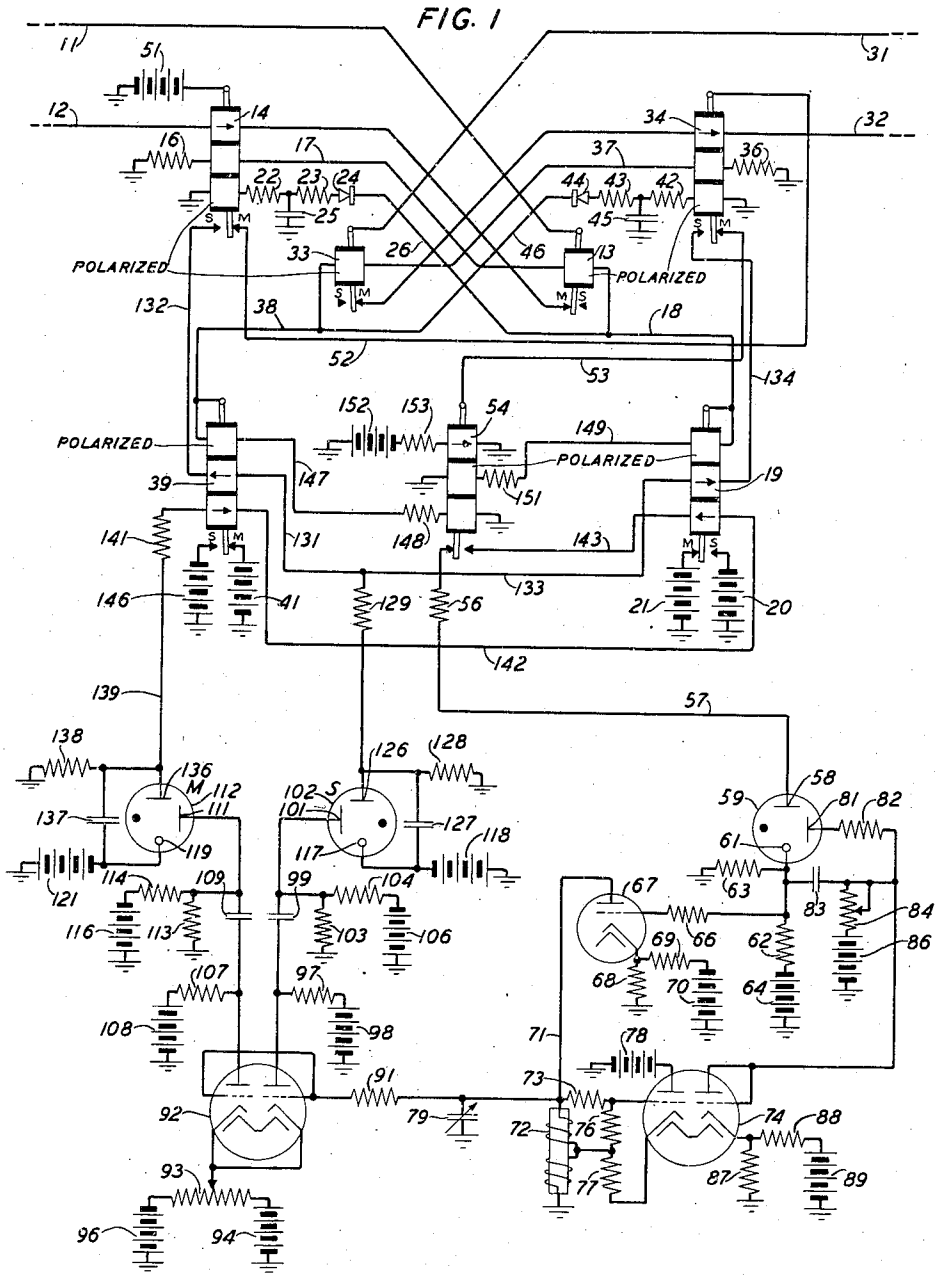
July 19, 1949. R. B. HEARN ET AL 2,476,864

TELEGRAPH REPEATER

Filed Sept. 29, 1944 2 Sheets-Sheet 1

FIG. 1



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TELEGRAPH REPEATER

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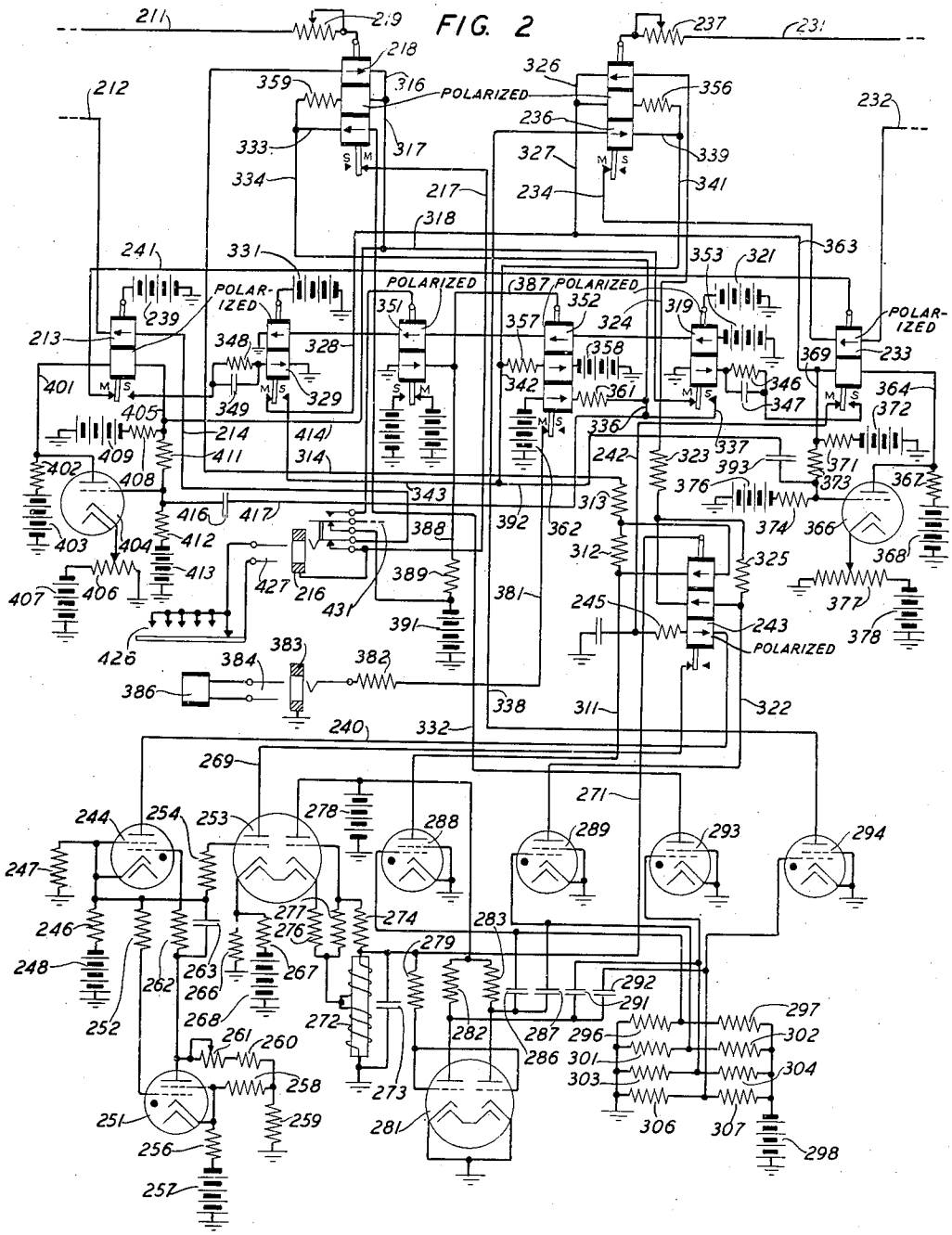
FIG. 2



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TELEGRAPH REPEATER

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Application September 29, 1944, Serial No. 556,352

18 Claims. (Cl. 178—71)

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This invention relates to telegraph repeaters and particularly to electronic regenerative repeaters.

An object of the invention is to control the retransmission of signals by selectively operable electronic means with complete assurance of proper selection as between two or more such electronic means.

Another object of the invention is to eliminate all possibility of false selection as between two or more selectively operable electronic means which might result from interaction among their selection circuits.

Another object of the invention is to isolate signal retransmitting means from electronic selecting means so as to provide for indirect control of the former by the latter.

The invention features the selective retransmission of marking or spacing signals under the control of gas-filled electron discharge tubes which are jointly conditioned to be fired and are rendered conductive selectively by the selective completion of their anode circuits so that no condition of interaction between the control electrode circuits of the tubes can result in the firing of more than one tube.

The invention also features a simple and convenient arrangement for regulating the biasing current of a polarized receiving relay, and for reversing the biasing current to prevent reflection of repeated signals back into a line over which they have been received.

In accordance with one embodiment of the invention, two telegraph lines interassociated through the repeater include the operating windings of their respective receiving relays and the armatures and marking contacts of their respective transmitting relays. The anode circuit of a normally conductive start-stop control electron discharge tube which is of the gaseous type is completed through the serially connected armatures and marking contacts of the receiving relays and through the armature and normal contact of a switching relay. The discharge tube, when conductive, holds in inactive condition an oscillator. Upon operation of either receiving relay to spacing in response to a spacing signal as, for example, the start impulse of start-stop telegraph signals, the anode circuit of the discharge tube is interrupted, quenching the tube, and either of two parallel paths is completed from positive battery through the operating winding of a relay individual to the particular path to the anode, common to the two paths, of a normally non-conductive timing electron discharge tube,

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which functions to control the operation of the transmitting relays to spacing, and is preferably of the gaseous type. The function of the relays in the two paths is to isolate from direct control by the timing tube, and to control individually, the two transmitting relays. A similar tube to the anode of which other windings of the two relays are connected in series, functions to control the operation of the transmitting relays to marking.

When the first-mentioned tube becomes deactivated the oscillator breaks into oscillation and oscillates at a frequency of one cycle per impulse interval of correctly timed telegraph signals and a detector circuit derives timing impulses at the rate of one impulse per cycle. These impulses are applied to the control electrode of the two timing electron discharge tubes previously mentioned. The timing impulse renders conductive the timing tube which has its anode circuit completed through one of the parallel paths to positive battery, this being the tube for controlling the retransmission of spacing signals, and the isolating relay included in this path operates, locks, and operates to spacing the transmitting relay which it is arranged to control, thereby initiating the retransmission of the spacing signal.

Either of the isolating relays, upon being operated to cause operation of its associated transmitting relay to spacing, operates the switching relay to its off-normal contact. This relay prepares a path for eventual completion of the anode circuit of the other timing tube, which is the tube for controlling the retransmission of marking impulses. Upon the application of the next timing pulse to the two timing control tubes, if the receiving relay which had gone to spacing has returned to marking the anode circuit which had been prepared by the switching relay will be completed to positive battery through the reversely poled windings of both of the isolating relays. The isolating relay which has previously operated to cause the retransmission of a spacing impulse will be restored to the initial condition and will reoperate its associated transmitting relay to the marking condition, thereby effecting the retransmission of a marking impulse. If the receiving relay has not returned to marking when the next timing impulse is applied to the timing tubes, that one of the timing tubes which pertains to the retransmission of a marking signal will not be fired because its anode circuit is not completed except when both of the receiving relays are in the marking condition, and the tim-

ing impulses will have no effect on the timing tube which pertains to the retransmission of a spacing signal because this tube remains conductive until such time as neither of the receiving relays is in the spacing condition.

Upon the return of the isolating relay to its initial condition it restores the switching relay to the normal condition, thereby interrupting the anode circuit of the timing tube which pertains to the retransmission of a marking impulse and reestablishing the positive battery connection to the anode of the start-stop control tube as in the initially described condition.

The start-stop control tube will not be fired upon the completion of its anode circuit because a condenser timing circuit is associated with its control electrode whereby upon the quenching of the tube its control electrode does not become reconditioned to refire the tube until an interval equal to a complete start-stop permutation code signal has elapsed. In response to each spacing impulse of a received code combination the timing tube pertaining to the retransmission of spacing impulses will be fired under the control of the timing impulses and in response to each marking impulse the timing tube pertaining to the retransmission of marking impulses will be fired, each of the tubes in turn operating the isolating relay associated with the receiving relay which is responding to the incoming signals and the isolating relay in turn operating the transmitting relay associated with the other line and also operating the switching relay.

