E. A. GRAY & E. C. MOLINA.

TELEPHONE CENTRAL SWITCHING SYSTEM.

APPLICATION FILED MAY 17, 1907.

1,102,907.

Patented July 7, 1914.

8 SHEETS—SHEET 1.

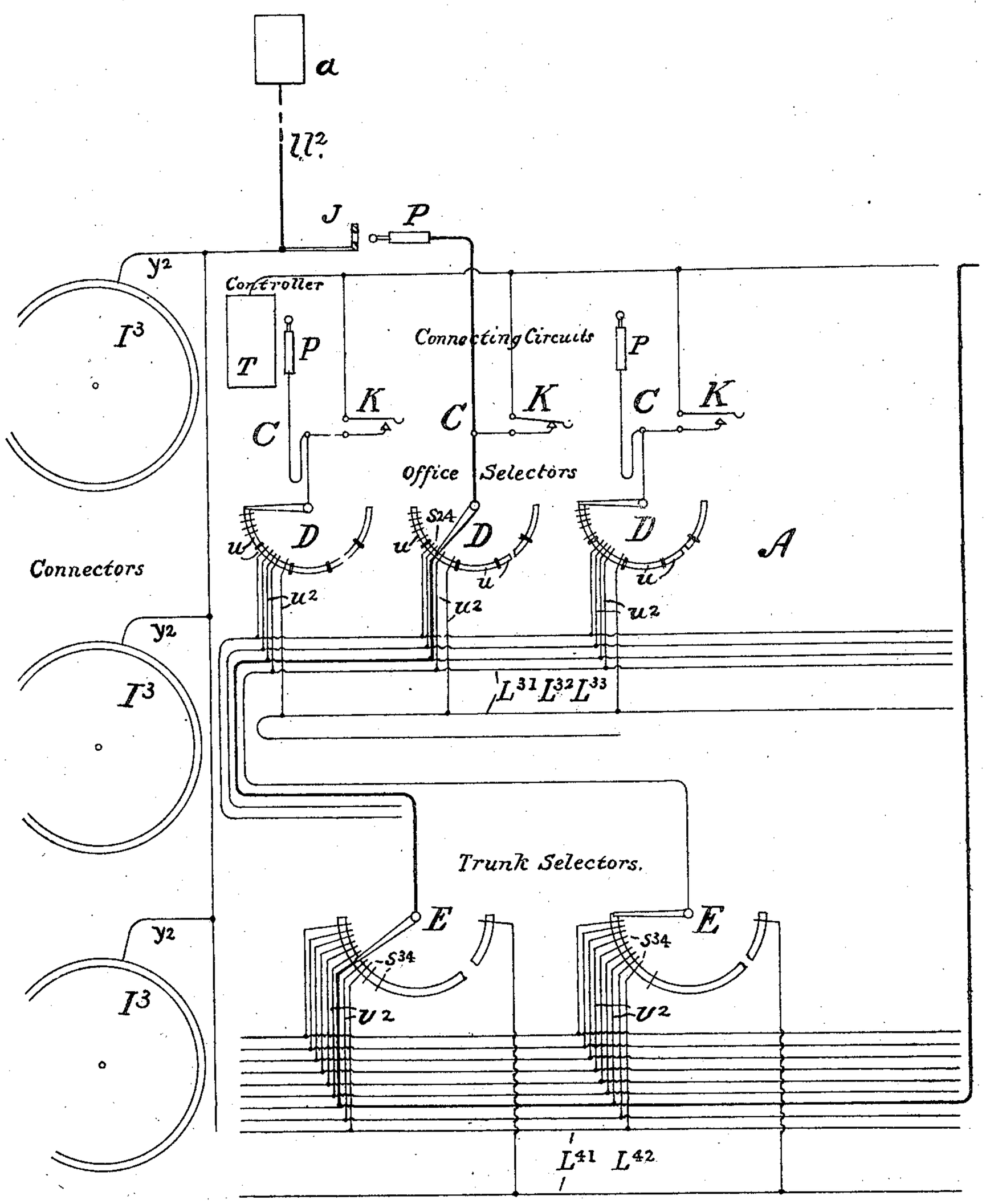

Fig. 1

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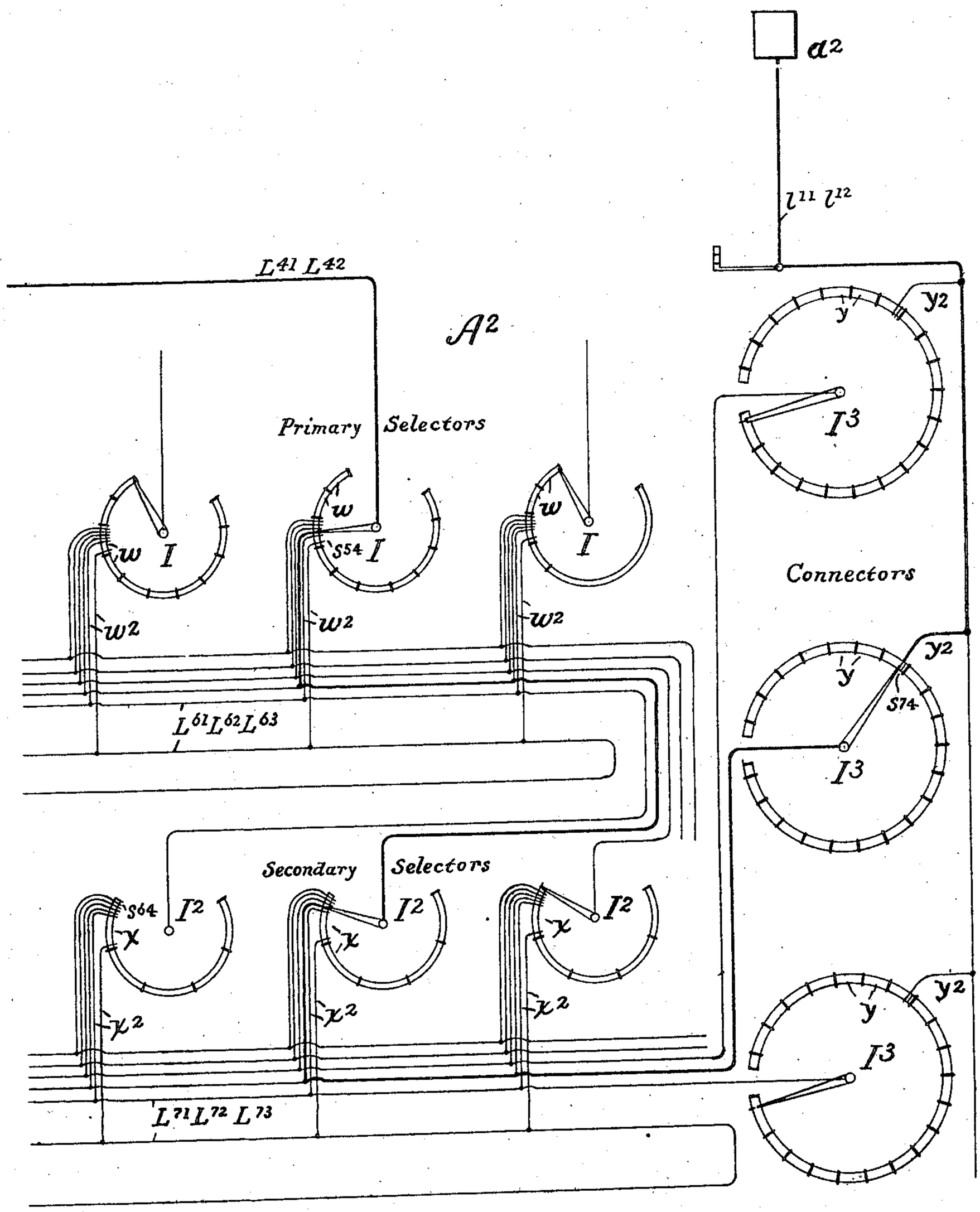

Fig. 2

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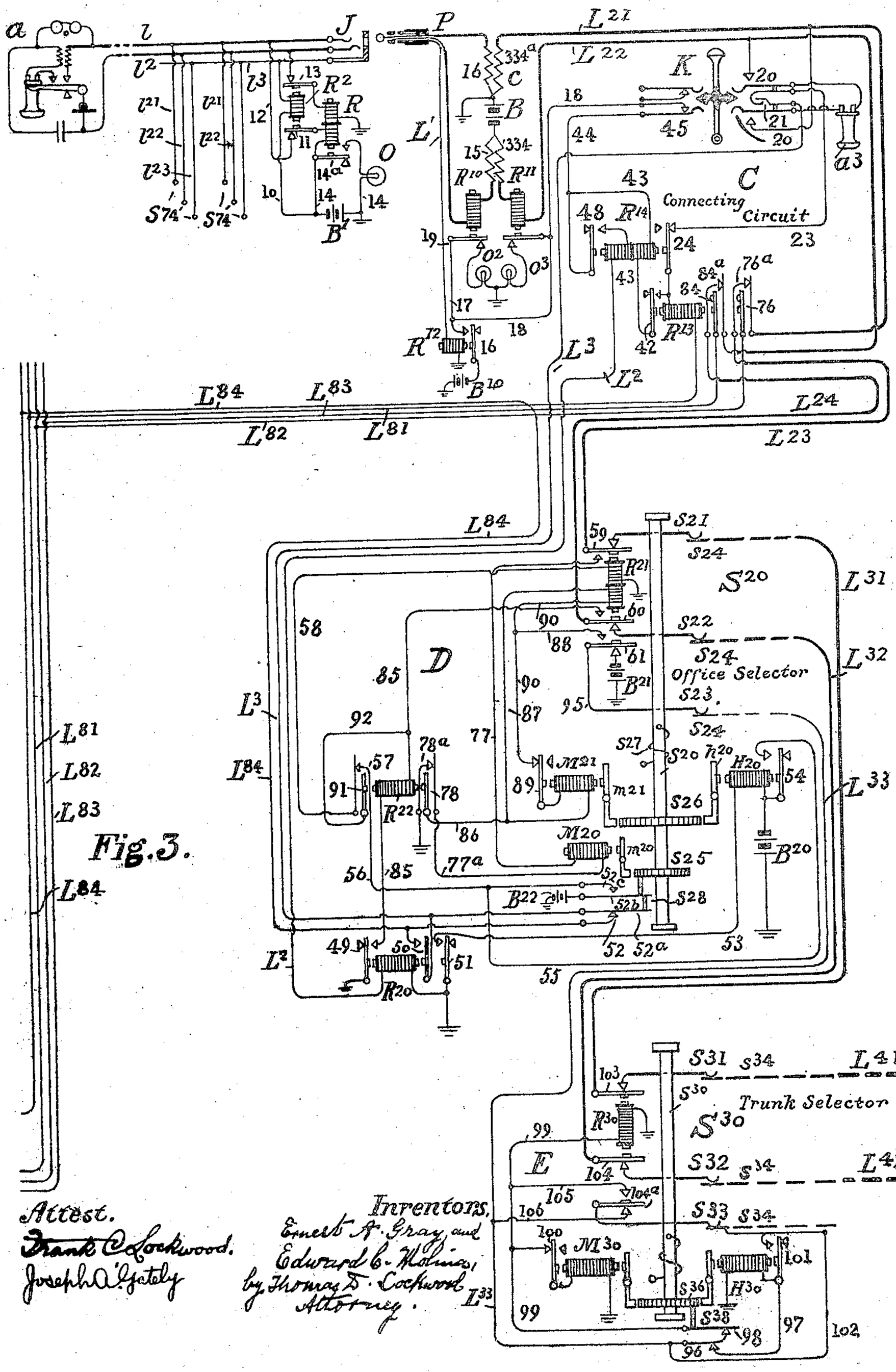

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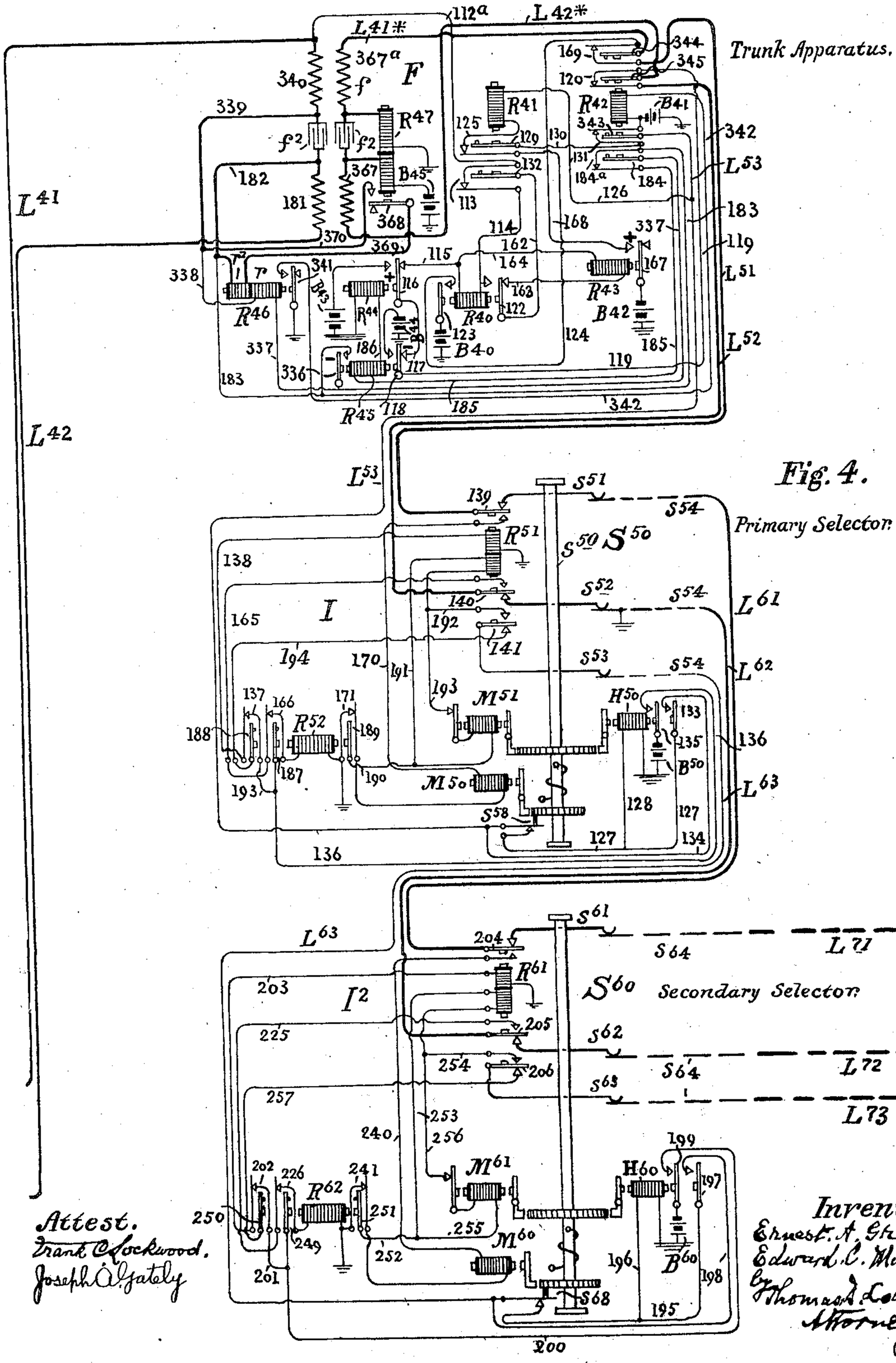

Fig. 4.

