

Nov. 19, 1929.

J. E. GARDNER

1,736,259

AUTOMATIC TELEPHONE SYSTEM

Filed May 11, 1927

4 Sheets-Sheet 1

Fig. 1.

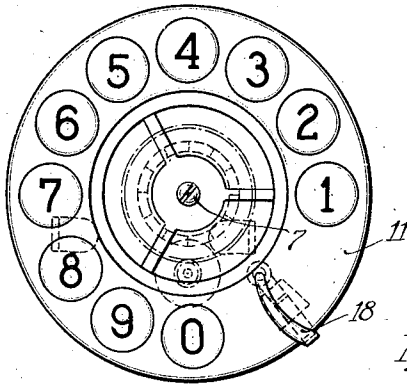


Fig. 3.

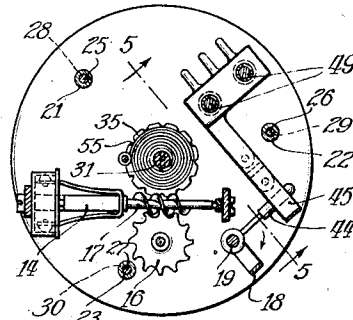


Fig. 5.

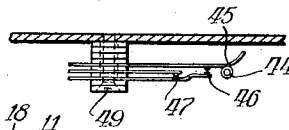


Fig. 2.

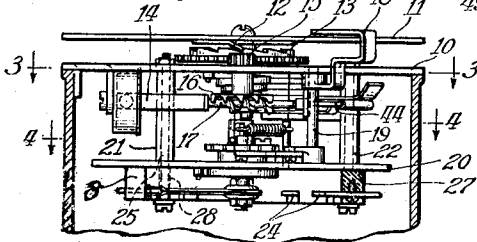


Fig. 4.

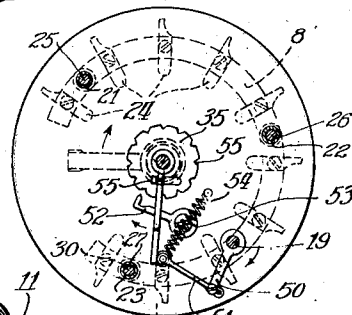


Fig. 10.

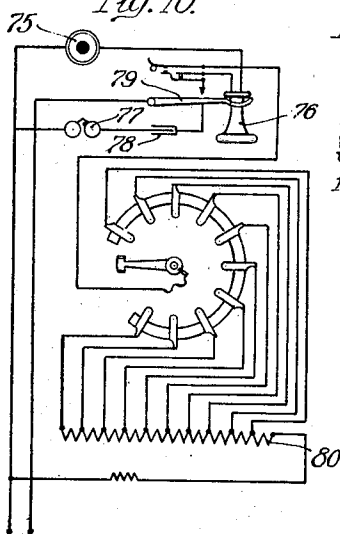
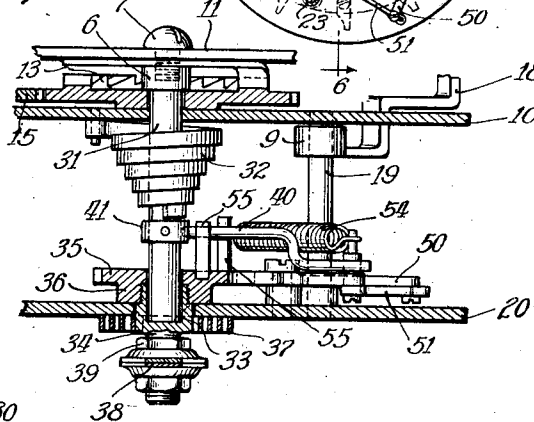


Fig. 6.



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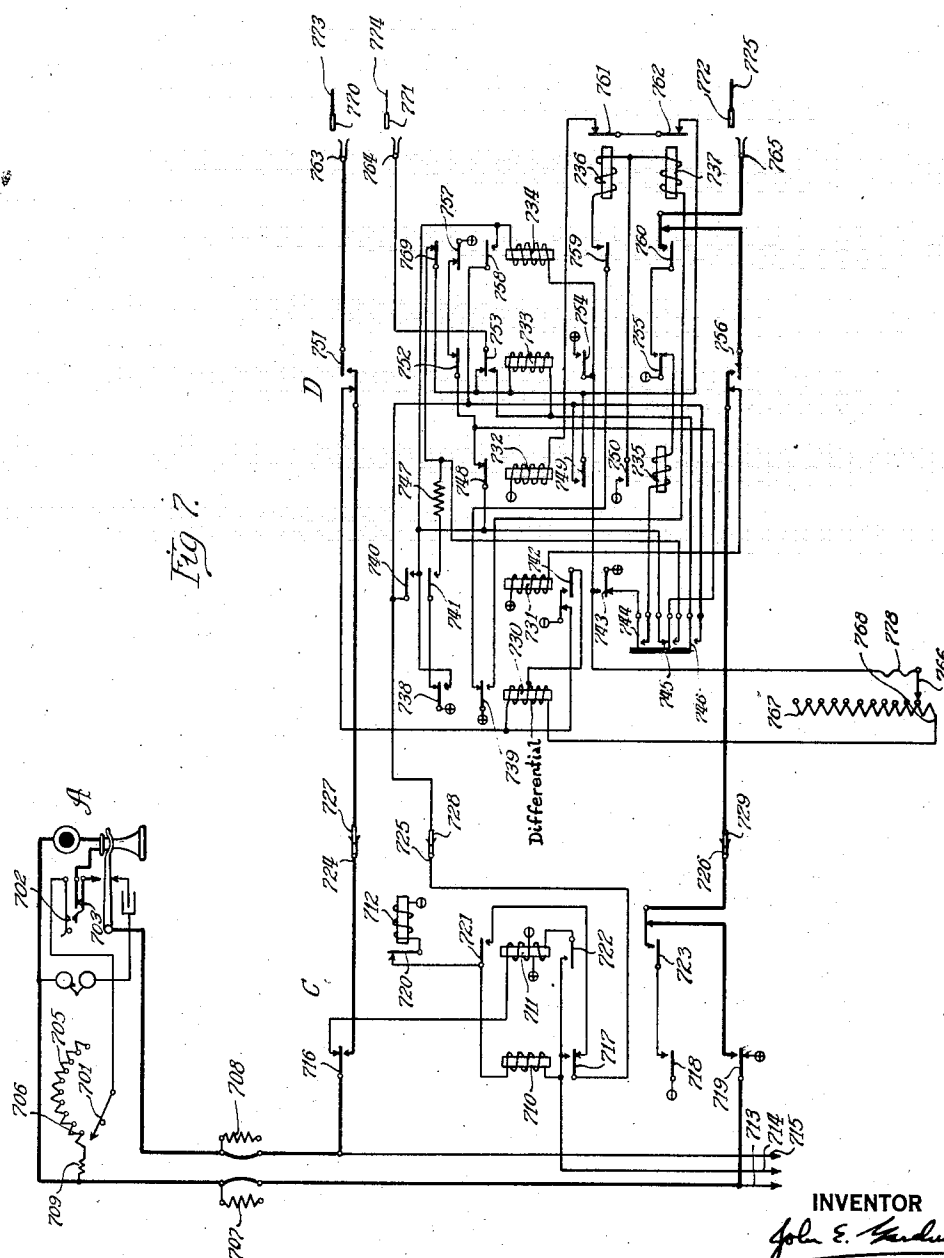
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AUTOMATIC TELEPHONE SYSTEM

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4 Sheets-Sheet 2



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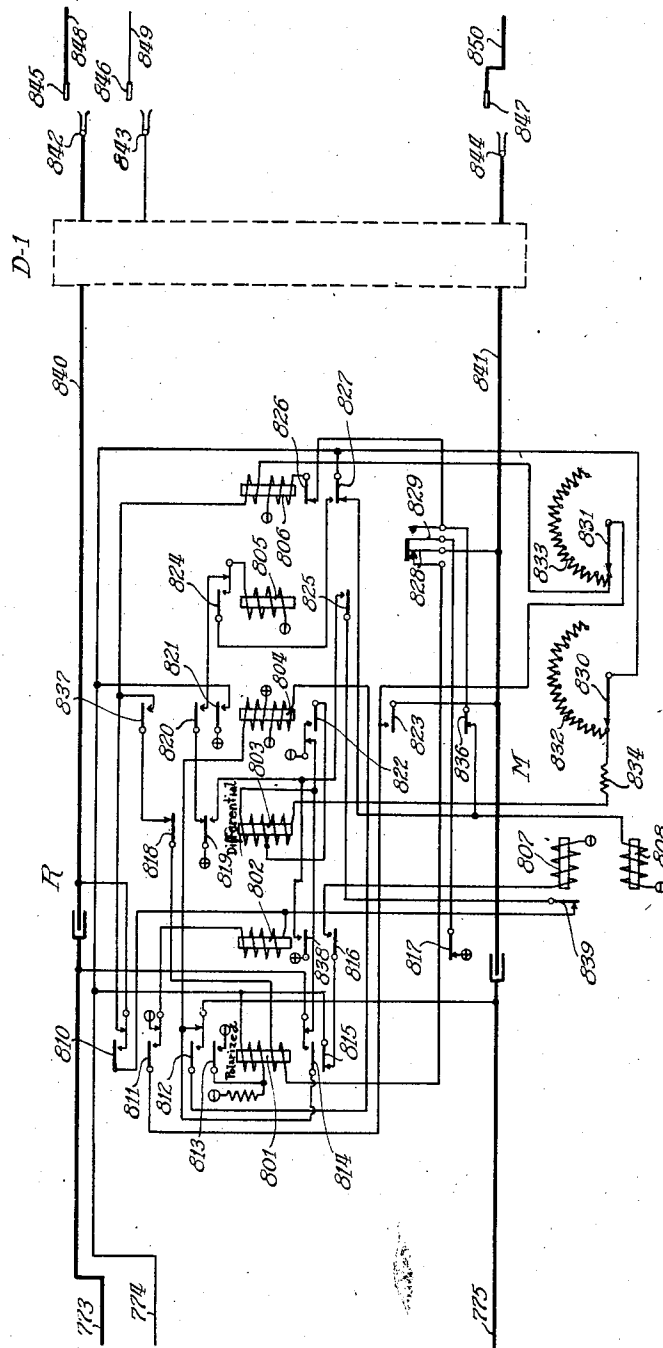
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AUTOMATIC TELEPHONE SYSTEM

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Fig. 8.



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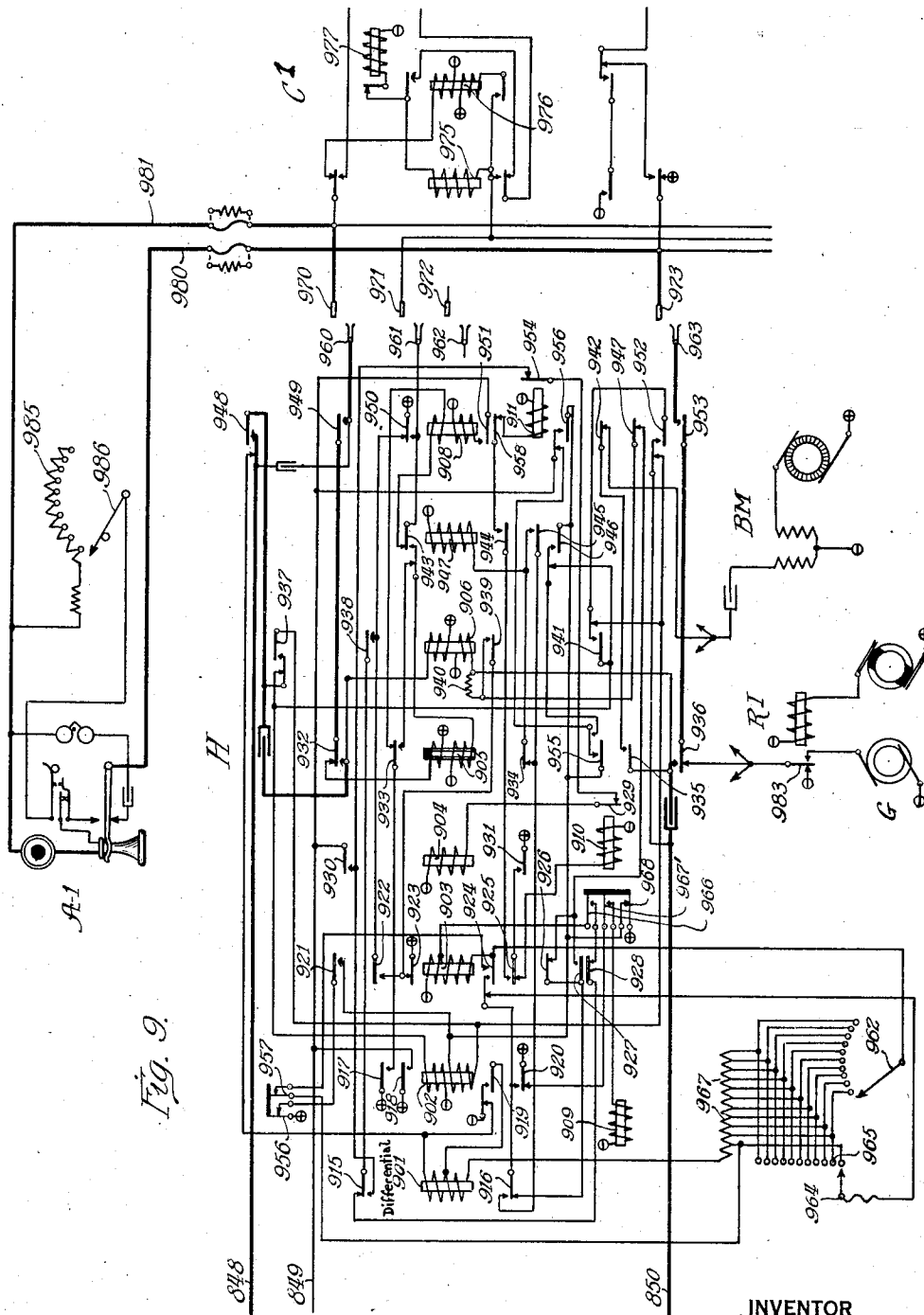
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AUTOMATIC TELEPHONE SYSTEM

Filed May 11, 1927

4 Sheets-Sheet 4



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AUTOMATIC TELEPHONE SYSTEM

Application filed May 11, 1927. Serial No. 190,397.

