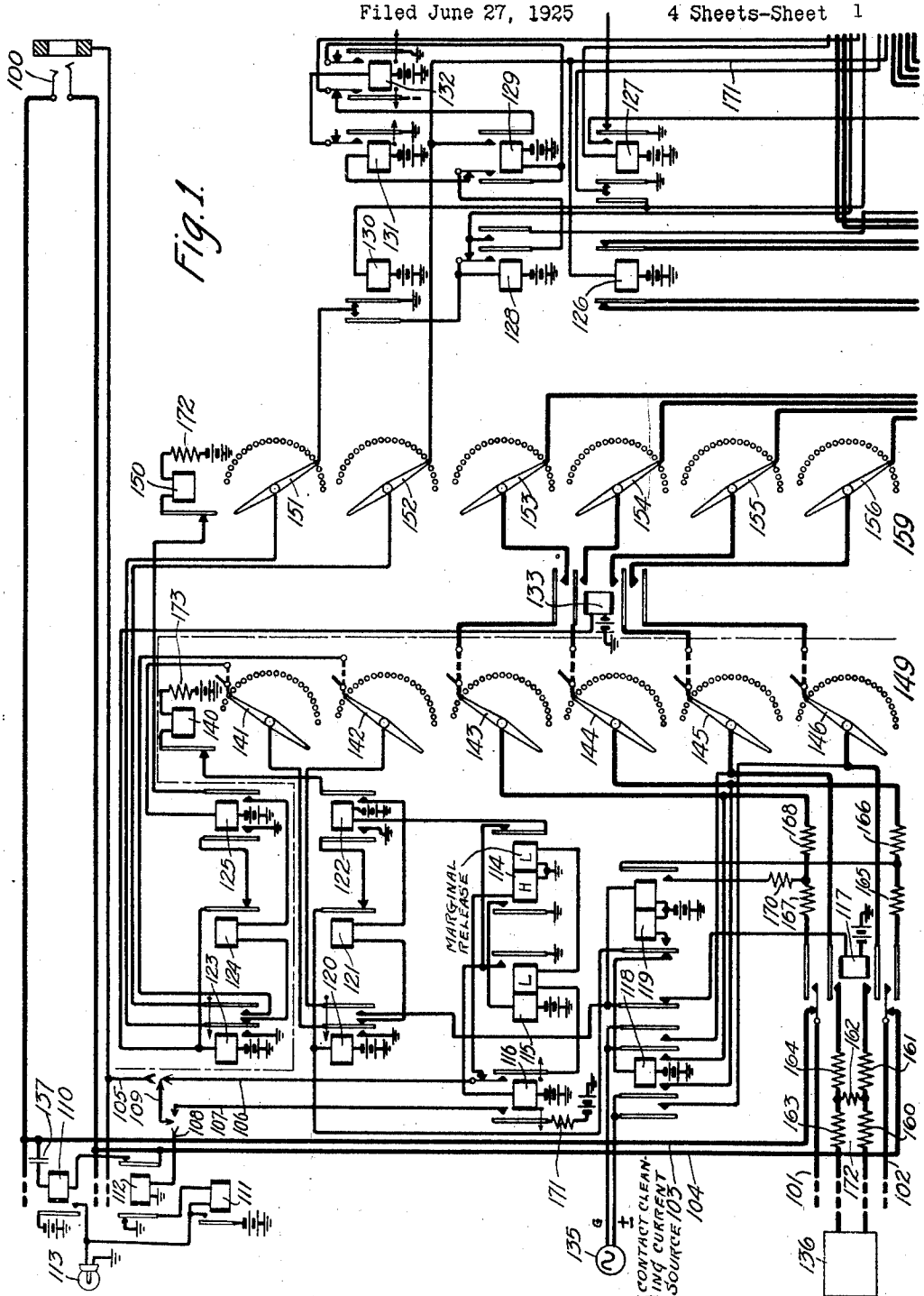
April 16, 1929. E. VROOM ET AL 1,708,982

REPEATER SELECTION FOR TOLL LINES

Filed June 27, 1925 4 Sheets-Sheet 1

Fig. 1.

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REPEATER SELECTION FOR TOLL LINES

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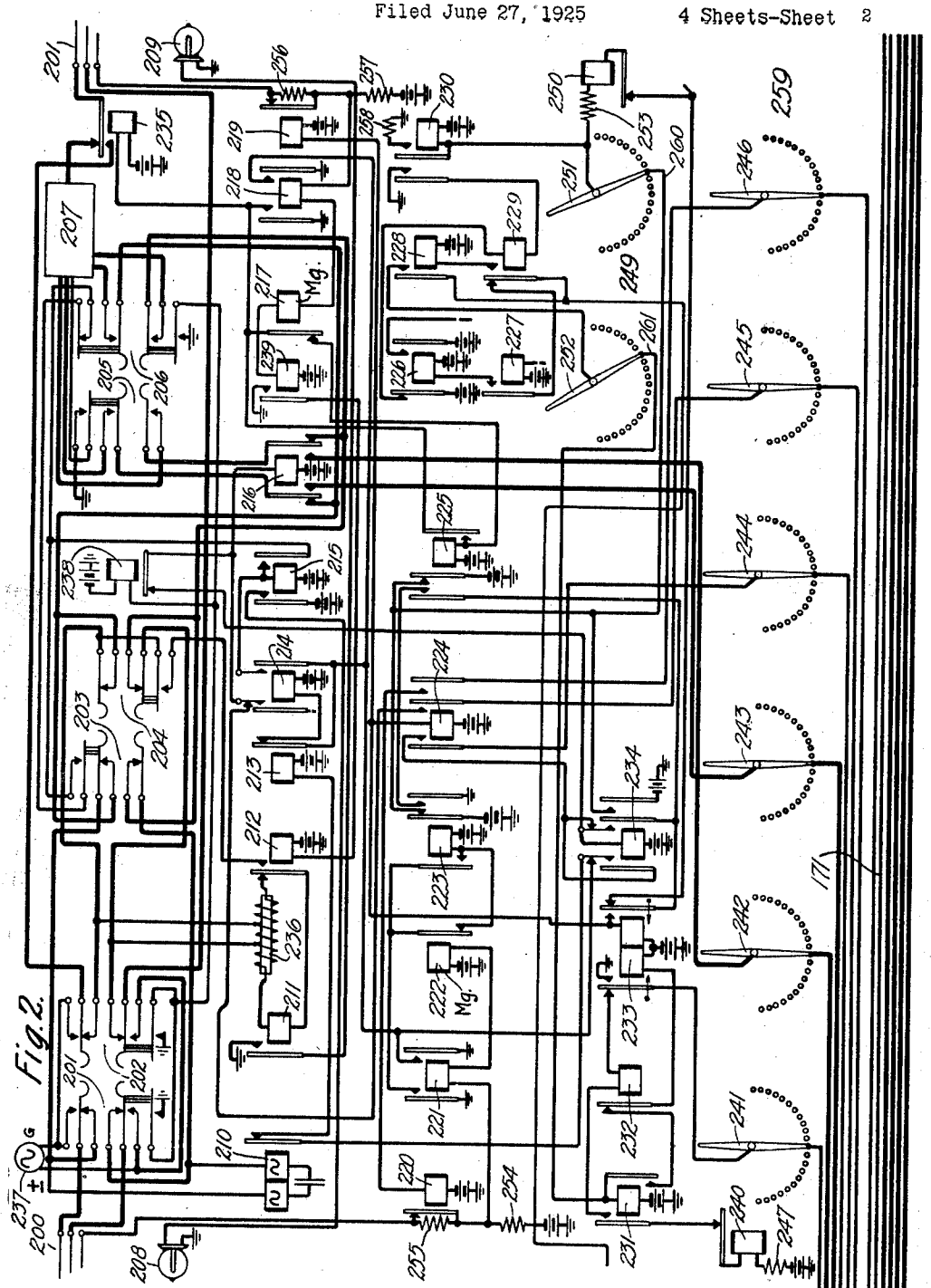

Fig. 2.

