June 9, 1942. M. A. LOGAN 2,285,524

TELEPHONE SYSTEM

Filed March 30, 1940 2 Sheets-Sheet 1

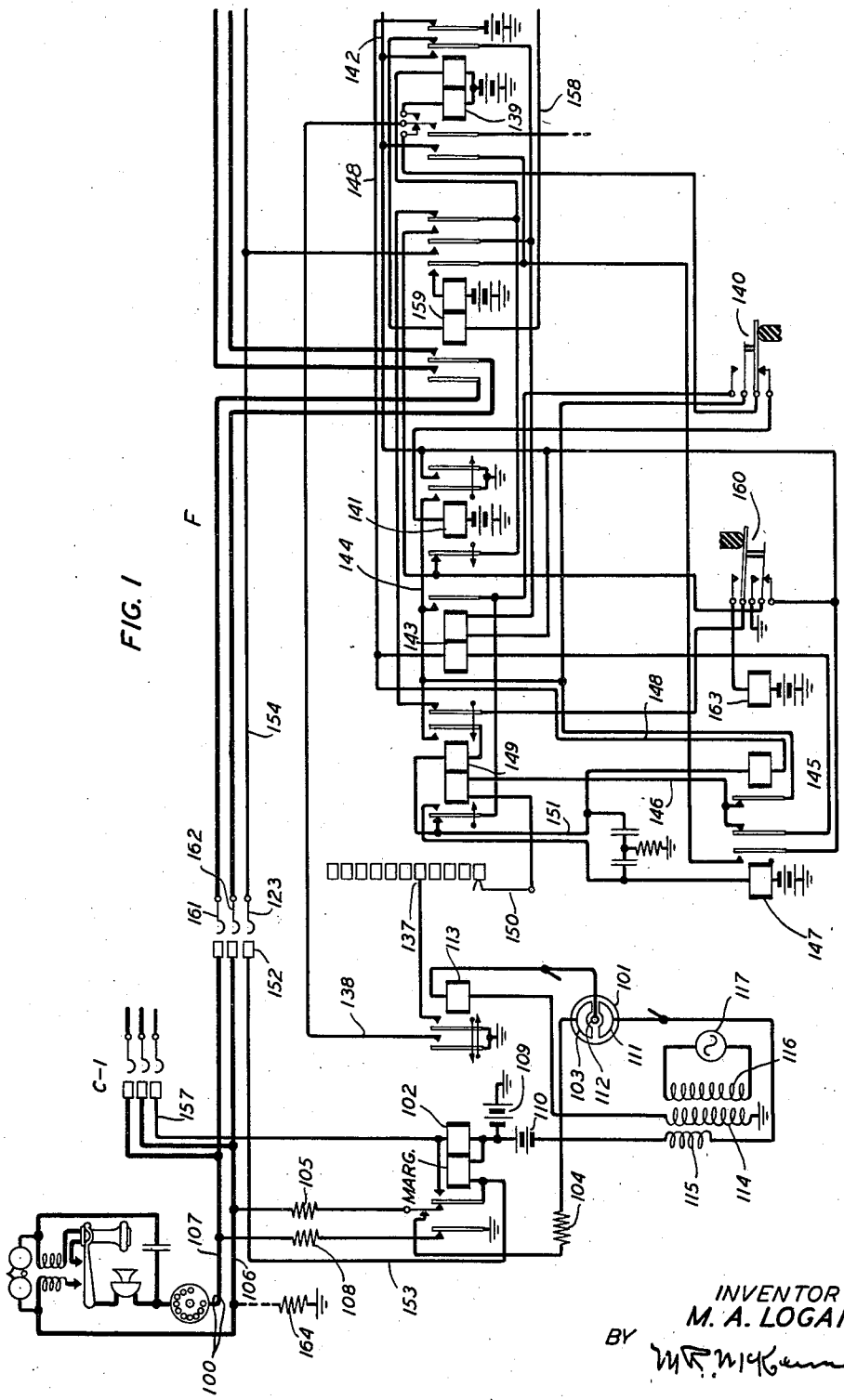

FIG. 1

F

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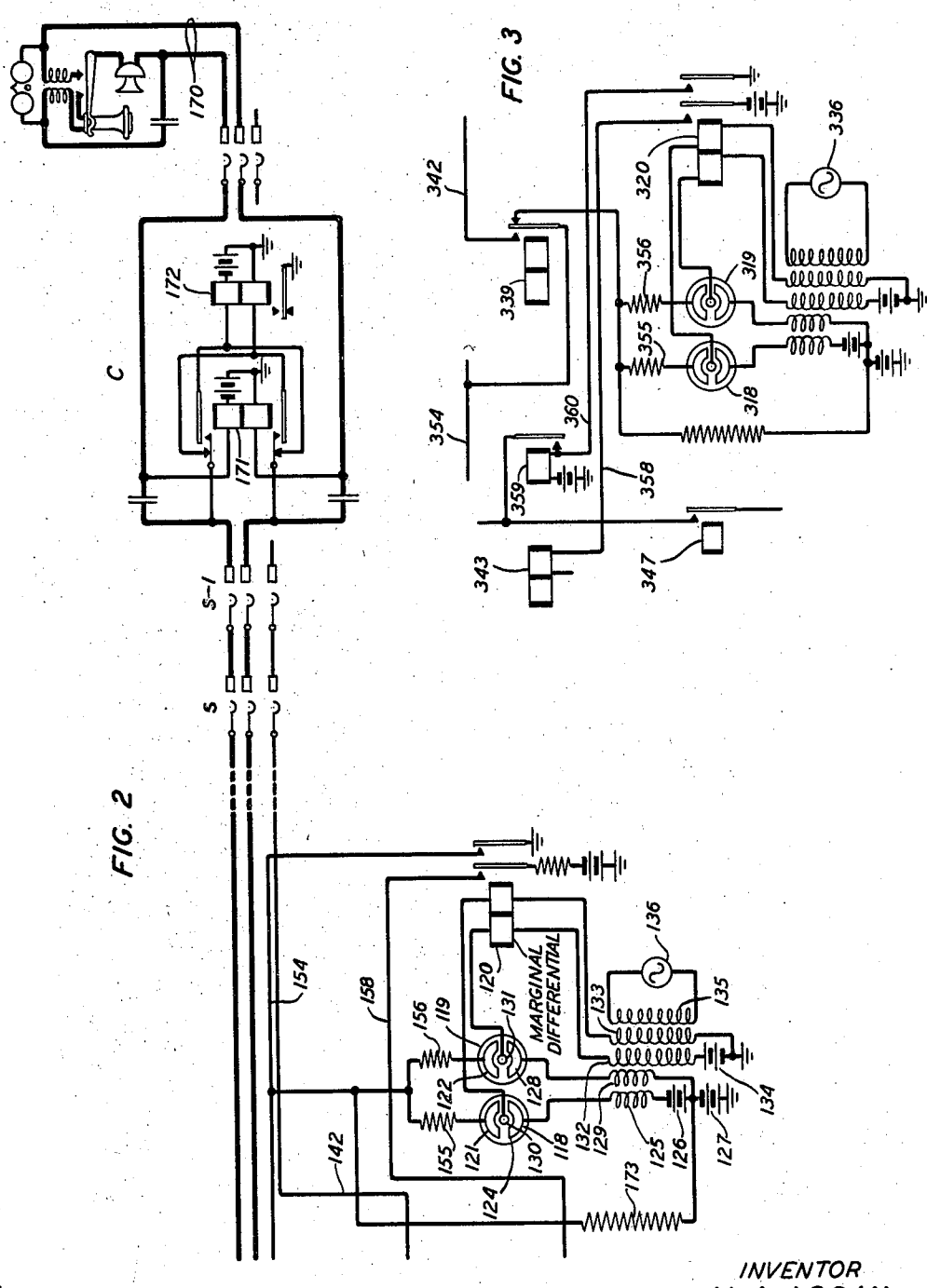

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TELEPHONE SYSTEM

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14 Claims. (Cl. 179—18)

This invention relates to telephone systems and particularly to the signaling, controlling, and switching facilities used in these systems.

The objects of the invention are to improve the signaling and controlling operations performed over telephone lines, such as subscribers' lines; to insure the proper operation of the signaling and controlling facilities despite the presence of line leakage or other adverse conditions; to increase the effectiveness of the means for testing and making connection with these lines; and to improve these systems in other respects.

Suggestions have been made in the past to improve the individual circuit associated with the subscriber's line by substituting a discharge tube for the usual line relay. In some cases these tubes and the circuits provided therewith have been arranged to eliminate both the line and cut-off relays ordinarily used in practice. It has been found, however, that these tube line circuits are frequently subject to false operation in the presence of excessive line leakage.

According to the present invention the advantages of using discharge tubes for performing the functions of a subscriber's line circuit are retained, and at the same time the disadvantage above noted is overcome. These results are obtained by means of a line circuit in which the control gap of a discharge tube ionizes in response to a voltage produced by the line closure at the substation and fires the main gap of the tube, a relay in the main gap circuit serving to start a line finder in operation; and in which two sources of