My invention relates in general to automatic telephone systems.

One of the objects of my invention is to provide a novel method for directly controlling the automatic switching equipment in the central exchange from the subscriber's station.

Another object of my invention is to provide means for increasing the speed at which the switching mechanism in the central office may be operated.

Another object is to provide means for directly controlling switching equipment in the central office in a more positive and efficient manner.

Another object is to provide means whereby the central office selecting switches may operate at as high a speed as their own mechanical construction and adjustment permits, to complete a connection under the control of the calling subscriber.

Another object is to provide novel means of controlling the central office switching mechanism from the subscriber's substation which will not be affected by change in line conditions such as inductive interference, or the distance of the subscriber's substation from the central office.

Another object is to do away with all slow-acting relays in the central office switching equipment and to provide a positive means of control of the switching equipment by means of quick-acting relays.

Another object is to reduce the amount of central office switching equipment needed.

Another object is to provide a novel method of directly controlling the central office switching mechanism from the subscriber's substation which is different from that employed to bring about the release of the central office mechanism.

A further object is to provide a novel method of directly controlling the central office switching mechanism from the subscriber's substation which renders it impossible for the subscriber to send a so-called preliminary impulse.

A further object is to provide a new and improved calling device for permitting or

controlling the operation of the central office equipment at a much higher rate of speed.

A further object is to provide a new and improved circuit for the subscriber's individual line switch.

Another object is to provide a new and improved circuit for the selector switches in the central office switching equipment.

Another object is to provide a new and improved repeater circuit.

Another object is to provide an improved connector circuit.

A still further object is to provide means for instantaneously releasing the switching equipment used in an established connection at the central office when the subscriber hangs up.

The most modern automatic telephone systems of the present day employ what is known as the "two wire" principle, whether the system uses the so-called Strowger switching equipment, the panel type switching equipment or relay selecting equipment, or not. The fundamental principle of this so-called "two wire" operation is timing relays.

The central office switching mechanism is operated from the subscriber's substation by the subscriber operating a calling device which produces a series of openings in the line. During this period of successive openings, a quick acting relay at the central office responds, while a slow acting relay is maintained energized. The quick acting relay serves to operate the selecting mechanism by sending out a series of impulses. A slow acting relay is maintained energized by this series of impulses. When the dial is restored to normal after one operation, the line is closed for a comparatively long period of time, the quick acting relay remains energized, and the slow acting relay, energized by the impulses sent out by the quick acting relay, is deenergized to cause the automatic trunk selecting movement of the directly controlled switch, so that the next stage of selecting operation may be performed. The switches are successively operated in this manner until the desired connection is established. After the conversation is completed, the connection is usually released by the call-

ing subscriber hanging up. This operation permanently opens the line until the next call. This opening of the line causes the quick acting relay under the subscriber's control to deenergize. A short interval of time after this deenergization, the selecting equipment is released upon the deenergization of the slow acting relay whose circuit is opened by the deenergization of the quick acting relay under the control of the calling subscriber.

Another great difficulty encountered in the practical operation of the two wire system, is the production of one or more openings of the line when the receiver at the calling telephone is removed from the switch hook. These openings cause the operation of the selecting equipment at the central office. This invariably causes a wrong number. Many attempts have been made to overcome this, the one that is used in practice involves the use of ten percent of the selecting equipment and still does not cure the difficulty entirely. The usual practice is to trunk the calls which start with the digit 1 to an operator who informs the subscriber to call again. In this case no number can be used starting with the digit 1. Not only is this method unsatisfactory, but it provides no solution of the problem where two preliminary impulses occur.

In view of the fact that the proper operation of the selecting equipment at the central office is dependent upon the functioning of fast and slow acting relays, it is highly important that these openings in the line circuit brought about by the manipulation of the subscriber's calling device be properly timed both as to duration and speed of occurrence. It is essential that the subscriber refrain from interfering with the return, or impulse producing movement of the calling device dial in any manner whatsoever.

It will be seen that any interference with this backward movement will so slow the action of the impulse sending, that the central office switching equipment will fail to operate properly. If the movement of the dial is interfered with so that the line is maintained open too long, the selecting equipment will be released. If the movement of the dial is stopped with the line closed, the trunk selecting movement of the switch occurs at an improper point. In addition, if the dial is forced in backward movement, impulses will be lost. In any of these cases a wrong number, or no number at all is obtained.

Before the advent of the two wire system, automatic telephone systems of the three wire type were in common use. The three wire principle involved the use of a ground connection at the subscriber's station. The switches at the central office are directly controlled by applying the ground connection to either one or the other of the lines leading to the subscriber's substation. The impulses are sent to directly control the

switching mechanism by successively grounding the vertical side of the lines a plurality of times. The automatic trunk selecting movement is initiated by momentarily grounding the rotary side of the line. The release of the selecting equipment is secured by grounding both sides of the line simultaneously. It will be seen that the three wire system had many advantages over the two wire system which was later adopted, since all the functioning of the selecting equipment was positively controlled. However, the difficulties arising in providing a ground connection at the telephone substation and the troubles arising therefrom, such as varying ground potentials, was great enough to overcome all the advantages of the three wire system.

As before stated, many attempts have been made to incorporate the advantages of the three wire system into the two wire system. So far as I know, all these attempts have proved unsuccessful. One of these attempts was simply to eliminate the use of the slow acting relay in the two wire system without deviating from the principle employed. This consisted in supplying condensers in the impulsing circuit of the relays which, in the two wire system, were made slow acting, but which, in this system, were quick acting. The period between the impulses was taken up by the condenser discharging into the circuit to maintain the quick acting relay energized during this interval of time.

Another attempt consists in employing a modification of the calling device which, at the end of the impulses, sends a series of high frequency impulses to which the usual quick action relay at the central office would not respond, but a special relay in circuit with it would respond. This special relay in responding initiated the trunk selecting or switch over action of the selecting equipment at the central office. This was termed the so-called "Zing impulse" system.

In another attempt the switch over was obtained by the slow acting principle above discussed, but the release was somewhat different. The subscriber's substation circuit was modified so that the calling device, instead of opening the line, simply removed the short circuit from a resistance at the subscriber's station. The usual quick acting relay at the central office was adjusted to respond to this opening of the line for removing the shunt around the resistance. However, there was another relay at the central station, which controlled the release, that was maintained energized in series with the comparatively high resistance at the station. After the connection was completed and the subscriber hung up, the line was completely opened so that this relay which was maintained operated during the impulsing would be deenergized to release the selecting equipment. This

was an attempt to eliminate the difficulty arising from the so-called "preliminary impulse".

Obviously, these attempts to obtain the advantages of the three wire system in the two wire were unsuccessful and did not go to the root of the trouble. The present invention is designed to obviate all the disadvantages of the two wire system and still to maintain a great advantage over the three wire system, that of having no ground connection at the subscriber's station. In addition, the present invention provides means whereby the central office switching equipment may be directly controlled at a much greater speed than has hitherto been the case. It also provides means for controlling the central office equipment much more positively and in a manner entirely different than that which has hitherto been employed. By the use of this principle, all slow acting relays and timing mechanism is eliminated. That principle also avoids the use of impulses and works upon one of the most efficient and accurate circuit principles that has yet been devised.

There are many other objects than those mentioned in the foregoing which, together with the above, will be described in the detailed specification which is to follow, taken in conjunction with the accompanying drawings, forming part of this specification.

While I have shown my invention applied to an automatic telephone system, it will be obvious that the selecting principle employed is equally applicable in any selecting system such as those employed in any telegraphy, supervisory control, train control and, in fact, in any selecting system where it is necessary to control the positioning of a device.

In practicing my invention, I provide a special type of calling device at the subscriber's station. This calling device is adapted to throw a certain amount of resistance in a line, depending upon the digits dialed by the subscriber. This resistance remains in the line until the dial restores to normal, whereupon it is withdrawn. Associated with the central office switching mechanism is a similar resistance. A differential relay is employed to control the operation of the switching equipment. When the subscriber removes the receiver, the usual automatic trunk selecting or line finding takes place, by which the subscriber's line is connected to a first selector. The differential relay in the first selector is connected to the line through one of its windings. When the subscriber operates the calling device, a resistance is thrown in this circuit. The other winding of the differential relay is connected to the resistor associated with the first selector switch. The introduction of resistance in the circuit of one winding of the differential relay permits this relay to operate. Thereupon, an automatic movement of the switch

occurs. As this movement takes place, resistance is introduced step by step in the circuit of the other winding of the differential relay. When sufficient resistance is introduced into the circuit of this other winding, the differential relay retracts its armature and the stepping movement of the switch ceases. The selecting switch is now in a position corresponding to the digit dialed by the subscriber. Inasmuch as this movement of the switch occurs over a circuit local to the switch and is merely controlled by the balancing action, it will occur very rapidly. It will be seen that the switches of the central office are controlled from the subscriber's station by a balancing arrangement. This is very accurate and corresponds to what might be termed a potentiometer method of control.

While in the drawings the invention has been shown and described as applied to the so-called Strowger type of automatic telephone equipment, it will be understood that it may be applied equally well to the so-called panel type, relay type, and, in fact, to all types of automatic telephone apparatus.

Referring now to the drawings, comprising Figs. 1 to 10, inclusive, sufficient apparatus and circuits have been shown by means of the usual conventional diagrams to enable my invention to be readily explained and understood.

Referring now to the drawings:—

Figs. 1 to 6 show the mechanism of my improved calling device at the subscriber's station;

Fig. 1 is a top plan view of my improved calling device;

Fig. 2 is a medial cross-section of the same;

Fig. 3 is a section along line 3—3 of Fig. 2 looking in the direction of the arrows showing certain mechanism that has to do with the backward movement of the calling device dial;

Fig. 4 is a section along the line 4—4 of Fig. 2 looking in the direction of the arrows showing the manner in which the resistance is cut into the line;

Fig. 5 is a detail section along the line 5—5 of Fig. 3, looking in the direction of the arrows and showing the so-called shunt springs;

Fig. 6 is an enlarged cross section along the line 6—6 of Fig. 4 showing certain details of construction;

Figs. 7, 8 and 9 show the necessary circuits to illustrate the operation of the apparatus.

Fig. 10 is a diagrammatic view of the subscriber's telephone substation circuit;

In Fig. 7 the substation A is of the type shown diagrammatically in Fig. 10.

The line switch C is of the usual rotary type, being provided with three wipers 724 to 726, inclusive, each adapted to engage a series of 25 bank contacts, such as 727 to 729, inclusive. The line switch C is provided

with the usual type of switching relay 710, line relay 711 and motor magnet 712. A special type of line relay 711 is provided having a low resistance lower winding which is adapted to maintain the relay energized in series with the relay 710 and motor magnet 712. The wipers 724 to 726, inclusive, are adapted to be advanced by the operation of the motor magnet 712 upon its deenergization. The motor magnet 712 interrupts its own circuit and operates as a buzzer, to advance its wipers into engagement with the bank contacts associated with an idle trunk.

The selector switch D is one of a plurality of such switches accessible to the individual subscriber's line switches, such as C. The selector D is of the usual Strowger type having a directly controlled vertical movement and an automatic rotary trunk selecting movement. The selector switch is provided with wipers 763-765, inclusive. These wipers are adapted to be moved vertically by the operation of the vertical magnet 737 and are adapted to be rotated into engagement with the bank contacts, such as 770 to 772, inclusive, the terminals of an idle trunk in the level selected, by the rotary magnet 736. In addition to the usual wipers 763 to 765, inclusive, the selector is provided with a vertical wiper 766. This wiper is adapted to be operated into engagement with vertical bank contacts, such as 768. There is one such vertical bank contact for each level of the switch. The vertical bank contacts are connected to a resistor 767 that is similar to the resistor 705 in the substation A. The vertical bank contacts are connected to the resistor 767 in such manner that the first vertical bank contact is connected to the same corresponding point in the resistor 767 that the bank contact, such as 706, in the subscriber's station, such as A, is connected to. The selector switch D is adapted to be released by the operation of the release magnet 735. For controlling the selector switch such as D, relays such as 730 to 734, inclusive, are provided. The relay 730 is of the differential type. Relay 731 is a quick acting release relay. Relay 732 is an interrupter relay. Relay 733 is a switching relay, and the relay 734 is a controlling relay.