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REPEATER SELECTION FOR TOLL LINES

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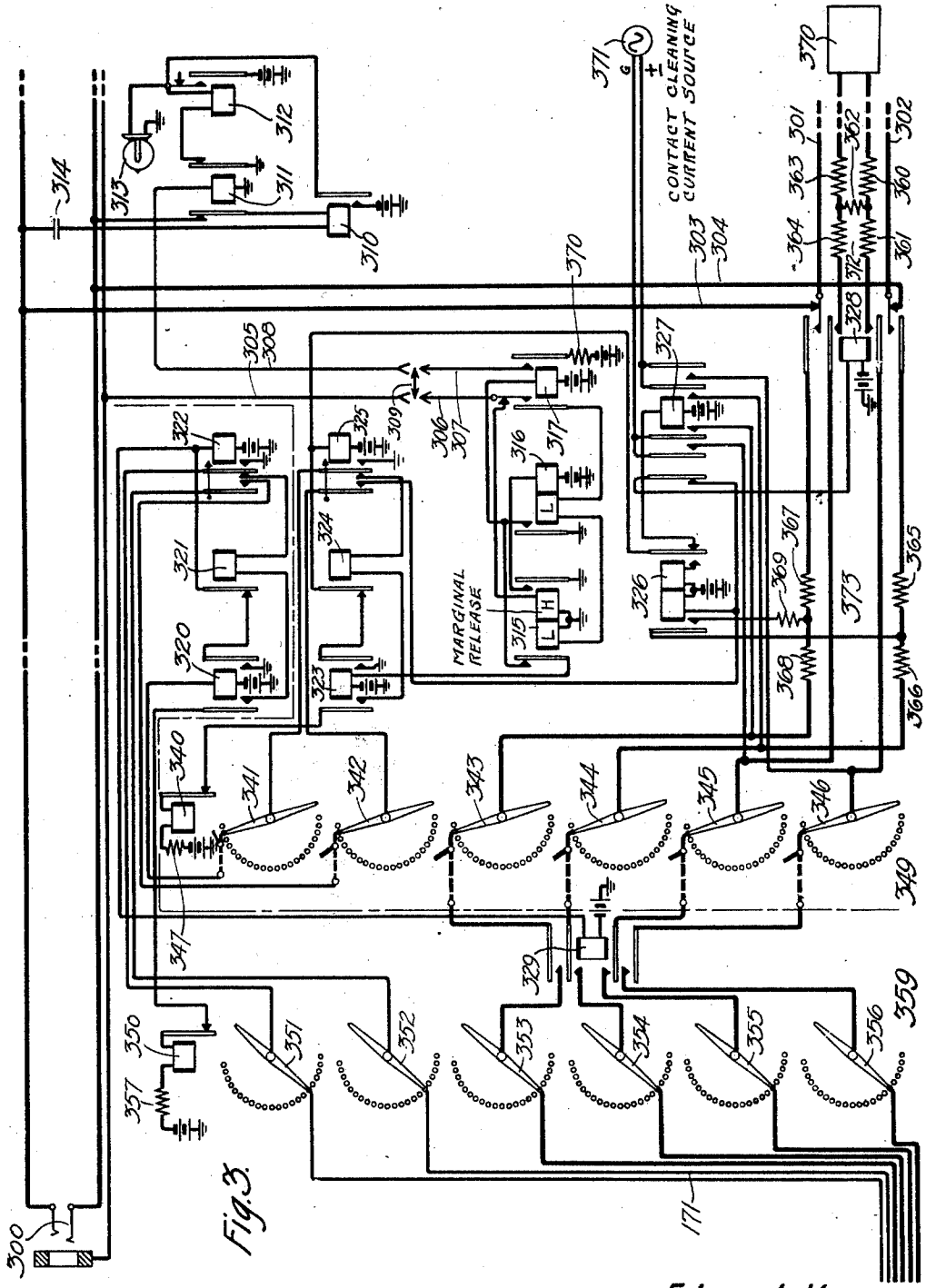


Fig. 3.

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REPEATER SELECTION FOR TOLL LINES

Filed June 27, 1925 4 Sheets-Sheet 4

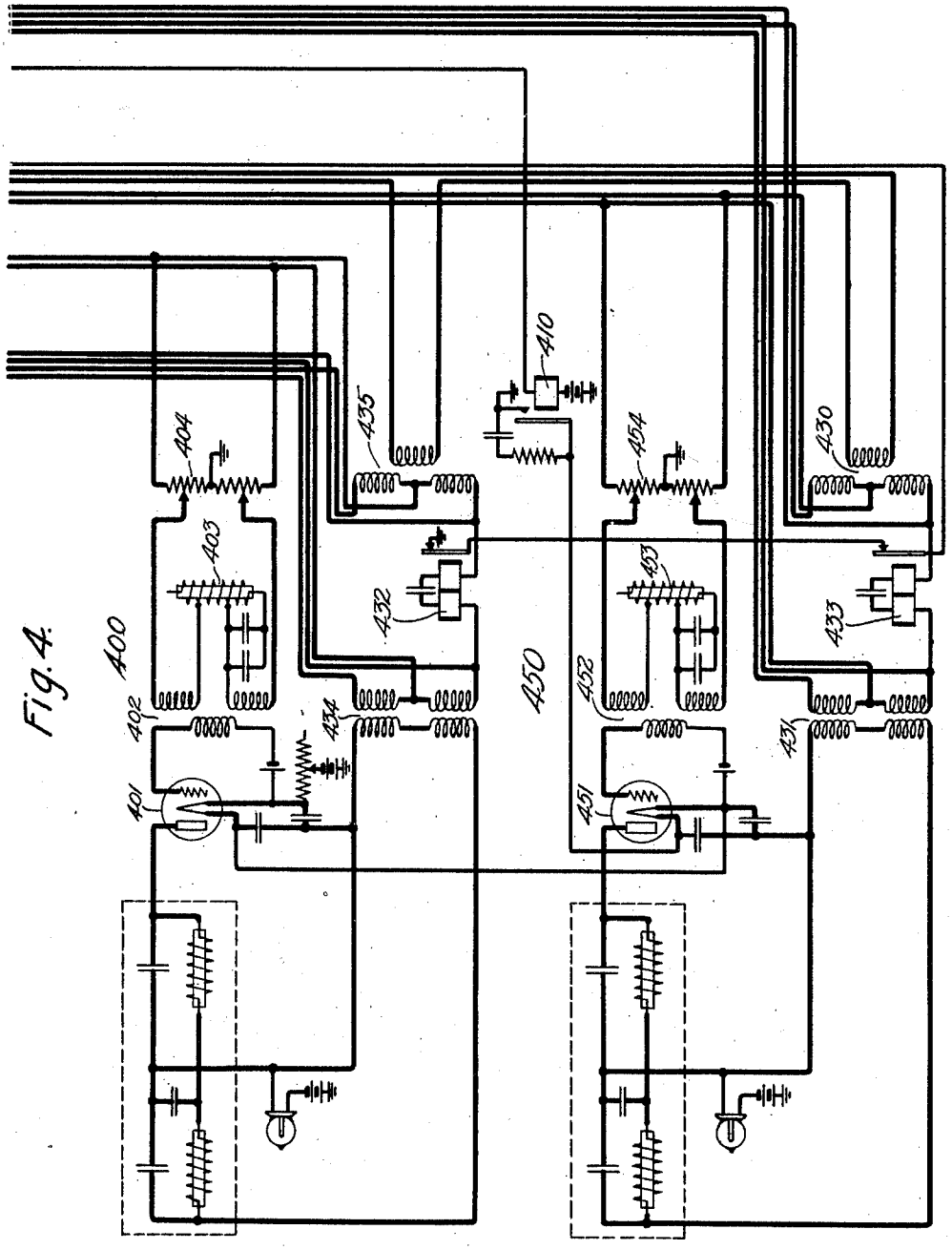


Fig. 4.

