Oct. 22, 1968 G. A. SAUM 3,407,322

INFRARED CAMERA TUBE WITH COOLING MEANS FOR INTERNAL ELEMENTS

Filed June 25, 1962

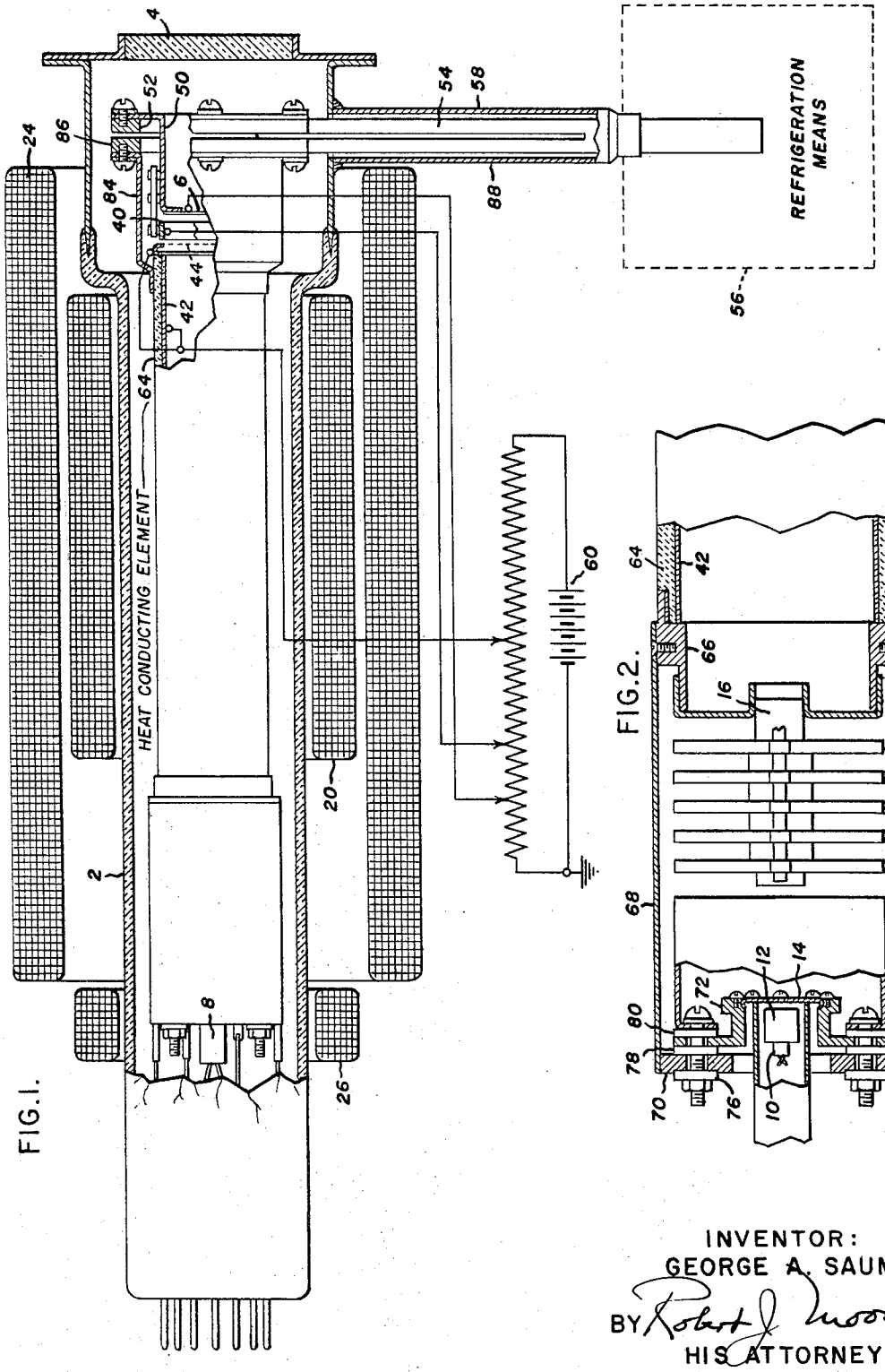

FIG. 1.