alternating potential of the same phase and frequency are connected respectively in the cathode and anode branches of the main gap circuit. The cumulative voltage of these two sources acts to quench the main gap discharge on each alternate half cycle, while the source in the cathode branch serves to oppose the voltage produced across the control gap by line leakage. This arrangement insures that the tube is quenched as soon as the control gap ionizing voltage is removed, since the voltage across the control gap resulting from leakage on the line, which might otherwise be sufficient to sustain the control gap ionization, is opposed simultaneously with the quenching of the main gap. Hence on the next opposing half cycle following the removal of the ionizing voltage from the control gap both gaps are quenched simultaneously, and the tube remains deionized. This prevents false operation, which might otherwise occur where line leakage currents are excessive.

A feature of the invention is a line-finder testing arrangement in which a differential test relay receives current in one or both of its windings from the anode circuits of two discharge tubes, the control circuits of which are connected to the test conductor to discriminate between the different potentials present on the test terminals of the subscribers' lines. If a line is idle when tested by the line finder, neither of the tubes operates, and no current flows through either winding of the differential test relay. If the line is busy both tubes discharge, but the test relay does not operate since equal currents flow through both of these differential windings. However, when the calling line is reached, only one of the tubes discharges, whereupon the corresponding winding of the test relay is energized and the relay operates to stop the hunting action of the finder switch.

These and other features of the invention will be described in detail in the following specification.

