907,582.

A. H. DYSON & F. W. DUNBAR.

TELEPHONE SYSTEM.

APPLICATION FILED JUNE 21, 1905.

Patented Dec. 22, 1908.

3 SHEETS—SHEET 1.

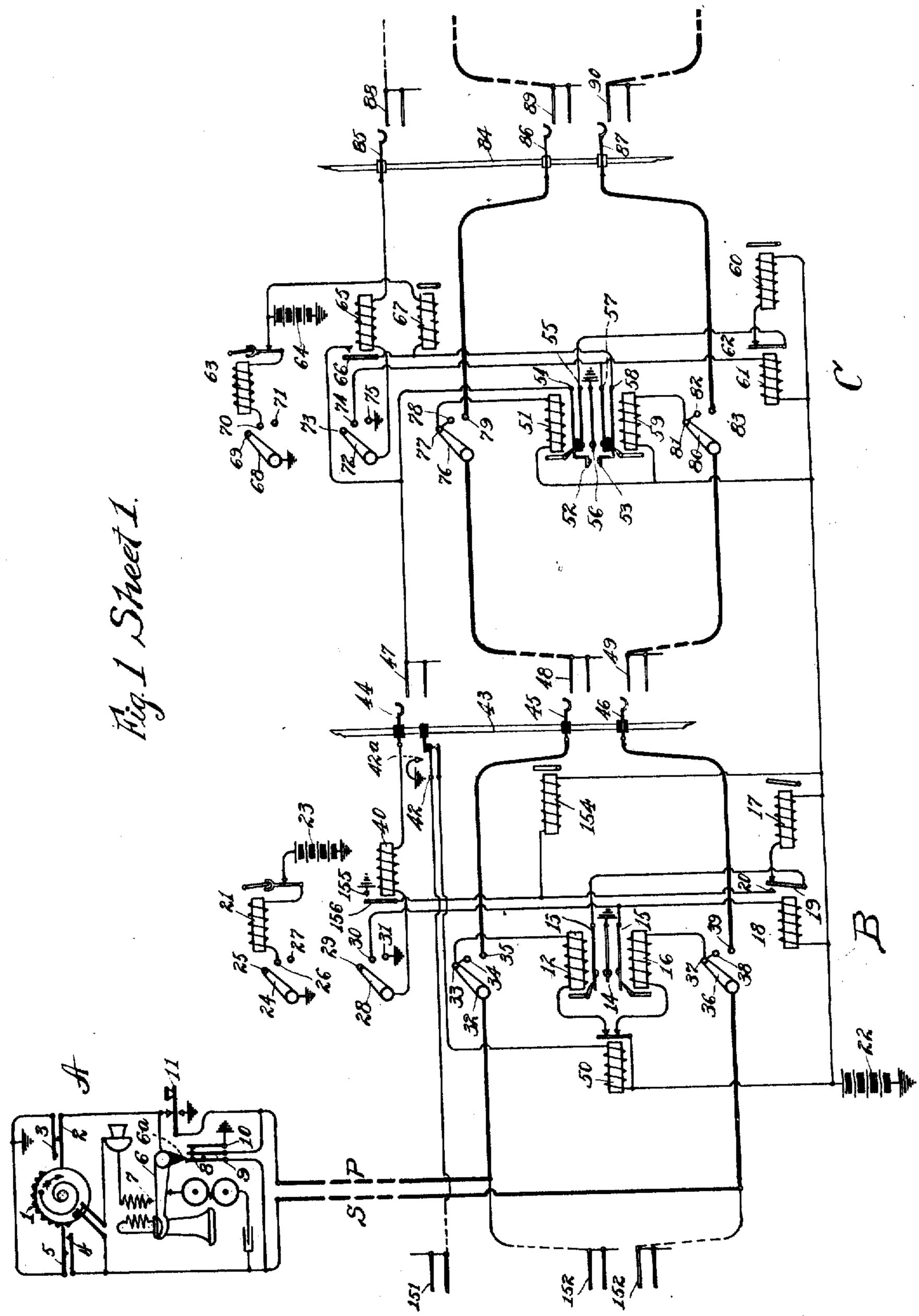


Fig. 1 Sheet 1.

WITNESSES:—

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3 SHEETS—SHEET 2.

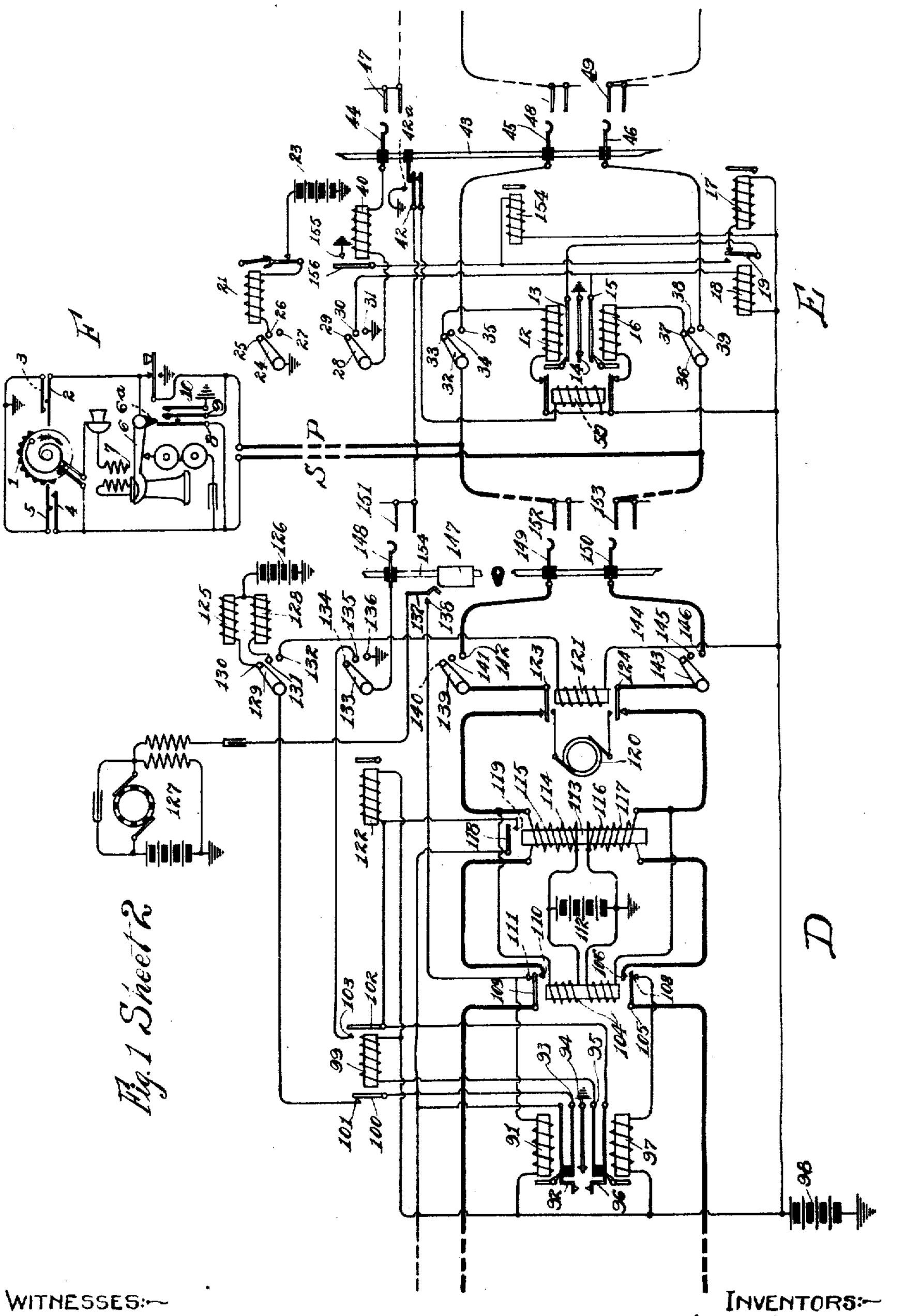


Fig. 1 Sheet-2

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3 SHEETS—SHEET 3.