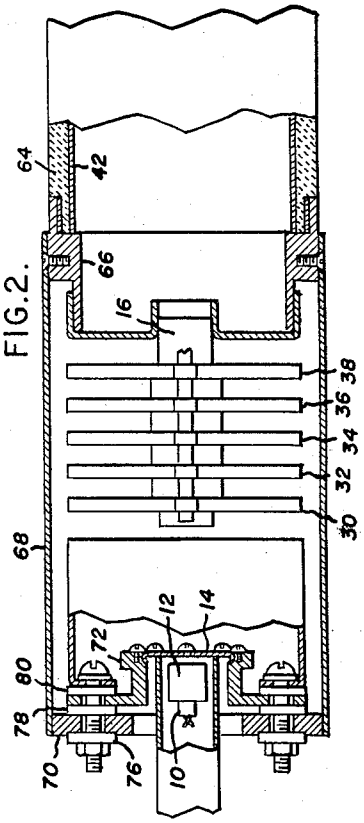

FIG. 2.

INVENTOR:
GEORGE A. SAUM,
BY Robert J. Mooney
HIS ATTORNEY.

United States Patent Office

3,407,322

Patented Oct. 22, 1968

3,407,322

INFRARED CAMERA TUBE WITH COOLING MEANS FOR INTERNAL ELEMENTS

George A. Saum, Liverpool, N.Y., assignor to General Electric Company, a corporation of New York

Filed June 25, 1962, Ser. No. 204,904

7 Claims. (Cl. 313—46)

The present invention relates to infrared sensitive devices and more particularly to infrared sensitive pickup or camera tubes.

Infrared sensitive pickup tubes are known in which an evacuated envelope is provided with an infrared radiation transparent window for admitting incident infrared radiation and an infrared sensitive photoelectric target is disposed within the envelope in the path of the admitted infrared radiation. Responsive to incidence of the infrared radiation on the target a two-dimensional pattern of electrical charge is formed at the target which is read out by means of a scanning electron beam, thereby developing a time varying electrical signal representative of the infrared image impressed on the target.

In devices of the foregoing character sensitivity of the target to infrared radiation and ability to generate an electrical charge pattern of desired signal-to-noise ratio and adequate for desired reading out is importantly dependent upon maintaining the target in a cooled condition at very low temperatures, for example of the order of —190° C., and avoiding exposure of the target to extraneous infrared radiation. Thus the requirement for generation of an electron beam for readout scan of the stored charge pattern, and the attendant requirement for a thermionic electron emitter within the tube envelope, presents the problem of preventing transfer of heat, by radiation or otherwise, from the thermionic emitter to the infrared sensitive target, and minimizing exposure of the target to extraneous infrared radiation from the vicinity of the thermionic emitter.

One object of the present invention is to provide an improved and simplified means for protecting the infrared sensitive target in an infrared sensitive pickup tube from exposure to extraneous heat or infrared radiation from the thermionic emitter or other parts of the device.

Another object is to provide, in an infrared sensitive pickup tube, improved means for refrigerating those parts of the electron gun which are located in radiation coupled relation to the target.

These and other objects of the present invention will be apparent from the following description taken in conjunction with the accompanying drawing wherein:

FIGURE 1 is a view, partially broken away in axial section, of an infrared pickup tube constructed in accordance with the present invention; and

FIGURE 2 is a fragmentary axial sectional view of a portion of the structure of FIGURE 1.

Referring to the drawing, an infrared sensitive device constructed in accordance with my invention includes an evacuated envelope **2** of generally cylindrical shape at one end of which is a window **4** of infrared radiation-transparent material, such as sapphire, for admitting infrared radiation to the envelope interior. Disposed within the envelope in the path of the admitted infrared radiation is a photoconductive target **6** such as a wafer of copper-doped germanium. Coaxially spaced from the target is an electron gun **8** for generating an electron beam for scanning the target. The electron gun includes an indirectly heated cathode **10** (FIG. 2), centrally apertured control grid **12**, and accelerating electrode **14**, and spaced coaxially apertured accelerating electrode **16**.

Coaxially surrounding the envelope in the region between the accelerating electrode **16** and the target are electromagnetic sweep coils **20**, for providing the necessary

horizontal and vertical sweeping of the electron beam across the target. Coaxially surrounding the sweep coils **20**, is a focus coil **24** for focusing the electron beam and collimating the beam after deflection into paths parallel to the tube axis for enhanced perpendicularity of incidence of the electron beam on the target. An additional alignment coil **26** surrounds the envelope in the vicinity of the accelerating grid **14** (FIG. 2) for the purpose of enabling centering of the electron beam relative to the coaxial aperture in the accelerating electrode **14** and aligning the beam with the focusing magnetic field.

