(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 149 337**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **84308697.6**

(22) Date of filing: **19.12.84**

(51) Int. Cl.⁴: **H 05 G 1/06**
H 05 G 1/10, H 05 G 1/52

(30) Priority: **16.01.84 US 570888**

(43) Date of publication of application:
24.07.85 Bulletin 85/30

(84) Designated Contracting States:
DE FR GB NL

(71) Applicant: **PICKER INTERNATIONAL, INC.**
595 Miner Road
Highland Heights Ohio 44143(US)

(72) Inventor: **Palermo, Anthony**
1715 Biltamy Boulevard
South Euclid, Ohio 44121(US)

(74) Representative: **Pope, Michael Bertram Wingate**
Central Patent Department Wembley Office The General Electric Company, p.l.c. Hirst Research Centre East Lane Wembley Middlesex HA9 7PP(GB)

(54) X-ray generating apparatus and method of operating an X-ray tube.

(57) An X-ray generating apparatus with a filament energizing transformer (Figure 8: 120, 121: Figure 9: 184) mounted inside the X-ray tube housing (11) while a high voltage generating transformer (112) remains outside that housing (11). This arrangement allows a single high magnitude negative polarity input (114) to be routed through the tube housing (11) and coupled to the tube cathode (24).

In one embodiment of the invention two cathode filaments (54, 56) are each energized when in use by an associated one of two filament transformers (120, 121) inside the housing (11). Selective energization of one or the other transformers determines which filament is to be energized. In an alternate embodiment a frequency sensing electronic switch (188) chooses which filament (54, 56) to energize depending on the energization frequency input to a single filament transformer (184).

A method of operating an X-ray tube is also provided.

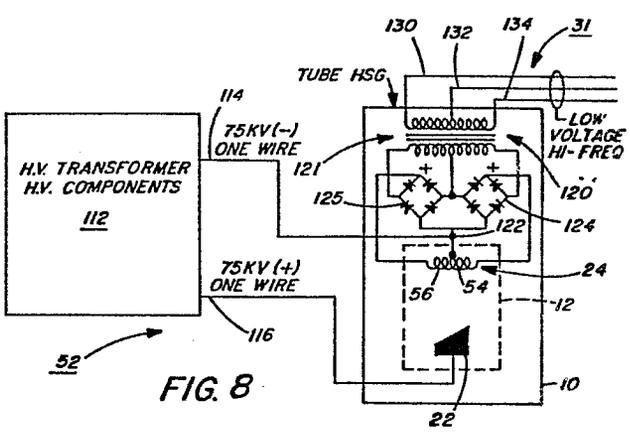

FIG. 8

EP 0 149 337 A2

X-ray generating apparatus and method of operating an X-ray tube

The present invention relates to X-ray generating apparatus, more especially X-ray tube heads, and to methods of operating X-ray tubes.

Prior X-ray tube heads have traditionally included a metallic enclosure with an X-ray transmissive window through which X-rays are transmitted. Inside the housing is mounted an X-ray tube surrounded by an oil or gas insulating dielectric. The X-ray tube itself includes an anode and cathode which are electrically biased or energized with large accelerating voltages which accelerate electrons from the cathode through an evacuated chamber striking the anode with enough kinetic energy to produce x-radiation.

In a typical prior construction, high voltage signals are routed through inputs into an X-ray tube housing to the cathode and anode. One or more cathode filaments for generating the electrons must also be energized. Typically a filament is electrically interconnected to the high voltage cathode input. A low magnitude alternating or D.C. voltage, superimposed on this high voltage, generates A.C. or D.C. current causing electrons to be thermionically emitted from the cathode. This filament excitation signal is routed from outside the tube housing via high voltage cabling and connectors leading to a so-called X-ray voltage generator. The generator

includes a filament transformer whose primary winding is typically part of a high voltage power transformer.

In a head using a conventional two filament X-ray tube, three fifteen gauge wires embedded in the central core of a high voltage cable pass through the housing exterior. The three wires carry the low voltage filament current. One of the wires is connected to the high voltage generated at the high voltage transformer which forces all three wires to be at high voltage. The filament voltages generally are a few volts (5-10) and may be either A.C. or D.C.

To facilitate inventory control, the anode generally is energized with an identical three conductor high voltage cable. For the anode, however, the three conductors are usually shorted together in the high voltage transformer and X-ray tube housing causing the cable to act as a single conductor.

A second type of prior X-ray tube head is used for dental X-ray or other low power applications. In this type of head the tube is housed in a self-contained unit having a metallic enclosure and beam window. Also enclosed in the metallic enclosure are both filament and high voltage transformers. These transformers receive low voltage signals from outside the X-ray tube head and generate high voltage signals for the anode and cathode as well as the cathode filament voltage. Since only low voltage is routed to these X-ray tube heads, the high voltage connectors mentioned above are not needed. U.S. Patent No. 2,356,645 to Atlee et al. discloses an X-ray tube head of this second type design.

