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H. B. McEuen
X-RAY APPARATUS

2,900,542

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3 Sheets-Sheet 1

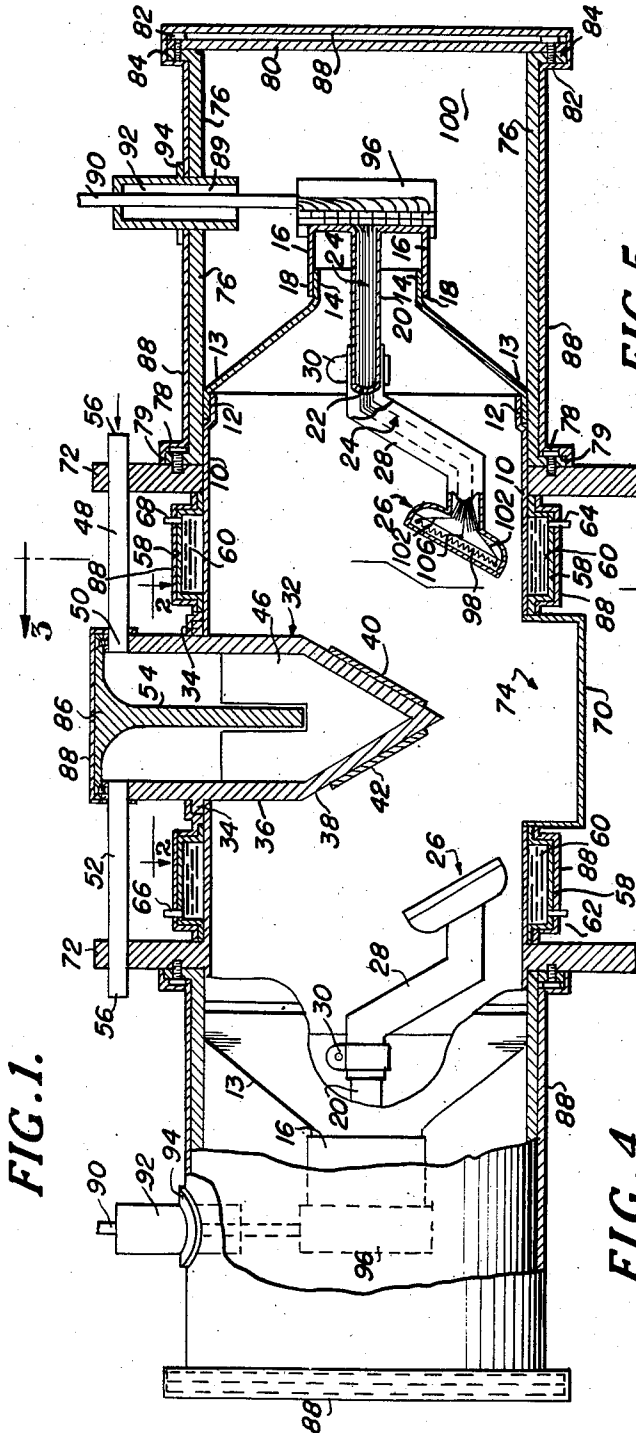


FIG. 5.

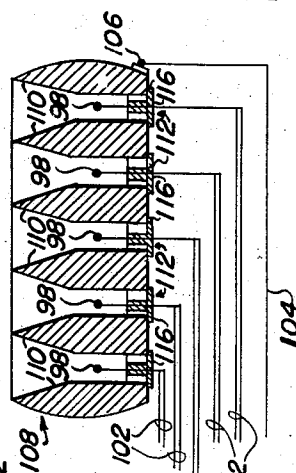


FIG. 6.

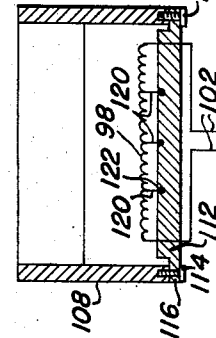
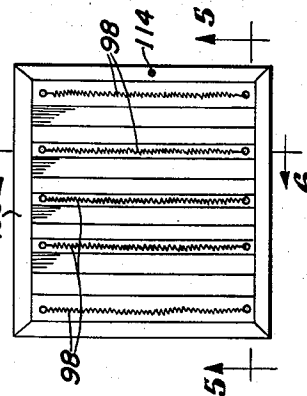


FIG. 4.



