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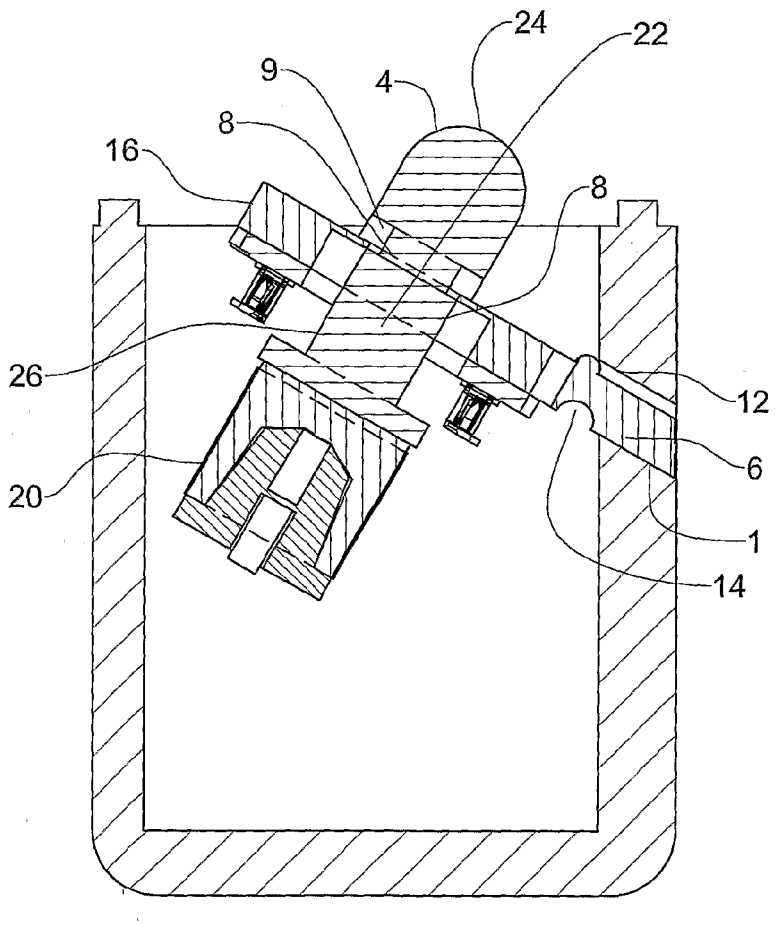
(54) Title: MICROPHONE MATRIX FOR RECORDING BODY SOUNDS



(57) Abstract: The invention provides a microphone matrix for recording body sounds, such as respiratory tract sounds. The matrix has a frame having one or more recesses or openings on one of its surfaces. A microphone assembly is disposed in each recess or opening in the frame. When a body portion is applied to the matrix, each microphone assembly moves from an extended, spring biased position in which at least a portion of the microphone assembly protrudes beyond the surface of the frame towards a retracted position in which the microphone assembly is deeper inside the recess.

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MICROPHONE MATRIX FOR RECORDING BODY SOUNDS

FIELD OF THE INVENTION

This invention relates to medical devices and more particularly to such devices for applying a microphone to a body surface.

BACKGROUND OF THE INVENTION

Body sounds are routinely used by physicians in the diagnosis of various disorders. A physician may place a stethoscope on a person's chest or back and monitor the person's breathing or heart sounds in order to detect adventitious (i.e. abnormal or unexpected) body sounds. The identification and classification of these adventitious sounds often provide important information about physiological abnormalities.

It is also known to affix a microphone to the body in order to record body sounds. The recorded sound signals may be amplified and filtered before being listened to by the physician. The recorded signals may also be analyzed by signal processing techniques.

It is also known to affix a plurality of microphones over a body surface in order to obtain a plurality of sound signals simultaneously from the body surface. Applicant's U.S. Patent No. 6,887,208 discloses a system in which a plurality of microphones are affixed to a person's back or chest for recording respiratory tract sounds. This patent teaches embedding the microphones in a matrix that may be in the form of a vest or garment securely worn by the person during signal acquisition. Different sized or shaped matrixes may be used for differently sized individuals, for different sexes, ages, etc.

U.S. Patent No. 6,394,967 discloses a system in which a plurality of microphones are affixed to a person's back or chest for recording respiratory tract sound. This patent teaches affixing the microphones to the body surface using tape or straps to prevent dislocation or movement during the data acquisition process.

Kompis *et al.* (Chest 120:4, 2001, 1309-1321) discloses affixing eight or sixteen microphones to an individual's chest for obtaining respiratory tract signals, but the method of attachment is not disclosed.

