

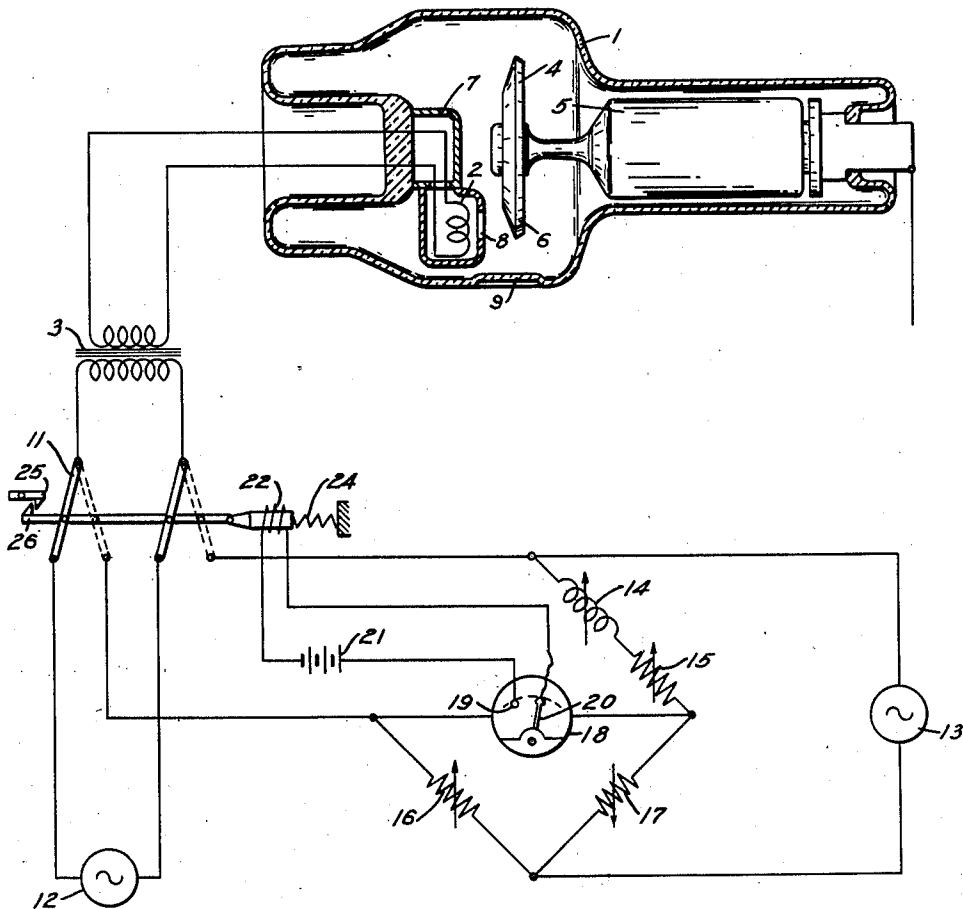
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METHOD OF PROTECTING ROTATING ANODE X-RAY TUBES

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WITNESSES:

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METHOD OF PROTECTING ROTATING
ANODE X-RAY TUBES

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My invention relates to X-ray tubes and, in particular, relates to protecting the anodes of such tubes from overheating.

In certain types of X-ray tubes, such as are illustrated in the attached drawing, the anode comprises a disk which is kept in continuous rotation by an electric motor in order that by continual exposure of a new portion of its surface to the impact of the electrons coming from the cathode, local heating at the point of incidence of the electron stream shall be minimized. Such tubes are adapted to operate with electron streams of much higher energy concentration than are tubes which employ stationary anodes. Even in such tubes, it is impossible, under some desired conditions of use, to maintain an electron stream in flow continuously or for a protracted time, but it suffices for most uses to be able to radiate the X-rays for a short period. The anode thus absorbs energy at a rapid rate during the short period in which the X-rays are turned on, and in the interval of non-use following thereafter, the heated portion of the anode is able to cool off substantially. However, after several short-interval exposures have been taken, separated by only moderate intervals of time, the general anode temperature has been so raised by heat which has not had time to be dissipated that further immediate use of the X-rays would cause overheating of the anode.

By determining the general surface temperature of the anode, it is possible to tell whether this dangerous general heating has occurred to such an extent as to render immediate use of the tube for X-ray production unsafe.

It is, accordingly, one object of my invention to provide means for determining the general surface temperature of the portion of the anode on which electrons from the cathode are incident during operation of the tube.

It is another object of my invention to provide automatic means which will prevent the use of the tube for X-ray production until the anode temperature has fallen to such a value as would make immediate operation for X-ray production safe.

Other objects of my invention will become apparent upon reading the following specification taken in connection with the drawing, in which the single figure is a schematic view showing an X-ray tube of the rotating anode type in section, together with circuit connections adapted to carry out my invention.

