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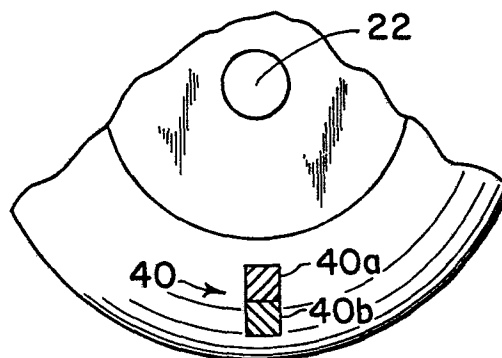
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54 **X-ray tubes.**

57 An x-ray tube wherein two or more cathode filaments (30, 32) respectively provide the electrons for respective contiguous portions (40a, 40b) of a single unitary anode spot region (40). An elongated spot region may thus be provided by multiple short filaments which are more robust than a single filament required to produce such a spot. Where the anode (12) is a rotating anode, the filaments (30, 32) may be differently energised to take account of the different speeds of anode rotation with distance from the axis (22) of anode rotation.



X-ray Tubes

The present invention relates to x-ray tubes.

In an x-ray tube electrons produced by a filament are directed on to an anode at a focal spot to produce x-rays.

5 State of the art x-ray tubes can generate multiple focal spots of different sizes for different diagnostic applications. One size spot is required for general purposes, a different size spot for arthograms, and an additional size spot for digital radiography. A
10 typical procedure for generating multiple size focal spots is to energize a different length filament for each of the focal spots.

 To produce the longer focal spots, longer filaments must be mounted in the tube cathode. The
15 longer the filament becomes, however, the greater the likelihood of a short or break in the filament occurring. This break can result in contact between the filament and a cathode cup to which the filament is mounted.

 A second problem results when longer filaments
20 are used. A very popular method of cooling x-ray tube anodes is to rotate them so that electrons strike a band about their surface rather than a single spot. The focal spot extends across this band with one end of the spot located at an inner region on the anode and an opposite
25 end of the focal spot on an outer region. The anode surface at the outer region is moving faster than the

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inner region, yet with a single filament the electron flux is the same for both inner and outer focal spot portions. This results in an undesirable energy distribution along the x-ray focal spot.

5 It is an object of the present invention to provide an x-ray tube wherein the above mentioned problems of longer filaments may be overcome.

According to the present invention there is provided an x-ray tube comprising: an anode and a cathode
10 including at least two filaments arranged to direct electrons at said anode so as to produce x-rays where the electrons strike the anode characterised in that the filaments are arranged so as respectively to produce x-rays substantially in respective contiguous
15 portions of a single unitary region.

It will be appreciated that in an x-ray tube according to the invention the two or more filaments may be made less prone to failure than an equivalent single filament.

20 Where the anode is a rotating anode and said region is elongated in a direction radial of the axis of rotation of the anode, the electron flux produced in said region is suitably arranged to increase with distance from said axis of rotation, for example, by
25 differences in the energising currents of the filaments.

One x-ray tube in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 shows an x-ray tube having a rotating
30 anode and a stationary cathode positioned to direct electrons to the anode;

Figure 2 is a partially sectioned view of the x-ray tube cathode showing two filaments mounted to the cathode for thermionically emitting electrons;

35 Figure 3 is an elevation view of the cathode as seen from the position of the anode;

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Figure 4 is a plan view of the anode showing a focal spot generated by simultaneous energization of the two filaments shown in Figures 2 and 3; and

Figures 5 and 6 show energization circuitry for energizing the two filaments.

Referring to the drawings, Figure 1 shows an x-ray tube 10 having a rotating anode 12 and stationary cathode 14. The anode and cathode are supported inside an evacuated chamber 16 having a transmissive window 18 through which x-radiation generated by electron impingement upon the anode can be transmitted for use in a diagnostic and/or clinical situation.

The anode 12 is supported in a bearing 20 for rotation about a centre axis 22 passing approximately through the centre of the evacuated chamber 16. Electrons impinging upon the anode 12 thus strike its surface along a ring rather than a single spot. In this way, excessive heat buildup on the anode is avoided.

