No. 743,564. PATENTED NOV. 10, 1903.

M. C. RORTY & A. M. BULLARD.

AUTOMATIC TELEPHONE EXCHANGE.

APPLICATION FILED AUG. 9, 1900.

NO MODEL. 4 SHEETS—SHEET 1.

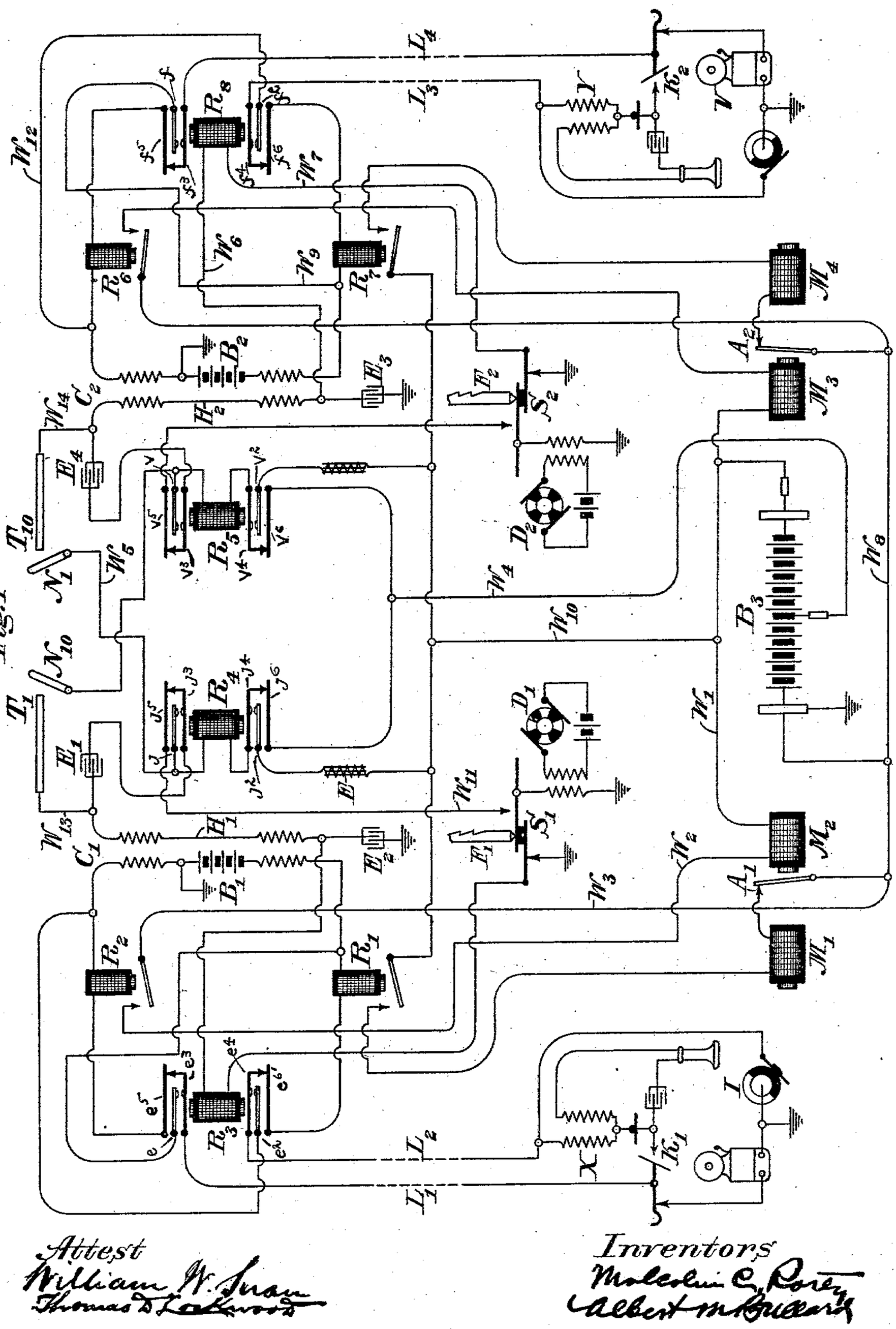

Fig. 1

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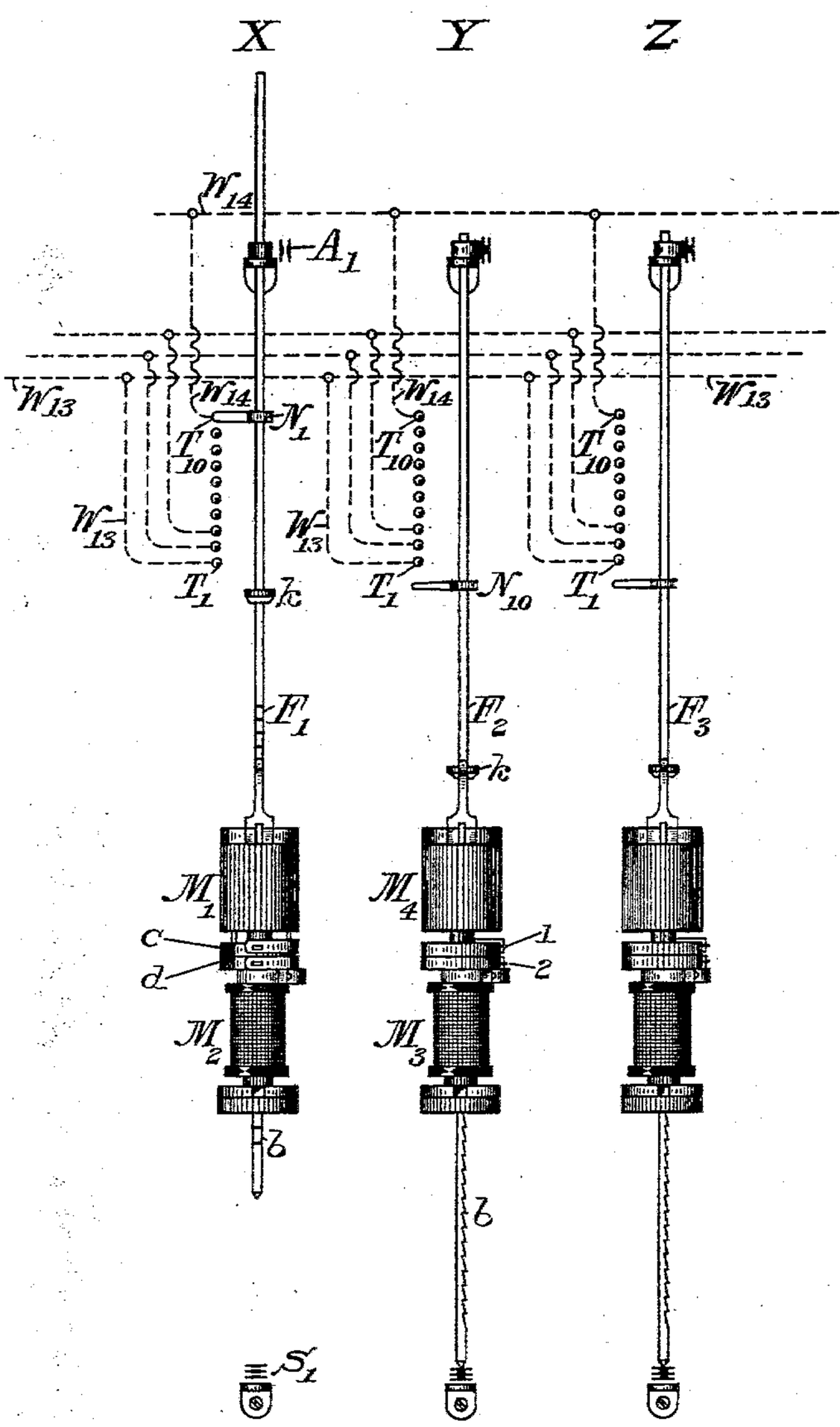

Fig. 2

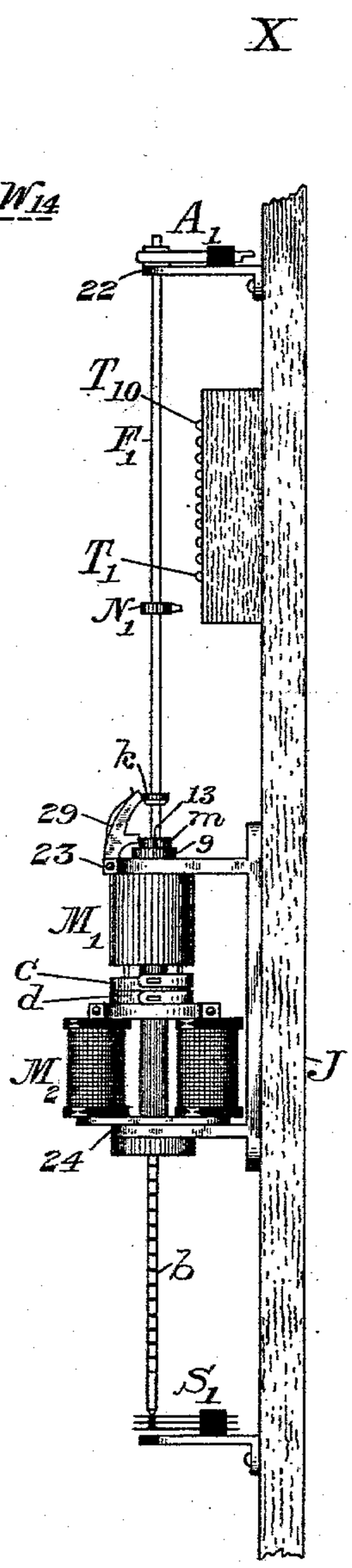

Fig. 3

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NO MODEL. 4 SHEETS—SHEET 3.

