Sept. 19, 1950 H. L. GLICK 2,523,247

TUBE CONTROL APPARATUS

Filed Dec. 17, 1948

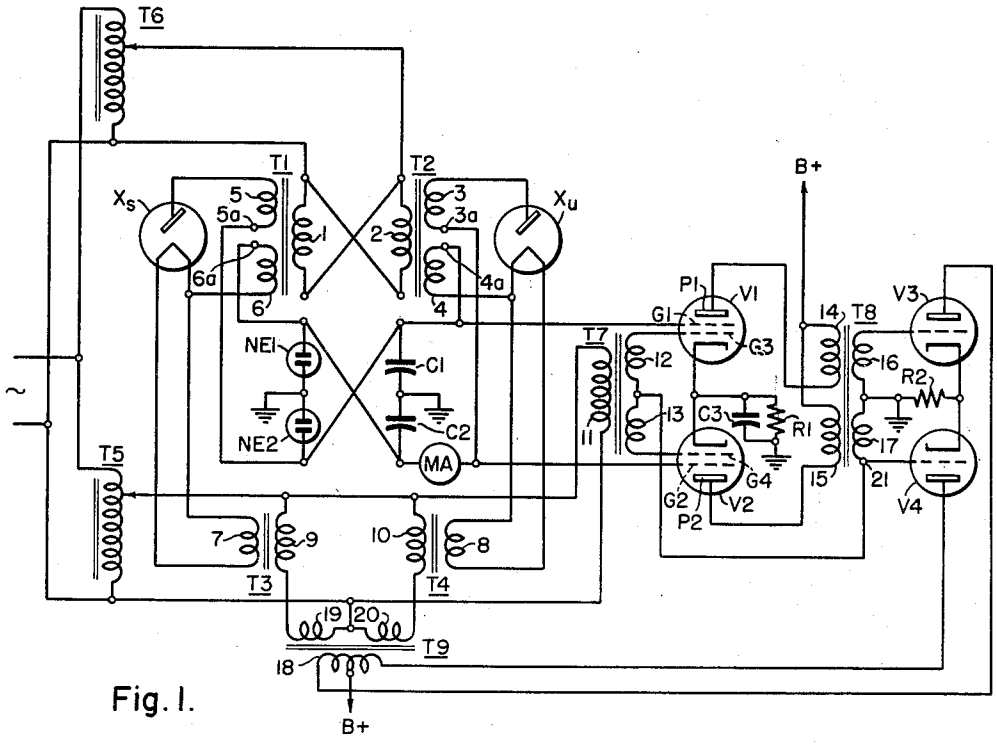


Fig. 1.

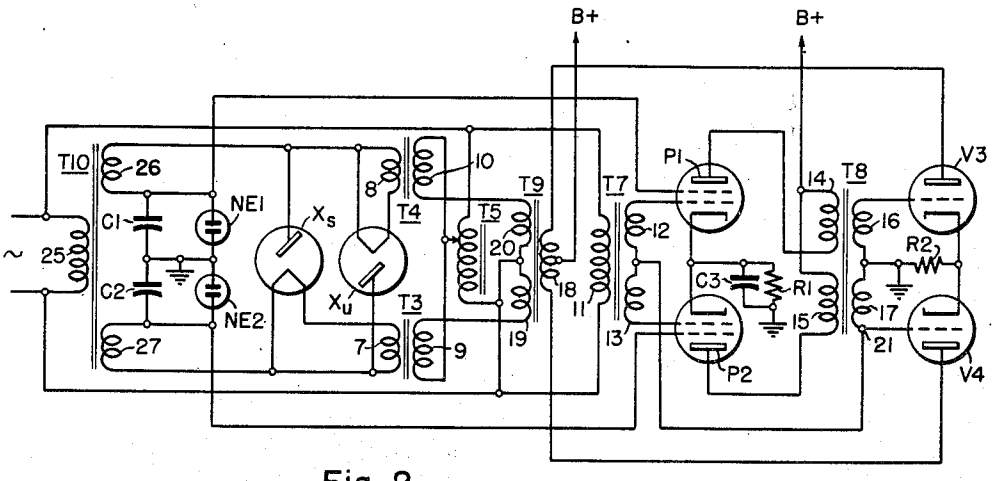


Fig. 2.

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Patented Sept. 19, 1950

2,523,247

UNITED STATES PATENT OFFICE

2,523,247

TUBE CONTROL APPARATUS

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Application December 17, 1948, Serial No. 65,946

7 Claims. (Cl. 250—94)

1

This invention relates to a control apparatus for electronic tubes and more in particular to a control for equalizing the emission of two temperature limited filaments.