Fig. 3

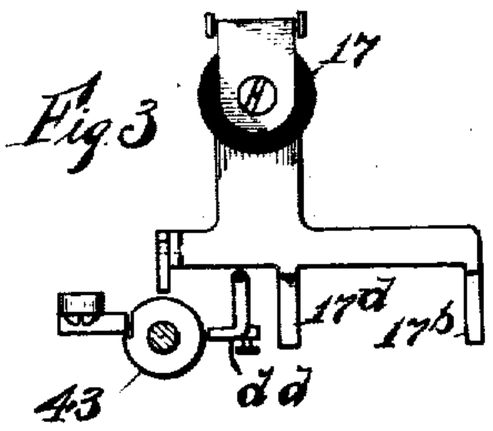


Fig. 5

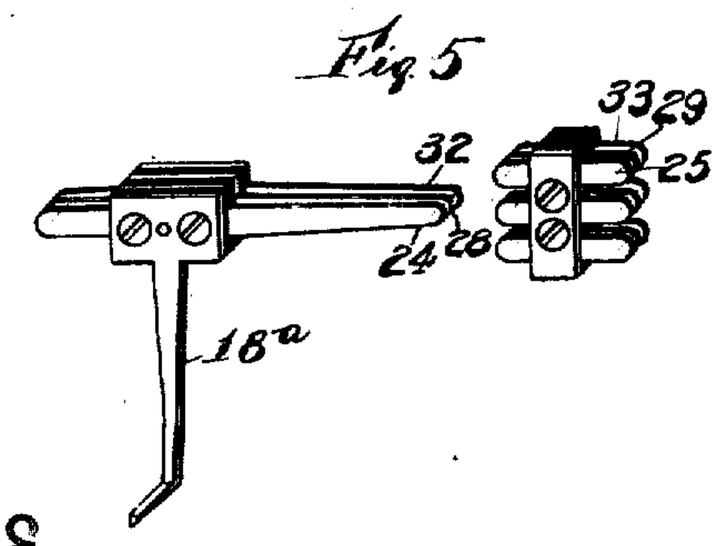


Fig. 4.

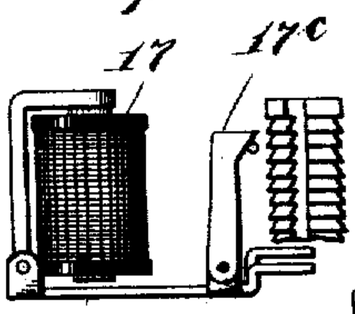


Fig. 2

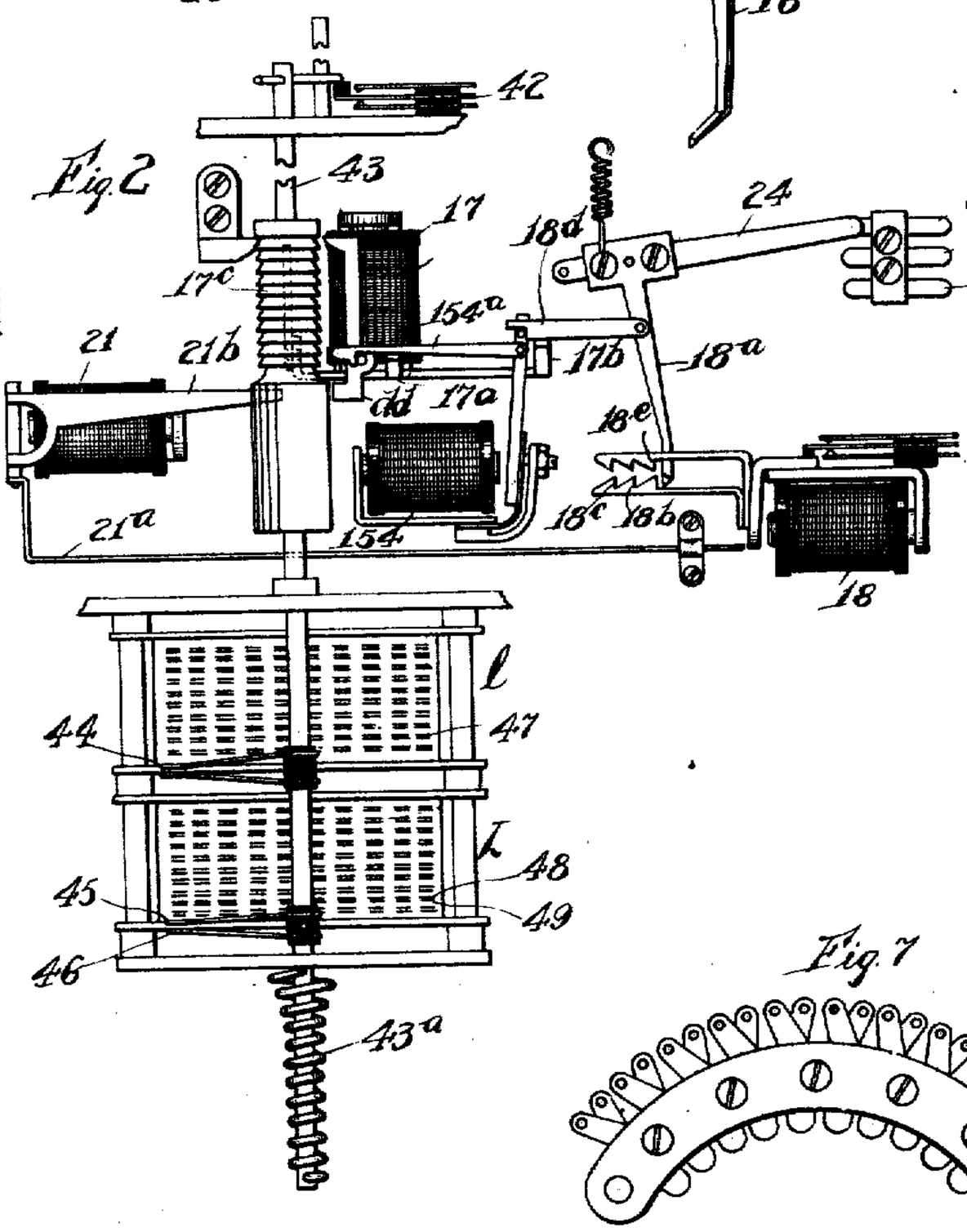


Fig. 7

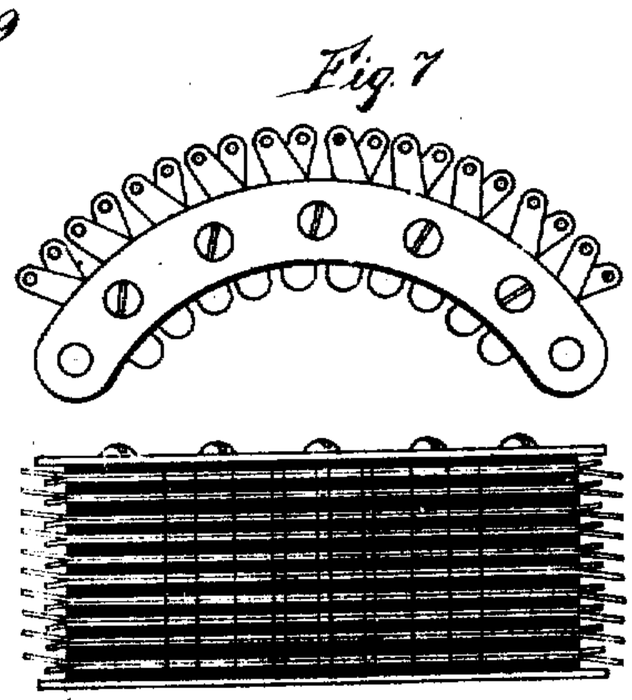

Fig. 6

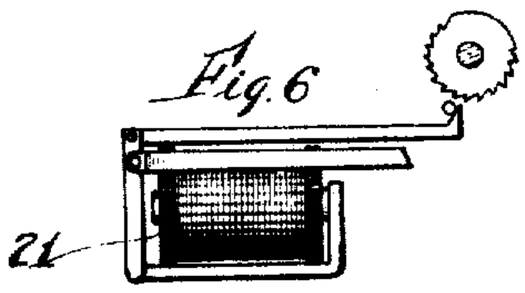


Fig. 8

WITNESSES:

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H. C. Olmstead.