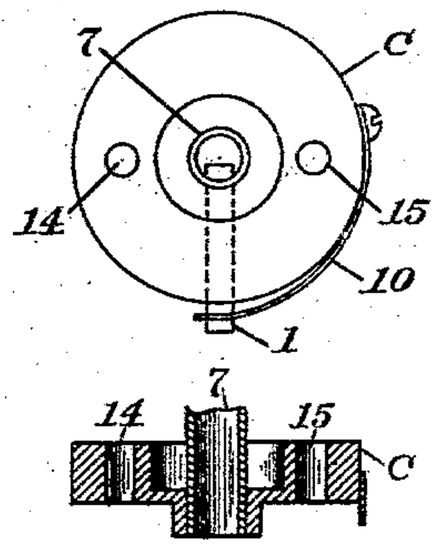
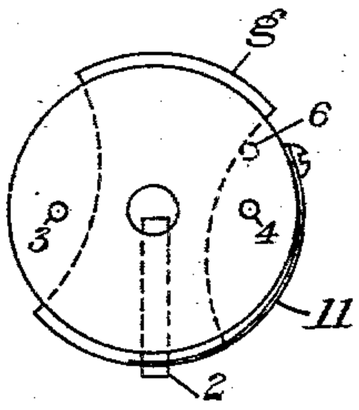


Fig. 9



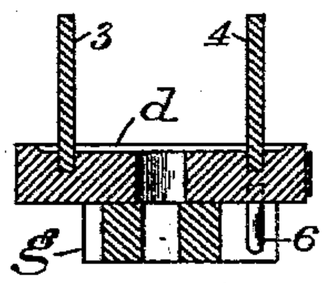


Fig. 8

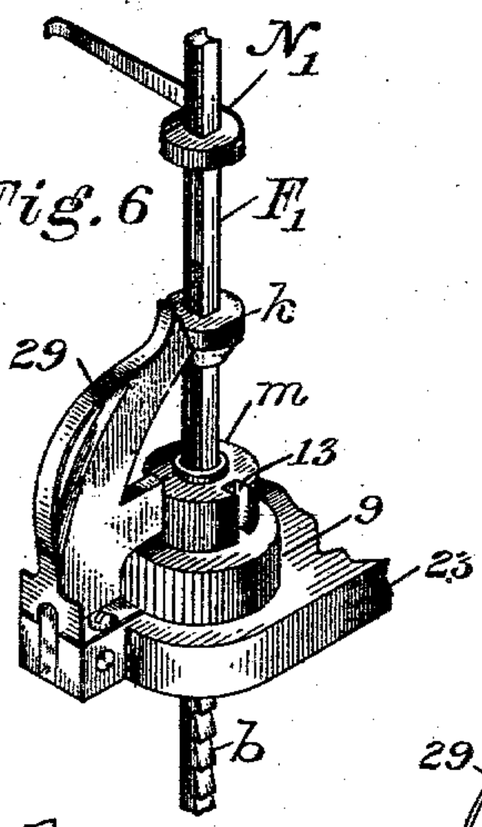


Fig. 6

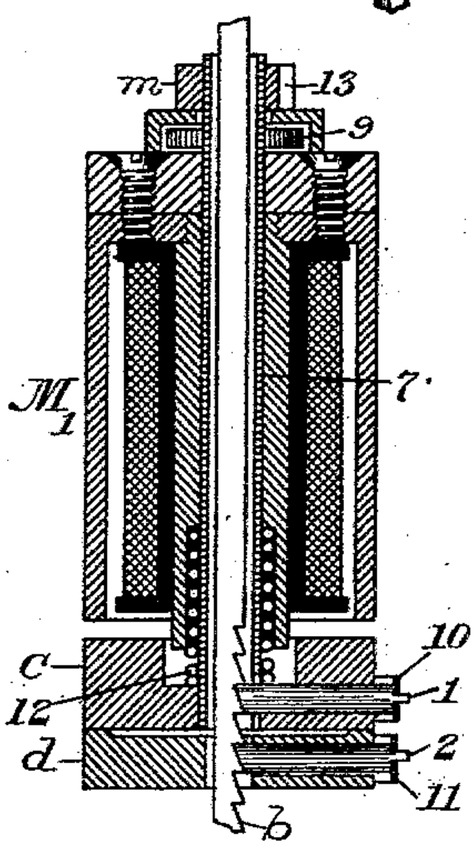


Fig. 5

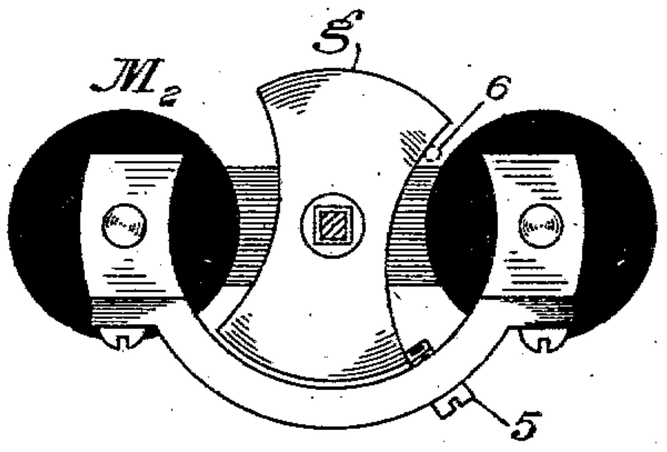


Fig. 7

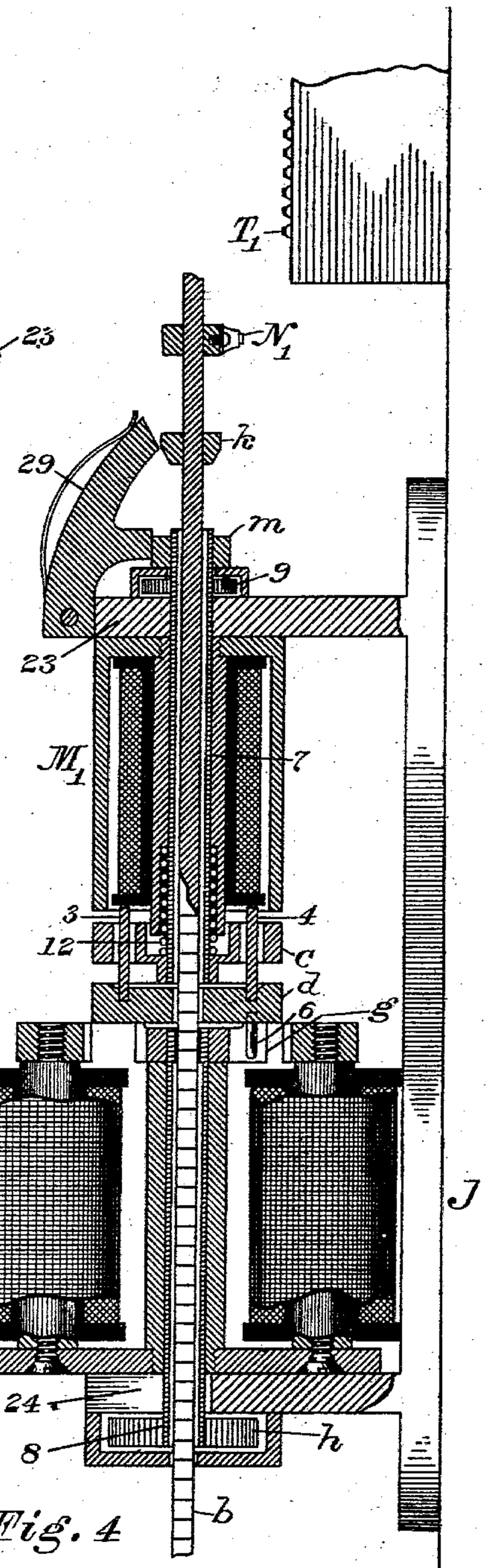


Fig. 4

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AUTOMATIC TELEPHONE EXCHANGE.

APPLICATION FILED AUG. 9, 1900.