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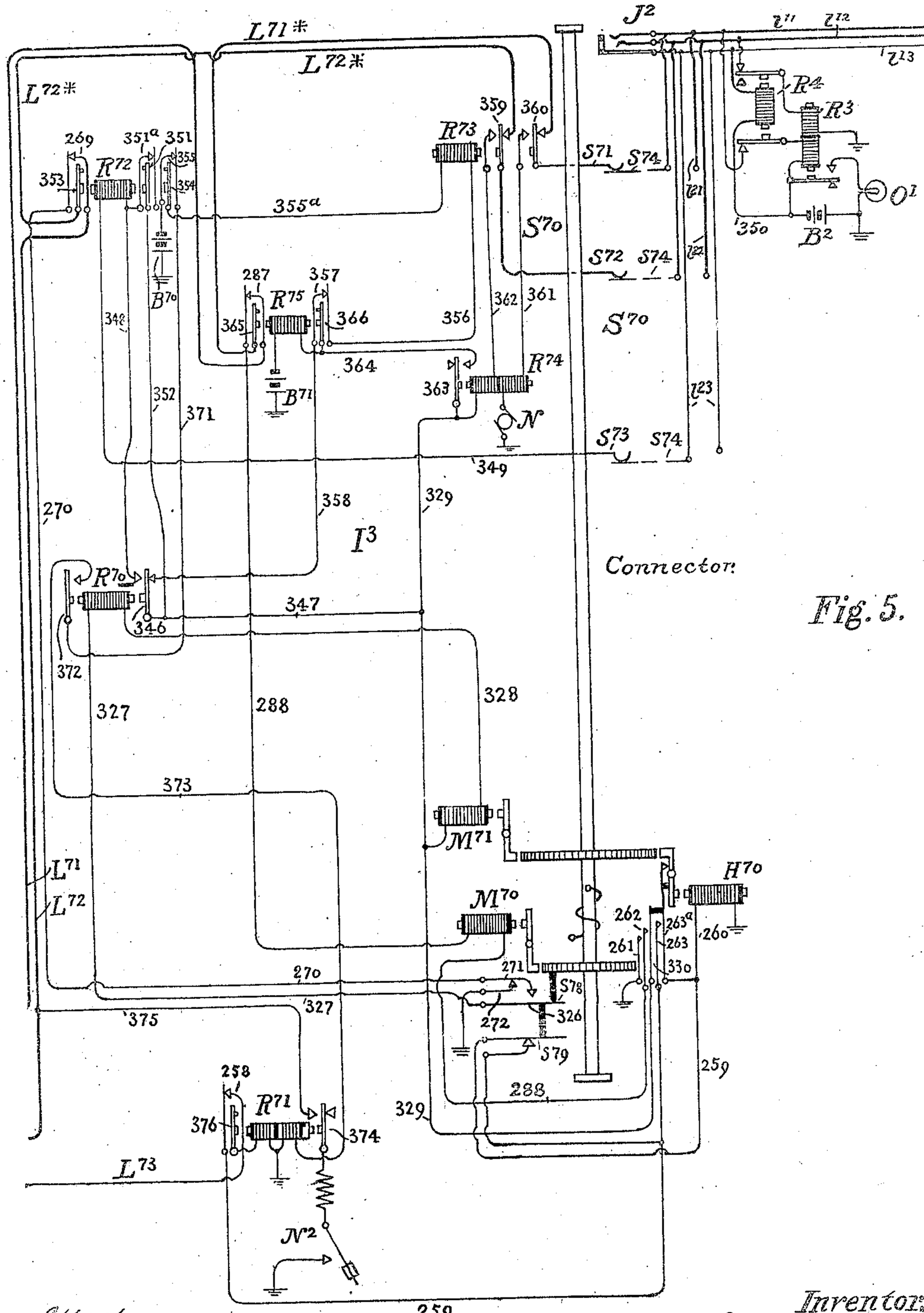

Fig. 5.

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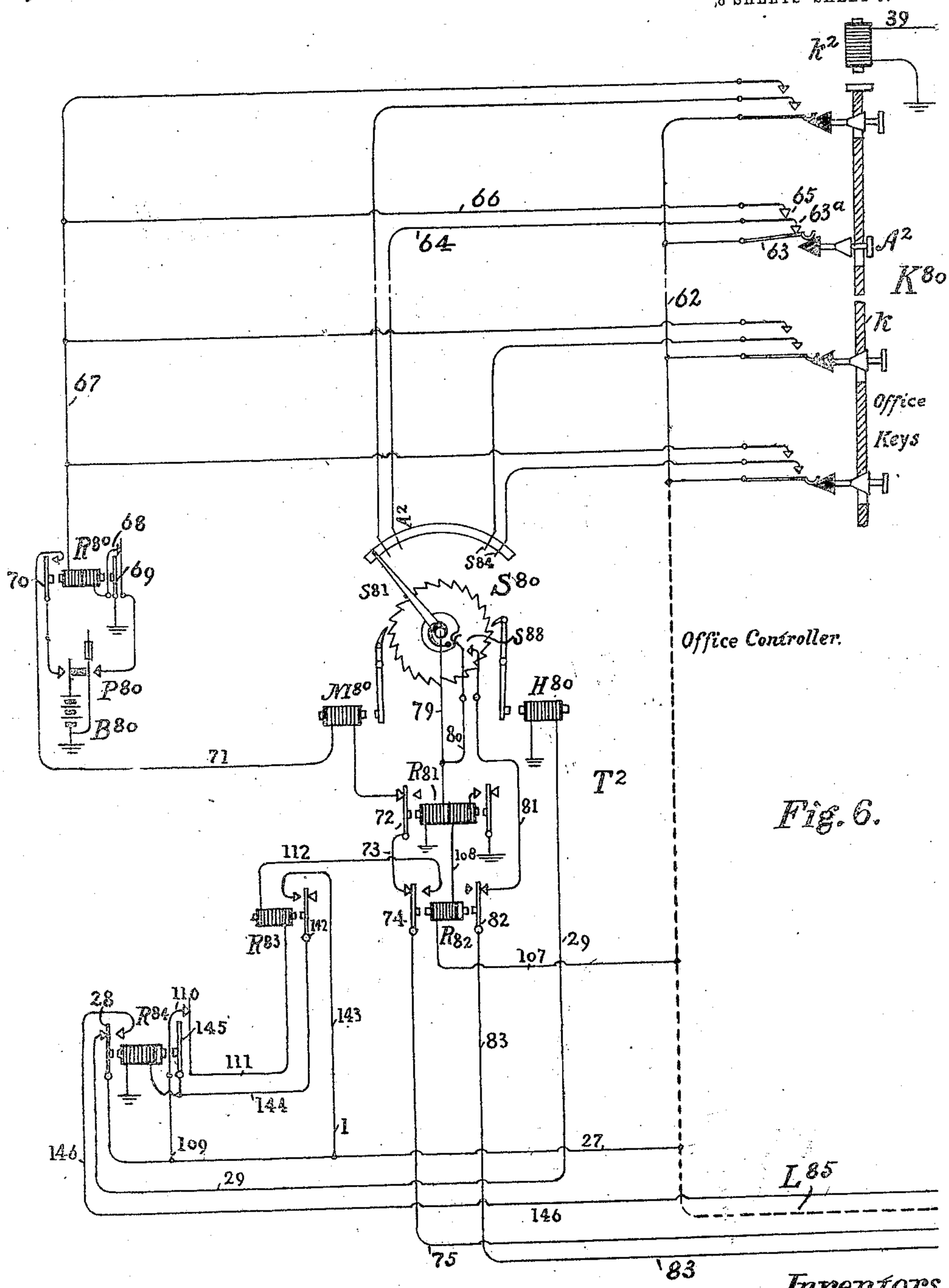

Fig. 6.

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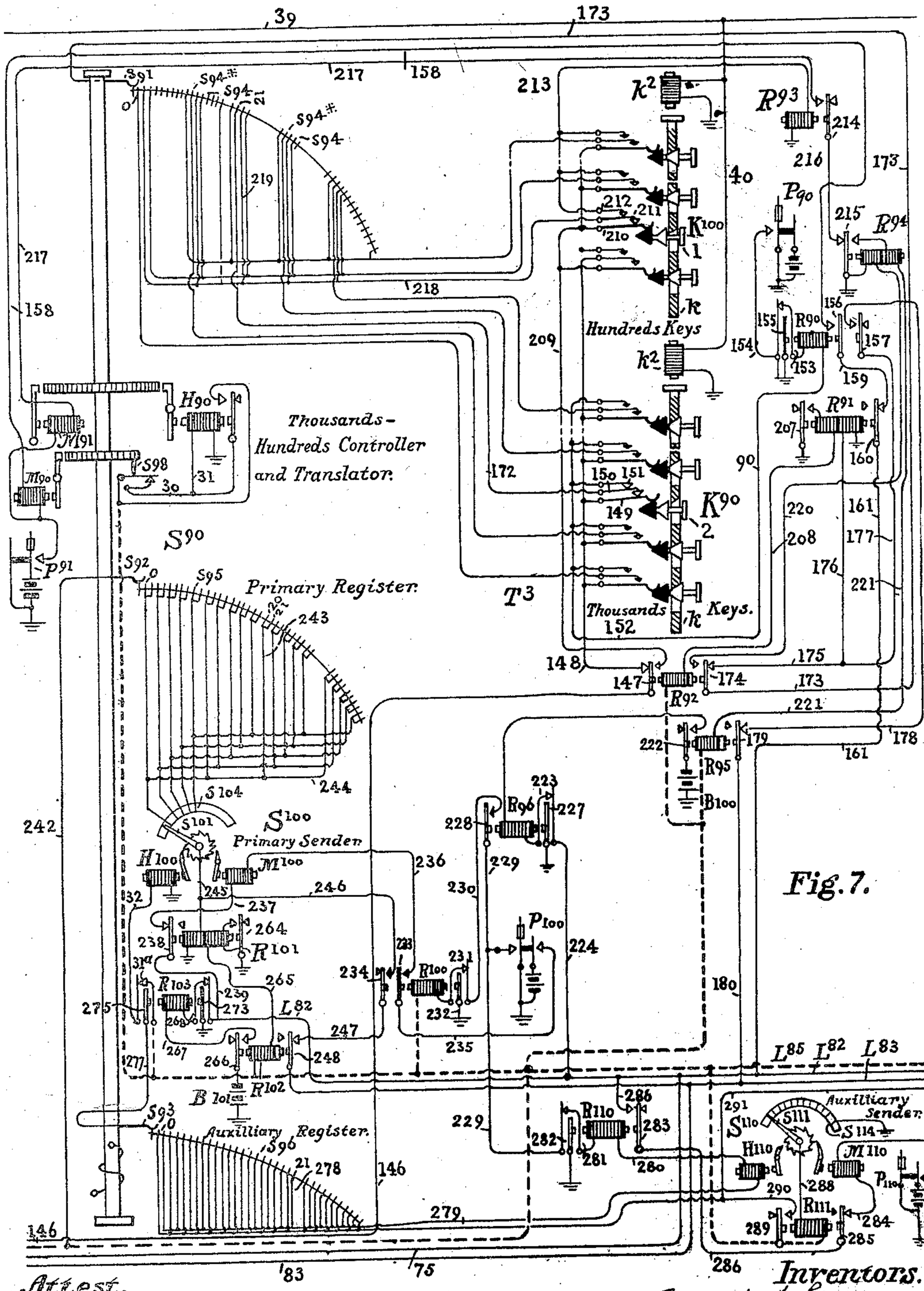

Fig. 7.

