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Holland

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[45] **Mar. 5, 1974**

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

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[22] Filed: **Feb. 28, 1972**

[21] Appl. No.: **230,053**

Related U.S. Application Data

[63] Continuation of Ser. No. 42,375, June 1, 1970, abandoned.

[52] **U.S. Cl.** **313/60,** 313/55, 313/330

[51] **Int. Cl.** **H01j 35/10**

[58] **Field of Search** 313/55, 60, 330

[56] **References Cited**

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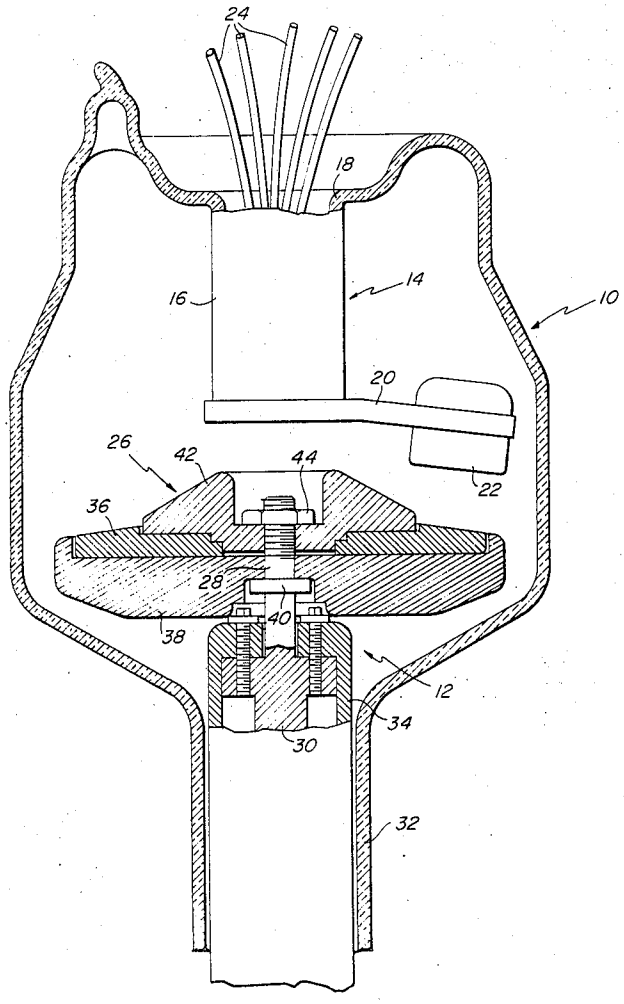
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Assistant Examiner—Darwin R. Hostetter
Attorney, Agent, or Firm—Harold A. Murphy; Joseph D. Pannone; John T. Meaney

[57] **ABSTRACT**

A target for x-ray tubes, which is comprised of separate elements mechanically connected together whereby the element which includes the x-ray generating focal area is of a selected material mechanically attached to at least one element of a second material by means which efficiently permits ready transfer of heat from the first element to the second while permitting free thermal expansion of the elements relative to one another.

