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[54] **THERMAL IMAGE CONVERTERS**

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[58] **Field of Search** 250/338, 332, 333, 330, 250/334

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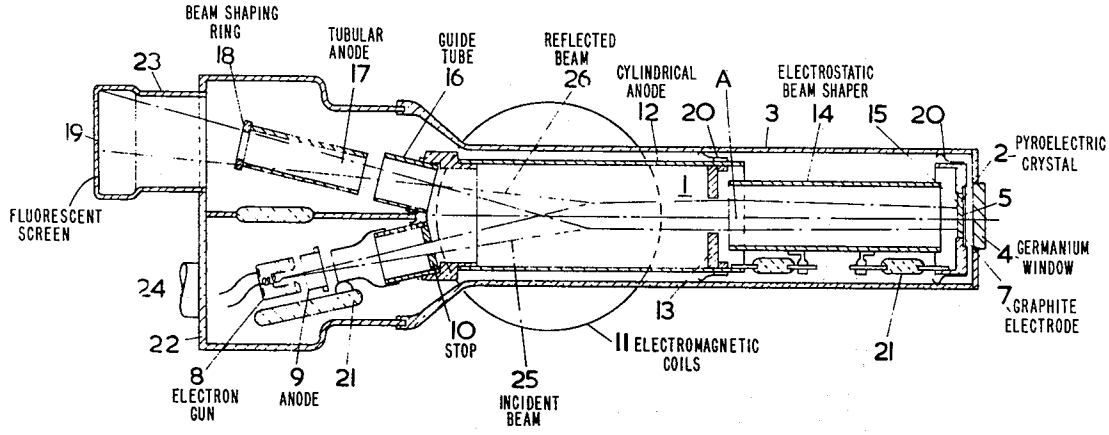
Primary Examiner—Harold A. Dixon

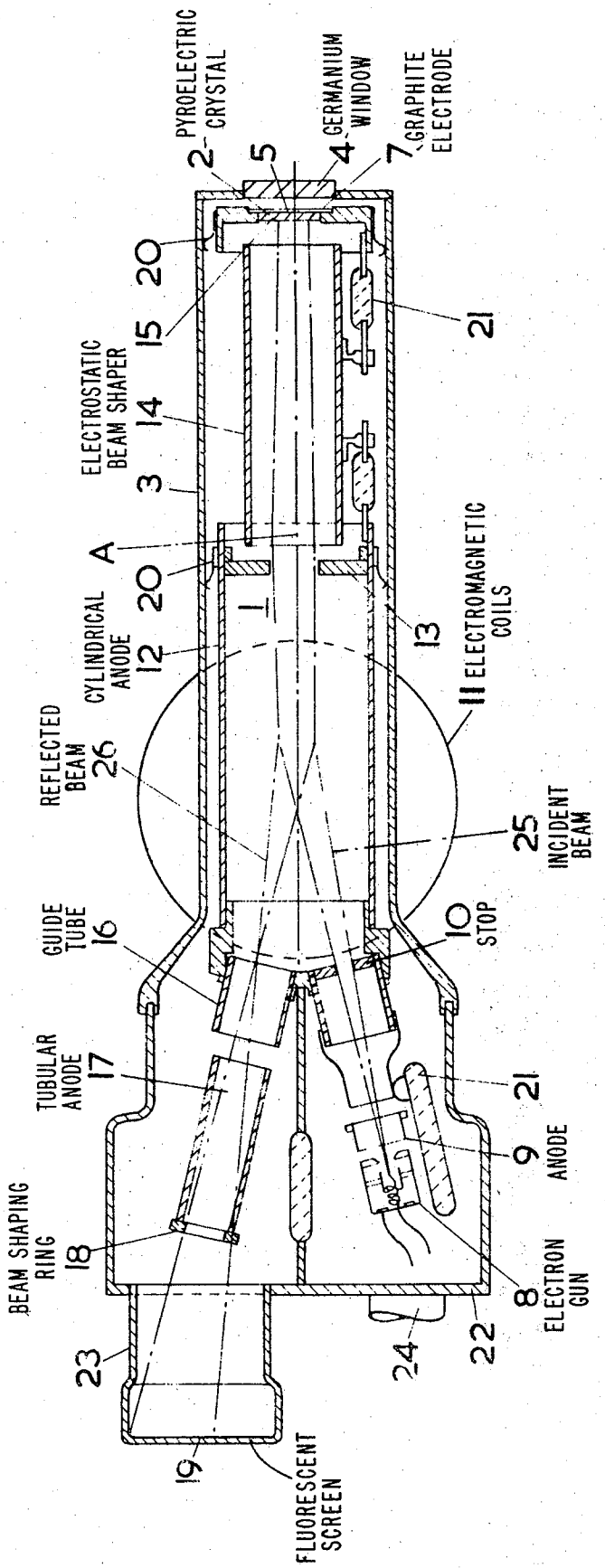
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[57] **ABSTRACT**

