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TANDEM X-RAY TUBE STABILIZER

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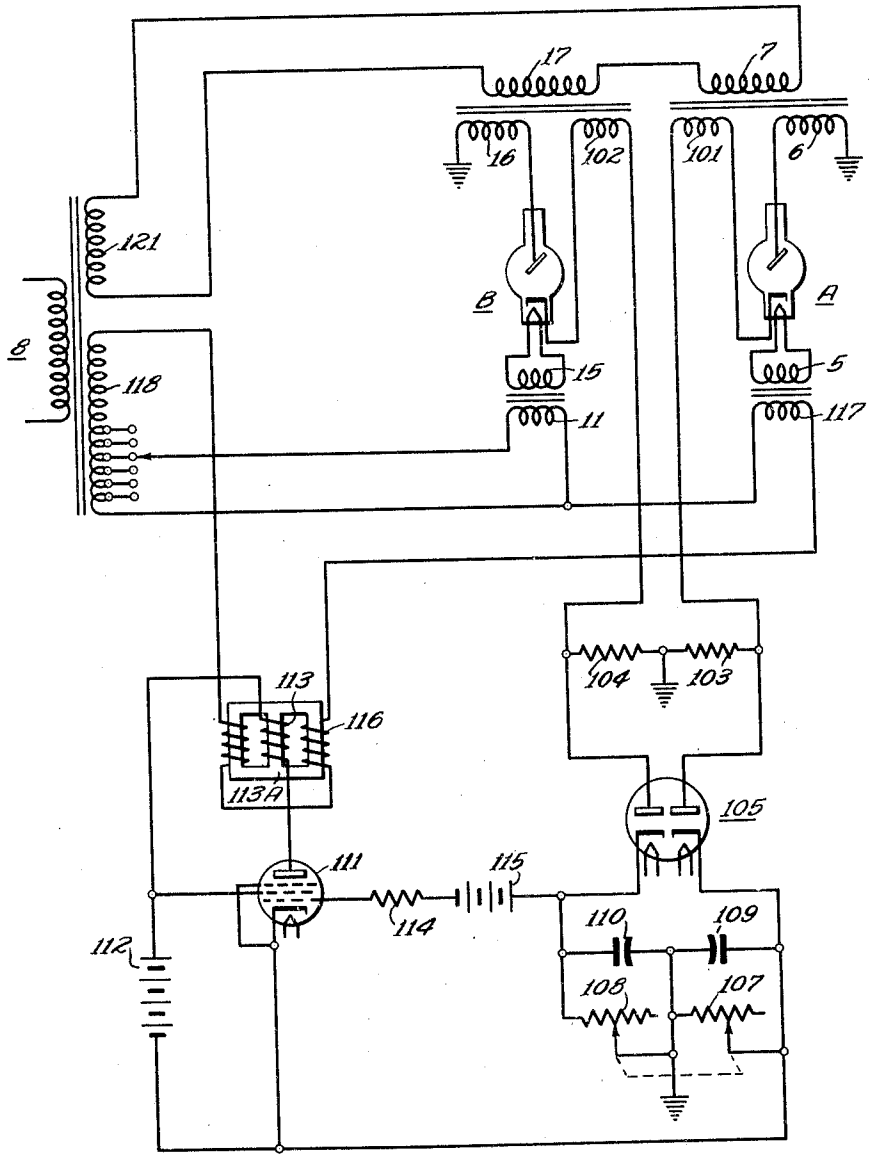

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TANDEM X-RAY TUBE STABILIZER

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Our invention relates to an arrangement for insuring maintenance of a constant ratio between the anode currents of two X-ray tubes or other hot cathode electrical discharge tubes fed with alternating current. For certain purposes, such as operating the two X-ray tubes of the X-ray thickness gauge, such as is described in Walter N. Lundahl application Serial No. 25,953 for an X-ray thickness gauge, filed concurrently herewith, it is desirable to maintain a constant ratio between the anode currents of two hot cathode electrical discharge devices under circumstances in which the ratio of these anode currents would normally tend to vary from time to time by reason of changes in the electron emissivity of the cathodes or in the voltages used to energize the cathodes or the anodes. Our invention provides a circuit network by which the cathode temperatures are varied to compensate for any deviation from a predetermined value in the above-mentioned ratio. In particular, for the Lundahl X-ray thickness gauge, the ratio is to be maintained at a constant value of unity.

One object of our invention is, accordingly, to provide a novel and improved arrangement for maintaining a constant ratio between the anode currents of two hot cathode electrical discharge tubes.