When the stop impulse is received the timing tube pertaining to the retransmission of a marking impulse will be operated under the control of the timing impulse if the last selecting impulse of the code combination was of spacing nature and the stop impulse of marking nature will be transmitted to the other line, or if the last selecting impulse of the code combination was of marking nature neither of the timing tubes will be fired because a marking condition is already being impressed upon the other telegraph line. In the first case, the switching relay will be operated to complete the anode circuit of the start-stop control tube incident to the retransmission of the stop impulse and in the second case the anode circuit of the start-stop control tube will have been completed previously. About the time of the generation of the timing impulse for the retransmission of the stop impulse the condenser timing circuit conditions the control electrode of the start-stop control tube to fire the tube and the tube fires and stops the oscillator, thus restoring the repeater to the initial or steady state condition, in which it remains until the next start impulse of a permutation code signal combination is received.

In accordance with another embodiment of the invention each of the telegraph lines includes the operating winding of a receiving relay and the armature and marking contact of a sending relay as in the previously described embodiment of the invention. Positive battery is serially connected through the armatures and marking contacts of the two receiving relays to a start-stop control tube which is preferably of the gaseous type and upon operation of either of the receiving relays to spacing the anode circuit of the start-stop control tube is interrupted and the tube is quenched. As in the previously described embodiment of the invention the start-stop control tube, upon being quenched, sets in operation an oscillator from which a detector circuit

derives timing impulses and applies them to the control electrodes of four timing electron discharge tubes which are preferably of the gaseous type.

Two of the timing tubes have their anodes connected through oppositely poled marking and spacing windings of the transmitting relay associated with one line to the two contacts of a selecting relay controlled by the receiving relay associated with the other line. The other two transmission controlling tubes have their anodes connected through marking and spacing windings of the other transmitting relay to the contacts of a selecting relay controlled by the receiving relay on the opposite side of the repeater. When either of the receiving relays is operated to spacing as in response to the start impulse of a permutation code signal combination it interrupts the anode circuit of the start-stop control tube thereby effecting the starting of the oscillator and also operates its associated selecting relay to the off-normal or spacing condition. The selecting relay interrupts the circuit through the marking winding of the transmitting relay associated with the other line to the anode of one of the transmission controlling tubes, thereby quenching that tube, and completes a circuit through the spacing winding of the same transmitting relay to another of the transmission control tubes. When the timing impulses are applied to the control electrodes of the four timing tubes the tube which has had its anode circuit completed through the spacing winding of the transmitting relay will be fired and the spacing winding of the relay will be energized to operate the armature to spacing and effect the retransmission of the start impulse of spacing nature. In response to the first marking selecting impulse of the code to be retransmitted the receiving relay will be restored to marking, the selecting relay will be restored to its normal or marking condition to interrupt the circuit to the anode of the tube associated with the spacing winding of the transmitting relay and to reestablish the anode circuit of the tube associated with the marking winding of the transmitting relay. The timing impulse will cause the firing of this tube and the flow of current in the marking winding of the transmitting relay, thereby restoring the relay to marking. In this way marking and spacing impulses are retransmitted and about the time that the timing impulse pertaining to the stop impulse of the telegraph signal combination is generated, a condenser timing associated with the start-stop control tube refires this tube providing both of the receiving relays are in the marking condition, so that the anode circuit of the start-stop control tube has been reestablished and this tube upon being refired stops the oscillator, thus restoring the system to the initial condition in which it awaits the start impulse of the next permutation code combination to be retransmitted in regenerative manner.

For a complete understanding of the invention reference may be had to the following detailed description to be interpreted in the light of the accompanying drawings wherein:

Fig. 1 is a schematic circuit diagram showing one embodiment of the invention; and

Fig. 2 is a schematic circuit diagram showing another embodiment of the invention.

Referring now the drawings and particularly to Fig. 1, a telegraph line comprising conductors 11 and 12 extends to a remote telegraph station (not shown) at which the telegraph signaling

battery is located. Conductor 11 of the line terminates in the regenerative repeater at the armature of a transmitting relay 13 and conductor 12 extends through the operating winding of a receiving relay 14 to the marking contact of transmitting relay 13. When the line comprising conductors 11 and 12 is closed at the remote station through the signaling battery, current in the operating winding of relay 14 holds the armature on the marking contact. Current flowing in the biasing winding of relay 14 in a circuit from ground through resistor 16, the biasing winding of the relay, conductor 17, winding of transmitting relay 13, conductor 18, armature and left-hand or marking contact of a selecting or transmission controlling relay 19 and grounded battery 21 seeks to drive the armature of relay 14 to the spacing contact but the operating winding dominates and holds the armature on the marking contact. A third or locking winding of receiving relay 14 is included in a circuit from ground through the locking winding, resistors 22 and 23, varistor 24, conductors 26 and 18 and armature and left-hand contact of relay 19 to battery 21. Varistor 24 is so connected in this circuit that it presents high resistance to the flow of current from battery 21 so that very little current flows in the locking winding of relay 14 and this relay is free to respond to the opening, at the remote station, of the line circuit comprising conductors 11 and 12 and to operate its armature to spacing. A condenser 25 is connected between ground and the junction of resistors 22 and 23.

The line circuit over which signals received on the line circuit comprising conductors 11 and 12 are adapted to be repeated, comprises conductors 31 and 32 which extend to a remote telegraph station at which the battery for supplying signaling current is located. Conductor 31 terminates in the repeater at the armature of transmitting relay 33 and conductor 32 extends through the operating winding of a receiving relay 34 to the marking contact of transmitting relay 33. The biasing winding of receiving relay 34 is connected in a circuit from ground through resistor 36, the biasing winding of the relay, conductor 37, winding of transmitting relay 33, conductor 38, and armature and right-hand or marking contact of a selecting or transmission controlling relay 39 to battery 41 which is connected between the right-hand contact of the relay and ground in the same polar sense as battery 21.

The circuit of the locking winding of receiving relay 34 extends from ground through the locking winding of the relay, resistors 42 and 43 varistor 44, conductors 46 and 38 and armature and right-hand contact of relay 39 to battery 41. Varistor 44 is connected so as to present high resistance to the flow of current from battery 41, so that there is very little current flowing in the locking winding of relay 34 and the relay is free to operate to spacing upon the opening of the line circuit comprising conductors 31 and 32 at the remote station. A condenser 45 is connected between ground and the junction of resistors 42 and 43. From this it will be apparent that the circuits of receiving relays 14 and 34 and of transmitting relays 13 and 33 are completely symmetrical. Relay 14 is adapted to receive signals from the line circuit comprising conductors 11 and 12 and relay 13 is adapted to transmit signals into this line circuit. Relay 34 is adapted to receive signals from the line circuit comprising conductors 31 and 32 and relay 33 is adapted to transmit signals into this line circuit. Signals may be repeated

from either line circuit into the other but not in both directions simultaneously. From this it will be apparent that the repeater is in the form generally known as a two-way half-duplex repeater.

A circuit is traced from the positive terminal of battery 51, the negative terminal of which is connected to ground, armature and marking contact of relay 14, conductor 52, armature and marking contact of relay 34, conductor 53, armature and left-hand contact of a switching relay 54, resistor 56 and conductor 57 to the main anode 58 of a cold cathode gas-filled electron discharge tube 59. The cathode 61 of tube 59 is connected to the junction of resistors 62 and 63 which are connected in series between the negative terminal of battery 64 and ground and which comprise a potential divider for establishing the desired potential of cathode 61 relative to main anode 58. In the idle condition of the repeater tube 59 is conductive in its main gap and the cathode 61 of the tube is positive with respect to ground.

The cathode of tube 59 is connected through current limiting resistor 66 to the grid of an electron discharge tube 67 which is preferably a vacuum tube. The cathode of tube 67 is connected to the junction of resistors 68 and 69 which are connected in series between the negative terminal of battery 70 and ground. The anode of tube 67 is connected through conductor 71 and tapped inductance winding 72 to ground. With cold cathode tube 59 conductive as the steady state condition and with the grid of tube 67 connected to the cathode of tube 61 the grid-to-cathode potential of tube 67 will be such that steady current flows in its anode-cathode circuit and through inductance winding 72.

The upper terminal of inductance winding 72 is connected through resistor 73 to the grid of the left-hand triode section of a hot cathode vacuum electron discharge tube 74. The tap or intermediate terminal of inductance winding 72 is connected through resistor 76 to the grid of the left-hand triode section of tube 74 and through resistor 77 to the cathode. The anode of the left-hand triode section of tube 74 is connected to the positive terminal of battery 78. The inductance winding 72 is shunted by a variable condenser 79. The elements comprising inductance winding 72, condenser 79 and the left-hand triode section of tube 74 and their interconnections will be recognized as an electron tube oscillator circuit. Condenser 79 is preferably adjusted so that the frequency of the oscillator is twice the telegraph signaling frequency, from which it follows that the duration of each cycle of the oscillator is equal to the duration of one impulse of correctly timed telegraph signals. However, with steady unidirectional current flowing in tube 67 and inductance winding 72 oscillation within the oscillatory circuit will be prevented, energy will be stored in the magnetic field of inductance winding 72 as a result of the flow of direct current therethrough and condenser 79 will have a small negative charge with respect to ground, this charge being equal to the ohmic potential difference across inductance winding 72 which is the product of the resistance of this winding and the direct current flowing therethrough.

Referring again to tube 59, the cathode 61 and control anode 81 thereof are interconnected through condenser 83 and resistor 82 connected in series. The junction of resistor 82 and condenser 83 is connected through variable resistor 84 to the positive terminal of battery 86, the negative

terminal of which is grounded. The same junction point is also connected to the anode and grid of the right-hand triode section of tube 74 whereby this section of the tube operates as a diode. The cathode of the right-hand triode section of tube 74 is connected to the junction of resistors 87 and 88 connected in series between the positive terminal of battery 89 and ground whereby the cathode of the right-hand section of the tube is adjusted to a potential which is positive with respect to ground. The left-hand plate of condenser 83 has the same potential as the cathode 61 of tube 59 and the right-hand plate has the same potential as the anode of the right-hand triode section of tube 74 which is positive with respect to ground by the potential different across resistor 87 plus the anode-cathode potential difference of the diode-connected section of tube 74. This potential is applied to the control anode 81 of tube 59 through resistor 82. Preferably the control anode is positive with respect to the cathode but the potential difference between them is considerably less than the ionizing potential of the tube.

The upper terminal of inductance winding 72 is connected through resistor 91 to both grids of a twin triode tube 92. Both cathodes of the tube are connected to the movable contactor of a potential divider 93 which is connected between positive and negative batteries 94 and 96, respectively. The right-hand anode of tube 92 is connected through load resistor 97 to positive battery 98 and through condenser 99 to the control anode 101 of a cold cathode gas-filled electron discharge tube 102. The control anode of tube 102 is also connected to the junction of resistors 103 and 104 connected in series between ground and negative battery 106. Similarly, the left-hand anode of tube 92 is connected through load resistor 107 to positive battery 108 and through condenser 109 to the control anode 111 of cold cathode gas-filled electron discharge tube 112. The control anode of the tube is also connected to the junction of resistors 113 and 114 connected between ground and the negative battery 116. The cathode 117 of tube 102 is connected to negative battery 118 and the cathode 119 of tube 112 is connected to negative battery 121. It will be noted that the connections thus far described for tubes 102 and 112 are identical and that they will be controlled identically and simultaneously by tube 92 since both sections of the tube 92 receive like grid, cathode and anode potentials.

The main anode 126 of tube 102 is connected through condenser 127 to the cathode of that tube, through resistor 128 to ground and through resistor 129 to branching paths, one of which extends to the spacing contact of receiving relay 14 and includes conductor 131, the middle winding of transmission control relay 39 and conductor 132, and the other of which extends to the spacing contact of receiving relay 34 and includes conductor 133, the middle winding of transmission control relay 19 and conductor 134. The main anode 136 of tube 112 is connected through condenser 137 to the cathode of that tube, through resistor 138 to ground and through conductor 139, resistor 141, lower winding of relay 39, conductor 142, lower winding of relay 19 and conductor 143 to the right-hand contact of switching relay 54. In the idle condition the armature of relay 54 engages its left-hand contact and as previously described relays 14 and 34 are in the marking condition so that neither of the tubes 102 and 112 has its anode path completed to battery and these tubes are not conductive.

The repeater is set in operation by the reception of the start impulse of a permutation code signal combination. This pulse is of spacing nature and will be assumed to be received over the telegraph line comprising conductors 11 and 12. The start impulse is evidenced by interruption of the current through the operating winding of receiving relay 14 and accordingly the biasing winding, which is the middle winding, assumes control of the armature and operates it from the marking to the spacing contact. As the armature of relay 14 leaves the marking contact it interrupts the previously traced circuit from battery 51 through the armature and marking contact of receiving relay 34 and through the armature and left-hand contact of switching relay 54 to the main anode of tube 59. This results in the quenching of tube 59. With the flow of current through tube 59 interrupted the potential of the cathode 61 of the tube abruptly changes from a positive value with respect to ground to a negative value with respect to ground determined by the flow of current from battery 64 through resistors 62 and 63. The grid of tube 67 is similarly carried negative with respect to ground to a sufficient value to cut off the flow of current through tube 67. This cuts off the flow of direct current through the inductance winding 72 and permits the oscillator circuit comprising inductance 72, condenser 79 and the left-hand triode section of tube 74 to break into oscillation. The oscillator circuit is critically damped so that it starts substantially without transients and generates oscillatory potentials at the rate of one cycle per impulse interval of the telegraph signals. The oscillatory potential appearing at the upper terminal of inductance winding 72 is applied to both grids of tube 92.

