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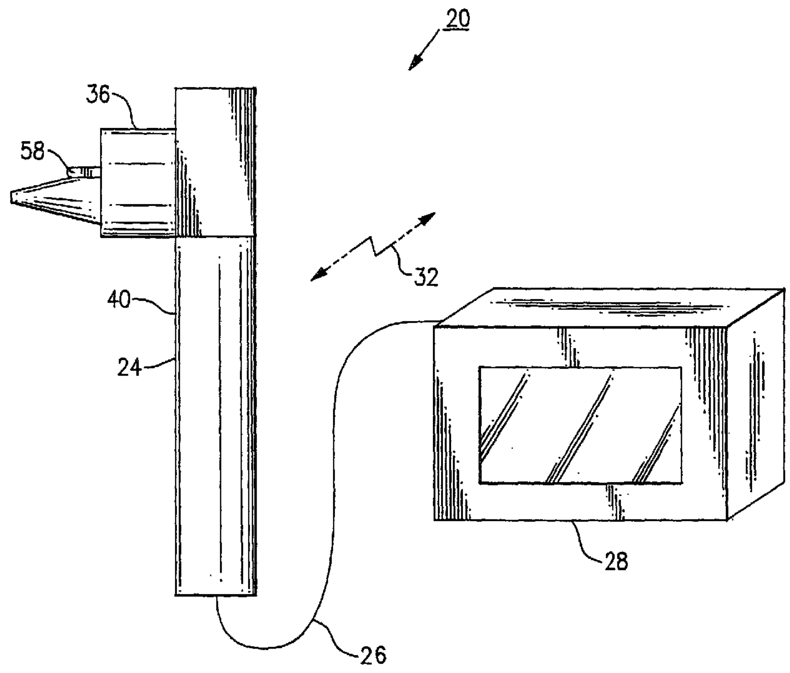
(54) **Title:** INFRARED THERMOMETER



(57) **Abstract:** At least one infrared sensor or a one dimensional sensor array are aimed at a target. A movable mirror scans the target of interest to provide a thermal "image" of the target area. Processing electronics detect the hottest spot of the target as indicated by output signals to directly indicate or estimate a temperature. Preferably, output can be utilized to determine the core temperature of a patient by examination of a target such as the tympanic membrane which is interconnected to the hypothalamus.

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INFRARED THERMOMETER

Field of the Invention

The invention is directed to the field of diagnostic instruments and more particularly to a diagnostic instrument which is suitable for use with the ear or other medical/industrial target in order to accurately determine a temperature or a temperature profile.

Background of the Invention

Medical diagnostic instruments such as infrared (IR) ear thermometers have traditionally been inaccurate as compared, for example, to thermistor type or mercury thermometers. This inaccuracy is due in large part to the large interrogation area found in the ear canal. This area includes not only the tympanic membrane (TM), but the ear canal walls as well. At present, there is not an adequate method of alerting the user when the instrument is not properly aligned with the TM. Similarly, the presence of foreign matter, such as ear wax, can block a direct line of sight to the TM and seriously affect the results indicated by the instrument. In addition, the narrowness of the ear canal, sometimes having large curves, also tends to prevent a suitable line of sight to the TM.

A basic assumption made in known IR thermometers is that the TM is within an interrogated area and that the TM subtends a specific portion of this interrogated area. Therefore, the manufacturers of these instruments will add a compensation factor arithmetically to the reading of the thermometer to make up for the fact that the device is reading the ear canal wall in addition to the TM. These devices are particularly inaccurate when the ear canal has been cooled, e.g., immediately after a patient has come indoors from the cold outdoors.

Recently, data have become available which demonstrate that the temperature of the TM in the lower anterior quadrant thereof is largely independent of ambient and skin temperature due to its interconnection with the hypothalamus. This temperature is highly representative of the body "core" temperature. The remainder of the TM is not necessarily at the same temperature. It is therefore quite desirable to measure this "hottest" spot in order to realize a more accurate reading.

Another issue to consider in the use of IR thermometers is how to deal with the IR radiation originating from the ear tip housing. Radiation from the tip housing combines with that of the target, such that temperature variations of the housing can affect the temperature reading from the sensor.

A known method of avoiding this problem is to keep the temperature of the housing isothermal and at a known level, as described in U.S. Patent No. 4,759,324. In actual practice, however, this is difficult to accomplish, in part because the ear tip is relatively long, leading to axial temperature gradients. In addition, the geometry of the ear canal is such that little radial room is available for insulation, resulting in heat transfer to and from the ear tip housing by the environment.

Summary of the Invention

It is a primary object of the present invention to improve the accuracy of medical diagnostic instruments.

It is a further primary object of the present invention to provide a medical diagnostic instrument which is capable of determining the hottest temperature of a medical target.

It is yet a further primary object of the present invention to provide a medical diagnostic instrument capable of determining body core temperature of a patient.

It is still another primary object of the present invention to provide a medical diagnostic instrument which is capable of estimating temperature of a target area if a portion thereof cannot be viewed directly; for example, if a portion of the target area is somehow obstructed.

It is still another object of the present invention to provide a means for negating or minimizing the effects of temperature changes in an ear thermometer on system response.

Therefore, and according to a preferred aspect of the invention, there is provided a temperature measuring apparatus for interrogating a medical target area, the apparatus comprising at least one infrared sensor capable of providing an output signal indicative of temperature of a portion of a medical target area, and processing means for processing output signals from the at least one infrared sensor. The processing means includes means for determining temperature based on the output signals of the at least one sensor. The apparatus also includes a movable mirror aligned with the at least one infrared sensor and focusing optics for focusing an optical image of a portion of the medical target area captured by the movable mirror onto the sensor, such that the entire target area can be scanned by the mirror.

The apparatus preferably includes means for displaying at least one output signal of the at least one infrared sensor and more preferably for displaying the maximum temperature detected by the at least one infrared sensor. Alternately, the display means can display all output signals, such as ranges, in a predetermined format, one example of which is false colors.

The apparatus can also include means for calibrating the at least one infrared sensor, which can, for example, include a small target having a known temperature and emissivity that is disposed in the path of the at least one infrared sensor. Preferably, the target can be moved selectively into and out of the optical path to the at least one infrared sensor.

According to another version, at least one optical element is aligned with the known target, wherein at least one of the at least one optical element and known target are movable relative to each other.

Another means for calibrating includes a temperature measuring element disposed in relation to the at least one infrared sensor and a supporting substrate in which the temperature measuring element is capable of measuring a reference temperature.

The apparatus can be used to examine a medical target area such as the tympanic membrane, the armpit, under the tongue, the colon, the rectum, the temple area or an in vivo portion of the skin.

The processing means includes means for determining the pulse of a patient based on transient variations in the output signals of portions of a scanned temperature profile.

The processing means further includes means for estimating the hottest temperature of the medical target area if portions thereof are obstructed from the at least one infrared sensor. Preferably, the estimating means estimates the hottest output signal from a scanned profile of output signals, the signal being extrapolated or interpolated therefrom. The apparatus can also provide an output signal to the user that the hottest temperature displayed is either not the hottest temperature of the medical target or is an estimated value.

The apparatus can also include directional guiding means for guiding a user to the portion of the medical target area having the hottest temperature. In addition, the display of the hottest temperature can be accompanied by audio, tactile, or light feedback.

The apparatus can also include means for thermally isolating the at least one sensor from input other than that of the medical target area, including an aperture stop in relation to the focusing optics and the at least one infrared sensor to allow only energy from the aperture stop and the medical target area to impinge on the at least one sensor. The aperture stop can be thermally connected to the substrate supporting the at least one infrared sensor such that the aperture stop and the substrate have substantially equivalent temperatures.

The apparatus includes means for measuring the temperature of the aperture stop, for example, by at least one infrared sensor.

According to another preferred aspect of the invention, there is disclosed a method for using an apparatus for accurately determining the temperature of a medical target, the apparatus including at least one infrared sensor and a movable mirror aligned with the target area and the at least one sensor. The method includes the steps of sequentially moving the mirror to receive an optical image of a portion of the target area and generating a temperature profile of the target area based on output signals from the at least one sensor of each portion of the target area.

The method also includes the step of outputting the signals representative of the temperatures of portions of the medical target, such as by displaying the value of selected individual output signals or the generated temperature profile, including the hottest temperature.

The method further includes the step of estimating the hottest temperature of the medical target (ear, colon, in vivo portion of skin, etc.) if portions of the medical target are obstructed from the sensor and displaying the estimated hottest temperature.

The method further includes the step of calibrating the sensor, such as by aiming the sensor at a target having a known temperature and emissivity.

The method further includes the step of thermally isolating the sensor from thermal input other than that from the medical target, such as by installing an aperture stop relative to the sensor which is configured to allow only energy from the medical target and the aperture stop to impinge on the sensor. Preferably, a substrate supports the sensor with the substrate and the aperture stop are thermally connected to the substrate such that the aperture stop and the substrate have substantially equivalent temperatures. Alternately, the method includes the step of measuring the temperature of the aperture stop and incorporating the measured temperature during the processing step.

The method further includes an indicating step including the step of directionally guiding the user until the hottest temperature of the medical target has been identified.

According to yet another preferred aspect of the present invention, there is provided an ear thermometer including at least one infrared sensor capable of providing an output signal indicative of a portion of a target area, processing means for processing output signals from the at least one sensor, the processing means including means for determining body core temperature based on the output signal, a movable mirror aligned with the at least one infrared sensor and focusing optics for focusing an optical image of at least a portion of the target area captured by the movable mirror onto the at least one sensor, wherein the entire target area can be scanned by the mirror.

An advantage of the present invention is that a target can be interrogated more accurately without transient thermal effects typically found in the vicinity of a medical target such as the ear canal.

Another advantage provided by the present invention is that the presence of inflammations, abscesses, ear wax, and other obstructions can be quickly identified and compensated for so as to more accurately estimate the hottest temperature of a defined target area.