The anode 12 and cathode 14 are separated by a large electrical potential which causes electrons to accelerate from the stationary cathode to the rotating anode. To accomplish this voltage separation, a single high voltage cable 24 is routed from the exterior of the chamber 16 and electrically coupled to the rotating anode 12. This cable 24 carries a positive voltage of approximately 75,000 volts. A high voltage input 26 to the cathode carries a high negative voltage of approximately the same magnitude as the positive voltage routed through the cable 24. In combination, these two inputs separate the cathode and the anode by 150,000 volts.

Figures 2 and 3 illustrate in more detail the structure of the cathode 14. As seen in those Figures, the cathode 14 includes a cathode cup 28 to which are mounted two cathode filaments 30, 32. The cathode cup 28 defines two elongated grooves 34 extending across the width of the cathode in which these two filaments are

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mounted. In operation, the energized cathode cup 28 creates an electric field in the vicinity of these grooves to focus and shape the electrons which are thermionically emitted from the two filaments 30, 32.

5 Once electrons are thermionically emitted from one of the filaments they experience a strong electric field due to the voltage separation between the anode and cathode. This field accelerates the electrons so that they strike the anode 12 with enough energy to create

10 x-rays.

As seen more clearly in Figure 3, the two filaments are mounted in an overlapping or staggered relationship. This orientation in combination with the focusing effect of the electric field from the cathode cup causes

15 electrons from the two filaments to strike the anode at different locations and in particular at respective contiguous portions of a single unitary region so that a single anode spot is formed. This is illustrated schematically in Figure 4 where a single unitary

20 elongated spot region 40 is seen to be made up of two spot portions 40a and 40b, wherein one of the portions 40a is generated by electrons thermionically emitted from the first filament 30 and the second portion 40b is generated by electrons from the second filament 32.

25 It is seen that the spot portion 40a corresponding to the filament 30 is closer to the anode axis of rotation 22 than the spot portion 40b corresponding to the filament 32. Hence, electrons from the filament 30 strike a part of the surface of the anode 12 which is

30 moving slower than the part which electrons from the filament 32 strike.

To compensate for this difference in speed the two filaments 30, 32 are energized by different currents and therefore produce different electron fluxes at the

35 anode. The filament 32 which generates the electrons

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for the outermost spot portion 40b produces a greater electron flux than the filament 30 generating the electrons for the innermost spot portion 40a. The appropriate electron power density P for a given spot portion
5 depends upon the distance R of that focal spot portion from the centre of the anode. The current for the filament for each spot portion is determined in accordance with a relationship so that the electron power density P impinging on the anode is equal to
10 a constant K times the square root of the distance:

$$P = K_x \sqrt{R}.$$

Figures 5 and 6 show alternate embodiments of circuitry for energizing the two filaments 30, 32 in this controlled manner. In the Figure 5 embodiment,
15 each filament 30, 32 is connected to its own filament transformer 42, 44. A high voltage source 50 provides a voltage between the anode and cathode. Two alternating current sources 52, 54 are each coupled to a respective one of the transformers 42, 44. When both
20 30, 32 filaments are energized, a single focal spot 40 is produced. Control of the filaments' electron output is achieved by varying the voltage of the two A.C. sources 52, 54. A high voltage pulse 60 energizes the cathode cup 28 in a selected mode to provide the required pulse
25 current of the x-ray tube.

In accordance with the Figure 6 circuit, a single transformer 56 is required for energizing the two filaments 30, 32. In this embodiment, a resistor 58 in series with filament 30 causes the current passing
30 through the filament 30 to be less than the current through the filament 32. By choosing the value of the resistor 58 the power distribution discussed above is provided.

