I. D. BUDD, C. I. CRONBURG, AND F. S. HURD.

ELECTROMECHANICAL SWITCHING SYSTEM.

APPLICATION FILED MAY 25, 1914.

1,411,478. **Patented Apr. 4, 1922.**

8 SHEETS—SHEET 1.

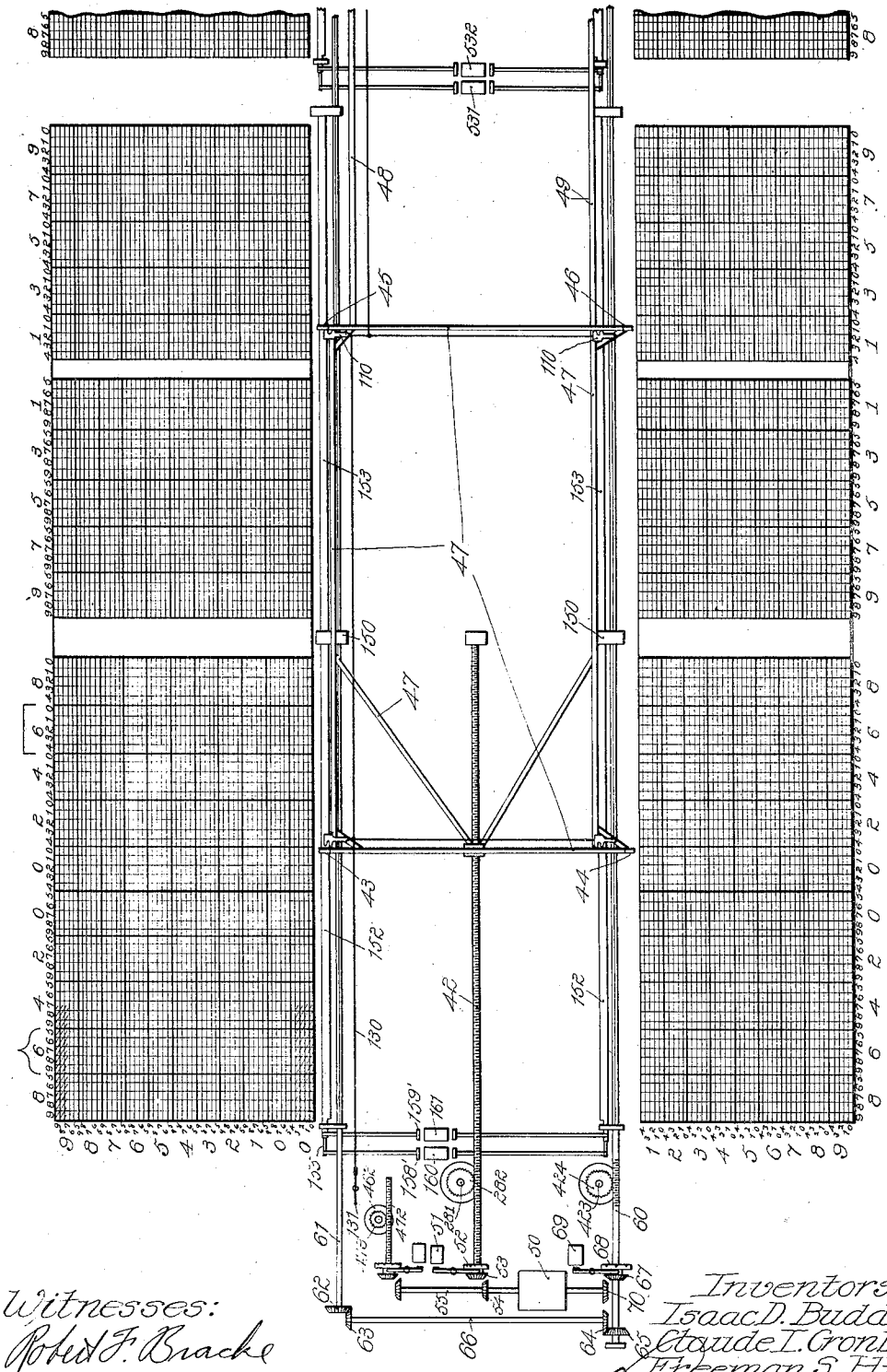


Fig. 1.

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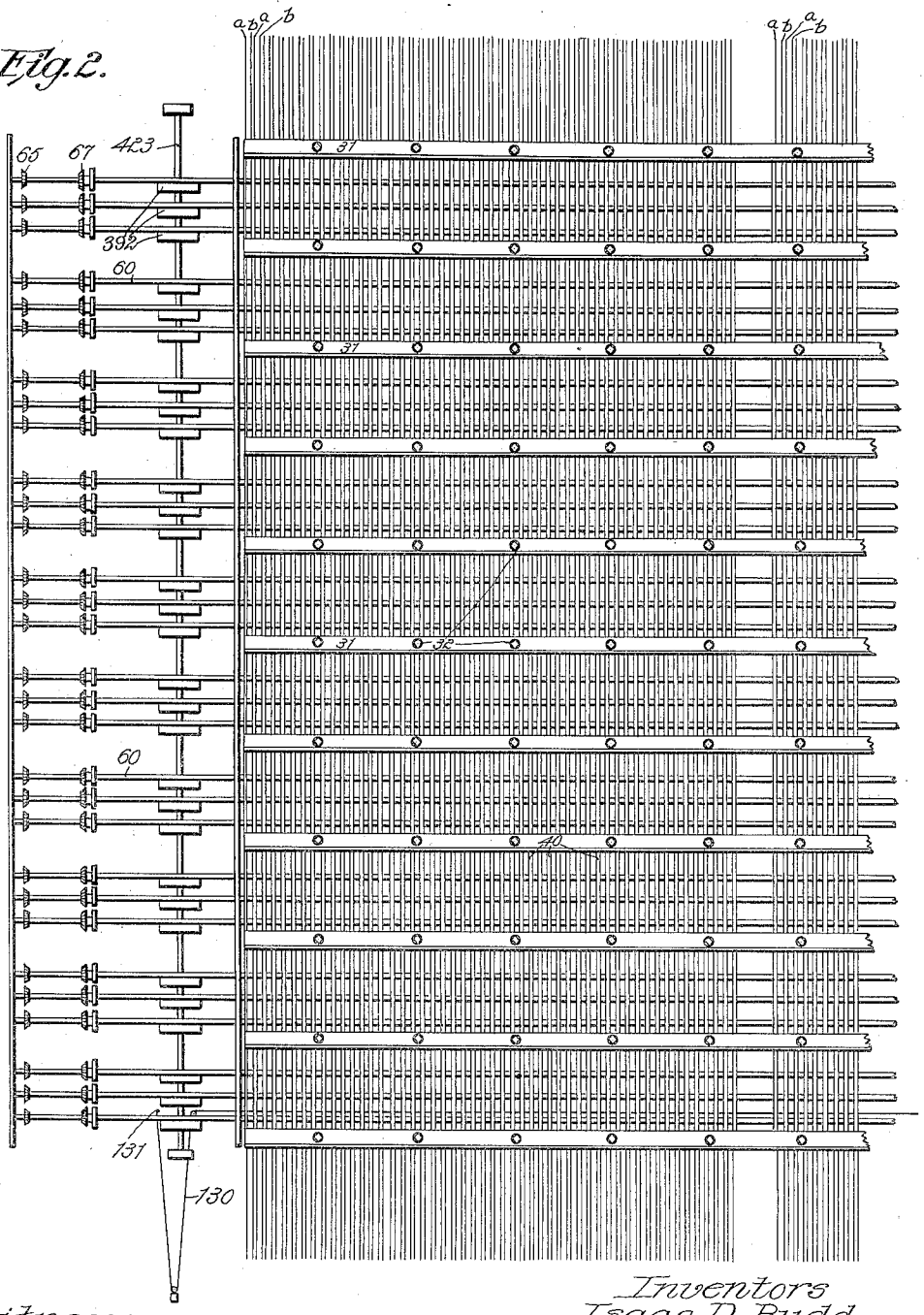
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8 SHEETS—SHEET 2.

Fig. 2.



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8 SHEETS—SHEET 3.

Fig. 7.

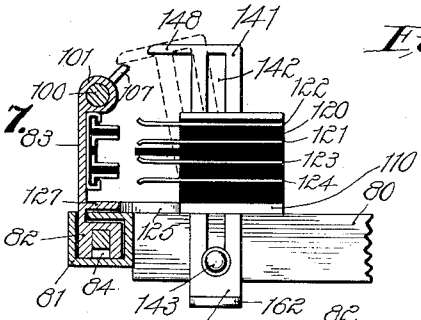


Fig. 9.

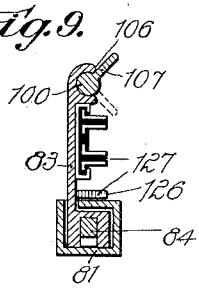
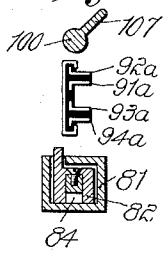


Fig. 8.



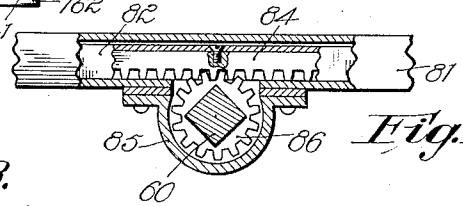
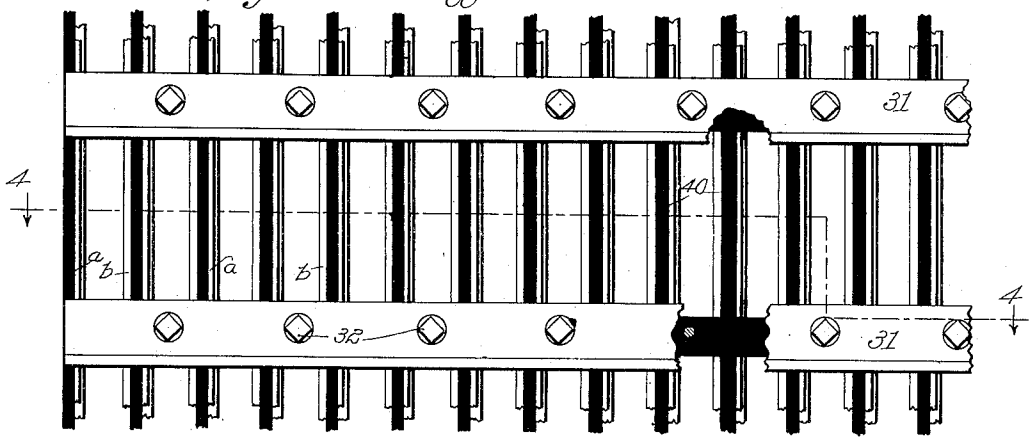


Fig. 10.

Fig. 3.



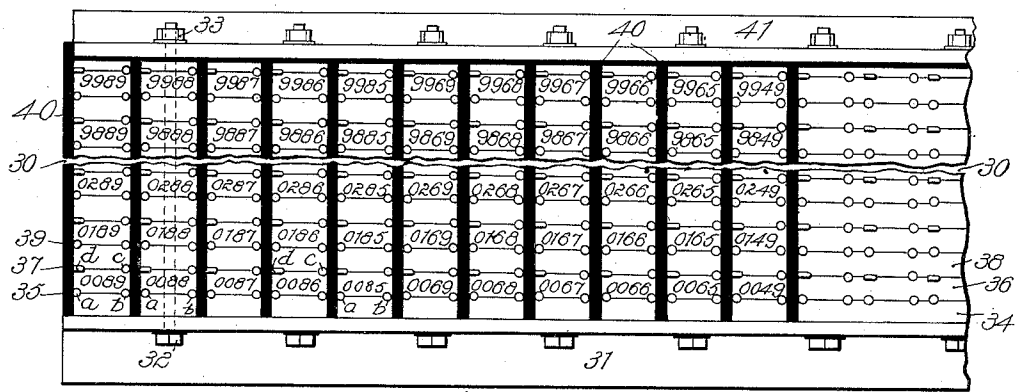


Fig. 4.

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8 SHEETS—SHEET 4.

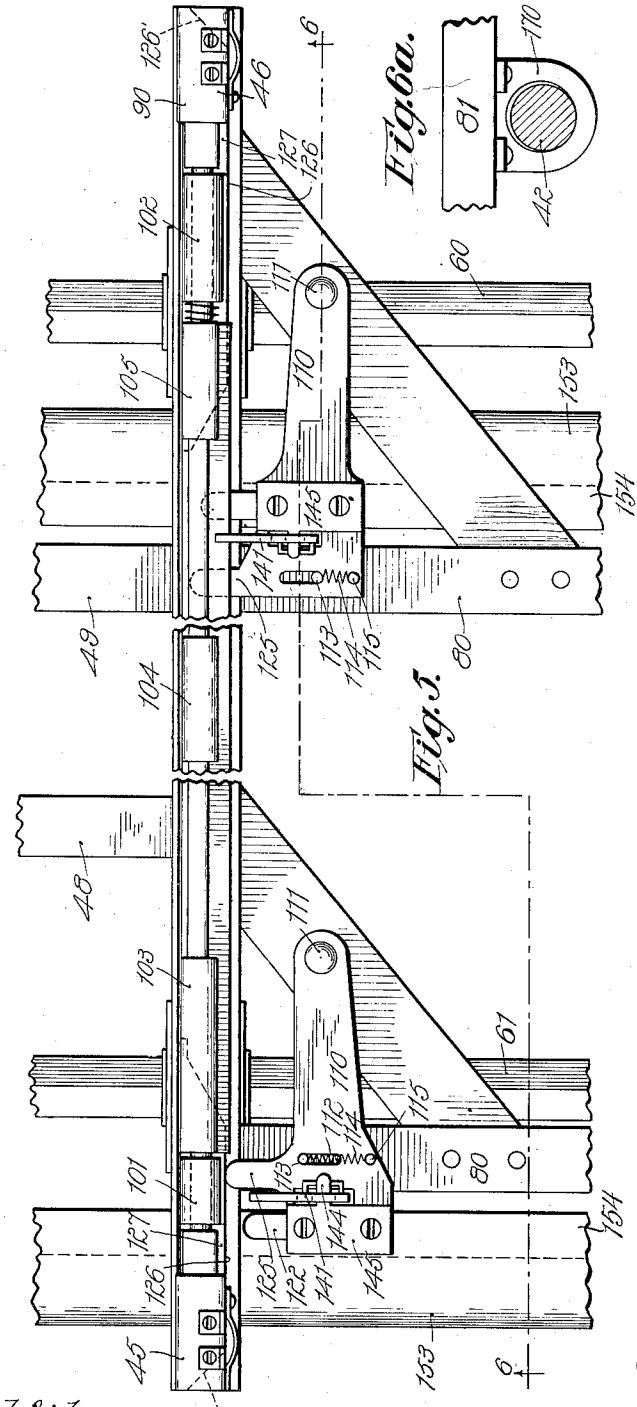


Fig. 6a.

Fig. 5.

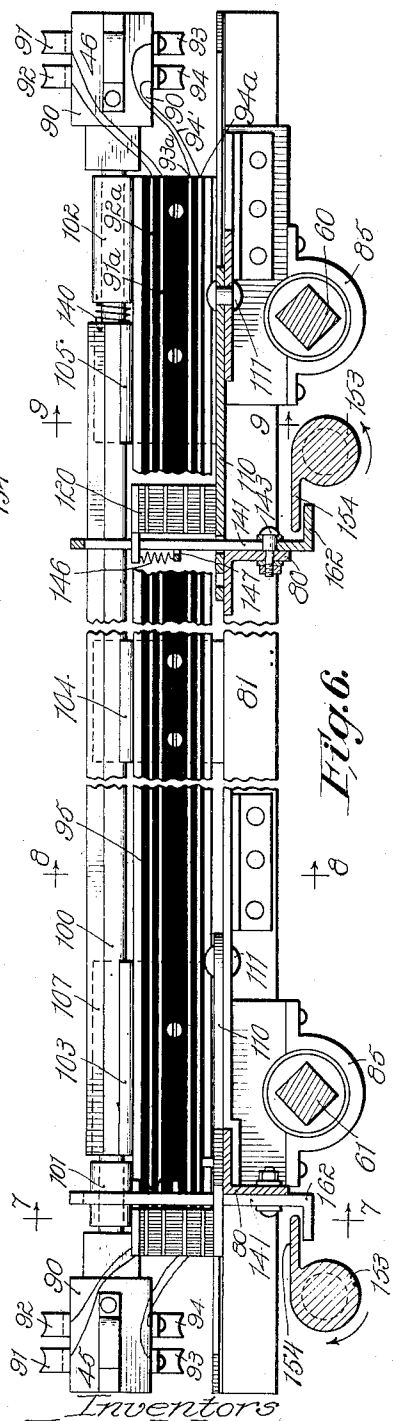


Fig. 6.

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8 SHEETS—SHEET 5.

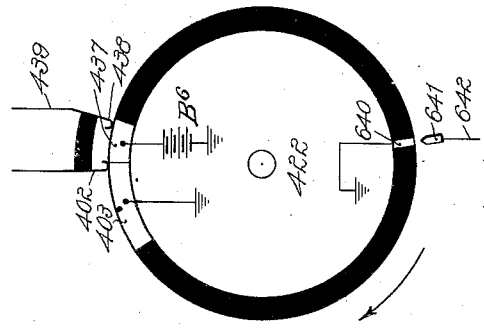


Fig.22.

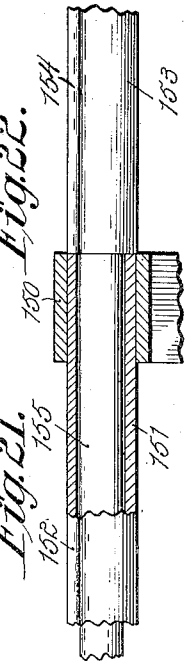


Fig.11.

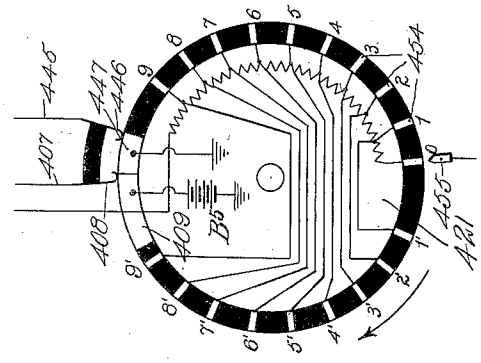


Fig.21.

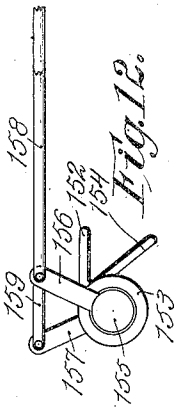


Fig.12.

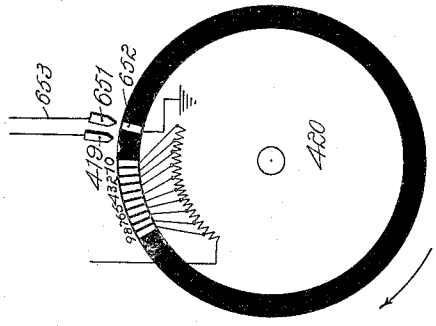


Fig.20.

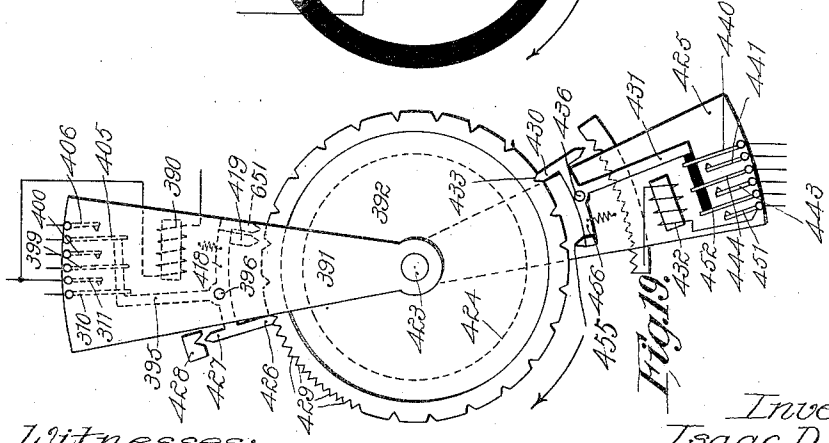


Fig.19.

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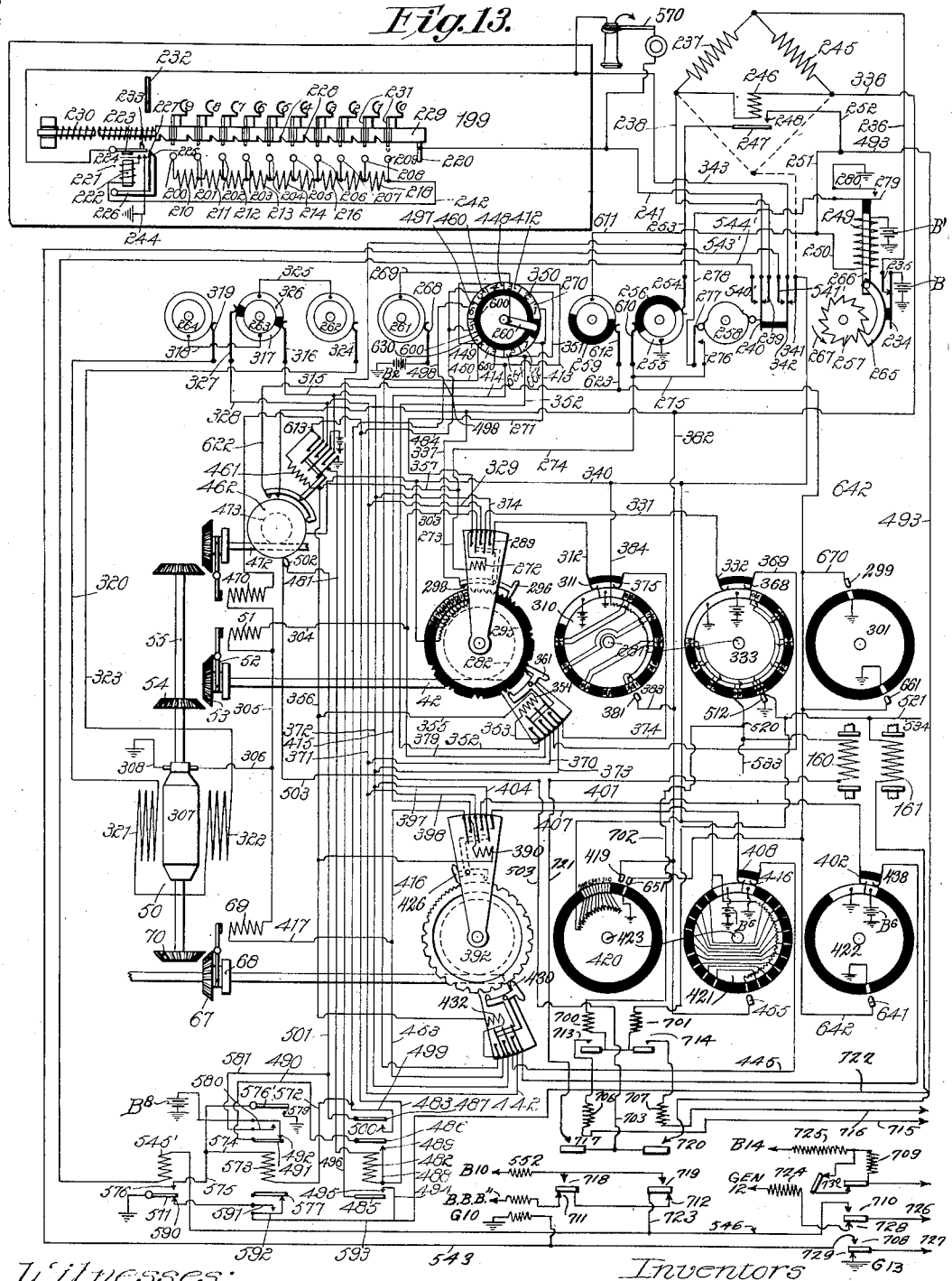
ELECTROMECHANICAL SWITCHING SYSTEM.