If the contactor associated with potentiometer 93 is at the mid-point the cathode of tube 92 will be at ground potential. During the positive half cycles the grids of tube 92 will be positive with respect to ground and during the negative half cycles they will be negative with respect to ground. Thus the current through the two triode sections of tube 92 is caused to rise and fall substantially in phase with the rising and falling potential at the upper terminal of inductance winding 72. As the current rises the potential difference across resistors 97 and 107 increases and therefore the potential of the anodes of tube 92 becomes a minimum at the instant of maximum current.

Condenser 99 is normally charged to a potential difference which is the difference between the potential at the junction of resistors 103 and 104 and the potential of the anode of the right-hand triode section of tube 92. Similarly, condenser 109 is charged to a potential difference which is the difference between the potential at the junction of resistors 113 and 114 and the potential of the anode of the left-hand triode section of tube 92. If the tube 92 is cut off at this time or is only slightly conductive the anodes of tube 92 will be positive with respect to ground by nearly the full voltage of the batteries 98 and 108. The upper terminals of condensers 99 and 109 and also the control anodes 101 and 111 of tubes 102 and 112, respectively, will be negative with respect to ground by the potential difference across resistors 103 and 113, respectively, and the potential difference across condensers 99 and 109 will exceed the potential of batteries

98 and 108, respectively, and will be negative toward the control anodes 101 and 111 of tubes 102 and 112, respectively. Since the cathodes 117 and 119 of tubes 102 and 112, respectively, are connected directly to the negative terminal of batteries 118 and 121, respectively, the control anodes 101 and 111 are less negative than the cathodes 117 and 119, respectively, by the potential difference across resistors 104 and 114, respectively. This potential difference is insufficient to ionize and break down the control gaps of these tubes.

As the two triode sections of tube 92 are brought to maximum conductivity at the peak of each positive half cycle of the oscillatory potential applied to their grids, the potential of the anodes is quickly reduced to the minimum positive value, thereby impressing a negative pulse through condensers 99 and 109 to the control anodes 101 and 111 of tubes 102 and 112, respectively, thereby driving the potential of the control anodes toward or possibly beyond and more negative than the cathodes 117 and 119 but not sufficiently beyond to develop the control gap breakdown potential between the cathodes and control anodes. Condensers 99 and 109 quickly discharge to the new potential difference between the anodes of tube 92 and the junction of resistors 103 and 104 in the case of condenser 99 and of the resistors 113 and 114 in the case of condenser 109. From the foregoing it will be apparent that the control gaps of tubes 102 and 112 are not fired as the two triode sections of tube 92 rise to maximum conductivity.

As the conductivity of the triode sections of tube 92 decreases in phase with the decreasing oscillatory potential supplied to the grids of the tube the anodes of tube 92 quickly rise to or possibly above their initial potentials. As the rise occurs, a positive pulse is applied through each of the condensers 99 and 109 to the control anodes 101 and 111, respectively, of tubes 102 and 112, respectively. This change in potential of the control anodes 101 and 111 is opposite in sense to the previous change and, accordingly, the control anodes are carried toward ground potential and away from the negative potential of the cathodes 117 and 119 by an amount sufficient to fire the control gaps of these tubes. Condensers 99 and 109 quickly recharge in accordance with the reduced conductivity of tube 92 but in the meantime if positive battery has been connected to the main anode of either of the tubes 102 and 112 in a manner which will be described hereinafter, the discharge in the control gap of that tube will transfer to the main gap and thereafter as condensers 99 and 109 recharge the control anodes 101 and 111 will be carried back to their initial potentials with respect to the cathodes 117 and 119 and the discharge in the control gaps will be quenched.

Referring again to the start-stop control tube 59, it was previously stated that in the idle or steady state condition the cathode was positive with respect to ground and that upon the quenching of the tube the cathode goes negative with respect to ground. The difference between the positive potential of the cathode 61 and the more positive potential of the control anode 81 of tube 59 is considerably less than the control gap breakdown potential. At the instant of the cutting off of discharge current through tube 59, when the cathode 61 of tube 59 is carried negative, a negative pulse is applied through condenser 83 to the control anode 81 of tube 59 and

to the anode of the diode connected section of tube 74 and the negative swing of the cathode 61 of tube 59 is sufficient to carry these electrodes from their previous positive potential with respect to ground to a potential slightly negative with respect to ground. Immediately current begins to flow through resistor 84 into condenser 83 to charge the condenser. Resistor 84 is of high value and slows the charging of condenser 83 so that the potential difference across condenser 83 will not reach the control gap firing potential of tube 59 until the selecting pulses of the telegraph code have been received and retransmitted and the retransmission of the stop impulse has been or is about to be initiated. Thus the control gap of tube 59 is fired an interval after the quenching of the tube substantially equal to the interval occupied by a complete telegraph signal code combination including the start and stop impulses thereof. Resistor 84 is made variable to permit adjustment of the charging cycle of condenser 83 to the desired interval.

Returning to consideration of the receiving relay 14, the armature, having left the marking contact, moves into engagement with the spacing contact and completes a conductive path from positive battery 51 through conductor 132, the middle winding of transmission controlling relay 39, conductor 131, resistor 129 to the main anode of timing tube 102. No current flows in this circuit until the control gaps of tubes 102 and 112 are fired by the first positive timing impulse applied through condensers 99 and 109 to the control anodes of those tubes. The discharge cannot transfer to the main gap in tube 112 because the main anode circuit is open at the right-hand contact of switching relay 54. However, the discharge transfers to the main gap in tube 102 and current flows in the middle winding of relay 39, driving the armature to the left-hand or spacing contact. Negative battery 146 on the left-hand contact of relay 39 is substituted for positive battery on the right-hand contact in several circuits. One of these circuits is traced from battery 146 through the left-hand contact and armature of relay 39, conductor 38, winding of transmitting relay 33, conductor 37, middle or biasing winding of receiving relay 34 and resistor 36 to ground. The reverse current caused by battery 146 operates the armature of relay 33 from the marking to the spacing contact, thus disconnecting line conductors 31 and 32 and effecting the retransmission of the start impulse of spacing nature. The reversed current in the middle or biasing winding of relay 34, which previously sought to operate the armature to the spacing contact, now holds the armature on the marking contact. Another path in which the battery polarity has been reversed is traced from negative battery 146 through the armature and left-hand contact of relay 39, conductors 38 and 46, varistor 44, resistors 43 and 42, and lower or locking winding of relay 34 to ground. Varistor 44 offers low resistance to the flow of current from battery 146 and this current flowing through the lower winding of relay 34 produces a magnetic field which supplements and aids the middle winding in holding the armature of relay 34 on the marking contact. Condenser 45 becomes charged to the potential at the junction of resistors 42 and 43.

Another circuit in which the battery polarity is reversed is traced from negative battery 146 through the left-hand contact and armature of relay 39, upper winding of this relay, conductor

147, resistor 148 and lower winding of switching relay 54 to ground. Relay 39 holds its armature on its spacing contact as a result of the reversal of current in the upper winding. Prior to the operation of relay 39 to its left-hand contact, and with positive battery 41 connected through the right-hand contact and armature of the relay and through conductor 147 and the lower winding of switching relay 54, this winding produced a magnetic field driving the armature to the left-hand contact. A similar circuit is traced from positive battery 21 on the left-hand contact of relay 19 through the armature, conductor 149, resistor 151 and the middle winding of switching relay 54 to ground. The magnetic field produced by this current also drives the armature of relay 54 to the left-hand contact. The upper winding of relay 54 is included in a circuit from negative battery 152 through resistor 153 to ground and the magnetic field produced by the current in this winding seeks to drive the armature to the right-hand contact. With magnetic fields produced by the middle and lower windings driving the armature to the left-hand contact the upper winding is subordinate to the additive effects of the two lower windings and the armature remains on the left-hand contacts. With current reversed through the lower winding as a result of the operation of relay 39 to its left-hand contact, the magnetic fields produced by current in the middle and lower windings oppose and neutralize each other, leaving the upper winding free to move the armature to the right-hand contact and, accordingly, the armature of relay 54 moves to that contact. This results in the completion of a path from the marking contact of receiving relay 14 through conductor 52, the armature and marking contact of receiving relay 34, conductor 53, armature and right-hand contact of relay 54, conductor 143, lower winding of relay 19, conductor 142, lower winding of relay 39, resistor 141 to the main anode 136 of timing tube 112.

With relay 39 locked on its left-hand contact and holding transmitting relay 33 in the spacing condition, receiving relay 34 in the marking condition and switching relay 54 on its right-hand contact, the armature of receiving relay 14 can return to its marking contact in response to a received marking signal without disturbing any of the other relays.

Upon the return of the armature of receiving relay 14 to the marking contact in response to a received marking impulse, positive battery 51 is connected over a previously traced circuit including the armature and marking contact of receiving relay 14, the armature and marking contact of relay 34, the armature and right-hand contact of switching relay 54 and the lower windings of signal retransmission controlling relays 19 and 39 in series to the main anode 136 of timing tube 112. Upon the application of the next positive timing impulse through condensers 99 and 109 to the control anodes 101 and 111 of tubes 102 and 112, respectively, the control gaps of these tubes will be fired. The discharge cannot transfer to the main gap in tube 102 because positive battery 51 is disconnected from the main anode 126 of this tube at the spacing contact of relay 14. The discharge will transfer to the main gap in tube 112, and current will flow through the lower windings of relays 19 and 39. The magnetic field produced by current in the lower winding of relay 39 overcomes the magnetic field produced by the holding current in the upper winding and restores the armature of relay 39 to its right-hand contact. The magnetic field produced in the lower winding of relay 19 is effective upon the armature to drive it to the left-hand contact but since the armature has not left this contact the condition of the armature of relay 19 is not changed.

Upon returning to engagement with the right-hand contact the armature of relay 39 again reverses the direction of current through transmitting relay 33 and restores that relay to the marking condition thereby effecting the retransmission of a marking impulse. Current is also reversed through the biasing winding of receiving relay 34, removing the marking bias and restoring the spacing bias. Current through varistor 44 to the lower winding of receiving relay 34 for locking in the marking condition is reduced substantially to zero due to the opposition offered by varistor 44 to the flow of current from battery 41, but condenser 45 discharges through the lower winding of relay 34, delaying the removal of the holding current in the marking direction for a short interval. Current is reversed in the upper winding of signal transmission control relay 39, locking this relay with the armature on its right-hand contact, and current is reversed in the lower winding of switching relay 54, so that the magnetic field produced by the lower winding aids the magnetic field produced by the middle winding, overcoming the upper winding and restoring the armature to the left-hand contact. The armature of switching relay 54 upon leaving the right-hand contact interrupts the path to the main anode of tube 112 and quenches this tube. On reaching the left-hand contact the armature of relay 54 reconnects battery 51 to the main anode 58 of tube 59. While the selecting impulses are being received and retransmitted condenser 83 has not changed sufficiently to fire the control gap of tube 59 so that the reconnection of battery 51 to the main anode of the tube does not alter the condition of the tube.

As spacing and marking signals continue to be received tubes 102 and 112 are fired alternately, tube 102 for spacing impulses and tube 112 for marking impulses to time the retransmission of these impulses. Since the timing impulses which control the timing tubes 102 and 112 are separated by intervals equal to the impulse intervals of properly timed telegraph signals, the transmitting relay 33 remains in the marking or spacing condition for a full impulse interval, thereby regenerating and retransmitting perfect signals although the signals received by relay 14 may be distorted. When two successive spacing impulses are received tube 102 remains conductive in its main gap unless and until the armature of receiving relay 14 leaves the spacing contact. Even if the armature of relay 14 should leave the spacing contact momentarily between two successive spacing impulses and should quench tube 129, the tube will be refired for the second of the two spacing impulses when the timing impulse corresponding to the second of the two spacing impulses is impressed upon the control anode 101 of the tube. The mere quenching of tube 126 has no effect on the relay 39 because this relay remains locked on its left-hand contact until tube 112 is fired and completes a circuit for driving the armature to the right-hand contact. When two successive marking impulses are received tube 112 does not remain conductive throughout the interval of the two

impulses but is quenched as soon as tube 112 operates relay 39 to its right-hand contact which in turn operates the armature of relay 54 to its left-hand contact. Accordingly, tube 112 does not become refired for the second of the two successive marking impulses because its main anode circuit has been interrupted at the right-hand contact of switching relay 54 upon operation of the armature thereof to the left-hand contact. However, the quenching of tube 112 has no effect on relay 39 because it remains locked on the right-hand contact until positively driven to the left-hand contact by tube 102 upon being fired to time the retransmission of a spacing impulse.