U.S. Patent No. 4,777,961 discloses affixing a microphone to a body surface by means of suction. A microphone embedded in the wall of a dome shaped stethoscope head is formed from an elastic flexible material. The stethoscope head is squeezed by fingertip pressure as it is applied to the body surface. When the fingertip pressure is removed, the head expands slightly so as to create a partial vacuum in its interior so as to keep the head affixed to the body surface. The membrane of the microphone, however, is not pressed against the body surface.

U.S. Patent No. 4,736,749 discloses a holder for a signal pick-up device, such as a microphone or electrode that is fixed to the body surface by vacuum. The holder has a chamber that is evacuated by an external source of negative pressure. When the chamber is evacuated, the holder is held firmly to the skin and the signal-pick up device is pressed to the skin inside the chamber.

US Patent No. 6,790,183 discloses embedding a plurality of microphones within a single structure referred to as a *"cassette"*. The cassette includes a core preferably made from foam, for supporting the microphones. Recesses formed in the foam core receive the microphones so that the microphones are flush with the upper surface of the core. The cassette is positioned on a hospital bed between the mattress and a patient and the patient lies on the cassette with the microphones positioned at a location of interest to for the recording of body sounds.

US Patent No. 7,011,087 discloses a mat that is placed beneath a lying patient. The mat contains measuring means to measure airway vibrations of the patient.

SUMMARY OF THE INVENTION

In its first aspect, the present invention provides a microphone matrix for recording body sounds. The microphone matrix of the invention comprises a housing having a surface with a plurality of recesses. A microphone assembly is suspended in each recess by means of one or more elastic elements. The elastic elements position the microphone assembly in a position in which at least a portion of the microphone assembly protrudes beyond the surface of the housing. When a force is applied to the microphone assembly towards the housing, the microphone assembly moves against the elasticity of the elastic elements towards the interior of the housing. Thus, when a body surface, such as a person's back is applied to the matrix, the microphone assemblies are pressed onto the body surface to create good acoustic coupling between the body surface and the microphone assembly.

The housing and the elastic elements are preferably formed from an acoustically dampening material. A spacer in each microphone assembly is preferably formed from an acoustically conducting material. Thus vibrations received in the spacer are conducted to the microphone while vibrations in the housing or the projection are essentially not conducted to the microphone. Cross-talk between the microphones is also reduced.

In one embodiment of the invention, the microphone matrix comprises a plurality of microphone units joined together by a flexible frame. In another embodiment, the microphone matrix has a housing contoured to receive a body portion from which body sounds are to be recorded. For example, the surface may be contoured so as to receive the back and neck region of the body when respiratory sounds are to be detected. A microphone is suspended in each of a plurality of recesses in the surface by means of two or more elastic elements, as explained above.

In its second aspect, the invention provides a system for recording and/or analyzing body sound signals. The system of the invention includes one or more microphone matrices of the invention. Each microphone in the matrix produces an

analog voltage signal indicative of pressure waves arriving at that microphone. In use, the matrix is placed on a surface such as an examination table or hospital bed. Since the microphones in the microphone matrix are elastically biased to protrude beyond the upper surface of the matrix housing, with a body surface applied to the surface of the housing, at least some of the weight of the individual is transferred to the microphones. In this way, the microphones are firmly applied to the body surface without the need of an attachment system, such as straps, tape, or vacuum. Respiratory tract sounds, or other body sounds at the body surface are detected by the microphones. The system of the invention also includes signal processing circuiting for processing signals obtained by the microphones, as required in any application. For example, the electronic circuitry for processing acoustic signals obtained from two or more microphones, as disclosed in U.S. Patent No. 6,394,967 to Murphy, Kompis *et al.* supra, and in Applicant's U.S. Patent 6,887,208 may be used in the system of the invention.

In its third aspect, the invention provides a method for recording body sounds. In accordance with this aspect of the invention, a body surface is applied to a microphone matrix of the invention and sounds detected by the microphones are recorded and/or analyzed.

This, in its first aspect, the invention provides a microphone matrix for recording body sounds, comprising:

(a) a frame having one or more recesses or openings on a surface of the housing or frame; and

(b) one or more microphone assemblies, each microphone assembly comprising a microphone, and each microphone assembly being disposed in a recess or opening in the frame, and wherein each microphone assembly is movable from an extended, spring biased position in which at least a portion of the microphone assembly protrudes beyond the surface of the frame to a retracted position in which the microphone assembly is deeper inside the recess.