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Francis W. Dunbar

# UNITED STATES PATENT OFFICE.

ALFRED H. DYSON AND FRANCIS W. DUNBAR, OF CHICAGO, ILLINOIS.

## TELEPHONE SYSTEM.

No. 907,582. Specification of Letters Patent. Patented Dec. 22, 1908.

Application filed June 21, 1905. Serial No. 266,281.

*To all whom it may concern:*

Be it known that we, ALFRED H. DYSON and FRANCIS W. DUNBAR, residents of the city of Chicago, county of Cook, and State of Illinois, have invented new and useful Improvements in Telephone Systems, of which the following is a specification.

Our invention relates to telephone systems in which the connection and disconnection of subscribers' lines is secured by means of automatic switches at the exchange, responsive to calling mechanisms at the substations.

Our invention relates more particularly to a system of the described character, in which a central source of current is used for the double purpose of operating the switches and supplying current for conversational purposes. It is common practice in systems of this character to effect the release of the automatic switches, used in an established connection, by causing a subscriber to simultaneously ground the two limbs of his telephone line at the substation, this act operating to throw out of balance the windings of a differential relay at the exchange, whereby the core of the relay becomes magnetized and attracts an armature to close circuit through the apparatus provided for returning the said switches to normal.

In accordance with the common practice mentioned, we provide a differential relay for the purpose, but arrange its windings in such manner that, in addition to the function above mentioned, it also acts during conversation as a repeating device, inductively uniting the conversational circuits of the two connected substations. Such a relay may be called a differential repeating relay.

Referring to the drawings, Figure 1, consisting of sheets 1 and 2, illustrates diagrammatically two telephone lines extending from substations to the exchange and apparatus at the exchange suitable for uniting them in a conversational circuit. In Fig. 2 is shown a general view of a selective switch mechanism for use in connection with the circuits of Fig. 1. Fig. 3 is a top view of the primary magnet of the said switch and its parts. Fig. 4 shows a side view of the primary magnet including the pawl and shaft ratchet. Fig. 5 is a perspective view of the side switch parts. Fig. 6 is a top view of the secondary magnet, its pawl and the associated shaft ratchet. Figs. 7 and 8 show respectively top and front views of the bank contacts of the switch.

Referring to Fig. 1, at A, we have illustrated, diagrammatically, substation apparatus including the usual transmitter, hook switch, receiver, induction coil, condenser and bell. We provide, in addition thereto, a calling device 1 and a releasing device, consisting of springs 8, 9 and 10, adapted to be operated by arm $6^a$ forming part of the hook lever. P and S are the two limbs of the telephone line extending to the exchange and there connected with the circuits of first selector switch B, which, in the system shown, is individual to the line of subscriber A. This switch may comprise shaft 43, wipers 44, 45 and 46 attached thereto, and multipled terminals of a plurality of second selector switches adapted to be engaged by the said wipers. The terminals of the latter switches may conveniently be arranged in groups, the switches of each group being assigned for connection to a division of one thousand subscribers' lines. The circuits illustrated at B include means, controllable from substation A by means of calling device 1, adapted to effect primary movements of shaft 43 to cause it to move wipers 44, 45 and 46 to positions adjacent to, but not engaging, terminals of the second selector switches of any group. It also provides means, responsive to calling device 1, for initiating secondary movements of shaft 43 to cause the wipers to move over the terminals of a selected group of second selector switches, their motion being arrested when they engage terminals of an idle switch. Second selector switch C may comprise shaft 84 and wipers 85, 86 and 87 attached thereto and terminals of connector switches adapted to be engaged by the said wipers. These terminals may be arranged in groups, the connector switches of each group being assigned for connection to a different one hundred-line division of the one thousand-line division to which the second selector switch is assigned. The second selector switch comprises means, adapted to be operated from the substation at A, when the line at the substation is connected through to the switch, by calling device 1, for imparting primary movements to shaft 84 to cause the wipers of the second selector switch to move to positions adjacent to the different groups of terminals of the connector switches described. Means are also provided, responsive to calling device 1, for imparting secondary movements to the shaft to cause the wipers to move over the terminals of a selected group, their motion being arrested

when they engage terminals of an idle connector switch. A connector switch, such as we have illustrated at D, may include a shaft 154 with wipers 148, 149 and 150 and multipled terminals of one hundred subscribers' lines adapted to be engaged by the wipers. The said terminals may conveniently be arranged in ten groups of ten each, the first group including lines numbered from 1 to 10; the second, lines numbered from 11 to 20; the third, lines numbered from 21 to 30, etc., of the one hundred to which the particular connector switch is assigned. The connector switch may also include means controllable from a substation, as A, by means of calling device 1 when the line at the substation is connected through to the connector switch, for imparting primary movements to the shaft to bring the wipers adjacent to, but not engaging, any one of the aforementioned ten groups of line terminals. It further provides means, responsive to calling device 1, adapted to impart secondary movements to the shaft to cause the wipers to move into engagement with terminals of any line of a selected ten-line group. The connector switch provides means whereby the calling subscriber may cause the bell of the called subscriber to ring. It further includes means for supplying talking current from a central source to the transmitters of connected subscribers, and a differential repeating relay such as we have before described.

An exchange, provided with switches of the three classes mentioned, may be used to supply service to several thousand subscribers. Second selector switches and connector switches may be much less numerous than first selector switches (which, as before stated, are individual to subscribers' lines), the system operating on the multiple trunking principle, well known in the art.

The mechanical connections between the shafts of the various switches and the electromagnets operating them, the arrangements of the terminals engaged by the wipers of the various switches and the mechanical forms of switches generally, may be of any approved character. Our invention does not require any particular arrangement of these mechanical parts, but consists rather in certain features of the circuit arrangement illustrated.

Having described our invention in a general way, the detailed relation to the different parts of the circuits, shown in Fig. 1, to one another may best be understood from a narrative of operation of the system. Assuming that subscriber A desires to be connected with subscriber F, whose number is assumed to be 2342, subscriber A effects switching movements as follows: He first removes his receiver from the switch hook, which act operates to close contact 6—7 and to move arm 6ª, attached to the hook lever. to the left of spring 8. He thereupon revolves calling device 1 in the direction indicated by the arrow, until two teeth of the ratchet shown thereon pass beneath spring 2. The revolution of the dial at its start brings the pin, shown upon the dial, to disengage the spring with which it is shown engaged, which by its tension disengages its associated contact spring, thereby opening circuit through the substation transmitter and conductively disuniting limbs P and S. These springs remain disengaged until the calling device returns to normal. Having moved two teeth below spring 2, subscriber A releases the calling device which thereupon revolves in the opposite direction, closing and opening contact, by the engagement of its teeth with spring 2, between springs 2 and 3 two times. Two impulses of current thereupon flow from ground at the substation, through contact 3—2 to limb P of the line, over the said limb to the exchange, through contact 32—33 of first selector switch B, through the winding of relay 12 to the active side of grounded battery 22, causing two energizations and deënergizations of the said relay and two attractions and releases of its armature. Two impulses of current are thereby caused to flow from ground at the first selector switch, through contact 14—13, through armature 19, through the winding of primary magnet 17 to battery 22. Two energizations of the said primary magnet are caused thereby, the said magnet imparting motion to shaft 43, such that wipers 44, 45 and 46 are moved to positions adjacent to terminals of a group of second selector switches assigned to a division of subscribers' lines, including numbers from 2000 to 2999. As soon as shaft 43 moves, contact 42—42ª is closed, placing ground on terminal 151 and its multiples, which thereupon test busy to connector switches having access to them.