A thermal image converter comprises a slice of pyroelectric material to act as a reflector for an electron beam. Exposure of one face of the slice to a thermal scene induces a charge distribution over the other face of the slice corresponding to temperature gradients in the thermal scene. The charge distribution modulates and deflects electrons in an incident electron beam which may be viewed by directing the reflected beam onto, for example, a fluorescent screen. A practical construction of sealed-off tube is described.

17 Claims, 1 Drawing Figure




PYROELECTRIC CRYSTAL
2
GERMANIUM WINDOW
4
GRAPHITE ELECTRODE
7
5
20
15
21
ELECTROSTATIC BEAM SHAPER
14
3
A
20
1
CYLINDRICAL ANODE
12
13
ELECTROMAGNETIC COILS
11
REFLECTED BEAM
26
25
INCIDENT BEAM
GUIDE TUBE
16
10
STOP
TUBULAR ANODE
17
21
9
ANODE
BEAM SHAPING RING
18
8
ELECTRON GUN
23
24
22
19
FLUORESCENT SCREEN

THERMAL IMAGE CONVERTERS

This invention relates to thermal image converters.

Commonly thermal image converters comprise a pyroelectric vidicon. Such a vidicon comprises a slice of pyroelectrically sensitive material, such as triglycine sulphate, electrically connected to a back plate of nichrome which is itself mounted against a window of infra-red transmitting glass. In use, the tube is directed towards a thermal scene and a charge distribution is generated on the pyroelectrically sensitive material. The pyroelectrically sensitive material is scanned by an electron beam to produce a signal on the nichrome back plate. The back plate is connected to signal processing circuits to process the signal and display it upon a cathode ray tube. Such a thermal image converter is very bulky and heavy and is not suitable for use by individuals in a field situation having to be carried usually in a vehicle or the like. Such converters are also very expensive in requiring sophisticated ancillary equipment.

It is an object of the present invention to provide a thermal image converter in which a sight of a thermal scene is obtainable without the necessity to employ ancillary equipment as in the prior-art systems.

According to the present invention a thermal image converter comprises an elongate envelope disposed about a central longitudinal axis, a slice of pyroelectric material mounted towards one end of the envelope and having first and second substantially plane parallel faces disposed transversely to the envelope, a window transparent to the infra-red radiation to admit a thermal scene to the first face, an electron gun to direct an incident beam of electrons towards the second face, an electrode to induce a negative charge on the second face, said negative charge being operative to reflect electrons in the incident beam to form a reflected beam, a beam forming arrangement to form the incident beam to flood the second face, and a viewing means, whereby, in use, a thermal scene admitted to the second face induces a charge distribution according to the temperature distribution in the thermal scene to both modulate and deflect electrons in the reflected beam and the reflected beam strikes the viewing means to reproduce visually the charge distribution on the second face.

Preferably in a thermal image converter in accordance with the invention the electrode comprises a conducting layer on the first face of the pyroelectric slice and transparent to infra-red radiation.

Preferably in a thermal image converter as described in the preceding paragraph the electrode comprises graphite.

Preferably in a thermal image converter according to the invention the pyroelectric material is of single crystal tri-glycine sulphate.

Preferably in a thermal image converter in accordance with the invention the window comprises germanium.

Preferably the electron gun is mounted on an axis convergent with the longitudinal axis of the envelope, and the thermal image converter additionally includes a deflection means to direct electrons in the incident beam to a path coaxial with the longitudinal axis of the envelope and to divert electrons in the reflected beam to a path whose axis is divergent with the longitudinal axis of the envelope and which is the mirror image in the longitudinal axis of the axis on which the electron gun is mounted.