The trunk lines accessible to the selector switch D may terminate in second selectors or in connectors, depending upon the size of the system. If the trunk lines terminate in second selectors and there is more than one exchange in the system, certain of these trunk lines lead to repeaters in order that two wire trunk lines may be used for interconnecting the various exchanges.

In the present case, the trunk line leading from the bank contacts 770 to 772, inclusive, extend by way of the conductors 773 to 775, inclusive, to the repeater R (Fig. 8). Repeater R comprises the relays 801 to 806, in-

clusive. The relay 801 is an electropolarized relay having an upper polarizing winding and a lower low resistance winding for operating the relay. The upper winding of the relay 801 is connected to battery in series with a fairly high resistance. The operation of the relay is such that the relay will not attract its armature until the current flow in both windings is in the same direction. When the current flow is in the same direction, the relay is energized. Upon energizing, the relay is adapted to cut out the resistance in series with its polarizing winding. The relay 803 is a differential control relay. The relay 804 is adapted to supply battery to the calling line. The relay 806 is a differential relay. There is a minor switch such as M associated with each repeater such as R. The minor switch M is of the usual construction having two wipers 830 and 831, each adapted to engage in their rotation a series of ten bank contacts. The wipers of the minor switch are adapted to be rotated by the stepping magnet 807 and released by the operation of the release magnet 808. There is a resistor 832 connected to the various bank contacts accessible to the wiper 830 so as to provide for a variation in resistance in the circuit of the lower winding of the differential control relay 803 corresponding to the change in resistance occasioned in the circuit of the upper winding by the operation of the calling device. Similarly, there is a resistor connected to the bank contacts accessible to the wiper 831 so that movement of this wiper may control the selecting mechanism in the distant exchange in the same manner as if the switching mechanism were controlled from a calling subscriber's telephone.

The trunk line comprising conductors 840 and 841 extending from the repeater R terminates at another exchange in an incoming selector D¹. This selector has a circuit that is similar to the selector D and is of the usual Strowger type. The second selector D¹ has access to the trunk lines leading to connector such as H (Fig. 9).

The connectors, such as H, are of the usual vertical and rotary type. The connector H is provided with vertical and rotary magnets 910 and 911 and a release magnet 909. The vertical and rotary magnets are adapted to operate the wipers 960 to 963, inclusive, first in a vertical and then in a rotary direction. The connector switches H are also provided with vertical wipers such as 964. These wipers are adapted to engage a vertical bank of ten contacts, such as 965. In addition, all the connector switches have an extra wiper, such as at 962, for controlling the rotary movement of the switches. This wiper and the associated bank contacts are identically the same as those employed on the so-called rotary connectors manufactured by the Automatic Electric Co. A resistor, such

as 967, is connected to the vertical bank contacts in the manner shown, and to the rotary bank contacts, corresponding rotary contacts at various levels are multiplied together. The connector switches H are provided with relays, such as 901 to 908, inclusive, of the usual telephone type. The relay 901 is a differential relay. The relay 902 supplies talking battery to the calling line. The relay 903 is what is known as a two-step relay. When the upper winding of the relay 903 is energized, only the armatures 923, 924 and 926 are operated. When both the upper and lower windings of the relay 903 are energized, all the armatures of this relay are operated. The relay 904 is an interrupter relay. The relay 905 is a ring cut-off relay. The relay 906 is a back bridge relay for supplying talking battery to the called line. This relay is also adapted to attract its armatures when its lower winding is energized in series with the resistance 940. The relay 907 is a busy control relay. The relay 908 is a switching or cut-in relay.

The connector switch H has access to called subscribers' lines, such as the line of the subscriber at the substation A¹. The substation A¹ is similar to the substation A previously described. The line switch C¹ is the called subscriber's line switch and is similar to the line switch C previously described.

The calling subscriber is supplied with a busy tone from the busy machine BM in the event that the called line is busy, while the called subscriber's substation is rung intermittently by the ringing current furnished by the ringing equipment RI. These devices are of the usual type and need not be described in detail.

Referring now to Figs. 1 to 6, inclusive, and Fig. 10, I shall now describe the novel calling device adapted for use in my improved system. Like reference characters in the various figures refer to similar parts.

The novel calling device consists of the usual base plate 10, finger hold dial 11 carrying on its underneath side a pawl 12 adapted to engage the crown ratchet 13 that is adapted to operate the usual governor mechanism 14 through the gears 15, 16 and 17. The above mentioned elements of the calling device are old and operate in identically the same manner as in the commercial calling device manufactured by the Automatic Electric Company of Chicago. A finger stop 18 is mounted upon a shaft 19 by a boss 9. The shaft 19 is supported between the base plate 10 and a subbase plate 20. The subbase plate 20 is held in spaced relation to the base plate 10 by means of bolts 25, 26 and 27 passing through holes in the periphery of the subbase plate and the hollow spacers 21, 22 and 23 and threaded into holes in the base plate 10. Mounted below the subbase plate 20 is a series of ten bank con-

tacts 24, these bank contacts are of the usual construction and may be mounted on a fairly thick circular insulating ring 8 by means of screws. The bank contact assembly is held in spaced relation with respect to the subbase plate by passing the bolts 25, 26 and 27 through holes 28, 29 and 30 in the insulating ring 8. The shaft 31 has an enlarged end spacing portion 6 and is attached to the dial 11 by means of the screw 7. The shaft 31 extends at its lower end into a recess 33 in the shaft 34. The upper portion of the shaft 34 is screwed into the centering or locking cam 35 which is provided with the shoulders 36 adapted to rest against the base plate 20 under tension of a spring 37, one end of which is attached to the subbase plate 20 and the other end to the shaft 34. The lower end of the shaft 34 is threaded to receive the wiper mounting carrying the wiper 38. The wiper 38 is insulated from the shaft 34 in any well known or approved manner. This wiper may be adjusted by moving the nuts 39 on the threaded end of the shaft 34, whereby the whole wiper assembly is moved up or down. The wiper 38 is adapted to engage the bank contacts 24 when rotated. The wiper is so positioned with respect to the bank contacts that, when the dial is operated for the digit 1, the wiper is moved into engagement with the first bank contact. A releasing member 40 is attached to the shaft 31 by means of a boss 41. The rotatable shaft 19 and the finger stop 18 carries an arm 44 that is adapted to operate the spring 45 to open the contacts 47 and to close the contacts 46; this latter operation performs certain functions in telephone substation circuit as will appear. The spring member assembly is mounted in position on the base plate by two screws 49. The whole spring assembly is, of course, insulated from the base plate in any well known or proved manner. The shaft 19 carries an arm 50 that is adapted to operate the centering pawl 52 through the link member 51. The centering pawl 52 is pivoted at 53 and is normally held in its inoperative position by the spring 54. When the shaft 19 is rotated the pawl 52 is adapted to engage the centering wheel 35. A number of notches 55 are cut in the periphery of this centering wheel. These notches are ten in number, corresponding to the ten positions of the calling device dial. When the shaft 19 is rotated by the operator's fingers striking the stop 18, the pawl 52 is adjacent to one of these notches and is forced into engagement therewith. This action serves to center the wiper 38 in engagement with the proper bank contact. The centering wheel 35 is rotated when the shaft 31 is turned by the member 40 engaging a pin 55 imbedded in the wheel 35. The movement of the wheel 35 causes the rotation of the wiper 38 and the tensioning of the spring

37. The pawl 52 is held in this operated position by the toggle mounting of the spring 54. Thus the wheel 35, as well as the wiper 38, are locked in their proper positions until the dial restores to normal, whereupon, the member 40 engages the end of the pawl 52 and it is released from its locking position. The centering wheel 35 is permitted to restore to normal under the action of the spring 37. Restoration of the centering wheel 35 also brings about release of the wiper 38 as they are mounted together.

Having described the mechanical construction of my calling device, I will now explain the manner in which the various elements function when the calling device is operated. In order to do this, it will be assumed that the subscriber desires to operate his calling device in accordance with the digit 5. The subscriber, therefore, places his finger in the finger hole marked 5 and brings it forward until his finger reaches the finger stop, whereupon, he withdraws the finger and permits the calling device dial to restore to normal position. During the forward movement of the calling device dial 11 the pawl 12 rides over the surface of the crown ratchet and this ratchet remains stationary. The shaft 31 attached to the dial 11 is, of course, rotated, thereby tensioning the spring 32. The arm 40 engages the member 55 attached to the centering wheel 35 and the centering wheel 35 is thereby rotated, carrying the wiper 38 into engagement with the fifth bank contact. The movement of the member 40 also permits the locking member or pawl 52 to be operated when the shaft 19 is rotated by the finger of the calling subscriber engaging the finger stop 18. When this occurs the pawl 52 is forced into engagement with the fifth notch in the centering wheel 35 whereby wiper 38 is centered into engagement with the fifth bank contact. The locking pawl 52 is held in this position by the action of the spring 54. The rotation of the shaft 19 also causes the movement of the member 44 from engagement with the spring 45, whereby this spring is permitted to engage the spring 46 and break the electrical connection previously existing between the spring 47 and the spring 46. This operation serves to open the transmitter and receiver circuit in the telephone substation.

When the calling subscriber removes his finger from the finger hold, the dial 11 is free to return to normal under the influence of the spring 32. The pawl 12 now engages a tooth in the crown ratchet 13 and turns this ratchet which in turn operates the governor through the gears 16 and 17. In the present instance the governor does not slow down the dial very materially. It is only provided to prevent the dial 11 from snapping back rapidly and causing injury to the equipment. Inasmuch as the centering wheel 35 is locked

by the pawl 52, the wiper 38 remains in engagement with the fifth bank contact since the shaft 31 is revolving in the opposite direction the member 40 has no connection with the locking wheel 35. Just before the dial reaches its normal position the member 40 strikes the end of the pawl 52 and withdraws it from engagement with the locking wheel 35, thereby permitting this wheel, together with the shaft 34, to restore to normal, thus carrying the wiper 38 to its normal position. The pawl 52 is maintained in its normal position by the action of the spring 54. The shaft 19 is rotated to its original position at this time and maintained there by the action of the spring 54; the rotation of the shaft causes the member 44 to operate the spring 45 to its original position, whereby the telephone substation circuit is restored to normal. Substantially the same operation occurs when any other digit is dialed.

It will be noted that the function of the calling device briefly is to position the wiper 38 in engagement with the proper bank contact at the end of its forward movement and permit it to remain there until the completion of its backward movement. The wiper 38 is locked in engagement with the proper bank contact until the dial 11 is restored to normal. Thus, so far as the operation is concerned, the calling subscriber may interrupt the backward rotation of the dial, bring it forward, or force it backward all without causing any different operation of the calling device. If the subscriber holds the dial from returning, the wiper 38 remains positioned until he does permit it to restore. If he moves the dial forward and attempts to rotate it beyond the point at which it is set, he cannot because the wiper is locked. Therefore, nothing the subscriber can do without actual violence can affect the prescribed operation of the calling device. The manner in which the circuit is designed prevents any false operations occurring under the above conditions and permits the proper number to be obtained in spite of it. This will appear fully hereinafter.

In Fig. 10 I have shown a diagrammatic view of a telephone substation equipped with my improved calling device. This substation consists of the usual transmitter 75, receiver 76, bell 77, ringing condenser 78, and hook switch 79. The calling device is of the type just described. The wiper and bank contacts and springs for controlling the telephone substation circuit only have been shown. It will be seen that the bank contacts are connected to a resistor 80. Thus, when the wiper is operated into engagement with a bank contact, a certain amount of resistance is placed into the line circuit. The points on the resistor to which the bank contacts are connected are determined by the average resistance of the line. Another determining factor is the

amount of current that the differential relay will be operated by. These factors will be discussed more fully in the detailed circuit description, which is to follow.

5 While in the drawings positive + and negative - signs have been used to indicate the battery connections, it will be understood that + indicates the usual ground connection, while - indicates the usual negative battery connection.

10 Referring now more particularly to Figs. 7, 8 and 9, a detailed description of the operation of my improved telephone system will be given. For this purpose, it will be assumed that the subscriber at substation A desired to call the subscriber at substation A¹. In order to do this, the subscriber at substation A will remove his receiver from the switch hook and will operate his calling device dial in accordance with the digits of the called subscriber's number.

When the receiver at substation A is removed from the switch hook, there is a circuit completed that extends from ground by way of back contact and armature 719 over one conductor of the line, transmitter and receiver of substation A, spring 703 of the control springs, switch hook springs, the other conductor of the line, armature 716 and its back contact, and the upper winding of line relay 711 to battery. The line relay 711 is energized to complete a circuit that extends from ground through its lower low resistance winding, relay 710, back contact and armature 720, and motor magnet 712 to battery. The operation of the relay 711 also serves to establish a shunt circuit for the one previously traced for relay 710 which extends from the test wiper 725 by way of armature 717 and its back contact, front contact and armature 721, to a point midway between the motor magnet and the switching relay 710. Another result of the operation of the relay 711 is that at armature 723, a circuit is prepared for energizing a relay in the selector switch, such as the relay 731, in the selector D.