NO MODEL

4 SHEETS—SHEET 4.

Fig. 11

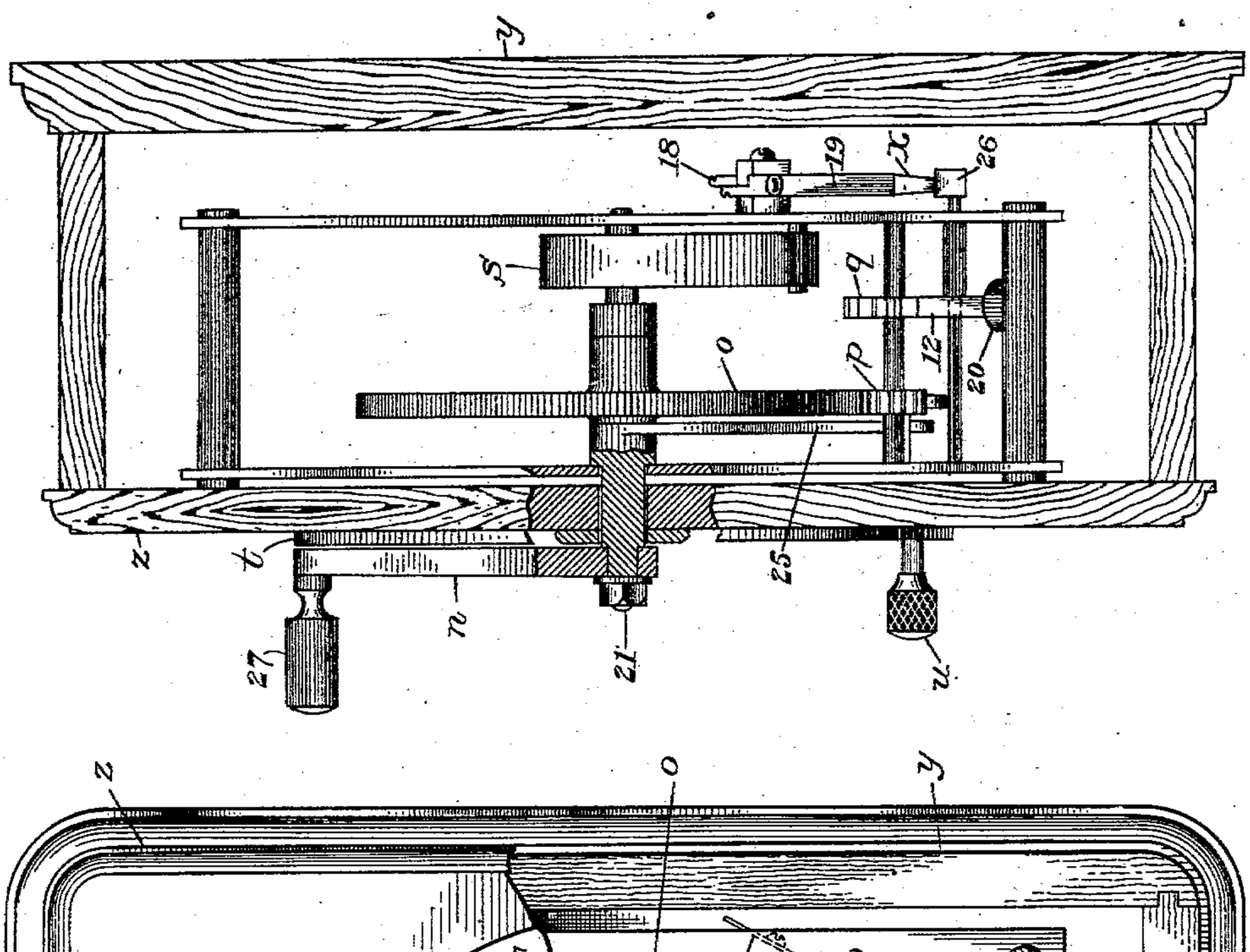
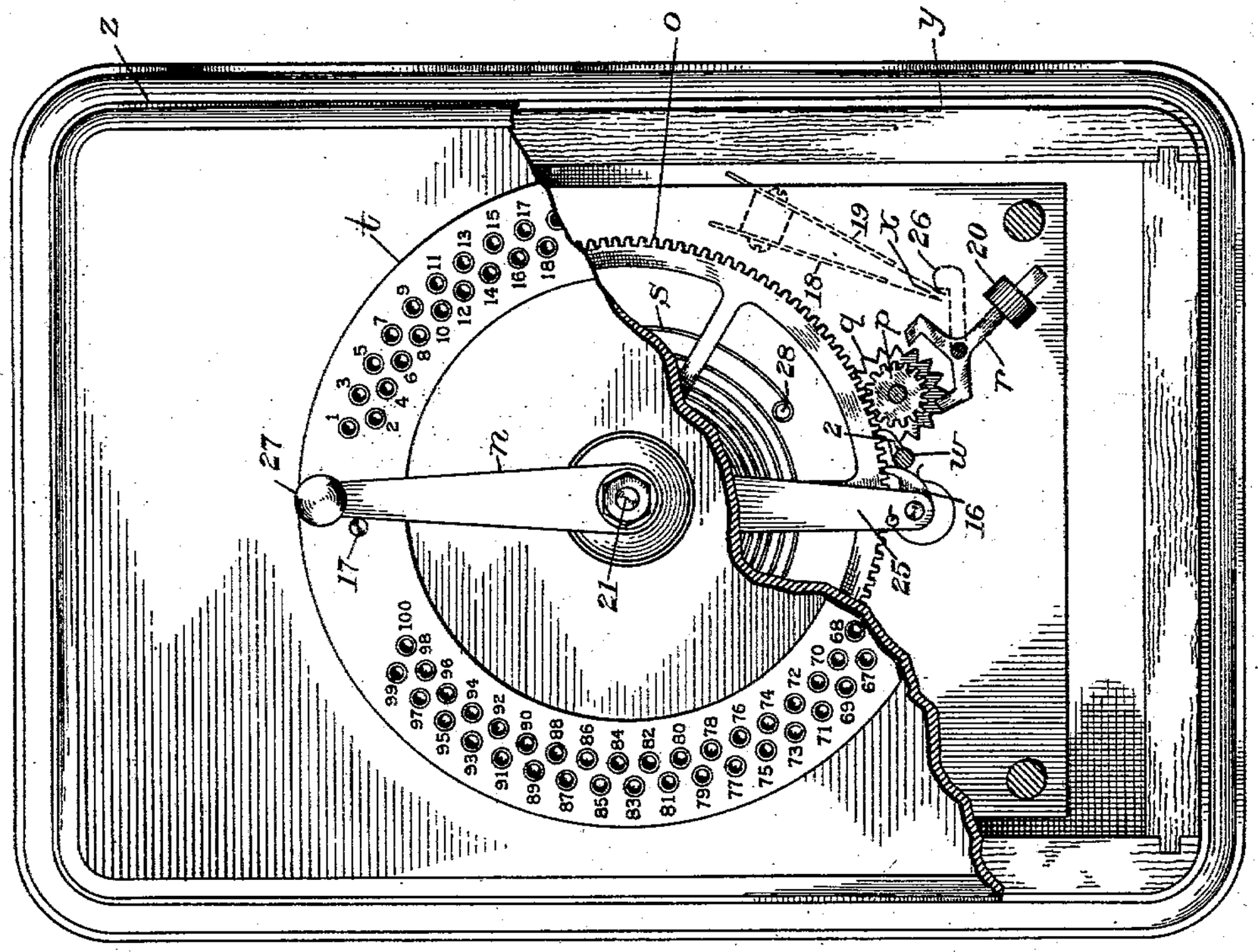


Fig. 10



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No. 743,564. Patented November 10, 1903.

UNITED STATES PATENT OFFICE.

MALCOLM C. RORTY, OF DEDHAM, AND ALBERT M. BULLARD, OF SOMERVILLE, MASSACHUSETTS, ASSIGNORS TO THE AMERICAN BELL TELEPHONE COMPANY, OF BOSTON, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS.

AUTOMATIC TELEPHONE-EXCHANGE.

SPECIFICATION forming part of Letters Patent No. 743,564, dated November 10, 1903.

Application filed August 9, 1900. Serial No. 26,441. (No model.)

To all whom it may concern:

Be it known that we, MALCOLM C. RORTY, residing at Dedham, in the county of Norfolk, and ALBERT M. BULLARD, residing at Somerville, in the county of Middlesex, State of Massachusetts, citizens of the United States, have invented a new and useful Improvement in Automatic Telephone-Exchanges, of which the following is a specification.

The principal object of the invention is the adaptation of leading features of a central-battery exchange to an automatic exchange.

The requisites of an automatic telephone-exchange are that each subscriber without the intervention of an operator at the central station shall be able to call any other subscriber without disturbing a third, that each subscriber when talking with another or when calling another or being called by another shall not be disturbed by a third, and that each calling subscriber desiring to call another subscriber may immediately ascertain whether or not such other subscriber is busy. By our invention provision is made for these requisites, accompanied by well-known advantages of the common or central-battery system in manually-operated exchanges.

