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Hurley et al.

[11] **3,830,970**

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[54] **AUTOMATIC INTENSITY CONTROL FOR PICTURE TUBE DISPLAY SYSTEMS**

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[52] **U.S. Cl.**..... **178/6.8**, 178/DIG. 2, 178/DIG. 8, 178/DIG. 26, 178/DIG. 36, 250/330, 250/334

[51] **Int. Cl.**..... **H04n 5/16**, H04n 7/18

[58] **Field of Search**... 178/DIG. 8, DIG. 5, DIG. 26, 178/DIG. 36, 6.8, DIG. 2; 250/83.3 HP, 217 CR, 330, 334

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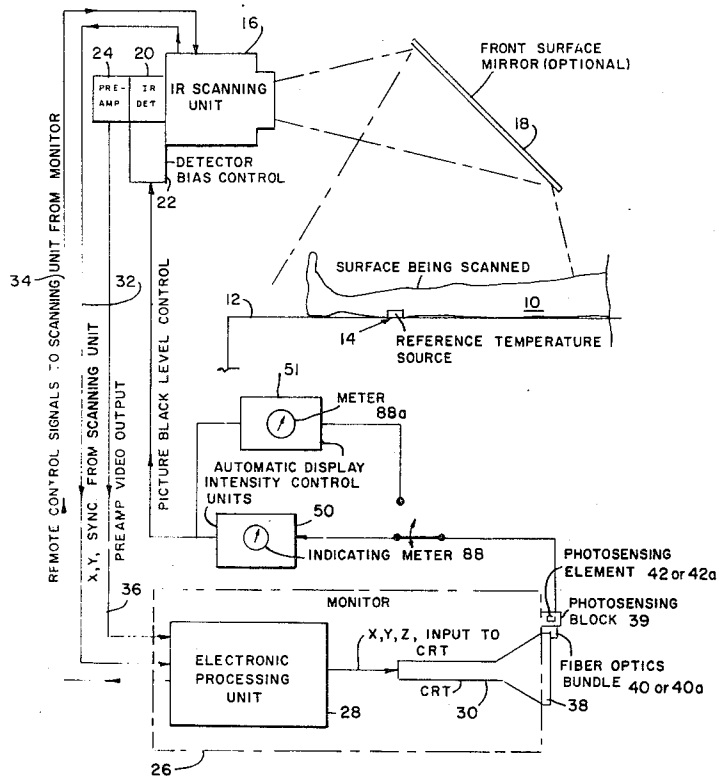
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Primary Examiner—Howard W. Britton
Attorney, Agent, or Firm—Irons, Sears & Santorelli

[57] **ABSTRACT**

An automatic display intensity control for picture tube, or cathode ray tube display systems, such as thermographic machines, has a feedback control means that is external to and independent of the picture tube system and that comprises fiber, or equivalent, optic means disposed against the surface of the picture tube screen within the area where a reference source is displayed for conveying reference display intensity signals to a photosensing element where input intensity control signals are generated and fed to an automatic display intensity control unit designed to accept the intermittent input intensity control signals from the photosensing element and to produce a reasonably stable output biasing potential that is used to maintain the screen intensity at a predetermined reference level setting.

17 Claims, 5 Drawing Figures



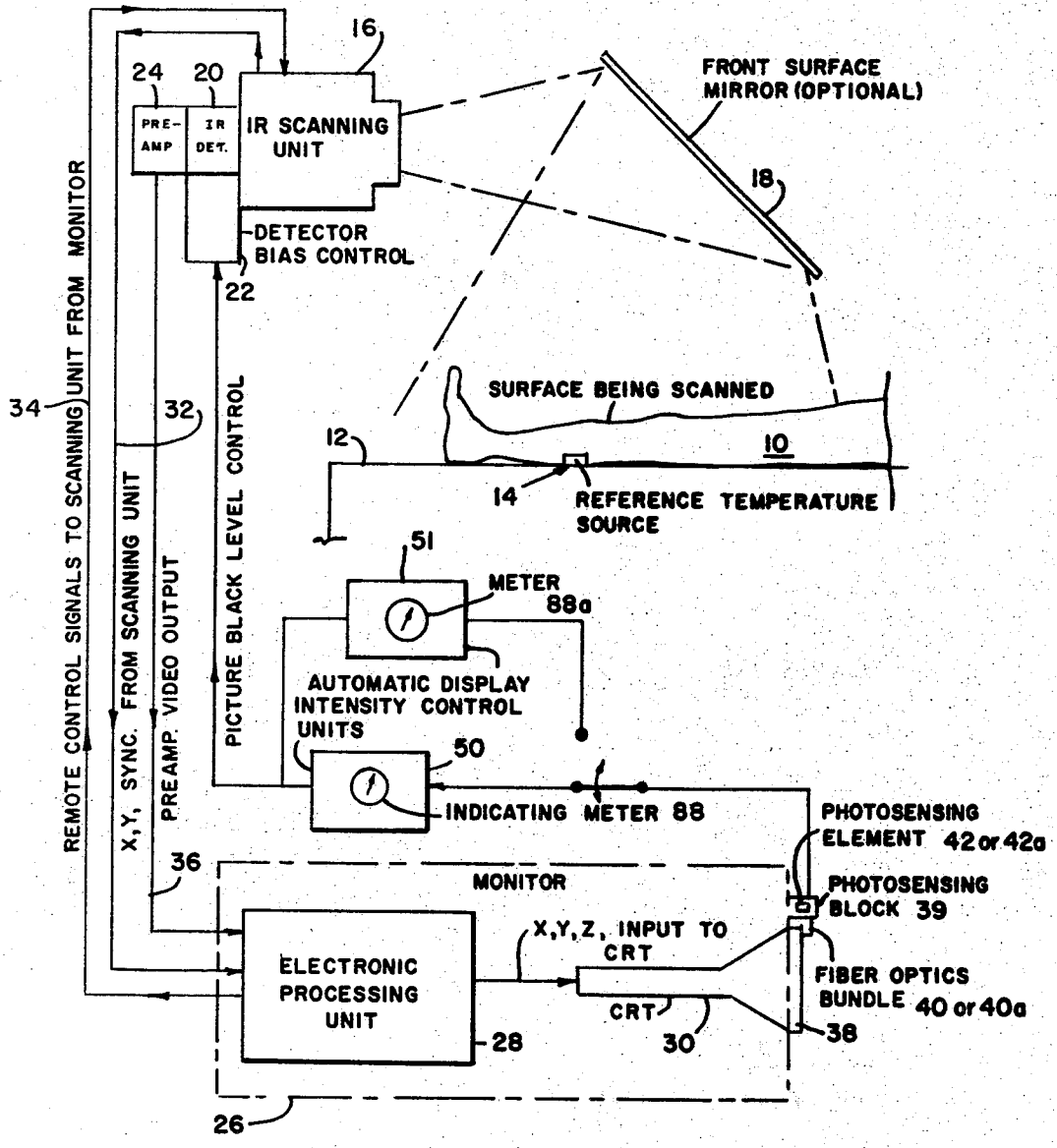
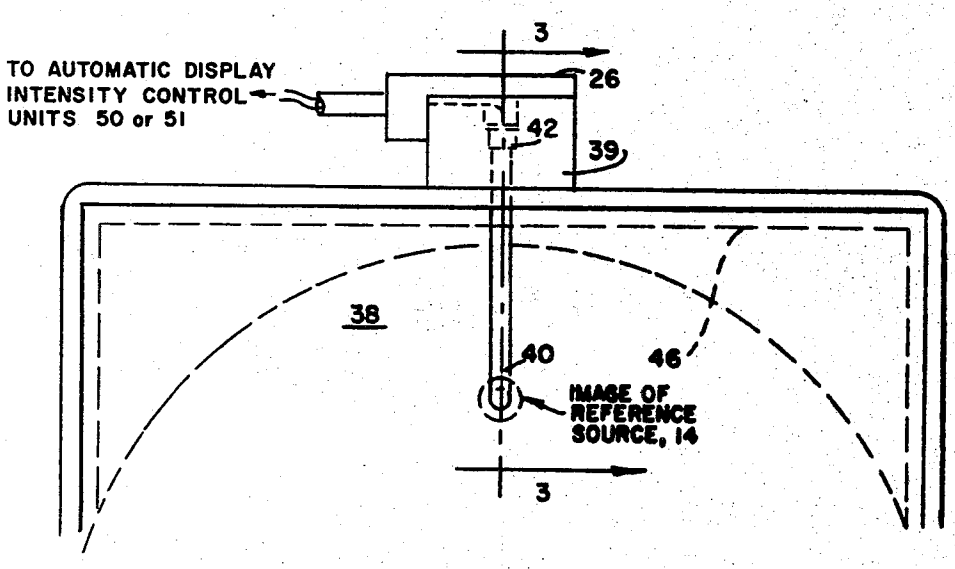