These and other objects, features and advantages will become apparent from the following Detailed Description which should be read in conjunction with the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a partial perspective view of a diagnostic instrument system in accordance with a preferred embodiment of the present invention;

Fig. 2(a) is a partially exploded top perspective view of the diagnostic instrument depicted in Fig. 1;

Fig. 2(b) is an exploded rear perspective view of a diagnostic instrument similar to that depicted in Fig. 2(a);

Fig. 3 is a side sectioned view of the instrument of Figs. 1-2(b);

Fig. 4 is a top sectioned view of the instrument of Figs. 1-3;

Fig. 5 is a partial ray trace diagram of the optical portion of the instrument of Fig. 1, including a thermal baffle according to a first embodiment of the present invention;

Fig. 6 is a partial ray trace diagram of the optical portion of the instrument of Fig. 1, including a thermal baffle according to a second embodiment of the present invention and further including calibration means for the instrument;

Fig. 7 depicts a typical output display indicating portion of a temperature profile according to the diagnostic instrument system of Fig. 1;

Fig. 8 is a display output indicating regions of various temperatures of a predetermined target area;

Fig. 9 depicts a digital temperature display for the instrument of Fig. 1;

Fig. 10 is an enlarged front view of the thermal sensor array of the instrument of Fig. 1;

Fig. 11 depicts a view of a target area including an occluded portion;

Fig. 12 depicts a relative plot of temperature for the target area of Fig. 11;

Fig. 13 depicts a predicted plot of temperature for the target area of Fig. 11;

Fig. 14 depicts another predicted plot of temperature for the target area of Fig. 11;

Fig. 15 illustrates a display portion for the diagnostic instrument made in accordance with a preferred aspect of the invention;

Fig. 16 illustrates the display portion of Fig. 15 indicating the centering of the hottest temperature value;

Fig. 17 illustrates a partial plan view of an instrument having a fixed thermal sensor used in conjunction with a scanning mirror assembly;

Fig. 18 illustrates an enlarged view of the thermal sensor and scanning mirror of Fig. 17;

Fig. 19 illustrates an alternate embodiment of a movable thermal element;

Fig. 20 is a side diagrammatic partial view of a diagnostic instrument having a movable optics assembly and

Fig. 21 illustrates a predicted plot of temperature using an interpolation technique.

Detailed Description

The following description relates to certain embodiments of a medical diagnostic instrument system used in conjunction with an otological medical device and particularly for measuring the body core temperature of a patient through interrogation of the tympanic membrane. It will be readily apparent from the following discussion, however, that the concepts detailed herein will find similar application in measuring other medical targets, such as under the armpit, under the tongue, the colon, portions of the skin for skin disorders, tumors, etc, as well as other anatomical areas of interest.

In addition, the concepts described herein can further be employed in devices intended for interrogating certain industrial targets. Finally, it should be pointed out that certain terms, such as “upper”, “lower”, “front”, “back”, “distally’, “proximally” and the like, are used frequently throughout the discussion. These terms, however, are merely provided to provide a frame of reference for use with the accompanying drawings and are not intended to specifically limit the inventive concepts described herein.

Referring to Fig. 1, there is depicted an instrument system 20 in accordance with a preferred embodiment of the present invention. A portable examination or diagnostic instrument 24 includes a tethered electrical/video signal connection 26 with a video monitor 28 or other video peripheral device (not shown), although alternately a wireless connection through RF, IRdA or other means, shown figuratively as 32, can also be employed.

Referring to Figs. 1-2(b), the portable examination instrument 24 includes an instrument head 36 which is attached, releasably or otherwise, to the top of a hand-grippable battery handle 40. The instrument head 36 is shown nearly identically in Figs. 2(a) and 2(b), except as noted specifically herein, though the hand-grippable handle 40A shown in Fig. 2(b) is a variation. Similar variations for use with the instant instrument head 36 are contemplated within the scope of the present invention. For example, and rather than using a video monitor, the instrument head could include a portable integral display.

Referring to the exploded views of Figs. 2(a) and 2(b), the instrument head 36 includes a detector assembly 42 and an optical assembly 70 which are each disposed within the confines of a housing 50. The housing 50 is attached to the hand-grippable handle 40, 40A, by conventional means. For example and as shown in Fig. 2(b), threaded fasteners 53, can be used to secure the handle 40A to the rear side of the housing 50 using threaded holes 52.

The detector assembly 42 includes an IR element or sensor array 44 having a plurality of miniature infrared sensors 45, Fig. 10, such as the bolometer array manufactured by TI/Raytheon, which are mounted onto a supporting body 48. According to the present invention, a two dimensional 16 x 16 element array is defined, though the parameters thereof can easily be varied depending on the application. Furthermore, a single element or a one dimensional array can also be utilized based on the inventive concepts of the present invention. An enlarged view of an IR sensor array 44 in accordance with the present invention is depicted in Fig. 10. Each of the individual elements 45 comprising the sensor array 44 senses infrared radiation of a portion of a target area, akin to individual pixels of an electronic imager, such as a CCD, and produces an output signal which can be processed through suitable electronics to provide temperature of that sensed portion.

Referring to Figs. 2(a) - Fig. 4, the optical assembly 70 includes a conically shaped aperture stop 60, which overlays the miniature IR sensor array 44, as well as an objective lens 61 and a relay lens 63 which focus incoming IR light onto the IR sensor array 44 of the detector assembly 42. The aperture stop 60 is mounted by conventional means such as threaded fasteners 65 (Fig. 2b) onto the supporting body 48. The aperture stop 60 includes a central through opening 64 which provides optical access to the IR sensor array 44. Preferably, the aperture stop 60 is aligned with the IR sensor array 44 and is attached onto the supporting body 48 using fasteners 65 inserted through the holes 66.

Still referring to Figs. 2(a) - 4, the housing 50 includes a substantially frusto-conical insertion portion 78 which is sized to receive a speculum (not shown) and which can be placed up to a predetermined distance into the ear canal of a patient (not shown) such as through the use of a locator 58. The lenses 61, 63 combine to focus incoming optical energy onto the miniature IR sensor array 44. The objective lens 61 is disposed at the distal end of the frusto-conical insertion portion 78 of the housing 50 while the relay lens 63 is placed adjacent the aperture stop 60. The housing 50 is attached to the handle 40, 40A by screws 53 that thread into the proximal end of the housing at threaded holes 52, Fig. 2(b).

Moreover, the objective lens 61 being placed at the distal tip opening of the insertion portion 78 permits a wide field of view in order to "see" the tympanic membrane and to avoid hair, ear wax, and a significant bending portion of the ear canal. The locator 58 is positioned and shaped to allow the distal end of the insertion portion 78 to be repeatably positioned a predetermined distance within the ear canal, but without contacting the tympanic membrane.

The relay lens 63 permits the detector assembly 42 to be positioned within the instrument head 36 wherein the image obtained by the objective lens 61 can be focused thereupon.

The locator 58 provides repeatability and consistency with regard to alignment, depth of field, and orientation of a thermally imaged target area. This provides an additional advantage. For example, a thermal image can therefore be superimposed or have superimposed thereupon, a corresponding digital image of the target area captured by an electronic otoscope (not shown). The image could otherwise be in the form of any other optical data; for example, a spectroscopic or other image of a target area could also be superimposed onto the thermal image using the locator to utilize the same field of view using multiple instruments for obtaining each image or using a single imaging instrument with multiple imaging (thermal, optical, etc.) systems.

The above optical assembly 70 can be adjusted using a focusing screw 57 inserted through opening 68 in the housing 50 and threaded into the supporting body at hole 51. A focus spring 62 provides a biasing force to permit adjustment of the assembly containing the supporting body 48 and aperture stop 60 relative to the housing 50. During adjustment, supporting body 48 slides on pins 47, Figs. 2(b) and 4, extending from the interior of the insertion portion 78.

Referring to Figs. 3, 4, and 6, the aperture stop 60 further limits the amount of energy passing through the optical subassembly 70 from a target area 100 to the IR sensor array 44.

An alternate aperture stop 104 is illustrated in Fig. 5, the aperture stop being thermally linked directly to the supporting body 48 of the detector assembly 42, to provide the same temperature of the aperture stop as that of supporting body 48 and IR thermal array 44 given that the aperture stop also emits energy which is detected by the IR sensor array 44.

Referring to Figs. 5 and 6, the aperture stops 60, 104, as used in conjunction with the optical subassembly 70, provide the following benefits. As noted, the small diameter objective lens 61 can be positioned at the distal end of the insertion portion 78 to bypass hair, ear wax, and significant bending of the ear canal and to provide a relatively wide field of view of the target area. Furthermore, the provision of an aperture stop for the energy focused on the detector assembly 42 by the relay lens 63, insures that the representative pixels of the sensor array 44 see energy emanating only from the target 100, the aperture stop 60, 104, and the relay lens 63. The relay lens 63 emits a negligible amount of energy as compared to the target 100 and the aperture stop 60, 104. The effect of the aperture stop 104, Fig. 5, is negligible in relation to the signals received by the sensor array 44 in calculating the temperature of the interrogated target area 100. The energy of the aperture stop 60, Fig. 6, can be accounted for by subtraction as part of calibration of the sensor array 44, such as described herein.

Referring to Fig. 6, a movable target 84, such as a diode or other form of calibration element, having a known temperature and emissivity is movably disposed in relation to the optical path 54 to the detector assembly 42 in order to initially calibrate the miniature IR sensor array 44. Alternately, an optical element 98 could be aligned with the target 84 such that either the target 84 and/or the optical element 98 "moves" the target into and out of the optical path 54 to the IR sensor array 44.

Referring to Fig. 10, and in lieu of the target 84, Fig. 6, a temperature measuring element 99, such as a thermocouple or thermistor, can be disposed on the supporting body 48 of the detector assembly 42 , the element 99 being capable of measuring the reference temperature of the supporting body 48 to permit calibration of the array 44. Alternatively, and still referring to Fig. 10, one of the pixels 101 of the array can be "blinded" to incoming energy from the target to achieve a similar effect. It should be further noted in passing that a temperature measuring element, such as described above, could otherwise be disposed (e.g., on the aperture stop 60, Fig. 6).

Referring to Figs. 7-9, the display output of the IR sensor array 44 can be demonstrated to cover various forms. In a first version shown in Fig. 7, the display output can take the form of a matrix or grid 106 having individual numeric processed temperature values 108. The displayed temperatures 108 can cover a portion of the grid 106, indicating only those temperature values exceeding a specific threshold temperature, as shown, or all of the sensor processed output values can be displayed.

According to Fig. 8, the display output 110 can be arranged into a predetermined format. For example and as shown, output signals of the individual sensors can be segregated into different visually perceivable forms, such as textures or false colors, such as first, second, third, and fourth ranges 112, 114, 116, 118, respectively, leading the user to identify a "hot" spot 122. It should be readily apparent that literally any visually perceivable form could be utilized in order to provide contrasts between ranges of temperatures as detected by the IR sensor array 44.

