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THERMOELECTRIC COOLING DEVICE FOR HEAT CONDUCTIVE LIGHT TRANSPARENT SURFACES

Filed Jan. 15, 1962 2 Sheets-Sheet 1

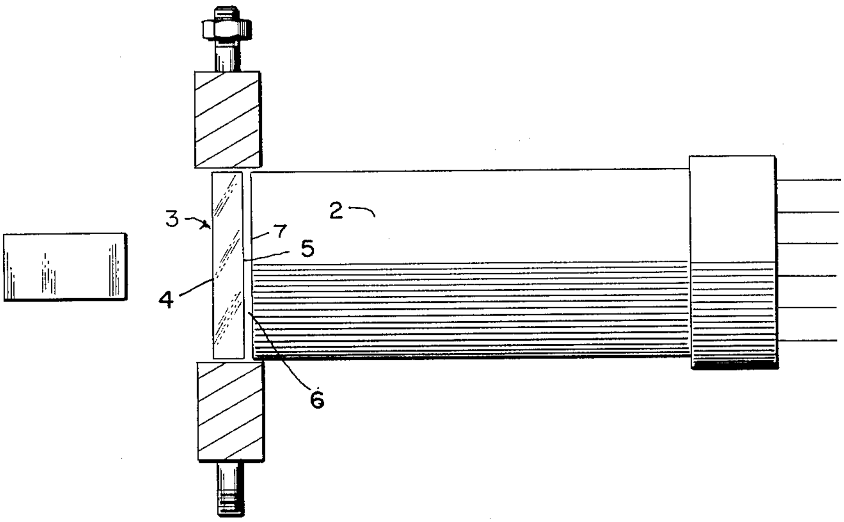

FIG. 1

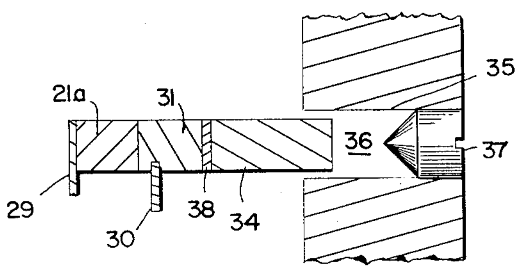

FIG. 2

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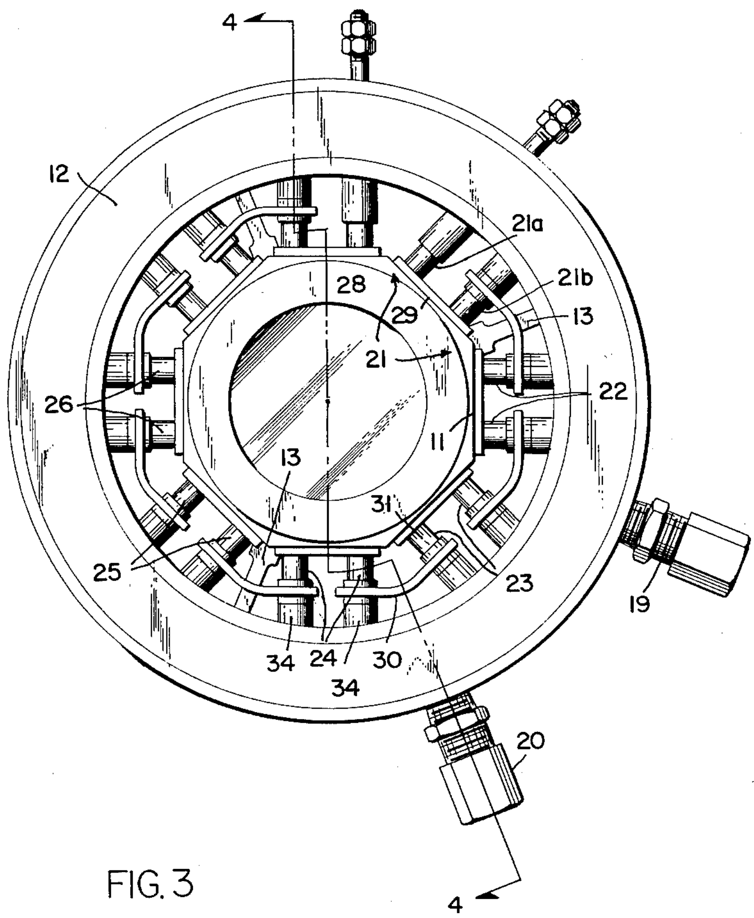

