

No. 709,739.

A. M. BULLARD.

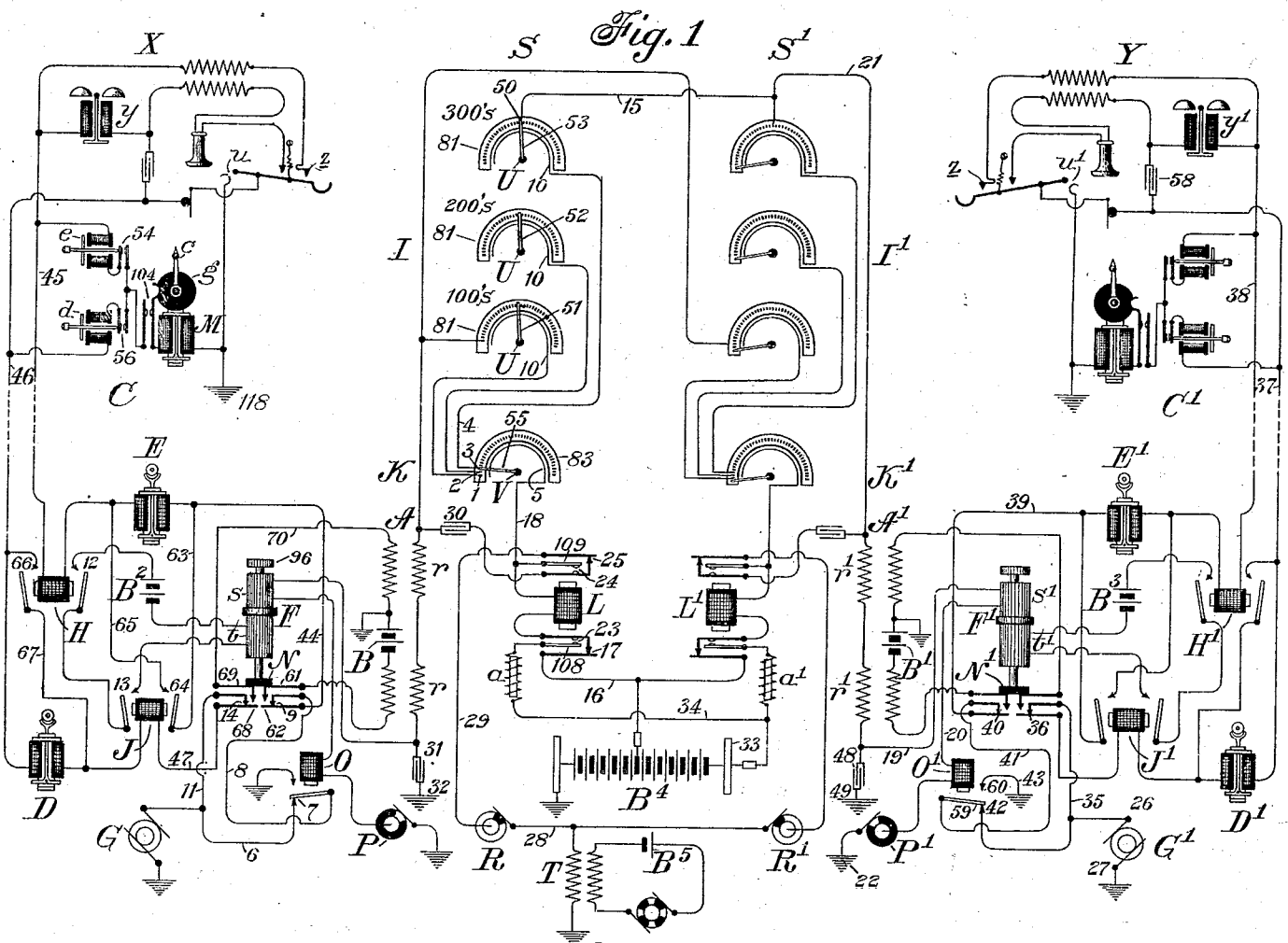
Patented Sept. 23, 1902.

AUTOMATIC TELEPHONE EXCHANGE.

(Application filed Nov. 16, 1900.)

(No Model.)

4 Sheets—Sheet 1.



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J. C. Lockwood,
Per my hand

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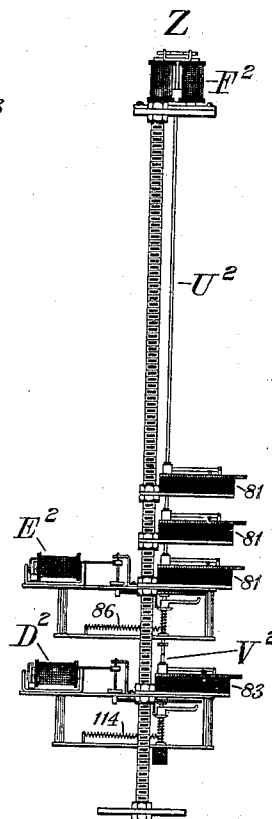
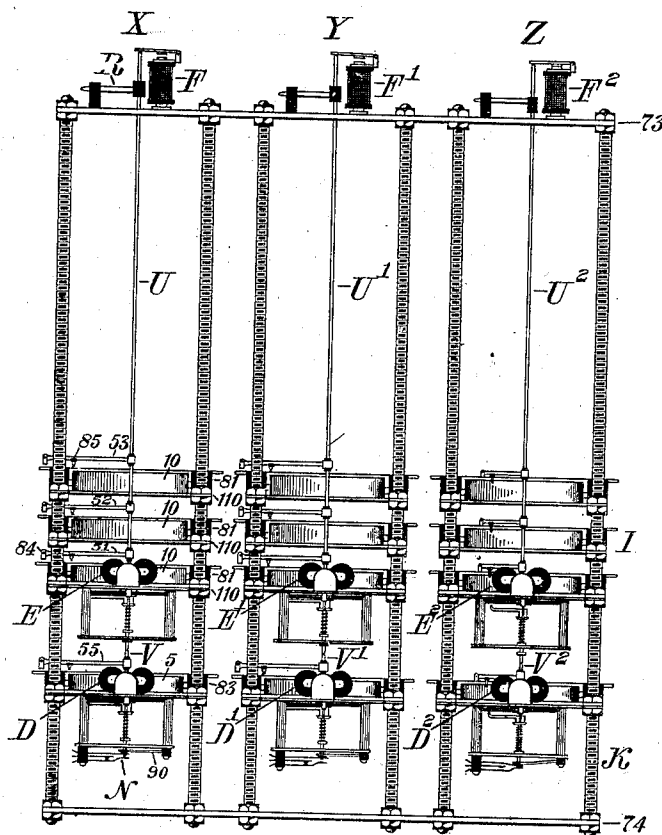
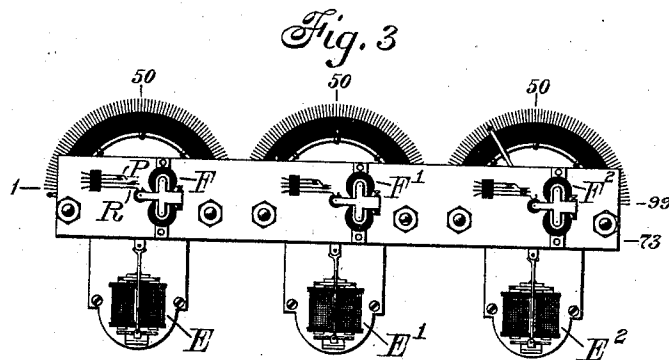
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4 Sheets—Sheet 2.