However, in higher power applications where it is not practicable to generate the required high voltage signals in the head, the required three conductor high voltage cables, in addition to being expensive in cost of materials, make the high voltage connections of low flexibility which is sometimes inconvenient, for example,

in computed tomography equipment, and other environments where repeated flexing of the cabling leading to the X-ray tube head is needed.

It is an object of the present invention to provide an X-ray generating apparatus and method of operating an X-ray tube whereby these difficulties may be alleviated.

According to the present invention there is provided an X-ray generating apparatus comprising: an X-ray tube having a cathode and anode; the cathode including at least one cathode filament for thermionically emitting electrons; a housing enclosing said X-ray tube; a filament transformer for energizing said filament; and coupling means for applying a high magnitude voltage from outside said housing between said cathode and anode to energize said cathode and anode and accelerate electrons from said filament to said anode with sufficient energy to generate x-radiation characterised in that said filament transformer is mounted in said housing and a low voltage alternating current input is routed through said housing to energize said filament transformer.

In one particular embodiment of the invention said tube includes at least two cathode filaments; a separate filament transformer is mounted in said housing for individually energizing each said filament; and low voltage alternating current inputs are routed through said housing for individually energizing each said transformer.

In another particular embodiment of the invention said tube includes at least two cathode filaments and said apparatus additionally includes a switch for selectively coupling an output from said filament transformer to a selected one of said filaments.

In such an apparatus said switch is suitably responsive to the frequency at which said transformer is energized when in use to determine which filament is

coupled to the transformer output.

The invention further provides a method of operating an X-ray tube comprising the steps of electrically energising the tube anode and cathode mounted inside a tube housing, energizing a filament transformer positioned within the housing by coupling a relatively low voltage alternating current signal through said housing to a transformer input, and energizing said cathode filament to thermionically emit electrons by coupling a transformer output to said filament.

It will be appreciated that in an apparatus and method according to the invention only a single conductor high voltage connection is required to the cathode, thus facilitating the design of the cabling and connections and in particular eliminating the use of multi-conductor cables entirely since the anode also requires only a single conductor high voltage connection. The use of single conductor high voltage connections enables the diameter of the cabling to be reduced to provide greater flexibility at lower cost.

Two arrangements in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is an elevational view of an X-ray tube head with a portion of its housing broken away to show an X-ray tube mounted inside the housing;

Figure 2 is a plan view of the Figure 1 head;

Figure 3 is an end elevational view of the Figure 1 head;

Figure 4 is a side elevational view of a high voltage tube energization connector including a high voltage cable and a high voltage receptacle and coupling;

Figure 5 is an end elevational view of the receptacle shown in Figure 4;

Figure 6 is a perspective schematic showing a filament transformer for energizing a cathode filament;

Figure 7 is an electrical schematic of a prior art X-ray tube head; and

Figures 8 and 9 are electrical schematics of two X-ray tube heads in accordance with the invention.

Turning now to the drawings, Figure 1 shows an X-ray tube head shown generally at 10. The head includes a housing 11 enclosing an X-ray tube 12. The tube housing 11 comprises two end portions 14, 16 separated by an intermediate portion 17. The intermediate portion is coupled to the end portions by fluid tight seals to allow the X-ray tube housing 11 to be filled with an insulating fluid, typically oil, that surrounds and insulates the X-ray tube 12. The end portions 14, 16 include electrical receptacles 18, 20 which transmit high electrical voltages to the X-ray tube 12.

The disclosed X-ray tube 12 includes a rotatable anode 22 and a fixed filament cathode 24 mounted within an evacuated glass envelope 26. Electrons emitted by a cathode filament accelerate to a target or focal spot 27 on the anode. Sudden deceleration of the electrons causes X-rays 28 to be emitted. The anode 22 is rotated in a conventional manner to distribute the heating about the anode circumference. This rotation is imparted by a motor 29 whose stator windings are energized with signals routed through a low voltage input cable 31.

The intermediate portion 16 of the X-ray tube housing 11 includes an X-ray transmissive window 30 of thin aluminium (0.5 mm) or high impact plastic material such as "Lexan". The window 30 is located adjacent to the anode focal spot 27 so that a portion of the generally spherical X-rays 28 from the focal spot pass through the window. Once it exits the housing the radiation can be collimated using techniques known in the art.

Further details regarding the construction and arrangement of an X-ray tube head may be obtained by referring to either U.S. Patent No. 3,859,534 to Loughlin or 4,097,759 to Furbee et al., both of which have been assigned to Picker International Inc., assignee of the present invention. Those patents are incorporated herein by reference.

Many X-ray tubes include multiple cathode filaments which can be independently energized to produce different size focal spots on the anode 22 for different X-ray diagnostic applications. U.S. Patent 4,109,151 to Pleil discloses one such multiple focal spot X-ray tube. The disclosure of that patent is also incorporated herein by reference.