For the purpose of amplifying return beam current from the target a signal amplifying dynode structure, forming no part of the present invention, is provided including dynodes **30**, **32**, **34**, reflector **36** and collector electrode **38**. The dynode structure is arranged in concentric surrounding relation with the electron beam path in the region between electrode grids **14** and **16**.

Adjustable bias potentials for the various electrodes are provided from a power supply shown schematically at **60**.

The electron beam from electron gun **8** is decelerated prior to incidence at the target by a decelerating electrode **40** of annular shape disposed immediately adjacent the target **6**. Extending coaxially from adjacent the decelerating electrode **40** to the accelerating electrode **16** is an electrostatically field-free space through which the electron beam travels toward the target, this field-free space being provided by a cylindrical coaxial electrode **42** maintained at the same potential as electrode **16**. Extending across the end of the cylindrical electrode **42** adjacent electrode **40** is a field flattening electron transparent mesh electrode **44** whose purpose is primarily to enhance perpendicularity of landing on the incident electrons of the target **6**.

To facilitate cooling or refrigeration of the target **6** it is mounted on one end of an annular support **50**, of good heat conductivity material such as copper, arranged coaxially adjacent the window **4**. The annular member **50** is in turn supported by a relatively thick ring of copper **52** which is thermally conductively or operatively connected by means such as a heavy copper rod or "cold finger" **54** to refrigeration means **56** such as a double walled Dewar flask of liquid nitrogen or other suitable refrigerant external to the tube envelope. In one preferred form of this invention copper rod **54** is essentially a solid conductance heat transfer means and extends to the external refrigeration means through a tubular envelope appendage **58** from which the rod **54** is inwardly spaced so as to minimize undesired heat transfer between the appendage **58** and the rod **54**. Thus there is defined a first cooling means or path for the target **6**.

In accordance with my invention improved separate or second cooling means is provided for effectively minimizing exposure of the target **6** to heat generated at the thermionic emitter of the electron gun **8** and other internal parts of the tube, and conducted or radiated toward the target. For this purpose there is provided a cylindrical member **64** which surrounds electrode **42** and is made of a material which is both an electrical insulator and has excellent heat conductivity at the temperature range of —100° C. to —200° C. involved in operation of the device. A preferred material for the cylinder **64** is aluminum oxide, though other high heat conductivity electrically insulative materials such as beryllium oxide may also be used. Cylinder **64** is also refrigerated, by means hereinafter described, and thereby serves to chill electrode **42**. Further according to the invention the electrode **42** is made very thin in order to have a sufficiently high resistance, in ohms per square, to inhibit eddy currents and eddy current heating resulting from its presence within the magnetic fields of the sweep coils **20**. Electrode **42** also makes good heat transfer contact with the cylinder

64 and is contiguous therewith so that cylinder 64 can serve with maximum effect as a heat sink for electrode 42. The electrode 42 may thus have thinness of as little as 1 mil or less and may conveniently be provided in the form of a conductive coating painted or sprayed or otherwise intimately affixed to the interior of the electrically insulative cylinder 64. Conveniently also the field mesh electrode 44 together with its annular support may be carried by cylinder 64 as by cementing it directly to the end of the cylinder 64 in electrical contact with electrode 42.

The cylinder 64 serves not only to cool electrode 42 and as a mechanical support for electrode 42 enabling electrode 42 to be of minimum thickness for minimum eddy current heating, but further according to the invention cylinder 64 also serves as an excellent heat conducting link in a second or separate heat transfer path for removing heat from the electron gun vicinity to the refrigeration means 56. For this purpose the ceramic cylinder 64 is joined at its rearward end, by a collar 66 of good heat conductivity such as copper, to a metal cylinder 68 of good heat conductivity such as copper which in turn envelops and is heat-conductively connected to the electron gun 8. The rearward end of the copper cylinder 68 is mechanically connected to the electrode 14 by means which provide a good path for conducting heat away from electrode 14 and to the copper cylinder. This heat conducting path between the cylinder 68 and electrode 14 of the electron gun includes annular members 70, 72 which are made of a good heat conductive material such as copper, and washers 76, 78 and 80 which are made of a material such as sapphire providing excellent heat conduction in the temperature range of −100° to −200° C. involved, but permitting the electrode 14 to be electrically insulated from the copper cylinder 68. Thus electrode 14, which has the principal heat radiating surface facing the target and warmed by the thermionic emitter, is effectively cooled through cylinder 64 to a low enough temperature, for example in the vicinity of −100° C. to minimize extraneous heat radiation to the target 6.