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Fig. 5

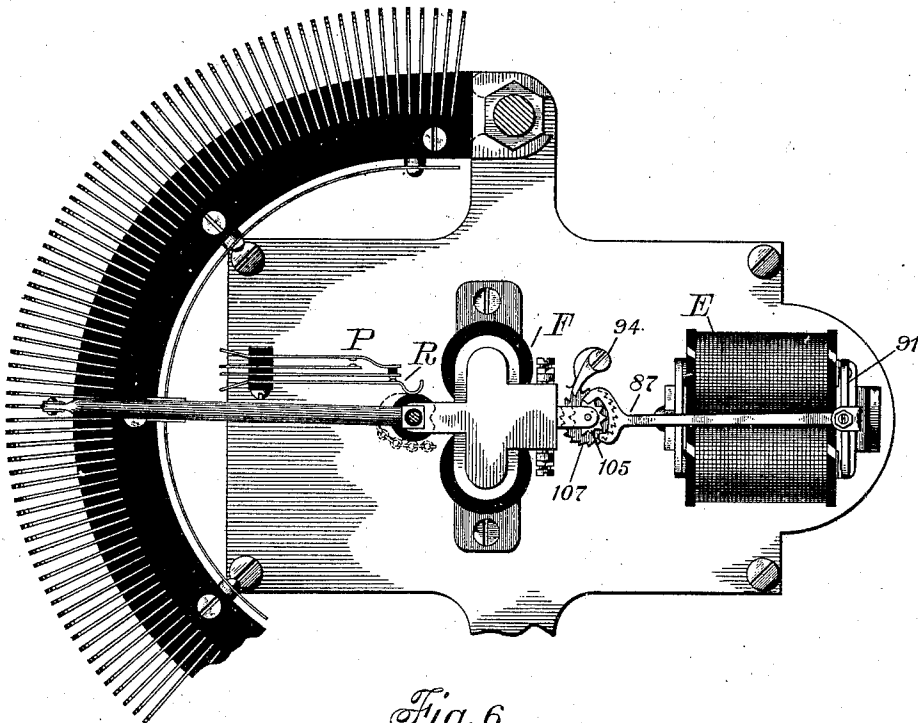
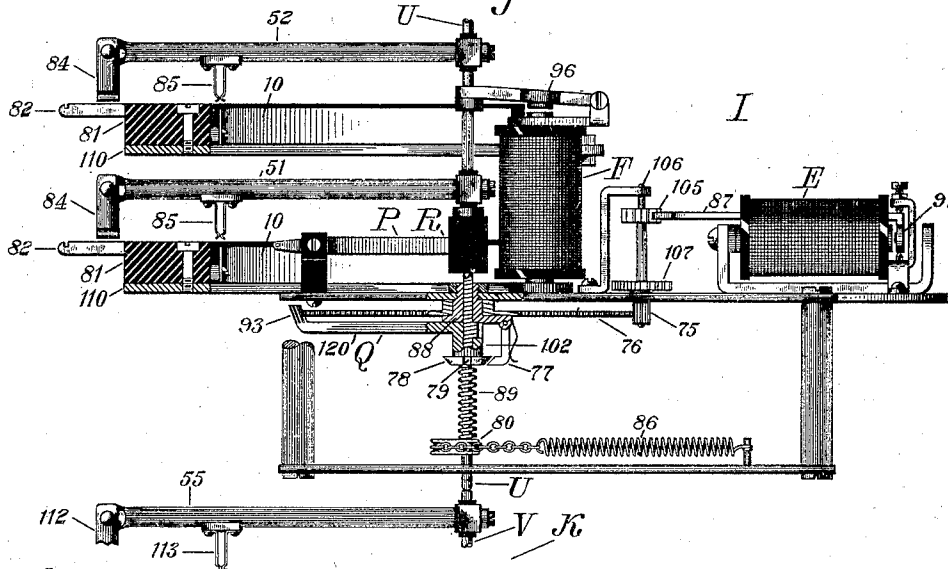


Fig. 6



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Fig. 8

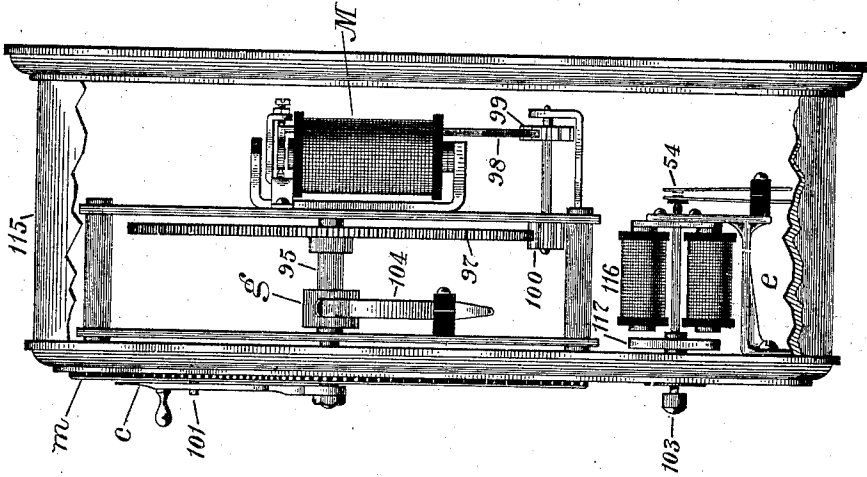
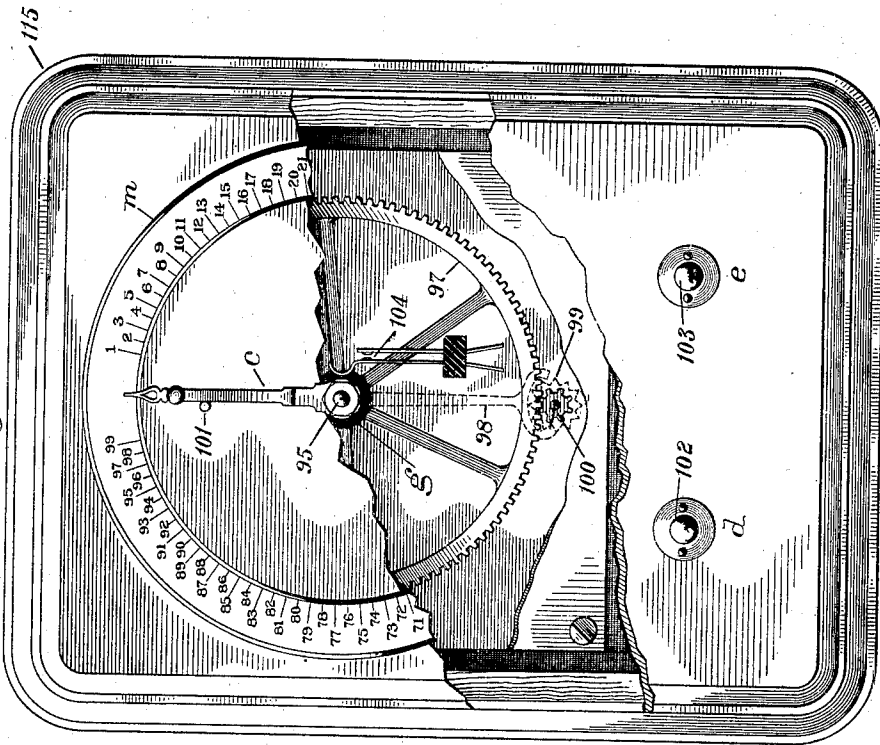


