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TELEGRAPH SIGNAL DISTORTION MEASURING APPARATUS

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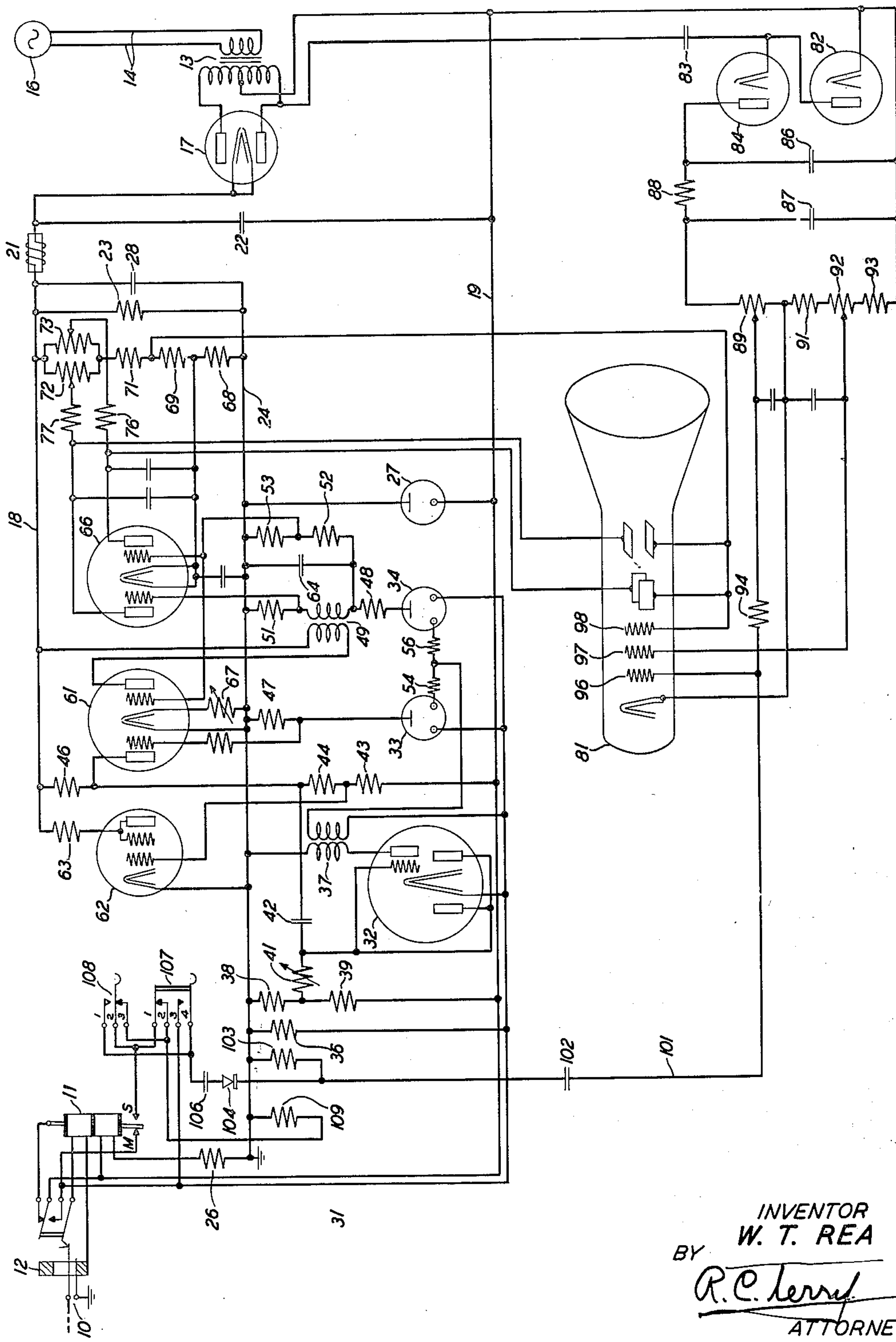

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TELEGRAPH SIGNAL DISTORTION MEASURING APPARATUS

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Original application December 20, 1943, Serial No. 515,064, now Patent No. 2,480,878, dated September 6, 1949. Divided and this application August 13, 1949, Serial No. 110,076

11 Claims. (Cl. 178—69)

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This invention relates to telegraph system testing devices and particularly to the measurement of distortion of telegraph signals.

This application is a division of copending application Serial No. 515,064 filed December 20, 1943, now Patent Number 2,480,878, issued September 6, 1949.

An object of the invention is to compensate for variations in space discharge currents in an electron tube system so that the full regulating capabilities of a voltage regulator instrumentality shall be available to compensate for voltage variations in a power supply source.

Another object of the invention is to derive from an alternating voltage source a plurality of rectified voltages connected in series aiding relation.

The invention features an electron discharge tube system in which certain tubes have their space discharge paths in tandem or cascade relation to the space discharge paths of other of the tubes, thus establishing a point of intermediate potential relative to the uppermost and lowermost potential points of such cascade system. When in the course of operating the system in the intended manner the conductivity of a tube or tubes on one side of said intermediate potential point undergoes a substantial change or the conductivity of a plurality of tubes on both sides of said intermediate potential point undergoes substantial change in different degrees and in the same or opposite sense as a necessary step in the operation of the system, one tube especially provided to serve the sole purpose of a compensator is caused to undergo a change in conductivity of such magnitude and sense as to compensate for all other changes in conductivity and to maintain substantially constant flow of current through certain conductive elements of the tandem system.

The invention also features a voltage regulated power supply for an electron discharge tube in which regulation is achieved by employing electron discharge regulator tubes characterized by substantially constant space discharge voltage drops for a relatively wide range of space discharge current values and in which compensation for current variations in the electron discharge tube system operated from such power supply is effected independently of the electron discharge regulator tubes, leaving the full range of voltage regulation of such regulator tubes available for compensating for voltage variations in the power source.

One embodiment of the invention contemplates a telegraph signal measuring system in which the signals to be measured are received by a polar relay having a biasing winding. Upon

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responding to the first impulse of a signal combination the relay causes a change to occur in the conductivity of certain electron discharge tubes and the result of the change in conductivity in these tubes is to set in operation an oscillatory circuit and an interval timing circuit. The interval timing circuit includes an electron discharge tube and this tube together with those which condition the timing circuit and start the oscillatory circuit are connected across a part of the output of a rectifying source of direct current. A voltage regulator tube and the biasing winding of the receiving relay are also connected across this part of the rectifying power supply. Signal measurement indications are obtained by employing a cathode-ray tube the electron beam of which is normally of insufficient intensity to produce a luminous spot on the screen of the tube, and signal responsive transits of the armature of the receiving relay cause the intensity of the electron beam to be increased momentarily to a value above the threshold of visibility. The sweep of the electron beam in the cathode-ray tube is controlled by an electron discharge tube which is connected across the other part of the power source of direct current. Also connected across this part of the power supply is a tube which serves the dual purpose of feeding energy into the oscillatory circuit to control the decrement thereof and controlling the timing circuit, and an electron discharge tube the sole purpose of which is to provide a current drain path in the output of the power supply.