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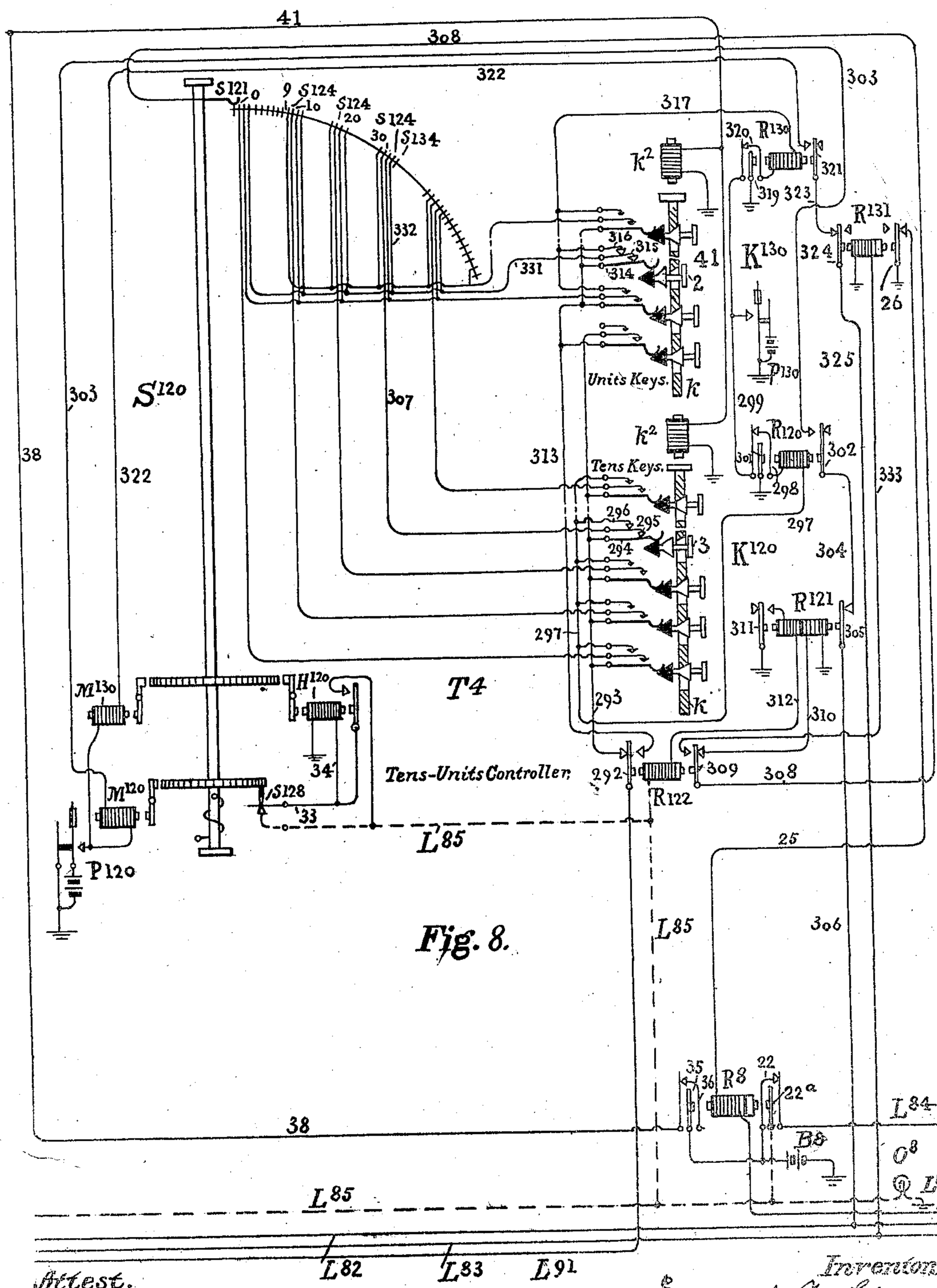

Fig. 8.

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UNITED STATES PATENT OFFICE.

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TELEPHONE CENTRAL SWITCHING SYSTEM.

1,102,907. Specification of Letters Patent. Patented July 7, 1914.

Application filed May 17, 1907. Serial No. 374,224.

To all whom it may concern:

Be it known that we, ERNEST A. GRAY and EDWARD C. MOLINA, residing at Boston and Arlington, in the counties of Suffolk and Middlesex and State of Massachusetts, respectively, have invented certain Improvements in Telephone Central Switching Systems, of which the following is a specification.

In telephone exchange practice there are two well-known types of switching systems employed in effecting through one or more offices connections between the lines of a calling and a called subscriber, these types being commonly termed the "manual" and the "automatic." In the first, a so-called "A-operator" at a central office answers the subscriber's call and receives the order, and with or without the assistance of a second or B-operator, depending upon whether the desired subscriber's line terminates at the same or another office of the district, tests the called line. If this is busy the operator so notifies the calling subscriber and disconnects the switchcord which has been employed from the answering jack, or, if the line is idle, completes the connection, rings the called subscriber and supervises and finally disconnects the lines. In automatic systems the operator is dispensed with, except, perhaps, in toll connections, and all the above-mentioned operations taking place at the central office are performed by electromechanical apparatus controlled by a mechanism situated at each substation and manipulated by the calling subscriber. Both of these systems possess inherent difficulties. In manual practice the number of acts which the operator must perform for each connection greatly limits the lines the calls of which she can answer, and since a considerable percentage of these calls must be trunked to another office, the introduction of a second operator still further increases the amount which must be expended in salaries and cuts down the economy of operation. The efficiency of the service also suffers because of the added liability to error in the transfer of calls between the A and B operators, and because of the assignment of trunks and the delay which this occasions. In automatic exchanges, not only is the central office apparatus comparatively costly, but the installing in the substations of the somewhat complicated controlling apparatus having many spring contacts and moving parts seriously increases this, while the maintenance of these widely separated mechanisms still further swells the expense. Then the burden of performing the operations controlling selection is thrown upon the subscriber, who not usually being skilled, and often laboring under the disadvantage of poor light upon the indicating numerals of the controller, is liable to error, wasting his own time and that of the person wrongly called, and uselessly tying up a portion of the central office equipment.

The present invention has for its principal object the provision of a system combining the best features of manual and automatic practice, attaining thereby results excelling both in economy and efficiency. The subscriber may call as in central energy manual exchanges, by simply removing his receiver from its hook and verbally communicating his order to an operator. This operator has merely to connect an element of the office apparatus and her telephone set to the calling line, receive the designation of the desired office and number of the subscriber to be called and register these upon a controlling apparatus. Thereafter all connecting steps are carried out by electrically controlled mechanisms without further effort upon the part of the answering operator, who is free to make other connections, and without the introduction of a second or B-operator. The only additional attention given to each call consists in the disconnection of the calling line from the central office apparatus, after the operator has been notified of the termination of the conversation by a signal following the hanging up of the receiver by the calling subscriber.

The invention consists in the various features and combinations hereinafter described and more particularly claimed.

In the accompanying drawings, Figures 1 and 2 show schematically the more important apparatus at two offices, arranged in accordance with our invention. Fig. 3 illustrates diagrammatically, but in greater detail, that portion of the system including the cord circuit and the office and trunk selectors. Figs. 4 and 5 are similar views of the primary and secondary selectors and the

final selector, respectively; and Figs. 6, 7 and 8 show respectively the office, thousands-hundreds and tens-units sections of the controller, the second of these including the translator.

Similar characters designate like elements throughout the several figures.

The system will be here considered as applied to an exchange having a plurality of central stations, and ten of these may be assumed, each of a capacity of ten thousand lines, so that in all one hundred thousand subscribers will be provided for.

In Figs. 1 and 2 the chief pieces of apparatus and intermediate conductors at the central stations or offices A and A^2 are shown, and since hereinafter, in describing the operation of the system, A will be taken as the station through which a call is originated and A^2 the station completing the connection with the called subscriber, the call answering and connection completing apparatus have been given special prominence at stations A and A^2, respectively, and either omitted or barely indicated at the other station. Moreover, in these figures for the sake of clearness the various circuits have been represented by single lines, though there are provided complete metallic circuits which may include in portions a third wire, as will be seen in Figs. 3 to 8, to which reference should be had for such minor mechanisms as relays and for details of the apparatus and circuits generally.

Apparatus of the connecting circuit.—Of the substations but a single one appears for each central station, these substations a and a^2 being provided with the apparatus usual in central energy systems, the first-named being joined by line conductors l and l^2 to a manually operable switch. This switch may be furnished by a jack J (Fig. 3), to the tip and ring contacts of which the line conductors lead and with which cooperates a plug P. With the line conductors, and with a third conductor l^3 connected to the sleeve contact of the jack are associated the wellknown line and cutoff relays R and R^2, the former of which has two windings, and the line signaling lamp O. A suitable number of these answering jacks J and their corresponding line lamps are situated at each operator's position, there being no multiple of said jacks.

The plug P furnishes one terminal of a connecting or cord circuit C, of which enough are assigned to each operator to permit the caring for the maximum number of simultaneous connections. As is customary, each cord has the main conductors or talking leads L^{21} L^{22} united, respectively, to the tip and ring of the plug, and a third conductor L′ leading to the sleeve. It includes a repeating coil c between the halves of which is bridged the central station battery B with its positive pole grounded. This battery may be common to all the conductors of the station, but to render the connection more clear others will be shown and referred to as independent. The cord also contains the operator's listening key K and the telephone set a^3, supervisory signal lamps O^2 and O^3 with the supervisory relays R^{10} and R^{11}, the latter of which is marginal, together with the originating relay R^{12}, controlling relay R^{13} and double wound guard relay R^{14}. The purposes of the relays and minor elements in the cord and throughout the system will be made to appear more fully in the description of operation, where mention will also be made of the many armatures, contacts and conductors, reference to which independently of the circuits of which they are a part and the functions which they perform would convey but little information.

Office and trunk selecting appartus.—The strands L^{21} L^{22} of the cord circuit are continued beyond the contacts of relay R^{13} by main leads or conductors L^{23} and L^{24} terminating in a selecting apparatus D, which serves in the present instance to pick out the office with which connection is desired. Additional conductors L^2 and L^3 also lead between the apparatus C and D. The office selecting apparatus includes an electromechanical switch S^{20}, of which there are several well-known forms available, this being here shown as provided with a rotatable shaft s^{20} which carries insulated from it main contact members or arms s^{21} s^{22} and a test contact member s^{23}, each of these arms coöperating with a series of stationary contacts s^{24}. The shaft also has fixed to it ratchet wheels s^{25} and s^{26} engaged by pawls m^{20} and m^{21}, respectively, movable with the armatures of motor magnets M^{20} and M^{21} to advance the contact arms in long and short steps over the fixed terminals upon the energization of said motor magnets. A spring s^{27} exerts its tension to hold the arms normally in a position out of contact with an active terminal. A pawl h^{20}, brought into engagement with the ratchet wheel s^{26} by the attraction of a retaining magnet H^{20}, temporarily holds the arms at the points to which they may have been advanced by the motor magnets. An off normal contact device s^{28} operates to vary the circuit connections when the arms are stepped from their initial positions, as will be hereinafter described. As illustrated, both in this device and those of the other switches of the system, the movable contact members are raised when the advance of the switch arms begins.

To allow the groups of trunk conductors which connect the office A with others in the district to efficiently serve the maximum number of subscribers, all the office selectors are given access to any one of the trunks in all groups, and this is accomplished by mul-

tiplying their fixed contacts to said trunks. But with as many offices as ten, which in this case have been assumed as comprised within the district, and with the number of trunks necessary to satisfactorily handle the calls of each office with the maximum efficiency and economy, it may be found that using the switches S^{20} for the direct selection of office trunks requires more fixed terminals for each switch than is practical, both because of structural considerations and speed of selection. For this reason we have shown associated with the office selectors groups of trunk selecting apparatus E, the arrangement being as follows, reference being had to Fig. 1: The terminals s^{24} of each switch S^{20} are divided into ten successive groups u corresponding to the total number of offices. The space covered by each subtends the angle through which the selector arms are advanced upon each energization of the motor magnet M^{20}. The terminals s^{24} are themselves separated by distances equal to the short steps produced by the magnet M^{21}. Similar contacts in each group u are multiplied together by conductors u^2 leading to triple conductors L^{31} L^{32} L^{33}, which may be connected to the arms of one of a suitable number of switches S^{30} of the trunk selecting apparatus E, these being best shown in Fig. 3. The trunk selecting switches are of the same character as those of the office selectors having revoluble contact arms s^{31} s^{32} s^{33} to which the main conductors L^{31} L^{32} and the third conductor L^{33} may be connected. The arms are mounted upon a shaft s^{30} and driven by a single motor magnet M^{30}, with a retaining magnet H^{30}, both provided with armatures and pawls acting upon a ratchet wheel s^{36}. This wheel operates an off normal contact device s^{38}. There are three sets of fixed contacts s^{34} over which the arms are moved. The connection of the contacts of the arm s^{33} is local to the apparatus F, being for test purposes as will later appear, but the contacts of the arms s^{31} and s^{32} are united to trunk conductors L^{41} and L^{42}, respectively, which lead to the distant office to which the section of the associated office selecting apparatus D corresponds. These trunks are arranged in groups of a magnitude sufficient to satisfy traffic conditions, and similar contacts throughout the groups of switches S^{30} are multiplied to the trunks by means of pairs of conductors v^2 (Fig. 1), so that any switch may have access to any one of the trunks. It will be seen, therefore, that under the influence of some appropriate controlling means, each apparatus D may first pick out a group of selecting apparatus E representing a particular office and then an idle trunk selector, which in turn may seek an idle trunk couple terminating in such distant office. In doing this the switch S^{20} of the apparatus D is required to (1) move its contact arms to the proper section u of the fixed terminals, (2) advance said arms until they reach contacts s^{24} connected to non-busy trunk selecting apparatus E, and (3) stop the arms and establish the circuit through the trunk selector. To vary the circuit connections for the accomplishment of this, each apparatus D includes three relays R^{20} R^{21} and R^{22}, the relay R^{21} having two windings. The first when energized puts the apparatus in condition for operation; condition (1) follows with R^{21} energized and R^{22} deënergized; for condition (2) R^{21} and R^{22} are both energized, and, finally, for condition (3), R^{21} is deënergized and R^{22} energized. The trunk selecting apparatus E has only to advance its contact arms to an idle trunk, and to aid in this a single relay R^{30} is provided. In addition the motor magnets M^{21} and M^{30} and the retaining magnets H^{20} and H^{30} have other armatures than those actuating the pawls, these sharing in the control of the circuit.

Line selecting apparatus.—From the fixed terminals, with which the arms s^{31} s^{32} of each trunk selecting switch coöperate, the two-conductor trunks L^{41} L^{42} extend to apparatus for selecting and connecting with the called line, which may, of course, belong either to the originating or to a distant office. In either case at their incoming ends each pair of trunk conductors is equipped with an apparatus F (Fig. 4) for furnishing energy to this portion of the circuit and for controlling the connection. This includes a repeating coil f, having one winding bridged across the trunk and the other winding joined to conductors L^{41*} and L^{42*}, which lead through relay contacts to the conductors L^{51} and L^{52} and extend the talking circuit. Condensers f^2 f^2 are inserted between the sections of each winding of the coil, permitting the passage of voice currents while preventing the short circuiting of the steady current operating the relays. Associated with the repeating coil is the office battery, hereinafter designated by different reference characters when describing the part it plays in the various circuits. The apparatus F also comprises a group of relays R^{40} R^{41} R^{42} R^{43} R^{44} R^{45} R^{46} and R^{47}. Of these relays R^{43} and R^{44} are positively polarized, R^{45} is negatively polarized, and R^{46} and R^{47} each have two windings, which in the relay R^{43} are of relatively high and low resistance, said windings being designated by the characters r and r^2, respectively. The functions of these relays and also those forming a part of the line selecting apparatus will be better understood after the mechanism composing said selecting apparatus have been enumerated.