Fig. 7



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UNITED STATES PATENT OFFICE.

ALBERT M. BULLARD, OF SOMERVILLE, MASSACHUSETTS, ASSIGNOR TO THE AMERICAN BELL TELEPHONE COMPANY, A CORPORATION OF MASSACHUSETTS.

AUTOMATIC TELEPHONE-EXCHANGE.

SPECIFICATION forming part of Letters Patent No. 709,739, dated September 23, 1902.

Application filed November 16, 1900. Serial No. 36,770. (No model.)

To all whom it may concern:

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

The invention has especial reference to automatic telephone exchanges whose source of electromotive force for connections, disconnections, signals, and conversation is located at the central station. It includes, however, mechanisms and details of mechanisms located at each subscriber's station and mechanisms and details of mechanisms located at the central station, whose use is not limited to an exchange in which the force of electromotive force for all the purposes enumerated is located at the central station.

A leading object of the invention is provision for the expansion or enlargement of the exchange. So, too, great rapidity in forming connections between subscribers has been attained.

The invention is an improvement upon an automatic telephone-exchange system jointly invented by Malcolm C. Rorty and myself which forms the subject-matter of an application for a patent filed August 9, 1900, Serial No. 26,441. Accordingly many of the features of the joint application, more especially those relating to the circuits, necessarily appear in the present description, some of them without modification. The principal features which distinguish the present invention from the said joint invention and from others of the general character of the present invention are, first, the use of alternating-current waves to actuate selecting and connecting mechanism at the central station in synchronism with mechanism under the control of the operator at a substation; second, the use of alternating current for both synchronizing and actuating, selecting, and connecting mechanism at the central station and mechanism at the substation; third, the use of a device at the substation which moves in synchronism with a similar device at a distance, the former adapted to break the

circuit through both when it has moved its arm or pointer a predetermined distance, thereby stopping the arm or pointer of the distant device at a corresponding point of travel; fourth, an alternating-current generator located at the central station and adapted to send out its current to the subscribers' stations for the purposes of selection and connection; fifth, to facilitate the process of selection, the division of each subscriber's number into two parts—the first part representing the hundreds and the second part representing both the tens and units—and the employment of an independent mechanism to select each part; sixth, in actuating the selector, the use of several (rather than one) waves or cycles of alternating current per each subscriber's contact-point in the multiple, and a self-centering selector-arm, in order to compensate for slight deviations from perfect synchronism.

The invention includes, further, various details of mechanism and modifications of circuits hereinafter fully set forth and explained.

The apparatus employed at each substation includes transmitting and receiving telephones, a bell, a condenser, a telephone-lever or similar switching device, a circuit-breaker, and hand-switches. With the exception of the last two these devices are of familiar construction. Each subscriber has what is commonly called a "metallic" circuit, or two line-wires leading to the central station. For talking purposes they are strictly in metallic circuit; but, as in many other telephone-exchanges, use is made of both line-wires in grounded circuits for other purposes. A novel feature consists in the momentary connection of both sides of the subscriber's line to ground for a purpose not attained by grounding simply one side or by simply bridging the line.

The apparatus at the central station includes an alternating-current generator common to all the subscribers for making connections and for signaling and a battery common to all the subscribers for conversation and to assist in making connections. Each subscriber is also represented at the central station by a selecting and connecting mechanism

anism, the selecting device of which is in two parts, (corresponding to the division of the subscriber's number,) herein termed the "hundreds-selector" and the "tens and units selector," and also by relays and other electromechanisms for operating his said selecting and connecting mechanism and for forming testing, signaling, and talking circuits. Only such of these devices as are new will be particularly described. Each subscriber, as in other exchanges of the same general character, is further represented at the central station by a number of multiple contacts, with a separate one of which any other subscriber may make electric connection by his respective selecting and connecting mechanism. These multiple contacts are normally in connection with the talking-circuits of the subscribers represented by them; but the selector-arms belonging to each subscriber's selecting and connecting mechanism are not normally in connection with the talking-circuit of said subscriber.

In the drawings, Figure 1 is a diagrammatic illustration of the mode of operation of the system. Fig. 2 is a general view of the front elevation of three central selecting and connecting devices belonging to subscribers X, Y, and Z, and Fig. 3 is a plan of the same. Fig. 4 is a side elevation of the selector of Z, which is shown with its selector-arms in engagement with the multiple and "hundreds" contacts. Figs 5 and 6 represent in detail the construction of the essential parts of one selective device. Figs 7 and 8 show by front and side elevation, respectively, the substation synchronous circuit-breaker.

Like letters and figures refer to like parts wherever used, but repetitions of letters and figures for like parts are very generally avoided for the sake of clearness. The figure 1 or 2 added to a letter usually indicates a device belonging to some other subscriber that is similar to the device belonging to subscriber X indicated by the same letter without the figure.

The system in which the invention has been embodied and, indeed, the invention itself will be most readily understood by tracing on the diagram at Fig. 1, with occasional reference to other figures, the operation by which two substations are connected at the central station. Many of the mechanisms employed are well known and are represented by the usual conventional symbols. Such mechanisms as are new and are in themselves embodiments of features of the invention will first be described.