APPLICATION FILED MAY 25, 1914.

1,411,478. **Patented Apr. 4, 1922.**

8 SHEETS—SHEET 6.

Fig. 13.



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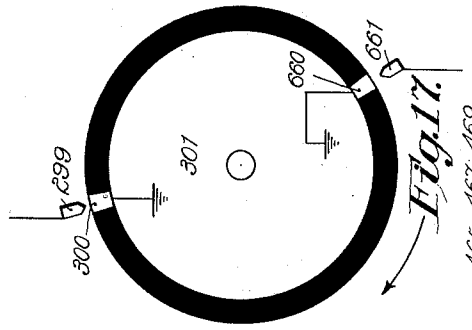


Fig. 17.

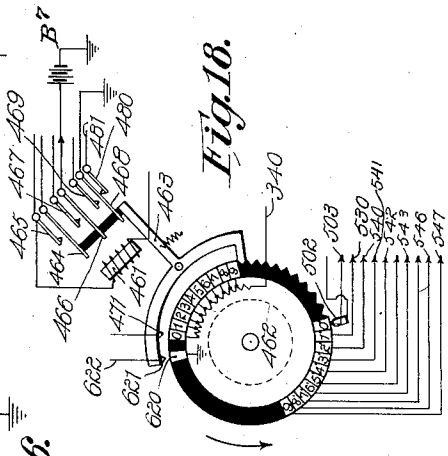


Fig. 18.

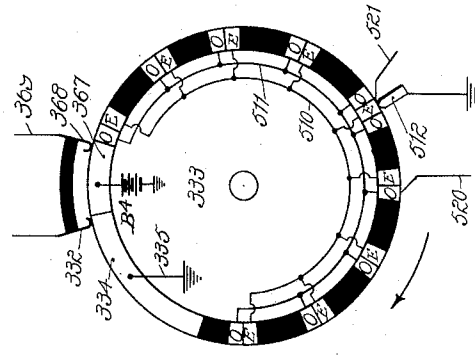


Fig. 16.

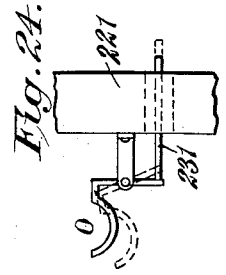


Fig. 24.

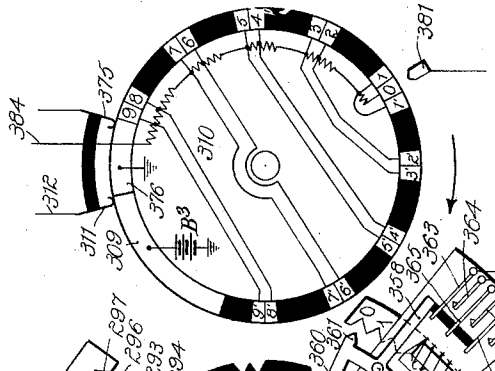


Fig. 15.

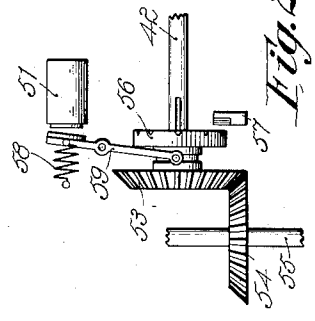


Fig. 23.

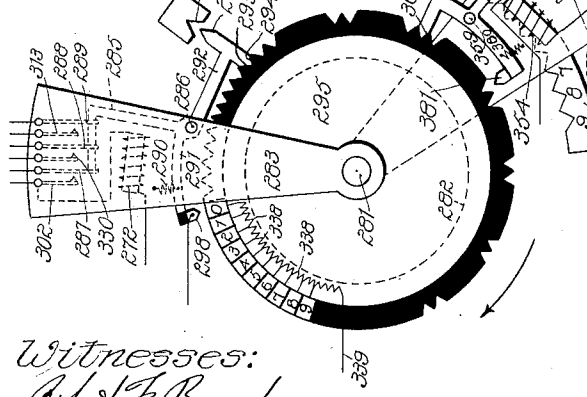


Fig. 14.

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ELECTROMECHANICAL SWITCHING SYSTEM.

APPLICATION FILED MAY 25, 1914.

1,411,478. **Patented Apr. 4, 1922.**

8 SHEETS—SHEET 8.

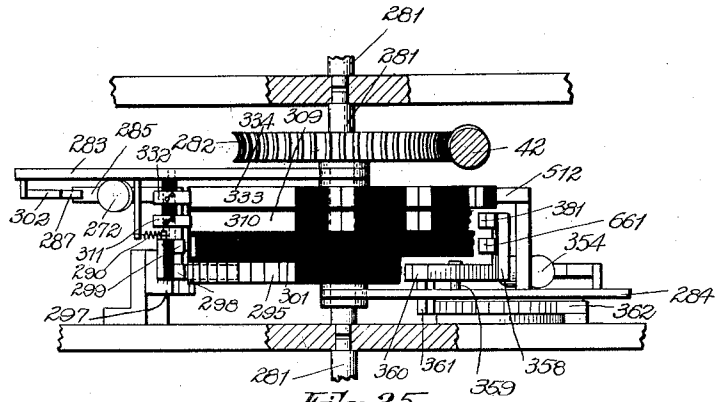
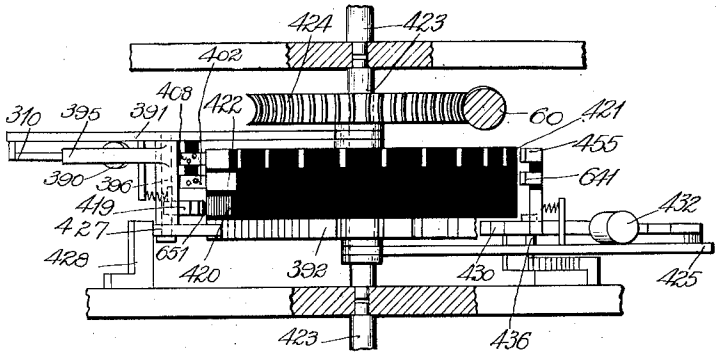


Fig. 25

Fig. 26



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UNITED STATES PATENT OFFICE.

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ELECTROMECHANICAL SWITCHING SYSTEM.

1,411,478. Specification of Letters Patent. Patented Apr. 4, 1922.

Application filed May 25, 1914. Serial No. 840,768.

To all whom it may concern:

Be it known that we, ISAAC D. BUDD, CLAUDE I. CRONBURG, and FREEMAN S. HURD, citizens of the United States, residing, respectively, at Chicago, in the county of Cook and State of Illinois, Chicago, in the county of Cook and State of Illinois, and Oak Park, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Electromechanical Switching Systems, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

Our invention relates to automatic switching apparatus and circuits, and while it may be applied to various purposes, it is particularly useful in telephone exchanges, either automatic or semi-automatic or so-called auto-manual or in trunking connections through otherwise fully manual exchange systems.

In order to illustrate an application of our invention we have worked out and shown in connection with this disclosure the details of the system as applied to the purpose of switching the in-coming calls on the A operator's board of a manual telephone exchange system to and through the B operator's board of the exchange. It is to be understood, however, that the electro-mechanical switching system of our invention is not limited to this particular use.

The general practice in manual telephone exchange systems is for a subscriber to call the operator located at the switchboard with which his line is permanently connected. The A operator at this switchboard answers the call by inserting the plug of one of her cords into the answering jack of the line upon which the call has been initiated. She inquires of the calling subscriber the number of the line wanted. In a majority of instances, in large cities at least, the line wanted is permanently connected with some other switchboard or exchange of the system. It is therefore necessary for the A operator to select an idle trunk line leading to the switchboard of the exchange with which the called subscriber's line is permanently connected. Having selected such an idle trunk line, either upon her own initiative or upon the receipt of instructions over an order wire from the B operator's board, the A operator inserts the calling plug of the cord pair into the out-going jack of the selected trunk line. The operator at the B board completes the connection by inserting the plug of the trunk cord into one of the multiple spring jacks of the line to be called. The called subscriber's bell is "rung" in the usual way. When he answers the ring of his bell the telephone connection is completed and continues in this condition until the conversation is completed, whereupon appropriate signals are displayed to the operators, who then take down the connection.

The mechanical and electrical installation necessary to switch calls in this manner is complicated and expensive. It involves, among other things, an enormous number of soldered connections with the multiple spring jacks of the B operator's board. The operation of such a system is also complicated and gives rise to mistakes in establishing the proper connections with the line initially called for by the calling subscriber.

Our invention may be applied for the purpose of eliminating the B operator and the work done by her in establishing connections as above outlined. Our invention substitutes automatic means under the control of the A operator for establishing connection with the called line, thereby eliminating the errors due to misunderstanding between the A and B operators. There are, of course, at each telephone exchange both the A and B operators, and the B operators and their boards will be eliminated in both of the exchanges referred to in the typical example as above outlined.

From the mechanical standpoint one of the important features of our invention is the multiple system of wiring or contacts, in which each line is provided with a large number of sets of contacts through any one of which connection may be established with the called line. In accordance with our invention this multiple is in the form of substantially continuous and rectilinear conduc-

tors taking the form of metallic strips or rods such, for example, as long narrow metallic strips bent into the form required for stiffness, for mounting or for convenient contact with movable contact members, or as piano wires tightly stretched between appropriate supports. In practice, these wires when wires are used, one, two or three or four for each line, as the conditions of the case may require, are stretched or mounted vertically or horizontally between appropriate frame pieces of insulating material, the multiple for any one line consisting simply of the one or two or three or four wires arranged in a group and extending from the floor or for some distance parallel to the floor and part or all of the way to the ceiling of or across the room in which the switching mechanism is located. All of the lines are provided with similar groups or sets of multiple wires or strips, the sets of multiple strips being conveniently arranged in numerical order and connected to other multiple strips by cabling or other means of cross-connecting when the number of switch contact sets used require more than one set or length of multiple strips.

Associated with this multiple system of stationary switch contacts is a set of moving switch contacts which, for convenience, we shall refer to as a plug. The plug is mounted upon a carriage adapted to travel longitudinally along the face of the multiple so as to carry the plug to a position in line with the set of multiple strips with which connection is to be established. The carriage is provided also with means for moving the plug laterally so that after it has been brought to the proper longitudinal position it may be moved laterally between the several sets of multiple contact strips until it has reached the lateral position occupied by the multiple strips of the line with which connection is to be established. When both the longitudinal and the lateral motions have been completed the plug is given a third motion, as for example a rotary movement, which rotary movement is adapted to throw out the moving plug contacts to bring them into engagement and electrical connection with the contact strips constituting the multiple of the line with which connection is to be established.

The line over which the in-coming call has been received will, of course, be connected through the carriage with the switch contacts of the plug so that the two lines will be interconnected upon the establishment of connections as above outlined.

A further feature of our invention relates to the step-by-step motion of the plug contacts which are brought to such position that they may be rotated into electrical connection with the appropriate set of multiple strips. In accordance with our invention the longitudinal motion of the carriage is divided into major steps and minor steps, corresponding with the major and minor orders of the numbers employed in designating the several telephone lines, and consequently designating the sets of contacts of the multiple system. The telephone lines are in conformity with the usual practice numbered in accordance with the decimal system. The multiple contacts are arranged in conformity with this system of notation, the banks of multiple sets being, for example, one hundred lines wide and one hundred lines long, thus taking care of the connections to ten thousand different telephone lines.

Instead of giving the carriage a longitudinal movement divided into one hundred steps, it is the practice, in accordance with our invention, to give the carriage anywhere from zero to nine major steps of movement in a longitudinal direction, each such major step having a length sufficient to move the plug over the space occupied by ten lines in the multiple system. The longitudinal movement of the carriage is divided also into minor steps, each such minor step corresponding with the longitudinal space occupied by one line. The plug may thus be brought opposite any one of the one hundred longitudinal positions by a movement comprising from zero to nine major steps and anywhere from zero to nine minor steps. While it is our preference to give the plug the requisite number of minor steps of movement before giving it the requisite number of major steps, it is entirely possible to reverse the order and give the carriage and the plug carried by it the requisite number of major steps before giving it the requisite number of minor steps to bring it opposite any one of the one hundred positions which must be assumed before the plug can be moved laterally into the position to make connection with the desired line.

The lateral movement of the plug is effected also by means of a combination of major and minor movements. The plug may be given the requisite number of major steps followed by the requisite number of minor steps, or, as we prefer, the plug may be given the requisite number of minor steps followed by the number of major steps necessary to bring the plug to the lateral position opposite the set of multiple contact strips with which engagement is to be made.

As a refinement of the above idea of carrying the plug to any one of ten thousand different positions in a given horizontal plane, it is our preference in practice to equip the carriage with four substantially duplicate plugs all connected in multiple with the same in-coming line. This enables us to divide the multiple into four sections, with each of which sections one of the four

plugs is adapted to co-operate. Thus the multiple may be divided longitudinally into halves or substantially into halves, whereby the plug or plugs at one end of the carriage will be employed in establishing connections with lines terminating in one end of the multiple, while the other plug will be employed in establishing connections with lines having contacts located in the other end of the multiple. In the same way the multiple may be divided laterally so that the multiple, instead of being located wholly upon one side of the carriage, is located half, or substantially half, on one side of the carriage and half, or substantially half, on the other side of the carriage. In accordance with this arrangement the plugs are adapted to be moved laterally in either direction from the carriage as may be necessary to establish connection with any line, depending upon the location of the multiple of that line upon one side or the other of the carriage. This division of the multiple both longitudinally and laterally into halves, or substantially into halves, together with an arrangement whereby the carriage and the plugs may be made to advance in either of two directions, materially reduces the total amount of movement which must be given to the plug contacts in order to bring them to a position in which they may establish connection with the desired line.

The carriages are preferably of a small vertical dimension so that a large number of carriages may be used within the limits of one length of multiple contact strips or wires, by mounting the carriages one above the other or side by side, each independent of the other in so far as its movements and the movements of its plugs are concerned. Thus a large number of carriages may be employed in moving a correspondingly large number of plugs into the positions necessary to establish connections with any one of the many lines terminating in the multiple system.

It will be understood that the line initiating the in-coming call is connected either permanently or temporarily with the plug or plugs of one of the carriages whereby the movement of the plug into position and then into electrical connection with the appropriate set of multiple wires will serve to establish the desired connection between the in-coming line and the line to be called.

It is not requisite to our invention that the multiple comprise the contacts of ten thousand different lines. On the other hand, our invention is not limited in capacity to a multiple of ten thousand lines. A set of multiple contacts for ten thousand lines may be duplicated immediately adjacent to the first set of contacts representing ten thousand lines, whereupon the capacity of the multiple is at once increased to twenty thousand lines. The carriage is correspondingly elongated or duplicated, whereby the plugs carried in both sections of the carriage are given corresponding movements both longitudinally and laterally. It is only necessary in this extension of our invention to provide means for limiting the turning of the plugs to one or the other section of the carriage as may be necessary to effect connection with a called line whose multiple set of contacts is located in one or the other longitudinal section of the entire multiple system. The longitudinal step-by-step movement of the carriage and the lateral step-by-step movement of the plugs is controlled by automatic commutating mechanism which may be controlled by electrical impulses under manual control, or by variations in electromotive forces or resistances controlled by the operator or calling subscriber or otherwise, as will occur to those skilled in the art.

The advantages of our invention as above outlined include the reduced expense of installation due to the simplicity of the multiple wiring and contacts, the decreased expense of operation because of the elimination of the operators employed in a purely manual system for moving the connecting plugs to the proper position on the face of a multiple switchboard, the certainty with which connection is established with the desired line, the celerity with which the connection may be accomplished, the compactness of both multiple and switching mechanism for establishing connections as above outlined, the facility with which extensions of the system may be made, the very large number of lines which may be connected in a given multiple system, with any of which connection may be established, the small number of serially-included contacts in the talking or switching circuits, and the simplicity and low cost of the automatic mechanism for thus establishing connection with any one of an extremely large number of lines. Furthermore, attention is called to the fact that the present automatic systems may be compared to the generally discarded and inefficient transfer systems used prior to the advent of the full multiple manually operated "B" board, while this switching system brings to automatic switching all the inherent advantages of a full multiple switchboard such as flexibility, simplicity of operation and circuits, and etc.

These and the other features of our invention and the details of the means by which it has been worked out will more readily appear by reference to the accompanying drawings, in which—

Figure 1 is a schematic plan or sectional view of the multiple system and the connecting mechanism arranged in accordance with our invention;

Figure 2 is a side elevation of a section

of the multiple system together with a diagrammatic representation of a part of the carriage-actuating mechanism;

Figure 3 is an enlarged view in side elevation of a part of the multiple system;

Figure 4 is a similarly enlarged cross-sectional view of a section of the multiple taken on line 4—4 of Figure 3;

Figure 5 is an enlarged plan view of a portion of the carriage and its actuating mechanism, showing in detail the plug-actuating mechanism;

Figure 6 is a cross-sectional view of the carriage and its associated mechanisms, taken on line 6—6 of Figure 5;

Fig. 6ª is a detailed view showing the connection between the lead screw for moving the carriage and the carriage.

Figure 7 is a partial cross-sectional view of the plug mechanism and the carriage, taken on line 7—7 of Figure 6;

Figure 8 is a partial cross-sectional view of the plug and carriage mechanism; taken on line 8—8 of Figure 6;

Figure 9 is a partial cross-sectional view of the plug and carriage mechanism, taken on line 9—9 of Figure 6;

Figure 10 is a detailed view in end elevation of a part of the plug-actuating mechanism, parts being broken away to more clearly reveal the internal construction;

Figure 11 is a detailed side elevation of the mechanism connecting two sections of the carriage, parts being broken away to more clearly reveal the internal construction;

Figure 12 is a detailed view of the plug-turner mechanism;

Figure 13 is a diagrammatic view representing the electrical circuits and electromagnetic apparatus employed in the operation of our invention;

Figures 14, 15, 16 and 17 are diagrammatic detail illustrations of the commutators controlling the longitudinal movement of the carriage mechanism;

Figure 18 is a diagrammatic view showing in detail the commutation and relay mechanism for controlling the plug turners and the selection of the ten thousand multiple units;

Figures 19, 20, 21, and 22 are diagrammatic views showing in detail the commutators controlling the lateral movement of the plugs;

Figure 23 is a view illustrating in some detail the clutch mechanism for connecting the operating shafts and the associated commutating mechanisms with the motor mechanism.

Figure 24 is an enlarged fragmentary view illustrating one of the finger pieces employed in connection with the sending device.

Figure 25 is a front elevational view of the commutators illustrated in Figures 14 and 17 inclusive, and the cooperating mechanism.

Figure 26 is a front elevational view of the commutators illustrated in Figures 19 to 22 inclusive, and the mechanism cooperating therewith.

In describing the detailed embodiment of our invention illustrated in the accompanying drawings we shall first describe the multiple, then the carriage and the plugs carried thereby and the motion thereof, after which we shall describe the circuits and mechanism for controlling the movements of the plugs.