The invention consists in the combination of telephone-lines converging to a central station from two or more subscribers' stations, signaling and talking apparatus at each of said subscribers' stations, a battery or similar source of electromotive force at said central station common to all the subscribers for connections, disconnections, signaling, and talking, and electromechanisms at said central station operated from said source of electromotive force by instruments included in said signaling and talking apparatus at said subscribers' stations.

The invention also consists in details of construction and arrangement of apparatus and circuits.

Each subscriber's substation equipment consists of telephones, induction-coil, condenser, bell, and circuit-closer. The connections with the central station are by metallic circuits. At the central station there is a battery or source of electromotive force to furnish current for the operation of all the relays and electromechanisms by which all connections are made between subscribers, by which all bells are rung or other signals given, and for all conversations. The central-station apparatus appropriated to each subscriber for the purpose of selecting, ringing, and talking by means of said battery or source of electromotive force, also located at said central station, consists of fixed multiple contacts or fixed terminals, a movable terminal, contact-arm or selector-arm to engage the fixed terminals of the other subscribers' lines, and electromagnets for operating it, relays controlling said magnets, a testing-relay, a reversing-relay, and a repeating-coil. A tone-busy-test apparatus located at the central station is common to all subscribers' circuits.

The movable contact-arm of each subscriber at the central station has two motions, by the first of which it may be brought opposite any fixed multiple contact, while by the second it may be brought into electrical connection with such fixed multiple contact as it may be opposite.

The circuit-closer at each subscriber's station is so constructed and arranged that by turning an index or pointer to a number upon a dial and releasing it the pointer will automatically return to the zero-point on the dial and in so doing will cause a circuit from the source of electromotive force located at the central station through one of the line-wires to earth to be made and broken a number of times corresponding to the number to which it was turned. This is the circuit-closer shown in the drawings; but, as hereinafter appears, any suitable device for alternately opening and closing a circuit may be substituted therefor.

As will presently be seen, the calling subscriber makes use of one line-wire and the circuit-closer to bring the movable contact-arm of his apparatus at the central station opposite the fixed multiple contact at the central station of the subscriber with whose line he desires a connection, and he makes use of both line-wires and his telephone-lever by re-

moving his receiving-telephone from the hook to cause his said contact-arm to make electrical connection with the said fixed multiple contact of the said subscriber whom he is calling. By these two operations his own metallic talking-circuit is completed from the source of electromotive force at the central station through a repeating-coil whose other winding is included in a secondary circuit which transmits the sound of the voice to the repeating-coil of the called subscriber. The called subscriber makes use of his telephone-lever by removing his receiving-telephone from the hook to complete his corresponding metallic talking-circuit ready to receive a conversation from the said repeating-circuit or, indeed to talk over said repeating-circuit, for provision is now made for mutual conversation.

In carrying out this invention as described herein a part of the apparatus appropriated to each subscriber at the central station consists of a selecting-magnet, a connecting-magnet, and two controlling-relays, one of the said controlling-relays being in a circuit of the battery or other source of electromotive force which is alternately closed and opened by the movement of the circuit-closer at the subscriber's station, as aforesaid, while the other controlling-relay is energized in another circuit of the battery or other source of electromotive force located at the central station by the movement of the telephone-lever at the subscriber's station to close said circuit when the receiving-telephone is taken from its hook. The operation of the first-mentioned controlling-relay alternately energizes and deënergizes the selecting-electromagnet in a local circuit from the common battery, the movement of whose armature causes the movable selector-arm appropriated to the subscriber's circuit to take a position opposite the fixed or permanent multiple contact appropriated to that subscriber with whom a connection is desired, while the operation of the second controlling-relay is to energize the connecting-magnet, the movement of whose armature causes the same selector-arm to make and maintain contact with such permanent multiple contact. It will presently be obvious, however, that the controlling-relays might be omitted and the selecting and connecting magnets be placed directly in the circuit between the substation and the central station. In practice, however, the plan of relaying has advantages and is preferable.

Another important feature of the invention consists in the employment in the apparatus appropriated to each subscriber at the central station of a third relay, herein called the "reversing-relay," which when energized reverses the normal connection of the common battery with the called-subscriber's line and causes the called-subscriber's vibrating bell to operate.

A lock-out or secrecy system forms yet another important feature of the invention. Closely associated with or strictly belonging to the contrivance for ringing the bell at a called-subscriber's station is a provision for cutting out the reversing-relay of the calling subscriber, by the reversal of which a third party might break in upon the calling subscriber while he is seeking a connection or has a connection with another subscriber. The first movement of the selector-arm to take a position opposite the multiple contact of the subscriber with whom a connection is desired opens a circuit from the common battery through the calling-subscriber's reversing-relay, and thereby prevents its operation in certain circumstances to reverse the connection of the subscriber's own bell with the common battery.

The operation of the reversing-relay not only rings the bell at the station with which it is associated, but also cuts out the selecting mechanism of the called subscriber, while permitting his talking-circuit and bell-ringing circuit to remain operative. So in the case of the calling subscriber if his reversing-relay is cut out by himself not only will his bell be prevented from being rung by a third party under any circumstances, but the third party cannot cut him off from his selecting mechanism.

The secrecy system consists, further, in the employment as a part of each subscriber's apparatus at the central station of a fourth relay, herein called the "testing-relay," in a subsidiary circuit, through the armature-contacts of which passes the talking-circuit from a calling subscriber to his own selector-arm, said talking-circuit being open at said contacts, except when said relay is energized, and said relay is energized only when said selector-arm is in contact with a multiple contact of a line not in use. When contact is made between the selector-arm and a multiple contact of a line which is in use, the testing-relay not being energized, the calling subscriber remains disconnected from his selector-arm and cannot intrude upon the busy line. The same contacts of the testing-relay are included in and control a busy-tone circuit.

In the drawings, Figure 1 is a diagram illustrative of the mode of operation of the exchange. Fig. 2 is a general view, in front elevation, of the selective devices at the central station of three subscribers X, Y, and Z. Fig. 3 is a side elevation of the device of X in its normal position before it is raised to the position shown at Fig. 2. Figs. 4, 5, 6, 7, 8, and 9 show details of construction of the selecting and connecting mechanism at the central station. Figs. 10 and 11 represent by front and side elevations the substation circuit-closer.

Like letters and figures refer to like parts wherever used.

The apparatus shown at Fig. 3 and at the left hand of Fig. 2 is supposed to belong to the circuit of subscriber X, a description of

which is very fully given in the explanation of the diagram shown in Fig. 1.

The selective devices at the central station associated with the subscribers' lines converging to the central station are the same for all such lines, and so likewise the apparatus at any subscriber's station is a duplicate of the apparatus at any other subscriber's station.

We proceed to a description of the circuits employed in practising our invention. Details of mechanism will be described later.

The diagram at Fig. 1 is illustrative of these circuits and, indeed, of the general mode of operation; but it is only necessary to show in the diagram, as will hereinafter clearly be seen, and there is represented therein only, first, the substation equipments and line-wires of two subscribers belonging to the exchange; second, the apparatus at the central station, of which all the subscribers make use in common, and, third, the apparatus at the central station appropriated to the same two subscribers whose substation equipments and line-wires are shown.

In describing the different circuits of which use is made we find it convenient to give them numbers. Before proceeding further, however, in explanation of the diagram it should be observed that there is, in fact, in the system delineated but a single battery employed and but a single battery represented, although for the sake of clearness in the drawings it is shown at three places—that is, B′, B², and B³ in the drawings and in the description all indicate precisely the same battery or source of electromotive force common to all the subscribers, and the wires shown as connected with B′, B², and B³ might all be shown as connecting with, for instance, B³. So likewise for economy of space the same battery is shown at B′ and B² with fewer cells than at B³. The same busy tone apparatus D′ and D² is also shown at two places. It is also to be observed that in this specification the source of electromotive force for selecting, signaling, and talking located at the central station and common to all the subscribers is at times called a "common" battery in accordance with general usage, whereas in practising this invention, as frequently is the case in "common" or "central" battery telephone systems, so called, the source of electromotive force may be any generator of electricity.

Now let us suppose that the subscriber at X wishes to establish a connection with the subscriber at Y, and at first let us assume that Y is not busy, and we will also assume that Y is represented at the central station by permanent multiple contact numbered "10." The subscriber at X accordingly turns the pointer of his circuit-closer I to that number "10" on his dial and immediately releases it.

First circuit.—At each resulting impulse a circuit is completed, which for convenience of reference we call the first circuit, (1,) as follows: from the grounded common battery or common source of electromotive force B′ to winding of repeating-coil C′ through selecting or controlling relay R′ to lower contact of relay R³, line-wire L² to ground through circuit-closer I.

Second circuit.—Selecting-relay R′ is thus energized and operated to complete a second circuit (2) as follows: from the common battery B³, wire W¹⁰, contact of selecting-relay R′, selecting-magnet M′, contact of connecting-magnet M² back to battery. Thus selecting-magnet M′ is energized at each impulse received at the selecting-relay R′. The successive movements of the armature of selecting-magnet M′ cause the selector-arm N′ to travel until it reaches a point opposite multiple contact T¹⁰, representing subscriber Y. The selector-magnet M′ at its initial step of selection operates the switch S′, which opens the path to ground through reversing-relay R³ to protect X's line from intrusion, as will presently more fully appear.