Differences between the prior art apparatus for energizing the X-ray tube to produce multiple focal spots and the present design are illustrated by comparing the energizing circuits 50, 52 of Figures 7 and 8. The Figure 7 circuit 50 discloses a prior art energization technique requiring three high voltage inputs for the cathode. As seen in Figure 7 the tube housing 10 encloses an X-ray tube 12 having a cathode 24 which includes two energizable electron emitting filaments 54, 56. The filaments share a common high voltage input 58 which in a typical X-ray tube carries a high magnitude direct current voltage on the order of 75,000 volts referenced to ground.

To cause electrons to be thermionically emitted from one or the other of the two filaments 54, 56 two additional high voltage inputs 60, 62 are needed. These inputs carry high voltage signals having a small magnitude A.C. or D.C. signal superimposed upon the high magnitude direct current signal carried by the input 58. Stated another way, the inputs 60, 62 also carry voltages on the order of 75,000 volts, plus or minus a small A.C. or D.C. signal on the order of 10 volts. This signal,

when imposed across the filaments 54, 56 sets up a current which thermionically produces electron emissions. It should be appreciated that generally only one or the other of the two filaments 54, 56 will be energized at a given time so that only two of the three inputs 58, 60, 62 will be energized.

A high voltage positive input 64 of approximately 75,000 volts referenced to ground is coupled to the anode 22 so that the voltage separation between the cathode 24 and the anode 22 is on the order of 150,000 volts. This large voltage difference accelerates electrons from an energized one of the two filaments 54, 56, causing them to accelerate and strike the anode 22.

Both positive and negative high voltage inputs to the tube housing 11 are generated by a voltage generator 70. This generator 70 includes circuitry (not shown) for generating a high voltage signal, includes two high voltage filament transformers 72, 73, and may or may not include rectifiers 74, 75 for generating the direct current signals needed for the three inputs 58, 60, 62. Use of three inputs 58, 60, 62 to the housing 11 for the rube cathode 24 requires three pin contacts in the receptacle 18 to carry these high voltage signals to the housing.

In accordance with the invention, the circuit 52 disclosed in Figure 8 is used to energize the two filaments 54, 56. In this embodiment a high voltage generator 112 transmits two inputs 114, 116 to the housing 11. A first input 114 carries a negative voltage having a magnitude of approximately 75,000 volts referenced to ground and the second input 116 carries a positive signal of the same magnitude. The positive polarity signal energizes the tube anode 22 and is completely analagous to the anode signal transmitted in the prior art circuitry 50 shown in Figure 7. The single negative input 114, however, replaces the three high voltage inputs 58, 60, 62 required to energize the prior

art cathode 24.

Filament energization signals are generated by one of two filament transformers 120, 121 insulated for high voltage mounted inside the tube housing 11. The secondary of each transformer 120, 121 is coupled to the high voltage input 114 at a junction 122. A first bridge rectifier 124 rectifies an output from the first filament transformer 120 to impose a low level direct current signal across the filament 54 and a second bridge rectifier 125 rectifies the output from the second transformer 121.

Which of these two filaments 54, 56 is energized depends upon the status of three low voltage high frequency inputs 130, 132, 134 to the tube housing 11. These inputs are coupled to the filament transformer so that when the two inputs 130, 132 are energized, the filament 56 has a low level direct current signal imposed across it to provide energization to thermionically produce electrons. Similarly, when the two inputs 132, 134 are energized the filament 54 emits electrons. These low voltage inputs 130, 132, 134 are routed through the housing via the low voltage cable 31.

The transformers 120, 121 are small, ferrite core, filament transformers insulated for 75,000 volts operating above 10 kilohertz with the secondary producing about 5 volts RMS at 5 amperes current. A schematic of one such transformer showing a core 136, coil 138, primary leads 140a, b and secondary leads 142a, b is shown in Figure 6.

The advantages a single high voltage input coupled to the cathode has over the prior art can be seen by referring to Figures 4 and 5 where a high voltage connection 148 is illustrated. The connector 148 includes a female receptacle 150 positioned inside the cathode receptacle 18 bounded by a cavity 152 in the housing 11. The female receptacle 150 includes a single high voltage contact 154 connected to the two filament transformers 120, 121. The

receptacle 150 includes a flanged shoulder 156 which contacts an O-ring seal 158 interposed between the housing 11 and the shoulder 156. This seal 158 prevents fluid within the cavity 152 from leaking outside the housing. This fluid helps isolate or insulate the connector 150 from the remaining portions of the X-ray tube housing 11.

A male connector 160 is inserted into the female receptacle 150 to route signals from the high voltage generator 112 to the cathode 24. The male connector 160 is coupled to a high voltage cable 162 and held in place against the tube housing by a cable retainer 164. Once the male connector 160 is inserted into the female receptacle 150 this retainer 164 is tightened down by a threaded coupling 166 which mates with a threaded portion 168 of the receptacle 18.

