

- [54] **METHOD AND APPARATUS FOR REMOVING HEAT FROM WITHIN A VACUUM AND FROM WITHIN A MASS**

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- [52] **U.S. Cl.****313/60, 313/30, 313/46**

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

- [58] **Field of Search** 313/60, 11; 315/32

- [56]
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Primary Examiner—Roy Lake

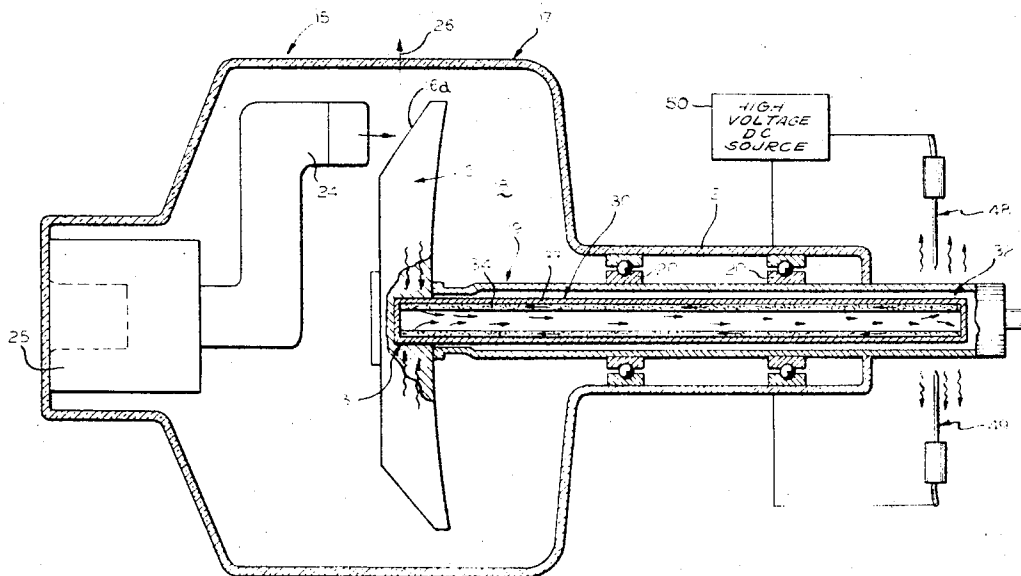
Assistant Examiner—Darwin R. Hostetter

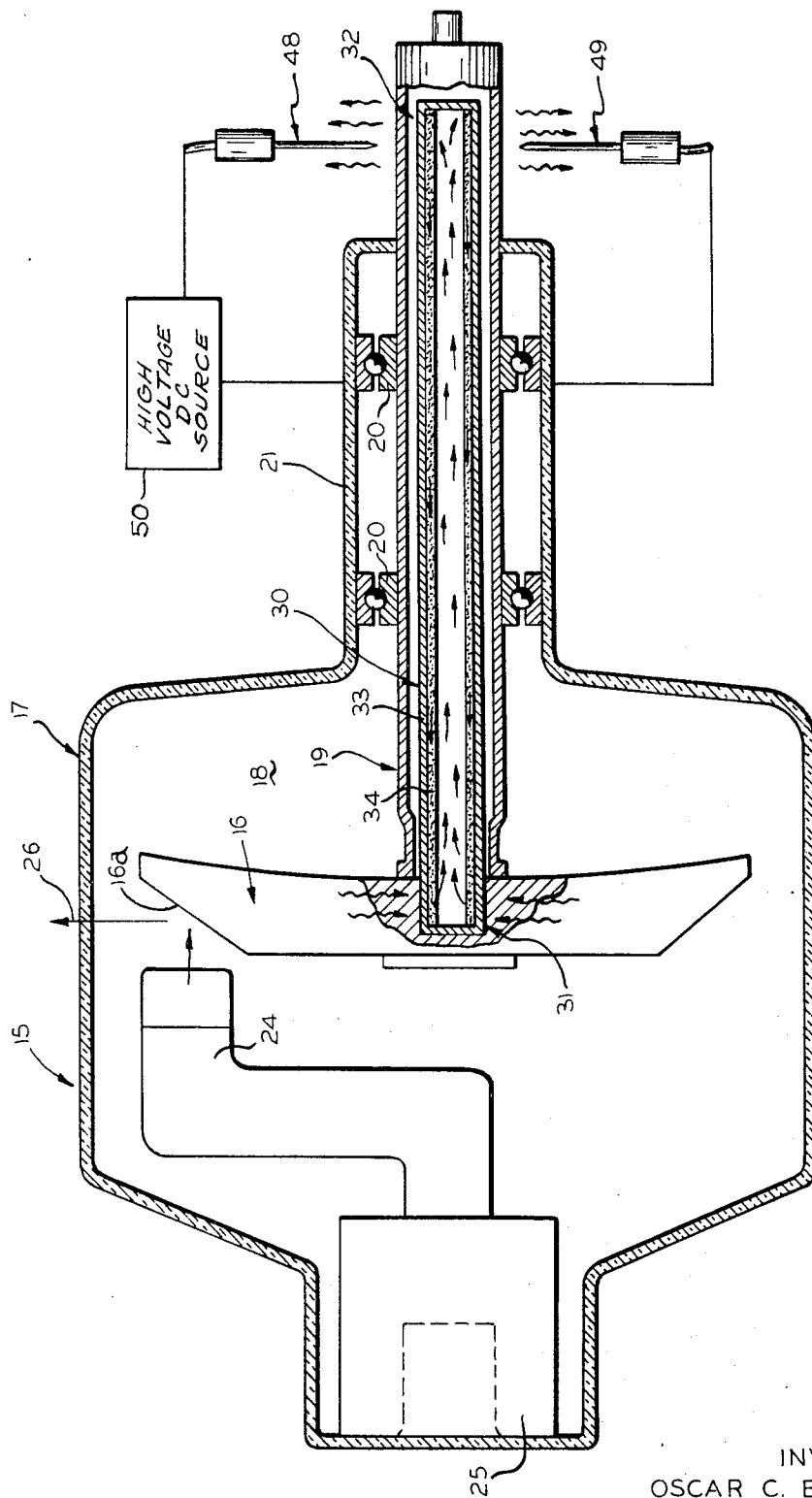
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- [57] ABSTRACT

