United States Patent [19]

Braun

[11] **3,753,021**

[45] **Aug. 14, 1973**

[54] **X-RAY TUBE ANODE TARGET**

[75] Inventor: **Martin Braun,** Stamford, Conn.

[73] Assignee: **The Machlett Laboratories, Incorporated,** Springdale, Conn.

[22] Filed: **Apr. 3, 1972**

[21] Appl. No.: **240,713**

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

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

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

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

1,219,042 1/1971 Great Britain 313/60

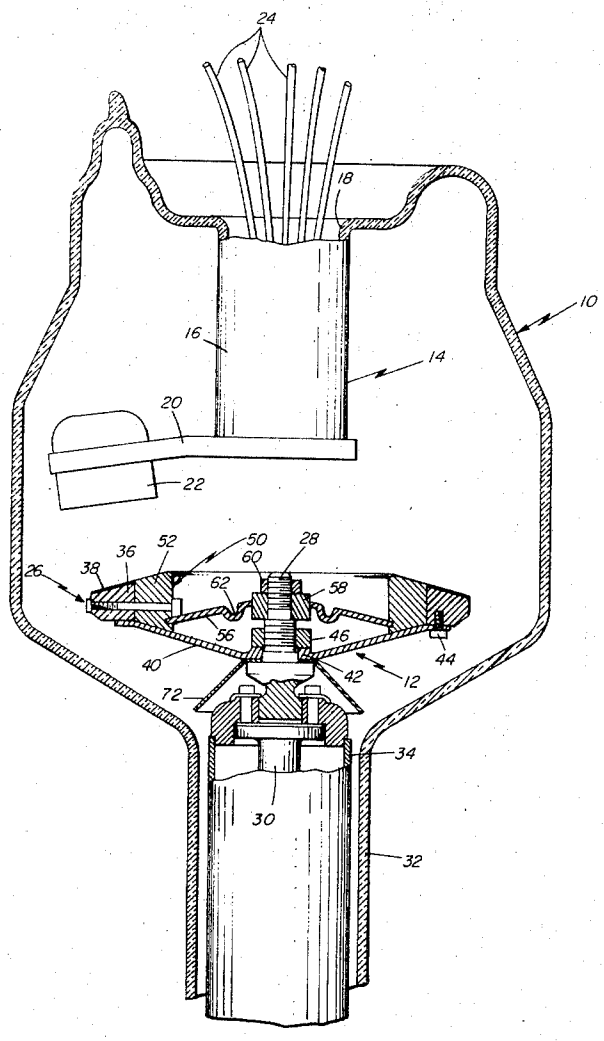
1,099,095 2/1961 Germany 313/60

Primary Examiner—Roy Lake
Assistant Examiner—Darwin R. Hostetter
Attorney—Harold A. Murphy et al.

[57] **ABSTRACT**

An X-ray tube having a rotating anode comprising a target which is provided with improved heat dissipation characteristics by means of an X-ray generating member and an associated heat sink of high thermal storage capacity material which during operation of the tube more closely engages the X-ray generating member for providing efficient thermal conductivity therebetween.