Unlike the prior art design wherein both connectors included three pin contacts, two of which went unused for the anode connector, the present invention employs single pin, high voltage contacts for both cathode and anode. Use of the single pin and single high voltage signal allows the diameter of the male and female connectors 150, 160 to be reduced from the diameter required for the three pin prior art connector. It should be readily apparent that savings in cost of materials as well as cabling can be achieved by this aspect or feature of the invention.

Positioning of the high voltage frequency transformer inside the tube housing 11 has required a modification in the construction of the housing. As seen most clearly in Figures 1-3, the cathode portion 14 of the housing must be widened to accommodate the transformers 120, 121. In the embodiment shown in Figure 8, the transformers 120, 121 comprise two transformer cores 136 as well as two coils 138 which are mounted inside the cathode portion 14 in close proximity to the single high voltage contact 154.

An alternate embodiment for energizing the filaments 54, 56 is illustrated in Figure 9. In this embodiment, single high voltage positive 170 and negative 172 inputs are employed so that the preferred connectors 150, 160 shown in Figure 4 can be utilized. In this embodiment, however, rather than requiring three low voltage A.C. inputs 130, 132, 134 (Figure 8) to the two filament transformer 120, 121 only two low voltage alternating current inputs 180, 182 to a single transformer 184 are needed. The inputs 180, 182 are coupled to a primary of the single core filament transformer 184 having a secondary output which is rectified by a bridge rectifier 186. The D.C. signal from this rectifier 186 is coupled across one or the other of the two cathode filaments 54, 56 depending upon the frequency of the inputs 180, 182. A frequency sensing electronic switch 188 also mounted inside the housing and interposed between the output from the rectifier 186 and the cathode filaments 54, 56 determines which filament will be energized. This frequency sensing switch determines the input frequency of the signals entering the X-ray tube housing and depending upon the frequency closes one of two contacts 190, 192.

In a preferred embodiment, an energization of 10 kilohertz causes the contact 190 to be closed so that a first filament 54 is energized. If the driving frequency is 10.5 kilohertz, the switch 188 closes the second contact 192 energizing the second filament 56.

The advantage of this embodiment is that one filament transformer can be used instead of two. The tube housing 11 need not be as large as the embodiment shown in Figures 1-3 since the frequency sensitive switch 188 requires very little space inside the housing 11.

While the invention has been described with a degree of particularity, it is evident that certain design

modifications could be made in the disclosed invention. It is the intent, however, that all such modifications and/or alterations falling within the spirit or scope of the invention as defined by the appended claims be protected.

CLAIMS

1. An X-ray generating apparatus comprising: an X-ray tube (12) having a cathode (24) and anode (22); the cathode including at least one cathode filament (54, 56) for thermionically emitting electrons; a housing (11) enclosing said X-ray tube; a filament transformer (Figure 8: 120, 121, Figure 9: 184) for energizing said filament; and coupling means (114, 116) for applying a high magnitude voltage from outside said housing between said cathode and anode to energize said cathode and anode and accelerate electrons from said filament to said anode with sufficient energy to generate x-radiation, characterised in that said filament transformer (Figure 8: 120, 121, Figure 9: 184) is mounted in said housing (11) and a low voltage alternating current input (Figure 8: 31, Figure 9: 180, 182) is routed through said housing to energize said filament transformer.

2. An apparatus according to Claim 1 wherein said tube includes at least two cathode filaments (54, 56); a separate filament transformer (120, 121) is mounted in said housing for individually energizing each said filament; and low voltage alternating current inputs (130, 132; 132, 134) are routed through said housing for individually energizing each said transformer.

3. An apparatus according to Claim 3 further including rectifying means (124, 125) coupled between the outputs of said transformers (120, 121) and said filaments (54, 56) to selectively impose a rectified signal across a selected one of said filaments in response to selective energization of said low voltage inputs (130, 132: 132, 134).

4. An apparatus according to Claim 1 wherein said tube includes at least two cathode filaments (54, 56) and said apparatus additionally includes a switch (188) for selectively coupling an output from said filament transformer (184) to a selected one of said filaments.

5. An apparatus according to Claim 4 wherein said switch (188) is responsive to the frequency at which said transformer (184) is energized when in use to determine which filament (54, 56) is coupled to the transformer output.

6. An apparatus according to any one of Claims 2 to 5 wherein said filaments (54, 56) are arranged to produce different size focal spots on said anode (22).

7. An apparatus according to any one of the preceding claims wherein said housing (11) contains a dielectric fluid for insulating said X-ray tube (12).

8. An apparatus according to any one of the preceding claims wherein said coupling means comprises means (114) for coupling said cathode (24) to a high voltage source of a first polarity and means (116) for coupling said anode (22) to a high voltage source of opposite polarity, said housing (11) including connection means (Figure 4) for routing said first and opposite polarity voltages through said housing (11) to said anode (22) and said cathode (24).