Referring to the drawing, an X-ray tube 1 of conventional rotating-anode type is provided with

a cathode 2 which is adapted to be raised to electron-emitting temperature by current flowing from a transformer 3. The anode 4, that is to say, the member adapted to act as a target upon which electrons from the cathode 2 impinge, is in the form of a disk adapted to be rotated about its central axis by an electric motor within the housing 5. Since the rotating anode and electric motor form no part of my invention and are well known in the art, further detailed description of them is believed to be unnecessary. The anode 4 has a beveled edge 6 which may be faced with tungsten or other metal suitable to constitute a target for X-ray production.

The cathode 2 is preferably housed within a metal enclosure 7 which has a window 8 through which electrons from the cathode 2 are attracted by the anode 4 (which is kept strongly positive in potential relative to the cathode 2 by means not shown), whereby X-rays are produced at any instant at the spot on the anode 4 on which the electron beam is incident, the X-rays being radiated through a window 9 in the wall of the tube 1. The window 8 is of oblong form, its dimension radial of the tube 1 being preferably approximately three times its circumferential width. The electrons from the cathode 2 thus impinge on a small area only of the entire beveled surface of the anode 4. As the anode 4 rotates, this area of electron-incidence thus traverses a circumferential path upon its beveled surface, and the development of heat at the anode surface is thus spread over a wide area instead of being maintained continually concentrated on one spot as in the case of stationary anode X-ray tubes. This distribution of the heat development over a wide area of the surface of the anode 4 minimizes the temperature rise at any one point and prevents the destructive heating of the surface layer of the anode.

While a certain amount of heat is radiated outward from the beveled surface of the anode 4, considerable quantities likewise flow by thermal conduction inward from the surface into the metallic body of the anode and accumulate there, being dissipated only slowly from its other surfaces. If several short but intense exposures to the electron stream are made, the general temperature of the anode 4 rises to such a value that further immediate exposure of the anode to electron incidence would cause overheating.

The mass of the cathode filament 2 is relatively small compared with that of the anode 4, and if current flow to it from the transformer 3 is cut off after an X-ray exposure, it quickly sinks to

the vicinity of room temperature. However, it is exposed to the radiation of heat from the heated anode 4 and the temperature of the cathode quickly attains a value which is fixed almost entirely by the general temperature of the beveled surface of anode 4. The resistance of tungsten or other metals suitable for the cathode is a function of their temperature at any instant, and I have found that by cutting off heating current from the cathode, permitting it to rest long enough so that its temperature is substantially determined by that of anode 4 and then measuring its resistance, I can determine with sufficient precision for practical purposes the temperature at any time of the anode 4. I am thus able to determine, after several exposures of the anode 4 to electron bombardment of short duration from the cathode 2, whether the general temperature of anode 4 is such as to render use of the X-ray tube for X-ray production safe, or whether it is necessary to wait for a time for the anode to cool further.

In order to measure the temperature of the cathode 2, I provide the primary circuit of the transformer 3 with a double-throw switch 11, in one position of which (that shown in full line in the drawing), the primary of transformer 3 is energized with current from a local source 12 for heating the cathode 2 in normal use of the X-ray tube. In the other position of the switch 11 (shown in dotted line), the primary of the transformer 3 is connected, through what amounts to an alternating-current Wheatstone bridge, to an alternating-current source 13. The above-mentioned Wheatstone bridge comprises one arm which comprises an inductance 14 and a resistance 15 in series therewith. The inductance 14 and resistance 15 are both variable and the inductance 14 is preferably set at a value approximately equal to the inductance equivalent of the leads as reflected into the primary of the transformer 3, its internal leakage inductance, the inductance of the leads from its secondary to the filament 2, and the inductance of filament 2 itself. The other two arms of the Wheatstone bridge comprise a pair of variable resistors 16 and 17 preferably equal in value. The source 13 is connected across one pair of diagonally-opposite corners of the Wheatstone bridge, while an alternating-current voltmeter 18 is connected across the other diagonally-opposite corners of the Wheatstone bridge. The Wheatstone bridge thus described may be used by methods well known in the electrical art to measure the temperature of the filament 2 and to determine thereby whether, at a suitable interval after movement of the switch 11 to disconnect the source 12 from transformer 3, it is safe to operate the X-ray tube 1.

While I have described the temperature of the cathode filament 2 as being measured by means of a Wheatstone bridge arrangement, it will be obvious that any of the other instrumentalities known in the electrical measuring art as means for measuring the resistance of an element positioned in the secondary of a transformer by readings taken on the primary circuit of the transformer may be used.