It being remembered that ten-thousand-line offices were assumed, the called line may

be conveniently arrived at by passing through three successive sections of apparatus: the first selecting the thousands group in which said line is located, the second the hundreds or an allied group and the third the tens group and the particular unit therein. These three assemblages of apparatus may be termed, respectively, the primary selectors I, the secondary selectors I^2 and the final selectors or connectors I^3. To the conductors L^{51} and L^{52} of each trunk is permanently assigned a primary selecting apparatus, which also has a third conductor L^{53} connecting it to the apparatus F. This primary apparatus I may be much the same as the office selecting apparatus D, the shaft s^{50} of its switch S^{50} carrying main contact arms s^{51} and s^{52} and a test arm s^{53}, movable in long and short steps over terminals s^{54} by successively acting ratchet mechanisms under the influence of motor magnets M^{50} and M^{51}, and temporarily held at the position to which it is driven, by detent mechanism associated with a retaining magnet H^{50}. An off normal contact device s^{58}, double wound relay R^{51} and a marginal relay R^{52}, and relay contacts upon the motor magnet M^{51} and retaining magnet H^{50} are features of the primary selector. The same general considerations of machine and trunk efficiency and economy obtain throughout the line selecting apparatus as in the office selectors, and it may be that it is found expedient, for example, to employ selecting switches having in all 200 fixed terminals. It will be assumed that such are to be used. In the primary switches these terminals are divided into ten groups w (Fig. 2) corresponding to the thousands of the total number of lines in the office, each of which groups may include twenty terminals. Similar terminals of each group in all the primary selectors are multiplied by conductors w^2, to inter-apparatus trunks having main leads or conductors L^{61} L^{62} and a third conductor L^{63} (Fig. 4). Each of the conductors L^{63} terminates in a contact device of secondary selecting apparatus I^2, while leads L^{61} and L^{62} extend to the contact arms s^{61} s^{62}, respectively, of switches S^{60} belonging to said secondary selecting apparatus. This enables one of the primary selectors to appropriate for the continuation of the connection the first idle secondary selector. The motor magnets M^{60} and M^{61}, retaining magnet H^{60}, off normal contact s^{68} and relays R^{61} and R^{62}, the latter being marginal, are here as in the primary selecting apparatus.

The fixed terminals s^{64} of the switches S^{60} are divided into secondary or hundreds groups x (Fig. 2), somewhat as are those of the switches S^{50} into primary or thousands groups, and for similar reasons are multiplied by conductors x^2 to trunk conductors L^{71} L^{72} L^{73} (Fig. 4) extending to final selectors I^3, but as already pointed out, the switches are of two hundred points each, so that the secondary groups will comprise two hundred instead of one hundred units, and there will be five of such groups to each thousand and five sections containing forty contacts s^{64} in the switches S^{60}.

The final selectors I^3 have connecting switches S^{10}, to the main arms s^{71} s^{72} of which the trunk conductors from the secondary selectors may be joined through extensions L^{71*} and L^{72*}. The connection of the test arm s^{73} is local to the apparatus I^3. The fixed terminals s^{74} of these switches are in twenty sections y (Fig. 2), representing the tens of the full group of two hundred; each section having ten unit terminals to which the substation lines, one of which is shown at l^{11}, l^{12}, with the third conductor l^{13} leading to the answering jack J^2, are multiplied by conductors l^{21}, l^{22} and l^{23} as shown in Figs. 3 and 5 but indicated collectively at y^2 in Figs. 1 and 2. Connected with this substation line are its line and cut-off relays R^3 and R^4 and a line lamp O'. A motor magnet M^{70} in this switch moves the contact arms in long steps from one tens section to another, while motor magnet M^{71} carries them by short steps over successive unit terminals until the line sought is reached. A retaining magnet H^{70} acts in the usual manner.

Having in mind the purpose and relation of the three kinds of line selecting switches, the functions of the relays at the incoming end of the trunk and included in the primary and secondary apparatus may be stated. Relay R^{47} assists in controlling the supervisory signal O^3. The remaining trunk relays affect three groups of results—first, to establish and maintain connection between battery and the conductor L^{53}, this rendering possible the succeeding operations of the primary selector, it applies current to the retaining magnet H^{50} of said primary selector, which in turn does the same for one winding of the primary selector relay R^{51}, then to the test arm s^{53} and relay R^{52}; second, to receive and repeat locally into the line selecting apparatus impulses transmitted from the calling office; third, to establish the talking circuit. These are brought about as follows: First, relay R^{40} momentarily establishes the desired connection with conductor L^{53}, which is then temporarily retained by relay R^{41} and ultimately by relay R^{42}; second, relay R^{43} receives and repeats into motor magnets M^{50}, M^{60} and M^{70} of the primary, secondary and final selecting switches, respectively, the series of impulses which correspond to the thousands, two-hundreds, and hundreds and tens of the desired number; relay R^{44} receives and repeats into relays R^{52} and R^{62} and motor magnet M^{71} of the final selector

the two single pulses and one series of pulses which are sent out from the calling office to start the primary and secondary selector arms seeking for non-busy inter-apparatus trunks and to move the final selector arms to the unit terminals of the desired number; third, as soon as all the selecting impulses have been received and the talking circuit is established in the cord by the de-energization of relay R^{13}, relay R^{45} is energized. This relay R^{45} shunts itself by relay R^{46}, which in turn energizes relay R^{42}. The last-named relay establishes the talking circuit, maintains the circuit of relay R^{46}, opens the circuits of relays R^{45} and R^{41}, and substitutes a direct connection between the conductor L^{53} and battery for the previous connection through the winding of relay R^{41}.

The ends attained by the relays of the primary and secondary selectors are closely analogous to those accomplished by the relays of the office selecting apparatus D. That is, in the primary selector I, to cause the arms of the switch S^{50} under the influence of the calling office to (1) seek the section *w* of its contacts from which conductors lead to the multiplied secondary selectors I^2 representing the thousand of the called line; (2) to continue the movement by shorter steps within said section to reach an idle trunk, and (3) to stop the arms and complete connection. The relays of the secondary apparatus I^2 effect the same result with respect to the final selecting apparatus I^3. The operations follow one another in the order given with (1) relays R^{51} and R^{61} energized, and R^{52} and R^{62} de-energized; (2) R^{51}, R^{61} and R^{52}, R^{62} all energized, and (3) with R^{51} and R^{61} de-energized and R^{52} and R^{62} energized.

Returning now to the final selector, all the apparatus of this class at the office would have associated with it a ringing generator N and a busy signal mechanism N^2. Each final selecting apparatus has assigned to it a group of relays. Of these, negatively polarized relay R^{70}, by means of a final impulse of current from the calling office, closes the circuit of the test arm s^{73} and of the busy signal mechanism; double wound sluggish relay R^{71} is adapted to control the display of a busy signal to the operator; R^{72}, which may be termed the primary connecting relay, completes one side of the line, cuts off the busy signal mechanism and closes the circuit of the relay R^{73}; relays R^{73} and R^{74}, the latter having two windings, apply ringing current to the called line, and relay R^{75}, the secondary connecting relay, interrupts the ringing current and completes the talking circuit. In varying the circuit connections, relay contacts upon the retaining magnet H^{76} and off normal contact devices s^{78} and s^{79} assist.

Controlling apparatus.—The search of the office, trunk and primary and secondary line selectors for an idle apparatus among the multiple of the succeeding class to which it has access takes place under the control of the previously mentioned relays without the direct intervention of an operator. The selection of the office at which the called subscriber's line terminates and of all the groups of units making up the number by which said called subscriber is designated is under the control of the calling subscriber's operator, therefore, to start the series of selective operations and to govern them, each operator is provided with a controlling apparatus T (Figs. 6, 7 and 8) which receives current from the office battery through a main lead L^{85}. Said current, in certain of the controlling circuits, is interrupted to furnish motive impulses by one or more pulsators of any convenient type. Like the battery, these pulsators have been shown in the drawings in a number of places and indicated by different characters of reference for convenience in description.

With such an exchange as that now under consideration the controlling apparatus, which is shown as connected with the apparatus of the cord circuit C by conductors L^{81} L^{82} and L^{83}, and with the office selector D by a conductor L^{84}, may have three sections T^2 T^3 and T^4, corresponding, respectively, to the offices of the exchange, the thousands and hundreds digits of the total number of subscribers, ten thousand, which may be connected to each, and the tens and units digits of said number. Each section is provided with a set of keys equaling in number the offices or digits, the selection of which it governs, there being ten office keys K^{80} in section T^2, ten thousands keys K^{90} and ten hundreds keys K^{100} in section T^3, and ten tens keys K^{120} and ten units keys K^{130} in section T^4, each being preferably designated in practice by the office or digit which it represents. The keys may be of any convenient form, and are each provided with two contacts normally open but closed upon the depression of a key. Each set of keys has a locking member *k* to maintain a depressed key in this position until released by the energization of an electro-magnet k^2. Combined with each set of keys is one or more electromechanical switches, preferably organized in the same general way as those of the selecting apparatus, and these will be hereinafter referred to without describing them in detail. Groups of relays are also associated with each set of keys and those will be more particularly mentioned and their functions stated after an enumeration of the major mechanisms of the controlling apparatus.

To affect the office selecting apparatus D in accordance with the condition registered upon the keys K^{80} of the controlling appa-

ratus, said keys (Fig. 6) are connected consecutively to one of ten fixed contacts s^{84} of a sending switch S^{80} which governs the number of selective impulses applied to the office apparatus D. This switch has a single contact arm s^{81} driven by a motor magnet M^{80} and temporarily locked by a retaining magnet H^{80}. An off normal contact device s^{88} is closed during the travel of the arm.

Attention has already been directed to the fact that although the primary groups of the line selecting apparatus are arranged by tens, that is, upon the decimal system, as naturally would also be the digit keys before the operators, the secondary groups in the thousands will all be of two hundred units each and therefore non-decimal. To cause the decimally designated keys to control selection non-decimally it becomes necessary to in some way change or translate the condition originated into a different condition actually transmitted. For this purpose the combined thousands and hundreds section is equipped both as a controlling and a translating apparatus. It has a switch mechanism S^{90} (Fig. 7) the shaft of which supports three contact arms s^{91} s^{92} and s^{93} revoluble in long and short steps by motor magnets M^{90} and M^{91}, respectively, and temporarily held by a retaining magnet H^{90}. Each arm coöperates with a set of fixed contacts designated, respectively, by the characters s^{94} s^{95} and s^{96}, there being 100 in each set, and thus equaling the possible combinations of ten thousands keys with ten hundreds keys. Every tenth point s^{94*} of the set s^{94}, or those separated by intervals equivalent to the long steps of the magnet M^{90}, is connected consecutively to a spring of a thousands key K^{90} and serves to control the sending of selective impulses to the primary apparatus I. The intermediate points are spaced from one another in accordance with the short steps produced by magnet M^{91}, every tenth point being multipled together in sets of ten and connected to a spring in the corresponding hundreds key. The contact s^{94} ultimately reached by the arm s^{91} determines the point at which the arms s^{92} and s^{93} shall rest upon the contacts s^{95} and s^{96}, and it may be considered that upon these the original numerical condition initiated by the hundreds keys k^{100} is registered. For this reason these will hereinafter be termed register contacts, s^{95} being primary and s^{96} auxiliary. It is now desired to transmit impulses to the secondary selectors I^2 according to their non-decimal arrangement of five two-hundreds groups to the thousand. For this purpose the contacts s^{95} of the primary register are connected in pairs, thus giving the five groups in each of the ten thousands which the entire hundred contacts represent. Then, as the only function of this portion of the apparatus is to fix the group in a particular thousand which has been already picked out with the aid of the thousands sending contacts s^{94*}, corresponding pairs throughout the ten thousands group are multipled together and united successively to the five fixed contacts s^{104} of a primary hundreds sending switch S^{100}. This switch is provided with a contact arm s^{101}, a motor magnet M^{100} and a retaining magnet H^{100}. If the number sought fell within the first hundred of the two-hundred group, it would only be necessary to proceed with selection therein through the final connecting apparatus by tens and units. If, however, it is in the second hundred the connector arms must be advanced over the first hundred before said selection begins. To accomplish this the first and every alternate contact s^{96} of the auxiliary register is multipled to a conductor leading to relay mechanism which puts the controlling section T^4 into action. The second contact s^{96} and every other alternate point is similarly multipled and is joined to relay mechanism to bring into play an auxiliary sending switch s^{110}, the motor magnet M^{110} of which causes its arm s^{111} to take ten steps, and ten impulses to be transmitted to the motor magnet M^{70} of the connector I^3 carrying it by tens over the first hundred of its two hundred contacts. At the termination of its ten steps, during which the arm is temporarily held under the influence of a retaining magnet H^{110}, the arm s^{111} rests upon an active contact s^{114} completing a circuit which transfers the control to the tens and units section T^4.

The section T^4 (Fig. 8) includes a combined tens and units sending switch S^{120}, of which the arm s^{121} first travels from one tens contact s^{124} to another under the influence of a motor magnet M^{120}, and then is moved from units contact s^{134} to units contact by motor magnet M^{130}. To govern these movements and the impulses sent to the connector each tens point is joined to a contact spring in a corresponding key K^{120}, while similar units points in each tens group are multipled and connected to the spring of the proper units keys K^{130}. The switch S^{120} further includes a retaining magnet H^{120} and an off normal contact device s^{128}.

Of the relays of the controller T which serve to vary its circuits, one, R^8, establishes initial connection with the main battery lead L^{85}, upon which all the operations of the controller depend, and after it has completed its work provides for the release of the keys. A lamp O^8 connected to the battery lead will show whether the controller is operating or idle. The remaining relays have three functions (1) to close a motor magnet circuit, (2) to open said circuit when the desired impulses have been transmitted,

and (3) to bring into action those next succeeding them. These relays may be grouped as follows, the individual members being mentioned in the order of function above-stated: office controller relays R^{80} R^{81} and R^{82}, thousands relays R^{90} R^{91} and R^{92}, transfer relays R^{93} R^{94} and R^{95}, hundreds relays R^{100} R^{101} and R^{102}, auxiliary hundreds relays R^{110} and R^{111}, tens relays R^{120} R^{121} and R^{122} and units relays R^{130} and R^{131}. In the exceptional case of the auxiliary hundreds group the third relay is not required, and in the units there is no further apparatus to be brought into circuit, instead the second relay R^{131} disconnects the controller from the cord. In addition to what have been mentioned, the controller has office test relays R^{83} and R^{84}, a thousands test relay R^{96} and a hundreds test relay R^{103}. Of the controller relays those numbered R^8 R^{82} R^{84} R^{92} R^{95} R^{102} R^{122} and R^{131} are sluggish, while relays R^{81} R^{91} R^{94} R^{101} and R^{121} have each two windings.

