# United States Patent [19]

**Holland et al.**

[11] **3,821,581**

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[54] **TARGETS FOR X-RAY TUBES**


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[52] **U.S. Cl.** .................................. **313/60,** 313/330
[51] **Int. Cl.** .......................................... **H01j 35/10**
[58] **Field of Search** .............................. 313/60, 330



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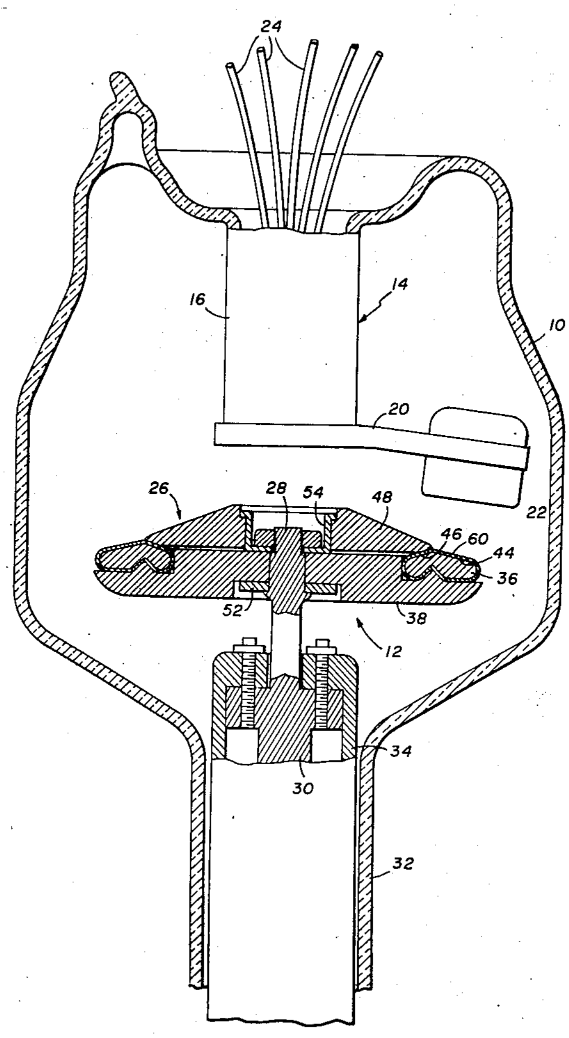
[57] **ABSTRACT**

An X-ray tube including a target structure having a focal area for receiving electrons from an adjacent cathode and generating X-radiation in response thereto, the focal area being provided with a surface designed to improve thermal properties such as by covering with a closely packed wrapping of relatively fine wire, the focal area preferably being a wire-wrapped annulus sandwiched between two discs of high thermal conductivity material.