16
24
20
PRE-AMP
IR DET.
IR SCANNING UNIT
FRONT SURFACE MIRROR (OPTIONAL)
18
DETECTOR BIAS CONTROL
22
34
REMOTE CONTROL SIGNALS TO SCANNING UNIT FROM MONITOR
32
X, Y, SYNC. FROM SCANNING UNIT
PREAMP. VIDEO OUTPUT
PICTURE BLACK LEVEL CONTROL
SURFACE BEING SCANNED
12
10
14
REFERENCE TEMPERATURE SOURCE
51
METER
88a
AUTOMATIC DISPLAY INTENSITY CONTROL UNITS
50
INDICATING METER 88
PHOTOSENSING ELEMENT 42 or 42a
PHOTOSENSING BLOCK 39
36
MONITOR
ELECTRONIC PROCESSING UNIT
X, Y, Z, INPUT TO CRT
CRT
30
28
FIBER OPTICS BUNDLE 40 or 40a
38
26

FIG. 1

FIG. 2


TO AUTOMATIC DISPLAY
INTENSITY CONTROL
UNITS 50 or 51
3
26
42
39
38
40
46
IMAGE OF
REFERENCE
SOURCE, 14
3

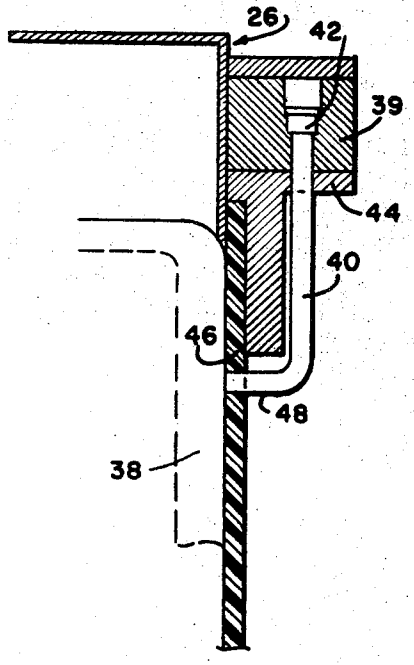

26
42
39
44
40
46
48
38

FIG. 3

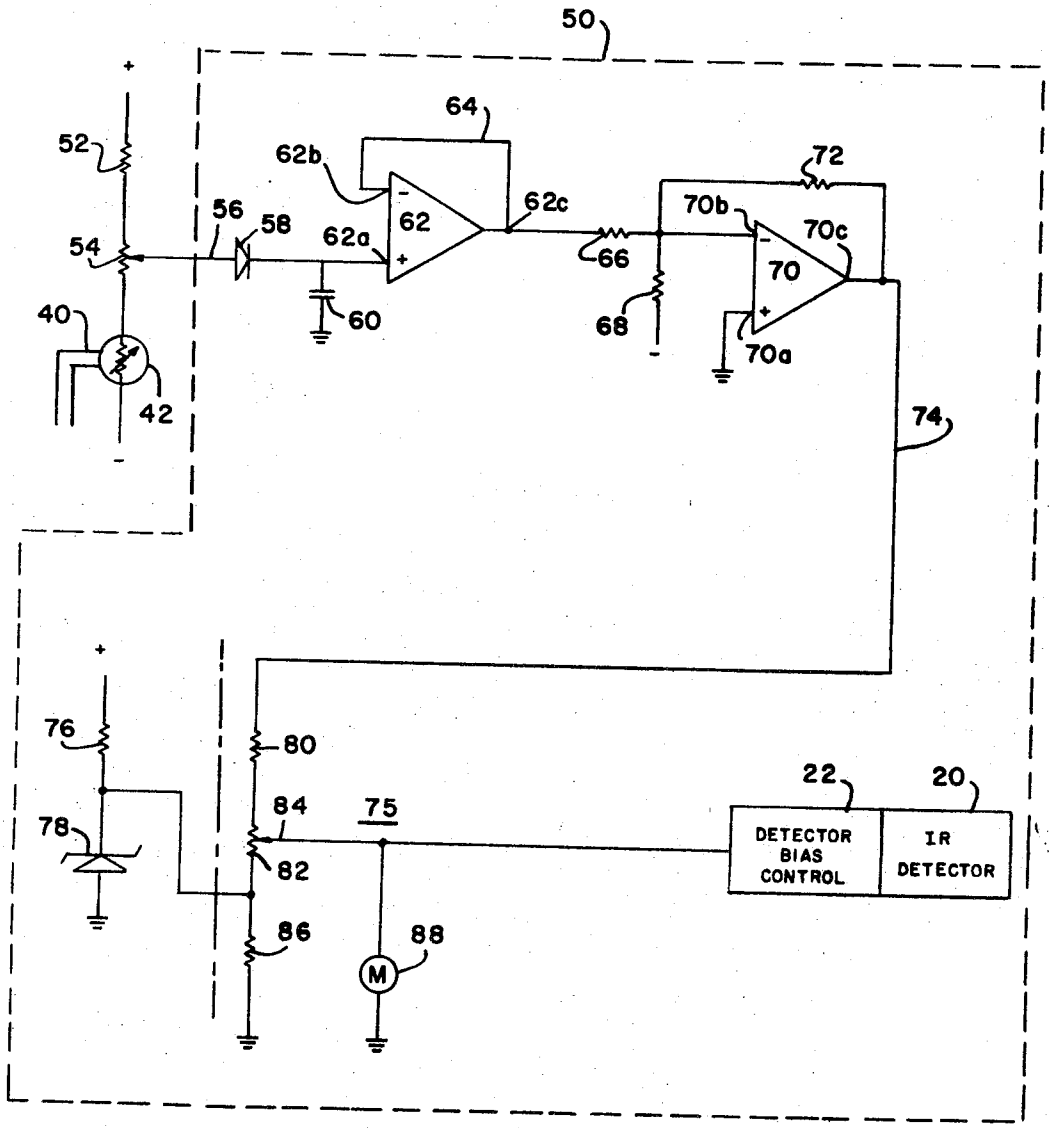

50
52
54
40
42
56
58
60
62
62a
62b
62c
64
66
68
70
70a
70b
70c
72
74
76
78
80
82
84
75
86
88
M
22
20
DETECTOR BIAS CONTROL
