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PROTECTIVE DEVICE FOR ROTATING ANODE TUBES

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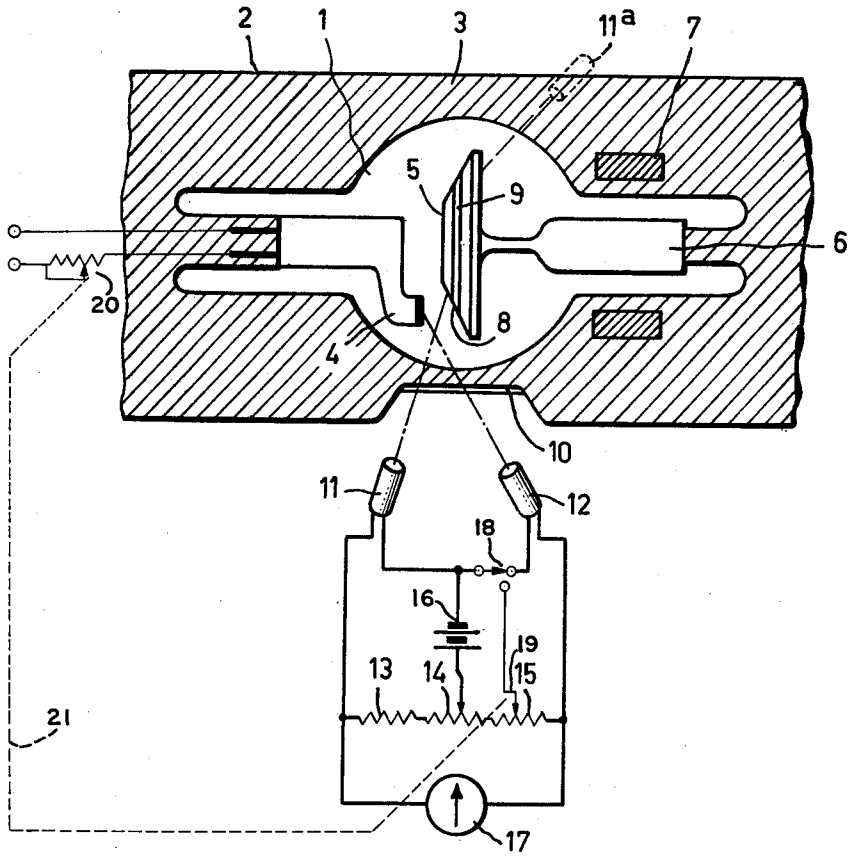

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PROTECTIVE DEVICE FOR ROTATING ANODE TUBES

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The present invention relates to an apparatus comprising an X-ray tube including an anode disk rotating during the operation of the tube. The invention has for its object to prevent overheating of the anode disk.

X-ray apparatus are usually provided with means for automatically controlling the load of the X-ray tubes, which acts in such a way that the load degree is dependent on the controlled load time, so that the load is high for short load times but is gradually decreased for longer load times. In this way a certain protection is obtained against the destroying of the X-ray tube by overheating. With an apparatus of this kind the starting temperature of the anode disk at the beginning of the load period is not taken into consideration, and if the anode disk is, at the moment, already highly heated the anode disk can nevertheless be destroyed during the load time.

The electron discharge in an X-ray tube is directed towards the anode and is incident on the anode surface in a limited area which is called the focus of the tube. Due to the rotation of the anode disk the area describes a circular path on the anode disk, which here is called the path of the focus. It has already previously been suggested to measure the temperature in the focus by means of a photoelectric cell or a similar light sensitive device in order to interrupt the load if this temperature should arrive at unallowable values and thus a risk of the destroying of the anode disk is present. Such a protective measure is, however, in many cases insufficient. For instance, series pictures and X-ray cinematography require very short load times, often only a few milliseconds, and then it is scarcely possible during the occurring exposure to interrupt the load in dependence upon a received temperature indication before overheating has already arisen. Another important fact is that the temperature of the focus of the tube is per se not decisive for the damages, which can arise on the anode disk. At a high heating of short duration the anode disk is heated substantially only on the surface and as the disk usually consists of tungsten, which is a comparatively bad conductor of heat, the heat disappears for the major part at once after the exposure and substantially through radiation. While the anode disk can resist a comparatively high heating on the surface it will be damaged already at a considerably lower temperature if the heat propagates to the bottom of the anode disk. Such penetrating heating causes already at yellow heat changes in the material of the anode disk which often causes warpings and cracking. Such damages make the X-ray tubes quite unusuable.