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Patented Apr. 16, 1929. 1,708,982

# UNITED STATES PATENT OFFICE.

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## REPEATER SELECTION FOR TOLL LINES.

Application filed June 27, 1925. Serial No. 39,882.

This invention relates to a telephone exchange system and more particularly to the automatic selection of speech amplifying apparatus for toll line.

Speech amplifying apparatus in the form of electron tube repeaters make possible good transmission over very long distances. They have also made possible the use of small gauge wire in cables for toll lines. The insertion of repeaters in toll lines at interconnecting stations has heretofore been accomplished by manual methods and the repeater gain control apparatus has been adjusted by the same method. It has been found that this is not the most efficient method of toll line control from a transmission viewpoint since it is difficult for operators to handle this apparatus in a manner to obtain the best results. An error by an operator in the interconnection of toll lines may result in poor transmission which is very annoying to the telephone subscriber.

It is the object of this invention to provide automatic selection of speech amplifying apparatus for toll lines that require speech amplification which is made possible by the use of apparatus for ascertaining the requirements of lines in addition to the use of non-adjustable repeater gain control apparatus.

A feature of this invention relates to the automatic selection of repeaters independent of control by a switchboard operator, including automatic discrimination between lines that require the addition of a repeater in series with the talking conductor and lines that do not require this addition.

A further feature of this invention relates to the provision of means for the elimination of contact resistance in the repeater selection apparatus in order to stabilize line balance so that non-adjustable gain control apparatus may be used.

Fig. 1 shows diagrammatically a toll line which may have either of two characteristics. One characteristic is that of a short toll line that does not require the addition of a repeater. This has the sleeve of jack 100 connected directly to the winding of relay 112 through conductors 105, 109, and 108. A second characteristic is that of a long toll line that requires the addition of a repeater and has the sleeve of jack 100 connected to a high resistance winding of relay 114, through conductors 105 and 106 and the right contact of relay 116. Non-adjustable gain control apparatus in addition to network 136 is shown associated with the toll line conductors. Switches 149 and 159 are arranged to connect a toll line with the apparatus of a repeater that has been selected by a cord circuit.

Fig. 2 illustrates a toll cord circuit arranged for the well-known functions of such cord circuits, in addition to the function of distinguishing between lines that require the addition of apparatus for speech amplifications, and means for selecting a repeater to be added in series with the line conductor for this speech amplification.

Fig. 3 illustrates a toll line and repeater selection apparatus similar to Fig. 1.

Fig. 4 illustrates electron tube repeater circuits of the type completely disclosed in Patent No. 1,511,423 issued October 14, 1924 to Donald A. Quarles et al.

### *General description.*

Let it be assumed for the following description that incoming and outgoing toll lines interconnected by the cord circuit Fig. 2 require the addition of a repeater Fig. 4 for speech amplification. Upon the initiation of an incoming call over the toll line Fig. 1, relay 137 is operated to light lamp 113 and operate relay 111. A switchboard operator inserts plug 200 into jack 100 to answer the incoming call. The operator ascertains the line wanted and inserts plug 201 into jack 300, which it will be assumed is the wanted line. The connection is thus completed by the operator, without regard as to whether the insertion of a repeater is necessary.

Since the incoming line is of sufficient length to require the addition of a repeater, it is equipped with apparatus, as shown in Fig. 1, with the exception of conductor 109. When the cord circuit is associated with such a line a marginal relay remains normal in order that another relay may be operated through its contacts to signify that a repeater is required for the line. The outgoing line Fig. 3 is also equipped with apparatus of such nature that the cord circuit apparatus associated with plug 201 is able to distinguish between this line and a line that does not require the addition of a repeater. When the cord

circuit apparatus associated with plug 200 and the apparatus associated with plug 201 has signified that the addition of a repeater is necessary for speech current amplification, a series circuit is established to energize the apparatus of a lock-out circuit to prevent interference from other cord circuits attempting to select a repeater.

When the lock-out circuit is operated, an idle repeater is selected by the cord circuit switch 259 and apparatus is operated to signify to one of the lines that a repeater has been selected. The apparatus of the line in Fig. 3 is first actuated to hunt for the repeater selected by the cord circuit through the contacts of switches 349 and 359. Upon the selection of the repeater by apparatus of the line Fig. 3, apparatus of the line Fig. 1, is actuated to associate this line with the opposite end of the repeater. As soon as the lines are associated with the repeater, that has been selected by the cord circuit, alternating current sources 371 and 135 are connected through the contacts of the switches 349—359—149—159 and the contacts of relays 133 and 329 to eliminate any contact resistance in the form of a film, oxidization or dirt that may be on the surfaces of said contacts. A train of relays is operated as a time measuring device to allow the alternating current to flow through the above recited contacts for a predetermined time period. When the train of relays has operated the alternating current sources are cut off.

A repeater has now been selected by the cord circuit and associated with the apparatus of Figs. 1 and 3 but has not as yet been associated with the line. As soon as the contact resistance has been eliminated from the contacts, relays 117 and 328 are operated to insert the selected repeater in series with the line conductors and associated gain control apparatus. The operation of these relays separates the toll line from the cord circuit and toll line multiples, represented by jacks 100 and 300. The elimination of contact resistance in the manner described makes it possible to use a non-adjustable repeater gain control apparatus in the form of resistances. Different gain control apparatus may be required for each line to adjust all lines to approximately an equal quality of transmission.

The repeater is equipped with relays 432 and 433 which may be operated over the line by ringing current. A circuit is established through the contacts of these relays to actuate the supervisory signaling apparatus in the cord circuit. The switchboard operator may actuate a key to release relays 117 and 328 to reassociate the toll lines with the cord circuit through jack 100 and plug 200, also through jack 300 and plug 201. In this manner the operator may supervise the lines in the standard manner for such operation. For monitoring upon a connection the operator may actuate key 205 which is associated with the repeater circuit through contacts of relay 216.

An interconnection between a long toll line and a short toll line or local line does not require the insertion of a repeater. Therefore, upon the insertion of the cord circuit plugs into the line jacks, apparatus associated with the plug inserted in the jack of the long line may signify that a repeater is required, but the apparatus associated with the plug inserted in the jack of the short line will signify that a repeater is not required. When such an interconnection is made the apparatus of the cord circuit for selecting a repeater is not operated and does not interfere with the selection of repeaters by other cord circuits. The apparatus of the cord circuit for distinguishing the type of line with which the plug is associated accomplishes the result of associating repeaters only with lines that require speech current amplification.

*Detailed description.*

The invention having now been briefly described it will be assumed that a call is incoming over a toll line to a toll switchboard which is to be connected by a cord circuit to an outgoing toll line both lines being of sufficient length to require a repeater in circuit with the talking conductors.

The incoming toll line is connected to conductors 101 and 102 which are extended through the contacts of relay 117, conductors 103 and 104, condenser 137, left contact of relay 112, and winding of relay 110. The ringing current impressed upon this toll line by a distant operator actuates relay 110, which in attracting its armature establishes a circuit to operate relay 111. The operation of relay 111 establishes a locking circuit for itself and a circuit through the filament of lamp 113 to cause its illumination. Lamp 113 represents a particular toll line associated with jack 100 in the face of the switchboard at which is located a plurality of cord circuits as shown in Fig. 2. The switchboard operator answers the call by inserting plug 200 in jack 100 in the usual manner.