Preferably a thermal image converter as described in the preceding paragraph additionally includes a pair of opposed electromagnetic coils one mounted either side of the envelope on an axis normal to the longitudinal axis of the envelope.

Preferably a thermal image converter of the type described in either of the preceding two paragraphs additionally includes a tubular anode and a stop with a central aperture mounted coaxially with the elctron gun.

Preferably a thermal image converter as described above includes a guide tube, tubular anode, and beam shaping ring mounted in a coaxial relationship about the axis followed by the diverted electons in the reflected beam.

Preferably in a thermal image converter according to the invention the viewing means is a fluorescent screen.

The thermal image converter of the present invention provides a thermal image converter of high sensitivity without requiring the heavy ancillary equipments of the prior-art devices, as the viewing means may be mounted directly on the envelope. The saving in ancillary equipment provides a considerable cost advantage over known devices.

Provision of the electrode as a layer on the first face of the slice of pyroelectric material is particularly advantageous in that it achieves fine control upon the points of reflection of the electrons in the incident electron beam. Provision of a grid as the electode intermediate the electron gun and the slice of pyroelectric material, as used in the known prior-art pyroelectric vidicon does not produce the same level of clarity of image as the arrangement utilized in the present invention.

The resistivity of the slice of pyroelecric material is of importance. The high resistivity of single crystal triglycine sulphate has been found to be particularly suitable for use in the invention, although, of course, this would not preclude the use of other materials.

It has been found that the shape of the incident beam on its approach to the second face of the pyroelectric material is of great influence upon the clarity of the image obtained in the viewing means. The preferred arrangement of cylindrical anode and cylindrical beam forming tube may provide an incident beam of parallel or slightly convergent shape and has provided a thermal image converter of quite unexpectedly high sensitivity.

Mounting the electron gun and viewing arrangement off the longitudinal axis avoids the necessity of providing complex systems to obtain the requisite beam shapes and complex optical systems to view the scene; it also avoids the need to provide aperture arrangements in the viewing means to permit passage of the incident electron beam.

In order that the invention might be more fully understood and further features thereof appreciated, the following description will refer, by way of example only, to the accompanying single FIGURE which is a longitudinal section of a thermal image converter according to the invention:

In FIG. 1 a thermal image converter 1 comprises an elongate glass envelope 3 disposed about a central longitudinal axis A. A slice of single crystal tri-glycine sulphate 2 as the pyroelectric material is mounted towards one end of the envelope 3 and has a pair of plane parallel faces 5, 15, the central longitudinal axis A of the en-

velope being normal to the plane parallel faces **5, 15.** At the end of the envelope **3** adjacent the slice of single crystal tri-glycine sulphate **2** a germanium window **4** is provided to admit a thermal scene to one face **5** of the slice of tri-glycine sulphate. A convex thermally transparent lens (not shown) of, for example, germanium is used to focus the thermal scene on the face **5.** Towards the opposite end of the envelope **3** an electron gun **8** is mounted, in a manner as hereinafter described, to direct an incident beam of electrons **25** towards the second face **15** of the slice of tri-glycine sulphate **2.** The face **5** is coated with a thin layer of graphite to form an electrode **7** transparent to infra-red radiation in the thermal scene. In use the electrode **7** acts to induce a negative charge on the second face **15** of the slice of tri-glycine sulphate **2.** The induced negative charge on the second face **15** acts effectively as a mirror for the electrons in the incident beam **25** reflecting the majority to form a reflected beam **26.** The reflected beam is directed, in a manner as hereinafter described, to a fluorescent screen **19.**