**8 Claims, 9 Drawing Figures**

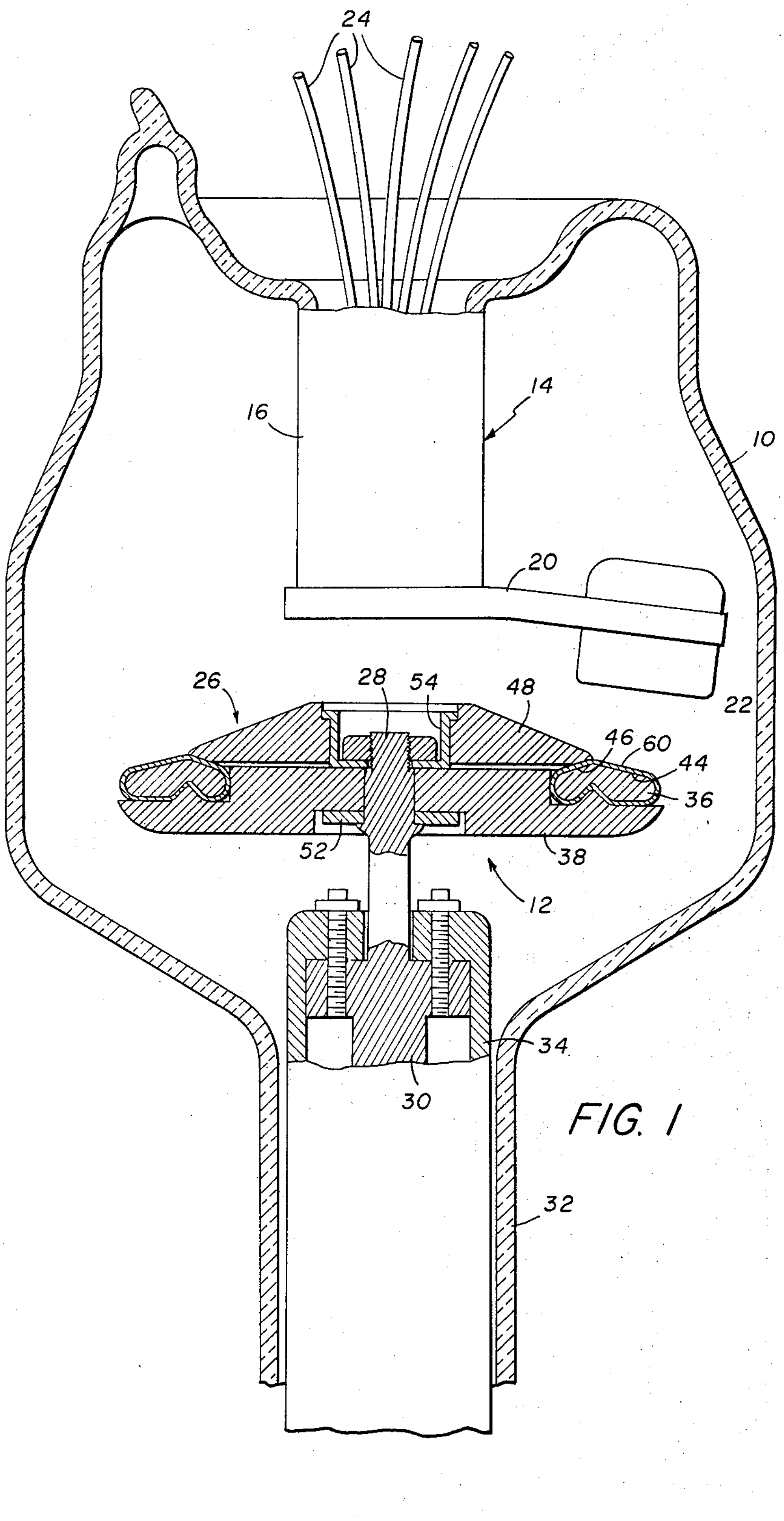
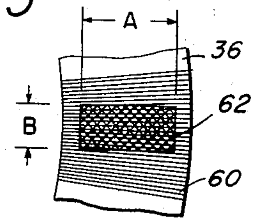