In the application of electronic tubes in various types of control apparatus it is frequently necessary to operate such tubes in pairs. When this is done, it is usually necessary, for proper operation, that the tubes be matched in certain respects.

In the application of X-ray tubes to sheet thickness measurement, the general practice is to provide two tubes, the beam of one of which irradiates the strip the thickness of which is to be measured, and the beam of the other of which irradiates the standard. Thickness measurements are determined by the absorption of the X-ray beam in the material irradiated thereby, and when two tubes are employed having the beam intensities thereof properly matched, comparison of the resulting beams, one of which is the standard, provides an indication of the thickness of the material being inspected.

In applications wherein automatic indications of sheet thickness are to be obtained from the differences in the intensities of the two X-ray beams, and particularly if a null measuring system is employed, it is necessary that the two beams be matched fairly well as to their intensities. Otherwise, errors in the resulting indication may occur.

Accordingly, it is an object of this invention to provide a control for electronic tubes whereby selected characteristics of at least a pair of such tubes are controlled in a predetermined manner.

More specifically, it is an object of this invention to provide a system of the character mentioned in which a control of emission currents of the tubes is obtained.

Still more specifically, it is an object of this invention to provide a system of the character referred to embodying a pair of X-ray tubes in which emission currents are controlled as a function of the difference of emission currents between the tubes.

The foregoing statements are merely illustrative of the various aims and objects of this invention. Other objects and advantages will become apparent from a study of the following disclosure when considered in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic illustration of an electrical system embodying the principles of this invention, and

2

Fig. 2 is a diagrammatic illustration of a modification of the circuit system of Fig. 1.

A requirement of an X-ray thickness gauge employing two X-ray tubes is that the target to filament currents, known as the emission currents, of the two X-ray tubes shall be equal. These tubes are operated under such conditions of filament temperature and target to filament voltage that the emission current is dependent only on filament temperature which in turn may be controlled by filament voltage. An example of a system employing X-ray tubes in this manner appears in the co-pending application of the applicant, Serial No. 65,945, filed on the same day as this application and entitled Continuous Strip Tester. With a system as briefly noted above, any emission equalizer must vary the filament temperatures until the emission currents are equal. As the filament characteristics change with time, the equalizer must operate continuously.

The energizing circuit arrangement for each of the tubes herein disclosed is a conventional circuit for a self-rectified X-ray tube and in each instance embodies a high-voltage transformer giving the required target to filament voltage which may be varied by changing the variable transformer associated therewith. Filament temperature and emission currents are adjusted by means of a second transformer feeding a step-down transformer connected with the filament of the tubes. The emission current of the tube is measured by means of a D. C. milliammeter, connected between the secondary windings of the high potential transformer.

Referring specifically to Fig. 1, the X-ray tubes therein employed are designated respectively X_s and X_u. The tube X_u, in a normal thickness measuring apparatus, would irradiate the material or strip being tested, while the beam of the X-ray tube X_s irradiates a standard material. Thereafter the beams are compared as generally described hereinbefore to obtain an indication of the strip thickness. In such an application it is convenient to operate the X-ray tubes on alternate half cycles of the energizing alternating current voltage so that the intensity of the respective beams may be separately viewed by suitable X-ray sensitive apparatus. This alternate operation is accomplished by providing separate high voltage transformers T1 and T2, the respective primaries of which, 1 and 2, are connected in a reversed sense with a suitable control transformer T6 energized from the source of alternating current indicated by the sinusoi-

dal waves. The transformer T6 is provided with a suitable tap so that the target to filament voltage of the X-ray tubes may be set at the desired value. Thus, with one half cycle of alternating current, it will be appreciated that the voltage on winding 1, for example, will be in a direction that the target potential is above the filament potential. As a consequence, the tube X_s will conduct. At this same instant, due to the reversal of the connection of the transformers, the voltage of the primary winding 2 of the transformer T2 will be in such a direction that the potential of the filament voltage of the tube X_u will be above the potential of the target of that tube. As a consequence, the tube X_u will not conduct in that half cycle. In the next half cycle of alternating current this condition is reversed and the tube X_s is cut off while the tube X_u becomes conducting.