When the relay 711 is energized, if the wipers 724 to 726, inclusive, are standing in engagement with bank contacts associated with an idle trunk, the relay 710 is immediately energized in series with the motor magnet 712. Because the relay 710 is of relatively high resistance with respect to the motor magnet 712, the latter is not operated in this circuit. In the event that the wipers 724 to 726, inclusive, of the line switch C are not in engagement with the bank contacts of an idle trunk, there will be a ground potential on the bank contact that is engaged by the wiper 725 and the relay 710 will be short circuited and the motor magnet 712 will operate as a buzzer to advance the switch wipers 724 to 726, inclusive, into engagement with the bank contacts associated with an idle trunk. It will be assumed that the bank contacts 727

to 729, inclusive, are the contacts of an idle trunk accessible to the line switch C. Then, when the switch wipers are rotated into engagement with the bank contacts, the relay 710 will be energized over the circuit previously described. The relay 710, upon operating, opens a point in the circuit of the motor magnet 712 at armature 717, places ground upon the bank contact 728 at the front contact of this armature, completes a circuit for the relay 731 in the selector D at armature 718, opens the circuit of the upper winding of the relay 711 at armature 716 and 719 and at the front contacts of these armatures extends the conductors of the calling line to the selector switch D. It will be noted that the bank contact 728 is grounded over a circuit that extends from ground through the lower winding of the relay 711, front contact and armature 717, wiper 725 and bank contact 728. This circuit serves to busy the selected trunk line, so that it is no longer accessible to the individual line switches such as C through its multiples.

The relay 731 in the first selector switch D is energized over a circuit that extends from ground, relay 731, normally closed springs controlled by armature 756, bank contact 729, wiper 726, front contact and armature 723, and front contact and armature 718 to battery. The relay 731 in the selector switch D is operated over this circuit to complete a circuit that extends from ground by way of armature 757 and its back contact, back contact and armature 752, off normal spring 745 and its resting contact, front contact and armature 740 to the release trunk conductor. The connection of ground to the release trunk conductor serves to short circuit the lower winding of the relay 711 in the line switch, and this relay deenergizes to open another point in the circuit of the motor magnet 712 at armature 721, to open a point in the circuit of the relay 710 at armature 722, and to open one point in the circuit of the relay 731 at armature 723, and to establish another circuit for this relay at the normally closed springs controlled by this armature.

It will be noted that when the line relay 711 in the line switch C energized, ground is applied through its lower winding to the private normal conductor 714 to busy the terminals of the calling line in the banks of the connector switches which have access to it.

The relay 731 is maintained energized when the relay 711 deenergizes over a circuit that extends from ground relay 731, normally closed springs controlled by armature 756, bank contact 729, wiper 726, normally closed springs controlled by armature 723, front contact and armature 719, calling subscriber's line, armature 716 and its front contact, wiper 724, bank contact 727, normally closed

springs controlled by armature 751, upper winding of differential relay 730, and armature 742 and its front contact to battery.

The results of the operation of the relay 731 are: that at armature 741 a circuit is completed that extends from ground by way of armature 738 and its back contact, armature 741 and its front contact, resistance 747, back contact and armature 769, back contact and armature 762, armature 761 and its back contact, and relay 732 to battery; to connect the battery to the midpoint of the differential relay 730 at armature 742, to open one point in the release circuit at armature 743 and to connect ground to the vertical wiper 766 at the front contact of this armature. The relay 732 is energized to open a point in the ground connection to the release trunk at armature 748, to establish a locking circuit for itself at armature 749, and to complete a point in the circuit of the vertical magnet 737 at armature 750. All these operations occur responsive to the removal of the receiver from the switch hook at the calling substation.

In automatic telephone systems the voltage of the battery is usually maintained between 46 and 52 volts. In order that the operation of my invention may be more readily understood and explained, it will be assumed that the voltage of the battery at the main exchange is 100 volts. It will be understood, of course, that any desired voltage may be employed.

For the best operation of the system, it is desirable that the resistance of the subscriber's lines, in any given exchange, be substantially alike. This result may be obtained by the insertion of a resistance in the subscriber's line at the main exchange so that the resistances of the shorter lines may be brought up to substantially the same as those of the longer lines. This is not altogether essential, as will appear from a consideration of the invention in the subsequent description. All that is necessary is that the difference in resistance between the shortest and the longest lines be considerably less than the change in resistance made by the steps of the calling device. For the moment, we will disregard the resistance of the line. The resistance of the upper and lower windings of the differential relay in the selector switches, such as D, will be assumed to be 250 ohms each. The resistance of the windings of the relay 731 in the various selectors will also be assumed to be 250 ohms. Thus, when the receiver is removed at the calling station, there will be 500 ohms in series with the battery in addition to the resistance of the line and the transmitter and receiver at the calling substation. The maximum current flow in milliamperes over any line will, therefore, be 200 milliamperes. The amount of resistance that can be used in the calling device

depends upon the sensitivity of a differential relays, such as 730. In the present instance I have assumed that a change in current flow in one winding of the differential relay of 10 mills will be sufficient to maintain the armature of the relay attracted. Obviously, this is a very simple matter, for, with the differential relay energized, there is a closed magnetic circuit, and only a fraction of the current flow is necessary in its windings to maintain the armature attracted of what would be required to originally attract the armature.

In view of the fact that the more resistance there is in any circuit, the greater the amount of resistance that will have to be thrown into the circuit to bring about a constant current change which, in this instance, is desired to be 10 milliamperes. It is therefore preferable to work with as much resistance in a line, as possible, so as to make the system immune to any change in line conditions. Under the above conditions, it will be found that if the total resistance of the line and the resistance included for the digit 0 is 5000 ohms, there will be 20 milliamperes of current flowing in the line circuit. For 30 milliamperes of current in a line circuit, the total resistance of the line and relays will be 3332 ohms; for 40 milliamperes current flow, the resistance will be 3000 ohms; for 50 milliamperes current flow, 2600 ohms; for a 60 milliamperes current flow, 1666 ohms; for 70 milliamperes current flow, 1428 ohms; for an 80 milliamperes current flow, 1250 ohms; for 90 milliamperes current flow, 1110 ohms; for 100 milliamperes current flow, 1000 ohms; and for 110 milliamperes current flow, 908 ohms.

If we assume that in the exchange under discussion the resistance of the average line is substantially 200 ohms, then we have the figure of 700 ohms for the combined resistance of the upper winding of the differential relays, such as 730, and for the relays, such as 731, plus the line resistance of 200 ohms. Now, if we deduct 700 ohms from the various resistances given above, we will have the point on the resistor to which the various contacts of the calling device bank must be connected. Below is a table giving the points on the resistor for the calling device:—

For digit 1 bank contact 1 is connected to the resistor at a point where 208 ohms are thrown in a line.

	Ohms	
2	300	
3	410	
4	550	
5	728	125
6	966	
7	1900	
8	2300	
9	2632	
0	4300	130

It is possible to disregard the line resistance in considering the operation of the circuit as a compensating line resistance is inserted in the circuit of the lower winding of the differential relays, such as 730. This will be described a little later.

From the foregoing, it will be seen that for each position of the calling device, a certain amount of resistance is thrown into line sufficient to cause a current variation in the line circuit of 10 milliamperes for each successive position.

The principle of selection employed depends upon the changes or variations in the conductivity of the circuit causing changes in current flow. It is obvious that by changing any electrical characteristics of a circuit in definite order, it is possible to control selecting apparatus as desired. However, it is well known that a change in conductivity is the most satisfactory manner of controlling a device such as a telephone switch so the present principle has been employed. It will be obvious after an understanding of the present invention is had how the desired results may be obtained by varying any other electrical characteristic or characteristics of the line circuit such as the impedance, capacitance, and inductance or reactance, and providing means in the central office switching equipment to respond to such variations either by balancing, as in the present case, or measuring the change in the characteristic and controlling the selecting device in accordance with the value measured.

In the description of the progress of the present call, it will be assumed that the calling subscriber operates his calling device in accordance with the number of the called subscriber at substation A¹, and it will be assumed further that this number consists of the digits 5432.

When the calling device is operated in accordance with the first digit 5, the wiper 701 of the calling device is placed in engagement with the fifth bank contact, whereupon, when the shunt springs 702 and 703 are operated, the transmitter and receiver are disconnected from the calling line circuit, and a certain amount of resistance is thrown in the line. In this instance, 728 ohms.

Referring now to the operation of the selector switch D, when the relay 731 energized it completed a circuit for the upper and lower windings of the differential relay 730 at armatures 742 and 743. The operation of the relay 731 takes place immediately upon the selector D being seized by the line switch C. Inasmuch as this occurs with the line relay 711 in the line switch energized, there is no circuit completed for the upper winding of the differential relay 730, and the differential relay 730 is energized through its lower winding. However, its operation under these conditions is without function, except to open the

circuit of the relay 732 at armature 728. When the line relay 711 is deenergized, a circuit is completed for the upper winding of the differential relay, which serves to balance the current flow through its lower winding, and permits the retraction of the armature 738 to complete the previously traced circuit for the relay 732. The resistor 778 of the selector switch D serves to balance the resistance of the calling line and that of the transmitter and receiver.

Now, when the calling device is operated in accordance with the digit 5, the transmitter and receiver at the substation A is cut out of the line circuit as before described. To compensate for the removal of the resistance of the transmitter and the receiver, the resistance 709 is substituted in series with the resistor 705 that is connected to the various bank contacts. With the values of line resistance assumed, there are 70 milliamperes of current flowing through the line and the upper winding of the relay 730 at this time. In the lower winding of the differential relay 730, there are approximately 143 milliamperes of current flowing. The relay 730 therefore operates to attract the armature 738 and 739. By the operation of the armature 738 a point in the circuit of the relay 732 is opened, while at the front contact of the armature 738 there is a circuit established for making another ground connection to the release trunk. By the operation of the armature 739, a point in the circuit of the rotary magnet 736 is opened, while, at the front contact of this armature, there is a circuit completed that extends from ground by way of said armature and its front contact, vertical magnet 737 and front contact and armature 750, to battery. The vertical magnet 737 is energized to raise the switch shaft, carrying vertical wiper 766 and the wipers 763 to 765, inclusive, opposite the first level of bank contacts. The operation of the vertical magnet 737 also interrupts the locking circuit of the relay 732 at armature 762. The relay 732 is deenergized to open another point in its locking circuit at armature 749, and to open the circuit of the vertical magnet at armature 750, and to complete a point in the ground connection to the release trunk at armature 748. The vertical magnet 737 will be energized to position its pawl and to complete a circuit at armature 762 for the relay 732. This circuit extends from ground by way of armature 757 and its back contact, back contact and armature 752, off normal spring 745 and its working contact, back contact and armature 762, armature 761 and its back contact, and relay 732 to battery.

Upon the first vertical movement of the switch shaft, the off normal springs are shifted and one ground connection is removed from the release trunk, though ground is still maintained connected thereto by way of armature 738 and its front contact. Upon

the first vertical step of the switch, the vertical wiper 766 is shifted into engagement with the second vertical bank contact. By this operation, a certain amount of resistance is placed in the circuit of the lower winding of the differential relay 730. The value of this resistance is equal to the value that is placed in the circuit of the upper winding of the relay 731 by the operation of the calling device at the calling station in accordance with the digit 1, whereby the wiper 701 is operated into engagement with the first bank contact. This is not sufficient to balance the differential relay 730 and it remains energized.

The relay 732, upon operating, again completes a locking circuit for itself at armature 749, and at armature 750 completes the circuit of the vertical magnet over a path that extends from ground by way of armature 739 and its front contact, vertical magnet 737, and front contact and armature 750 to battery. The vertical magnet 737 is operated to advance the switch shaft carrying the switch wipers 763 to 765, inclusive, opposite the second level of bank contacts. The vertical wiper 766 is also shifted into engagement with the third vertical bank contact. By the latter operation more resistance is inserted into the circuit of the lower winding of the differential relay 730,—in this case 300 ohms. This is not sufficient to balance the relay and the differential relay remains operated.

The vertical magnet, upon operating, also opens the locking circuit of the interrupter relay 732 at armature 762. The interrupter relay 732 is deenergized to open a point in its locking circuit and to open the circuit of the vertical magnet 737, which deenergizes. In this manner, the interrupter relay 732 and the vertical magnet 737 operate alternately until the switch wipers 763 to 765, inclusive, are advanced opposite the fifth level of bank contacts. When this occurs, the vertical wipers 766 will be in engagement with the sixth vertical bank contact.

With the vertical wiper in this position, 728 ohms resistance are inserted in series with the circuit of the lower winding of the differential relay 730. Under these conditions, the same amount of current is flowing in both the upper and lower windings of the differential relay 730, and this relay is balanced, and, therefore, immediately retracts its armatures 738 and 739. By the operation of the armature 739, the circuit of the vertical magnet 737 is opened, and the vertical movement of the switch cases. The interrupter relay 732 is energized, of course, over the circuit through the off normal spring 745 previously traced.

