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A. BOUWERS

2,053,176

X-RAY APPARATUS

Filed June 14, 1934

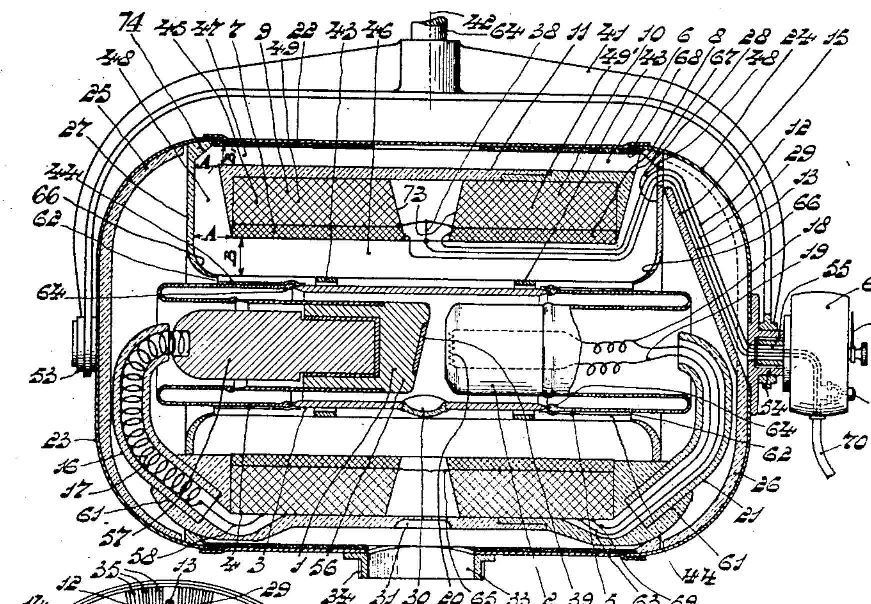

Fig. 1

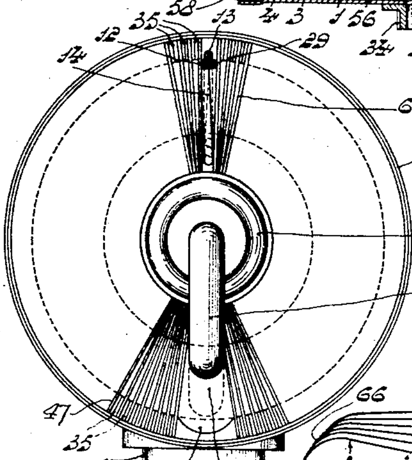

Fig. 2

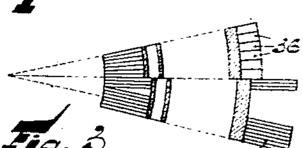

Fig. 3

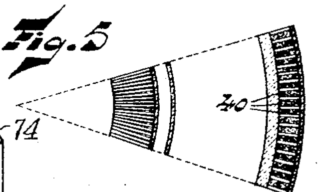

Fig. 5

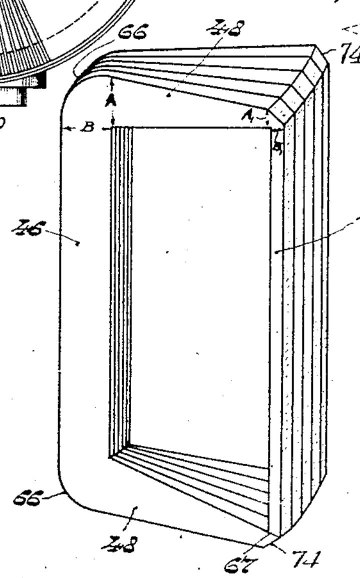

Fig. 4

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X-RAY APPARATUS

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Application June 14, 1934, Serial No. 730,661
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3 Claims. (Cl. 175—361)

This invention relates to certain improvements and modifications of electrical apparatus of the type described in my copending application Ser. No. 703,461, filed December 21, 1933, of which the present application forms a continuation in part.

In my prior application I have described certain electrical apparatus in which a radial or shell-type transformer and a high tension load device closely surrounded by the transformer are combined in a compact unit. Such arrangement of the apparatus results in a considerable saving of space and weight, gives a high efficiency, provides for easy handling of the apparatus, and offers further advantages, specially if an X-ray tube forms the load device.