Another object of our invention is to provide an improved arrangement for varying the heating current in the cathode of one of a pair of hot cathode electrical discharge tubes to maintain a constant ratio between their anode currents.

Still another object of our invention is to provide an improved arrangement for simultaneously operating a pair of X-ray tubes to maintain a constant ratio between the magnitudes of their anode currents.

Other objects of our invention will become apparent upon reading the following description, taken in connection with the drawing, in which the single figure shows a pair of X-ray tubes operated from a source of alternating current voltage and provided with a regulating device embodying the principles of our invention.

Referring in detail to the drawing, a pair of X-ray tubes A and B is arranged to be energized from a single alternating-current source 8. The X-ray tubes A and B are preferably similar to each other and are provided with electron-emissive cathodes heated, respectively, by alternating currents from a pair of secondary windings 5 and 15. The anodes of the X-ray tubes A and B are, respectively, supplied with voltage by a pair of secondary transformer windings 6 and 16, each

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having one end grounded. Energy is supplied from the alternating-current source 8 to the secondary winding 5 through a primary winding 117 and to the secondary winding 15 through a primary winding 11, the latter of which is connected to receive energy from a variable tap on the transformer 118 energized by the alternating-current source 8. The secondary windings 6 and 16 are, respectively, energized from the alternating-current source 8 through the agency of primary windings 7 and 17 energized from said source through a primary winding 121.

Thus the cathodes of the X-ray tubes A and B are, respectively, connected to the grounded terminals of the transformer secondaries 6 and 16 which supply these tubes with anode voltage through control windings 101 and 102 positioned on the magnetic cores of the respective transformer primaries 7 and 17. In series with the windings 101 and 102 are two equal resistors 103 and 104 having their opposite terminals connected to the anodes of a pair of substantially identical diode rectifiers which may conveniently be embodied in an electron tube 105. The cathodes associated in the tube 105, respectively, with the above-mentioned anodes are connected to ground through a pair of similar variable resistors 107 and 108 which are, respectively, shunted by capacitors 109 and 110.

One cathode of the double diode 105 is connected to the cathode of an amplifier tube 111 having an anode supplied with current from a voltage source 112 through a winding 113 positioned on a magnetic core 113A to control the degree of saturation thereof. The control electrode of the tube 111 is connected to the other cathode of the double diode 105 through a resistor 114 and a bias battery 115.

It will be evident, upon examination, from the above description that the anode current of the X-ray tube A will flow to earth through the resistor 103 and the channel which is in parallel with resistor 103 and which comprises the right-hand diode in the tube 105 and the resistor 107. Similarly, the anode current of the X-ray tube B will flow to earth through the resistor 104 and the channel comprising the left-hand diode in the tube 105 and the resistor 108. It will be clear that when the anode current of the X-ray tubes A and B are equal to each other, the potential drops in the resistors 103 and 104 are equal and opposite to each other and correspondingly the potential difference between the opposite terminals of the resistors 107 and 108 is zero. The latter potential difference, in series with the bias

voltage source 115 and the resistor 114 is impressed between the cathode and the control electrode of the amplifier tube 111 and will fix the value of the direct current in the winding 113 which controls the saturation of the magnetic core 113A for the winding 116. The said core and the winding 116, accordingly, constitute a saturable reactor controlled in value by the direct current through the tube 111 and variation of the latter will, accordingly, control the voltage impressed on the primary winding 117 from the source 118. The net result of the foregoing situation is that the potential difference between the opposite terminals of the resistors 107 and 108 will control the cathode temperature of the X-ray tube A.

The initial value of the heating current for the cathode of either the tube A or B may be initially adjusted by varying the voltage sources 112 or 115 or by varying the tap point on the transformer 118 so that the anode currents of the X-ray tubes A and B have the desired equal values at which they are to be maintained. If thereafter the anode current of the tube A increases above the value of the anode current of the tube B a potential difference will be produced across the outside terminals of the resistors 107 and 108 which will make the control grid of the tube 111 less positive thereby decreasing current flow through the winding 113. The winding is so poled as to decrease the saturation in the magnetic core for the winding 116 thereby increasing its reactance and decreasing the heating current for the cathode of X-ray tube A. In consequence, the anode current of the tube A will decrease to substantial equality with that of the X-ray tube B.