IR DETECTOR

FIG. 4

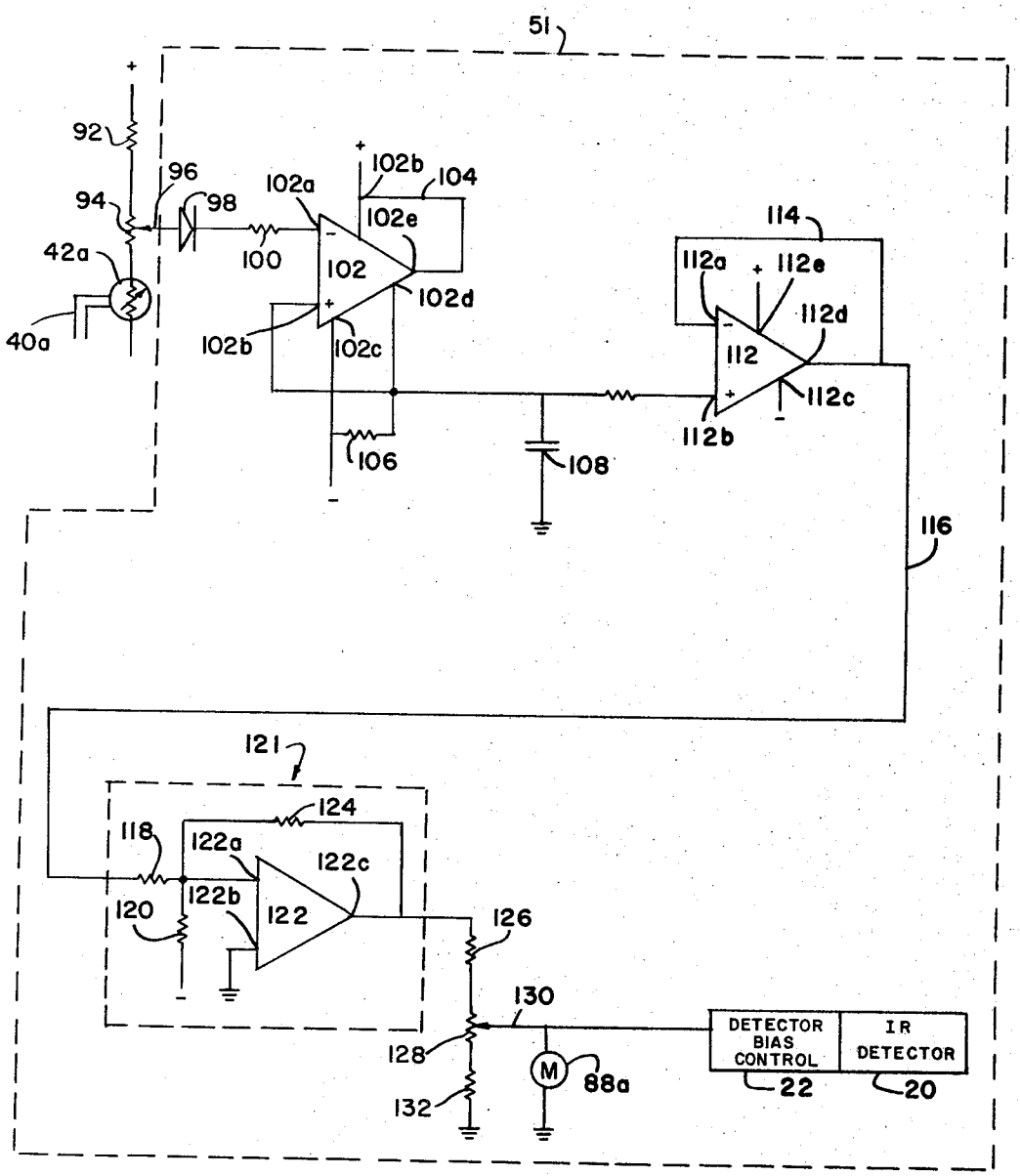

51
92
96
94
98
102a
102b
104
102e
100
102
102d
42a
40a
102b
102c
106
108
114
112a
112e
112d
112
112c
112b
116
121
124
118
122a
122c
120
122b
122
126
130
128
132
M
88a
DETECTOR BIAS CONTROL
22
IR DETECTOR
20

FIG. 5

AUTOMATIC INTENSITY CONTROL FOR PICTURE TUBE DISPLAY SYSTEMS

BACKGROUND OF THE INVENTION

1. Field Of The Invention

The present invention generally appertains to new and novel improvements in picture tube display systems and is especially directed to a new and novel apparatus for stabilizing the intensity on a picture or cathode ray tube display through an independent, external feedback system, and, in particular, for stabilizing the picture tube intensity in thermographic machines through an independent, external feedback system so as to effect the accurate display of quantitative temperature data.