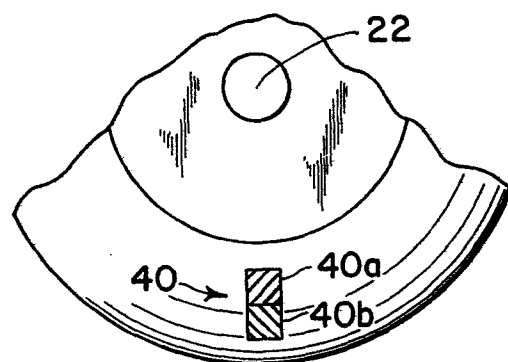
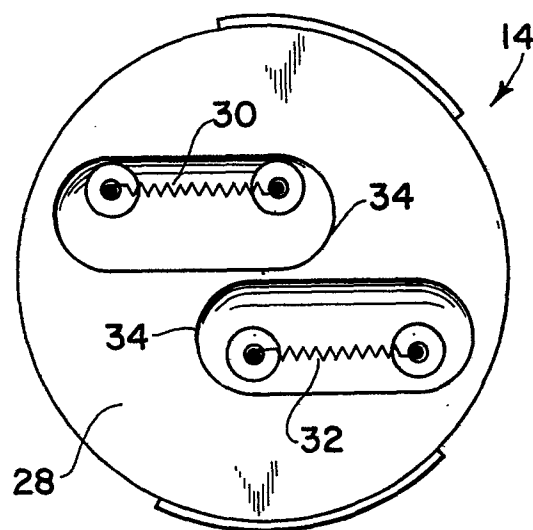
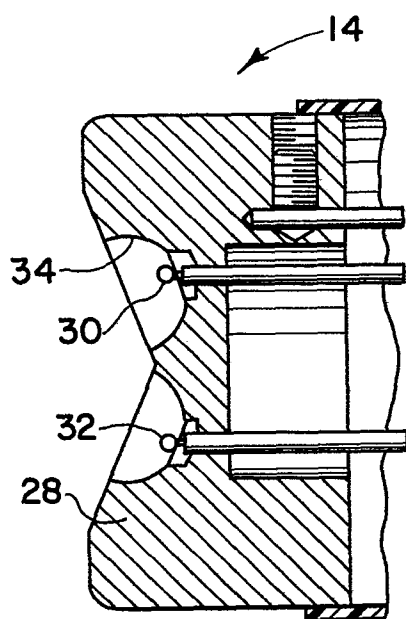
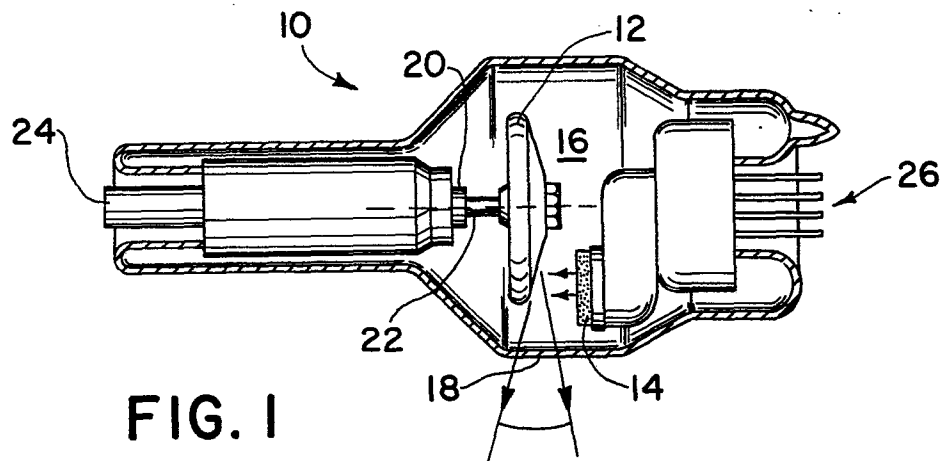
The Figure 6 embodiment generates a single size
35 focal spot from the x-ray tube whereas the Figure 5