In the drawings accompanying the specification:

Figs. 1 and 2 disclose a portion of an automatic telephone system incorporating one form of the present invention. Fig. 1 shows the details of a calling subscriber's line and line circuit and a part of a line-finder switch, and Fig. 2 illustrates the remainder of the finder circuit, and also selector and connector switches partly in diagrammatic form and partly in detail. Fig. 3 is a modification of the testing circuit of the line finder.

The advantages of using discharge tubes to perform the functions of line relays in subscribers' line circuits have been explained above. There are, however, certain conditions under which these tubes may be exposed to false operation, particularly if the line is subject to leakage. In order that the tube may be ready to respond to the closure of the subscriber's loop when a call is made, the control electrode and the central office battery are connected in series with resistances through normal contacts of the cut-off relay to the subscriber's line. If the leakage resistance of the line is relatively low, substantial leakage currents flow from the central office battery through the coupling resistance, producing a voltage across the control gap of the tube. This voltage, although too small to ionize the control gap of the tube, may be sufficient when added to the normal biasing voltage of the control gap to sustain the ionization once it has started. The conditions under which this leakage voltage would, unless some provision were

made to the contrary, be sufficient to cause false operation will now be explained.

As soon as the line finder has found the line in response to the calling condition thereon, the cut-off relay operates in the usual manner and disconnects the line tube, opening the control gap circuit and permitting the quenching of the anode gap to release the start relay connected in circuit therewith. When the called subscriber answers, the usual current reversal is made, and the capacity of the calling subscriber's line is charged in the opposite direction from the charge it receives from the central office battery connected thereto through the normal contacts of the cut-off relay when the line is idle. When, therefore, the connection is released and the cut-off relay closes its back contacts to reconnect the central office battery to the line, a relatively heavy charging current flows through the coupling resistance to discharge the line in one direction and recharge it in the opposite direction. This discharge current creates a voltage across the control gap which may be sufficient to ionize it, thereby causing current to flow in the anode circuit and through the group start relay. If at this time the leakage voltage on the line is sufficient to raise the total voltage across the control gap above the sustaining value, the tube will remain ionized after the line charging current has ceased to flow, and the group relay will fully operate and cause the false starting of a line finder.

Another condition under which false operation may occur exists where the line finder is designed to test in its hunting operation for a marginal potential on the sleeve conductor of the line, the presence of which depends upon the flow of current over the subscriber's closed loop. With an arrangement of this kind should the subscriber replace his receiver after the finder has started in operation but before it reaches the calling line, the potential identifying the calling line is removed and is replaced by the usual idle line potential. Therefore, the finder fails to stop on the line that initiated the call, and the cut-off relay is not operated to open the control gap of the tube, which remains ionized because of the excessive leakage voltage. The result is that the main anode gap continues its ionization and the group start relay falsely indicates a calling condition.

In the system disclosed herein these possible false operations are prevented by the use of sources of alternating potential in the circuits of the line tube.

Referring to the drawings, the subscriber's line 100 appears at the central office in the terminal bank of the line-finder switch F and is provided with a line circuit comprising a line tube 101, preferably of the gas-filled tube, and a cut-off relay 102. The control electrode 103 of the tube is connected through a high resistance 104 through normal contacts of the relay 102 and a coupling resistance 105 to the ring conductor 106 of the subscriber's line. The tip conductor 107 of the line is connected through a coupling resistance 108 to ground through a back contact of the cut-off relay 102. The negative pole of the central office battery 109 is connected through the left winding and normal contacts of the cut-off relay to the junction point between resistances 104 and 105. The left winding of relay 102 serves as a resistor for conducting the currents which flow over the line from battery 109 when the line loop is closed and when leakage paths are present on the line. The battery 110 is normally connected across the control gap of the tube, formed by the control electrode 103 and the cathode 111, through the left winding and normal contacts of the cut-off relay 102. The voltage of the battery 110, which may be of the order of 55 volts, is insufficient either to ionize the control gap or to sustain the ionization thereof. The main discharge circuit of the tube comprises a section or branch connected to the anode 112 and includes the group start relay 113 and a secondary winding 114 of the transformer. The other section or branch of the main discharge circuit is connected to the cathode 111 and includes the secondary winding 115 of the transformer and batteries 110 and 109 in series. The primary winding 116 of the transformer is connected to a suitable source 117 of alternating current.

It will be noted that the main discharge circuit of the tube, including the gap formed by the anode 112 and cathode 111, is not provided with any relay or switch contacts for quenching the discharge and releasing the group start relay 113. Accordingly the source 117 is coupled to the anode-cathode circuit by the transformer to quench the anode gap once per cycle, so that the tube will cease to hold relay 113 as soon as the control gap is permanently deionized. To this end the secondary windings 114 and 115 are so connected in the anode and cathode branches of the circuit that they aid each other and cumulatively oppose the batteries 109 and 110 sufficiently during alternate half cycles of the source 117 to quench the anode discharge. During these periodic interruptions of the current flow in the anode-cathode circuit the relay 113 retains its armatures attracted by reason of its sluggish characteristic, and the relay only releases after the anode discharge has been permanently quenched. The alternating voltage produced by the secondary winding 114 is considerably greater than that produced by the winding 115. These windings may produce voltages of the order of 40 volts and 5 volts, respectively, and the sum of these two when subtracted from the total voltage of the batteries 109 and 110, which may have the values of 48 and 55 volts, respectively, reduces the anode-cathode voltage below the sustaining value.