FIG. 3

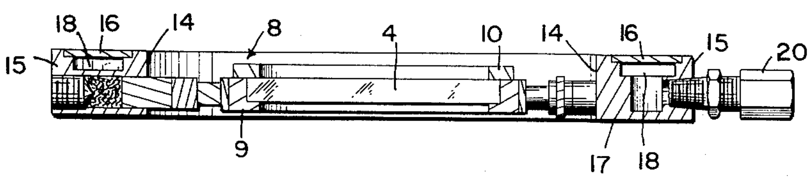

FIG. 4

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THERMOELECTRIC COOLING DEVICE FOR HEAT CONDUCTIVE LIGHT TRANSPARENT SURFACES

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The present invention relates to a means for thermally controlling an energy responsive surface with minimum interference of the impingement of energy on said surface.

There are several applications where it is desirable to provide a means for effectively controlling the temperature of a surface while simultaneously allowing certain forms of energy to impinge upon the surface. For example, it is desirable to provide a means for cooling a photomultiplier tube surface without interfering with light impinging upon the tube. Similarly, it is desirable under certain circumstances to control the temperature of infrared cells without interfering with the impingement of infrared rays upon the cell.

It is therefore, an object of the present invention to provide a compact and relatively simple device for thermally controlling a surface of an object, such as a photomultiplier tube or infrared cell without interfering with the pasage of energy in wave form onto the surface.

The problem of cooling photomultiplier tubes is particularly acute. Heretofore, various methods of cooling have been attempted. A common method has been to place the photomultiplier tube and associated mechanism in a commercial type of freezer. Such an arrangement is unsatisfactory because parts of the apparatus which operate best above room temperature are cooled with the tube. In addition, the arrangement is clumsy. More recently, Kolenko, Protopopov, Fleyshman and Yur'yev have taught that photomultiplier tubes may be cooled with the aid of thermoelectric coolers. (Electronic Design, October 28, 1959.) The arrangement as described therein, however, is inadequate as it severely obstructs the passage of light to the photomultiplier tube, and does not permit replacement of the photomultiplier tube separately from the cooling device.

It is, therefore, an object of the present invention to provide a means for cooling a photomultiplier tube wherein the face of the photocathode is not obstructed. Heat is also abstracted in a relatively uniform manner from the entire surface of the photocathode without lateral conduction of heat across the thin glass face of the photocathode. Photomultiplier tubes may be replaced without simultaneous replacement of the cooling mechanism. It is also an object of the present invention to provide a means for cooling the surface of a photomultiplier tube to approximately 10° C. whereby thermal noises of the tube may be reduced by a factor of at least 5.

In the present invention there is provided an arrangement wherein a heat-conductive light-transparent sheet is supported by a primary heat conductive ring extending about the periphery of the sheet. A secondary ring comprising an annular tubular member through which a heatable fluid medium such as water may be circulated is positioned in spaced coaxial relation with the primary ring. Disposed between the rings are a plurality of thermoelectric couples or elements, preferably connected in electrical series. Each thermoelectric element has a hot and a cold end. The cold ends are in thermal engagement with the primary ring while the hot ends are in thermal engagement with the secondary ring. The secondary ring acts as a heat sink for the thermoelectric elements and is connected thermally to each thermoelectric element by means of rods which support the thermoelectric element at one end and which at the other are secured in a hole in the secondary ring, with suitable means for providing a thermal contact.

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These and other objects and advantages of the present invention will be more clearly understood when considered in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic view of an embodiment of the present invention for use in conjunction with a photomultiplier tube,

FIG. 2 is a schematically illustrated detail of the present invention,

FIG. 3 is a plan view of a preferred embodiment of the present invention, and,

FIG. 4 is a cross sectional view of the embodiment illustrated in FIG. 3 taken along the line 4—4 of FIG. 3.