8 Claims, 9 Drawing Figures



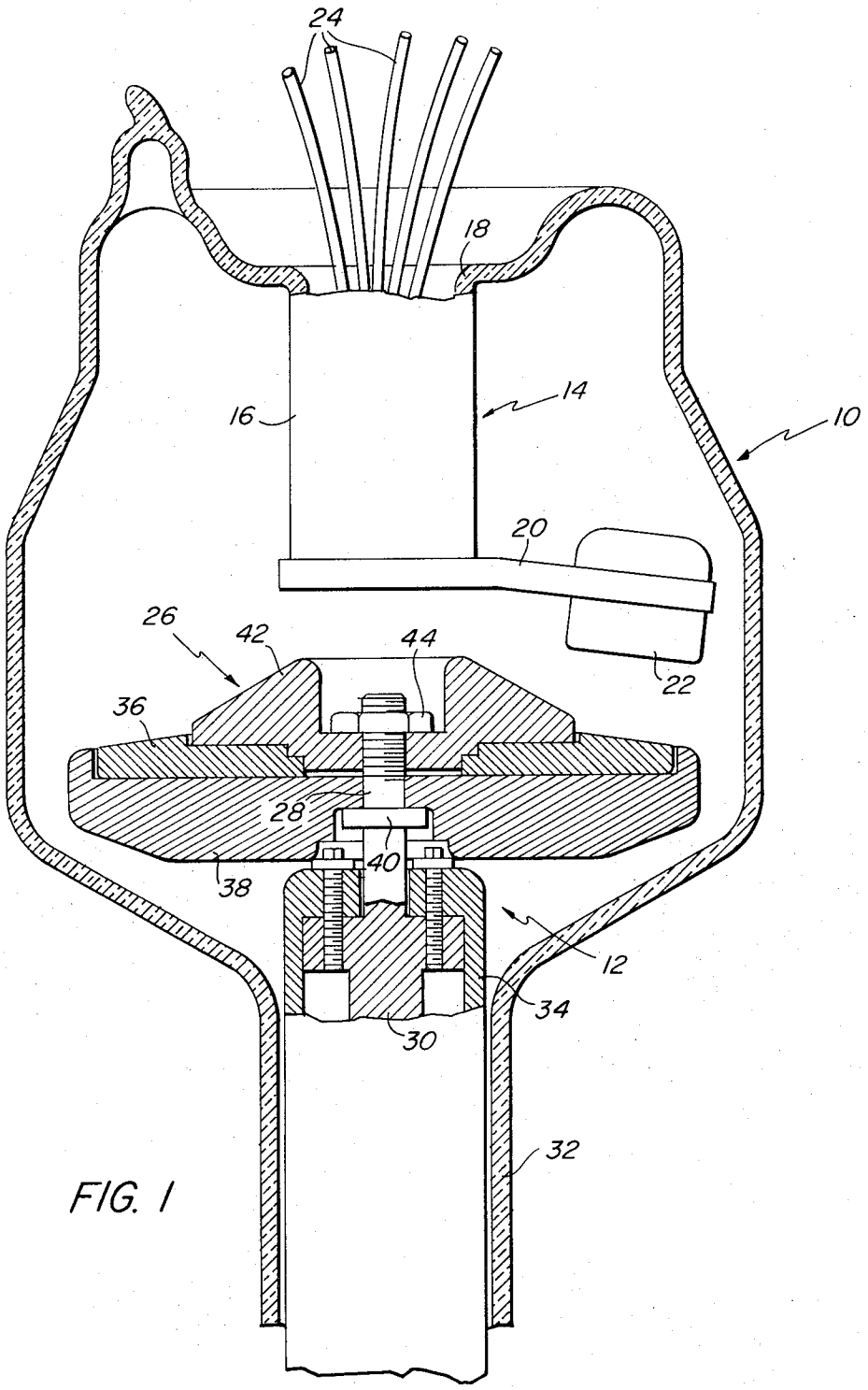


FIG. 1

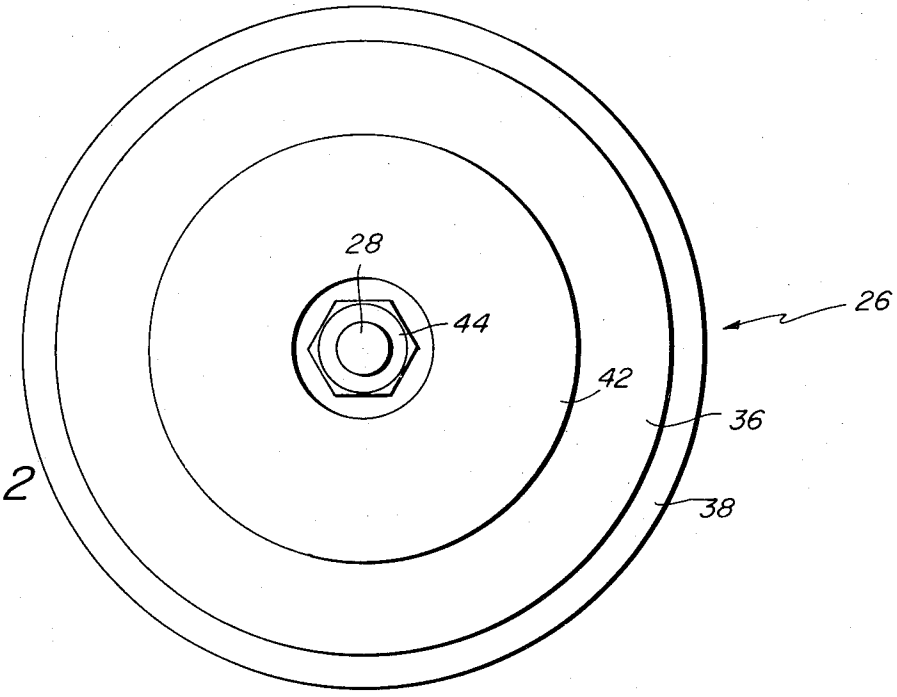


FIG. 2

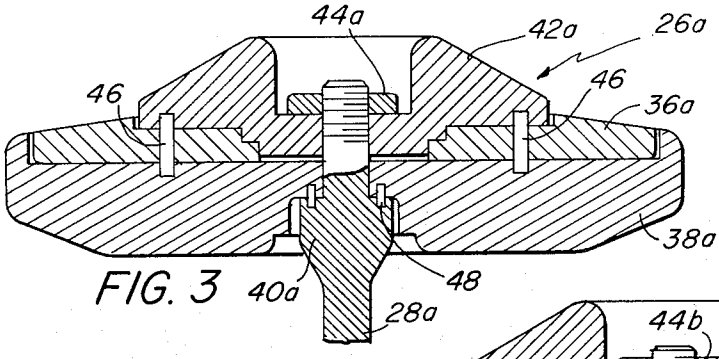


FIG. 3

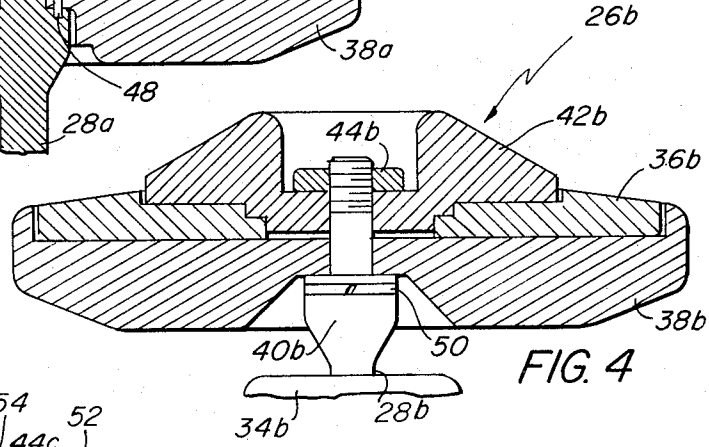


FIG. 4

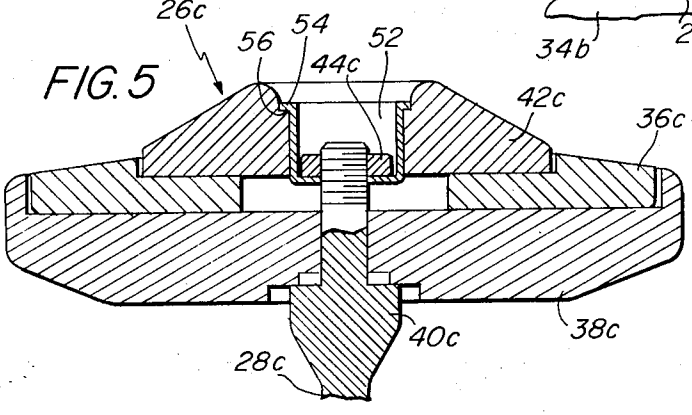


FIG. 5

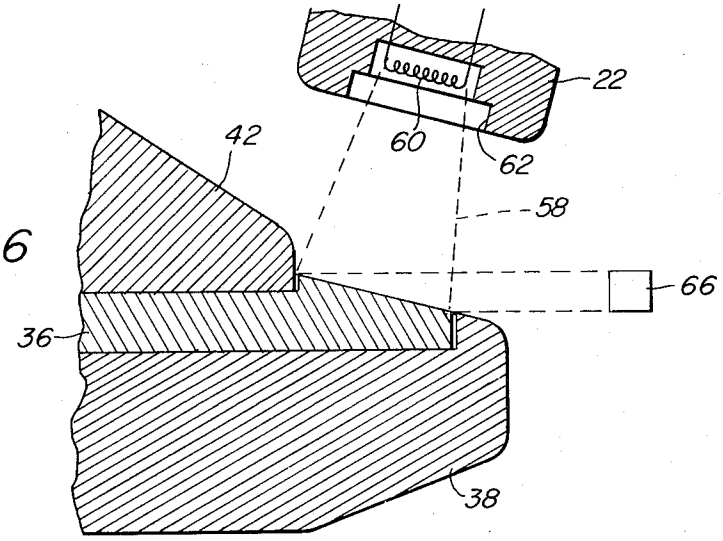


FIG. 6

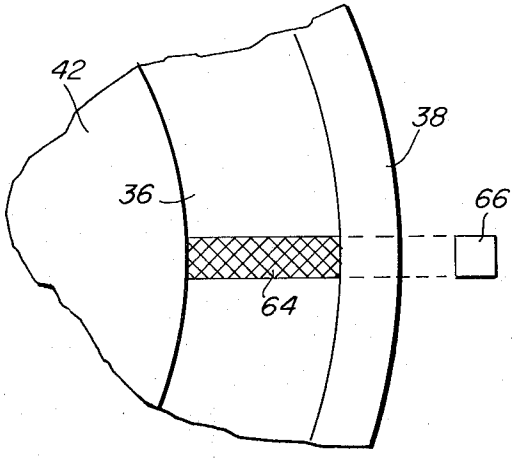


FIG. 7

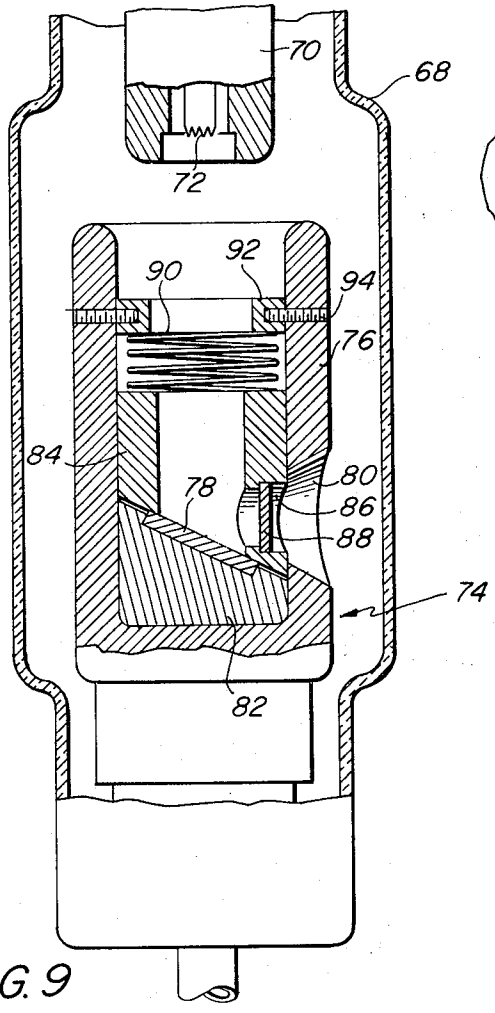


FIG. 9

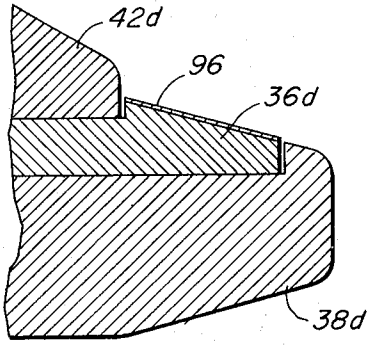


FIG. 8

TARGET FOR X-RAY TUBES

This application is a continuation of Ser. No. 42,375 filed June 1, 1970, now abandoned.

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 track 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 radial 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 termal capacity, such as molybdenum or graphite, for example. On this base material is deposted 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 includes a first element of high atomic number mechanically connected in intimate relation to a base element, wherein the first element comprises the focal area which is to be impacted by electrons during subsequent operation of the device, and the base element comprises a suitable material which will rigidly retain the first element in its prelocated position but will also act as an efficient heat sink to carry heat away from the first element and to radiate such thermal energy away from the target.

