′*, which is similarly movable over fixed contacts j^2 j^3 j^4 j^5, the last-mentioned contacts being situated in a different path to that occupied by the contacts i^4 to i^{12}. This switch G may conveniently be movable about a pivot and actuated from the armature of the electromagnet E^4, through a click g^2 and ratchet-quadrant, or the switch G might have a rectilineal motion by a click and ratchet-rack. In either case the switch G receives a sudden and complete return motion by the action of a spring g^4, which is allowed to come into action when the electromagnet E^5, energized by a current, releases the click g^3, which happens simultaneously with the return motion of the traveling switches A′ B′. The ratchet-quadrant is also engaged by a detent g^5, which retains it during each retrograde motion of the click g^2, the simultaneous release of g^2 and g^5 from the ratchet-quadrant being effected by a rod e^5, attached to the armature of electromagnet E^5, the head of the rod e^5 sliding against a fixed inclined cam-surface e^6, and so lifting the click g^2, while the rod e^5, which engages by a stud with the tail of the detent g^5, draws said detent out of engagement. Lastly, there are three terminals K L M, which may be designated the "terminals of the normal contacts." The terminal L is the "call" terminal, the terminal M is the "conversation" terminal, while the terminal K serves in common for the completion both of the call and conversation circuits.

The terminal K is in permanent connection with one terminal of the relay F, and consequently with one member of the subscriber's line, the other member of the subscriber's line being in permanent connection, through the other terminal of the relay, with the terminal L. The terminal K is permanently connected with the normal contact K′, on which slides the spring-contact *k*, carried by the switch B′, which latter is consequently always in connection with one member of the subscriber's line

The terminal L is connected through an automatic interrupter with the normal contact *l*, situated at the commencement of the row A, the interrupter being so arranged that the connection between L and *l* is severed in either of the following events—namely, when switch B′ has moved at all from its initial position, or when switch A′ has moved more than the distance of one tooth of its ratchet-wheel D′ from its initial position.

The terminal M is permanently connected with the normal contact *m*, which is the first division of the row A^2.

All the call terminals L of all the cells C at the central station are connected electrically with their respective normal contacts *l*, each through an automatic interrupter, as above mentioned, and all the normal contacts *l* are made of a length equal to two metallic contacts and the intervening insulating division, so that each normal contact *l* includes in itself the first division of the row A of contacts. The normal contacts *l* of different cells are not connected together, and consequently the first divisions of the rows A are not connected together. This applies to the first hundred cells and also to all others.

All the normal contacts *l* of the second hundred cells are connected each with the second division of the row A of its cell, as shown diagrammatically in Fig. 4^x. All the second divisions of the rows A of the second hundred cells are connected together by an external grouping-wire 2A, whereby the normal contacts *l* and terminals L of the second hundred cells are connected in a group, this wire 2A, however, also connecting together the second divisions of the rows A of all the other cells. Similarly all the normal contacts *l* of the third hundred cells are connected each with the third division of the row A of its cell, as shown diagrammatically in Fig. 4^y, and all the third divisions of the rows A of the third hundred cells are connected together by an external grouping-wire 3A, whereby the normal contacts *l* and terminals L of the third hundred cells are connected in a group, the wire 3A, however, also connecting together the third divisions of the rows A of all the other cells. Similarly for all the other groups of one hundred each, the number of such groups being preferably limited (for the rows A) to ninety-nine groups of one hundred each, for a purpose hereinafter mentioned.

It will be seen by the drawings that Fig. 4^z belongs to the twelfth group, its normal contact *l* being connected with the twelfth division of row A. These rows of divisions A may be designated "call" divisions.

All the terminals K of the first group of one hundred cells are connected each with a division of the row B of its cell different to those divisions to which the other terminals K of that hundred cells are connected in their cells. The terminal K of the first cell of each hundred cells—that is to say, No. 1, No. 101, No. 201, &c., up to No. 9,901—is connected with the first division of the row B of its cell, and all the first divisions of the rows B of all the first cells of each hundred cells are connected together to constitute a group by the wire 1B, whereby the terminals K of those particular cells are consequently connected in a group, this wire 1B, however, connecting together the first divisions not only of the cells forming that group, but the first divisions of the cells of all the other groups.

The terminal K of the second cell of each hundred cells (No. 2, No. 102, No. 202, No. 302, &c., up to No. 9,902) is connected with the second division of the row B of its cell, and all the second divisions of the rows B of all these cells are connected together by the wire 2B to form a second group, this wire 2B connecting together the second divisions not only of the cells forming that group, but also the second divisions of the cells of all the other groups. The terminals K of the other cells of each hundred cells are similarly grouped and connected with the divisions corresponding to those groups.

It will be seen by the drawings that Fig. 4^x belongs to the group 1B, Fig. 4^y belongs to the group 2B, and Fig. 4^z belongs to the group 15B.

The conversation terminals M of all the cells are connected each with its normal contact *m*, and this normal contact is connected to the contact of the row A^2, which is opposite to the contact of row A, to which the normal contact *b* of the same cell is connected, the grouping of L and M being identical. Consequently the terminal M in Fig. 4^x is connected to the second division of the row A^2, the terminal M in Fig. 4^y is connected to the third division of the row A^2, and the terminal M in Fig. 4^z is connected to the twelfth division of row A^2. The corresponding metallic divisions of all the rows A^2 of all the cells are connected together by wires, such as $2A^2$ $3A^2$ $4A^2$ $12A^2$. Each row A^2 of conversation divisions is placed, as above described, parallel to the "call" row A, the call and conversation divisions (which are identically grouped) being, respectively, opposite each other, so that the solenoid-core of the traveling switch A', before described, may at the required moment be transferred quickly from any division of the call row A (to which it has been moved by its propelment mechanism) to the corresponding division of the conversation row A^2. It is, however, to be observed that the terminals M, although grouped identically with the grouping of terminals L, are not normally in connection with either member of any subscriber's circuit, this connection being only made when the solenoids of the subscribers entering into conversation are transferred to their respective rows A^2.