The incident electron beam **25** floods the second face **15** of the slice of tri-glycine sulphate **2.** It has been mentioned that to obtain best results the beam forming arrangements should provide a parallel sided or slightly convergent beam shape in the approach to the second face **15.** The beam forming arrangements comprise the electron **8** mounted on an axis convergent with the longitudinal axis A of the glass envelope **3.** Electrons derived from the electron gun **8** are formed into a beam of conical shape by tubular anode **9** and stop **10** having a central aperture mounted coaxially with the electron gun **8.** The incident beam **25** thus formed is diverted to follow the longitudinal axis A of the glass envelope **3** by a pair of electromagnetic coils **11** mounted one either side of the glass envelope **3** on an axis normal to the longitudinal axis A. The incident beam then enters cylindrical anode **12** and subsequently passes through electrostatic beam forming tube **14** both of which are coaxial with the envelope **3.** The electrostatic beam forming tube **14** is mounted in overlapping relationship with the cylindrical anode **12** and is of lesser diameter. The combination of cylindrical anode **12** and electrostatic beam shaping cylinder **14** constrains the incident electron beam **25** to a parallel sided or slightly convergent beam shape before flooding the said second face **15.**

By virtue of the electrode **7,** the capacitance of the slice of tri-glycine sulphate **2,** and the few electrons which do land, a negative charge distribution is built up on the face **15** acting effectively as a mirror for the majority of electrons in the incident electron beam **25.** These reflected electrons form the reflected beam **26** and return through the beam shaping cylinder **14** and cylindrical anode **12** where the magnetic field of the electromagnetic coils **11** divert the return beam onto a path whose axis is the mirror image in the axis A of the axis whereon the electron gun **8** is mounted. The reflected beam **26** passes through a guide tube **16,** tubular anode **17,** and beam shaping ring **18** mounted in coaxial relationship about the axis of the path followed by the diverted reflected beam. A cross over point occurs in the reflected electron beam **26** in this region, whereafter the reflected electron beam diverges again to strike the fluorescent screen **19.**

The cylindrical anode **12** is maintained in position by spring tangs **20** bearing against the internal surface of glass envelope **3.** Other parts of the thermal image converter are held in position with respect to the tubular anode **12** by insulators **21.**

The glass envelope **3** is provided with a circular end plate **22** which is penetrated by two apertures, one of which retains a screen tube **23** at the extremity of which is mounted the fluorescent screen **19,** and the second aperture **24** retains electrical connections from a control panel (not shown) to the electron gun **8,** to the target electrode **7,** and the anodes **9, 12,** and **17** and the beam forming tube **14.**

Application of a positive potential to the target electrode **7** induces a negative charge distribution over the face **15** by virtue of the high resistivity of the slice of tri-glycine suphate **2.** An infra-red thermal image falling upon the face **5** of the target induces a charge distribution on the second face **15** corresponding to the image temperature distribution. This charge distribution both modulates the electron beam by reducing or increasing the small number of higher energy electrons in the beam which land on the target, and by deflecting those electons which are reflected. It will be appreciated that the potential gradients at the edges of thermal images will be greatest and consequently the deflections will be greatest; it will be seen therefore that the mechanism of electron deflection will generally give the outline of thermal bodies, whereas it is the mechanism of beam modulation which details the interior of the thermal body. When the reflected beam strikes the fluorescent screen **19,** the modulations and deflections of electrons in the beam serve to show visually the temperature distributions and gradients in the thermal scene.

For the sake of clarity the electrical connections to the various components of the thermal image converter shown have been omitted. However, as an example of the operational parameter involved, it has been found convenient to evacuate the interior of the glass envelope **3** to a pressure of 10^{-6} Torr before sealing. Typical potentials applied to anodes **9, 12,** and **17** have been 250 volts, 2,500 volts and 4,000 volts respectively. A potential of 1,000 volts is typical for the electrostatic beam shaper **14** and a potential of 4 volts for the electrode **7.** To provide the necessary degree of diversion for the incident beam **25** and reflected beam **26** in the field of the electromagnetic coils **11,** a field of **8** gauss was necessary, however this FIGURE would be very much dependant upon, for example, the relative inclination of the axis on which the electron gun is mounted to the longitudinal axis A.

When the thermal image tube is directed towards a stationary thermal scene, over a period of time the reduction or increase of electrons landing on particular portions of the target will equalize the charge distribution over the face **15,** and the thermal image will disappear from the fluorescent screen **19;** this can be overcome by either by manually moving thermal image converter about, or where this image is stationary, providing a chopper to modulate the scene.

Poling of the tri-glycine sulphate slice is no problem in the present invention, as in use the pyroelectric target has a field across it which will repole it during an initial "warming-up" period. However, should it be particularly desired, a separate means for providing rapid repoling of the target may be incorporated in the tube.

