Jan. 5, 1943. W. F. WESTENDORP 2,307,612

HIGH VOLTAGE APPARATUS

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Fig. 1.

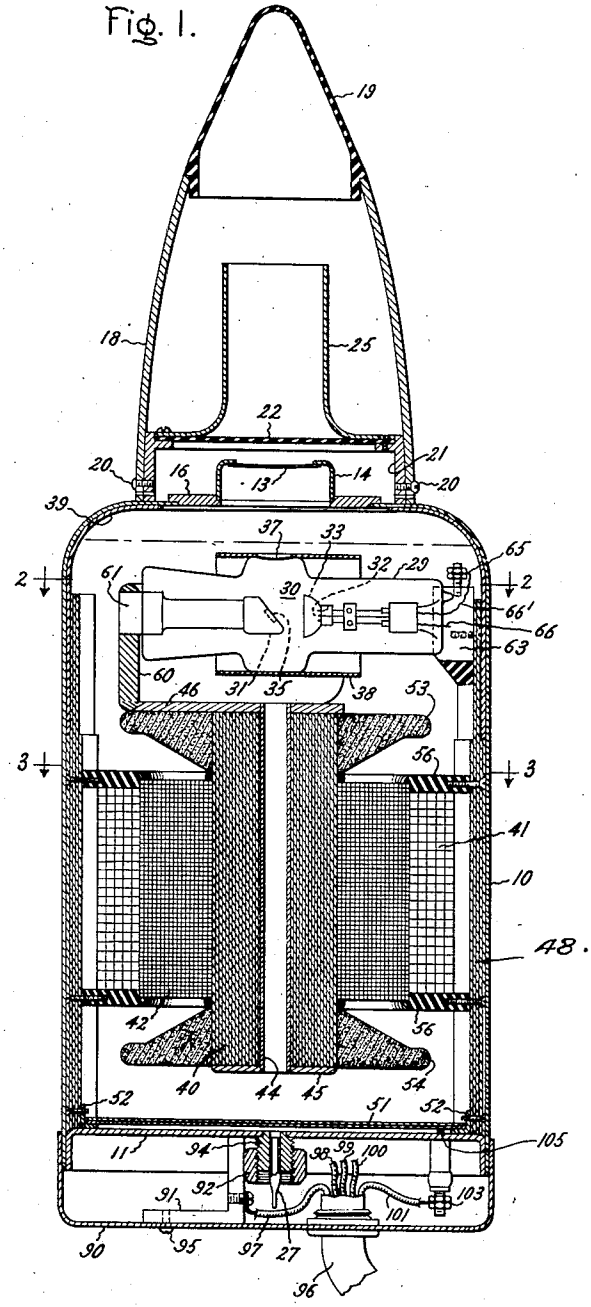

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Fig. 4.

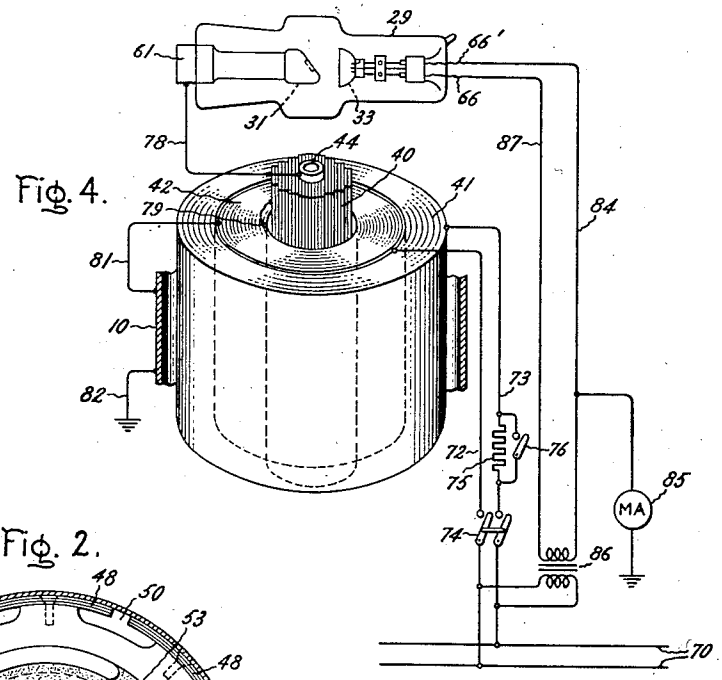


Fig. 2.