The consequence of the system of grouping above described is that the number of metallic divisions or contacts in each row will be only equal to the square root of the number of subscribers in connection with the exchange, (assuming that the two rows have equal numbers of divisions,) and this is the cardinal feature of the invention, the importance of which will be readily appreciated.

It will thus be seen that the function of the traveling switches A' B', which correspond to the two members of a subscriber's circuit, is to place the two members of the circuit of that subscriber (when he desires to call another subscriber) in electrical communica-

tion, respectively, with any one division of a call row and of a "communication" row, and consequently with the two members of the circuit of the subscriber to be called and to whom this particular combination of call and communication divisions corresponds. The traveling motion of these two switches is effected independently the one of the other by means of the propelment mechanism described or by any other mechanical movement operated by the electromagnet E or E', the step-by-step motions of the one or other traveling switch corresponding to the impulses of the current sent from the transmitter placed in the telephone of the subscriber "calling," these impulses acting on the distributing-relay F according to their direction, so that the communication-switch B' is actuated by the local battery β when the relay F receives a current of the one direction and the switch A' is actuated by the local battery β when the relay F receives a current of the other direction.

The switch B' is, as above mentioned, in constant electrical connection with one of the terminals of the relay F, whereas the magnetized core of the solenoid A' (so long as B' has not moved and so long as this solenoid is still on its normal contact *l*) is in electrical connection (by wire *t*, contacts t^3 t^4 t^5, wire t^{11}, contacts t^6 t^7, finger t^8, and wire t^{12}, as shown clearly in Fig. 4^{x2}) with the call terminal L, so that the solenoid-core is thus in electrical connection with one of the terminals of the distributing-relay F, and consequently with one member of the subscriber's line to which the cell C under consideration corresponds. It is thus evident that once the switch B' (of the subscriber who is about to call another subscriber) has commenced to traverse the communication row of divisions B the circuit between the solenoid-core and the line of the subscriber calling will be opened, so that no current (emanating from another subscriber who may at that moment desire to call the first-mentioned subscriber) can pass into the line of this subscriber while this same subscriber is himself manipulating his apparatus. As to the normal "conversation" contact *m*, the core of the solenoid A' is never in electrical connection with this contact *m* unless it is so placed by the special action of the telephonic transmitter of the subscriber to whom this cell corresponds when this subscriber is called. It is also to be remarked that when the core of the solenoid A' traverses the call row L by sliding from one division to the next a temporary interruption is produced between the solenoid-core and the line of the subscriber calling in order to avoid operating the apparatus in the cells corresponding to the metallic divisions with which the solenoid-core is only in transitory contact. This temporary interruption is due to the fact that as the switch B' must be operated before the solenoid-switch A' is set in motion the circuit will have been broken by the insulated spring-contact t^5 (mounted on the switch-carrier B') having already left the plates t^3 t^4.

By the employment of an independent electromechanical propelment for each of the traveling switches A' B' the subscriber calling is enabled to move them along the rows A B as far as necessary and to arrest them at any given moment in order to effect all necessary commutations of the apparatus in the cell corresponding to the subscriber to be called, and also to ring up and enter into conversation with the subscriber called; and when this conversation is finished to return all the mechanisms in the cells corresponding both to the subscriber calling and to the subscriber called to their initial positions.

Referring now to the subscriber's telephonic transmitter, it is sufficient to say that it consists of an ordinary transmitter as generally used, the construction, connections, and working being unchanged so far as the calling and conversation are concerned; but when the bell-ringing mechanism is actuated by alternating currents produced by a magneto-electric generator, as in the system of telephone in general use in London, these currents must be rectified and converted into negative currents in any suitable way, as will be readily understood without explanation; but to the ordinary transmitter there is added a special transmitting mechanism for the purpose of enabling a subscriber to call any other subscriber and put himself in communication with him. This special transmitting mechanism will now be described with reference to Figs. 4^x and 4^z and to Figs. 10 to 17, whereof Fig. 10 shows a face view of the special transmitter with the cover and front plate removed, Fig. 11 being a part sectional plan, and Fig. 12 a part sectional side elevation, of same. Figs. 13, 14, 15, and 16 show details, and Fig. 17 is a plan of the current-commutating levers.

The special transmitting mechanism comprises two numerator mechanisms R R' of suitable construction for the purposes intended, and these numerators may be actuated electromechanically by means of return-currents consequent on the manipulations of the traveling switches A' B' at the central station, in which case each numerator would be actuated by a separate electromagnetic propelment mechanism, such a mode of actuating the numerators affording a means of verifying the working of the traveling switches A' B'; but in view of the precision with which these switches are operated by the means hereinbefore described such verification is in practice unnecessary, and the numerators may for all practical purposes be operated mechanically, as hereinafter described, in which case only one electromagnet will be required in my special transmitter, and this for the purpose of operating an indicator bearing surface inscriptions. These numerators record visibly by the figures exhibited at the front of the in-

strument the current impulses sent by the subscriber calling to the relay F for the purpose of closing the circuit of the local battery at the central station through the electromagnet of one or other of the propelment mechanisms of the switches A' B' in the cell C (corresponding to this transmitter) at the central station, the numerator R counting the step-by-step motions of the switch B' and the numerator R' counting those of the switch A'.