Toll lines of sufficient length to require a repeater in series with the talking conductors are equipped with relays 114, 115 and 116 associated with the sleeve conductor of the jack and cut-off relay of the line and connected as shown by conductors 105, 106, 107 and 108. Toll lines that are not of sufficient length to warrant the insertion of a repeater do not have such relay equipment and the sleeve of the jack is connected from conductor 105 through conductors 109 and 108 and the winding of cut-off relay 112.

Upon the insertion of plug 200 into jack

100 a circuit is established to operate sleeve relays which determine whether a repeater is required for the incoming line. This circuit may be traced from grounded battery, through the windings of relays 222 and 221, contact of relay 220, sleeve of plug 200, sleeve of jack 100, conductors 105 and 106, right contact of relay 116, left winding of relay 114 to ground. It will be noted that resistance 254, connected to grounded battery is in multiple with relays 221 and 222 to form the proper marginal conditions for relay 222. Relays 114 and 221 operate in the circuit traced. Relay 222 is marginal and does not operate in series with the high resistance winding of relay 114. The marginal condition for relay 222 is arranged so that when it is associated with a line that requires a repeater it remains unoperated in order that the operation of relay 221 may establish a circuit from ground through its left contact and the contact of relay 222 to operate relay 223. Relay 223 establishes a locking circuit for itself through its left contact to the operating ground. The operation of relay 223 also prepares through its right outer contact, a part of the circuit to indicate that a repeater is required for the connection. It, however, only indicates that a repeater is required for the incoming toll line and as previously described it is necessary that a repeater be required for both the incoming and outgoing toll lines to cause the actuation of the cord circuit repeater selecting apparatus.

The operation of relay 114 establishes an obvious circuit to operate relay 115 which in turn establishes an obvious circuit to operate relay 116. Sufficient time is occupied by the operation of relays 115 and 116 to allow relay 223 to operate and establish its locking circuit. The operation of relay 116 establishes a circuit through its left contact to operate cut-off relay 112 from grounded battery, through resistance 171, left contacts of relay 116, conductors 107 and 108 to ground through the winding of relay 112. The operation of relay 112 releases relay 111 and extinguishes lamp 113 and further opens through its right contact the circuit of the ring-up relay 110 which is bridged across the toll line conductors. The cut-off relay 112 remains operated during the connected period of the line. The operation of relay 116 further establishes a low resistance circuit through the winding of relay 222. This may be traced from ground, through the right winding of relays 114 and 115, right contact of relay 116, conductors 106 and 105, sleeve of jack 100, sleeve of plug 200, contact of relay 220, windings of relays 221 and 222. Relay 222 is now operated but has no function at this time. The relays 114 and 115 are now maintained operated through this low resistance circuit.

The operator actuates talking key 206 at the time when lamp 113 is lighted, to associate the telephone circuit, represented by the small rectangle 207, with the incoming toll line conductors in order to determine what line is wanted. Let it be assumed that a toll line, Fig. 3, of sufficient length to require a repeater is desired by the calling line. The operator therefore inserts plug 201 into jack 300. This line is equipped with relays 315, 316 and 317 which operate in the same manner as relays 114, 115 and 116. A circuit is thus established from ground through the high resistance winding of relay 315, left contact of relay 317, conductors 306 and 305, sleeve of jack 300, sleeve of plug 201, right contact of relay 219, windings of relays 218, 217 and 239 to grounded battery in multiple with resistance 257 to grounded battery. Relays 239, 218 and 315 operate in the circuit traced. Since it is a line that requires a repeater, relay 217 does not operate until the line sleeve resistance has been reduced by the operation of the line relays. The operation of relay 218 establishes a circuit to operate relay 225 from grounded battery, through its winding, contact of relay 217, to ground through the left contact of relay 218. The operation of relay 225 completes an obvious locking circuit for itself through its right contact and a series circuit for the selection of a repeater through its left outer contact which will be described later. The operation of relay 239 establishes an obvious circuit to energize relay 212. The energization of relay 212 establishes a circuit for bridging the left winding of coil 236 and the winding of relay 211 across the tip and ring conductors through alternate contacts of key 204 whenever this key is operated after the lines are connected. The operation of this key is for splitting the lines and this bridge is used to give operators supervision as is done in general practice for toll line control.

The operation of relay 315 establishes an obvious circuit to energize relay 316, through its right contact, and the energization of relay 316 establishes an obvious circuit to energize relay 317. A circuit is now established from grounded battery, through resistance 370, right contacts of relay 317, conductors 307 and 308, winding of cut-off relay 311 to ground. The operation of relay 311 disassociates the ring-up relay 310 from the toll line conductors in order that it may be removed to prevent transmission loss. A circuit is further established from ground through the low resistance left windings of relays 315 and 316, left contact of relay 317, conductors 306 and 305, sleeve of jack 300, sleeve of plug 201, right contact of relay 219, windings of relays 218, 217 and 239 to grounded battery. Relay 217 now operates in this low resistance circuit but serves no purpose at this time since relay 225 is maintained in a locked circuit to

ground through the left contact of relay 218.

The initial circuit employed in the selection of a repeater to be placed in circuit with the incoming and outgoing toll lines, is established through the contacts of relays 223 and 225. This circuit may be traced from ground through the right outer contact of relay 223, left outer contact of relay 225, right back contact of relay 233, contact and winding of stepping switch magnet 250 of switch 249, resistance 253 to grounded battery through winding 230 and to grounded battery associated with the switch terminals over which brush 251 must rotate in search of an idle circuit. Busy circuits are characterized by direct battery associated with the switch terminals through the right outer contact of relay 234 which is in an operated position during the busy period of a cord circuit that has initiated the selection of a repeater. It will further be noted that battery is connected to these terminals through the normal contacts of relays 223 and 225 of the cord circuits not selecting repeaters, but is not connected to a terminal when relays 223 and 225 are operated and relay 234 is not operated. In this manner the switch magnet 250 is energized when brush 251 is associated with any terminal of the switch other than the terminal connected to the cord circuit in use and thus the brushes 251 and 252 are rotated to conductors 260 and 261 where the switch brushes are arrested by the absence of direct battery. Relay 230 is shunted during the time that brush 251 is associated with terminals connected to direct battery. It, however, operates as soon as the brush is associated with conductor 260. The operation of relay 230 establishes a locking circuit for itself through resistance 258 to ground and an operating circuit for relay 229 from ground through its left outer contact, winding of relay 229 to grounded battery through the left contact of relay 226. The operation of relay 229 establishes an operating circuit for relay 228 from grounded battery, through its winding, contact of relay 229 to ground through the right normal contact of relay 127.

The locking circuit of relay 230 further associates ground through resistance 258 with resistance 253 and switch magnet 250. This prevents the operation of magnet 250 by other cord circuits served by switch 249 until a repeater has been selected and this locking circuit released. In effect this is a cord lock-out circuit arrangement. The cord circuits equipped for repeater interconnection are divided into groups with a number of cord circuits in each group. Each group is served by a switch the same as switch 249 and each cord circuit of the group is connected to a particular terminal of the switch. Each switch is served by a pair of relays such as relays 228 and 229. This lock-out circuit serves each group of cord circuits in such manner that only one cord circuit in a plurality of groups may select a repeater at any one time. The switch and its associated contacts and apparatus is known as a primary lock-out circuit and is served by the secondary lock-out circuit of which relays 228 and 229 serve part of a major group and relays 226 and 227 serve another part of the same major group. By this arrangement only one cord circuit of a major group may be in the process of repeater selection and interconnection at any one time. When the interconnection of a repeater is completed by a cord circuit the primary and secondary lock-out circuits are released as hereinafter described thus allowing further selection of repeaters by other cord circuits in the group.