The last selecting impulse received by relay 14 is followed by the stop impulse which is of marking nature. If the last selecting impulse has been of spacing nature the armature of switching relay 54 is engaging the right-hand contact and has completed the battery path from the marking contact of relay 14 to the main anode 136 of tube 112. When the timing impulse pertaining to the stop impulse is applied to the control anodes of tubes 102 and 112 both tubes will be fired in their control gaps and the discharge will transfer to the main gap in tube 112 and initiate the retransmission of the stop impulse by operating relay 39 to its right-hand contact whereupon relay 33 will be operated to the marking condition. This will be accompanied by operation of relay 54 to its left-hand contact whereupon battery 51 will be connected to the main anode 58 of tube 59. By the time the main anode circuit of tube 59 has been completed and preferably a little before the completion of this circuit condenser 83 should have become charged sufficiently to fire the control gap of tube 59. As soon as the armature of relay 54 reaches its left-hand contact the discharge will transfer to the main gap, thereby raising the potential of cathode 61 to its initial positive value. This causes the grid of tube 67 to be made more positive with respect to its cathode whereupon the tube becomes conductive and the anode current flows through inductance windings 72 of the oscillator, thereby restoring the oscillator to the original steady state condition and stopping oscillation. The oscillator is critically damped and stops substantially without transients.

When the last selecting impulse of a code combination is marking relay 54 is restored to the left-hand contact before the reception of the stop impulse and the connection of battery 51 to the main anode of tube 59 is completed. As soon as condenser 83 fires the control gap of tube 59 the discharge will transfer to the main gap, tube 67 will be rendered conductive and the oscillator will be stopped. The stopping of the oscillator may occur prior to the application of the timing impulse pertaining to the retransmission of the stop impulse to the control anodes of tubes 102 and 112. This is permissible because it is not necessary to fire the main gap of tube 112 since relay 39 is already engaging its right-hand contact and the transmitting relay 33 is transmitting a marking condition to the line circuit comprising conductors 31 and 32. From this it will be apparent that the adjustment of resistor 84 to control the charging of condenser 83 is not too critical. Condenser 83 should fire the control gap of tube 59 a sufficient interval after the generation of the timing impulse pertaining to the last selecting impulse of the code combination to assure that the stopping of the oscillator will not interfere with the production of this timing impulse and before or not later than immediately after the generation of the timing impulse pertaining to the stop impulse. Tube 59 must be rendered conductive in its main gap a sufficient interval before the next start impulse is received to assure that the oscillator has been stopped and that a steady state of direct current has been produced in inductance winding 72.

When condenser 83 fires the control gap of tube 59 the control gap potential decreases from the breakdown potential to the discharge sustaining potential, which is between the breakdown potential and the potential applied to the control gap by condenser 83 during idle periods when tube 59 is conductive in the main gap. Due to the sudden positive increase in the potential of cathode 61 of the tube as the discharge current flows through resistor 63, a positive pulse is impressed through condenser 83 before the condenser has an opportunity to discharge, so that the control anode 81 of tube 59 tends to become more positive with respect to ground by the increase of potential of the cathode represented by the potential difference across resistor 63. The positive pulse is also applied to the anode of the diode connected section of tube 74 so that this anode tends to become more positive thereby increasing the conductivity of the diode section. The impedance of the diode connected section of tube 74 is relatively low and accordingly it furnishes a discharge path for condenser 83 so as to prevent the potential of the control anode 81 from rising above a predetermined value with respect to ground. Accordingly, the sudden increase in the potential of the cathode 61 of tube 59 with respect to ground is not accompanied by a corresponding increase in the potential of the control anode 81. Condenser 83 discharges through the diode connected section of tube 74 to a potential which is less than the discharge sustaining potential of the control gap and accordingly this gap is quenched. The diode connected section of tube 74 establishes a substantially fixed maximum potential for the control anode 81 of tube 59 with respect to ground.

The repeater operates in exactly the same way when signals are received over line conductors 31 and 32 and are to be retransmitted over conductors 11 and 12. Receiving relay 34 upon going to spacing disconnects battery 51 from the main anode of start-stop control tube 59 due to the fact that the armature and marking contact of relay 34 are in series with the armature and marking contact of relay 14, tube 59 is quenched and the oscillator circuit is set in operation. Upon the reception of spacing impulses the anode circuit of tube 102 is completed through the alternate path including conductor 133, the middle winding of transmission controlling relay 19, conductor 136 and the spacing contact and armature of relay 34 and then over conductor 52 and the marking contact and armature of relay 14 to battery 51. Relay 19 is operated to its right-hand contact over this path, and its armature receives negative potential from battery 20, to operate transmitting relay 13 to spacing, to change the spacing bias current to marking bias current in the middle winding of receiving relay 14, to cause current to flow in the marking direction through varistor 24 and the lower winding of receiving relay 14, to lock relay 19 on its right-hand contact, and to operate switching relay 54 to its right-hand contact by reversing the flow

of current through its middle winding so that this winding opposes and neutralizes the effect of the lower winding. The retransmission of a marking impulse is effected by the completion of the only anode circuit provided for tube 112 which includes the lower windings of both of the relays 19 and 39 and the marking contacts and armatures of both of relays 14 and 34. When this circuit is completed the armature of relay 19 is restored to its left-hand contact and it becomes locked on this contact and restores transmitting relay 13 to the marking condition and also restores relay 54 to its left-hand contact. The establishment of a flow of current in this circuit in addition to energizing the lower winding of relay 19 and causing the armature of this relay to be operated to the left-hand contact also energizes the lower winding of relay 39 but the armature at this time is engaging the right-hand contact to which the lower winding seeks to operate it so that the condition of the armature of relay 39 is not changed. The reactivation of start-stop control tube 59 and the stopping of the oscillator is the same when signals are being received over conductors 31 and 32 as when they are being received over line conductors 11 and 12.

When signals are being transmitted through the repeater in one direction as from the line conductors 11 and 12 to the line conductors 31 and 32 a break signal may be transmitted in the opposite direction. The break signal is a steady spacing condition and is produced by interrupting the closed loop through conductors 31 and 32 and the transmission battery at the remote station. If the transmitting relay 33 should be transmitting a spacing signal over conductors 31 and 32 at the instant that the transmission of the break signal toward the repeater is initiated, receiving relay 34 will not respond to the break signal because it is locked in the marking condition by the reverse or marking bias through the middle winding and by the locking current through the lower winding, all under the control of relay 39 at this time on its left-hand contact. As soon as a marking impulse is received over conductors 11 and 12 by receiving relay 14 and relay 39 is operated to its right-hand contact and in turn operates relay 33 to marking and removes the locking current from the lower winding of relay 34 and restores the spacing bias current in the middle winding of relay 34, this relay will operate to spacing and upon the production of the next timing impulse relay 19 will be operated to its right-hand contact and will operate transmitting relay 13 to spacing to effect the retransmission of the break signal of spacing nature. As long as the break signal is continued it will be retransmitted over lines 11 and 12 and in the meantime condenser 83 will become charged to the breakdown potential of the control gap of tube 59 and this gap will be fired. Condenser 83 will then discharge as the potential in the control gap of the tube becomes adjusted to the discharge sustaining potential but the discharge will not transfer to the main gap because the armature of relay 54 has been operated to its right-hand contact under the control of relay 19. When the break signal is terminated by the restoration of line conductors 31 and 32 to the marking condition, receiving relay 34 returns to marking and connects battery 51 to the main anode of tube 112. Upon the generation of the next timing impulse by the oscillator the armature of relay 19 will be operated to the left-hand contact, whereby relay 13 will be restored to marking condition and the armature of relay 54 will be restored to its left-hand contact, thereby completing the main anode circuit of tube 59 so that the discharge will transfer to the main gap, tube 67 will be rendered conductive, and the oscillator will be stopped.

The potential divider 93 which has its contactor connected to the cathodes of detector tube 92 provides an orientation adjustment of the repeater, by which is meant that the instant of firing of the control gaps of timing tubes 102 and 112 and therefore the instant of operation of either of the transmitting relays 13 and 33 may be varied with respect to the incoming signals in order to place the transmitting relays under the control of the most effective portions of the received signal impulses, thereby accommodating the repeater to various conditions of signal distortion. If the contactor is moved leftwardly toward battery 96 the cathodes will be made less positive and therefore the negative bias on the grids of tubes 92 will be reduced. Under these circumstances the conductivity of the two triode sections of tube 92 will begin to increase from the minimum value earlier with respect to the positive half cycles of the oscillator and will return to the minimum conductivity later with respect to the cycles of the oscillator. Tube 92 is preferably operated well beyond cut-off in the negative half cycles of the oscillator and well beyond saturation current in the positive half cycles of the oscillator, so that in the positive half cycles current in tube 92 rises quickly to saturation value, remains substantially constant while the grid potential swings above saturation value and drops quickly to cut-off. As the contactor of potential divider 93 is moved leftwardly the current rises to saturation earlier and decreases to cut-off later for each cycle of the oscillator, and, accordingly, the positive pulses applied through condensers 99 and 109 to the control anodes of tubes 102 and 112 occur later with respect to received impulses. Conversely, if the contactor is moved rightwardly the cathode is made more positive and thereby the negative bias on the grids of tubes 92 is increased. Accordingly, the rise of current to saturation will occur later and the decrease to cut-off will occur earlier in each positive half cycle of the oscillator. In this way the positive impulses applied through condensers 99 and 109 may be caused to occur earlier with respect to received impulses. If the received signals are distorted so that the armature of the receiving relay remains on the marking or spacing contacts for lesser intervals than full telegraph impulse intervals, the contactor of potential divider may be moved leftwardly or rightwardly until the firing of the control gaps of tubes 102 and 112 is caused to occur when the most effective part of each signaling impulse is being received and the armature of the receiving relay is at rest on the marking or spacing contact.

Fig. 2 shows a modified form of electronic regenerative repeater which is shown arranged for operation upon neutral telegraph lines with remote battery as in the arrangement exemplified in Fig. 1. However, the system shown in Fig. 2 may be arranged for operation on other line systems, such as two-path polar telegraph lines, in which signals are transmitted over one of the two paths comprising one line and are received over the other path.

The conductors 211 and 212 represent one of the telegraph lines entering the repeater. Conductor 212 is connected through the operating winding of receiving relay 213, conductor 214, tip spring and normal contact of jack 216, conductor 217, marking contact and armature of transmitting relay 218 and line current adjusting resistor 219 to line conductor 211. At the remote station, battery is connected to lines 211 and 212, and, receiving relay 213 being a polar relay, the polarity is such that when the circuit is closed at the remote station, the armature is operated to marking by the upper or operating winding, and when the circuit is open at the remote station, the armature is operated to the spacing contact by the current in the lower or biasing winding.

Similarly, the other line entering the repeater consists of conductors 231 and 232. Conductor 232 is connected through the operating winding of receiving relay 233, conductor 234, marking contact and armature of transmitting relay 236 and line current adjusting resistor 237 to line conductor 231. The circuit just traced does not include contacts of a jack comparable with jack 216, for reasons which will be set forth hereinafter.

With the repeater in the idle condition, in which the receiving and transmitting relays are in the marking condition, a circuit is traced from positive battery 239 through the armature and marking contact of receiving relay 213, conductor 241, armature and marking contact of receiving relay 233, conductor 242, resistor 245 and the lower winding of a relay 243 and conductor 240 to the anode of a start-stop control tube 244 which is preferably a grid-controlled gas-filled electron discharge tube. In the idle condition tube 244 is conductive and plate current flows over the path just traced and through the anode-cathode discharge path of the tube. The cathode of the tube is connected to the junction of resistors 246 and 247 which are connected in series between negative battery 248 and ground. Tube 244 has a low and substantially constant anode-to-cathode voltage drop when conductive and the values of resistor 245 in the anode circuit and 247 and 246 in the cathode return circuit are such that the cathode is slightly positive with respect to ground when tube 244 is conductive.

The control grid of a tube 251 which is similar to tube 244, is connected to the cathode of tube 244 through resistor 252. The control grid of the left-hand triode section of a twin triode electron discharge tube 253 which is preferably a vacuum tube is also connected to the cathode of tube 244 through resistor 254. The cathode of tube 251 is connected through resistor 256 to negative battery 257 and through resistors 258 and 259 in series to ground. The anode of tube 251 is connected through variable resistor 261 and fixed resistors 260 and 259 to ground and through resistor 262 to the control grid of tube 244. A condenser 263 is connected between the anode of tube 251 and the cathode of tube 244.