In Figure 1 the cross-lined and serially numbered areas at either side of the longitudinal axis may be taken as diagrammatically illustrating in plan or cross-section the banks of multiple contact strips. Figure 4 illustrates in horizontal cross-section a fragment of a multiple bank, while Figure 3 illustrates a front elevation of the same fragment. It will be noted that this fragment is broken on line 30—30 in Figure 4 because of lack of space to illustrate the entire fragment. The parts of an entire bank which are thus shown substantially full-sized in Figure 4 are indicated by the diagonally cross-hatched patches at the upper left-hand corner of Figure 1. Separated by a vertical distance of, say, six or eight inches are a series of steel angle irons 31, 31. These may be regarded as located at the side of the multiple bank adjacent to the carriage. The construction can conveniently be described in connection with the assembly of the parts. The clamping bolts 32, 32 will be inserted from the carriage side of the angle irons 31 to assume the positions shown in Figure 4, the nuts 33, 33 being omitted for the time being. The bolts having been placed in position, a hard rubber spacing strip 34, which is drilled with appropriately spaced holes for the reception of the bolts, is slipped over the clamping bolt from the back or side opposite that occupied by the carriage. One such spacing strip will be slipped into place at the back of each of the several angle irons 31, which, as best indicated in Figure 2, may be of any number, one above the other, such as may be necessary to give proper support to the multiple contact strips. When the first series of spacing strips one above the other has been brought into position immediately behind the several angle iron supports, one of the four contact strips or wires of each multiple set is laid in position in a semi-cylindrical notch cut in the rear face of each strip at each of the positions assigned to a line. We have indicated four contact strips or wires assigned to each line, the four strips assigned to each line being designated by the characters *a*, *b*, *c* and *d*, respectively. We have thus endeavored to

point out that after the first vertical series of spacing strips is in place, all of the multiple contact strips designated by the character *a* will be laid in position in the notches formed in the rearward sides of the spacing strips. So also the contact strips or wires designated by the letter *b* are laid in position in semi-cylindrical notches formed also in the rear faces of the several spacing strips of the frontmost series. When all of the wires or contact strips lying in the plane indicated at 35 in Figure 4 have been laid in position, the second series of spacing strips 36 is slipped over the clamping bolts from the rear and brought into engagement with the wires *a*, *b*; *a*, *b*; *a*, *b* lying in the plane 35. The spacing strips 36 of this second series are provided with semi-cylindrical notches to receive and clamp the wires *a*, *a* and *b*, *b* on the side toward the carriage and are provided with appropriate notches on the rearward side also to receive the wires *d*, *d*, and *c*, *c* lying in the plane indicated at 37 in Figure 4. After the second series of spacing strips has been placed in position as indicated in Figure 4, the wires *d*, *c*; *d*, *c*; *d c* lying in the plane indicated at 37 are laid in position. Thereupon the next series of spacing strips 38 is slipped over the bolts. This is followed by the series of multiple contact wires lying in the plane 39. The entire bank is laid up in this way. First a series of hard rubber spacing strips and then a series of multiple contact strips or wires. When the entire bank has thus been laid up from front to back, the hard rubber backing plates 40, 40 in the shape of thin hard rubber sheets are pushed in between the vertically separated groups of spacing strips 34, 36, 38, etc., the backing plates being supported vertically by the spacing strips upon which they rest and being supported laterally also by the multiple contact wires between which they are slipped from the rear and being held in position also at the front by the rearward faces of the angle irons against which they abut. After the backing plates have been slipped into position as above described, the metallic clamping plate 41 is slipped over the bolts, whereupon the nuts 33, 33 may be screwed onto the bolts ends and tightened to clamp the component parts of the multiple bank in place upon the angle iron supports 31, 31. The backing plates serve principally to support the multiple contact wires against the pressure of the plugs, as subsequently to be described, thereby effectively and certainly insulating the several wires from one another. For simplicity, we have not attempted to show the framework which will support the construction as above outlined in place. This can be supplied by those skilled in the art to meet the particular requirements of each installation. The multiple bank as above described can be completely assembled in the factory before shipment to the exchange in which it is to be installed. While the foregoing description of the multiple arrangement and the following outline of the apparatus and circuits have, for the sake of brevity, been limited to an arrangement consisting of four wire groups, it is conceivable and eminently practicable to arrange the multiple into one wire, two wire, three wire or other combinations as needed to fit conditions, by simply changing the arrangement of the multiple, apparatus and circuits.

We have not made particular point of the fact that the multiple contact strips, *d*, *d* are flat or ribbon-shaped in cross-section, whereas the other wires of the multiple may be round. Our purpose in illustrating one of these wires as of flat or ribbon shape cross-section is to indicate that one of the wires may be located so that its contact face will project farther into the space between the wires of each multiple set. This location of one wire of each set in the multiple may be availed of if desired to control by appropriate electromagnetic apparatus the movement of a plug, as for example, in selecting or picking an idle trunk line. In case this construction is employed, the plug will be moved between the multiple wires of the several sets until one contact on the plug wipes across the inwardly projecting face of a multiple wire *d* whose electrical condition is in one way or another different from that of the other multiple wires *d* across which it has passed, and when it thus reaches the multiple wire having the different electrical or mechanical condition referred to, apparatus will be controlled to effect the turning of a plug or in some other way the engagement of its other contacts with the multiple wires of the set which has thus been automatically selected. This construction may, therefore, be employed to stop automatically either by electrical or mechanical means the traveling of a plug in order to secure the advantages to be obtained in the use of certain automatic and semi-automatic exchange systems of the prior art.

Figure 2 is an illustration upon a smaller scale of that side of the multiple bank away from the carriage. So far as the multiple is concerned it illustrates principally the fact that the multiple can be extended indefinitely in a vertical direction. No attempt has been made to illustrate all of the details of the multiple in this Figure 2. Its purpose is principally to indicate the vertical disposition of the plug carriages one above the other, several of the plug carriages and their actuating mechanisms being located between each vertically separated pair of angle irons, spacing strips, etc. In Figure 2 we have indicated the multiple contact strips as continuing beyond the lowermost and the upper-

most sets of spacers. It will be understood that these wires may be provided at their upper and lowermost ends with means for maintaining them taut and straight if they do not have the inherent rigidity necessary to maintain them in proper position as illustrated in Figure 4. For the sake of simplicity the foregoing description shows a vertical arrangement only of the multiple and associated plug carriages. It is evident that an equally good or even better arrangement may be obtained by mounting the multiple wires horizontally and the plug carriages side by side, thus permitting the use of many more associated plug carriages in relation to a particular sectional length of multiple than would be possible in a vertical arrangement which may be more limited by the height of the ceiling. Furthermore, in order to shorten the description, only one method of mounting the multiple contact strips is shown; it is evident that flat or other shaped strips may be used, and that the strips may be mounted differently by fastening them to an insulating backing and mounting the backings in a frame, or as may be most practicable in practice.

It is to be understood also that each telephone line will be more or less permanently connected through the usual distributing frames with a particular set of these multiple wires. In Figure 4 we have indicated in the spaces between each group or set of multiple wires the call number of the telephone line to which the group or set is assigned and connected through the distributing frame. The assignment of the numbers to the several sets of multiple wires follows a definite prearranged plan, in accordance with which the numbers have been filled in upon the fragment of the multiple bank illustrated in Figure 4. These numbers as thus arranged in detail, taken in conjunction with the numbering appearing upon the margins of the banks as shown in Figure 1, will sufficiently indicate the scheme of designation and distribution.

In describing the assignment of the telephone numbers to the several sets of multiple wires or contact strips we shall refer to the direction in which lies the carriage lead screw 42 as the longitudinal direction and the direction at right angles to this lead screw as being lateral. It may clarify the description of the assignment and distribution of the numbers to anticipate our description slightly by saying at this point that in Figure 1 four multiply connected plugs are indicated at 43, 44, 45 and 46. The connecting carriage which as a whole is indicated at 47 in Figure 1 is given a longitudinal motion sufficient to move a plug longitudinally until it occupies a position opposite the space between the set of four multiple wires with which connection is to be established. The plug which is to establish the connection is then moved laterally away from the carriage and between the several sets of multiple wires or contacts until it reaches a lateral position opposite the particular set of multiple contact wires with which the connection is to be established. The plug is then rotated or given a motion of a third character such that the contacts of the plug will establish electrical connections with the set of multiple wires connected with the line with which connection is to be established. We shall not stop at this point to describe in detail the mechanism for effecting these movements of the plugs, this being a matter which will be fully explained during the subsequent description of this embodiment of our invention.

It will be apparent now or a little later that the general plan of our invention might be employed in a system having but a single plug for each carriage, in which case the single plug must be capable of a longitudinal motion from one end of the entire multiple bank to the other end of the entire bank, and in which case also the plug must be capable of a lateral motion sufficient to reach the multiple wires of any line no matter how far removed from the carriage. This arrangement is applicable for a small office or for use when the selectors are arranged for connection to interoffice trunks in a full automatic system, but for the sake of compactness, however, and for the sake also of minimizing the amount of travel necessary to give the plugs, both longitudinally and laterally, it is our preference especially when there is a large number of lines to provide each carriage with at least four plugs, one only of which, however, becomes effective in establishing the desired connection. These plugs rest normally in the positions shown in Figure 1. The carriage and therefore the plugs are first given anywhere from zero to nine minor steps of longitudinal motion, the number of these minor steps corresponding with the digit in the units order of the number of the telephone line to be called. Let us assume, for example, that the number of the line to be called is 9867. Since the digit in the units order is a seven, the carriage is first given seven minor steps of movement in a longitudinal direction and toward the left as shown in Figure 1. Each minor step of longitudinal movement corresponds in length with the distance between sets of multiple wires, as illustrated in detail in Figure 4 and as indicated by the finest vertical lines representing the multiple banks in Figure 1. It will be noted that the row of sets of multiple wires opposite which plug 43 stands normally is numbered at the upper

margin of Figure 1 as "0". Seven minor steps of motion will therefore carry plug 43 to a position opposite a row of multiple contacts numbered at the upper margin with a small numeral 7. The digit representing the tens order in the assumed number 9867 is a 6. The carriage is, therefore, to be given a number of major steps of movement in the left-hand direction. The major steps of longitudinal movement are toward the left rather than toward the right because the digit in the units order of the number to be called is a 5, or a 6, or a 7, or an 8, or a 9 rather than a 0, or a 1, or a 2, or a 3, or a 4. If the digit in the units order were a 0, or a 1, or a 2, or a 3, or a 4, the major steps of longitudinal motion would be to the right instead of the left. Reverting now to the order of procedure in the case of the number 9867, the carriage, and therefore the plug 43, is given three major steps of movement toward the left. The major steps of longitudinal movement have a length equal to five of the minor steps,—in other words, a length equal to the length of five sets of multiple wires. The first major step of movement toward the left will, therefore, carry the plug 43 from a position opposite the small numeral 7 at the upper margin of the multiple bank in Figure 1 to a position opposite the next small numeral 7 to the left and, as it happens, directly under the larger numeral 2 at the upper margin of the figure. The second major step of movement will bring the plug 43 to a position opposite the row of multiple sets marked with the next succeeding small numeral 7, this time directly under the larger numeral 4. The third major step of movement toward the left will bring the plug 43 opposite that row of multiple wires designated with the small numeral 7 next to the left and in this instance directly under the larger numeral 6. The larger numeral 6 at the upper margin of the figure and over which is placed a brace (—) is intended to designate the five lateral rows of multiple contacts within the brace as connected with lines designated with numbers having the digit 6 in the tens order. The five lateral rows of multiple contacts within this brace are, first, the lines having numbers with the digit 5 in the units order; second, the lines having numbers with the digit 6 in the units order; third, the lines having numbers with the digit 7 in the units order; fourth, the lines having numbers with the digit 8 in the units order; and fifth, the lines having numbers with the digit 9 in the units order.

It may be well now to point out that there is another group of multiple wires or sets assigned to lines whose numbers have the digit 6 in the tens order. These are the lines, however, whose numbers have the digits 0, 1, 2, 3, or 4 in the units order. This additional group of multiple sets assigned to lines whose numbers have the digit 6 in the tens order are designated by the larger numeral 6 at the upper margin of Figure 1 and around which we have placed a bracket (—).

If, therefore, the number called had been 9863 instead of 9867, the first motion would have been three minor longitudinal steps to the left, followed by three major longitudinal steps to the right. This would have brought plug 43 opposite the multiple section enclosed within the bracket and bearing the larger numeral 6 and opposite the particular row within this section which is designated with the small numeral 3.

To further decrease in the same general way the distance which it is necessary to move the carriage in a longitudinal direction, we divide the multiple contacts of the bank into two major groups, longitudinally divided, and connect all of the lines having numbers with an even digit in the tens order with multiple contact sets in the left-hand group, and all of the lines having odd numbers in the tens order with multiple contacts in the right-hand major group. Corresponding with this sub-division of the multiple bank we provide the carriage with two plugs or lines of plugs longitudinally separated, it being the purpose of the plugs at the left-hand end of the carriage to cooperate with and establish connections with multiple wires in the left-hand half of the multiple bank, and it being the purpose of the plugs at the right-hand end of the carriage to establish the connections with the lines terminating in the right-hand major group of the entire bank.

Having adapted this arrangement, it will be apparent that the two plugs or lines of plugs will be given the same longitudinal motion or motions, since the two plugs or lines of plugs are mounted upon the same carriage through which all of the longitudinal movements are imparted to the plug mechanism. If we were to provide certain more or less complicated means for determining which of the two plugs or lines of plugs is to be turned to establish connection with a line, it would be entirely feasible to arrange the multiple sets in both of the major groups of the bank in exactly the same way. This would result in bringing the plug at the left-hand end of the carriage opposite a certain number having an even digit in the tens order, at the same time bringing the plug at the right-hand end of the carriage opposite a multiple set having the same number except in the tens order, where the number would have an odd digit in the tens order instead of an even digit. If, now, we were to provide means for selecting or determining which of the two plugs was to be turned or otherwise brought

into electrical connection with a multiple set, it would be entirely feasible to arrange the two groups of the multiple bank precisely as we have already described in connection with the left-hand group.

By slightly altering the arrangement of the right-hand group of the multiple it is, however, possible to simplify greatly and to make entirely automatic in its operation the means for determining which of the two plugs or lines of plugs is to be made effective in establishing the final connection with the called line.

Referring to Figure 1 it will be noticed that the right-hand group of multiple sets and its relation to the plug or line of plugs at the right-hand of the carriage differs from the arrangement at the left-hand end in two particulars: First, in that the plug 45 normally stands opposite a row of multiple sets designated by the digit 1 (instead of 0) in the units order; and second, in that there is, through the center of the group, a vacant space equal in width to the distance between two rows of multiple sets of contacts.

In conformity with these differences in the arrangement of the multiple in the right-hand group and the arrangement of the multiple in the left-hand group, the first step of the movements employed in making a set-up in conformity with the digit in the tens order has a length equal to that one of the minor movements heretofore described instead of the length of a full major movement.

It will be apparent that if the digit in the tens order is a 0, it will not be necessary to impart any movement to the plug 43 in conformity with the set-up of the digit in the tens order. This is for the reason that the plug 43 normally stands opposite the rows of multiple wires connected with lines whose numbers are zeros in the tens order. When, therefore, the plug 43 has been given a number of minor movements corresponding with the digit in the units order, it is already opposite the proper row of multiple wires or contacts, all of whose multiple wires are connected with lines whose numbers have zeros in the tens order.

One would expect ordinarily that in the case of the multiple wires connected with lines whose numbers have the digit 1 in the tens order, it would be equally unnecessary to impart any additional motion to the plug 45 in effecting a set-up corresponding with a called number having the digit 1 in the tens order. One would naturally expect this to be the case because of the fact that the plug 45 normally stands opposite the group of multiple contacts assigned to lines having numbers containing the digit 1 in the tens order.

But for the sake of simplicity in the commutating and actuating mechanism, it is desirable to give both sets of plugs, that is the set 43 and 44 and the set 45 and 46, the same lateral motions and by means of the same mechanism. It is necessary, therefore, to determine which of the two plugs or sets of plugs is to be turned to establish the final electrical connection with a multiple set, and in order to secure the commutation necessary to determine which plug or set of plugs is to be turned it is convenient to give to the carriage one extra step of longitudinal motion whenever the called number has an odd digit in the tens order. This extra step of longitudinal motion must, therefore, be given to the carriage and the plugs whenever the digit in the tens order of the called number is a 1, as well as whenever the digit in the tens order of the called member is any other odd digit.

While it would be entirely feasible to make this extra step of longitudinal motion of a length equal to the major motions heretofore described, space and motion can be saved by making this extra step of movement of a length equal to the minor movements heretofore described, and the minor movement is sufficient to effect the necessary commutation. It is our preference, therefore, to make this extra step of longitudinal motion of the length of the minor steps heretofore described, but the motion can most conveniently be regarded as the first step of the major or second series of longitudinal motions because it is employed in effecting the set-up corresponding with the digit in the tens order rather than the digit in the units order.

This will be more readily understood by illustration than by abstract description. Let us assume, for example, therefore, that the number to be called is 9817 instead of 9867: The carriage is first given seven steps of minor movement toward the left. This will carry plug 45 from its position opposite a row of multiple sets assigned to lines having the digit in the units order to a position opposite the row of multiple sets assigned to lines whose numbers have the digit 6 in the units order. The row of multiple sets opposite which the plug 45 will be left are assigned to lines whose numbers have the digit 6 in the units order and the digit 1 in the tens order—in other words, opposite the row of multiple sets assigned to lines whose numbers end in "16." The number to be called, however, was 9817 and not 9816.

When the second series of longitudinal movements occurs the carriage is first given an extra movement of a length equal to the minor movements, in view of the fact that the digit in the tens order is an odd number rather than an even number. The carriage and the plug 45 are, therefore, given one step of movement toward the left as deter-

mined by the fact that the digit in the tens order is a 1 rather than a 3, or a 5, or a 7, or a 9, and since this movement is of a length equal to the minor movements heretofore described, the plug 45 will be moved from a position opposite the row of the multiple sets assigned to lines having numbers with the digit 6 in the units order to a position opposite the row of multiple sets assigned to lines having the digit 7 in the units order. In other words, the plug 45 will thus be brought opposite the row of multiple sets assigned to lines whose numbers terminate in "17." This conforms with the number to be called, namely, 9817.

If the number called had been 9813 instead of 9817, the carriage, and therefore the plug 45, would first be given three minor steps of movement toward the left. This would bring plug 45 opposite the row of multiple sets assigned to lines whose numbers have the digit 4 in the units order and the row opposite which the plug is thus brought would be within the group assigned to lines having the digit 1 in the tens order. This, however, is not the row of multiple sets within which connection is to be established. When, however, that part of the set-up corresponding with the fact that the called number has the digit 1 in the tens order is effected, the carriage, and therefore the plug 45, will be given an extra step of movement having a length equal to the minor movements heretofore described. This time, however, the carriage and the plug 45 will be moved one step to the right instead of one step to the left. This is determined by the fact that in the units order of the called number there is a 0, or a 1, or a 2, or a 3, or a 4 rather than a 5, or a 6, or a 7, or an 8 or a 9. The first of the second series of longitudinal movements having the length of a minor movement will, therefore, move the plug 45 from a position opposite the row of multiple sets assigned to lines whose numbers terminate in "14" to a position opposite the row of multiple sets assigned to lines whose numbers terminate in "13." In the case of the number 9813, selected as an example, the second series of movements will consist of this single movement only, because no former movement is required to bring the plug 45 opposite the proper row of multiple sets.

Let us illustrate further by assuming an example in which the second series of movements involves or requires more than one step. Let us assume, for example, that the number called is 9857 instead of 9817, as previously selected. The seven steps of minor movement conforming with the digit 7 in the units order will first take place, thus bringing the plug 45 opposite the row of multiple sets assigned to lines terminating in "16", as previously described. Following this and conforming with the part of the set-up which takes care of the digit in the tens order, the carriage and the plug 45 will be given first the extra one step of movement of a length equal to the minor steps heretofore described. This will carry the plug 45 from a position opposite the row of multiple sets assigned to lines terminating in "16" to a position opposite the row of multiple sets assigned to lines terminating in "17". The next step of the second series of longitudinal steps is of the major length as heretofore described, and as the movement will be in the left-hand direction as determined by the magnitude of the digit in the units order, the plug 45 will be moved from a position opposite the row of multiple sets assigned to lines whose numbers terminate in "17" to a position opposite the row of multiple sets assigned to lines whose numbers terminate in "37". The third of the second series of longitudinal movements is also of a major length and will carry the plug 45 from the position opposite the row of multiple sets assigned to lines whose numbers terminate in "37" to a position opposite the row of multiple sets assigned to lines whose numbers terminate in "57". This example is typical and illustrates the fact that whenever the called number has an odd digit in the tens order, the first of the second series of longitudinal movements will be of a length corresponding with the minor movements which take care of the set-up representative of the digit in the units order, after which the remaining steps of the second series of movements will all be of the major length, the number of major steps being determined, of course, by the particular odd digit in the tens order of the number to be called. As previously described, the movements will be to the left or to the right, as the case may be, depending upon whether the digit in the units order of the number called falls between 0 and 4, inclusive, or between 5 and 9, inclusive.

In the example last selected and described it will be seen that the plug 45 has been brought opposite the row of multiple sets assigned to lines whose numbers terminate in "57". To further illustrate a typical example, let us assume now that the number called had been 9853. In this case the plug 45 would first be moved three minor steps toward the left, thus bringing the plug 45 opposite the row of multiple sets assigned to lines having numbers terminating in "14". The fact that the number to be called has a 5 in the tens order will determine that the second series of longitudinal movements is to be of three steps, and the fact that the digit in the units order of the called number is less than five will determine that the second series of movements is to be toward the right rather than the left. In effecting the set-up

corresponding with the digit in the tens order, the carriage and the plug 45 will first be moved one step toward the right, this step being equal to the minor steps in length and moving the plug 45 from a position opposite the row of multiple sets assigned to lines whose numbers terminate in "14" to a position opposite the row of multiple sets assigned to lines whose numbers terminate in "13". The second of the second series of longitudinal movements is of a major movement in length and will carry the plug 45 from its position opposite the row assigned to lines whose numbers terminate in 33. The next step of longitudinal movement is also of a major step in length and will carry the plug 45 from the position opposite the row assigned to lines whose numbers terminate in "33" to a position opposite the row assigned to lines whose numbers terminate in "53". This second series of longitudinal movements, three steps in number—first, the extra step of minor length and then the regular steps of major length—will carry the plug 45 to a position opposite the row of multiple sets at some point within which the line having the called number 9853 is connected.

It may be well to call attention again at this point to the fact that both lines of plugs,—that is, the line represented by plugs 43 and 44, as well as the line represented by plugs 45 and 46—are brought opposite a row of multiple wires or contact sets. The plugs 43 and 44 will be brought to rest opposite a row of multiple sets assigned to lines whose numbers have even digits in the tens order, while the plugs 45 and 46 will be brought to rest opposite a row of multiple sets assigned to lines whose numbers have an odd digit in the tens order. Both lines of plugs are now moved laterally by equal amounts, but the commutation which is effected in connection with the extra step of movement of a minor length falling within the second series of longitudinal movements as above described is made available in determining automatically whether it is the line of plugs represented by 43 and 44 or that represented by the plugs 45 and 46 which is turned at the conclusion of the set-up to establish connection with the called line. The commutation is effected in such a manner as to effect the turning of one line of plugs, and it will be apparent from the general description and the examples cited that it must be the line of plugs represented by 43 and 44 which is to be turned in case the called number has an even digit in the tens order, whereas it will be the line of plugs represented by 45 and 46 which must be turned in case the called number has an odd digit in the tens order.

We come now to a consideration of the lateral motions or movements which must be given to the plugs in order to bring them to the lateral positions opposite the longitudinal rows of multiple sets assigned to lines whose numbers have the digits in the hundreds and thousands orders conforming with the digits in the hundreds and thousands orders of the called numbers.

It will be noted that the multiple bank is divided laterally into two groups, the group containing the multiple sets assigned to lines whose numbers contain the digits 5, 6, 7, 8 or 9 in the hundreds order lying on one side of the carriage, and the multiple sets assigned to lines whose numbers contain the digits 0, 1, 2, 3 or 4 in the hundreds order lying on the other side of the carriage. This division into the two lateral groups is not followed in the case of the multiple sets assigned to lines of the zero thousand and containing the digits 0, 1, 2, 3 or 4 in the hundreds order, these multiple sets being grouped with the multiple sets assigned to lines whose numbers contain the digits 5, 6, 7 or 8 in the hundreds order. There are, therefore, more multiple sets in the lateral group at the upper side of the carriage than at the lower side, as illustrated in Figure 1.