The present invention relates to the experience that the hitherto existing difficulties in avoiding overload of the X-ray tube with accompanying destruction of the anode disk can be eliminated by an observation of the bottom temperature of the anode disk, that is the temperature which exists outside the path of the focus of X-rays. The

invention is intended to prevent overheating on account of a too high initial temperatuer of the anode disk.

The invention is characterized especially by a temperature sensitive member directed towards a limited surface of the anode disk outside the path of the focus, suitably a light-sensitive member such as a photoelectric cell, photo-transistor or the like with an associated temperature-indicator preferably an electrically excited measuring instrument.

When using a light-sensitive member, e.g. a photoelectric cell or the like it may be difficult to arrange the member in such a way that it is not also influenced by light from the cathode filament of the tube, which illuminates the anode disk at the area towards which the temperature-sensitive member is directed. As the light reflected by the anode disk does not inconsequential strength in relation to the light, which is produced by heating the anode at the temperature, for which the device is to react, the temperature indicating member should not be influenced only in dependence on the temperature of the anode disk but also in dependence on the existing filament heating current intensity, if no special steps were taken. In order to compensate for the influence of light produced by the cathode on the anode disk according to an embodiment of the invention a current or voltage, which is on the whole proportional to the light radiation towards the anode disk caused by the cathode filament of the X-ray tube, is included in the control circuit of the temperature-indicating member as negative feed back. This negative feed back current or voltage can either be derived from the heating current circuit or from its control member. A special light-sensitive member may also be provided in order to arrive at the desired compensation, which member is directed towards the cathode filament and gives an output current or voltage, which directly represents the radiated light.

The invention will now be described in connection with the accompanying drawing, which shows a preferred embodiment of the same by way of example.

In the figure **1** designates an X-ray tube and **2** the envelope which includes the same. The envelope is filled with oil **3** as cooling liquid. The cathode of the tube is designated **4** and its anode disk **5**. The latter one is combined with a rotor **6**, which is included in a driving motor for the anode disk, the field windings of which are designated **7**. The electron discharge from the cathode **4** is concentrated on a very limited area of the anode disk, so that a focus of X-rays **8** occurs there. When rotating the anode disk the focus describes a circular path, the focus path **9**.

For the supervision of the temperature of the anode disk a photoelectric cell **11** is arranged in front of the window **10** in the envelope of the X-ray tube, which is provided with a suitable optical system so that light is directed towards the same only from a restricted range outside the focus path, i.e., in the example shown near the central part of the anode disk. When loading the X-ray tube the anode disk will glow up more and more and can at high loads be yellow-warm. The photoelectric cell **11** changes its resistance in correspondence to the light radiated from the anode disk. However, the mentioned part of the anode disk is also illuminated by light from the cathode, and the light thus reflected by the anode disk will also excite the photoelectric cell **11**, which thus without

extra steps would give an incorrect indication of the temperature of the anode disk. In this connection it may be mentioned that the reflected light varies from case to case, as different values of the heating current intensity are used for different load cases. In order to compensate the above mentioned reflected light a further photoelectric cell **12** with an accompanying optical system and conceivably a light filter is provided, and this cell is directed toward the cathode **4**. The photoelectric cells **11** and **12** are included in a balanced bridge circuit including resistances **13**, **14** and **15**, of which **14** is a rheostat, which with its movable tapping is connected to one terminal of a battery **16**, the other terminal of which is connected to the opposite supply point in the bridge circuit. A galvanometer **17** is connected in the zero-branch of the bridge. Through the potentiometer **14** the bridge is adjusted that the galvanometer shows zero. The galvanometer reading will then be a measure of the bottom temperature of the anode disk, and with the guidance of this reading one can adjust necessary intervals between the succeeding loads, e.g. at series exposures, so that the anode disk will not be overheated. Similarly one can at a more prolonged load interrupt this for the event that the anode disk would be excessively heated. It is certainly within the scope of the invention to complete the instrument **17** or substitute this with a relay device, which at a certain value of the voltage or the current in the zero-branch of the bridge switches off the anode voltage of the X-ray tube and keeps this switched off as long as the anode disk shows an unallowable high bottom temperature. E.g., this relay can block the contactor, which normally is arranged for switching-on and -off the tube.