Operation of the system.

To show the operation of the system, the manner of receiving a call will now be described, together with the completion of the desired connection with an idle line and the failure to so connect with a busy line; at the same time the circuits involved will be traced. It may be assumed that the subscriber at substation *a*, which has an answering jack and its signal at central station A, wishes to communicate with subscriber at a^2 whose line belongs to central station A^2 and whose number is 2132. The subscriber at substation *a* (Fig. 3) takes the receiver from its hook, completing a circuit from battery B′ through conductor 14, one winding of relay R, armature 11 and its back contact in cutoff relay R^2, conductor 12, limb *l* of the line, substation set *a*, limb l^2 of the line, back contact and armature 13 of relay R^2 and second winding of relay R to ground. This energizes the line relay, thereby closing a local circuit 14 including armature 14^a, battery B′ and the line signal lamp O, which is thus illuminated. In response to the signal, the operator before whom it is situated inserts the plug P of one of the cords C at her position in the answering jack J of the calling subscriber's line. This results in the energization of the cutoff relay R^2, originating relay R^{12} and supervisory relay R^{10} by the simultaneous closing of two circuits, one from battery B′ to ground through the winding of the cutoff relay, conductors l^3 and L′ and winding of relay R^{12}; the other from the negative pole of battery B, one winding 15 of the repeating coil *c*, winding of supervisory relay R^{10}, limb l^2 of the subscriber's line, substation set, limb *l* of the line, and winding 16 of the repeating coil. The energization of relay R^2 disconnects relay R from the subscriber's line, resulting in the falling back of the armature 14^a and the extinguishing the line lamp O. The operation of relay R^{12}, through its armature 16 and its front contact, places battery B^{10} on conductors 17 and 18 and lights supervisory lamp O^3, which is connected to ground. The energization of relay R^{10} opens the contact of its armature 19 and prevents the lighting of the supervisory lamp O^2.

The operator throws the key K in the cord employed into the listening position and connects her telephone set a^3 through the springs 20 20 with the talking strands L^{21} L^{22} of said cord, and at the same time closes at the springs 21 21 of the key a circuit from the battery B^8 (Fig. 8), through spring 22 of the controller connecting relay R^8, conductor L^{84}, normally closed springs 52 52^a of the contact device s^{28} of the office selector D, conductors L^3 and 23, back contact and armature 24 of cord relay R^{14}, winding of connecting relay R^{13}, conductor L^{81}, winding of relay R^8, conductor 25 and back contact and armature 26 of units relay R^{131}. On operating the relay R^8 by its armature 22^a disconnects battery B^8 from the conductor L^{84} and connects it to the main battery lead L^{85}, which with its branches is shown in heavy broken lines so that it may be readily distinguished, and to thus avoid the necessity for tracing back to the battery B^8 the many circuits of the controller. When battery is connected to this lead holding magnets H^{80} of the office switch S^{80}, H^{90} of the thousands-hundreds switch S^{90}, H^{100} of sending switch S^{100} and H^{120} of the tens-units switch S^{120} are energized by current to ground. The path of the first is through conductor 27, armature 28 and its back contact in relay R^{84} and conductor 29; the second through off normal contact s^{98} of switch S^{90} and conductors 30 and 31; the third through spring 31^a of relay R^{103} and conductor 32, and the last by off normal contact s^{128} of switch S^{120} and conductors 33 and 34. At the same time the lamp O^8 is illuminated and so continues while the controller is in operation. The armature 35 of controller relay R^8 closes contact with spring 36 before breaking the resting contact of the spring, with the result that by means of conductors 38, 39, 40 and 41 the key releasing magnets k^2 of all the controller sections are momentarily energized by current from battery B^8. The object of this is to free any key which might have been accidentally depressed before the operator is ready to register the desired number.

The operation of controller connecting relay R^{13} in the cord, which was energized simultaneously with the starter relay R^8, disconnects by its armatures 76 and 84 the talking leads L^{23} L^{24} of the office selector D

from the cord strands L^{21} L^{22} and joins the former to the controlling apparatus through conductors L^{82} and L^{83}. Armature 42 of relay R^{13} closes a by-path by conductor 43 through one winding of cord relay R^{14}, conductor 44, contact 45 of key K, conductor 18 and front contact and armature 16 of relay R^{12} to battery B^{10}. This by-path serves the double purpose of energizing the guard relay R^{14} and substituting a path to battery for the circuit of relays R^{13} and R^{8} in place of that to battery B^{8} through armature 24 of relay R^{14}, which circuit was closed by the operation of key K but which is now opened by the energization of relay R^{14}. This prevents any subsequent throwing of the key into the listening position from interfering with the circuits, and the attraction of the other armature 48 of this relay R^{14} completes a circuit from battery B^{10} to ground through the armature 16 of relay R^{12}, conductor 18, contact 45 of key K, second winding of relay R^{14}, conductor L^{2} and winding of office selector relay R^{20}. This energizes relay R^{20} and locks relay R^{14} making it independent of the circuit established through its first mentioned winding.

On operating the relay R^{20} closes the front contacts of its three armatures 49, 50 and 51. Armature 49 connects ground to the winding of relay R^{22}. Armature 50 prevents the complete opening of the circuit of conductors L^{84} and L^{3}, which would otherwise take place upon the separation of the springs 52 and 52^{a} of the off normal device s^{28}, when the motor magnet of the office selector responds to the impulses which it is to receive. Armature 51 closes a circuit through conductor 53 from ground to battery B^{20} through the winding of retaining magnet H^{20}. Then the office selector relay R^{21} is energized by current in one winding from battery B^{20} to ground through the armature 54 and its front contact in the retaining magnet H^{20}, conductors 55 and 56, spring 57 and its resting contact in relay R^{22} and conductor 58. When energized the relay R^{21} disconnects its armatures 59, 60 and 61 from the arms s^{21} s^{22} and s^{23} of the office selecting switch and closes their front contacts. The apparatus is now ready for automatic selection to begin when the operator has registered the office and number upon the controller keys.

The selection of the office and a trunk leading thereto.—In accordance with the number A^{2}—2132, the operator depresses the office key A^{2} K^{80}, thousands key $2K^{90}$, hundeds key $1K^{100}$ tens key $3K^{120}$ and units key $2K^{130}$. The depression of the office key connects the second fixed contact point s^{84} of the office sending switch S^{80} to the main battery lead L^{85} by conductor 62, springs 63 and 63^{a} of the key and conductor 64, and also closes a path from the battery lead through conductor 62, key springs 63, 63^{a} and 65, conductors 66 and 67, winding of relay R^{80} and its spring 68 to an intermittent ground provided by pulsator P^{80}. Since the pulsator is in constant motion relay R^{80} will be energized at a time substantially coincident with the depression of the office key. On operating this relay locks itself to ground by its armature 69, disconnects itself from the intermittent ground of the pulsator, and closes the following path from the spring of the pulsator P^{80} which is connected to battery B^{80} to ground; armature 70, conductor 71, winding of motor magnet M^{80}, back contact and armature 72 of relay R^{81}, conductor 73, back contact and armature 74 of relay R^{82}, conductors 75 and L^{82}, armature 76 and spring 76^{a} of relay R^{13}, talking lead L^{23}, armature 59 and its front contact in relay R^{21}, conductor 77, winding of motor magnet M^{20}, conductor 77^{a} and spring 78^{a} of relay R^{22}. Since this circuit contains the windings of two motor magnets, either of which may be more sensitive, it is essential that the first pulse of current over the circuit when it is closed by the operation of the controller relay R^{80} shall be complete and not fractional. This is accomplished by including in the initial circuit of the relay R^{80} the intermittent ground contact of the pulsator P^{80}, as has been already described, thus fully energizing it before the pulsator applies current to the motor magnets. Said magnets M^{80} and M^{20} now will drive forward simultaneously the contact arms of the office controller switch S^{80} and the selector switch S^{20}, the latter covering a section *u* at each step. When two pulses have been transmitted through the motor magnets the arm of the controlling switch will close a path from the battery lead L^{85} to ground through conductor 62, springs 63 63^{a} of the depressed key, conductor 64, switch arm s^{81}, conductor 79 and one winding of relay R^{81}. This relay then operates and breaks the circuit of magnets M^{80} and M^{20} at its armature 72. The arms of the office selector are now at rest on the first triple set of contacts of its second section. If the trunk selector E connected with this set of contacts is not busy it is only necessary to release relay R^{21}; if the trunk selector is busy the movement of the arms must be continued until they are brought to rest on contacts leading to a non-busy apparatus.

It will be noted that the previously described path through the winding of relay R^{81} is only one of two which run from conductor 79 to ground. The other path consists of conductor 80, off normal contact device s^{88}, which is now closed, conductor 81, back contact and armature 82 of relay R^{82}, conductors 83 and L^{83}, armature 84 and spring 84^{a} of relay R^{13}, talking lead L^{24}, armature 60 and its front contact in relay

R^{21}, conductor 85, winding of relay R^{22} and front contact and armature 49 of realy R^{20}. Therefore, relay R^{22} of the office selector was energized simultaneously with relay R^{81} of the controller when the contact arm of the office sending switch reached its second point. On operating the armature 78 of relay R^{22} disconnects ground from the motor magnet M^{20} and closes from ground to armature 61 of relay R^{21}, which armature is joined to the test arm s^{23} of the office selecting switch, a multiple circuit consisting of (1) conductors 86 and 87, one winding of relay R^{21} and conductors 90 and 88, and (2) conductor 86, the winding of the motor magnet M^{21}, its armature 89 and conductors 90 and 88. The operation of the armature 91 of relay R^{22} opens the circuit of the winding of relay R^{21} connected to conductor 58, and locks relay R^{22} to the battery B^{20} by means of spring 57, conductors 56 and 55 and armature 54 of retaining magnet H^{20} and its front contact. If the trunk selector with the leads of which the arms of the office selector are now in contact is busy, conductor L^{33} will be connected with the battery B^{21} of the office selector already associated with it. Therefore, although the circuit of one winding is open, relay R^{21} will be kept energized by current passing from conductor L^{33} through the test arm s^{23} of the office selector, conductor 95, armature 61 and its front contact, conductors 88 and 90, second winding of relay R^{21}, conductors 87 and 86 and armature 78 and spring 78^a of relay R^{22}, which is now energized. Current will also flow through the other branch of this circuit which includes the winding of motor magnet M^{21}, and hence the contact arm will be driven forward until the test arm comes to rest on a lead which is not connected to battery, that is, until a non-busy trunk selector is attained. Then, since current no longer flows through either winding of relay R^{21}, it is deënergized, breaks at its front contacts all its circuits previously described, connects talking leads L^{23} L^{24} through the two upper arms to the talking leads L^{31} L^{32} and unites battery B^{21} to conductor L^{33} by means of the test arm. This renders the chosen trunk selector busy, to guard, as has just been outlined, against its appropriation by another office selector. When this occurs current will flow from the conductor L^{33} to ground by three paths: (1) through spring 96 of the off normal device s^{38}, conductor 97 and the winding of the retaining magnet H^{30}; (2) springs 96 and 98, conductor 99, back contact and armature 100 of motor magnet M^{30} and winding of said magnet, and (3) springs 96 and 98, conductor 99 and the winding of relay R^{30}. The magnet H^{30} applies the retention pawl, and by its armature 101 closes a path through conductor 102 to conductor L^{33}, which makes the circuit for the retaining magnet independent of the off normal contact device s^{38}. The energizing of relay R^{30} temporarily disconnects the arms s^{31} and s^{32} of the trunk selector from the talking leads L^{31} L^{32} at the armatures 103 and 104, and connects at armature 104^a the test arm s^{38} to conductor 99 through conductor 105. The motor magnet M^{30}, in response to the current flowing through its winding, propels the arms from their normal position and opens contact springs 96 and 98. Although the opening at these springs disconnects conductor L^{33} from relay R^{30} and magnet M^{30}, these will be supplied with current by means of the test arm from the battery B^{21} of an office selector associated with a busy trunk selector through the multiple of the test contacts, until said test arm and the main contact arms come upon the terminals of a non-busy trunk, then current no longer being found at the test contact, relay R^{30} will be released, thereby reëstablishing the connection between the arms s^{31} and s^{32} and the talking leads L^{31} and L^{32} at the armatures 103 and 104, disconnecting the test arm from conductor 105 and joining it to conductor L^{33} by conductor 106. The conductor L^{33} being connected to battery B^{21}, the test arm establishes on the test terminal corresponding to the selected trunk the condition which will prevent its being taken by some other trunk selector.

The selection of the thousand group.—Returning to the consideration of the controlling apparatus, relay R^{81} when energized not only opened the contact of armature 72 to stop the advance over the sections *u* of the office selector arms, but also closed a circuit from ground to the main battery lead L^{85} through its second winding and the winding of relay R^{82} by way of the conductors 107 and 108. This latter relay is designed to operate sluggishly, in order that its armature 82 will not open the back contact before office selctor relay R^{22} has had time to lock up. Upon operating the armature 74 of relay R^{82} opens its back and closes its front contact. No further action occurs in the controlling apparatus until the office selector has completed the finding of a non-busy trunk selector, and subsequently the latter of a non-busy trunk. But when trunk selector relay R^{30} is deënergized and the connection between the lead L^{31} and arm s^{31} is reëstablished, current flows from the battery lead L^{85}, through conductors 27 and 109, spring 110 of relay R^{84}, conductor 111, winding of relay R^{83}, conductor 112, front contact and armature 74 of relay R^{82}, conductors 75 and L^{82}, armature 76 and spring 76^a of relay R^{13}, talking lead L^{23}, armature 59 and its back contact in relay R^{21}, office selector arm s^{21}, talking lead L^{31}, armature 103 and its back contact in relay R^{30}, trunk

selector arm s^{31}, talking lead L^{41} of the interoffice trunk, conductor 112^a, spring 113 of relay R^{41}, conductor 114, winding of relay R^{40}, conductor 115, back contact and armature 116 of relay R^{44}, conductor 117, back contact and armature 118 of relay R^{45}, conductor 119, spring 120 of relay R^{42}, talking lead L^{52}, armature 140 and its back contact in relay R^{51} and primary selector arms s^{52} to ground at its resting contact. Controller relay R^{83} and trunk relay R^{40} are both energized by the closing of this circuit. The armature 122 of relay R^{40} are both energized by the closing of this circuit. The armature 122 of relay R^{40} opens its back and closes its front contact, preparing for circuits to be later pointed out, while armature 123 closes a path from battery B^{40} to ground through conductor 124, spring 125 and winding of relay R^{41}, conductors 126 and L^{53}, off normal contact s^{58}, conductors 127 and 128 and winding of the retaining magnet H^{50} of the primary selector. This circuit energizes the relay R^{41} and said retaining magnet.