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FIG. 2.

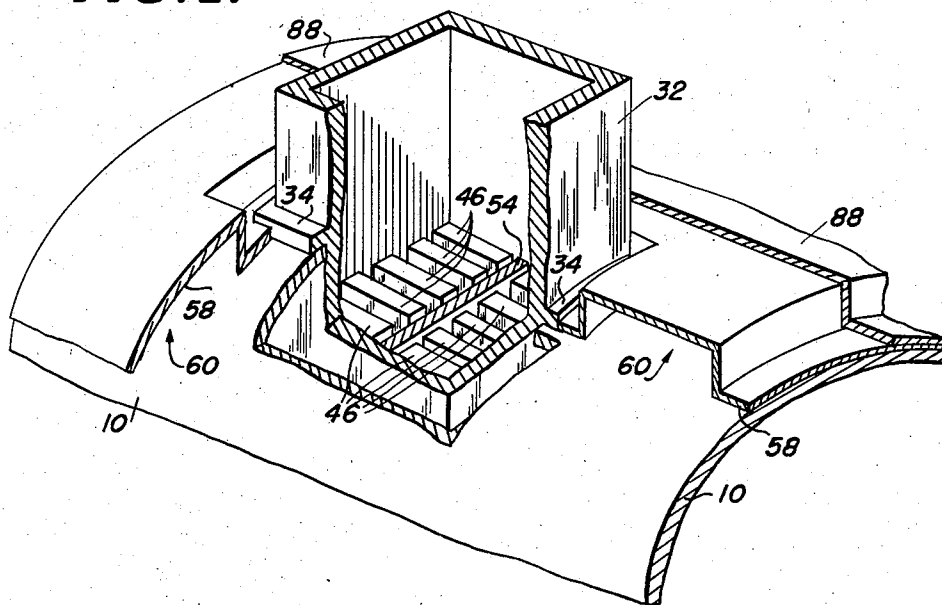
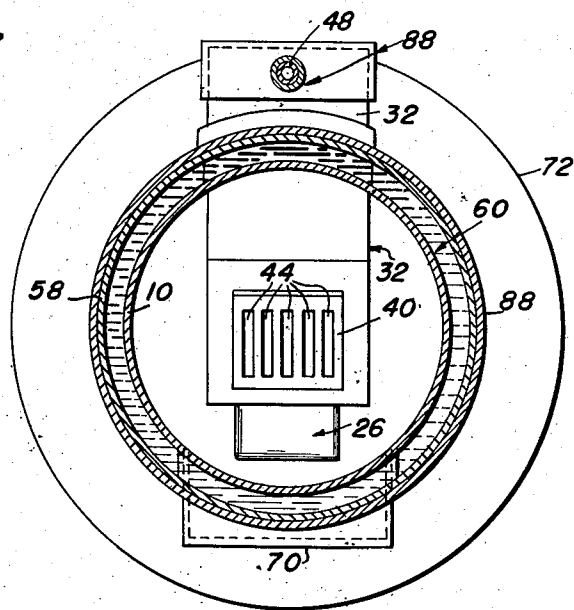


FIG. 3.