Central-station apparatus.—The subscriber's selecting and connecting mechanism at the central station is shown in diagram at Fig. 1 and in sufficient detail as to actual construction of instruments at Figs. 2, 3, 4, 5, and 6. Referring first to the figures representing actual construction, and more especially to Figs. 2, 3, and 4, 73 74 represent a general framework supporting the selecting and con-

necting mechanism of three subscribers, including three sets of multiple contacts, a separate set for each of three selecting and connecting mechanisms. Confining the description, except where otherwise necessary, to one of the selecting and connecting mechanisms—viz., that designated X—110 110 110 are three semicircular strips of metal one above the other supported at their ends by the framework 73 74 and carrying each a semicircular block of insulating material 81, in each of which are embedded multiple contacts in the form of strips projecting from the periphery of the blocks, as shown. The multiple contacts in each semicircular block are numbered from 1 to 99, and each has at its outer end a notch 82, by which it is permanently connected with the multiple wires of the central station. Corresponding numbers in the different rows are in the same vertical plane. U is a vertical shaft supported in the general framework. It has a rotary and longitudinal motion, as will be described, and carries insulated therefrom three fixed selector-arms 51 52 53, one above the other in the same vertical plane and one over each set of multiple contacts to pass thereover from end to end as the vertical shaft U rotates. Each selector-arm 51, &c., is provided with a double spring 84, which upon the depression of the vertical shaft embraces and makes electrical contact with that portion of any multiple contact projecting beyond the block of insulating material 81. These springs are made self-centering by bending the tip of each outward, so as to form a V-shaped end, which guides itself into contact with the multiple strips. Each selector-arm is also provided with a second double spring 85, which is adapted to make contact with a continuous curved contact-strip 10, that lies close to and parallel with the semicircular block of insulating material 81. Rotary motion is imparted to the shaft U by the polarized electromagnet E, whose rocking armature 91, by means of an escape 87, rotates a star-wheel 105, mounted upon shaft 106, which in turn carries a pinion 75, engaging with spur-gear 76 (the latter upon a fixed bushing 88) and imparting motion by means of a mechanical clutch Q to said vertical shaft U. The star-wheel 105 moves forward one tooth for each wave of alternating current. The relation of the pinion 75 to the spur-gear 76 is such that several waves are required to rotate the selector-arm from one multiple point to the next. The clutch is of peculiar construction, consisting of an arm 120, projecting from a hub 120, keyed to the shaft U and adapted to move up and down upon said shaft, the said arm terminating in an oblique tip, in which are teeth 93, adapted to engage the teeth of the gear 76. The clutch is normally held in engagement with the gear 76 by means of a spiral spring 89, but may be released from such engagement by a depression of the shaft U, carrying it

downward, in which depressed position it is locked by a spring-catch 77, falling back of a shoulder 78 on the hub of the clutch. A ratchet-wheel 107 on shaft 106, having twice the number of teeth of the star-wheel 105, retains with the help of its pawl 94 every forward motion of the shaft U against the recovery-spring 86, which exerts its force upon shaft U by means of a chain and equalizing-cam 80. Downward motion is imparted to shaft U by means of the connecting-magnet F (which in practice is at the top of the framework, as shown in Figs. 2 3 4, but in Figs. 5 and 6 has been brought down near the selector-arms) and its armature 96. The armature of connecting-magnet F forces downward the shaft U (and also a shaft V directly under shaft U and partaking of its longitudinal motion) against the force of a spring 90 beneath the shaft V, which spring restores both shafts to their normal position when the magnet F is deenergized. The manner in which magnet F is energized and deenergized will be explained hereinafter. It is energized when the calling subscriber takes his receiving-telephone from its hook and deenergized when he restores his receiving-telephone to the hook. The shaft V, as just stated, is immediately below the shaft U. Like shaft U it has a rotary motion imparted to it by a polarized electromagnet D, which is an exact duplicate of polarized electromagnet E and is rotated by electromagnet D through a precise duplicate of the intervening mechanism that has been described in connection with electromagnet E and shaft U, including the clutch. Shaft V carries a single insulated selector-arm 55, which passes over the "hundreds contacts," inserted in a semicircular block of insulating material 83 in every way identical with the blocks described above, and also over a continuous semicircular connecting-strip 5. So, too, selector-arm 55 is provided with two sets of double springs 112 and 113, which makes electrical contact, respectively, with one of the hundreds contacts and with the semicircular contact-strip 5 at each downward depression of the shaft V. Each hundreds contact inserted in the semicircular block of insulating material 83 has a notch by which it is connected by wire with one of the semicircular contact-strips above, as diagrammatically shown in Fig. 1. The semicircular strip 5 is electrically connected with the test-circuit of the subscriber X, to whom belongs the apparatus now under consideration. When shaft V descends, as above described, its clutch is disengaged and locked in precisely the same manner as the clutch of shaft U. When the connecting-magnet F is deenergized, both shafts recover their normal positions by force of the spring 90, leaving behind their respective clutch-arms retained by the spring-catches. The double-contact springs 84, 85, 112, 113 are now free from their contacts, multiple or otherwise, and permit recovery-spring 86 to restore shaft

U to its normal position and a similar recovery-spring 114, Fig. 4, to restore shaft V to its normal position. When shaft U has returned to its original position, a slot 79 in shoulder 78 permits the shoulder to free itself from the spring-catch 77, and clutch Q by spring 89 reengages with the spur-gear 76. Similar provision for release and reengagement is made for shaft V. Two sets of commutator-springs P and R are actuated by the rotary movement of the shaft U. A second commutator N is actuated by the longitudinal movement of the shaft V.

Substation apparatus.—Most of the apparatus at the subscribers' stations is of conventional construction. The apparatus, however, at each subscriber's station, as has been said, is of peculiar construction. It is shown in detail at Figs. 7 and 8. The circuits, however, appear more clearly in the diagram at Fig. 1. Confining the description at present, except where otherwise especially stated, to Figs. 7 and 8, 115 is a box or supporting-case. Within the box is a shaft 95, supported by a suitable frame, upon which shaft is mounted, outside of the box, a pointer or arm *c*, while within the box is a spur-gear 97 and the circuit-controller *g*, provided with springs 104, said gear being adapted to be revolved by a polarized magnet M, escapement 98, star-wheel 99, and pinion 100, so that shaft 95 is rotated at the subscriber's station in precisely the same manner as shafts U and V at the central station, and it may be stated at once that shaft 95 rotates synchronously with either shaft V or shaft U, as the case may be, the operating-magnets being energized and their armatures actuated in synchronism by the same alternating current in one and the same circuit. Upon the cover or outside face of the box 115 is mounted a dial *m*, having numbers from "1" to "99" and a stop 101, against which the pointer *c* normally rests. As clearly shown, the construction of star-wheel 99 and escapement 98 is such that pointer *c* is free to be moved manually, the rotation of the star-wheel in consequence of the movement of the pointer operating (by reason of the cam-like action of the inclined sides of the teeth of the star-wheel upon the arms of the escapement) to oscillate the escapement on its pivot. Beneath the mechanism thus far described in box 115 are two magnetic clutch-switches *d* and *e*, (only *e* is seen in Fig. 8, but both are shown at Fig. 1,) operated by two plungers 102 and 103, projecting outside of the box. These switches are identical, each consisting of a magnet 116, whose armature 117 is rigidly mounted upon the plunger-rod 103, which when depressed pushes together the contact-springs 54 and remains depressed as long as the magnet 116 remains energized. The energizing of magnet 116 is, however, dependent upon the bringing together of the circuit-controller springs 104, which occurs when the pointer *c* is moved away from stop 101 and