The mechanism by which the current impulses are sent and the numerators are operated comprises a spring-barrel O, (or its equivalent,) the operation of the mechanism depending on the finger pressing upon one or other of two buttons N N', the button N corresponding to the part of the mechanism whereby the relay is so operated that current impulses are sent from the local battery to the propelment mechanism of the switch B', and the button N' corresponding to the part of the mechanism whereby the relay is operated for sending current impulses from the local battery to the propelment mechanism of the switch A'. These two mechanisms are similar in construction, and it will be sufficient to describe one of them, the barrel O actuating the one or other of them through the medium of a pinion o' and a toothed wheel O'. The wheel O' is constantly in gear with the pinions of two clutches p p', which are so adjusted by mechanism actuated from the buttons N N' that when the left-hand button N is operated the right-hand clutch p' is disengaged, and vice versa, at the same time that (whichever button N or N' is operated) the spring-barrel (which is normally prevented from revolving by the disks P P') is released and allowed to revolve for actuating the one or other of the circuit-closing and impulse-registering mechanisms. When, then, the button N is operated, the clutch p is left in gear and drives the disk P, whose motion is limited to a half-revolution for each simple pressure on the button N; but the motion of the disk P may be permitted to continue for as many revolutions as may be necessary, the means by which this is accomplished being as follows: The button N, mounted in the front of the transmitter-case, bears upon a spindle n, which is free to slide longitudinally in its bearings and is kept in the forward position by a spring n'. The spindle n is provided with a conical cam n^2, adapted to act on a lever q, fast on a rocking spindle Q, which also carries a detent-lever q', whose cranked end is adapted to engage with one or other of two escapement-pins p^3 p^4, of which there are two diametrically opposite sets fixed on the face of disk P. The pins p^3 p^4 are on different radii and at different radial distances, so that the oscillation of the detent-lever q' by the cone-cam n^2 will move said detent out of the path of pin p^3 into the path of pin p^4, the return motion of the cam permitting the detent to return into the path of pin p^3 of the other set of pins, whereby one half-revolution of the disk P is permitted. The rock-shaft Q is capable of sliding longitudinally in its bearings, so as to move the detent-lever q' entirely out of the plane of rotation of the escapement-pins p^3 p^4, thus leaving the disk P at liberty to make any number of revolutions. The rearward sliding movement of the rock-shaft Q is effected by turning the outer head n^3 of the button N, so that a hole in the back of the outer head engages with a stud n^4, fixed in a revolving bush n^5, provided with a crank-arm whose pin n^6 acts, when so turned, against the inclined cam-surface of a quadrant-groove n^7, made in the face of the lever q. The groove n^7 being concentric with spindle n, the pin on entering said groove prevents the lever q from oscillating, while the pin n^6, acting on the inclined cam-surface of the groove, forces the rock-shaft Q backward, so as to remove the detent-lever q' out of the path of the escapement-pins p^3 p^4, the lever q' being returned to position by a spring q^2 when the head n^3 is turned back to its normal position. The torsion of this spring q^2 acts to give the return angular motion of the detent-lever q', and the compression of the same spring produces the return sliding motion of the rock-shaft Q, as the case may be.

Each clutch-pinion with which the wheel o' gears is in one with the corresponding half of the clutch and is loose on the spindle P^2, the other half of the clutch being free to slide on but turning with said spindle and being pressed into gear with the loose half by a spring p^{10}.

The disengagement of the one clutch and the leaving of the other clutch in gear is effected through the medium of a rock-lever p^5, engaging by slots p^6 with the tail ends of the clutch-levers p^7, each end of the rock-lever being formed with an inclined cam-face p^8, against which bears a corresponding cam-face formed on the end of a pin p^9, which projects rearward from the detent-lever q', so that whether the rock-spindle Q be rocked or be moved longitudinally, as above described, the corresponding arm of the rock-lever p^5 will be moved backward and its opposite end will be moved forward, the backwardly-moving end of lever p^5 not affecting the clutch-lever at that end by reason of the play in the slot p^6, while the forwardly-moving end of said lever effects the disengagement of the clutch at that end. A spring q^3 on the rock-spindle allows forward motion of said spindle and of pin p^9 when that end of the rock-lever is moved forward and clearance is left between the other parts of the mechanism necessary to permit of this motion.

Two tappet-pins r, fixed at diametrically opposite points on the disk P, act on a lever-arm r', fixed to a rock-spindle r^2, which is actuated in the other direction by a torsion-spring r^3. Another lever-arm on the spindle r^2 carries a crank-pin r^4, to which is jointed a pawl r^5, which engages with a ratchet-wheel

r^6, which is in one with a large ratchet-wheel r^7, the wheel r^7 being engaged by a spring-pawl r^8, acting as a jumper and preventing retrograde motion of the wheel r^7, which is geared by a pawl r^9 with a ratchet on the units-wheel of the series. A notched wheel S at the opposite end of the numerator R, Figs. 18, 19, and 20, determines the oscillation of a lever s, whose free end acts as a circuit-closing device to close the circuit of the subscriber's battery between two contacts $s' s^2$ at the passage of each tooth of wheel S, which wheel S is fast with the axis of the wheel r^7, so that the circuit of the subscriber's battery is closed at $s' s^2$ at each change of figure exhibited by the units-wheel of the numerator R during its forward motion. Suitable means are provided whereby the numerator-wheels are returned to zero without causing the transmission of current impulses when the conversation is terminated. The return of both the numerators to zero is permitted by pressing on a button N^4, whereby longitudinal motion is imparted to a rod R^2, carrying cone-cams r^{10}, each of which is thus made to act on a pin r^{11}, fixed to the pawl r^9, and so disengage the driving-ratchet from the units-wheel, so that all the wheels of both the numerators are free to be returned to zero by any suitable means. The other circuit-closing and impulse-registering mechanism being similar, it will be sufficient to refer to it in the general description of the working of my automatic telephone.

It is to be noted that as the numerator R would not require to be operated if there were any subscriber's number lower than "No. 100" it follows that the use as subscribers' serial numbers of all numbers below "100" is inadmissible in the apparatus as here described. It is also to be observed that as the normal contact l and the first division of row A are one and the same no number which terminates with "00" or "01" can be used as a subscriber's number in the present example—that is to say, in addition to the figures "1" to "99" being inadmissible, as above stated, the numbers "100," "101," "200," "201," "300," "301," "400," "401," and so on, are excluded from use when the apparatus is constructed as in the present example. The numerator R' of the subscriber calling must therefore of necessity always be moved from zero a distance not less than the distance of two teeth of its ratchet, in order to attain to the serial number of the subscriber to be called, as hereinafter explained.