The secondary winding system of each of the transformers T1 and T2 includes a pair of windings. For the transformer T2 these windings are designated 3 and 4. One side of the winding 3 is connected to the target of the tube X_u and one side of the winding 4 is connected to the filament of the tube. The remaining terminals 3a and 4a of the secondary windings 3 and 4 are connected across a pair of series connected capacitors C1 and C2, the two common terminals of which are connected to ground. The secondary windings 5 and 6 of the transformer T1 are connected in a manner similar to the secondary windings 3 and 4 of transformer T2, one terminal of the winding 5 being connected to the target of the tube X_s and one terminal of the winding 6 being connected to the filament of the tube X_s. The remaining terminals 5a and 6a are connected across a pair of series connected gas tubes NE1 and NE2, the common terminals of which are grounded and the terminals 5a and 6a are then connected in reversed order across the capacitors C1 and C2. The filament voltages for the tubes X_s and X_u are supplied respectively by the transformers T3 and T4, the secondary windings 7 and 8 of which are connected across the respective filaments of X-ray tubes. Energizing voltage for these filament transformers is provided by means of a transformer T5 having an adjustable tap and this transformer is connected across the source of alternating current.

By reason of the grounding of the common terminals of the capacitors C1 and C2, the terminals 3a and 4a of the secondary windings 3 and 4 and the terminals 5a and 6a of the secondary windings 5 and 6 are maintained at ground A. C. potential, but the circuit system provides for the circulation of the rectified currents of the X-ray tubes, and these rectified currents must flow through both secondary windings of each of the transformers T1 and T2 and through both X-ray tubes in series. Such a circuit may be traced beginning at the terminal 5a and following through the secondary winding 5 to the target of the tube X_s, thence to the filament of this tube and through the secondary winding 6 to the outer terminal of the gas-filled tube NE1, thence to the outer terminal of the capacitor C2 through the milliammeter MA and the secondary winding 3 to the target of the tube X_u. From the target of this tube the circuit is traceable to its filament and through the secondary winding 4 to the outer terminal of the capacitor C1 and the outer terminal of the gas-filled tube NE2 and thence back to the terminal 5a to complete the series circuit. Thus, it will be appreciated that the rectified currents of both of the tubes flow through a series circuit and that these currents are employable in charging of the capacitors C1 and C2 in one direction or the other, depending upon which of the tubes has the greater emission current. If the emission of one X-ray tube filament is less than that of the other, the current difference between the two tubes will charge the capacitors C1 and C2 to a D. C. potential, the polarity of this D. C. potential depending upon which X-ray tube has the greater emission. This potential appears across the grids G1 and G2 of the two vacuum tubes V1 and V2, and thus affords a control of the output of each of these tubes. The cathode circuit of the tubes V1 and V2 conventionally includes the capacitor C3 and the resistor R1 in parallel, and this circuit is grounded.

The circuit connections for the tubes V1 and V2 include a transformer T7, having a primary winding 11, which, as illustrated, is connected across the transformer T5. In view of this connection, adjustments of the tap of transformer T5 produce changes in voltage across the primary winding 11. This may be obviated, if necessary, by connecting the primary winding 11 directly to the source of alternating current. The transformer T7 includes a pair of secondary windings 12 and 13, the inner terminals of which are connected together and the outer terminals of which are respectively connected to the grids G3 and G4 of the vacuum tubes V1 and V2. With this arrangement, an alternating voltage control is imposed upon the tubes V1 and V2, such that the instantaneous polarity of the potential, or phase of the potential, on the grid G1 is opposite to that on G2. The tubes V1 and V2 amplify the alternating current voltages on their respective grids G1 and G2, the magnitude of the alternating current output of V1 being controlled by the essentially D. C. voltage on the grid G1 and the alternating current output of V2 being controlled by the essentially D. C. voltage on G2. The plate circuits of the tubes V1 and V2 include the primary windings 14 and 15 of the transformer T8, the plates P1 and P2 being connected to the lower ends of the windings 14 and 15, respectively. Plate voltage is supplied to this plate circuit at the upper ends of both windings from the source designated B+. It will be appreciated that since the phase of the A. C. voltage on G1 is opposite to that on G2, the phase of the alternating current through the tube V1 and the winding 14 of T8 will be opposite in phase to the alternating current through the tube V2 and the winding 15 of T8, but these currents will generally be of different magnitude. It will be further appreciated that the effective current in the windings 14 and 15 will be the algebraic sum of the currents in these windings, and that this effective current will have the phase sense of the larger of the two currents. By means of these currents the tubes V1 and V2 control a second set of amplifier tubes V3 and V4 in one embodiment of my invention. In this embodiment the transformer T8 includes a pair of secondary windings 16 and 17 having their inner ends connected together to ground and their outer ends connected to the respective grids of the tubes V3 and V4. An electrical connection is made from the lower end 21 of the winding 17 of T8 to the common connection of the windings 12 and 13 of T7, thus giving inverse feedback to the tubes V1 and V2 which has the well known effect of reducing amplifier distortion. The cathodes of these two

tubes are grounded through the resistor R2, and the plates of the tubes V3 and V4 are connected across the primary winding 18 of the transformer T9, plate voltage designated B+ being applied to a center tap of this primary winding.

