

May 9, 1939.

A. MUTSCHELLER

2,157,718

X-RAY TUBE

Filed Feb. 26, 1935

2 Sheets-Sheet 1

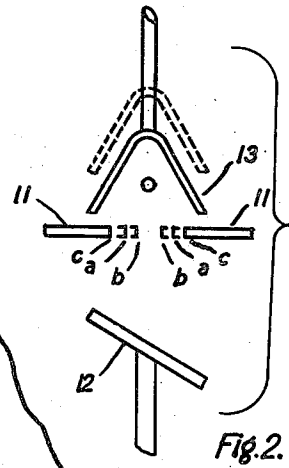
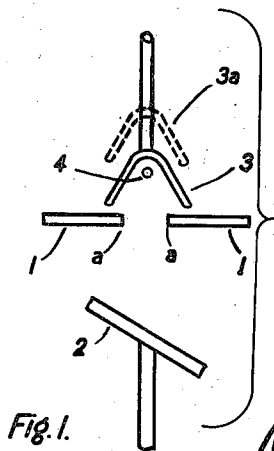
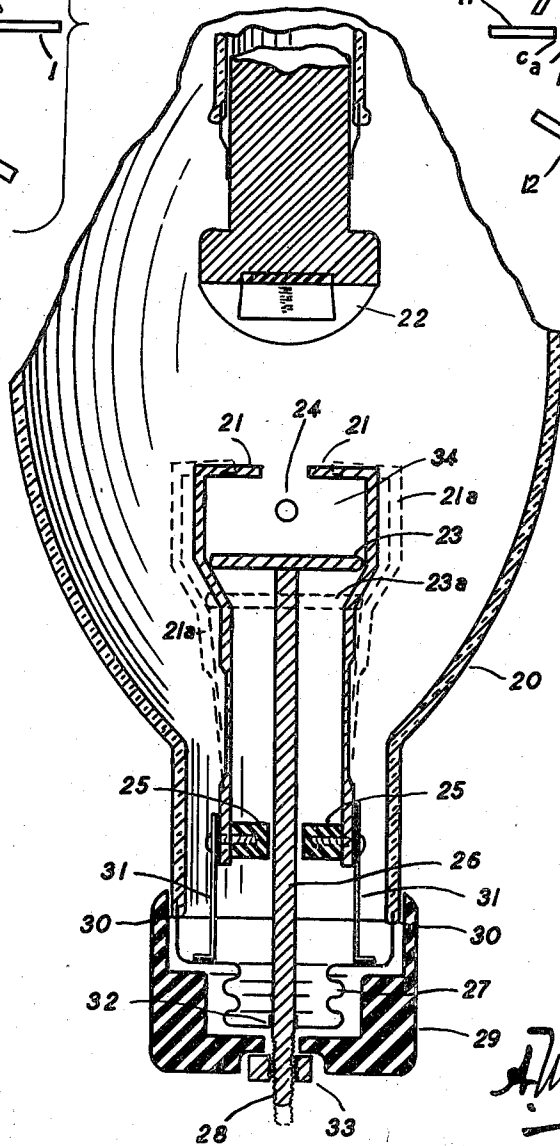


Fig. 3.



A. Mutscheller
INVENTOR.

May 9, 1939.

