April 12, 1938. A. BOUWERS 2,114,070

X-RAY APPARATUS

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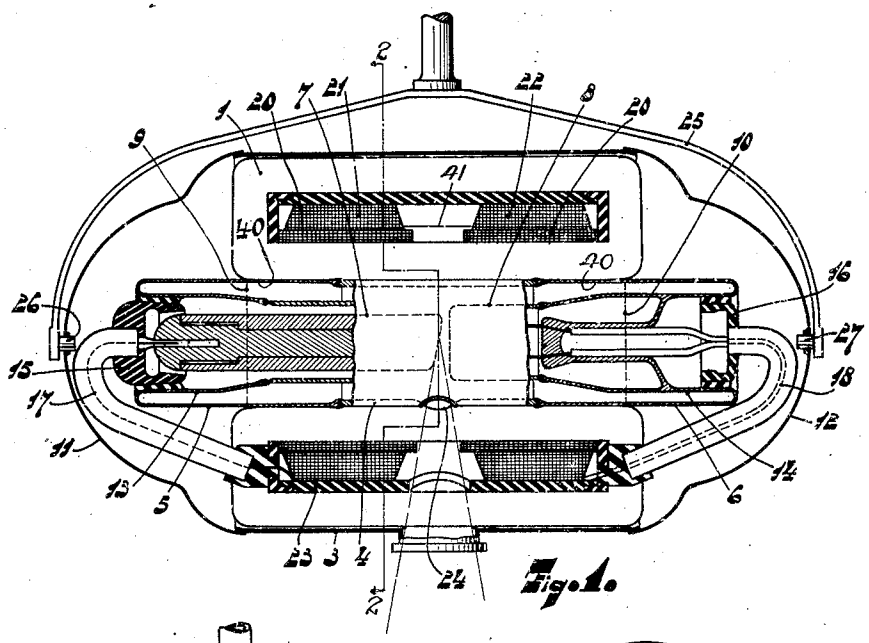


Fig. 1.

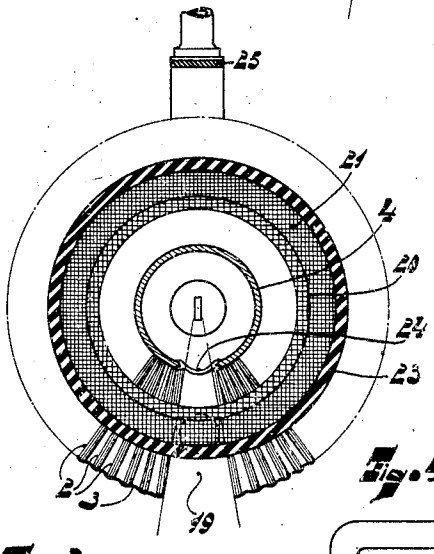


Fig. 2.

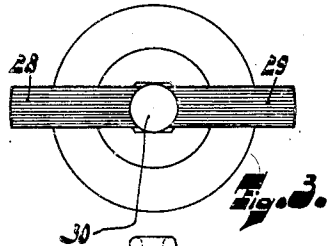


Fig. 3.

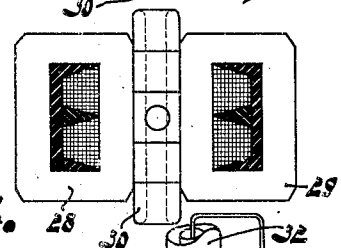


Fig. 4.

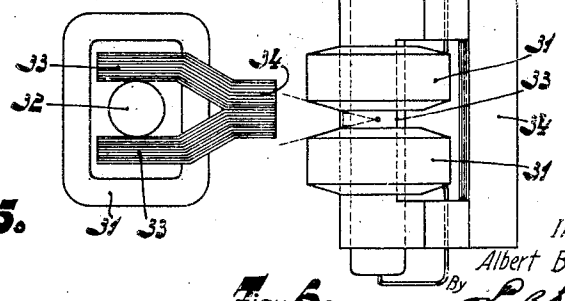


Fig. 5.

Fig. 6.

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X-RAY APPARATUS

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In Germany December 27, 1932

16 Claims. (Cl. 250—34)

My invention relates to X-ray apparatus and similar devices.

While I shall describe my invention in connection with X-ray devices, it is not limited thereto but is also applicable to other electric devices in which a load is supplied from a transformer, for example devices using discharge tubes for illuminating purposes.