Alternately and in lieu of providing a field of view as shown in Figs. 7 and 8, a simplified display output 126 can include merely the hottest temperature in the field of view as a single temperature value, 130, such as shown in Fig. 9. It will be readily apparent that other forms of representation can be contemplated by one of sufficient skill in the field. There may be situations, as described herein below, in which the displayed temperature is not the hottest temperature of the target area. In those instances, the display output 126 can also include an indicator 134 which informs the user that the displayed temperature 130 is estimated.

The detection of the hottest temperature of a medical target area, such as the ear, indicates body core temperature given that the arteries in the tympanic membrane are closely tied to the hypothalamus, the temperature regulator of the human body. Identification of body core temperature as described herein through the use of an IR sensor array provides an improvement in accuracy and reliability in the field of thermometry. In addition, and based on an adequately high signal to noise ratio, the pulse rate of the patient can also be determined due to flow of hot blood into the arteries. The transient effect can be included in each of the above display representations or separately to indicate this value.

As alluded to above, it is possible that the hottest temperature might not be directly discernible based on either the presence of an obstruction or that the hottest temperature of the target area is not in the immediate field of view of the IR sensor array 44. For example, and as shown in Fig. 11, it is possible that a portion 129 of an overall target area 120 (in this case a portion of the tympanic membrane 121) is obstructed, as denoted by phantom line 124, such as by ear wax, an abscess, ear canal wall etc., which blocks the hottest spot 128 (that is the spot having the highest temperature) from view.

Referring to Figs. 11-14, a methodology of estimating a hottest temperature is illustrated pictorially. The processing electronics provided in the detector assembly 42, Fig. 3, includes a microprocessor (not shown) having sufficient memory for storing the calibrated values of the output signals of each of the IR sensors 45, Fig. 10, of the IR sensor array 44, Fig. 3.

Due to the presence of the obstruction shown in Fig. 11, a corresponding temperature profile 132 would be detected by the present sensor array. In actuality, however, the obstructed portion of the temperature profile 132 would be correctly represented by the profile depicted as 136 including the hottest spot, depicted as 128 in Fig. 11, and indicated as 140 in Fig. 12, if the obstruction did not exist.

Referring to Fig. 13, a predetermined number of points 144, 145, 146 along the profile 132 are processed due to the increase in temperature. A highest point is then extrapolated by curve fitting through the points 144, 145, 146 to determine an estimated hottest spot 140a, Fig. 14 through fitted curve 136a, Fig. 14.

Referring to Fig. 21, a hottest temperature of a target area can also be interpolated through curve fitting, for example, if the hottest spot is "between" pixels of the sensor array 44, Fig. 10, such as fitting an appropriate curve or temperature profile 157 through a number of predetermined temperature points 152 and interpolating an estimated hottest temperature 158.

Referring to Figs. 15 and 16, and as noted, it is also possible that the hottest temperature is not within the field of view of the instrument. According to a preferred embodiment of the invention, the instrument includes an indicator 150 connected in relation to the processing electronics of the device, the indicator having a set of directional guides 154 arranged in 90 degree intervals about a center guide 156. It should be readily apparent that the above description is exemplary as any varied number of directional guides can be suitably placed along a periphery. As the instrument is used, the hottest temperature in the field of view of the IR sensor array is determined and the locale of the hottest temperature is indicated by a corresponding directional guide 154. The guide 154 aids the user in adjusting the field of view of the instrument by moving the instrument in the direction indicated by the indicator 150. As the instrument is adjusted by the user, the directional guide 154 will shift until the hottest temperature value is eventually located in the center guide 156, as shown in Fig. 16, thereby indicating that the hottest temperature value has been centered in the field of view. During the adjustment, it is possible that a new hottest temperature will be located, the value of this temperature being stored into memory and compared using the processing electronics during use as the field of view is changed. Alternately, and rather than using multiple LEDs as shown in Figs. 15 and 16, a single LED could be provided. In this instance, the LED could provide the user with a visual indication when the hottest temperature has been detected by the microprocessor.

Alternately, other indicating means could be employed to notify the user that the hottest temperature of a target area has been located or identified, such as, for example, an audio signal or tactile feedback, such as a vibrational signal.

Referring to Figs. 17-19, alternate techniques are herein described in lieu of using a two dimensional IR sensor array. That is, alternately, an examination instrument 160 can utilize a single sensor or one dimensional IR sensor array 166 in conjunction with a movable mirror 170 to scan the target area of interest, as defined by 176 in two dimensions. The mirror 170 is retained within an instrument housing 164 and is made rotatable, for example, as supported within a frame 180 having rotatable sections 184, 188 to provide rotation as indicated by arrows 189 about respective axes 187 to define a scan field 190 of the target area. An alternate micro-machined sensor support 192, in this case for a single IR sensor 166, is illustrated in Fig. 19, the support being translatable along orthogonal axes 196, 198. In this case mirror 170, Fig. 17, is stationary and the single IR sensor 166 translates in the two orthogonal directions to capture each portion of field 190. As in the preceding, the sensor 166 can be calibrated using a movable or dedicated reference temperature element (not shown), or the other methods described in the preceding embodiment.

Finally, referring to Fig. 20, a further embodiment partially depicts an apparatus 200 including a single IR sensor 202 disposed within a housing 203. The sensor 202 or linear (one-dimensional) sensor array can be translated along orthogonal directions 208, 210 with respect to a target area 212 through a lens or aperture 204. The aperture 204 or lens can alternately be moved (i.e. translated) in a similar manner to effectively scan a thermal image of the target area 212.

Though the above invention has been described in terms of certain embodiments, it will be appreciated that variations and modifications are possible within the scope of the invention as claimed herein, including use for various medical and industrial targets capable of being thermally imaged. For example, a similar IR sensor array assembly could be incorporated into an endoscope or laparoscope in order to examine a polyp or the appendix. Likewise, a sensor assembly as described could also be included in a borescope for examining the interior of an industrial target, such as the interior of an aircraft engine.

<u>We Claim</u>

1. A temperature measuring apparatus for interrogating a medical target area, said apparatus comprising:

at least one infrared sensor capable of providing an output signal indicative of temperature of a portion of a medical target area;

processing means for processing output signals from said at least one infrared sensor, said processing means including means for determining temperature based on the output signals of said at least one sensor; and

a movable mirror aligned with said at least one infrared sensor and focusing optics for focusing an optical image of a portion of said medical target area captured by said movable mirror onto said sensor, such that the entire target area can be scanned by said mirror.

2. An apparatus as recited in Claim 1, including means for displaying the output signal of said at least one infrared sensor.

3. An apparatus as recited in Claim 2, wherein said displaying means includes at least one LCD capable of displaying at least one output signal from said at least one infrared sensor.

4. An apparatus as recited in Claim 2, wherein said displaying means includes a video monitor capable of displaying at least one output signal from said at least one infrared sensor.

5. An apparatus as recited in Claim 2, wherein said displaying means includes means for displaying the hottest temperature(s) of the medical target area interrogated by said at least one infrared sensor.

6. An apparatus as recited in Claim 2, wherein said displaying means includes means for displaying all output signals scanned by said at least one infrared sensor.

7. An apparatus as recited in Claim 2, wherein said displaying means includes means for displaying ranges of a scanned temperature profile of said medical target area to a user in a predetermined format.

8. An apparatus as recited in Claim 7, wherein said range displaying means includes means for determining core body temperature from said scanned temperature profile.

9. An apparatus as recited in Claim 1, including means for calibrating said at least one infrared sensor.

10. An apparatus as recited in Claim 9, wherein said calibration means includes a small target having a known temperature and emissivity disposed in the optical path to said at least one infrared sensor.

11. An apparatus as recited in Claim 10, including means for moving said target into and out of the optical path to said at least one infrared sensor.

12. An apparatus as recited in Claim 10, including at least one optical element aligned with said target of known temperature, said at least one of said at least one optical element and said target being movable relative to the other to move the target selectively into and out of the optical path to said at least one infrared sensor.

13. An apparatus as recited in Claim 9, including a temperature measuring element disposed in a least one of a position adjacent said at least one infrared sensor and a substrate supporting said at least one infrared sensor, said temperature measuring element being capable of measuring a reference temperature.

14. An apparatus as recited in Claim 1, wherein said focusing optics includes at least one lens disposed in relation to said at least one infrared sensor along an optical axis, said at least one of said at least one lens and said at least one infrared sensor being movable

for variably focusing an image of said medical target area onto said at least one infrared sensor.

15. An apparatus as recited in Claim 1, wherein said infrared sensor includes a one dimensional sensor array.

16. An apparatus as recited in Claim 1, wherein said medical target area is the tympanic membrane.

17. An apparatus as recited in Claim 1, wherein said medical target area is the armpit.

18. An apparatus as recited in Claim 1, wherein said medical target area is under the tongue.

19. An apparatus as recited in Claim 1, wherein said medical target area is the colon.

20. An apparatus as recited in Claim 1, wherein said medical target area is the rectum.

21. An apparatus as recited in Claim 1, wherein said medical target area is the temple area of a patient.

22. An apparatus as recited in Claim 1, wherein said medical target area is an in vivo portion of skin.

23. An apparatus as recited in Claim 1, wherein said processing means includes means for determining pulse based upon temporal variations in the output signals of certain portions of said scanned temperature profile.

24. An apparatus as recited in Claim 1, wherein said processing means includes means for measuring each output signal of said at least one infrared sensor and determining the output signals indicative of the hottest temperatures of said scanned medical target area.

25. An apparatus as recited in Claim 1, wherein said processing means includes estimating means for estimating the hottest temperature(s) of said medical target area.

26. An apparatus as recited in Claim 25, wherein said estimating means predicts the hottest output signals of at least one estimated temperature from a profile of output signals.

27. An apparatus as recited in Claim 26, wherein said estimating means includes means for interpolating the hottest temperature from the output signals of said at least one infrared sensor.

28. An apparatus as recited in Claim 26, wherein said estimating means includes means for extrapolating the hottest temperature from a series of output signals if portions of said medical target are obstructed from the at least one infrared sensor.

29. An apparatus as recited in Claim 1, including means for indicating to a user that the output signal corresponding to the hottest temperature of the at least one infrared sensor does not indicate the hottest temperature of the medical target area.

30. An apparatus as recited in Claim 29, wherein said indicating means includes directional guiding means for guiding a user to that portion of the medical target area having the hottest temperature.