FIG. 1

FIG. 5



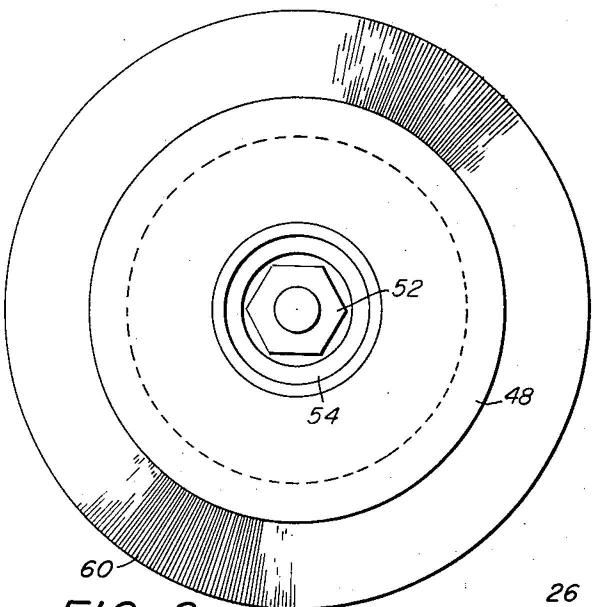




FIG. 2

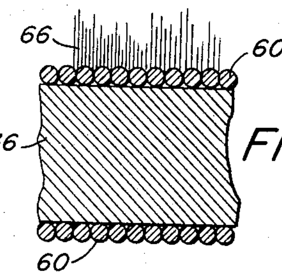



FIG. 6

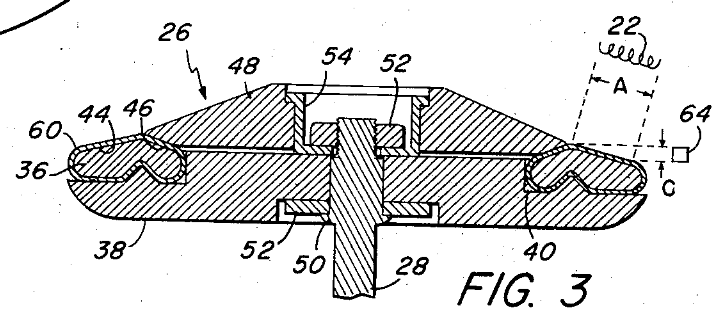
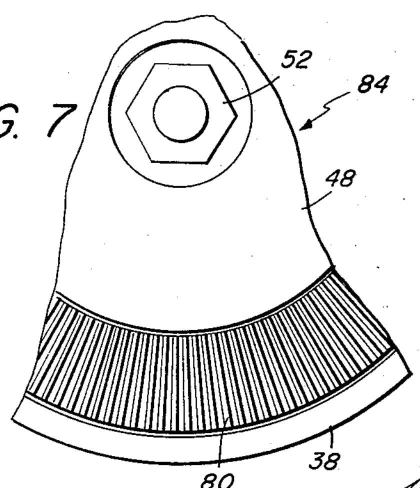



FIG. 3

FIG. 7



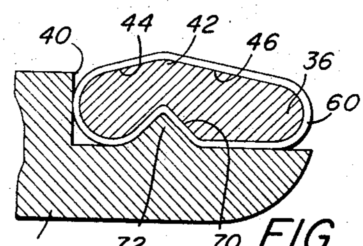




FIG. 4

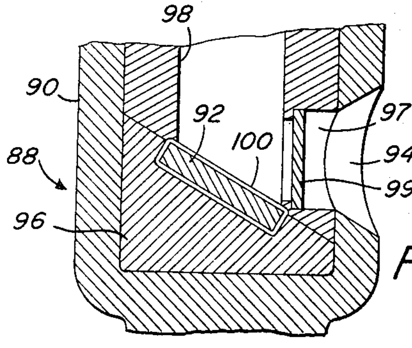



FIG. 9

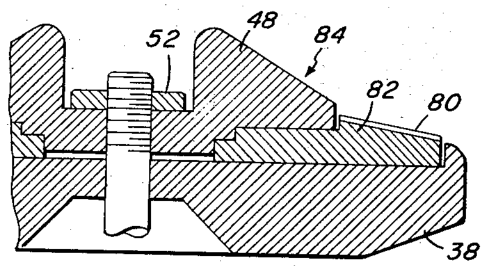



FIG. 8

# TARGETS FOR X-RAY TUBES

## BACKGROUND OF THE INVENTION

In the manufacture of targets for X-ray tubes, the portion of the target which is to be subjected to electron bombardment for the resultant production of X-rays is preferably made of a high atomic number material except in cases where characteristic radiation is required. However, it has been found that many problems exist when making the entire target of high atomic number material, due at least in part to the fact that during operation of the device the target will become seriously damaged through high thermal gradients causing severe mechanical stresses which result from bombardment by high energy electrons. This produces cracking, warping, and focal area disruption. For example, the temperature assumed by a conventional tungsten target at the focal spot may approach 3,400°C and such heat may create hoop stresses which produce cracking, resulting in mechanical failure, or warpage which alters the target angle and thereby changes the focal spot size.

Attempts to overcome these and other problems have been made by forming a target of a selected refractory base material having high thermal capacity, such as molybdenum or graphite, for example. On this base material is deposited a layer of high atomic number material which has high melting point and low vapor pressure. This layer, which may be vapor deposited, flame sprayed, or brazed, may cover one side of the base or may cover the entire base surface. Such materials as rhenium, tungsten, or suitable alloys are deposited in the selected area or areas and are attached by a metallurgical bond to the base material.