After the plugs have been given the necessary longitudinal movements as heretofore described, they are given the necessary lateral movements. These lateral movements are accomplished step by step, as in the case of the longitudinal movements. The lateral movements are divided into two series: first, a series of minor movements from one to ten in number, and then a series of major movements from zero to nine in number, the minor movements always taking place in one direction and the major movements taking place in either of two directions.

These movements may conveniently be described in connection with particular examples. Let us assume, therefore, that line 9867 is to be called, and let us assume also that plug 43 has been moved longitudinally until it stands opposite the row of multiple sets assigned to lines whose numbers terminate in "67." The digit in the hundreds order will in this case be an 8. The two lines of plugs—namely, the line represented by 43 and 44, and the line represented by 45 and 46—will be given nine steps of minor movement toward the top of Figure 1. The first step of minor movement will carry the plugs within the upper group, as illustrated in Figure 1, and opposite the lateral row of multiple sets assigned to lines having numbers the first two of whose digits are 0, 0. The second minor step will carry the plugs into the lateral row representing numbers beginning with "01." The third step of lateral movement will carry the plugs opposite the lateral row assigned to lines whose numbers begin with "02." This step-by-step movement will be continued until at the end of the ninth minor step the plugs will lie within the lateral row of multiple sets as-

signed to lines whose numbers begin with "08." This ends the first series of lateral movements.

In the case of the selected number, 9867, there will then follow the second series of lateral movements, each step of this second series of movements having the length of a major movement, i. e., a distance equal to five minor steps of movement. The first major step, which in this instance takes place from the carriage toward the top of Figure 1, will carry the plugs from the lateral row representing numbers beginning with "08" to the lateral row representing numbers beginning with "18." The next major step of movement will carry the plugs into the row representing numbers beginning with "28." Successive major steps will carry the plugs into the rows representing numbers beginning with "38," "48," "58," "68," "78," "88" and "98," nine such major steps being required to carry the plugs into the 800 row assigned to 9000. The plug 43 will at the end of these two series of lateral movements lie within the area defined by the four multiple wires assigned to number 9867. When, therefore, plug 43 is turned upon its axis, its four contact points will be brought into electrical connection with the four multiple wires to establish connection with the called line.

The major steps of lateral movement will not always take place toward the top of Figure 1. These major steps will take place in that direction only when the digit in the thousands order of the called number is more than zero and when the digit in the hundreds order is a 5, or a 6, or a 7, or an 8, or a 9. If we had assumed that line 9367 was to be called, the minor steps of lateral movement would take place as before, except that the minor steps would in this case be four in number instead of nine in number as previously described. The four steps of minor movement would carry the plugs 43 and 45 into the lateral row representing lines having numbers beginning with "03". After this nine steps of major movement will ensue, and since the digit in the hundreds order of the number to be called is less than five, the movement will take place toward the bottom of Figure 1 instead of toward the top, as previously described in connection with the number 9867. The first major step of movement will carry the plugs 43 and 45 outside the lateral group at the top of Figure 1, but will carry plugs 44 and 46 into the lateral group at the bottom of Figure 1 and into the lateral row assigned to lines having numbers beginning with "13." The second major step will carry plugs 44 and 46 into the lateral row representing lines having numbers beginning with "23." The successive major steps will carry the plugs 44 and 46 successively into the lateral row representing lines having numbers beginning with "33," "43," "53," "63," "73," "83" and "93," it being apparent that nine major steps of movement will have carried the plugs 44 and 46 into the lateral row representing the lines having numbers in the thousands and hundreds orders in which the number of the called line is located, namely, 9367.

Here again the turning of plugs 44 upon its axis will effect the connection with the called line. While the lateral movements necessary to bring plug 44 into the position corresponding with line 9367 have taken place, the plug 46 will have been carried into the position occupied by the multiple set assigned to line number 9376. The commutation controlled by the second series of longitudinal movements will determine, however, that it is plug 44 which is to be turned rather than plug 46. Plug 46 will not, therefore, be rotated upon its axis to establish connection with line 9376.

If the number called had been 0367, the first series of lateral movements would have comprised four minor steps toward the top of Figure 1, as previously described. This first series of lateral movements would have brought plugs 43 and 44 into the lateral row assigned to lines having numbers beginning with "03." No further movement of the plug is necessary, therefore, and the second series of lateral movements may in this instance be regarded as zero in number. In the case of called numbers having the digit 0 in the thousands order, it is, however, necessary to give the plugs one step of minor movement, as a result of which the first series of lateral movements may be regarded as comprising a single minor step.

It will be apparent now that the multiple bank contains a set of multiple contacts assigned to each of the lines numbered from 0000 to 9999, and that at each vertical level an inch or two apart may be located a plug carriage and plugs which, by a series of longitudinal movements followed by a series of lateral movements, may be brought into an area lying between multiple wires assigned to any line. The proper plug having been brought to the proper position within the multiple bank, it is only necessary to turn the plug upon its axis in order to establish connection with the called line.

Thus far we have described the multiple bank and the carriage and plug mechanism as though limited in capacity to 10,000 lines. An exchange equipped with our invention is not, however, thus limited to a capacity of 10,000 lines. In order to secure a capacity of 20,000, it is only necessary to duplicate the multiple banks which are shown in full in Figure 1, these multiple banks being arranged immediately to the right of the banks shown in Figure 1. A fragment of the second multiple bank of 10,000 is illustrated at

the extreme right of Figure 1. The number of the lines assigned to multiple sets in this duplicate bank will be from 10,000 to 19,999, the digit 1 in the ten thousands order being the symbol which will distinguish lines terminating in the duplicate bank from those terminating in the first bank already described. Between the two lateral groups constituting the duplicate bank is a carriage equipped with plugs identical with those designated by the reference letters 43, 44, 45, 46 and 47, this duplicate carriage being mechanically connected with the carriage shown in Figure 1 by means of the angle irons 48 and 49. The duplicate carriage will, therefore, move longitudinally in exact conformity with the carriage 47, shown in Figure 1.

The mechanism not yet described for moving the plugs of carriage 47 in either of the two lateral directions is carried through the duplicate carriage so that the plugs of the duplicate carriage will be moved laterally in exact conformity with the plugs of the carriage 47.

Each of the carriages is provided with its own individual plug-turning mechanism and commutation is provided to determine automatically whether it shall be a plug in the duplicate carriage or in the main carriage 47 which shall be turned at the end of the series of longitudinal and lateral movements heretofore described. Since means is thus provided for determining whether it shall be a plug in the main carriage or a plug in the duplicate carriage which is to be turned, we provide a means for establishing connection with any one of 20,000 lines. The number of multiple banks and carriages is not limited to two. We may provide a triplicate multiple bank assigned to lines having numbers from 20,000 to 29,999 and equipped with a triplicate carriage mechanically connected with the two carriages heretofore described. The triplicate carriage will be provided with its own independent plug-turners controlled by appropriate commutation such that a plug in any one of the three carriages will alone be turned to effect connection with the called line and no other.

The system and its principles are not limited to three multiple banks adapted to accommodate 30,000 lines, but as a matter of theory or principle at least may be extended indefinitely. We do not fail to appreciate, however, that there may be practical limits which it would be unwise to exceed.

While it is conceivable that the carriages and plugs might be actuated manually to move longitudinally and laterally as hereinbefore described, it is our purpose to provide automatic mechanism for controlling and actuating the carriages and plugs. This automatic controlling and actuating mechanism might utilize mechanical, pneumatic or other power, but it is our preference to employ electromagnetic means for controlling and effecting the actuation of the carriage and plug mechanism.

The controlling and actuating mechanism can best be described by following the diagrammatic circuit drawing of Figure 13 with such incidental reference now and then to the details of the mechanical illustrations as may be necessary or helpful in following the circuits and the functions thereof.

Before proceeding to a detailed description it may be well to outline the circuit arrangement and the controlling and actuating mechanism. The longitudinal movements of the carriage are effected by means of the lead screw 42. An electro-mechanically controlled clutch is arranged to throw the lead screw into mechanical connection with an electric motor, the motor thus serving to drive the lead screw and to move the carriage forward or backward as may be necessary.

The plugs are mounted upon the ends of racks guided to permit of their transverse movement across the carriage in either direction. The racks upon the ends of which the plugs are mounted are in mesh with pinions splined upon driving shafts running from end to end of the space over which the carriage is adapted to travel, with the result that the rotation of the splined shafts will effect the lateral or transverse movement of the racks upon the ends of which the plugs are mounted. The splined shafts are adapted to be connected through suitable clutch mechanism at the forward end with the electric motor previously referred to.

Associated with each carriage is also a plug-turning rod, the rotation of which is adapted to effect the rotation of a plug, no matter where the plug may be located, longitudinally and laterally relative to the multiple bank. The plug-turning rod or rods are actuated by electromagnets.

The operation of the motor which supplies the power to the lead screw and the spindle shafts and the electromagnets controlling the clutches is under the control of electromagnetic relay and switching mechanism primarily controlled by a suitable sending device adapted to be manipulated by the operator or telephone subscriber upon the calling line. The manipulation of the second device determines the sequence and extent to which the automatic switching mechanism is operated in controlling the application of current to the devices which supply and control the application of power to the carriage and the plugs mounted therein.

The mechanism which is directly effective in actuating the carriage and the plugs is best illustrated in Figures 1, 5, 6, 7, 8, 9

and 10. The mechanism is only digrammatically illustrated in Figure 1, where the electric motor or other source of power is indicated at 50. The electromagnet 51, when energized, operates the clutch 52 to throw the beveled pinion 53 into mesh with the beveled pinion 54 which is mounted upon the shaft 55 of the motor. When, therefore, the electromagnet 51 is energized, the rotation of the shaft of the motor 50 will effect the rotation of the carriage lead screw 42. The clutch 52 is normally disengaged, as indicated in Figure 1, and, as best shown in Figure 23, the clutch is provided with a notched detent wheel 56 which co-operates with the detent 57 to determine the exact angular position in which the lead screw 42 comes to rest, the detent 57 and the notched detent wheels 56 serving to retain the lead screw in a fixed position of rest due to the pull of the retracting spring 58 upon the upper end of the clutch lever 59. It will be understood that the energization of the electromagnet 51 slides the gear 53 and the notched detent wheel 56 upon the spindle end of the lead screw 42, thereby disengaging the detent 57 and throwing the gear 53 into mesh with the gear 54 mounted upon the motor shaft 55. When, therefore, the electromagnet 51 is energized, the lead screw is thrown into mechanical connection with the motor to be driven thereby. When, on the other hand, the electromagnet 51 is de-energized, the lead screw 42 is mechanically disconnected from the motor and is exactly positioned and held by the detent mechanism described.

The carriage is mounted upon and its weight is supported by the transverse actuating shafts 60 and 61, of square cross-section, these being the shafts which control the transverse or lateral movement of the plugs. These two transverse actuating shafts are permanently geared together so as to rotate in conformity with one another by means of the beveled gears 62, 63, 64 and 65, and the cross shaft 66. Splined upon the transverse actuating shaft 60 is a clutch member comprising a beveled gear 67 and a notched detent wheel 68 substantially like that illustrated in Figure 23. The electromagnet 69, when energized, throws the gear wheel 67 into mesh with the gear wheel 70 mounted upon the motor shaft 55, whereby the rotation of the motor will effect the rotation of the transverse actuating shafts 60 and 61. The angle iron framework of the carriage is indicated at 80, 80 in Figures 5, 6, 6ª and 7. At each end of the carriage frame is mounted a hollow rectangular guide channel 81 illustrated in transverse cross-section in Figures 7, 8, and 9 and in elevation, with part broken away, in Figure 10. Within this guide channel is mounted the lower edge 82 of the plug frame 83, there being a section of gear-toothed rack 84 fastened within a suitable groove in the bottom of the lower edge 82 of the plug frame 83. This rack is continuous from end to end of the plug frame as indicated in Figure 10.

Directly beneath the guide channel 81 and near either end thereof is fastened a pinion chamber 85. A pinion 86 having gear teeth in mesh with the teeth of the rack 84 is mounted in each of these pinion chambers, the gear being provided, as best shown in Figure 10, with a square hole fitting over the square transverse actuating shaft 60 or 61 as the case may be, the arrangement being such that the carriage can slide upon the transverse actuating shafts 60 and 61, these shafts serving not only to rotate the pinions 86 and thus to effect the lateral movement of the plug frames, but also to support the weight of the carriage and the mechanism mounted thereon.

Figures 5 and 6 best illustrate the details of the plugs 45 and 46. Each plug comprises a support 90 of insulating material such, for example, as hard rubber, and to this hard rubber support are fastened four metal contact members marked, respectively, 91, 92, 93 and 94. The contacts 94, 94 of the plugs 45 and 46 are connected by means of short flexible wires 94′, 94′ with the metallic conducting strip 94ª. The contacts 93, 93 are serially connected with the metallic conducting strip 93ª. The contacts 91, 91 are serially connected with the metallic conducting strip 91ª, and the contacts 92, 92 are serially connected with the metallic conducting strip 92ª, all of these conducting strips being mounted in suitable insulating material 95 upon the side of the plug frame 83.

The plugs 45 and 46 are rigidly mounted upon the ends of a plug spindle 100, rotatably mounted in the bearings 101 and 102 which form the upper part of either end of the plug frame 83. Similar bearing members 103, 104 and 105 are located at convenient intermediate points upon the plug frame 83, these intermediate bearing members being cut away on one side as indicated at 106 in Figure 9, in order to permit of the 90 degrees rotation of the plug spindle 100, upon one side of which is formed a continuous fin 107. The dotted lines in Figure 9 indicate the position of the fin when the plug spindle 100 is rotated through an angle of ninety degrees, as must occur in the operation of the mechanism subsequently to be described.

It is necessary to provide means for establishing and maintaining electrical connections wth the metallic conducting strips 91ª, 92ª, 93ª and 94ª. For this purpose we provide at either side of the carriage a contact supporting lever 110, 110, these contact supporting levers being pivoted to the frame

at 111, 111. They are slotted at 112, 112 to receive the spring supporting pins 113, 113 fixed to the carriage frame and connected by means of the springs 114, 114 with spring posts 115, 115, fixed as shown in Figure 5 to the outer end of each contact supporting lever 110. It will be seen that these springs 114 tend to draw or force the ends of the contact supporting levers toward the associated plug frame. Upon each of the contact supporting levers is mounted a block of insulating material 120, in which are mounted a series of contact springs 122, 121, 123 and 124. Each of the contact supporting levers 110, 110 is provided with a projecting rider 125, 125. These riders are adapted to co-operate with a cam surface 126 cut upon the face of the ledge 127 which projects, as best shown in Figures 7 and 9, from the side of the plug frame 83 at and near the ends thereof.

Referring to Figure 5, it will be noted that the cam surface 126 is normally in such a position that the projecting rider 125 of the contact supporting lever 110 at the right-hand side of the figure is not engaged by the cam surface, as a result of which the free end of this contact supporting lever is drawn toward the plug frame by the spring 114, the movement of the lever being limited by the engagement of the end of the slot 112 with the pin 113.

When carried into this forward position by the associated contact supporting lever 110 the contact springs 122, 121, 123 and 124 embrace and engage the upper and lower surfaces of the metallic contact strips 92^a, 91^a, 93^a and 94^a, mounted upon the side of the plug frame 83. Electrical connection is thus established between the contact springs 122, 121, 123 and 124 with the metallic contacts 91, 92, 93 and 94, forming parts of the plugs 45 and 46.

Referring still to Figure 5, it will be noted that the projecting rider 125 of the contact supporting lever 110 at the left-hand side of the figure is engaged by the cam surface 126 of the ledge 127 which forces the free end of the contact supporting lever away from the plug frame, thus withdrawing the set of contact springs supported upon this lever from electrical connection with the metallic contact strips 91^a, 92^a, 93^a and 94^a mounted upon the side of the plug frame.

If, now, the plug frame were to be moved toward the left as will occur in the operation of the mechanism, the cam surface 126 will, by co-operation of the projecting rider 125, permit the free end of the contact supporting lever 110 at the left of Figure 5 to move toward the plug frame, thus bringing its contact clips 122, 121, 123 and 124 into engagement and electrical connection with the metallic contact strips mounted on the side of the plug frame. A slightly increased movement of the plug frame toward the left will cause the cam surface 126 at the right-hand end of Figure 5 to engage the projecting rider 125 of the lever 110 at the left of the figure, to effect the withdrawal of the relatively stationary contact clips from engagement and connection with the metallic conducting strips upon the side of the plug frame. If the plug is moved into an extreme position toward the left, the projecting rider 125 will travel across the bevelled end 126′ of the cam surface, but at this time the entire plug frame will have been moved so far to the left that the contact clips mounted upon the left-hand supporting lever will not engage the metallic contact strips upon the side of the frame; but no harm will be done on this account because the return of the plug frame to its normal central position will effect the lifting or retraction of the right-hand supportng lever 110 as soon as the part of the cam surface marked 126′ engages the projecting rider 125 of the right-hand supporting lever. It will be apparent that the contacts mounted upon the left-hand supporting lever 110 will maintain electrical connection with the metallic contact strips of the plug frame and thus with the plug contacts each at the extreme left-hand position of the plug frame and plugs.

A corresponding part of the cam surface 126^2 controls the movement of the left-hand contact supporting lever 110 as the plug frame is moved toward the right and rotated to its normal central position.

In Figures 1 and 2 we have indicated a flexible switchboard cord of five or more conductors 130 provided with a suitable weight and pulleys in the usual manner, to maintain electrical connection between the several contact clips 121, 122, 123 and 124 mounted upon the several contact supporting levers at a fixed point 131. It will be understood that when the carriage moves toward the right (Figures 1 and 2), the weight upon the cord will permit the cord to move forward to accommodate itself to the position assumed by the carriage. When the carriage moves toward the left the weighted pulley will take up the slack of the cord in the well-known manner. The connections of the cord with the contact clips mounted upon the supporting levers are not shown in Figure 5, but those skilled in the art will readily understand how the connections are to be made between the strands of the cord and the several clips. It may be desirable to point out that the strands of the cord associated with each carriage are connected in multiple with the clips mounted upon each of the supporting levers 110.

It will now be understood that in no matter what longitudinal position the carriage

may be, the rotation of the transverse actuating shafts 60 and 61 will, by means of the pinions 86 and the racks 84 move the plug frames and the plugs to the right or the left as may be necessary to bring a plug into line with the proper longitudinal row of multiple sets.

We have previously explained that the final operation in establishing a connection with a called line is to turn the plug. The plugs mounted upon either end of the plug spindle 100 are normally maintained in their vertical positions, as shown in the drawings by the operation of a spring 140, one end of which is fixed to the bearing 102 and the other end of which is attached to the spindle 100, or the fin 107 formed integral therewith.

Each of the contact supporting levers 110 carries at its free end a plug rotating hook 141. Each of these hooks is provided with a slot 142, the lower end of the slot engaging the head of a rivet 143 fixed in the carriage frame 80, as best illustrated in Figure 7, and the upper end of the slot engaging a pin 144 which may be formed integrally with the strip of metal 145 which forms the top support for the associated group of contact clips, as a result of which the pin 144 is adapted to move toward and away from the associated plug frame in conformity with the movements of the free end of the supporting lever 110 upon which it is mounted. The plug-turning hook 141 is normally maintained in its uppermost position due to the tension of a spring 146, one end of which is attached to a projection 147 extending from the side of the plug-turning hook, and the other end of which is attached to the lower side of the projecting pin 144.

Whenever a contact supporting lever swings into its forward position, in which its contact clips establish electrical connection with the metallic contact strips upon the side of the plug frame, the associated plug-turning hook 141 will be swung forward at its upper end so as to bring the projecting arm 148 of the contact hook into a position immediately above the fin 107 of the plug spindle 100, this alternate position of the plug-turning hook being indicated in dotted lines in Figure 7.

It has heretofore been pointed out that as a final step in the operation establishing a connection it is necessary to turn the plugs at one end of the carriage or at the other end of the carriage, but not at both ends in establishing any given connection. The mechanism for effecting the turning of the proper plug includes two longitudinal lines of plug-turning rods, one at either side of the carriage, these lines of plug-turning rods extending from end to end of the space over which the carriage may travel. Each line of plug-turning rods is made up of two sections longitudinally divided at the point represented by the bearings 150, 150 represented in Figure 1. The sections of the rods to the left of the bearings 150 are effective in turning the plugs 43 and 44, while the sections of the rods to the right of the bearings 150 are effective in turning the plugs 45 and 46. For convenience, the plug-turning rods are rotatably mounted upon a common axis. The sections of the rods to the left of the bearings 150 are hollow or tubular, as indicated at 151 in Figure 11. This tubular section 151 is provided with a projecting fin 152. To the right of the bearings 150 the plug-turning rod is of solid cross-section, as indicated at 153 in Figures 6 and 11, these sections of the rod also being provided with projecting fins 154. The power for rotating the right-hand sections of the rods upon their axes is derived through the extension 155, which is led through the hollow tubular bore of the section 151 to the left-hand end of the space over which the carriage travels. As best illustrated in Figures 1 and 12, the plug-turning rods are provided at their left-hand extremities with projecting levers, the lever 156 being connected with the inner and solid rod 155 which is integral with the right-hand section 153, and the lever 157 being connected with the hollow tubular section 151 of the line of plug-turning rods. The connecting rods 158 and 159 are connected with these levers 156 and 157, respectively, and at their opposite ends are provided with armature mechanism diagrammatically indicated at 158′ and 159′, the armatures being adapted for actuation upon the energization of the associated electromagnets 160 and 161, respectively.

It will be noted that the electromagnet 160 is adapted, upon energization, to effect substantially 45 degrees of rotation of the sections of the plug-turning rods at the right-hand end of Figure 1, while the electromagnet 161 is adapted, upon energization, to effect substantially a 45 degree rotation of the section of the plug-turning rods at the left-hand end of Figure 1. It will be apparent also that the plug-turning rods at both sides of the carriage are turned simultaneously and by equal amounts.

The purpose of this is to effect the rotation of plugs 43 and 44 or 45 and 46, no matter to which side of the carriage the plugs may have been projected. This will be a little more apparent by reference to Figures 5 and 6, where the fins 154 projecting from the plug-turning rods 153 are shown directly above the feet 162 extending from the lower ends of the plug-turning hooks 141, 141. It will be apparent that 45 degrees of rotation of the rods 153, 153 in the direction of the arrow, as shown in Figure 6, will cause the fins 154, 154 to engage the

feet 162 of the plug-turning hooks 141, 141, to move both hooks downwardly a short distance. If the plug frame and plugs are in the position shown in Figure 5, the hook 141 at the left-hand side of the figure will not be effective in engaging the fin 107 projecting from the side of the plug spindle 100, but the projecting arm 148 of the hook 141 at the right-hand side of Figure 5 will be effective in engaging the fin 107 of the plug spindle to cause substantially 90 degrees of rotation of the plug spindle and the plugs mounted at the ends thereof.