To complete the heat transfer path from the electron gun vicinity through the ceramic cylinder 64 to the refrigeration means 56, the forward end of the ceramic cylinder 64 is connected directly to an annular member 84 of good heat conductivity such as copper, which in turn is operatively connected through a thick copper ring 86 and rod 88 to the refrigeration means 56. Thus a cooling path is provided through the ring 86 and rod 88 for the ceramic cylinder 64, copper cylinder 68 and electron gun 8 environment, which cooling path is separate and distinct from that provided exclusively for the target and thereby does not interfere with direct cooling of the target. Cooling paths or rods 54 and 88 are joined externally of the envelope proper or at a point remote from the target 6 and effectively, adjacent refrigeration means 56. This arrangement in combination with the structural relationship of parts which maintain the paths separate minimize heat transfer directly between the electron beam generating means and the target.

It will therefore be evident that, in accordance with the present invention, all the internal tube parts most susceptible to extraneous heating and generation of extraneous infrared radiation are effectively cooled, and cooled by parallel heat paths, i.e., a heat transfer path for cooling the electron gun structure which is separate and distinct from that heat transfer path for cooling the target, thereby substantially minimizing heat transfer between paths in the envelope and enabling the target to be effectively maintained at the desired low temperature for best performance, and at the same time minimizing exposure of the target to extraneous infrared radiation. Moreover the electron gun cooling heat transfer chain includes a ceramic cylinder and electrode support within the electron beam sweep field which effectively minimizes eddy current losses and eddy current heat generation,

thereby further enhancing the heat isolation and extraneous infrared exposure of the target. This enhanced protection of the target from extraneous heat in turn enables the target-to-electron-gun spacing to be reduced, and thus an infrared sensitive pickup tube constructed in accordance with the present invention has the advantage of minimum over-all length consistent with desired refrigeration of the target for optimum performance.

It will be appreciated by those skilled in the art that the invention may be carried out in various ways and may take various forms and embodiments other than the illustrative embodiments heretofore described. Accordingly it is to be understood that the scope of the invention is not limited by details of the foregoing description, but will be defined in the following claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In an infrared sensitive device comprising a target arranged to intercept infrared radiation, electron beam generating means spaced from the target and including a thermionic electron emitter, means for directing electrons from said emitter into incidence with said target, first cooling means operatively connected to said target for withdrawing heat from said target to maintain said target in cooled condition for enhanced sensitivity to infrared radiation intercepted thereby, second and separate cooling means in the form of an electrically insulative heat-conducting member heat conductively connected to and extending between said electron beam generating means and said heat-withdrawing means, said separate cooling means minimizing heat transfer therebetween in said device, and beam control electrode means ad,acent and in heat transfer relationship with said heat conductive member and extending between said electron beam generating means and said target.

2. An infrared sensitive device comprising a target adapted to intercept infrared radiation and electron beam generating means including a thermionic electron emitter spaced from the target, heat extraction means heat conductively coupled to said target and adapted to be heat conductively coupled to refrigeration means for maintaining said target in a cooled condition for enhanced sensitivity to infrared radiation intercepted thereby, and heat conducting means separate from said heat extraction means and heat-conductively coupled to said electron gun and adapted to be heat-conductively coupled to said refrigeration means, means maintaining said heat extraction and conducting means separate to minimize transfer of heat between said electron beam generating means and said target, said heat conducting means including an electrically insulative heat conducting ceramic member extending adjacent the path of said electron beam and a metallic electrical conductor contiguous with the surface of said ceramic member facing said electron beam path.