2. State Of The Prior Art:

The problems of stabilizing the intensity of brightness of the displayed image on a picture tube screen in a system such as a closed circuit TV system are often relieved by the automatic pupillary reaction of the iris of the human eye. However, in systems where the maintenance of a consistent brightness of the displayed image is critical to obtaining meaningful results from the system, as where photometers are used for absolute or differential measurements or cameras are used for photographic recording, the iris of the eye is not present and/or competent to act as a buffer. A typical example of a system requiring very close and continuous control of the intensity of the display is found in thermography.

Thermography is a method for translating the information contained in a portion of the infrared spectrum to the visible; it permits graphic presentation of thermal data. The temperatures of the various areas of a surface being scanned are measured as a function of the intensity or brightness of the light from a picture tube monitor display the surface of interest. In practicing the thermographic method, an infrared sensing unit scans a surface and senses the infrared radiation emitted from that surface; the surface is then displayed on the screen of a picture tube monitor and the infrared radiations from the surface are used to modulate the intensity of the displayed image. The infrared energy emitted from a surface follows the Stefan-Boltzman Fourth Power Law, stated in a modified form in equation (1), as follows:

1.

$$W = \sigma \epsilon T^4$$

Where:

W = Radiant emittance (flux) per unit area (W/em^2)

σ = Stefan-Boltzmann constant (5.673×10^{-12} $W/(em^2)$ $(°K^4)$

ϵ = Emissivity (a numeric)

T = Absolute temperature ($°K$)

The thermographic method has been used to great advantage in both industrial and medical environments. Thermographic machines are used industrially for remote scanning of hot and cold objects in order to monitor temperature and detect faults in items such as power transformers, power insulators and insulated surfaces of refrigerated bodies and furnaces. Thermographic machines are used medically to monitor general and local body temperatures because variations in body temperatures have been found to be one indication of disease or abnormality.

The utilization of thermography in the medical field has many advantages such as the elimination of hazard to the patient, rapidity, and ease of frequent reexamination. As determined experimentally, the wave lengths of the radiations emitted by the human body are typically 2 to 20 micrometers; thus, medical thermography pertains to the infrared portion of the spectrum. Extensive tests have shown that the emissivity of the surface of the skin can be considered to be unity in the IR (infrared) region of the spectrum; that is, the body is considered to absorb and emit radiation like a true black-body. These and many other advantages have accelerated the use of thermography in the medical field.

Prior to 1969, the vast majority of scientific papers published on various phases of medical thermography concentrated on methods of detecting and locating breast tumors. However, in the more recent literature, a distinct change has been observed. Medical thermography is now used in conjunction with mammography and physical examinations to detect breast tumors. Statistical data indicate that the three methods must be used in a coordinated effort to reduce the false negative and false positive results found deriving from the use of any one of the examination methods alone. Medical thermography is also concurrently being used on many other areas such as the diagnoses of pulmonary disease, angina pectoris, cerebrovascular disease, cerebral circulation abnormalities, peripheral vascular disorders, carotid artery occlusions, local skin effects of corticosteroids, scleroderma, health screening, and abnormalities of the endocrine glands.

The clinical studies being conducted in many of the above mentioned and other areas require accurate quantitative results; that is, the thermographic machines utilized in these diagnoses must provide for accurate measurement of temperatures. By referring to equation (1) above, it will be evident that the radiant energies emitted by the human body, at normal body temperatures, are of very low intensities. Furthermore, while a change of 1°C in body temperature is diagnostically significant medically, the change in the amount of emitted radiation involved in a body temperature change of 1°C. is minuscule in the physical sense; thus, in order to provide a thermographic machine that is useful for medical purposes, a very stable and sensitive system must be developed.

Present thermographic machines utilize an optical system to focus successive areas of the surface to be measured onto an IR detector. The IR signals are greatly amplified and are then presented in the same sequence on the screen of a picture tube such as a CRT; the CRT image may then be visualized, photographed, or measured. A sensitivity range for the particular machine and surface temperatures expected is selected, and then the operator must adjust the picture black level to bring the image of the areas of interest within the limits of the grey scale of the CRT. The grey scale represents various levels of luminance from black to white on the CRT for the temperatures within the sensitivity range selected. Temperatures below the range selected will not be displayed and temperatures above the selected range will be displayed on the screen as a saturated white. Customarily, brighter spots on the CRT represent the warmer regions of the scanned objects; of course, the converse may easily be accomplished electronically. Images may also be dis-

played as a series of colors corresponding to different temperatures. To make quantitative measurements possible, a small test object of known temperature and of unity emissivity (a black body) is introduced into the same field as the surface to be scanned thereby permitting comparative densitometry.

The problems in maintaining such a machine sufficiently stable for quantitative and reproducible measurements are well known to those familiar with the art; and these same problems stand in the path of the clinician trying to obtain quantitative diagnostic measurements. Many of these problems are related to the present state of the art of IR detectors and amplifiers used in thermographic machines. Some IR detectors are capable of detecting and utilizing only a relatively small percentage of the entry emitted by the skin. The large gain in the amplification required in converting the radiated energy into a display makes the system very susceptible and sensitive to system drift. The slight shift in the sensitivity of the detector or other component of the system will also result in a change in the intensity of the display with respect to the temperature of the surface being scanned. Thus, the detectors and amplifiers presently used in thermographic machines do not retain a specific level of the gray scale to permit quantitative measurements. For example, when A.C. amplifiers are used, the black level of the image will shift as the temperature and/or the area being scanned changes. When D.C. amplifiers are used, a continuous drifting of the black level is experienced.

Several techniques have been devised to reduce or compensate for these intensity stability difficulties in thermographic machines with varying degrees of success. Automatic brightness controls have been developed and are currently being used. One automatic brightness control technique depends upon the amplitude of the signal received for the warmest area of the surface being scanned; but this technique does not show the relationship of the intensity of the display with respect to the temperature of the surface unless a relatively high temperature source is placed within the area being scanned. Quantitative measurements are still questionable due to drifting within the components of the automatic brightness control; and shifts in the sensitivity of the IR detector its related components would not be compensated by a change in the brightness level of the display.

A second currently used technique for controlling the intensity of a thermographic display involves frequent and periodical recalibration of the thermographic machine using a recording photometer and one or more temperature reference objects. Experimental data indicates that systems utilizing a periodic recalibration technique do not follow any given pattern of drift from one calibration to the next. Thus, the recalibration process may be a relatively short and simple task or it may involve numerous and tedious procedures.

A third technique for controlling the intensity comprises the continuous scanning of temperature reference objects which are built into the IR camera. This technique has several questionable areas such as (1) possible differences in the optical and electronic systems used to scan the patient and the reference objects; (2) the differences in attenuation of the energy when the patient is scanned from various distances; and (3) the use of auxiliary front surface mirrors can introduce unequal optical paths which have been known to cause clinically intolerable errors of 1.0°C.