set opposite one of the numbers upon the dial. When the pointer *c* is thus displaced in clockwise direction and one of the magnetic switches, as *e*, is depressed, an alternating current flows, as will presently be shown, from the generator at the central station through the magnet *M*, springs 104 of circuit-controller *g*, the magnet 116, and springs 54, thereby locking the switch *e*, as above described, and causing the polarized magnet *M* to rotate in contraclockwise direction the shaft 95 and all parts mounted thereon until pointer *c* arrives at stop 101. At this instant circuit-controller *g* separates springs 104, thereby opening the circuit, thus deenergizing magnets *m* and 116. The latter allows the plunger 103 to resume its normal position, thereby separating springs 54. It will presently be seen that when pointer *c* is moved away from stop 101 and plunger *d* depressed a circuit is established from the alternating generator at the central station through polarized selector-magnet *D* at central station and polarized magnet *M* at the subscriber's substation, use being made of one of the line-wires 46, and that when pointer *c* is moved away from stop 101 and plunger *e* is depressed a similar circuit is established through polarized selector-magnet *E* at central station and polarized magnet *M* at the substation, use being made of the other line-wire 45. Thus the armatures of polarized magnets *D* and *M* vibrate in synchronism and the selector-arm 55 and pointer *c* are moved through equal arcs and again the armatures of polarized magnets *E* and *M* vibrate in synchronism and the selector-arms 51 52 53 and the pointer *c* are moved through equal arcs. It may be added that the numbers on the dial "1" to "99" are equidistant. To return the pointer *c* from No. 3 to the position of rest requires precisely the same number of alternations of current as are required to move any selector-arm at the central office from its position of rest to the third contact-strip. This applies as well to any number from "1" to "99." In accordance with this system of calling the number of the first subscriber is "101," so that both parts *K* and *I* of the selector are invariably used; but it is obvious that for less than one hundred subscribers only one part, as *I*, need be used and that equipped with but one multiple ring and one selector-arm. The subscribers are arranged in groups of ninety-nine, and the magnetic switch *d* is used in selecting the proper hundreds group. Say subscriber No. 350 is to be called. The calling subscriber at *X* first sets the pointer *c* at No. 3 on his dial and depresses magnetic switch *d* in order to select at the central station the "300's" group. The magnetic switch *e* is used to select "50," the other portion of the desired number "350," and in exactly the same way as magnetic switch *d* is used for the first portion, the pointer *c* being first set opposite No. 50. When the pointer has re-

turned the second time to stop 101, the subscriber lifts the receiver from the hook, thereby completing the connection with subscriber No. 350, as will be described in connection with Fig. 1, and thus the subscriber at *X* by movements of the pointer *c* and the switches *d* and *e* at his own station controls his selecting and connecting mechanisms at the central station by current derived from an alternating-current generator at the central station.

Circuits and operation.—It remains to trace the circuits and describe the operation. Many of the instruments used at the central station as well as at the substations need only be referred to by well-known names descriptive of their general character without stating exactly how they perform their work, either mechanically or electrically.

Referring hereinafter, except where otherwise particularly mentioned, to Fig. 1, *X* and *Y* represent two substations, with the local apparatus thereof, the line-wires leading from *X* to the central station being marked 45 46, while 37 38 represent the line-wires leading to the central station from *Y*. Let us suppose that the subscriber at substation *X* wishes to call substation *Y*, No. 350. The selector *S* of subscriber *X* is shown in Fig. 1 as having already selected that number. The three upper semicircular flat rings 81 at *S* represent blocks of insulating material containing the multiple contacts at the central station with any one of which the subscriber at *X* may make a connection. *Y*'s multiple contact is among them. For clearness these blocks in the diagrams are shown in the same plane instead of one above the other. So, also, the small disk *U* at the center of each of these plates is a section of the same vertical rotating shaft *U* passing up through the centers of all the plates and carrying three selector-arms—viz., 51, which swings over the contacts numbered from 101 to 199, marked "100's," 52, which swings over the "200's," and 53, which swings over the "300's." These selector-arms are insulated from the shaft *U*. Concentric with each semicircle of multiple contacts is a contact-strip 10. A fourth semicircular block 83 below the others contains another set of contacts, called the "hundreds contact." For convenience it is made and shown like the others, with ninety-nine contacts; but in the apparatus shown in the diagram but three are needed. In other words, one "hundreds contact" is needed for each one hundred subscribers. The first contact 1 is in permanent electrical connection with the semicircular connecting-strip 10 in the "100's" group. The second contact 2 is similarly connected with the connecting-strip 10 in the "200's" group, and the third contact 3 with strip 10 in the "300's" group. *V* is a separate vertical shaft rotating beneath shaft *U* and carrying the insulated selector-arm 55. Semicircular block 83 has also a connecting-strip 5, which, as will presently appear, is in connection with

the testing-circuit of X. At S' is shown as belonging to subscriber Y apparatus similar to that which has been described as belonging to X. A single alternating-current generator is employed at the central station, but for convenience it is shown at two points G G'. So, too, there is but a single battery, which is indicated at several places, B B' B² B³ B⁴, in order to simplify the diagram, and so, too, for ready interpretation, magnets and relays are shown at convenient places without regard to the mechanisms operated thereby. For instance, upright shaft U, carrying selector-arms 51 52 53, is rotated by the selector-magnet E, while upright shaft V is rotated by selector-magnet D. Vertical motion is imparted to both shafts by the connecting-magnet F. Proceeding with the description of X's act of calling Y, No. 350, and making reference mainly to Fig. 1, X sets the pointer *c* of his apparatus at No. 3 and by the magnetic clutch-switch *d* closes a circuit to ground along wire 46, as follows: alternating-current generator G, wire 11, contact 14, wire 47, relay J, hundreds-selector-magnet D, line-wire 46, switch-magnet *d*, contacts 56, contacts 104 of circuit-controller *g*, magnet M to ground 118. The alternating current energizes the magnet of switch *d*, causing its armature to hold together the contacts 56. It also energizes magnets D and M, causing their polarized armatures to oscillate, thereby rotating circuit-controller *g* at the substation until it has been returned to its normal position, wherein it opens the circuit above traced, thus instantly stopping the movement of the polarized armature of magnets M and D and restoring switch *d*. Now each of the magnets M and D has received the same number of waves of alternating current, let us say in this case three waves, and said three waves have caused the polarized armature of magnet D to move the arm 55 of hundreds-switch K three steps forward, so that said arm is exactly above point 3, from which wire 4 leads to the "300's" group of the tens and units selector I. Subscriber X next moves his pointer to No. 50 and depresses switch *e*, thereby completing the following circuit to ground via the other side of his metallic line: generator G, wire 6, contact 7, wire 8, contact 9, selector-magnet E, relay H, line-wire 45, switch-magnet *e*, contact 54, contacts 104 of circuit-controller *g*, magnet M to ground 118. The alternating current actuates in synchronism selector-magnet E and magnet M until fifty waves have occurred, when circuit-controller *g* breaks the circuit in the same way as before, releasing switch *e* and causing the movement of the armatures of E and M to cease. The selector-arms 51 52 53 have now been rotated to a point where each is over the No. 50 of its own semicircle of ninety-nine. When X lifts his receiver from the switch-hook, these three selector-arms 51 52 53 of switch I and selector-arm 55 of switch K are brought into connection with the contact-points they are