The voltage of the secondary winding 115 opposes at each half cycle the voltage produced across the control gap 103—111 by the batteries 109 and 110. But this opposing voltage is comparatively small and does not reduce the control gap voltage below the sustaining value as long as the subscriber has his receiver off the hook and the cut-off relay is in its normal position. When the cut-off relay operates in the normal manner upon the seizure of the line by the finder, the control gap circuit is opened and the tube ceases to discharge. Similarly when the subscriber replaces his receiver at the end of a call the voltage across the control gap is reduced, provided the line leakage is not excessive, below the sustaining voltage, and the tube ceases to discharge. Under these normal conditions the opposing voltage of the winding 115 is not required to effect the release of the tube. If, however, the line leakage is excessive, the tube may be held in a locked condition, since the additional voltage applied to the control gap may be sufficient to raise the total voltage to a value above the sustaining voltage of the gap even though the subscriber's loop is open. In such a case the voltage sup-

plied by the winding 115 becomes effective and opposes the voltage across the control gap at each alternate half cycle, reducing said voltage below the value sufficient to sustain ionization. Since the opposing voltage of the winding 115 is in phase with the voltage of the other winding 114, the control gap is quenched simultaneously with the quenching of the main gap, and on the next half cycle of the source 117 neither of the gaps reionize because the voltages across them are insufficient to refire the tube.

Excepting the testing and other controlling circuits, the line finder F may be of the usual step-by-step type having vertical and rotary motions for selecting the calling subscribers' lines. The testing functions, whereby the finder discriminates between idle lines, busy lines and calling lines are performed by the discharge tubes 118 and 119 operating in conjunction with the differential test relay 120 and also in cooperation with the other circuits of the finder switch. The control electrodes 121 and 122 of these tubes are connected to the test brush 123 of the switch. The cathode 124 of tube 118 is connected through the transformer winding 125 to ground through batteries 126 and 127, the voltages of which may be 20 and 80 volts, respectively. The cathode 128 of tube 119, however, extends to ground through the transformer winding 129 and battery 127 only. Thus the normal potential of the cathode 124 is 100 volts whereas that of the cathode 128 is only 80 volts. The anode 130 is connected through the right winding of the differential relay 120 and through the transformer winding 133 directly to ground, whereas the anode 131 is connected through the left winding of the relay and the transformer winding 132 to the positive pole of the 20-volt battery 134. The sum of the voltages in the windings 133 and 125, induced therein by the primary winding 135 of the transformer, which is energized by the source 136, is sufficient to quench the main gap discharge of the tube 118, and the voltage of winding 125 simultaneously opposes the voltage across the control gap to insure quenching of the tube in case the control gap voltage rises to an excessive value for any reason. Similarly the voltages of windings 132 and 129 cause the deionization of the tube 119. As will be explained more fully hereinafter, both of the tubes 118 and 119 fire when a busy line is tested, and the relay 120, being differential, remains inert; neither tube fires when an idle non-calling line is tested: and when a calling line is tested only tube 118 operates, whereupon the test relay 120 attracts its armatures and stops the finder switch. A high resistance 173, connected between conductor 154 and the point intermediate batteries 126 and 127, serves to prevent false operation of tubes 118 and 119 due to surges or spurious potentials on control electrodes.

The line finder F is connected to the usual first selector switch S which has access through succeeding switches, including selector S—1 and connector C, to the called subscribers' lines. A second connector switch C—1, having access to the subscriber's line 100 is also illustrated to show the manner in which the line circuit is connected thereto.

The selector and connector switches, like the finder F, may be of the well-known step-by-step type, although it should be understood that the invention is not limited to any particular type of system nor to the use of any particular type of switch.

The operation of the system will now be described in detail. Assume for this purpose that the subscriber of line 100 wishes to converse with the subscriber of line 170. When the calling subscriber removes his telephone, a circuit is closed from the negative pole of battery 109 through the left winding and normal contacts of cut-off relay 102, resistance 105, conductor 106 thence through the loop of the calling line to conductor 107, resistance 108 to ground through the normal contact of relay 102. Relay 102 is marginal and does not respond to the current flowing from battery 109 through its left winding as long as resistance 105 is in series with it. But the voltage produced by the current flowing through the winding of relay 102 is applied in series with the voltage of battery 110 across the control gap 103—111 of the tube. The control gap ionizes, and on each aiding alternation of the source 117 thereafter current flows in the main discharge circuit, which may be traced from the negative pole of battery 110 through the winding 115, cathode 111, anode 112, winding of relay 113, transformer winding 114 to the grounded positive pole of battery 109. Relay 113 operates and applies ground potential to the commutator segment 137 for the level of terminals in the finder switch containing the line 100. Relay 113 also places ground on the start conductor 138 which extends through the normal contacts of relay 139, contact springs 140, which are actuated on the tenth rotary step of the switch, winding of slow-release relay 141 to battery. Relay 141 operates and places ground on the sleeve conductor 142. Relay 141 also closes an energizing circuit for the stepping relay 143. This circuit may be traced from ground through the contact of relay 141, conductor 144, normal contacts of vertical stepping magnet 145, normal contacts of the rotary stepping magnet 147, left winding of the relay 143 to battery through the normal contacts of relay 139. Relay 143 controls the vertical stepping action of the switch.