Third circuit.—Subscriber X now takes his receiving-telephone from its hook K′, by which a third circuit (3) is established as follows: from common battery B′, lower winding of repeating-coil C′, winding of relay R′, lower contact of relay R², line-wire L² through his own talking apparatus, switch-hook K′, line-wire L′, upper contact of relay R³, winding of relay R², upper winding of repeating-coil C′ back to battery.

Fourth circuit.—By the establishment of this last circuit (3) connecting-relay R² is energized and now operates to close a fourth circuit (4) as follows: from common battery B³, wire W′, connecting-magnet M², wire W², contact of connecting-relay R², wire W³ back to battery. By the establishment of this circuit (4) connecting-magnet M² is energized, thereby bringing the selector-contact or contact-arm N′ into contact with the fixed multiple contact T¹⁰, opposite which it has been brought.

As will presently appear, the selector-contact and fixed multiple contact of the diagram, whose mode of operation is here explained, have been embodied in mechanism shown at Figs. 2 to 9.

The energizing of the connecting-magnet M² breaks the contact between its armature and the contact-point upon which the armature rests, and thereby opens the second circuit (2) above described, which presents waste of battery-power. It may be here observed that connecting-magnet M² remains energized while the calling subscriber's receiving-telephone is off the hook, insuring continued contact between N′ and T¹⁰.

Fifth circuit.—This contact between N′ and T¹⁰ closes a fifth circuit (5) in the apparatus at the central station, which may be called the "testing-circuit;" but it is to be remembered that we have assumed that the line of subscriber Y is disengaged. This testing-circuit (5) is as follows: from the middle point of battery B, wire W⁴, lower contact of testing-

relay R^4, winding of relay R^4, wire W^5, selector-contact N', multiple contact T^{10}, wire W^{14}, winding H^2 of repeating-coil C^2, wire W^6, winding of reversing-relay R^8, wire W^7, lower contact of switch S^2 to ground. This testing-circuit is a subsidiary circuit, and a portion of its conductor is common also to the intermediate portion of the conversation-circuit (7) and to an independent subsidiary circuit, (10,) both presently to be described.

It will be observed that the multiple contact T^{10}, repeating-coil C^2, relay R^8, and magnet M^4 are appropriated to the called subscriber Y and that T^{10} corresponds to T', C^2 to C', R^8 to R^3, and M^4 to M' of the calling subscriber. So, too, R^6 and R^7 correspond, respectively, to R^2 and R'.

The establishment of the testing-circuit 5 energizes relays R^4 and R^8. These relays R^4 and R^8, as well as the corresponding relays R^5 R^3, are of like construction, each working two sets of contacts. Relays R^4 and R^5 we term "testing-relays," and relays R^3 and R^8 are "reversing-relays," the functions of relays R^5 and R^8 being the same in respect to the subscriber's circuit of Y as those of relays R^4 and R^3 are in respect to the line of X. In each relay the middle contact-pieces are supposed to be the armatures acted upon directly by the electromagnet of the relay, the said armatures normally or when in their retracted positions permitting the establishment of contact between the remaining two contact-pieces, while when attracted into their forward positions the said contact is dissolved and a new one substituted between the armature itself and that one of the said two other contact-pieces which is shown as being in front of the said armature.

The reference-letters e e^2, j j^2, v v^2, and f f^2 indicate the armature contact-pieces of the relays R^3, R^4, R^5, and R^8, respectively. The contact-pieces of the said relays wherewith the said armature-contacts engage when attracted are indicated by the letters e^3 e^4, j^3 j^4, v^3 v^4, and f^3 f^4, respectively, and those with which the latter normally engage are indicated by the reference-letters e^5 e^6, j^5 j^6, v^5 v^6, and f^5 f^6.

In the testing-relays R^4 R^5 of the two lines concerned the normal contacts j^4 j^6 and v^4 v^6 maintain the continuity of the testing-circuit (5) between the middle of battery B^3 and the movable contact or selector arm of their respective lines, while their normal contacts j^3 j^5 and v^3 v^5 complete the tone-test circuit, (9,) hereinafter to be described, for a line in the act of calling for another circuit which has called for a third and has established a connection. When on the excitation of said relays the original contacts are disestablished, the new contacts formed between the armature and front contact-pieces j j^3 or v v^3 control the continuity of the intermediate talking-circuits, (7,) also presently to be described, while those formed between the remaining armature and front contact-pieces j^2 j^4 or v^2 v^4 change the test-circuits leading through the windings of the said relays from their connection with the middle of the battery B^3 to one which includes the entire battery and the retardation-coil E.

The normal contacts e^3 e^5 e^4 e^6 f^3 f^5 f^4 f^6 of the reversing-relays R^3 R^8 maintain the continuity of the two line-circuits of X and Y through their controlling-relays R' R^2 and R^6 R^7, respectively, the central-station-battery ground connection and the substation ground connection being so relatively placed that the substation-bells V are between them in one side of the line where there is no battery; but when the reversing-relay magnets are excited and their armatures attracted the normal contacts mentioned above are disestablished and a new one made which (for example, in relay R^8) causes the union of contact-pieces f and f^3 and also f^2 and f^4, the result being that the magnets of the controlling-relays R^6 and R^7 are withdrawn from the talking-circuit, while the relation between the battery B^2 and the two line-wires L^3 L^4 is reversed, so that the bell V at the substation Y is brought into circuit with the battery and is operated by the current thereof and caused to ring and give the necessary call-signal.

Sixth circuit.—The bell-ringing circuit (6) is as follows: ungrounded side of battery B^2, winding of repeating-coil C^2, wire W^9, armature of relay R^8, wire L^4, through bell V to ground. It is to be noted here that X, listening at his receiving-telephone, can hear bell V ring by induction, making use of the talking-circuit which has already been established and has been described as the third circuit, (3,) together with repeating-circuit, (7,) which is as follows:

Seventh circuit.—Starting at ground of condenser E^2, winding H' of induction-coil C', condenser E', armature of relay R^4, wire W^5, contact-arm N', fixed contact T^{10}, wire W^{14}, winding H^2 of repeating-coil C^2, through condenser E^3, back by ground or common return-wire (not shown) to other side of condenser E^2. This repeating-circuit forms the link between talking-circuit (3) of the calling subscriber and the talking-circuit (8) of the called subscriber, next to be described.

Eighth circuit.—Subscriber Y now takes his telephone from its hook, which act cuts out his bell V and establishes his talking-circuit, (8,) as follows: starting at common battery B^2, through lower winding of repeating-coil C^2, wire W^9, upper contact of relay R^8, line-wire L^4, subscriber Y's talking apparatus, line-wire L^3, lower contact of relay R^8, wire W^{12}, upper winding of induction-coil C^2, back to battery. Conversation may now be had by subscribers X and Y over circuits (3, 7, and 8) which are inductively associated together by means of repeating-coils C' and C^2. When conversation is ended, subscribers X and Y replace their receiving-telephones upon their respective hooks. The action on the part of subscriber X releases relays R' and R^2, there-

by opening circuit (4) containing connecting-magnet M^2, the recovery of whose armature withdraws selector-arm N′ from multiple T^{10} and causes it to return to its starting-point. This opens circuit (5) through reversing-relay R^8, the recovery of whose armatures restores the normal relation of the common battery to bell V. When X hangs his telephone on its hook, he is ready to receive or initiate another call, as is also Y.

Let us take up the case of engaged lines, of which there are two classes, a calling engaged line and a called engaged line. First let us assume that Y has called a third subscriber (Z) and when engaged with the third subscriber is called by X. The calling subscriber X operates his circuit-closer just as before and upon placing the receiver to his ear hears a busy-tone signal, which notifies him that Y's line is already in use. This happens as follows: Circuits one,(1,) two,(2,) three,(3,) and four (4) are completed as before; but when N′ touches T^{10} circuit number five (5) through relays R^8 and R^4 is not completed, having been broken at switch S^2 by Y's act of calling Z. It is now seen that any calling subscriber is protected from interruption from a third party by the opening of the circuit to ground at his switch corresponding to S^2. It is not necessary to show Z's circuit or Z's apparatus, as they are identical with circuit and apparatus shown and described when X established a talking connection with Y. Relays R^8 and R^4 therefore are not actuated, which means two things—first, that Y's line is not reversed and his bell is not rung, and, second, that X's talking-circuit is not connected with his selector-arm N′, but with a busy-tone apparatus through the upper contact of relay R^4 and switch S′.

Ninth circuit.—The busy-tone circuit (9) is as follows: from busy-tone apparatus D′, switch S′, wire W^{11}, upper contact of relay R^4, condenser E′, winding H′ of repeating-coil C′, returning through condenser E^2. The alternations in the first winding of repeating-coil C′ are taken up by the other winding and are heard in X's receiver.