A self-contained X-ray apparatus made in accordance with the invention of my above application results in a more compact unit having smaller dimensions and less weight than any known prior X-ray apparatus of equal performance.

The present invention relates to various novel features making possible still further important reductions in weight and overall dimensions of such a unit. For example, a unit which is suitable for simple radiographic work, as dental work, examination of collar bone, hands, etc., can be made so small and light, that a support can be altogether dispensed with; the operator merely holding the apparatus in the hands when taking the X-ray picture.

The improvements of the present invention comprise a more efficient construction of the magnetic core of the transformer, and of the high tension insulation.

I have found that by a construction of the transformer yoke or core, which minimizes or altogether avoids the interspaces between the individual laminations of the core normally present in the radial shell-type transformer, a very considerable reduction in size and weight of the apparatus may be obtained. This I achieve, for instance, by filling out the interspaces between the laminations, with magnetizable material, for instance, with strips or pulverized material. Or again, the laminations, instead of having uniform thickness are increasing in thickness toward the periphery of the transformer. This leads to a more efficient utilization of the space and a decrease of the dimensions and the weight.

According to a further feature of my invention, the aperture or window of the laminations may be formed as an isosceles trapezoid, the base of which falls towards the periphery of the transformer. This, combined with a preferred arrangement of the transformer windings, as will be more fully explained in connection with the drawing, permits a simpler coil construction, and a more efficient arrangement of the high-tension insulation between the core and the transformer coils, and results in further saving in weight and reduction in dimensions of the apparatus.

A still further feature is to have the envelope of the X-ray tube oppose the core with conductive members throughout the entire length of the core and to bring these conductive members and the core at the same, and preferably ground potential.

Another feature of the invention is to resiliently support the X-ray tube in the transformer, the support also acting as electrical connectors between the core and the metal portion of the envelope.

Further features of the invention will appear as the specification progresses.

In order that the invention may be clearly understood and readily carried into effect, it will be more fully described with reference to some embodiments thereof, and in connection with the accompanying drawing, in which:

Figure 1 is a sectionized front view of an X-ray apparatus showing one embodiment of my invention.

Figure 2 is an end view of the apparatus shown in Figure 1, with certain parts removed.

Figure 3 is two cross-sectional views arranged above and below a dot and dash line of transformer portions, one of which shows an embodiment of the present invention, and the other of which shows an embodiment according to the prior application.

Figure 4 is a perspective view showing the lamination made in accordance with the present invention and corresponding to the lamination in the upper portion of Figure 3.

Figure 5 is a cross-sectional view of a transformer portion showing a further embodiment of the invention.

The apparatus shown in Figure 1 comprises an X-ray tube having an anode structure 1 and a cathode structure 2. The X-ray tube has preferably a cylindrical shape and is of the type which comprises a metallic waist portion 3, to the two ends of which are sealed re-entrant vitreous insulating members 4 and 5 carrying the anode structure 1 and the cathode structure 2 respectively. While other types of tubes may be used in connection with my invention, the presence of an equipotential middle section at the envelope is highly desirable.

The X-ray tube is closely surrounded by a cylindrical transformer which is coaxial with the tube.

While the tube is shown to slightly extend beyond the transformer on the two sides thereof, it may be flush therewith or even shorter than the transformer. Preferably the transformer and tube are so dimensioned with respect to each other that they are of substantially equal length, this giving as a rule, the most compact arrangement of the apparatus.

The transformer is of the so-called "radial type" and comprises a laminated yoke or core, the lamination being of silicon steel or other similar material of high magnetic efficiency.

The individual laminations 6, as shown in Figure 1, have the general shape of a buckle or window frame comprising a central aperture 45. The laminations thereby comprise an inner and an outer axially extending leg 46 and 47 respectively and two radially extending connecting legs 48—48. The laminations are split as shown at 67 and can thus be bent open and slipped over the transformer coils when the transformer is assembled.

The apertures 45 of the assembled laminations form a cylindrical space in which are disposed the transformer windings together with their insulation. The transformer windings are subdivided into two coil assemblies, one assembly 49 being formed of a primary coil 7 and a secondary coil 9, and the other assembly 49' being formed of a primary coil 8 and a secondary coil 10. The primary coils 7 and 8 are the inner coils, and the secondary coils 9 and 10 are wound around them. The two primary coils 7 and 8, are connected in series and the two secondary coils 9 and 10 are also connected in series. The preferred organization and the interconnections of the coils, as well as their outside connections, will be later described.