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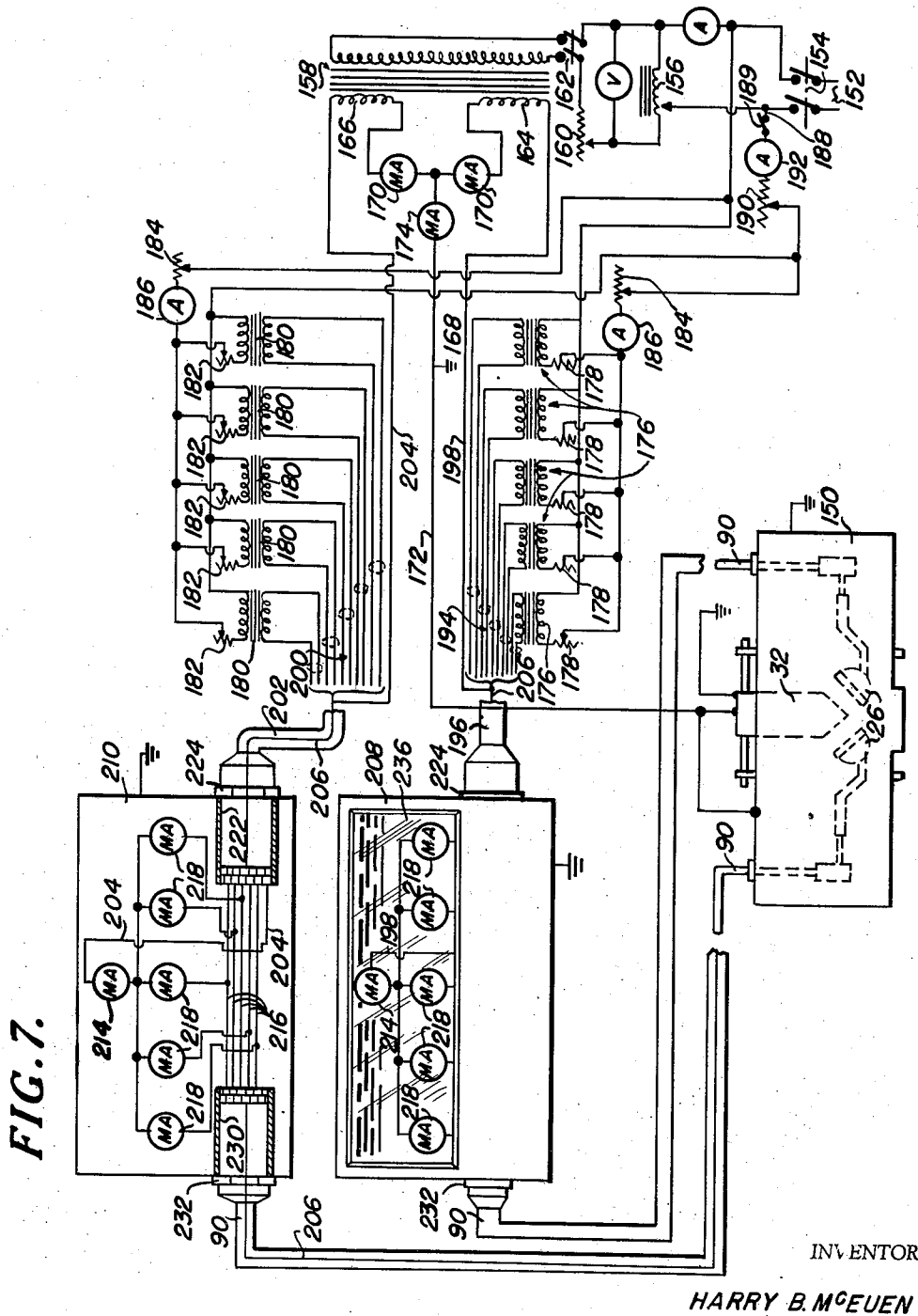
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3 Sheets-Sheet 3



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X-RAY APPARATUS

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6 Claims. (Cl. 313—56)

This invention relates to improvements in X-ray apparatus and more particularly to a new type X-ray generator or tube and attendant circuitry and control apparatus, the capacity and output of which is at least tenfold that of the present day standards. This marked increase in the output of X-rays will enable the use of denser filters or an increased thickness in present filters, and it will also enable the radiologist to increase the distance between the anode and the patient's skin from the present day standard distance of twenty inches to as much as six feet without increasing the time of treatment. This will increase the depth dose markedly in comparison to the surface dose of present day techniques, a factor which is very desirable in the treatment of deep-seated cancer. The increase in output is accomplished by using several anode target or focal areas, each of which generates X-rays upon electron impingement and radiates said X-rays outwardly in a crossfire manner.

Although this invention is particularly useful in X-ray therapy and is described in connection therewith, it is not restricted thereto, but is intended to apply to X-ray apparatus of any type whenever the invention as set forth herein may be utilized.