X-ray devices are known in which an X-ray tube is integral with a high-tension supply transformer, however, due to the comparatively large circumference of the transformer, such devices have a comparatively large size and are not adapted to be readily moved. To reduce the size of such devices, and to allow the X-ray tube to be brought close to the transformer, it has been proposed to immerse the X-ray tube and transformer in oil. Such oil-immersed devices have, however, the disadvantage that the same oil which absorbs the heat developed in the X-ray tube, which is very low relative to the heat losses of the transformer, is also in contact with the transformer.

The present invention relates to an X-ray device which has smaller dimensions than those of prior constructions. According to the invention the high-tension transformer of the X-ray device is preferably formed as a radial transformer (i. e. a transformer in which the magnetic core material is distributed about the periphery of the coils) and comprises a column which is divided in half in the direction of the length, or which is axially bored, and in which the X-ray tube is housed. In this case, the circumference of the device is altered not at all or only to a slight extent by the load.

In one embodiment of my invention I form the core of the transformer of buckle-shaped sheets or laminations radially arranged to surround a load which is supplied from this transformer. These sheets may be united in a manner known per se into a number of bundles, in which case the transformer is preferably surrounded by a corrugated sheath, whose corrugations extend in the direction of the length of the bundles and engage the edges thereof to support same.

When applying my invention to an X-ray device I prefer to use a cylindrical X-ray tube which is symmetrically surrounded by the transformer, and when the length of the X-ray tube is greater than that of the transformer, tube-ends of substantially equal length protrude from either side of the transformer. These tube-ends are preferably surrounded, with some intermediate space, by metal or metalized protective hoods which may also serve for the attachment of an electric fan for cooling the transformer and X-ray tube.

The magnetic core of the transformer may be provided with a longitudinal slot for the passage of the X-rays. This slot is preferably also used for passing the current conductors, in an insulated manner through the magnetic body, from the high-tension coil to the tube-ends at the two end surfaces of the transformer. In order that the usual re-entrants parts of the X-ray tube may be capable of withstanding a considerable portion of the potential difference existing between the electrode carried thereby and the transformer core, the current conductors which pass through the re-entrant parts are supported by centrally-bored insulating stoppers or bushings mounted in the re-entrant parts.

The transformer windings which radially surround the X-ray tube are disposed within the annular window of the magnetic core, and are separated from the X-ray tube by the inner parts of the laminations. Thus, the space is utilized more efficiently than, for example, with a well-known form of construction of an X-ray device in which a neck of the X-ray tube extends into a window of the transformer.

To economize on the insulation between the X-ray tube and the surrounding metal, an X-ray tube is used in which the part of the tube wall opposite the transformer body is entirely of metal, or is provided with a metal layer. If the length of the metal middle portion of the X-ray tube is less than that of the hollow portion of the transformer core in which the tube is arranged, the metal portion should be extended on either side by means of metal layers, such as coatings of tinfoil on the outside of the tube wall, at least as far as the sides of the transformer. Preferably, the transformer sheets, the narrow side of which is adjacent the tube, are sloped or rounded at their ends to reduce the electrostatic loading of the adjacent insulating portions of the tube wall.

In order that my invention may be clearly understood and readily carried into effect, I shall describe same more fully with reference to the accompanying drawing, in which:

Figure 1 is a partly sectionized side view of a device according to the invention;

Fig. 2 is a sectionized view of the device of Figure 1 taken along line 2—2;

Fig. 3 is a top view of another embodiment of the invention comprising a shell transformer;

Fig. 4 is a partly sectionized side view of the device shown in Fig. 3;

Fig. 5 is a top view of a device according to the

invention comprising a core-type transformer;

Fig. 6 is a side view of the device shown in Fig. 5.

The device shown in Figures 1 and 2 comprises a cylindrical transformer having an iron core built up of buckle-shaped sheets or laminations 1. The sheets 1 are grouped together in lots of, for instance 5 to 10, into bundles 2, which are surrounded by a corrugated iron sheath 3, for instance of tin plate. As is shown in Fig. 2, the corrugations of sheath 3 extend in the direction of the length of the transformer, and the outer ends of the bundles fit into the corrugations so that the relative spacing of the bundles remains unvaried.

Symmetrically arranged within the central cavity formed by the transformer core is an X-ray tube having a wall comprising a metal middle portion 4 to the ends of which are sealed glass members 5 and 6 having re-entrant portions 13 and 14 carrying an anode 7 and a cathode 8 respectively.

The portions of glass members 5 and 6 opposite the transformer are coated with a satisfactorily-adhering layer of tinfoil 40 extending to the dotted lines 9 and 10, which reduces the danger of flash-overs and of deterioration of the glass members. This is probably due to the fact that the quantities of air which are unavoidably entrapped between the tube wall and the transformer core are electrostatically protected by the metal coatings so that no ionization can occur therein.