The finder switch is stepped in its vertical movement by the magnet 145 which energizes as soon as relay 143 operates. The energizing circuit of the magnet may be traced from battery through the normal contacts of relay 139, conductor 148, winding of magnet 145, normal contacts of relay 149, closed contacts of relay 143 to the grounded conductor 144. At each energization of the magnet 145 the switch is advanced one step, and the circuit of relay 143 is opened. Each time the circuit of relay 143 is opened, the relay releases the magnet 145, which in turn recloses the circuit of the relay. This action continues until the commutator brush 150 engages the grounded segment 137, at which time a circuit is extended from the grounded brush 150 through the left winding of relay 149, normal contacts of magnet 147, left winding of relay 143 to battery. Relay 143 remains energized in this circuit and holds the magnet 145 in an energized condition to prevent further stepping of the switch. Relay 149, being slow to operate, attracts its armatures after an interval following the closure of the above-traced circuit through the winding of the relay. Relay 149 in operating locks in a circuit traceable from battery through the contacts of relay 139, conductor 148, winding of vertical magnet 145, conductor 151, right winding and contact of relay 149 to the grounded conductor 144. Relay 149 locks, but magnet 145 releases in series with the high resistance winding of the relay.

Relay 149 also initiates the rotary stepping movement of the switch. This movement is performed by the rotary magnet 147 which now energizes in a circuit from battery through its winding, front contact of relay 149, front contact of relay 143 to the grounded conductor 144. Magnet 147 advances the brushes of the switch to the first set of terminals in the selected level and also opens the circuit of the stepping relay 143. Relay 143 in turn opens the circuit of the magnet, and the latter releases. On the first rotary step of the switch the commutator brush 150 disengages the grounded segment and opens the circuit in which relay 149 was originally operated and relay 143 was held at the completion of the vertical movement. Relay 143 now reoperates in the circuit previously traced through its left winding, normal contacts of magnet 147 and the normal contacts of magnet 145 to the grounded conductor 144. The reoperation of relay 143 causes the reoperation of magnet 147, and the switch takes a second step. This stepping action continues until the test wiper 123 encounters the test terminal of the calling line 100.

As the finder switch hunts in the selected level its brushes may encounter both idle non-calling lines and busy lines before reaching the calling line. If a line, such as the line 100, is in an idle non-calling condition, the full negative potential (48 volts) of the central office battery 109 will be present on the test terminal 152. This potential is applied to the terminal 152 over the path extending through the left winding of the cut-off relay 102 and sleeve conductor 153. Assuming no leakage currents are flowing over the subscriber's line, the full potential of the battery 109 is present on terminal 152 since the loop of the line is open at the substation and no current is flowing over the line through the winding of the cut-off relay. When, therefore, the test brush 123 of the hunting finder engages the terminal 152 of an idle non-calling line, a negative potential of 48 volts is applied over test conductor 154 and through the resistances 155 and 156 to the control electrodes 121 and 122, respectively, of the test tubes 118 and 119. The resultant voltage of the battery 109 and batteries 126 and 127, thus applied to the control gap of the tube 118 is insufficient, even when aided by the voltage produced in the transformer winding 125, to ionize the control gap. Hence no current flows in the anode circuit of the tube, which includes the right winding of relay 120. Also the voltage resulting from batteries 109 and 127, applied to the control gap of the tube 119, is insufficient to ionize the tube, and no current flows through the left winding of relay 120. Relay 120 remains deenergized, and the finder passes over the terminals of the idle line thus encountered.

When a subscriber's line is in a busy condition, the test terminal thereof, such as the terminal 152 of the line 100, is identified by the presence of a ground potential thereon. This potential may be supplied to the terminal 152 from a linefinder switch which previously selected the line over one of its multiple appearances; or the ground may be supplied thereto from a connector switch C—1 over the sleeve conductor 157 through the front contacts of the cut-off relay 102 and conductor 153. In either case this ground potential is extended over the brush 123 of the searching finder and conductor 154 to the control electrodes 121 and 122. Under these conditions the full voltage of batteries 126 and 127 aided by the winding 125 is supplied to the control gap of tube 118 and the potential of battery 127 aided by the winding 129 is applied to the control gap of tube 119. Both tubes ionize, whereupon current flows through both windings of the relay 120, the circuit for the right winding being traceable from the negative pole of battery 126, transformer winding 125, cathode 124, anode 130, right winding of the relay, transformer 133 to ground, and the circuit for the other winding being traceable from the negative pole of battery 127, winding 129, cathode 128, anode 131, left winding of the relay, winding 132 to the positive pole of battery 134. The voltage of battery 134 is substantially equal to that of battery 126; therefore, substantially equal currents flow through the two windings of the relay 120. Since this relay is differential and also marginal, the flux resulting from the current flowing through these windings is not sufficient to cause the attraction of the armature. Therefore, the finder switch passes the busy line and continues to search for a line having a calling condition thereon.

If, as has already been assumed, the subscriber's line 100 is in a calling condition, the test terminal 152 is characterized by the presence of a negative potential of some intermediate value, such as 25 volts. Since the line is calling and the cut-off relay 102 is still in its normal condition, current flows from the battery 109 through the left winding and normal contacts of the relay, resistance 105 over the loop of the line as previously described. This current flowing through the winding of the cut-off relay reduces the normal negative potential on the terminal 152 to the intermediate value. When the test brush 123 encounters this terminal, the resultant voltage applied to the control gap of the tube 118 causes the tube to ionize, whereas the voltage applied to the tube 119 is insufficient to ionize it. Therefore, current flows through one winding of the relay 120 alone, and the relay attracts its armature.