7 Claims, 4 Drawing Figures



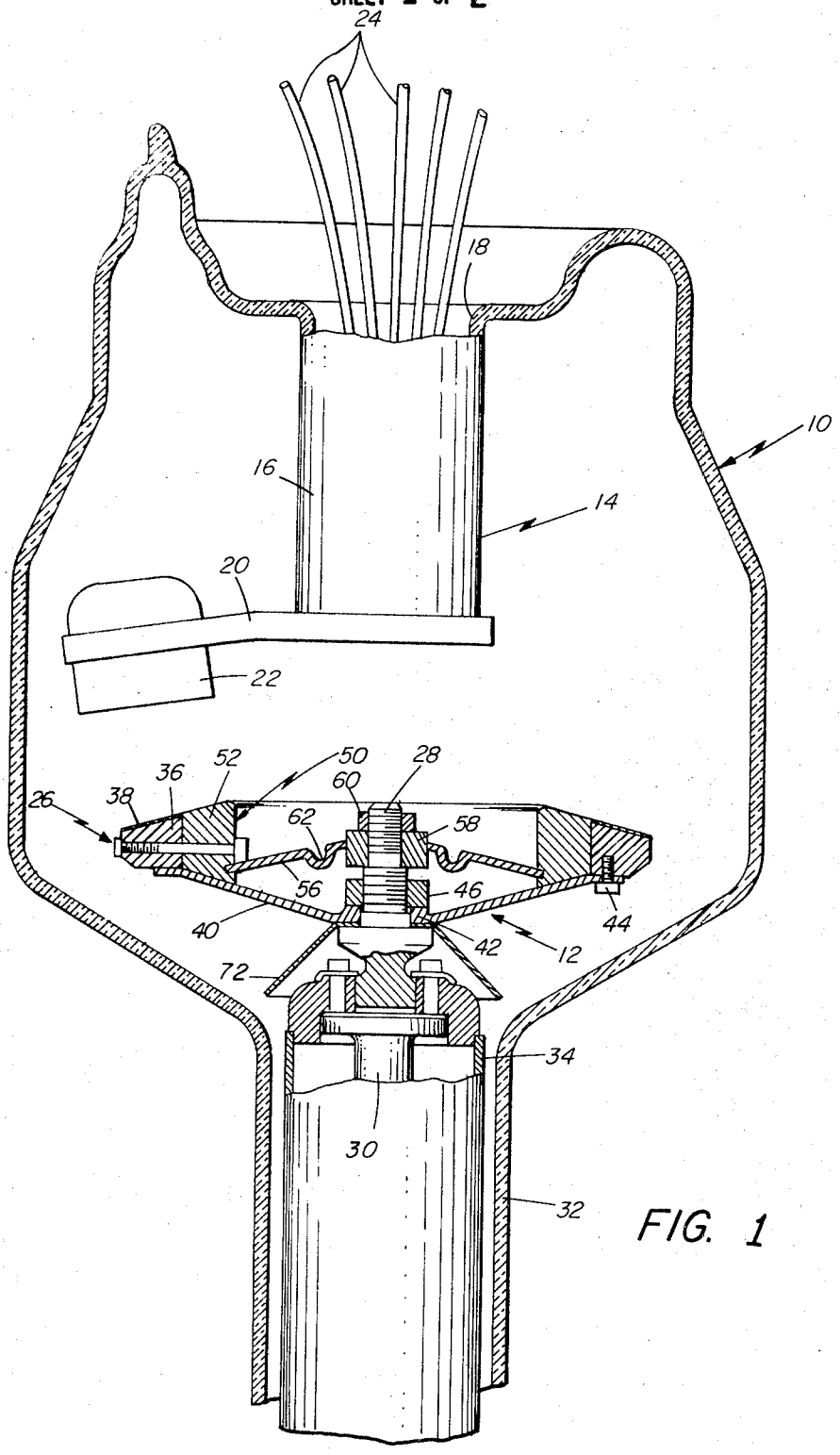

24
18
10
16
14
20
22
26
38
36
52
50
28
60
62
58
56
46
40
44
42
12
72
34
30
32

FIG. 1

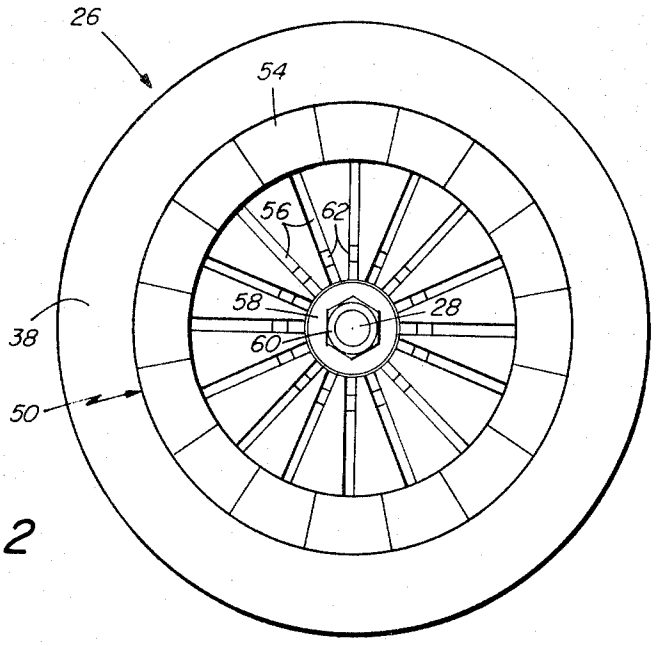


FIG. 2

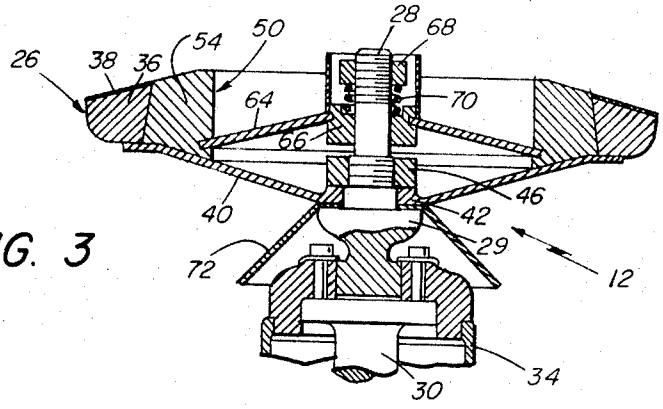


FIG. 3

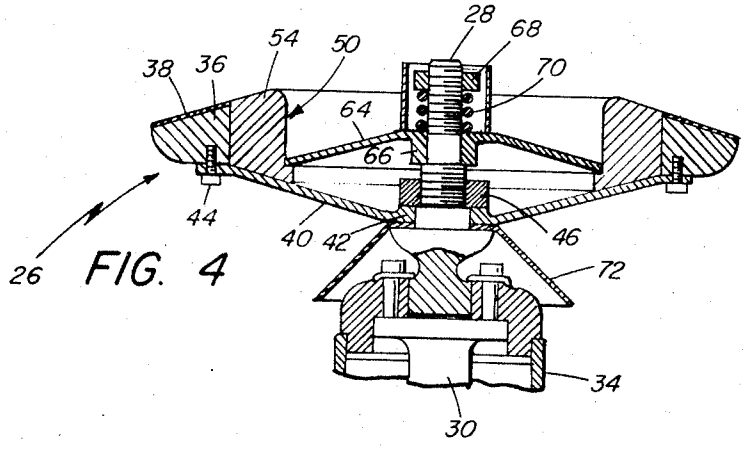


FIG. 4

X-RAY TUBE ANODE TARGET

BACKGROUND OF THE INVENTION

In the X-ray field new techniques have become commonplace which require that an X-ray generator or tube be operated at higher power levels. It has been found that where once it was merely necessary to rotate an X-ray generating target to constantly present cooler areas to an impinging electron beam, it is now necessary to provide more exotic means for dissipating heat from the target.

Heat dissipation has been improved in some cases by increasing the rotational speed of the anode, and by judicious choice of material from which the target is made. For example, molybdenum has often been used as a replacement for the commonly used tungsten since it was found to provide bettr thermal storage capacity. However, in order to obtain the desired efficient X-ray generation it became necessary to coat the focal track with a thin layer of tungsten or tungsten-rhenium alloy. This presented problems due to deformation or separation of the coating from the target body.

A later greater improvement in target structures is disclosed in pending U. S. patent application Ser. No. 42,375, filed June 1, 1970, now abandoned, and owned by the assignee of the present invention, wherein a multi-piece target is described which comprises an annular focal track ring of refractory material which is sandwiched between discs or members of higher thermal storage capacity than the ring. In this structure heat built up in the ring is quickly transferred to the discs which have the capacity for storing this heat without damage for extended periods of time during a series of exposure cycles. During and after the exposure cycles the heat is dissipated by radiation. This has enabled the X-ray tube containing the target to be operated for lengthier periods of time and at higher power levels then theretofore.