Between the core and the coils is provided an insulating structure 11, which forms a cylinder of uniform thickness between the outside surface of the secondary windings and the core, and extends radially at the two ends of the windings, with decreasing thickness towards the tube. This decrease in insulating capacity, as will be shown later on, is made possible by the corresponding decrease of the voltage difference between the windings and the core. The trapezoidal shape of the aperture 45 of the laminations takes care of the inwardly decreasing thickness of the insulation.

Furthermore, the height of the inner leg 46 of the lamination is greater than that of the outer leg 47 and the radial connecting legs 48—48 decrease in width from the inside to the outside. The reason for and the advantages of so shaping the laminations will be explained later on.

The transformer is closely surrounded by a cylindrical metal housing 22 provided at its two ends with rounded hoods 23 and 24.

Provided on the hoods 23 and 24, along the longitudinal axis of the tube are pivots 53 and 54, at least one of which (shown in the drawing as the right side pivot 54) is apertured. Through this aperture 55 pass the leads 12 and 13 for the outside connection of the primary winding and a ground wire 29.

The leads 12, 13 and 29 pass through the housing 69 of a time switch secured to the pivot 54, and form an electrical cord 70 carrying a plug (not shown) adapted to be inserted in a standard light socket. The time switch is electrically included in one of the leads 12 and 13, and the other leads are led through the housing 69 without interruption as schematically shown in dotted lines. The time switch is of the usual type having a time adjusting device 71 and a current closing device 72 on one dial.

As shown in Fig. 2, a radial recess 14 is provided in the core for the leads 12 and 13, which are connected to the opposite ends of the primary windings 8 and 7 respectively, the other ends of which are connected at 65. The ground wire 29 is connected to the core (as shown at 38), to which is also connected the junction point or midpoint of the secondary windings 9 and 10. Preferably an insulator 15 is also provided for the mechanical and electrical protection of the leads 12, 13 and 29.

The anode structure 1 comprises a cylindrical body 56 of copper or other good heat-conducting metal which carries a target 39 of tungsten or other refractory metal.

The anode body 56 may be fused directly to the reentrant portion of the vitreous cylinder 4, preferably by means of an intermediate chrome iron member.

Instead of using a single piece anode body I prefer, for convenience of assembly to make it of two pieces, whereby a copper body 57, which is rounded at its outer end, is fittingly inserted into a corresponding cavity of the body 56 and serves to provide a sufficiently high heat capacity.

For the leads which connect the secondary winding with the electrodes a recess 60 is provided in the core (see Fig. 2). The free end 58 of the high voltage coil 9 is connected by means of a coiled wire 17 to the anode body 57, the lead 17 being surrounded by an insulating tube 16 of high insulating capacity, for instance of glass. The wire 17 is made in the form of a spring so that a good contact is obtained between this wire and the body 57 to which it is applied without being secured thereto.

The free end 59 of the secondary coil 10 is connected by means of a lead 19 to one end of the cathode-filament 20, and a tap 63 provided on the secondary winding close to terminal 59 is connected by means of a lead 18 to the other end of the filament; the voltage between the taps 59 and 63 being of such value as to bring the filament 20 to the desired operating temperature. The leads 18 and 19 are surrounded by an insulating tube 21 of high insulating capacity, for instance of glass.

The insulator 11 forms suitably shaped pockets 61—61 around the outer ends of the insulating sleeves 16 and 21.

The housing 22 is electrically connected to the core and is thus grounded, when during the operation of the apparatus the lead 29 is connected to ground. In order to prevent rattling, a resilient layer 68 for instance of felt is provided between the transformer and the housing 22. As stated before, the transformer closely surrounds the X-ray tube, but instead of snugly inserting the tube in the transformer, I prefer to provide a resilient support for the tube. For this purpose I provide contact springs 43—43, which embrace the metallic portion 3 of the tube and directly contact with the core. The springs 43—43 thereby also establish electrical connection between the core and the metal portion 3 and thus ground the latter, when the lead 29 is connected to ground.