The first element, in accordance with this invention may be any suitable refractory metal, such as tungsten or tungsten-rhenium alloy, for example, which has a high enough melting point and which generates x-rays in copious supply when bombarded by electrons in the known manner. The base element may be any suitable material which will support the first element and act as a heat sink to carry the heat away from the first element and dissipate it through radiation. The base element, preferably, should be a relatively low density material such as molybdenum, titanium or graphite, for example, which will meet vacuum tube processing requirements.

In further accordance with this invention, a rotating anode may be made which comprises a ring of the selected material for the electron impinging area or focal track, and inner and outer rings or discs of the base material which mechanically sandwich the focal area member between them. The materials of the focal area member and the base material do not need to possess similar expansion coefficients since one may expand and contract relative to the other without destroying the efficient heat transfer relationship achieved by mechanically joining the parts together. It has been found that heat flow across the interface between the focal track area and the backing is surprisingly efficient with a mechanical interconnection, while a metallurgical bond is unsatisfactory, as pointed out above.

In one form of the invention, a focal area member of tungsten or tungsten-rhenium alloy is mounted in intimate physical engagement upon a backing of graphite and held thereupon by bolts. In another form, the focal area member rests in a cavity in the face of the backing and is firmly held in place by spring means. In a preferred form of rotating anode, the focal area member comprises a ring of the selected material which is sandwiched between two discs or rings of the selected base material, and is held therein through pressure exerted by the threaded clamping means which serves to attach the anode in place on a central rotatable shaft.

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 a target having means for preventing relative rotary motion between the target members;

FIG. 4 is an axial sectional view of a target illustrating an alternative means of applying pressure to the parts;

FIG. 5 is an axial sectional view of a target illustrating a further means for physically connecting together the parts of the target;

FIG. 6 is an enlarged fragmentary sectional view of a target illustrating flow of electrons to it from an adjacent cathode;

FIG. 7 is an enlarged elevational view of the target shown in FIG. 5 illustrating a focal spot area thereon;

FIG. 8 is an enlarged fragmentary sectional view of a slightly modified target embodying the invention; and

FIG. 9 is a side elevational view partly in axial section of an x-ray tube with a stationary target embodying the 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-emitted filament (see FIG. **6**) 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** and 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.

The focal target of conventional x-ray tubes usually comprises the entire target **26** or is a metallurgically deposited coating upon a suitable backing of high thermal capacity material. For example, the entire target **26** may be made of tungsten, or a target backing of tungsten, graphite, molybdenum or the like may carry on its surface a focal target of a deposited or metallurgically bonded material such as tungsten or tungsten-rhenium alloy.

It has been found that solid targets of tungsten do not have satisfactory thermal characteristics and, when bombarded by high density electrons, become damaged by the resulting severe mechanical stresses. It has also been found that a coating of target material upon the surface of a backing will not prove satisfactory since the metallurgical bond between the target and backing will not withstand the stresses resulting from the thermal shock of the impinging electron beam. Furthermore, it is difficult to obtain a thermal expansion match with suitable backing materials over a full operating temperature range which may extend from room temperature to approximately 3,000°C. Also, even if a satisfactory metallurgical bond could be achieved, when graphite is used as the backing the weak bond between atom layers will not withstand the mechanical stresses involved.

In accordance with this invention, the focal target member **36** is made as a completely separate element or part which is physically located upon a separate and independent backing **38** which comprises in itself a selected suitable high thermal capacity, high thermal emissivity material. While the two elements **36** and **38** are entirely separate, it is essential that they be maintained in physical contact throughout an extended area so that heat may be efficiently conducted from the focal target **36** into the backing **38.**

As applied to a rotating anode tube as shown in FIG. **1,** the focal target member comprises a ring **36** having its lower surface positioned upon a surface of a backing disc **38,** which surface is shaped to mate with the adjacent surface of the target ring. The upper surface of the backing disc or ring **38** is recessed to receive the target disc **36** as shown. However, as will be noted, the outer periphery of the recess is of a slightly larger diameter than the outer periphery of the target disc **36** so that disc **36** may thermally expand without damaging the backing disc which has a lower coefficient of expansion. Likewise the upper surface of the target disc **36** is recessed except in the actual focal track area which is to be exposed to the cathode. In this way a second backing ring or dome **42** can be nested within the recess, with clearance being provided between the outer peripheral edge of the dome and the outer side wall of the recess in the disc **36** so as to permit expansion of the disc **36** without damage to the dome. With a nested structure of this type the target disc **36** engages the adjacent surfaces of the backing disc **38** and dome **42** throughout relatively expansive surface areas to achieve efficient conduction of heat from disc or ring **36** to the disc **38** and the dome **42** 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 an enlarged portion or collar **40,** and backing ring **38** is mounted over the end of shaft and seated upon the collar. The lower surface of the backing ring may be suitably recessed as illustrated to receive the collar. 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 **42** is then mounted on the shaft **28** and slid down into intimate physical contact with the opposite adjacent surface of ring **36,** and the complete assembly is compactly and firmly pressed into an assembled unit by means such as a nut **44** which is threaded onto the end of the shaft into engagement with the second backing ring or dome **42,** preferably within a recess provided therefor, as illustrated.