The voltage appearing across the primary winding T9 in magnitude corresponds to the amount of correction required to restore the emission currents of the tubes X_s and X_u to equal levels. The instantaneous phase relation of this voltage with respect to the source of alternating current indicates the sense or direction in which the correction must be made to achieve equality of emission currents. This control voltage is introduced into the filament transformer circuits by means of the secondary windings 19 and 20 of the control transformer T9 which are respectively connected in series with the primary windings 9 and 10 of filament transformers T3 and T4 across the tapped portion of the filament control transformer T5. Thus, for example, the voltage of the secondary winding 19 for one condition of correction will add to the voltage of the winding 9, while the voltage of the winding 20 for the assumed condition will substract from that of the winding 10. For this assumed condition, the voltage applied to the filament of the tube X_s will be increased while that supplied to the tube X_u will be decreased. Since the filament temperature is a function of the voltage applied to the filament, it will be appreciated that the filament having the higher voltage will operate at the higher temperature and as a consequence, its emission will be the greater. Thus, for the assumed condition, the emission of the tube X_s was less than that of the tube X_u and the correction in this instant is of a magnitude and a direction to oppositely vary the emission currents in the direction of zero difference. In a second embodiment of my invention, the tubes V3 and V4, and the transformer T9 are left out, and the windings 16 and 17 of T8 are connected directly in place of the windings 20 and 19 of T9. These changes merely change the sensitivity of the system, but do not change the principles of my invention.

The modification of the invention illustrated in Fig. 2 differs from that of Fig. 1 only in the sense that a single high voltage transformer is provided to energize the tubes X_s and X_u. In this embodiment of the invention the high voltage transformer is designated T10. Its primary winding 25 is connected to the source of alternating current and its two secondary windings 26 and 27 are connected across the two X-ray tubes. As before, the common terminals of the windings 26 and 27 are connected across the capacitors C1 and C2 and similarly are connected across the tubes NE1 and NE2, the common terminals of the capacitor and the tubes being grounded. The remainder of this circuit system corresponds to that illustrated in Fig. 2 and its function is the same as that of Fig. 1. Accordingly, the preceding description of this aspect of the circuit applies equally in Fig. 2, and further description thereof in that connection is deemed unnecessary.

The circuit connections which are now provided for energizing the two X-ray tubes again afford alternate operation of the tubes. This will be appreciated upon a consideration of the function for a full cycle of alternating current. For the first half cycle, let it be assumed that the potential across the secondary windings 26 and 27 places the target of the tube X_s at a higher potential than the filament. Thus tube X_s conducts, but since the tube X_u is inverted in this circuit, its filament is above its target in potential and the tube is therefore non-conducting. In the next half cycle of alternating current the voltage across the tubes reverses and the target of the tube X_u is at a potential higher than its filament and is thus conducting while the filament of the tube X_s is at a potential higher than its target and is non-conducting. Thus, the tubes are conducting on alternating half cycles.

The discharge tubes NE1 and NE2 are provided as a safety measure in each of the circuits. In case of circuit failure, the tubes NE1 and NE2 break down and become conducting. This prevents excessive voltage from building up upon the capacitors C1 and C2.

While three embodiments of this invention have been illustrated, it will be appreciated that one skilled in the art, particularly after having had the benefits of the teachings of this disclosure, may produce other devices differing in detail but not in principle. Thus, it is intended that the foregoing disclosure and the showings made in the drawing shall be considered only as illustrative and not interpreted in a limiting sense.

I claim as my invention:

1. Apparatus for controlling the filament voltages of a pair of tubes each having an anode and a filament comprising, in combination, circuit means connecting the anode of one tube to the filament of the other tube and the anode of said other tube to the filament of said one tube to provide a series circuit for the emission currents of said tubes, circuit means electrically connected with said series circuit for applying energizing voltages to said tubes, capacitor means connected across said series circuit and having a common terminal thereof grounded, a control voltage circuit connected to each filament for energizing the filament of each tube, and circuit means electrically connected across said capacitor means to respond to the voltage across said capacitor means for increasing the voltage of one control voltage circuit while decreasing the voltage of the other control voltage circuit.