The desirability of crossfire radiation is based upon the theory that radiation from a single point when used in cancer treatment misses some of the submolecular atomic structures in cancer cells, whereas numerous X-ray groups originating from slightly different locations present a radiation which traverses all minute sections of the tissue being treated with a crossfire dose of X-rays throughout the depth penetrated by these rays.

During treatment of a patient it is, of course, essential that all X-rays emerging from their respective target areas be equal in quantity and intensity in order to prevent burning of tissue by some X-rays while others insufficiently accomplish their purpose.

Therefore, it is the primary object of this invention to provide an X-ray generator which will supply homogeneous crossfiring X-rays from a plurality of anode target areas, there being an equal number of rays emitted from each target area with all rays having the same force of penetration or intensity.

A further object is the provision of a cathodic filament for each of a plurality of target areas and means for producing equal electron flows therefrom and onto the associated target area.

Still a further object is the provision of an evacuated, substantially all-metal X-ray tube having a filter directly attached thereto, thereby avoiding the passage of X-rays through insulative oil or glass and, consequently, preventing uneven filtration.

Another object is the provision of means for cooling the metallic tube and anode without danger of the operator being shocked by the operating potentials of the tube.

Yet another object is the provision of means to insulate the high potential measuring and carrying means

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in a shock-proof manner so that the measuring means can be easily read.

Still other objects of this invention will become obvious to those skilled in the art by reference to the following description of exemplary embodiments of the apparatus and the appended claims. The various features of the exemplary embodiments may be best understood with reference to the accompanying drawings wherein:

Figure 1 is a side elevational fragmentary longitudinal sectional view of an X-ray tube constructed in accordance with the invention;

Figure 2 is a sectional view of the tube in Figure 1 on line 2—2;

Figure 3 is a fragmentary sectional view of the tube and anode of Figure 1 taken approximately on the line 3—3;

Figure 4 is a face view of a cathode for use in an X-ray tube such as shown in Figure 1;

Figures 5 and 6 are sectional views of the cathode shown in Figure 4 on lines 5—5 and 6—6, respectively; and

Figure 7 is a diagrammatic and schematic showing of X-ray apparatus illustrative of this invention.

Figure 1 illustrates the tube proper without any supporting mount being shown. The main body or wall 10 of the tube is cylindrical and is composed of metal, preferably copper, the thickness of which may be approximately 5 mm.

At both ends of the wall 10 is a joint 12 which is silver soldered or otherwise suitably connected to a metallic throat-like collar 13 narrowing to a hollow cylindrical neck 14 of the tube. The collar 13 may also be made of copper or a similar metal which can be spun to shape. Attached to each metallic neck 14 is a cap 16 which is preferably, but not necessarily, glass and is joined by an appropriate seal-off 18. If the cap 16 is glass, the seal-off 18 may be, for example, a chrome-iron ring fused to the neck 14 and the cap 16. The cap 16 has a re-entrant portion extending inwardly of the tube ends forming a hollow protrusion or cathode stem 20, at the inward end of which is a seal-off 22 around the several filament wires 24. A cathode 26 having a metallic supporting neck 28 is fitted over the cathode stem 20 during assembly and held thereon by a metallic clamp 30.

The anode 32 for the X-ray tube is located near the longitudinal center thereof and extends both inwardly and outwardly of the main wall 10. The anode is silver soldered or otherwise suitably mechanically and electrically connected to the wall 10 at the shoulders 34 on the anode. The upper portion 36 of the anode may be of any shape, but is preferably square as shown in Figure 3, the sides of which are approximately four inches in length. At its lower portion 38 two sides of the anode are directed inwardly at an angle of approximately 45° to each other forming a V-shaped lower portion. On opposite sides of the V there are located, respectively, the anode faces 40 and 42, each face having thereon five tungsten target or focal areas 44 which may be more readily seen in Figure 3. Each target area 44 is separated from its adjacent target area approximately one-fourth inch, and the dimensions of each target area are approximately one-fourth inch in width and two and one-half inches in height. The anode 32 is hollow, but heat dissipating fins 46 (Figures 1 and 2) of relatively thin silver are silver soldered or otherwise suitably connected to the inside wall of the anode 32 and extend from the lower tip of the anode to approximately three-fourths its height. The fins 46 transmit the heat generated in the tungsten targets on each side of the anode rapidly upwardly and furnish a large surface for