31. An apparatus as recited in Claim 29, wherein said indicating means includes at least one of the group of audio, tactile, and light feedback.

32. An apparatus as recited in Claim 30, wherein said indicating means includes at least one of the group consisting of audio, tactile, and light feedback.

33. An apparatus as recited in Claim 25, including at least one display for displaying the hottest temperature(s) of said medical target area and including means for indicating to a user that the hottest temperature being displayed is an estimated value.

34. An apparatus as recited in Claim 1, wherein said at least one infrared sensor is disposed on a substrate, said processing means including at least one of a thermocouple and a thermistor disposed on said substrate and a measuring circuit for determining the temperature of said substrate in order to compensate said at least one infrared sensor.

35. An apparatus as recited in Claim 1, including means for thermally isolating said at least one infrared sensor from input external to that of the apparatus and other than that of the medical target area.

36. An apparatus as recited in Claim 35, wherein said thermal isolation means includes an aperture stop disposed in relation to said focusing optics and said at least one infrared sensor to allow only energy from said medical target area and said aperture stop to impinge on said at least one infrared sensor.

37. An apparatus as recited in Claim 36, including a substrate supporting said at least one infrared sensor, said aperture stop being thermally connected to said substrate such that said aperture stop and said substrate have substantially equivalent temperatures.

38. An apparatus as recited in Claim 36, including means for measuring the temperature of said aperture stop.

39. An apparatus as recited in Claim 38, wherein said at least one infrared sensor can be compensated for using the measured temperature of said aperture stop.

40. An apparatus as recited in Claim 38, wherein said aperture stop temperature measuring means includes at least one infrared sensor.

41. An apparatus as recited in Claim 1, wherein said processing means includes means for determining the core body temperature based on the output signals of said at least one infrared sensor.

42. An apparatus as recited in Claim 1, including an instrument housing retaining said at least one infrared sensor, said housing including an insertion portion including a locator which enables said insertion portion to be positioned a predetermined distance in relation to said medical target area.

43. An apparatus as recited in Claim 42, wherein said locator permits said insertion portion to be positioned at said predetermined distance in relation to said at least one infrared sensor and with means for providing an image other than a thermal image of said medical target area onto which said thermal image can be superimposed.

44. An ear thermometer comprising:

at least one infrared sensor capable of providing an output signal indicative of temperature of a portion of a target area;

processing means for processing output signals from said at least one infrared sensor, said processing means including means for determining temperature based on the output signals;

a movable mirror aligned with said at least one infrared sensor; and

focusing optics for focusing an optical image of at least a portion of said target area captured by said movable mirror onto said at least one infrared sensor, wherein the entire target area can be scanned by said mirror.

45. An ear thermometer as recited in Claim 44, including means for displaying the output signals of said at least one infrared sensor.

46. An ear thermometer as recited in Claim 45, wherein said displaying means includes means for displaying all output signals of said at least one infrared sensor.

47. An ear thermometer as recited in Claim 45, wherein said displaying means produces a thermal image of at least a portion of the tympanic membrane.

48. An ear thermometer as recited in Claim 45, wherein said displaying means displays a thermal image of at least a portion of the ear canal.

49. An ear thermometer as recited in Claim 45, wherein said displaying means is capable of displaying a thermal image of at least a portion of an obstruction in the outer ear.

50. An ear thermometer as recited in Claim 45, wherein said displaying means is capable of displaying a thermal image of at least a portion of an abscess in the outer ear.

51. An ear thermometer as recited in Claim 45, wherein said displaying means includes means for displaying specified ranges of temperatures of said thermal image in an predetermined format.

52. An ear thermometer as recited in Claim 45, wherein said displaying means includes at least one LCD capable of displaying at least one output signal from said at least one infrared sensor.

53. An ear thermometer as recited in Claim 45, wherein said displaying means includes a video monitor capable of displaying at least one output signal from said at least one infrared sensor.

54. An ear thermometer as recited in Claim 45, wherein said displaying means includes means for displaying the hottest temperature(s) of the medical target area interrogated by said at least one infrared sensor.

55. An ear thermometer as recited in Claim 51, wherein said range displaying means includes means for displaying ranges of temperatures of a scanned temperature profile in false colors.

56. An ear thermometer as recited in Claim 44, wherein said processing means includes means for determining body core temperature from said temperature profile.

57. An ear thermometer as recited in Claim 44, including means for calibrating said at least one infrared sensor.

58. An ear thermometer as recited in Claim 57, wherein said calibration means includes a small target having a known temperature and emissivity disposed in the optical path of said at least one infrared sensor.

59. An ear thermometer as recited in Claim 58, including means for moving said target into and out of the optical path of said at least one infrared sensor.

60. An ear thermometer as recited in Claim 58, including at least one optical element aligned with said target of known temperature, said at least one of said at least one optical element and said at least one infrared sensor being movable relative to the other of said at least one optical element and said at least one infrared sensor.

61. An ear thermometer as recited in Claim 57, including a temperature measuring element disposed adjacent to said at least one infrared sensor and a substrate supporting said at least one infrared sensor, said temperature measuring element being capable of measuring a reference temperature.

62. An ear thermometer as recited in Claim 44, wherein said focusing optics includes at least one lens for focusing a thermal image of said target area onto said at least one infrared sensor.

63. An ear thermometer as recited in Claim 44, wherein said focusing optics includes at least one lens disposed in relation to said at least one infrared sensor and said movable mirror along an optical axis, said at least one of said at least one lens and said at least one

infrared sensor being movable for variably focusing the thermal area being imaged onto said at least one infrared sensor.

64. An ear thermometer as recited in Claim 44, wherein said processing means includes means for determining pulse based upon temporal variations in the output signals of certain portions of a scanned temperature profile.

65. An ear thermometer as recited in Claim 56, wherein said core body temperature determining means includes means for measuring each output signal of said at least one infrared sensor and determining the output signals indicative of the hottest temperature in the outer ear.

66. An ear thermometer as recited in Claim 56, wherein said processing means includes estimating means for estimating the hottest temperature(s) in the outer ear.

67. An ear thermometer as recited in Claim 66, wherein said estimating means predicts the hottest output signals of at least one estimated temperature from a profile of output signals .

68. An ear thermometer as recited in Claim 66, wherein said estimating means includes means for interpolating the hottest temperature from the output signals of said at least one infrared sensor.

69. An ear thermometer as recited in Claim 67, wherein said estimating means includes for extrapolating the core body temperature from a series of output signals if portions of the outer ear are obstructed from said at least one infrared sensor.

70. An ear thermometer as recited in Claim 56, including means for indicating to a user that the output signal corresponding to the hottest temperature measured by said at least one infrared sensor is not the core body temperature.

71. An ear thermometer as recited in Claim 70, wherein said indicating means includes directional guiding means for guiding a user to that portion of the outer ear having the hottest temperature.

72. An ear thermometer as recited in Claim 70, wherein said indicating means includes at least one of the group consisting of audio, tactile, and light feedback.

73. An ear thermometer as recited in Claim 71, wherein said indicating means includes at least one of the group consisting of audio, tactile, and light feedback.

74. An ear thermometer as recited in Claim 56, including at least one display for displaying the core body temperature(s) and including means for indicating to a user that the core body temperature being displayed is an estimated value.

75. An ear thermometer as recited in Claim 44, wherein said at least one infrared sensor is disposed on a substrate, said processing means including at least one of a thermocouple and a thermistor disposed on said substrate and a measuring circuit for determining the temperature of said substrate in order to compensate said at least one infrared sensor.

76. An ear thermometer as recited in Claim 62, including means for thermally isolating the at least one infrared sensor from input external to the thermometer other than from the target area.

77. An ear thermometer as recited in Claim 76, wherein said thermal isolation means includes an aperture stop disposed in relation to said focusing optics and said at least one infrared sensor to substantially allow only energy from said target area and said aperture stop to impinge on said at least one infrared sensor.

78. An ear thermometer as recited in Claim 77, including a substrate supporting said at least one infrared sensor, said aperture stop being thermally connected to said substrate such that said aperture stop and said substrate have substantially equivalent temperatures.

79. An ear thermometer as recited in Claim 77, including means for measuring the temperature of said aperture stop.

80. An ear thermometer as recited in Claim 79, wherein said at least one infrared sensor can be compensated for using the measured temperature of said aperture stop.

81. An ear thermometer as recited in Claim 79, wherein said aperture stop temperature measuring means includes at least one infrared sensor.

82. An ear thermometer as recited in Claim 44, wherein said at least one infrared sensor is a linear one dimensional array.

83. An ear thermometer as recited in Claim 44, including an instrument housing retaining said at least one infrared sensor, said housing including an insertion portion including a locator which enables said insertion portion to be positioned a predetermined distance in relation to said target area.

84. An ear thermometer as recited in Claim 83, wherein said locator permits said insertion portion to be positioned at said predetermined distance in relation to said at least one infrared sensor and with means for providing an image other than a thermal image of said target onto which said thermal image can be superimposed.

85. A method for using an apparatus for accurately determining the temperature of a medical target, said apparatus including at least one infrared sensor and a movable mirror aligned with said target area and said at least one sensor, said method including the steps of:

sequentially moving said mirror to receive an optical image of a portion of said target area; and generating a temperature profile of said target area based on output signals from the at least one sensor of each portion of said target area.

86. A method as recited in Claim 85, including the step of outputting the signal representative of temperature of said portion of the medical target.

87. A method as recited in Claim 86, wherein the outputting step includes the step of displaying the value of at least one output signal.

88. A method as recited in Claim 86, wherein the outputting step includes the step of displaying a thermal image of said medical target .

89. A method as recited in Claim 87, wherein said displaying step includes the step of displaying at least one output signal of said at least one infrared sensor using a video monitor.

90. A method as recited in Claim 87, wherein said displaying step includes the step of displaying the hottest temperature(s) of the medical target interrogated by said at least one infrared sensor.

91. A method as recited in Claim 87, wherein said displaying step includes the step of displaying all of the output signals of said at least one infrared sensor.

92. A method as recited in Claim 87, wherein said displaying step includes the step of displaying ranges of a scanned temperature profile of said medical target in a predetermined format.

93. A method as recited in Claim 85, wherein said determining step includes the step of determining the core body temperature of a patient.

94. A method as recited in Claim 92, wherein the step of displaying ranges of the temperature profile includes the step of determining the core body temperature of a patient.

95. A method as recited in Claim 85, including the step of calibrating said at least one infrared sensor.

96. A method as recited in Claim 95, wherein said calibrating step includes the step of positioning a target having a known temperature and emissivity in the optical path to said at least one infrared sensor.