I claim:

1. A thermal image converter comprising:
a. an elongate envelope disposed about a central longitudinal axis;
b. a slice of pyroelectric material mounted towards one end of the envelope and having first and second substantially plane parallel faces disposed transversely to said envelope;
c. a window transparent to infra-red radiation to admit a thermal scene to said first face;
d. an electron gun to direct an incident beam of elecrons towards said second face;
e. an electrode comprising a conducting layer on said first face and transparent to infra-red radiation to induce a negative charge on said second face said negative charge to reflect electrons in said incident beam to form a reflected beam;
f. a cylindrical anode coaxial with said envelope,
g. a cylindrical beam forming tube coaxial with said envelope, of lesser diameter than said cylindrical anode, mounted in overlapping relationship with said cylindrical anode and in closer proximity to said second face than said cylindrical anode,
h. a viewing means;
whereby, in use, a thermal scene admitted to said first face induces a charge distribution on said second face according to the temperature distribution in the thermal scene to both modulate and deflect electrons in said reflected beam and said reflected beam to strike the viewing means to reproduce visually the charge distribution on said second face, and the incident electron beam passes through said cylindrical anode and said beam forming tube to be constrained to the required shape.

2. A thermal image converter according to claim 1 said electrode comprising graphite.

3. A thermal image converter according to claim 1 wherein the slice of pyroelectric material comprises single crystal triglycine sulphate.

4. A thermal image converter according to claim 1 wherein the window comprises germanium.

5. A thermal image converter according to claim 1 additionally including an end plate of the envelope, a tube maintained in said end plate and said tube receiving the viewing means.

6. A thermal image converter according to claim 1 wherein the viewing means comprises a fluorescent screen.

7. A thermal image converter comprising:
a. an elongate envelope disposed about a central longitudinal axis;
b. a slice of pyrolelectric material mounted towards one end of the envelope and having first and second substantially plane parallel faces disposed transversely to said envelope;
c. window transparent to infra-red radiation to admit a thermal scene to said first face;
d. an electron gun to direct an incident beam of electrons towards said second face, said electron gun mounted on an axis convergent with the longitudinal axis of the envelope,
e. an electrode comprising a conducting layer on said first face and transparent to infra-red radiation to induce a negative charge on said second face said negative charge to reflect electrons in said incident beam to form a reflected beam;
f. a cylindrical anode coaxial with said envelope,
g. a cylindrical beam forming tube coaxial with said envelope of lesser diameter than said cylindrical anode, mounted in overlapping relationship with said cylindrical anode and in closer proximity to said second face than said cylindrical anode;
h. a viewing means;
i. a pair of opposed electromagnetic coils one mounted either side of the envelope on an axis normal to the longitudinal axis of the envelope to divert electrons in the incident beam to a path coaxial with the longitudinal axis of the envelope and to divert electrons in the reflected beam to a path whose axis is convergent with the longitudinal axis of the envelope and which is the mirror image in the longitudinal axis of the axis on which the elctron gun is mounted;
whereby in use, a thermal scene admitted to said first face induces a charge distribution on said second face according to the temperature distribution in the thermal scene to both modulate and deflect electrons in said reflected beam and said reflected beam to strike the viewing means to reproduce visually the charge distribution on said second face, and the incident electron beam passes through said cylindrical anode and said beam forming tube to be constrained to the required shape.

8. A thermal image converter according to claim 7 additionally including a tubular anode and stop with a central aperture mounted coaxially with the electron gun.

9. A thermal image converter according to claim 8 additionally including a guide tube, tubular anode, and beam shaping ring mounted in coaxial relationship about the axis followed by the diverted electrons in the reflected beam.

10. A thermal image converter according to claim 9 additionally including an end plate of the envelope, a tube maintained in said end plate and said tube receiving the viewing means.

11. A thermal image converter according to claim 10 wherein the viewing means comprises a fluorescent screen.

12. A thermal image converter according to claim 11 wherein said electrode comprises graphite.

13. A thermal image converter according to claim 12 wherein the slice of pyroelectric material comprises single crystal triglycine sulphate.