By the release of the armature 738 of the differential relay 730, the direct ground connection is removed from the release trunk. There is a ground connection to the release trunk to maintain the relay 710 in the line

switch C energized over a path that extends from ground by way of armature 743 and its front contact, relay 734, and front contact and armature 740 to the release trunk. The relay 734 is therefore energized. This relay has not been previously energized because it has been short circuited by the ground through armature 738 and its front contact. In order to insure that the relay 732 is operated before the relay 734 is energized, there is a short circuiting ground connection to the release trunk that extends from ground by way of armature 757 and its back contact, back contact and armature 752, back contact and armature 748, and front contact and armature 740. The relay 734 is energized to open another point in this short circuiting ground connection at armature 757, to open one point in the circuit of the relay 732 at armature 769, to establish a locking circuit for itself at armature 758 exclusive of the armature 740 and its front contact, to prepare a point in the circuit of a relay corresponding to relay 731 in the next succeeding switch at armature 760, and to complete a circuit for the rotary magnet 736 at armature 759 over a path that extends from ground by way of armature 739 and its back contact, armature 759 and its front contact, rotary magnet 736 and armature 750 and its front contact to battery.

The rotary magnet 736 is immediately energized over this circuit and operates to rotate the switch wipers one step. In addition, the rotary magnet 736 opens the circuit of the interrupter relay 732 at armature 761. This relay is therefore deenergized to open a point in the circuit of the rotary magnet. The rotary magnet is also deenergized.

If the wipers 763 to 765, inclusive, are in engagement with the bank contacts of an idle trunk, the switching relay 733 is energized. However, it will be assumed that the wipers are in engagement with a busy trunk. In this event, there will be a ground potential present upon the private bank contact that is engaged by the private wiper 764. A circuit will therefore be completed from ground by way of the private wiper 764, armature 753 and its back contact, back contact and armature 762, armature 761 and its back contact, and interrupter relay 732, to battery. The interrupter relay 732 is immediately energized to establishing a locking circuit for itself at armature 749, and to complete a circuit for the rotary magnet 736 at armature 750. The rotary magnet 736 is energized to rotate the switch wipers another step and to open the circuit of the interrupter relay 732 at armature 761. The interrupter relay is deenergized to open the circuit of the rotary magnet. The interrupter relay 732 and the rotary magnet 736 continue to operate alternately until the wipers 763 to 765, inclusive, engage the bank contacts associated with an idle trunk.

It will be assumed that the bank contacts 770 to 772, inclusive, are the bank contacts associated with an idle trunk. Under these conditions when the wipers of the selector switch D engage these bank contacts, there will be no ground present upon the bank contacts 771 with which the private wiper 764 is in engagement. Under these conditions there is a circuit completed for the switching relay 733. The circuit for energizing the relay 733 extends from the ground by way of armature 743 and its front contact, relay 734, front contact and armature 758, working contact of off normal spring 746 and said spring, relay 733, back contact and armature 762, armature 761 and its back contact, and relay 732 to battery. The relay 733 is energized over this circuit though the relay 732 remains deenergized. This is true because of the relative high resistance of the winding of the relay 733. Upon operating, the relay 733 opens a point in the circuit of the release magnet 735 at armature 755 to close a maintaining circuit for itself at armature 754 to make its own circuit independent of the deenergization of the relay 731, to prepare a holding circuit for itself at armature 753, to open a point at the previously mentioned shunting circuit at armature 752, to open the circuit of the relay 731 and the upper winding of the differential relay 730 at armatures 751 and 756 and to extend the conductors of the calling line to the repeater R which has been selected by the trunk selecting operation of the selector D.

The relay 731 is deenergized to open the circuit of the differential relay 730 at armature 742, to open one point in the circuit of the relay 733 at armature 743, and to prepare a release circuit at the back contact of this armature.

When the calling line is extended to the repeater R in the manner described, there is a circuit completed for the relay 804 over a path that extends from ground through the upper winding of said relay, normally closed springs controlled by armature 812 of relay 801, trunk conductor 775, bank contact 772, wiper 765, front contact and armature 760, and armature 755 and its front contact to battery. Relay 804 is energized over this circuit and operates to place ground upon the release trunk conductor 774. The grounding of release trunk conductor 774 establishes a circuit for the relay 733 in the selector switch D and for the relay 710 in the line switch C exclusive of the ground connection supplied through the relay 734. The relay 734 is thus short-circuited and deenergizes. The relay 734 is deenergized to open its locking circuit at armature 758, to open a point in the circuit of the rotary magnet 736 at armature 759, to open the previously traced circuit for the relay 804 at armature 760, and to establish

another circuit for this relay at its normally closed springs over a path that extends from ground, upper winding of relay 804, normally closed springs controlled by armature 812, trunk conductor 775, bank contact 772, normally closed springs controlled by armature 760, armature 756 and its front contact, bank contact 729, wiper 726, normally closed springs controlled by armature 723, front contact and armature 719, over the calling line, armature 716 and its front contact, wiper 724, bank contact 727, front contact and armature 751, wiper 763, bank contact 770, trunk conductor 773, normally closed springs controlled by armature 814, upper winding of differential relay 803, armature 822 and its front contact to battery. The relay 804 is maintained energized over this circuit.

It will be seen that the directly controlled movement of the vertical magnet 737 takes place under the control of the differential relay 730. The vertical magnet 737 is operated together with relay 732 over a local circuit to raise the switch shaft vertically. It will be appreciated that this vertical movement takes place very rapidly and is only limited by the mechanical construction and adjustments of the switch. The speed of this vertical movement is comparable to the speed of a finder switch. In fact the selector switch operates in identically the same manner as a finder in both its vertical and rotary movements. Since the directly controlled speed of the selector switch is so great it is possible to adjust the calling device so that the digit constituting the number will be sent out very much more rapidly. In fact, the dial may be permitted to come back very, very rapidly. If the dial should be adjusted to a relatively slow backward movement, the selector switch may complete this vertical movement and trunk selecting movement before the wiper 701 of the calling device is restored to normal. Under these conditions, if special provision is not made, a false operation would be the result. This is true because there will be a certain amount of resistance inserted in the calling line when the next selecting device is connected with. The manner in which this is taken care of will now be described. In the event that a trunk line leading to a second selector switch is selected instead of a trunk line leading to the repeater R, the result of such procedure, if the calling device is not yet restored to normal, will be considered. This second selector will be identically the same as the selector D and we will consider the operation with respect to the selector D. When the second selector switch is seized, a relay similar to the relay 731 is energized to throw the differential relay 730 into the line circuit. If the calling device has not been restored to normal, the differential relay is energized, consequently there is no circuit for the relay 732. Until the relay, such as 732 is energized,

no vertical operation of the switch can occur. The resistance 747 is inserted in series with the relay 732 to make it slower to operate. The armature 741 is also adjusted to engage its contact after the other armatures have
 5 contacted with their front contacts so as to give the relay 730 time to operate before the circuit for the relay 732 is closed. When the calling device restores to normal the resistance is removed from the line circuit and the
 10 relay such as 730 in the second selector will retract its armature. This operation brings about the energization of the relay such as 732 in the second selector. Thereafter, the selector switch may be operated in the same
 15 manner as before described with respect to the operation of the selector switch D. Thus, should the selector such as D select the next switch before the dial of the calling device has restored to normal, no false operation of
 20 the selected switch will occur.

At this point it will be well to discuss the operation of the selector switch D should the calling subscriber interfere with the back-
 25 ward movement of the dial of his calling device. From the description of the operation of the calling device, it will be recalled that the only effect of interference with the return movement of the dial is to change the
 30 time period during which the resistance is placed in the line circuit. It is obvious that if the subscriber retards the return movement of the dial, the resistance placed in the line circuit by the calling device remains there
 35 until the dial is permitted to restore to normal. It will be apparent from the description of the effect of the selector D, seizing the next switch before the calling device dial restores to normal, that this does not in any
 40 manner effect the progress of the call except to increase the time necessary to establish the connection.

Now should the calling subscriber force the dial of the calling device during its back-
 45 ward movement, the result, if any, is merely to reduce the time during which the resistance is placed in the line circuit. Since the dial returns very rapidly of its own accord, the effect of this is negligible on account of the
 50 speed of the selecting apparatus. However, by reason of the construction of the calling device, an attempt to force the dial in the return movement is controlled by the governor therein, since the governor will have greater
 55 braking effect when the dial is forced.

Referring now to the operation of the repeater R to which we have progressed in the description of the connection about to be made
 60 by the subscriber at substation A. Other results of the operation of the relay 804 in the repeater R are that battery is connected to the mid-point of the differential relay 803 at armature 822, a circuit is prepared for the
 65 relay 805 at armature 820, a point in the circuit of the release magnet 808 is completed

at armature 836, a circuit for the lower winding of the electropolarized relay 801 in bridge of the trunk conductors 840 and 841 is completed at armature 837, and the relay 806 is placed in bridge of the trunk conductors 840
 70 and 841 over circuit that extends from the trunk conductor 840, normally closed springs controlled by armature 810, upper winding of relay 806, wiper 831, in engagement with its normal bank contact, and front contact and
 75 armature 823 to the conductor 841. The relay 806 is then energized over this circuit to prepare a locking circuit for the relay 805 at armature 827 and to open a point in the circuit of the release magnet 808 of the minor switch
 80 M at the back contact of this armature and open a point in the circuit of its lower differential winding at armature 826.

If the calling device at the substation A has not yet restored to normal the differential
 85 relay 803 is operated immediately after the operation of relay 804 and the high impedance relay 805 is not energized. No further operations occur until the calling device restores to normal, whereupon, both windings of the
 90 relay 803 will have the same amount of current flowing through them and the armatures thereon will be retracted. A circuit is thereby completed for the relay 805 over a path that extends from ground by way of armature 819
 95 and its back contact, armature 820 and its front contact, normally closed springs controlled by armature 824 and high impedance relay 805 to battery. The relay 805 is energized to prepare a circuit for the relay 802 at
 100 armature 825. Another result of the operation of the relay 805 is to open its original energizing circuit at armature 824 and to establish a locking circuit for itself at this same armature to ground upon the release
 105 trunk.

When the calling device at the calling substation A is operated in accordance with the next digit 4, the wiper 701 of the calling
 110 device is moved into engagement with the fourth bank contact. By this operation, a resistance of 550 ohms, with assumed values given before, is thrown into the line circuit of the differential relay 803. The differential relay
 115 803 is thereupon operated to open the circuit of the lower winding of the relay 801, which is in bridge of the trunk conductors, at armature 818, to open another point in the circuit of the relay 805 at armature 819, and to complete a circuit at the front contact of this
 120 armature that extends from ground, by way of armature 819 and its front contact, front contact and armature 825, armature 839 and its back contact, relay 802, and normally closed springs controlled by armature 811 to
 125 battery.

The relay 802 is energized over this circuit to open a point in the circuit of the lower winding of relay 806 at armature 817, and to complete a circuit at armature 816 that ex- 130

tends from ground by way of armature 821 and its front contact, armature 815 and its back contact, armature 816 and its front contact and stepping magnet 807 of minor switch M to battery. Another result of the operation of the relay 802 is that it establishes a locking circuit for itself at armature 838. The stepping magnet 807 of the minor switch M is operated to advance the switch wipers 830 and 831 one step. Another result of the operation of stepping magnet 807 is that at armature 839 the circuit of the relay 802 is opened and this relay is deenergized. Upon the first movement of the minor switch, the off normal springs 828 and 829 are shifted, whereby the circuit of the lower winding of the relay 801 is opened, while a circuit is prepared for the lower winding of the relay 806.

It will be seen that there is a resistor connected to the bank contacts accessible to both the wipers 830 and 831. These resistors correspond to the resistor 706 in the calling device at the substation A and to the resistor 767 of the selector D. By the operation of the wiper 830 certain resistance is connected in circuit with the lower winding of the differential relay 803. In this case the resistance is 208 ohms, however, the relay 803 still remains energized because of the unbalanced current flow in the two windings. By the movement of the wiper 831 a certain amount of resistance is thrown in the circuit extending in bridge of the trunk conductors 840 and 841 which may be traced from conductor 840, normally closed springs controlled by armature 810, upper winding of relay 806, second bank contact engaged by wiper 831, said wiper, and front contact and armature 823, to trunk conductor 841. The connecting of this resistance in bridge of the trunk conductors 840 and 841 serves to unbalance the differential relay, such as 730 in the selector D¹, which is the incoming selector at the second exchange. This initiates the operation of the selector D¹ in identically the same manner as has been described with respect to the selector D.

The relay 802 in repeater R is deenergized to open its locking circuit at armature 838, to prepare a circuit for the lower winding of the relay 806 at armature 817, and open the circuit at the stepping magnet 807 at armature 816. Stepping magnet 807 is deenergized to complete a circuit for the relay 802. The relay 802 operates to close the circuit for the stepping magnet 807. The alternate operation of the relays 802 and the stepping magnet 807 continues until the wipers 830 and 831 of the minor switch M are moved into engagement with the fourth off normal set of bank contacts. In this position of the wiper 830, a resistance of 550 ohms is inserted in circuit with the lower winding of the relay 803, and the same amount of current then flows in each winding of the differen-

tial relay 803 in opposite directions. The relay 803 is immediately deenergized to open the circuit of the relay 802. When the relay 802 deenergizes to open the circuit of the magnet 807, the wipers 830 and 831 are in engagement with their respective fifth bank contacts. There is no further movement of the wipers 830 and 831 for the present.

By the movement of the wiper 831 into engagement with the fifth bank contact, the same amount of resistance is placed in bridge of the trunk conductors 840 and 841, as was inserted in the circuit of the upper winding of the differential relay 803 by the operation of a calling device of substation A in accordance with the digit 4.