opposite; but obviously only arm 53 is in electrical connection with switch K. This connecting movement is accomplished in the following manner: While X's receiver-hook is rising the contact-spring *u* unites for a moment both sides of his metallic line to ground 118, the yielding contact-spring *z* being attached to the forward contact-point of the said receiver-hook to insure connection with the main conductor 45, when the lever of said receiver-hook makes its transient contact with the grounding-spring *u*. During this brief interval alternating current flows along both sides of the line to ground. Relays H and J are thereby energized, and their contacts 12 and 13 being both closed simultaneously complete a local circuit through connecting-magnet F, as follows: battery B², contact 12, contact 13, winding *t* of connecting-magnet F back to battery. The effect of energizing magnet F is to force the arms of X's selectors into contact with the terminals which they face, thus forming a connection between the testing apparatus of X and the line of Y, No. 350. It may be here stated that to prevent accidental shifting of the selector-arms by reason of magnets D and E being actuated by alternating current at the moment when the receiver-hook of X is being lifted the relays H and J have each been provided with a second armature, whose contacts 66 and 64 when closed shunt or short-circuit the selector-magnets D and E, thereby preventing the latter from acting. The armatures of the relays H and J are so constructed as to respond more quickly than those of the selector-magnets, and the former therefore shunt or short-circuit the selector-magnets before the armatures of the latter can move. Furthermore, this short-circuiting results in the exclusion from the talking-circuit of the comparatively high impedance-magnets D and E. Returning to connecting-magnet F, which has just been actuated by the lifting of X's receiver, this magnet serves the further purpose of operating switch N, by means of which current from common battery B is supplied to the line of X in place of alternating current, thus furnishing the current necessary in a common-battery system for the transmission of speech. After the operation of switch N the relays H and J are energized by battery B instead of by generator G, thus maintaining their two functions just described. Now assuming that Y's line is not already in use, the operation continues as follows: The above-described connections between selector-arms and contact-points establish a preliminary or testing circuit from the middle point of common battery B⁴ through testing-relay L and X's selector to Y's apparatus, where, if the line of Y is not in use, a return-path to battery is found. In detail the circuit may be traced from the middle or twelve-volt point of battery B⁴, wire 16, contact 17, winding of relay L, wire 18, contact-strip 5, arm 55, contact-point 3,

wire 4, contact-strip 10, arm 53, contact-point 50, wire 15, wire 21, windings r' r' of repeating-coil A', wire 19, low-resistance winding s' of magnet F', wire 20, winding of relay O', circuit-opener P' to ground 22. This current actuates testing-relay L, whose armature-contacts transfer its winding to a twenty-four-volt lead from the common battery B⁴. This new circuit is from terminal 33 of battery B⁴, wire 34, retardation-coil α , armature 108, contact 23, winding of relay L, wire 18, and thence to ground 22, as before. Tracing out the path of the testing-circuit, it will be seen that the winding s' of magnet F' is energized, but nevertheless its armature is not drawn up, the ampere-turns of said winding being inadequate for a purpose hereinafter stated. The armature of relay O' is actuated, however, and its contacts alter the connection of Y's line with the generator G', so that instead of both sides of his line being connected with the ungrounded terminal of generator G' one side is connected with the grounded terminal 27 and the other side left connected with ungrounded terminal 26. There is now a difference of potential between the two sides of Y's line, and alternating current therefore passes through and rings Y's signal-bell y' along a circuit from generator G', terminal 26, wire 35, contact 36, winding of relay J', winding of selector-magnet D', line-wire 37, condenser 58, signal-bell y' , line-wire 38, winding of relay H', winding of selector-magnet E', wire 39, contact 40, wire 41, armature 59, contact 60, and ground 43 back to terminal 27 of generator G'. On account of the high resistance of the signal-bell y' and condenser 58 the current passing is not strong enough to actuate relays H' J' and magnets D' E'. When Y lifts his receiver from the hook, thus bridging the line with the low resistance of his telephone set, relays H' J' are first actuated, their armature-contacts short-circuiting or shunting magnets D' E' before the armatures of the latter can act and in addition closing a local circuit from battery B³ through the winding t' of connecting-magnet F' and actuating its armature, which causes switch N' to substitute direct current for alternating current, just as was done in X's apparatus when he lifted his receiver in the act of calling Y. It will be noted that the connecting-magnet of any called subscriber performs the function of a relay only, in that it operates the switch N', but completes no circuit through the selector-arms, which are left at the 0 or normal position. X and Y may now talk over the following path, in which the use of the repeating-coils A and A' will be understood by any one familiar with the art: X's telephone set receives current from common battery B through lower winding of repeating-coil A, spring 61, spring 62, wire 44, wire 63, contact 64 of relay J, wire 65, winding of relay H, line-wire 45, telephone set of X, line-wire 46, contact 66 of relay H, wire 67, winding of

relay J, wire 47, spring 68, spring 69, wire 70, upper winding of repeating-coil A, back to battery. Y's telephone set is energized through repeating-coil A' over a circuit identical with X's. The two repeating-coils are connected together inductively along the following path, beginning at X's side: ground 32, condenser 31, windings r r of repeating-coil A, condenser 30, contact 24, armature 109, wire 18, strip 5, selector-arm 55, contact-point 3, wire 4, strip 10, selector-arm 53, multiple point 50, wire 15, wire 21, windings r' r' of repeating-coil A', condenser 48, back to ground 49. The grounds indicated at 32 and 49 constitute in practice a metallic common return-circuit within the central station. When the conversation is ended, the hanging up of X's receiver returns his selector-arms to their starting-points by deenergizing relays H and J, and consequently magnet F, which up to this moment has been holding down the selector-arms. The return of these arms opens the testing-circuits through relays L O' and the winding s' of magnet F'. Switch N disconnects battery B from X's line and restores alternating current, ready for the next call. When Y hangs up his receiver, his relays H' and J' become deenergized, thereby opening the local circuit from battery B³, which deenergizes magnet F', switch N' resuming its normal position wherein alternating current is impressed upon the line in the place of direct current. Normal conditions have now been restored at all points in the system in so far as X and Y are concerned. Should Y chance to hang up before X hangs up, magnet F' is kept from releasing its armature by means of the winding s' , which is still energized by the testing-circuit from X, said winding sufficing to hold up said armature after it has once been drawn against the poles of the magnet. The switch N' is under these conditions not restored, and as generator-current is not impressed upon the line until switch N' is restored Y's signal-bell will not be rung needlessly. When X hangs up, the winding s' of magnet F' is deenergized, switch N' restored, and normal conditions reestablished. Should any subscriber attempt to connect with a subscriber whose line is already in use, means are provided for keeping out the interloper, at the same time automatically notifying him that the desired line is busy. A line may be busy from two causes—the subscriber may have originated a call or he may have received a call. In either case the present system protects the engaged subscriber's line from intrusion. This is accomplished by establishing a relay L in the testing or preliminary circuit, which keeps each subscriber's talking-circuit normally disconnected from his own selector-arms. This testing-relay must be actuated before the calling subscriber can talk, and said relay will not be actuated if the desired line is already in use. The testing-relay is rendered inoperative in two ways—first, by

an interrupted return-circuit to battery, (such is the case when the multiple wire of a busy calling subscriber is tested;) second, by the establishment of this relay in the testing-circuit in such relation to the multiple wire of a busy called subscriber that no current flows through its winding. Let us consider the first case and assume that X wishes to call Y, who has already called Z, a third subscriber.

