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X-RAY TUBE

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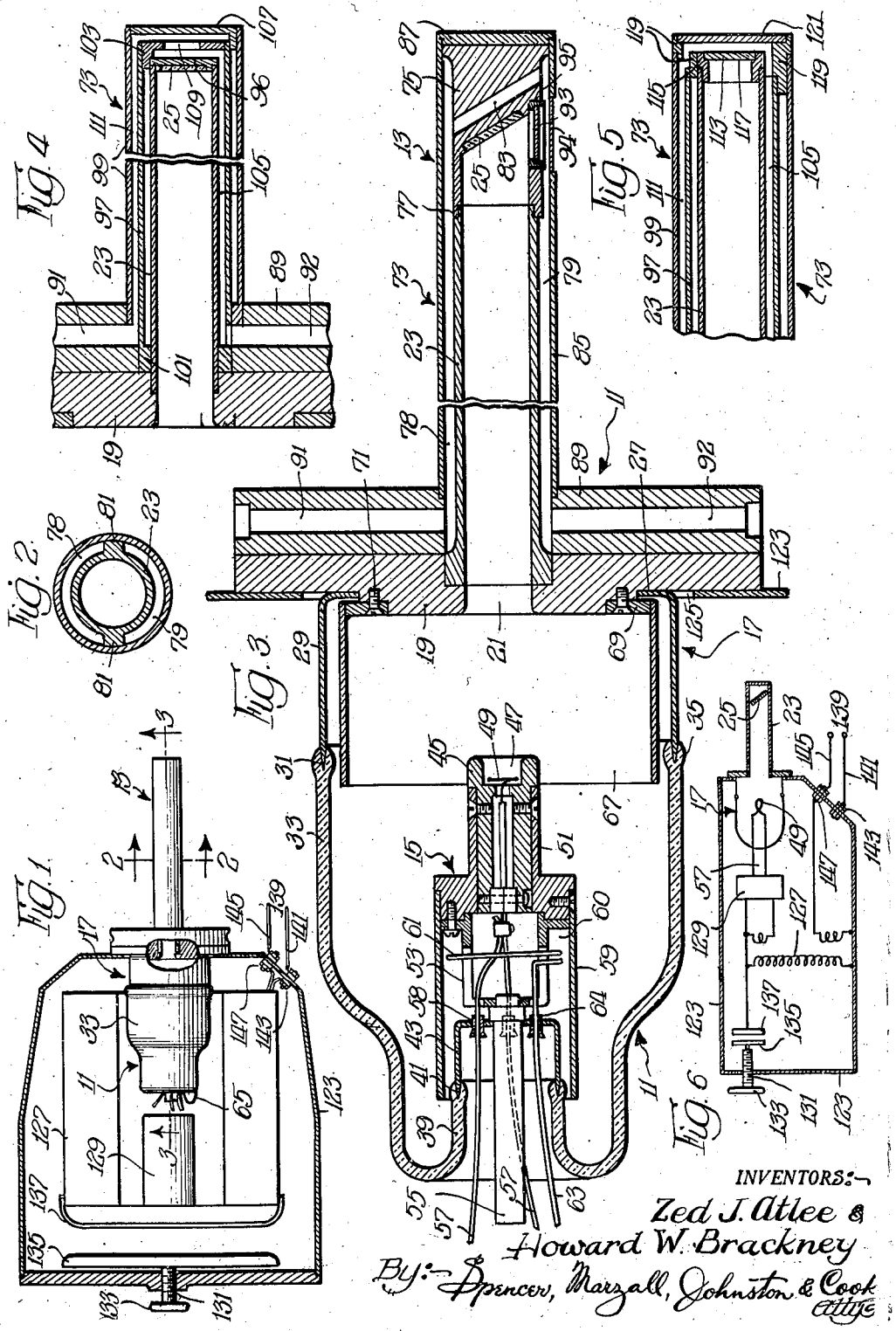

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X-RAY TUBE

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5 Claims. (Cl. 250—87)

This invention relates in general to electronics and has more particular reference to the construction of X-ray generators, more especially general purpose generators adapted for the application of X-rays for body cavity therapy, for superficial therapy and for radiography.

An important object of the invention is to provide a shockproof X-ray apparatus comprising a transformer and an X-ray generator having compact arrangement of the generator and the transformer within an enclosing casing; a further object being to provide adjustable capacity means within the casing and operable outwardly thereof to tune the generator energizing system for operation within a predetermined frequency range.