97. A method as recited in Claim 96, including the step of selectively moving said target into and out of the optical path to said at least one infrared sensor.

98. A method as recited in Claim 96, including the step of selectively moving at least one of said known target and an optical element aligned with said target in order to move the target into and out of the optical path to said at least one infrared sensor.

99. A method as recited in Claim 95, wherein said calibration step includes the step of measuring a reference temperature from a temperature measuring element disposed in at least one of adjacent at least one infrared sensor and a substrate supporting said at least one infrared sensor.

100. A method as recited in Claim 85, including the step of focusing a thermal image of said medical target onto said at least one infrared sensor.

101. A method as recited in Claim 85, including the step of moving at least one of at least one lens disposed in the optical path to said at least one infrared sensor and for variably focusing an image of said medical target onto said at least one infrared sensor.

102. A method as recited in Claim 85, wherein said medical target is the tympanic membrane.

103. A method as recited in Claim 85, wherein said medical target is the armpit.

104. A method as recited in Claim 85, wherein said medical target is under the tongue.

105. A method as recited in Claim 85, wherein said medical target is the colon.

106. A method as recited in Claim 85, wherein said medical target is the rectum.

107. A method as recited in Claim 85, wherein said medical target is the temple area of a patient.

108. A method as recited in Claim 85, wherein said medical target is an in vivo portion of the skin.

109. A method as recited in Claim 85, including the step of determining pulse based on temporal variations in predetermined output signals of said at least one infrared sensor.

110. A method as recited in Claim 109, wherein said medical target is the tympanic membrane.

111. A method as recited in Claim 85, further including the steps of measuring each output signal of said at least one infrared sensor and determining the output signals of the hottest temperature(s) of said medical target.

112. A method as recited in Claim 85, further including the step of estimating the hottest temperature of portions if the medical target are one of obstructed and not detected by the at least one infrared sensor.

113. A method as recited in Claim 112, wherein said estimating step includes the step of predicting the hottest output signals for at least one estimated temperature from a profile of output signals.

114. A method as recited in Claim 113, wherein said estimating step includes the step of interpolating the hottest temperature from the output signals of said at least one infrared sensor.

115. A method as recited in Claim 113, wherein said estimating means includes the step of extrapolating the hottest temperature from a series of output signals if portions of the medical target are obstructed from the said at least one infrared sensor.

116. A method as recited in Claim 86, further including the step of indicating to a user that the output signal corresponding to the hottest temperature scanned by said infrared sensor does not indicate the hottest temperature of the medical target.

117. A method as recited in Claim 116 further including the step of directionally guiding a user to the portion of the medical target having the hottest temperature.

118. A method as recited in Claim 116, wherein said indicating step includes the step of providing at least one of audio, tactile, and light feedback to the user.

119. A method as recited in Claim 117, wherein said indicating step includes the step of providing at least one of audio, tactile and light feedback to the user.

120. A method as recited in Claim 112, further including the steps of displaying the hottest temperature of the medical target and indicating to a user that the displayed temperature is an estimated value if portions of the medical target are obstructed.

121. A method as recited in Claim 85, wherein said at least one infrared sensor is disposed on a substrate, said method including the further steps of measuring the temperature

of the substrate and compensating the at least one infrared sensor to account for the measured temperature of the substrate.

122. A method as recited in Claim 100, including the step of thermally isolating said at least one infrared sensor from input external to said apparatus and other than that of the medical target prior to said aiming step.

123. A method as recited in Claim 122, wherein the thermal isolating step includes the step of placing an aperture stop in relation to focusing optics and said at least one infrared sensor in order to allow substantially only energy from said medical target and said aperture stop to impinge on said at least one infrared sensor.

124. A method as recited in Claim 123, further including the steps of measuring the temperature of the aperture stop and compensating the at least one infrared sensor using the measured temperature of said aperture stop.

125. A method as recited in Claim 123, including the step of thermally connecting the aperture stop to a substrate supporting said at least one infrared sensor such that the aperture stop and substrate have substantially equivalent temperatures.

126. A method as recited in Claim 85, wherein said at least one infrared sensor is disposed in an instrument housing, said housing including an insertion portion having a locator to enable said insertion portion to be positioned a predetermined distance in relation to said at least one infrared sensor.

127. A method as recited in Claim 88, including the step of superimposing the thermal image of said target with an optical image of said target.

128. A method as recited in Claim 127, wherein said at least one infrared sensor is disposed in an instrument housing, said housing including an insertion portion having a

locator to enable said insertion portion to be positioned a predetermined distance in relation to said at least one infrared sensor.

129. A method as recited in Claim 85, wherein said apparatus includes a one dimensional infrared sensor array. Said method further including the step of scanning said mirror in relation to said array in order to receive said optical image of said target area.

