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2,215,426

X-RAY TUBE

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Fig. 1,

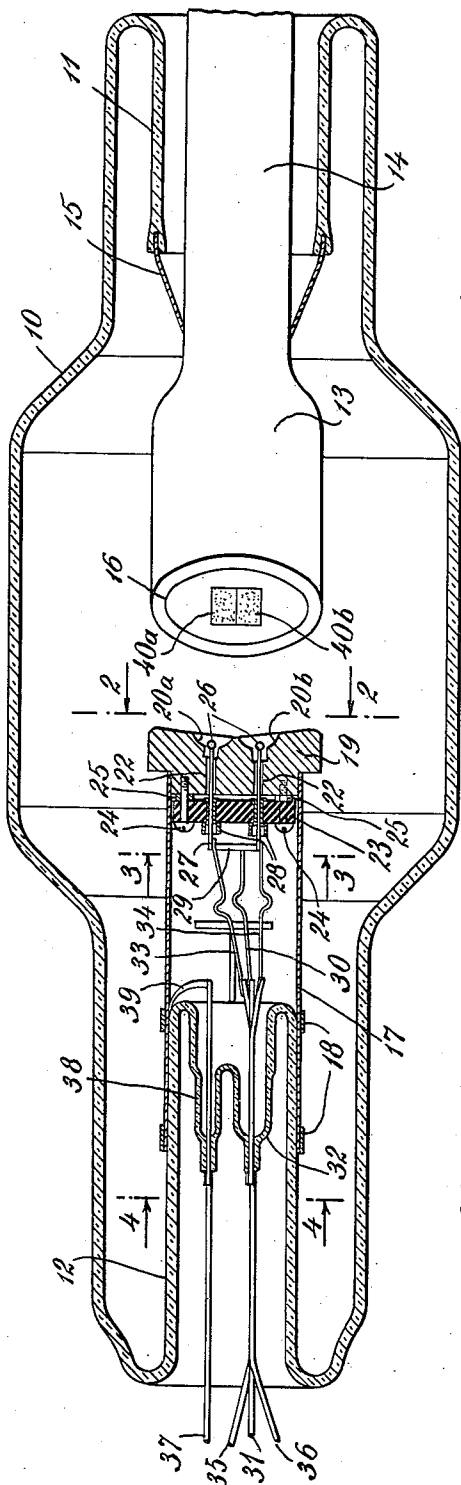


Fig. 2,

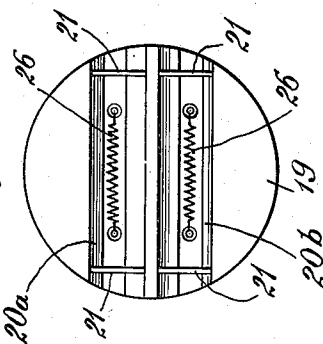


Fig. 3,

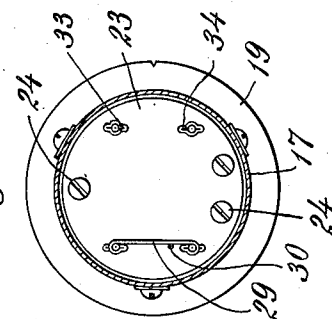


Fig. 4,

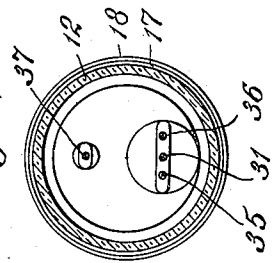
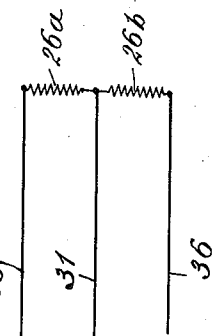


Fig. 5,



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X-RAY TUBE

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3 Claims. (Cl. 250-144)

This invention relates to X-ray tubes for therapy and radiographic purposes and is concerned more particularly with a novel X-ray tube which may be operated at high energy values for the prolonged periods required in therapy treat-
5 ments and may also be utilized to produce X-rays of high quality at unusual efficiency.