Due to the divided nature of the output of the power supply the discharge path of the tubes connected across one part of the power supply are in tandem or series with the discharge paths of the tubes connected across the other part of the power supply. There are also certain fixed resistance paths across both parts of the power supply. In the idle condition of the apparatus the electron tubes in that part of the power supply with which the voltage regulator tube is associated draw current aggregating a predetermined amount and during a signal receiving cycle they draw no current. During the idle condition of the apparatus the tubes in the other part of the power supply, which control the sweep of the electron beam of the cathode-ray tube, feed back energy into the oscillator circuit and control the interval timing circuit, draw current aggregating a predetermined amount, and during an operating cycle draw more current. If there were no tube in this part of the power supply for compensating for current changes in other electron tubes in the circuit, the voltage regulator tube would be subjected to a large increase in current upon the change from idle to running condition due to the decrease to zero of the discharge current in the tubes in parallel with it in one part of the power supply circuit and due to the increase in current through the tubes in the other part of the power supply. Thus the voltage regulating capabilities of the regulator tube would be devoted to accommodating changes in conductivity as between the idle and running conditions, greatly reducing the capability of the regulator tube to accommodate voltage changes in the alternating current source from which the rectifying power supply is operated. With the provision of the compensating electron discharge tube that tube may be adjusted so that in the idle condition it draws current equal to that drawn by the electron discharge tubes in the part of the power supply with which the regulator tube is associated, plus current in an amount equal to the increase in conductivity of the tubes in the part of the power supply with which the compensating tube is associated. When the change from idle to running condition occurs, current through the electron discharge tubes in the regulated portion of the power supply and through the compensating tube in the unregulated portion of the power supply is cut off. The other tubes in the unregulated portion of the power supply undergo a change in conductivity due to a functional change in their condition of operation which is equal to the difference between the current drawn by the compensating tube when it was operating and the current drawn by the discharge tubes in the regulated portion of the power supply when they were operating. In this way the voltage regulator tube is required to undergo no change in current as between the idle and operating conditions of the system and its full voltage regulating capabilities are at all times available to compensate for voltage variations in the alternating current source from which the rectifying power supply is operated.

In accordance with another embodiment of the invention, which is fully described in the specification and shown in the drawings of the hereinbefore identified copending application that resulted in Patent 2,480,878, granted September 6, 1949, but which is neither described in detail in the present specification nor shown in detail in the accompanying drawings, the signals to be measured are received by a receiving relay which has a biasing winding. As in the case of the previously described embodiment this is the only electromagnetic relay employed in the system, all other operations involved in operating the cathode-ray tube which indicates the characteristics of received signals being performed or controlled by electron discharge tubes. In this embodiment of the invention the biasing winding of the receiving relay and certain other resistive paths are connected across a part of the power supply and a voltage regulator tube is connected across this part of the power supply to stabilize the voltage applied to the biasing winding of the receiving relay and to the other resistive paths. None of the electron discharge tubes is contained in this part of the power supply but these tubes are connected across another part of the power supply the voltage of which is regulated by regulator tubes. These regulator tubes compensate for the net change in conductivity of the several electron discharge tubes as between the idle and the running conditions so that the current through the voltage regulator tube which stabilizes the biasing winding of the receiving relay remains substantially constant and the full voltage regulating capabilities of the relay stabilizing voltage regulator tube are available for compensating for variations in the source of alternating current from which the power supply is operated.

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 single figure of the drawing which is a schematic circuit diagram showing a telegraph signal measuring system in accordance with one embodiment of the invention.

Referring to the drawing, reference numeral 11 designates a telegraph signal receiving relay the operating winding of which is connected to the tip and sleeve terminals of jack 12. The jack is adapted to receive a plug 10 connected to a full metallic or ground return telegraph loop over which signals to be measured are transmitted. Relay 11 is a biased polar relay and has a biasing winding to which a biasing voltage must be supplied. For supplying operating voltages for the biasing winding of relay 12 and for all other purposes including operation of a plurality of electron discharge tubes, a step-up transformer 13 has its primary winding connected to mains 14 which carry alternating current from a generating source 16 and has the terminals of its secondary windings connected to the anodes of a full wave rectifier tube 17. The indirectly heated cathodes of tube 17 represent the positive side of the direct current output and the center tap of the secondary of transformer 13 represents the negative side of the output. From these two points, the positive and negative conductors or bus bars 18 and 19, respectively, extend, the former including filter inductance 21. A filter condenser 22 is connected between these conductors.

From the positive conductor 18, a voltage dropping resistor 23 is connected to a conductor or bus bar 24. The biasing winding of receiving relay 11 in series with resistor 26 is connected between conductor 24 and negative conductor 19. Thus a direct current path is established from positive conductor 18 through resistors 23 and 26 and the biasing winding of receiving relay 11 to negative conductor 19. Since conductor 24 is connected at the junction of resistors 23 and 26, it assumes an intermediate potential less positive than conductor 18 by the potential difference across resistor 23 and more positive than conductor 19 by the potential difference across resistor 26 and the biasing winding of relay 11.

A voltage regulator tube 27 has its anode connected to conductor 24 and its cathode connected to conductor 19 so that its discharge path is bridged between these conductors. The function of voltage regulator tube 27 is to maintain a constant potential difference between low and intermediate potential conductors 19 and 24 and thus across the biasing winding of receiving relay 11. The reason for this is that the voltage available at commercial power mains, represented by conductors 14, may vary considerably with varying load conditions, and in the absence of regulation of that portion of the output of rectifier tube 17 which supplies the biasing potential for relay 11, such potential may vary correspondingly and may upset the desired relation of received signal potential to biasing potential. The regulator tube 27 holds the potential difference constant although passing current of varying values as the output voltage of rectifier tube 17 varies.

High and intermediate potential conductors 18 and 24 are bridged by a filter condenser 28. Various conductive paths additional to those through resistor 23, regulator tube 27 and the biasing winding of relay 11 are provided, as required by the telegraph signal measuring system between conductors 18 and 24, between conductors 24 and 19, and between conductors 18 and 19 without connection to conductor 24, these paths including space discharge paths of electron discharge tubes, potential dividers, and discharge tube anode and cathode load resistors as will be developed hereinafter.

Jack 12 is provided with auxiliary contacts comprising a swinger spring, a normal contact and an off-normal contact. The swinger spring is connected to low potential conductor 19. The off-normal contact is connected to the armature of relay 11. The normal contact is connected to the marking contact of relay 11 and to a conductor 31 which extends to the cathode of vacuum electron discharge tube 32, and to the cathodes of cold cathode gas-filled electron discharge tubes 33 and 34. With no plug inserted into jack 12, conductor 31 is connected to low potential conductor 19 through the swinger spring and normal contact of jack 12. With a plug inserted into the jack and a marking condition applied to the operating winding of relay 11 to hold the armature on the marking contact, conductor 31 is connected to low potential conductor 19 through the marking contact and armature of relay 11, the off-normal contact and swinger spring of jack 12. A resistor 36 is connected between intermediate potential conductor 24 and conductor 31 and thereby is in parallel with voltage regulator tube 27 in either of the abovementioned conditions of jack 12.