In currently used thermographic machines, the intensity of the image on the screen is usually controlled by adjusting a bias voltage on the IR detector. When the typical Indium Antimonide (InSb) or HgCdTe IR detector is in an uncooled condition it can be considered to be a short circuit. However, when the temperature is lowered to −196°C with liquid nitrogen in the required and known fashion, the detector assumes the characteristics of a diode. Two or more biasing sources are generally used to maintain a zero potential across the detector when the camera is viewing a background of a given temperature.

When the temperature of the background is changed, the biasing potential must also be changed to maintain the null signal from the detector. To compensate for changes in background temperature, one fixed biasing source is usually built into the detector preamplifier. The preamplifier is usually adjacent a dewar retaining the liquid nitrogen and the dewar serves as a mounting block for the detector. Various types of drift compensators and automatic zero biasing circuits are often added in the preamplifier circuit. However, a manual control, referred to by many manufacturers as the "picture black level" control, is used by the operator to adjust the intensity of the display. This manual intensity control and the one or more biasing circuits on a thermographic machine are connected directly to the detector, the control requires less than a 40 millivolt change in the biasing potential to shift the intensity of the screen from black to a saturated white.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide an automatic and continuous intensity stabilization control for a picture tube, such as a cathode ray tube, in a way to overcome the aforementioned and other drawbacks attendant with known picture tube stabilizing apparatus and in a manner to maintain a consistent brightness level on the screen of a picture tube displaying an image.

Another important object of the present invention is to provide an independent, external feedback control for a picture tube display system for automatically and continuously maintaining a consistent brightness on such picture tube.

A further important object of the present invention is to provide an independent, external feedback control for a picture tube monitor in a thermographic machine so as to accurately control the intensity of the display and thereby allow quantitative temperature measurements to be obtained.

Another important object of the present invention is to provide a picture tube feedback control wherein one end of a fiberoptic light bundle, or equivalent optical means, having an angular bend is positioned against the tube screen in an area where a reference source is displayed and the other end of the light bundle is positioned adjacent a photosensing element in the feedback path, in a manner to permit an external feedback control to maintain the black level setting of the tube display without obstructing the view of the displayed image.

Further important objects of the present invention are to provide external feedback control circuits for

use with thermographic machines having relatively high frame rates or having relatively low frame rates.

Broadly stated, the apparatus of the present invention comprises a picture tube display having an external feedback control including light sensing means for monitoring the image brightness at a preselected reference spot on the tube screen, and means for adjusting the brightness of the image in relation to the brightness of such reference spot.

More specifically considered, a thermographic machine has an infrared scanning device for scanning a surface of which the temperature is to be measured. A reference temperature source is disposed adjacent the scanned surface. A picture tube displays the scanned surface. One end of a fiber optic light bundle, having an approximately 90° bend therein, is disposed against the front surface of the picture tube screen within the area where the reference temperature source is displayed. The other end of the light bundle is disposed adjacent a photosensing element which is connected to an automatic display intensity control unit. An infrared detector is disposed adjacent to the scanning unit to generated video signals representative of temperature of the surface. The video signals are fed to the picture tube to control the intensity of the image displayed thereon. The IR detector has a bias control which determines the magnitude of the video signal fed to the picture tube. The intensity control unit generates a signal which is used to control the bias level of the IR detector and to thereby control the intensity of the image displayed on the picture tube. Thus, the temperatures or the surface being scanned appear as a function or the brightness or intensity of the displayed image.

While this invention has been particularly described in connection with its use in thermography, it is to be distinctly understood that this system may be used with equal facility in fields other than those relating to thermography, thus, in any discipline where monitoring is used and a reference source can be supplied on the screen.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating the automatic intensity control apparatus of the present invention used to stabilize the intensity of the picture tube display in a thermographic machine.

FIG. **2** is a broken elevational view illustrating the fiber optics light bundle of the automatic intensity control apparatus mounted on a picture tube.

FIG. **3** is a vertical cross-sectional view taken substantially on lines **3—3** of FIG. **2** so as to further illustrate the fiber optics light bundle mounted on a picture tube.

FIG. **4** is a schematic diagram of the circuit of the automatic intensity control unit of the present invention adapted for use with thermographic machines having relatively high frame rates.

FIG. **5** is a schematic diagram of the automatic intensity control unit adapted for use with thermographic machines having relatively low frame rates.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now more particularly to the accompanying drawings and initially to FIG. **1**, the automatic intensity control apparatus is illustrated as being applied to a thermographic machine which is shown in use for displaying the temperatures at the surface of a human leg **10** disposed on a platform **12.** The use of a thermographic machine with a human limb is for illustration purposes only, and it must be remembered that the apparatus functions equally well with other types of display systems and with animate and inanimate masses.

A temperature source **14** is disposed adjacent the leg **10** and functions as a temperature reference. An infrared sensing unit **16** scans the leg **10** to pick up the radiant energies emitted by the leg. The IR scanning unit **16** can scan the leg **10** directly or an optional front surface mirror **18** may be used.

The IR energy emitted by the leg **10** and picked up by the IR scanning unit **16** is fed to an IR detector **20** where video signals indicative of the temperatures present on the leg surface are generated. A detector bias control **22** determines the relationship between the magnitude of the IR signals received at IR detector **20** and the amplitude video signals generated by the IR detector. The video signals control the intensity of the image displayed on the CRT, as described below. A preamplifier **24** can be used to amplify the IR detector output as required.

A display monitor **26** includes an electronic processing unit **28** and a picture tube in the form of a CRT **30.** The electronic processing unit **28** contains circuitry for receiving the X- and Y- axis sync signals via an electrical connector **32** from the scanning unit **16** and for feeding these sync signals to the CRT **30.** Further, the electronic processing unit **28** remotely and electronically controls operation of the scanning unit **16** through the electrical connection **34.** The electronic processing unit **28** also receives the video signal via an electrical connection **36** and feeds the video signal in sync with the X- and Y- axis signals to the CRT **30,** where the video signal is used to intensity modulate the electronic beam of CRT **30.**

The CRT **30** has a display screen **38** where an image of the leg **10** is displayed. The scanning beam of the CRT **30** is driven in sync with the X- axis and Y- axis scanning signals of the scanning unit **16** and the video signal from the IR detector **20** is used to intensity modulated the CRT election beam so that areas of the leg **10** having a higher temperature relative to other areas will appear brighter on the display screen **38.** The video signal, in effect creates a third, or Z- axis, by intensity modulating the electronic beam of the CRT **30**; as explained above, the intensity of the displayed image represents the temperature of the leg **10.**

As best illustrated in FIGS. **1, 2** and **3,** one end of a fiber optics light bundle **40** is mounted adjacent the CRT screen **38** by means of a photosensing mounting block **39,** a monitor bezel **44** and a CRT transparent graticule **46.** This one end of the light bundle is positioned on the CRT screen **38** where the reference temperature source **14** is displayed; the constantly mounted image of the temperature reference source provides a stable frame of reference for temperature measurements relative to that absolute setting. The light bundle **40** has an approximate 90° bend **48,** and the other end of the light bundle is disposed adjacent a photosensitive element **42.** The use of the light bundle **40** allows the photosensing element **42** to be shielded from spurious magnetic and electric fields of the CRT **30.** By using a light bundle having a 90° bend therein, any obstruction to the CRT screen **38** is re-

duced to a minimum by the offset photosensing unit; and any screen obstruction is limited to a small portion of the screen area wherein the reference temperature source is displayed. Further, use of the fiber optic light bundle to convey light from the face of the CRT to the photosensor reduces the effect of extraneous light signals; and permits minimal vignetting of the image.