If the plug frame and plugs as shown in Figure 5 were moved to the left, then the plug-turning hook 141 associated with the left-hand contact supporting lever 110 would be effective in causing the plug spindle and plugs to be turned. The two lines of plug-turning rods, one at or near either side of the carriage cooperating with the duplicate plug-turning hooks, are, therefore, effective to turn the plug spindle and the associated plugs, no matter which way the plug frame and the plugs may be projected into the multiple bank.

It will be apparent that the longitudinal division of the plug turning rods in the two sections affords means whereby the energization of the electromagnet 160 will cause plugs 45 and 46 to be turned, while plugs 43 and 44 are not turned, and whereby the energization of electromagnet 161 will cause plugs 43 and 44 to be turned, while the plugs 45 and 46 remain in their vertical positions, as shown in the drawings.

Figure 2 is rather a diagrammatic view, which, however, will suffice to indicate how the several carriages may be located one above the other within a given multiple bank. This figure indicates three carriages mounted between each level of insulating strips. It will be apparent, however, that the number of carriages between each level of supporting strips is not thus limited. Each of the carriages is equipped with mechanism such as has been described, it being understood that each end of each carriage is provided with a plug frame, a plug spindle, two plugs, and the cooperating mechanism for actuating the plugs as illustrated in detail in Figures 5, 6, 7, 8, 9, and 10.

It may be well to point out specifically that underneath the left-hand end of the carriage frame, as illustrated in Figure 1, is fastened a lead screw nut 170, as shown in Figure 6a, through which is threaded the lead screw 42 to effect the longitudinal movement of the carriage.

We shall now describe the circuits over which electrical currents flow to control and effect the actuation of the mechanism already described:

The sending device is represented at 199 in Figure 13. It comprises essentially a series of rheostat contact points marked 200, 201, 202 * * * 209, between each pair of which contacts is connected a resistance of 100 ohms, the resistances being marked, respectively, 210, 211, 212 * * * 218, and a moving contact 220 adapted to be brought into electrical connection with any one of the rheostat contacts in conjunction with an electromagnetic locking device 221. The electromagnetic locking device comprises an electromagnet 222 of 100 ohms resistance, the resistance of which acts in certain respects like the resistances connected between the rheostat contact points. The electromagnet is provided with two armatures, the armature 223 controlling contacts 224 and 225 and the armature 226 being provided with a latch 227 adapted to engage in any one of the saw-toothed notches 228 cut in the edge of the sliding bar 229, upon the end of which the contact 220 is mounted. The sliding bar 229 is provided with a spring 230 which tends normally to maintain the sliding bar in the psition shown in Figure 13 and which tends also to return the bar to this normal position when it has been moved away from that position. Mounted upon the sliding bar 229 are a series of ten finger catches marked, respectively, 0, 1, 2, 3, 4 * * * 9. The finger catches are in the form of bell crank levers pivotally mounted upon the short arms diagrammatically represented as extending upwardly from the sliding bar 229, each of the finger catches being arranged to force an associated actuating pin 231 downwardly through the bar 229 whenever the finger catch is engaged and manipulated. The construction will appear from a description of the operation, which is as follows:

The calling telephone subscriber or the A operator in case the system of our invention is used only in automatically establishing the necessary connections at the B board of the telephone exchange, places his or her finger upon the finger catch corresponding with the first digit in the number of the called line and pulls the catch, together with the sliding bar 229, toward the left until the motion is stopped by the engagement of the operator's finger with the stop piece 232, which is in line with the hooks of the finger catches. If, therefore, the operator places his or her finger in the hook of the catch marked "0" and pulls the sliding rod 229 toward the left until his or her finger engages the stop 232, the pin 231 associated with the finger pawl marked "0" will be projected downwardly as indicated in dotted lines in Figure 13, with the result that when the motion of the slide 229 is arrested, the stop pin 231 of the catch marked "0" will engage the cam 233 upon the armature 223 to force the armature toward its electromagnet and therefore to close electrical

connection between the contacts 224 and 225 and the armature 223. As soon as this armature 223 has thus been mechanically actuated an electrical circuit will be closed as follows: from a battery connection B indicated near the upper right-hand corner of the figure, through contact springs 234 and 235, through wire 236, and thence through two parallel paths, one of which may be traced through the 1000 ohm resistance 237 of a Wheatstone bridge circuit, thence through wire 238 to contact 239, to contact 240, thence through wire 241 to the contact 220 mounted upon the slide 229. The movement of the slide will have brought this contact 220 into engagement with the rheostat contact 200, through which the circuit may be traced, as also through the nine 100 ohm resistances marked, respectively, 210, 211 * * * 218, thence through wire 242 to the winding of the electromagnet 222, thence through contact 224, the armature 223, contact 225 and the wire 244 to the ground indicated, it being understood that the battery from the live side of which current flows as above described is provided with a permanent ground connection at one terminal. The branch bridge circuit through which current flows also at the same time may be traced from wire 236 through another 1000 ohm resistance 245 of the Wheatstone bridge circuit, thence through electromagnet 246 to wire 238, and also as previously traced to the ground connected with wire 244. The current flowing over this circuit will effect two electromagnetic results. First, the armatures 223 and 226 of the electromagnetic locking device 225 will be attracted. The effect of this will be to hold the armature 223 in a position in which it maintains electrical connection with the contacts 224 and 225. The attraction of armature 226 serves to force the catch 227 into engagement with the notch of the slide 229, which at that time will be in a position opposite the catch 227. The notch of the slide which will be engaged when the finger piece marked "0" has been actuated will be the notch at the right-hand end of the series shown upon the lower side of the slide rod 229.

The other electromagnetic result of the flow of current over the circuit just traced is to cause the energization of the electromagnet 246, with the consequent attraction of its associated armature 247.

If the finger catch marked "6" had been manipulated instead of the finger catch marked "0", the rod would have been pulled to the left only until the contact 220 mounted upon the slide rod engaged the rheostat contact 206. The pin projected from the finger catch 6 would at this time have engaged the cam 233 of the armature 223 to close a circuit exactly like that already traced except for the fact that the current in this instance would flow only through the 100 ohm rheostat resistances to the right of the rheostat contact 206. In other words, the selection of any one of the finger catches of the slide rod as that to be manipulated will determine the number of the sections of resistance of 100 ohms each which are connected in the circuit already traced. It is the selection of the proper finger piece and the connection in circuit, therefore, of the proper number of resistances of 100 ohms each which determines the operation of the automatic connecting mechanism to establish connection with the proper line.

It may be well at this point to call attention to the fact that the numbers of the called subscribers' lines as printed in the telephone directory will be printed in an order exactly the reverse of that in which it is convenient to refer to them in describing the multiple and the operation of the switching mechanism. We have, for example, in describing the construction of the multiple bank and the operation of the carriages and plugs referred to a line having the number 9867. The number of this line as printed in the telephone directory would be 7689. The reason for this apparent discrepancy is that the first movement of the switching mechanism conforms with the digit in the units order of the number of the line as conveniently designated in the multiple bank. It is more convenient, however, to instruct the subscribers to manipulate the sending device in the order in which the numbers appear in the directory and as read from left to right in the usual manner. In describing the line we have referred to as number 9867, the subscriber will see before him the number 7689, and in conformity with this arrangement of the numbers as printed in the directory he will grasp the finger catch bearing the numeral "7" and pull it until the stop 232 is engaged. After the slide has served its purpose in effecting a setting up of the switching mechanism corresponding with the digit 7 in the units order, the subscriber will grasp the hook catch bearing the numeral "6" and will pull the slide as before. Thereafter he will engage the finger catch bearing the numeral "8", and finally the finger catch bearing the numeral "9", in each instance pulling the slide as previously described and in each instance closing a circuit such as that already described except that the number of rheostat resistances connected in the circuit will vary in conformity with the number of the finger catch which has been manipulated.

The energization of the relay 246 will cause the attraction of the armature 247 to engage the associated contact 248, which will cause current to flow over a circuit

which may be traced as follows: from the live side of the battery marked B′ near the upper right-hand corner of Figure 13 through the winding of a combined relay and ratchet actuating magnet 249, through wire 250, wire 251, wire 252, contact 248, armature 247, wire 253, and the contact brush 254 which bears normally upon the metallic semi-circular segment 255 of the commutator 256.

It will be well at this point to explain the fact that the commutator 256, as also the ratchet wheel 257, the cam 258, the commutator 259, the brush 260, the contact ring 261, the contact ring 262, the commutator 263, and the contact ring 264 are all mounted upon a common shaft not shown in the drawing. This commutator shaft is adapted to be rotated by means of power supplied through the ratchet wheel 257, which in turn is adapted to be engaged by the hooked pawl 265 pivotally mounted upon the end of the movable solenoid core 266 of the electro-magnetic winding 249. The effect, therefore, of the energization of the electromagnetic winding 249 due to the flow of current over the circuit last traced will be to move the solenoid core 266 in an upward direction and through the agency of the pawl 265 and the ratchet wheel 257 to rotate the commutator shaft one step in the direction indicated by the arrow 267 associated with the ratchet wheel 257. This commutator shaft is capable of assuming any one of twelve angular positions corresponding with the twelve teeth of the ratchet wheel 257, and it will be understood that the single energization of the electromagnet 249 will cause the rotation of this commutator shaft and all of the commutators, cams, contact rings and brushes mounted upon it through an angle of 30 degrees.

This one-step advancement of the commutator shaft associated with the ratchet wheel 257 will result in the flow of current over a circuit which may be traced from the connection B^2 associated with the brush 268, through contact ring 261, connector 269, brush 260, commutator segment 270, wire 271, electromagnet winding 272, wire 273, wire 274, wire 275, contact 276, contact 277, which is normally elevated by the projection on the cam 258, but which will be dropped into engagement with the contact 276 upon the one-step angular rotation of the commutator shaft associated with the ratchet wheel 257 and upon which the cam 258 is mounted, thence through wire 278, relay contact 279, contact 280, and thence to the ground indicated and with which the contact 280 is permanently connected. The flow of current over this circuit will cause the energization of electromagnet 272. The effect of the energization of this electromagnet will be more clearly understood after a brief description of the mechanism associated therewith.

This electromagnet and its associated mechanism which are diagrammatically indicated in Figure 13 are illustrated in more detail in Figures 14, 15, 16 and 17, and we shall therefore revert to these figures before attempting to proceed with the description of the more general circuit arrangements.

The four commutators illustrated in these figures may be regarded as rigidly mounted upon a common shaft 281, this shaft being provided also with a worm wheel 282, which in Figure 1 is shown as in mesh with the threads of the lead screw 42. When, therefore, the lead screw 42 is rotated, the worm wheel 282, together with the shaft 281, will be rotated, the pitch of the part of the lead screw in mesh with the worm wheel and the size of the worm wheel being arranged to give the rate of angular rotation to the commutators necessary to accomplish the results hereinafter described.

The commutators stand normally in the relation to the brushes bearing upon them as shown in Figures 14, 15, 16 and 17. Rotatably mounted upon the same shaft 281, but not rigidly connected therewith, are two metal sectors, the sector 283 being mounted at one end of the four commutators and the sector 284 being mounted at the other end of the four commutators. The electromagnet 272 is mounted upon the sector 283 and is provided with an armature 285 pivoted to the sector 283 at 286. This armature is adapted, as shown, to actuate the live relay contacts 287, 288 and 289, the purpose of these contacts being described hereinafter. The armature is retained in its normal position by means of a retracting spring 290, which is attached to the arm 291 of the bell crank lever forming the armature 285. This armature is provided also with a second lever arm 292. The arm 292 is provided with a double catch, one end 293 of which is adapted to engage under certain circumstances in the notches 294 cut in the periphery of the commutator 295, and the other end 296 of which is adapted to engage the notch in the stationary stop 297. When the electromagnet 272 is energized over the circuit last described, the armature 285 is attracted to throw the projection 296 at the end of the lever arm 292 into engagement with the notch in the stop 297, thus holding the sector 283 in fixed position and against rotation. At the same time the brush 298 carried on the end of the armature lever arm 291 is thrown into a position in which it will engage with electrical contact the commutator segment marked with a "0" on the periphery of the commutator 295. The brush 299 (Figure 17) is also carried upon the arm 291 of the armature of the electromagnet 272 and in

line directly behind the brush 298 illustrated in Figure 14. When, therefore, the electromagnet 272 is energized, the brush 299 is brought into electrical contact with the segment 300 on the periphery of the commutator 301 shown in Figure 17.

When the electromagnet 272 is energized it closes circuit between the live relay contact 287 and the stationary relay contact 302 associated therewith. Upon the closure of these contacts circuit may be traced as before from the live battery connection B^2 associated with brush 268 of contact ring 261, through brush arm 260, commutator segment 270, wire 271, relay contact 302, relay contact 287, wire 303, wire 304, the electromagnet 51 associated with clutch 52, thence through wire 305 and wire 306 to the armature 307 of the motor 50, and thence through wire 308 to the ground connection shown in connection therewith. At the same time the field magnets of the motor will be energized over a circuit which may be traced as follows: from the live side of battery B^3 (Figure 15) to segment 309 of commutator 310, to brush 311, which is rigidly but by means of proper insulation mounted upon the sector 283, thence through wire 312 (Figures 15 and 13), thence through the live relay contact 289 now in engagement with the stationary relay contact 313, thence through wire 314 and wire 315 to brush 316, which now rests upon segment 317 of commutator 263, thence through wire 318 to contact ring 264, thence to brush 319 and through wire 320 to the field coils 321 and 322 of the motor 50, thence through wire 323 to brush 324, which bears upon the surface of contact ring 262, thence through wire 325 to segment 326 of commutator 263, thence through brush 327 now in electrical engagement therewith, and thence through wire 328 and wire 329 to contact 330 and contact 288 now in electrical connection therewith, and thence through wire 331 to brush 332, which bears upon the periphery of commutator 333 (Figure 16), and thence through segment 334 and the wire 335 to ground, as shown.

Both the armature and field magnets of the motor 50 having been energized over the circuits described, the motor 50 will be caused to rotate and the clutch 52 having been thrown due to the energization of electromagnet 51, the lead screw 42 will be caused to rotate to advance the carriage 47. Since the worm wheel 282 mounted upon the commutator shaft 281 is in mesh with the threads of the lead screw 42, the commutator shaft 281, together with all of the commutators mounted thereon, will be caused to rotate in this instance in the direction of the arrows, as shown in Figures 14, 15, 16 and 17.

This rotation and the consequent movement of the carriage will continue until the resistances in the various arms of the Wheatstone bridge circuit have been made such as to balance the potentials at the terminals of the Wheatstone bridge resistances 237 and 245. When this point has been reached, the electromagnet 246 will be deprived of current and will become de-energized.

The bridge arms over which current flows may be traced as follows: one bridge arm includes resistance 237 (a resistance of 1000 ohms), wire 238, contact 239, contact 240, wire 241, contact 220, and, for example, five sections of the resistances 214, 215, 216, 217, 218 (of 100 ohms resistance each), wire 242, electromagnet winding 222 (100 ohms resistance), contact 224, armature 223, contact 225 to ground. It will be seen that the bridge arm beyond the terminal of the resistance 237 has a resistance of 600 ohms (due to the setting of the slide 229), plus whatever slight resistance there may be in the wiring and contacts.

The other bridge arm may be traced from the terminal of resistance 245, through wire 336 and wire 337 to brush 298, and then at the commencement of the rotation of the motor and the movement of the carriage through segment marked "0" on the periphery of commutator 295, thence through all of the 100 ohm sections of resistance 338, 338 which are connected between the commutator segments upon the periphery of commutator 295 as shown, to wire 339, thence through wire 340 to contact 341, contact 342, wire 343 to armature 223, and thence through contact 225 to the ground wire 244. The resistance in this circuit is at the outset of the movement 1000 ohms, made up of the ten sections of resistance bridged between the segments 0 to 9 of commutator 295, plus the slight resistance of the wiring and the line to the sending station, the line wire being represented in this instance by the wire 343 and in the instance of the circuit last traced by the wire 241.

It will be seen that the resistance in the bridge arm last traced is something more than 1000 ohms as compared with a resistance of slightly more than 600 ohms in the bridge arm previously traced. The potential across the terminals of the electromagnet 246 will, therefore, be unbalanced and current will flow through this electromagnet over a circuit previously traced. As the motor rotates, however, the commutator 295 will be rotated and the brush 298 will make contact successively with the commutator segments marked 1, 2, 3, 4, 5, etc. in Figure 14. When commutator segment 1, of Figure 14, comes into contact with the brush 298, the resistance in the bridge arm last traced will be reduced from 1000 ohms to 900 ohms. When the commutator has rotated sufficiently to bring commutator segment num-

bered 2 into contact with the brush 298, the resistance in this Wheatstone bridge arm will have been reduced to 800 ohms. The engagement of the next segment of the commutator with the brush 289 will reduce the resistance to 700 ohms, and the engagement of the next commutator segment, number 4, will reduce the resistance in this Wheatstone bridge arm to 600 ohms.

When, therefore, the resistance, in the Wheatstone bridge arm controlled by the rotation of the commutator 295 has become equal to the resistance in the Wheatstone bridge arm containing the resistance controlled by the slide rod 229, a balance of potential across the terminals of electromagnet 246 will have been attained, whereupon the flow of current through the electromagnet 246 will cease and this electromagnet will become de-energized. It will be understood, of course, that the amount of resistance included in the bridge arm controlled by the slide rod 229 will depend upon the identity of the finger catch which has been pulled. If, for example, finger catch number 3 had been pulled instead of number 4, 700 ohms of resistance would be included in the bridge arm controlled by the slide rod. Under these circumstances, the commutator 295 would have rotated only until commutator segment number 3 came into contact with the brush 298, for at this time 700 ohms of resistance would have been included in the Wheatstone bridge arm controlled by the commutator 295, and at this time rather than one step later the potential across the terminals of the electromagnet 246 would have become equalized to effect the de-energization of that electromagnet.

If finger catch numbered 0 upon the sending device had been pulled, 1000 ohms of resistance would have been introduced into the Wheatstone bridge arm controlled by the slide rod. When, therefore, brush 298 is actuated by the electromagnet 272, to make contact with the commutator segment marked "0", in Figure 14, 1000 ohms of resistance would immediately have been introduced into the bridge arm controlled by the commutator 295. This would at once establish a balance of potential across the terminals of the electromagnet 246, with the result that the electromagnet 246 will have become de-energized immediately after the electromagnet 272 has become energized. In other words, the balance of potential would be attained without there being any rotation of the motor 50 and without there having been any longitudinal movement of the carriage 47.

It will be understood from the above description that the mechanism is such that the carriage will be moved in a longitudinal direction a number of the so-called minor steps corresponding with the number of the finger piece of the sending device first actuated. When the electromagnet 246 becomes de-energized in the manner described, the circuit between contacts 247 and 248 will be opened. It will be remembered that it was a circuit through these contacts which effected the energization of the electromagnet 249. When, therefore, the circuit of this electromagnet is opened it will be de-energized. This will in turn open the circuit between contacts 279 and 280. It was the circuit through these contacts which controlled the energization of the electromagnet 272, which will therefore become de-energized as soon as the electromagnet 246 has become de-energized. It was, in turn, the energization of electromagnet 272 which controlled the energization of the electromagnet 51 of the clutch 52, and which controlled also the energization of fields and armature of the motor 50. When, therefore, electromagnet 246 is de-energized, the clutch 52 will be opened and both the fields and the armature of the motor 50 will be deprived of current. The result, therefore, will be to stop the further longitudinal movement of the carriage 47 and to stop also the rotation of the commutator mechanism shown in Figures 14, 15, 16 and 17. When the electromagnet 272 (Figure 14) is de-energized in the manner described, the projection 296 on one lever of the armature 285 will be withdrawn from the stop 297 and the projection 293 will be pressed into one of the notches 294 in the periphery of the commutator 295, the identity of the notch into which the projection 293 is dropped depending upon the angle through which the commutator 295 has been rotated before the balance of the Wheatstone bridge arms has been attained. If, for example, the finger piece numbered 4 of the sending device had been actuated, the commutator 298 would have rotated through an angle represented by four of the notches and the projection 293 would have been dropped into the fourth notch at the end of the first series of longitudinal movements. When the projection 293 rests in one of the notches in the periphery of the commutator 295, the sector 283 is locked to the commutator 295 to rotate therewith.

The rotation of the sending device to its normal position so that it may be utilized in effecting a set-up corresponding with the second digit in the number of the line to be called is accomplished in the following manner and for the following reason: It will be remembered that the circuit traced through the locking relay 222 included contacts 234 and 235 associated with the pawl 265 which operates the ratchet wheel 257. The construction is such that upon the energization of the electromagnet 249 the pawl

265 will be drawn up without effecting a separation of the contacts 234 and 235. When, however, the electromagnet 249 is de-energized, the pawl 265 must ride over one tooth of the ratchet wheel in order to drop into the space between it and the next succeeding tooth, and thus riding over the ratchet tooth, the pawl 265 is raised to effect a momentary separation of the contacts 234 and 235. The momentary interruption of this circuit over which the current for the energization of the electromagnet 222 is flowing will cause the electromagnet 222 to be de-energized, whereupon its armature 223 will be dropped back to open the locking circuit of the magnet and also to permit the catch 226 to drop back, thereby releasing the slide rod 229 and permitting it to be returned to its normal position, due to the expansion of the spring 230.

In this manner the carriage will have been given a longitudinal advancement corresponding in length with a number of minor steps represented by the first digit of the number set up upon the sending device, and in the manner subsequently described the mechanism will have been restored to a position in which may be accomplished the necessary number of major steps of longitudinal movement corresponding with the set-up of the second digit of the called number.