Now let us take the case of a busy called subscriber, in which X calls Y, who has been called by Z. Again, it is not necessary to show Z's apparatus, since it is identical with that of X and Y, already fully described. X completes his circuits corresponding to circuits one,(1,) two,(2,) three,(3,) and four,(4,) thereby bringing his selector-arm into engagement with multiple contact T^{10}; but, as in the former case, his testing-relay R^4 remains unoperated and Y's reversing-relay R^8 cannot be affected, having already been operated by the establishment of the existing connection between the lines of Z and Y; but this inaction is now owing to the fact that N′ and T^{10} are at the same potential, because T^{10} is already in contact with N′ of Z—viz., twelve volts, or half the potential of the common battery—and no current flows through relays R^4 and R^8, in accordance with a well-known law that current does not flow between two points at the same potential. To assist in understanding this balance of potential, let us assume temporarily that X has obtained connection with Y and that a third subscriber tests the multiple T^{10} of Y with his selector-arm.

Tenth circuit.—It will be observed that the point T^{10} is midway between the terminals of the common battery B^3 and with an exactly equal amount of resistance on each side, the circuit (10) which may be termed the "lock-out" circuit being as follows: from ungrounded side of the twenty-four-volt common battery B^3, wire W^{10}, forty-ohm retardation-coil E, lower contact of relay R^4, eighty-three-ohm winding of relay R^4, selector-arm N′ to multiple contact T^{10}, making a total resistance to this point of one hundred and twenty-three ohms. Continuing, the circuit back to battery is through wire W^{14}, forty-ohm winding H^2 of repeating-coil C^2, the eighty-three-ohm winding of relay R^8, through switch S^2 to battery, making one hundred and twenty-three ohms resistance between point T^{10} and the grounded side of the common battery B^3. The result of this equal distribution of resistance is to establish the point T^{10} at a potential of twelve volts, or one-half the potential of the common battery B^3. These resistances may of course be of any desired amount, the essential point being to maintain a balance on either side of point T^{10}. The forty-ohm retardation-coil E, besides helping to establish this balance, performs the function of shutting out voice-currents from subsidiary circuit (10) and restricting it to connecting-link circuit, (7.) The condensers E′, E^2, E^3, and E^4 confine the battery-current to subsidiary circuit, (10,) but permit the voice-currents to pass freely along connecting-link circuit, (7.)

It remains to show why N′ or the selector-arm of any calling subscriber is at a potential of twelve volts, and the explanation is that the selector-arm is in direct connection with the middle or twelve-volt point of the twenty-four-volt common battery B^3, the circuit being from said middle point, wire W^4, lower contact of relay R^4, winding of relay R^4, wire W^5, calling-subscriber's selector-arm, as shown in the testing-circuit, (5,) before described, up to the point T^{10}; but in this case no current will flow through the circuit, (5,) since the selector-arm of the calling subscriber is at the same potential as the multiple contact T^{10}. Therefore the testing-relay of the calling subscriber and the reversing-relay of the called busy subscriber will not be actuated. The results of protection on the one hand to the called subscriber and notice by busy-tone signal on the other hand to the calling subscriber follow precisely as when the calling subscriber by the act of cutting off his own ground at the selector-rod switch rendered inoperative his own revers-

ing-relay, and hence so far as he is concerned the testing-relay of any calling subscriber. In other words, when the selector-contact of a calling subscriber touches one of the multiple contacts of a subscriber's line already in use the testing-relay of the calling subscriber does not receive current requisite for its operation. So, too, the multiple contacts of a subscriber's line when in use are in such electrical relation to the selector-contact of any calling subscriber that they prevent the passage of current requisite for the operation of the relay used to complete the talking-circuit of the calling subscriber.

It is obvious that a common metallic return may be substituted for the ground of the second windings of the repeating-coils at the central station, and, in fact, such metallic return is used, the grounded construction being shown merely for clearness. It is obvious, also, that increased simplicity and economy in the construction of circuits and apparatus at the central station result from the use of this common return for the second windings of the repeating-coils, since for all connections made in signaling, testing, and talking but a single wire is required. However, we do not confine ourselves to the use of a single wire for this purpose, as the system can be operated quite as well, although at greater initial expense, on a two-wire basis and without other essential modification.

Central-station apparatus.—Thus far the description has been almost wholly confined to electrical circuits, which, while forming a distinct feature of our invention, might be employed to advantage in the operation of electromechanisms already in use in automatic exchanges. Our invention, however, as stated above, consists in part in the construction and arrangement of electro mechanisms or apparatus, as well as circuits, and we proceed to describe electromechanisms employed at the central exchange, which, while a part of the present invention consists in their adaptation to or combination with the circuits already described, might as to some of their features be employed with advantage in circuits of former automatic exchanges.

The selecting instrument at the central station has been referred to in general terms as the "selector-arm" or as the "movable contact-arm," &c., and it has appeared that it has two movements, one a step-by-step motion, by which the contact-arm is brought opposite a desired multiple contact belonging to a called subscriber, and the other a rotary motion, by which the contact-arm is at any time brought into connection with the multiple contact opposite which it happens to be. As in former automatic telephone-exchanges, two movements at right angles to one another are caused by the use of separate magnets separately energized. The peculiar arrangement of the selector instrument or the way in which it is combined with the two operating-magnets and their armatures is as follows: A long rod with the selector-arm projecting at right angles from its upper end passes freely through both said operating-magnets and through the armatures of both magnets, while a pawl-and-ratchet mechanism operated by the reciprocating movement of the armature of one of the magnets when a connection is desired serves to move the rod step by step longitudinally and hold it in the advanced position. The rotary movement of the rod to turn the selector-arm into contact with a desired multiple contact is obtained by giving to the other magnet a rotating armature and making provision that the rod shall turn with such armature, although at liberty to pass through it longitudinally. The rotating armature and rod turn together in either direction, and the turning of the armature in either direction must turn the rod in the same direction. Again, the release of the selecting mechanism or the manner of its restoration to its normal position of rest is another striking feature of this branch of the invention. The release contrivance is as follows: The two magnets are placed end to end with their armatures between them, or, as shown, the magnet with the reciprocating armature is placed directly above the magnet having the rotating armature; but while the reciprocating armature is below its magnet the rotating armature is above its magnet. Between the two armatures is a disk of convenient thickness, which carries the retaining-pawl of the pawl-and-ratchet mechanism, the rack of which is upon one side of the rod that carries the selector-arm. The rod in its longitudinal movement passes freely through the disk as well as through the magnets and armatures. The lifting-pawl is carried by the reciprocating armature. It is obviously necessary that the two pawls shall always have the same relation to each other, one holding or making good what the other lifts, and in order that the holding or retaining pawl may continue to engage the rack when the rod is rotated it is necessary that the disk shall turn with the rotating armature. This is accomplished by providing the disk with a downwardly-projecting pin against which the rotating armature strikes when turning to rotate the rod, and to turn the reciprocating armature and the upper pawl the disk is provided with two pins rigidly fixed therein, but projecting upward through the reciprocating armature, having clearance in the latter, so as not to interfere with its reciprocating movement. Now when current ceases to flow through the magnet provided with the rotating armature that armature is released and returns by the help of a spring to its normal position and carries back with it the rod. This disengages the pawls from the rack upon the rod, and they now are in contact with one of the smooth sides of the rod, which also with the help of a spring returns to its normal position. The rod when cleared from the

pawls has clearance in its longitudinal motion through both armatures, both magnets, and the disk. Provision is made, however, that the rod just as it reaches its normal position shall cause the disk, and consequently the reciprocating armature, to return to their normal positions ready for the pawls to engage the rack to make another call when required.

The apparatus for making connections, together with the corresponding releasing or restoring devices, is clearly shown at Figs. 2 to 9, where F′ is the sliding rod appropriated at the central station to a subscriber X of the exchange. F^2 and F^3 are similar sliding rods appropriated to subscribers Y and Z, having precisely the same environment and mode of operation as rod F′, and therefore, except where otherwise stated in terms, this description is confined to sliding rod F′ and its cooperating accompanying mechanism. J is the supporting-frame of the central exchange. T′ to T^{10}, &c., are the fixed multiple contact-points, a separate set of which is provided for each sliding rod F′ F^2, &c., belonging to the exchange. These points T′, &c., are supported on the frame J, as shown, and are connected up as in ordinary multiple switchboards. (See Fig. 2.) M′ is the magnet by whose action the step-by-step longitudinal motion is imparted to rod F′, the said magnet M′ being provided with a reciprocating armature *c*, which carries a plunger-pawl 1, that engages with a rack *b*, cut in one side of the rod F′, and lifts the rod one step whenever the magnet is energized. M^2 is the magnet by whose action a rotary movement is imparted to the rod F′, the said magnet M^2 being provided with a rotary armature *g*, arranged to rotate through one-quarter of a revolution when the magnet M^2 is energized. The magnets M′ and M^2 are held between projections 23 and 24 from the frame J, and these projections, together with a long tube 7, rigidly connected with armature *c*, and tube 8, rigidly connected with armature *g*, serve as guides for the rod F′ in its longitudinal movements. Further guidance for said rod is furnished by projection 22. The rotary armature *g*, as already stated, is above its magnet M^2, while the reciprocating armature *c* is below its magnet M′. The disk *d*, as also before stated, is located between the two said armatures, a downwardly-projecting pin 6 causing said disk *d* to turn in one direction with armature *g* when the armature strikes against it. Armature *c* rests upon disk *d*, and disk *d* lies upon armature *g*. A stop-pawl 2, which, like pawl 1, is a plunger-pawl, is carried by disk *d*, and the said pawl 2 and disk *d* are constantly associated with armature *c* by pins 3 and 4, which pass with clearance through holes 14 and 15 in armature *c*, said clearance allowing the armature *c* to rise and fall as magnet M′ is alternately energized and deënergized. These pins 3 and 4 serve the further purpose of holding down the disk *d*, in which they are embedded, their upper ends pressing against the magnet M′. A helical spring 12 assists in the recovery of the armature *c* after each lifting movement. The stop-pawl 2 holds the rod F′ in the position to which it is raised by pawl 1. Both pawls tend to engage the rack *b* of the rod by virtue of springs 10 and 11 at their outward extremities. We shall see presently that when disk *d* is rotated and removes holding-pawl 2 from engagement with the rack armature *c* by virtue of pins 3 and 4 turns with the disk and removes also pawl 1 from engagement with the rack.