9. A method of operating an X-ray tube characterised by the steps of electrically energizing the tube anode and cathode mounted inside a tube housing, energizing a filament transformer positioned within the housing by coupling a relatively low voltage alternating current signal through said housing to a transformer input, and energizing said cathode filament to thermionically emit electrons by coupling a transformer output to said filament.

10. A method according to Claim 9 wherein the output from said filament transformer is directed to one of two cathode filaments depending upon the frequency with which said transformer is energized.

11. A method of operating an X-ray tube of the type where an anode and cathode are mounted in a tube housing characterised by coupling a high voltage signal to each of

said cathode and anode to electronically energize said cathode and anode; energizing a low voltage filament transformer inside said housing and coupling an output from said transformer to a cathode filament forming part of said cathode; and energizing said filament by coupling a low voltage alternating signal to an input of said transformer.

12. A method according to Claim 11 where an output from said filament transformer is rectified before it is connected to said filament.

0149337

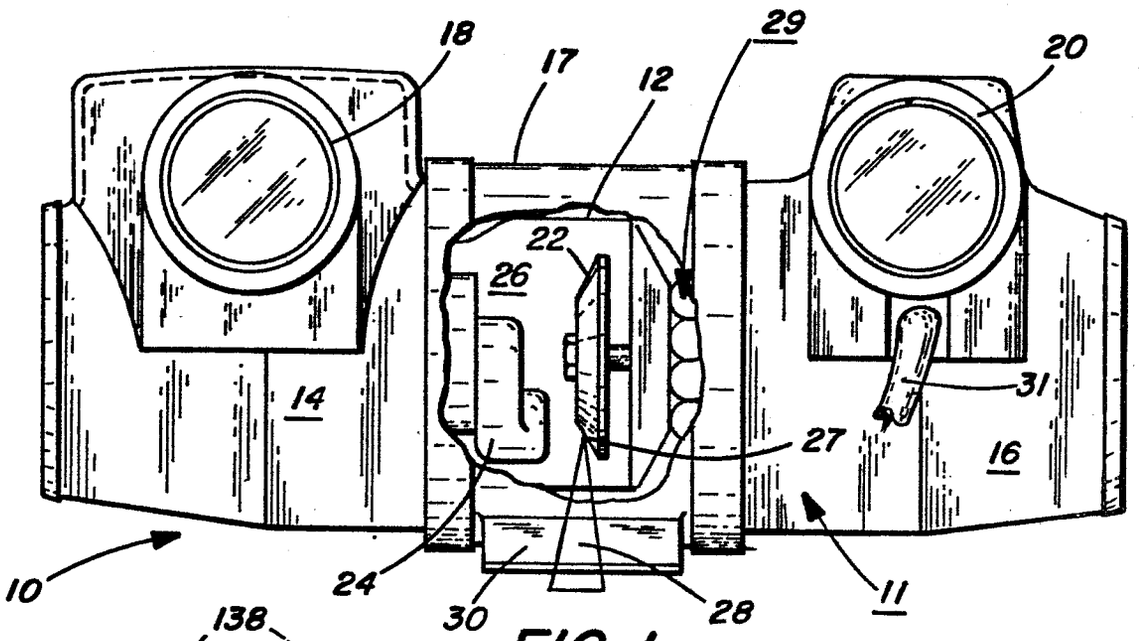

FIG. 1

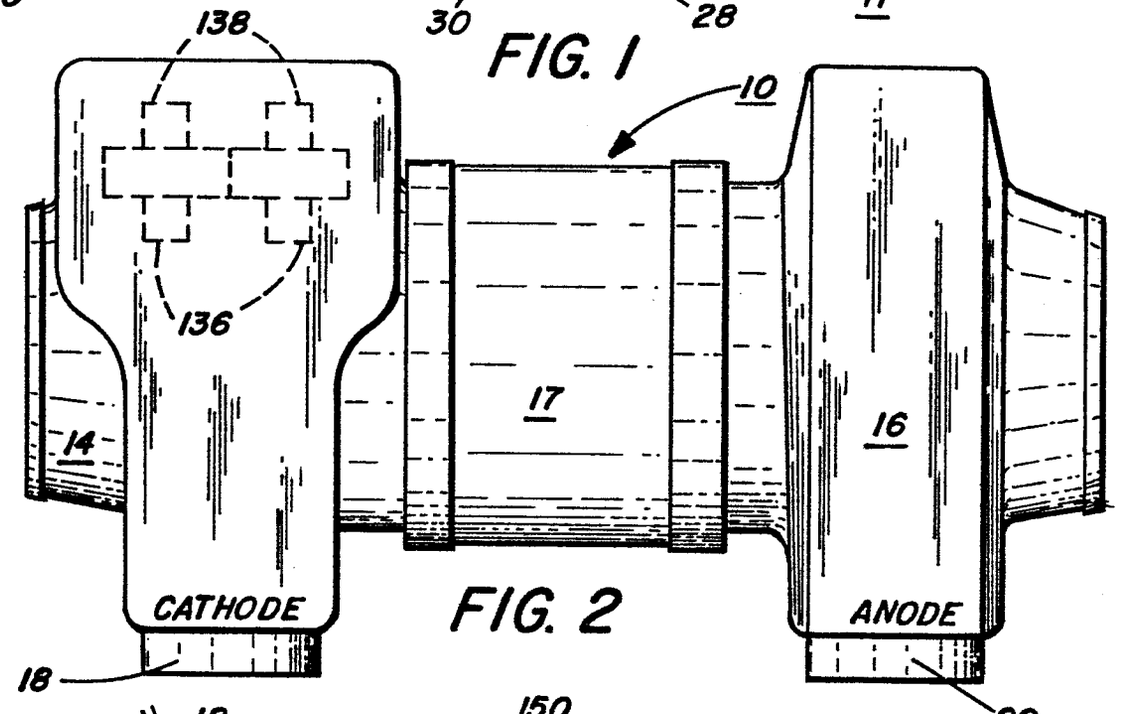

FIG. 2

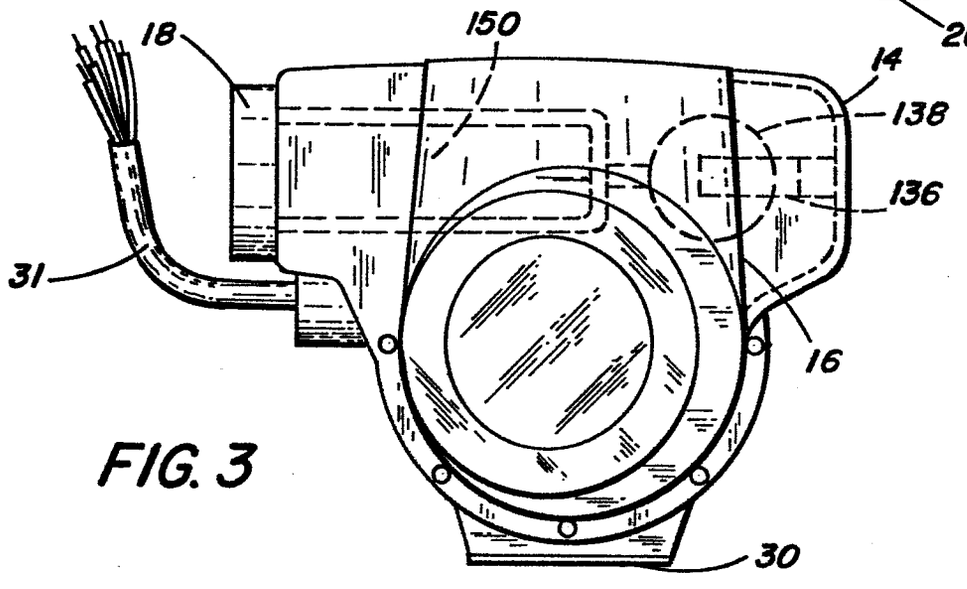

FIG. 3

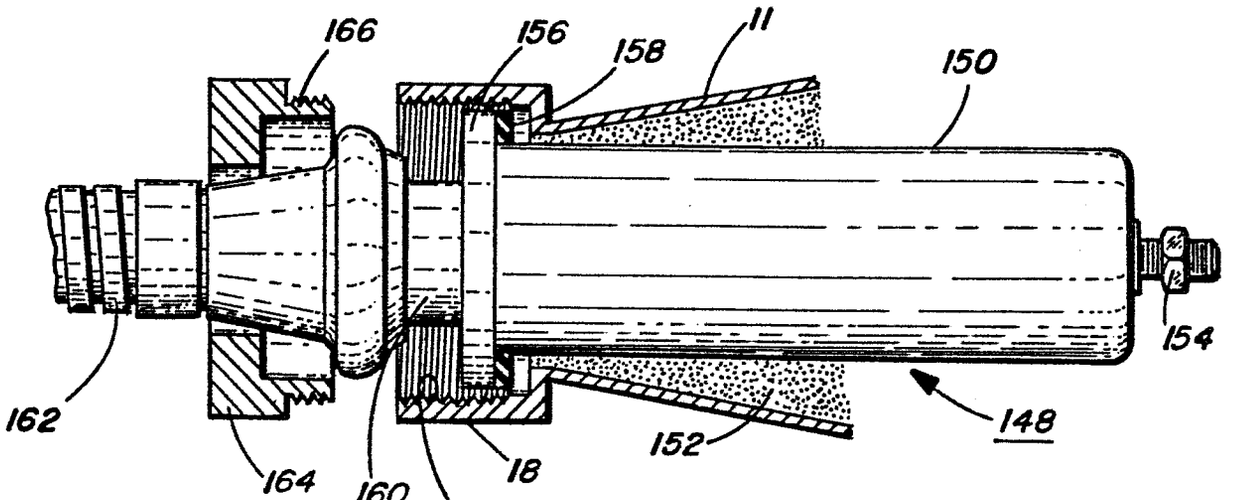

FIG. 4

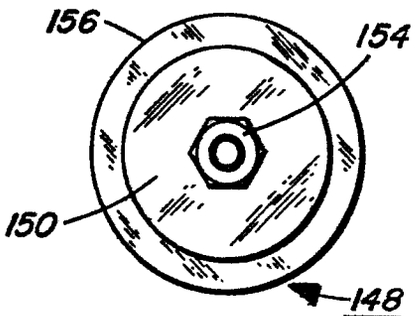