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dissipation of heat. The anode 32 is further cooled by circulation of fluid, preferably water, through the inside of the anode and around the fins. The water enters through a fluid carrying conductor or pipe 48 connected to the upper and outside portion of the anode at an opening 50 in one side wall of the anode and leaves the anode through pipe 52 similarly connected to the opposite side of the anode. Upon entering the anode the cooling fluid is deflected downwardly by a barrier 54 attached to the top end of the anode. A flexible hose (not shown) may be attached to each pipe end 56 so that the pipes 48 and 52 may be suitably connected, respectively, to a suitable source of water supply and a water disposal system.

Since the anode generates an enormous amount of heat, part of which is transmitted to the metallic tube wall, the wall 10 of the tube should be cooled also. This is accomplished as shown in Figure 1 by adding an annular jacket 58, of copper or similar material, around the central portion of the wall 10 so as to form a channel 60 for flow therewithin of a cooling fluid which is again preferably water. The jacket 58 may be silver soldered or otherwise suitably connected to the wall 10 at each outer end of the channel 60 and around the anode 32 and the filter 70. The channel has two inlets 62 and 64 and two outlets 66 and 68 for purposes of better circulation of the fluid through the whole channel; however, it will be understood that only one inlet and one outlet may be used since the channels 60 on either side of the anode as shown in Figure 1 communicate fully with each other in a direction longitudinally of the tube except for the area immediately surrounding the anode at shoulders 34 and the area immediately surrounding the filter 70. The use of water as the cooling fluid in the channel 60 and within the anode 32 provides direct cooling of the wall 10 of the tube and the faces 40 and 42 of the anode. Water is preferred since it is the best cooling media known, and may be used, regardless of its electrical conducting property, since the anode 32 and the tube wall 10 are at ground potential as is described more fully hereinbelow.

No mounting device for the tube is shown; however, there are provided two annular supports or rings 72 snugly fitted around tube wall 10 and attached thereto; each ring may be attached to a supporting stand and will permit a rotatable mounting thereon. The rings 72 also form a support for the water pipes 48 and 52 thereby taking all the stress off the anode.

In order to allow the X-rays generated at the target areas 46 to be utilized, there is provided a window area 74 in the wall 10 of the tube. A filter 70 of beryllium or other suitable material is permanently silver soldered or otherwise suitably attached to the wall 10 and projects outwardly through the window area 74. It should be noted at this point that the X-ray tube is highly evacuated with the filter 70 being the only filtering medium for the X-rays between the anode 32 and the outside atmosphere. The filter being permanently attached and having a thickness predetermined by the desired filtration will provide a constant filtering effect upon the X-rays, there being no oil or glass through which the X-rays need to pass.

At each end of the tube there is a tubular metallic sleeve 76, preferably steel, fitted snugly over the tube wall 10 and attached to rings 72 by bolts 78 disposed through an annular flange 79 integral with sleeve 76. A closure plate 80 of steel or similar material covers the opposite open end of the sleeve 76 and is attached by bolts 82 spaced around the periphery of plate 80 to another annular flange 84 integral with sleeve 76. Oil-tight gaskets (not shown) may be necessary between the sleeves 76 and the rings 72 and also between the sleeves and closure plates 80.

All exposed portions of the sleeves 76, plates 80, tube

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wall 10, jacket 58, anode top 86, and the wall pipes 48 and 52 near the anode are covered with a protective thickness of lead 88 to stop any extraneous and undesired radiation of X-rays. The exposed sides of the anode may be lead covered; however, the thickness of the anode walls is usually sufficient to absorb undesirable radiations.