In the operation of X-ray tubes for therapy purposes, it is well known that an increase in efficiency may be obtained by insulating the focusing cup so that it may be maintained more highly negative than the filament itself. In such a tube, the cup functions in a manner analogous to the grid of a three element electron tube, so that when the tube is operated from unrectified or pulsating rectified generators, the negative bias on the cup permits electrons originating at the filament to reach the anode only when the voltage waves are near their peak values. As a result,
15 the X-rays are of high quality otherwise obtainable only by the use of expensive constant potential generators.

Heretofore X-ray tubes with biased focusing cups, or grids, as they are sometimes called, have commonly been made with spiral filaments and the cups have been of concentrically symmetrical form, so that a round focal spot is produced on the target face of the anode. This arrangement is satisfactory for therapy at moderate energy values, but has definite limitations where high energies are required. Thus, in such a tube of conventional construction, the leads of the spiral filament are supported by a block of insulation which may readily be designed to permit the maintenance of a potential difference of about
25 3000 volts between the focusing cup and filament without electrical leakage. With such a cathode, the electrons reaching the anode originate almost entirely at the surface of the filament facing the anode and, since the focal spot on the anode is an image of the filament and the electron stream is divergent, the spot is larger than the filament to an extent depending upon the spacing between the anode and cathode. In a tube having a spacing of about 5", a filament spiral of a diameter of about $\frac{1}{8}$ " will produce a focal spot about $\frac{5}{8}$ " in diameter when a bias voltage of the value above mentioned is applied to the cup.

A focal spot of such a size will continuously withstand about 1.5 kilowatts, if the tungsten target is suitably cooled, but if greater energy is required, a larger focal spot must be employed to permit efficient cooling. The design of a grid biased round focus cathode to produce such a focal area presents great difficulties, because if

the diameter of the filament spiral is increased, maintaining it in its initial condition against the electrostatic pull to which it is subjected is a serious problem. Moreover, an increase in the filament spiral size requires an increase in the spacing between the filament and focusing cup and this in turn requires an increase in the biasing voltage. The problem of insulating the cathode assembly to take care of the increased biasing voltage is difficult of solution as a practical matter, so that for the several reasons mentioned, definite limitations are imposed on the energy rating of a biased round focus tube by practical considerations.

X-ray tubes for radiographic use now frequently operate on the line-focus principle and such tubes include a helical filament so disposed with relation to the target surface as to produce a foreshortened focal spot. In such a tube, the electron stream impinging upon the target is made up of electrons originating at the front of the filament and electrons originating at the rear. The electrons from the front of the filament proceed along divergent lines from the filament to the target, while those from the rear are caused to change direction by the walls of the focusing cup and proceed along lines which converge and cross somewhere between the filament and target and then diverge from that point on to the target. For optimum conditions of operation, the areas on the target against which the two electron streams impinge should be substantially coincident with the portions of the focal spot adjacent its boundaries relatively heavily loaded, and the interior more lightly loaded.

If the focusing cup of such a tube is given a negative bias with respect to the filament, the effect of the cup on bending the path of the electrons is disproportionately increased and, therefore, with a particular cup construction, the desired electron distribution in the focal area can be maintained only with a particular biasing voltage. However, in the operation of such tubes, different anode-cathode voltages are employed in the making of radiographs of different types and in order to obtain X-rays of high quality, it is necessary to adjust the biasing voltage for each of the different anode-cathode voltages employed. Any such variation in the biasing voltage results in a distortion of the focal spot or undesirable electron distribution over the spot. Accordingly, if a negative bias is applied to the focusing cup of a radiographic tube of conventional construction operating on the line-focus principle, it is impossible to obtain both high-quality X-rays

and high radiographic efficiency throughout the range of anode-cathode voltages which it may be necessary to use.

The present invention is accordingly directed to the provision of a novel X-ray tube which may be operated for the prolonged periods required for therapy treatments at energy values greatly in excess of those permissible with tubes as heretofore constructed and may also be operated with its focusing cup biased so as to produce X-rays of high quality. The new tube is also useful for radiographic purposes and, when so used, produces high-quality X-rays without loss of radiographic efficiency.