When relay 120 operates, a circuit is closed from battery through its contacts over conductor 158, through the left winding of relay 159, normal contacts of relay 139, right winding of relay 143 to ground at the front contacts of relay 141. Relay 159 operates in this circuit, and relay 143 remains energized to prevent any further stepping movement of the switch. Relay 159 locks in a circuit from battery through its right winding and front contacts, through the closed contacts of the magnet 147 to ground at the front contacts of relay 141. Relay 159 operates relay 139 in a circuit from battery through the right winding of relay 139, front contacts of relay 159 to ground at the off-normal springs 160, which shifted when the switch took its first vertical step. With relay 139 operated a second locking circuit for relay 159 may now be traced from battery through the right winding and front contact of relay 159, front contacts of relay 139 to ground at the front contacts of relay 141. Relay 139 causes the release of relays 143 and 149. When relay 159 operates it extends the calling subscriber's line over the tip and ring conductors through to the impulse relay associated with the first selector switch S. The operation of the impulse relay causes ground potential to be applied to the holding conductor 142 to hold the linefinder switch in its operated condition after the release of relay 141 as explained below. Relay 120 in operating also completes a circuit from

ground over its contacts, conductor 154, brush 123, terminal 152, conductor 153 through the left winding of the cut-off relay 102 to battery 109. Now the resistance 105 is not in series with the left winding of relay 102, so relay 102 operates and locks in a circuit from battery 109, right winding and front contacts of relay 102 and thence to ground as above traced. Relay 102 in operating disconnects the control electrode 103 of the tube 101 from the calling line, whereupon the control gap of the tube becomes deionized. On the next opposing alternation of the source 117 the voltage produced by windings 114 and 115 opposes the batteries 109 and 110 to quench the discharge in the main gap of the tube. After an interval the group start relay 113 releases, disconnecting ground potential from the commutator segment of the line finder and opening the original energizing circuit of relay 141. Relay 141 is slow to release and retains its armatures until the calling line is extended through to the selector switch S in the manner above described. When relay 120 applies ground potential to the conductor 154, the tube 119 also fires, causing the other winding of relay 120 to energize and release the armature. Relay 159, however, does not release since it is now locked in a circuit from battery through its right winding and contacts, front contacts of relay 139 over conductor 142 to ground applied at the selector switch S. This ground potential on the conductor 142 is also extended over the front contacts of relay 139 and the front contacts of relay 159 to conductor 154 and the multiples of the calling line test terminals to hold the line in a busy condition and to maintain the ionization of tubes 118 and 119.

The calling subscriber manipulates his dial to operate the selector switches S and S—1 and the connector switch C to complete the connection to the called subscriber's line 170. When the called party answers, relay 171 operates and reverses the direction of current flowing back over the connection and over the calling subscriber's line. The circuit for supplying current to the calling line may now be traced from battery through the upper winding of relay 172, upper front contacts of relay 171, thence over the tip side of the connection through the brush 161 of the line finder over the tip conductor 107 of the calling line and returning over the ringing conductor 106 through the finder brush 162 thence over the ring side of the connection through the lower front contacts of relay 171 and the lower winding of relay 172 to ground. Current flowing over the calling line from this source charges the capacity of the calling line in the direction corresponding to the application of the positive pole of battery to the ring conductor 106. This direction, it will be noted, is opposite the direction in which the subscriber's line is normally charged by the central office battery 109 when connected to the line during the idle condition thereof.

When the subscribers have finished the conversation, they replace their receivers, and relays 171 and 172 release. In the well-known manner the holding ground potential is removed from conductor 142, and relay 159 releases. A circuit is now closed from battery through the release magnet 163, off-normal contacts 160, normal contacts of relay 149, normal contacts of relay 159, normal contacts of relay 141 to ground at the off-normal contacts 150. The magnet 163 releases the finder switch to its normal position, and the springs 160 are shifted to open the holding circuit of relay 139 and the circuit of the release magnet 163. The removal of ground potential from the conductor 154 also causes the extinguishment of the tubes 118 and 119.

When ground potential is removed from test brush 123 at the time the line finder releases, the cut-off relay 102 releases and reconnects the negative pole of battery 109 through resistance 105 to the ring conductor 106 of the subscriber's line. Since this side of the line is charged with positive potential, the reconnection of the negative pole of battery thereto causes a substantial current to flow from the battery 109 over the line to recharge it in the opposite direction. This current flowing through the right winding of relay 102 produces sufficient voltage across the control gap of the tube 101 to cause it to ionize. Thereupon current flows in the main anode circuit of the tube through the winding of relay 113. As soon as the line charging current diminishes, the voltage across the control gap falls below the sustaining value, provided it is free from leakage paths. However, if we assume that the line has a leakage path, represented by the resistance element 164, the current flowing from the battery 109 through the left winding of relay 102 and thence over the line to ground through the resistance 164 may produce a voltage which, when added to the voltage of the battery 110, is sufficient to sustain ionization in the control gap of the tube after the line charging current ceases to flow. This continued ionization of the tube would cause the operation of the group start relay 113 and the line-finder switch were it not for the opposing alternating voltages applied to the tube circuit by the transformer windings 114 and 115. But the alternating voltage produced by the transformer winding 115 is in opposition to the voltage that tends to maintain the control gap ionized and is sufficient to overcome the effect of the leakage current and quench the discharge of said gap. This quenching of the control gap occurs simultaneously with the quenching of the main gap to insure that the tube will not refire when the alternating voltage reverses its polarity.