3. An infrared sensitive device comprising an envelope containing a target arranged to intercept infrared radiation and electron beam generating means including a thermionic electron emitter spaced from the target, parallel path cooling means for cooling said device, said parallel path cooling means including a first path comprising heat extraction means heat conductively coupled to said target and adapted to be heat conductively coupled to refrigeration means for maintaining said target in a cooled condition for enhanced sensitivity to infrared radiation intercepted thereby, and a second and separate path comprising heat conducting means heat-conductively coupled to said electron gun and adapted to be heat-conductively coupled to said refrigeration means, said parallel paths substantially minimizing the transfer of heat therebetween in said envelope, said heat conducting means including an electrically insulative heat conducting metal oxide member extending adjacent the path of said electron beam and an electrical conductor within said ceramic member supported from and cooled thereby.

4. An infrared sensitive device comprising an envelope

containing a target arranged to intercept infrared radiation and electron beam generating means including a thermionic electron emitter spaced from the target, parallel path heat removal means for cooling said device, one of said paths comprising heat extraction means heat conductively coupled to said target and adapted to be heat conductively coupled to refrigeration means for maintaining said target in a cooled condition for enhanced sensitivity to infrared radiation intercepted thereby, and the other of said paths comprising heat conducting means heat-conductively coupled to said electron gun and adapted to be heat-conductively coupled to said refrigeration means, said parallel paths being separate in said envelope to minimize the transfer of heat therebetween, said heat conducting means including an electrically insulative heat conducting ceramic member extending adjacent the path of said electron beam, said ceramic member including an oxide taken from the group consisting of the oxides of aluminum, and beryllium, and a metal electrical conductor contiguous with the surface of said ceramic member facing said electron beam path.

5. An infrared sensitive device comprising an envelope containing a target arranged to intercept infrared radiation, electron beam generating means including a thermionic electron emitter spaced from the target, at least a portion of the space between said target and beam generating means providing a beam deflection region for accommodating a magnetic beam deflecting field for scanning said beam on said target, essentially solid conductance heat extraction means heat conductively coupled to said target and adapted to be heat conductively coupled to refrigeration means for maintaining said target in a cooled condition for enhanced sensitivity to infrared radiation intercepted thereby, and heat conducting means extending between said electron gun and said heat extraction means, and separate from said heat extraction means to minimize transfer of heat therebetween in said envelope, means joining said heat conducting means and said heat extracting means at a point remote from said target, said heat conducting means including an annular electrically insulative heat conducting ceramic member surrounding said path of said electron beam in said beam deflection region, said ceramic member comprising at least one oxide taken from the group consisting of aluminum oxide and beryllium oxide, and an electrically conductive metallic coating on the interior of said annular member in heat conducting relationship thereto for defining an eddy current resistant electrode therewithin.

6. An infrared sensitive device comprising an envelope having a target arranged to intercept infrared radiation, electron beam generating means including a thermionic

electron emitter spaced from the target, at least a portion of the space between said target and beam generating means providing a beam deflection region for accommodating a magnetic beam deflecting field for scanning said beam on said target, heat extraction means heat conductively coupled to said target and adapted to be heat conductively coupled to refrigeration means for maintaining said target in a cooled condition for enhanced sensitivity to infrared radiation intercepted thereby, and heat conducting means extending between said electron gun and said heat extraction means, said heat conducting means including an annular electrically insulative heat-conducting ceramic member surrounding the path of said electron beam in said beam deflection region, and a thin electrically cconductive metallic coating on the interior of said annular member for defining the eddy current resistant electrode therewithin.

7. An infrared sensitive device comprising an envelope having a window for admitting infrared radiation, a target within the envelope mounted in the path of infrared radiation admitted through the window, electron beam generating means including a thermionic electron emitter spaced from the target, at least a portion of the space between the target and beam generating means providing a beam deflection region for accommodating a magnetic beam deflecting field for scanning said beam on said target, target heat extraction means extending from said target and adapted to be heat conductively coupled to refrigeration means for maintaining said target in a cooled condition for enhanced sensitivity to infrared radiation admitted through said window, and heat transfer means extending between said electron gun and said target heat extraction means, said heat transfer means including an annular electrically insulative heat conducting metallic oxide member surrounding the path of said electron beam in said beam deflection region, and a thin electrically conductive metallic coating on the interior of said annular member for defining an eddy current resistant electrostatic field-determining electrode therewithin, and heat conductive coupling means extending from said metallic oxide member and adapted to be heat-conductively coupled to refrigeration means.

References Cited

UNITED STATES PATENTS

3,082,340 3/1963 Schneeberger ------- 250—83.3

JAMES W. LAWRENCE, *Primary Examiner.*

P. C. DEMEO, *Assistant Examiner.*