These coated targets, however, have also been found to be unsatisfactory because of the extreme difficulty in obtaining good adhesion of the deposit to the base material. Differences in thermal expansion coefficients have caused much of the failure in devices of this character.

## SUMMARY OF THE INVENTION

The above and other objections to the prior art are overcome in the present invention by a novel target structure which comprises a focal area which is provided with a surface of increased area for improved thermal properties, such being achieved by locating on the surface a layer of relatively fine closely packed wires. This may be done, for example, by wrapping the entire focal area in a wire winding.

In a rotating anode X-ray tube the target comprises a disc having an inclined annular focal track defining a portion of a cone. This focal track is covered by wires disposed in close side-by-side relation and extending along the generatrices of the cone in accordance with this invention. By "generatrices" is meant lines extending radially from the tip of the geometric cone to points on the outer periphery of the cone.

The annular focal track area may comprise a portion of a one-piece solid disc or, preferably will comprise a separate annulus or ring having the wire wrapped around it, the ring thereafter being sandwiched between two discs of high thermal conductivity material. The focal area may be any suitable refractory material such as tungsten or tungsten-rhenium alloy, for example. The supporting discs may be any refractory material such as molybdenum, titanium or graphite, for example. In a fixed anode tube, the target may comprise a wire-wrapped disc inset into a block of copper or the like.



More specifically, the rotating anode may be basically constructed as shown and described in U.S. patent application Ser. No. 230,053, filed Feb. 28, 1972.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other advantages of the invention will become apparent from the following description taken in connection with the accompanying drawings, wherein

FIG. **1** is an axial section through an X-ray tube of the rotating anode type showing a target structured in accordance with this invention;

FIG. **2** is an elevational view of the target in the tube of FIG. **1**;

FIG. **3** is an axial section through the target of FIG. **2**;

FIG. **4** is an enlarged view of a portion of the target of FIG. **3**;

FIG. **5** is an enlarged elevational view of a portion of a target focal track;

FIG. **6** is a diagram illustrating an electron beam impinging upon a target;

FIG. **7** is a fragmentary elevational view of a modified rotating anode target;

FIG. **8** is a fragmentary axial sectional view of the target shown in FIG. **7**, and

FIG. **9** is a fragmentary axial sectional view of a portion of a stationary anode X-ray tube having a target embodying the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, there is shown in FIG. **1** an axial sectional view of an X-ray tube of the rotating anode type which embodies a dielectric envelope **10** in which is supported an anode **12** and a cathode **14**. The cathode **14** includes a supporting cylinder **16** one end of which is sealed to a reentrant end portion **18** of the envelope. On the inner end of cylinder **16** is mounted one end of a transversely extending angled support bracket **20**, in the free end of which is located a cathode head **22**. The cathode head **22** contains an electron-emitting filament (see FIG. 3) to which a suitable electrical potential is applied through leads **24** extending externally of the tube through cylinder **16**.

The opposite end of the envelope **10** carries the anode **12** which includes a target **26** mounted on one end of a rotor shaft **28** extending from a rotor **30** rotatably located in a neck portion **32** of the envelope. The rotor carries a skirt **34** bolted thereto, and the assembly is adapted to rotate rapidly when the tube is mounted in suitable inductive means surrounding the neck **32** when the inductive means is energized.

In accordance with this invention, the anode target assembly comprises a focal track member **36** in the form of a ring made of suitable high atomic number material, such refractory materials as tungsten or tungsten-rhenium being particularly suitable. The focal track member **36** produces X-rays when bombarded by electrons from the cathode **22** in the usual manner of X-ray generators. The exposed surface or track of the focal target member **36** is inclined so that X-rays will pass from the surface out of the tube through the side wall of the envelope. This surface defines a portion of a cone having its longitudinal axis coincident with the axis of the target **26** and particularly of the rotor shaft **28.**

The target **26** is preferably made of a plurality of superimposed members as described in the aforementioned U.S. application Ser. No. 230,053. Briefly, the focal track member comprises a ring **36** having its lower side positioned upon a surface of a backing disc **38,** which surface is shaped to receive the adjacent surface of the focal track ring. For this purpose the disc **38** is provided with a peripheral groove **40** in its upper surface within which the ring is nested. The upper surface of the focal track ring **36** is provided with a circumferential ridge **42** which inclines on either side thereof to form first and second or inner and outer inclined surfaces **44** and **46** respectively. Outer surface **44** is the exposed focal track surface and is at an appropriate predetermined angle to provide proper focal spot size, as will be described.