The photosensing element **42** generates a signal that is related to the brightness or intensity of the image on the screen **38** in the area of the reference temperature source **14.** This signal from the photosensing element **42** serves as the input to an automatic display intensity control unit **50.** The intensity control unit **50** is designed to accept the intermittent input signals caused by the scanning action of the scanning unit and to produce a stable output biasing potential which is used to maintain the screen intensity at a predetermined level. The intensity control unit **50** is designed to be adaptable to suit the basic characteristics of the make and model of any thermographic machine on which it is to function. FIG. **4** illustrates a schematic diagram of the circuit of this invention that has been found to function successfully on thermographic machines having relatively high frame rates.

One existing machine scans at the rate of 100 lines per frame, with 16 frames per second. This combination produces 1,600 lines per second and results in five signals from the temperature reference source during each frame, or about 80 reference signals each second. Actually, the reference signals are received at the photosensing element **42** in bursts, with 16 bursts per second and five signals per burst at a frequency of 1,600 lines per second. In selecting a photosensing element **42,** for a thermographic machine having these operating characteristics, the frequency of the signal is but one of several factors that must be considered; the color of phosphorescence and the persistence of the CRT display also play an important part.

The relatively high frequency of signals used in the above mentioned machine allows a cadmium sulfide photoconductor having a relatively slow decay rate to be used, and eliminates the necessity of using clamping circuits. The photoconductor **42** chosen is color matched to the CRT screen phosphor and has a sufficiently short time constant to permit recovery by the automatic display intensity control unit **50** before subsequent frames occur.

In FIG. **4** an automatic display intensity control unit **50** useful with thermographic machines having relatively high frame rates is illustrated. The photosensing element **42,** which can be a cadmium sulfide photoconductor is connected in series with a 22K/ohm resistor **52** and a 20K/ohm potentiometer **54** across a source of biasing potential as illustrated. A movable tap **56** on the potentiometer **54** connects through a diode **58** to an input capacitor **60** and to one input **62***a* of an operational amplifier **62.** The primary design consideration for the capacitor **60** is that the capacitor, for the frequencies involved, retain the biasing potential at an acceptable level between signal bursts.

The operational amplifier **62** has a feedback line **64** connected between its output **62***c* and a second input **62***b*, and further has its output **62***c* connected through a resistor **66** (47 K/ohm) to one input **70***b* of a second operational amplifier **70.** A second operational amplifier input **70***a* is connected directly to ground; and the input **70***b* is connected to a source of negative potential (−) through a resistor **68** (47 K/ohm). A resistor **72** (68 K/ohm) is connected to a feedback path from an output **70***c* to the input **70***b* of the operational amplifier **70.** The 68 K/ohm value of the resistor **72** may require changes depending upon the CdS cell and the required gain of the feedback unit. The output **70***c* of op amp. **70** is connected through a line **74** to an output stage indicated at **75.** The line **74** connects through a resistor **80** (500 ohms), a potentiometer **82** (1 Kohm) and a resistor **86** (500 ohm) to ground. A movable output tap **84** connects to a meter **88** and to the IR detector bias control **22.**

An optional circuit comprising a resistor **76** and a zener diode **78,** connected in series between a positive source of potential and ground, can be used to provide a reference to the lowest potential required for saturating the screen **38.** In the optional circuit, the junction between the resistor **76** and the zener diode **78** is connected to the junction between the potentiometer **82** and the resistor **86.** The two potentiometers **54** and **82** are only required for purposes of initially balancing the intensity control unit **50.** After the output of the intensity control unit **50** is adjusted to meet the requirements of an individual thermographic machine, the potentiometers **54** and **82** may be replaced with resistors.

The output of the intensity display control unit **50,** illustrated in FIG. **4,** produces a ripple of less than 0.2 millivolts when applied to the aforementioned existing machine. This is equivalent to 0.5 percent of the total black-to-white biasing potential of the IR detector **20.**

The addition of the galvanometer **88** at the output of the automatic display intensity control unit provides several advantages including: (1) indicating the need for any adjustments in the capacitance **60** chosen for the circuit; (2) allowing the biasing potential and the light-to-dark ratio of the display to be adjusted to meet the requirements of the system to which the automatic display intensity control unit is to be applied prior to installation; and (3) serving the function of the photometer which may normally be used in such a system.

A review of the operating characteristics for each type of currently marketed thermographic machine revealed that the scanning rates employed therein varied from 75 to 600 lines per frame, with frame rates from two-thirds (2/3) frames per minute to 60 frames per second. This broad range of scanning characteristics would cause the input signal to the intensity control circuit **50,** illustrated in FIG. **4,** to vary from 0.011 bursts per second, five signals per burst at a frequency of 1.0 signals per second; to 60 bursts per second, five signals per burst at a frequency of 6,000 signals per second. The low rate of 0.011 bursts per second obviously requires a different approach to automatic control of the intensity of the screen image than the solution provided by the automatic display intensity control unit **50** illustrated in FIG. **4.**

Since the sensitivity of the IR detector biasing potential is critical, one approach to the problem of the thermographic machines having low frame rates (longer periods between bursts) would be to use clamping circuits in the design of the intensity control unit **50.** However, because of the relative complexity of clamping circuits, an operable and satisfactory intensity control unit for thermographic machines having low frame

rates was designed utilizing a voltage comparator having low input currents. A schematic diagram of this low frame rate intensity control circuit is illustrated in FIG. 5.

With particular reference to FIG. 5, an automatic display intensity control unit 51 for use with thermographic machines having relatively low frame rates is illustrated. A series circuit includes resistor 92, a potentiometer 94, a photosensitive element 42*a* and a 15 volt source. Intensity related light signals are conveyed to the photosensitive element or photosensor 42*a* by a light bundle 40*a* so that the conductance of the photosensor 42*a* is varied causing a varying input signal to be picked up by the movable potentiometer tap 96. The movable tap 96 is connected through an input diode 98 and resistor 100 (2 K/ohm) to the input 102*a* of a voltage comparator 102.