The set-up of this second digit of the called number is accomplished in exactly the same manner as is the set-up of the first digit of the called number, the appropriately numbered finger catch of the slide rod being grasped and pulled into a position in which the locking relay 222 will be actuated as before, to hold the sending mechanism in the position determined by the identity of the finger piece grasped by the operator. This second actuation of the sending device will, through the agency of the electromagnets 246 and 249, cause the one-step advancement of the ratchet wheel 257, together with the shaft upon which the devices 258, 255, 259, 260, 261, 262, 263—and 264 are located. This second one-step advancement of this commutator mechanism will shift the brush 260 from its position in electrical engagement with the commutator segment 270 into a position in which it will engage the commutator segment 350. This will cause a flow of current over a circuit which may be traced from the live pole of battery B^2, through brush 268 associated with the contact ring 261, thence through wire 269, brush 260, commutator segment 350, wire 351, wire 352, wire 353, and the electromagnet 354 mounted, as best illustrated in Figure 14, upon sector 284 associated with commutator 295. The energizing circuit for this electromagnet may be further traced through wire 355, wire 356, wire 357, wire 274, wire 275, contact 276, contact 277, wire 278, contact 279, contact 280, and thence to ground. Current flowing over this circuit will, therefore, cause the energization of electromagnet 354. Associated with this electromagnet is an armature 358 which is pivoted to the sector 284 at 359 and which is provided with projecting catches 360 and 361. The armature and catch mechanism is normally in the position shown in Figure 14, but when the armature 358 is attracted, due to the energization of the associated electromagnet 354, the catch 360 is withdrawn from the notch in the periphery of the commutator 295, and the catch 361 is driven into a notch in the stationary notched stop segment 362.

It will be apparent from the previous description that the sector 284, being locked to the periphery of the commutator 295 through the instrumentality of the catch 360, will have been shifted angularly in the direction of the arrow shown in association with Figure 14 a number of spaces corresponding with the number of spaces through which the commutator 295 has been moved before the electrical balance necessary to effect the de-energization of electromagnet 246 has been accomplished. If we assume, therefore, that the commutator 295 has been moved through an angle corresponding with four minor steps of advancement of the carriage, the catch 361 will stand opposite the fourth notch beyond the "0" notch of the segment 362. When, therefore, the electromagnet 354 is energized, the catch 361 will be driven into the notch bearing the number 4 of the segment 362. This will lock the sector 284 in a stationary position, dependent upon the angle through which the commutator 295 has been moved in conformity with the set-up of the called number. If we assume that the first digit set up in calling the subscriber wanted was a 4, and that the mechanism has operated to give the carriage four minor steps of movement in conformity with such an actuation of the sending device, then the energization of electromagnet 354 will effect the following results: First relay contacts 363 and 364 and 365 and 366 will have been closed to effect the energization of the field magnets 321 and 322 of the motor 50, the circuit in this instance being traced from the live pole of battery B^4 (Fig. 16) through commutator segment 367, stationary brush 368, wire 369, contact 365, contact 366, wire 370, wire 371, wire 328, brush 327, commutator segment 326, wire 325, contact ring 262, brush 324, wire 323, field magnet windings 322 and 321, wire 320, brush 319, contact ring 264, wire 318, commutator segment 317, brush 316, wire 315, wire 372, wire 373, contact spring 364, contact spring 363, wire 374,

stationary brush 375, commutator segment 376, and thence to ground with which commutator segment 376 is permanently connected.

A second result of the energization of the electromagnet 354 is to close circuit between the relay contacts 377 and 378, which control the energization of the clutch 52 and the armature of the motor 50, the circuit being traced from the live pole of battery B^2, through brush 268, contact ring 261, wire 269, brush 260, commutator segment 350, wire 351, wire 352, contact spring 378, contact spring 377, wire 379, wire 304, the electromagnet 51 of the clutch 52, wire 305, wire 306, and thence through the armature 307 of the motor 50, and thence through wire 308 permanently connected to ground. Current flowing over this circuit last traced will throw the clutch 52 to connect the armature of the motor 50 with the lead screw 42, which effects the longitudinal movement of the carriage 47, and current flowing over this circuit will serve also to energize the armature 307 of the motor to cause its rotation. It will be remembered that the multiple bank is so arranged that if the digit in the units order of the number called, that is the first number set up in the sending device, is a 0, or a 1, or a 2, or a 3, or a 4, the major steps of longitudinal movement of the carriage must occur from left to right, whereas if the digit in the units order of the number called is a 5, or a 6, or a 7, or an 8, or a 9, the major steps of longitudinal movement of the carriage must occur from right to left. The circuits and commutation are, therefore, arranged to effect this right-hand or left-hand movement of the carriage automatically in conformity with the magnitude of the digit in the units order of the number called. Before tracing the circuits for energizing the fields and armature of the motor we assumed that the digit in the units order of the number called was a 4. It was this fact which determined the angular position of the commutators shown in Figures 14, 15, 16 and 17, and although the commutators shown in Figures 15 and 16 had been rotated, due to the set-up of the number 4 as the first digit of the called number, they had been rotated only four angular steps as measured by the distance between the numbered segments of commutator 295. If, now, attention is directed to the normal positions of the commutator shown in Figures 15 and 16 and to the positions in which the stationary brushes 368 and 375 rest normally upon the commutator segments 367 and 376, it will be seen that these commutator segments 367 and 376 will remain in electrical contact with their respective brushes 375 and 368 even if these commutators have been rotated one, two, three or four angular steps in the direction of the arrows shown in association with these commutators. Under the assumed conditions, therefore, the circuits operative in effecting the second series of longitudinal movements of the carriage are to be traced as last described.

If, however, the digit in the units order of the called number, i. e. the first digit set up in the sending device, had been a 5, or a 6, or a 7, or an 8, or a 9, the commutator 295 would have been advanced either five, or six, or seven, or eight, or nine angular steps as measured by the distance between the segments of this commutator, and the angular length of commutator segments 367 and 376 is such that whenever these commutators are given a rotation of more than four angular steps during the first or minor series of longitudinal movements, then the electrical connections of the brushes 368 and 375 will be shifted from commutator segments 367 and 376 to commutator segments 334 and 309, respectively. It will be noted that commutator segment 367 is permanently connected with the live pole of the battery, while commutator segment 376 is permanently connected with ground; while, on the other hand, commutator segment 309 is permanently connected with the live pole of the battery. The circuit over which we traced the flow of current for effecting the energization of the field magnets of the motor 50 proceeded from brush 368 and back to brush 375. If, therefore, the connections of the commutator segments upon which these brushes rest with respect to the terminals of the battery are reversed, due to the initial set-up of the digit 5, 6, 7, 8 or 9, then current will flow over the field magnet energizing circuit in a direction the reverse of that in which it will flow as previously described, upon the assumption that the first digit set up in the sending device is a 0, or a 1, or a 2, or a 3, or a 4.

If the direction in which the current flows through the field magnets of the motor is reversed, the direction in which the armature of the motor rotates will also be reversed. It is, therefore, the magnitude of the digit first set up in the sending device which determines the direction in which the major series of longitudinal movements of the carriage will occur, the critical point being that between the digits 4 and 5, the carriage moving from left to right in case the first digit is less than five and moving from right to left in case the first digit is larger than a four.

We have now to consider the means for automatically determining the distance which the carriage will travel in order to complete this second series of longitudinal movements. Attached to the lever arm 380 of the armature 358 is an insulated contact brush 381. When, therefore, the electromagnet 354 is energized, the brush 381 is

moved into a position in which it will bear upon the periphery of the commutator 310 shown in Figure 15. If the digit in the units order of the number to be called, and therefore the first digit set up on the sending device had been a 0, the commutator 310 would stand in the position shown in Figure 15, as a result of which the brush 381 would have been brought to bear upon a commutator segment marked with the numeral 0, which segment is normally directly opposite the brush 381. Under such circumstances, the energization of the circuits of the motor 50 upon the set-up of the sending device in conformity with the second digit of the called number would effect a rotation of the lead screw 42 and consequently a rotation of the commutators shown in Figures 14, 15, 16 and 17 in a direction opposite to that indicated by the arrows in these figures. If we assume that the digit in the tens order of the called number is a 7, then the amount of resistance included in the bridge arm controlled by the slide rod 229 is 300 ohms. The armature of the motor will, therefore, rotate until the commutator 310 reduces the resistance in the commutator controlled arm of the Wheatstone bridge to 300 ohms, at which point a balance will be effected. The Wheatstone bridge arm whose resistance is controlled by the sending device has previously been traced. The Wheatstone bridge arm controlled by the commutator may be traced from the terminal of the 1000 ohm resistance 245 through wire 336, wire 382, wire 383, brush 381, the segment numbered "0" of commutator 310, thence through the several resistances connected between segments of commutator 310 to wire 384, thence through wire 340, contact 341, contact 342, line wire 343, armature 223, contact 225, to ground indicated at 244. It will be seen that the resistance initially included in this arm of the Wheatstone bridge circuit is 1000 ohms plus the line and wire resistance. As previously stated, the motor, and therefore the commutator 310, will rotate in the direction of the arrow shown in Figure 15 until the brush 381 engages the commutator segment numbered 7′ at the left-hand side of Figure 15. When this point is reached there are but three sections of resistance of 100 ohms each included by the commutator 310 within the Wheatstone bridge arm whose circuit was last traced. This means that the resistance included in this arm of the Wheatstone bridge will have been reduced to an amount corresponding with that included in the other arm of the Wheatstone bridge circuit by means of the sending device. A balance of potential across the terminals of the electromagnet 246 will, therefore, have been attained as a result of which the electromagnet 246 will be de-energized to permit the retraction of its armature 247. This retraction of the armature will open the circuit between the armature 247 and the contact 248, as a result of which the magnet 249 will be de-energized, the magnet 354 will be de-energized, and the de-energization of electro-magnet 354 will effect the de-energization of the clutch magnet 51 and serve also to open the circuits through which current has been flowing to the field and armature of the motor 50. As soon, therefore, as the Wheatstone bridge circuits have become balanced, the motor 50 will stop and the connection between the motor and the lead screw of the carriage will be opened, thereby arresting the longitudinal movement of the carriage, the exact position at which the carriage comes to rest being mechanically determined by the detent mechanism associated with the clutch as previously described.

If the digit in the units order of the called number had been a 4 instead of a 0, the operation would have been substantially the same as that last described, because while the commutators 295 and 310 would have been rotated four angular steps as measured by the distance between the segments of commutator 295, the catch 360 of armature 358 would have remained in engagement with a notch in the periphery of commutator 295, as shown in Figure 14, and this would have caused the sector 284 to swing in the direction of the arrow shown in Figure 14 through an angle corresponding with the angular movement of the commutator mounted upon shaft 281. In other words, the brush 381, which is carried by the armature 358, pivoted at 359 upon the sector 284, would have been swung around the axis of the shaft 281 by an amount corresponding with the angle through which the commutators themselves have been rotated. The brush 381 will, therefore, stand opposite the segment of commutator 310 which is numbered 0, no matter how far the commutator 310 may have been rotated in conformity with the first or minor series of longitudinal movements of the carriage. When, therefore, the electro-magnet 354 is energized to effect the closure of the circuits controlling the operation of the motor 50, the commutator 310 will co-operate with the brush 381 to stop the longitudinal movement after a series of major steps corresponding with the digit in the tens order of the called number.

As previously explained, however, it may be necessary for the second series of longitudinal movements to take place either from right to left or from left to right, depending upon the magnitude of the digit in the units order of the called number. For example, we have already explained that the direction of rotation of the motor will be reversed to effect a movement of the carriage from left to right whenever the digit in the

units order of the called number is an 0, or a 1, or a 2, or a 3, or a 4. Since the commutators shown in Figures 14, 15, 16 and 17 are geared to the lead screw which controls the longitudinal movement of the carriage, these commutators will be rotated in a direction the reverse of that indicated by the arrows in these figures whenever the second series of longitudinal carriage movements takes place from left to right. The commutator 310 will, nevertheless, control the resistance in the Wheatstone bridge arm to stop the carriage movement at the proper point. This is true because, as will be seen by reference to Figure 15, the commutator 310 is provided with a duplicate set of segments proceeding to the left from the segment numbered 0, this duplicate set of segments being numbered, in Figure 15, as 1′, 2′, 3′, 4′, 5′, 6′, 7′, 8′ and 9′. This duplicate set of commutator segments is cross-connected by means of the wires shown with the first set of commutator segments numbered 1, 2, 3, 4, 5, 6, 7, 8 and 9. When, therefore, the commutator 310 has been rotated in a direction opposite to that indicated by the arrow until commutator segment 7′ comes into connection with the brush 381, the resistance in the Wheatstone bridge arm controlled by the commutator will have been reduced to 300 ohms just as though the brush 381 were brought into electrical connection with the commutator segment numbered 7 in Figure 15. The effect will, therefore, be to stop the further longitudinal motion of the carriage as previously described.

It will be noted that the angular distance between the even numbered segments of commutator 310 is equal to the angular distance between five of the commutator segments of commutator 295. The angular distance between the segments of commutator 295 corresponds with a longitudinal movement of the carriage of one minor step in length. The angular distance between the even numbered segments of commutator 310 will, therefore, correspond with a longitudinal carriage movement of one major step, which major step, as previously explained, is equal in length to five minor steps. It was explained in connection with the multiple bank and the carriage movement that when the digit in the tens order of the called number was an odd digit, the second series of longitudinal carriage movements comprised a first step which had the length of a minor step of movement, the subsequent steps of the second series being of the full major length. The spacing of the segments upon commutator 310 is arranged to bring about this result. It will be seen that the segments numbered 1 and 1′, in Figure 15, are angularly spaced from the segment marked 0 by the same distance as that which separates the segments of commutator 295. If, therefore, the second digit to be set up in the sending device is 1, the motor 50 will advance the carriage and the commutator 310 only until the segment numbered 1 or the segment numbered 1′ of commutator 310 comes into contact with the brush 381, whereupon the circuits will be opened to arrest and prevent further movement. This first step of advancement is, therefore, only a minor step in length due to the proximity of the segments numbered 1 and 1′ to the segment numbered 0. The angular distance from the segments numbered 1 and 1′ to the segments numbered 3 and 3′, and the angular distance between the remaining segments bearing odd numbers is the same as the angular distance between the segments bearing even numbers. This means, of course, that all but the first step of the second series of longitudinal movements in the case of an odd digit in the tens order will be of the same length as the major steps of movement in the case of even digits in the tens order.

Having explained the means for effecting and for controlling the two series of longitudinal carriage movements, we come now to a consideration of the means for effecting and controlling the lateral movements of the plugs which, as in the case of the longitudinal movements of the carriage, take place in two series: first a series of minor movements always in one direction, and then a series of major movements which may be in either of two directions. The mechanism for effecting these lateral movements of the plugs is in part identical with that already described, and where different apparatus is employed it is essentially like that already described in connection with the means for effecting the longitudinal carriage movements.

The lateral or transverse plug movements are controlled by the sending device and are employed in effecting the part of the set-up corresponding with the third and fourth digits in the number as set up in the sending device, that is to say, the digits in the hundreds and thousands order of the telephone number as related to the multiple bank. The lateral movements of the plugs are controlled by a second set or line of commutators illustrated in Figures 19, 20, 21 and 22. If we assume that the third number to be set up in the sending device is a 6, the finger piece numbered 6 will be grasped and the slide rod 229 operated to introduce a resistance of 400 ohms into the Wheatstone bridge arm controlled by the sending device. This will effect the energization of the electromagnets 246 and 249 to advance the line of commutators controlled by the ratchet wheel 257 into their third angular position. This swinging operation will effect the energization of electromagnet 390, which is mounted upon sec-

tor 391 associated with the notched wheel 392, which in many respects serves the same functions as the notched wheel 295 of Figure 14, in which latter case, however, the notched wheel is provided also with a series of commutator segments not present in the case of the notched wheel 392. The energization of electromagnet 390 causes the closure of the circuits of the motor 50 and also the closure of the energizing circuit of the electromagnet 60, which controls a clutch 68 to connect the shaft of the motor 50 with the shafts 60 and 61 (Figure 1), which, through the agency of the mechanism previously described, effect the lateral movements of the plugs. The electromagnet 390 is provided with an armature 395 pivoted to the sector 391 at 396, this armature serving to control a set of contacts which are instrumental in closing circuits as follows: First, a circuit which energizes the field magnets of the electric motor 50. It will be remembered that the circuit for energizing these field magnets was previously traced from the battery terminals and through wires 371 and 372, from which wires lead the branch wires 314 and 329, and 370 and 373. The commutator mechanism for controlling the lateral plug movements is provided also with similar branch wires, in this instance wires 397 and 398 branched through wires 371 and 372. When, therefore, the electromagnet 390 is energized, the motor field energizing circuit may be traced from wire 371 through wire 398, contact 399, contact 400, wire 401, brush 402, and commutator segment 403 to ground. The other side of this circuit may be traced from wire 372, through wire 404, contact spring 405, contact spring 406, wire 407, brush 408, and commutator segment 409 to the live pole of battery as represented at B^5. Current flowing over this circuit will energize the field magnets 321 and 322 of the motor 50.

The energization of electromagnet 390 will cause the closure also of contacts 310 and 311 to energize the clutch magnet 69 and the armature of the motor 50, the circuit in this instance being traced from the live pole of battery represented at B^2, through brush 268, contact ring 261, wire 269, brush 260, commutator segment 412, wire 413, wire 414, wire 415, contact spring 311, contact spring 310, wire 416, wire 417, electromagnet 69, wire 306, armature 307, and wire 308 to ground.

Current flowing through the clutch magnet 69 will throw the clutch and the circuits closed through the fields and armature of the motor 50 will cause it to rotate to drive the transverse plug actuating shafts 60 and 61. The sets of plugs 43 and 44 and 45 and 46 will, therefore be moved toward the top of Figure 1 until the motor energizing circuits are opened.

The circuits will be opened by commutator mechanism which may be described as follows: The armature 395 associated with the electromagnet 390 is provided with a lever arm 418 upon the end of which is mounted with suitable insulating supports a brush 419. When the electromagnet 390 is energized this brush 419 is brought into engagement with the periphery of the commutator 420 illustrated in Figure 20. When, therefore, the actuating shafts 60 and 61 are set in motion, they will drive the notched wheel 392 and the commutators 420, 421 and 422, all of which are rigidly mounted upon a common shaft 423, upon which also is mounted a worm wheel 424 (Figure 1). It will be understood that the sector 391 is loosely mounted upon the shaft 423 at one end of the set of commutators and notched wheels, and that the sector 425 is loosely mounted upon this shaft at the other end of the set of wheels and commutators.

The energization of the magnet 390 will not only bring the brush 419 into engagement with the periphery of the commutator 420, but will also withdraw the catch 426 from the periphery of the notched wheel 392 and will insert the catch 427 into the stationary stop notch 428 to hold the sector 391 in fixed position.

The motor will operate to rotate the lateral actuating shafts 60 and 61 until the brush 419 engages one of the numbered commutator segments of commutator 420 such that the resistance in the commutator controlled arm of the Wheatstone bridge circuit shall equal the resistance included in the other arm of the Wheatstone bridge circuit by means of the sending device. It will be seen that resistance sections of 100 ohms each are connected between each pair of segments of the commutator 420. The commutator 420 will rotate, therefore, until the brush 419 makes connection with a segment such as to equalize the resistance in the Wheatstone bridge circuit as previously described. When this condition has been reached, the electromagnet 246 will be de-energized. This will result in the de-energization of the electromagnet 249, whereupon the return of the pawl 265 over the top of the ratchet tooth will momentarily open the circuit between contact springs 234 and 235 to effect the unlocking of the relay 222 and the return of the slide rod 229 to its normal position. The de-energization of the electromagnet 249 will also open the circuit of the electromagnet 390, whereupon the circuits conveying current to the armature and field magnets of the motor and also to the clutch magnet 393 will be opened to stop the further rotation of the lateral actuating shafts 60 and 61.

The angular distance between the numbered commutator segments on the periphery of the commutator 420 is such that the

distance between each pair of commutator segments will correspond with an amount of rotation of the actuating shafts 60 and 61 necessary to advance the plugs through the distance represented by one longitudinal row of multiple sets. It will be noted that the brush 419 is angularly removed from the commutator segment bearing the numeral 0. This is for the reason that a slight movement of the plugs must take place in order to carry them within the multiple bank and into the longitudinal row of mutiple sets representing the lines whose numbers have 0's in the hundred order.

The notched wheel 392 will have been rotated through an angle corresponding with the angle through which the commutator 420 has been rotated. As soon as the rotation of the commutator 420 is stopped, the electromagnet 390 will be de-energized to withdraw the catch 427 from the notched stop 428 and to insert the catch 426 into one of the notches 429, 429 in the periphery of the wheel 392.

The sector 425 will have been rotated with the notched wheel 392 because the projecting catch 430 of the armature 431 associated with the electromagnet 432 is engaged in the notch 433 in the periphery of the notched wheel 392.

When, therefore, the first series of lateral movements has come to an end, the numbered finger catch of the sending device 199 corresponding with the fourth digit in the number of the called line will be engaged and the sending device operated to bring the contact 220 into engagement with one of the rheostat contact points to include in the Wheatstone bridge arm controlled by the sending device an amount of resistance dependent upon the digit in the fourth order of the number to be called. As soon as the sending device is actuated for this, the fourth, time, the electromagnet 246 will be energized, thereby effecting the energization of the electromagnet 249, which will actuate its pawl 265 to advance the line of commutators controlled by the ratchet wheel 257 through another step of rotation. This fourth one-step rotation of the ratchet wheel 257 and its commutating devices will effect the closure of a circuit substantially identical with that previously described to energize the electromagnet 432 mounted upon the sector 425. This will result in the attraction of the associated armature 431, which is pivoted to the sector at 436, whereupon circuits will be closed to effect the energization of the clutch magnet 69 and the field and armature coils of the motor 50. The field circuit of the motor may be traced in this instance from the live pole of battery represented at B^6 through commutator segment 437, brush 438, wire 439, contact 440, contact 441, wire 442, wire 371, wire 328, brush 327, commutator segment 326, wire 325, contact ring 262, brush 324, wire 323, field magnet coil 322, field magnet coil 321, wire 320, brush 319, contact ring 264, wire 318, commutator segment 317, brush 316, wire 315, wire 372, contact 443, contact 444, wire 445, brush 446, commutator segment 447, and thence to ground. Current flowing over this circuit will effect the energization of the field magnets of the motor 50.

The energization of the electromagnet 432 will also cause current to flow through the clutch magnet 69 and the armature of the motor 50 over a circuit which may be traced from the live pole of battery as represented at B^2 to brush 268, contact ring 261, wire 269, brush 260, commutator segment 448, wire 449, wire 450, contact 451, contact 452, wire 453, wire 417, electromagnet 69, wire 306, armature 307, and thence through wire 308 to ground.

Current flowing over these circuits will cause the motor to operate to rotate the lateral actuating shafts 60 and 61. In tracing these circuits we have assumed that the digit in the third order of the called number was a 0, or a 1, or a 2, or a 3, or a 4, and that, therefore, the rotation of the shaft 423 and the commutators mounted thereupon in conformity with the set-up of the third digit of the called number would not be sufficient to rotate the commutators 421 and 422 through an angle large enough to shift the commutator segments 403 and 409 into contact with the brushes 438 and 446, respectively. If, however, the third digit in the called number had been a 5, or a 6, or a 7, or an 8, or a 9, the first series of lateral movements would have rotated the commutators 421 and 422 through an angle sufficient to bring the commutator segment 403 into engagement with the brush 438 and to bring the commutator segment 409 into engagement with the brush 446, in which instance the flow of current through the field magnets of the motor 50 would have been in a direction the reverse of that heretofore described and in which case the direction of the rotation of the motor armature would have been reversed. Under the assumption that the third digit in the called number is more than 4, the direction of the rotation of the motor is such as to move the plugs upwardly in Figure 1.