The present invention may be used in connection with a variety of devices wherein it is desirable to control the temperature of a surface of the device without obstructing the impingement of energy, primarily in the form of light, onto the surface of the device. The principal utility of the present invention, however, is for cooling photomultiplier tubes. Accordingly, the present invention will be described in connection with an embodiment of the invention for such purpose.

Photomultiplier tubes such as illustrated at **1** in FIG. 1 normally operate more reliably when the photomultiplier dark current is reduced. This dark current may be reduced considerably by supressing thermionic emission from the cathode. In addition, cooling a photomultiplier tube noticeably reduces leakage current.

The device illustrated generally at **3** (FIG. 1) has a light-transparent heat-conductive sheet **4** with a flat surface **5** adapted to be positioned in parallel face to face contact with the flat surface **6** at the cathode end of the tube **2**. For photomultiplier tube coolers, the sheet **4** preferably should be of glass having an index of refraction substantially equal to the index of refraction of the glass envelope of the photomultiplier tube. By equating the index of refraction, loss of light transmission due to internal reflections at the interface of the sheet **4** and surface **6** is minimized. A common index of refraction for such tubes is 1.5000.

To further minimize the internal reflection at the interface of the sheet **4** and surface **6**, a thin layer of oil **7** may be spread between the tube **1** and sheet **4**. Such oil must not freeze or be voltaile at room temperatures. It must have the same index of refraction or close to the same index or refraction as the transparent sheet **4**. It must be transparent and must not act as a substantial heat barrier. It has been found that various silicon oils are satisfactory for such purpose.

The sheet **4** is preferably a disc of substantially the same diameter as the photomultiplier tube. (FIGS. 3 and 4.) It is supported at its periphery by a primary ring **8** of heat conductive material such, for example, as aluminum. This ring **8** may be formed in two sections including the base rim **9** having an annular cross section as illustrated in FIG. 4 and a clamping ring **10**. The sheet **4** is sandwiched between the base rim **9** and clamping ring **10** with the base rim **9** and clamping ring **10** suitably secured together by solder or other suitable means. The outer edge of the ring **8** is polyhedric in shape and, as illustrated in FIG. 3, may have an octagonal configuration with sides illustrated at **11**.

A secondary ring **12** is positioned coaxial with and surrounding the primary ring **8**. This secondary ring **12** is maintained in spaced relation with the primary by a series of radially extending braces **13** interengaging the primary and secondary rings. The secondary ring comprises a tubular member having walls **14**, **15**, **16** and **17** forming a passage **18** through which a heat exchange fluid medium may pass. Inlet and outlet connections **19** and **20** are connected to the passage **18** so that water may be pumped into the inlet **19** and drained from the passage **18** at the outlet **20**. A plurality of thermoelectric couples **21**, **22**, **23**, **24**, **25**, **26**, **27** and **28** are arranged in electrical series, and are disposed between the primary and secondary rings **8** and **12** respectively. Each thermoelectric couple is identical in construction and has thermoelectric positive and negative members such as illustrated respectively at **21***a* and **21***b*. These members **21***a* and **21***b* are interconnected by a silver plated copper connecting strap **29**. This strap **29** is electrically and thermally conductive and is secured in face to face relation with one of the octagonal sides of the ring **8**. These straps **29** also form the cold junction of the thermoelectric couple. Adjacent thermoelectric couples are connected in series by a connecting copper web **30** with the web **30** secured at its ends to end caps **31** and **32**. The caps **31** and **32** are soldered or otherwise suitably secured to the hot ends of thermoelectric members. The copper end caps are also each secured to a thermally conductive rod or plunger **34** with the rod or plunger **34** electrically insulated from the caps **31** and **32**. (FIG. 2.) The rod **34** is preferably secured to the caps **31**, **32** by a thin layer of an electrically insulating, but thermally conductive glue **38**. Such glue must provide a solid interengagement between the cap and rod and may comprise a wide range of resin glues. Epoxy glues are preferred. The rods **34** each slideably fit a hole **35** formed in the secondary ring **12**. The rod **34** and walls of the hole **35** have a relatively tight sliding fit so that a good thermally conducting interface is formed between each rod **34** and ring **12**. The rod **34** is preferably an anodized aluminum member with a relatively electrically nonconductive surface.