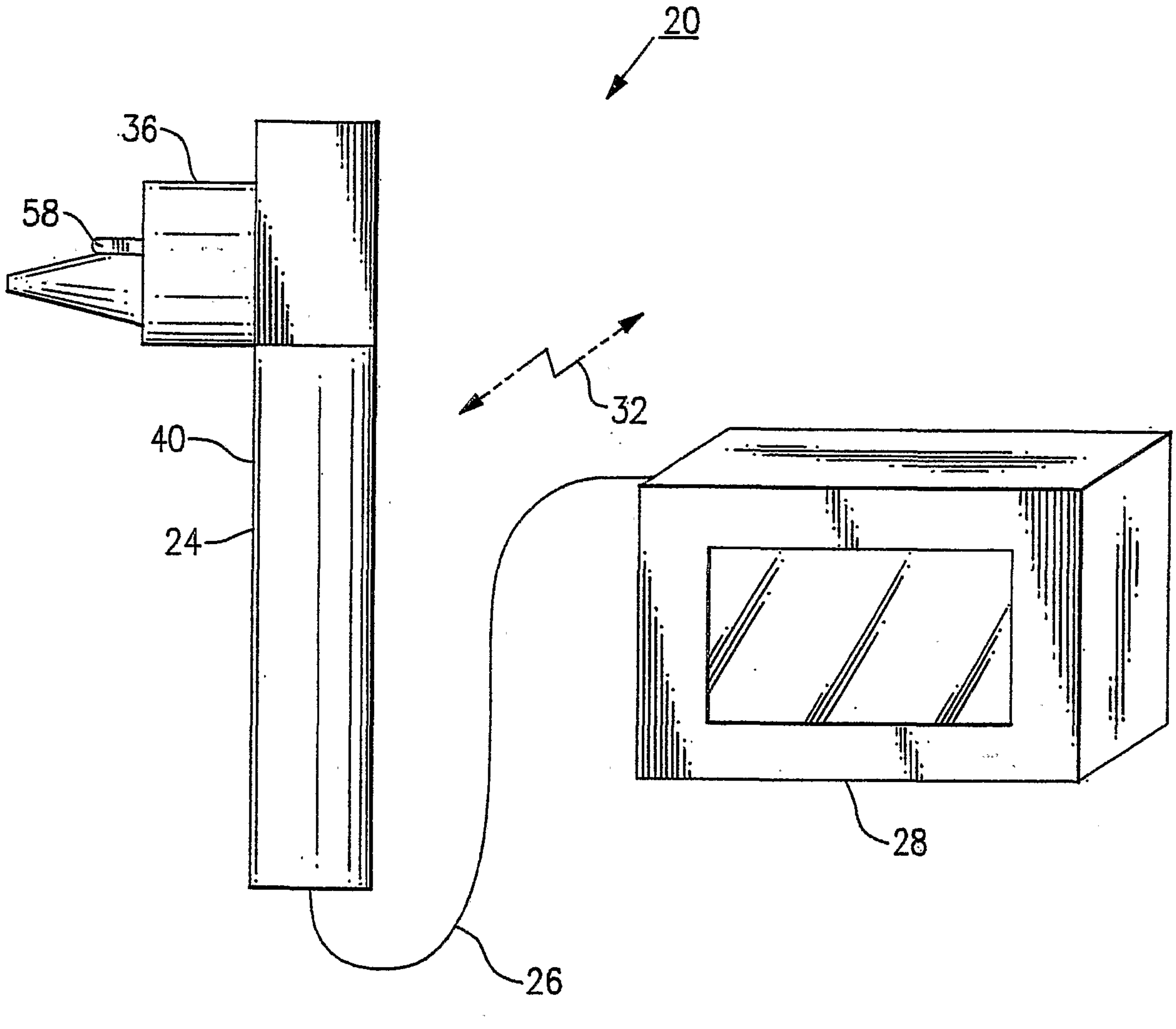


FIG.1

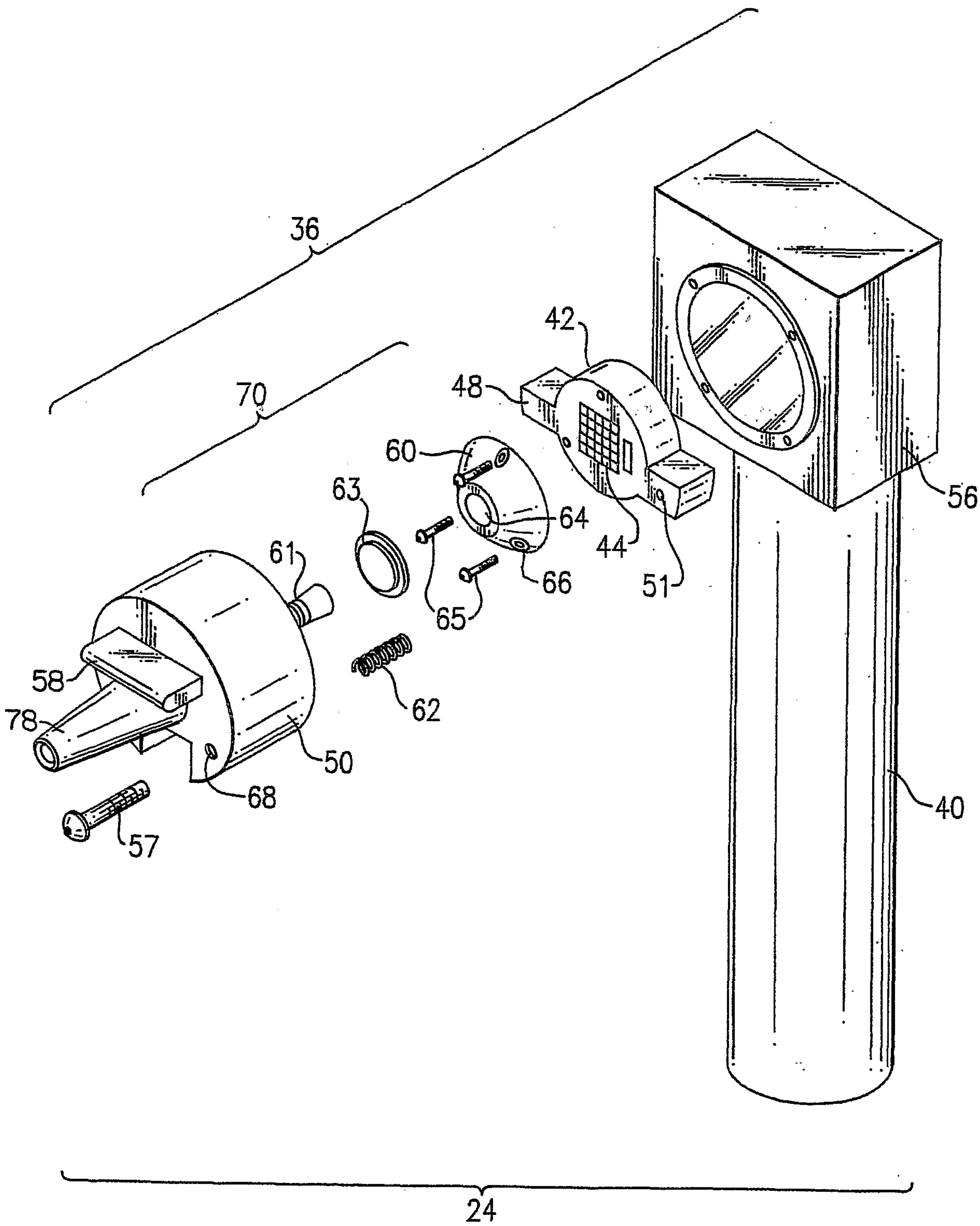


FIG.2A

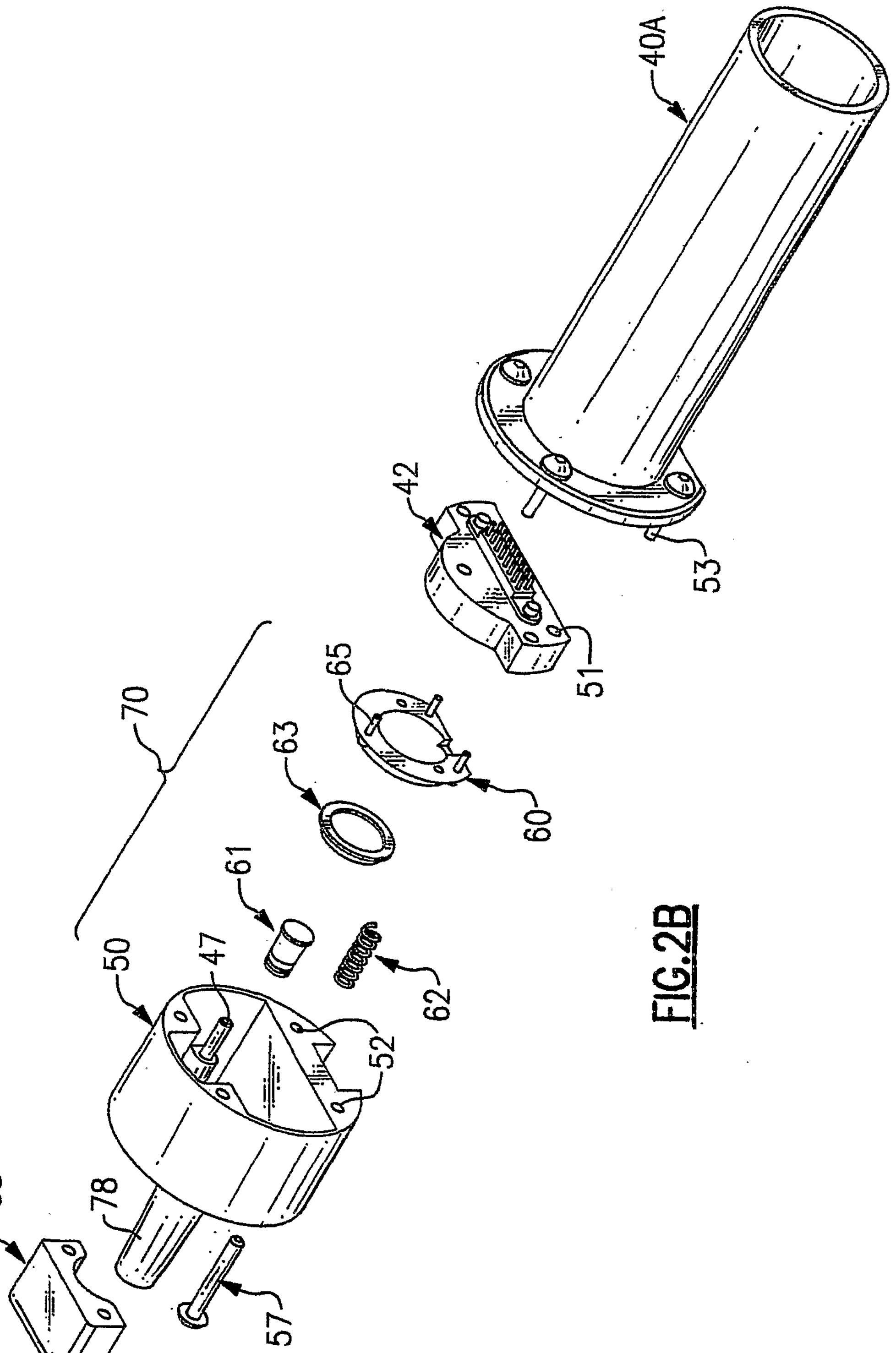


FIG.2B

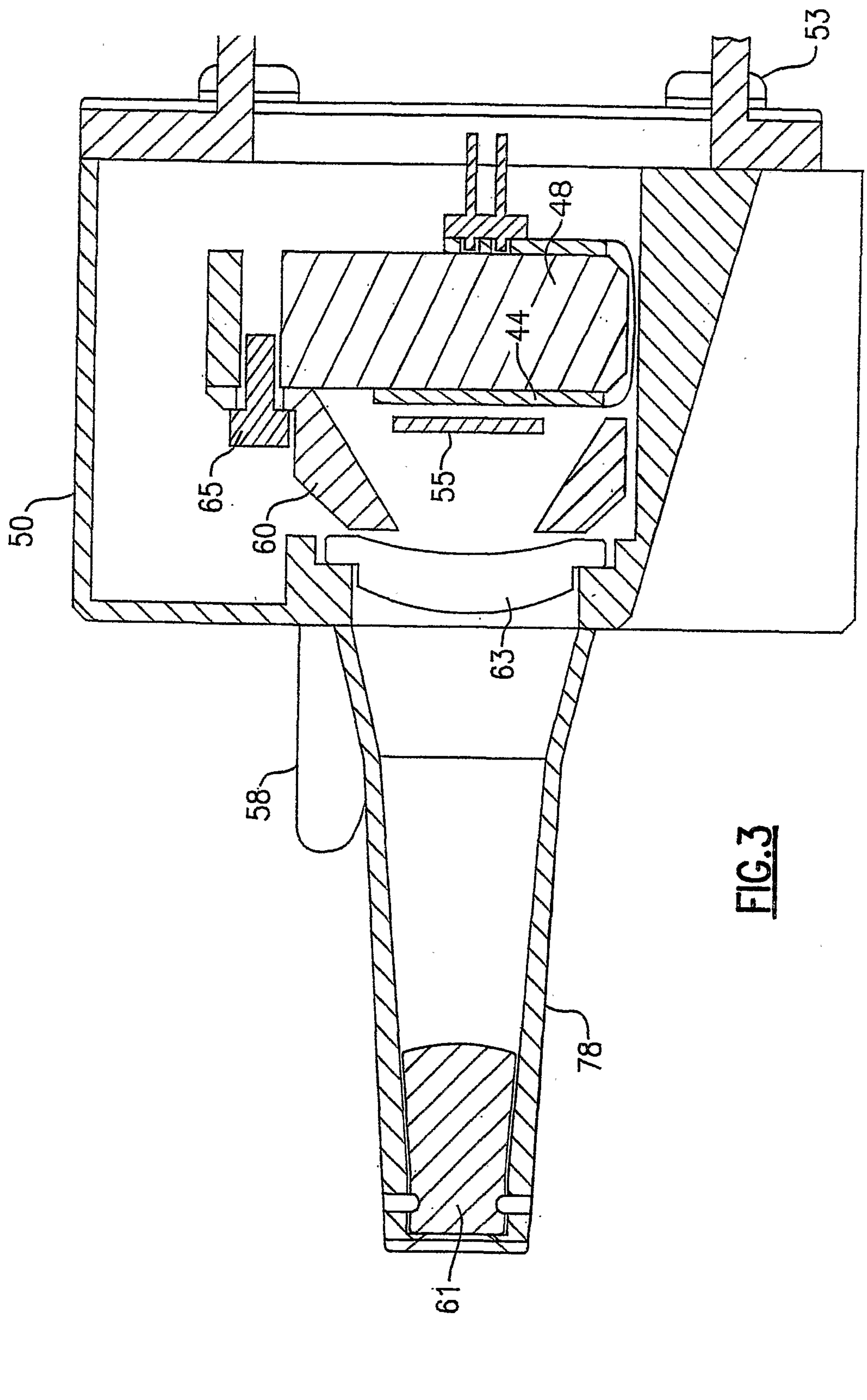


FIG.3

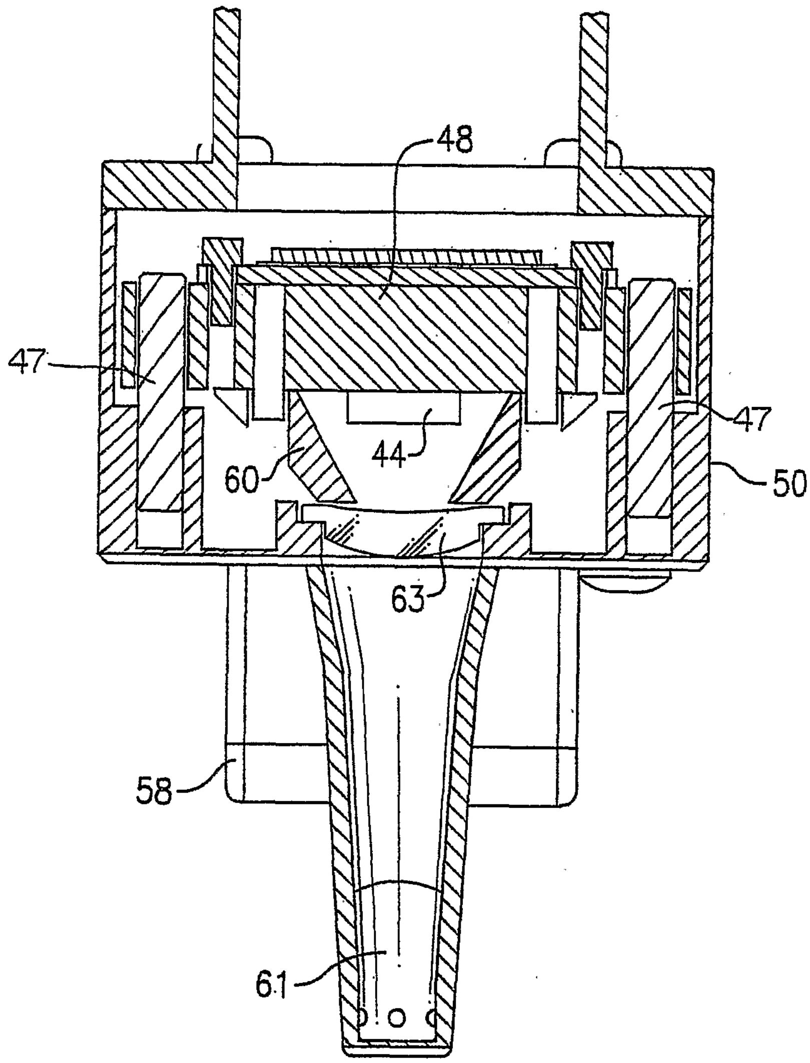


FIG.4