The terminal 102*b* of the voltage comparator is connected through a resistor 106 (1 Meg ohm) to a terminal 102*c* which is also connected directly to a potential of minus 15 volts. A terminal 102*d* is connected directly to the terminal 102*b*. The terminals 102*e* and 102*f* are connected to a 15 volt source of positive potential. The terminal 102*b* is further connected through the capacitor 108 to a ground and through the resistor 110 (10Kohm) to a terminal 112*b* of a voltage follower 112.

The voltage follower 112 and the connections shown are for a typical can package. The terminals 112*c* and 112*e* are connected to 15 volt negative and potentials, respectively. The terminal 112*a* is connected through internal feedback line 114 to the output terminal 112*d*. The output terminal 112*d* of the voltage follower 112 is connected through the line 116 to an additional amplification circuit shown at 121. This additional amplifier stage 121 is optional; additional amplification may be needed on some thermographic machines if a gain of a greater than unity is required. The amplifier 122 used in the circuit 121 may be an operational amplifier type, or equivalent unit. The resistors 118, 120 and 124 are chosen to so that the desired gain is provided. An output stage for the automatic display intensity control comprises a resistor 126 (500 ohm) in series with a potentiometer 128 (1 K/ohm) in series with a resistor 132 (500 ohm) which is connected to ground. A movable tap 130 is connected through a galvanometer 88*a* to ground and directly to the detector bias control 22.

In the control unit 51 designed for low frame rate thermographic machines, the capacitor 108 of the peak detector is located at the output of the voltage comparator 102. The potential of the capacitor 108 is also the input to the voltage comparator 112 which requires an extremely low input current. Depending on the characteristics of the particular thermographic machine, the output of the voltage follower may be connected directly to the IR detector biasing control with appropriate voltage dividers to suit the individual make and model of the machine. Experimental test results with this design indicate the desirability of having the gain of the circuit to approach unity. Therefore, if the output voltage of the photosensing element 42*a* and the slope of the intensity curve of the machine do not meet the requirements of the biasing circuit, it may be necessary to add an additional stage of amplification as illustrated at 121 in FIG. 5.

The maximum input current of the voltage follower 112 in FIG. 5 is 10 nanoamperes, and the maximum output leakage current of the voltage comparator 102 is 50 nanoamperes. In view of these relatively low magnitudes, the time constant in seconds of the voltage follower can be considered to be equal to the value of the capacitor 108 in microfarads if the one (1) megohm resisotr 106 is used. Experimental tests on this circuit, using capacitors as large as 50 microfarads, were conducted and the relatively large capacitances were found to function satisfactorily. Further, it is often found desirable to include a booster stage between the voltage comparator 102 and the voltage follower 112 when currents larger than 5 milliamps are involved.

Experiments with the circuit of FIG. 5 indicate that it is a true peak follower within the frequency range of 1Hz to 100Khz. This feature and the unity gain throughout this frequency range make a circuit of this type ideal for CRT intensity control providing the appropriate capacitor is selected for the frequency of the input signals to retain the biasing potential at an acceptable level between bursts. The term true peak follower is used to emphazise the excellent ability of this circuit to follow, without a change in gain, the peak values of the input signals over a broad band width.

An oscilloscope can be used in the initial design of the automatic display intensity control units 50 or 51 presently described. By using the output of a signal generator as the vertical input to the scope and adjusting the frequency to the appropriate value, and by setting the full horizontal sweep rate of the oscilloscope equal to the number of frames per second of the thermographic machine to be controlled, the oscilloscope pattern can be made the equivalent of a picture display to the photosensing element. In monitoring the output of the automatic display intensity control unit under these conditions, differences in the color and persistance of the phosphors on the CRT and the oscilloscope must be considered. Generally, the persistence of the phosphors on the CRT screen to be controlled will be longer than the persistence of the oscilloscope phosphors.

A galvanometer, placed at the output of either of the automatic display intensity control units, as at 88 or 88*a*, when the photosensing element is monitoring a reference area on a CRT screen or a test pattern on an oscilloscope, will serve as an indicator of the excellent stability of this design. The galvanometer also indicates the need for any adjustments in the capacitance chosen for the circuit. Further, the galvanometer allows the biasing potential and the light-to-dark ratio to be adjusted to meet the requirements of the thermographic machine to which the automatic display intensity control unit is to be applied prior to installation. The automatic display intensity control units with the galvanometers will serve as an excellent photometer.

In a prototype design of the automatic display intensity control units, a section of methyl methacrylate rod was used for piping the light from the CRT screen to the photosensing element. This preliminary circuit design required another stage of amplification and complete shielding of the light pipe from the ambient room lights. After installing the fiber-optics light bundle, the gain required in the circuit shown in FIG. 4 was slightly greater than unity with the CdS photoconductor, and, the shielding of the ambient light became less critical. The energy loss through the glass fiber-optics light bundle used as described is less than 1 watt per 50 feet. Less than 3 inches of rod are required for the design of the automatic display intensity control units disclosed.

The fiber-optics light bundle finally selected is an image conduit consisting of 71,000 fibers formed into a 0.317 CM diameter light rod bundle.

The necessity for an extremely sensitive output from the automatic intensity display control unit requires a very high signal-to-noise ratio. Although the damping features of the control unit are advantageous, the source of power for the circuit is very important. The power requirement for both the control unit of FIG. 4 and FIG. 5 is 75 MW. If this small quantity of power required can be supplied by the power supply of the machine to be monitored, the use of zener diodes with adequate blocking of any noise or feedback will serve as an excellent power supply. If an external power supply is used, the reference grounds must be firmly united and remote; and potential-sensing circuits should be included as a built-in feature of the external supply.

In reviewing the schematic diagrams of several existing types of thermographic machines, a series of resistors with two or more capacitors were found in the manual intensity control circuit. Since the automatic intensity control units disclosed herein will act as an external feedback direct to the IR detector, a delay in the response of the system caused by damping in the transmitting line will create hunting and produce cycling in the intensity of the screen. The period of the cycling will be proportional to the damping in the transmitting line. It was found advantageous to connect the output of the automatic intensity control unit directly to the detector with a resistance in series to avoid possible damage. A selector switch was used to remove the existing manual control circuit completely from the detector when the automatic control unit was so directly connected.

The use of the automatic display intensity control units disclosed herein: (1) eliminates the shift in the datum plane of the gray scale as the temperature and/or the area of the scanned surface changes when A.C. amplifiers are used in scanning-monitoring systems; (2) compensates for the continuous drifting commonly found in D.C. amplification; (3) allows consistent photographs of the CRT screen which are representative of the quantitative values of the areas being scanned; (4) eliminates adjusting the black level "by eye" which introduces erroneous measurements and does not allow photographs to be of consistent exposure; (5) automatically compensates for the effects of changes in line voltages, the decay of the response of the surface of the monitor screen, and the changes in the response of the detector and interface components; and, (6) compensates for changes in the ambient temperatures.