A method and apparatus for cooling elements generating heat within a vacuum and the center of a large mass of hot material including a heat pipe having the input end within a vacuum or a large mass of material and the output end exterior thereof, and means for subjecting the output end to an electrostatic field to materially increase the rate of heat transfer into the atmosphere.

5 Claims, 4 Drawing Figures





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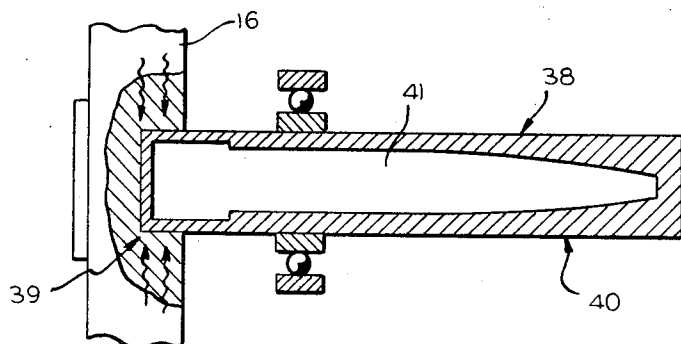


FIG. 2

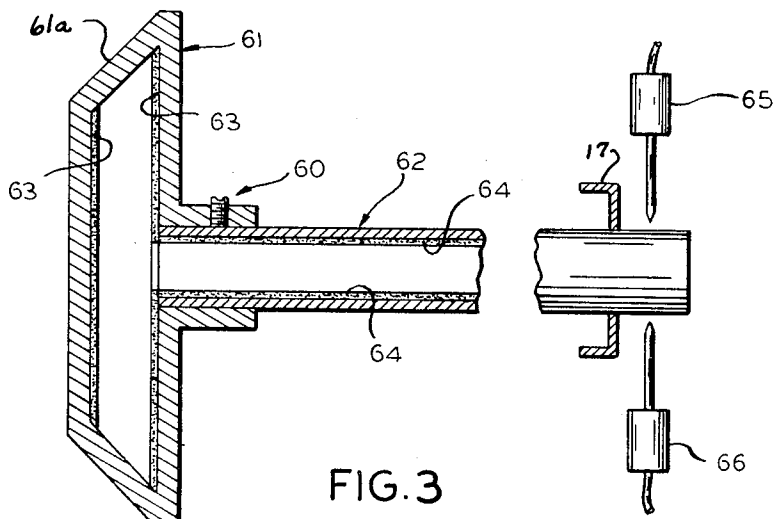


FIG. 3

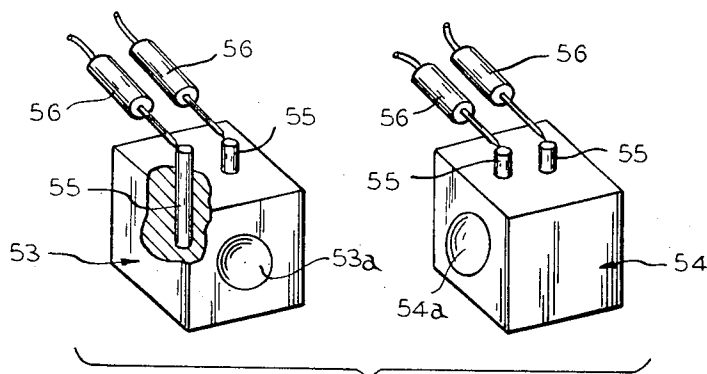


FIG. 4

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METHOD AND APPARATUS FOR REMOVING HEAT FROM WITHIN A VACUUM AND FROM WITHIN A MASS

This invention relates in general to a method and apparatus for removing heat from an element located within a vacuum or removing heat from within a large mass of hot material, and more particularly to a method and apparatus including the use of a heat pipe and electrostatic cooling.

Heretofore, it has been difficult to remove heat from an element operating within a vacuum. Likewise, it has been difficult to remove heat from within a large mass of hot material.

The present invention overcomes the problems above referred to in combining the use of a heat pipe and electrostatic cooling. For example, in connection with an X-ray tube, a heat pipe may be mounted within the shaft of a rotating target, wherein the input end of the heat pipe is at the target to absorb heat, while the output end of the heat pipe is exterior of the envelope within which the target is mounted. An electrostatic field is generated about the output end of the heat pipe to materially increase the rate of heat transfer into the atmosphere. The improved cooling of the target enhances the life of the X-ray tube.

The present invention may be similarly applied to masses of hot material, such as die casting mold parts. Here the heat pipe may be mounted in the mold so that the input end is located at the center of the mold and the output end is located exterior of the mold and exposed to the atmosphere. Again, the output end of the heat pipe is subjected to an electrostatic field to materially increase the rate of heat transfer into the atmosphere. It should further be appreciated that any number of heat pipes may be used in connection with a die casting mold part.