The incoming second selector D¹ is thereby operated until it has positioned its wipers opposite the fourth level of bank contacts in identically the same manner as has been described with respect to the operation of the selector D. When this occurs the differential relay, similar to the relay 730, in the selector D¹ is deenergized to initiate the rotary movement of the switch. Now, when the vertical movement of the selector switch D¹ ceases, the relay similar to the relay 734 in this selector is operated. When an idle trunk has been found, the relay similar to the relay 733 in the selector D¹ is operated. However, since the relay, such as 734 in the selector D¹ remains energized until the relay similar to the relay 902 in the connector switch H is operated, the trunk line comprising conductors 840 and 841 is opened to the connector switch H at a point in the selector switch D¹.

The relay 806 in the repeater R is thereby deenergized, since its circuit is opened. Upon deenergizing, the relay 806 opens the locking circuit of the relay 805 at armature 827 and completes a circuit for the release magnet 808 at the back contact of this armature. Another result of the operation of the relay 806 is that at armature 826 a circuit is established for maintaining the armatures of the relays 806 in a normally inoperative condition. This is true because there is a circuit completed extending from ground by way of back contact and armature 817, off normal spring 829 and its working contact, back contact and armature 826 and lower winding of relay 806 to battery. The relay 806 cannot be energized by current flow through its upper winding in the same direction as before, for the reason that the lower winding of this relay is wound so that the magnetic field set up by this winding neutralizes the magnetic field set up by the current flow on the other winding. The relay 805 is deenergized to open a point in the circuit of the relay 802, and to establish a point in its original energizing circuit. The relay 806 is also adjusted so that the current flow through its lower winding is not sufficient to operate its armatures.

The release magnet 808 of the minor switch M operates to restore the wipers 830 and 831 to their normal position. The off normal springs are thereupon shifted and the relay 806 may be operated when the relay such as 734 in the selector switch D¹ is deenergized to complete the line circuit to the connector H.

It will be assumed that the operation of the incoming selector switch D¹ has been such as to select the connector switch H.

When the calling device at substation A is operated in accordance with the next digit of the calling subscriber's number, namely 3, a certain amount of resistance is placed in the circuit of the upper winding of the differential relay 803 in the repeater R. In the present case, the value of this resistance is 410 ohms. The differential relay 803 is thereupon operated. It will be recalled that the minor switch M of the repeater R was released by the operation of the relay 806. The operation of the relay 806 also brought about the deenergization of the relay 805. In addition, by the operation of the armature 827 on the relay 806, the circuit was closed for the release magnet 808 of the minor switch M. The restoration of a wiper 830 to normal removes the resistance from the lower winding of the differential relay 803. In the event that the calling device at the substation A had not yet returned to normal, the relay 803 would be energized. The energization of the relay 803 at this time is of no particular function, for the reason that the relay 805 is now deenergized. When the calling device restores to normal the relay 805 is energized over a previously traced circuit to prepare a circuit for the interrupter relay 802 at armature 825 and to complete a locking circuit for itself at armature 824. This locking circuit is established when the relay 806 is again energized at the time that the off normal springs 828 and 829 are shifted to their normal positions upon the release of the wipers 830 and 831 to their normal position.

Now, when the resistance is inserted into the calling line by the operation of the calling device at substation A, the relay 803 is again energized. Since the relay 805 is now operated, a circuit is completed for the interrupter relay 802. The interrupter relay 802 serves to establish a locking circuit for itself at armature 838, and to complete a circuit for the stepping magnet 807 at armature 816. The stepping magnet 807 is operated to open the circuit of the interrupter relay 802. The alternate operation of the relay 802 and the stepping magnet 807 continues until the switch wipers 830 and 831 are advanced into engagement with the fourth set of bank contacts. In this position the wiper 830 has placed a resistance in the circuit of the lower winding of the differential relay 803 which corresponds with the amount of resistance

placed in the upper winding by the operation of the calling device at substation A. The differential relay 803 is thereupon deenergized to connect the lower winding of the electric polarized relay 801 in bridge of the trunk conductor 840 and 841.

By the operation of the wiper 831 of the repeater R, a resistance corresponding to the resistance connected in the circuit of the upper winding of the differential relay 803 is placed in bridge of the trunk conductors 840 and 841.

When the relay 902 in the connector H is energized in the manner before described, the operation of this relay serves to connect ground to the release trunk at armature 918, to connect battery to the mid-point of the differential relay 901 at armature 919 to complete a circuit at armature 920 that extends from ground by way of said armature and its front contact, armature 916 and its back contact, armature 926 and its back contact, back contact and armature 947, resistance 940 and lower winding of the relay 906 to battery. The relay 906 is energized, to prepare a circuit for the upper winding of the relay 902 at armature 937, to connect ground to armature 915 of the differential relay 901 at armature 938, to establish a locking circuit for itself at armature 939, and to prepare another point in the circuit of the relay 902 at armature 941.

When the wiper 831 in the repeater R is operated to place the resistance in bridge of the trunk conductors 840 and 841, the differential relay 901 in the connector H is unbalanced and attracts its armatures 915 and 916. By the operation of the armature 916 a circuit is completed that extends from ground by way of armature 920 and its front contact, armature 916 and its front contact, back contact and armature 934, and relay 907 to battery. The operation of the armature 915 serves to complete a circuit which extends from ground by way of armature 950 and its back contact, front contact and armature 938, armature 915 and front contact, back contact and armature 954, back contact and armature 929 and relay 904 to battery.

The operation of the relay 907 serves to complete an additional circuit for the lower winding of the relay 902 over a path that extends from ground by way of armature 918 and its front contact, normally closed springs controlled by armature 956, normally closed springs controlled by armature 955, front contact and armature 946, to one terminal of the lower winding of the relay 902. This circuit is closed in order to maintain the relay 902 energized after the off-normal springs 966, 967' and 968 are shifted, which occurs upon the first off normal step of the switch.

The relay 904 is energized to establish a locking circuit for itself at armature 930 over a circuit which extends from ground upon re-

lease trunk conductor 849, armature 930 and its front contact, back contact and armature 954, back contact and armature 929, and relay 904 to battery. Another result of the operation of the relay 904 is that at armature 931 a circuit is completed that extends from ground by way of armature 931 and its front contact, armature 925 and its back contact, and vertical magnet 910 to battery. The vertical magnet 910 is operated to raise the switch shaft carrying the switch wipers 960 to 963, inclusive, opposite the first level of bank contacts. By this operation also, the vertical wiper 964 is raised into engagement with the second vertical bank contact. Another result of the operation of the vertical magnet 910 is that an armature 929, the locking circuit of the relay 904 is opened and this relay is deenergized to open the circuit of the vertical magnet 910. The vertical magnet 910 is deenergized to position its pawl and to complete a circuit for the relay 904. The operation of the vertical wiper 964 serves to insert a resistance into the circuit of the lower winding of the differential relay 901. This resistance is insufficient to balance the current flow in the two windings of relay 901 and it remains energized to again complete a circuit for the relay 904. The interrupter relay 904 and the vertical magnet 910 are alternately operated until the switch wipers 960 and 963, inclusive, are raised opposite the third level of bank contacts and the vertical wiper 964 is placed in engagement with the fourth vertical bank contact. By the operation of the vertical wiper 964 sufficient resistance is inserted into the circuit of the lower winding of the relay 901 so that the current flow in both windings of this relay is equal. In the present instance the operation of the vertical wiper 964 into engagement with the fourth vertical bank contact causes the insertion of approximately 410 ohms resistance into the circuit of the lower winding of the differential relay 901. This resistance corresponds to the resistance that has been inserted into the circuit of the upper winding of the relay 901 by the repeater R.

The relay 901 is thereupon deenergized to open the circuit of the interrupter relay 904. The vertical operation of the switch wipers ceases. By the operation of armature 916 of the relay 901, the circuit of the relay 907 is opened and this relay is deenergized, and at the back contact of this armature a circuit is prepared for energizing the relay 906. By the operation of the armature 915 there is a circuit completed which extends from ground by way of armature 950 and its back contact, front contact and armature 938, armature 915 and its back contact, working contact of off normal spring 966 and said spring, and the upper winding of the two-step relay 903 to battery. The energization of the upper winding of the relay 903 serves to attract the arma-

tures 923, 924 and 926. The operation of the armature 926 of the relay 903 serves to open a point in the original energizing circuit of the relay 906. The operation of the armature 923 of the relay 903 opens the locking circuit of the relay 906, whereupon the relay 906 is deenergized. The operation of the armature 924 of the relay 903 serves to open the circuit of the lower winding of the differential relay 901 through vertical wiper 964, to complete a new circuit for the lower winding of relay 901 over a path that extends from ground by way of armature 920 and its front contact, front contact and armature 924, resting contact of rotary off normal spring 957, lower winding of relay 901, and armature 919 to battery, and to establish a circuit for the lower winding of the relay 903. The rotary off normal springs 956 and 957 are of the usual construction and are adapted to be operated upon the first rotary step of the switch. It will be noted that the circuit for the lower winding of the relay 903 is ineffective at the present time for the reason that it is short circuited by the circuit previously traced for its upper winding. Consequently, the armatures 921, 922, 925 and 927 of the relay 903 remain in their normal position for the present. By the deenergization of the relay 907, the armature 946 of this relay is retracted to open the circuit of the lower winding of the relay 902. The relay 902 is not deenergized because there is a circuit completed for its upper winding over a path that extends from ground upon release trunk conductor 849, normally closed springs controlled by armature 956, normally closed springs controlled by armature 955, normally closed springs controlled by armature 946, and the upper winding of relay 902 to battery.

The opening of the circuit of the lower winding of the relay 902 serves to open the circuit of the relay 806 in the repeater R. The results following the deenergization of this relay will be described hereinafter. The relay 906 is deenergized to open its locking circuit at armature 939 and to remove ground from armature 915 of the relay 901 at armature 938. This latter operation brings about the opening of the circuit of the upper winding of the relay 903. The relay 903 is now energized over a circuit that includes both its upper and lower windings in series. As a result of this, all the armatures of the relay are attracted. The operation of the armature 921 serves to re-establish a circuit for the relay 902 over a path extending from ground by way of rotary off normal spring 956 and its resting contact, armature 921 and its front contact, to one terminal of the lower winding of relay 902. The operation of the armature 922 serves to prepare a locking circuit for the relay 906. The operation of the armature 925 serves to prepare a circuit for the rotary magnet 911, as well as to open the cir-

cuit of the vertical magnet 910. The operation of the armature 927 of the relay 903 serves to prepare a circuit for the relay 906, while the operation of the armature 928 opens the original energizing circuit for the upper winding of relay 903. In the present instance the relay 906 is energized because the current flow in both the upper and lower windings of the relay 901 is equal, and this relay is deenergized. This is true, because of the functioning of the repeater R responsive to the deenergization of the relay 806. The relay 906 is energized over a circuit which extends from ground by way of armature 920 and its front contact, armature 916 and its back contact, armature 927 and its front contact, back contact and armature 947, resistor 940, and the lower winding of the relay 906 to battery. The relay 906 is energized to connect ground to the armature 915 of the relay 901 at armature 938 and to establish a locking circuit for itself at armature 939.

Referring now to the repeater R, when the relay 806 is deenergized there is a circuit established for its lower winding over a path which extends from ground by way of armature 817, off normal spring 829 and its working contact, back contact and armature 826 and the lower winding of relay 806 to battery. This circuit is to maintain the relay 806 inoperative. The operation of the armature 827 of the relay 806 serves to open the locking circuit of the relay 805 and to complete a circuit for the release magnet 808 of the minor switch M. The restoration of the minor switch M serves to prepare the repeater to receive the next digit from the calling subscriber's substation. The remaining operations in the repeater R occur in substantially the same manner as has been before described following the deenergization of the relay 806.

When the subscriber at substation A operates his calling device in accordance with the last digit 2 of the called subscriber's number, a certain amount of resistance is inserted into the circuit of the upper winding of the differential relay 803 of the repeater R. For the values given, this resistance is 300 ohms. The relay 803 in the repeater R is thereupon operated to bring about the interaction of the relay 802 and the stepping magnet 807 to advance the switch wipers 830 and 831 into engagement with their third set of bank contacts. When this occurs, the wiper 830 has inserted into the circuit of the lower winding of the differential relay 803, the same amount of resistance that has been inserted in the circuit of the upper winding of this relay by the calling device at substation A. The relay 803 is thereupon deenergized to stop further movement of the switch wipers.