Referring again to substation A, it will be noted that calling device 1, after effecting the second closure of contact between springs 2 and 3, causes contact between springs 5 and 4 to be made and broken a single time in its return to its normal position illustrated. An impulse of current thereupon flows from ground at the substation, through contact 5—4, to limb S of the line, over the said limb to the exchange, through contact 36—37, through the winding of relay 16 to battery 22. The consequent attraction and release of the relay's armature establishes a path for the flow of current from ground at the first selector switch, through contact 14—15, through the winding of relay 18 to battery 22. The resulting energization and deënergization of relay 18 moves arms 24, 28, 32 and 36 into engagement, respectively, with contact points 26, 30, 34 and 38. The engagement of arm 28 with contact point 30 connects wiper 44 through relay 18 to bat-

tery 22. The engagement of arm 24 with contact point 26 closes circuit through secondary magnet 21 which thereupon attracts its armature and imparts a secondary movement to shaft 43 in such manner that wipers 44, 45 and 46 engage the terminals of the first second selector switch of the before mentioned group. In case this second selector switch is idle, the deënergization of secondary magnet 21, which ensues immediately upon its energization, due to the vibratory character of its circuit, operates to move arms 24, 28, 32 and 36 into engagement with contact points 27, 31, 35 and 39, respectively.

In case the second selector switch is already in use, the engagement of wiper 44 of first selector switch B with contact terminal 47 of the first second selector switch of the group establishes a circuit, causing a second energization of relay 18 of the first selector switch of subscriber A as follows: from ground at the first selector switch then rendering the second selector switch busy, through contact 31—28 of said first selector switch, through relay 40 to wiper 44 of the said first selector switch, to a multiple of the terminal engaged by wiper 44 of the first selector switch of subscriber A, to the terminal engaged, to wiper 44 (Fig. 1), through the winding of relay 40, through contact 28—30 and through the winding of relay 18 to the active side of battery 22. The windings of relays 40 are so proportioned to that of relay 18 that this flow of current is insufficient to cause the attractions of their armatures. The energization of relay 18 operates to prevent movement of arms 24, 28, etc. to engage contact points 27, 31, etc. upon the deenergization of secondary magnet 21. Owing to the fact that contact 24—26 thus remains closed, magnet 21 is energized and deënergized a second time, imparting another secondary movement to shaft 43 such that wipers 44, 45 and 46 are moved to engage terminals of the second second selector switch of the group. Should this switch be also busy, circuit is continued through relay 18 unbroken, the relay continuing to prevent the movement of arms 24, 28, etc. Secondary magnet 21 continues to vibrate, imparting successive secondary movements to shaft 43, which move wipers 44, 45 and 46 into engagement with terminals of successive second selector switches of the group, until terminals of an idle switch are engaged. In such case, no first selector switch is connected to a multiple of terminal 47 of such second selector switch; the circuit through relay 18 is broken, and the relay deënergized, which then allows the retraction of the armature of secondary magnet 21 to move arms 24, 28, 32 and 36 into engagement with contact points 27, 31, 35 and 39, respectively. Wipers 44, 45 and 46 are now in engagement with terminals 47, 48 and 49 of idle second selector switch C, terminal 47 of the second selector switch rendering its multiples busy, due to the closing of contact 28—31, thus preventing intrusion from other first selector switches having access to switch C.

The closure of contacts 32—35 and 36—39, as above described, extends the circuits of limbs P and S of the telephone line of subscriber A through to wipers 45 and 46 and to the circuits of second selector switch C, rendering it controllable from substation A. Subscriber A now revolves calling device 1 until three teeth have passed below spring 2, and releases it, the device in its return to normal closing and breaking contact three times between springs 2 and 3. Three impulses of current are thereby caused to flow from ground at the substation, through contact 3—2 to limb P of the telephone line, over the said limb, through contact 32—35, contact 45—48, contact 76—77, through the winding of relay 51 to the active side of battery 22, causing three energizations and deenergizations of the said relay. Three resulting attractions and releases of the relay's armature cause three impulses of current to flow from ground at second selector switch C, through contact 56—55, through armature 62, through the winding of primary magnet 60 to battery 22, causing three energizations and deënergizations of said magnet. The said magnet operates to impart three primary movements to shaft 84, which moves wipers 85, 86 and 87 to positions adjacent to, but not engaging, multipled terminals of a group of connector switches assigned for connection to a division of subscribers' lines including numbers from 300 to 399 of the second one thousand division, or from 2300 to 2399.

Referring again to substation A, calling device 1, as it reaches normal, closes and breaks contact a single time between springs 5 and 4, causing an impulse to flow from ground at the substation, through contact 5—4, to limb S of the telephone line, over the said limb, through contact 36—39, contact 46—49, contact 80—81, through the winding of relay 59 to battery 22, which causes the energization and deënergization of the said relay. The resulting attraction and release of its armature causes an impulse of current to flow from ground at second selector switch C, through contact 56—57, through the winding of relay 61 to battery 22, causing the energization and deënergization of the said relay. This operates to move arms 68, 72, 76 and 80 into engagement with contact points 70, 74, 78 and 82, respectively. The engagement of arm 68 with contact point 70 causes secondary magnet 63 to become energized, its deënergization immediately following, due to the vibratory character of its circuit. The energization of the said magnet operates to impart a second-

ary movement to shaft 84, such that wipers 85, 86 and 87 are moved into engagement with terminals of the first connector switch of the before mentioned group. Should this be an idle switch, the deënergization of magnet 63 and the consequent retraction of its armature operates to move arms 68, 72, 76 and 80 into engagement with contact points 71, 75, 79 and 83, respectively, the closing of contact 68—71 preventing further energization of magnet 63, and the closing of contact 75—72 putting ground upon the multiples of the terminal of the connector switch engaged by wiper 85, rendering the said switch busy. Should, however, the first connector switch be busy, upon the engagement of wiper 85 with its terminal 88, circuit is closed through relay 61 of second selector switch C as follows: from ground at the second selector switch then connected with the said connector switch, through contact 75—72, relay 65 to wiper 85 of the second selector switch rendering the connector switch busy, to a multiple of the terminal engaged by wiper 85 of second selector switch C, to the terminal engaged by wiper 85, through relay 65 of second selector switch C, through contact 72—74 and through the winding of relay 61 to battery 22. The windings of relays 65 are so proportioned to that of relay 61 that this flow of current is insufficient to cause the attractions of their armatures. The energization of relay 61 prevents the movement of arms 68, 72, etc. to engage contact points 71, 75, etc. upon the retraction of the armature of secondary magnet 63. Arm 68 therefore remaining in engagement with contact point 70, magnet 63 is alternately energized and deënergized, each time causing a secondary movement of shaft 84 which moves wipers 85, 86 and 87 to engagement with terminals of successive connector switches, until terminals of an idle one are reached. When this occurs, circuit through relay 61 is broken, the relay is deënergized and the retraction of the armature of magnet 63 now operates to move arms 68, 72, 76 and 80 into engagement with contact points 71, 75, 79 and 83, respectively. Arm 68 disengaging contact point 70, further energization of magnet 63 is prevented and wipers 85, 86 and 87 rest in engagement with terminals 88, 89 and 90 of idle connector switch D. The engagement of arm 72 with contact point 75 places ground, through relay 65, upon terminal 88 and its multiples, rendering the connector switch busy with respect to other second selector switches having access to it. The closing of contacts 76—79 and 80—83 extends the circuits of limbs P and S through to wipers 86 and 87 and through them to the circuits of the connector switch selected, rendering it controllable from substation A by calling device 1.