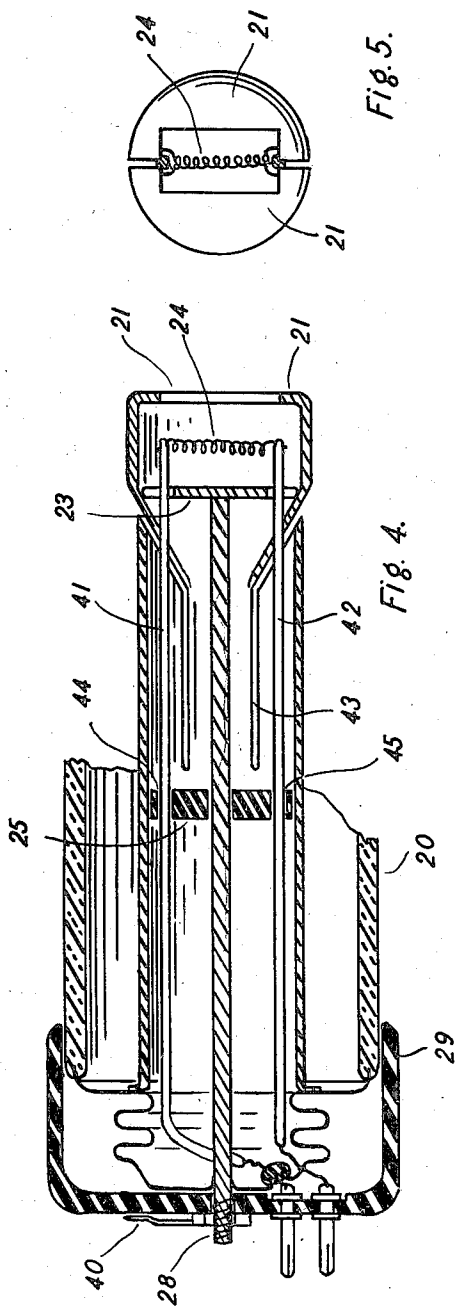
A MUTSCHELLER

2,157,718

X-RAY TUBE

Filed Feb. 26, 1935

2 Sheets-Sheet 2



A. Mutscheller
INVENTOR.

UNITED STATES PATENT OFFICE

2,157,718

X-RAY TUBE

Arthur Mutscheller, New York, N. Y.

Application February 26, 1935, Serial No. 8,234

4 Claims. (Cl. 250—145)

This invention relates to new and useful improvements in X-ray tubes whereby a wider range of application, greater regularity of performance and a longer useful life of X-ray tubes of the various kinds is obtained by specific improvements in the construction of the electron emitting cathode.

It is usual to provide in X-ray tubes an anode with a surface of tungsten upon which the discharge from the cathode is focused. It is then found, that if the specific intensity of the discharge or the electron current per unit area of focal spot on this anode surface surpasses certain values, then the focal spot is injured by overheating, melting, erosion or cracking and the performance of the tube becomes irregular and often uncontrollable or it becomes entirely unusable.

Attempts have been made to devise means for varying the size of the focal spot in conformity with the requirements for the particular exposure or so to adjust its area that, for a discharge intended to be used for a certain purpose the allowable maximum per unit area is not exceeded. Through this adjustability of the focal spot the useful range of the tube is materially extended, but it is still possible, by heating the cathode to give a larger tube current than that permissible for the particular focal spot either unintentionally or accidentally to exceed the allowable discharge intensity per unit focal spot area which results in injury to the focal spot and a shortened useful tube life. Hence, if such overloading of the focal spot could be prevented, it would render the tube much safer to operate and extend its useful life.

The technical literature contains some vague and conflicting data indicating that under certain conditions the size of the focal spot depends not only on the size of the opening in the focusing device but that the size and shape of the compartment in back of the focusing opening and in which the filament is located have a considerable influence on the size and form of the focal spot on the anode.

It is further known, that the magnitude of the cathode discharge depends on the size of the opening in the focusing shield in front of the hot cathode, so long as the tube is operated below voltage saturation. It is then probable, that a variation in the size of the opening causes corresponding changes in the space charge and thus there is a corresponding variation of the discharge current from a constantly heated cathode.

I have discovered that in tubes operated at or

above voltage saturation the discharge from the cathode depends also on the size of the opening in the shield in front of the cathode filament, if the width of this opening is smaller than what we shall call the effective area of emission of the electron source from the hot cathode. This effective area of emission of the electron source is determined by the width or diameter of the hot cathode filament or filament coil plus the additional lateral space through which electrons travel coming around the hot filament from the sides and the rear of the hot cathode in order to get out through the focusing device and to be accelerated and to converge upon a focal spot on the anode. This effective area of emission of the electron source is therefore in a plane perpendicular to the direction of the electron discharge, and the focusing opening is also in a plane also perpendicular to the discharge direction but in front of the cathode and thus nearer to the anode.

It can, therefore, be said that the electron discharge is approximately in the form of a pyramid having its apex located on the anode target. The radius (or the length of its side) is then equal to the distance between the focal spot on the anode and the focusing shield and the solid angle (or the tangent of the solid angle) of the electron discharge and of the field acting upon the electrons emitted from the cathode is defined by the largest dimension of the opening in the focusing shield or diaphragm in front of the emissive cathode.

But if a small shield or shell is placed in back of the hot cathode so that it shields the back and sides of it and is about 1 mm from it, and this shell is either connected to the hot cathode or a negative potential with respect to the cathode is applied to it, then the electrons can not travel far out and around the sides of the cathode, many or all are prevented from leaving the back and the sides of the hot cathode and the diameter of the electron source is small and actually just about equal to the actual size of the hot cathode. If, however, the shield is larger and about 1 cm or more away from the back and the sides of the hot cathode, then the electrons can get out from the rear and the sides of the hot cathode and they travel further around and out around the sides of the hot cathode and thus the diameter of the electron source as well as the total number of electrons becomes larger.

But if then the size of the shield or box of conducting material in back of the hot cathode

and the distance is fixed and only the size of the focusing opening is varied then, space charge limitations at saturation being no longer present, the size of the opening determines the solid angle or arc of the field from the anode which is able to act on the area of the source of electrons.