The operation of relay 228 associates ground, from the right contact of relay 127, with brush 252 and its associated contact, conductor 261, winding of relay 231, to grounded battery. Relay 127 is operated when all the repeaters are busy which operation prevents the completion of the circuit traced for relay 231. Let it be assumed that the circuit for relay 231 is completed to cause its operation. The operation of this relay establishes a circuit from grounded battery through resistance 247, winding and contact of switch magnet 240, left contact of relay 231, winding of relay 232, left contact of relay 233 to brush 241 of switch 259. The brushes of this switch are shown in the selected position associated with an idle repeater circuit. If, however, brush 241 is resting upon one of the preceding terminals which is connected to a busy terminal characterized by ground, a circuit is established to energize switch magnet 240 and relay 232 in series. The magnet and relay are energized in synchronism as the switch brush rotates over its associated contacts until brush 241 is associated with an idle repeater circuit which arrests the movement of the brush assembly and causes relay 232 to remain in its normal position. Ground is now connected from the operating circuit for relay 231 through its right contact, contact of relay 232, left winding of slow to operate relay 233 to grounded battery operating relay 233. The operation of this relay connects ground through its left contact to brush 241 to make the terminal busy to other cord circuits which may hunt for idle repeater circuits. The busy ground further establishes a circuit to operate relay 127 which may be traced through brush 241 and its associated contact, winding of relay 127 to grounded battery. The operation of relay 127 removes ground from the operating circuit of relay 231 to cause its release. It will be noted, however, that a locking circuit is established for relay 233 to maintain it in an operated position which circuit may be traced from grounded battery through its right winding and contact, left outer contact of relay 225

to ground through the right outer contact of relay 223.

Each cord circuit is equipped with a switch similar to switch 259. Repeater circuits are connected to the terminals of these switches and are multipled from switch to switch. When the repeater has been selected by a cord circuit, relay 233 is operated as previously described to associate ground with the brush 241 so that the repeater associated with that circuit is made busy on all of the switches to which it is multipled.

During the selection of a repeater by brush 241 it will be noted that the operation of relay 233 is prevented by the continuous operation of relay 232 in series with the switch magnet. Relay 232 is extremely fast in its operation and relay 233 is sluggish in its operation so that during the released moments of relay 232 there is not sufficient magnetism built up by the left winding of relay 233 to cause its operation.

It will be remembered that an operating circuit is established for relay 127 when an idle repeater is found. The operation of this relay establishes a circuit to operate relay 410 from grounded battery through its winding, to ground through the right contact of relay 127. The operation of relay 410 closes the filament circuits of repeater tubes 451 and 401 from ground at the contact of relay 410, through the filament to the filament battery.

The locking circuit traced for relay 233 further establishes an operating circuit for relays 224 and 219 which may be traced from the right contact of relay 233 which is supplied with ground for its locking circuit, through the windings of relays 224 and 219 to grounded battery. The operation of relay 224 establishes control circuits through its contacts which will be described as the control circuits are associated with the operating mechanism. The operation of relay 219 adds resistance 256 in series with the windings of line relays 316 and 315 to cause the release of relay 315. Relay 316, however, remains operated. A circuit is now established to operate relay 323 from grounded battery through its winding, left normal contact of relay 315 to ground through the contact of relay 316.

The operation of relay 323 establishes circuits to cause the outgoing toll line apparatus to be associated with the repeater selected by the cord circuit. The brushes of the switches 349 and 359 are shown associated with the repeater that has been selected by the cord circuit. It is, however, ordinarily necessary for these switches to hunt for the selected repeater. There is one switch 349 for each toll line arranged for repeater selection. The switches 349 are connected to switches 359 by trunk conductors through relay 329. There is one relay 329 for each trunk and there are as many trunks as are necessary for the selection of repeaters by a given number of lines. The trunks are connected successively to the switch terminals around the arc and multipled to all of the line switches similar to 349. The switch 359 may have any number of terminals associated with its brush members dependent upon the number of repeaters necessary for the line equipment of an office. Switch 359 is arranged to select either end of a repeater arranged alternately upon the terminals of the switch. It is therefore apparent that a line may be used for an incoming or outgoing call. Plug 200 is always inserted in the jack associated with an incoming call and plug 201 is inserted in the jack of the outgoing called line. Switch 359 is arranged for both the east and west ends of a repeater so that the incoming call will always get the same end of the repeater.

Let it be assumed that brush 341 is associated with a trunk terminal characterized by a busy ground from the left inner contact of relay 325 in a line associated with a trunk and repeater similar to the line shown in Fig. 3. The operation of relay 323 establishes a circuit to energize magnet 340 and relay 324 in series to rotate the brush assembly of switch 349 in search of an idle trunk. This circuit may be traced from grounded battery, through resistance 347, winding and contact of magnet 340, left contact of relay 323, winding of relay 324, left inner contact of relay 325, brush 341 and associated contact, terminal and brush of a line switch similar to 349 that is connected to a busy trunk, to ground through the left inner contact of relay 325 of the line that is connected to said trunk. Magnet 340 and relay 324 energize synchronously to advance the brushes over busy trunks. Upon the selection of an idle trunk relay 324 is released to establish an operating circuit for relay 325 from ground through the right contact of relay 323, normal contact of relay 324, winding of relay 325 to grounded battery. Relay 327 is also operated in multiple with relay 325 through the right normal contact of relay 326. The operation of relay 327 associates alternating current with brushes 343, 344, 345 and 346 to prepare a path through the contacts of relay 329 when said relay is operated. The utility of the alternating current through the switch brush contacts will be described later. The operation of relay 325 associates ground through its left inner contact to brush 341 to hold the trunk busy so that it will not be selected by other line switches similar to switch 349. This ground is extended through the winding of relay 320 to cause its operation. The circuit established through the left outer contact of relay 325 is not effective at this time.

The operation of relay 320 establishes a circuit to energize switch magnet 350 in series with relay 321 to rotate the brush members of

switch 359 in search of the repeater selected by the cord circuit. The terminals associated with brush 351 are all characterized by busy grounds from the lines or from the cord circuits except the one that has been selected by the cord circuit for the lines in process of interconnection. The ground connection to the terminals associated with brush 351 may be traced from the left inner normal contacts of relays 127 associated with cord circuits not in use and from the left inner contacts of relays 322 of lines that are already connected to repeater circuits. It will be remembered that the relay 127 of the cord circuit being described is operated and thus the terminal associated with this cord circuit and repeater is not characterized by ground. The brush 351 must now rotate until it is associated with the terminal characterized by the absence of ground. The circuit for energizing magnet 350 and relay 321 may be traced from grounded battery through resistance 357, winding and contact of magnet 350, left contact of relay 320, winding of relay 321, left inner normal contact of relay 322, brush 351 and thence to the busy ground connections previously described. The rotary movement of switch 359 is arrested when brush 351 is associated with the terminal not characterized by ground. The magnet 350 and relay 321 are deenergized and a circuit is thus established to energize relays 322 and 329 from ground through the right contact of relay 320, contact of relay 321 to grounded battery through the windings of these relays. The operation of relay 322 associates ground through its inner contact with the brush 351 and its associated terminal to characterize said terminal as busy and to establish an operating circuit for relays 130 and 220. These operating circuits may be traced from the switch terminal through the left outer contact of relay 127 to battery through the winding of relay 130 and to brush 246 and its associated terminal, right outer contact of relay 224 to grounded battery through the winding of relay 220. The circuits established by the operation of relays 130 and 220 will be described later.