The operation proceeds as before up to the point when X's selector-arm is brought in contact with Y's multiple wire; but X's testing-circuit back to the grounded terminal of the battery is now incomplete, the circuit having been broken by commutator P', which operated at the first movement of Y's selector in calling Z. Hence X's testing-relay L will not be actuated, and therefore although X's selector-arm is actually in contact with Y's multiple wire X cannot interfere with Y's conversation, nor can he hear it, because his talking-circuit is not in connection with his selector-arm, as already stated. X hears only the sound of the busy-tone signal which proceeds from the apparatus T along wire 28 through commutator R, (which closed this portion of the busy-tone circuit at the first movement of X's selector,) wire 29, contact 25, condenser 30, windings *r r'* of repeating-coil A, condenser 31 to ground 32. The busy-tone vibrations are taken up by the other windings of repeating-coil A and are heard in X's receiver. Taking up the second case, let us assume that X is calling Y, who has already been called by Z. In this case X's testing-relay L is rendered inoperative not by the opening of Y's ground, (for Y being the called party has not rotated his own selector and commutator P',) but by the fact that Y's multiple wire is at the same potential—*i. e.*, twelve volts—as X's selector-arm, which at that moment is in connection with a twelve-volt lead from the middle or twelve-volt point of the twenty-four-volt battery B⁴. This may be explained as follows: Y's multiple wire is at a potential of twelve volts, because it is midway between the terminals of the twenty-four-volt battery, with an equal amount of resistance on each side of the multiple-wire. The elements which cause this balance will be comprehended if we assume for the moment that X has called and is talking with Y and consult Fig. 1. The subsidiary circuit, which places Y's multiple wire at twelve-volts potential, may be traced from terminal 33 of twenty-four-volt battery B⁴ through eighty-ohm retardation-coil *a*, armature 108, contact 23 of relay L, eighty-three-ohm winding of relay L, wire 18, selector-arms 55 and 53 to the multiple wire of Y at 50, making up to this point a total resistance of one hundred and sixty-three ohms. On the other side of multiple point 50 the circuit continues via wire 15, wire 21, forty-ohm winding *r' r'* of repeating-coil A', forty-ohm winding *s'* of magnet F', and eighty-three-ohm winding of relay O' back to the grounded terminal of battery B⁴,

making again a resistance of one hundred and sixty-three ohms. We thus find that the multiple point 50 is in a circuit from a twenty-four-volt battery, with equal resistances on each side, and is therefore at a potential of twelve volts. Returning to the process of X calling Y, already called by Z, when X's selector-arm touches Y's multiple both are at the same potential, as just described, and as in accordance with a well-known law no current will flow between two points at the same potential testing-relay L will not be actuated, and X upon listening will hear only the busy tone-signal, as before.

It has already appeared that subscribers' numbers below one hundred are disregarded in the selecting and connecting apparatus, as described in detail. This is because all connections when made include in the established circuit the hundreds selector-arm as well as the tens and units selector-arm, and a subscriber would be quite likely to forget to set the pointer of his dial at "0" to bring in the "0" hundreds selector-arm after having set it at the desired number below one hundred. For a somewhat-similar reason the "0" points are omitted on the calling-dial at the subscribers' stations and in the multiple-contact rows at the central station. It is obvious, however, that these omissions for many features of the system are not essential and that apparatus within many features of the invention could be readily constructed which would involve the use of but a single row of multiple contacts for each subscriber at the central station and but one magnet for imparting a rotary movement to the single selector-arm used in connection with such single row. In this construction the connecting-strip concentric to the semicircular row of multiple contacts would be in normal electric connection with the calling-subscriber's testing apparatus instead of being adapted to be connected thereto through a hundreds contact, a hundreds selector-arm, and the concentric connecting-strip in juxtaposition to the hundreds row of contacts. An original plant thus constructed, however, is not adapted to be so readily increased with the growth of the exchange as where it contains at the beginning provision for dividing the calling-number of each subscriber into two parts.

It has been stated above that the shaft carrying the pointer at the substation, is rotated in precisely the same manner as shafts U and V at the central station carrying selector-arms. It is to be remembered, however, that while the operation at the central station is wholly automatic the operation at the subscriber's station is in part manual. Further, it is the forward movement of the substation device that is effected by the hand of the subscriber, while it is the forward movement of the central station that is effected by alternating current. On the other hand, the return movement of the substation

device is effected by alternating current, and the return movement of the central-station device is effected by a spring. Thus of these four movements necessary for the two devices the two movements in synchronism resulting from the use of the same alternating current are the return movement of the pointer and the forward movement of the selector-arm. This, in view of the use of alternating current as a means of propulsion, is an important feature of the invention, since it allows the automatic and necessarily simultaneous cessation of the two movements. Any slight deviation from synchronism in the movements of the selector-arm and pointer finds a remedy in the use of several waves of alternating current to move the selector-arm from one contact-point to the next and use of self-centering contact-springs connected by the selector-arm.

Another important feature of the invention is the use of the mechanical clutch, as above described, for transmitting power from the propelling mechanism to the shafts carrying the selector-arms at the central station. The use of the clutch permits the disengagement of the shaft from the propelling mechanism without interference with the propelling mechanism.

I claim—

1. In an automatic telephone-exchange, a selecting device, a polarized electromagnet for operating the same, and an alternating-current generator all at the central station, and a normally open circuit between said central station and a substation, in combination with an indicating mechanism, a polarized electromagnet, and a circuit-controller, all at the said substation, the said indicating mechanism being adapted to be operated in one direction by hand and in the opposite direction by said electromagnet, and the said circuit-controller being adapted to be actuated by said indicating mechanism to close the said circuit through both said electromagnets and said generator while said indicating mechanism is in operation, and to open the same when said mechanism is at rest, substantially as described.

2. In an automatic telephone-exchange, a selecting device in two parts, a separate polarized electromagnet for each of said parts to operate it independently of the other part, and an alternating-current generator, all at the central station, and two normally open circuits between said central station and a substation each including one of said polarized electromagnets, in combination with a polarized electromagnet, an indicating mechanism provided with a zero-point and adapted to be operated away from said zero-point by hand and restored thereto by said electromagnet, two electromagnetic clutch-switches associated with the said two circuits respectively, and a circuit-controller, all at the said substation, the said electromagnetic switches being adapted to connect each the conductor of its

respective circuit to said circuit-controller, and the said circuit-controller being adapted to be actuated by said indicating mechanism to close either circuit in which such connection has been made through its own central-station electromagnet, the said generator, and the substation electromagnet, while said indicating mechanism is in operation, and to open the same when said mechanism is at rest, substantially as described.