Another important object is to provide an improved cathode structure for electron flow devices, such as X-ray generators.

Another important object is to provide an improved electrode configuration and relationship, including the immersion of the cathode in the anode, to insure complete shielding of the electron source at the cathode and the entire electron beam between the source and the anode target from the intense electrical charges that collect upon the walls of the generator envelope during operation, thereby completely eliminating the biasing effect that would otherwise be imposed by said well charges upon the electron beam.

Another important object is to provide a tubular anode structure of the character mentioned, including an anode target therein and low absorption means allowing X-rays generated at the target within the tube to escape thence in substantially unimpeded fashion for useful application outwardly of the tubular anode structure; a further object being to provide a low absorption window in the tubular anode, through which window the X-rays may pass without appreciable absorption.

Another object is to arrange the anode for substantially unimpeded X-ray emission therefrom in a direction radially of the tubular anode structure, such arrangement being particularly well suited to the application of X-rays in superficial therapy; a further object being to provide an anode structure and target arrangement for the transmission of X-rays in an axial direction outwardly and at the end of the tubular anode structure.

Another important object is to utilize a beryllium disc as a low absorption window in the anode structure.

Among the numerous other important objects of the invention is to provide a safe X-ray generator for contact and cavity therapy and for radiography; to provide a generator of simplified design having an improved anode structure, in combination with an immersed cathode, to improve the operating characteristics of the device with respect to the uniformity of electron flow; to provide a device of the character mentioned having a shockproof casing in which all high voltage parts, including the generator operating transformer, are oil immersed and thus safely insulated, the casing including novel means for tuning the generator energizing system; and, in general, to provide an extremely useful general purpose generator for radiography, as well as contact and cavity therapy purposes.

These and numerous other important objects, advantages, and inherent functions of the invention will be fully understood from the following description, which, taken in connection with the accompanying drawing, discloses a preferred embodiment of the invention.

Referring to the drawing:

Figure 1 is a sectional view taken longitudinally through a generator and casing embodying the present invention;

Figure 2 is a sectional view taken substantially along the line 2—2 in Figure 1;

Figure 3 is an enlarged sectional view taken substantially along the line 3—3 in Figure 1;

Figures 4 and 5 are sectional views showing modified forms of the anode structure, Figure 4 illustrating an anode structure particularly adapted for radiographic purposes and Figure 5 showing a preferred structure for contact and cavity therapy; and

Figure 6 is a diagram of electrical connections.

To illustrate the invention the drawing shows an X-ray generator 11 comprising an anode 13, a cathode 15, and envelope means 17 enclosing the anode and cathode. The envelope means 17 comprises a preferably steel plate or disc 19 forming a frame having a central opening 21 in which is sealingly secured, as by welding or brazing, an end of a preferably copper tube 23, said tube forming a part of the anode structure and carrying at its other end means carrying an anode target 25. The tube 23 projects on one side of the disc 19, which on its other side is formed with an annular shoulder providing a seat 27 for receiving the annular flanged end of a metal mounting sleeve 29 which forms a part of the envelope means 17. The sleeve 29 preferably comprises steel containing appreciable

quantities of nickel and provides an annular rim 31 remote from the seat 27. The generator envelope also comprises a glass cathode carrying portion 33 sealed on the rim 31 by a glass-to-metal seal 35. The end of the envelope portion 33 remote from the seal 35 preferably forms a re-entrant sleeve portion 39 having an annular edge forming a glass-to-metal seal 41 with the rim of a metallic cup-shaped end seal 43, which serves also as a support for the cathode structure 15.

The cathode structure 15 comprises a head 45 formed with a socket 47 in alignment with and facing toward the end of the tube 23 in the opening 21. An electron emitting element, preferably a filament 49, is supported in the head 45 adjacent the bottom of the socket 47. The head 45, in turn, is supported, as by means of intermediate frames 51 and 53, on a stem 55 which projects through and is sealed in a central opening formed in the bottom of the cup-shaped seal member 43. The head 45 and the support members 51 and 53 are hollow to accommodate electrical conductors 57 which are connected with the filament 49 and which extend thence through the head and the hollow support members and through seals 58 formed in the bottom of the seal member 43. The member 51 may also carry a cylindrical skirt 59 which surrounds and encloses the support member 53, the seal member 43 and the glass-to-metal seal 41 for the purpose of shielding the seal 41 against impingement of stray electrons. The skirt 59 also defines a chamber 60 in which may be disposed gettering means 61, the same preferably comprising a hollow metallic wire containing a gettering medium, such as barium, one end of the wire being grounded on the frame member 53 and the other end being connected to a conductor 63 which extends through a seal 64 in the member 43.