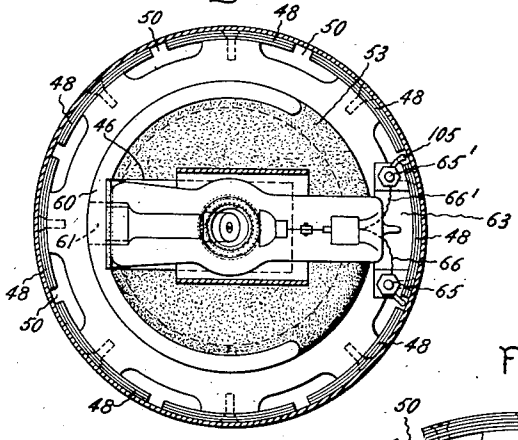
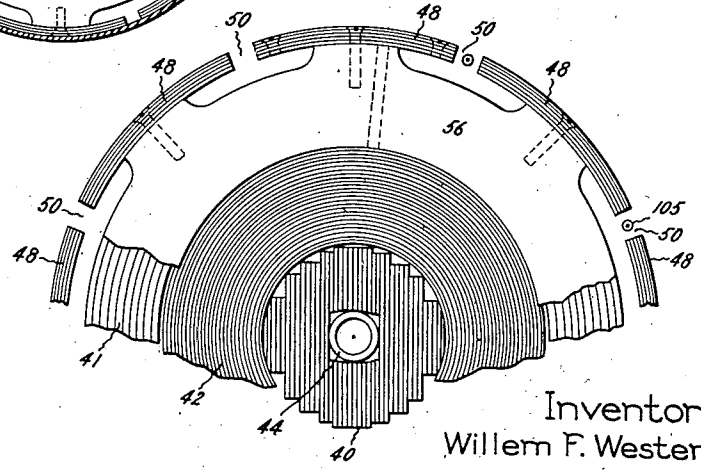


Fig. 3.



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Patented Jan. 5, 1943

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UNITED STATES PATENT OFFICE

2,307,612

HIGH VOLTAGE APPARATUS

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Application February 18, 1941, Serial No. 379,497

7 Claims. (Cl. 250—87)

The present invention relates to improvements in ray-generating discharge apparatus, especially X-ray equipment and the like.

It is a primary object of the invention to provide an improved shock-proof apparatus of the type in which a ray-generating tube and voltage supplying means for the tube are enclosed within a common container. It is particularly proposed to provide an arrangement of this kind which is characterized by a high degree of compactness and facility of use.

The aspects of the invention which are desired to be protected herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 is a longitudinal sectional view of an X-ray apparatus suitably embodying the invention; Figs. 2 and 3 are respectively cross-sections taken on lines 2—2 and 3—3 of Fig. 1; and Fig. 4 is a schematic representation illustrating the circuit connections for the device of Fig. 1.

Referring particularly to Fig. 1 there is shown a dental X-ray apparatus comprising an elongated metal casing or enclosure 10, which, as viewed from above, is of generally cylindrical configuration. The lower end of the casing is closed by means of a flanged circular floor plate 11. At the upper end of the casing there is provided a slightly bowed glass window 13 which is fusion sealed at its periphery to a metal ring 14 consisting, for example, of a nickel-iron-cobalt alloy. The ring is hermetically joined to the enclosure by means of an annular member 16.

In the use of the apparatus, the window 13 is covered by a conically shaped cap 18 which is constituted principally of metal but which has a pointed tip portion 19 of an organic plastic material. It is the function of this pointed cap to facilitate the proper orientation of the apparatus when it is used in dental radiography and the like. The cap is attached by screws 20 to an annular metal part 21 which is secured at its lower edge of the casing, as by being welded thereto.