These results are obtained with the new tube by the use of a plurality of helical filaments of similar size and a focusing cup in which the filaments are mounted, the cup being so formed as to direct the electron streams from the filaments upon contiguous areas on the target face of the anode. The cup has surfaces so disposed with relation to the filaments as to block and prevent the emission of electrons from the rear thereof, and a negative bias may be applied to the cup to cause the production of X-rays of high quality only. In therapy treatments, the number of filaments used depends on the energy values to be employed and since those values are ordinarily high, at least two filaments are usually operated for that purpose. For radiographic use, one filament is sufficient. Since in all cases, the spacing between the cup and the filament or filaments is relatively small, the bias voltage required is correspondingly small and no difficulty is presented in insulating the cup and maintaining the desired bias on it.

For a better understanding of the invention, reference may be made to the accompanying drawing, in which

Fig. 1 is a longitudinal section through an X-ray tube constructed in accordance with the invention;

Figs. 2, 3, and 4 are sectional views on the lines 2—2, 3—3, and 4—4, respectively, of Fig. 1; and

Fig. 5 is a diagram illustrating portions of the circuits for supplying current to the filaments of the tube.

The tube shown in Fig. 1 comprises an evacuated envelope 10 of glass or other suitable material, this envelope, in the construction illustrated, having re-entrant end portions 11 and 12. An anode 13 is mounted to lie along the axis of the tube at one end and has a shank 14 which projects out through the end portion 11 and is sealed by a suitable sealing sleeve 15. The anode, which is ordinarily of copper, is provided with a target disk 16 of tungsten embedded in the inclined face thereof in the usual manner. This anode will ordinarily be cooled by the circulation of a cooling liquid through passages and a coil therein, in the usual manner.

Aligned with the anode at the other end of the tube is the cathode which comprises a split metallic tube 17 mounted on the closed re-entrant end portion 12 and held in place by clamping rings 18. At the inner end of the tube is a focusing cup 19 of electro-conductive material, such as a suitable metal, this cup having a front face formed in two planes intersecting at the center of the face to form a re-entrant angle. In each of the planes adjacent the line of intersection is a recess 20a, 20b, and these recesses are formed with an outer semi-cylindrical portion from which another portion of square or rectangular section extends inwardly. The recesses, which lie paral-

lel, extend across the face of the cup from edge to edge and at the end of each recess is a shield 21 welded or otherwise suitably secured in position.

Leading from the recesses through the body of the cup are passages 22, and a block or plate 23 of insulation, such as a ceramic material, is secured to the rear face of that portion of the cup which lies within the tube 17. The plate 23 has openings therethrough in line with the passages 22 and other openings through which pass screws 24 threaded into the body of the cup. Spacing collars 25 mounted on the screws space the plate 23 from the rear face of the cup.

Within each recess 20a, 20b is a filament 26 which is of fine wire wound helically to form an extended coil. Each end of each filament coil is attached to a lead 27 and the leads extend through the passages 22 in spaced relation to the walls thereof. The leads also pass through bushings 28 in the ceramic plate 23 and their fit in the bushings is such that the portions of the leads within the passages and the filaments are kept out of electrical contact with the cup. Two leads 27 connected to similar ends of the filaments are connected by a metal strip 29 which is connected by a wire 30 lying within the tube 17 to a lead-in wire 31 sealed through the wall of a neck 32 formed as an outward extension from the re-entrant end portion 12 of the envelope. The other ends of the filaments are connected by wires 33, 34 to lead-in wires 35, 36 also sealed through the wall of the neck 32 and lying on either side of the lead-in wire 31. A fourth lead-in wire 37, which is sealed through another neck 38 extending outwardly from the re-entrant portion 12, is connected by a strip 39 to the metallic sleeve 17 and provides a means by which the focusing cup may be maintained more highly negative than the filaments during operation.

As shown in Fig. 5, current may be supplied to the filaments 26a, 26b through the lead-in wires 35, 36, the lead-in wire 31 serving as a common return. If desired, a suitable switching device may be provided so that the filaments may be utilized either singly or in combination. Also, if desired, the focusing cup may be provided with additional recesses so that more than two filaments may be employed, in which event, appropriate electrical connections similar to those described will be employed so that the filaments may be used singly or in various combinations.