The indicator-dial U is a ring divided into four segments respectively bearing inscriptions indicative of the phases of operation of the mechanism and serving to direct the subscriber in the manipulation of the transmitter. These inscriptions are brought successively into view at an aperture in the cover and may be the following or their equivalents: "Off," which signifies the position of repose; "Call," which is intended to signify only to the subscriber called that a call has been given; "Ring" which is a direction to the subscriber calling that he should "ring up" the subscriber to be called; "Are you there?" which is the equivalent of the usual telephone inquiry and indicates that the subscriber called is ready to proceed with the conversation.

The dial-operating mechanism is shown in front elevation in Fig. 18 and in horizontal section (in two positions) in Fig. 19, Fig. 20 being a side view of the circuit-closing lever S, operated by the numerator R.

The dial U is carried by a circumferentially-grooved ring U^2, connected by screws u' to a boss U', which turns upon a fixed stud u. Across the groove U^2 project four pins u^2, fixed to a conical cam-disk W, adapted to slide upon and to turn with the boss U', the pins u^2 acting as driving-teeth for engagement by a detent u^3 and by the click u^4, attached to a lever u^5, connected by a link u^6 with the armature of the electromagnet E^6. The screws u' pass through longitudinal slots in a tube w, fixed to the cam-disk W and sliding on the boss U', its closed front end being in position to receive pressure from the stem of the spring press-button N^4, so that when the latter is pressed inward the cone W will be moved backward, thus withdrawing the studs u^2 from their position across the groove U^2 and therefore out of the path of the driving-click u^4 and detent u^5, lying in the said groove, leaving the boss and dial U free to be rotated to the left under the action of a coiled spring U^3, attached to the boss U' and to a fixed point and which is wound up during the four step-by-step motions of the dial to the right, the motion of the dial in both directions being limited to a complete revolution by an arm w' (shown separately in side view in Fig. 21) and pivoted stop w^2. A spring w^3 returns the cam-disk W and pins u to their normal position when the pressure on the button N^4 ceases. The cone-cam W acts upon a lever W^4, whose other end engages with the rod R^2, so that when the cam W is pressed backward by the button N^4 the cone-cams r^{10}, carried by rod R^2, act on the driving-ratchets of the respective numerators R R', as above mentioned, the return motion of the rod R^2 being effected by a spring.

It has been mentioned that it is preferred that the number of contacts or divisions in each row A should not exceed ninety-nine, even although there are more than ten thousand subscribers on the same telephonic system. By this limitation of the number of contacts in the rows A the numerator R' is limited to a units and a tens wheel, so that the series of figures exhibited by the numerators R R' conjointly (when these have been actuated, as above described, so as to place the switches B' A' on the divisions or contacts whose conjugation corresponds to a subscriber whose serial number is higher than ten thousand) shall always correspond to the serial number of that subscriber. The number

of contacts in the rows B may, however, exceed one hundred and may theoretically be as many as nine hundred and ninety-nine, without requiring more than three wheels for the numerator R, it being understood that when the figures of both numerators are read together as one the figure exhibited by the units-wheel of the numerator R occupies the "hundreds" place in the conjoined figures. Where, then, the number of divisions in rows B differs from that in the rows A, the number of subscribers thus provided for may not be a square number, but will equal the product of the number of divisions in row B multiplied by the number of divisions in row A, and in that case the number of divisions in a row A (which is the square root of the whole number of subscribers when A and B have equal numbers of divisions) is equal to the whole number divided by the number of divisions in row B, and vice versa.

Having described generally the construction of the various parts of the mechanism of this improved automatic telephone apparatus, I will now proceed to describe its mode of working, assuming, for the sake of example, that it is desired to establish telephonic communication between two subscribers, and this without the possibility of a third subscriber overhearing the conversation. These three subscribers will be distinguished by the letters X Y Z.

Fig. 4[x] represents the telephonic transmitter in the office of the subscriber X and likewise the corresponding cell C at the central station. Fig. 4[y] represents the same apparatus belonging to the subscriber Y, and Fig. 4[z] represents the apparatus belonging to the subscriber Z. The dot-and-dash lines indicate the wires connecting the transmitters with their respective cells C at the central station and likewise the connections between the mechanisms of the same cell and between the mechanisms of the one cell and those of the others.

It is to be understood that, although only three sets of apparatus are represented as an example, the connections would be similar for any number of cells, this number being limited to a number equal to the product of the number of insulated contacts contained in one of the rows A multiplied by the number of contacts contained in one of the rows B, the mechanisms of all the cells being actuated from the same local battery.

Let it be supposed that subscriber X wishes to enter into communication with subscriber Z, whose number, for the sake of example, is 1,512. It will be seen by the diagram Fig. 2 that this number corresponds to the conjunction of division 15 of row B, with division 12 of row A, and as the correspondingly-numbered divisions of the rows B of all the cells are connected together and the correspondingly-numbered divisions of the rows A of all the cells are also connected together it follows that the number 1,512 corresponds to division 15 of the rows B and division 12 of the rows A of all the cells. If now subscriber X, by the manipulation of his special transmitter, causes the traveling switches B′ and A′, which are contained in the cell C at the central station corresponding to subscriber X, to be placed, respectively, upon division 15 of the row B and division 12 of the row A, those switches will be in electrical communication with the switches B′ A′ corresponding to the subscriber-Z, (by the lines 15B and 12A,) assuming that the switches B′ A′ of that subscriber are in their normal position. Consequently the switches B′ A′ of subscriber X will be in connection with the distributing-relay F of subscriber Z, and therefore with the line-wire and telephonic receiver of that subscriber. Then the subscriber X, after certain manipulations of his transmitter, which will be hereinafter described, will be in position to ring up subscriber Z. In order that subscriber X shall place his switch B′ upon division 15, it is necessary that he should manipulate button N until by the action of the spring-barrel O the numerator mechanism R exhibits the number "15," which denotes that the circuit-closer *s* has closed the circuit at s' s^2 fifteen times, and has consequently sent fifteen successive current impulses from the subscriber's battery to the distributing-relay F in the cell of the subscriber X. As the contact s' is connected to the positive pole of the subscriber's battery, and as the contact s^2 is connected through one member of the line-circuit with one pole of the distributing-relay F in the corresponding cell C, the other pole of that relay being connected through the other member of the line with the negative pole of the battery, the current impulses sent as above described will be positive in direction. Each positive current impulse sent into the relay causes the armature *f* to oscillate so that the tongue-switch f^2 bears against the contact f^4, and thus closes the circuit of the local battery β. The fifteen positive current impulses sent as above mentioned will therefore close the circuit of the local battery fifteen times in succession through the coils of the electromagnet E′, provided that the switch A′ of this same cell is in its initial or normal position. This is effected in the following manner: The tongue-switch f^2 is in permanent communication with the positive pole of the local battery at the central station, and the contact f^4 is in electrical connection with a metal rod T, fixed in the same cell C in such position that a spring-contact *t*, attached to the carrier of the switch A′, will rub upon said rod throughout the traveling motion of the switch. Another spring-contact t', which is the continuation of *t*, bears (when the switch-carrier is in its initial position) upon a small contact t^2, which is in electrical connection with one terminal of the electromagnet E′, whose other terminal is permanently in connection with the negative pole of the local battery at the