The focal track ring or target ring **36** is thus firmly sandwiched between the two backing rings so that heat is efficiently transmitted from the ring **36** into the relatively massive bulks of the two backing rings.

Although the second backing ring or dome **42** is shown and described, there may be certain instances where this ring need not be provided, in which case the nut **44** is made to directly engage and exert pressure upon the target ring **36.** Other desirable reasons for utilizing the second backing ring will be set forth, however, in a later part of this description.

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 of the target ring **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 was found that with a target assembly strucutred as described, under normal operating conditions the heat dissipation characteristics are greatly improved, with maximum temperatures of the three rings **36, 38** and **42** all being within about 750°C to 1,040°C during the tests performed, while with conventional target discs as presently made the temperature will approach about 1,500°C. No damage to the target results at the achieved lower temperatures because of the improved heat storage capacity and heat dissipation of the sandwich structure described. Because of the high emissivity and increased overall surface area the target assembly cools much more rapidly than known prior art targets, and these thermal improvements reduce the amount of heat flow to adjacent rotor bearings, thus also improving rotational performance and extending the life of the tube.

Referring now to FIG. **3**, there is shown a rotating anode target assembly **26***a* which is similar to the target assembly shown in FIG. **1.** However, in FIG. **3** the target ring **36***a* is sandwiched between backing rings **38***a* and **42***a* and are interconnected thereto by pins **46** as shown so that slippage between the respective rings is prevented. Furthermore, pins **46** can be adjusted by control of weight, size, location, etc. so as to provide means for dynamically balancing the target assembly. It will be noted that collar **40***a* is also similarly interconnected to backing ring **38***a* by pins **48.** This will insure that the target assembly **26***a* will rotate with rotor shaft **28***a* without slippage.

It has been found that a strong spring pressure will suitably retain the rings in assembled and intimate physical relation. One example of such a spring arrangement is shown in FIG. **4** wherein the target assembly **26***b* includes backing rings **42***b* and **38***b* between which is sandwiched a target ring **36***b*. The rotor shaft **28***b* is provided with the aforementioned nut **44***b* which engages the second backing ring or dome **42***b*. However, instead of the previously described collar **40,** this embodiment is provided with a spring device **50** of suitable shape which extends between backing ring **38***b* and the adjacent end of the rotor skirt **34***b*. Thus, the spring device constantly urges the three rings of the assembly into firm physical abutting relation so that efficient heat conduction is provided from target ring **36***b* into the backing rings.

In FIG. **5** there is shown a still further modification of a rotating anode target assembly **26***c* embodying the invention. In this embodiment, the free end of the rotor shaft **28***c* is threaded to receive thereon a cup-shaped retainer **52** having an outwardly extending peripheral flange portion **54** which overlies and firmly engages a ledge or shelf **56** provided therefor on the inner wall of the recess in backing ring or dome **42***c*. In this embodiment the collar **40***c* engages the backing disc **38***c* while the flange **54** engages the dome **42***c*. A nut **44***c* threaded onto shaft **28***c* then is moved into engagement with the base or bottom of the cup **52** as shown. Tightening of nut **44***c* will urge the three rings or discs of the target assembly into firm physical engagement with one another and cooperates with the flange **54** in retaining the assembled parts in such relationship.