Near the outside ends of each sleeve 76 there is provided an opening 89 for the insertion of a flexible cable 90 carrying filament energizing wires with a high tension current thereon. The flexible cable 90 passes through opening 89 with an insulator 92, which is secured to sleeve 76 by a packing nut 94, and further extends to an electrical coupling adapter 96 at the two cathode ends of the tube. The coupling adapter 96 has a male and female section, one of which is attached to the cable 90 and the other of which is permanently connected to the glass cap 16. The incoming cable 90 carries five pairs of wires (plus a single cathode biasing wire if desired) and each wire connects to a separate terminal within adapter 96 for further connection by wires 24 passing through cathode stem 20 and neck 28 to the individual filaments 98 in cathode 26. Since the cable 90 and the adapter 96 carry a high potential, the space 100, defined by sleeves 76, plates 80 and the ends of the tube, is filled with an insulating fluid, such as oil. Therefore, the gaskets, mentioned above in connection with the bolting of sleeves 76 to rings 72 and the closure plates 80, may well be necessary.

Each pair 102 of wires from the cable 90 is connected to a separate filament as shown for one of the filaments 98 in Figures 1 and 6 and for all filaments in Figure 5. If it is necessary to use cathode biasing, another wire 104 carried in cable 90 is brought through the cathode stem 20 and neck 28 to the cathode structure 108 and attached thereto by a screw 106 (Figures 1 and 5). Referring now to the housing for the filaments or the cathode structure 108 as shown in Figures 4, 5 and 6, it will be noted that the structure comprises five focusing cups 110 integrally or separately constructed and an equal number of filament holders 112, each holder providing a solid floor section for the cup 110. The filament holders or floor sections 112 are connected to the bottom of the cups by screws 114, the aperture through a floor section 110 for a screw 114 being a slot (not shown) providing for sidewise adjustability of the filament. Thus, a technician will be able to assemble the entire filament assembly to the closest or most accurate dimensions necessary. The transverse cross section of a filament holder forms an inverted T, the base 116 of which completely covers the aperture through the bottom of a focusing cup 110, and thereby preventing any backward emergence and subsequent escaping of electrons. The filament holder material may be reflective in nature, if desired, in order to return any backward flowing electrons towards the anode. Spaced along the length of the cup filling portion 118 (Figure 6) of a filament holder 112, there are supporting members 120 for securing the filament intermediate its ends. These supporting members composed of insulative material are embedded in insulation 122 on the top ledge of a removable filament holder 112. The lead-in wires 124 to the filament 98 are insulated at least along their length passing through a filament holder.

Referring now to Figure 7 wherein there is shown the electrical circuits, apparatus and connections therefrom to the X-ray tube, it will be noted that a tube 150 is shown in miniature diagrammatic form with an anode 32, cathode 26 and flexible lead-in cables 90. The original source of potential 152 is led in through a double pole master switch 154 and placed across a variable autotransformer 156, thence to the primary of the high potential transformer 158 through a rheostat 160 and high tension double pole switch 162. The transformer 158 has two separate secondary windings 164 and 166

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one side of each being connected to ground 168 through milliammeters 170 and 174. In order to assure a grounded connection at the anode 32 and the tube 150, a wire 172 may be connected from the ground point 168 of the secondaries of the high potential transformer to the anode 32 and the tube. The other side of the secondaries 164 and 166 supply the high potential necessary for the operation of the X-ray tube and will be more fully described below.

Each of the five filaments 98 located in cathodes 26 is separately connected to a filament transformer. The primaries of the transformers 176 leading to one of the cathodes 26 are connected in parallel and have an individual balancing rheostat 178. The source of potential to the primaries of transformers 176 is taken from the main source 152 with connection thereto being made after switch 154. Another set of five transformers 180 is similarly connected and the primary circuit of each contains a balancing rheostat 182 but the secondaries thereof supply voltage individually to the filaments in the other cathode 26. Each pair of lines leading to the two sets of five transformers 176 and 180 has an individual rheostat 184 and ammeter 186 for total amperage control to each set of five filaments. Connected in the line 188 before the bifurcation to the two sets of transformers 176 and 180 are a filament switch 189, a master rheostat 190 and an ammeter 192 for control of the overall filament heating current and the flow of electrons to the anode as will be seen hereinafter.