Subscriber A now operates the calling device to send four impulses of current over limb P of the line, the said impulses passing through contact 86—89, switch C, through the winding of relay 91 of the connector switch, to the active side of grounded battery 98. Four energizations and deënergizations of the relay are effected thereby, the resulting attractions and releases of its armature causing four impulses of current to flow from ground at the connector switch, through contact 94—93, through contact 100—101, through contact 129—130, through the winding of primary magnet 125 to the active side of grounded battery 126. Four energizations of primary magnet 125, caused thereby, effect four primary movements of shaft 154, which moves wipers 148, 149 and 150 to positions adjacent to, but not engaging, terminals of a group of lines including those numbered from 2341 to 2349 inclusive, followed by terminals of line 2340.

Referring to substation A, the return of dial 1 causes a single impulse to flow from ground at the substation, through contact 5—4, over limb S of the line, through contact 87—90, switch C, through contact 105—108, through the winding of relay 97 to battery 98, causing the relay to be energized and deënergized. The attraction and release of its armature causes an impulse of current to flow from ground at the connector switch, through contact 94—95, through the winding of relay 99 to battery 98. The resulting energization and deënergization of relay 99 operates to cause arms 129, 133, 139 and 143 to engage, respectively, contact points 131, 135, 141 and 145. Subscriber A now operates calling device 1 to send two impulses of current from ground at the substation, through contact 3—2, over limb P of the line, through the winding of relay 91 to battery 98. The resulting attractions and releases of the relay's armature cause two impulses of current to flow from ground at the connector switch, through contact 94—93, contact 100—101, contact 129—131, through the winding of secondary magnet 128 to battery 126. Secondary magnet 128 is twice energized and deënergized, effecting two secondary movements of shaft 154 which moves wipers 148, 149 and 150 into engagement with terminals of the second subscriber's line of the before mentioned group, or of line #2342 of the called-for subscriber, whose substation is assumed to be F. The return of the calling device of subscriber A to normal causes an impulse of current to flow from ground at the substation, through relay 97 of connector switch D, causing the relay to attract its armature and, as before described, thereby cause the energization of relay 99. Assuming the line of subscriber F to be already in use or busy, the attraction of armature 102 to engage anvil 103, upon the energization of relay 99, causes current to

flow from ground, through contact 151—148, through contact 133—135, through contact 103—102, through the winding of release magnet 122 to battery 98. When relay 99 is deënergized upon the cessation of the impulse, contact 103—102 is opened and release magnet 122 is deënergized, causing the return of shaft 154 and its wipers, together with arms 129, 133, 139 and 143, to normal. The ground connection to terminal 151 may be established in either of the following ways. Should subscriber F, at the time connection is made with his line, be a calling subscriber, the first primary movement of the shaft of his first selector switch E allowed spring 42 to engage anvil 42ª, thus placing ground, through the said contact 42ª—42, upon terminal 151. Should another subscriber already have established connection with the line of subscriber F, terminal 151 is connected to ground at the connector switch already connected with a multiple of the said terminal, through contact 133—136 of the said connector switch. Subscriber A now depresses key 11, grounding limb P of the line at his substation, this being the switching operation for ringing the bell of the called subscriber, should his line be idle. Under the circumstances described, however, the connector switch having been released and returned to normal, this grounding of limb P of the line of subscriber A causes the energization of relay 91 of the connector switch which, in turn, causes the energization of primary magnet 125, which imparts a primary movement to shaft 154. The first primary movement of the said shaft, which may be in a vertical direction, causes lug 147 to move spring 137 into engagement with anvil 138. The closing of contact 137—138 causes, in the subscriber's receiver, the characteristic busy signal from busy back machine 127, circuit being traced through contact 137—138, contact 111—109, over the talking circuit at the exchange, as identified by the heavy lines, to limb P of the line of subscriber A; the current returning through the substation, over limb S and the talking circuit at the exchange, through contact 108—105, through the winding of relay 97 and through the circuits of battery 98.

While primary movements of shaft 154 cause the closure of contact 137—138, the first secondary movement of the shaft operates to open the said contact and cut busy back machine 127 out of circuit with the calling subscriber's line. While the connector switch is executing switching movements in response to the transmission, by the calling subscriber, of the impulses representing the third digit of the called subscriber's number, the calling subscriber hears the busy signal. As soon, however, as the first impulse of the fourth digit is transmitted, the busy signal is no longer heard. This method of operation is found in practice not to be objectionable. Subscriber A, being notified that the called line is busy, replaces his receiver upon hook lever 6, the lever resuming its normal position as shown in the illustration, arm 6ª causing contact to be momentarily made between springs 8, 9 and 10 and thereupon broken. The closing of contact between the said springs connects the two limbs P and S of the line to ground at the substation, which results in a simultaneous energization of relays 91 and 97 of connector switch D. The armatures of the said relays are simultaneously attracted and contact is closed between springs 92 and 96, establishing a path for the flow of current from ground at second selector switch C, through contact 75—72, through the winding of release relay 65, energizing the said relay, through contact 85—88, through contact between springs 92 and 96, through the winding of release magnet 122 of the connector switch, energizing the said magnet, and to battery 98.

The energization of release relay 65 of second selector switch C attracts the relay's armature, establishing a path for the flow of current from ground at the first selector switch B, through contact 31—28, through the winding of release relay 40, through contact 44—47, through armature 66 of release relay 65, through release magnet 67 of the second selector switch, to battery 64. Release relay 40 of the first selector switch attracts its armature to close current from ground, through contact 155—156, through the winding of release magnet 154 to battery 22, causing the energization of the said magnet. When contact between springs 8, 9 and 10 is broken, relays 91 and 97 of connector switch D are deënergized, and contact 92—96 is opened. Release relays 65 and 40, and release magnets 67 of the second selector switch and 154 of the first selector switch, are deënergized, which effects the release of second selector switch C and first selector switch B, and the return of their mechanisms to normal, as illustrated. When contact 92—96 is opened, release magnet 122 is deënergized and the connector switch is restored to normal.

In case the line of subscriber F is idle at the time when subscriber A establishes connection therewith, as before described, terminal 151 is connected to battery and the attraction, by relay 99, of its armature 102 to engage anvil 103, as before described, fails to energize release magnet 122. Relay 99 becomes deënergized and arms 129, 133, 139 and 143 are thereby caused to engage contact points 132, 136, 142 and 146, respectively. The closing of contact 136—133 of connector switch D establishes ground to terminal 151, rendering the line of subscriber F busy, and also establishes a path for the flow of current from ground at connector

switch D, through contact 136—133, through contact 148—151, through the winding of relay 50 of first selector switch E, to battery 98, causing the said relay to attract its armatures and cut off the circuits of the first selector switch from the limbs of the line of subscriber F. Subscriber A now depresses key 11, grounding limb P of the line, current flowing from ground at the substation, over the said limb, through relay 91, causing its energization. The resulting attraction of its armature establishes a path for the flow of current from ground at the connector switch, through contact 94—93, through contact 100—101, through contact 129—132, through the winding of ringing relay 121, to battery 98. The said relay 121 is energized and attracts its armatures 123 and 124 to include ringing generator 120 in circuit with the line of subscriber F, causing his bell to ring. When subscriber A releases key 11, generator 120 is cut out of circuit. Subscriber F, in response to the call, removes his receiver from hook 6, which thereupon closes contact 6—7, establishing a path for the flow of current as follows: from the grounded side of battery 112, through winding 117 of relay 113, the current thereupon joining current from the grounded side of battery 112, through the lower winding of relay 104, the joint flow proceeding through armature 124 of relay 121, through contact 143—146, contact 150—153, over limb S of the line of subscriber F, through the transmitter, supplying talking current thereto, through contact 7—6; returning over limb P of the line, through contact 152—149, through contact 141—139, through armature 123 of relay 121, the current then dividing; a portion flowing through winding 115 of relay 113, to the active side of battery 112; the other portion flowing through the upper winding of relay 104 to the active side of the said battery.