3. In a selecting and connecting mechanism at the central station of an automatic telephone-exchange, two shafts each provided with a selector-arm, and each provided with a separate electromagnet whereby it may be rotated separately, and the two provided with a third electromagnet whereby they may be moved together longitudinally, substantially as described.

4. In an automatic telephone-exchange, the combination of a dial-pointer at a substation, and a selector-arm at the central station, motor mechanism for each adapted to impart rotary motion thereto, a polarized electromagnet for each adapted to actuate said mechanism, an alternating-current generator at said central station, an electric circuit between said central station and substation containing said generator and said polarized electromagnets, and a circuit-controller for said circuit associated with the motor mechanism of said pointer and adapted to be operated thereby to break the said circuit after said pointer has moved a predetermined distance, whereby the said pointer and selector-arm move synchronously and stop simultaneously, substantially as described.

5. In an automatic telephone-exchange, multiple-contact central-station apparatus for each subscriber's line, consisting of a separate row of fixed contacts for each group of one hundred subscribers, *i. e.* a row for the subscriber's lines numbered from 100 to 199, a second row for the subscriber's lines numbered from 200 to 299, &c., each said contact being electrically united to a separate subscriber's line, and to all of the multiple fixed contacts thereof, a stationary common contact for each row of said multiple contacts adapted to be bridged to any one of the multiple contacts in its respective row by a movable conducting member, a further row of contacts similar to the said row or rows of multiple contacts, there being one contact in such further row for each one hundred subscribers in permanent electrical connection with the said stationary common contact appropriated to the row of multiple contacts belonging to the same one hundred subscribers, and a further stationary common contact likewise adapted to be bridged by a movable member with any of the multiple contacts in said further row, substantially as described.

6. In an automatic telephone-exchange separate rows of multiple contacts each representing a different group of lines, *i. e.* those

from one group of subscribers in one row, those from another group of subscribers in a second row, &c., a common contact for each said row of multiple contacts in juxtaposition thereto, a further row of contacts in permanent connection each respectively with a separate one of said common contacts, and a common contact in juxtaposition to said further row, in combination with a shaft adapted to both rotate and move longitudinally, the said shaft being provided with selector-arms projecting therefrom, one for each row of multiple contacts adapted to pass along such row of multiple contacts during the rotary motion of the said shaft, and to make electrical connection between a multiple contact in such row and the common contact in juxtaposition thereto upon the longitudinal movement of said shaft, and a second shaft, also adapted to both rotate and move longitudinally, and provided with a single selector-arm adapted to pass over the said further row of contacts during the rotary motion of said second shaft, and to make electrical connection between any contact in said further row and the common contact in juxtaposition to said further row upon the longitudinal motion of said second shaft, substantially as described.

7. In an automatic telephone-exchange apparatus at the central station for each subscriber consisting of separate rows of multiple contacts for the several groups of one hundred lines each centering at said station, *i. e.*, the multiple contacts for lines numbered from 100 to 199 in one row, those for lines numbered from 200 to 299 in a second row, &c., a common contact for each row of said multiple contacts in juxtaposition thereto but normally insulated therefrom, a further row of contacts similar to said rows of multiple contacts, there being one contact in said such further row for each of said groups of subscribers in permanent electrical connection with the common contact appropriated to the row of multiple contacts belonging to the same group, and a further common contact in juxtaposition to said further row, in combination with selecting and connecting electromechanism in two parts, whereby an electrical connection can be established between any separate multiple contact in any of said rows of multiple contacts appropriated to a group of subscribers and the said common contact in juxtaposition to said row, and also an electrical connection be established between the contact in said further row appropriated to the same group of subscribers and the common contact in juxtaposition to said further row, substantially as described.

8. In an automatic telephone-exchange, two shafts each provided with a selector-arm, and each provided with a separate polarized electromagnet whereby it may be rotated separately from the other, and the two provided with a third electromagnet whereby they may be moved together longitudinally, an alternating-current generator, two relays and a

battery, all at the central station in combination with two line-wires leading from the central station to a substation, a circuit-breaker at said substation provided with a polarized electromagnet for operating it adapted to be connected up separately in circuit with said generator and either of the said two central-station polarized electromagnets employed for imparting rotary motion to said shafts, and a telephone switch-hook at said substation adapted to act automatically when the telephone is removed from the hook to establish momentarily a current from said generator through both said line-wires and said relays, whereby in turn a local circuit is established from said battery through said third electromagnet at the central station employed to impart longitudinal motion to said shafts, substantially as described.

9. In an automatic telephone-exchange, two shafts each provided with a selector-arm, and each provided with a separate electromagnet whereby it may be rotated separately from the other, and the two provided with a third electromagnet whereby they may be moved together longitudinally, two relays and a source of electromotive force, all at the central station in combination with two line-wires leading from the central station to a substation, a circuit-breaker at said substation provided with an electromagnet for operating it adapted to be connected up separately in circuit with said source of electromotive force and either of the said two central station electromagnets employed for imparting rotary motion to said shafts, and a telephone switch-hook at said substation adapted to act automatically when the telephone is removed from the hook to establish momentarily a current from said source of electromotive force through both said line-wires and said relays, whereby in turn a local circuit is established from said source of electromotive force through said third electromagnet at the central station employed to impart longitudinal motion to said shafts, substantially as described.

10. The combination with a semicircular row of multiple contacts, a shaft provided with a selector-arm and also with a polarized electromagnet for imparting a rotary movement to said shaft and thereby causing said selector-arm to swing over said semicircular row of contacts, electromechanical means for imparting a longitudinal motion to said shaft, and an alternating-current generator all at the central station, of a circuit-breaker at the substation provided with a polarized electromagnet for operating it adapted to be connected up in circuit with said generator and said polarized electromagnet employed for imparting rotary motion to said shaft, the said selector-arm being provided with a self-centering contact for making connection with a desired contact in said row of multiple contacts upon the longitudinal movement of said shaft, whereby compensation is made for

slight deviations in synchronism between the action of the selector-arm at the central station and the circuit-breaker at the substation, substantially as described.

- 5 11. In a selecting and connecting mechanism at the central station of an automatic telephone-exchange the combination with two rows of multiple contacts, two shafts each provided with a separate electromagnet where-
10 by it may be separately revolved, and selector-arms carried by the said shafts respectively and adapted to pass over the said two rows of contacts respectively, of motor mech-

anism interposed between the said shafts and their respective actuating electromagnets, a 15 mechanical clutch for each shaft adapted to transmit power thereto from said mechanism to rotate the said shafts independently of each other, and a third electromagnet adapted to act upon both shafts and to move them 20 together longitudinally, substantially as described.

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Witnesses:

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