The armature 129 of relay R^{41} makes the circuit containing this relay independent of the momentary battery connection established by relay R^{40} by connecting its winding to the battery B^{41}, through the conductor 130 and spring 131 of relay R^{42}. The armature 132 of relay R^{41} substitutes its contact with the spring 113 for the resting contact thereof, but this has no effect until relay R^{40} is deënergized and its armature 122 assumes its normal position. Armature 133 of holding magnet H^{50}, by closing at its front contact a connection between conductors 127 and 134, prevents the separation of conductors L^{53} and 127 when the off normal contact device s^{58} is opened upon the actuation of the switch S^{50}. The armature 135 closes a path from battery B^{50} to ground through conductors 136 and 193, spring 137 of relay R^{52}, conductor 138 and one winding of relay R^{51}. The functions of this relay are analogous to those of the office selector relay R^{21}. It temporarily disconnects leads L^{51} L^{52} from arms s^{51} and s^{52} and closes the front contacts of its armatures 139 140 and 141.

Considering again the controller relay R^{83}, which was energized simultaneously with the trunk relay R^{40}, its armature 142 closes the circuit of relay R^{84} from the battery lead L^{85} through conductors 27, 143 and 144. This relay R^{84} by means of its armature 145 locks its winding to battery by way of conductors 27 and 109 and spring 110, and opens the resting contact of said spring and the energizing circuit of relays R^{83} and R^{40}, thereby releasing them. The armature 28 of relay R^{84} opens at its back contact the circuit of the retaining magnet H^{80} of the office sending switch S^{80}, the arm s^{81} of which is returned by its spring to its initial position. Upon its front contact the armature 28 closes a path from the main battery lead through conductors 27 and 146, armature 147 and its back contact in relay R^{92} and conductor 148 to the springs 149 of the thousands keys K^{90}. Since the key of the digit 2 is depressed, current will flow on from conductor 148 through springs 150 and 151, conductor 152, winding of relay R^{90} and its spring 153 and conductor 154 to an intermittent ground at pulsator P^{90}. Then relay R^{90} attracts its armatures, locks itself to a permanent ground connected to the armature 155, opens the contact leading to the pulsator, and closes the front contacts of its armature 156 and 157. There is now a closed circuit from the pulsator P^{91} through the winding of motor magnet M^{90}, conductor 158, front contact and armature 156 of relay R^{90}, conductor 159, back contact and armature 160 of relay R^{91}, conductors 161 and L^{82}, armature 76 and spring 76^a of relay R^{13}, which is still energized, lead L^{23}, armature 59 and its back contact in relay R^{21}, arm s^{21} of the office selector, lead L^{31}, armature 103 of relay R^{30}, arm s^{31} of the trunk selector, lead L^{41}, conductor 112^a, spring 113 and armature 132 of relay R^{41}, conductor 162, back contact and armature 122 of relay R^{40}, conductor 163, winding of relay R^{43}, conductors 164 and 115, back contact and armature 116 of relay R^{44}, conductor 117, back contact and armature 118 of relay R^{45}, conductor 119, spring 120 of relay R^{42}, lead L^{52}, armature 140 and its front contact in relay R^{51}, conductor 165, and spring 166 and winding of relay R^{52} to ground. The closing of the circuit allows pulsator P^{91} to send a series of impulses through the motor magnet M^{90}, the relay R^{43} of the trunk and relay R^{52} of the primary selector. Relay R^{52} being marginal will not be energized by the series of pulses passing through it, on account of the high resistance of relay R^{43} and motor magnet M^{90}. The first pulse which passes through the motor magnet drives the arms of the thousands-hundreds switch S^{90} from their normal position to the zero member of the coöperating set of fixed contacts; the second pulse will drive the arms from the zero contact to the first tens contact s^{94*} while the third will advance them to the second tens contact s^{94**}. As will appear shortly, not more than three impulses will be sent through the circuit under consideration. At the same time, by means of trunk relay R^{43}, the following circuit from battery B^{42} to ground through the winding of motor magnet M^{50} of the primary selector will be closed three times—armature 167 of relay R^{43}, conductor 168, spring 169 of relay R^{42}, lead L^{51}, armature 139 and its front contact in relay R^{51}, conductor 170, winding of magnet M^{50} and spring 171 of relay R^{52}. Thus it will be seen that the three impulses which the pulsator

P^{91} transmits through motor magnet M^{90} and relay R^{43} not only propel the arms of the thousands-hundreds switch, but, by means of the relay R^{43} and its local circuit, drive the arms of the primary selector to the beginning of the third section *w* of its fixed contacts.

When the arm s^{91} of the thousands-hundreds switch S^{90} comes in contact with the twenty-first point s^{94*} or that corresponding to the numeral 20, current will flow from lead L^{85} to conductor 148, as previously traced, through springs 149 and 150 of the depressed thousands key K^{90}, conductor 172, arm s^{91}, conductor 173, armature 174 and its back contact in relay R^{92}, and conductor 175 to ground through two paths—one through conductor 176 and one winding of relay R^{91}, thereby energizing it; the other through conductor 177, armature 157 and its front contact in relay R^{90}, conductor 178, back contact and armature 179 of the relay R^{95}, conductors 180 and L^{83}, armature 84 and spring 84^a of relay R^{13}, lead L^{24}, armature 60 and its back contact in relay R^{21}, arm s^{22} of the office selector, lead L^{32}, armature 104 and its back contact in the relay R^{30}, arm s^{32} of the trunk selector, lead L^{42}, one winding 181 of the repeating coil *f*, conductors 182 and 183, spring 184^a of relay R^{42}, conductor 185, winding of negatively polarized relay R^{45}, conductor 186 and winding of positively polarized relay R^{44}, energizing the latter but not the former because the current flows from the positive pole of the battery B^8. The operation of the armature 160 of the controller relay R^{91} breaks the circuit containing the motor magnet M^{90} and relay R^{43}, and therefore the local circuit through the motor magnet M^{50} is also interrupted. The armature 116 of relay R^{44} opens its back contact and closes a circuit from battery B^{43} to ground through conductor 117, back contact and armature 118 of relay R^{45}, conductor 119, spring 120 of relay R^{42}, lead L^{52}, armature 140 and its front contact in relay R^{51}, conductor 165 and spring 166 and winding of relay R^{52}, thereby energizing said relay. The armature 187 of relay R^{52}, before breaking the resting contact of spring 166, locks the relay to battery B^{50} through conductor 136, and armature 135 of retaining magnet H^{50}. The armature 188 of relay R^{52} makes contact with its spring 137, which at this time has no effect, and opens the resting contact of said spring, thus breaking the circuit containing a winding of relay R^{51}. The armature 189 of relay R^{52} opens the resting contact of its spring 171, and therewith completes a circuit from ground to the test arm s^{53} through armature 141 and its front contact in relay R^{51} and the parallel paths consisting of (1) conductors 190 191 and 192 with the second winding of relay R^{51}, and of (2) conductors 190 193 and 192 with the winding of the motor magnet M^{51}. In the same manner as described in connection with the office selector, the test arm s^{53} of the primary selector will retain relay R^{51} energized and operate motor magnet M^{51} until the arms of the primary selector come into contact with leads to a non-busy secondary selector I^2, then relay R^{51} is de-energized, armatures 139 and 140 connect leads L^{51} and L^{52} to arms s^{51} and s^{52}, and a circuit is closed from battery B^{50} to ground through the armature 135 of holding magnet H^{50}, conductors 136 and 193, spring 137 and armature 188 of relay R^{52}, conductor 194, armature 141 and its back contact in relay R^{51}, test arm s^{53}, lead L^{63}, off normal contact device s^{68}, conductors 195 and 196 and the winding of the retaining magnet H^{60}. Upon the energization of this magnet its armature 197 closes a contact between conductors 195 and 198, which short circuits the off normal contact device. The armature 199 of magnet H^{60} closes a path from battery B^{60} to ground through conductors 200 and 201, spring 202 of relay R^{62}, conductor 203 and one winding of relay R^{61}. Upon operating this relay disconnects its armatures 204 205 and 206 from the arms s^{61} s^{62} and s^{63}, respectively, and closes its front contacts.

The translation and selection of the hundreds group.—In the previous reference to the energization of the controller relay R^{91}, the opening of the contact by means of its armature 160 only was considered. Its armature 207 completes a circuit from ground to the main battery lead L^{85} through one of its windings, conductor 208 and winding of relay R^{92}, which is designed to operate sluggishly in order that it will not open the resting contact of its armature 174 before relay R^{44} of the trunk had time to start the series of operations at the primary selector, as already described. The armature 147 of relay R^{92}, by opening its back contact and closing the front, disconnects the conductor 146, which with the conductor 27 extends to the main battery lead from the thousands keys, and connects it to the hundreds keys through conductor 209. The hundreds key $1K^{100}$ being depressed, current now flows from conductor 209 through springs 210, 211 and 212, conductor 213 and winding of relay R^{93} to ground. This, by its armature 214, closes a circuit from ground to pulsator P^{91} through the armature 215 and its back contact in relay R^{94}, conductors 216 and 217 and winding of motor magnet M^{91}. As soon as one impulse has been transmitted, and therefore the arms of the switch S^{90} have moved one short step from the fixed contact s^{94*} numbered 20, where they had been carried under the influence of the long step motor mag-

net M^{90}, current will flow from conductor 209 through springs 210 and 211 of the depressed hundreds key, conductors 218 and 219, the latter being connected to the point of the contacts s^{94}, numbered 21, arm s^{91}, conductor 173, armature 174 and its front contact in relay R^{92}, conductor 220 and winding of relay R^{94} to ground. Relay R^{94} then destroys the circuit of motor magnet M^{91} at its back contact, and closes at its front contact a circuit from the main battery lead to ground and containing its second winding, conductor 221 and winding of relay R^{95}. The energization of relay R^{95} opens the contact of armature 179, which is no longer required, and by its armature 222 closes a path from the negative pole of battery B^{100} through the winding of relay R^{96}, its spring 223, conductors 224 and L^{82}, armature 76 and spring 76^a of relay R^{13}, lead L^{23} armature 59 and its back contact in relay R^{21}, arm s^{21} lead L^{31}, armature 103 and its back contact in relay R^{30}, arm s^{31}, lead L^{41}, conductor 112^a, spring 113 and armature 132 of relay R^{41}, conductor 162, back contact and armature 122 of relay R^{40}, conductor 163, winding of relay R^{43}, conductors 164 and 115, back contact and armature 116 of relay R^{44}, conductor 117, back contact and armature 118 of relay R^{45}, conductor 119, spring 120 of relay R^{42}, lead L^{52}, armature 140 and its back contact in relay R^{51}, arm s^{52}, lead L^{62}, armature 205 and its front contact in relay R^{61}, conductor 225, spring 226 and winding of relay R^{62} to ground. This circuit only energizes relay R^{96} of the controller, since relay R^{43} in the trunk, being positively polarized, will not operate on flow of current from the negative pole of the battery, while relay R^{62}, being marginal, cannot operate in series with the high resistance of relays R^{96} and R^{43}. On operating controller relay R^{96} locks itself to ground through its armature 227, opens at its spring 223 the circuit which has just been described, and closes by its armature 228 a circuit from intermittent ground at pulsator P^{100} through conductors 229 and 230, spring 231 and winding of relay R^{100} to the battery lead L^{85}. This relay R^{100} locks itself to a permanent ground by its armature 232 and spring 231, disconnects itself from the intermittent ground at its spring, and closes the front contacts of its armature 233 and 234. We now have a path from the pulsator P^{100} to ground through conductor 235, armature 233 and its front contact in relay R^{100}, conductor 236, winding of motor magnet M^{100} belonging to the sending switch S^{100}, conductor 237, back contact and armature 238 of relay R^{101}, conductor 239, lead L^{82}, and to ground at the secondary selector through the windings of relays R^{43} and R^{62} by the same course as that just traced in describing the energization of relay R^{96}. As before relay R^{62} will remain quiescent, but this time relay R^{43} will be energized, as pulsator P^{100} transmits positive current. Motor magnet M^{100} and relay R^{43} now operate simultaneously. The former drives forward the arm s^{101} of the switch S^{100}, while the latter closes a circuit from battery B^{42} to ground through its armature 167, conductor 168, spring 169 of relay R^{42}, lead L^{51}, armature 139 and its back contact in relay R^{51}, arm s^{51} of switch S^{50}, lead L^{61}, armature 204 and its front contact in relay R^{61}, conductor 240, winding of motor magnet M^{60} of the secondary selecting switch S^{60} and spring 241 of relay R^{62}.