2. Apparatus for controlling the filament voltages of a pair of tubes each having an anode and a filament comprising, in combination, circuit means connecting the anode of one tube to the filament of the other tube and the anode of said other tube to the filament of said one tube to provide a series circuit for the emission currents of said tubes, circuit means electrically connected with said series circuit for applying energizing voltages to said tubes, a pair of capacitors connected in series across said series circuit, circuit means grounding the common terminals of said capacitors, a control voltage circuit connected to each filament for energizing the filament of each of said tubes, and circuit means electrically connected across said capacitors to respond to the voltage across said capacitors for increasing the voltage of one control voltage circuit while decreasing the voltage of the other control voltage circuit.

3. Apparatus for controlling the filament voltages of a pair of X-ray tubes each having a target and a filament comprising, in combination, circuit means connected with the target and filament of each X-ray tube for applying energizing A. C. voltages to said tubes to effect operation

thereof on alternate half cycles of alternating current, circuit means connecting said target and said filament of each X-ray tube in a common series circuit, so that the emission currents of said tubes flow in said series circuit, a pair of capacitors connected in series across said series circuit, circuit means grounding the common terminals of said pair of capacitors, control circuit means for energizing the filament of each X-ray tube, and circuit means responsive to the voltage across said capacitors for controlling said control circuit means.

4. Apparatus as set forth in claim 3 in which said control circuit means comprises a pair of transformers each having a primary and a secondary winding, the secondary winding of each of said transformers being connected across the associated one of said filaments, a control transformer having a primary winding and a pair of secondary windings, circuit means connecting a secondary winding of the control transformer in series with the primary winding of one of said pair of transformers so that each primary winding of each of the pair of transformers is connected in series with the corresponding secondary winding of the control transformer, circuit means for applying alternating current across said series connected windings and circuit means connecting said primary winding of said control transformer to be energized in dependence of the voltage across said capacitors.

5. Apparatus for controlling the filament voltages of a pair of tubes each having an anode and a filament comprising, in combination, a pair of transformers each having a primary winding and at least one secondary winding, circuit means including the secondary winding of each transformer connecting the anodes and filaments of said tubes in a series loop, circuit means connecting the primary windings of said transformers together and providing for the common connection of said transformers to a source of alternating current, the phase relation of the secondary winding voltages in said series loop energizing one tube while blocking the other and energizing said other tube while blocking said one tube on successive half cycles of alternating current, impedance means connected across said series loop to respond to the difference of emission currents of said tubes and produce an electrical quantity in dependence thereof, an energizing circuit for each filament connected to the filament of each of said tubes, and circuit means for applying said electrical quantity to each energizing circuit.

6. Apparatus for controlling the filament voltages of a pair of tubes each having an anode and a filament comprising, in combination, a pair of transformers each having a primary winding and at least one secondary winding, circuit means including the secondary winding of each transformer connecting the anodes and filaments of said tubes in a series loop, circuit means connecting the primary windings of said transformers together and providing for the common connection of said transformers to a source of alternating current, the phase relation of the secondary winding voltages in said series loop energizing one tube while blocking the other and energizing said other tube while blocking said one tube on successive half cycles of alternating current, impedance means connected across said series loop to respond to the difference of emission currents of said tubes and produce and electrical quantity in dependence thereof, an energizing circuit for each filament connected to the filament of each of said tubes, and circuit means for applying said electrical quantity to one energizing circuit in an aiding sense and to the other energizing circuit in an opposing sense.

7. Apparatus for controlling the filament voltages of a pair of tubes each having an anode and a filament comprising, in combination, circuit means connecting said anodes and filaments of said tubes in a series loop, circuit means adapted for connection to a supply of alternating current and electrically connected with said series loop for applying an energizing voltage to one tube and a blocking voltage to the other tube on one half cycle of alternating current and an energizing voltage to said other tube and a blocking voltage to said one tube on the other half cycle of alternating current, circuit means electrically connected with said series loop to respond to the difference of emission currents of said tubes and produce an electrical quantity in dependence thereof, an energizing circuit connected with each filament for applying an alternating current voltage to the corresponding filament, and circuit means responsive to said electrical quantity and electrically connected with each energizing circuit for applying said electrical quantity in aiding relation in one energizing circuit and in a subtractive relation in the other energizing circuit.

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