In addition to the improved efficient heat transfer characteristics of this invention, an additional feature of importance is achieved by this invention. Referring to FIGS. **6** and **7,** it will be seen that control of the size of the focal spot in one direction may be achieved by strict control of the width of the surface of the focal track which is exposed to the cathode. The focal track of target ring **36** is exposed throughout an annular surface area as shown and described, and it is upon this area that electrons in the form of a beam as indicated at **58** in FIG. **6** are directed from a filament **60** in cathode head **22.** The cavity **62** within which the filament **60** resides is designed to perform some control of the size of the focal spot on the focal track which is impinged by the electron beam **58.** However, such requires critical control and adjustment of the configuration of the recess **62** and the potentials applied to the filament **60** and to the head **22.** In accordance with this invention, the width of the exposed focal track **36** is of a size which is intended to be the size desired of the focal spot length. Such a focal spot is indicated by the shaded area **64** in FIG. **7.**

It is well known in the x-ray tube industry that it is desirable in most cases to provide a source of x-rays which emanates from a focal spot as small as possible. A conventional rotating target with its large surface area of relatively high atomic number is exposed to scattered secondary and primary high field emission electrons causing extrafocal radiation. This unwanted off focus radiation contributes to added patient dosage and degradation of radiographic image quality. Electron impingement, either primary or scattered, onto the low density elements **38** or **42** produce low energy x-rays which are absorbed in the envelope **10.** This off focus radiation is virtually eliminated except for that which occurs adjacent to the focal spot **64** on the target ring **36.** This low energy radiation, however, is absorbed in the glass envelope of the tube and in other filtering material which may be placed in the x-ray beam. As shown in FIGS. **6** and **7,** a focal spot as viewed from the side of the tube desirably will appear as a substantially square spot as indicated by numeral **66.**

A definite x-ray focal spot length, therefore, can be established by the appropriate selection of the width dimension of the exposed focal track as shown in FIGS. **6** and **7.** This feature precisely controls the focal spot length dimension even at high tube current levels where the electron beam tends to enlarge.

While the foregoing description has dealt with a composite target wherein the middle element of the sandwich is primarily of x-ray generating material, it is also possible to make the middle element, such as disc **36** in FIG. **1,** of high thermal capacity material such as molybdenum or a mixture of about 95 percent molybdenum and about 5 percent tungsten, for example. In this case the focal track area will be comprised of a relatively thin layer of efficient x-ray generating material such as a mixture of about 90 percent tungsten and about 10 percent rhenium, for example. This is illustrated in FIG. **8** wherein disc **36***d* is sandwiched between discs **38***d* and **42***d*, and the exposed focal track area is provided with a thin layer or coating **96** of the selected x-ray generating material which may be deposited by evaporation, flame spraying or other selected method.

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. 8. The stationary anode tube shown in FIG. 8 includes an envelope 68 within one end portion of which is a cathode head 70 housing an electron emitting filament 72 which is intended to direct a beam of electrons toward an anode 74. Anode 74 is a body of copper, usually, which is provided with a hollow cylindrical extension portion 76 having an open end directed toward the cathode. An x-ray emitting target button 78 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 80 and then through the wall of the envelope 68.

In accordance with the present invention, a block or body of graphite or other selected backing material 82 is deposited in the bottom or the hollow anode extension and is provided with an inclined surface having a recess therein in which the target button 78 is positioned. A sleeve or shell 84 of graphite or other selected high thermal capacity material is then positioned in the extension with one end thereof engaging the target button 78. Sleeve 84 is provided with an opening 86 which may contain a window 88 of beryllium or other material highly transmissive to x-radiation which is suitably aligned with opening 80 in extension 76 whereby x-rays emanating from the target button 78 will pass outwardly through the window 88 and opening 80.

It is, of course, necessary that there be efficient conduction of heat from the target button 78 into the adjacent graphite bodies 82 and 84. Therefore, means is provided for continually urging the sleeve 84 against the target button 78 and to thereby maintain efficient heat conductive relationship of the button 78 with backing 82. Such means is illustrated in exemplary form as a spring 90 which at one end engages the outer end of the shell 84 and at its other end engages the inner side of a retaining ring or collar 92 which is attached to the inner circumference of the anode extension 78 as by set screws 94 or the like.

Thus, there is described one type of stationary anode tube which has most, if not all, of the advantages of the rotating anode structure described hereinbefore. Other stationary anode tubes may be provided with this invention, however, such as the type which embodies a metal housing without the glass envelope, as is well known.