The utility of the application of alternating current at a comparative high voltage, through the talking conductor contacts of switches 349 and 359 will now be described. It is well known in the art that toll lines must be accurately balanced for good transmission and proper repeater efficiency. If resistance exists between the surfaces of contacts through which the talking conductors are carried the lines can not be accurately balanced by the use of non-adjustable repeater gain control apparatus shown in the form of bridged resistance 360 to 364 inclusive, network 370 and bridged resistance 365 to 369 inclusive. Should the resistance of the contacts greatly vary, a manual adjustment of the gain control apparatus would be required. This is sometimes substituted by an automatic gain selection. It is a well known fact that contact resistance exists especially upon rubbing contacts in the form of a film, oxidation or dirt. This resistance at times becomes very high and is especially disruptive to electrical currents of low potential. An electrical current of high potential will however break down such a film or oxidation and obtain approximately a zero contact resistance between the surfaces of the contacts.

In order to eliminate this contact resistance alternating current of proper potential is carried through the switch contacts in the following manner: The application of alternating current is made from source 371, through the contacts of relay 327, brushes 343, 344, 345 and 346 and their associated contacts, contacts of relay 329, brushes 353, 354, 355 and 356 and their associated contacts and thence through the windings of the output transformer and potentiometer of the repeater. The alternating current remains connected through these contacts for a period of time sufficient to eliminate contact resistance. It is then automatically cut off by the operation of relay 326, the operating circuit of which will be described upon the completion of the selection of the repeater by the calling toll line.

75 to 125 volts alternating current is found to satisfactorily reduce a very high resistance between contacts to a fraction of an ohm when applied to said contacts for one second. Resistance is placed in series with the contacts to bring about a current flow of approximately .015 ampere. It is also found that the current must be increased when direct current is used for cleaning purposes. 120 to 150 volts direct current may be used for cleaning the contacts in place of the lower voltage alternating current. The time duration for the application of direct current voltage is the same as for the alternating current voltage. Resistance is placed in series with the contacts to bring about a current flow of approximately .040 ampere. From the above the potential may be computed in accordance with the resistance of the medium between the contacts. It is not intended that the invention be limited to the use of the foregoing voltage and current values or the time given for its application to the contacts.

It will be remembered that relays 130 and 220 were operated upon the selection of the repeater by switch 359. The operation of relay 130 removes ground from the switch terminal associated with brush 151 to mark that terminal for the repeater selection in the same manner as previously described for brush 351 of switch 359. The operation of relay 220 adds resistance 255 in series with the line relays 114 and 115 in order to reduce the effective ampere turns for the magnetization

of relay 114 and cause its release. Relay 115, however, remains operated. A circuit is thus established to energize relay 122, from ground through the contact of relay 115, right normal contact of relay 114, winding of relay 122 to grounded battery.

The energization of relay 122 establishes a circuit to energize magnet 140 in series with relay 121, if brush 141 is resting upon a busy trunk. Magnet 140 and relay 121 energize in a circuit from grounded battery, through resistance 173, winding and contact of magnet 140, right contact of relay 122, winding of relay 121, right inner contact of relay 120, brush 141 to busy grounds associated with the switch terminals. Upon the location of an idle trunk the brush assembly is arrested and relay 121 released. A circuit is thus established to energize relays 120 and 118 over a circuit from ground, through the left contact of relay 122, contact of relay 121, winding of relay 120 to grounded battery, and through the left contact of relay 119, winding of relay 118 to grounded battery. The operation of relay 118 associates alternating current source 135 with the brushes of switch 149. The operation of relay 120 associates a busy ground through its inner contact to brush 141 and its associated terminal. This busy ground further establishes a circuit to energize relay 125 to establish an energizing circuit for switch magnet 150. This circuit may be traced from grounded battery, through resistance 172, winding and contact of magnet 150, right contact of relay 125, winding of relay 124, right inner contact of relay 123, brush 151 to ground associated with all the terminals except the terminal shown connected to relay 130. The terminals over which brush 151 rotates are characterized by ground from the normal contact of relays similar to 130 in other non-busy circuits and from ground through the inner contact of relays similar to 123 in other circuits that have selected repeaters. The brush assembly of switch 159 is thus rotated and relay 124 operated in synchronism with the operation of magnet 150 until the switch brushes are associated with the repeater that has been selected by the cord circuit. Relay 124 is then released to establish an operating circuit for relay 123 from ground, through the left contact of relay 125, contact of relay 124, winding of relay 123 to grounded battery. Relay 133 is also operated from the operating ground for relay 123 to associate the trunk talking conductors with brushes 153 to 156 inclusive of switch 159. The alternating current from source 135 now passes through the switch contacts to eliminate contact resistance which may have become accumulated in the form of a film or oxidation. This alternating current passes through the output transformer and potentiometer of repeater 400 in the manner described for the elimination of contact resistance for switches 349 and 359.

The arrangement of the switches 149 and 159 with the associated trunks and repeater connection is the same as described for the switch arrangement in Fig. 3.

The operation of relay 123 associates ground through its inner contact with brush 151 to characterize the terminal upon which it rests with a ground to energize the magnets of other switches that may rotate in search of a selected repeater. This ground further establishes a circuit to energize relay 128 through the outer contact of relay 130. Relays 234 and 216 are also energized from this ground or from ground associated with the outer contact of relay 128. This latter circuit may be traced from ground through the contacts of relays 432 and 433, outer contact of relay 128, brush 244 and its associated terminal, left contact of relay 224, right inner contact and winding of relay 234 to grounded battery. The circuit for relay 216 extends in parallel from the inner contact of relay 234 through the contact of relay 238 to battery through the winding of relay 216. The operation of relay 234 establishes a locking circuit for itself through its right inner contact, left outer contact of relay 225 to ground through the right outer contact of relay 223. The operation of relay 234 further associates grounded battery through its right outer contact with the contact of switch 249 that is associated with brush 251. This direct battery releases relay 230 by shunting it, which in turn releases relays 228 and 229 to place the lock out circuit again in its normal condition for use by other cord circuits under its control.

Relay 234 establishes a circuit through its left contact for supervision under the control of the repeater circuit. Previous to the operation of relay 234 a circuit is maintained from ground through the right contact of relay 221, left contact of relay 234, contact of relay 210 to grounded battery through the winding of relay 213. The operation of relay 213 opens a circuit which would otherwise be established for the operation of relay 214 from grounded battery, through the contact of relay 213 to ground through the right contact of relay 221. The operation of relay 214 would establish an obvious operating circuit for relay 215 which would in turn establish a circuit from grounded battery through its left contact, filament of lamp 208 to ground to light this lamp. It will further be noted that the control of relay 234 is now through the contact of relay 238 which is in turn under the control of the cord circuit keys. Upon the operation of relay 234 the relay 213 is connected to ground through the contacts of the repeater relays 432 and 433 through the left alternate con-

tacts of relay 234. The supervision is thus placed under the control of the repeater circuits in order that the cord circuits may be eliminated from the talking circuit conductors.