In conditioning the X-ray generator for operation, it is necessary to remove all gas and other impurities present within the envelope, together with any gas occluded in the electrodes and in the material of the envelope itself. If such occluded gases are not substantially entirely removed, they will be gradually released within the envelope and will impair the exhausted condition in which the device is designed to operate.

After the envelope has been formed in hermetic fashion, removal of the gases therefrom is accomplished by heating the entire device at a temperature short of the softening temperature of the glass envelope portion 33, while maintaining the envelope in connection with a suitable exhaust pump. At the same time the electrodes also are heated to a high temperature, either by electronic bombardment or by placing the electrodes in a magnetic field fluctuating at frequencies of the order of radio frequencies.

After all gas, including occluded gases and other impurities, have thus been removed from the envelope, the exhaust connection may be sealed off, as at 65, and, as a final step, the gettering material carried by the wire 61 may be volatilized within the envelope in order to form gettering end products in which any trace of gas or other impurities are combined with the gettering material to form inert and innocuous material which remains in situ disposed upon the interior surfaces of the cathode portions forming the chamber 60, upon which surfaces the gettering end products condense as a film-like deposit.

The gettering material, which is preferably barium and/or magnesium contained in the hollow wire 61, may be volatilized by applying an electrical potential between the conductor 63 and the projecting end of the stem 55, thereby heating the wire 61 and vaporizing the gettering material contained therein, the wire having a weakened wall portion longitudinally thereof, through which weakened wall portion the vaporized gettering material may be expelled into the chamber 60.

It should be understood that an X-ray generator functions to produce X-rays at the target 25 by the impingement thereon of electrons generated and emitted at the cathode filament 49 and directed as an electron stream upon the target under the influence of electrical potential applied between the cathode filament and the anode target. The cathode is energized for electron emission by the application of filament energizing potential between the conductors 57, while the emitted electrons are impelled toward the target 25 by electrical potential applied between the cathode and the target, as by connecting to a suitable potential source one of the cathode conductors 57 and the frame 19, to which the target is electrically connected.

Although the operating potential applied between the cathode filament and anode target, in conjunction with the shape of socket cathode head 45, serves to impel the electrons in a stream focused upon the target, various disturbances may cause some of the electrons to escape from the stream and become stray electrons within the envelope. Such stray electrons ultimately may impinge upon the envelope wall, and particularly on the glass portions of the envelope, thus building up charges having deleterious effects upon the generator. Such charges may etch and weaken the glass envelope walls and may puncture the envelope, particularly at the end seals 35 and 41. Furthermore, when operated at high voltage, the charges built up on the envelope walls, as a result of stray electron impingement, may exert electrostatic effects upon the electron stream and cause it to deviate from the desired flow path between the cathode filament and the target 25. In order to minimize the effects of such electrostatic forces, the head of the cathode is immersed within the anode by providing a sleeve forming a cylindrical shield 67 embracing and enclosing the electron emitting cathode portions, said shield 67 at one end being secured, as by soldering or brazing the same on a mounting ring 69 which is fastened, as by means of screws 71, upon the plate 19 adjacent the seat 27. The shield 67 not only serves to minimize the occurrence of stray electrons within the envelope, but also aids in guarding the electron stream from the effects of electrostatic charges built up on the envelope walls during operation of the device.

It will be seen from the foregoing that the invention contemplates the provision of an X-ray generator having an anode target forming an X-ray source arranged at the projecting end of the tube 23; the tube being of relatively restricted diameter, allowing for insertion of the same, as in a body cavity, for the treatment of the tissues of the cavity, although, of course, the generator may be arranged for general radiographic purposes and for the therapeutic treatment of other than body cavity tissues. The arrangement of the target at the end of the relatively slender, elongated tube 23,

which may be from six to eighteen inches in length, affords convenient means for cavity therapy.