By the operation of the wiper 831, a certain amount of resistance is inserted in bridge of the trunk conductors 840 and 841, corre-

sponding to the amount that has been inserted in the calling subscriber's line by the operation of the calling device thereat. The insertion of this resistance into the line extending between the repeater R and the connector H, serves to unbalance the differential relay 901, since its circuit has been previously completed by the operation of armature 921 of the relay 803. The relay 901 is energized, the operation of the armature 916 serves to open a point in the original energizing circuit of the relay 906 and to complete a circuit at the front contact of this armature for the relay 907. The operation of the armature 915 of the relay 901 serves to complete a circuit which extends from ground by way of armature 950 and its back contact, front contact and armature 938, armature 915 and its front contact, back contact and armature 954, back contact and armature 929, and relay 904 to battery. The relay 907, upon energizing, connects the private wiper 961 to the lower winding of the relay 905, prepares a circuit for the rotary magnet 911 at armature 944, prepares a circuit for itself exclusive of the armature 934 of the relay 905 at armature 945, and at armature 946 serves to prepare an alternative circuit for supplying ground to the lower winding of the relay 902. The relay 904, upon energizing, establishes a locking circuit for itself at armature 930, and at armature 931 completes a circuit which extends from ground by way of armature 931 and its front contact, armature 925 and its front contact, armature 944 and its front contact, and rotary magnet 911 to battery. The rotary magnet 911 is energized to rotate the switch shaft carrying the switch wipers 960 to 963, inclusive, into engagement with the first set of bank contacts on the third level. Another result of the operation of the rotary magnet 911 is that the locking circuit of the relay 904 is opened at armature 954. The relay 904 is deenergized to open the circuit of the rotary magnet and the rotary magnet is deenergized to position its pawl and to complete another circuit for the interrupter relay 904. The relay 904 is energized to complete the circuit of the rotary magnet which operates to advance the switch wiper 960 to 963, inclusive, into engagement with the second set of bank contacts into third level, which it will be assumed are the terminals of the line of the called substation A¹ in the connector H designated by the bank contacts 970 to 973, inclusive. Upon the first rotary step of the switch, the off normal springs 956 and 957 are shifted, whereby one ground connection is removed from the lower winding of relay 902 at spring 956 and the circuit of the lower winding of the relay 901 is shifted to the wiper 962 at spring 957. By the operation of the wiper 962, a certain amount of resistance is placed in the circuit of the lower winding of the differential relay 901. As the

digit 2 has been dialed by the calling subscriber, the rotation of the wiper 962 into engagement with the second bank contact will cause the insertion of the proper amount of resistance into the circuit of the lower winding of the relay 901. The relay 901 is thereupon deenergized to open the circuit of the interrupter relay 904 and to open the circuit of the relay 907.

Should the called line be busy at this time, there will be a ground potential present upon the bank contact 971 which is engaged by the private wiper 961 of the connector H. Assuming this to be the case, when the wipers 960 to 963, inclusive, are rotated into engagement with this set of bank contacts, there is a circuit completed which extends from ground on the bank contact 971, wiper 961, armature 943 and its front contact and lower winding of the relay 905 to battery. The relay 905, upon operating, prepares a point in the talking circuit at armature 932, closes a locking circuit for itself at armature 933, opens a point in the circuit of the relay 907 at armature 934 and at armature 935 completes a circuit for connecting the busy tone from the busy machine BM to the line of the calling subscriber. The relay 907 is deenergized following the deenergization of the relay 901, to open a point in the circuit of the rotary magnet 911 at armature 944, to establish the locking circuit of the relay 905 at armature 943, to open a point in its own circuit at armature 945, and to open the circuit of the lower winding of the relay 902 at armature 946, and to close a circuit for the upper winding of the relay 902 at the normally closed springs controlled by this armature.

Another result of the operation of the relay 905 is that an armature 955, the locking circuit, of the upper winding of the relay 902 is opened, and a circuit is simultaneously completed for the lower winding of this relay. In this manner the relay 902 is again placed under the control of the calling subscriber.

When the calling subscriber hears the busy tone, he will replace his receiver upon the switch hook to bring about the release of the selecting equipment in a manner that will be described more fully hereinafter.

Referring to the connector H, it will be noted that the circuit of the relay 907 is opened at armature 934 of the relay 905. This is to prevent the relay 907 being energized should the calling subscriber move his dial again. Since the circuit of the rotary magnet is closed through armature 944 and its front contact on the relay 907, it will be apparent that the rotary magnet 911 cannot be operated after the busy tone is heard.

Should the calling subscriber hang up before hearing the busy tone, the relay 804 in the repeater R is deenergized to open one

point in the original energizing circuit of the relay 805 at armature 820, to remove ground from the release trunk conductor 774 at armature 821, to disconnect battery from the differential relay 803 at armature 822, to open the bridge across the trunk conductors 840 and 841 at armature 823 and to complete a circuit for the release magnet 808 of the minor switch M over a circuit which extends from ground by way of back contact and armature 817, off normal spring 829 and its working contact, armature 836 and its back contact and release magnet 808 to battery. The release magnet 808 is energized to restore the switch wipers 830 and 831 to normal. The circuit of the release magnet is opened by the shifting of the off normal springs when the wipers 830 and 831 reach their normal position. By the opening of the bridge across the trunk conductors 840 and 841, the relay 806 is deenergized to open the locking circuit of the relay 805.

In the connector H, the removal of the bridge across the trunk conductors 840 and 841 in the repeater R opens the circuit of the relay 902, and this relay is deenergized to open the locking circuit of the relay 905 at armature 917, to remove ground from the release trunk conductor 849 at armature 918, to remove the battery connection from the midpoint of the differential relay 901 at armature 919 and to open a point in the original energizing circuit of the relay 906 at armature 920. Another result of the operation of the armature 920 is that a circuit is completed for the release magnet 909. The release magnet 909 operates to restore the switch shaft carrying the wipers 960 to 964, inclusive, to its normal position. The circuit of the relay 903 is also opened by the retraction of the armature 920. The relay 903 is thereby deenergized to restore the circuits that it controls to normal. The relay 905 is deenergized to restore the circuits which it controls to their normal condition. The relay 905 is also deenergized to remove the busy tone from the calling subscriber's line. By removal of ground from the release trunk conductor 849, the circuit of the switching relay, such as the switching relay 733 of the selector D is opened in the selector D¹. The deenergization of this relay brings about the release of the selector D¹ in a manner that will be better understood from the description given with respect to the selector D.

When ground is removed from the release trunk conductor 774 by the deenergization of the relay 804 in the repeater R, the holding circuit of the switching relay 733 in the selector D and 710 in the line switch C, is opened. The relay 733 in the first selector D is deenergized to prepare a circuit for the relay 731 at armatures 751 and 756, and to complete a circuit for the release magnet 735 over a path that extends from battery by way of arma-

ture 755 and its back contact, release magnet 735, working contact of off normal spring 744 and said spring, and back contact and armature 743 to ground. The release magnet 735 is energized to bring about the release of the selector D in a well known manner.

In the line switch C the deenergization of the relay 710 disconnects the calling line from the selector D and prepares circuits whereby it may be again operated upon the removal of the receiver at substation A. An additional result of the removal of ground from the release trunk conductor 774 is that the ground connection extending to the multiplied private bank contacts of the calling line in the various connectors which have access to it, is removed so that this line may be selected and connected to if it is called.

In this manner all the selecting apparatus in both the firsts and second exchanges that has been operated by the calling subscriber to establish the connection with the called line, has been released responsive to the replacement of the receiver on the switch hook at substation A after the subscriber thereat has been informed that the called line is busy. Inasmuch as there are no slow acting relays involved in the release circuit, or anywhere else for that matter, the release, above described, occurs substantially instantaneously.

It will now be assumed that when the connector H connected with the terminal of the line of the substation A¹, that this line was idle. In this case there will be no ground connection present upon the bank contact 971 with which the wiper 961 of the connector H is in engagement and the relay 905 will not be energized at this time. Now, when the differential relay 901 retracts its armature 916, the circuit of the relay 907 is opened and this relay is deenergized to complete a circuit for the relay 908 at armature 943, to open the circuit of the lower winding of the relay 902 at armature 946, thereby bringing about the deenergization of the relay 806 in the repeater R, and to close a locking circuit for the upper winding of the relay 902 at the normally closed springs controlled by armature 946.

The relay 908 is energized over a circuit which extends from ground by way of armature 917 and its front contact, armature 933 and its back contact, upper winding of relay 908, back contact and armature 943, private wiper 961, bank contact 971, relay 975 and motor magnet 977 in the called line switch C to battery. The relay 908 is energized over this circuit at least sufficiently to bring the armature 951 into engagement with its front contact, thereby establishing a locking circuit for itself.

The relay 975 in the line switch C is energized over this circuit, but, because of a mechanical interlocking device controlled by the armature of the line relay 976, the relay

975 can only attract its armature sufficient to disconnect the called line from the battery and ground connections in the line switch C'.

The relay 908, upon energizing, disconnects the upper winding of the differential relay 901 from the trunk conductor 848 at armature 948, and at this same armature connects this trunk conductor to battery through the upper winding of the relay 902, to complete one point in the ringing circuit at armature 949, to remove ground from the armature 915 of the relay 901 and to open the locking circuit at the relay 906 at the back contact of armature 950 and to place ground directly upon the wiper 961 at the front contact of this armature. Further results of the operation of the relay 908 are that at armature 942 one point in the circuit by which the relay 905 applies a busy tone to the calling line is opened, and at armature 947 the original energizing circuit for the relay 906 is opened. At armature 952 the trunk conductor 850 is connected to the lower winding of the relay 902, and at armature 953 ringing current is applied to the called line. The circuit of the rotary magnet 911 is opened by the operation of armature 958 so that the magnet may not be again operated if the calling subscriber should operate his calling device.

The operation of the armature 956 of the relay 908 serves to open the locking circuit of the upper winding of the relay 902 and to simultaneously complete a circuit for its lower winding. The relay 902 is thereby placed under the control of the calling subscriber. Thus any time after the operation of the relay 908, the relay 902 is deenergized when the calling subscriber replaces his receiver upon his switch hook.

At the repeater R the relay 806 is deenergized when the relay 907 in the connector H retracts its armature as described. The operations in the repeater following the deenergization of the relay 806 are the same as before described.

Ringing current is now applied to the called line over a circuit which extends from the generator G, front contact and armature 983, back contact and armature 936, armature 953 and its front contact, wiper 963, bank contact 973, conductor 980 of the called line, switch hook springs, ringing condenser, bell coils, conductor 981, bank contact 970, wiper 960, front contact and armature 949, armature 932 and its back contact, and upper winding of ring cut-off relay 905 to ground. Inasmuch as there is a condenser in the above ringing circuit at the substation A¹, only alternating current flows over the circuit. The relay 905 is adjusted and constructed so as not to respond to alternating current. It is of the usual type of ring cut-off relay.

When the called subscriber removes his receiver, a direct current path is provided, extending from battery through the generator G during a ringing period or from battery at the back contact of armature 983 during a silent period, and over the previously traced circuit through the upper winding of the ring cut-off relay 905 to ground. The ring cut-off relay 905, is immediately energized to establish a locking circuit for itself at armature 933. The operation of the armature 934 of the relay 905 serves to open a point in the circuit of the relay 907. The operation of the armatures 935 and 955 of the ring cut-off relay is without function at the present time because the relay 908 is operated. The ring cut-off relay 905 also operates to connect the two windings of the back bridge relay 906 to the called line. Battery is supplied to the called subscriber's telephone from the windings of the back bridge relay 906.

Relay 906 is thereby energized to reverse the connections of the relay 902 with respect to the trunk conductors 848 and 850, that is, the current flow in these conductors is reversed.

The results of this reversal of current flow in the repeater R will now be considered. The electropolarized relay 801 in the repeater R is now energized since the current flow in both its winding is in the same direction. The relay 801, upon operating, short circuits the resistance that is in series with its lower winding to permit it to attract its armatures 810, 811, 812, 814 and 815. The operation of the armature 815 of the relay 801 serves to open a point in the circuit of the magnet 807. The operation of the armatures 812 and 814 serves to reverse the battery connections of the relay 804 with respect to the trunk conductors 773 and 775 and, in addition, connects the upper winding of the relay 804 in the circuit extending to the calling line, so that the relay 804 may supply battery for the operation of the transmitter and receiver of the calling telephone substation A. The operation of the armature 814 also disconnects the upper winding of the differential relay 803 from the talking circuit. The operation of the armature 810 serves to disconnect the upper winding of relay 806 from across the trunk conductors 840 and 841. The operation of the armature 810 and the armature 811 places the relay 802 in bridge of the trunk conductors 840 and 841 to increase the transmission efficiency of the talking circuit.

The reversal of battery by the connector switches and by the repeater R is ordinarily used to give the operator supervision in case of one it employed in establishing the connection, and to meter the call in the event that metering is used.

The calling line is supplied with talking battery from the windings of the relay 804

in repeater R while the called line is supplied with talking battery from the windings of the back ridge relay 906 in the connector switch H. The talking circuit is shown in the drawings by the heavy lines.

After the conversation is terminated the whole connection is released by the calling subscriber replacing his receiver upon the switch hook. This brings about the deenergization of the relay 804 in the repeater R, and the release of the selecting apparatus takes place in substantially the same manner as has been described before.

Should the called subscriber at substation A¹ replace his receiver before the calling subscriber at substation A, the back bridge relay 906 in the connector switch H is deenergized to reverse the connection of the relay 902 with respect to the trunk conductors 848 and 850. This reversal of battery causes the current flow in the two windings of the relay 801 to be in opposite directions. The relay 801 in the repeater R is thereby deenergized to reverse the connections of the relay 804 with respect to the trunk conductors 773 and 775. Now, when the calling subscriber hangs up, the release takes place as before described.

For a more complete understanding of the invention, certain special situations will now be described.

In the event that the subscriber at substation A desires a connection with a subscriber located in his own exchange, the connection is established in substantially the same manner as before described, with the exception that there is no repeater in the circuit and the second selector and the connector are controlled directly from the calling subscriber's dial in an obvious manner.