Within the cap 18 and mounted on the part 21 there is provided a supplemental cover plate 22 which serves as a guard for the window 13 in the event the cap is removed. The part 21 also supports a funnel-shaped element 25 which is constituted of an X-ray impermeable substance, such as lead, and which serves to increase the directional effect of X-rays projected through the window 13.

The casing 10 is preferably filled with a dielectric medium such as a liquid or a gas or vapor having an insulating strength greater than that of air. An example of a vapor suitable for this use comprises dichlorodifluoromethane, or a related chlorine-fluorine derivative of an aliphatic hydrocarbon. The dielectric may be introduced into the casing through an appropriate tubulation 27 affixed to the central region of the floor plate 11, the tubulation being thereafter sealed off.

Within the enclosure 10, there is provided a ray-generating device 29 (in this case an evacuated X-ray tube) which is mounted with its axis transverse to the principal axis of the enclosure. The tube 29 includes, in addition to its envelope, a cathode 30 and an anode 31, the former having a separately heated filament 32 (shown in dotted outline) and a focusing cup 33, and the latter having a target 35 of tungsten or other effective X-ray producing metal embedded in it. The envelope of the tube, which is constituted of glass, preferably has a thinned area at 37 to facilitate the issuance of X-rays. A tubular lead shield 38, having an opening in registry with the window, surrounds the tube and serves to prevent excessive radiation from the target in undesired directions. Additional shielding is provided by means of a lead sheath applied to the interior surface of the casing 10 at its upper portion as indicated at 39.

For the purpose of energizing the tube 29, which is capable of self-rectifying operation, there is provided within the enclosure 10 a transformer comprising a ferromagnetic core 40, a low voltage primary winding 41 and a high voltage secondary winding 42. The core 40 is of roughly circular cross-section and may be built up of laminar elements of magnetic steel assembled about a central metal tube 44 as indicated in Fig. 3. Metal parts 45 and 46 which are applied to the extremities of the core and secured to the tube 44 serve to prevent longitudinal displacement of the laminar elements.

The core 40 is insulatingly spaced from both the lateral and end walls of the enclosure and is therefore adapted to be maintained at high potential with respect to them. For a purpose which will be stated at a later point, the magnetic circuit through the core is left open at both its extremities by the omission of means for providing a complete magnetic loop. However, the reluctance of the external flux path is substantially reduced by the provision around the core of a hollow magnetic structure formed of

steel laminations 48 arranged to conform to the interior surface of the enclosure. As appears more clearly in Fig. 2, these laminations, which should be at least coextensive in length with the core, are arranged in spaced groups having channels 50 between them. Additional laminations 51 (Fig. 1) are provided at the floor of the enclosure, being there supported by suitable brackets 52.

The magnetic circuit which includes the core 40 and the laminations 48 is further augmented by the provision of ferromagnetic flanges 53 and 54 extending outwardly from the ends of the core. These flanges, which may appropriately consist of iron particles bonded with a phenolic molding resin, are of circular outline and have generally rounded surfaces so as to minimize the danger of an electrical discharge between these surfaces and the walls of the enclosure 10 upon the establishment of a potential difference between them.

The core 40 and the ancillary parts above referred to provide the magnetic system for a voltage transformer of which the primary and secondary windings are respectively indicated at 41 and 42. The secondary winding 42 directly surrounds the core and is so applied (as by a multilayer construction) that the full voltage of the winding appears between its inner and outer layers. With this arrangement the preferred connection of the winding is such as to cause its outer terminal to be maintained at approximately the potential of the enclosure walls, as by the provision of a grounding connection between them (see Fig. 4). The inner, or high voltage, terminal of the winding may then be connected directly to the core 40, the spacing of the core with respect to the surfaces of the casing 10 being relied upon to prevent breakdown between them.