The abandonment of a call by the subscriber is another condition under which it is necessary to quench the tube 101 to prevent false operation. Assume that the subscriber initiates a call as above described; whereupon the tube ionizes, the group start relay 113 energizes, and a finder F is set in motion to hunt for the calling line. If the subscriber decides to abandon the call and replaces his receiver on the switchhook while the finder is still hunting the calling line, the potential on the terminal 152 is immediately raised from the intermediate value of 25 volts to the full value of 48 volts present on the terminals of idle non-calling lines. In the meantime, however, the control gap and the main gap of the tube have ionized, and relay 113 is operated. If the leakage resistance 164 on the line is sufficiently low, the leakage current flowing from battery 109 increases the voltage across the control gap to a value which exceeds the sustaining voltage. Hence the tube will remain ionized, and the finder will pass by the line and continue to search for a calling line which does not exist. This false operation, however, is prevented as above explained by the opposing alternating voltages set up by the transformer windings 114 and 115, and the tube 101 is restored to its normal condition, and the group start

relay 113 releases to discontinue the hunting movement of the finder switch.

Fig. 3 shows an improvement in the line-finder test circuit whereby the discharge tubes, such as the tubes 118 and 119 of Fig. 2, are deionized during the conversational period. The advantage of this arrangement is a substantial increase in the life of the tubes.

To facilitate an understanding of the test circuit shown in Fig. 3 the relays, tubes, and other elements are given reference characters which differ only in the first digit from those assigned to the corresponding elements in Figs. 1 and 2. The test conductor 354 from the test brush 123 of the line finder F extends through the armature and normal contact of relay 339 and through resistances 355 and 356 in parallel to the control electrodes of the test tubes 318 and 319. The anode and cathode elements of these tubes are connected through the windings of relay 320 and through the windings of the transformer, which is excited by the alternating current source 336, to battery in the manner disclosed in Fig. 2.

When the line finder encounters a calling line, the potential on the test conductor 354 causes tube 318 alone to ionize. Current now flows through the right winding of relay 320, and the relay operates. Relay 320 closes a circuit from battery through its front contact, conductor 358 through the right winding of the stepping relay 343 thence to ground as shown in Fig. 1. This circuit holds the relay 343 to prevent further stepping of the finder switch. Relay 320 also closes a circuit from ground through its front contacts, conductor 360, through the winding of relay 359 to battery. Relay 359 operates and locks through the front contact of the rotary magnet 347. Relay 359 operates relay 339, and these relays lock as previously described. When relay 339 operates, the test and holding conductor 354 is disconnected from the tubes 318 and 319 and is extended to the corresponding conductor 342 leading to the selector switch. Tube 318 deionizes, relay 320 releases, and the tubes remain deionized during the conversational period.

It will be understood that the invention is not limited to the specific embodiments chosen to illustrate it herein. Numerous variations and changes may be made in the circuits and devices illustrated. For example, the tube structures may vary, and different values of the potential sources may be used. Also different means may be employed for supplying the alternating potentials used in the anode and cathode circuits of the tubes.

What is claimed is:

1. The combination with a line of a discharge device having a main gap and a control gap, circuit means controlled over said line for causing a discharge across said control gap, means for causing a discharge across said main gap in response to the discharge of said control gap, a source of potential acting to quench the discharge of said control gap, and a second source of potential connected in serial relation with said first source to quench the discharge of said main gap.

2. The combination with a line of a discharge tube having a main gap and a control gap, circuit means including said line for causing a discharge across said control gap, means for causing a discharge across said main gap in response to the discharge of said control gap, a source of potential and means for applying the same to quench the discharge of said control gap, and a second source of potential and means for applying the same in series aiding relation with said first source to quench the discharge of said main gap.

3. The combination with a telephone line of a discharge device having a main gap and a control gap, circuit means including said line for ionizing said control gap, means for causing a discharge across said main gap in response to the ionization of said control gap, a source of alternating potential serving to oppose the continued ionization of said control gap, a second source of alternating potential, and means for applying said sources in series aiding relation to quench the discharge of said main gap.

4. The combination with a telephone line of a discharge device having a main gap and a control gap, circuit means including said line for ionizing said control gap, means for causing a discharge across said main gap in response to the ionization of said control gap, a source of alternating potential acting on each cycle to quench the ionization of said control gap, a second source of alternating potential acting cumulatively with said first source to quench the discharge of said main gap concurrently with the quenching of said control gap.

5. The combination with a telephone line of a discharge tube having a cathode, a control electrode forming a control gap with said cathode, an anode forming a main gap with said cathode, circuit means including said line for causing the ionization of said control gap, an operating circuit including said main gap, means responsive to the ionization of said control gap for causing discharge current to flow across said main gap and in said operating circuit, a source of alternating potential connected in circuit with said cathode for quenching the ionization of said control gap, and a second source of alternating potential connected to said anode and in phase with said first source, said sources of potential acting in series relation for the purpose of quenching the discharge across said main gap.