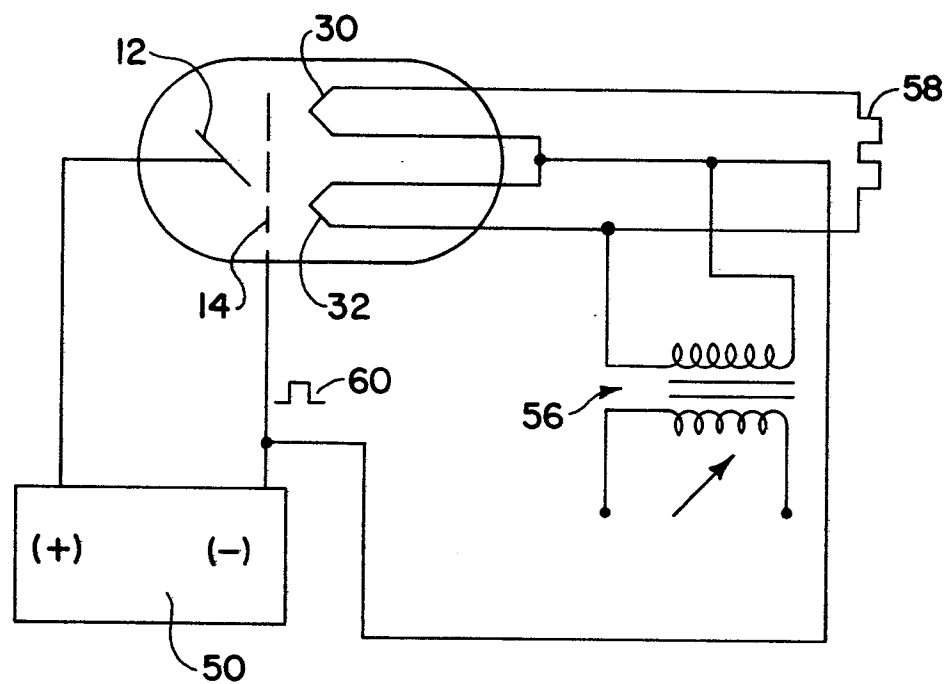
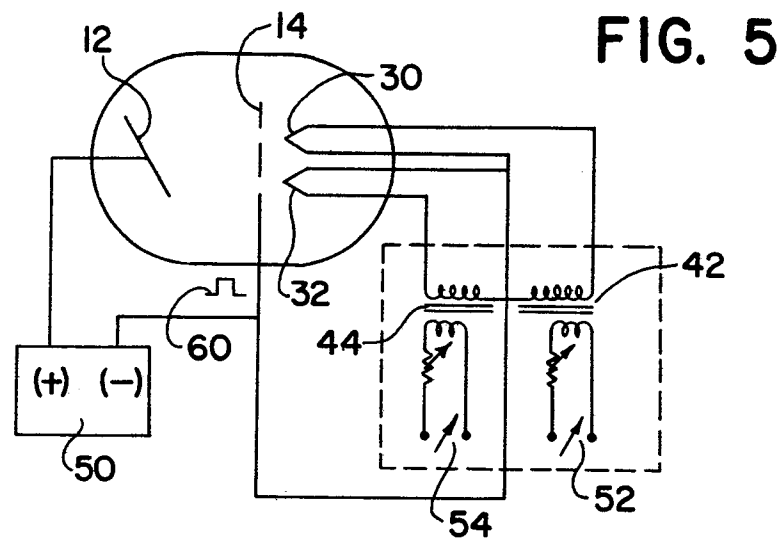
embodiment through selective energization of both
or one or the other of the two filaments can provide
multiple size focal spots. Thus, if one filament 30
is energized, a focal spot 40a from that filament is
5 produced on the anode. If filament 32 is energized,
focal spot 40b will be produced. If both are
simultaneously energized, the combined spot 40 is
produced.

10 It will be appreciated that although the
embodiment of the invention described by way of example
has only two filaments, the invention could be readily
extended to greater numbers of filaments to provide
longer focal spots.

CLAIMS

1. An x-ray tube comprising: an anode (12) and a cathode (14) including at least two filaments (30, 32) arranged to direct electrons at said anode (12) so as to produce x-rays where the electrons strike the anode (12) characterised in that the filaments (30, 32) are arranged so as respectively to produce x-rays substantially in respective contiguous portions (40a, 40b) of a single unitary region (40).
2. An x-ray tube according to Claim 1 wherein said region (40) is an elongated region and said portions each comprise a different section of the length of said region.
3. An x-ray tube according to Claim 2 wherein said anode (12) is a rotating anode and said region (40) is elongated in a direction radial of the axis of rotation (22) of the anode (12).
4. An x-ray tube according to Claim 3 wherein the electron flux in said region (40) increases with distance from said axis of rotation (22).
5. An x-ray tube according to Claim 4 wherein said increase in electron flux is produced by differences in the energising currents of the filaments (30, 32).
6. An x-ray tube according to any one of the preceding claims wherein the anode (12) and filaments (30, 32) are housed in an evacuated chamber (16) provided with an x-ray transmissive window (18) via which x-rays produced at the anode (12) emerge from the chamber (16).
7. An x-ray tube according to any preceding claim associated with means (42, 44, 52, 54) for energising all or a selection of the filaments (30, 32).



**FIG. 6**