When one impulse has been transmitted by the pulsator P^{100}, and the arms of switch S^{60} have reached the first set of contacts s^{64} of the first group x, or that corresponding to the first final group of two hundred numbers, the arm s^{101} of the primary hundreds sending switch S^{100} closes a circuit from the main battery lead through conductor 242, arm s^{92} of the thousands-hundreds primary register of switch S^{90}, which it will be remembered is resting upon its twenty-second point s^{95} (numbered 21), conductors 243, 244 and 245, and then to ground by two paths, one through a winding of relay R^{101}; the other through conductor 246, front contact and armature 234 of relay R^{100}, conductor 247, back contact and armature 248 of relay R^{102}, conductor L^{83}, armature 84 and spring 84^a of relay R^{13}, lead L^{24}, armature 60 and its back contact in relay R^{21}, arm s^{22}, lead L^{32}, armature 104 and its back contact in relay R^{30}, arm s^{32} lead L^{42}, one winding 181 of the repeating coil f, conductors 182 and 183, spring 184^a of relay R^{42}, conductor 185, winding of relay R^{45}, conductor 186 and winding of relay R^{44}. These two paths energize simultaneously relay R^{101} of the controller and relay R^{44} of the trunk, but not the negatively polarized relay R^{45}. The armature 238 of relay R^{101} opens its back contact, thereby destroying the circuit from the pulsator P^{100}. Relay R^{44} opens the back contact of its armature 116 and closes a circuit from battery B^{43} to ground through conductor 117, back contact and armature 118 of relay R^{45}, conductor 119, spring 120 of relay R^{42}, lead L^{52}, armature 140 and its back contact in relay R^{51}, arm s^{52} of switch S^{50}, lead L^{62}, armature 205 and its front contact of relay R^{61}, conductor 225 and spring 226 and the winding of relay R^{62}. When attracted the armature 249 of relay R^{62} locks the winding of the relay to battery B^{60} through conductor 200 and the armature 199 of the retaining magnet H^{60}, and also opens the resting contact of its spring 226. The armature 250 of the relay breaks the circuit 200, 201 and 203, containing one winding of relay R^{61} and makes

contact with its spring 202. The armature 251 of relay R^{62} raises the spring 241 from its contact, and connects the test arm s^{63} to ground through the armature 206 and its front contact in relay R^{61} and the multiple circuit consisting of (1) conductors 252, 253 and 254 and the second winding of relay R^{61}, and (2) conductors 255, 256 and 254 and the winding of motor magnet M^{61}. As in the office and primary selectors the test arm s^{63} of the secondary selector will retain relay R^{61} energized and operate the motor magnet M^{61} until the arms of the switch S^{60} pick out a set of contacts in the first section x connected with an idle final selector. Then relay R^{61} is deënergized, the front contacts of its three armatures opened, leads L^{61} and L^{62} connected to the arms s^{61} and s^{62}, and a path closed from battery B^{60} to ground through the armature 199 of the retaining magnet H^{60}, conductors 200 and 201, spring 202 and armature 250 of relay R^{62}, conductor 257, back contact and armature 206 of relay R^{61}, test arm s^{63}, conductor L^{73}, spring 258 of busy-test relay R^{71}, conductor 259, off normal contact device s^{79} of the final selecting switch S^{70}, conductors 259 and 260 and the winding of retaining magnet H^{70}. The latter is energized, causing the springs 261, 262 and 263 to close their contacts.

Again considering the controller relay R^{101}, in addition to opening the motor magnet circuit by its armature 238, its armature 264 closes a path from ground to battery lead L^{85} through its second winding, conductor 265 and the winding of relay R^{102}, the sluggish operation of which avoids opening the contact of its armature 248 before relay R^{44} has time to bring about the trunk selecting operations described in connection with the apparatus I^2. The armature 266 of relay R^{102} completes a circuit from the negative pole of battery B^{101} to ground through conductor 267, the winding of relay R^{103} and its spring 268, conductor L^{82}, armature 76 and spring 76^a of relay R^{13}, lead L^{23}, armature 59 and its back contact in relay R^{21}, arm s^{21}, lead L^{31}, armature 103 and its back contact in relay R^{30}, arm s^{21}, lead L^{41}, conductor 112^a, spring 113 and armature 132 of relay R^{41}, conductor 162, back contact and armature 122 of relay R^{40}, conductor 163, winding of relay R^{43}, conductors 164 and 115, back contact and armature 116 of relay R^{44}, conductor 117, back contact and armature 118 of relay R^{45}, conductor 119, spring 120 of relay R^{42}, lead L^{52}, armature 140 of relay R^{51}, arm s^{52} of switch S^{50}, lead L^{62}, armature 205 of relay R^{61}, arm s^{62} of switch S^{60}, lead L^{72}, spring 269 of the connector's primary relay R^{72}, conductor 270, and springs 271 and 272 of the off normal contact device s^{78}. This circuit energizes relay R^{103} but not relay R^{43}, because it is positively polarized and will not respond to current flowing from the negative pole of battery B^{101}. Relay R^{103} locks itself to ground by armature 273, opening the resting contact of its spring 268. Armature 275 breaks the circuit of the retaining magnet H^{100}, allowing the arm of the sending switch S^{100} to return to its initial position, and also closes at the spring 31^a a circuit from the main battery lead through conductor 277, arm s^{93} of the switch S^{90} and its twenty-second auxiliary register contact s^{96} (number 21), conductors 278 and 279, winding of retaining magnet H^{110}, conductor 280, winding of relay R^{110} and its spring 281 and conductor 229 to the intermittent ground at the pulsator P^{100}. On operating the armature 282 of relay R^{110} coöperates with the spring 281 to lock the circuit through the windings of this relay and the retaining magnet H^{110}, and opens the resting contact of the spring. The armature 283 of relay R^{110} completes a path from pulsator P^{110} through motor magnet M^{110} of the auxiliary hundreds sending switch S^{110}, conductor 284, back contact and armature 285 of relay R^{111}, conductors 286 and L^{82} and then on through the winding of trunk relay R^{43}, as just set forth in connection with the energization of relay R^{103}. Relay R^{43} now operates upon the positive impulses from pulsator P^{110}. As will be hereinafter explained, ten pulses will be transmitted through the motor magnet M^{110} and relay R^{43}. The armature 167 of said relay will therefore close ten times in succession a circuit from battery B^{42} to ground through conductor 168, spring 169 of relay R^{42}, lead L^{51}, armature 139 of relay R^{51}, arm s^{51}, lead L^{61}, armature 204 of relay R^{61}, arm s^{61}, lead L^{71}, spring 287 of relay R^{75}, conductor 288, winding of the tens motor magnet M^{70} and springs 262 and 261 of the retaining magnet H^{70}. The motor magnet M^{70} drives the connector arms over ten contacts at each stroke, and as this magnet is energized ten times the arms will therefore be driven past the first hundred fixed contacts. The arms of the connector consequently rest upon the first set of contacts in the eleventh section y, ready for the selection of the tens group, which, in the number of the line sought, falls in the second hundred of the full final group of two hundred.

The selection of the tens group.—After the ten pulses have traversed the motor magnet M^{110} of switch S^{110} the arm s^{111} will close a path from its grounded contact s^{114} to the battery lead L^{85} through the conductor 288 and the winding of relay R^{111}. The armature 285 of this relay breaks the circuit of motor magnet M^{110} and relay R^{43}, while armature 289 closes a path from the main battery lead through conductors 290 and 291, armature 292 and its back contact in relay R^{122} and conductor 293 to the springs

294 of the tens keys K^{120}. As key $3K^{120}$ is depressed, current will then pass from conductor 293 through springs 294, 295 and 296, conductor 297, winding of relay R^{120} and its spring 298 and conductor 299 to intermittent ground at pulsator P^{130}. On operating relay R^{120} locks itself to a permanent ground and opens the normal contact of its spring 298 by its armature 301, and closes the front contact of its armature 302. There is now a path from the pulsator P^{120} through motor magnet M^{120}, conductor 303, front contact and armature 302 of relay R^{120}, conductor 304, back contact and armature 305 of relay R^{121}, conductors 306 and L^{82} and through the winding of the trunk relay R^{43} to ground at the apparatus I^8 by the course given in describing the advance of the final connector arm over the first hundred points; except, that as the springs 271 and 272 have been separated and springs 271 and 326 brought together by the movement of the switch S^{70} from its initial position, the path, from this point is by conductor 327, winding of relay R^{70}, conductor 328, winding of motor magnet M^{71}, conductor 229 and springs 262 and 261 of magnet H^{70}. Motor magnet M^{120} and relay R^{43} are energized together by each impulse transmitted from pulsator P^{120} and the relay operates locally motor magnet M^{70}, continuing the movement of the arms of switch S^{70} in long steps or over ten fixed contacts at a time. When three pulses have been sent the arm s^{121} of the tens-units switch S^{120} will close a path from the depressed key $3K^{120}$, which is connected to the main battery lead, through conductor 307, the thirty-point s^{124}, conductor 308, armature 309 and its back contact in relay R^{122}, conductor 310 and one winding of relay R^{121} to ground. The last-named relay, by opening the back contact of its armature 305, prevents more pulses from being transmitted through the motor magnet M^{120} and trunk relay R^{43}, so that three will have been repeated locally through the motor magnet M^{70}. The arms of the connector, which had previously been driven past the 100 contacts under the control of the switch S^{110}, will now rest upon the contacts s^{74} which are numbered 130.

The selection of the called subscriber's line and the release of the controlling apparatus.—Returning to relay R^{121}, its armature 311 closes a circuit from ground to the main battery lead through the second winding of this relay, conductor 312 and the winding of relay R^{122}. The latter will now open the resting contacts of its armatures 292 and 309 and close the front contacts. Armature 292 transfers battery from the tens to the units keys, and therefore current will flow from the conductor 313 through the springs 314, 315 and 316 of the depressed units key $2K^{130}$, conductor 317, winding and spring 320 of relay R^{130} to the ground of pulsator P^{130}. Relay R^{130} connects its winding by armature 319 and spring 320 to a permanent ground, opens the resting contact of its spring, and by means of its armature 321 closes a circuit from the pulsator P^{120} through the motor magnet M^{130}, conductors 322 and 323, back contact and armature 324 of relay R^{131}, conductors 325 and L^{83}, armature 84 and spring 84^a of relay R^{13}, lead L^{24}, armature 60 and its back contact in relay R^{21}, arm s^{22} of switch S^{20}, lead L^{32}, armature 104 and its back contact in relay R^{30}, arm s^{32} of switch S^{20}, lead L^{42}, one winding 181 of the repeating coil f, conductors 182 and 183, spring 184^a of relay R^{42}, conductor 185, winding of relay R^{45}, conductor 186 and winding of relay R^{44} to ground. Each impulse transmitted from the pulsator P^{120} energizes the motor magnet M^{130} and positively polarized relay R^{44}. Each time the relay is energized its armature 116 opens its back contact and closes a circuit from the positive pole of battery B^{43} to ground through conductor 117, back contact and armature 118 of relay R^{45}, conductor 119, spring 120 of relay R^{42}, lead L^{52}, armature 140 of relay R^{51}, arm s^{52} of switch S^{50}, lead L^{62}, armature 205 of relay R^{61}, arm s^{62} of switch S^{60}, lead L^{72}, spring 269 of relay R^{72}, conductor 270, springs 271 and 326 of off normal device s^{78}, conductor 327, winding of relay R^{70}, conductor 328, winding of motor magnet M^{71}, conductor 329 and springs 330, 262 and 261 of magnet H^{70}. This local circuit energizes motor magnet M^{71} but not the negatively polarized relay R^{70}. The arm of the tens-units sending switch S^{120} and the arms of the connector are now advanced simultaneously by short steps until two pulses have been transmitted, when current from battery lead L^{85} will flow through the springs of the depressed key $2K^{130}$, conductors 331 and 332, contact s^{134}, numbered 32, of the tens-units switch S^{120}, arm s^{121}, conductor 308, armature 309 and its front contact in relay R^{122}, conductor 333 and winding of relay R^{131} to ground. The armature 324 of this relay breaks the circuit containing the motor magnet M^{130} and relay R^{44}. The contact arms of the final selector, or connector are now at rest upon the one hundred thirty-third set of terminals s^{74}, or those numbered 132, and belonging to the line designated as 2132. The armature 26 of the relay R^{131} opens the circuit of controller connecting relay R^8 and cord relay R^{13}, with the result that both of these relays are deenergized. On releasing its armatures relay R^{13} disconnects leads L^{23} and L^{24} from conductors L^{82} and L^{83}, reconnects them to leads L^{21} and L^{22} and opens the by-path through one winding of relay R^{14}, which re-

lay, since it remains locked by its companion winding, by retaining the contact of its armature 24 open guards against any subsequent energization of the relay R^8 in association with the relay R^{13} during the same connection. This release of relay R^8 disconnects battery B^8 from the controller's main battery lead, but by closing the resting contact of spring 36 before opening that of the armature 35 with said spring, allows current to flow momentarily from battery B^8 through conductors 38, 39, 40 and 41 and releasing magnets k^2, thus permitting the keys to resume their inactive position. Disconnecting battery B^8 from the main battery lead releases all the relays and retaining magnets of the controller. The apparatus is thus restored to its normal condition, this being indicated by the extinguishment of lamp O^8, and is ready to operate in conjunction with any other cord in response to another call.

Upon the reconnection of the leads L^{23} and L^{24} with leads L^{21} and L^{22}, current flows from the negative pole of battery B through the winding 334 of the repeating coil *c*, winding of the supervisory relay R^{11}, leads L^{22}, and L^{24}, arm s^{22}, lead L^{32}, arm s^{32}, lead L^{42}, winding 181 of repeating coil *f*, conductors 182 and 183, resting contact of spring 184^a of relay R^{42}, conductor 185, winding of relay R^{45}, conductor 186 and winding of relay R^{44} to ground, only energizing negatively polarized relay R^{45}. Upon operating the armature 336 of relay R^{45} closes a path from conductor 183 through conductor 337, high resistance winding *r* of relay R^{46}, conductors 338 and 339, winding 340 of repeating coil *f*, and from there back to the ground connection in the repeating coil *c* of the cord by way of one side of the talking leads, the trunk and office selectors and winding 334^a of the coil *c*. This allows current to flow from the battery B through the winding of relay R^{11} and the other side of the talking leads, winding 181 of the repeating coil *f*, conductors 182, 183 and 337, winding of relay R^{46} and to ground at the cord as just indicated. On account of the amount of resistance in the circuit marginal relay R^{11} does not operate, but relay R^{46} attracts its armature 341, which closes a circuit from ground to battery B^{41} through conductor 342 and winding of relay R^{42}, causing its energization. The armature 343 of this relay disconnects battery B^{41} from conductor 130, thereby releasing the relay R^{41}, and connects said battery directly to the conductor L^{53}. The armature 184 of relay R^{42} connects conductor 183 to the conductor 337, thereby continuing the temporary connection made by the armature 336 of relay R^{45}, and by raising the spring 184^a disconnects conductor 183 from relays R^{45} and R^{44}. The armatures 344 and 345 of relay R^{42} open now the useless contacts of springs 120 and 169, and connect the talking leads L^{51} and L^{52} through the leads L^{41*} and L^{42*} to the repeating coil *f* of the trunk. The talking circuit is now established from the calling substation as far as the primary and secondary connecting relays R^{72} and R^{75} of the final selecting apparatus I^3.