central station. The electromagnet E′ being thus energized fifteen times in succession will (through the medium of the propelling mechanism before described) move the switch B′ on to the fifteenth metallic division of the row B, where it will remain.

By similarly operating the button N′ of the transmitter the numerator R′ is actuated until it exhibits the number "12," whereby the lever s^4 will have closed the circuit twelve times between the contacts s^5 s^6. The contact s^5 is connected with the negative pole of the subscriber's battery, and the contact s^6 is connected (through the same member of the line-circuit as that to which s^2 is connected) with one pole of the distributing-relay F, the other pole of which is connected with the positive pole of the subscriber's battery. The negative impulses thus sent to the relay F cause its tongue-switch f^2 to bear against the contact f^3, thus closing the circuit through the electromagnet E, provided that the bridge-switch G is in its initial position. To produce this result, the contact f^3 is connected directly with one terminal of the electromagnet E, the other terminal of which is connected with a contact j^2, on which (when this bridge-switch is in its initial position) bears the spring-contact j. The contact j is in one with the smaller contact j', which latter at the same time bears on the contact j^5, this contact j^5 being connected with the negative pole of the local battery β, the positive pole of which, as before mentioned, is connected to the tongue-switch f^2 of the relay F. This electromagnet E being thus energized twelve times in succession will operate the propelment mechanism of the switch A′ and place it on the twelfth division of the row A, where it will remain. The number of the subscriber to be called being now exhibited by the instrument of the subscriber calling, it is necessary (in order to prevent the position of the switch A′ being altered by the subsequent manipulations of the transmitter) to cut off the electromagnet E from all communication with the relay F, thus blocking the electromagnet E. It will be evident that once the switches B′ A′ have been placed in the requisite positions the electromagnets E′ E are no longer required to act. It will be remembered that as the switch A′ has been moved the contact t' has quitted the contact t^2, and consequently the electromagnet E′ is already cut off from the relay, and as this electromagnet E′ was energized by positive impulses all positive impulses now entering the relay F will pass through the electromagnet E^4, one terminal of which is connected directly with the negative pole of the local battery, while the other terminal is connected with a metal rod T″. This rod T″ is placed in the path of the spring-contact t', so that when the carrier of the switch A′ has been moved from its initial position the circuit will be closed between T″ and T, which, as before mentioned, is connected with the contact f^4 of the relay F, against which contact the tongue-switch f^2 bears when a positive impulse traverses the relay, which tongue-switch, as before mentioned, is connected to the positive pole of the local battery. Thus it will be seen that when switch A′ is moved from its initial position each positive impulse sent into the relay F will cause the bridge-switch G to be moved to the extent of one tooth by the electromagnet E^4, (energized by the local battery,) thus breaking the circuit of the electromagnet E at j and j^2, so making it impossible to actuate that electromagnet by a negative current. By the same movement of the bridge-switch G the contact j is placed on another contact j^3 and the contact j' upon the contact j^4, thus closing the connection between j^3 and j^4, which connection will remain closed during the remainder of the forward movement of the bridge-switch G.

The positive current, by which the bridge-switch G has thus been moved the distance of one tooth, is sent to the relay F by the subscriber pressing upon a third button N^2, and thereby operating certain switches in the transmitter, which will be hereinafter described, it being sufficient to here state that their operation is such that by a single pressure upon the button N^2 there will be sent to the relay F a succession of three current impulses: first, the positive current above referred to; secondly, a negative current, and, thirdly, a positive current. The first of these currents cannot pass through the solenoid because the communication of the solenoid-core of the subscriber's line has been cut by the fact that the switch B′ has been moved from its initial position, and has consequently broken the circuit of the solenoid-core at the contacts t^3 t^4, which are only connected (when the switch B′ is in its initial position) by the spring-contact t^5, mounted on the carrier of that switch. The first of these three currents (which is positive) therefore acts only on the relay F and causes the electromagnet E^4 to be energized by the local battery, and the bridge-switch G to be thereby moved the distance of one tooth, thus cutting at j j^2 j' j^5 the connection between the relay F and the electromagnet E, and by the same movement restoring the connection of the solenoid-core with the line by the contact of j with j^3 and j' with j^4. The same movement of the bridge-switch has also brought the first division of the series g into connection with the roller-contact g'. The divisions g are all in direct communication with the positive pole of the local battery, while the contact g' is connected with one terminal of the relay F, the other terminal of which is connected with the negative pole of the local battery, while, as before stated, the two members of the subscriber's line are connected with the two terminals of the relay, and they are also connected in the subscriber's transmitter with the two terminals of an electromagnet E^6. The effect of closing this circuit between g and g' is that