In practice, this is manifested by the fact that the electron discharge from a constantly heated cathode can be controlled, at voltage saturation and when keeping the cathode box or shield fixed, by varying the size of the focusing opening, so long as this opening is smaller than the area of the effective electron source. Therefore, the electron discharge current is that fraction of the total electrons emitted by the cathode which is roughly represented by the area of the effective opening in the focusing opening in relation to the effective area of the electron source.

But it must be understood, that the magnitude of the discharge from the cathode is also influenced by the size of the shield or box in which the cathode is located. Therefore, if the focusing opening is kept fixed and constant, a variation of the size of the box will also bring about a variation of the discharge current due to the fact that when the box is in very close proximity to the cathode, it may prevent some or all of the electrons which come from the rear and the sides of the hot cathode to get out and to become part of the discharge. But this variation of the size of the box causes also a variation in the focal area or of the size of the focal spot on the anode.

Thus recognizing the fact that a variation of the size of the cathode box causes a variation of both the magnitude of the discharge and of the area of the focal spot, it would follow, that this method of control of the discharge and of the focal area might result in a uniform density of the electron discharge on the anode or an automatic variation of the size of the focal spot with a variation of the discharge. But this variation is usually not in the required exact ratio to accomplish this end. Therefore, it is found necessary to make use of the principle of controlling the magnitude of the discharge also by means of the variation of the focusing opening. But then, when these two variable factors are correctly adjusted in their relation to each other, the desired concomitant variation of the size of the focal area and of the magnitude of the discharge can be accomplished and a desired uniform electron density per unit area on the anode target can be obtained irrespective of the magnitude of the discharge.

On the basis of these observations, I have developed an X-ray tube having a cathode which can be adjusted to produce any desired size focal spot which may be either round or circular or in band or line form while at the same time the maximum of the electron discharge that can be passed upon the given focal spot can not exceed the permissible maximum intensity for the particular metal through which injury to the focal spot does not result. In other words, the maximum discharge current is covariant with the size of the focal spot or band and so overloading of the focal spot through a too high electron density is not possible.

At the same time, I have found that in an X-ray tube of this description the discharge current is very effectively stabilized and made constant even if variation in the cathode heating current does take place. The heating of the cathode is no longer highly critical for the discharge depends more on the effective area of the

focusing opening of the cathode than on the absolute temperature of the cathode.

Figs. 1 and 2 represent schematically, the principle of the invention;

Fig. 3 is a side view in section of one method of carrying out the invention;

Fig. 4 is a view showing the cathode structure of Fig. 3 in elevation, but illustrating a modification of the base;

Fig. 5 is an end view of the cathode shown in Figs. 3 and 4.

Referring to Fig. 1, which is a diagrammatic and schematic cross section of the cathode of an X-ray tube, 4 is a heated cathode filament seen endwise such as a helically wound tungsten wire; 1 is a focusing device with a slit $a-a$ and 3 is a shield which determines the size of the filament compartment or box all being electrically interconnected and therefore at the same potential. When in this position, the focal spot on the anode 2 is smaller than when the shield 3 is moved back to the position $3a$ shown in dotted line; then the focal spot is considerably larger.

In Fig. 2 is shown a similar cross section but the slit in the focusing device 1 is shown with three different sizes of opening such as $c-c$, $a-a$ and $b-b$. The shield 13 is then in the same relative position as the shield $3a$ in Fig. 1. In this case the size of the focal spot on the anode 12 changes with each size of the focusing shield and is largest for the opening $c-c$ and smallest for the opening $b-b$. In this case, the size of the box or filament compartment is relatively small.

But let the shield 13 be moved back to position shown in dotted lines thereby making the box or filament compartment larger. Then the variation of the size of focal spot on the anode when the size of the opening in the focusing shield is varied, is much less or it may be made equal to zero by making the box large enough and the slit sufficiently small. But then with each of the various slit sizes a different discharge is obtained. Thus slit $b-b$ gives the smallest and slit $c-c$ gives the largest discharge. Of course, this is all without varying the heating of the cathode filament.