In its second aspect, the invention provides a method for recording body sounds comprising :

(a) providing a microphone matrix for recording body sounds, the matrix comprising:

(i) a frame having one or more recesses or openings on a surface of the housing or frame; and

(ii) one or more microphone assemblies, each microphone assembly comprising a microphone, and each microphone assembly being disposed in a recess or opening in the frame, and wherein each microphone assembly is movable from an extended, spring biased position in which at least a portion of the microphone assembly protrudes beyond the surface of the frame to a retracted position in which the microphone assembly is deeper inside the recess.

(b) placing the microphone matrix on a surface; and

(c) applying a body surface of an individual to the surface of the frame.

In its third aspect, the invention provides a system for analyzing body sounds comprising:

(a) a microphone matrix for recording body sounds, the matrix comprising:

(i) a frame having one or more recesses or openings on a surface of the housing or frame; and

(ii) one or more microphone assemblies, each microphone assembly comprising a microphone, and each microphone assembly being disposed in a recess or opening in the frame, and wherein each microphone assembly is movable from an extended, spring biased position in which at least a portion of the microphone assembly protrudes beyond the surface of the frame to a retracted position in which the microphone assembly is deeper inside the recess.; and

(b) electronic circuitry for analyzing signals obtained by the one or more microphones.

The invention also provides a microphone assembly for use in the microphone matrix of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a perspective view of a microphone unit for use in a microphone matrix of the invention;

Fig. 2 shows the projection of the microphone unit of Fig. 1;

Fig. 3 shows a cross-section of the microphone unit of Fig. 1 in the absence of a force applied to the microphone assembly;

Fig. 4 shows a cross-section of the microphone unit of Fig. 1 in the presence of a force applied to the microphone assembly;

Fig. 5 shows a microphone matrix in accordance with one embodiment of the invention comprising the microphone unit of Fig. 1;

Fig. 6 shows a microphone matrix in accordance with another embodiment of the invention having a contoured housing;

Fig. 7 shows a section of the microphone matrix of Fig. 6;

Fig. 8 shows the microphone matrix of Figs. 6 and 7 in the presence of a force applied to the microphone assemblies;

Fig. 9 shows a system for recording and analyzing body sounds in accordance with one embodiment of the invention; and

Fig. 10 shows exemplary electronic circuitry for use in the system of Fig. 9.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Fig. 1 shows a microphone unit **1** for use in a microphone matrix for recording body sounds in accordance with one embodiment of the invention. The microphone unit **1** has a housing having the general shape of a rectangular parallelepiped. The housing **1** has an opening **2** on an upper side. A microphone assembly **4** is supported by a projection **6** shown alone in Fig. 2. The projection **6** has an aperture **8** surrounded by a collar **9** configured to receive the microphone assembly **4.** The projection **6** has a tab portion **10** configured to be inserted into a slot **12** formed into the wall of the housing **1,** as shown in Fig. 1. A groove **14** is formed in the bottom surface of the projection **6** that separates the tab portion **10** from a tongue portion **16**. The groove **14** creates a resiliently flexible hinge at the boundary between the tab portion **10** and the tongue portion **16**.

Fig. 3 shows a cross-sectional view of the microphone unit **1** through the microphone assembly **4.** The projection **6** is inserted into the slot **12** and is bonded in place. The slot **12** is formed in a wall **18** of the housing at an oblique angle so that the projection **6** extends obliquely from the wall **18**. The microphone assembly **4** includes a microphone **20** and a spacer **22**. The spacer **22** has a narrow neck portion **26** configured to be immobilized in the aperture **8** in a snap-fit, and a dome portion **24** having a hemispherical surface.

The hinge in the projection **6** formed by the groove **14** and is biased in a straight position, as shown in Fig. 3, when an external force is not applied the dome portion **24**. In this configuration, the dome portion **24** protrudes beyond the walls of the housing **2.** When a downward force is applied to the dome portion **24**, the projection **6** bends at the hinge **14**, with the tongue portion **16** moving downwards towards the interior of the housing **2.** For example, as shown in Fig. 4, when a body part **28**, such as a person's back is applied to the dome portion **24**, the tongue portion **16** is deflected downwards. Due to the resiliently flexible character to the hinge **14**, the dome portion **24** is pressed onto the surface of the body part **28** to create good acoustic coupling between the body part **28** and the dome portion **24**.

The housing **2** and the projection **6** are formed from an acoustically dampening material. The spacer **22** is formed from an acoustically conducting material. Thus vibrations received in the dome portion **24** of the spacer **22** are conducted to the microphone **20**. Vibrations received in the housing **2** or the projection **6** are essentially not conducted to the microphone **20**. Thus, vibrations originating in the body part **28** are received in the dome portion **24** and conducted to the microphone **20**.