The output lines 194 of the filament transformers 176 are grouped together and entered into a flexible shock-proof cable 196. Also coming into the cable is a high potential line 198 from the secondary winding 164 of transformer 158. The output lines 200 of the filament transformers 180 are similarly grouped and entered into flexible shock-proof cable 202 with the high potential line 204 from the secondary winding 166 of the transformer 158 also entering the cable 202. Cables 196 and 202 separately carry their wires, represented as a single line 206 within the cables, into measuring tanks 208 and 210, respectively, said tanks being preferably located near the operator's station for convenience to the operator in reading the meters within the tanks. The high potential current on line 198 in tank 208 and on line 204 in tank 210 is measured respectively by milliammeters 214, there being one in each tank, and is superimposed through milliammeters 218 upon one side 216 of each filament circuit in its associated tank. (Only one side of each circuit is shown in tank 214.) The filament lines are made available for connection to the high potential lines 198 and 204 by utilizing a coupling adapter 220 (similar to adapter 96 described above) connected to the flexible cables 196 and 202 and the filament lines inside the tanks 208 and 210, said cables being covered within the tank by a glass or Bakelite insulating sleeve 222. A packing nut 224 located on the outside of the tank secures the cable in position. The filament lines are attached to an out-going cable 90 by an adapter 228 in the same manner as described above. Cable 90 is also insulated within the tanks by a glass or Bakelite sleeve 230 with packing nut 232 securing the cable to the tanks. The tanks 208 and 210 are filled with a transparent insulative fluid 234 such as oil, are grounded, and may be wholly constructed of a transparent material such as glass or of metal with a transparent window 236 for reading the milliammeters. It will be understood that the connections in tank 210 and for the cable 202 described above apply also to the tank 208 and cable 196. Flexible output cables 90 are connected respectively to cathodes 26 within the X-ray tube 150.

Although the source of high potential has been conveniently described and shown in connection with a transformer 158 having two secondary windings, it is obvious that any two sources supplying proper voltages may be utilized. Also each filament circuit need not be

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supplied with voltage through a transformer, the only requirement being that each filament be supplied with a separately regulatable source. Either the high or low voltage sources may have alternating or direct current.

The structure and circuitry of the X-ray apparatus having been described, the operation of the apparatus will now be considered. Upon energizing the filaments 98 and supplying a high potential between the anode and filaments, each filament will be heated sufficiently to emit electrons, and the high potential will cause an electron flow to the anode. In order to equalize the quantity and intensity of X-rays generated at the anode target areas, it is necessary that the flow of electrons from each filament to the target area upon which it is focused be equal, thus requiring that all ten of the milliammeters 218 record the same amount of high potential current going onto the separate filament circuits. Adjustment of the balancing rheostats 178 and 182 will change the amount of high potential current allowed to flow through milliammeters 218. Whenever any one or all of the milliammeters 218 is out of balance (i.e. does not record the same amount of current as the others), its associated balancing rheostat is adjusted to bring the current through the milliammeter back into balance. In this manner, an equal flow of electrons will result from each filament, and an equal distribution of heat will be created upon the anode. In addition to preventing any "hot spot" on the anode (which is rather common in present day tubes), X-rays generated from the ten linear focal areas 44 provide crossfire radiation in a homogeneous manner.

It will be understood that although this invention has been described in connection with X-ray apparatus having two cathodes each with five filaments placed upon a dual faced anode and other structural and circuit details, the matter contained in the foregoing description and accompanying drawings should be interpreted as merely illustrative and not limitative, the scope of the invention being defined in the appended claims.

What is claimed is:

1. X-ray apparatus capable of producing homogeneous crossfire radiations comprising an evacuated X-ray tube, an anode at least partially disposed within the tube and having a plurality of uniform target areas, a filter located in predetermined relation to the anode and sealed directly to said X-ray tube at an opening in the periphery thereof to allow passage of X-rays, a cathode structure having at least one filament associated with each target area, said structure comprising a plurality of focusing cups, each having a separate adjustable and removable solid floor section holding one of said filaments at a predetermined focus and completely covering the bottom of the cup; means for superimposing a high potential between each filament and its corresponding target area, a separate regulatable source of current for each filament for providing equal electron flow therefrom, means for measuring each superimposed high potential current for assuring equalization therebetween during operation of the filament current source, and a tank disposed adjacent said tube, said tank being composed at least partially of a transparent material and containing a transparent high potential insulative fluid for housing the measuring means in a readable yet shockproof manner.