Application of the electrostatic field may be accomplished by the use of needle-like or sharp tooth-shaped probes directed toward but spaced from the output end of a heat pipe. The probes are negatively or positively charged with a high voltage direct current potential, while the ends of the probes are spaced from the heat pipe a distance slightly greater than that which would normally cause arcing therebetween. The heat pipe would be grounded and the level of potential chosen would be such as to accomplish the cooling action desired. Normally, the high voltage, low current DC potential would be about 10,000 to 250,000 volts.

Accordingly, it is an object of the present invention to provide a new and improved method and apparatus for removing heat from within a vacuum and for removing heat from within a large hot mass.

It is another object of the present invention to employ a heat pipe and electrostatic field for removing heat from within a vacuum chamber and from within a large mass of hot material.

Other objects, features and advantages of the invention will be apparent from the following detailed disclosure, taken in conjunction with the accompanying sheets of drawings, wherein like reference numerals refer to like parts, in which:

FIG. 1 is a longitudinal, sectional view taken through an X-ray tube incorporating the apparatus of the invention and illustrating some parts broken away for purposes of clarity;

FIG. 2 is a fragmentary longitudinal, sectional view taken through a shaft of a target for an X-ray tube and illustrating another type of heat pipe;

FIG. 3 is a fragmentary cross-sectional view of a modified wheel and shaft arrangement; and

FIG. 4 is a perspective view of a die casting mold unit utilizing the method and apparatus of the present invention.

Referring now to the drawings, and particularly to FIG. 1, an X-ray tube of the usual kind with the exception that the present invention is built therein, generally indicated by the numeral 15, illustrates the application thereto of the present invention for cooling the target wheel 16 which is located within the usual glass envelope 17 defining a vacuum chamber 18. The target wheel 16 is mounted on the end of a wheel shaft 19 that is rotatably supported by a pair of bearings 20 carried by a necked-down portion 21 of the glass envelope. A continuation of shaft 19 also defines it as an armature shaft for a motor (not shown) which would drive the target wheel. A suitable seal, not shown, would be provided between the rotatable shaft 19 and the glass envelope to maintain the integrity of the vacuum chamber 18.