The operation of relay 128 further establishes a circuit to operate relay 131 from the ground connected to brush 151, through the outer contact of relay 130, inner contact of relay 128, left contact of relay 129, winding of relay 131 to battery. The operation of relay 131 establishes an obvious operating circuit to energize relay 132. The operation of relay 132 establishes a circuit to energize relay 129 which operates and opens the energizing circuit for relay 131 which releases in turn releasing relay 132. Relay 129 in operating further establishes a locking circuit for itself to the ground associated with switch brush 151. The operation of relays 131, 132 and 129 is for the purpose of allowing a period of time for the alternating current to flow through the brush contacts of switches 349, 359, 149 and 159 to eliminate contact resistance. The operation of relay 129 prepares circuit paths to operate relays which cut off the alternating current sources 371 and 135. A circuit is established to energize the windings of relays 126, 119 and 326 from ground, through the right outer contact of relay 223, left outer contact of relay 225, right inner contact of relay 234, contact of relay 238, left contact of relay 214, right inner contact of relay 224, brush 245 and its associated terminal, left normal contact of relay 132, right contact of relay 129 where the path is divided, one branch extending through brush 152 and its associated terminal, outer contact of relay 123, brush 142 and its associated terminal, outer contact of relay 120 to grounded battery through the right winding of relay 119. The second branch of the circuit is extended through the winding of relay 126 to grounded battery to energize this relay. This path is further carried over conductor 171 to brush 352 and its associated terminal, outer contact of relay 322, brush 342 and its associated terminal, outer contact of relay 325 to grounded battery through the left winding of relay 326. The operation of relay 119 opens the energizing circuit for relay 118 thus disestablishing the circuit from the alternating current source 135 through the switch brushes. Relay 119 establishes a locking circuit for itself through its left winding and contact, contact of relay 121 to ground through the left contact of relay 122. It further establishes through its right contact a balancing bridge across the line conductors. Upon the relase of relay 118 the ground traced for the operation of relay 119 is connected through the right outermost normal contact of relay 118 to establish an energizing circuit for relay 117. The operation of relay 117 disassociates the line conductors from jack 100 and the cord circuit and associates the line conductors directly through the repeater circuit. The operation of relay 117 further associates bridge 172 and network 136 with the repeater circuit.

The operation of relay 326 opens the energizing circuit for relay 327 to cause its release, which disassociates the alternating current source 371 from the switch brushes of switches 349 and 359. Relay 326 establishes a locking circuit for itself through its right winding and contact, contact of relay 324 to ground through the right contact of relay 323. It further establishes a circuit through its left contact to associate bridge 373 with the outgoing toll line. The release of relay 327 establishes a circuit from the operating ground for relay 326 through its left outermost contact, winding of relay 328 to grounded battery. Relay 328 is operated to disassociate jack 300 and the cord circuit from the line conductors which are now associated directly with the repeater circuit. The operation of relay 328 further associates bridge 372 and netwok 370 with the outgoing line and repeater circuit. The operation of relay 126 removes the short circuits from the potentiometers of the repeater.

The repeater, Fig. 4, has now been added in series with the talking conductors of the incoming and outgoing toll lines to make the proper transmission gain. This has been done automatically and independent of manual operation by the switchboard operator. The relays 432 and 433 in the repeater circuit control the lighting of cord circuit lamps and are operated by ringing current from a distant station in the usual manner of ringdown toll line service. Should the cord circuit signal be lighted the switchboard operator actuates a key in the usual manner which closes an obvious operating circuit through the winding of relay 238. The operation of relay 238 releases relays 117 and 328 in order that the toll lines may be associated with the cord circuit for supervision. When the key is released to restore relay 238 to normal relays 117 and 328 are again operated over the circuits previously traced through the contact of relay 238.

It will be remembered that relay 216 was energized in parallel with relay 234 upon the release of relay 238 at such time as the operator completed the connection of plugs 200 and 201 and restored the cord circuit keys to normal. Relay 216 in operating establishes a circuit path through the repeater circuit in order that the switchboard operator may associate the telephone circuit 207 through the contacts of key 205 with the line connection for monitoring purposes.

Let it now be assumed that a call is incoming upon the toll line represented by lamp 113 and jack 100 and that the cord cir-

cuit plug 200 has been inserted in jack 100. This line is of sufficient length to require a repeater in series with the talking conductors and a repeater will be selected if the outgoing end of the cord circuit represented by plug 201 is inserted into a line of sufficient length to require a repeater. If, however, the outgoing line is short, no repeater is required. For a connection between a long and a short line the differentiating means in the cord circuits must properly function so that a repeater is not selected.

Upon the insertion of plug 200 in the jack 100 relays 114 and 221 operate in the manner previously described. Relay 222 is marginal and remains normal since the energizing circuit is through the high resistance winding of relay 114. During the period of time that relay 222 remains normal a circuit is established to energize relay 223 through its contact in the manner previously described. It will be remembered that the operation of relay 114 establishes an energizing circuit for relay 115 which in turn establishes an energizing circuit for relay 116. At this time the sleeve resistance is carried through low resistance windings of relays 115 and 114 to cause the operation of relay 222. This sleeve resistance is reduced to a low resistance also for the reason that a normal busy test condition must be maintained at the sleeve of jack 100.

Since it has been assumed that the line into which plug 201 is inserted is a short line it will not be arranged for repeater selection. Therefore, the sleeve circuit is carried through conductors 305, 309 and 308, winding of relay 311 to ground. The winding of relay 311 is the normal low resistance winding for such sleeve circuits. Upon the insertion of plug 201 into jack 300 a circuit is established from ground through the winding of relay 311, sleeve of jack 300, sleeve of plug 201, contact of relay 219, windings of relays 218, 217 and 239 to grounded battery. All relays in the circuit traced now operate including the marginal relay 217, which remains normal when the cord circuit is connected to a toll line requiring the selection of a repeater. The immediate operation of relay 217 opens the operating circuit for relay 225 to prevent the establishment of the series circuit previously described for actuating the lock out switch magnet 250.

It is apparent from the foregoing description that a repeater is only selected by an automatically differentiating cord circuit when it is required for both the incoming and outgoing lines and since under this condition the lock out circuit is not energized there is no interference with other cord circuits that require the selection of a repeater.

The talking conductors for toll connections that do not require a repeater are carried through the cord circuit key contacts and the supervision of the line is the same as in an ordinary toll cord circuit, which practice is well known in the art.

What is claimed is:

1. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, and automatically operable means to distinguish a line that requires the addition of a speech current amplifier.

2. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, means for speech current amplification, and automatically operable means to distinguish lines that require amplification for speech current and to add said means for speech current amplification in series with said lines.

3. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, an electron tube repeater, and automatically operable means to distinguish lines that require the addition of an electron tube repeater.

4. In a telephone exchange system, lines of different lengths, a cord circuit for interconnecting said lines, repeaters and automatically operable means responsive to the interconnection of two long lines but unresponsive to the interconnection of two short lines to cause the interpolation of a repeater in series with said long lines.

5. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, repeaters and means in said cord circuit responsive to electrical conditions in said lines to cause the selection and connection of repeaters between certain of said lines.

6. In a telephone exchange system, lines of different lengths, cord circuits for interconnecting said lines, repeaters and means in said cord circuits responsive to the interconnection of two long lines to cause the interpolation of a repeater in series with said long lines, but unresponsive to the interconnection of a long and a short line to cause such interpolation.

7. In a telephone exchange system, lines of different character, cord circuits for interconnecting said lines, speech current amplifiers, means in said cord circuits responsive to electrical conditions in said lines for distinguishing between lines that require the addition of speech current amplifiers and lines that do not require speech current amplifiers, and means actuated by said distinguishing means to select speech current amplifiers.

8. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, repeaters, means in said cord circuit responsive to electrical conditions in said lines for distinguishing between lines that require the addition of a repeater and lines that do not require this ad-

dition, means responsive to said distinguishing means to select a repeater, and means operative upon the selection of a repeater to disconnect said cord circuit from said lines and to interpose said repeater therebetween.

9. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, repeaters, means in said cord circuits responsive to electrical conditions in said lines for distinguishing between lines that require the addition of a repeater and lines that do not require this addition, means actuated by said distinguishing means to select a repeater, and means operative only upon the selection of a repeater to disconnect said cord circuit from said lines and to interpose the selected repeater therebetween.