a positive current is sent from the central station, through the electromagnet E^6, the effect of which is to cause the indicator-dial U in the transmitter to rotate to the extent of one division of the indicator. The effect of the second current sent from the transmitter to the central station (which current is negative) is as follows: It enters the relay F, but produces no effect on the electromagnet E, whose circuit is cut, and consequently the mechanism of subscriber X remains in the position to which it has been brought. The two switches B' A' being connected to the terminals of the relay, this current therefore enters these switches, passes through the contacts 15 and 12, on which they have respectively been placed, and consequently passes through the wires 15B and 12A, which connect these divisions, respectively, with the corresponding divisions in the cell belonging to the subscriber to whom the combination "15-12" corresponds, according to the diagram Fig. 2. This subscriber in the present example is subscriber Z, whose number, it will be remembered, is 1,512. The switches A' B' of subscriber Z being in their normal position—that is to say, being in contact with the normal or line contacts—the current passes through them and enters the terminals of the relay F of subscriber Z. The current being a negative one causes the tongue-switch f^2 of Z's relay to bear against the contact f^3, thus closing the circuit of the local battery through the electromagnet E of Z's apparatus, it being supposed that Z's bridge-switch G is in its normal position. The effect of this is to send a single impulse through the electromagnet E, in consequence of which the wheel D' is moved to the extent of one tooth, and the switch A' is moved a corresponding distance. By this movement the switch A' does not leave the normal contact l and spring t^8 does not quit the two contacts t^6 t^7, which are of equal length to that of contact l, but the spring-contact t' quits t^2, and consequently breaks the circuit of the electromagnet E' of Z's apparatus. By this same movement the spring-contact t' has passed on to the contact-rod T', so as to connect the electromagnet E^4 with the contact f^4 of the relay F. Although this negative current passes through Z's line, it produces no action upon the electromagnet E^6 in Z's transmitter, which, it will be remembered, is only capable of being actuated by a positive current. The third current sent by subscriber X (being a positive current) causes the tongue-switch f^2 of X's relay to bear against the contact f^4, again closing the circuit of the local battery through the electromagnet E^4, thereby moving the bridge-switch G to the extent of another tooth, which is the second from its initial position. The effect of this movement is to again close, at g g', the circuit of the electromagnet E^6 in X's transmitter, and consequently to again send a positive current from the local battery at the central station, whereby X's indicator is moved to the extent of another segment, (the second,) so that it then exhibits a direction to X to "ring up." This same third current, (which is positive,) besides thus actuating the relay, passes through the switches B' A' through the divisions of the rows B A on which they are placed, through wires 15B and 12A to the corresponding divisions of the rows B A in Z's apparatus, through Z's switches B' A' to the terminals of Z's relay F. It therefore causes the tongue-switch f^2 of Z's relay to bear against contact f^4, thus closing the circuit of the local battery through the electromagnet E^4, (the switch A' being no longer in its initial position,) so that the electromagnet moves the bridge-switch G of Z's apparatus the distance of one division. The effect of this movement on Z's apparatus is exactly the same as that which was produced by the movement of the bridge-switch G in X's apparatus—that is to say, the circuit of the electromagnet E is cut at j and j', and a positive current is sent from the local battery through g g', which current, entering Z's line-wire, joins the positive current coming from X, energizes the electromagnet E^6 in Z's transmitter, and moves Z's indicator the extent of one division, thereby notifying to Z that he is called. Subscriber X now proceeds to follow the direction (exhibited by his indicator) to ring up, and this he does by sending negative currents—the apparatus of X and Z, in the positions to which they have now been brought, being able to give passage to negative currents—without any other action being produced than that of ringing. These negative currents, whether galvanic currents or rectified magneto-electric currents, are sent in the ordinary way.

I will now describe how the three currents—positive, negative, and positive—are sent by the subscriber in the order indicated by pressing the button N^2. The stem of button N^2 acts on two lever-commutators v^3 v^4, which are connected mechanically but insulated from one another, and which are constantly connected, respectively, with the two members of the subscriber's line and are normally held in the position shown by a spring. By pressing the button N^2 these commutators are caused to pass, first, over a pair of contacts v^5 v^6, whereof v^5 is connected to the positive pole of the subscriber's battery and v^6 to the negative pole of the same battery, whereby a positive current is sent through the subscriber's line to the corresponding cell at the central station, as above described. By the continued movement of the commutators v^3 v^4, under the pressure of the button N^2, the commutator v^3 is brought on to contact v^6, and v^4 passes on to a third contact v^7, which, like v^5, is connected to the positive pole of the subscriber's battery, so that v^6 being always connected with the negative pole a negative current is now sent through the subscriber's line to the corresponding cell at the central station. On releasing the button N^2 the spring