The target wheel 16 is made of dense and heavy metal and is bombarded at its reflecting surface 16a by a stream of electrons emitted from a high voltage electrode 24 which is connected through a suitable fitting 25 to a source of high voltage direct current potential. Because the X-ray tube includes a vacuum chamber, electrons emitted from the electrode 24 accelerate to great speed, and when they strike the target wheel surface 16a, they produce X-rays that are given off at a right angle as indicated by the direction of arrow 26. Tremendous heat is generated in the process of operation, and the heat together with the impact of the electrons tends to erode the target wheel. The erosion effect is equally distributed over the reflecting surface 16a by rotating the target wheel at high speed, but subjecting the wheel to continued heat and erosion crazes the surface 16a causing the surface to reflect X-rays at angles other than 90° away from the intended target. The misguided X-rays become hazardous. Additionally, the heat eventually deteriorates the bearings causing shaft wobble and misguided X-rays. These conditions necessitate the frequent replacement of the X-ray tube.

The method of cooling according to the present invention involves inserting a conventional heat pipe in the tube so that the input end receives heat from the target wheel, while the output end expends heat to the atmosphere. Additionally, to materially increase the rate of heat transfer from the output end of the heat pipe to the atmosphere, an electrostatic field is generated at the output end. The apparatus for carrying out this method is shown in FIG. 1, wherein a heat pipe 30 is illustrated as being arranged within the target wheel shaft 19, and as having its input end 31 arranged within the target wheel at the center thereof, and the output end 32 arranged within the shaft at the exterior of the glass envelope so that it can be exposed to the atmosphere. The heat pipe 30 may be of any suitable type and is shown in FIG. 1 as including a metal sheath or casing 33 lined with a capillary structure or wick 34. The casing defines a vacuum chamber, and the wick is saturated with a suitable volatile working fluid capable of vaporizing and condensing in response to tempera-

ture conditions. Heat generated at the target wheel 16 is transferred to the input end 31 of the heat pipe. The volatile liquid within the heat pipe is vaporized at the input end and travels toward the cool end where it is condensed and where heat is given off at the output end 32. Thereafter, the condensed liquid travels back through the wick 34 to the input end. This type of heat pipe is commonly referred to as a capillary type, but it should be appreciated that a non-capillary type of heat pipe, such as shown in FIG. 2, may be employed here where located within a rotating shaft.

The non-capillary heat pipe of FIG. 2 is generally designated by the numeral 38, and includes an input end 39 adapted to be mounted within the center of the target wheel 16 and an output end 40 adapted to be exposed to the atmosphere. While the heat pipe 30 in FIG. 1 is illustrated as being within a hollow drive shaft 19, it could act as the drive shaft if properly constructed. To this end, the heat pipe 38 is illustrated as being so constructed that it not only functions as a heat pipe, but also as the drive shaft for the target wheel. The heat pipe 38 includes a vacuum chamber 41 within which a suitable volatile working fluid will be placed. As the pipe rotates, the working fluid therein collects at the input end 39 where heat causes part of the fluid to evaporate and move to the cool or output end 40. The vapor at the output end is then condensed and centrifuged back to the input end along the tapered walls.

At the output end 32 of the heat pipe 30, heat given off is passed into the atmosphere at a rate dependent upon the heat transfer rate at the exterior surface of the heat pipe and the drive shaft 19. To enhance the heat transfer rate and actually materially increase same so that heat is more rapidly passed into the atmosphere, an electrostatic field is generated at the output end of the heat pipe, and as illustrated at the exterior surface of the shaft 19, by means of a pair of probe assemblies 48 and 49. These assemblies would be connected to a high voltage, low current DC potential, as indicated by the numeral 50, of such a level, such as between 10,000 and 250,000 volts, as to effect the desired heat transfer rate. While the probe assemblies are illustrated as including needle-like ends, they could take the form of sharp tooth-shaped sections. The very ends of the probes are spaced from the shaft just outside of incipient arcing. The shaft and heat pipes would be preferably connected to ground. Inasmuch as a high voltage DC potential is usually supplied to an X-ray tube, such could easily be supplied to the probe assemblies 48 and 49. It should be further appreciated that it is not possible to electrostatically cool any element within a vacuum chamber, and therefore it is necessary, as illustrated, to set up the electrostatic field outside of the X-ray tube envelope.