The portions of the tube protruding from the interior of the transformer are surrounded by metal hoods 11 and 12. If the power of the device is sufficient to render cooling of the X-ray tube and the transformer desirable, an electric fan (not shown) may be attached to one of the hoods, preferably to hood 11 adjacent the anode.

Although the insulating length of the glass members 5 and 6 is materially reduced by the metal coatings, this is not necessarily a disadvantage. It is, however, preferable that the re-entrant portions 13 and 14 withstand a substantial part of the potential drop. To render this possible the re-entrant portions have arranged in them centrally-bored stoppers or bushings 15 and 16 of insulating material, which bushings also support the current conductors 17 and 18, which pass from the transformer to the electrodes of the tube and which are surrounded by good insulating material.

To allow the X-rays to pass through the transformer core without interference, a longitudinal slot 19 having the width of the cone of X-rays (see Fig. 2) is provided in the core and which, owing to its wedge shape, conforms closely to the cone of the X-rays. The slot 19 also allows the passage of the current conductors 17 and 18 through the transformer core. As the entire remaining part of the circumference of the coils can be provided with the transformer iron, a great saving in space is obtained.

Windings 20, 21, and 22, which have the form of concentric cylindrical coils, are located in the annular window formed within the transformer core. The primary windings 20 are surrounded by the secondary windings 21 and 22 and are insulated from these windings by low-tension insulation (not shown). The secondary windings 21 and 22 are adjacently disposed and are spaced apart in the direction of their width to provide a space through which the X-rays may pass. The secondary windings 21 and 22 have their inner ends interconnected at 41, and are so wound that the voltages induced in them are additive. Thus, when the X-ray tube is in use, the innermost layers of windings 21 and 22 will have substantially the same potential as the core, in which case the interconnection 41 of the secondary windings, together with the iron body, can be grounded. The high tension ends of the secondary windings are located on the outer side and a cylinder 23 of insulating material prevents the occurrence of flashing-over between the outermost layers of windings and the transformer core.

To avoid flashing-over between the parts of the secondary windings which have the total voltage relative to each other, the ends of windings 21 and 22 are tapered, i. e., the layers of the windings are made narrower towards the outside. Consequently, flashing-over to the transformer core in the length direction cannot occur so easily. As the windings have only half the voltage relative to the transformer core, it is entirely in agreement with the load conditions that the increase of the distance from the transformer core to the end of the adjacent secondary winding is only half as great as the increase of the distance between adjacent ends of the secondary windings. The trapezoidal form of these windings has the further advantages that this shape, as well as the shape of the slot 19 of the iron core, corresponds to the form of the X-ray beam emerging from a window 24.

The device may be supported by a bail 25 provided with trunnions 26 and 27 engaging apertures of the metal hoods 11 and 12.

As shown in Figure 1, the transformer sheets have rounded corners, whereby at the point at which the electrostatic load of the tube wall commences, the electric field at the corner of the sheets is weakened and the tube wall is thus loaded to a lower degree.

It is possible, in the above-described manner to make a complete X-ray device for powers which are not excessive, for example X-ray devices for use in dentistry. A device of this type has been made having a length of about 20 cms. and a diameter not exceeding 12 cms. Devices of such construction may also be used for larger powers, for example for diagnostical purposes. In the latter case the provision of a fan and a slightly greater copper section of the transformer windings may lead to the desired increase of the loading capacity. The form of the transformer is particularly effective in view of the possibility of cooling.

Although it has been proposed to surround an X-ray tube by the transformer windings and, if desired, to arrange the magnetic core within the tube, the device according to the invention offers, in comparison with such construction, the advantage of using a transformer having a closed core.

If it is desired to unite the X-ray tube with a shell transformer of the usual form, this may be effected in the manner diagrammatically shown in Figs. 3 and 4. In this case, the transformer column is divided in the direction of the length, the sheets of the bundles 28 and 29 being arranged as the leaves of a bound book so as to form a recess bearing against the cylindrical X-ray tube 30. Also in this construction an excessive concentration of the lines of force of the electric field on the corners of the transformer core is avoided by sloping the corners.

Even a core transformer may be united with the tube in accordance with the principles of the

invention, for example, in the manner shown in Figs. 5 and 6. As shown in these figures, an X-ray tube **32** is surrounded by the transformer coils **31** and is housed in the column **33** of the transformer, which column is divided into two parts in the direction of the length (see Fig. 5). The magnetic circuit is closed through the yoke **34** to surround the transformer coils.