Electron discharge tube 32 is a multiple section tube comprising a triode and two diodes, the cathode being common to all three sections. The anode of the triode section is connected to intermediate potential conductor 24 through the left-hand winding of a transformer 37. A potential divider comprising resistors 38 and 39 is connected between intermediate and low potential conductors 24 and 19, respectively, and thus is in parallel with voltage regulator tube 27 so that the voltage drop across this potential divider is constant. The junction point of resistors 38 and 39 is connected through a variable resistor 41 to the control grid of the triode section of tube 32 and to the anodes of the two diode sections of this tube. The control grid of the triode section of the tube is also connected through a condenser 42 to a potential divider comprising resistors 43, 44 and 46 in series bridged between high potential conductor 18 and low potential conductor 19, the condenser being connected to the junction point of resistors 44 and 46. The anode of cold cathode gas-filled discharge tube 33 is connected to intermediate potential conductor 24, through resistor 47. The anode of cold cathode gas-filled discharge tube 34 is connected through resistor 48 and then in branching paths through the right-hand winding of a transformer 49 and resistor 51 as one path and through resistors 52 and 53 as the other path to the intermediate potential conductor 24. From this it will be apparent that with no plug in jack 12 or with a plug inserted in jack 12 and the operating winding of relay 11 responding to a marking condition, the potential between the intermediate and low potential conductors 24 and 19, respectively, as regulated by the regulator tube 27 will be applied across the space discharge path of the triode section of tube 32, and across the main gap of cold cathode gas-filled tubes 33 and 34.

From this point on in the description, the presence of a plug in jack 12 connected to a telegraph line over which signals are to be received will be assumed and initially the relay 11 will be assumed to be responding to a steady marking condition. Under these circumstances, cold cathode tubes 33 and 34 are conductive through their main gaps and current will be flowing in the triode section and both diode sections of tube 32 due to the fact that the diode anodes and the control grid of the triode are more positive than the cathode by the potential difference across resistor 39. The grid, being positive, draws current, and this current, together with the diode plate current, flows through variable resistor 41 and lowers the potential of the grid and diode anodes with respect to the junction of potential divider resistors 38 and 39, but as a steady state condition the grid is slightly positive with respect to the cathode, and anode current flows in the triode section through the left-hand winding of transformer 37. Since the current through the left-hand winding of transformer 37 has a steady value, no voltage is developed in the right-hand winding of the transformer, one terminal of which is connected to conductor 31 and the other terminal of which is connected to the control anode of gas-filled tube 33 through resistor 54 and to the control anode of gas-filled tube 34 through resistor 56.

The control grid of the left-hand triode section of a twin triode tube 61 is connected to the low potential end of resistor 47 and the cathode of tube 61 is connected to intermediate potential conductor 24. With tube 33 conductive as previously stated, the control grid of the left-hand triode section of tube 61 is negative with respect to the cathode so that anode current does not flow in this triode section. The anode of the left-hand triode section is connected to the junction of resistors 46 and 44 so that resistor 46 is the load resistor for the left-hand triode section. There being no anode current, the current flowing through resistor 46 is the same as the current flowing through the resistors 44 and 43 and the charge on condenser 42 is represented by a potential difference equal to the voltage drop across resistors 43 and 44 less the slight voltage difference between the grid and diode anodes of tube 32 and the cathode of that tube. The potential divider comprising resistors 43, 44 and 46 provides a further control potential by virtue of the connection of the junction of resistors 43 and 44 to the control grid of an electron discharge tube 62 which has its cathode connected to the intermediate potential conductor 24 and its anode connected to the high-potential conductor 18 through resistor 63. Resistors 43, 44 and 46 are so proportioned that the potential difference across resistor 43 is substantially equal to the potential difference between conductors 19 and 24 so that the control grid of tube 62 is at substantially the same potential as its cathode and tube 63 draws anode current which flows through resistor 63. The value of resistor 46 is very low by comparison with resistors 43 and 44 being about one part in 300 of the total resistance of resistors 43 and 44. Resistor 44 has about twice the resistance of resistor 43.

Discharge current through the cold cathode tube 34 flows through the series circuit comprising the right-hand winding of transformer 49 and the resistor 51 in parallel with the series circuit comprising resistors 52 and 53. A condenser 64 is in parallel with these two paths and therefore is charged to the potential across them. The point of interconnection of resistors 52 and 53 is connected to the control grid of the right-hand triode section of tube 61 and also to the control grid of the right-hand triode section of a twin triode tube 66. The cathode of the right-hand triode section of tube 61 is connected to intermediate potential conductor 24 through a variable resistor 67. The resistance value of resistor 51 and the right-hand winding of transformer 49 is small as compared with resistor 48 so that the drop across resistor 51 and the right-hand winding of the transformer is low. Thus the drop across resistors 52 and 53 is low. Furthermore, the resistance of resistor 53 is small as compared with that of resistor 52, so that the junction of those resistors and the grid of the right-hand triode section of tube 61 is only slightly negative with respect to the cathode. The right-hand triode section of tube 61 is thus conductive. The anode of the right-hand triode section of tube 61 is connected to high potential conductor 18 through the left-hand winding of transformer 49 and a steady current flows through this winding. Since both windings of the transformer are conducting steady current, neither winding has any inductive effect on the other.

A potential divider bridged between intermediate potential conductor 24 and high potential conductor 18 comprises resistors 68, 69 and 71 in series with parallelled resistors 72 and 73. Both cathodes of the twin triode tube 66 are connected to the junction of resistors 68 and 69 so that the cathodes are more positive than intermediate potential conductor 24 by the potential difference across resistor 68. The junction of resistor 51 and the right-hand winding of transformer 49 is connected to the control grid of the left-hand triode section of tube 66. Since the grid of the right-hand triode section is connected to the junction of resistors 52 and 53 along with the grid of the right-hand section of tube 61, it is only slightly less positive than the potential of the intermediate potential conductor 24. The very large portion of the total discharge current of tube 34 flowing through resistor 51 causes the grid of the left-hand triode section of tube 66 to be considerably more negative with respect to the intermediate potential conductor 24 than the grid of the right-hand triode section. The potentials of the two grids with respect to the cathodes are such that an appreciable anode current flows in the right-hand triode section whereas the anode current in the left-hand triode section is very nearly cut off.

The anode of the right-hand triode section of tube 66 is connected through a resistor 76 to a contactor which is variable with respect to resistor 73, this resistor being in itself a potential divider. The anode of the left-hand triode section of tube 66 is connected through a resistor 77 to a contactor which is variable with respect to resistor 72 which is also a potential divider. The anode current which the control grid of the right-hand triode section of tube 66 permits to flow is sufficient to produce a potential difference across resistor 76 which is substantially equal to the potential difference across the resistor 71 plus the portion of resistor 73 up to the contactor of that resistor. The anode of the right-hand triode section of tube 66 is connected to one of the horizontal deflecting plates of a cathode-ray tube 81. The other horizontal deflecting plate is connected to the junction of resistors 71 and 69. It follows from the previously stated relation of equality between the potential difference across the resistor 76 and the potential difference from the point of engagement of contactor associated with resistor 73 to the junction of resistors 71 and 69 that the two horizontal deflecting plates of the cathode-ray tube are at substantially the same potential and there is little or no horizontal deflecting potential on the cathode-ray tube. The anode of the left-hand triode section of tube 66 is connected to the upper vertical deflecting plate of cathode-ray tube 81. The lower vertical deflecting plate is connected to the junction of resistors 69 and 71. Since there is little or no anode current in the left-hand triode section of tube 66 and therefore little or no potential difference across resistor 77, it follows that the potential of the anode of the left-hand triode section is more positive than the junction of resistors 69 and 71 by the potential difference from the contactor of resistor 72 through the lower section of that resistor plus the potential difference across resistor 71. Thus the upper vertical plate of cathode-ray tube 81 is positive with respect to the lower plate.