The primary winding 41, which is provided with terminals (not shown in Fig. 1) appropriate for connection to a source of A. C. power (70—Fig. 4), is applied directly over the secondary coil 42 and requires to be only slightly insulated from it. Indeed, in some cases a direct connection between the inner layer of the primary winding and the outer layer of the secondary winding may be employed.

After the windings 41 and 42 are formed, they may advantageously be impregnated with a bonding material such as a thermosetting resin, which, upon setting, is capable of consolidating the windings into a rigidly self-supporting structure. If this is done, the transformer as a whole may be mounted, as is illustrated in Figs. 1 and 2, by insulating rings 56 which are bolted to the laminar groups 48 and which engage the end surfaces of the primary coil 41.

Inasmuch as the only components of the above-described transformer which are maintained at high potential with respect to the casing are those which are interiorly disposed, and since all these parts, including especially the transformer core 40, are adequately separated from the casing wall, there is no necessity for any substantial spacing between the casing and the outer turns of the primary winding. Consequently, the former needs to be only slightly larger in diameter than the latter. Indeed, if desired, the surface of the primary coil 41 may be made to conform closely to the inner circumference of the cylindrical structure formed by the laminar groups 48, the slight spacing shown in the present instance being mainly for the purpose of permitting free circulation of the dielectric medium with which the enclosure is filled. As a result of these considerations, an extremely compact arrangement is achieved.

In addition to the foregoing, the axial symmetry of the transformer and the resultant cylindrical shape of the enclosure are highly advantageous in apparatus of the type under consideration. In particular, the elongated cylindrical form of the enclosure considerably facilitates the mounting of the equipment and its convenient manipulation in connection with the taking of dental radiographs and the like.

The X-ray tube 29 is positioned within the casing 10 in the free space at one end of the core 40 and is supported at its anode end by a semi-circular metal member 60. This member directly engages an outwardly projecting portion 61 of the anode stem and serves both as a heat-dissipating radiator for the anode and as a means for conducting current to it. In this latter connection it is to be observed that the member 60 is hard soldered to one edge of the metal part 46 and is thus connected directly to the core 40. By virtue of this fact and of the previously specified connection of the core to the high voltage terminal of the winding 42, the anode obviously comprises the high potential component of the tube.

The cathode end of the tube 29 is supported by means of an insulating bracket 63 which is screwed or otherwise secured to one of the lamination groups 48. Terminals 65 and 65' mounted on bracket 63 (see Fig. 2) provide appropriate connecting points for lead-in conductors 66 and 66' which supply heating current to the cathode filament.

The circuit connections for the apparatus as a whole are indicated schematically in Fig. 4 in which parts which have been previously described are identified by similar index numerals.

The primary energizing circuit of the apparatus comprises a power source 70 and conductors 72 and 73 which extend from the source to the terminals of the transformer primary winding 41. This circuit is controlled by means of a double-pole switch 74 connected in the circuit. A resistor 75 connected in series with the conductor 73 serves to limit the current surge in the primary winding 41 when the switch 74 is first closed. After the connection is once made, however, the resistor is short circuited by means of a switch 76 provided for that purpose.

One side of the high voltage or secondary circuit may be traced from the anode terminal 61 through a conductor 78 (corresponding to the parts 60 and 46 of Fig. 1) and thence through the conductive tube 44 and the transformer core 40 to a terminal 79 provided in connection with the inner layer of the high voltage secondary winding 42. The other side of the secondary winding is connected to the wall of the enclosing casing 10 by conductor 81, the casing being grounded as indicated at 82. The return circuit, that is, the circuit from the cathode 33 to ground, proceeds through the lead-in conductor 66', through an associated conductor 84, and thence through a milliammeter 85 to ground. It is the function of the milliammeter 85 to measure the rectified current flowing in the high voltage circuit upon the occurrence of a discharge through the X-ray tube 29.

The heating circuit for the filament of the cathode 33 includes a filament transformer 86 having one terminal of its secondary windings

connected with the filament lead-in conductor 66' through the conductor 84 and its other terminal connected with the lead-in conductor 66 through a connection 87. The primary of the transformer 86 is shown as being connected directly across the current supply source 70, although it will be understood that a current regulating means may be provided in this circuit.