returns the commutators to their original position, the commutators in passing over the contacts v^6 v^5 on their return movement again sending a positive current through the line-wire to the corresponding cell at the central station. The subscriber Z (having been rung up, as before described, and the call being confirmed by the inscription exhibited on his instrument) operates the button N^2 of his transmitter, and thus sends three currents from his transmitter to his corresponding cell at the central station, these three currents being likewise positive, negative, and positive, in the order above mentioned. The first of these three currents arriving at the relay F of Z's apparatus causes the tongue-switch f^2 to bear against the contact f^4 and thus close the circuit of the local battery through the electro-magnet E^4. This electro-magnet thereby moves the bridge-switch G the distance of one tooth, so that the contact g' is now on the second division g. The effect of this is to close the circuit of the local battery at g g', and therefore to send a positive current through the electromagnet E^6 of Z's transmitter. The electromagnet E^6 consequently turns the indicator of that transmitter the distance of one segment and exhibits a direction to Z to ring-up. Besides producing this effect the same positive current from the subscriber's instrument passes through the switches B' A' of Z's cell and through the normal contacts on which they are situated to the terminals K L. The terminals K L are respectively connected, K with division 15 of row B and L with division 12 of row A of Z's cell, and as the correspondingly-numbered divisions of the rows A of all the cells are connected together, and as those of rows B are likewise connected together, it follows that the positive current sent by the subscriber Z enters the switches B' A' of X's apparatus, and passing to the terminals of the relay F this current enters X's line and (by causing the tongue-switch of that relay to bear against the contact f^4) closes the circuit of the local battery through the electromagnet E^4, thereby moving the bridge-switch G of X's apparatus a third time the distance of one tooth. The effect of this is to place the contact g' upon the third division g of the bridge-switch and thereby to send a positive current from the local battery (simultaneously with the positive current which enters the line directly) through the electromagnet E^6 of X's transmitter, whereby X's indicator is moved the distance of one division, so that it now exhibits an inscription denoting that the subscriber can now speak. The effect of this third movement of the bridge-switch G of X's apparatus is to place the spring contact-bars i i', respectively, on the contacts i^{10} i^{11} and to place the spring contact-bars i^3 i^5 upon the contacts i^4 i^6. The contact i^{10} being connected with the positive pole and the contact i^{11} with the negative pole of a few elements only of the local battery β, and the contacts i^4 i^6 being connected with the winding of the solenoid-switch A', the effect of placing the bridge-switch G in the position just described is to send a current of a certain direction, through the winding of the solenoid of X's apparatus, which current by the inductive action that it produces in the magnetized core of the solenoid causes the said core to be moved in the direction of its axis until its other contact-point bears upon the corresponding division (*i. e.*, No. 12) of row A^2, where it remains. The second current sent by subscriber Z (which is negative) produces no effect whatever; but the third current (which is positive) produces the same effect upon the apparatus of Z as that produced on the apparatus of X by the first positive current, so that the bridge-switch G in Z's apparatus has now been turned to the third position, the indicator has been turned so as to exhibit the third segment, and the core of the solenoid-switch A' of Z's apparatus has been transferred from the first division of row A to the first division of row A^2, which division is in permanent connection with the terminal M of Z's apparatus. It will be remembered that the terminals M of the normal contacts m are grouped in exactly the same way as the terminals L of the normal contacts l of rows A, and therefore the solenoid-core of Z's apparatus is now in direct communication with that of X. It is also to be noted that the last-mentioned positive current has not acted upon the mechanism in X's cell, because the solenoid-core in that cell has been moved out of contact with the row A, so that the circuit was thereby broken. It is only now that the two subscribers are in position to enter into conversation with each other, which they now proceed to do. The telephonic communication thus established will be apparent by diagram Fig. 2, supposing the solenoids to have been transferred to the rows A^2 in X's and Z's apparatus. When the conversation is completed, the subscriber X presses the button N^3, whereby he so operates two commutators v^8 v^9 as to bring them into passing contact with the contacts v^{11} v^{10}, which are connected, the first with the negative pole of the subscriber's battery and the second with the positive pole of the same battery, whereby a positive current is transmitted. When the pressure on the button ceases, these commutators return, and in returning produce the same contacts with the same result—viz., the transmission of a positive current. The first positive current sent by X closes the circuit of his battery through the relay F of his cell C, thereby causing the tongue-switch f^2 to bear against the contact f^4, thus closing the circuit of the local battery through the electromagnet E^4. This electromagnet consequently turns the bridge-switch G to the extent of another tooth, and has for effect to place the fourth contact g in contact with g' and so send a return-current to X's transmitter, where the circuit of the local battery be-

ing closed through the electromagnet E^6 the latter moves the indicator so that it exhibits its fourth segment, bearing the indication denoting repose or that communication is "off."

By the same movement of the bridge-switch G the spring contact-bars i i' are placed in communication with the contacts i^{11} i^{12}, (whereof the first is connected with the negative pole and the second with the positive pole of a portion of the local battery,) and the spring contact-bars i^2 i^3 are also placed upon the contacts i^5 i^7, which, it will be remembered, are in communication with the winding of the solenoid. In this position of the bridge-switch G a current (of opposite direction to that which was previously sent through the winding of the solenoid) will pass through the solenoid-winding and will cause its magnetized core to make a return movement within the coil or winding, so that the core is again placed on the row A of divisions. The same first positive current enters by the switches A' B' of X's cells and thence through the grouping-wires (by which the divisions whereon those switches are now situated are connected with the normal contacts of Z's cell) to the switches A' B' of Z's cell. It there produces the same effects upon the mechanisms of Z's cell and Z's transmitter as was described in respect of the apparatus of subscriber X. The second positive current sent by X (as above described in respect of the first positive current) will cause the bridge-switch G of X's cell to move forward to the extent of another tooth, but as soon as the spring contact-bars i^2 i^3 connect the two contacts i^8 i^9 the circuit of the local battery will be closed through the three electromagnets E^2 E^3 E^5. The electromagnets E^2 E^3 will act on the propelment mechanisms (whereof one is illustrated in Figs. 5 and 6) and so cause the clicks of the propelment mechanisms of A' B' to be thrown out of gear and enable these parts to return to their initial position, the electromagnet E^5 performing the same office in respect of the bridge-switch G, as will be readily understood. For this purpose i^8 is connected with the positive pole of the battery and i^9 with one of the terminals of each electromagnet E^2 E^3 E^5, whose other terminals are connected with the negative pole of the local battery. The same positive currents also enter the mechanism of Z's cell and there produce absolutely the same effects, so that the whole of the mechanism (with the exception of the numerators) has now returned to its normal position and is therefore in condition to permit of the manipulation being recommenced when it is again desired to establish communication.

It will be seen that throughout the manipulation of the apparatus belonging to the two subscribers X and Z the apparatus of the subscriber Y has remained entirely undisturbed, and this remark applies to the apparatus of all the other subscribers in connection with the telephonic system. It is furthermore to be observed that since the solenoid-switches A' of X's and of Z's apparatus have quitted their normal contacts l while conversation was going on between those subscribers, and since the transfer of the solenoid-cores from rows A to rows A^2 can only be effected by the operation of the mechanism of the subscriber who has been called and will then only put that subscriber in telephonic communication with the subscriber by whom he was called, it follows that it was impossible for Y or any other subscriber to ring up X or Z or to overhear telephonically the conversation carried on between X and Z.

Instead of the subscriber being required to press a special button N^4 for the purpose of acting on the mechanism whereby the number-wheels of the two numerators in his transmitter are returned to zero, this effect may be produced by the weight of the telephonic receiver itself when hung on the ordinary switch-hook.