The metal portion 3, while forming a comparatively large portion of the outer envelope of the short tube, and extending on both ends beyond the operative portions of the electrodes, does not extend the full length of the core. However, metal foils 44—44, which I provide at the metal-glass seals 64—64 to protect in accordance with the teaching of my U. S. Patent 1,824,755 the glass against puncture at the seal, I extend to points 62—62 at the ends of the core. Thus the entire length of the metal core is opposed by either the metal portion 3 or by the metal foils 44—44. Thereby during the operation of the tube those portions of the insulating cylinders 4 and 5 which fall between the points 62 and the sealed joint of the respective electrode take up each one-half of the operating voltage.

To prevent flash-over between the high tension parts and the housing, I provide the housing at its rounded hoods with insulating coatings shown at 25 and 26. Similarly, to prevent flash-overs between high tension parts and the transformer core, the latter is provided at its frontal ends and around the corners with insulation, for instance coatings 27 and 28.

The X-rays produced at the target 39 of the anode, emerge from the tube through a ray-window 30, shown as a glass window sealed into the metal sleeve 3. Opposite to the ray-window the housing 22 is provided with an opening 33, surrounded by an outwardly extending bushing 34, serving for the attachment of a centering tube or cone (not shown).

To minimize the absorption of X-rays by the insulating cylinder 11, this cylinder is considerably weakened at its portion intercepting the X-rays as indicated at 31. The reduction of the insulating capacity at this point can be accomplished without danger as at this point the core is also interrupted.

The apparatus is preferably provided with a U-shaped arm 41 on which it is pivotally suspended by means of the pivots 53 and 54. The arm 41 is preferably rotatably mounted on a shaft 64, the axis 42 of which passes through the focal spot of the tube and is perpendicular to the longitudinal axis of the tube.

The apparatus, due to its pivotal suspension on the arm 41, is also rotatable about the longitudinal axis of the tube.

In view of the radial, rather than parallel arrangement of the laminations 6 of the core, laminations having a uniform thickness cause interspaces to form between adjacent laminations, and as is shown in Fig. 2 the width of these interspaces increases towards the periphery of the transformer.

While such interspaces are generally regarded as desirable because they promote air circulation and thereby increase the heat dissipation and thus the load capacity of the transformer, I have found that the partial or preferably complete filling out of such interspaces with a material having magnetic properties suitable for a magnet core, results in very marked advantages.

More specifically I have found that by such filling out of these interspaces, the diameter of the transformer can be considerably reduced and for a given load capacity, smaller dimensions and less weight are required, or for a given weight and volume, the load capacity of the transformer is increased compared with a transformer having interspaces between the laminations.

Figure 2 shows the end view of the apparatus of Fig. 1 seen from the right, with the hood 24 and the insulators omitted.

As shown in Figure 2, the interspaces between legs 47 of the laminae are filled out with strips 35 of magnetic material, whereby the outer portion of the yoke forms a closed cylinder.

For instance, as shown in the drawing, by inserting in the interspace between adjacent legs 47, two strips 35 having the same thickness as the laminations, the iron cross-section of the outer portion of the yoke is increased threefold and thus the height of the legs 47 can be reduced to about one-third.

Thus the diameter of the transformer and hence of the whole device can be correspondingly reduced.

For the strips 35 the waste material which results from the stamping of the window 45 of the lamination can be utilized.

If desired the remaining interspaces between adjacent lamellae, thus betweeen the legs 48—48 and 46, can be filled out with suitable powered magnetic material thus forming a completely closed yoke body.

A somewhat more expensive but still more efficient construction is obtained by making the laminations, instead of a uniform thickness, of a thickness which increases toward the periphery in such a manner that the assembled laminations form a completely closed and solid hollow cylindrical body.

The laminations 36 of such a yoke are shown in Fig. 4, and also in Fig. 3 above the dash and dot line. Below the dash and dot line of Fig. 3, a portion of a transformer is shown designed for the same load capacity and made according to the prior construction, in which the laminations 37 are united to form bundles.

Not only can the outside diameter of the transformer and of the apparatus be thus decreased, but also its length. This is accomplished because the filling out of the interspaces between the portions 48—48 of the laminations increases the effective magnetic cross-section, taken in the cylindrical plane of the legs 48, and thus the width of the legs can be reduced without reducing the magnetic cross-section. It is evident that by reducing the width of the legs 48—48 the total axial length of the apparatus can be reduced.