The form of construction described with reference to Figs. 1 and 2 is, however, preferable to the other example of construction on account of the very efficient use of the space occupied.

As has been stated, my invention is not limited to X-ray devices, but may be used in other electric devices in which a load is supplied by a transformer and in which a compact structure is desirable.

While I have described my invention in connection with specific examples and in specific applications, I do not wish to be limited thereto, but desire the appended claims to be construed as broadly as permissible in view of the prior art.

What I claim is:—

1. An X-ray device comprising an X-ray tube having a cylindrical envelope and adapted to emit X-rays through a central portion thereof, a high-tension supply transformer for said X-ray tube having windings and a magnetic core having portions forming an elongated space, said X-ray tube being mounted within said space concentrically and symmetrically with respect to said portions and with its ends extending beyond the ends of said transformer, each turn of said windings encircling said core portions and said X-ray tube, said windings and core portions forming a radially-extending space for the exit of the X-rays, and electric supply leads connecting the ends of said tube to said windings.

2. A shock-proof X-ray device comprising a high-tension radial shell-type transformer having windings and a magnetic core having portions forming an elongated space, an X-ray tube disposed within said space with its ends projecting from the sides of the transformer and comprising an envelope having a conductive outer surface extending the length of said core portions and disposed adjacent thereto, a protective housing having a substantially closed surface of conductive material enclosing said tube and transformer and comprising two hoods each surrounding one end of said X-ray tube, said housing being electrically connected to the core of said transformer, and electric leads within said hoods and connecting said X-ray tube and transformer.

3. An X-ray device comprising an X-ray tube adapted to emit X-rays radially through a central portion thereof, and having a cylindrical envelope provided at its central portion with a conductive surface, a high-tension supply transformer for said X-ray tube having windings and a magnetic core having portions forming an elongated space, said X-ray tube being mounted within said space concentrically and symmetrically with respect to said portions and with its ends extending beyond the ends of said transformer and with said conductive surface extending the width of said portions, each turn of said windings encircling said core portions and said X-ray tube, said windings and core portions forming a radially-extending space for the exit of the X-rays, and electric supply leads connecting the ends of said tube to said windings.

4. An electric device comprising an elongated electric discharge tube and a high-tension supply transformer therefor, said transformer having a magnetic core and windings, said core having a leg enclosed by said windings and branching in two branches which are spaced apart to form a longitudinal intermediate space, said tube being longitudinally disposed in said space, and supply leads connecting the tube to said transformer, said leads extending from each end of the tube to the adjacent end of said windings.

5. An X-ray apparatus comprising an X-ray tube and a high-tension supply transformer therefor, said transformer having a primary winding, a secondary winding and a magnetic core, said core being composed of substantially rectangularly-shaped and rectangularly-apertured laminations arranged in radial symmetry, said windings being disposed in the toroidal space formed by said apertures, and said tube being disposed in the central cylindrical space formed by said laminations, and electric supply leads connecting the ends of the two secondary windings to said X-ray tube.

6. An X-ray apparatus comprising an X-ray tube having an envelope and electrodes therein, a high-tension radial-type transformer having a magnetic core and windings, and supply leads for said X-ray tube connected to the high voltage ends of said windings, said core forming a toroidal space in which said windings are located and forming a central cylindrical space in which said tube is symmetrically mounted, the central portion of said envelope adjacent to the core being provided with a metallic surface.

7. An X-ray apparatus comprising an X-ray tube and a high-tension radial-type supply transformer therefor having a magnetic core and coils, said core forming a toroidal space having a casing of insulating material located therein and forming a central cylindrical bore having the X-ray tube disposed therein, said casing enclosing said transformer coils and having apertures in its ends, tubes of insulating material fitting in said apertures, and electric supply leads connecting the high voltage ends of the coils to the ends of the X-ray tube and passing through said insulating tubes.

8. An X-ray apparatus comprising an X-ray tube having an envelope and electrodes therein, a high-tension radial-type supply transformer for said tube having a magnetic core and windings, said core forming a toroidal space in which said windings are located and forming a central cylindrical space in which said tube is symmetrically mounted, electric supply leads for said X-ray tube connected to the output ends of said transformer, and a conductive member covering portions of the tube envelope adjacent to the core to prevent the setting up of an electric field between the core and the adjacent envelope portions.

9. An X-ray apparatus comprising an X-ray tube having electrodes, an envelope consisting of a central metal portion and glass portions sealed to the ends of said metal portion, a high-tension radial-type supply transformer having windings and a magnetic core, and supply leads for said X-ray tube connected to the high voltage ends of said windings, said core forming a toroidal space in which said windings are located and forming a central cylindrical space in which said tube is symmetrically mounted, and a metallic coating in electrical contact with said metal portion and covering said glass portions throughout the length of the transformer core beyond said metal portion.