In conclusion it is to be observed that the terms "positive" and "negative" as applied to the two members of the subscriber's circuit and the mechanism in connection therewith are used merely by way of contradistinction and are interchangeable or may be replaced by other terms whereby the members may be distinguished the one from the other.

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, I declare that what I claim is—

1. A system of automatic telephone exchange wherein the members of each pair (constituting a subscriber's circuit entering the central station) terminate in independently-movable switches capable of being electromechanically propelled along rows of insulated contacts, the positive members of all the pairs (and consequently the switches in which they terminate, and the contacts on which the switches normally rest), being connected in a certain order in groups, which groups are respectively connected to corresponding contacts of all the rows of contacts appropriated to positive members; the negative members of all the pairs being connected in a certain order (different to that in which the positive members are connected) in groups which are likewise respectively connected to corresponding contacts of all the rows of contacts appropriated to negative members; the difference between the orders of grouping the positive and negative members being such that any one group of positive members comprises the positive members of pairs or couples whose negative members are comprised each in a different group of negative members, and reciprocally, so that a different pair or couple corresponds to each of the different combinations formed by conjoining any one of the positive set of contacts with any one of the negative set of contacts, the numbers of the groups in the two sets of groups of which the contacts are the terminals, (and consequently

the numbers of wires in the two sets of wires connecting corresponding contacts) being factors whose product equals the number of possible combinations and consequently the number of subscribers who may automatically intercommunicate through the central station, as specified.

2. In a system of automatic telephone exchange, wherein the positive members of all the subscribers' lines, the switches in which they terminate, and the contacts on which said switches normally rest are connected in groups, and likewise the negative members, their switches, and normal contacts are connected in groups differently formed, so that any one group of positive members comprises the positive members of pairs or couples whose negative members are comprised in as many different groups of negative members and vice versa, the groups of positive and negative members being respectively connected to all the contacts occupying corresponding positions in all the rows of positive and negative contacts respectively; and wherein the two members of each pair terminate in electrically-propelled switches independently movable over the rows of positive and negative contacts respectively; the combination with the one switch and its row of contacts, of a third row of contacts opposite thereto and grouped similarly to the grouping of the elements to which those contacts correspond, the switch in question being electromagnetically transferable from the one row of said contacts to the other or third row so as to provide an alternative circuit of communication which by such transfer of the switches from the one set of contacts to the other, becomes for the time being an exclusive circuit for the purpose of maintaining secrecy, as described.

3. In a system of automatic telephone exchange wherein the two members of each subscriber's line constituting a pair terminate in electrically-propelled switches independently movable over rows of positive and negative contacts respectively, and wherein the positive members of all the subscribers' lines, the switches in which they terminate, and the contacts on which said switches normally rest are connected in groups, and likewise the negative members, their switches and normal contacts in groups differently formed, (so that any one group of positive members comprises the positive members of pairs or couples whose negative members are comprised in as many different groups of negative members and vice versa, the groups of positive and negative members being respectively connected to contacts occupying corresponding positions in all the rows of positive and negative contacts respectively,) the combination, with electromagnetic propelment mechanisms for operating the respective switches and with means of closing the circuit of the local battery through the electromagnetic propelment mechanism of the one or other switch (according to the direction of the current received from the transmitter) of circuit-closing mechanisms respectively adapted to send, the one a succession of impulses of the one direction, and the other a succession of impulses of the other direction from the transmitter to the relay, and of numerator mechanisms for recording the number of impulses so sent, substantially as specified.

4. In an automatic telephone-exchange system wherein the two members of each subscriber's line constituting a pair terminate in electrically-propelled switches independently movable over rows of positive and negative contacts respectively, and wherein the positive members of all the subscribers' lines, the switches in which they terminate and the contacts on which said switches normally rest are connected in groups, and likewise the negative members their switches and normal contacts in groups differently formed, (so that any one group of positive members comprises the positive members of pairs or couples whose negative members are comprised in as many different groups of negative members and vice versa, the groups of positive and negative members being respectively connected to contacts occupying corresponding positions in all the rows of positive and negative contacts respectively) the combination, with electromagnetic propelment mechanisms for operating the respective switches and with means of closing the circuit of the local battery through the electromagnetic propelment mechanism of the one or other switch (according to the direction of the current received by it from the transmitter) of circuit-closing mechanisms respectively adapted to send the one a succession of impulses of the one direction, and the other a succession of impulses of the other direction from the transmitter to the relay, and of numerator mechanisms for recording the number of impulses so sent, the movements of the one switch and consequently the number of contacts in the row over which it moves being limited to ninety-nine the corresponding numerator therefore having only a units and a tens wheel of figures, while the movements of the other switch and the contacts over which it moves and the figure-wheels of the corresponding numerator are unlimited in number so that the figures conjointly exhibited by the two numerators may always correspond to the serial number of the subscriber on whose combination of contacts the switches may for the time being be placed.

5. In an automatic telephone-exchange system wherein the members of each subscriber's line the switches in which they terminate and the contacts on which said switches normally rest and over which they are traversed are connected in groups differently formed for the positive and negative members as herein described, the combination with each switch-carrier of a screw-spindle mounted to rotate and of electromagnetically-operated mechanism adapted to impart step-by-step rotary mo-

tion to the screw-spindle, the switch-carrier being formed as a nut adapted to be traversed upon the screw-spindle when it is revolved by the electromagnetic propelment mechanism for traversing said switch over the corresponding row of contacts, as specified.

6. In an automatic telephone-exchange system wherein the members of each subscriber's line, the switches in which they terminate, and the contacts on which said switches normally rest and over which they are traversed, are connected in groups differently formed for the positive and negative members as herein described, the combination with each switch-carrier of a screw-spindle mounted to rotate and of electromagnetically-operated mechanism adapted to impart step-by-step rotary motion to the screw-spindle, the switch-carrier being formed as a nut adapted to be traversed upon the screw-spindle when it is revolved, and of mechanism for quickly returning the switch-carrier to its initial position, said mechanism being operated substantially as described.

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