The motor and clutch circuits will continue to energize the motor and clutch until a balance of the Wheatstone bridge arm is attained. This balance is controlled in this instance by commutator 421, which is provided with a set of commutator segments 454, 454, numbered from 0 to 9 in Figure 21, a resistance of 100 ohms being connected between successive commutator segments as shown in that figure. The co-operating brush 455 is in this instance mounted upon

the arm 456 of the armature 431 of the electromagnet 432. When the electromagnet 432 is energized, the brush 455 is brought into engagement with the periphery of the commutator 421 and at the outset into engagement with segment numbered 0 of this commutator. The brush 455 will have been shifted with the previous rotation of commutator 421 by virtue of the fact that the sector 425 upon which the electromagnet 432 and its associated mechanism are mounted was at that time locked to the periphery of the notched wheel 392 by means of the catch 430. If the fourth digit in the called number as set up upon the sending device is a 0, the engagement of the brush 455 with the associated commutator segment numbered 0 will at once introduce 1000 ohms of resistance into the commutator-controlled arm of the Wheatstone bridge. This resistance will at once effect a balance of the Wheatstone bridge circuits because in this instance the sending device will have introduced a resistance of 1000 ohms into its arm of the bridge circuit. If, however, some other digit is the fourth to have been set up upon the sending device, the motor 50 will operate to rotate the lateral actuating shafts 60 and 61 and with them the commutator 421, thereby bringing the brush 455 successively into electrical contact with the commutator segments numbered 1, 2, 3, 4, etc. When the commutator has rotated through an angle such as to bring the appropriate commutator segment into contact with the brush 455, the resistance in the commutator-controlled arm of the Wheatstone bridge circuit will have been reduced to a point where it will balance the resistance previously introduced into the arm of the Wheatstone bridge controlled by the sending device, whereupon the flow of current through the electromagnet 246 will cease and whereupon the various circuits will be opened in the manner previously described to effect the de-energization of the clutch magnet 393 and the de-energization of both field and armature of the motor 50.

And again, as in the case of commutator 310 illustrated in Figure 15, a duplicate set of commutator segments numbered 1′, 2′, 3′, 4′, 5′, 6′, 7′, 8′ and 9′ is cross-connected with the set of commutator segments numbered 1, 2, 3, 4, 5, 6, 7, 8 and 9. This duplicate set of commutator segments is provided to stop the second series of lateral movements of the plugs in case the third digit of the called number is a 0 or, a 1, or a 2, or a 3, or a 4, in which case the motor will have been caused to operate in the reverse direction, thereby causing the commutators mounted upon shaft 423 to rotate in a direction the reverse of that indicated by the arrows shown in Figures 19, 20, 21 and 22.

Assuming now that the second series of lateral movements has been completed and that the sending device has been released and restored to its normal position, we shall assume that the number of the line to be called has five orders or digits. The fifth digit will, therefore, be set up upon the sending device, whereupon the electromagnet 246 will be energized. This, in turn, will cause the energization of the electromagnet 249 to advance the ratchet wheel 257 the space of another tooth. This will shift brush 260 into engagement with commutator segment 460, whereupon the stationarily mounted electromagnet 461 associated with commutator 462 (Figure 18) will be energized to attract its armature 463. The energization of the electromagnet 461 will, for one thing, close the circuit between contacts 464 and 465, 466 and 467, and contacts 468 and 469. The circuits controlled by these contacts will, in the manner previously described, effect the energization of the clutch magnet 470 and of the fields and armature of the motor 50, the only difference between the circuits in this instance and in those previously described in detail being that contact 466 is directly and permanently connected with the live pole of battery as indicated at B^7, while contact 468 is permanently connected with ground as shown in Figure 18, there being no occasion in this instance to effect a reversal of the direction in which the motor will run.

The energization of the electromagnet 461 causes the brush 471 to be brought into engagement with the periphery of the commutator 462. This commutator is provided, as shown, with segments numbered 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 there being a resistance of 100 ohms connected between each pair of commutator segments as indicated in Figure 18. The clutch controlled by magnet 470 having connected the commutator 462 with the motor, through the agency of a worm 472 and a worm wheel 473, the rotation of the motor will effect the rotation of the commutator 462 in the direction indicated by the arrow in Figure 18. The commutator will therefore rotate until the resistance in the Wheatstone bridge arm controlled by commutator 462 is reduced until it equals the resistance introduced into the other Wheatstone bridge arm by means of the sending device 199. When this point is reached, the de-energization of electromagnet 246 will be effected to open the circuits effective in causing the rotation of commutator 462.

If the digit in the fifth order of the called number is a 0, 1000 ohms of resistance will have been introduced into the bridge arm controlled by the sending device 199 when the fifth digit, namely a 0, is set up on the sending device. When, therefore, brush 471 is brought into contact with the segment numbered 0 of commutator 462, 1000 ohms

of resistance will be introduced into the arm of the Wheatstone bridge circuit controlled by the commutator 462, whereupon a balance will at once be struck and the electromagnet 246 will at once be de-energized. As an indirect result of the de-energization of this electromagnet 246, the electromagnet 461 will be de-energized to permit the retraction of its armature 463. The retraction of this armature 463 will cause contact spring 468 to make electrical connection with contact spring 480, thereby closing a circuit which, for convenience, may be traced backwardly from the ground connected with contact spring 468, through contact spring 480, wire 481, relay magnet 482, wire 483, wire 484, to commutator segment 460, thence through brush 260, wire 269, contact ring 261, and brush 268 to the live pole of battery as indicated at B^2. Current flowing over this circuit will energize the relay whose magnet is represented at 482 to cause the attraction of its armatures 485, 486 and 487. This relay 482 locks itself up over a circuit which may be traced from the electromagnet winding 482, through wire 488, contact 489, armature 486, wire 490, relay contact spring 491, contact 492, and thence to the live pole of battery as represented at B^8.

The energization of electromagnet 482 causes the attraction of armature 485 to close a circuit which may be traced from the live pole of battery as represented at B^1 through magnet 249, wire 250, wire 251, wire 493, wire 494, contact 495, armature 485, wire 496, brush 254, and commutatory segment 255 to ground. Current flowing over this circuit energizes electromagnet 249 to cause an additional one-step rotation of the shaft upon which the ratchet wheel 257 is mounted, this one-step advancement of the shaft serving to advance the brush 260 from its position in engagement with commutator segment 460 to its position in engagement with commutator segment 497.

The circuit closed by the brush 260 and commutator segment 497 supplies current to the plug selecting relays 700 and 701 (these relays select the plugs to be operated and also control, in conjunction with the plug turner control or busy test relays 706 and 707, the plug turners through a circuit to be described later), the circuit being traced from the live pole of battery B^2 through contact ring 261, wire 269, brush 260, commutator segment 497, wire 498, wire 499, contact 500, armature 487, wire 501, brush 502 associated with commutator 462 and in this case assumed to be in contact with segment numbered 0′, thence through wire 503 which is connected with this segment 0′, of commutator 462, thence through the plug selector relay 700, or the plug selector relay 701 as the case may be, the circuit being completed to ground through wire 520, or wire 521, by way of commutator 333 illustrated in Fig. 16.

It will be remembered that the plug-turning magnet 160 is to be energized to turn the line of plugs represented by 45 or 46 (Figure 1) in case the called number has an odd digit in the second or tens order, and that plug-turning magnet 161 is to be energized to turn the line of plugs represented by 43 and 44 in case the called number has an even digit in the tens order. It is, therefore, the function of the commutator 333 to determine which of the multiply-connected plug-turning magnets 160 and 161 is to have its energizing circuit completed to ground and therefore to determine which of these two electromagnets is to be energized.

The commutator 333, as shown in Figure 16, is mounted upon shaft 281 to rotate with the commutators 295, 310 and 301. This commutator 333 is provided with segments corresponding in angular position with the numbered segments of commutator 310, certain of the segments of commutator 333 being marked with the letter E and certain of the segments of commutator 333 being marked with the letter O. All of the segments marked E are connected together by means of the wire 510, and all of the segments marked with the letter O are connected together by the wire 511. Commutator 333 will at all times assume an angular position corresponding with the angular position of commutator 310. It will be noted that the segments of commutator 333 which are marked with the letter E correspond in position with the segments of commutator 310 which bear even numbers, while the segments of commutator 333 which are marked with the letter O correspond in position with the segments of commutator 310 which bear odd numbers. The brush 512, which bears upon the periphery of commutator 333, is mounted rigidly, but with proper insulation, upon sector 284 (Figure 14). This brush 512 is directly and permanently connected with ground as indicated in Figures 13 and 16. It will be remembered that the termination of the second series of longitudinal movements of the carriage is controlled by brush 381, which comes into contact with one or another of the numbered segments of commutator 310. If, therefore, the commutator 310 comes to rest in a position in which brush 381 bears upon a commutator segment having an even number, the brush 512 associated with commutator 333 will be in engagement with a segment of commutator 333 marked with the letter E. If, on the other hand, brush 381 were to bring the commutator 310 to rest in a position in which the brush 381 bears upon a commutator segment having an odd number, then brush 512 would rest upon

a segment of commutator 333 marked with the letter O. Assuming, therefore, that brush 512 rests upon a commutator segment marked with the letter O, the circuit last traced will be closed through relay 700, wire 702, wire 520, one of the commutator segments marked 0, and thence directly or through wire 511, as the case may be, to brush 512 and thence to ground.

If the commutator 333 should come to rest in a position in which brush 512 bears upon a commutator segment marked with a letter E, then the plug selecting circuit would be traced through relay 701, wire 703, wire 521, thence through a segment of the commutator 333 marked with the letter E, and thence directly or through wire 510, as the case may be, to brush 512 and thence to ground.

In either event, one or the other of the plug-selecting relays 700 or 701 will have been operated, thereby setting up conditions for effecting the partial rotation of the line of plugs represented by 45 and 46 or by 43 and 44, as the case may be provided the line is not busy. It will be remembered that it was important that one and only one line of plugs should be turned at the conclusion of the set-up, and the mechanism and circuits last described insure the turning of the line of plugs which will cause connection to be made with the desired line and no other.

We have heretofore referred to the fact that our system contemplates not merely a single multiple bank, but rather a plurality of multiple banks each provided with its own carriage, and we have referred also to the fact that the plug-turning mechanism can be controlled to determine which of the several carriages shall have its plug or plugs rotated to effect final connection with a called line. The determination as to which of the carriages is to have a set of its plugs thus rotated is controlled by commutator 462, illustrated in Figure 18. It will be remembered that the circuit which effects the energization of the plug selecting relay 700 or 701, as the case may be, was traced through brush 502 and the segment numbered 0′ of commutator 462, and thence through wire 503 to the plug selecting relays 700 and 701. It was possible to trace the circuit of the plug selecting relays 700 and 701 through the commutator segment 0′ of commutator 462 because of the assumption that the called number had a zero in the fifth order. If the called number had, for example, the digit 1 in the fifth order, then the commutator 462 would have been rotated through one angular step of advancement before the brush 471 reached a commutator segment upon which the Wheatstone bridge balance would have been struck. This would have rotated segment 1′ of commutator 462 into a position to contact with brush 502. In this case the plug-turning circuit could not have been traced through wire 503, but must have been traced through wire 530, which is a part of the plug selecting relays (not shown) similar to relays 700 and 701, which control the circuit of plug-turning magnets 531 and 532 (Figure 1), the circuits of these plug selecting circuits and plug-turning magnets 531 and 532 being led to wires 520 and 521, respectively, through branch wires 533 and 534, respectively, as indicated in Figure 13. It will be understood that the plug-turning magnet 531, when energized, effects the turning of the right-hand line of plugs of the duplicate carriage next to the right of that shown in Figure 1, and that the energization of the plug-turning electromagnet 532 effects the turning of the left-hand line of plugs of this duplicate carriage.

In Figure 18 we have indicated a plurality of other wires marked 540, 541 * * * 546, 547, connected, respectively, with segments numbered 2′, 3′ * * * 8′, 9′ of commutator 462, these wires leading in like manner to pairs of plug selecting circuits and plug-turning magnets corresponding with those more fully illustrated in the drawings at relays 700 and 701, 706 and 707, also magnets 160 and 161, and 531 and 532. It will be understood that the commutator 462 will be rotated through an angle corresponding with the digit in the fifth order of the called number and that the segments of this commutator numbered 0′, 1′, 2′ * * * 8′, 9′ will control the selection of that pair of plug-turning magnets necessary to effect the turning of a line of plugs associated with the carriage which is adapted to reach the multiple set assigned to the called line.

Coincident with the operation of a plug controlling circuit to bring the contacts of a plug into connection with the multiple wiring of the called line, the setting-up circuits are largely cleared to put the calling line in connection with the called line for the purpose of carrying on telephonic conversation. It will be remembered that the ratchet wheel 257 has been advanced to bring the brush 260 into engagement with commutator segment 497. For one thing, the roller associated with the spring contacts 240 and 342 will have been dropped down onto the part of the surface of the cam 258 of short radius so that the connection of contact spring 240 will be switched from contact 239 to contact 540′ and spring 342 will have been switched from connection with contact 341 to a connection with contact 541′. The line wires 343 and 241 leading from the sending station represented at 199 will, therefore, have had their connections switched from the Wheatstone bridge circuit, which is diagrammatically shown in dotted lines at 542, to connections with wires 543′ and 544′, wire

543 leading through contact 708 when closed, on relay 709, wire 727, to one strand of the flexible cord 130, which is permanently connected with one of the four contacts of each of the plugs 43, 44, 45, 46, etc., and wire 544, through relay 545′ to wire 546′, through contact 710 when closed, on relay 710, wire 726, directly to another strand of the flexible cord 130 which is connected with another of the contacts in each of the plugs.

At this stage of the operation it is necessary (when the apparatus is arranged for telephone switching) to make a busy test, and to ring the called line if it is not busy. If the line is busy the plug turner control or busy test relay 706, or 707 as the case may be, will not operate in parallel with a similar relay on another selector connected to the same line, through the busy test or projecting wire of the multiple, which is connected through resistance to ground. This busy test feature may be used to select idle trunks by inserting another marginal operating relay in series with each busy test relay, and using its front contacts in conjunction with an extra set of back contacts on relays 706 and 707 to control the motor circuits and move the plugs laterally in the direction assumed on the fourth digit, and thus connect with a non-busy trunk. As the result of the non-operation of the busy test relay 706, or 707, on a busy line, busy-back tone battery is sent to the calling station over a circuit which may be traced from busy tone battery B^{11}, through back contact 711 of relay 706 and back contact 712 of relay 707, wire 723, wire 546, relay 545, wire 544, line wire 241, telephone 570, back on line wire 343, wire 543, to impedance 551, to ground G^{10}. If the line is not busy and the fourth digit of the called number is an even numeral, then relay 706 is operated by battery coming from commutator 462 over wire 503 (it being remembered that relay 700 has been operated from this circuit through wire 702, wire 520 to commutator 333), through contact 713 of relay 700, relay 706, wire 715 which is bridged to the sliding contacts connecting to one of the four contacts on plugs 45 and 46, thence through the busy test multiple wire and through resistance to ground. Wire 716 from relay 707 is connected to plugs 43 and 44.

The operation of relay 706 closes its contacts 717 and 718. Closing contact 718 sends battery B^{10} through impedance 552, contact 718, back contact 712 on relay 707, wire 723 and 546, relay 545, thence to the calling station and back to G^{10} as described for the busy back tone. The general arrangement of this means for testing a busy line and for informing a calling subscriber that the called line is busy, is shown in the patent to McBerty No. 1,125,579, January 19, 1915. The means for closing the line circuit at the sending station are but diagrammatically indicated in Figure 13 by means of the switch 570. When current flows through relay 545′ its armature 571 is attracted to close a circuit which may be traced from the live pole of battery indicated at B^2, through brush 268, contact ring 261, wire 269, brush 260, commutator segment 497, wire 498, wire 572, relay 573, wire 574, wire 575, contact 576, armature 571, and thence to ground as indicated. Current flowing over this circuit will energize relay 573 to attract its armatures 576′, 491 and 577. The attraction of armature 576′ will connect the ground connection associated with contact 579 with wire 574 to lock up relay 573, so that the connections controlled by the energization of this relay 573 will be maintained after relay 545 has been de-energized, as, for example, at the restoration of the receiver to its switch hook at the sending end of the line as represented at 570. The energization of magnet 573 will cause the attraction of armature 491 to close a circuit from the live pole of battery represented at B^8, through contact spring 492, to contact 580, wire 581, wire 501, brush 502, a segment, as for example O′, of segment 462, a wire leading to a pair of plug selecting relays, as for example 503, a plug-selecting relay, as for example 700, a wire, as for example 520, a segment, as for example one of those marked with the letter O, of commutator 333, and thence to brush 512, which is permanently connected with ground. Current flowing over this circuit serves to maintain the energization of the selected plug-turning magnet to hold the selected plug in engagement with the multiple set of the called line. After the previously traced circuit between contact 492 and armature 491 is broken, as a result of which the locking circuit for relay 482 will be opened, it is the energization of relay 482 which effects the energization of the plug-turning magnet, and it is necessary, therefore, to substitute another circuit for maintaining the energization of the plug-turning magnet after the de-energization of magnet 482 is effected. It is desirable to de-energize magnet 482 at this point to clear the circuits controlled thereby.

The closing of contact 717 on relay 706 sends battery from wire 503, through wire 703, contact 717, wire 721, plug turner 160, wire 520 to ground at commutator 333, thus operating the plug turner and bringing the three remaining contacts on plug 45, or 46 as the case may be, into contact with the multiple wires of the called number. The third set of contacts on the plugs are permanently connected to wire 548, and are used in conjunction with generator trip relay 725 and generator cut-off relay 709 to control the ringing current and talking circuit. At the time the plug contacts are con-

nected to the multiple, ringing current is sent over the called line from generator G^{12}, through generator trip relay 724, back contact 728 on relay 709, wire 726, plug contact, multiple and line wire to the ringer at the telephone, thence to local ground or back over the line to wire 727, back contact 729 of relay 709, to ground G^{13}. In the meantime battery is flowing from B^{14}, through resistance 725, relay 709 and back contact of relay 724 in parallel, wire 548, plug contact, multiple wire and resistance to ground. Due to the shunting effect of the back contacts of relay 724, relay 709 does not operate until relay 724 operates. The generator trip relay 724 is unaffected by the current passing through the high resistance ringer circuit, but immediately operates when the talking circuit at the called station is closed. The operation of relay 724 due to this cause breaks the shunt around relay 709 causing it in turn to operate, thus breaking the shunt contact 730, its generator and ground contacts 728 and 729 and closing the talking contacts 708 and 710. This ringing arrangement is similar to that shown in the patent to Williams, No. 1,097,204, May 19, 1914.

We have now completed the connection with the called line and have established a clear talking circuit, at the same time having effected the energization of relay 573, which maintains this condition while conversation is carried on between the connected lines.

When the subscribers have finished with their conversation, they will hang up their receivers in the usual way, thus opening the line circuits at the talking stations. When the line circuit at the sending station is opened, relay 545′ will be deprived of current, whereupon its armature 571 will fall back to make connection with the back relay contact 590. Electromagnet 573 was, however, locked up and therefore maintains a connection between contact 591 and contact spring 592. A circuit may, therefore, be traced, from the live battery connection B^1 through relay 249, wire 250, wire 251, wire 493, wire 593, contact spring 592, contact 591, contact 590 and thence through armature 571 to ground. Current flowing through the magnet 249 will actuate the pawl 265 to advance the ratchet wheel 257 a space of one tooth. This will shift the brush 260 onto segment 600 of the associated commutator. The first effect of this switching operation is to remove the battery connection from relay 573, whereby its armatures are retracted to open the circuits previously closed through them, thereby causing the deenergization of the plug-turning magnet to permit the turned line of plugs to be restored to their normal upright position. A second result of the one-step rotation of the ratchet wheel 257 as effected by the energization of the magnet 249 is to reverse the battery connections with respect to the motor 50 so that the motor will operate to return the plugs both laterally and longitudinally to their normal positions. In general, the operations are the reverse of those previously described in connection with the setting up of the plug mechanism, the principal difference being that the commutator mechanism connected with the mechanism for effecting the movements of the plugs is provided with ground connections which operate automatically at the completion of each stage of the restoration to effect an energization of the magnet 249. Whenever this magnet 249 is energized it effects the one-step rotation of the associated ratchet wheel 257 to shift the brush 260 onto the next succeeding segment of the associated commutator, thereby switching the motor controlling relays successively into circuit, but in the reverse order with respect to that in which they were previously considered, with the result that the motor is automatically connected in succession with the several mechanisms which effect the movement of the plugs and carriages and with the result that the motor is under each set of these changed connections operated to effect the necessary movement of plug restoration.

The circuits and operations are not essentially different from those previously described, and it will not be necessary to trace the circuits and follow the operations of the electromagnets and mechanism in elaborate detail.

The operation of the circuits during the restoration of the plugs will be most readily understood if it is borne in mind that the ground connection for the electromagnet 249 was supplied through relay contacts 247 and 248, while the ground connection for operating the electromagnets associated with the several commutators was supplied through a connection between contacts 279 and 280 associated with electromagnet 249. During the operation of restoration the ground connection previously supplied through contacts 279 and 280 is now replaced by a permanent ground connection by way of commutator segment 255, which has now been restored into a position in which it will contact with brush 610, and the ground connection for the energization of relay 249 is now supplied through wire 611 and a connection between the metallic segment of commutator 259 and brush 612, which connection will have been established upon the seventh one-step advancement of the ratchet wheel 257 and which connection will continue until this rachet wheel has been restored to its normal resting position.

The first commutator magnet to be energized in effecting the restoration of the plug mechanism is magnet 461 associated with

commutator 462 (Figure 18). This magnet is now energized over a circuit which may be traced from the battery connection B^2 through brush 268, contact ring 261, brush 260, commutator segment 600, wire 484, wire 613, electromagnet 461, wire 357, wire 274, brush 610, and thence through commutator segment 255 to ground. The energization of this electromagnet 461 will close the circuit of the clutch magnet 470 and also the field and armature circuits of motor 50, the armature and clutch circuit being identical with that over which the setting-up current flowed, and the field magnet circuit being identical with that previously traced, except that the connections with battery and ground will have been reversed, due to the face that commutator 263 will now have been advanced by the ratchet wheel 257 to an angular position in which brush 327 will engage commutator segment 317 and brush 316 will engage commutator segment 326. This reversal of the connection of the field magnets of the motor 50 will cause the motor to rotate in a direction the reverse of that in which it rotated in the setting-up operation of the mechanism.