On this basis the practical cathode of an X-ray tube shown in Fig. 3 is constructed. In an evacuated envelope 20 is located an anode 22 and a filamentary cathode 24 of the usual helical form; the heating connections leading to the outside of the tube are of the conventional type and are not shown in the diagram. At 30 is fused on to the envelope 20 a metal cap 27 having an elastic part in the form of corrugated convolutions through which at 32 the stem 26 extends. It is there securely soldered on to the cap and the emerging portion of this stem 26 is provided with a threaded section 28. On the shoulder of the cap 27 rests another cap 29 of insulating substance and thus the stem 28 projecting through this cap 29 can be caused to move in or out of the tube by turning the nut 33. Several prongs 31 are welded on to the inner side of the cap 27 and these support the block of supporting material 25 to which are attached the two members 21, 21. These constitute the focusing device and box or filament compartment 34 and they are so bent, as illustrated, that if the plate 23 carried by the stem 26 is moved in or out of the tube by means of the nut 33, the opening of the focusing slit as well as the size of the box are varied together. Thus in the position 23 and 21, 21 as shown in heavy lines, the focal spot is narrow and small but also the maximum of current that can be

passed through the tube is limited by the width of the slit which must have been adjusted to that which gives the maximum of current that the focal spot will stand. This is accomplished by adjusting the relation of the width of the slit to the size of the box so that the correct maximum of tube current for the given size slit is obtained. But if the disc 23 is moved to position 23a by turning the nut 33, then the two members 21, 21 will bend and change to position 21a, 21a respectively. The width of the focusing slit and the size of the box 34 are then greater and a larger focal spot or area as well as a larger milliamperage of tube current will be obtained.

To the nut 33 a pointer may be attached and a scale may be engraved on the cap 29 indicating the milliamperage of tube current obtained with each position of the nut 33.

Fig. 4 is a cross sectional side view and Fig. 5 is a front view of the cathode aforescribed; 41 and 42 are the supporting and current conducting leads of and for the cathode 24. These are supported in the holes 44 and 45 of the block of dielectric support material 25. In this the rod 28 may slide back and forth as determined by rotating the nut 33 carrying a pointer 40 which indicates the setting of the cathode in millamperes of tube current on a dial engraved on the end cap. Thus the tube current may, without trial, be preset by means of this nut and pointer on the scale indicating the setting.

In this way the size of the focal spot and the milliamperage of tube current are varied together and accidental damaging of the focal spot by overloading it unintentionally or by reason of lack of technical knowledge of operating X-ray tubes, are made impossible. Thus the tube can be adjusted to the particular size of focal spot which is required for the specific exposure intended and so the advantages of many tubes each designed specifically for one special purpose are combined in one tube and with the protective feature by virtue of which damaging of the focal spot by overloading is made impossible.

Having thus described one specific form or application of my invention, I do not limit myself to this specific form but to the spirit of the discovery which is that expressed in the claims.

I claim,

1. In an X-ray tube having an anode and a cathode mounted into an evacuated glass envelope, said cathode having a heated portion producing an electron emission depending on the absolute temperature and the effective area of emission from said heated portion, a metal housing surrounding said cathode and being adjustably variable in size and maintained at a definite potential with respect to said cathode to determine the effective area of emission of said heated

portion, an adjustably variable opening in said housing directing an electronic discharge there-through to fall upon said anode, said opening being smaller than the said effective area of emission as indicated by a small decrease of the size of said opening causing a decrease of the discharge current while the temperature of said heated portion of said cathode is maintained constant, and means for mechanically varying the size of said housing and said opening to control the discharge through said X-ray tube.

2. An X-ray tube having a variably adjustable discharge comprising an evacuated envelope of dielectric substance, an X-ray anode and a cathode to be heated for a normal thermoelectronic discharge, said cathode being surrounded with a housing of conducting material and maintained at a definite potential with respect to said cathode, an adjustably variable opening in said housing for passing electrons through it and causing them to fall upon a predetermined area upon said anode, said opening being smaller than the distance at right angle to the discharge direction between said cathode and the inside wall of said housing and mechanical means for varying the size of said opening.

3. An X-ray tube having a variably adjustable discharge comprising an evacuated envelope of dielectric material, an X-ray anode and a cathode to be heated constantly for a maximum thermoelectronic discharge, said cathode being surrounded with a housing of conductive material and maintained at a definite potential with respect to said cathode and having an opening for transmitting electrons so as to fall upon said anode, said opening being adjustably variable in size and when in its widest open position transmitting less than said maximum discharge, and mechanical means for varying the size of said opening thereby to vary and to adjust the discharge between said cathode and said anode.

4. An X-ray tube having an adjustably variable discharge comprising an evacuated envelope of dielectric material, an X-ray anode and a cathode to be heated constantly for a thermoelectronic discharge depending on its effective area of emission, said cathode being surrounded with a housing of conductive material and maintained at a definite potential with respect to said cathode and having an opening for the passage of electrons so as to fall upon said anode, the diameter of said housing at right angle to a discharge between said cathode and said anode being larger than said opening and the walls of said housing being movable to vary the size of said housing and mechanical means for moving the walls of said housing to vary its size, thereby to vary the effective area of emission of said cathode.

ARTHUR MUTSCHELLER.