It should be understood, however, that the operation of an X-ray generator is accomplished by the generation of appreciable quantities of heat, particularly where the generator is designed for high tension operation, and the invention embraces means not only for rendering the device shockproof, but also for cooling the anode structure sufficiently to enable the same to be used for therapeutic purposes in direct contact with body tissues without causing undue patient discomfort. To render the device shockproof, the cathode carrying portions of the generator are enclosed in a casing, on which the anode structure is electrically connected whereby the casing and anode structure may be kept at ground potential when the device is in operation. In order to cool the anode structure, the tube 23 may be provided with jacketing means 73, enclosing the tube 23, including the target carrying end thereof, and providing for circulating a cooling fluid, such as water, around the tube and at the target carrying end thereof.

As shown in Figure 3 of the drawing, the anode target may comprise a tungsten button mounted on a support head 75 in turn sealed, as at 77, on the end of the tube 23. The tube 23 and the head 75 are cut away to form a pair of channels 78 and 79, extending longitudinally and on opposite sides of the anode structure from the plate 19 to adjacent the end of the head 75, said arcuate channels being separated by ribs 81 and being interconnected by means of a duct 83 in the head 75, said duct extending in the head immediately behind the target 25. Embracing the tube 23 and the head 75 is a jacketing sleeve 85, the outer end of which is closed by a disc 87 soldered or otherwise sealingly secured in the end of the jacketing sleeve. The other end of the sleeve 85 is sealed in a central opening formed in a plate 89, which plate may be secured, as by bolting or otherwise, to the plate 19. The plate 89 is preferably formed with diametrically extending channels 91 and 92 opening on the peripheral edges of the plate and connecting, respectively, with the channels 78 and 79 formed in the tube 23. By introducing a cooling fluid, such as water, through the channel 91, the cooling fluid may be circulated in the channel 78 along the sides of the tube 23, thence through the duct 83 and discharged thence through the channels 79 and 92 in order to cool the anode structure.

The target 25 is mounted at an angle with respect to the longitudinal axis of the tube 23 so that X-rays generated as a result of electron impingement on the target 25 travel thence radially outwardly of the anode structure. In order that the X-rays so generated may pass outwardly of the anode structure substantially without absorption by the walls of the anode structure, the same is provided with a prefereably beryllium window, beryllium being substantially transparent to X-rays. To this end, as shown in Figure 3, the beryllium window is placed in the walls of the anode structure opposite the target. As shown, the target 25 comprises a tungsten disc mounted on the inclined bottom of a cavity formed in the head 75, and the transmission window comprises a beryllium disc 93 which is mounted in an opening formed in the walls of the head 75 defining the target cavity. The jacketing sleeve 85 overlies the window 93 and may be formed with a beryllium insert or may be made with a window portion of reduced thickness, as shown, to minimize X-ray absorption.

In order to mount the disc 93 in hermetically sealed fashion in the anode tube, the same is sealed at its edges in a mounting ring 95, preferably comprising Monel metal or other metal containing a high proportion of nickel, the sealing of the edges of the disc to the ring 95 being accomplished by means of solder containing copper and silver. The ring 95, in turn, is hermetically sealed, as by means of silver solder, in the head 75, which preferably comprises copper.

The anode structure illustrated in Figure 3 is particularly well adapted for use in intermediate and superficial X-ray therapy. In Figure 4 of the drawing is shown an anode structure particularly well suited for general radiographic purposes, in which it is desirable to emit X-rays outwardly of the anode at the end thereof in an axial direction. As shown in Figure 4, the target 25 is carried at the projecting end of the tube 23 in position at right angles to the longitudinal axis of the tube. The target 25 is carried on an end plate 96 which is sealed in the end of the tube 23. The jacketing means 73 comprises a pair of concentric sleeves, including an inner sleeve 97 and an outer sleeve 99. The inner sleeve is provided at one end with an inwardly extending rim 101 which snugly fits the outer surfaces of the tube 23 adjacent the plate 19, said end of the tube 97 being sealed in the member 89. The other end of the tube 97 is sealingly secured to a collar plate 103 which also receives the outer end of the tube 23, including the plate 96 so that the tube 97 defines a channel 105 around the tube 23, said channel being in communication with the duct 92 on the frame 89. The outer tube 99 is fitted at one end in the plate 89 in open communication with the duct 91, the other end of said tube 99 being sealed upon an end plate 107 which forms a support for the collar plate 103, the plate 107 being disposed outwardly from and in spaced relationship with respect to the collar plate 103. The collar plate 103 likewise is disposed outwardly of and in spaced relationship with respect to the end plate 96 of the anode tube, and said collar plate 103 is provided with a perforation 109, thereby placing the channel 105 in communication with the channel 111 defined between the inner sleeve 97 and the outer sleeve 99 of the jacketing means. Cooling fluid introduced to the channel 105 through the duct 92 may travel along the outer surfaces of the tube 23, and in heat exchange relationship therewith, from the mounted end to the target carrying end thereof, thence through the opening 109 and through the channel 111, being discharged through the duct 91 in order thus to cool the anode structure. If desired, the plates 103 and 107 may comprise beryllium in order to facilitate the passage of X-rays outwardly through the end of the anode structure.