Power for operating the cathode-ray tube 81 is derived from one-half of the high voltage secondary winding of transformer 13 in a voltage doubler circuit. The center tap of the high voltage secondary of transformer 13 is connected to the cathode of a half-wave rectifier tube 82 and one of the terminals of the high voltage secondary winding is connected through a condenser 83 to the anode of half-wave rectifier tube 84 and to the cathode of a half-wave rectifier tube 82. The output of the voltage doubler power supply is represented by the anode of tube 84 and the cathode of tube 82. Condenser input filtering is provided by the condensers 86 and 87, the former of which has one terminal connected to the cathode of tube 82 and the other terminal connected to the anode of tube 84, and the latter of which has one terminal connected to the cathode of tube 82 and the other terminal connected through a resistor 88 to the anode of tube 84. Load resistors 89, 91, 92 and 93 are connected in series across the output of the filter. When the lower terminal of the high voltage secondary winding of transformer 13 is positive and the center tap is negative during a half cycle of alternating current impressed on the high voltage secondary winding of the transformer, current flows through the space discharge path of tube 82 to charge condenser 83. In the next half cycle of the alternating current the polarities on the high voltage secondary winding are reversed, the lower terminal being at negative potential and the center tap at positive potential. These polarities are in series-aiding relation to the charge on condenser 83 and current flows through condenser 83, the space discharge path of tube 84 and filter condensers 86 and 87, the condensers becoming charged to the voltage across one half of the high voltage secondary winding of transformer 13 plus the voltage across condenser 83. Thus the condensers 86 and 87 are charged once in each half cycle of the alternating current, the rectification is half wave, the output conductor which includes resistor 88 is the negative side of the output and the conductor connected to the cathode of tube 82 is the positive side of the output.

Load resistor 89 is a potential divider, its contactor being connected through resistor 94 to the intensity control electrode 96 of cathode-ray tube 81. The cathode of the tube is connected to the junction of resistors 89 and 91. The junction of resistors 89 and 91 is more positive than the opposite end of resistor 89 so that the intensity control electrode 96 is negative with respect to the cathode when the contactor of potential divider 89 is moved away from the lower terminal of potential divider 89. Resistor 92 is a potential divider and its contactor is connected to the focusing electrode 97 of tube 81. The focusing electrode is therefore more positive than the cathode by the potential difference across resistor 91 plus the potential difference across the portion of potential divider 92 between the contactor and the junction of resistor 91 and potential divider 92. It will be noted that the conductor 19 previously referred to as the low potential conductor of the power supply served by rectifier tube 17, being connected to the mid-point tap of the high voltage secondary winding of transformer 13 to which the positive side of the output of the voltage doubler is connected, is at the same potential as the positive side of the power supply for cathode-ray tube 81. In this way, the power supply for the cathode-ray tube is placed in series-aiding relation with the power supply served by rectifier tube 17 at the extreme negative side of that power supply. Since the beam accelerating electrode 98 and one each of the horizontal and vertical deflecting plates of cathode-ray tube 81 are connected to the junction of resistors 69 and 71 between intermediate and high potential conductors 24 and 18, respectively, of the output of rectifier tube 17, these electrodes of the cathode-ray tube are more positive than the cathode by the potential difference across resistors 69 and 68 plus the potential difference across regulator tube 27 plus the potential difference across resistors 93, 92 and 91 in series.

As previously described, the normal operating condition of the cathode-ray tube 81 is to have the intensity control electrode 96 sufficiently negative with respect to the cathode that the electron beam does not have sufficient intensity to produce a luminous spot on the screen of the cathode-ray tube.

In order to adjust the electron beam to its proper initial position, the contactor associated with potential divider resistor 89 is moved along the resistor until the beam reaches the fluorescent screen with sufficient intensity to produce a luminous spot. Plug 10 should be removed from jack 12 to permit the armature of relay 11 to move to spacing and remain there. This sets up oscillatory current in the oscillatory circuit comprising the right-hand winding of transformer 49 and condenser 64. Variable resistor 67 is adjusted to maximum decrement to permit oscillatory current to die out. With no current flowing in the oscillatory circuit the grids of the two triode sections of tube 66 are at the same potential and substantially equal anode currents will flow. By adjusting the potential dividers 72 and 73 the potentials on the beam deflecting plates of cathode-ray tube 81 may be varied to bring the beam to the center of the screen.

This adjustment having been made, plug 10, connected to a source of signals having no bias or distortion, is inserted into jack 12. If the source of signals has not yet been started, the armature of relay 11 will be restored to and remain on marking and since condenser 42 has had time to recharge during the adjustment of the cathode-ray tube beam, tube 32 will be restored to conductivity and tubes 33 and 34 will be refired. This restores the system to the steady state condition, producing a substantial change in the conductivity of the left-hand triode section of tube 66 and very little change in the conductivity of the right-hand triode section. The beam of cathode-ray tube accordingly becomes deflected vertically but not horizontally from the center of the screen.

With the apparatus restored to the steady state condition it is in condition to receive the unbiased and undistorted signals for the purpose of completing the preliminary adjustments. Since the initial condition of the various electron discharge tubes has been set forth in the description of the circuit connections of those tubes it is summarized at this point that the triode section and both diode sections of tube 32, the gas tubes 33 and 34, the vacuum tube 62, the right-hand triode section of vacuum tube 61, and the right-hand triode section of vacuum tube 66 are conductive, the left-hand triode section of vacuum tube 66 is only slightly conductive and the left-hand triode section of vacuum tube 61 is not conductive. It should also be noted that the gas tubes 33 and 34 are conductive only through their main gaps. The cathodes of these tubes are connected to conductor 31 and the control anodes of the tubes are connected through resistors 54 and 56 and through the right-hand winding of transformer 37 to conductor 31. Since there is steady current in the left-hand winding of transformer 37 and no voltage is being developed in the right-hand winding, the control anodes of the tubes are at the same potential as the cathodes.

Relay 11 responds to the start impulse of a start-stop telegraph signal by moving its armature to the spacing contact. The disengagement of the armature from the marking contact opens the connection between low potential conductor 19 and conductor 31, thus opening the main discharge path of gas-filled tubes 33 and 34. These tubes therefore are extinguished. Also, the lower terminal of resistor 36 and the cathode of tube 32 become disconnected from low potential conductor 19. The flow of current through resistor 36 ceases and the potential of the cathode of tube 32 is raised to the potential of intermediate potential conductor 24. The potential of the cathode is thus made equal to that of the anode and is made more positive than the grid and diode anodes by the potential difference across resistor 38. Thus no current will flow from the cathode to any of the anodes in tube 32. As the triode current in tube 32 dies out in the left-hand winding of transformer 37 an impulse is impressed on the control anodes of gas tubes 33 and 34 through resistors 54 and 56, respectively. The polarity of this impulse is such as to reduce the potential of the control anodes with respect to the cathodes. Since the cathodes and control anodes in tubes of this type are usable interchangeably and a discharge in the control gap will be produced if a sufficient potential difference is impressed across the gap irrespective of polarity, a momentary firing of the control gap in the two tubes 33 and 34 may occur. However, the discharge will not transfer to the main gap because the cathodes are disconnected from the low potential conductor 19 as are also the control anodes.