Since the cathode of tube 244 is slightly positive with respect to ground as previously stated, the grid of tube 251 is also slightly positive with respect to ground. The cathode of tube 251 is negative with respect to ground by virtue of the potential divider comprising resistors 256, 258 and 259 so that the control grid of tube 251 is positive with respect to the cathode and the tube is conductive. Resistors 261 and 260 are both of high value so that only a very small current is drawn by tube 251. Condenser 263 is charged to the difference in potential between the cathode of tube 244 and the anode of tube 251 and the charge on the condenser is positive on the upper plate by virtue of the fact that the cathode of tube 244 is slightly positive with respect to ground and negative on the lower plate by virtue of the fact that the anode of tube 251 is negative with respect to ground by the potential difference across resistor 259 and the total potential difference across resistors 260 and 261 due to anode current through the tube.

The cathode of the left-hand triode section of tube 253 is connected to the junction of resistors 266 and 267 connected in series between negative battery 268 and ground. Accordingly the cathode of the left-hand triode section of tube 253 is negative with respect to ground. The grid of the left-hand triode section of tube 253 is positive with respect to ground by virtue of its connection to the cathode of tube 244. It follows that the grid to cathode potential is such as to render the left-hand triode section of the tube conductive. The left-hand anode is connected through conductor 269, the left-hand contact and armature of relay 243, conductor 271 and winding of tapped inductance 272 to ground. Since the left-hand triode section of tube 253 is conductive, a steady direct current flows in the inductance 272. The inductance is shunted by a condenser 273 and the inductance and condenser together form an oscillatory circuit which is held in a non-oscillating condition by the direct current through the inductance winding 272, with a small charge on condenser 273 equal to the ohmic potential difference across inductance 272 and with energy stored in the magnetic field produced by the steady direct current through the inductance winding.

The upper terminal of inductance winding 272 is connected through the resistor 274 to the grid of the right-hand triode section of tube 253. The tap terminal of inductance winding 272 is connected through resistor 276 to the cathode of the right-hand triode section of tube 253. The grid is also connected to the tap terminal of inductance winding 272 through resistor 277. The elements comprising inductance winding 272, condenser 273 and the right-hand triode section of tube 253 and their interconnections will be recognized as an electron tube oscillator circuit similar to the oscillator circuit in Fig. 1. As in the case of Fig. 1, the condenser 273 is preferably adjusted so that the frequency of the oscillator is twice the telegraph signaling frequency, so that the duration of each cycle of the oscillator is equal to the duration of one impulse of correctly timed telegraph signals. The anode of the hight-hand triode section of tube 253 is connected to positive battery 278.

The upper terminal of inductance winding 272 is slightly negative with respect to ground by the amount of the steady potential difference across inductance winding 272. This negative point is connected through resistor 279 to the grids of both triode sections of a twin triode tube 281 which is preferably a vacuum tube. The cathodes of tube 281 are connected to ground and the left and right-hand anodes are connected through equal load resistors 282 and 283, respectively, to positive battery 278. With the grids of tube 281 slightly negative with respect to the cathodes, there may be a small discharge current flowing in both halves of the tube and therefore the current flowing through resistors 282 and 283 may cause the anodes of tube 281 to be slightly less positive than the full potential of battery 278. The right-hand

anode of tube 281 is connected through condensers 286 and 287 to the control grids of electron discharge tubes 288 and 289, respectively which are preferably gas-filled tubes and may be similar to the tube 244. The cathodes of these tubes are connected to ground. Similarly the left-hand anode of tube 281 is connected through condensers 291 and 292 to the control grids of tubes 293 and 294, respectively, which are identical with tubes 288 and 289 and which have their cathodes connected to ground.

The control grid of tube 288 is also connected to the junction of resistors 296 and 297 connected in series between negative battery 298 and ground. From this it will be apparent that the grid of tube 288 is negative with respect to its grounded cathode and condenser 286 will be charged to the difference in potential between the potential at the right-hand anode of tube 281 and the potential at the junction of resistors 296 and 297. Similarly the control grids of tubes 289, 293 and 294 are connected to the junction of resistors 301 and 302, the junction of resistors 303 and 304, and the junction of resistors 306 and 307, respectively, which are connected in series in pairs as enumerated between negative battery 298 and ground. Resistors 296, 301, 303 and 306 are of equal value and resistors 297, 302, 304 and 307 are of equal value so that tubes 288, 289, 293 and 294 have identical negative grid potentials with respect to their grounded cathodes.

The anode of tube 288 is connected through conductor 311, resistor 312 and upper winding of relay 243 in parallel therewith, resistor 313, conductor 314, upper winding of transmitting relay 218, conductors 316, 317 and 318 and left-hand or marking contact and armature of relay 319 to positive battery 321. The anode of tube 289 is connected through conductor 322, resistor 325 and the middle winding of relay 243 in parallel therewith, resistor 323, conductor 324, the upper winding of transmitting relay 236, conductors 326, 327 and 328 and the left-hand or marking contact and armature of relay 329 to positive battery 331. The anode of tube 293 is connected through conductor 332, lower winding of transmitting relay 218, conductors 333, 334, 336 and 337 to the right-hand or spacing contact of relay 319. The anode of tube 294 is connected through conductor 338, the lower winding of transmitting relay 236, conductors 339, 341, 342 and 343 to the right-hand or spacing contact of relay 329. The circuit of the operating winding of relay 319 which includes resistor 346 shunted by condenser 347 is at this time open at the spacing contact of receiving relay 233 and the circuit of the operating winding of relay 329 which includes resistor 348 shunted by condenser 349 is open at the spacing contact of receiving relay 213. These windings, when energized, operate the armatures to the spacing contacts but when these windings are not energized, the armatures are held to the marking contacts by current in the biasing windings which together with the biasing windings of relays 351 and 352 are connected in series between battery 353 and ground. Thus, the anode circuits of tubes 293 and 294 terminate at the spacing contacts of relays 319 and 329, respectively, and neither of these tubes can be conductive in the idle or steady marking condition of the repeater. The anode circuits of tubes 288 and 289 are completed to battery through the marking contacts and armatures of relays 319 and 329, respectively, and these tubes are conductive, although their grids are considerably negative with respect to their cathodes, the conductivity being maintained with negative bias on the grid due to the fact that they are gas-filled tubes and having been fired, they may not be quenched under the control of their grids.

Upon the operation of one of the receiving relays, such as the relay 213, to spacing in response to a spacing signal, such as the start impulse of a telegraph signal combination, battery 239 is disconnected from the path traced from the marking contact of relay 213 through conductor 241, the armature and marking contact of relay 233, resistor 245, the lower winding of relay 243 to the anode of tube 244. This causes the tube to be quenched. With tube 244 quenched, the potential of the cathode of the tube drops abruptly to that maintained by the potentiometer comprising resistors 246 and 247 and battery 248. The grid of tube 251 and the grid of the left-hand triode section of tube 253 will undergo a corresponding drop in potential and in the case of tube 251, the new grid potential is below the firing potential. The abrupt decrease in the potential of the cathode of tube 244 causes a negative pulse to be impressed through condenser 263 on the anode of tube 251, reducing the anode potential below the discharge sustaining potential and thus cutting off this tube. In the case of the left-hand triode section of tube 253, the new grid potential is below the cut-off value of the tube so that the flow of direct current through the anode circuit of this tube, which includes the left-hand contact and armature of relay 243 and inductance winding 272, is interrupted.

Due principally to the energy stored in the magnetic field of inductance 272 and also to a small extent to the charge on condenser 273, this circuit begins to oscillate at a frequency of one cycle per impulse interval of telegraph signals and oscillation at uniform amplitude is maintained by the right-hand triode section of tube 253. The grids of tube 281 are connected to the upper terminal of inductance winding 272 as previously described and starting from a slightly negative potential with respect to ground, these grids will swing positive in the first half cycle of oscillation of the oscillatory circuit which is the positive half cycle and in each succeeding odd half cycle. As the grids swing positive, the flow of current in both triode sections of tube 281 increases and the anodes become less positive due to the increase in potential difference across resistors 282 and 283. As the anodes swing less positive in potential, negative impulses are applied through condensers 286, 287, 291 and 292, respectively, to the grids of tubes 288 and 289, 293 and 294, thus decreasing the potential of these grids with respect to their cathodes. As the conductivity of the triode sections of tube 281 decreases, in the second half of the positive half cycle of oscillation of the oscillatory circuit, the anodes of tube 281 swing more positive in potential and positive pulses are impressed through condensers 286, 287, 291 and 292 on the control grids of tubes 288, 289, 293 and 294, momentarily carrying those grids above the firing potentials with respect to their cathodes. This occurs once for each cycle of oscillation of the oscillatory circuit.

In the meantime, condenser 263, having applied to its upper plate the reduced potential of the cathode of tube 244, discharges. The discharging circuit includes high fixed resistor 260 and high variable resistor 261 so that the discharging of the condenser is slow and is adjustable by means of variable resistor 261. The discharging

of condenser 263 is a character timing operation as will be described later.

Returning again to consideration of relay 213, when the armature reaches the spacing contact, it completes the energizing circuit of the lower or operating winding of relay 329 and operates the armature of that relay from the left-hand, or marking, to the right-hand, or spacing, contact. The armature of relay 329 in leaving the left-hand, or marking, contact, disconnects positive battery 331 from a path traced through conductors 328, 327 and 326, the upper winding of transmitting relay 236, conductor 324, resistor 323, the middle winding of relay 243 to the main anode of tube 289, thus quenching this tube and leaving only the tube 288 of the four tubes 288, 289, 293 and 294 conductive. Battery 331 also becomes disconnected from a path through conductors 328, 327, the middle winding of transmitting relay 236, resistor 356, conductor 341, resistor 357 and middle winding of relay 352 to negative battery 358. Prior to the disconnection of battery 331 from this path, the resistor 356 limited the current through the middle winding of relay 352 to a value insufficient to overcome the effect of the current in the upper or biasing winding which is holding the armature of the relay on its left-hand contact. A path similar to the one just traced extends from battery 321 through the armature and left-hand, or marking contact of relay 319, conductors 318 and 317, middle winding of transmitting relay 218, resistor 359, conductor 334, resistor 361, and lower winding of relay 352 to negative battery 362. Current in this circuit is kept to a low value by resistor 359 and although the lower winding also seeks to move the armature of relay 352 away from the left-hand contact and therefore adds its effect to that of the middle winding, the upper or biasing winding dominates the relay. The disconnection of battery 331 from the path through the middle winding of transmitting relay 236 in the middle winding of relay 352 merely interrupts the flow of current in this path.

Battery 331 also becomes disconnected from a path including conductor 328, conductor 363, lower, or biasing winding of receiving relay 233 and conductor 364 to the anode of electron discharge tube 366 which is preferably a vacuum triode tube. The anode of tube 366 is also connected through resistor 367 to positive battery 368. A path is also traced from conductor 363 through conductor 369 through resistor 371 to negative battery 372, and through conductor 369 and resistors 373 and 374 to negative battery 376. The grid of tube 366 is connected to the junction of resistors 373 and 374. The cathode of tube 366 is connected to the movable contactor of a potential divider resistor 377 which is connected between negative battery 378 and ground.

Prior to the operation of the armature of relay 329 away from its left-hand, or marking, contact, the grid of tube 366 was maintained at a fixed potential dependent on the relative values of resistors 373 and 374 by a flow of current from battery 331 through the armature and marking contact of relay 329, conductors 328, 363, and 369, resistors 373 and 374 to negative battery 376. Biasing current seeking to operate relay 233 to the right-hand or spacing contact was flowing from battery 331 through the armature and marking contact of relay 329, conductors 328 and 363, biasing winding of relay 233, conductor 364, the anode to cathode discharge path of tube 366 to the potential divider comprising resistor 377 connected between the negative battery 378 and ground. The biasing current is adjustable to the desired value by means of potential divider 377, which varies the cathode-to-grid potential of the tube, and thereby varies the anode current.

With battery 331 disconnected from the path including conductors 328 and 363 as the armature leaves the marking contact, current ceases to flow in conductors 328 and 363 and a new circuit for the biasing winding of relay 233 is traced from positive battery 368 through resistor 367, the biasing winding of relay 233, conductor 369, resistor 371 to negative battery 372, and in parallel with this resistor and battery through resistors 373 and 374 to negative battery 376. Due to the fact that positive battery 368 is connected to the right-hand terminal of the biasing winding of relay 233, whereas positive battery 331 was previously connected to the left-hand terminal, the direction of current flow through the biasing winding of relay 233 is reversed and the biasing winding now operates to hold the armature of relay 233 on the left-hand, or marking, contact to prevent this relay from responding to a spacing signal should such signal at this time be received over lines 231 and 232, and also to prevent relay 233 from operating to spacing when transmitting relay 236 becomes operated to spacing and opens the circuit through the operating winding of relay 233.