With such a target structure the heat transfer from ring to discs is intended to be by conductivity. However, at high power levels with generation of extremely high temperatures non-symmetrical heat input and differences in expansion coefficient sometimes cause deformation of the geometry of the parts. For example, the ring sometimes becomes slightly warped and this tends to produce small gaps between the parts and, therefore, to introduce some deterioration in the transfer of heat by conduction between the parts. While transfer of heat by radiation through these gaps then takes place, overall heat transfer may be reduced. In fact, in some cases where spacing between the parts exist the disc material instead of functioning as a heat sink functions more as a heat shield. Therefore, it is essential that the ring and discs be maintained in good heat conductive relation.

Probably the best way a contact between the two materials can be made is by brazing. However, because of high temperature stresses the brazed joint easily breaks apart. If mechanical fastening is used, the contacting surfaces very often won't stay in contact for the reasons pointed out above in the discussion of the invention described in the aforementioned application.

SUMMARY OF THE INVENTION

The foregoing and other disadvantages sometimes found in anodes of X-ray tubes operated at high power levels are overcome by the present invention wherein

the anode comprises a target ring of refractory material having heat sink material located on its inner periphery and retained there in such a manner that during operation of the tube the heat sink material will tend to more closely engage the target ring either through the influence of centrifugal force or by thermal expansion. This will enable the heat generated in the target ring to be efficiently conducted into the heat sink which has the capability of storing the heat in large quantities without damage for relatively lengthy exposure cycles. During and after the exposure cycles, the heat is removed from the sink by radiative dissipation.

The target ring is preferably a solid unbroken annulus of molybdenum or the like having an X-ray generating surface disposed to be revolved into and out of the path of an electron beam as the target ring rotates about its axis. The ring may be supported by suitable means such as a disc or cone mounted on the anode arbor or shaft. Within the ring is an annular arrangement of heat sink members of graphite, beryllia or the like which are disposed upon or closely adjacent the inner periphery of the ring. Each member is attached to the outer end of radially extending segments or arms formed in a supporting structure or web which also is mounted on the shaft for rotation therewith. The segments or arms are flexible so that when the shaft is rotated to rotate the target ring, centrifugal force acting upon the heat sink members will urge them outwardly and tend to insure close physical engagement of the members with the ring. Thus, heat will be efficiently transferred by conduction from the ring to the heat sink members.

In another embodiment of this invention, the heat sink may comprise in itself a ring of heat sink material which has a higher thermal coefficient than the material of the target. An example of a suitable heat sink material for this purpose is beryllia which may be matched with target material of tungsten or molybdenum. When making a structure of this sort it is important that the heat sink ring be initially in reasonably good contact with the target ring so that sufficient heat will enter it to cause it to expand into efficient heat conductive relation with the target ring.

In either case, the conductivity of heat from the target ring into the heat sink is intended to efficiently relieve the target ring of accumulations of heat as will cause it to deform.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features of this invention will become apparent from the following description taken in connection with the accompanying drawings, wherein:

FIG. 1 is an elevational view partly in axial section illustrating an anode embodying one preferred form of this invention;

FIG. 2 is a plan view of the anode shown in FIG. 1;

FIG. 3 is an enlarged axial sectional view illustrating primarily a modification in the heat sink supporting structure; and

FIG. 4 is a view similar to FIG. 3 illustrating a different embodiment of 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-emitting filament 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 or molybdenum 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 or molybdenum 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 such a solid backing will not prove satisfactory when a tube is operated at high power levels 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 of the coating with suitable backing materials over a full operating temperature range which may extend from room temperature to approximately 3,000°C.