An anode construction particularly well suited for contact and cavity therapy is illustrated in Figure 5 of the drawing, in which the anode comprises a disc 113 of material such as beryllium, which is substantially transparent to X-rays. The disc is sealed in a collar 115 comprising Monel metal or other material containing a substantial proportion of nickel. The collar 115 in turn is sealed in the end of the anode 23, as by means of silver solder, the beryllium disc being

sealed in the collar preferably by means of solder comprising copper and silver.

In order to develop X-rays at the disc 113, it is necessary to provide a suitable target for the reception of electrons and capable of developing X-rays in response to electron impingement thereon. To this end the target may comprise any suitable target material, but gold is preferably employed for the purpose. Consequently the surface of the disc 113 facing into the tube carries a layer of gold 117 thereon for the purpose of providing an anode target. The gold layer forming the target is preferably applied on the beryllium disc by electroplating the gold thereon to a thickness of the order of 2.0 microns, which is the thickness of gold capable of stopping substantially all electrons impinging thereon, at the voltage at which the tube is intended to operate, say 30–100 kv. p., thereby providing for the efficient generation of X-rays, substantially all of which may escape outwardly through the disc 113.

The jacketing means 73 comprises inner and outer sleeves 97 and 99 similar to the sleeves employed in the structure shown in Figure 4 and similarly mounted at the target remote end of the anode structure. At the other end of the jacketing structure the sleeves 97 and 99 are secured in a support collar 119 providing for the interconnection of the jacket channels 105 and 111 in a manner causing flow of cooling fluid behind the disc 113. Said collar 119 preferably comprises Monel metal or other material containing nickel in substantial proportions. The collar furthermore sealingly receives an end plate 121, preferably of beryllium, through which X-rays generated at the target layer 117 may be projected substantially without absorption.

It will be noted that, for the sake of safety, the anode structure including the tube 23, the jacketing means, the mounting plate 19 and the sealing rim 29 may be grounded. The ungrounded or high tension portions of the tube, which are supported on the glass envelope portion 33, may be enclosed in a suitable casing 123 by securing the plate 19 in an opening 125 formed in the casing at one end thereof. The plate 19 is preferably secured on the casing in demountable yet liquid-tight fashion, as by means of readily removable screw fasteners, so that the tube may be easily removed from the casing for inspection or repair and replacement. The casing 123 preferably contains a suitable insulating medium such as oil, in which the cathode carrying portions of the generator are immersed while the generator is in service.

Within the casing 123 also is preferably mounted a transformer 127 which preferably comprises a high frequency coreless transformer adapted for operation at frequencies ranging between five hundred and one thousand cycles per second. This transformer is of annular shape and is disposed in the casing in position encircling the glass cathode carrying portions of the generator, said portions occupying substantially one-half the space within the coils of the transformer. Electrical apparatus for regulating filament current is disposed in a casing 129 occupying the remaining portions of the space within the coils of the transformer.

In order to provide for tuning the transformer and its control circuits for operation at any desired frequency within the range of the apparatus, the casing 123, in its end remote from the generator receiving opening 125, is provided with a preferably screw threaded stem 131, said stem being preferably in axial alignment with the longitudinal axis of the transformer, which axis also coincides with the longitudinal axis of the X-ray generator. The stem 131 is provided with an operating handle 133 extending outwardly of the casing 123, and the inner end of the stem 131 carries a plate 135 forming one plate of a condenser, the other plate 137 of which is electrically connected with the transformer 127. By manipulating the handle 133 outwardly of the casing, the transformer may be tuned to deliver operating potential of desired frequency to the X-ray generator.