Completing the talking circuit and ringing the called subscriber. — Considering again the relay R^{45}, the action of the armature 336 of which has just been stated, its other armature 118 at that time opened its back contact and closed at its front contact a circuit from the negative pole of battery B^{44} to ground through conductor 119, spring 120 of relay R^{42}, lead L^{52}, arm s^{52}, lead L^{62}, arm s^{62}, lead L^{72}, spring 269 of relay R^{72}, conductor 270, springs 271 and 326 of off normal device s^{78}, conductor 327, winding of negatively polarized relay R^{70}, conductor 328, winding of motor magnet M^{71} (which does not have time to operate), conductor 329 and springs 330, 262 and 261 of retaining magnet H^{70}. When the relay R^{70} operates it closes at its armature 346 a circuit from ground to battery B^2 through springs 261, 262 and 330, conductors 329, 347 and 348, winding of relay R^{72}, conductor 349, test arm s^{73} of switch S^{70}, third conductors l^{23} and l^{13} belonging to substation a^2, winding of cut-off relay R^4 and conductor 350, thereby energizing relays R^{72} and R^4. The latter relay opens the circuit of the line relay R^3, thus preventing the lighting of the line signal lamp O′ when the called subscriber answers. The armature 351 of relay R^{72}, by substituting a by-path 352, makes the circuit of relays R^{72} and R^4 independent of the contact established by the armature 346 of relay R^{70}. The armature 353 of relay R^{72} opens the resting contact of its spring 269, thereby releasing relay R^{70}, and connects lead L^{72} to lead L^{72*}. The armature 354 of relay R^{72} opens the normal contact of its spring 355, and closes a circuit from battery B^{70} to ground through conductor 355^a, the winding of relay R^{73}, conductor 356, spring 357 of relay R^{75}, conductor 358, back contact and armature 346 of relay R^{70}, conductors 347 and 329 and springs 330, 262 and 261 of the retaining magnet H^{70}. The relay R^{73} at its armatures 359 and 360 disconnects the contact arms s^{71} and s^{72} from the leads L^{71*}, and L^{72*}, and closes a circuit from the ringing generator N through one winding of relay R^{74}, conductor 361, arm s^{71}, conductors l^{21} and l^{11} of the called subscriber's line, through the ringing circuit of the substation set, conductors l^{12} l^{22}, arm s^{72}, conductor 362, the other winding of relay R^{74}, conductor 329 and the springs of the retaining magnet H^{70} to ground. Since the ringing circuit of the substation includes the usual condenser, the current sent out from

the generator N merely rings the subscriber's bell and does not operate relay R^{74}. But as soon as the subscriber responds to the call by removing the receiver from its hook, he completes a metallic circuit; relay R^{74} is then energized and makes at its armature 363 a circuit from battery B^{71} to ground through the winding of relay R^{75}, conductors 364 and 329 and springs of retaining magnet H^{70}, thereby energizing relay R^{75}. The operation of the armature 365 of this relay opens the contact of its spring 287 and connects lead L^{71} to lead L^{71*}. The armature 366 opens the contact of its spring 357, thus releasing relay R^{73}, which breaks the circuit of the ringing generator and connects the leads L^{71*} L^{72*} to the contact arms s^{71} and s^{72}. The armature 366 also locks the winding of relay R^{75} to ground through its spring 357, conductor 358, back contact and armature 346 of relay R^{70}, conductors 347 and 329 and the springs of the retaining magnet H^{70}.

A complete metallic circuit has now been established from the battery B^{45} through one winding of the trunk supervisory relay R^{47}, winding 367 of the repeating coil *f*, lead L^{42*}, armature 345 of relay R^{42}, lead L^{52}, armature 140 of relay R^{51}, arm s^{52}, lead L^{62}, armature 205 of relay R^{61}, arm s^{62}, lead L^{72}, spring 269 and armature 353 of relay R^{72}, lead L^{72*}, armature 359 of relay R^{73}, arm s^{72}, conductor l^{22}, limb l^{12} of the line of substation a^2, the substation set, and back over the opposite side of the line and talking leads, through the associated switch arm and relay armatures, winding 367^a of the coil *f* and the second winding of relay R^{47} to ground. This relay operates and through its armature 368 and conductors 369 and 370 shunts the high resistance winding *r* of relay R^{46} by the companion low resistance winding r^2, permitting sufficient current to flow from the battery B to energize the supervisory relay R^{11}, which extinguishes the supervisory lamp O^3, whereby the operator is advised that the connection is completed.

The release of the selecting apparatus.—In describing the release of the selecting apparatus when the subscribers have hung up the receivers after a conversation has terminated, attention will first be called to the circuits which remain complete out of the total number which were closed from the time that the calling subscriber took down his receiver until the connection he desired was secured. Beginning at the office to which the calling subscriber is connected we have the following circuits: battery B′, conductor 10, winding of cutoff relay R^2, conductors l^8 and L′ and winding of relay R^{12}; battery B^{10}, armature 16 of relay R^{12}, conductor 18, springs 45 of key K, conductor 44, armature 48 and one winding of relay R^{14}, conductor L^2 and winding of relay R^{20}; armature 51 of relay R^{20}, conductor 53, winding of retaining magnet H^{20} and battery B^{20}; armature 49 of relay R^{20}, conductor 85, winding of relay R^{22}, conductor 92, armature 91 and spring 57 of relay R^{22}, conductors 56 and 55, armature 54 of retaining magnet H^{20} and battery B^{20}; battery B^{21}, armature 61 of relay R^{21}, conductor 95, test arm s^{23} of switch S^{20}, conductors L^{33} and 102 and armature 101 and winding of retaining magnet H^{30}; battery B, winding 334 of repeating coil *c*, winding of relay R^{11}, lead L^{22}, spring 84^a of relay R^{13}, lead L^{24}, armature 60 of relay R^{21}, arm s^{22} of switch S^{20}, lead L^{32}, armature 104 of relay R^{30}, arm s^{32} of switch S^{30}, lead L^{42}, winding 181 of repeating coil *f*, conductors 182 and 183, spring 184^a and armature 184 of relay R^{42} conductor 337, high resistance winding *r* of relay R^{46} shunted by its low resistance winding r^2, conductors 338 and 339, winding 340 of repeating coil *f*, lead L^{41}, arm s^{31} of switch S^{30}, armature 103 of relay R^{30}, lead L^{31}, arm s^{21} of switch S^{20}, armature 59 of relay R^{21}, conductor L^{23}, spring 76^a of relay R^{13}, lead L^{21} and the winding 334^a of the repeating coil *c*; armature 341 of relay R^{46}, conductor 342, winding of relay R^{42} and battery B^{41}; battery B^{41}, armature 343, conductors L^{53} and 134, armature 133 of retaining magnet H^{50}, conductors 127 and 128 and winding of the retaining magnet H^{50}; battery B^{50}, armature 135 of retaining magnet H^{50}, conductor 136 and armature 187, spring 166 and winding of relay R^{52}; battery B^{50}, armature 135 of retaining magnet H^{50}, conductors 136 and 193, spring 137 and armature 188 of relay R^{52}, conductor 194, armature 141 of relay R^{51}, arm s^{53} of switch S^{50}, conductors L^{63} and 198, armature 197 of retaining magnet H^{60}, conductors 195 and 196, and the winding of the retaining magnet H^{60}; battery B^{60}, armature 199 of retaining magnet H^{60}, conductor 200 and armature 249, spring 226 and winding of relay R^{62}; battery B^{60}, armature 199 of retaining magnet H^{60}, conductors 200 and 201, spring 202 and armature 250 of relay R^{62}, conductor 257, armature 206 of relay R^{61}, arm s^{63} of switch S^{60}, conductor L^{73}, spring 258 of relay R^{71}, conductor 259, springs 263 and 263^a of retaining magnet H^{70}, conductor 260 and winding of retaining magnet H^{70}; battery B^{71}, winding of relay R^{75} and its armature 366 and spring 357, conductor 358, armature 346 of relay R^{70}, conductors 347 and 329 and springs 330, 261 and 262 of retaining magnet H^{70}; battery B^2, conductor 350, relay R^4, conductors l^{13} and l^{23}, arm s^{73} of switch S^{70}, conductor 349, winding of relay R^{72} and its spring 351^a and armature 351, conductors 352, 347 and 329 and springs 330, 262 and 261 of retaining magnet H^{70}.

When the calling subscriber opens his con-

ductive line circuit by the return of the receiver to its hook, it destroys the circuit of the relay R^{10} whereupon its armature 19 falls back and the supervisory lamp O^2 is lighted by current from the battery B^{10}. The similar opening of the called subscriber's line breaks the circuit of the trunk relay R^{47}, which removes the shunt of the low resistance winding of relay R^{46} from its high resistance winding, and by the consequent cutting down of the current causes the deënergization of the supervisory relay R^{11} so that the lamp O^3 also lights. The operator, seeing that the connection is no longer desired, withdraws the plug P from the jack J opening the circuit of the relays R^2 and R^{12}. The latter breaks the first of the series of circuits previously mentioned, and as each of these serves to maintain a contact included in that succeeding it, they open consecutively, allowing all the selecting switches, by the deënergization of their retaining magnets, as well as the associated relays, to be returned by their springs to the normal position. This removes the busy condition from both lines and renders the entire chain of apparatus free for other service.

If it were not guarded against, certain switches of the system would be liable to reenergization during their return to the normal position, thus destroying the proper relation between their movable and fixed contacts for the reception of selective impulses. In the controlling apparatus this error might be introduced by a new setting of the keys, and in any of the selecting apparatus by the contact of the arms of other pieces of mechanism with the fixed terminals of its multiple. To prevent this the off-normal devices of the switches S^{90} S^{120} S^{30} S^{50} S^{60} and S^{70} (that in the last-named switch being the one indicated by the character s^{79}) act to hold the circuits of the respective retaining magnets open until the contact arms are restored to their initial position. In the switch S^{80} this function is performed instead by the armature 28 of relay R^{84}; in the switches S^{100} and S^{110} it is rendered unnecessary by the fact that they enter into the controlling operations at a time so late in the sequence that their complete restoration is assured, and as to switch S^{20} its constant association with the cord-circuit guards it against appropriation by other selective mechanism.

Besides the above-mentioned contact devices, and those the action of which has been previously described, there is also the off-normal device s^{28} of the switch S^{20}. Here the springs 52 and 52^a, by their separation upon the movement of the switching arms, open the connection between conductors L^3 and L^{84} and prevent the association of the cord relay R^{13} with the controller relay R^8, if the key K should be thrown into the listening position while the arms of the switch S^{20} are returning after release. The normally separated springs 52^b and 52^c of this contact device s^{28} are introduced in order that relay R^{21} may be energized by current from battery B^{22} through conductor 56, spring 57 of relay R^{22} and conductor 58, while the arms of the switch S^{20} are returning to rest. The purpose of this is to separate the arms s^{21} and s^{22} from the ground and battery connections of the repeating coil c, in order that no disturbance shall be produced in the telephone receiving apparatus connected to the multiple of the leads from the fixed contacts which said arms wipe over.

Connection with a busy line.—If at the time the relay R^{70} was energized the line sought happened to be busy, either by having been selected by some other connector or by a plug inserted in its answering jack, relay R^{72} would be shunted at the conductor l^{23}, either by the corresponding relay of said connector or by the relay R^{12} in the third conductor of the cord, the plug of which is inserted in the jack. In either case relay R^{72}, on account of the shunt, does not receive enough current to cause its operation when the armature 346 of relay R^{70} closes the path from the test arm s^{73} to ground through the winding of the former relay. Under such circumstances current will flow from battery B^{70} to ground through spring 355 of relay R^{72}, conductor 371, armature 372 and its front contact in relay R^{70}, conductor 373 and one winding of relay R^{71}. When attracted the armature 374 of this relay connects the intermittent ground of the busy signal mechanism N^2 to lead L^{72} of the talking circuit through the conductor 375. The armature 376 locks relay R^{71} to conductor L^{73}, and by opening the contact of its spring 258 releases the retaining magnet H^{70}, resulting in the return of the contact arms and relay armatures of the connecting apparatus to their normal position. The intermittent ground upon lead L^{72} gives a like flow of current through the trunk relay R^{47} and will energize it intermittently. This will vibrate the armature 368 of said relay and thus shunt the high resistance winding of the relay R^{46} by its low resistance winding. Supervisory relay R^{11} therefore will be intermittently energized and the lamp O^3 flashed. In this manner the operator will be notified that the desired line is busy and after informing the calling subscriber that this is the case, will remove the plug P from the answering jack. This causes the restoration of the remainder of the selecting apparatus in the manner hereinbefore described.

We claim as our invention and desire to secure by Letters Patent:

1. In a telephone line switching system, the combination with answering jacks and mechanical switching apparatus, of a cord

circuit terminating in a plug for coöperation with the jacks and in a movable member of the mechanical switching apparatus, and means operating when the plug is removed from a jack for restoring the movable member to its normal position.

2. A telephone system comprising a central station with substation lines extending thereto, a connection circuit adapted for connection with a substation line at the central station, a plurality of extension circuits to any one of which said connection circuit is adapted to be connected, an electromechanical switch forming a part of the connection circuit and adapted to connect the latter to one of said extension circuits, other extension circuits, and a second electromechanical switch adapted to be automatically set into operation upon the connection of the connection circuit to one of said first named extension circuits and to thereupon operate free of control by an operator to automatically select an idle one of said other extension circuits and to connect said first-named extension circuit thereto.

3. An exchange system comprising central stations with substation lines extending thereto and groups of trunks between the central stations, circuits at the central stations for connection with substation lines, an electromechanical switch individual to each connecting circuit and provided with groups of terminals and being under the control of an operator to select a group of said terminals, said switch upon selection of a group of terminals being adapted to operate automatically to hunt for an idle terminal in the selected group, and other electromechanical switches connected with the terminals in each of said groups and to corresponding trunk groups and adapted to operate free of control by said operator to automatically pick out an idle trunk in the selected group of trunks.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses, this fifteenth day of May, 1907.

ERNEST A. GRAY.
EDWARD C. MOLINA.

Witnesses:
GEO. WILLIS PIERCE,
JOSEPH A. GATELY.