In the operation of the tube, the walls of the focusing cup adjacent each filament direct the electron stream therefrom upon the target face of the anode and the cup is so formed that, when both filaments are functioning, the focal areas produced are contiguous, as indicated at 40a, 40b. Also, the geometrical relations of the filaments and target face are such that each focal spot is foreshortened in accordance with the line-focus principle. Consequently, if the tube is to be used for radiographic purposes, the advantages of line-focus construction are obtained.

By employing a number of long helical filaments, each with its own focusing groove in the new tube, each filament produces a focal area of band form on the anode and by the use of a suitable number of filaments of the same or different shapes, any desired focal area may be obtained. This effect is secured without increasing the bias voltage required for efficiency in operation and the tube may, therefore, operate at an energy value greatly in excess of that per-

missible with the spiral filaments heretofore employed. Also, the focal area may be given any desired configuration and when the tube is employed for industrial radiography, a focal area can be obtained which will give the minimum projected focal size for maximum loading capacity under the conditions of operation.

It is to be noted that the new tube does not involve merely the use of the biased focusing cup with a cathode of conventional line-focus design. If it were desired to increase the focal area with such a filament, the normal approach to the problem would be to increase the size of the filament and widen the groove in the focusing cup. This, however, would be impractical because, with the normal spacing between the filament and the sides of the focusing groove, a voltage of 10,000 volts or more would have to be applied to the focusing cup in order to secure an appreciable biasing effect and it would be impossible, or at least extremely difficult as a practical matter, to provide the internal insulation in the cathode assembly which would be required if such a high voltage were used.

With the new construction, the surfaces of the exposed walls of that portion of the focusing cup which is of rectangular shape are brought sufficiently close to the filament as substantially to block electrons originating from the rear surface of the filament. As a result, excessive biasing voltages are not required and, accordingly, no serious problem in insulating the cup is presented. Also, no difficulty arises with respect to electron distribution, as above pointed out. The total focal area on the target face required for the use of high energy values may, therefore, be obtained without sacrificing other advantages and, in a tube for radiographic purposes, the line-focus principle may be employed without sacrifice in the quality of the X-rays or in the radiographic efficiency.

I claim:

1. An X-ray tube suitable for continuous operation for prolonged periods as in therapy treatments which comprises an evacuated envelope containing an anode having a target face formed throughout of a single metal and a cathode, the cathode including at least two parallel helical filaments of the same size, a focusing cup mounted within the envelope and provided with recesses in which the cathode filaments lie, the walls of

the recesses being so formed as to direct the electron streams from the filaments upon contiguous areas on the target face of the anode to provide a symmetrical focal spot of substantially twice the size produced by either filament acting alone, means for supplying heating current to either of the filaments alone or to both filaments simultaneously, and insulating mounting for the cup, and a lead electrically connected to the cup and extending through the wall of the envelope by which the cup may be maintained at a potential negative to the filaments during operation of the tube.

2. An X-ray tube suitable for continuous operation for prolonged periods as in therapy treatments which comprises an evacuated envelope and a cathode, the cathode including at least two parallel helical filaments of the same size, a focusing cup mounted within the envelope and provided with recesses in which the cathode filaments lie, the walls of the recesses being so formed as to direct the electron streams from the filaments upon adjacent nonoverlapping areas on the target face of the anode, means for supplying heating current to either of the filaments alone or to both filaments simultaneously, and means for maintaining the focusing cup at a potential negative to the filaments during operation of the tube.

3. An X-ray tube suitable for continuous operation for prolonged periods as in therapy treatments which comprises an evacuated envelope and a cathode, the cathode including at least two parallel helical filaments of the same size, a focusing cup mounted within the envelope and provided with recesses in which lie the cathode filaments, the walls of the recesses being so formed as to direct the electron streams from the filaments upon adjacent nonoverlapping areas on the target face of the anode, means for supplying heating current to either of the filaments alone or to both filaments simultaneously, and means for maintaining the focusing cup at a potential negative to the filaments during operation of the tube, the filaments lying within the recesses in such proximity to the walls thereof that when said filaments are in operation, the said walls block electrons originating at the rear surfaces of the filaments.

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