14. A thermal image converter according to claim 13 wherein said window comprises germanium.

15. A thermal image converter comprising:
a. an elongate envelope disposed about a central longitudinal axis;
b. a slice of pyroelectric material mounted towards one end of the envelope and having first and second substantially plane parallel faces disposed transversely to said envelope, said pyroelectric material comprising a single crystal of tri-glycine sulphate;
c. a germanium window to admit a thermal scene to said first face;
d. an electron gun to direct an incident beam of electron towards said second face, said electron gun mounted on an axis convergent with the longitudinal axis of the envelope;
e. a tubular anode and stop with a central aperture mounted coaxially with said electron gun;
f. a cylindrical anode coaxial with said envelope;

g. a cylindrical beam forming tube coaxial with said envelope of lesser diameter than said cylindrical anode, mounted in overlapping relationship with said cylindrical anode and in closer proximity to said second face than said cylindrical anode;

h. a graphite electrode comprising a layer on said first face;

i. a pair of opposed elctromagnetic coils one mounted one either side of the envelope on an axis normal to the longitudinal axis of the envelope to divert electrons in the incident beam to a path coaxial with the longitudinal axis of the envelope and to divert electrons in the reflected beam to a path whose axis is convergent with the longitudinal axis of the envelope and which is the mirror image in the longitudinal axis on which the electron gun is mounted;

j. a guide tube, tubular anode, and beam shaping ring mounted in coaxial relationship about the axis followed by the diverted electrons in the reflected beam;

k. an end plate of the envelope, a tube maintained in said end plate, and a fluorescent screen mounted in said tube,

whereby in use, a thermal scene admitted to said first face induces a charge distribution on said second face according to the temperature distribution in the thermal scene to both modulate and deflect electrons in said reflected beam and said reflected beam to strike the fluourescent screen to reproduce visually the charge distribution on said second face, and the incident beam passes through said cylindrical anode and said beam forming tube to be constrained to the required shape.

16. A thermal image converter comprising an elongated envelope disposed about a central longitudinal axis; a slice of pyroelectric material mounted towards one end of the envelope and having first and second substantially plane parallel faces disposed transversely to said envelope; a window transparent to infra-red radiation for admitting a thermal scene to said first face; an electron gun for directing an incident beam of electrons towards said second face; a beam forming arrangement for forming said incident beam to flood said second face, said beam forming arrangement comprising a cylindrical anode coaxial with said envelope and a cylindrical beam forming tube, of different diameter than said anode, mounted in coaxial overlapping relationship with said cylindrical anode and in closer proximity to said second face than said cylindrical anode, the incident electron beam passing through said cylindrical anode and said beam forming tube to be constrained to a required shape; an electrode operative to induce a negative charge on said second face which negative charge reflects electrons in said incident beam to form a reflected beam; and a viewing means; whereby a thermal scene admitted to said first face induces a charge distribution on said second face according to the temperature distribution in the thermal scene to both modulate and deflect electrons in said reflected beam and said reflected beam strikes the viewing means to reproduce visually the charge distribution on said second face.

17. A thermal image converter comprising an elongated envelope disposed about a central longitudinal axis; a slice of pyroelectric material mounted towards one end of the envelope and having first and second substantially plane parallel faces disposed transversely to said envelope; a window transparent to infra-red radiation to admit a thermal scene to said first face; an electron gun operative to direct an incident beam of electrons towards said second face; an electrode for inducing a negative charge on said second face, said negative charge being operative to reflect electrons in said incident beam to form a reflected beam; a beam forming arrangement operative to form said incident beam to flood said second face; and a viewing means; said electron gun being mounted on an axis convergent with the longitudinal axis of the envelope and additionally including deflection means comprising a pair of opposed electromagnetic coils one mounted either side of the envelope on an axis normal to the longitudinal axis of the envelope, said deflection means being operative to divert electrons in the incident beam to a path coaxial with the longitudinal axis of the envelope and being operative to divert electrons in the reflected beam to a path whose axis diverges from the longitudinal axis of the envelope and is the mirror image relative to said longitudinal axis of the axis on which the electron gun is mounted, whereby, in use, a thermal scene admitted to said first face induces a charge distribution on said second face to both modulate and deflect electrons in said reflected beam, and said reflected beam strikes the viewing means to reproduce visually the charge distribution on said second face.

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