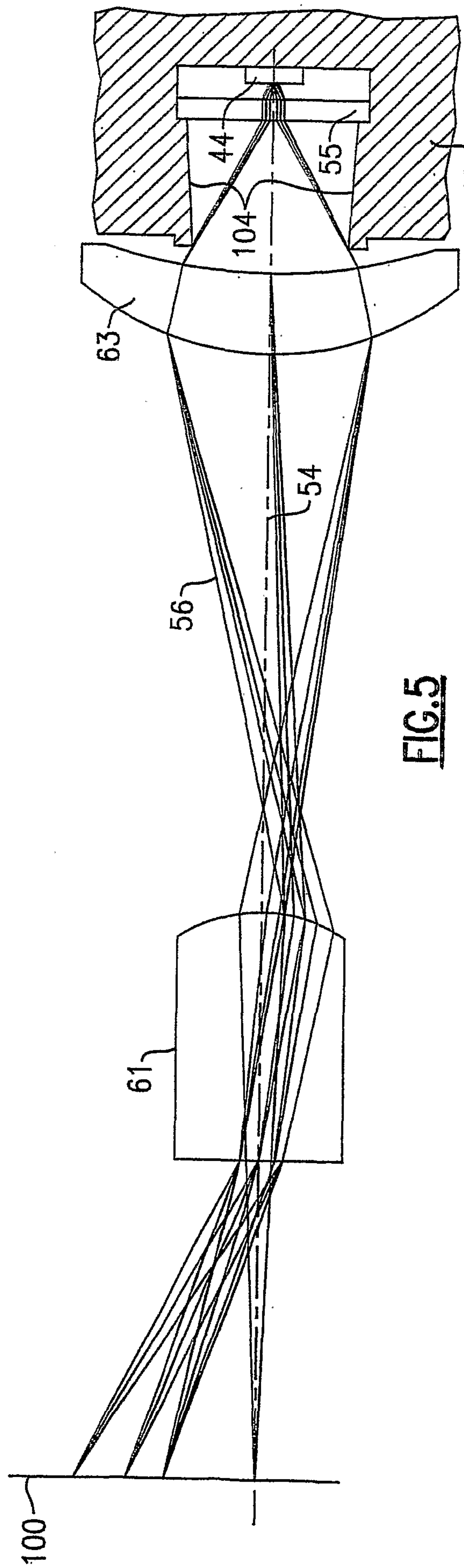


FIG.5

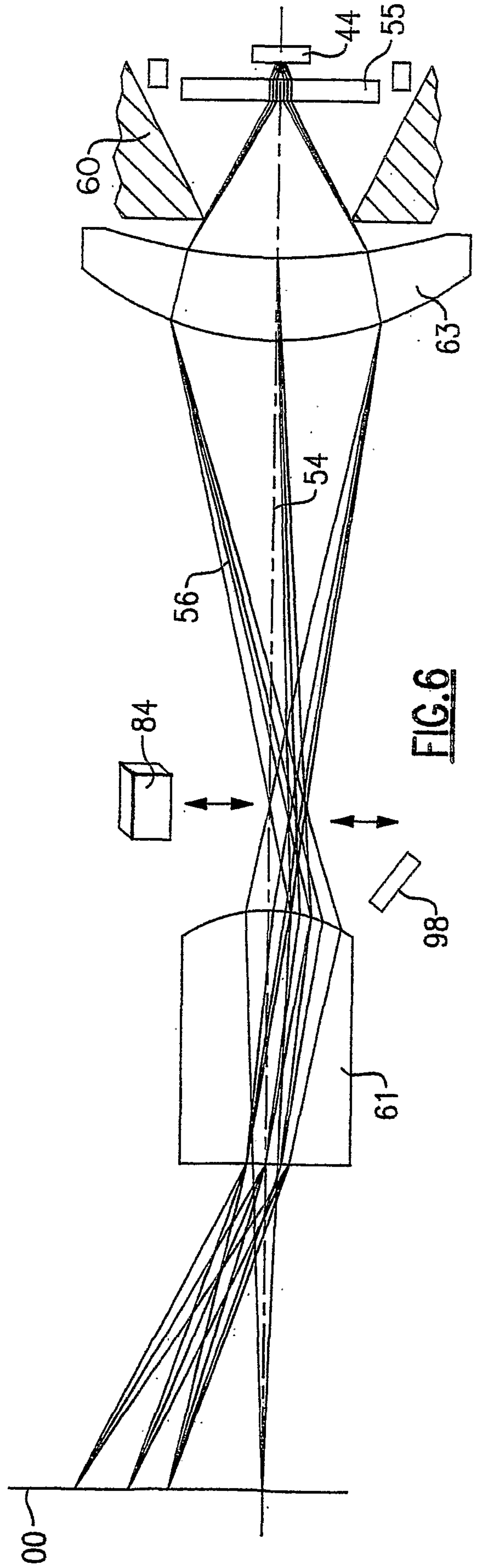


FIG.6

FIG.7

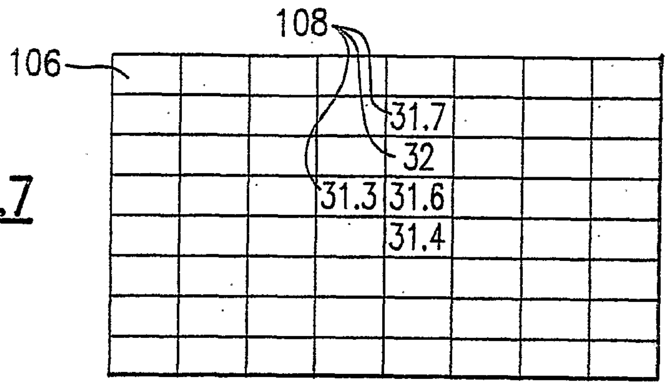


FIG.8

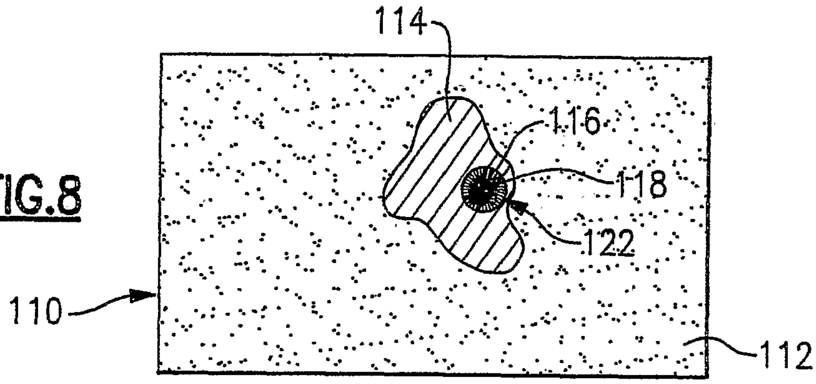


FIG.9

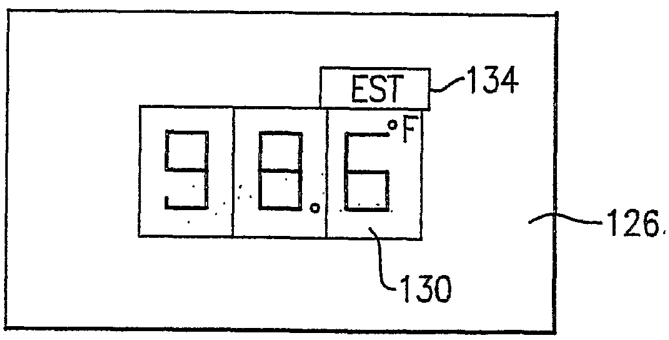
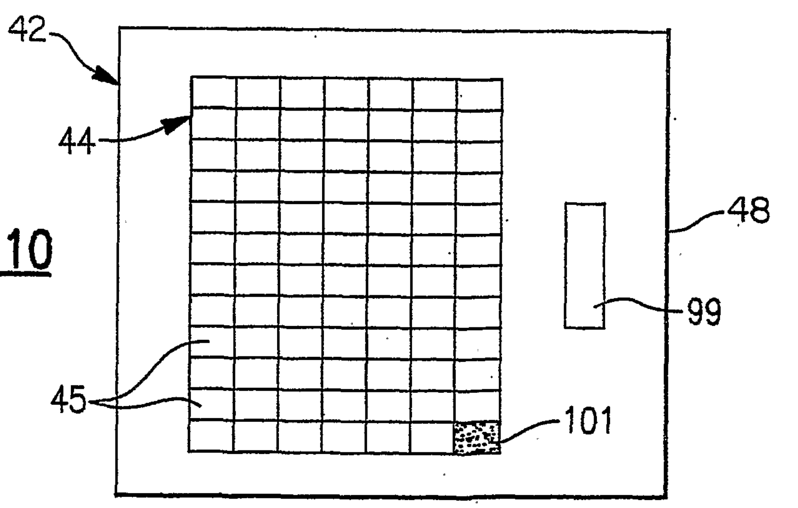