FIG. 5

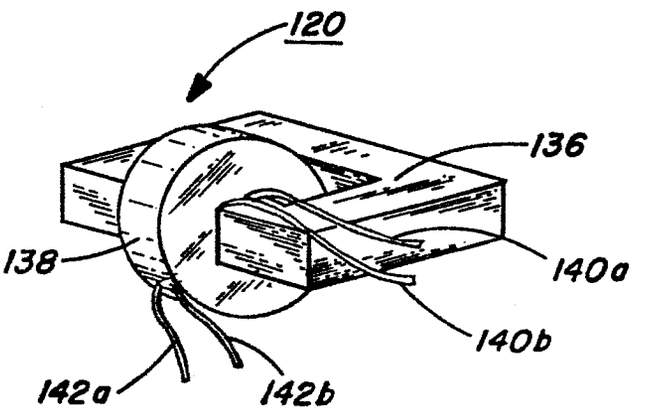

FIG. 6

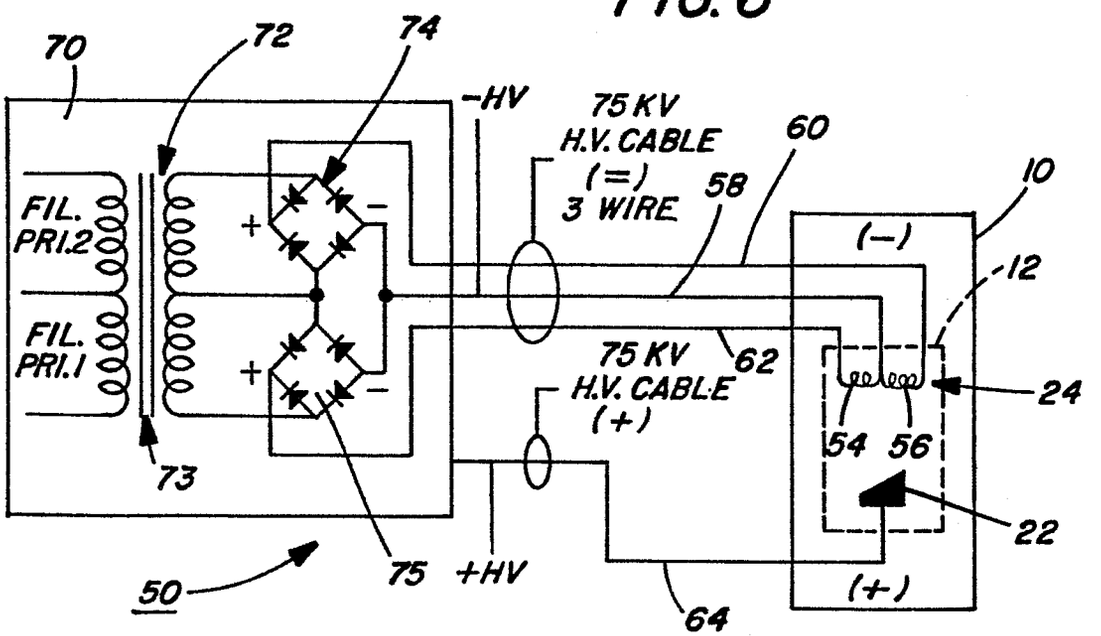

FIG. 7

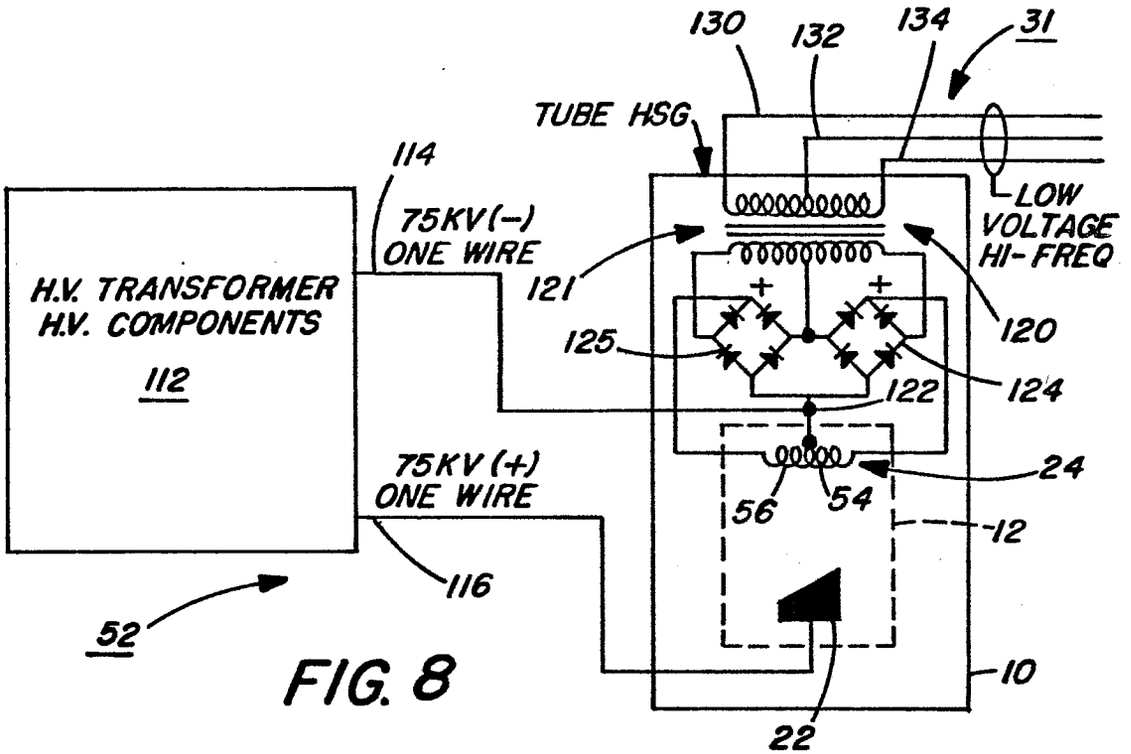
130
132
134
31
TUBE HSG
114
75KV(-)
ONE WIRE
H.V. TRANSFORMER
H.V. COMPONENTS
112
121
LOW
VOLTAGE
HI-FREQ
120
125
122
124
24
56
54
12
75KV(+)
ONE WIRE
116
52
10
22

FIG. 8

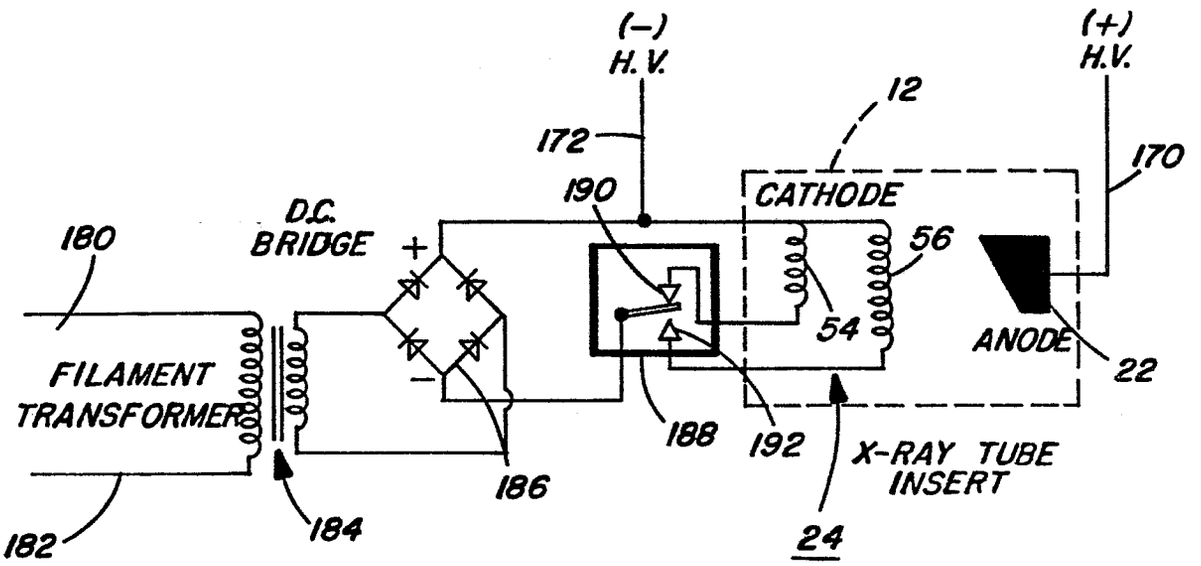
(-)
H.V.
(+)
H.V.
12
172
170
190
CATHODE
D.C.
BRIDGE
180
56
54
ANODE
22
FILAMENT
TRANSFORMER
188
192
X-RAY TUBE
INSERT
186
182
184
24

FIG. 9