It is apparent that the selector switches, such as D, may be released at any point in their operation since the relay, such as 731, is under the control of the calling subscriber at all times except after the next succeeding switch has been selected. Should the subscriber at substation A hang up just at the time the switching relay 733 is energized, it will be seen that the relay 734 in the selector switch D will remain energized until it is short circuited by an application of direct ground to the release trunk in the next succeeding switch, whether it be a selector or a repeater. The relay, such as the relay 731, in the next switch is energized over a circuit that extends from battery by way of armature 755 and its front contact, armature 760 and its front contact, and wiper 765. This circuit is established whether or not the calling subscriber's receiver has been hung up. When direct ground is applied to the release trunk, the relay 734 is short circuited and deenergized to open the circuit of the relay similar to the relay 731 in the next switch. The release of the equipment now follows in the usual manner.

If the calling subscriber should hang up at any time when connected with the repeater R, the deenergization of the relay 804 brings about the release of the established connection in the same manner as before described.

Should the calling subscriber hang up when the connection has been extended to a connector switch such as H, before the calling device has been operated to initiate the selecting operation of the connector, the release is a little bit different. To describe this, it will be assumed that the subscriber at substation A has extended his connection to the connector switch H, and then he replaces his receiver upon the switch hook. The replacement of the receiver on the switch hook at the calling station A opens the circuit of the lower winding of the relay 902, but this relay is locked energized over a circuit which extends from ground by way of armature 918 and its front contact, normally closed springs controlled by armature 956, normally closed springs controlled by armature 955, normally closed springs controlled by armature 946, and the upper winding of the relay 902 to battery. Now, when the calling subscriber hangs up the circuit of the upper winding of the differential relay 901 is opened, the circuit of the lower winding of this relay remaining closed. The relay 901, therefore, attracts its armature. A circuit is now completed which extends from ground by way of armature 920 and its front contact, armature 916 and its front contact and relay 907 to battery. The relay 907 is energized to open the previously traced locking circuit for the relay 902. This relay is then deenergized to bring about the release of the connector switch in the same manner as before described. The release of the connector switch occurs in this manner until the relay 905 or 908 is energized. When the relay 905 is energized it will be seen that at armature 955 the locking circuit of the upper winding of the relay 902 is opened. The same thing occurs when the relay 908 is energized by the operation of the armature 954. Thus, with either of these relays energized, the relay 902 is deenergized immediately upon the calling subscriber replacing his receiver upon the switch hook.

Attention is directed to the fact that only one resistor 967 is employed to control both vertical and rotary movements of the connector switches such as H; that is, there is one such resistor in each connector switch.

Since it is only necessary that the telephone lines in any given exchange be of substantially the same resistance, the resistance of the telephone lines in the different exchanges may vary. The selecting devices in the different exchanges may be controlled from another exchange in the same manner as described through a repeater, such as R. Under these conditions, it is necessary that the resistor,

such as 833, and the manner in which it is connected to the bank contacts accessible to the wiper 831 of the minor switch M, be similar to the manner in which the resistors, such as 985, are connected to the bank contacts accessible to the wiper 986. This is obvious, since the minor switch M must function to control the switching mechanism in the distant office in the same manner as the calling device of any telephone in that exchange.

It will be appreciated that since the selecting devices, such as the selector D and the connector H are permitted to operate under a local circuit in all of their directly controlled movements, this movement will occur very rapidly and is only limited by the mechanical adjustment and construction of the switch. This means that the selecting mechanism will operate several times as fast in the present instance as it would if it were controlled in any other manner. In fact, the speed may be increased four or five times using the present mechanical construction of Strowger switching equipment. This high selecting speed permits the calling devices to be adjusted so that they will operate very quickly. It will be appreciated that since connections may be established very much more quickly by the calling subscribers and by the operators if any are employed, that the amount of switching equipment necessary may be considerably reduced. This reduction is somewhat added to by the speed at which the selecting equipment may be released after the calling subscriber replaces his receiver upon his switch hook.

Since no slow acting relays are employed in any of the switching devices to perform any functions whatever, it will be appreciated that all the time margins are eliminated and the operations are rendered much more satisfactory and positive. The use of the balancing arrangement disclosed in the present invention for determining the change in conductance of the line circuit responsive to the operation of the calling device, is very accurate and is not subject to the changes in the line circuit to which the impulsing principle is subjected. By the use of this balancing arrangement, a cumulative effect is sent over the line for a plurality of impulses. It takes no longer to transmit this effect for the digit 10 of the calling device than the digit 1. That is to say, the calling device operates to modify a characteristic of the line and means are provided in the switching mechanism for controlling the switching mechanism responsive to this modified line characteristic. By the use of this balancing principle of selection, it is possible to eliminate a great many of the marginal operations and circuits that have heretofore been employed. In addition, since for any given number only a certain characteristic of the line is changed, it is possible to send a number of designations, such

as are necessary in call indicator systems, very much more rapidly and a great deal more positively than has been heretofore possible using the light and heavy positive and negative impulses.

It is obvious that since all that is necessary to establish a connection is to modify an electrical characteristic of the line in accordance with a predetermined plan, push buttons may be used for the calling device in a very simple manner. Many other forms of calling devices will suggest themselves.

It is obvious that this balancing principle of selection may be employed in various selecting schemes, and may be used in a multitude of places in automatic telephone systems, both to increase the speed of operation, to save equipment, and to render the operation of the equipment more positive. In addition, the length of line over which a change of an electrical characteristic can cause a selecting operation is practically unlimited.

It will be understood that while I have shown my invention operating as a result of a change in conductance of the line circuit, that the change of any other electrical characteristic of the line may be employed for such control.

It is also obvious that instead of the method of making a call disclosed in the present invention, the so-called translator or director may be used to make a call. In this event the balancing principle of selection may, of course, be employed to very great advantage.

Since selecting apparatus is directly controlled from the subscriber's station by modifying one of the electrical characteristics of the line, and the release of the selecting apparatus is brought about by opening the line, and it is obvious that it is impossible to cause any movement of the directly controlled selecting devices at the central office by removing the switch hook or working it up and down in any manner. This eliminates the so-called "preliminary impulse" difficulty with which there has been so much trouble in automatic telephone systems. In fact, the present practice has gone so far as to do away with all selection that begins with a No. 1. Thus, should a preliminary impulse occur, the subscriber may be trunked to an operator who will inform him to hang up his receiver and call again. Not only is this very wasteful of the selecting equipment, but in the event that two preliminary impulses are sent there is no solution to the difficulty. In addition, the subscriber finds it unsatisfactory to be informed to hang up again and call his number. In the present invention, any number of operations of the switch hook cause nothing but the release. The only way that the selecting apparatus at the central office may be controlled is by the operation of his calling device. Thus all preliminary impulse difficulty is obviated.

While I have shown one particular embodiment of my invention, I am aware that many changes, modifications, and deviations may be employed, and it will be understood that I desire to protect by Letters Patent all such modifications, changes, variations and deviations as come within the scope of the appended claims.

I claim:—

1. The method of controlling a selecting device having a directly controlled and an automatic movement which consists in modifying the electrical conductance of a circuit extending to said device while maintaining the circuit closed and causing a single means in said device to become operative responsive to such modification to control the operation of the device in its directly controlled movement and to initiate its automatic movement.

2. The method of controlling an automatic telephone switch having a primary and secondary movement, which consists in producing a single modification of the conductance of a circuit extending to said switch to a predetermined value and causing a single means in said switch to become operative responsive to said modification to initiate the primary movement of said switch and prepare the switch for the secondary movement.

3. In a selecting system, the combination with a selecting device having a primary and secondary movement and a circuit leading therefrom, of means for modifying the conductance of said circuit, means responsive to such modification for operating said device in its primary movement, another circuit associated with said device, means controlled by said device in operating for changing the conductance of said other circuit, and means operative when the change of the conductance in said other circuit is equal to the modification of the conductance in the first circuit for stopping the operation of said device and for initiating the secondary movement of said device.

4. In a telephone system, the combination with a calling line, an automatic switch, means for connecting said line to said switch, a telephone substation associated with said line, of means at said substation for modifying the conductance of said line while maintaining a closed circuit through said telephone substation, trunk lines accessible to said switch, and means for operating said switch responsive to such modification to select one of said trunk lines.

5. In a telephone system, the combination with a telephone line, a substation associated therewith, an automatic switch, trunk lines accessible thereto, and automatic means for connecting said line to said switch, of a calling device at such substation for varying the electrical conductance of said line while maintaining a continuous circuit of said line

through said sub-station, and means responsive to such variation for operating said switch to select one of said trunk lines.

6. In a telephone system, the combination with a telephone line, a substation associated therewith, said line forming a continuous circuit through said substation, an automatic switch, trunk lines accessible thereto, means for connecting said line to said switch, of means at said substation for modifying the electrical conductance of said line while maintaining said circuit closed, a circuit associated with said switch, means responsive to the modification of the electrical conductance of said line for operating said switch to select one of said trunk lines, and means controlled by the operation of said switch for modifying the same electrical conductance of said circuit.

7. In a telephone system, the combination with a telephone line, and a substation associated therewith, of a resistor at said substation, an automatic switch, lines accessible thereto, means for connecting said telephone line to said switch, means at said substation for connecting a certain portion of said resistor into said line circuit without opening it, and means responsive to such connection for completely operating said switch to select a predetermined one of said lines.

8. In a telephone system, the combination with a telephone line, a substation associated therewith, an automatic switch, lines accessible thereto, and means for connecting said telephone line to said switch, of means at said substation for modifying the electrical resistance of said line to a single finite value, and a relay responsive to such modification for causing the operation of said switch to select one of said lines.

9. In a telephone system, the combination of a telephone line, an automatic switch associated therewith having a plurality of wipers adapted to be moved in a single plane, a motor magnet for operating said wipers, a switching relay, a line relay, busy and idle trunk lines terminating in bank contacts accessible to said switch, means operative upon the removal of the receiver at the substation associated with the telephone line for operating said line relay to cause said motor magnet to operate to advance said wipers into engagement with the bank contacts of an idle trunk line, an automatic switch associated with said trunk line, a trunk conductor extending from the first mentioned automatic switch to the last mentioned automatic switch, means in the last mentioned automatic switch for applying a ground connection to said conductor, and a circuit for maintaining said line relay energized until said conductor is grounded.

10. In a telephone system, a repeater, an automatic switch, a trunk line permanently connecting said repeater and said switch, and means in said repeater for modifying the

electrical conductance, other lines accessible to said switch of said trunk line, and means in said switch operative responsive to a single change in electrical conductance in said trunk line for operating said switch to establish a connection with one of said other lines.

11. In a telephone system, an automatic switch, trunk lines divided into groups accessible to said switch, a circuit leading from said switch, means operative in said switch to select a trunk line in any predetermined group and means for controlling said operation by a single variation of the conductance of said circuit.

12. In a telephone system, an automatic switch, trunk lines divided into groups accessible to said switch, and a circuit leading to said switch, means for operating said switch to select a trunk line in any predetermined group, and means for controlling said switch in its trunk selection by impressing a predetermined unvarying current flow on said circuit to thereby direct the group selection and to start the trunk selection in that group.

13. In a telephone system, an automatic switch, trunk lines divided into groups accessible to said switch, said switch having a group selecting movement and a trunk selecting movement, a circuit leading from said switch, means for producing a single variation in conductance of said circuit, and means in said switch responsive to said variation for operating said switch to select any one of said groups of trunk lines and one of the trunk lines in the group selected.

14. In an automatic telephone system, a switch having reciprocating means for driving it through a plurality of steps in a primary movement, a subscriber's line, means for connecting said line to said switch through a closed loop circuit extending over the line, sub-station equipment on said line including subscriber controlled means for producing a single variation in conductance of the line without opening said closed loop to thereby directly control said switch in its primary movement, and means in the switch responsive to said change in line conductance for controlling said reciprocating means to step said switch through a number of steps determined by the conductance of said line, and for then stopping it.

15. In an automatic telephone system, a switch having reciprocating means for driving it through a plurality of steps in a primary movement, and other means for driving said switch in a secondary movement, a subscriber's line, means for connecting said line to said switch through a closed loop circuit extending over the line, sub-station equipment on said line including subscriber controlled means for producing a single variation in conductance of the line without opening said closed loop to thereby directly

control said switch in its primary movement, means in the switch responsive to said change in line conductance for controlling said reciprocating means to step said switch through
5 a number of steps determined by the resistance of said lines, and for then stopping it, and means operated after said steps have been taken for operating said switch through its secondary movement.

10 16. In an automatic telephone system, a subscriber's line terminating in a switch, trunks accessible to said switch, a line relay in said switch, means responsive to the initiation of a call on said line for energizing said
15 line relay, means responsive to the energization of said line relay for operating said switch to establish a connection with an idle one of said trunks, means for sending a ground connection over said trunk to said
20 switch to hold it operated, and means including a winding of said line relay for holding it energized until said ground connection is received.

17. In an automatic telephone system, a
25 subscriber's line terminating in a switch, trunks accessible to said switch, a line relay in said switch having two windings one of which is energized responsive to the initiation of a call on said line to energize said relay,
30 means responsive to the energization of said relay for operating said switch to establish a connection with an idle one of said trunks, means for sending a ground connection over said trunk to hold said switch operated, and
35 means including the second winding of said line relay for holding it energized until said ground connection is received.

In witness whereof, I hereunto subscribe my name this 9th day of May, 1927.

JOHN E. GARDNER.