FIG.10



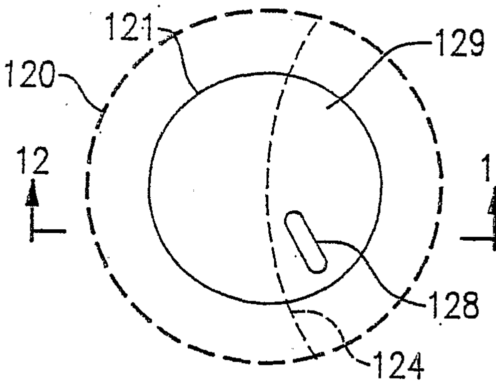


FIG.11

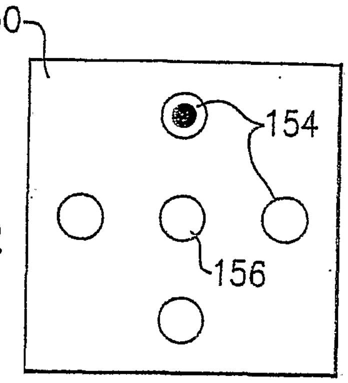


FIG.15

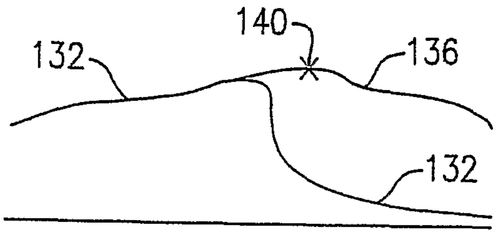


FIG.12

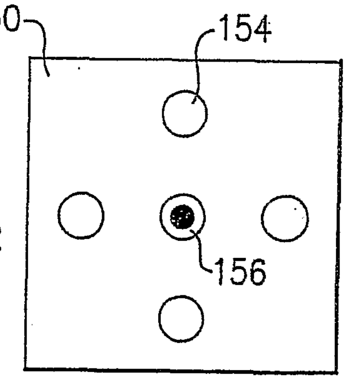


FIG.16

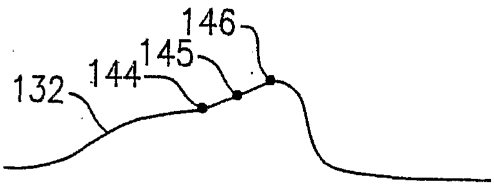


FIG.13

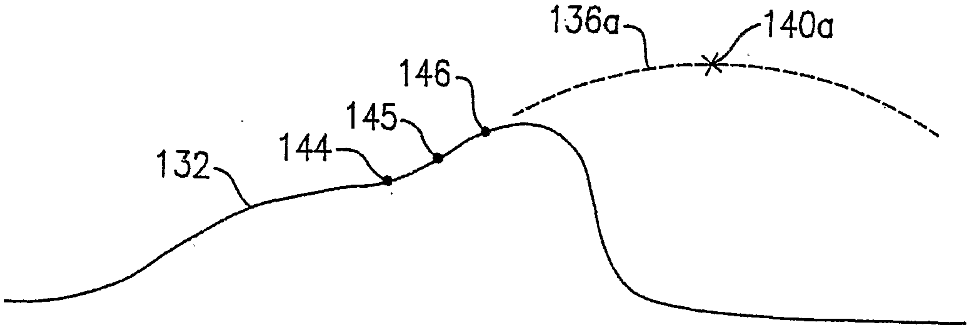


FIG.14

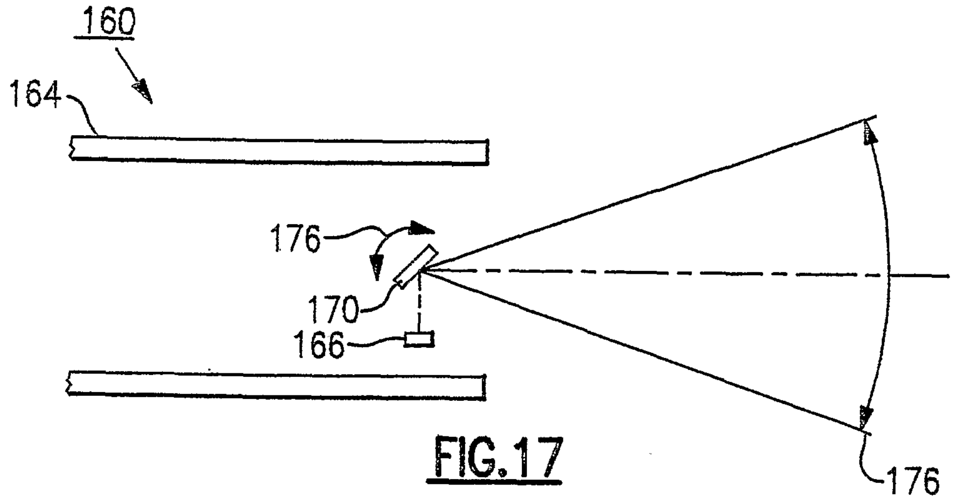


FIG.17

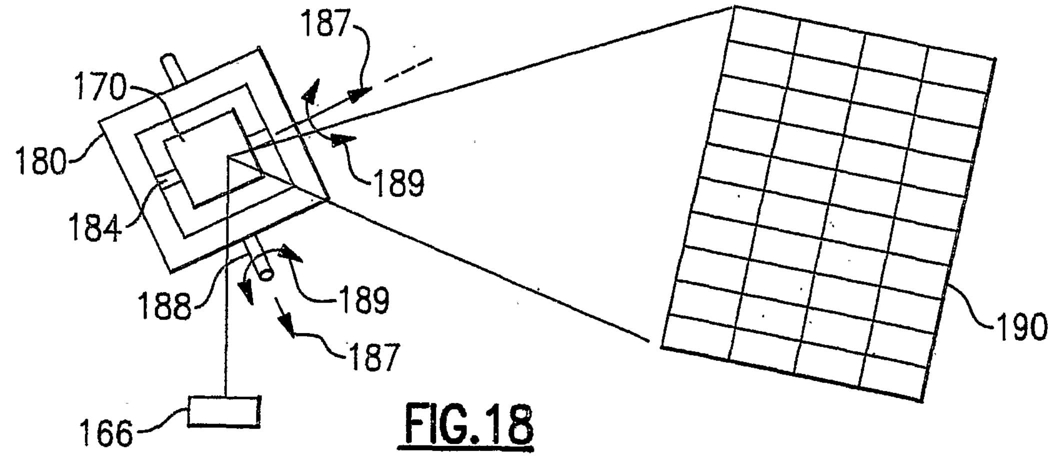


FIG.18

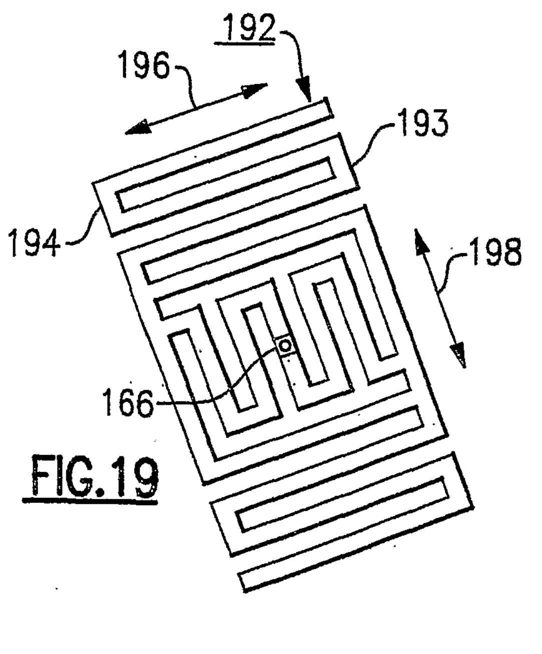


FIG.19

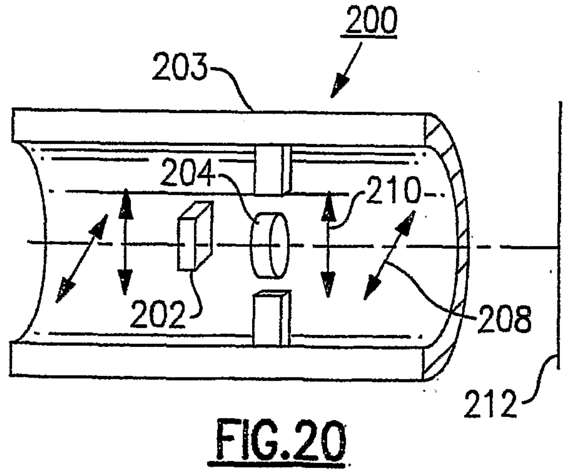


FIG.20

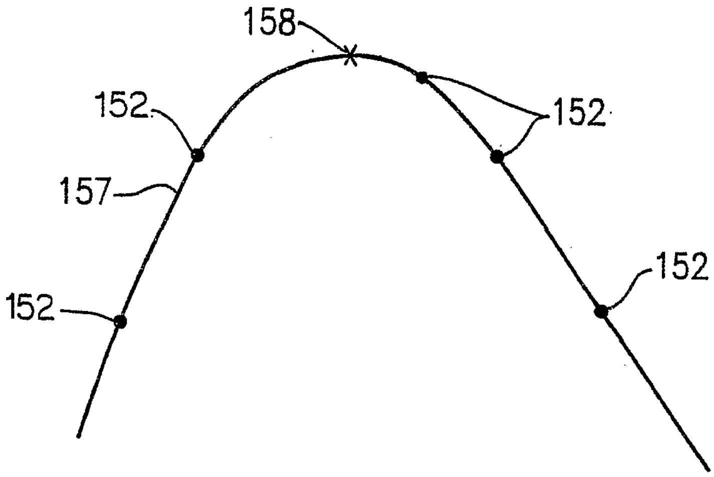


FIG.21