The extinguishment of gas-filled tube 33 stops the flow of current through resistor 47 and raises the potential of the grid of the left-hand triode section of tube 61 to that of the cathode, rendering the left-hand triode section conductive. Anode current in the left-hand triode section of tube 61 flows through resistor 46, increasing the potential difference across resistor 46 and rendering the junction of resistors 46 and 44 and the junction of resistors 44 and 43 less positive with respect to the low potential conductor 19 than they previously were. Prior to the extinguishment of tubes 32, 33 and 34 and the activation of the left-hand triode of tube 61, condenser 42 has been charged to a potential represented by the difference between the potential of the grid and diode anodes of tube 32 and the potential of the left-hand anode of tube 61. Upon the substantial reduction in the potential of the anode of the left-hand triode section of tube 61 as the anode current flows through resistor 46 condenser 42 discharges through the anode-cathode discharge path of the left-hand triode section of tube 61, conductor 24 and resistors 38 and 41.

As a further result of the activation of the left-hand triode section of tube 61 and the increase in the potential difference across resistor 46 the junction of resistors 44 and 43 to which the grid of tube 62 is connected is made very much less positive than it previously was and the grid of tube 62 is made negative with respect to its cathode. This cuts off the flow of current in tube 62. The sole purpose of tube 62 is to balance and compensate for current changes in other portions of the circuit and its operation to accomplish this purpose will be described in detail hereinafter.

With the extinguishment of gas-filled tube 34 steady current ceases to flow through the right-hand winding of transformer 49 and resistor 51 and through resistors 52 and 53 in parallel therewith. The inductive energy stored in the right-hand winding of transformer 49 causes current to flow which charges condenser 64, which thereafter discharges through the inductance and thus the circuit oscillates. The voltage developed across resistor 53, starting at slightly negative value, breaks into oscillation by crossing zero and swinging positive to a maximum value that is equal in magnitude to the maximum voltage developed across resistance 51. It follows from this that the oscillatory voltages developed across resistors 53 and 51 are in quadrature and are equal in amplitude. These voltages appearing on the grids of tube 66 are amplified and are applied respectively to the horizontal and vertical deflecting plates of cathode-ray tube 81. The electron beam in the cathode-ray tube is thus caused to describe a path on the screen of the tube. The voltage developed across resistor 53 is also applied to the grid of the right-hand triode section of tube 61. This causes the plate current of this triode section to vary in accordance with the oscillation and since the left-hand winding of transformer 49 is included in the anode circuit of the right-hand triode section of tube 61 energy is fed back into the oscillatory circuit to replace the energy dissipated in resistors 51, 52 and 53. The gain of the feedback circuit may be varied by adjusting resistor 67 and thus the decrement of the oscillations may be controlled.

With the voltage relationships mentioned above, namely the voltage applied to the grid of the right-hand triodes of tubes 61 and 66 slightly negative with respect to conductor 24 and prepared to rise through zero to positive values, and the voltage applied to the grid of the left-hand triode of tube 66 at a negative maximum and prepared to rise, the quadrature relationship is at once apparent, the voltage on the grids of the right-hand triodes of tubes 61 and 66 leading that on the grid of the left-hand triode of tube 66 derived from resistor 51. Current in the right-hand triodes of tubes 61 and 66, varying in phase with the voltage applied to their grids, rises substantially to maximum in the first quarter cycle of the oscillator, falls substantially to initial value in the second quarter cycle, decreases substantially to minimum in the third quarter cycle and returns to initial value in the fourth quarter cycle. By comparison with these voltage and current relationships, the voltage on the grid of the left-hand triode of tube 66 rises to zero during the first quarter cycle, rises to positive maximum during the second quarter cycle, falls to zero during the third quarter cycle and returns to negative maximum during the fourth quarter cycle. It is to be remembered that this is the voltage derived from resistor 51.

The current in the right-hand triode of tube 61 flows through the primary winding of transformer 49 and induces voltage therein. Since it is well known that the current in an inductance lags behind the impressed voltage and induces a voltage which opposes the impressed voltage, it follows that the induced voltage lags behind the current, and this lag is substantially a quadrature relationship. Thus the induced voltage starts at a negative maximum, rises to zero in the first quarter cycle, rises to positive maximum in the second quarter cycle, returns to zero in the third quarter and to negative maximum in the fourth quarter. It is noted that this voltage induced in the primary of transformer is in phase with the voltage across resistor 51.

The voltage induced in the secondary as a result of the current in the primary is opposite to that induced in the primary, and therefore is opposite in phase to the voltage across the resistor 51. Thus there is fed back into the oscillatory circuit by induction a voltage opposing and substantially nullifying the resistive voltage drop across resistor 51, thereby replacing and compensating for the resistive losses in the oscillatory circuit, which are confined almost entirely to resistor 51, the resistance of the secondary of transformer 49 being low by comparison with resistor 51 and the resistive loss in the secondary therefore being negligible. This is accomplished without tuning the primary of the transformer 49 or effecting phase correction in any other way. The adjustable cathode resistor 67 permits the amplitude of the voltage fed back into the oscillatory circuit to be varied. If resistor 67 is so adjusted that the voltage just compensates for resistive losses, the circuit will oscillate at constant amplitude, and if the adjustment is such that the voltage fed back is less than that which compensates for resistive losses the oscillator operates decrementally.

The decrement should be adjusted until the path traced is a closed geometrical figure which will ultimately be adjusted to conform to a circle, or until it traces a spiral which will probably not be symmetrical with respect to both axes of the screen. The path, whether a closed geometrical figure or a spiral, may be made symmetrical with respect to the axes of the screen by first adjusting potential divider 72 until the beam has the desired maximum deflection in the vertical direction, which preferably brings the beam to a point near the edge of the screen for maximum vertical deflection, and then by adjusting the potential divider 73 until the deflection at the horizontal axis is equal to the deflection at the vertical axis, in the case of a circular sweep, or until symmetry with respect to the axes of the screen is achieved in the case of a spiral sweep.

Following these adjustments, the intensity of the electron beam is reduced by readjustment of potential divider 88, until the beam ceases to be visible on the screen of tube 81 except for dots produced by signal responsive transits of the armature of relay 11. In addition to being connected to potential divider 89, the intensity control electrode 96 of cathode-ray tube 81 is also connected by conductor 101 to one side of a condenser 102. The other side of the condenser is connected through resistor 103 to intermediate potential conductor 24 and to one terminal of a unilateral conducting device or half-wave rectifier 104. The other terminal of unilateral conducting device 104 is connected to one side of a condenser 106, the other side of which is connected to spring 4 of a key 107 and to spring 1 of a key 108. The spacing contact of relay 11 is connected to spring 2 of key 108 and spring 1 of key 107. Spring 3 of key 108 and spring 2 of key 107 are connected through resistor 109 to intermediate potential conductor 24. Spring 3 of key 107 is connected to conductor 31 to which the marking contact of relay 11 is also connected.

With keys 107 and 108 in the unoperated condition as shown, the upper end of the conductive path including condenser 106, unilateral conducting device 104 and condenser 102 has no circuit connection. Upon operation of key 107 the upper end of this path becomes connected through springs 3 and 4 of the key to conductor 31 and thus to the marking contact of relay 11. At springs 1 and 2 one of two parallel paths from the lower terminal of resistor 109 to the spacing contact is opened but the other path remains closed through springs 2 and 3 of key 108.

Assuming that the system has been adjusted for operation including the provision of the proper potential on the intensity control electrode of cathode-ray tube 81 before relay 11 began to receive signals, upon movement of the armature of the relay out of engagement with the marking contact the conductive path from low potential conductor 19 through the armature and the marking contact of the relay to the upper side of condenser 106 is interrupted. This causes an impulse to be applied through condenser 106, unilateral conducting device 104 and condenser 102 to the intensity control anode 96 of cathode-ray tube 81. The impulse is positive and momentarily makes the intensity control electrode more positive than it previously was, causing the point of impingement of the electron beam on the fluorescent screen of the tube to become momentarily visible as a luminous spot. As the armature comes into engagement with the spacing contact a conductive path is completed from low potential conductor 19 through the armature and spacing contact of the relay, springs 2 and 3 of key 108 and resistor 109 to intermediate potential conductor 24, but the intensity control electrode of the cathode-ray tube is not affected, because it is connected through condenser 102, unilateral

conducting device 104 and springs 3 and 4 of key 107 only to the marking contact.