Another embodiment of the invention is illustrated in FIG. 3 wherein a combination target wheel and shaft 60 may be employed in place of the shaft and target wheel assembly of FIG. 1 or that of FIG. 2. This assembly includes a hollow target wheel 60 secured onto one end of a hollow shaft 62, the outer end of the shaft being outside of the glass envelope 17. The wheel 61 includes an annular frusto-conical reflecting surface 61a against which the electron bombardment of the electrode is received. It is at this surface that the heat is primarily generated. The hollow wheel 61 is provided with a wick or capillary structure 63, while the hollow shaft 62 is provided with a wick or capillary structure 64, wherein

both the hollow wheel and the shaft act as a heat pipe structure to carry the heat to the end of the shaft outside of the glass envelope. At this point, probe assemblies 65 and 66 facilitate the heat transfer rate to the atmosphere by generating an electrostatic field around the end of the shaft. The hollow wheel and hollow shaft function as a heat pipe structure like the heat pipe 30 of FIG. 1, and therefore the structure includes a vacuum chamber having a working fluid therein which coacts with the wick to transfer heat from the wheel surface 61a to the end of the shaft 62.

Illustration of the invention in connection with the removal of heat from the interior of a large mass of hot material is depicted in FIG. 4, wherein a die casting mold unit includes separable mold halves 53 and 54. Each mold half includes a mold cavity 53a and 54a which coact to define a molding form. Further, the mold halves would be made of a suitable metal for use in die casting. In accordance with the present invention, each mold half includes a pair of heat pipes 55 extending into the mold halves with the input ends at the interior or approximately center of the material and the output ends at the exterior of the mold halves and exposed to the atmosphere. Inasmuch as the heat pipes would be stationary, they would be of the capillary type as disclosed in FIG. 1. Adjacent the output ends of the heat pipes, probe assemblies 56 having needle-like or tooth-shaped probes directed thereto produce an electrostatic field with respect to the heat pipe to increase the rate of heat transfer at the exterior surfaces of the heat pipe and thereby enhance the conductance of heat from the heat pipes into the atmosphere. As is the case with the probe assemblies 48 and 49 in FIG. 1, the probe assemblies 56 would be connected to a source of low current, high voltage DC potential, of positive or negative polarity, while the mold halves would preferably be connected to ground potential thereby placing the heat pipes at ground potential. The terminal ends of the probes would be spaced from the heat pipes just outside of the point of incipient arcing. Accordingly, the heat from within the mold halves would be transferred through the heat pipes to the output ends exteriorly of the mold halves where the heat would be dissipated to the atmosphere at a rapid rate by virtue of the electrostatic field generated at the output ends. While reference is made to removing heat from within mold halves, it should be appreciated that the invention could be applied to other masses of hot material.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention, but it is understood that this application is to be limited only by the scope of the appended claims.

The invention is hereby claimed as follows:

1. In an X-ray tube having a casing defining a vacuum chamber, a rotating target therein mounted on a shaft extending from the casing and an electrode therein adjacent the target adapted to be connected to a source of power to direct a stream of electrons against the target, the method of removing heat from the target comprising the steps of inserting a heat pipe in the shaft so that the input end absorbs heat from the target, and electrostatically cooling the output end.

2. The method of claim 1, wherein the step of electrostatically cooling the output end of the heat pipe includes spacing probe means adjacent the output end of the heat pipe, and connecting the probe means to a

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source of high voltage direct current potential such that will cause rapid cooling.

3. In an X-ray tube having a casing defining a vacuum chamber, a rotating target therein mounted on a shaft extending from the casing and an electrode therein adjacent the target adapted to be connected to a source of power to direct a stream of electrons against the target, apparatus for removing heat from the target and from within the vacuum chamber which comprises, a heat pipe extending through the shaft from adjacent the target to a point outside of the chamber exposed to the ambient atmosphere, and means for subjecting the output end of the heat pipe outside the chamber to an electrostatic field of such intensity as to substantially increase the transfer of heat from the pipe into the atmosphere.

4. The combination as defined in claim 3 wherein said means for subjecting the output end of the heat pipe to an electrostatic field includes a probe means

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spaced adjacent the output end of the heat pipe, and a source of high voltage direct current potential of such a level that the transfer of heat from the heat pipe to the atmosphere will be materially increased.

5. In an X-ray tube having a casing, defining a vacuum chamber, a rotating target therein mounted on a shaft extending from the casing and an electrode therein adjacent the target adapted to be connected to a source of power to direct a stream of electrons against the target, apparatus for removing heat from the target and from within the vacuum chamber which comprises, said rotating target and shaft therefor being hollow and in the form of a heat pipe, and means for subjecting the end of the shaft extending from the casing to an electrostatic field of such intensity as to substantially increase the transfer of heat from the shaft into the atmosphere.

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