The inner surface **46** is inclined so as to effectively produce an annular recess within which a second backing ring or dome **48** is nested in a manner which permits thermal expansion and contraction between the parts without damage. With a nested structure of this type the focal track ring **36** is firmly engaged by adjacent surfaces of the backing disc **38** and dome **48** throughout relatively expansive surface areas to achieve efficient conduction of heat from disc or ring **36** to the disc **38** and the dome **48** as is desired.

When mounting a target assembly **26** on its supporting anode structure, it is important to insure that the two rings or discs **36** and **38** are at all times held in the required closely abutting relationship. Therefore, there must be some means provided for this purpose. In the example shown in FIG. **1,** this is achieved by providing the rotor shaft **28** with a collar **50,** and backing ring **38** is mounted over the end of shaft and seated against a ring **52** which rests upon the collar. The lower surface of the backing ring may be suitably recessed as illustrated to receive the ring **52.** Then the focal track ring **36** is slid down over the shaft into intimate engagement with the backing ring **38.** As shown in FIG. **1,** the second backing ring or dome **48** is then mounted on the shaft **28** and slid down into intimate physical contact with the adjacent inclined surface **46** of ring **36,** and the complete assembly is compactly and firmly pressed into an assembled unit by means such as a nut **52** which is threaded onto the end of the shaft into engagement with a cup-shaped retainer **54** carried by the second backing ring or dome **48,** as illustrated.

From the above it will be apparent that when the tube is operated a stream or beam of electrons will be emitted by the cathode **22** in the well-known manner and will impinge upon the adjacent inclined surface **46** of the focal track **36,** whereupon x-radiation will be emitted by this surface and will pass out of the tube through the X-ray transparent wall of the envelope **10.** During this operation considerable heat is generated within the target ring **36.** Therefore, to partially aid in the distribution of heat throughout the ring, as opposed to a localized area thereof, the target assembly **26** is caused to rotate at a relatively high speed so that a new surface area is constantly and continuously being presented to the electron beam, as is well known.

It is known, however, that X-ray tube anodes have a limited high load capability determined by the electron beam current density, among other parameters. At sufficiently high current densities even rotating anodes have been found to produce some surface melting and this, therefore, requires that limits be set on X-ray pulse duration and intensity of tube loading. Heat dissipation in X-ray anodes is accomplished primarily through radiation.

It is well known that improvements can be achieved by selection of materials for the focal track area of a target which have desirable thermal dissipation properties. Graphite is a particularly suitable material for this purpose while tungsten, rhenium-tungsten alloy, and molybdenum are examples of other relatively satisfactory materials from which the focal track ring **36** may be made. Graphite, tungsten or molybdenum, for example, may be employed as the material for the base ring or disc **38** and the dome **48.**

However, even greater performance may be achieved by increasing the surface area of the focal track ring **36** in accordance with this invention. A preferred structure of this type is depicted in FIGS. **2–6** wherein the focal track ring **36** is fabricated with a closely packed wrapping **60** of wire formed of suitable target material such as tungsten, rhenium-tungsten alloy or molybdenum, for example. The wire **60** is tightly wrapped throughout the annulus of the ring **36** so that the individual turns extend substantially radially from the geometric center of the ring.

The wire **60** is preferably of a diameter selected in accordance with the size of the focal spot which is to be produced by the tube. If the focal spot is to be relatively large, for example 1.5–2 mm. wide, the wire will preferably be about 0.008 inch in diameter. If a small focal spot of 0.3–1 mm., for example, is to be produced, the wire diameter will preferably be about 0.003–5 inch. These examples of wire size are only exemplary and the wire diameter may vary substantially from these examples.