6. The combination with a subscriber's line of a discharge tube having a cathode, a control electrode forming a control gap with said cathode, an anode forming a main gap with said cathode, an operating circuit including said main gap, said operating circuit having one section connected to the anode and another section connected to said cathode, means controlled over the subscriber's line for causing the ionization of said control gap, a source in said operating circuit for causing current to flow therein and across said main gap in response to the ionization of said control gap, a source of potential in said cathode section for acting to quench the ionization of said control gap, and a second source of current in said anode branch coacting with the source in said cathode branch to quench the discharge of said main gap simultaneously with the quenching of said control gap.

7. The combination with a telephone line of a source of current, a discharge device having a control electrode, resistance means for coupling said control electrode to said line and to said source of current, a cathode for said device forming a control gap with said control electrode, an anode for said device forming a main gap with said cathode, means under the control of said line for closing a circuit including said source of current to increase the voltage across said

control gap above the ionizing value, means responsive to the ionization of said control gap for causing a discharge across said main gap, a source of alternating potential for opposing the ionizing voltage across said control gap, and a second source of alternating potential connected in series circuit relation with said last-mentioned source for quenching the discharge across said main gap.

8. In a telephone system, a telephone line, means for closing said line, a space discharge device for said line having a control gap and a main gap, a source of current connected to said line, a resistor in series with said source for conducting from said source the current flowing over said line as a result of the closure thereof and also serving to conduct the leakage currents flowing over said line, the current flowing through said resistor as a result of line closure serving to increase the voltage across said control gap above the ionizing value, means for causing current to flow in said main gap in response to ionization of the control gap, a source of potential opposing the voltage across the control gap caused by said leakage currents to reduce said control gap voltage below the sustaining value when said line is opened, and a second source of potential for quenching the flow of current in said main gap when the voltage across said control gap is reduced below the sustaining value.

9. In a telephone system, a subscriber's line, means controlled by the subscriber for closing said line to initiate a call, a space discharge tube having a control electrode and a cathode forming a control discharge gap, an anode forming with said cathode a main discharge gap, a source of current, a resistor for coupling said source to the line and to said control electrode, said resistor serving to conduct the current flowing from said source over said line as a result of line closure and to conduct the leakage currents flowing over said line from said source, the current flowing through said resistor as a result of line closure serving to increase the voltage across said control gap above the ionizing value, means for causing current to flow in said main gap in response to the ionization of the control gap, a source of alternating potential connected to said cathode for nullifying the voltage produced across the control gap as a result of the leakage currents flowing through said resistor, and a second source of alternating potential connected to said anode and acting in phase with said last-mentioned source to quench the discharge across said main gap.

10. The combination with a line of a discharge tube having a main gap and a control gap, circuit means including said line for causing a discharge across said control gap, means for causing a discharge across said main gap in response to the discharge of said control gap, a transformer having a winding for applying a voltage in opposition to the discharge of said control gap, a second winding on said transformer for applying a voltage in series aiding relation to the voltage of said first winding for opposing the discharge of said main gap, and means for energizing said transformer windings.

11. The combination with a discharge tube having a cathode, a control electrode forming a control gap with said cathode, an anode forming a main gap with caid cathode, circuit means for causing the ionization of said control gap, an operating circuit including said main gap, means responsive to the ionization of said control gap for causing discharge current to flow across said main gap and in said operating circuit, a transformer having a winding in circuit with said cathode for producing a voltage quenching the ionization of said control gap, a second winding on said transformer connected to said anode for producing a voltage in phase with the voltage of said first winding for the purpose of quenching the discharge across said main gap, and means for energizing said transformer windings.

12. In combination, telephone lines, a switch having access to said lines, two discharge tubes having their control electrodes connected to the test circuit of said switch for testing the condition of said lines, means for operating said tubes in different combinations according to the condition of the line tested, and a test relay having a plurality of windings energized in different combinations in response to the operation of said tubes.

13. In combination, telephone lines, a finder switch having brushes for making connections with said lines, two discharge tubes having their control elements connected to the test brush of said switch for testing the condition of said lines, means for ionizing said tubes in different combinations according to the condition of the line, a differential test relay having a winding in circuit with one of said tubes and a second winding in circuit with the other tube, said windings being energized in different combinations in response to the ionization of said tubes, and means controlled by said relay for stopping said finder switch when the line tested has a particular condition thereon.

14. In a telephone system, a subscriber's line subject to the flow of leakage currents when a source of current is connected thereto, means controlled by the subscriber for closing the loop of the line to initiate a call, a space discharge tube having a control electrode and a cathode forming a control discharge gap, an anode forming with said cathode a main discharge gap, a source of current, a resistor for coupling said source to the line and to said control electrode, said resistor serving to conduct the current flowing from said source over said line as a result of line loop closure and to conduct leakage currents flowing over said line from said source, the current flowing through said resistor as a result of line loop closure serving to increase the voltage across said control gap above the ionizing value, the current flowing in said resistor as a result of the leakage on said line acting to increase the voltage across said control gap above the sustaining value, means for causing current to flow in said main gap in response to the ionization of the control gap, a source of alternating potential connected to said cathode and of a magnitude sufficient to overcome the voltage produced by the flow of leakage currents and to reduce the voltage across the control gap below the sustaining value when the line loop is open, and a second source of alternating potential connected to said anode and acting in phase with said last-mentioned source to quench the discharge across said main gap.

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