The filament transformer 86 is obviously at low potential and for this reason does not require to be enclosed within the casing 10. This is a factor which contributes to the compactness of the enclosed unit.

The manner in which the circuit connections described in the foregoing are actually made is indicated in a general way in Fig. 1. In this figure it will be noted that the bottom of the casing 10 is provided with a cover 90 which is secured to an angular bracket 91, the bracket in turn being welded or otherwise fixedly secured to a large nut 92. The nut 92 engages a cooperatively threaded member 94 which is attached to the casing floor plate 11 in the region surrounding the seal-off tubulation 27. In applying the bracket 91 to the bottom of the casing, the bracket and the nut 92 are rotated in clockwise fashion until the movement of the nut along the threaded surface of the member 94 brings the bracket into abutting engagement with the floor plate 11. The cover 90 can then be fastened to the bracket by means of one or more screws 95.

The cover 90 is provided with a hollow conduit 96 which extends through the cover and which is adapted to receive a number of mutually insulated conductors 97 to 101. One of these (the conductor 97) is connected directly to the bracket 91 and thus provides an effective connection for grounding the casing structure as a whole. Another (the conductor 101) connects with a stud 103 which forms the terminal of a conductor 105 insulatingly sealed through the floor plate 11. The conductor 105 extends upwardly within the casing 10 through one of the vertical channels or gaps 50 existing between the lamination groups 48 (see Figs. 2 and 3) and connects at its upper end with the cathode terminal stud 65'. In a similar fashion the conductors 98, 99 and 100 are assumed to be connected with insulated lead-in terminals corresponding to the terminal 103, although these connections have been omitted from Fig. 1 in order to avoid overcomplication of the drawings.

While the invention has been described by reference to a particular embodiment thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I therefore aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Ray-generating apparatus for excitation from an alternating current source comprising a generally cylindrical enclosure, a ferromagnetic core arranged coaxially within the enclosure, the magnetic circuit provided by said core being open at the extremities of the core and the core being insulatingly spaced from the walls of the enclosure, a secondary winding closely surrounding the core and having a part thereof which is at high potential with respect to the enclosure during the operation of the apparatus, a low voltage primary winding surrounding said secondary winding and interposed between the secondary winding and the walls of the enclosure, connections for supplying alternating current to the said primary winding for energizing the same and for thus exciting the secondary winding, a ray-generating tube of a type adapted for self-rectifying operation within the enclosre, and means connecting the terminals of the said tube to terminals of the said secondary winding.

2. Ray-generating apparatus for excitation from an alternating current source comprising a generally cylindrical enclosure which contains a dielectric medium, a ferromagnetic core arranged coaxially within the enclosure, the magnetic circuit provided by said core being open at the extremities of the core, and the core being insulatingly spaced from the walls of the enclosure, a multi-layer secondary winding surrounding the core and having a terminal associated with the inner layers of the winding which is at high potential with respect to the enclosure during the operation of the apparatus, a connection for maintaining the said terminal and the said core at least approximately at the same potential, a low voltage primary winding surrounding said secondary winding and having terminals for connection to a power source, the outer diameter of said primary winding approximating the diameter of the said enclosure, whereby the existence of substantial free space between them is avoided, a ray-generating discharge tube capable of self-rectifying operation within the enclosure at one end of the said core, and means connecting the said tube to terminals of the said secondary winding.