Windings 115 and 117, disposed upon opposite ends of the core of differential repeating relay 113, are so proportioned and arranged as to neutralize their magnetic effects upon the core of the said relay which, under these circumstances, does not attract its armature 118. Relay 104, on the other hand, is not differentially wound. The above described flow of current effects the magnetization of its core, which attracts armatures 108 and 109 to engage anvils 106 and 110. This establishes an additional path for the flow of current from the grounded side of battery 112, through winding 116 of relay 113, through contact 106—108, over the talking circuit at the exchange, as indentified by the heavy line, to limb S of the line of subscriber A, through the transmitter at the substation, supplying talking current thereto, through contact 7—6; returning over limb P of the line, over the other side of the talking circuit through the exchange, through contact 109—110, through winding 114 of relay 113, to the active side of battery 112. Windings 114 and 116 are so proportioned and disposed upon the core of relay 113 that they neutralize their magnetic effects upon the core, armature 118 not being attracted. Subscribers A and F are now in conversation. The alternating voice currents, when subscriber F is speaking in his transmitter, are repeated by coils 115 and 117 of differential relay 113 in circuit with the called subscriber's line, to coils 114 and 116, respectively, in circuit with the line of the calling subscriber, and by means of the induction coil at the substation, to the receiver of subscriber A. When subscriber A is speaking, the voice currents are repeated from coils 114 and 116 to coils 115 and 117 and by means of the induction coil at the substation, to the receiver of subscriber F. During conversation, no impedance is connected to the talking circuit, other than that of relay 104. It will be noted that the arrangement of the coils of relay 113 is such that the amount of current flowing through the transmitters of the two subscribers in conversation is independent of the relative resistances of their respective lines. It will also be noted that the neutral condition of the core of differential relay 113 is independent of the relative resistances of the lines of connected subscribers, the two windings in circuit with each line independently neutralizing one another. When the subscribers have finished their conversation, they replace their receivers upon the hooks, which operates to close and then break contact between springs 8, 9 and 10 at their respective substations. Assuming that subscriber F does this first, the resulting grounding of the two limbs of his line short circuits winding 117 of relay 113, while current continues flowing through winding 115 in undiminished volume. This unbalances the neutralizing effect of the two windings; armature 118 closes contact 118—119, establishing a path for the flow of current from ground at second selector switch C, through contact 75—72, through the winding of release relay 65 of the second selector switch, energizing said relay, through contact 85—88, through contact 118—119, through the winding of release magnet 122 energizing it, and to battery 98. The energization of release relay 65 of second selector switch C effects the energization of release magnet 67 of the said switch, as before described, and of release relay 40 of the first selector switch which, in turn, effects the energization of release magnet 154 of the said switch.

Referring again to substation F, when springs 8, 9 and 10 disengage one another, circuit is broken through windings 115 and 117 of relay 113 and the windings of relay

104, deënergizing the relay whose retracted armatures take current from the line of A and windings 114 and 116. Under these circumstances, armature 118 disengages anvil 119, opening circuit through release magnet 122 of the connector switch, whose deënergization causes the switch to return to normal. It also opens circuit through release relay 65 of second selector switch C, which is deënergized; it deënergizes release magnet 67, returning the second selector switch to normal, and also release relay 40 of the first selector switch. The latter relay deënergizes release magnet 154 of the first selector switch which thereupon returns to normal. All apparatus, used in establishing the connection, has been returned to normal and, in this case, the act of subscriber A in replacing his receiver is nugatory.

Assuming that subscriber A replaces his receiver in advance of subscriber F, causing contact between springs 8, 9 and 10 to be closed and the two limbs of his line to be grounded at the substation, winding 116 of relay 113 is short circuited, while current continues flowing in undiminished volume through winding 114 of the said relay. The neutralizing effect of the two windings upon one another is destroyed; the core of relay 113 is magnetized and attracts armature 118 to engage anvil 119. This effects the energization of the release magnets of the connector switch, the second selector switch and the first selector switch in the manner described in the case in which subscriber F accomplished the release. When springs 8, 9 and 10 disengage one another, circuit is opened through windings 114 and 116, and their unbalancing effect upon the core of relay 113 is destroyed; and assuming that subscriber F has not yet replaced his receiver upon the hook, armature 118 disengages anvil 119 and the release magnets of the various switches are deënergized, causing them to return to normal.

It will be noted that should limbs P and S of both subscribers' lines be simultaneously grounded, windings 116 and 117 of relay 113 will be simultaneously short circuited, current continuing to flow through windings 114 and 115. There will thus be a greater unbalancing effect upon the core of relay 113 than in the cases in which one subscriber alone accomplished the release operation, joint actions of the subscribers in releasing coöperating with each other. In this case, however, the release of armature 118 of relay 113 does not occur until ground has been removed from the two limbs of the line of substation F. We also provide means to enable the calling subscriber, should he desire on account of an error in transmitting a call, or for any other reason during the time he is establishing a connection, to return the apparatus to normal, to accomplish this result. Assuming that the calling subscriber A has operated switch B to connect the switch C, he thereupon replaces his receiver upon the hook, grounding the two limbs of his line, and relays 12 and 16 of switch B are simultaneously energized. The energization of relay 16 closes circuit through electromagnet 18, drawing up armature 19. Current thereupon flows from ground, through contact 14—13, through contact 19—20, through the winding of release magnet 154 to battery 22, energizing magnet 154. When ground is removed from the two limbs of the line, relays 12 and 16 are deënergized and also magnet 154, which effects the return of switch B to normal.

Assuming that the calling subscriber has operated switch B and switch C, the latter to connect with the connector switch, and then replaces his receiver, in this case relays 51 and 59 of switch C are simultaneously energized, establishing a path for the flow of current as follows: from ground at switch B, through contact 31—28, through the winding of release relay 40, through contact 44—47, through contact 52—53, through the winding of release magnet 67 of switch C to battery 64, energizing relay 40 and magnet 67. The energization of relay 40 effects the energization of release magnet 154; and when ground is removed from the two limbs of the line at the substation, the resulting opening of contact 52—53 results in the deenergization of release magnets 67 and 154, and the return of switches C and B to normal.

Assuming that the calling subscriber has operated switches B, C and D, and desires to return the apparatus to normal, the grounding of the two limbs of the line simultaneously energizes relays 91 and 97 of switch D, the path for the flow of current thereby being established from ground at switch C, through contact 75—72, through release relay 65, contact 85—88, through contact 92—96 of switch D, the winding of release magnet 122 to battery 98. Relay 65 of switch C and magnet 122 of switch D are energized, the drawing up of the former preparing the release mechanisms of switches C and B for the return of the switches to normal, as heretofore described. When ground is removed from the limbs of the line at the substation, the deënergization, resulting therefrom, of relays 91 and 97 of switch D, opens contact 92—96, and the release magnets of all three switches are deënergized and the switches returned to normal.