A thermally conductive wad **36** of metal wool made of aluminum, copper or other similar metals is packed in the hole **35** in thermal and pressure contact with the secondary ring **12** and rod **34**. The wool is secured within the hole **35** by the pointed plug **37** which is threaded into the outer end of the hole **35**. Such an arrangement permits good thermal conductivity between the ring **12** and rod **34** while maintaining a very high electrical resistance and providing expansion compensation.

What is claimed is:

1. A means for conducting heat from an electron emissive glass surface comprising a heat-conductive light-transparent glass sheet having one side parallel and closely spaced in thermal contact with said surface,
   - a thin layer of an optically and thermally conductive material interposed between and contiguous with said surface and side,
   - and means at the periphery of said sheet for conducting heat therefrom,
   - said means comprising a first heat conductive ring surrounding and in clamping engagement with said glass sheet and a plurality of thermoelectric devices thermally connected to said ring.

2. A means for controlling temperature on a surface while said surface is illuminated comprising a heat-conductive light-transparent sheet adapted to be positioned with a side thermally contacting said surface,
   - heat-conductive means arranged about the periphery of said sheet supporting said sheet in clamping engagement and,
   - thermoelectric means arranged about the periphery of said heat-conductive means and in direct thermal and electrical contact therewith, for cooling said heat-conductive means,
   - and means in slidable contact with and arranged about the periphery of said thermoelectric means for conducting heat from said thermoelectric means.

3. A means for controlling heat on a surface while said surface is illuminated comprising a heat-conductive light-transparent sheet having an index of refraction substantially equal to the index of refraction of said sheet adapted to be positioned with a side thermally contacting said surface,
   - primary and secondary concentric rings,
   - said primary ring comprising a metallic thermally conductive member engaging said surface,
   - said secondary ring comprising an annular tubular member through which a heat exchanging fluid may be circulated for establishing a predetermined temperature level of said secondary ring,
   - a plurality of thermoelectric elements arranged radially about said sheet and each having a cold and hot end with said cold ends disposed against said metallic ring in electrical contact therewith and said hot ends disposed against the other of said rings.

4. A means for controlling heat on a surface while said surface is illuminated comprising a heat-conductive light-transparent sheet adapted to be positioned with a side thermally contacting said surface,
   - primary and secondary concentric rings,
   - said primary ring comprising a thermally conductive member engaging said surface,
   - said secondary ring comprising an annular tubular member through which a heat exchanging fluid may be circulated for establishing a predetermined temperature level of said secondary ring,
   - a plurality of thermoelectric elements arranged radially about said sheet and having hot and cold ends,
   - said hot ends thermally engaging said secondary ring through a high electrical resistance joint and said cold ends thermally engaging said primary ring in electrical contact therewith.

5. A device as set forth in claim 4 having means forming a plurality of radially extending holes formed in said tubular member,
   - a plurality of rods secured at one end in one of said holes,
   - and means supporting and thermally interengaging and electrically insulating the other end of each of said rods and a thermoelectric element.

6. A device as set forth in claim 5 having metallic wool positioned in said holes thermally interengaging said rod and said means forming said hole.

7. A device for conducting heat from the electrom emissive surface of a photomultiplier tube or the like comprising a heat-conductive light-transparent sheet,
   - a metallic heat conductive ring positioned about in clamping engagement therewith and supporting said sheet,
   - a second tubular ring having a passage therethrough for circulating a fluid coolant,
   - a plurality of thermoelectric elements radially disposed about said sheet with each having one end thermally engaging said first mentioned ring and another end thermally engaging said second ring in sliding contact therewith through a high electrical resistance joint,
   - said thermoelectric elements adapted to respond to a power input to make said first end cooler than said second end.

8. A device as set forth in claim 7 wherein said sheet is glass.

9. A device as set forth in claim 7 wherein said sheet is quartz.

10. A device as set forth in claim 7 wherein said sheet is transparent to infrared rays.

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