In accordance with this invention the focal target member **26** is made as a completely separate element which is in the form of a ring of material such as molybdenum which has a coating **38** of rhenium or rhenium-tungsten alloy on its surface facing the cathode **22.** A concave disc or cone **40** of metal such as molybdenum is provided with a central aperture and hub **42** by which it is mounted on shaft **28** and the target ring **36** is fixed to the out edge of the cone **40** as by short bolts **44** or the like. Th hub **42** of cone **40** rests upon an enlarged portion **29** of the shaft **28** and is held there by means such as a nut **46.**

The target ring **36** is preferably relatively thick in the direction of the tube's axis to assist in avoiding warpage under thermal stress. The focal track coating **38** need be of a width corresponding to or only slightly larger than the length of the focal spot formed by impingement of the electron beam from the cathode **22,** as taught in the aforementioned U. S. patent application. The thickness of the ring **36** in a radial direction with respect to the tube's axis is preferably kept to a minimum so as to reduce weight. The cone **40** is preferably made relatively thin such as 1/16 inch, for example, since its only function is to support the ring **36.** Cone **40** is preferably slotted radially so as to allow the cone to adapt to dimensional changes of the focal track members caused by heat expansion, and to aid in preventing any substantial amounts of heat from passing from the target ring into the shaft **28** and associated bearing structure of the tube.

The target ring **36** is of a material having a known relatively low thermal coefficient of expansion and having a known thermal storage capacity per unit weight. This ring will, as pointed out above, accumulate large amounts of heat when bombarded by electrons from the cathode **22.**

In order to efficiently remove this heat rapidly from the target ring **36** there is provided a heat sink **50** in the form of a ring **52** of a selected material which has a thermal storage capacity per unit weight which is much higher than that of the target ring **36.** Heat sink ring **52** is disposed in close physical relation to the inner side of the target ring as shown clearly in FIG. **1** so that heat will be transferred by conduction into the heat sink material from the target ring.

In accordance with one embodiment of the invention centrifugal force is utilized to insure firm physical engagement of the heat sink ring **52** with the target ring **36.** This may be achieved in several ways, one particularly efficient way being shown in FIGS. **1** and **2** wherein the target ring **52** is formed as an annularly arranged series of separate members **54** each of which is fixed to the outer end of a respective spike **56,** the spokes **56** having their inner ends secured to a collar **58** which is mounted on shaft **28** and held against a ledge formed thereon by means of a nut **60.** The spokes **56** are formed of resilient material such as tungsten, for example, and may be provided with one or more convolutions **62** therein to enhance the flexibility thereof. It will be apparent that when the shaft **28** is rotated at high speed, the collar **58,** spoke **56** and heat sing members **54** will all rotate therewith and the members **54** will be urged by centrifugal force outwardly from the center of the structure into intimate and firm engagement with the target ring **36.** Thus, during operation of the tube the heat sink members **54** will tend to increase their physical contact with the target ring and thus efficient conductivity of heat from the target ring to the heat sink members will be achieved.

In a modification of this embodiment of the invention, FIG. **3** illustrates the utilization of an inverted cone **64** which carries the individual heat sing members **54** on its outer periphery. The cone is provided with a central aperture which fits around a hub **66** which is slidably mounted on the shaft **28.** A nut **68** is threaded onto the outer end portion of the shaft **28** and a coiled tension spring **70** is mounted over the shaft between the nut and the hub. The cone **64** is of thin flexible material and is adapted to exert pressure upon the heat sink members **54** upon urging of the spring against hub **66** when nut **68** is tightened. As the shaft **28** is rotated,

centrifugal force will cause the heat sink members **54** to move outwardly into firm physical contact with the target ring **36**, causing a slight flattening of the cone **64** and lengthening of spring **70**. Upon cessation of rotary movement of the shaft, the centrifugal force will be removed from the heat sink members **54**, whereupon they will tend to relax their physical contact with the target ring **36**. The cone **64** will tend to return to its initial shape against the tension of spring **70**. However, spring **70** will constantly exert sufficient pressure upon the cone **64** so that a desired initial and continued physical contact will be maintained between the members **54** and target ring **36**.

It will be apparent that heat from the target ring **36** and heat sink members **54** will tend to be restricted from its conductive passage into the shaft **28** and beairng structure of the device of the disc or cone **40**, as has been described. To prevent heat in these elements from being transferred by radiation into the rotor structure there is provided an inverted metal cone shield **72** which is fixed to the shaft between hub **42** and the adjacent enlarged shaft portion **29**, the shield extending downwardly over the adjacent portions of the rotor structure.