The voltmeter 18 may be provided with a contact 19 which will be closed upon its needle 20 when the latter stands at the temperature corresponding to the maximum value of the resistance of the cathode 2 at which it is safe to operate the tube 1. The contact 19 may be connected through a voltage source 21 to the ener-

gizing coil 22 of a solenoid arranged upon closure of the contacts 19 and 20 to move the switch 11 from the position in which it connects the primary of transformer 3 to the source 13 to the position in which switch 11 connects the primary of transformer 3 to source 12. A spring 24 should then be arranged to bias the switch 11 to connect the primary of transformer 3 to source 13. A latch 25, 26 adapted for manual release should be arranged to releasably retain the switch of the circuit breaker 11 in a position in which the primary of transformer 3 is connected to source 12.

The switch 11 is maintained in the last-mentioned position by the latch 25 whenever an X-ray exposure is being made and until it is desired to measure the resistance of the cathode tube. Whenever the latter desire arises, the latch 25, 26 is released and the spring 24 moves the circuit breaker 11 to connect the primary of transformer 3 to source 13. The voltmeter 18 then moves to such a position as to indicate the instantaneous temperature of the cathode 2. The latter temperature will, immediately after employment of the tube 1 for X-ray production, be so high that the needle 20 of galvanometer 18 will indicate a higher temperature than that corresponding to the position of the contact 19. As the cathode cools, the needle 20 will gradually move until it meets the contact 19, whereupon the winding 22 will be energized from source 21 to move the switch 11 back into the position in which it connects the source 12 to the primary of transformer 3; and the switch will be latched in this position through closure of the latch 25, 26. This position of the circuit breaker will then persist until the latch 25, 26 is manually reopened by the X-ray tube operator to make another measurement of the temperature of cathode 2.

While I have described the instrument 18 as a voltmeter, it will be recognized that it may be replaced by any other well known type of relay operative to close the circuit of the winding 22 when a predetermined value of voltage exists across the diagonally-opposite terminals of the Wheatstone bridge.

While I have described a particular embodiment of my invention, it will be recognized that its principles are of broader application in ways which will be evident to those skilled in the art.

I claim as my invention:

1. In combination with an electrical discharge tube having a thermionically-emissive cathode and an anode, said cathode being positioned in such proximity to said anode that its temperature is dependent upon the temperature of said anode, a transformer connected to deliver heating current for said thermionically-emissive cathode, means for connecting the primary of said transformer to an energy supply and for connecting the primary of said transformer to an instrument responsive to the resistance of the said thermionically-emissive cathode.

2. In combination with an electrical discharge tube having an anode and a thermionically-emissive cathode positioned in such proximity thereto that its temperature is dependent upon the temperature of said anode, means for measuring the temperature of said thermionically-emissive cathode when it is in a deenergized condition.

3. In combination with an electrical discharge tube having an anode and a thermionically-emissive cathode positioned in such proximity thereto that its temperature is dependent upon

the temperature of said anode, means for measuring the resistance of said cathode when it is in a deenergized condition.

4. The method of determining the temperature of the anode of an electrical discharge device having a cathode sufficiently close to said anode so that its temperature is responsive to the temperature of the anode which consists in measuring the resistance of said cathode.

5. The method of measuring the temperature of the anode of an X-ray tube having a thermionically-emissive cathode supplied with heating current which consists in interrupting the flow of heating current and, at a substantial interval thereafter, measuring the resistance of said cathode.

6. In combination with an X-ray tube having a rotating anode and a cathode positioned in such proximity thereto that its temperature is dependent upon the temperature of said anode and provided with means for supplying it with heating current from a local energy source, means for interrupting the flow of heating current to said cathode, and means for thereafter measuring the temperature of said cathode.

7. In combination with an X-ray tube having a rotating anode and a cathode positioned in such proximity thereto that its temperature is dependent upon the temperature of said anode and provided with means for supplying it with heating current from a local energy source,

means for interrupting the flow of heating current to said cathode, and means for thereafter measuring the resistance of said cathode.

8. In combination with an X-ray tube having a rotating anode and a cathode positioned in such proximity thereto that its temperature is dependent upon the temperature of said anode and provided with means for supplying it with heating current from a transformer of which the primary is connected to a local energy source, means for interrupting the flow to said primary of current from said local source and for thereafter measuring through the primary winding thereof the resistance of the load on said transformer.

9. In combination with an X-ray tube having a rotating anode and a cathode positioned in such proximity thereto that its temperature is dependent upon the temperature of said anode and provided with means for supplying it with heating current from a transformer of which the primary is connected to a local energy source, means for interrupting the flow to said primary from said local source, and means for connecting said primary winding to a relay system adapted to automatically reinitiate the flow of current to said transformer primary from said local source when the resistance of said cathode reaches a predetermined value.

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