In response to the first code impulse of marking nature following the start impulse the armature of relay 11 leaves the spacing contact and returns to the marking contact. As the armature comes into engagement with the marking contact a negative impulse is applied to the intensity control electrode of the cathode-ray tube. Since this current impulse flows through the unilateral conducting device in a reverse direction the device presents a high resistance to the passage of the impulse. The resulting slowness of charge of condenser 106 therefore causes the negative impulse to be of fairly low peak magnitude and of fairly long duration as applied to the intensity control electrode 96 of the cathode-ray tube. Hence should the relay chatter, the positive impulse produced by the contact break involved in the chattering of the armature fails to cause a dot to be produced on the screen of the cathode-ray tube. In this manner parasitic spots due to ordinary relay chatter are prevented. Upon each transit of the armature away from the marking contact as a spacing impulse is received during the reception of the code combination a luminous spot will appear on the screen of the cathode-ray tube.

When key 108 is operated and key 107 is left unoperated the spacing contact of relay 11 remains connected through resistor 109 to intermediate potential conductor 24 through springs 1 and 2 of key 107 and becomes connected through springs 1 and 2 of key 108 through the conductive path including condensers 106 and 102 and unilateral conducting device 104. Under these circumstances the intensity control electrode 96 of cathode-ray tube 81 is not influenced when the armature of relay 11 leaves its marking contact or returns to the marking contact. When the armature moves into engagement with the spacing contact it applies a long negative impulse of low amplitude to the intensity control electrode, which is the opposite of the polarity that will render the beam visible on the screen of tube 81. A positive impulse is applied to the intensity control electrode 96 each time the armature leaves the spacing contact. In this way the time of beginning of relay armature transits from spacing to marking is registered. When keys 107 and 108 are both operated the marking and spacing contacts are both connected to the upper side of condenser 106 and resistor 109 is disconnected from the spacing contact. Under these circumstances the cathode-ray in tube 81 produces a luminous spot each time the armature leaves the marking or the spacing contact and thus both kinds of armature transits from marking to spacing and from spacing to marking are registered.

With the electron beam of tube 81 being moved through a circle or spiral at the rate which is preferably one revolution per telegraph impulse interval all luminous spots produced by unbiased and undistorted signals will fall on a radial line extending vertically from the center of the screen of the cathode-ray tube. In the case of circular rotation of the beam such luminous spots will be superimposed and appear as a single spot. In the case of spiral rotation of the beam the spots will be aligned along the vertical radial line, those representing successively later impulses in a received telegraph signal being successively nearer the center of the fluorescent screen. If the frequency of the oscillatory circuit is not one cycle per telegraph signaling impulse interval, the dots will not appear on the vertical radius, but will fall on one side of that radius if the cycles are too long, and on the other side if the cycles are too short. Accordingly the final adjustment of the system is to set the frequency of the oscillatory circuit at such value that the luminous dots fall on the vertical radius of the screen. This is accomplished by varying the capacity of condenser **64**.

Following this adjustment the system is in condition to measure telegraph signals and indicate bias or distortion thereof. If received signals are biased or distorted the dots will occur early or late with respect to the radius corresponding to zero distortion or bias and the displacement of any transition may be read directly in percentage of a unit pulse length by providing either directly on the fluorescent screen end of the tube or on a transparent plate adjacent to that end of the tube one hundred equally spaced radial lines. For example, when received signals are affected by positive or negative bias, all space-to-mark transitions occur early or late respectively, whereas the mark-to-space transitions are not shifted relative to the start transitions; hence the mark-to-space transitions will cause dots to appear on the zero displacement radius and the space-to-mark transitions will cause dots to appear on the radius which corresponds to the bias of the received signals. If, for instance, the bias is 25 per cent, the space-to-mark dots will appear on a radius 90 degrees in either direction from the zero displacement radius depending upon whether the bias is positive or negative. In the case of distortion other than bias both space-to-mark and mark-to-space transitions will in general be displaced. The dots will therefore be more or less scattered. By observing the average displacement of the space-to-mark and mark-to-space transitions independently the bias component may be determined. The total distortion is determined by observing the maximum deviation of any dot from the zero displacement radius.

During the reception of the several impulses comprising a telegraph signal code combination condenser **42** is discharging. Its capacity is such that substantially the full interval occupied by the significant impulses of the code is required for the condenser to become discharged sufficiently to bring the grid of tube **32** to the cathode potential. If at the time the grid comes to this potential the stop impulse is being received, holding the armature of relay **11** on the marking contact, the cathode of tube **32** will be connected to the low potential conductor **19** through the marking contact and armature of the relay, and the triode and diode sections of the tube can become conductive. The tube cannot become conductive while the armature of relay **11** is off the marking contact because the cathode is not then at negative potential with respect to the anode. As the anode current in the triode section of tube **32** rises to its full value a voltage is induced in the right-hand winding of transformer **37** which is applied between the cathodes and the control anodes of the two gas-filled tubes **33** and **34**. These tubes become conductive across their control gaps and the discharge immediately transfers to the main anodes. Tube **33** reestablishes a potential difference across resistor **47** thereby reducing the potential of the left-hand grid of tube **61** with respect to the cathode and cutting off anode current in this tube. This reduces the potential difference across the resistor **46** thereby raising the potential of the grid of tube **62** to the potential of the cathode of that tube and rendering the tube conductive.

Tube **34**, upon again becoming conductive, stops oscillation of the oscillatory circuit by providing again a steady flow of current through the right-hand winding of transformer **49** and resistor **51** and also through resistors **52** and **53**. As a result of the stopping of oscillation and the restoration of steady potential to the grids of tube **66** and to the right-hand grid of tube **61**, the initial potentials are restored to the beam-deflecting plates of cathode-ray tube **81**, thus arresting rotaton of the beam and restoring it to initial position at a distance vertically from the center of the fluorescent screen. The value of resistance **48** is so chosen that the oscillator circuit attains steady state condition in a critically damped manner. This causes the cathode ray beam to return quickly to its initial position. Condenser **42**, having raised the potential of the grid of tube **32** to cathode potential so that the tube has become conductive, tends to cause the grid of the tube to become positive with respect to the cathode, but current flowing in the diode circuit of the tube quickly charges the condenser and prevents the grid from going to a high positive value with respect to the cathode. In this way the circuit is restored to its initial steady state condition ready for reception of the start pulse of the next telegraph signal code combination.