2. X-ray apparatus comprising an evacuated X-ray tube composed substantially of metal and at ground potential, said tube having a jacket adjacent its periphery forming a channel for passage of cooling fluid therethrough, a fluid cooled anode at least partially disposed within said tube and connected electrically thereto, a filter located in predetermined relation to said anode and sealed directly to the metal portion of said X-ray tube at an opening in the periphery thereof for allowing passage of X-rays directly to the outside atmosphere for utilization, a plurality of cathodic filaments associated with the anode, a different focusing cup for each filament, each cup having a separate adjustable and removable solid floor section holding

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its filament at a predetermined focus and completely covering the bottom of the cup, and a source of high potential connected on one side to each filament and on the other side to ground and thereby to said tube and anode so that all exposed portions of the apparatus are at ground potential.

3. X-ray apparatus capable of producing homogeneous crossfire radiations comprising an evacuated X-ray tube, an anode at least partially disposed within the tube and having a plurality of uniform discrete target areas, a cathode structure having at least one filament associated with each target area, means for superimposing a high potential between each filament and its corresponding target area, and means for providing an equal flow of electrons from each filament so that an equal emission of X-ray results from each anode target area upon impingement by said electrons, said cathode structure comprising a plurality of focusing cups each having a separate adjustable and removable solid floor section holding one of said filaments at a predetermined focus and completely covering the bottom of the cup.

4. X-ray apparatus comprising an evacuated X-ray tube composed substantially of metal and at ground potential, an anode at least partially disposed within the tube and connected electrically to said tube, a plurality of cathodic filaments associated with the anode, a source of high potential connected on one side to said filament and on the other side to ground and thereby to said tube and anode so that all exposed portions of the apparatus are at ground potential, and a different focusing cup for each filament having a separate adjustable and removable solid floor section holding its filament at a predetermined focus and completely covering the bottom of the cup.

5. A new use of X-ray apparatus including an anode having a plurality of uniform discrete target areas and at least one cathodic filament associated with each target area, said use being the production of homogeneous crossfire radiations and including the steps of applying a high potential between said anode and each of said filaments,

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applying separate low voltages simultaneously across each of said filaments, separately but simultaneously indicating the amount of the respective high potential filament currents resulting, and regulating said low voltages to cause the indicated high potential filament currents to be simultaneously equal so as to assuredly cause an equal flow of electrons from each filament simultaneously onto the respective target areas and thereby provide uniform X-ray emission from all the different target areas at the same time.

6. An X-ray tube having an anode and a cathode with a plurality of filaments, said cathode comprising a focusing cup for each different filament, each cup having a separate adjustable and removable solid floor section holding its filament at a predetermined focus relative to a given area on said anode and completely covering the bottom of the cup.

References Cited in the file of this patent

UNITED STATES PATENTS

688,458	Caldwell	Dec. 10, 1901
1,907,508	Coolidge	May 9, 1933
1,986,466	Ehrke	Jan. 1, 1935
2,049,275	Simon	July 28, 1936
2,130,020	McEuen	Sept. 13, 1938
2,139,966	Loebell	Dec. 13, 1938
2,213,112	Timmons	Aug. 27, 1940
2,215,426	Machlett	Sept. 19, 1940
2,350,642	Schwartzner	June 6, 1944
2,362,816	Harker	Nov. 14, 1944
2,471,298	Atlee	May 24, 1949
2,515,021	Simpson	July 11, 1950
2,517,171	Bernreuter	Aug. 1, 1950
2,518,539	Graves	Aug. 15, 1950
2,597,498	Kerkhoff	May 20, 1952
2,663,812	Jamison et al.	Dec. 22, 1953
2,692,340	Reiniger	Oct. 19, 1954