In any of the aforementioned embodiments of the invention thermal expansion between the target member and the high thermal conductivity backing elements is permitted. This, then, opens up the possiblity of a large number of materials which may be used to serve the desired functions. Low density elements can serve the function of the target backings while selected different materials may be used for the x-ray producing elements of the structures.

From the foregoing description it will be apparent that all of the objects and advantages of this invention have been achieved by the various structures shown and described. It will be apparent, however, that various modifications may be made by those skilled in the art without departing from the spirit of the invention as expressed in the accompanying claims. Therefore, all matter shown and described should be interpreted as illustrative and not in a limiting sense.

I claim:

1. An anode for X-ray tubes having a cathode which operates to produce an electron beam of known cross-sectional dimensions, said anode including a target assembly comprising a target member of material having a known thermal storage capacity per unit weight and capable of X-ray emission when impinged by said electron beam, a pair of supporting members one on each side of the target member, and means for engaging said supporting members to sandwich the target member therebetween, said supporting members overlying the target member in a manner whereby only a selected surface area of the target member is exposed and both having substantially higher thermal storage capacity per unit weight than the material of said target member, said surface area being of a size in one direction which corresponds to one cross-sectional dimension of said electron beam impinging thereon, and said supporting members comprising means for preventing substantial production of off-focus radiation.

2. An anode for X-ray tubes as set forth in claim 1 wherein said supporting members are disclike in shape, said target member is annular in shape, and said focal area is an annular surface portion of the target member.

3. 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 cathode electrode comprising means for producing an electron beam of known cross-sectional dimensions, said anode electrode including a target assembly comprising a target member of material having a known thermal storage capacity per unit weight and capable of emission of X-rays and secondary electrons when impinged by said electron beam, a pair of supporting members one on each side of the target member, and means for engaging said supporting members to sandwich the target member therebetween, said supporting members overlying the target member in a manner whereby only a selected surface area of the target member is exposed and both having substantially higher thermal storage capacity per unit weight than the material of said target member, said supporting members further being of a material incapable of substantial production of X-rays when impinged by secondary electrons from said target, said exposed surface area being of a size in one direction which corresponds to one cross-sectional dimension of said electron beam impinging thereon.

4. An X-ray tube as set forth in claim 3 wherein said supporting members are disclike in shape, said target member is annular in shape, and said focal area is an annular surface portion of the target member.

5. A rotating anode 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 cathode electrode comprising means for producing an electron beam of known cross-sectional dimensions, said anode electrode comprising a rotatable shaft and a target assembly mounted on the shaft for rotation therewith, said target assembly comprising a target member of material having a known thermal storage capacity per unit weight and capable of emission of X-rays and secondary electrons when impinged by said electron beam, a pair of supporting members one on each side of the target member, both of which members have a thermal storage capacity per unit weight which is sub-

stantially higher than the target member, and means for engaging said supporting members to sandwich the target member therebetween, said supporting members overlying the target member in a manner whereby only a selected surface area of the target member is exposed and having substantially higher thermal storage capacity per unit weight than the material of said target member, said supporting members further being of a material incapable of substantial production of X-rays when impinged by secondary electrons from said target, said surface area being of a size in one direction which corresponds to one cross-sectional dimension of said electron beam impinging thereon.

6. A target assembly for X-ray tube anodes comprising a target member and a pair of supporting members located one on each side of the target member, said supporting members overlying the target member except for an elongated focal track thereon, said focal track being of a size in the lateral direction which corresponds to one dimension of a desired X-ray generating focal spot to be produced thereon, and said supporting members being of material incapable of production of substantial amounts of X-radiation when impinged by secondary electrons from said focal track.

7. 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 a support, and an X-ray generating target assembly mounted on the support, said target assembly comprising a target member having a focal track on the side thereof facing the cathode electrode of a material capable of emission of X-rays and secondary electrons when impinged by electrons from said cathode electrode, and a pair of supporting members one on each side of the target member, said supporting members overlying the surface of the target member facing said cathode electrode with only said focal track being exposed, said exposed focal track being of a size in the lateral direction which corresponds to one dimension of a desired X-ray generating focal spot to be produced thereon, and said supporting members being of a material incapable of substantial production of X-radiation when impinged by secondary electrons from said focal track.

8. An X-ray tube as set forth in claim **7** wherein said supporting members are disc-like in shape, said target member is annular in shape, and said focal track is an annular surface portion of the target member.

* * * * *