Although this invention has been disclosed and described for use with thermographic machines, it is directly applicable to other types of remote visual display systems where the level of the luminance of the screen is important. The photographing of a monitor on a TV or CCTV system is a typical example. The basic principles of this device are also applicable to comparing the intensities of other areas on a monitor screen with the intensity of a given reference area.

What is claimed is:

1. Apparatus for stabilizing the intensity of the image on a picture tube screen of an area which partially includes an intensity reference source, wherein the area is scanned by a scanning device and the image thereof is displayed on the picture tube screen, comprising:

means for continuously monitoring the image of the intensity reference source displayed on the picture tube screen, said means comprising a bundle of light transmitting optical elements having opposite ends, one end of said bundle being disposed at that part of the picture tube screen whereat the image of the intensity reference source is displayed, a photosensing element, the other end of said bundle being optically coupled to the photosensing element whereby light from said part of said picture tube screen whereat the image of the intensity reference source is displayed radiates said photosensing element through said bundle thereby generating a signal, and electronic means responsive to said signal for controlling the intensity of said image of said area displayed on said picture tube screen.

2. The invention of claim **1** wherein said electronic means comprise a circuit having an input terminal, an input capacitor connected to said input terminal, a first amplifier having first and second input terminals and an output terminal, said first input terminal being connected to receive a voltage on said capacitor, said second input and said output terminals being connected by a feedback line, a second amplifier having first and second input terminals and an output terminal, said first amplifier output terminal being connected to said first input terminal of said second amplifier, said second input terminal and said output terminal of said second amplifier being connected by a resistive feedback circuit, a voltage divider connected to said second amplifier output terminal, and a circuit output terminal connected to said voltage divider.

3. The invention of claim **2** further comprising a galvanometer connected to said circuit output terminal.

4. The invention of claim **1** wherein said electronic means comprise a circuit having a circuit input terminal, a voltage comparator having first and second input terminals, an output terminal and at least two additional terminals thereon, said first voltage comparator input terminal being connected to said circuit input terminal, a resistor connected in a feedback path between said two additional voltage comparator terminals, a capacitor, said voltage comparator second input terminal being connected to said capacitor, a voltage follower having first and second input terminals and an output terminal, said voltage follower first input terminal being connected to said capacitor, said second input terminal and said output terminal of said voltage follower being connected by a feedback circuit, a voltage divider connected to said output terminal of said voltage follower, and a circuit output terminal connected to said voltage divider.

5. The invention of claim **4** further comprising a galvanometer connected to said circuit output terminal.

6. The apparatus recited in claim **1** wherein said bundle is disposed with respect to the picture tube screen in a manner such as to minimize obstruction of the part of the picture tube screen upon which the image of the area being scanned is being displayed.

7. The apparatus of claim **6** wherein said bundle has an angular bend therein adjacent to the picture tube screen.

8. An automatic display intensity control for stabilizing the intensity of an image displayed on a picture tube screen in a thermographic machine comprising:

a. IR sensing means for scanning a surface to produce an image of the IR radiant energy pattern emitted by such surface;
b. IR detector means disposed adjacent said scanning means for sensing said IR radiant energy pattern emitted by said surface, and for generating an intensity control signal in response to the sensed radiations;
c. bias control means for controlling the magnitude of said control image of the scanned surface;
d. a picture tube having a display screen for displaying an image of the scanned surface;
e. electronic means connected between said detector and said picture tube for controlling the intensity of the image displayed on said screen with said intensity control signal;
f. a photosensing element;
g. a reference source on said screen;
h. fiber optic light bundle means operatively disposed between said screen and said photosensing element for conveying light from the reference source on said screen to said photosensing element so that a reference signal is generated by said photosensing element; and,
i. circuit means connected between said photosensing element and said bias control means for receiving the reference signal from the photosensing element and generating a bias control signal to automatically maintain the intensity of the displayed image at a predetermined level.

9. The invention of claim **8** wherein said fiber optic light bundle means has an angular bend therein adjacent to the picture tube.

10. The invention of claim **8** further comprising a reference temperature source disposed adjacent to the scanned surface whereby said temperature source will appear on said display screen, and wherein the one end of the light bundle is disposed against the screen within the area where the reference temperature source is displayed.

11. The invention of claim **8** wherein said electronic means comprises a circuit having a circuit input terminal, an input capacitor connected to said input terminal, a first amplifier having first and second input terminals and an output terminal, said first input terminal being connected to receive a voltage on said capacitor, said second input terminal and said output terminal being connected by a feedback circuit, a second amplifier having first and second input terminals and an output terminal, said first amplifier output terminal being connected to said first input terminal of said second amplifier, said second input terminal and said output terminal of said second amplifier being connected by a resistive feedback circuit, a voltage divider connected to said second amplifier output terminal, and a circuit output terminal connected to said voltage divider.

12. The invention of claim **8** wherein said electronic means comprise a circuit having a circuit input terminal, a voltage comparator having first and second input terminals, an output terminal and at least two additional terminals thereon, said first voltage comparator input terminal being connected to said circuit input terminal, a resistance feedback circuit connected between said two additional voltage comparator terminals, a capacitor, said voltage comparator second input terminal being connected to said capacitor, a voltage follower having first and second input terminals and an output terminal, said voltage follower first input terminal being connected to said capacitor, said voltage follower second input terminal and said voltage follower output terminal being connected by a feedback circuit, a voltage divider connected to said voltage follower output terminal, and a circuit output terminal connected to said voltage divider.

13. The invention of claim **12** further comprising a galvanometer connected to said circuit output terminal.

14. The invention of claim **12** wherein said photosensing element is a photoconductor and the photoconductor is connected in a circuit that is common to said circuit input terminal.

15. The invention of claim **8** wherein said electronic means comprise a circuit havingan input terminal, a voltage comparator having one input thereof connected to said input terminal, a resistor connected in a feedback path between two terminals of said voltage divider, a capacitor, another input of said voltage comparator connected to said capacitor, a voltage follower having a first input connected to receive a voltage on said capacitor, a feedback connecting the voltage follower output terminal to a second voltage follower input, a voltage divider connected to said voltage follower output terminal, and a circuit output terminal connected to said voltage divider.

16. The invention of claim **15** further comprising a galvanometer connected to said circuit output terminal.

17. The invention of claim **15** wherein said photosensing element is a photoconductor and the photoconductor is connected in a circuit that is common to said circuit input terminal.

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