10. In a telephone exchange system, lines of different character terminating in jacks, cord circuits terminating in plugs, means actuated by the insertion of the plug of a cord circuit into a line jack to determine whether the line associated with said jack requires the addition of an amplifier for speech current.

11. In a telephone exchange system, lines of different character terminating in jacks, cord circuits terminating in plugs for interconnecting said lines, means actuated by the insertion of the plugs of a cord circuit into line jacks to determine whether the lines associated with said jacks require amplification for speech current, speech current amplifiers, and means operable in accordance with said determining means to add speech current amplifiers in series with said lines.

12. In a telephone exchange system, lines of different character, cord circuits for interconnecting said lines, means automatically operable in response to the interconnection of lines to distinguish lines that require the addition of speech amplifying apparatus, a common group of speech amplifying apparatus, and means responsive to said distinguishing means to cause the selection of an idle speech amplifying apparatus.

13. In a telephone exchange system, lines of different character, cord circuits for interconnecting said lines, means automatically operable in response to the interconnection of lines to distinguish lines that require the addition of speech amplifying apparatus, a common group of speech amplifying apparatus, means responsive to said distinguishing means to cause the selection of an idle speech amplifying apparatus, and means responsive to said selecting means to place said amplifying apparatus in series with said lines.

14. In a telephone exchange system, lines of different character, cord circuits for interconnecting said lines, means automatically operable in response to the interconnection of lines to distinguish lines that require the addition of speech amplifying apparatus, a common group of speech amplifying apparatus, means responsive to said distinguishing means to cause the selection of an idle speech amplifying apparatus, and means responsive to said selecting means to place said amplifying apparatus in series with said lines and to disconnect said cord circuit from said lines.

15. In a telephone exchange system, lines of different character, cord circuit for interconnecting said lines, means automatically operable in response to the interconnection of lines to distinguish lines that require the addition of speech amplifying apparatus, a common group of speech amplifying apparatus, means responsive to said distinguishing means to cause the selection of an idle speech amplifying apparatus and the interpolation of said apparatus between said lines, and means to prevent interference between selecting apparatus when a plurality of said interconnected lines require the addition of speech amplifying apparatus.

16. In a telephone exchange system, lines of different character, cord circuits for interconnecting said lines, signals in said cord circuits, means automatically operable in response to the interconnection of lines to distinguish lines that require the addition of speech amplifying apparatus, a common group of speech amplifying apparatus, and means responsive to said distinguishing means to cause the selection of an idle speech amplifying apparatus, means responsive to said selecting means to place said amplifying apparatus in series with said lines and to disconnect said cord circuit, means in said amplifying apparatus responsive to signaling current over either of two interconnected lines to actuate the signal in said cord circuit, and means in said cord circuit to reassociate said lines with said cord circuit.

17. In a selecting circuit, apparatus contacts, means for variably connecting together said apparatus contacts, a source of electrical current of sufficient potential to break down contact resistance between said contacts, means automatically operable for connecting said current source in a circuit through apparatus contacts connected together, means for maintaining said current through said circuit for a time period of sufficient duration to eliminate resistance between the contacts so connected.

18. In a selecting circuit, apparatus contacts having resistance in the form of a film or oxidation over the surfaces of said contacts, means for variably connecting together said apparatus contacts, a source of electrical current of sufficient potential to break down such contact resistance, means automatically operable for connecting said current source in a circuit through apparatus contacts connected together, timing apparatus, means for-

operating said timing apparatus for maintaining said current through said circuit for a time period of sufficient duration to eliminate resistance between the contacts so connected, and means for disconnecting said current source from said contacts at the termination of said time period.

19. In a telephone exchange system, toll lines, repeaters, means to select repeaters for said lines, a gain control apparatus and network in each of said lines to control the transmission gain of said repeaters, apparatus contacts in said selecting means, the resistance between the surfaces of said contacts being such as to unbalance said lines and cause said gain control apparatus to be ineffective, a source of current of sufficient potential to break down said contact resistance, and means automatically operable to connect said current source through said apparatus contacts for a predetermined time period to break down said resistance and eliminate unbalance.

20. In a telephone exchange system, lines, speech current amplifying apparatus, means to select speech current amplifying apparatus for said lines, non-adjustable gain control apparatus in each of said lines, apparatus contacts in said selecting means, the resistance between the surfaces of said contacts being such as to unbalance said lines and cause said non-adjustable gain control apparatus to be ineffective, a source of alternating current of sufficient potential to break down said contact resistance, and means to connect said alternating current source through said apparatus contacts for a predetermined time period to break down said resistance and eliminate unbalance.

21. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, repeaters, means in said cord circuit responsive to electrical conditions in said lines to cause the selection of an idle repeater, and means operative upon the selection of a repeater to connect each of said interconnected lines with said repeater.

22. In a telephone exchange system, lines of different character, a cord circuit for interconnecting said lines, repeaters, means in said cord circuit responsive to electrical conditions in said lines to cause the selection of an idle repeater, and automatic switching means associated with each of said interconnected lines to connect said lines with said repeater.

23. In an electrically operable system for interconnecting conductors, apparatus contacts, means for selectively positioning said contacts for interconnecting said conductors, contact resistance existing between said contacts as positioned, a source of electrical current of sufficient potential to eliminate said contact resistance, means automatically operable for passing said current through said contacts for a predetermined period of time of sufficient duration to eliminate said contact resistance, and means to maintain said conductors disconnected from said contacts during the elimination of said contact resistance.

24. In an electrically operable system for interconnecting conductors, apparatus contacts, means for selectively positioning said contacts for interconnecting said conductors, contact resistance existing between said contacts as positioned, a source of electrical current of sufficient potential to eliminate said contact resistance, means automatically operable for passing said current through said contacts for a predetermined period of time of sufficient duration to eliminate said contact resistance, means to maintain said conductors disconnected from said contacts during the elimination of said contact resistance, means operable at the termination of said time period for disconnecting said current source from said contacts, and means operable in response to the operation of said disconnecting means to connect said conductors to said contacts.

25. In a telephone exchange system, lines, repeaters, means for interconnecting said lines, and means automatically operable in response to said interconnection to distinguish lines that require the addition of a repeater.

26. In a telephone exchange system, lines, repeaters, means for interconnecting said lines, means automatically operable in response to said interconnection to distinguish lines that require the addition of a repeater and to add a repeater in series with said lines.

27. In a telephone exchange system, lines, repeaters, means for interconnecting said lines, means automatically operable in response to said interconnection to distinguish lines that require the addition of a repeater, and means actuated by said distinguishing means to select a repeater for said lines.

28. In a telephone exchange system, lines, repeaters, means for interconnecting said lines, and means automatically operable in response to said interconnection to distinguish lines that require the addition of a repeater and lines that do not require such addition.

29. In a telephone exchange system, lines, repeaters, means for interconnecting said lines, means automatically operable in response to said interconnection to distinguish lines that require the addition of a repeater and lines that do not require such addition, and means to select a repeater for lines requiring such addition.

30. In a telephone exchange system, lines of different lengths, repeaters, means for interconnecting said lines, and means auto-

matically operable in response to said interconnection to distinguish lines of a length that require the addition of a repeater.

31. In a telephone exchange system, lines, a group of repeaters common to said lines, means for interconnecting said lines, means automatically operable in response to said interconnection to distinguish lines that require the addition of a repeater, and means responsive to the actuation of said distinguishing means for selecting an idle repeater in said group for said lines.

In witness whereof, we hereunto subscribe our names this 20th day of June, A. D., 1925.

EDWARD VROOM.
JOSEPH A. KRECEK.