It will be noted that, as shown in Figure 6 of the drawing, the anode, including the target 25, is electrically connected to ground comprising the metallic portions of the generator as well as the casing in which the generator is mounted. The adjustable side of the condenser likewise is connected to ground. One end of the transformer likewise is grounded, as by connecting the same on the casing. The secondary windings of the transformer are electrically connected through the regulating means 129 to the filament conductors 57. Consequently the only electrical connection that need be made when mounting the generator in the casing is the connection of the filament conductors 57 to appropriate terminals of the regulating apparatus 129. The transformer 127 may be powered from a suitable external low voltage power source 139 through a grounded conductor 141 connected to a terminal 143 on and electrically connected to the casing 123 and a conductor 145 electrically connected with the transformer 127 by means of an insulated terminal 147 mounted in the walls of the casing 123.

The claims of the present application are directed to an X-ray tube and the transformer unit, while the claims to the cooling means for the X-ray tube are claimed in applicants' application Serial No. 539,884, filed June 12, 1944. and assigned to the present assignee.

It is thought that the invention and its numerous attendant advantages will be fully understood from the foregoing description, and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing any of its attendant advantages, the form herein disclosed being a preferred embodiment for the purpose of illustrating the invention.

The invention is hereby claimed as follows:

1. X-ray generating apparatus comprising an X-ray tube having a metal mounting portion, a closed casing in which said tube may be mounted by securing the mounting portion on said casing, tube energizing means having high and low voltage portions and including a transformer enclosed in said casing and having windings adapted for electrical connection to said tube and a grounded winding electrically connected to and grounded on said casing, means to deliver electrical energy to the primary winding from a source of power disposed outwardly of the casing, and adjustable means for tuning the transformer for operation at a selected frequency, all high voltage carrying portions of the generating apparatus being enclosed within said casing.

2. X-ray generating apparatus comprising an X-ray tube having a metal mounting portion, a closed casing in which said tube may be mounted by securing its mounting portion on said casing,

tube energizing means having high and low voltage portions and including a transformer enclosed in said casing and having coils disposed in position encircling said tube, the transformer having windings adapted for electrical connection to said tube and a grounded winding one end of which is electrically connected to and grounded on said casing, a condenser having a condenser plate mounted on and electrically connected to the other end of the grounded winding of said transformer, and an adjustable condenser plate on and electrically connected to said casing to adjust the frequency of operation of said energizing means.

3. X-ray generating apparatus comprising an X-ray tube having a metal mounting portion, a closed casing in which said tube may be mounted by securing the mounting portion on said casing, tube energizing means having high and low voltage portions and including a transformer enclosed in said casing and having coils disposed in position encircling said tube, the transformer having windings adapted for electrical connection to said tube and a grounded winding one end of which is electrically connected to and grounded on said casing, a variable condenser comprising a condenser plate mounted and electrically connected to the other end of the grounded winding of said transformer, and an adjustable condenser plate within and electrically connected to said casing whereby the frequency of operation of said energizing means may be adjusted.

4. X-ray generating apparatus comprising an X-ray tube having a metal mounting portion, a closed casing in which said tube may be mounted by securing the mounting portion on said casing, tube energizing means having high and low voltage portions and including a transformer enclosed in said casing and having coils disposed in position encircling said tube, the transformer having windings adapted for electrical connection to said tube and a grounded winding one end of which is electrically connected to and grounded on said casing, a variable condenser comprising a condenser plate mounted and electrically connected to the other end of the grounded winding of said transformer, an adjustable condenser within and electrically connected to said casing whereby the frequency of operation of said energizing means may be adjusted, and means without said casing in operative connection with said adjustable condenser plate for adjusting the same.

5. X-ray generating apparatus comprising an X-ray tube having a metal mounting portion, a closed casing in which said tube may be mounted by securing the mounting portion on said casing, tube energizing means having high and low voltage portions and including a transformer enclosed in said casing and having coils disposed in position encircling said tube, the transformer having windings adapted for electrical connection to said tube and a grounded winding one end of which is electrically connected to and grounded on said casing, a variable condenser comprising a condenser plate mounted and electrically connected to the other end of the grounded winding of said transformer, an adjustable condenser within and electrically connected to said casing whereby the frequency of operation of said energizing means may be adjusted, and means without said casing in operative connection with said adjustable condenser plate for adjusting the same, said last mentioned means being in axial alignment with the longitudinal axis of the transformer.

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