3. Ray-generating apparatus for excitation from an alternating current source comprising a generally cylindrical enclosure which contains a dielectric medium, a ferromagnetic core arranged coaxially within the enclosure, the magnetic circuit through the said core being open at the extremities of the core and the core being insulatingly spaced from the walls of the enclosure, a hollow cylindrical ferromagnetic structure conforming to the inner circumference of the enclosure for decreasing the reluctance of the magnetic path outside the said core, a multi-layer secondary winding closely surrounding the said core, said winding having a terminal associated with the inner layers thereof which is at high potential with respect to the enclosure during operation of the apparatus, a connection for maintaining the said terminal and the said core at least approximately at the same potential, a primary winding closely surrounding the said secondary winding and having terminals for connection to a power source, the outer diameter of the said primary winding conforming relatively closely to the inner diameter of the said ferromagnetic structure to avoid the existence of substantial free space between them, a ray-generating discharge tube capable of self-rectifying operation within the enclosure, and means for connecting the tube to terminals of the said secondary winding.

4. Ray-generating apparatus comprising a generally cylindrical enclosure, a ferromagnetic core arranged coaxially within the enclosure, a hollow ferromagnetic structure conforming to the inner circumference of the enclosure, radially extending ferromagnetic flanges secured to the extremities of the said core and cooperating with the said hollow magnetic structure for decreasing the reluctance of the magnetic path outside the

said core, the outer edges of said flanges being insulatingly spaced from said ferromagnetic structure and from the walls of the enclosure, a high voltage secondary winding closely surrounding the said core and having a part thereof which is at high potential with respect to the enclosure during operation of the apparatus, a primary winding closely surrounding the said secondary winding and interposed between the secondary winding and the walls of the enclosure, said primary windings having terminals for connection to a power source, a ray-generating discharge tube within the enclosure, and means for connecting the tube to terminals of the said secondary winding.

5. In combination, a generally cylindrical enclosure, a ferromagnetic core arranged substantially coaxially within the enclosure and insulatingly spaced from the walls of the enclosure including the end walls thereof, the magnetic circuit through the said core being open at the ends of the core, a multi-layer secondary winding closely surrounding the said core, said winding having a terminal associated with the inner layer thereof which is at high potential with respect to the enclosure, a connection for maintaining the said terminal and the said core at least approximately at the same potential, a low voltage primary winding closely surrounding the said secondary winding and interposed between said primary winding and the lateral walls of the enclosure, connections for energizing the primary winding from an alternating current source, an X-ray tube capable of self-rectifying operation arranged within the enclosure at one extremity of the said core, means connecting the tube in circuit with the said secondary winding, and means for facilitating the directional emission from the enclosure of X-rays generated by the tube upon operation thereof.

6. In combination, a generally cylindrical enclosure, a ferromagnetic core arranged coaxially within the enclosure, the magnetic circuit through the core being open at the extremities of the core and the core being insulatingly spaced from both the lateral and end walls of the enclosure, a multi-layer secondary winding closely surrounding the said core, said winding including a terminal associated with the inner layers thereof which is at high potential with respect to the enclosure, a connection for maintaining said terminal and the said core at least approximately at the same potential, a low voltage primary winding surrounding said secondary winding and interposed between the secondary winding and the lateral walls of the enclosure, a ray-generating tube capable of self-rectifying operation located within the enclosure in the space between an end wall thereof and the corresponding extremity of the said core, the tube being arranged with its axis transverse to the axis of the container, means for connecting the tube in circuit with the said secondary winding, and means for facilitating the directional emission from the extremity of the enclosure of rays generated by the tube upon energization of the said primary winding by connection to an alternating current source.

7. In combination, a generally cylindrical enclosure, a ferromagnetic core arranged substantially coaxially within the enclosure and insulatingly spaced from the walls of the enclosure including the end walls thereof, the magnetic circuit through the said core being open at the extremities of the core, a multi-layer secondary winding closely surrounding the said core, said winding having a terminal associated with the inner layer thereof which is at high potential with respect to the enclosure, a connection for maintaining the said terminal and the said core at least approximately at the same potential during normal operation, a low voltage primary winding closely surrounding the said secondary winding and interposed between the said secondary wniding and the lateral walls of the enclosure, an X-ray tube arranged within the enclosure near one extremity of the said core, common means for conductively connecting the anode terminal of the said tube to the said core and for mechanically supporting the tube from the core, and means for connecting the cathode terminal of the tube to another terminal of said secondary winding.

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