The above stated reduction of the width of the legs 48—48 of course depends upon the amount of the magnetic material which is added to fill out the interspaces between the laminations, and as this amount increases toward the periphery the width of the leg 48 may be and is decreased towards the periphery. Thus the width of the leg 48 gradually decreases from a value A, (which substantially corresponds to the height of the leg 46, shown as B), to a dimension A_1, (which substantially corresponds to the height of the leg 47, shown as B_1). Thereby the aperture of the lamination has a cross-section of an isosceles trapezoid. For the purpose of saving weight the laminations are rounded at the corners 66 and 74. Rounding the corners 66 is also advantageous in preventing flash-overs.

In connecting the secondary windings, as above discussed, namely with the mid-point of the windings grounded at 38, the potential increases towards the periphery of the transformer, and it is evident that the required insulation between the frontal ends of the coils and the adjacent legs 48 of the yoke has to radially increase in thickness. In such case the insulation requirements are met by an insulation 11, the general shape of which has already been described, and the thickness of the frontal portions of which increases towards the periphery of the transformer.

Because of such a radial increase of the thickness of the insulation 11, and a similar decrease of the width of the legs 48, the front ends of the legs 48 and the end surfaces of the transformer coils can be made parallel and perpendicular to the axis of the tube, without any loss in space.

It is evident that the above-described shape of the yoke and of the insulation 11 results in a transformer which has the shortest axial length.

The inner ends of the primary and secondary coils are tapered, as shown at 73, so that the air-gap between the coils increases toward the periphery of the transformer with the increasing voltage. This tapering gives the further advantage that the coils do not intercept the emerging X-ray beam.

In Figure 5 a further embodiment is shown in which the laminations have a uniform thickness and the interspace 40 between the laminations is filled out with a powdered magnetizable material, such as iron powder of suitable permeability. The results obtained are similar to those obtained with the embodiment shown in the upper part of Figure 3. While the arrangement of Fig. 5 is less expensive than that according to Figure 4, it is somewhat less efficient in view of the fact that the magnetic lines of force are interrupted in the portions composed of powdered material.

An X-ray apparatus manufactured according to the invention is extremely compact and small in size. The self-contained apparatus, including the transformer and the tube, adapted to be connected directly to the light plug and suitable for voltages up to from 30 to 40 kilovolts, can be built having a diameter of 4 inches and a length of seven inches and with a weight of only about fifteen pounds. Such an apparatus, which can be used in dentistry or in other types of radiography, for example, examinations of the hand, collar bone, etc., can be used with a very light standard or altogether without a standard; the apparatus being held in the hands.

The same principle, of course, can be applied to apparatus of larger capacity. In every case, however, a great saving in weight and size is obtained by applying the principles of my invention.

Nor is my invention limited to electrical apparatus, of which the load device consists of an X-ray tube, but the same principle can be applied to other types of apparatus.

Also various departures from the embodiment shown can be made without departing from the spirit of the invention.

What I claim is:

1. A radial shell-type transformer comprising a hollow yoke and windings disposed within the hollow of said yoke, said yoke comprising radially-disposed laminations of magnetizable material, said laminations having an apertured rectangular cross section, the axial width of said aperture increasing towards the periphery, and an insulator between said windings and said yoke, said insulator having radially extending portions the thickness of which decreases from the periphery and in a radial direction to the same extent as increases the axial width of the aperture.

2. A radial shell-type transformer comprising a cylindrically-shaped core provided with an annular cavity whose axial width increases towards the periphery, windings disposed within the cavity of said core, and a member of insulating material disposed between the windings and the core and having radially-extending portions whose thickness increases toward the periphery.

3. A radial shell-type transformer comprising a hollow magnetic core having a central cylindrical bore and a magnetic circular thickness which increases toward the periphery of the transformer, primary and secondary windings disposed in the hollow of said core, the end surfaces of said core and said windings being perpendicular to the axis of the transformer, said core having radially-extending legs whose axial width decreases toward the periphery of the transformer to form between the end surfaces of said windings and the adjoining surfaces of said core spaces whose width in the direction of the transformer axis increases toward the periphery, and an insulating member disposed between said core and said windings, said member having radially-extending portions whose width in the direction of the transformer axis decreases toward said axis, said portions fitting in the spaces between the core and the end faces of said windings.

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