The current determined by the photoelectric cell **12** thus acts as a negative feed-back in the measuring circuit. Such a negative feed-back for obtaining the intended compensation can of course also be obtained with other connections than the bridge circuit shown. It is even possible to use other means to represent the intensity of the heated cathode light instead of the photoelectric cell **12**. So it is, e.g., possible in the embodiment shown to dispense with the photoelectric cell **12**, and instead thereof to connect the terminal **16** of the battery by means of switch **18** to a movable tap **19** on the resistor **15**, which thereby is thus a rheostat. This may then either be adjusted separately in correspondence to the adjustment of the original heating current rheostat **20** or this special rheostat can also be mechanically connected via member **21** with the heating current rheostat, so that when changing the heating current, a corresponding change of the resistance value of the rheostat **15** is automatically obtained. The last mentioned one is then so dimensioned and arranged, that the feed-back current in each position will, with a permissible degree of accuracy, represent the illumination of the anode disk caused by the cathode.

On the drawing shown with dotted lines is an embodiment, in which the photoelectric cell **11***a*, which supervises the temperature of the anode disk, is directed so that it is excited by light coming from the back of the anode disk. The photoelectric cell **11***a* can then be arranged outside a special window in the envelope or inside the envelope itself. In this case the reflected light from the heating current of the cathode can be so unimportant, that any special compensation for this need not be arranged.

It is clear that also other temperature-sensitive members than light-sensitive ones, as photoelectric cells and phototransistors, can be used within the scope of the present invention.

What is claimed is:

1. X-ray apparatus comprising, in combination, an X-ray tube including a cathode and an anode, means to rotate the anode relative to the cathode whereby electrons emitted by the cathode impinge upon the anode and describe a circular path thereon, a light sensitive member directed toward an area of the anode outside the circular path of electron impact to detect the anode temperature, and means operatively associated with said temperature responsive member to indicate the anode temperature.

2. X-ray apparatus comprising, in combination, an X-ray tube including a cathode and an anode, means to rotate the anode relative to the cathode whereby electrons emitted by the cathode impinge upon the anode and describe a circular path thereon, a light-sensitive member directed toward an area of the anode outside the circular path of electron impact to detect the anode temperature, and means operatively associated with said light-responsive member to indicate the anode temperature including means to compensate for light-radiation from the cathode reflected by the anode.

3. X-ray apparatus comprising, in combination, an X-ray tube including a cathode and an anode, means to rotate the anode relative to the cathode whereby electrons emitted by the cathode impinge upon the anode and describe a circular path thereon, a light-sensitive member directed toward an area of the anode outside the circular path of electron impact to detect the anode temperature, and means operatively associated with said light-responsive member to indicate the anode temperature, said latter means including circuit means coupling said light-sensitive member to a temperature indicator and means to generate negative feed-back proportional to the light emitted by the cathode towards the anode to compensate for the light radiation from the cathode reflected by the anode.

4. X-ray apparatus comprising, in combination, an X-ray tube including a cathode and an anode, means to rotate the anode relative to the cathode whereby electrons emitted by the cathode impinge upon the anode and describe a circular path thereon, a first light-sensitive member directed toward an area of the anode outside the circular path of electron impact to detect the anode temperature, and means operatively associated with said light-responsive member to indicate the anode temperature, said latter means including a temperature indicator, a second light-sensitive member directed toward the cathode for detecting the light emitted by the cathode reflected by the anode, and circuit means coupling said first and second light-sensitive members to said temperature indicator with the output of said second light-sensitive member opposing the output of said first light-sensitive member to thereby cancel from the latter a component corresponding to light-radiation from said cathode reflected by said anode.

5. X-ray apparatus comprising, in combination, an X-ray tube including a cathode and an anode, means to rotate the anode relative to the cathode whereby electrons emitted by the cathode impinge upon the anode and describe a circular path thereon, a light-responsive member directed toward an area of the anode outside the circular path of electron impact to detect the anode temperature, and means operatively associated with said light-responsive member to indicate the anode temperature, said latter means including a temperature indicator, and circuit means coupling said light-sensitive member to said temperature indicator, said circuit means further including means to generate an electrical current proportional to the current supplied to said cathode in opposition to the output of said light-sensitive member to compensate for light-radiation emitted by said cathode in the direction of said anode.

6. X-ray apparatus comprising, in combination, an X-ray tube including a cathode and an anode, means to rotate the anode relative to the cathode whereby electrons emitted by the cathode impinge upon the anode and describe a circular path thereon, a light-responsive member directed toward an area of the anode outside the circular path of electron impact to detect the anode temperature, and means operatively associated with said light-responsive member to indicate the anode temperature, said latter means including a temperature indicator, and cir-

cuit means coupling said light-responsive member to said temperautre indicator, said circuit means further including control means for regulating the current supplied to said cathode and impedance means operatively associated with said control means for generating an electrical current proportional to the cathode current in opposition to the output of said light-responsive member to compensate for light-radiation emitted by said cathode in the direction of said anode.

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