As previously stated the vacuum electron discharge tube **62** which has its anode current path connected between high potential conductor **18** and intermediate potential conductor **24** is employed as a compensating or current balancing tube. Its activation and deactivation have no functional relation to the starting and stopping of the rotation of the electron beam in the cathode-ray tube nor to the operation of the intensity control electrode **96** of the tube in accordance with received signals. The currents drawn from the output of rectifier **17** under the idle and under the signal receiving conditions are shown in columns I and II in the following table, in which the distribution of the currents in the principal paths between the high and intermediate potential conductors is shown in the upper part of the table and the distribution of currents in the principal paths between the intermediate and low potential conductors is shown in the lower part of the table:

	I	II
Resistor 23 .... mils	20.00	22.10
Resistors 68, 69, 71, 72 and 73 .... do	20.00	22.15
Tube 66—Right triode .... do	0.40	0.275
Tube 66—Left triode .... do	0.10	0.275
Tube 61—Right triode .... do	10.00	11.10
Tube 61—Left triode .... do	0.00	14.10
Tube 62 .... do	45.50	0.00
Totals .... do	96.00	70.00
Voltage .... volts	238	263.5
	I	II
Voltage regulator tube 27 .... mils	17.50	17.50
Tube 34 .... do	10.75	0.00
Tube 33 .... do	5.25	0.00
Tube 32 .... do	10.00	0.00
Resistors 36 and 109 .... do	21.25	21.25
Relay 11—Biasing winding .... do	31.25	31.25
Totals .... do	96.00	70.00
Voltage .... volts	106	106

Only the principal paths have been included in the above table because all other paths are of such high resistance as to contribute negligible current. From the table it will be noted that the reduction in current due to the cutting off of tubes 32, 33 and 34 totals 26 milliamperes. At the same time, in the absence of tube 62 the activation of the left-hand triode of tube 61 would increase the current flowing between conductors 18 and 24. Since the voltage regulator tube fixes the voltage between conductors 24 and 19 and therefore fixes the current through resistive elements connected between those conductors, the current drawn by tubes 32, 33 and 34 prior to cutting off of those tubes plus the additional current between conductors 18 and 24 drawn by the left-hand triode of tube 61 could pass to the low potential conductor 19 only through regulator tube 27. The increase would be of the order of 40 milliamperes plus changes in current through resistive paths between conductors 18 and 24 due to the internal resistance of the rectifier circuit. Commonly available types of voltage regulator tubes are rated to carry not more than 30 milliamperes and must carry a minimum of 5 milliamperes for reliable voltage stabilization. Thus the voltage regulator tube could not accommodate current changes within the system supplied by the output of the rectifier tube 17 and would be deprived of all ability to stabilize the voltage between low and intermediate potential conductors 19 and 24 for varying voltages in the supply main 14.

With tube 62 included in the system this tube is arranged to absorb all current changes between the idle and operating conditions of the system, so that the current through the voltage regulator tube 27 will remain constant. Thus tube 62 carries the anode current, totaling 26 milliamperes, of tubes 32, 33 and 34, its anode circuit being in series with the anode circuits of these three tubes, and also carries the anode current which will subsequently be carried by the left-hand triode of tube 61, the anode circuit of which is in parallel with the anode circuit of tube 62. The value of this current is 14.1 milliamperes. In addition, the current through each other path between conductors 18 and 24 increases because, as indicated by the table, the drain on the output of rectifier tube 17 has been reduced by 26 milliamperes, and it is the characteristic of vacuum rectifier tubes that as the drain decreases the output voltage rises. In the present instance, as indicated by the table, the voltage changes from 238 volts to 263.5 volts, an increase of 25.5 volts. This voltage rise affects the current through resistors 23, 68, 71, 72 and 73, both triode sections of tube 66, and the right-hand triode section of tube 61. The total curren through these elements as derived from the chart is 50.5 milliamperes at the lower voltage. The factor of increase is the quotient of the voltage increase and the voltage before increase, 25.5/238 which, upon reduction to a decimal fraction, becomes .107. This factor of increase applied to the current value of 50.5 milliamperes yields a current increase of 5.4 milliamperes. The increase, added to the current of 14.1 milliamperes which the right-hand triode section of tube 61 carries after tube 62 is cut off, and to the current of 26 milliamperes by which the cutting off of tubes 32, 33 and 34 reduces the current drain, totals 45.5 milliamperes as indicated by the table. In this way tube 62 is made to carry all of the current drawn by tubes 32, 33 and 34, part of the current which resistors 36 and 109 and regulator tube 27 continue to carry after tubes 32, 33 and 34 are cut off and which transfers to the left-hand triode section of tube 61, and another part of the current which resistors 36 and 109 and regulator tube 27 continue to carry and which transfers to the right-hand triode of tube 61, both triodes of tube 66 and resistors 23, 68, 69, 71, 72 and 73. Regulator tube 27 is relieved by tube 62 of the burden of accommodating current changes resulting from functional variations in the conductivity of tubes 32, 33, 34, 61 and 66, and its current remains constant in spite of such changes. This leaves its full voltage regulation capability available to accommodate voltage variations in the supply mains 14, and its current may increase or diminish by 12.5 milliamperes before reaching its upper or lower limits in accommodating such variations, while holding constant the voltage between conductors 19 and 24, and therefore across the biasing winding of relay 11.

Although a specific embodiment of the invention has been shown in the drawing and described in the foregoing specification it will be understood that the invention is not limited to such specific embodiment 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 measuring system, a source of direct-current voltage having positive and negative output conductors, a first plurality of electron discharge tubes having their cathodes connected to said negative conductor, a second plurality of electron discharge tubes having their anodes connected to said positive conductor, a conductor connected to the anodes of said first plurality of tubes and to the cathodes of said second plurality of tubes and established by said tubes at a potential intermediate the potentials of said positive and negative conductors, a signal responsive relay having a biasing winding and operable in response to a signal train to cut off current through said first plurality of tubes, a plurality of other conductive paths connected between said negative and intermediate potential conductors including said biasing winding and a voltage stabilizing device adapted to fix the voltage between said negative and intermediate potential conductors, and means responsive to the cutting off of current through said first plurality of tubes for reducing the total current flow through said second plurality of tubes by substantially the amount of the reduction in current through said first plurality of tubes whereby to maintain constant the flow of current through said other conductive paths including said voltage stabilizing device so as to afford the full stabilizing capabilities of said stabilizing device to compensate for voltage variations in said voltage source.

2. In a telegraph signal measuring system, a source of direct-current voltage having positive and negative output conductors, a first plurality of normally conductive electron discharge tubes having their cathodes connected to said negative conductor, a second plurality of electron discharge tubes having their anodes connected to said positive conductor, a conductor connected to the anodes of said first plurality of tubes and to the cathodes of said second plurality of tubes and established by said tubes at a potential intermediate the potentials of said positive and negative conductors, a signal responsive relay having a biasing winding and operable in response to a signal train to cut off current through said first plurality of tubes, a plurality of other conductive paths connected between said nega-

tive and intermediate potential conductors including said biasing winding and an electronic voltage stabilizing device adapted to fix the voltage between said negative and intermediate potential conductors, and means responsive to the cutting off of current through said first plurality of tubes for reducing the total current flow through said second plurality of tubes by substantially the amount of the reduction in current through said first plurality of tubes whereby to maintain constant the flow of current through said other conductive paths including said electronic voltage stabilizing device so as to afford the full stabilizing capabilities of said stabilizing device to compensate for voltage variations in said voltage source.