While tungsten, rhenium-tungsten alloy, and molybdenum have been mentioned above as the material for the wire, the relative simplicity of the wire-making process, in comparison to known processes for making X-ray targets, permits a much wider choice of materials for this purpose. Additionally, during a wiremaking process it is possible to add selected doping materials or other additives which may control X-ray generating or other characteristics of the resultant wire.

The term focal spot refers to the spot or area of the target surface which is impinged by electrons from the cathode **22.** Referring to FIGS. **3** and **5,** the length of the focal spot **62** will be controlled primarily by the length of the filament in the cathode and somewhat by the geometry of the focusing cup or grid (not shown) in which the filament is mounted, as is well known. The width dimension B of focal spot **62** is almost entirely controlled by the grid or cup as is also well known. Therefore, when a tube is operated and a cathode **22** is pulsed to emit electrons in a normal manner, the electrons will bombard the target in the area indicated by numeral **62** in FIG. **5.** However, the resultant X-ray beam to be utilized will be directed along a path extending from the spot **62** in a direction substantially perpendicular to the axis of the tube. This effective X-ray beam is directed, therefore, in the general direction indicated by the dotted lines denoted C in FIG. **3,** which also indicate the width of the focal spot as viewed along a line perpendicular to the tube's longitudinal axis. Thus the effective shape and size of the effective focal spot is illustrated by the configuration **64** in FIG. **3.**

It will be apparent that the effective spot **64** will be as small and uniform as possible. Therefore, in some conventional X-ray tubes the effective focal spot **64** will be anywhere from 0.3–2 mm. square, for example. Therefore, it will also be apparent that the electron beam from cathode **22** will impinge upon any number of turns of wire **60,** depending upon the size of the wire and of the filament, as well as the electrical effect of the cathode upon the beam. This is illustrated diagrammatically in FIG. **6** wherein lines **66** denote an electron beam which impinges upon wires **60** carried by focal track ring **36.**

It will be seen that the beam **66** impinges simultaneously upon a number of turns of wire **60.** Therefore, electrons will fall not only on the surfaces of the wires which lie closest to the cathode but will also fall upon some of the side surfaces of the wires. This, consequently, effectively distributes the electrons over a greater surface area of the target than is possible when the focal track surface is relatively smooth. As a result, some of the electrons penetrate less deeply into the bombarded surface. This all leads to the generation of less heat in the same surface of the target than was previously the case by more widely distributing such heat, permitting tubes to be operated at higher power levels without target damage.

It will be understood, however, that the turns of the wire **60** should be relatively tight. Therefore, the under surface of the focal track ring **36** is provided with an annular circumferential groove **70** as shown in FIG. **4,** and the adjacent surface of supporting disc on ring **38** is provided with an annular projection or ridge **72** which is aligned with the groove **70** and extends thereinto as shown. When disc **38** is being assembled with ring **36** the ridge **72** projects into the aligned groove **70** and in doing so it exerts considerable pressure upon the adjacent portions of the wire **60,** tending to tighten it.

It will be understood that possibly with some wire sizes some of the turns of wire **60** may be slightly spaced from adjacent turns. This is the case near the outer peripheral edge of surface **46** when extremely fine wire is being employed. However, in such an event the electrons impinging upon the target in these areas will engage the small exposed surface areas of the focal track surface **46** and will generate X-radiation directly from this surface. Alternatively, the layer of wire may be overlaid with an additional layer or layers of windings to cover the exposed surface areas of the focal track surface.

It will be noted that the convolutions provided by the wire should extend radically from the geometric center of the focal track ring **36.** If the convolutions were to extend perpendicularly in the direction of the curve of the annulus, it will be apparent that some of the high portions of the convolutions will effectively intercept and block escape of some of the desirable X-radiation.

In some cases it would be satisfactory to form the convolutions by providing radically extending grooves **80** (FIGS. **7** and **8**) in the exposed surface of a focal track ring **82.** In this modification the target **84** is constructed as shown and described in aforementioned application Ser. No. 230,053. Grooves of this type are disclosed in a solid one-piece target in the U.S. Pat. No. 2,071,696 which does not, however, provide the improved heat dissipation characteristics achieved by the combination with the multi-piece target.