N′ is the contact-arm rigidly attached to rod F′ and normally below the multiple contacts T′ T^{10}, &c., the rod F′, from which it projects, resting normally on switch S′, the operation of which has been explained.

The rod F′ has easy clearance through the tubes 7 and 8 and also easy clearance through the disk *d* and armature *c;* but in order that the rotating armature *g* may turn with rod F′ and that rod F′ may turn with rotating armature *g* the hole through the latter for the passage of the rod in its longitudinal movement is made square to conform to the shape of the rod.

The rod F′ is kept from accidentally rotating out of position by spiral spring *h*, attached to tube 8, upon which armature *g* is mounted, said spring holding armature *g* firmly against stop 5 and armature *g* holding in place rod F′ by its square hole. A locking mechanism for armature *c* consists in a slotted collar *m*, rigidly secured to tube 7, and a stop 29, pivoted to projection 23 from the frame J. When armature *c* turns, which it does when rod F′ is turned to bring contact-spring N′ into contact with a multiple point—for instance, T^{10}—the slotted collar *m* turns also, bringing its slot 13 into engagement with an arm of stop 29, and thus preventing the recovery of armature *c*, and consequently disk *d*, independently of pressure from armature *g* of the still energized magnet M^2. It will be remembered that this latter magnet remains energized during all the time that the receiver of the calling subscriber is off the hook. The rotary movement of the armature *c* and tube 7, rigidly attached thereto, is made against the pressure of spiral spring 9, attached to the upper end of tube 7 and projection 23. The operation of these instruments in selecting and connecting is as follows, X being the calling subscriber: Each time the substation circuit-closer I energizes magnet M′, as explained in connection with Fig. 1, the armature *c* and pawl 1 by engagement with rack *b* lift rod F′ one tooth. If each step lifts the rod a distance equal to that separating the multiple contact-points, ten steps will raise the rod F′ and contact-spring N′ to a place where the latter is opposite (but not in contact with) the multiple point T^{10} of subscriber Y. It is obvious, however, that the selector can be arranged to take more than one step per subscriber, the essential feature in practice

being the employment of an equal number of steps for each subscriber. When the calling subscriber X takes up his receiver, magnet M^2 is energized, as already explained in connection with Fig. 1, and its armature *g* rotates one-quarter of a revolution, turning with it the rod F′ and spring N′ and also the disk *d* and armature *c* for the following reasons: First, the rod F′ is turned because of the fit between its square corners and the square hole in the center of armature *g;* second, the disk *d* is turned because its fixed pin 6 is caught and pressed upon by the side of armature *g;* third, the armature *c* is turned by the pins 3 and 4 embedded in disk *d* which pass through holes 14 and 15 in armature *c*. When rod F′ is turned, contact-spring N′, attached to one of its faces, is brought firmly into contact with the multiple point T^{10}, thus connecting X's circuit with that of the chosen subscriber Y. Up to this point the pawls 1 and 2 are still engaged with rack *b*, both the rack and the pawls having rotated together through the same distance. The upper portion of this group—viz., the armature *c* and disk *d*—is being held out of normal position against spiral spring 9. The lower portion—viz., armature *g*—is being held out of normal position against spiral spring *h*. When the calling subscriber hangs up his receiver, magnet M^2 is deënergized and its armature *g* flies back to its initial place under pressure from spiral spring *h*. With it turns the square rod F′ because of the square hole in armature *g* as already described. The upper portion of the group remains behind, being detained by stop 29 and slot 13. The rod F′ is now free to fall because its contact-arm N′ has been turned away from the multiple point T^{10} and because its rack *b* has been turned from engagement with pawls 1 and 2, which now bear ineffectively upon one of the smooth sides of the rod F′. When the rod has fallen almost to the end of its limit, the tapering collar *k* strikes against the upper face of stop 29, disengaging it from slotted collar *m*, and thereby releasing armature *c* and disk *d*, which are restored by spring 9, pin 6 limiting said retrogression by striking upon and resting against armature *g*. This restoration swings the pawls 1 and 2 into reëngagement with rack *b* and X's apparatus is now in condition to initiate another call.

To assist in associating Figs. 2 and 3 with Fig. 1, it should be noted that switch S′ is actuated by the rise and fall of rod F′. It should also be noted that the contact of magnet M^2 (indicated in Fig. 1 for sake of clearness as an armature-contact) is in practice separated from it and located at any convenient point, as at A′ in Fig. 2, where it takes the form of a commutator rotated by rod F′, which it will be remembered is turned by rotating armature *g* of magnet M^2.

Substation circuit-closer.—The substation circuit-closer is illustrated by Figs. 10 and 11, of which Fig. 10 is a front elevation and Fig. 11 a side elevation. The inner mechanism is mounted upon the cover *z* of the box *y*, on the outside of which are an arm *n* and handle 27, rigidly attached to the central shaft 21, a numbered and perforated circular plate *t*, and a peg *u* for insertion therein. Within the box is a second arm 25, also rigidly attached to shaft 21. Upon the extremity of arm 25 is a pawl 16, which engages with a spur-gear *o*, loosely mounted upon shaft 21. A spiral spring *s* has one end attached to shaft 21 and the other end to post 28. A pinion *p* meshes with gear *o* and turns a star-wheel *q*, with which engages the weighted escapement *r*, whose reciprocal play is utilized to close and open the contact-points at *x* by the arm 26.

The operation of calling is begun by the insertion of plug *u* in the numbered hole of the desired subscriber, as 10. The arm *n* is then moved by the subscriber in a clockwise direction until it is stopped by plug *u*. The subscriber thereupon removes his hand from handle 27, and the arm *n* by the power stored in spring *s* by his act begins to return. Now when the arm *n* was moved, as just described, the arm 25, rigidly attached to shaft 21, moved also and through an arc of precisely the same degree as that of arm *n*. While the arm 25 moved, its pawl 16 slipped backward ineffectively over ten of the teeth of gear *o*, which remained stationary, being steadied and held by the stop-pawl *w*. When shaft 21 begins its contraclockwise rotation, the arm 25 by means of pawl 16 now engages and turns gear *o* and also pinion *p* and star-wheel *q*, whose escape *r* retards and regulates said return movement. The arm 26, mounted rigidly upon the same shaft as the escape *r*, alternately presses together and allows to separate the contact-springs 18 and 19, thereby closing and opening the circuit to ground, explained in connection with Fig. 1, in this instance ten times. The return motion of shaft 21 is stopped by pawl 16 coming against stop *w* and by arm *n* striking post 17. The device is now in readiness for the initiation of another call. Wherever the peg *u* is set, the arm 25 and pawl 16 pick up the idler-gear *o* and move it through a distance always the same for a given peg-hole, each hole in the plate *t* representing one tooth of the gear *o* and of the pinion *p*, and hence of the star-wheel *q*, which has the same number of teeth as pinion *p*.

We claim—

1. In a central-battery automatic telephone-exchange, the combination with telephone-lines converging to a central station from two or more subscribers' stations, signaling and talking apparatus at each subscriber's station, and multiple contacts at the central station for each subscriber's line, of a source of electromotive force at said central station common to all the subscribers for connections and disconnections, signals and conversations, and electromechanisms at said central station operated from said source of

electromotive force at said central station by circuit closing and switching devices included in said signaling and talking apparatus at said subscribers' stations, substantially as described.

2. In a central-battery automatic telephone-exchange, telephone-lines converging from two or more subscribers' stations to a central station and an outfit at each subscriber's station consisting of a telephone or telephones, bell, telephone-lever and circuit-closer, in combination with, at said central station, a source of electromotive force common to all the subscribers for connections, disconnections, signals and conversations, representative contacts one or more for each subscriber's line and electromechanisms operated from said common source of electromotive force and appropriated, a separate set thereof, to each subscriber's line, substantially as described.