By virtue of the provision of resistor 367 in the path traced from battery 368 through this resistor, conductor 364, biasing winding of relay 233, conductor 369 and resistors 373 and 374 to negative battery 376, the flow of current through resistors 373 and 374 is reduced relative to the current which flowed when battery 331 was connected without intermediate resistance through resistors 373 and 374 to battery 376 and therefore the grid of tube 366 connected to the junction of resistors 373 and 374 is made sufficiently negative with respect to the cathode that tube 366 is cut off. The anode is also made less positive by virtue of the flow of biasing current for relay 233 through resistor 367. The provision of tube 366 in association with the biasing winding of relay 233 provides a simple and convenient means for regulating the current in the biasing winding of the relay and also for effecting the reversal of the biasing current when relay 329 is operated away from its marking contact.

Upon arrival of the armature of relay 329 on its right-hand or spacing contact, a path from positive battery 331 is traced through conductors 343 and 342, resistor 357, and the middle winding of relay 352 to negative battery 358. Thus the circuit of the middle winding of relay 352 no longer includes high resistance 356, the current in the winding is increased to a value producing a magnetic field which overpowers the field produced by the current in the biasing winding and operates the armature away from the left-hand contact to the unconnected right-hand contact. The left-hand or marking contact is connected through conductor 381 and resistor 382 to the tip spring of a jack 383. Jack 383 has its sleeve grounded and is adapted to receive a plug 384 having connected thereto the selector magnet 386 of a printing telegraph receiving recorder which may be of any desired type, such as, for example, the telegraph printer shown in Patent 1,904,164 granted April 18, 1933 to S. Morton et al. The disclosure of the Morton et al. patent is incorporated herein by reference as part of

the present specification, and the selector magnet 386 is intended to symbolize the entire printer, which may be employed as a monitoring printer. The armature of relay 352 is connected through conductors 387 and 388 and resistor 389 to battery 391. With the armature of relay 352 on its left-hand or marking contact and plug 384 inserted into jack 383, selector magnet 386 is energized which is the marking condition. When the armature of relay 352 is operated to spacing by relay 329, the energizing circuit for selector magnet 386 is interrupted and the magnet becomes deenergized which is a spacing impulse condition. From this it follows that the function of relay 352 is to repeat received marking and spacing impulses to the monitoring printer symbolized by selector magnet 386 directly as received and without being regenerated. By virtue of the connection of the lower winding of relay 352 to the spacing contact of relay 319 which is controlled by receiving relay 233, the relay 352 is adapted to be operated to spacing in response to spacing signals received over lines 231 and 232 in the same manner that it repeats signals received over lines 211 and 212.

Another path is traced from battery 331 through the armature and spacing contact of relay 329, conductors 343, 342 and 341, lower winding of transmitting relay 236 and conductor 338 to the anode of tube 294. Thus a path is prepared for the firing of tube 294 when the grid of that tube shall receive the firing potential through condenser 292 from the left-hand triode section of tube 281 under the control of the oscillator.

Another path is traced from battery 331 through the armature and spacing contact of relay 329, conductors 343, 342 and 341, resistor 356, middle winding of transmitting relay 236, conductors 327, 363 and 369 and resistor 371 to negative battery 372 and in parallel with this resistor and battery through resistors 373 and 374 to negative battery 376. This represents a reversal of the polarity on the middle winding of relay 236 and whereas the direction of current in the middle or biasing winding of relay 236 was previously in the direction to operate the armature to the spacing contact, the biasing current now flows in the direction to hold the armature on the marking contact. This is desirable because the flow of current through the upper winding of relay 236 has been interrupted upon the quenching of tube 289 as previously described and the reversal of bias in the middle winding to a marking bias prevents premature operation of transmitting relay 236 to spacing by the biasing winding.

Still another path is traced from positive battery 331 through the armature and spacing contact of relay 329, conductors 343 and 392 to one terminal of a condenser 393, the other terminal of which is connected to the junction of resistors 373 and 374 and therefore to the grid of tube 366. Prior to the operation of the armature of relay 329 away from its marking contact, condenser 393 had a potential on its lower terminal which is negative by a few volts with respect to ground, being the difference between the potential of battery 376 and the potential difference across resistor 374 and had a potential on its upper terminal considerably negative with respect to ground, being the difference between the potential of battery 358 and the potential difference across resistor 357. Thereafter, the charge on condenser 393 reverses, the upper terminal becoming positive with respect to ground to the extent of the full voltage of battery 331 and the lower terminal remaining considerably negative with respect to ground, as previously described.

With the operations performed by relay 329 upon operation to spacing completed, the apparatus awaits the timing impulse derived by the two triode sections of tube 281 from the oscillator. The current in the two triode sections of tube 281 rises to a maximum and then decreases and as the decrease occurs the potential of the two anodes of the tube increases and positive impulses are impressed through condensers 286, 287, 291 and 292 to the control grids of tubes 288, 289, 293 and 294. Tube 288 is already conductive in a circuit previously traced through the upper winding of transmitting relay 218 and the marking contact and armature of relay 319 to battery 321 so that this tube is not affected by the timing impulse and relay 218 remains in the marking condition under the control of tube 288. Tube 289 was quenched when the armature of relay 329 left its marking contact and although paths may be traced from the anode of tube 289 to positive battery 369 and also to positive battery 331, these paths include relatively high resistances and have connections to negative battery so that the anode of tube 289 is at reduced potential and the tube will not fire. The anode of tube 293 is also at reduced potential and it will not fire. The anode circuit of tube 294 has been prepared by the operation of the armature of relay 329 to spacing and accordingly this tube fires and energizes the lower winding of relay 236 thus operating the armature away from the marking contact and into engagement with the unconnected spacing contact. Upon movement of the armature out of engagement with the marking contact, the terminating loop for the line comprising conductors 231 and 232 through the armature and marking contact of relay 236 and the operating winding of receiving relay 233 is interrupted, thus effecting the retransmission of the start impulse of spacing nature. Although the circuit through the operating winding of receiving relay 233 is interrupted, the relay remains in the marking condition because it is held in this condition by the reversed or marking current through the biasing winding as previously described.

If the first significant impulse of the code combination which follows the start impulse should be of spacing nature, relay 213 will remain in the spacing condition and relay 329 will remain in the spacing condition under the control of relay 213. No change will occur in the paths through the anodes of the four tubes 288, 289, 293 and 294 and when the grids of these tubes are momentarily made more positive by the timing impulse, tubes 288 and 294 already being conductive, will remain conductive and tubes 289 and 293 will remain quenched.

If instead the first significant impulse of the code combination should be of marking nature or when the first marking impulse of the code combination is received over line conductors 211 and 212, relay 213 will be reoperated to marking and will in turn reoperate relay 329 to marking. As the armature of relay 329 leaves its spacing contact, it removes the direct battery connection through resistor 357 and the middle winding of relay 352, thereby permitting the biasing winding of that relay to restore the armature to marking to repeat the received marking impulse

to selector magnet 386 of the monitoring printer. The relay 329 interrupts the anode circuit of tube 294 through the lower winding of relay 236 thus quenching the tube 294, and reestablishes the path to the anode of tube 289 through the upper winding of relay 236 thus preparing for the firing of tube 289. It reestablishes the positive battery connection directly to the left-hand terminal of the biasing winding of receiving relay 233 and through resistor 373 to the grid of tube 366 and to the lower terminal of condenser 393. With a flow of current reestablished from battery 331 through the armature and marking contact of relay 329, conductors 328, 327, middle winding of relay 236, resistor 356, conductor 341, resistor 357 and middle winding of relay 552 to negative battery 358, the potential at the left-hand terminal of resistor 357 applied through conductors 342 and 392 to the upper terminal of condenser 393 goes almost immediately from a positive value with respect to ground of the full voltage of battery 331 to a negative voltage with respect to ground of the difference between the voltage of battery 358 and the potential difference across resistor 357. Resistor 373 through which positive battery 331 is reconnected to the lower terminal of condenser 393 has a high value and delays return of condenser 393 to its original slightly negative charge, thus holding the tube non-conductive. The grid of tube 366 is gradually restored to its original potential and when it has been restored normal spacing bias current flows in the biasing winding of relay 233, which is in the anode circuit of tube 366. In this way the restoration of spacing bias on the receiving relay 233 is delayed. Preferably this delay in the restoration of full spacing bias to receiving relay 233 is of the order of a few code impulse intervals but less than a full code combination interval so that the repeater shall not be responsive to momentary interruptions of the telegraph line comprising line conductors 231 and 232 which if permitted to become effective during transmission of signals from the line comprising conductors 211 and 212 into the line comprising conductors 231 and 232 might put the character timing apparatus out of phase with the signals incoming over line conductors 211 and 212 and result in the multilation of several signal combinations before the character timing circuit should return to proper phase relation to the incoming signals.

As the reception of the impulses of a code combination continues, receiving relay 213 follows the received signals and operates relay 329 in correspondence therewith to control selectively the completion of the anode circuit of tube 289 or tube 294. After these paths have been selectively prepared, the tube 281 under the control of the oscillator circuit generates the positive timing impulses so that the impulses of full and uniform length are retransmitted. Following the retransmission of the last significant impulse of the code combination, receiving relay 213 responds to the stop impulse of marking nature and returns to the marking condition, or remains in the marking condition in case the last significant impulse of the code combination was of marking nature, and relay 329 is correspondingly operated. If the last significant impulse of the code combination was of spacing nature, tube 294 has been conductive and this tube is quenched and the anode circuit of tube 289 is prepared as relay 329 returns to marking or if the last significant impulse of the code combination was of a

marking nature, tube 289 is already conductive. When the timing impulse pertaining to the retransmission of the stop impulse is applied to the grids of tubes 288, 289, 293 and 294, tube 289 becomes or remains conductive and relay 236 is operated to or remains in the marking condition to effect the retransmission of the stop impulse.

Each time that relay 213 responds to a marking impulse, it reestablishes the anode circuit of timing tube 244 from battery 239 through the armature and marking contact of relay 213, conductor 241, armature and marking contact of relay 233, conductor 242, lower winding of relay 243, and conductor 240 to the anode of tube 244. During the reception of the code impulses, condenser 263 has been discharging to cause the grid of tube 244 to approach the potential of the cathode of that tube but the grid does not reach the firing potential during the reception of the significant impulses of the code so that tube 244 does not become fired incident to the reception of any of the significant impulses of marking nature. About the time that the positive impulse for effecting the retransmission of the stop impulse is impressed through condensers 286, 287, 291 and 292, condenser 263 has discharged to such value that the grid of tube 244 reaches the firing potential relative to the cathode and accordingly tube 244 is fired. Immediately upon the firing of the tube the potential of its cathode rises abruptly to the steady state potential which is slightly positive with respect to ground and carries the control grid of tube 251 and the grid of the left-hand triode section of tube 253 to the same potential. The increase in potential of the grid of the left-hand triode of tube 253 restores this section of the tube to conductive state and causes direct current to flow in the inductance winding 272 included in the anode circuit of the left-hand triode section of the tube. This stops oscillation of the oscillatory circuit and consequently the production of positive pulses to fire tubes 288, 289, 293 and 294, and the timing pulse generating circuit awaits the next start impulse and quenching of tube 244. The increase in potential of the control grid of tube 251 causes the firing of this tube and the discharge current flows to recharge condenser 263 to the initial steady state condition. Thus the character timing and impulse timing circuits are restored to normal.

When transmission is in the opposite direction, namely, from the line comprising conductors 231 and 232, toward the line comprising conductors 211 and 212, receiving relay 233 responds to the signals and operates relay 319 in correspondence therewith, the relays 233 and 319 corresponding to the relays 213 and 329 respectively. Relay 233 in responding to the start impulse interrupts the anode circuit of tube 244 and the tube becomes quenched in the manner heretofore described, to start the production of timing impulses. Relay 319, upon operating to spacing, interrupts the circuit through the upper winding of transmitting relay 218 to the anode of tube 288 which becomes quenched and prepares a circuit through the lower winding of relay 218 to the anode of tube 293 which becomes conductive upon the application of the firing impulse to the grids of the four tubes 288, 289, 293 and 294. Tube 289 remains conductive steadily during the transmission of signals from the line comprising conductors 231 and 232 to the line comprising conductors 211 and 212, tube 294 remains

quenched and the tubes 288 and 293 are fired alternately for the marking and spacing impulses respectively. Relay 218 is operated to spacing under the control of its lower winding and is restored to marking under control of its upper winding.