Referring now to Fig. 2, we show a switch mechanism generic to the circuits B, C and E of Fig. 1, being adapted for use to perform the mechanical functions of any of said circuits, and with minor modifications hereafter indicated may be used in connection with circuit D of Fig. 1. To avoid repetition of

drawings, we show a single switch, and for convenience supply reference characters thereto, corresponding to circuit B. The switch comprises essentially the contact banks L and 1, concave in shape as indicated in Figs. 7 and 8, and including each one hundred sets of contacts arranged in ten superposed rows of ten contacts each. In front of the banks is placed the shaft 43, journaled to the bank supports and carrying wipers 44, 45 and 46. Above the banks, a double ratchet, having horizontal and vertical teeth, is fastened to the shaft. Adapted to engage the horizontal teeth and lift the shaft and wipers to select contact rows, is the armature-driven pawl $17^c$ controlled by magnet 17; while adapted to engage the vertical teeth and rotate the shaft and wipers to select contacts of the selected rows, is provided armature-driven pawl $21^b$ controlled by magnet 21. The side switch mechanism comprises magnet 18 with its armature-controlled spring including teeth $18^b$ and $18^c$ controlling the movements of pivoted side switch pawl $18^a$ and consequently of switch-arm 24 fastened to the pawl. For restoring the shaft and side-switch, the release magnet 154 is provided.

In the operation of the switch, one or more current impulses are first transmitted through primary magnet 17. The first attraction of the magnet's armature is effective to accomplish three simultaneously occurring results, namely: First, arm $17^a$ lifts arm $154^a$ upward to disengage the pin on double detent *d d*, which then moves toward the shaft ratchets, engaging with its upper part a tooth of the horizontal shaft ratchet, and with its lower part a tooth of the vertical ratchet; second, the attraction of the armature effects a thrust of pawl $17^c$ to engage the upmost tooth of the horizontal ratchet, lifting the shaft a step, in which position it is held by the upper part of detent *d d*; third, arm $17^b$ lifts arm $18^d$ so that it frees the pin upon the end of the armature of release magnet 154, pawl $18^a$ then moving a slight distance to the left so that arm $18^d$ rests upon the top of the said pin. This serves to unlock the side switch for its operation, as hereafter described. Successive impulses through primary magnet 17, after the first, serve only to raise the shaft successive steps upward, double detent *d d* engaging, with each thrust, successive teeth of the ratchet and holding the shaft in the raised position. After the last impulse through magnet 17, a single impulse is caused to flow through magnet 18, as described in connection with the circuits. The said magnet attracts its armature, whose associated ratchet is drawn downward to a position such that the end of side switch pawl $18^a$ rests against tooth $18^e$. When the magnet is thereafter deënergized, its armature is retracted and the end of pawl $18^a$ slips down from tooth $18^e$ to engage tooth $18^b$. By this means, side switch arm 24, fastened to pivoted pawl $18^a$, is moved to disengage contact 25 and to engage contact 26.

In Fig. 5 is indicated the manner in which a plurality of circuit-changing arms 24, 28, 32, etc., may be associated with a single side switch pawl $18^a$, suitable sets of insulated contacts being provided for each arm so that each movement of the side switch pawl is effective for a plurality of simultaneous circuit changes. The next step in the operation of the switch is the sending of one or more impulses through secondary magnet 21. Each is effective to cause the attraction of the magnet's armature and a thrust of pawl $21^b$ fastened thereto, which, engaging successive vertical ratchet teeth of the shaft, rotates the shaft and wipers 44, 45 and 46 from contacts to contacts along selected rows. Each time the armature of magnet 21 is attracted, arm $21^a$ engages the armature of side switch magnet 18; and unless the said magnet has become energized a second time, (as described in connection with the circuits, after the first actuation of secondary magnet 21,) arm $21^a$ with the first energization of magnet 21 thrusts the armature of magnet 18 to the right and then releases it, whereby side switch pawl $18^a$ is advanced another step to the left to engage tooth $18^c$, and arm 24 moved to disengage contact 26 and to engage contact 27. It is apparent, however, that if magnet 18 becomes energized because the switch wipers are passing over busy contacts, no second step of side switch pawl $18^a$ is possible (such movement occurring only when the armature of the magnet is retracted) until magnet 18 becomes deënergized, which of course occurs when the switch wipers engage idle contacts. When this does occur, arm $21^a$ will be in a position retracted from the armature of magnet 18, the armature returns to normal, and the side switch pawl is advanced to engage tooth $18^c$. The restoration of the shaft and side switch mechanism is accomplished by an impulse of current sent through magnet 154. The said magnet, attracting its armature, brings arm $154^a$ to the left so that it engages the pin upon double detent *d d*, while the pin upon the armature is drawn to a position such that it engages the off-set of arm $18^d$. When, now, magnet 18 is deënergized, its armature is retracted by its associated spring withdrawing, by arm $154^a$, the double detent from engagement with the shaft ratchets, and by its pin moves arm $18^d$ and side switch pawl $18^a$ to their normal positions, as shown, whereby the side switch arms are also restored. Upon the withdrawal of double detent *d d*, the shaft is free to be rotated by spring $43^a$, against whose torsion it was turned, to a position

such that wipers 44, 45 and 46 disengage the bank contacts, when the shaft descends by gravity, assisted by spring 43ª, to its normal position. It will be understood that when the switch structure of Fig. 2 is used as a connector (the connector circuit being shown at D of Fig. 1), the arm 21ª is omitted.

While, for convenience of illustration, we have shown a plurality of batteries in Fig. 1, it is to be understood that they may be one and the same battery.

Our invention is not limited in its application to the precise structures shown, and we desire not to be limited thereto, as applications of our invention other than those shown will readily suggest themselves to those skilled in the art.

We claim:—

1. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with a calling subscriber's line and a called subscriber's line extending from substations to the exchange and connected for conversation thereat, of an electromagnet adapted to control disconnection of said lines, provided with a core and four energizing windings therefor, two of said windings being in circuit with the calling subscriber's line and the other two in circuit with the called subscriber's line, a central source of current in circuit with said windings, a disposition of the windings in circuit with each line such that during conversation they neutralize one another with respect to the core of the electromagnet, independently of the windings in circuit with the other line, and apparatus at each substation under control of the subscriber, adapted to destroy the neutralizing effect of the windings in circuit with his line, independently of the windings in circuit with the other line, to effect actuation of said electromagnet.

2. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with a calling subscriber's line and a called subscriber's line extending from substations to the exchange and connected for conversation thereat, of an electromagnet provided with a core and four energizing windings therefor, two of said windings being in circuit with the calling subscriber's line and the other two in circuit with the called subscriber's line, a central source of current in circuit with said windings, a disposition of the windings in circuit with each line such that during conversation they neutralize one another with respect to the core of the electromagnet, independently of the windings in circuit with the other line, apparatus at each substation under control of the subscriber, adapted to destroy the neutralizing effect of the windings in circuit with his line, independently of the windings in circuit with the other line, to effect magnetization of said core, and armature mechanism for said electromagnet controlling disconnection of said lines, adapted to be attracted by the magnetization of said core.

3. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with a calling subscriber's line and a called subscriber's line extending from substations to the exchange and connected for conversation thereat, of an electromagnet provided with a core and four energizing windings therefor, two of said windings being in circuit with the calling subscriber's line and the other two in circuit with the called subscriber's line, a central source of current in circuit with said windings, a disposition of the windings in circuit with each line such that during conversation they neutralize one another with respect to the core of the electromagnet, independently of the windings in circuit with the other line, apparatus at each substation under control of the subscriber, adapted to destroy the neutralizing effect of the windings in circuit with his line, independently of the windings in circuit with the other line, to effect magnetization of said core, switching mechanism adapted to be actuated by the magnetization of said core and apparatus, responsive to said mechanism, for disconnecting said lines.

4. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with two telephone lines extending from substations to the exchange, of a central source of current, a repeating device associated with said lines at the exchange, inductively uniting them for conversation, provided with four windings disposed about a core of magnetic material, a disposition of said windings such that two are in closed circuit with each line, the windings of each line neutralizing one another with respect to the core during conversation, independently of the windings of the other line, apparatus at each substation under control of the subscriber, adapted to destroy the neutralizing effect of the windings in circuit with his line, independently of the windings in circuit with the other line, to effect magnetization of said core, and apparatus responsive to the magnetization of said core, for disconnecting said lines.