3. In an automatic central-battery telephone-exchange, the combination at the central station with multiple contacts appropriated to the line of one subscriber, a selector-arm belonging to another subscriber, metallic talking-circuits of the two subscribers energized from a common source of electromotive force at the central station and a talking or connecting link between them, of a testing-relay in a subsidiary circuit from said common source of electromotive force and adapted when energized to close the circuit of said connecting-link, the said relay being so arranged as not to receive current when the link to which said multiple contacts belong, is busy, substantially as described.

4. The combination with the permanent multiple contacts and a selector-arm at the central station, of a testing-relay also at said central station, a subscriber's metallic circuit which includes his equipment at his own station and one winding of a repeating-coil and the common battery at the central station, an incomplete circuit from the middle of said common battery through the winding of said relay to the said selector-arm, and a second incomplete circuit from a common return-point at the central station through the other winding of said repeating-coil to one of the contact-springs of said relay, the arrangement being such that the first-mentioned incomplete circuit through the winding of the relay is only completed by contact made between the said selector-arm and the multiple contact or contacts of a line not in use, and the second incomplete circuit is only completed by the operation of said relay, substantially as described.

5. In a central-battery telephone-exchange, multiple contacts belonging to one subscriber's line, a selector-arm belonging to another subscriber's line, and means for making contact between said arm and one of said multiple contacts in a circuit including a common source of electromotive force at central station, and a reversing-relay in a subsidiary circuit from said common source of electromotive force adapted to be energized when contact is established between said selector-arm and a multiple contact, in combination with a bell at a subscriber's station normally grounded at said station and normally connected through the contacts of said reversing-relay with the grounded side of the said source of electromotive force at said central station so that current flows through said bell only when said reversing-relay is energized and its contacts thereby reversed, substantially as described.

6. In a common-battery automatic telephone-exchange the combination at the central station of a number of pairs of line conductors, each pair composing a main telephone-circuit leading from a substation and having an associated selector-arm or movable terminal and a fixed contact-terminal adapted to be engaged by the movable terminal of other substation-circuits, with a repeating-coil for each pair of line conductors, one winding of which is in circuit with said pair of conductors and a source of electromotive force common to all the main circuits, while the other winding of said coil is grounded at one end and branches at the other end, one branch extending to the fixed contact-terminal associated with said pair of line conductors, and the other branch being normally open, substantially as described.

7. In a common-battery automatic telephone-exchange, two or more metallic telephone-circuits converging from several substations to the central station each including at said central station a source of electromotive force common to them all for connections, disconnections, signals and conversation, and one winding of a separate repeating-coil, in combination with an equal number of local circuits at said central station, each including the other winding of one of the said separate repeating-coils, and a common return, with means of uniting any two of said local circuits, substantially as described.

8. In apparatus appropriated to a subscriber at the central office of an automatic telephone-exchange, the combination of multiple contacts, selecting mechanism, the subscriber's talking-circuit, a reversing-relay through whose armature-contacts the said subscriber's talking-circuit passes, a switch normally closed but adapted to be opened by said selecting mechanism, a circuit from said multiple contacts through said switch and the winding of said reversing-relay, and means for operating said selecting mechanism, substantially as described.

9. In a central-battery automatic telephone-exchange, the combination with the source of electromotive force at the central station of a grounded bell at each subscriber's station, a reversing-relay and one winding of a repeating-coil for each subscriber at the central station, and means for energizing said relay, the said bell being normally connected

with the grounded side of said source of electromotive force through said winding of the repeating-coil and one of the armature-contacts of said relay, and the ungrounded side of said source of electromotive force being normally connected with another of the said armature-contacts, substantially as described.

10. In a central-battery automatic telephone-exchange, the combination with the source of electromotive force at the central station of a grounded bell at each subscriber's station, a reversing-relay for each subscriber at the central station, and means for energizing said relay, the said bell being normally connected with the grounded side of said source of electromotive force through one of the armature-contacts of said relay, and the ungrounded side of said source of electromotive force being normally connected with another of the said armature-contacts, substantially as described.

11. In a central-battery automatic telephone-exchange, the combination with the common source of electromotive force and a busy-tone apparatus, and multiple contacts appropriated to one subscriber at the central station, of apparatus appropriated to another subscriber at the central station, consisting of selecting mechanism, a talking-circuit, a testing-relay through whose armature-contacts the said talking-circuit passes, a switch normally opened but adapted to be closed by said selecting mechanism, a normally open circuit from said busy-tone apparatus through said switch and contacts of said testing-relay to the said talking-circuit, a third circuit also normally incomplete from the middle point of said common source of electromotive force through the winding and contacts of said testing-relay to the selector-arm of said selecting mechanism, and means for operating said selecting mechanism, substantially as described.

12. In a central-battery automatic telephone-exchange, the combination with the common source of electromotive force and a common busy-tone apparatus, and apparatus appropriated to a subscriber at the central station consisting of multiple contacts, one winding of a repeating-coil, a talking-circuit embracing said repeating-coil, a reversing-relay, a normally closed switch, and a normally open circuit from said multiple contacts through said winding of said repeating-coil, the winding of said reversing-relay and said normally closed switch to ground, of apparatus appropriated to another subscriber at the central station, consisting of selecting mechanism, a talking-circuit, a testing-relay through whose armature-contacts the said talking-circuit passes, a switch with two sets of contacts, one set normally opened but adapted to be closed by said selecting mechanism, and the other normally closed but adapted to be opened by said selecting mechanism, a second normally open circuit from said busy-tone apparatus through the first of said set of contacts of said switch and contacts of said testing-relay to the said talking-circuit, a third circuit from the common source of electromotive force through the other set of contacts of said switch to ground, a fourth circuit also normally incomplete from the middle point of said common source of electromotive force through the winding and contacts of said testing-relay to the selector-arm of said selecting mechanism, and means for operating said selecting mechanism, substantially as described.

13. In a central-battery automatic telephone-exchange switch apparatus, a lock-out circuit extending between the terminal poles of the common source of electromotive force, the movable terminal appropriated to one subscriber's circuit and a fixed terminal appropriated to another subscriber's circuit included therein and connected with the two poles of said source respectively, and equal resistances interposed between the said movable and fixed main-circuit terminals and the said poles to which they are respectively connected, substantially as described.

14. In a central-battery automatic telephone-exchange switch apparatus, the combination with two substation main circuits united for through communication, and an established subsidiary or lock-out circuit therefor comprising the common source of electromotive force, the united selector-arm or movable terminal of one, and fixed terminal of the other of said main circuits, and equal determinate resistances between the said main-circuit movable and fixed terminals, and the poles of said source respectively, of a third substation or main circuit, also provided with a selector-arm or movable terminal, a testing-relay therefor, and an associated incomplete testing-circuit extending from the middle of said source through the exciting-coil and contacts of said relay to the movable terminal of said third main circuit, substantially as and for the purposes set forth.

15. In an automatic telephone-exchange, the combination with multiple-contact points, of a selecting mechanism consisting of a sliding rod provided with a rack upon one side thereof and a selector-arm projecting therefrom, an electromagnet and reciprocating armature, the latter carrying a pawl to engage said rack and move it longitudinally, a second electromagnet provided with a rotating armature, said armature being adapted to rotate said rod in either direction, and means for energizing said magnets, substantially as described.

16. In an automatic telephone-exchange, the combination with multiple-contact points, of a sliding rod provided with a contact-arm projecting therefrom and a rack, an electromagnet provided with a reciprocating armature through the center of which the said sliding rod may freely pass and turn, an actuating-pawl mounted on said armature

to engage said rack, a stop-pawl, a second electromagnet having a rotating armature through the center of which the said sliding rod may freely pass but in which it cannot turn, and means for energizing said magnets, substantially as described.

17. In an automatic telephone-exchange selecting mechanism consisting of a sliding rod having a rack upon one side thereof and a selector-arm projecting therefrom, a magnet provided with a reciprocating armature having an actuating-pawl thereon to engage said rack and move it longitudinally, a magnet provided with a rotating armature, said armature being adapted to rotate said rod in either direction, a disk carrying a holding-pawl to engage said rack, and means for energizing and deënergizing said magnets, the said rod having free clearance longitudinally through said disk and through both said magnets and said armatures, and the said reciprocating armature and disk being so locked together that while the armature is free to move reciprocatingly in the longitudinal direction of the rod independently of the disk, the said reciprocating armature and disk rotate together in either direction either imparting its rotary motion to the other, and the said disk is so related to the said rotary armature that it is rotated by the movement of the armature in one direction only and the armature is free to rotate in the opposite direction independently of the disk, substantially as described.

18. In an automatic telephone-exchange, the combination with substation telephone-lines converging to a central station, signaling and talking apparatus at each substation, and fixed multiple contacts at the central station for each substation-line, of a source of electromotive force at said central station for connections and disconnections signals and conversation, and electromechanism at said central station operated from said source of electromotive force at said central station by circuit closing and switching devices included in said signaling and talking apparatus at substations, substantially as set forth.

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