Should the anode current of the X-ray tube A become smaller than that of the X-ray tube B, the opposite effects on the amplifier tube 111 and the reactance of the winding 116 to those above described will obviously follow, with the result that the anode current of the X-ray tube A will be raised to equality with that of the X-ray tube B. Our stabilizer is thus an effective agency to maintain equality of currents at all times through two electron tube circuits, such as those of the X-ray tubes A and B. It will be noted that the interposition of the diode rectifiers in tube 105 ahead of the resistors 107 and 108 insures that any alternating current due to distributed capacitance between the windings of the transformers supplying power to X-ray tubes A and B will be excluded from effect on the grid potential of the amplifier tube 111. The capacitors 109 and 110 filter out any ripples in the voltages impressed by the anode currents of the two X-ray tubes A and B across the resistors 107 and 108.

While we have described the anode currents of the X-ray tubes A and B as maintained at a constant ratio of unity, it will be obvious that any other ratio may be maintained between these anode currents by appropriately changing the value of the resistors 103 and 104. Thus, if it is desired that the ratio of the anode current in the tube A to the anode current in the tube B shall be maintained at a constant value N, the ratio of the value at the resistor 104 to resistor 103 should be N.

It will likewise be obvious that while we have described our invention as applied to control of the anode currents of X-ray tubes, it may be applied to the control of the anode currents of any electrical discharge tubes having electrically-heated thermionically-emissive cathodes.

We claim as our invention:

1. In combination with a pair of X-ray tubes each having a thermionically-emissive cathode heated by electric current, a circuit supplying heating current to one of said cathodes and embodying a reactor having a saturable magnetic core, a saturating winding on said core, an electrical discharge tube provided with a control electrode supplying direct current to said saturating winding, a pair of first resistors respectively traversed by the anode current of said X-ray tubes, and having a common terminal, a channel comprising a rectifier in series with a second resistor shunted across each said first resistor, and means for impressing a voltage equal to the difference in the voltage drops through said second resistors on the control electrode of said discharge tube, to cause the latter to vary the direct current supplied to said saturating winding with attendant variation in the heating current supplied to the thermionic cathode of one of said X-ray tubes to maintain a constant anode current ratio of unity between said pair of X-ray tubes.

2. In combination with a pair of X-ray tubes each having a thermionically-emissive cathode heated by electric current, a circuit supplying heating current to one of said cathodes and embodying a reactor having a saturable magnetic core, a saturating winding on said core, an electrical discharge tube provided with a control electrode supplying direct current to said saturating winding, a pair of first resistors respectively traversed by the anode current of said X-ray tubes, and having a common terminal, a channel comprising a rectifier in series with a second resistor, which is shunted by a capacitor, shunted across each said first resistor, and means for impressing a voltage equal to the difference in the voltage drops through said second resistors on the control electrode of said discharge tube, to cause the latter to vary the direct current supplied to said saturating winding with attendant variation in the heating current supplied to the thermionic cathode of one of said X-ray tubes to maintain a constant anode current ratio of unity between said pair of X-ray tubes.

3. In combination with a pair of electrical discharge tubes each having a cathode heated by electric current, a circuit for supplying current to one of said cathodes and embodying an impedance provided with a regulating winding, an electron tube provided with a control electrode controlling current flow through said winding, a pair of first resistors having a common terminal and respectively connected to carry the anode currents of said two electrical discharge tubes, each said first resistor being shunted by a channel comprising a rectifier in series with a second resistor, and means for impressing on said control electrode a voltage proportional to the difference in potential drops produced by current flow through said rectifiers in said second resistors, to cause the latter to vary the direct current supplied to said saturating winding with attendant variation in the heating current supplied to the thermionic cathode of one of said X-ray tubes to maintain a constant anode current ratio of unity between said pair of X-ray tubes.

4. In combination with a pair of electrical discharge tubes each having a cathode heated by electric current, a circuit for supplying current to one of said cathodes and embodying an impedance provided with a regulating winding, an electron tube provided with a control electrode

controlling current flow through said winding, a pair of first resistors having a common terminal and respectively connected to carry the anode currents of said two electrical discharge tubes, each said first resistor being shunted by a channel comprising a rectifier in series with a second resistor which is shunted by a capacitor, and means for impressing on said control electrode a voltage proportional to the difference in potential drops produced by current flow through said rectifiers in said second resistors, to cause the latter to vary the direct current supplied to said saturating winding with attendant variation in the heating current supplied to the thermionic cathode of one of said X-ray tubes to maintain a constant anode current ratio of unity between said pair of X-ray tubes.

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