One terminal of the biasing winding of receiving relay 213 is connected through conductor 401 and resistor 402 to positive battery 403, these elements corresponding to conductor 364, resistor 367 and battery 368. Likewise the same terminal of the biasing winding of relay 213 is connected to the anode of a vacuum tube 404 which corresponds to vacuum tube 366 and has its cathode connected to the contactor of potential divider resistor 406 which is connected between negative battery 407 and ground. The other terminal of the biasing winding of relay 213 is connected through conductor 405, resistor 408, to negative battery 409, which correspond to conductor 369, resistor 371 and battery 372 respectively, and this terminal of the biasing winding of relay 213 is also connected through resistors 411 and 412 to negative battery 413 and the junction of resistors 411 and 412 is connected to the grid of tube 404. The right-hand terminal of the biasing winding of relay 213, which is connected through conductor 405 to the junction of resistors 408 and 411 is connected by conductor 414 to conductor 318 over which positive battery connection from battery 321 is supplied through the armature and marking contact of relay 319 for establishing spacing bias in the biasing winding of relay 213 through the discharge path of tube 404 as in the case of relay 233 and tube 366. When relay 319 is operated to spacing, this direct battery connection is removed and the current through the biasing winding of relay 213 is reversed, establishing marking bias. The junction of resistors 411 and 412 and the grid of tube 404 are connected to one terminal of a condenser 416, the other terminal of which is connected through conductor 417 to the spacing contact of relay 319. Condenser 416 operates in the same manner as condenser 393 to delay the restoration of spacing bias to receiving relay 213 when a spacing condition impressed on the line comprising conductors 211 and 212 by the repeater is replaced by a marking condition.

It will be noted that the anode circuit of tube 288 which operates transmitting relay 218 to marking, includes the upper winding of relay 243 shunted by resistor 312, that the anode circuit of tube 289 which operates transmitting relay 236 to marking includes the middle winding of relay 243 shunted by resistor 325, and that the anode circuit of tube 244 includes the lower winding of relay 243. It will also be noted that the anode circuit of the left-hand triode section of tube 253 includes the armature and left-hand contact of relay 243. Current in the upper and middle windings produces magnetic fields urging the armature to the left-hand contact. Current in the lower winding produces a magnetic field urging the armature to the right-hand contact. With current flowing in the lower winding and in only one of the two other windings, the armature of relay 243 will be operated to its right-hand contact and will interrupt the anode circuit of the left-hand triode section of tube 253. When no current is flowing in the lower winding, the armature will be held on the left-hand contact by current in either one of the other two windings and when current is flowing in all three windings which is the idle or steady state condition, the two upper windings will overcome the effect of the lower winding and hold the armature on the left-hand contact. The relay 243 is provided to prevent a lock-out condition in the event that either one of the transmitting relays 218 and 236 fails to respond to the last marking impulse of a series of signal combinations received by the receiving relay associated with the opposite side of the repeater.

Suppose, for example, that relay 213 has been responding to signals received over the line comprising conductors 211 and 212 and has been operating relay 236 to effect their retransmission into the line comprising conductors 231 and 232. Suppose further that relay 326 fails to respond to the stop impulse of the final code combination before any interruption in or cessation of transmission and remains in the spacing condition. This failure might be due to failure of tube 289 to fire. Accordingly, there would be no current in the middle winding of relay 243. There would be current in the upper winding because tube 288 has remained conductive steadily. Relay 213, upon responding to the final marking impulse, assumed to be the stop impulse, completes the anode circuit of character timing tube 244. Almost immediately the condenser 263 completes its timing-out operation and fires tube 244 which raises the potential of the grid of the left-hand triode section of tube 253 along with the grid of tube 251 as previously described. As tube 244 becomes conductive, the flow of anode current through the lower winding of relay 243 energizes that winding which operates the armature to the unconnected right-hand contact due to the fact that only the upper of the other two windings of the relay is energized. This interrupts the anode circuit of the left-hand triode section of tube 253 and prevents this section of the tube from becoming conductive in response to the raising of the potential of its grid. Accordingly, the flow of direct current through the inductance winding 272 is prevented, the stopping of the oscillator is delayed and the oscillator continues to generate oscillatory potentials and to apply firing potentials to the grids of tubes 288, 289, 293 and 294. If the failure of tube 289 to fire in response to the stop impulse was merely fortuitous, it should fire in response to one of the subsequently generated pulses produced by the oscillator and when it does fire, it will operate relay 326 to marking thus completing the terminating loop for line conductors 231 and 232 in the repeater. Upon the firing of tube 289, the anode current flows in the middle winding of relay 243, aiding the current in the upper winding and providing a sufficient total magnetic field to restore the armature to the left-hand contact. Upon the restoration of the armature to the left-hand contact, the anode circuit for the left-hand triode section of tube 253 is completed and this section at once becomes conductive and direct current flows through the inductance winding 272 stopping the oscillatory operation of the resonant circuit.

Assume now that the relay 243 is not included in the repeater nor any apparatus for performing an equivalent function. Under these circumstances the tube 244 upon being fired in response to the stop impulse received over line conductors 211 and 212 would render the left-hand triode section of tube 253 conductive and anode current would flow whether or not relay 236 had been operated to marking in response to the stop impulse of marking nature. The anode current in

the left-hand triode section of tube 253 would flow through inductance winding 272 and stop the generation of impulses for firing tubes 288, 289, 293 and 294. Relay 236 would remain in the spacing condition interrupting the terminating loop for line conductors 231 and 232 through the operating winding of relay 233. A few impulse intervals after response of relay 329 to the final marking impulse received over line conductors 211 and 212, dependent upon the value of condenser 393 and the resistors associated therewith, the spacing bias would be restored to receiving relay 233 and this relay would operate to spacing, in turn operating the relay 319 to spacing, quenching tube 244 and restarting the oscillator. The oscillator would be restarted and another series of firing impulses would be applied to the grids of tubes 288, 289, 293 and 294. With relay 233 operated to spacing, the relay 319 is also operated to spacing, tube 286 is quenched, the anode circuit of tube 293 is prepared, the spacing bias on relay 213 is changed to marking bias and upon the firing of tube 293 in response to the first timing impulse, relay 218 is operated to spacing. At the time of the firing of tube 293 the anode circuit of tube 289 which is presumed to have failed to operate previously is prepared through the upper winding of relay 236 and tube 289 should also fire. If it does relay 236 will be operated to marking and will restore relay 233 to marking which in turn will restore relay 319 to marking. Accordingly, the next and all succeeding pulses transmitted to line conductors 211 and 212 during the timing out interval of condenser 263 will be marking, and upon the firing of tube 244 by condenser 263 the oscillator will be stopped with both sides of the repeater in the full marking condition. It will be noted that without relay 243, the restoration of relay 236 to marking after it has failed to be operated to that condition in response to the final marking impulse received over line conductors 211 and 212 involves the transmission of at least one spacing signal over line conductors 211 and 212 to the remote station connected thereto whereas with relay 243 included in the system relay 236 is restored to marking condition without the transmission of any signals over line conductors 211 and 212 toward the remote station. Relay 243 has even greater importance to the system when the line circuits terminating in the repeater are arranged for two-path polar operation. Under these circumstances the line conductors 211 and 212 and the line conductors 231 and 232 do not terminate in the repeater in loop circuits but have independent terminations for polar operation of the lines. Under these circumstances, relay 233 is operable to spacing solely under the control of a transmitter at a remote station arranged to transmit signals over line conductor 232 and relay 233 will remain in the marking condition even though relay 236 should falsely remain in the spacing condition for an indefinite interval. Thus with relay 236 remaining in the spacing condition, receiving relay 233 will not automatically initiate operations involving the quenching of tube 244, the restarting of the oscillator and the transmission of one or more spacing signals by means of relay 218 over conductor 211, as it will when the line circuits are arranged for neutral operation and relay 236 would remain in the spacing condition until one or the other of the remote station initiated transmission and thereby deactivated tube 244 to restart the oscillator.

It will be noted that the delay in the restoration of spacing bias to the receiving relays 213 and 233, afforded by the condensers 416 and 393, respectively, accommodate the function to be performed by the relay 243. The delay of a few impulse intervals prevents the receiving relays from interfering with the extended operation of the oscillator under control of relay 243 independently of a recycling of the timing circuit associated with tube 244. In the heretofore assumed circumstance that relay 236 might not be operated to marking in response to the final marking impulse, if the spacing bias should be restored to relay 233 substantially instantaneously upon the return of relay 329 to marking, and thereupon should relay 233 operate to spacing due to the open condition of the terminating loop of line conductors 231 and 232 at the armature and marking contact of relay 236, tube 244 would be quenched and a complete character timing cycle of condenser 263 would be initiated before relay 243 had an opportunity to assume control over the oscillator for the purpose of effecting the restoration of relay 236 to marking, and the purpose in providing relay 243 might thereby be defeated.

It will be understood that although the description of the operation of relay 243 was predicated upon an assumed failure of relay 236 to be operated to marking, the relay 243 operates in the same manner and for the same purpose if and when relay 218 fails to be operated to marking upon an interruption in or cessation of transmission into the repeater from the line conductors 231 and 232 for transmission onwardly over line conductors 211 and 212.

The repeater is provided with means for transmitting locally generated signals into the lines interconnected by the repeater, this means comprising the transmitting contacts 426. These transmitting contacts are connected to a plug 427 which is insertable into jack 216. When plug 427 is inserted into jack 216, the contacts 426 are inserted into the loop circuit which terminates the line comprising conductors 211 and 212. When the transmitting contacts 426 are operated, the terminating loop circuit interconnecting the line conductors 211 and 212 is opened for each spacing signal, thereby transmitting the spacing signals directly into those line conductors without operating transmitting relay 218. Since the receiving relay 213 is included in the terminating loop circuit, it responds to spacing and marking signals generated by transmitting contacts 426 in the same manner that it responds to marking and spacing signals received over line conductors 211 and 212 and these signals are repeated by the regenerative repeater in the manner heretofore described into the telegraph line comprising conductors 231 and 232.

In addition to the tip and sleeve contacts through which the loop circuit terminating line conductors 211 and 212 is adapted to include transmitting contacts 426 when plug 427 is inserted into jack 216, the jack has a closed circuit contact associated with the tip spring for closing the line terminating loop circuit of line conductors 211 and 212 when the plug is not inserted into the jack. Also, jack 216 has certain other contacts for adapting transmitting contacts 426, for cooperation with the repeater when the latter is arranged for two-path polar operation by switching means (not shown). The relay 351 is brought under the control of transmitting contacts 426 when the repeater is arranged for two-path polar operation and the armature thereof,

which finds negative battery on its marking contact and positive battery on its spacing contact becomes connected through the uppermost pair of contact springs to a conductor shown as a dotted line 431 in Fig. 2 which becomes connected through the switching means (not shown) to the marking contacts of both of the transmitting relays 218 and 236, the circuits of the operating windings of receiving relays 213 and 233 being then dissociated from the armatures and the marking contacts of transmitting relays 218 and 236 and being associated only with the receiving conductors 212 and 232, respectively. With this arrangement of the apparatus, relay 351 impresses polar signals directly on both of the line conductors 211 and 231 the relays 213 and 233 remain in the marking condition and the repeater does not operate to repeat the signals into either of the lines 211 and 231. Relay 351 is placed under the control of transmitting contacts 426 by rearranging the connections through the switching means (not shown) so that the operating winding of relay 351 is connected to battery 391 through transmitting contacts 426 and the tip and sleeve terminals of jack 216. The selector magnet 386 of the monitoring printer, having its operating circuit extending through the armature and marking contact of relay 352 to the right-hand terminal of relay 351, also receives its connection to battery 391 through the transmitting contacts 426 when the repeater circuit is rearranged for two-path polar operation. Thus when transmitting contacts 426 are operated to transmit signals into the two lines interconnected by the repeater, selector magnet 386 of the monitoring printer is operated directly under the control of transmitting contacts 426 along with relay 351, the relay 352, which operates only when the repeater operates to regenerate signals, remaining idle.

When signals are being received from one of the telegraph lines such as that comprising conductors 211 and 212, and are being transmitted into the other telegraph line which comprises conductors 231 and 232, the transmission may be interrupted at the receiving end by the transmission of a break signal, which is a steady spacing condition. If the transmission of the break signal is initiated upon line conductors 231 and 232 from the remote station at the time that a spacing signal is being repeated toward that station, the break signal will not become effective because the receiving relay 233 is held in marking condition by the marking bias imposed when relay 329 is in the spacing condition. Furthermore, the relay 233 will not respond to the break signal the instant that relay 329 returns to the marking condition because of the delay in the removal of the marking bias and the restoration of the spacing bias imposed by condenser 393. The receiving relay 233 will remain in the marking condition until the relay 213 receives a signal combination containing a sufficient number of successive marking pulses, during which the armatures of relays 213 and 329 remain on their marking contacts, to permit condenser 393 to time out the delay interval for the bias reversal, whereupon the biasing winding will operate relay 233 to spacing. This spacing condition of relay 233 will cause the spacing bias on relay 213 to be replaced by marking bias, thereby preventing that relay from operating to spacing, and the break signal of spacing nature will be repeated by relay 218 into the telegraph line comprising conductors 211 and 212 as long as the break signal is transmitted into line conductors 231 and 232 at the remote station connected thereto. Upon the termination of the break signal, the repeater will return to marking condition, awaiting transmission of signals in either direction.