3. In a telegraph signal measuring system, a source of direct-current voltage having positive and negative output conductors, a first plurality of normally conductive electron discharge tubes having their cathodes connected to said negative conductor, a second plurality of electron discharge tubes having their anodes connected to said positive conductor, a conductor connected to the anodes of said first plurality of tubes and to the cathodes of said second plurality of tubes and established by said tubes at a potential intermediate the potentials of said positive and negative conductors, a signal responsive relay having a biasing winding and operable in response to a signal train to cut off current through said first plurality of tubes, a plurality of other conductive paths connected between said negative and intermediate potential conductors including said biasing winding and a voltage stabilizing device having a constant voltage drop for a predetermined range of current values and adapted to fix the voltage between said negative and intermediate potential conductors, and means responsive to the cutting off of current through said first plurality of tubes for reducing the total current flow through said second plurality of tubes by substantially the amount of the reduction of current through said first plurality of tubes whereby to maintain constant the flow of current through said other conductive paths including said voltage stabilizing device so as to allot all of said range of current values at constant voltage drop to accommodation of current variations resulting from voltage variations in said voltage source.

4. In a telegraph signal measuring system, a source of direct-current voltage having positive and negative output conductors, a first plurality of normally conductive electron discharge tubes having their cathodes connected to said negative conductor, a second plurality of electron discharge tubes having their anodes connected to said positive conductor, a conductor connected to the anodes of said first plurality of tubes and to the cathodes of said second plurality of tubes and established by said tubes at a potential intermediate the potentials of said positive and negative conductors, a signal responsive relay having a biasing winding and operable in response to a signal train to cut off current through said first plurality of tubes, a plurality of other conductive paths connected between said negative and intermediate potential conductors including said biasing winding and a voltage stabilizing device having a constant voltage drop for a predetermined range of current values and having its current adjusted to substantially the mid-point of said range, said voltage stabilizing device being adapted to fix the voltage between said negative and intermediate potential conductors, and means responsive to the cutting off of current through said first plurality of tubes for reducing the total current flow through said second plurality of tubes by substantially the amount of reduction of current through said first plurality of tubes whereby to maintain constant the flow of current through said other conductive paths including said voltage stabilizing device so as to allot all of said range of current values at constant voltage drop to accommodation of current variations resulting from voltage variations in said voltage source.

5. In an electrical system, a source of direct-current voltage having positive and negative output conductors, a plurality of conductive devices having non-linear voltage current characteristics having one terminal of each connected to said negative conductor, a plurality of conductive devices having non-linear voltage current characteristics having one terminal of each connected to said positive conductor, a conductor connected to the other terminal of each of said conductive devices and established by said devices at a potential intermediate the potentials of said positive and negative conductors, a plurality of other conductive paths extending between said negative and intermediate potential conductors including a voltage stabilizing device adapted to fix the potential of said intermediate conductor relative to said negative conductor, means for cutting off the flow of current through the first-mentioned conductive devices connected between said negative and intermediate potential conductors, and means automatically responsive to the cutting off of said current for reducing the flow of current through the conductive devices connected between said positive and intermediate potential conductors by the same amount.

6. In an electrical system, a source of direct-current voltage having positive and negative output conductors, a plurality of conductive devices having non-linear voltage-current characteristics having one terminal of each connected to said negative conductor, a plurality of conductive devices having non-linear voltage-current characteristics having one terminal of each connected to said positive conductor, a conductor connected to the other terminal of each of said conductive devices and established by said devices at a potential intermediate the potentials of said positive and negative conductors, a plurality of other conductive paths extending between said negative and intermediate potential conducors including a voltage stabilizing device having a constant voltage drop for a predetermined range of current values and adapted to fix the potential of said intermediate conductor relative to said negative conductor, means for cutting off the flow of current through the first-mentioned conductive devices connected between said negative and intermediate potential conductors, and means automatically responsive to the cutting off of said current for reducing the flow of current through the conductive devices connected between said positive and intermediate potential conductors by the same amount.

7. In an electrical system, a source of direct-current voltage having positive and negative output conductors, a plurality of conductive devices having non-linear voltage-current characteristics having one terminal of each connected to said negative conductor, a plurality of conductive devices having non-linear voltage-current characteristics having one terminal of each connected to said positive conductor, a conductor connected to

the other terminal of each of said conductive devices and established by said devices at a potential intermediate the potentials of said positive and negative conductors, a plurality of other conductive paths extending between said negative and intermediate potential conductors including a voltage stabilizing device having a constant voltage drop for a predetermined range of current values and having its current adjusted to substantially the mid-point of said range of current values, said stabilizing device being adapted to fix the potential of said intermediate conductor relative to said negative conductor, means for cutting off the flow of current through said first-mentioned conductive devices connected between said negative and intermediate potential conductors, and means automatically responsive to the cutting off of said currents for reducing the flow of current through the conductive devices connected between said positive and intermediate potential conductors by the same amount whereby to maintain constant the flow of current through said other conductive paths including said voltage stabilizing device.

8. In an electron discharge tube system, a plurality of normally conductive electron discharge tubes having their space discharge paths in parallel, an electron discharge tube having its space discharge path in series with the first-mentioned electron discharge tubes for supplying the space discharge current drawn by said first-mentioned tubes, a plurality of other conductive paths in parallel with said first-mentioned tubes, means for rendering said first-mentioned tubes non-conductive, and means controlled by the last-mentioned means for rendering said second-mentioned tube non-conductive whereby to maintain constant the current through said other conductive paths.

9. In an electron discharge tube system, a plurality of normally conductive electron discharge tubes having their space discharge paths in parallel, a plurality of other conductive paths in parallel with said tubes including a voltage stabilizing device, an electron discharge tube having its space discharge path in series with said first-mentioned tubes and said other conductive paths for supplying the space discharge current drawn by said first-mentioned tubes, a plurality of other conductive paths in parallel with said second-mentioned tube for supplying current drawn by the first-mentioned other conductive paths, means for rendering said first-mentioned tubes non-conductive, and means controlled by the last-mentioned means for rendering the second-mentioned tube non-conductive whereby to maintain constant the current drawn through said second-mentioned other conductive paths by said first-mentioned other conductive paths including said voltage stabilizing device.

10. In an electron discharge tube system, a plurality of normally conductive electron discharge tubes having their space discharge paths in parallel, a plurality of other conductive paths in parallel with said tubes including a voltage stabilizing device, a normally conductive electron discharge tube having its space discharge path in series with said first-mentioned tubes and said other conductive paths for supplying the space discharge current drawn by said first-mentioned tubes and part of the current drawn by said other conductive paths, a plurality of other conductive paths in parallel with said second-mentioned tube including a plurality of electron discharge tubes at least one of which is normally conductive for supplying the remainder of the current drawn by said first-mentioned other conductive paths, means for rendering said first-mentioned tubes non-conductive, means controlled by the last-mentioned means for rendering said second-mentioned tube non-conductive and the non-conductive one of the other tubes in parallel therewith conductive to the extent of the part of the current for said first-mentioned other conductive path previously carried by said second-mentioned tube whereby to maintain constant the current drawn through said second-mentioned other conductive paths by said first-mentioned other conductive paths including said voltage stabilizing device.

11. In an electrical system, a source of direct-current voltage having positive and negative supply conductors, a plurality of circuit paths each having one terminal connected to said negative conductor and including a conductive element, a plurality of other circuit paths each having one terminal connected to said positive conductor and including a conductive element, a conductor connected to the other terminal of each of said paths and established thereby at a potential intermediate the potentials of said positive and negative conductors, a voltage stabilizing device comprising the only conductive element in at least one of said first-mentioned paths adapted to fix the potential of said intermediate conductor relative to said negative conductor, means for cutting off the flow of current through at least one of said first-mentioned paths excluding any containing a voltage stabilizing device, and means automatically responsive to the cutting off of said current for reducing the flow of current between said positive and intermediate conductors through said second-mentioned paths by the amount of current cut off as set forth above.

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