The commutator 462 will, therefore, be rotated in a direction the reverse of that indicated by the arrow in Figure 18, and this reverse rotation will continue until the commutator reaches its normal position, as shown in Figure 18, at which time the permanently grounded commutator segment 620 will be brought into engagement with the brush 621 upon the end of a lever associated with the armature 463, which armature is at this time attracted, due to the energization of the associated electromagnet 461. When commutator segment 620 has reached a position such that it engages brush 621 a circuit may be traced in the reverse order from ground through commutator segment 620, brush 621, wire 622, wire 623, brush 612, the metallic segment of commutator 259, wire 611, wire 250, electromagnet winding 249, and thence to the live pole of battery as represented at B^1. As soon as current flows over this circuit it will cause the energization of electromagnet 249 to advance the associated ratchet wheel 257 through the space of another tooth, thereby moving the switch arm 260 from commutator segment 600 to commutator segment 630, thereby interrupting the circuit previously traced through commutator segment 600, upon which connection depended the continued energization of electromagnet 461. Electromagnet 461 having been deenergized by the movement of switch arm 260, permits its armature to be retracted, thereby opening the motor circuits and the circuit through clutch magnet 470.

The switch arm 260 having been transferred to a position in which it contacts with segment 630 of the associated commutator, a circuit will be closed through electromagnet 432 associated with commutators 392, 420, 421 and 422. The energization of electromagnet 432 will again close the armature and field circuits of the motor 50, as also the circuit through clutch magnet 69. As previously explained, the field magnet circuit of the motor is permanently reversed by means of the commutator 263, as a result of which the motor will run in a direction opposite to that previously described throughout the various stages of the restoring operations.

The motor will, therefore, rotate in the reverse direction to withdraw the plugs from their extended lateral positions, the amount of lateral movement of restoration corresponding exactly with the amount of lateral movement employed in effecting the second series of lateral movements. The movement of restoration is limited by the commutator mechanism which is geared to the lateral actuating shaft 60 and particularly by segment 640 of commutator 422. This commutator segment co-operates with brush 641, which by means of suitable insulation is mounted upon the arm 456 of the armature 431, which, as previously explained, will now be in its attracted position, due to the energization of the associated magnet 432. The brush 641 having, therefore, been brought into engagement with the periphery of the commutator 422, the commutator 422 will be rotated in a direction such as may be necessary to restore it toward its normal position, as shown in Figure 22. It will continue to rotate as driven by the motor 50 until commutator segment 640 makes connection with brush 641, at which time a circuit may be traced in the reverse direction from ground through commutator segment 640, brush 641, wire 642, wire 623, brush 612, the metallic segment of commutator 259, wire 611, wire 250, electromagnet winding 249, and thence to the live pole of battery as represented at B^1. When, therefore, the commutator 422 has reached this position, electromagnet 249 will be energized to cause a further one-step advancement of the ratchet wheel 257. This advancement of the ratchet wheel will transfer switch arm 260 from commutator segment 630 to commutator segment 650. The circuit of the electromagnet 432 previously traced through commutator segment 630 and brush 260 will now be interrupted, as a result of which the motor circuits and the circuit of clutch magnet 69 will be opened to arrest the reverse movement corresponding with the second series of lateral movements.

When connection is established between switch arm 260 and commutator segment

650, a circuit will be closed through electromagnet 390. The energization of this electromagnet will close the field and armature circuits of the motor in a reverse direction, also the circuit of clutch magnet 69. The ensuing reverse movement of the plugs and commutators mounted upon shaft 423 will now continue until brush 651 establishes connection with the permanently grounded commutator segment 652. As soon as this condition is attained a circuit may be traced in the reverse direction from the grounded commutator segment 652 through brush 651, wire 653, wire 642, and thence, as before, through electromagnet 249 to the live pole of battery. Current flowing over this circuit will again energize magnet 249 to cause a further one-step advancement of the ratchet wheel 527 and the switch arm 260.

When switch arm 260 is transferred from commutator segment 650 it will open the circuit of electromagnet 390, thereby causing its de-energization, with the consequent stoppage of the motor and the consequent release of the clutch controlled by magnet 69, and the establishment of a connection between switch arm 260 and commutator segment 654 will close the energizing circuit of electromagnet 354. The energization of this electromagnet will in turn effect the energization of the motor circuits in such a direction as to cause a rotation in the reverse direction, and also the energization of the clutch magnet 51. A longitudinal return movement of the carriage corresponding with the second series of setting-up movements will, therefore, take place, with a consequent rotation of the commutators mounted upon the shaft 281 in a direction opposite to that in which these commutators were rotated during the second series of longitudinal setting-up movements. This return movement of carriage and associated commutators will continue until the segment 660 of commutator 301 comes into engagement with brush 661, which the energization of the electromagnet 351 carried by means of the armature lever 380 into engagement with the periphery of the commutator 301. When this position is reached another circuit substantially like those already traced will be closed through electromagnet 249 to effect a further one-step rotation of the ratchet wheel 257 and with it the switch arm 260.

As switch arm 260 is moved off from commutator segment 654, the energization of electromagnet 354 will be terminated to open the motor and clutch circuits and thus stop the longitudinal movement of the carriage and the rotation of the associated commutator mechanism.

When switch arm 260 makes connection with commutator segment 662 a circuit will be closed through electromagnet 272 mounted upon sector 283, whereupon the associated armature will be actuated to close the circuit 51 and the energizing circuits of the motor, the direction of connection through the field magnets of the motor again being such as to cause its rotation in the reverse direction. Here again the rotation of the motor will move the carriage longitudinally in a reverse direction by an amount corresponding with the amount of movement represented by the first series of longitudinal setting-up motions. This return movement will continue in this instance until the permanently grounded commutator segment 300 comes into engagement with the brush 299, which is mounted with proper insulation upon the arm 291 of armature 285. When this position of commutator 301 has been attained, a circuit will be closed from the grounded commutator segment 300 through brush 299 and wire 670 over the path previously traced to electromagnet 249, the consequent energization of which will effect a further one-step-advancement of the ratchet wheel 257 and the commutator mechanism mounted upon its shaft.

This will have restored all of the mechanism to its initial position as represented in the drawings and as it existed prior to any of the operations which have been described herein.

We have not deemed it necessary to describe certain comprehensive modifications or many modifications of detail which may be made in the system of our invention. On the contrary, we have confined ourselves rather closely to a description of the preferred manner in which our invention may be embodied, leaving it for those skilled in the art to make such modifications as will readily occur in putting the invention into practice.

What we claim as new and desire to secure by Letters Patent is:—

1. In a system of the class described, the combination of a plurality of sets of contact strips arranged in transverse and longitudinal rows and extending in a direction perpendicular to and through a plurality of parallel planes in each of which they are thus arranged in transverse and longitudinal rows, a switch contact set, actuating mechanism associated with said switch contact set adapted to move the switch contact set transversely and longitudinally in a plane perpendicular to the direction in which the said contact strips extend, other duplicate switch contact sets in the other parallel planes, and an actuating mechanism associated with each switch contact set adapted to move it longitudinally and transversely in a plane parallel to the plane in which the first switch contact set is moved by its associated actuating mechanism.

2. In a telephone exchange system, the combination of a plurality of telephone

lines leading from a central office to subscribers' stations, a set of multiple contact strips connected with each line at the central office, the contact strips connected with the several lines being arranged in transverse and longitudinal rows and extending in a direction perpendicular to and through the plane in which they are thus arranged in transverse and longitudinal rows, a switch contact set, actuating mechanism associated with said switch contact set longitudinally and transversely in a plane perpendicular to the direction in which the said contact strips extend, other duplicate switch contact sets, and an actuating mechanism associated with each switch contact set adapted to move it longitudinally and transversely in a plane parallel to the plane in which the first said switch contact set is moved by its associated actuating mechanism.

3. In a system of the class described, the combination of a plurality of superposed plug carriages, a laterally movable plug or set of plugs mounted upon each carriage, means for moving each carriage in one direction, means for moving each plug or set of plugs relative to its carriage, and long and thin switch contacts extending perpendicular to the planes of movement of a plurality of said plugs and adapted for electrical connection with the switch contacts of any of said plugs.

4. In a telephone system, the combination with a plurality of long and slender stationary contactors arranged in parallel rows with aisles between them, of a plurality of travelling plugs carrying contacts for engagement with said contactors, and mechanism adapted to move each of said plugs in a plane individual to itself outside said group of contactors and then in a direction at an angle to its first movement but in the same plane and along the aisle between said contactors to a position adjacent the particular contactors with which connection is desired.

5. In an electrical switching system, a movable switch contact member, automatic mechanism for imparting a series of minor longitudinal movements to said switch contact member, automatic mechanism for imparting a series of major longitudinal movements to said switch contact member, automatic mechanism for imparting a series of minor transverse movements to said switch contact member, automatic mechanism for imparting a series of major transverse movements to said switch contact member, and stationary switch contacts adapted for electrical connection with the said movable switch contact member.

6. In an electrical switching system, a movable switch contact member, automatic mechanism for imparting a series of minor movements in one direction to said switch contact member, automatic mechanism for imparting a series of major longitudinal movements in the same direction to said switch contact member, automatic mechanism for imparting a series of minor movements in another direction to said switch contact member, automatic mechanism for imparting a series of major movements in the said second direction to said switch contact member, and stationary switch contacts adapted for electrical connection with the said movable switch contact member in any position to which it may be moved.

7. In an electrical switching system, a movable switch contact member, means for imparting a series of minor movements in one direction to said switch contact member, means for imparting a series of major movements in the same direction to said switch contact member, means for imparting a series of minor movements in another direction to said switch contact member, means for imparting a series of major movements in the said second direction to said switch contact member, and stationary switch contacts adapted to make electrical connection with the said movable switch contact member in any of the positions to which it may be moved.

8. In an electrical switching system, a movable switch contact member, means for imparting a series of minor movements in one direction to said switch contact member, means for imparting a series of major movements in the same direction to said switch contact member, means for imparting a series of minor movements in another direction to said switch contact member, means for imparting a series of major movements in the said second direction to said switch contact member, electromagnetic mechanism for controlling the operation of each of said means, and stationary switch contacts adapted to make electrical connection with the said movable switch contact member in any of the positions to which it may be moved.

9. In an electrical switching system, a movable switch contact member, means for imparting a series of minor movements in one direction to said switch contact member, means for imparting a series of major movements in the same direction to said switch contact member, means for imparting a series of minor movements in another direction to said switch contact member, means for imparting a series of major movements in the said second direction to said switch contact member, electromagnetic mechanism for controlling the operation of each of said means, electrical switching mechanism for controlling the actuation of said electromagnetic controlling mechanism, and stationary switch contacts adapted to make electrical connection with the said movable switch

contact member in any of the positions to which it may be moved.

10. In a system of the class described, the combination of a plurality of sets of contact strips arranged in transverse and longitudinal rows and extending in a direction perpendicular to and through the plane in which they are thus arranged in transverse and longitudinal rows, a switch contact set, actuating mechanism associated with said switch contact set adapted to move the switch contact set transversely and longitudinally in a plane at an angle to the direction in which the said contact strips extend, other duplicate switch contact sets adapted for connection with the physical extensions of said contact strips in other planes, and an actuating mechanism associated with each switch contact set adapted to move it longitudinally and transversely in a plane parallel to the plane in which the first switch contact set is moved by its associated actuating mechanism.

11. In a telephone exchange system, the combination of a plurality of telephone lines leading from a central office to subscribers' stations, a set of multiple contact strips connected with each line at the central office, the contact strips connected with the several lines being arranged in transverse and longitudinal rows and extending in a direction perpendicular to and through the plane in which they are thus arranged in transverse and longitudinal rows, a switch contact set, actuating mechanism associated with said switch contact set to move it longitudinally and transversely in a plane at an angle to the direction in which the said contact strips extend, other duplicate switch contact sets for connection with the physical extensions of said strips, and an actuating mechanism associated with each switch contact set adapted to move it longitudinally and transversely in a plane parallel to the plane in which the first said switch contact set is moved by its associated actuating mechanism.

12. In a switch for automatic telephone systems, the combination with a plurality of conducting elements extending parallel to one another and arranged in a plurality of parallel planes with aisles between them, of a plurality of traveling contacts each adapted to move outside said conducting elements to a position opposite a particular aisle and then to move along the aisle and into contact with particular ones of said conducting elements, said travelling contacts being arranged to travel in different parallel planes, and electro-mechanical mechanism for moving said contacts in accordance with predetermined digits of a desired number.

13. In a telephone system, the combination with a plurality of long and slender electrical conducting elements arranged in a plurality of parallel planes with aisles between them, of electro-mechanically propelled contact makers arranged in a plurality of planes extending substantially perpendicular to said conducting elements, and guiding means for said contact makers adapted to guide each of them in its particular plane across the planes of certain of said conducting elements and along the aisle between said conducting elements to a position before a predetermined conducting element.

14. In a telephone system consisting of a combination of a plurality of telephone lines leading from a central office to subscribers' stations, groups of multiple contact strips connected to the telephone lines at the central office, together with the movable switch contact sets and their controlling and actuating mechanisms as outlined, an arangement whereby one or more of the contact strips of each of the various groups of stationary multiple contact strips projects into the aisle so as to allow passing contact between it and the sliding contact member or members of the movable switch contact sets.

15. In a system of the class described, the combination of sets of contact strips, said contact strips being arranged in sets or groups in transverse and longitudinal rows and extending in a direction perpendicular or at an angle to and through a plurality of parallel planes or sections, one or more switch contact sets arranged to move longitudinally and transversely between the groups or sets of said contact strips and to make contact with them, an actuating mechanism for each switch contact set designed to give it longitudinal and transverse movement and to operate the switch contact members, and a directing mechanism or switch arranged to control the operation of the switch contact set actuating mechanism and circuits during some of their functions.

16. In a system of the class described the combination of a plurality of contiguously arranged plug carriages, laterally movable plugs mounted on each carriage, means for giving each carriage progressive and retrograde motion in either direction through one line of action, means for giving each plug, or each group of plugs, progressive and retrograde movement in either direction in a line of action relative to the carriage, stationary sets of multiple contact strips extending at an angle to the plane of movement of a plurality of said carriages and adapted for electrical connection with the movable switch contacts, and means for bringing said switch contacts into connection with said multiple contact strips.

17. In an electro-mechanical switching system, movable switch contact members, means for imparting a series of progressive and retrograde minor movements to said

switch contact members in either direction in a given line of action, means for imparting a series of progressive and retrograde major movements to said switch contact members in the same line of action, means for imparting a series of progressive and retrograde minor movements to said contact members in either direction in another line of action, means for imparting a series of progressive and retrograde major movements to said switch contact members in the second line of action, stationary contact strips, means for bringing said contact members into connection with said stationary contact strips, mechanism for controlling the operation of each of said means, and switching mechanism for guiding the operation of said controlling mechanism.

18. In an electro-mechanical switching system, movable switch contact members, means for imparting a series of progressive and retrograde major movements in either direction to said switch contact members in one line of action, means for imparting a series of progressive and retrograde minor movements in either direction to said contact members in the same line of action, means for imparting a series of progressive and retrograde major movements to said switch contact members in either direction in another line of action, means for imparting a series of progressive and retrograde minor movements to said switch contact members in either direction in the second line of action, stationary contact strips adapted for connection with the movable switch contact members, means for bringing said switch contact members into connection with said stationary contact strips, mechanism for controlling the operation of each of said means, and switching mechanism for guiding the controlling mechanism.

19. In a switching system of the class described, the combination of a plurality of stationary contact points or strips arranged in parallel rows with aisles between them and arranged in groups to accommodate a large number of said contact strips, of a plurality of traveling switch contact sets carrying contacts for engagement with said stationary contact strips, and mechanism adapted to move each of said switch contact sets in a plane individual to itself outside of the groups of stationary contact strips and then in a direction at an angle to its first movement but in the same plane and along the aisles between said stationary contact strips to a position adjacent to the particular contact strips with which connection is desired, said mechanism being adapted to bring the movable contact members into connection with the stationary contact strips said contact strips extending vertically through the planes of motion of said switch contact sets.

20. In a telephone switching system, a plurality of longitudinally extending contact strips mounted in transverse parallel planes and divided into sets with a plurality of strips in each set, each strip of each set having a plurality of contact portions longitudinally thereof, a plurality of movable contact sets each comprising a plurality of contact members adapted to engage the several contact strips of a set, said contact sets being spaced longitudinally of said contact strips, and actuating mechanism for moving a contact set in one direction to select a group of contact strips and in another direction to select contact strips in the group.

21. In a telephone switching system, a plurality of longitudinally extending contact strips mounted in transverse parallel planes and divided into sets with a plurality of strips in each set, each strip of each set having a plurality of contact portions longitudinally thereof, a plurality of movable contact sets spaced longitudinally of said contact strips, each of said contact sets comprising a plurality of contact members adapted to engage the several contact strips of a set, and actuating mechanism for moving a selected contact set perpendicularly to the plane of said contact strips to select a group and transversely thereto to select contacts in the group.

22. In a telephone switching system, a plurality of longitudinally extending contact strips mounted in transverse parallel planes and divided into sets with a plurality of strips in each set, each strip of each set having a plurality of contact portions longitudinally thereof, a plurality of movable contact sets spaced longitudinally of said contact strips each of said movable sets comprising a plurality of contact members adapted to simultaneously engage the several contact strips of a set, and an actuating mechanism for each of said movable contact sets controlled by a calling subscriber.

23. In a telephone switching system, a plurality of longitudinally extending wires mounted in transverse parallel planes and divided into sets with a plurality of wires in each set, each wire of each set having a plurality of contact portions longitudinally thereof, a plurality of movable contact sets spaced longitudinally of said wires, each of said contact sets comprising a plurality of contact surfaces adapted to simultaneously engage the several wires of a set, a subscriber's telephone line connected to each of said sets of wires, a calling subscriber's line adapted to be associated with a selected one of said movable contact sets, and actuating mechanism controlled by a calling subscriber

for moving a selected one of said movable contact sets perpendicularly to the planes of the wires to select a group and transversely to the planes to select wires in the group.

24. In a telephone switching system, a plurality of longitudinally extending contact strips mounted in transverse parallel planes and divided into sets with a plurality of strips in each set, each strip of each set having a plurality of contact portions longitudinally thereof, a plurality of movable contact sets spaced longitudinally of said contact strips, each of said movable sets comprising a plurality of contact members adapted to simultaneously engage the contact strips of a set, and actuating mechanism for imparting selective movements of different degrees to a movable contact member to select a set of contacts on said strips.

25. In a telephone switching system, a plurality of longitudinally extending metallic contact strips mounted in transverse parallel planes and divided into sets with a plurality of strips in each set, each strip of each set having a plurality of contact portions longitudinally thereof, a plurality of movable contact sets spaced longitudinally of said contact strips, each of said sets comprising a plurality of contact members adapted to simultaneously engage the contact strips of a set, and actuating mechanism for imparting movements of different directions and degrees to a contact set to move it into engagement with a selected set of contact strips.

26. In a telephone switching system, a plurality of longitudinally extending contact strips mounted in transverse parallel planes and divided into sets with a plurality of strips in each set, each strip of each set having a plurality of contact portions longitudinally thereof, a plurality of movable contact sets spaced longitudinally of said contact strips, each of said sets comprising a plurality of contact members adapted to simultaneously engage contacts of a set of strips, and actuating mechanism for moving a selected one of said movable contact sets perpendicularly to the planes of the contact strips to select a group and transversely to the planes to select a set in the group and in movements of different degrees.

27. Selective switching apparatus comprising stationary terminals so arranged as to be identified in a two coordinate system, a switch member having selective movement in the two principal directions of said coordinate system, means for setting said member, means for causing said member to be set from a starting position to one side in a principal direction and means for causing said member to be set from the same position to the opposite side in the same principal direction.

28. Selective switching apparatus comprising stationary terminals so arranged as to be identified in a two coordinate system, a switch member having selective movement in the two principal directions of said coordinate system, means for setting said member, means for causing said member to be set from its normal position to either side in one principal direction and means for causing said member to be set from an intermediate position to either side in the other principal direction.

29. Selective switching apparatus comprising a number of groups of stationary terminals so arranged as to be identified in a two coordinate system, a switch member having selective movement in the two principal directions of said coordinate system and located normally in a central position relatively to said group of terminals, means for setting said member, means for causing said member to be set from a starting position to one side in a principal direction and means for causing said member to be set from the same position to the opposite side in the same principal direction.

30. Selective switching apparatus comprising four groups of stationary terminals so arranged as to be identified in a two coordinate system, a switch member having selective movement in the two principal directions of said coordinate system and located normally in a central position relatively to said groups of terminals, means for setting said member, means for causing said member to be set from its normal position to either side in one principal direction and means for causing said member to be set from an intermediate position to either side in the other principal direction.

31. Selective switching apparatus comprising stationary terminals in the form of parallelly extending, uncovered wires, so arranged as to be identified in a two coordinate system, a switch member having selective movement transversely to said wires in the two principal directions of said coordinate system, means for setting said member, and means for causing said member to be set from a starting position to either side in a principal direction.

32. Selective switching apparatus comprising four bundles of parallelly extending uncovered wires so arranged as to be identified in a two coordinate system, switch members having selective movement transversely to said wires in the two principal directions of said coordinate system and located normally in a central position relatively to said bundles of wires, machine driven means for setting said members, means for causing each member to be set from its normal position to either side in one principal direction and means for causing each member to be

set from an intermediate position to either side in the other principal direction.

33. Selective switching apparatus comprising stationary terminals so arranged as to be identified in a two coordinate system, a switch member having selective movement in the two principal directions of said coordinate system, means for setting said member, a register device for controlling the setting of said member, and means for causing the said member to be set from a starting position to either side in a principal direction.

34. In a telephone exchange system, lines arranged in numerical order, a designation for each of said lines comprising a plurality of designations placed in the reverse order to the numerical designation, means for registering such designations, selective switches for interconnecting said lines, and means responsive to said registering means for actuating said switches in accordance with the numerical designation of said lines.

In witness whereof, we hereunto subscribe our names, in the presence of two witnesses, this 20th day of May, A. D. 1914.

ISAAC D. BUDD.
CLAUDE I. CRONBURG.
FREEMAN S. HURD.

Witnesses:
H. A. NEIBURGER,
MARY A. COOK.