It is to be further understood that a stationary anode X-ray tube may be provided with this invention as illustrated in FIG. **9.**

While the foregoing description relates primarily to X-ray tubes having rotating anodes, the invention is also particularly well suited for use in stationary anode tubes such as, for example, the type shown in FIG. **9.** The stationary anode tube shown in FIG. **9** includes an envelope within one end portion of which is an anode **88.** Anode **88** is a body of copper, usually, which is provided with a hollow cylindrical extension portion **90** having an open end directed toward the cathode. An X-ray emitting target button **92** is provided in the base of the cavity thus formed in the anode for the purpose of receiving electrons from the cathode and directing resultant X-rays out through an opening **94** and then through the wall of the envelope **68.**

In accordance with the present invention, a block or body of graphite, copper, or other selected backing material **96** is deposited in the bottom of the hollow anode extension and is provided with an inclined surface having a recess therein in which the target button **92** is positioned. A sleeve or shell **98** of graphite or other selected high thermal capacity material is then positioned in the extension with one end thereof engaging the target button **92.** Sleeve **98** is provided with an opening **97** which may contain a window **99** of beryllium or other material highly transmissive to X-radiation which is suitably aligned with opening **94** in extension **90** whereby X-rays emanating from the target button **92** will pass outwardly through the window **99** and opening **94.**

In accordance with the present invention the target button **92** is covered with a wire winding **100** similar to the winding **60** in the rotating anode described hereinbefore. In the stationary anode, however, it is important that the wires extend substantially in the direction of the angle of inclination of the button **92** so that the convolutions formed by the wires will not block escape of any of the X-radiation out through window **99.** Thus, there is provided a stationary anode target which has the improved capabilities described in connection with the rotating anode.

In accordance with the foregoing description it will be understood that a focal track surface area is increased $\pi/2$ that of flat surfaces whereby greater power loads can be applied to the focal track. In addition, the increased surface allows greater radiative heat dissipation.

It will be apparent, however, that various modifications and changes may be made by those skilled in the art without departing from the spirit of the invention as expressed in the accompanying claims. Accordingly, it is to be understood that all matter shown and described is to be interpreted as illustrative and not in a limiting sense.

We claim:

**1.** A target for X-ray tube anodes comprising a target member of material capable of X-ray emission when a surface thereof is impinged by electrons, and at least one backing member of high thermal capacity material engaging one side of the target member, said target member being an annulus extending around a perpendicular axis, and said surface of the target member is provided with means for increasing the area thereof, said means comprising at least one layer of wires arranged in side-by-side relation, each individual wire extending substantially radially with respect to said axis.

**2.** A target as set forth in claim **1** wherein said wires comprise parts of turns of a wire winding wound around the annulus.

**3.** A target as set forth in claim **2** wherein said target member and an adjacent abutting surface of the backing member are provided with interfitting means for tightening said wire winding.

**4.** A target as set forth in claim **3** wherein said interfitting means comprises an annular ridge in the adjacent abutting surface of the backing member and a comating annular groove in the target member, and further comprises means for mechanically clamping said members together to force the ridge into the groove and thereby tightening the wire therebetween.

**5.** An X-ray tube comprising a hermetically sealed envelope, a cathode electrode and an anode electrode located in spaced relation within the envelope, and means for connecting said electrodes to external sources of electrical energy, said anode comprising an axial support, and an X-ray generating target assembly mounted on the support, for rotation about the axis of the support said target assembly comprising a first member composed primarily of high thermal capacity material sandwiched between second and third members of high thermal capacity material, a focal track area of said first member being exposed, and means for mechanically retaining said members in intimate physical heat conductive relation, said focal track area comprising parallel corrugations, said corrugations comprising surfaces of wires disposed on said area in substantially side-by-side relation, each individual wire extending substantially radially of said axis.

**6.** An X-ray tube as set forth in claim **5** wherein said first member is covered by a wire winding and said corrugations comprise a surface of said winding.

**7.** An X-ray tube as set forth in claim **6** wherein said first member is an annulus extending about a geometric axis, and the turns of said winding extend substantially radially with respect to said center.

**8.** An X-ray tube as set forth in claim **7** wherein abutting surfaces of said first member and one of said other members are provided with interfitting means which engages and stretches said winding therebetween.

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