Although specific embodiments of the invention have been shown in the drawings and described in the foregoing specification, it will be understood that the invention is not limited to such specific embodiments but is capable of modification and rearrangement without departing from the spirit of the invention and within the scope of the appended claims.

What is claimed is:

1. In a telegraph signal repeater, a signal responsive relay, a normally inactive impulse generator comprising electron discharge means, means controlled by said relay for setting said generator in operation, a signal retransmission controlling relay, a pair of electron discharge tubes adapted to have activating potentials simultaneously applied to their control electrodes by said impulse generator and having their main space discharge paths associated with oppositely effective windings of said signal retransmission controlling relay, and means for selectively completing either of said space discharge paths externally of the tubes according to the operation of said signal responsive relay whereby to energize one or the other of said oppositely effective windings of said signal retransmission controlling relay.

2. In a telegraph signal repeater, a relay adapted to operate to marking or spacing in accordance with incoming signals, a signal retransmission controlling relay, a pair of electron discharge tubes having their main space discharge paths associated with oppositely effective windings of said signal retransmission controlling relay and with the marking and spacing contacts of said first-mentioned relay, means for applying activating potentials to the control electrodes of said tubes at intervals of unit length telegraph impulses, and a source of anode potential for said tubes connected to the armature of said first-mentioned relay whereby said tubes are selectively activated upon the application of the activating potentials to their control electrodes and operate said signal retransmission controlling relay correspondingly.

3. In a telegraph signal repeater, a relay adapted to operate to marking or spacing in accordance with incoming signals, a signal retransmission controlling relay, a pair of gas-filled electron discharge tubes having their main space discharge paths associated with oppositely effective windings of said signal retransmission controlling relay and with the marking and spacing contacts of said first-mentioned relay, means for momentarily applying activating potentials to the control electrodes of said tubes at intervals of unit length telegraph impulses, and a source of anode potential for said tubes connected to the armature of said first-mentioned relay whereby said tubes are selectively activated upon the application of the activating potentials to their control electrodes and operate said signal retransmission controlling relay correspondingly.

4. In a telegraph repeater, a receiving relay responsive to incoming signals and having an armature at positive potential engageable with marking or spacing contacts of said relay, a relay having oppositely effective windings, a pair of electron discharge tubes having their anodes connected through said windings to said marking and spac-

ing contacts, means for momentarily applying activating potentials to the control electrodes of said tubes at intervals of unit length telegraph impulses whereby to activate one or the other of said tubes and energize one or the other of said windings, and a retransmitting relay controlled by said second-mentioned relay.

5. In a telegraph repeater, a receiving relay responsive to incoming signals and having an armature at positive potential engageable with marking or spacing contacts of said relay, a relay having oppositely effective windings, a pair of electron discharge tubes having their anodes connected through said windings to said marking or spacing contacts, means for momentarily applying activating potentials to the control electrodes of said tubes at intervals of unit length telegraph impulses whereby to activate one or the other of said tubes and energize one or the other of said windings, means for holding said second-mentioned relay in either condition established by said oppositely effective windings, and a retransmitting relay controlled by said second-mentioned relay.

6. In a telegraph repeater, a pair of relays responsive to signals received over lines individual to said relays, each of said relays having an armature and marking and spacing contacts, a pair of relays each having a winding energizable in common through the armatures and marking contacts of both of said signal responsive relays and each having a second winding oppositely effective to said first-mentioned windings and energizable individually and selectively through the armature and spacing contact of each of said signal responsive relays, means for holding said second-mentioned relays in either condition established by said oppositely effective windings, and a retransmitting relay controlled by each of said second-mentioned relays.

7. In a telegraph repeater, a pair of relays responsive to signals received over lines individual to said relays, each of said relays having an armature and marking and spacing contacts, a pair of relays each having a winding energizable in common through the armatures and marking contacts of both of said signal responsive relays and having a second winding oppositely effective to said first-mentioned winding and energizable individually and selectively through the armature and spacing contact of each of said signal responsive relays, means for holding said second-mentioned relays in either condition established by said oppositely effective windings, a retransmitting relay controlled by each of said second-mentioned relays and means controlled by both of said second-mentioned relays for interrupting the energizing circuit of said first-mentioned windings upon operation of said second-mentioned relays under the control of said windings and for preliminarily preparing said circuit for restoration upon operation of either of said second-mentioned relays under the control of their second-mentioned windings.

8. In a telegraph repeater, a pair of relays responsive to signals received over lines individual to said relays, each of said relays having an armature and marking and spacing contacts, a pair of electron discharge tubes, means for applying activating potentials to the control electrodes of said tubes at intervals of unit length telegraph impulses, a pair of relays each having a winding energizable in common through the armatures and marking contacts of both of said signal responsive relays and the discharge path of one of said tubes and having a second winding oppositely effective to said first-mentioned winding and energizable individually and selectively through the armature and spacing contact of each of said signal responsive relays and the discharge path of the other of said tubes, means for holding said second-mentioned relays in either condition established by said oppositely effective windings, a retransmitting relay controlled by each of said second-mentioned relays, and means controlled by both of said second-mentioned relays for disconnecting the discharge path of one of said tubes from said first-mentioned windings upon operation of said second-mentioned relays under the control of said windings and for reconnecting the discharge path of said tube to said first-mentioned windings upon operation of either of said second-mentioned relays under the control of their second-mentioned windings.

9. In a telegraph repeater, a pair of relays responsive to signals received over lines individual to said relays, each of said relays having an armature and marking and spacing contacts, a source of timing impulses, means including a normally activated electron discharge tube having its discharge path completed serially through the armatures and marking contacts of said relays for disabling said source of timing impulses, a pair of electron discharge tubes adapted to receive activating potentials on their control electrodes from said source of timing impulses, a pair of relays each having a winding energizable in common through the armatures and marking contacts of both of said signal responsive relays and the discharge path of one of the tubes of said pair of electron discharge tubes and having a second winding oppositely effective to said first-mentioned winding and energizable individually and selectively through the armature and spacing contact of each of said signal responsive relays and the discharge path of the other tube of said pair, means for holding said second-mentioned relays in either condition established by said oppositely effective windings, a retransmitting relay controlled by each of said second-mentioned relays, and switching means controlled by both of said second-mentioned relays for transferring the circuit of the armatures and marking contacts of said signal responsive relays from the discharge path of said one of the tubes of said pair to the discharge path of said first-mentioned tube upon operation of said second-mentioned relays under control of their first-mentioned windings and for reconnecting the circuit of the armatures and marking contacts of said signal responsive relays to the discharge path of said first-mentioned tube.

10. In a telegraph signal repeater, a signal responsive relay, a pair of electron discharge tubes each having a control electrode and a discharge gap, timing means for periodically applying activating potentials to the control electrodes of said tubes, means controlled by said signal responsive relay for selectively completing the discharge gap circuit of one or the other of said tubes externally thereof whereby to control the selective activation of the discharge gap of either tube, and a signal retransmitting relay selectively operable into marking or spacing condition in response to activation of the discharge gap of one or the other of said tubes.

11. In a telegraph signal repeater, a signal responsive relay, a pair of gas-filled electron discharge tubes each having a control electrode and a discharge gap, means controlled by said signal responsive relay for selectively completing the

discharge gap circuit of one or the other of said tubes externally of the tubes, timing means for periodically and momentarily applying activating potentials to the control electrodes of said tubes whereby to activate the discharge gap of the tube having its discharge gap circuit completed, and a signal retransmitting relay selectively operable into marking or spacing condition in response to activation of the discharge gap of one or the other of said tubes.

12. In an electronic selector mechanism, two pairs of electron discharge tubes each having a control electrode and a discharge gap, means for selectively completing the discharge gap circuits of any two of said tubes externally of the tubes, and timing means for applying activating potentials to the control electrodes of all of said tubes whereby to cause to be activated the two tubes having completed discharge gap circuits.

13. In a telegraph signal repeater, a signal responsive relay, a normally inactive impulse generator comprising electron discharge means, means controlled by said relay for setting said generator in operation, a signal transmitting relay, a pair of gas-filled electron discharge tubes adapted to have activating potentials simultaneously applied to their control electrodes and having their main space discharge paths associated with oppositely effective windings of said transmitting relay, and means controlled by said receiving relay for selectively completing either of said space discharge paths externally of the tubes.

14. In a telegraph repeater, a pair of telegraph lines, a receiving relay associated with each of said lines, a retransmitting relay associated with each of said lines having oppositely effective windings for operating said retransmitting relays to marking or spacing conditions, electron discharge tubes equal in number to said windings having their anodes connected to said windings individually and having control electrodes, means controlled by said receiving relays for selectively completing the external anode circuits of said tubes through said windings, and means for periodically applying activating potentials to the control electrodes of all of said tubes whereby to activate those of the tubes having completed anode circuits and to energize the windings included in said completed circuits.

15. In a telegraph repeater, a pair of telegraph lines, a receiving relay associated with each line having operating and biasing windings, an electron discharge tube individual to each of said relays and having its anode connected through a low resistance path including the biasing winding of its associated relay to a source of anode potential and having its anode also connected through a high resistance path to a source of anode potential, a source of potential of opposite polarity connected to each of said biasing windings on the terminal remote from the anode connection thereto, and means controlled by each of said relays upon operation thereof to spacing for disconnecting the first mentioned source of anode potential from the low resistance path including the biasing winding of the other relay whereby to stop the flow of current through said biasing winding of the other relay to the anode of its associated tube and to cause current to flow in the opposite direction in the biasing winding of said other relay in a circuit including said source of potential of opposite polarity, said biasing winding and said high resistance path and associated source of anode potential.

16. In a telegraph repeater, a pair of telegraph lines, a receiving relay associated with each line having operating and biasing windings, a grid-controlled electron discharge tube individual to each of said relays and having its anode connected in a low resistance path including the biasing winding of its associated relay to a source of anode potential and having its anode also connected through a high resistance path to a source of anode potential, a potential divider network including a source of potential of opposite polarity connected to each of said biasing windings on the terminal remote from the anode connection thereto, a connection from said network to the grid of the tube having anode connection to the winding associated with said network whereby to establish a predetermined grid potential through the conjoint action of said first mentioned source of potential, said network and said source of potential of opposite polarity, and means controlled by each of said relays upon operation thereof to spacing for disconnecting the first mentioned source of potential from the low resistance path including the biasing winding of the other relay whereby to shift the potential of the grid toward that of said source of potential of opposite polarity, to stop the flow of current through said biasing winding of said other relay to the anode of its associated tube and to cause current to flow in the opposite direction in the biasing winding of said other relay in a circuit including the source of potential of opposite polarity associated with said network, said biasing winding and said high resistance path and source of anode potential.

17. In a telegraph repeater, a pair of telegraph lines, a receiving relay associated with each line having operating and biasing windings, a grid-controlled electron discharge tube individual to each of said relays and having its anode connected in a low resistance path including the biasing winding of its associated relay to a source of anode potential and having its anode also connected through a high resistance path to a source of anode potential, a potential divider network including a source of potential of opposite polarity connected to each of said biasing windings on the terminal remote from the anode connection thereto, a connection from said network to the grid of the tube having anode connection to the winding associated with said network whereby to establish a predetermined grid potential through the conjoint action of said first mentioned source of potential, said network and said source of potential of opposite polarity, means controlled by each of said relays upon operation thereof to spacing for disconnecting the first mentioned source of potential from the low resistance path including the biasing winding of the other relay whereby to shift the potential of the grid toward that of said source of potential of opposite polarity, to stop the flow of current through said biasing winding of said other relay to the anode of its associated tube and to cause current to flow in the opposite direction in the biasing winding of said other relay in a circuit including the source of potential of opposite polarity associated with said network, said biasing winding and said high resistance path and source of anode potential, and capacitative means associated with said grid for delaying the return thereof to said predetermined potential upon reconnection of said first mentioned source of potential to said low resistance path by said disconnecting means in con-

sequence of restoration of said one relay to marking.

18. In a telegraph repeater, a receiving relay, a retransmitting relay, a normally conductive electron discharge tube having its discharge circuit completed through the armature and marking contact of said receiving relay and adapted to be quenched upon operation of said receiving relay to spacing, an oscillatory circuit comprising inductive and capacitative components, means controlled by said electron discharge tube and conditioned when said tube is conductive for causing steady direct current to flow in the inductive component of said oscillatory circuit whereby to preclude oscillatory operation thereof, means controlled jointly by said receiving relay and said oscillatory circuit during oscillatory operation of said circuit for operating said retransmitting relay to marking or spacing condition, timing means for rendering said tube conductive a predetermined interval after the quenching thereof, and means effective whenever said retransmitting relay has been operated to spacing for preventing a flow of steady direct current in said inductive

component of said oscillatory circuit whereby to preclude interruption of oscillatory operation of said oscillatory circuit.

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