5. In a telephone exchange system pro-

vided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with two telephone lines extending from substations to the exchange, of a central source of current, a repeating device associated with said lines at the exchange, inductively uniting them for conversation, provided with four windings disposed about a core of magnetic material, a disposition of said windings such that two are in closed circuit with each line, the windings of each line neutralizing one another with respect to the core during conversation, independently of the windings of the other line, apparatus at each substation under control of the subscriber, adapted to destroy the neutralizing effect of the windings in circuit with his line, independently of the windings in circuit with the other line, to effect magnetization of said core, switching mechanism adapted to be actuated by the magnetization of said core and apparatus responsive to said mechanism, for disconnecting said lines.

6. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with two telephone lines extending from substations to the exchange and connected thereat, of a repeating device associated with said lines at the exchange, inductively uniting them for conversation, provided with windings disposed about a core of magnetic material, a central source of current for operating and conversational purposes, supplying current through said lines to the transmitters of the two substations, in quantities independent of the comparative resistances of the lines, the path of said current including windings of said device, a disposition of said windings with respect to the core, such that during conversation their magnetic effects are balanced and the core neutral, apparatus at each substation under control of the subscriber adapted, independently of the other subscriber, to unbalance the magnetic effects of said windings to magnetize said core, armature mechanism associated with said device, actuated by magnetization of said core, and apparatus responsive to said mechanism, for disconnecting said lines.

7. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with two telephone lines extending from substations to the exchange and connected thereat, of a repeating device associated with said lines at the exchange, inductively uniting them for conversation, provided with windings disposed about a core of magnetic material, a central source of current for operating and conversational purposes, supplying current through said lines to the transmitters of the two substations, in quantities independent of the comparative resistances of the lines, the path of said current including windings of said device, a disposition of said windings with respect to the core, such that during conversation their magnetic effects are balanced and the core neutral, apparatus at each substation under control of the subscriber adapted, independently of the other subscriber, to unbalance the magnetic effects of said windings to magnetize said core, and apparatus responsive to magnetization of said core, for disconnecting said lines.

8. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with two telephone lines extending from substations to the exchange and connected thereat, of a central source of current, a differential repeating electromagnet in circuit therewith, inductively uniting said lines for conversation, means for maintaining the core of said electromagnet neutral during conversation, apparatus at each substation, under control of the subscriber, adapted to independently destroy neutrality of and magnetize said core, and apparatus responsive to such magnetization, for disconnecting said lines.

9. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with a calling subscriber's line and a called subscriber's line extending from substations to the exchange, of an electromagnet at the exchange in circuit with the line, and adapted to be energized upon the response, of the called subscriber, switching mechanism responsive to the energization of said electromagnet, and a repeating coil relay for connecting said lines for conversation switched into operative relation with the calling line by said mechanism.

10. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with two telephone lines extending from substations to the exchange and connected for conversation thereat, of an electromagnet associated with said lines at the exchange, provided with four windings disposed about a core of magnetic material, two of said windings being in circuit with each line, a central source of current supplying

talking current to the transmitters of the substations, in quantities independent of the comparative resistances of the lines, the path for each substation including the two windings in circuit with its line, a disposition of said windings with respect to the core, such that during conversation those in circuit with each line balance one another to maintain the core neutral, apparatus at each substation under control of the subscriber, adapted to destroy the neutralizing effect of the windings in circuit with his line, independently of the windings in circuit with the other line, to effect magnetization of the core, and apparatus responsive to such magnetization, adapted to disconnect said lines.

11. In a telephone exchange system provided with switching mechanisms at the substations and automatic switches responsive thereto at the exchange for connecting and disconnecting subscribers' lines, the combination with two telephone lines extending from substations to the exchange and connected for conversation thereat, of an electromagnet associated with said lines at the exchange, provided with four windings disposed about a core of magnetic material, two of said windings being in circuit with each line, a central source of current supplying talking current to the transmitters of the substations, in quantities independent of the comparative resistances of the lines, the path for each substation including the two windings in circuit with its line, a disposition of said windings with respect to the core, such that during conversation those in circuit with each line balance one another to maintain the core neutral, apparatus at each substation under control of the subscriber, adapted to destroy the neutralizing effect of the windings in circuit with his line, independently of the windings in circuit with the other line, to effect magnetization of the core, switching mechanism adapted to be actuated by the magnetization of said core, and apparatus responsive to said mechanism for disconnecting said lines.

12. In a telephone exchange system, the combination with two telephone lines extending from substations to the exchange, of an electromagnet provided with a core and four windings therefor, two of said windings being in circuit with the line of each subscriber, a central source of current in circuit with said windings, a disposition of the windings in circuit with each line such that when equal current is flowing in them, they neutralize one another with respect to the core, independently of the other windings, and apparatus at each substation under control of the subscriber, adapted to effect a preponderance of current in one of the windings in circuit with his line to magnetize said core independently of the windings in circuit with the other line.

13. A telephone circuit with resistances therein; a repeating coil having equal and opposite windings of equal resistances; a battery bridged between said windings and connected to ground; a controlling circuit, controlled by the called party; a circuit controlling mechanism in the controlling circuit whereby the resistances are cut out of the telephone circuit and the repeating coil is substituted therefor; an armature adjacent to the coil; a restoring magnet circuit containing said armature, and a restoring magnet; a restoring magnet armature operatively connected with the circuit controlling mechanism to restore the apparatus employed to normal position; and electromagnetic means whereby an unbalancing of the repeating coil causes the repeating coil armature to complete the restoring magnet circuit, thereby causing the restoring magnet armature to restore the circuit controlling mechanism and hence to cut out the repeating coil by restoring all the apparatus employed to normal position.

14. An automatic telephone exchange system including a pair of connected telephone lines, a plurality of selective switches associated therewith through which the conversational circuit extends, a differential repeating relay having windings in circuit with said lines, release magnets one for each of said switches, and means at a substation for controlling said relay to operate said release magnets at the will of the subscriber.

15. An automatic telephone exchange system including a calling line, a called line, a connector adapted for operation by currents over the calling line to connect directly with the called line, a normally open link-circuit for said connector, a differential repeating relay having windings for inductively uniting said lines for conversation, a relay operative after connection made with the called line to render said normally open circuit conductively continuous whereby said differential relay is rendered effective to unite said lines, and means at the substation of a line for temporarily effecting a preponderating flow of current in a winding of said differential relay to restore said connector to normal.

16. In an automatic telephone exchange system, a calling subscriber's line, switching mechanism at the substation, a called subscriber's line, selective switches at the exchange of a plurality of classes arranged for successive operation responsive to said mechanism in completing a connection between said lines, a differential repeating relay at the exchange with windings adapted for connection to said lines, a central source of current connected to said windings to supply current there through to said lines for conversational purposes in quantities independent of the relative resistances of the lines, and means at the substation of a line for causing a prepon-

derating flow of current in a winding of said relay.

17. A telephone circuit with resistances therein; a repeating coil; a controlling circuit controlled by called party; a circuit controlling mechanism in the controlling circuit whereby the resistances are cut out of the telephone circuit; and the repeating coil is substituted therefor, and a talking circuit results.

18. A telephone circuit with resistances therein, a repeating coil, a controlling circuit controlled by the called party, a circuit controlling mechanism in the controlling circuit whereby the resistances are cut out of the telephone circuit and the repeating coil is substituted therefor and a talking circuit results, a restoring relay circuit, an armature in said circuit, and electromagnetic means whereby the apparatus employed may be restored to normal position.

In witness whereof, we hereunto subscribe our names this 19th day of June, A. D., 1905.

ALFRED H. DYSON.
FRANCIS W. DUNBAR.

Witnesses:
A. B. McDONOUGH,
CHAS. JUSSY.