10. An X-ray apparatus comprising an X-ray

tube and a high-tension supply transformer having windings and a magnetic core, and output leads connecting the high voltage ends of said windings to the ends of said X-ray tube, said core consisting of radially-arranged rectangular O-shaped laminations, said laminations forming a toroidal space in which said windings are located and forming a central cylindrical space in which said tube is mounted, the corners of the lamination edges adjacent to the X-ray tube being rounded.

11. An X-ray apparatus comprising an X-ray tube and a high-tension supply transformer therefor, said transformer comprising a magnetic core and windings, said core being provided with a toroidal space in which are located the windings of the transformer, and having a central cylindrical aperture in which is symmetrically located the X-ray tube, and a longitudinal slot in said core, said windings being divided in two parts spaced from each other at the equatorial plane of the transformer, said slot and the coil interspace together forming a lateral passageway for the X-rays emitted by said tube, and high-tension insulated supply cables connecting said windings to the adjacent ends of the tube and extending into said slot.

12. An X-ray apparatus comprising an X-ray tube having an envelope and generating a laterally-emerging X-ray beam, and a high-tension radial-type transformer for said tube, said transformer having a magnetic core, a primary winding, and a secondary winding, said core forming a toroidal space in which said windings are located and forming a central cylindrical space in which said X-ray tube is symmetrically disposed, said secondary winding comprising two coils spaced apart to form about the equatorial plane of the transformer a space, said X-ray beam passing through said space, said space increasing toward the periphery to correspond to the increasing width of the X-ray beam, and electric supply leads connecting the high voltage ends of said secondary coils to said X-ray tube.

13. An X-ray installation comprising an X-ray tube having an envelope and electrodes therein, said envelope having re-entrant portions of insulated material carrying said electrodes, a high-tension supply transformer for said tube having a magnetic core, said core being provided with a central duct in which said tube is disposed, the ends of said tube extending beyond said core, a centrally-bored insulated stopper in each re-entrant portion, insulating tubes inserted in said stoppers and supported thereby, said insulating tubes extending outwardly toward the transformer, and current supply leads connecting the electrodes to the transformer, said leads being enclosed in said insulating tubes.

14. An X-ray apparatus comprising an X-ray tube and a high-tension supply transformer therefor having primary and secondary windings, said transformer having a core provided with a toroidal space in which said windings are located, said core having a central cylindrical space in which said tube is located, each of said windings consisting of two coils spaced apart symmetrically with respect to the equatorial plane of the transformer, a conductor having substantially the same potential as the magnetic core and connecting the coil parts in series with each other, the coils of the secondary windings being wound in concentric layers with the interconnected ends lying at the inner side and the other ends at the outer side, electric leads connecting said latter ends to the X-ray tube, and a space between the outer layers of the secondary winding and the core, which is at least partly filled with insulating compound.

15. An X-ray apparatus comprising an X-ray tube and a high-tension transformer having windings and a magnetic core, said core being provided with a toroidal space in which said windings are disposed and forming a central cylindrical space in which said tube is symmetrically mounted, said transformer windings consisting of a primary winding and of a two-coil secondary winding, the coils of said secondary winding having a substantially trapezoidal section with the longer parallel side turned toward the axis of the transformer, a conductor interconnecting the inner ends of said secondary coils to form a series connection, high-tension insulated conductors connecting the other ends of the secondary coils to the X-ray tube, and an insulating layer around the outer surface and the ends of the coils.

16. An X-ray apparatus comprising an X-ray tube having electrodes and a laterally emerging X-ray beam, said tube having an envelope comprising a central metal portion and glass portions sealed to the ends of said metal portion and carrying said electrodes, a window in said metal portion for the exit of the X-ray beam, a radial-type transformer having primary windings, secondary windings, and a magnetic core, said core having laminations forming a hollow space in which said windings are located and forming a central cylindrical bore in which said tube is disposed with the tube-ends protruding therefrom, said primary windings being adapted to be electrically connected to the ordinary supply network, said secondary windings having a mid-tap electrically connected to said core and to said metal portion to ground the same, the voltage difference between the secondary winding and the core increasing toward the periphery of the transformer, an insulating member disposed between the secondary windings and the laminations, a metal housing surrounding the transformer and having hood-shaped portions extending over the protruding ends of the X-ray tube, a window in said housing in alignment with the window in the tube envelope, and a supporting bracket for said apparatus connected to said hood-shaped portions.

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