Further in the embodiment of FIG. **1**, it will be noted that the heat sink members **54** may be attached to the target member **36** by means of a bolt **74**. In this case, the heat sink member must be constructed with the opening therein slightly larger than the diameter of the bolt so that it will be enabled to efficiently move longitudinally on the bolt under centrifugal forces in order to increase the force of its physical engagement with the target ring **36**.

The second embodiment of this invention is illustrated in FIG. **4** wherein the heat sink ring **54** is a solid unbroken annulus mounted on the outer periphery of cone **64** which is supported on shaft **28** by the mechanism described in connection with FIG. **3**. In this embodiment, the heat sink member **54** is of a material such as beryllia which has a much higher coefficient of expansion than the tungsten or molybdenum used for the target ring **36**. The heat sink member **54** is initially located in good physical contact with the inner periphery target ring **36** so that in the initial exposure cycle period heat will be efficiently conducted from the target ring **36** into the heat sink **54**. Then as heat builds up in the heat sink member **54**, which for this purpose is constructed of material having a thermal storage capacity per unit weight which is much higher than that of the target ring **36**, such heat in the member **54** will cause thermal expansion thereof. Such thermal expansion will cause the heat member **22** to even more closely engage the target member **36**. Therefore, this construction results in the same type of improvement as is found in the structures of FIGS. **1 – 3**.

From the foregoing it will be apparent that all of the objects and advantages of this invention have been achieved by the structures shown and described wherein efficient transfer of heat by conductivity from a target member into an associated heat sink member is achieved. It is to be understood, however, that modifications and changes in the structures shown and described may be made by those skilled in the art without departing from the spirit of the invention as expressed in the accompanying claims.

I claim:

1. A rotating target assembly for an X-ray tube, comprising a rotatable shaft, a target member and adjacent heat sink means carried by said shaft for rotation therewith, said heat sink means being disposed adjacent said member, first supporting means rigidly mounting said target member on the shaft, and second supporting means yieldably mounting said heat sink member on the shaft independently of said target member, said heat sink means during rotation of the sahft being responsive to centrifugal force and consequently movable into close heat conductive physical contact with the target member to remove heat therefrom.

2. A target assembly as set forth in claim **1** wherein said target member is annular in shape, and said heat sink means comprises an annular arrangement of individual heat sink members disposed adjacent the inner periphery of the annular target member, and wherein said heat sink members are individually movable in response to centrifugal force into contact with the adjacent portion of the target member.

3. A target assembly as set forth in claim **2** wherein said second supporting means includes resilient means for normally urging said heat sink members into contact with said target member in the absence of centrifugal force.

4. A rotating target assembly as set forth in claim **1** wherein said target member is molybdenum and said heat sink means is beryllia.

5. A rotating anode X-ray tube comprising an evacuated envelope, a cathode within the envelope for generating a beam of electrons, an anode in the envelope in spaced relation to the cathode for generating X-radiation in response to impingement by said electrons said anode comprising a shaft, means for rotating said shaft, and a target assembly mounted on said shaft for rotation therewith, said target assembly comprising a target member carried by said shaft for rotation through said beam of electrons, first supporting means rigidly mounting said target member on the shaft, heat sink means disposed adjacent said target member, and second supporting means yieldably mounting said heat sink means on the shaft independently of said target member, said heat sink means during rotation of said shaft being responsive to centrifugal force and consequently movable into close heat conductive physical contact with the target member to remove heat therefrom.

6. An X-ray tube as set forth in claim **5** wherein said target member is annular in shape, and said heat sink means comprises an annular arrangement of individual heat sink members disposed adjacent the inner periphery of the annular target member, and wherein said heat sink members are individually movable in response to centrifugal force into contact with the adjacent portion of the target member.

7. An X-ray tube as set forth in claim **6** wherein said second supporting means includes resilient means for normally urging said heat sink members into contact with said target member in the absence of centrifugal force.

* * * * *