Fig. 5 shows a microphone matrix **30** comprising a plurality of the microphone units **1.** The matrix **30** has a frame **32** formed from a flexible acoustically dampening material in which a plurality of apertures **34** are formed. Each aperture **34** is configured to receive a microphone unit **1** that is grasped in the aperture by a snap fit. Due to the flexibility of the frame **32**, the matrix **30** is flexible and can conform to the shape of a surface applied to it. For example, when the matrix is placed on a mattress and person's back is applied to the matrix, the matrix will conform to the shape of the person's back. The matrix **30** includes a cable **36** of electrical wire leads from each microphone. In another embodiment (not shown), the microphone leads are in the form of a printed circuit on the surface of the support **2.** In yet another embodiment (not shown), the microphones **4** are wireless, in which case each microphone includes a transmitter for transmitting signals to the electronic circuitry.

Figs 6 and 7 show a microphone matrix **41** for recording body sounds in accordance with another embodiment of the invention. The matrix **41** is shown in a perspective view in Fig. 6 and in a sectional view in Fig. 7. The matrix **41** includes a frame **42** in which one or more microphones **44** are embedded. The frame **42** has an upper surface **46** that is contoured to receive a body portion from which body sounds are to be recorded. For example, as shown in Fig. 6, the upper surface **46** may be contoured so as to receive the back and neck region of the body when respiratory tract sounds are to be detected. The frame **42** has a generally flat bottom surface **48** to allow the matrix **41** to be placed on a flat surface, such as a bed, as explained below. The frame **42** is made from an

acoustically damping material in order to dampen vibrations originating on the surface upon which the matrix **41** is placed.

The frame 42 is provided with one or more recesses **48**. A microphone **42** is disposed in each of the recesses **50**. A microphone **44**, for example, the microphone **44a** is suspended in its respective recess **48a** by means of two or more elastic cords **52**, so that the microphone **44a** is not in direct contact with the frame 42. By not placing the microphones **42** in direct contact with the frame 42, any extraneous vibrations in the frame **42** are essentially not picked up by the microphones **2**.

Each of the microphones **44** is provided with a spacer **43** made from an acoustically conducting material. The microphones **44** are disposed in the recesses **48** so that the spacer **43** of each microphone protrudes above the upper surface 46 of the frame **42**, as shown in Fig. 6. As shown in Fig. 8, due to the elasticity of the cords **52**, when a body surface **53** is applied to the upper surface **46** of the frame **42**, each of the microphones **44** is applied to the body surface **53**. In one embodiment of the invention, leads **56** extend from each microphone **44** to the exterior of the frame **42** via a system of channels **58** connecting each recess **48** with the exterior, so that the leads may be attached to signal processing circuitry (not shown), as required in any application. The microphone leads **56** extending from the frame **42** are collected into a single cable **68** that terminates in a plug **69** for connection to electronic circuitry for recording and/or analyzing voltage signals from the microphones **44.** In another embodiment (not shown), the microphone leads are in the form of a printed circuit on the surface of the frame **42**. In yet another embodiment, the microphones **44** are wireless, in which case each microphone includes a transmitter for transmitting signals to the electronic circuitry.

Fig. 9 shows a system **65** for recording and/or analyzing body sound signals, in accordance with the invention. The system **65** includes one or more microphone matrices **61** of the invention, for example the microphone matrix **30** described above in reference to Fig. 5 or the microphone matrix **44** described above in reference to Figs. 6 and 7. Each microphone in the matrix **61** produces an analog

voltage signal indicative of pressure waves arriving at that microphone. As shown in Fig. 10, in use, the matrix **61** is placed on a surface **62** such as an examination table or hospital bed. The upper surface of the microphone matrix **61**, may be covered with an acoustically transparent disposable film (not shown) such as hospital grade *"clean wrap"* before a body surface, such as the back of an individual **64**, is applied to the microphone matrix 61. The surface **62** may be completely flat as shown in Fig. 9, or may be articulated so as to allow the individual **64** to sit up during recording of body sounds.

As explained above, the microphones in the microphone matrix **61** are elastically biased to protrude above the upper surface of the matrix housing. Thus, with the back of the individual **64** properly positioned on the upper surface of the housing of the microphone matrix **61,** at least some of the weight of the individual **64** is transferred to the upper surface of the support housing. In this way, the microphones are firmly applied to the individual's back without the need of an attachment system, such as straps, tape, or vacuum. Since the spacer of the microphone assembly is preferably made from an acoustically conducting material, respiratory tract sounds, or other body sounds originating in the thorax are detected by the microphones in the matrix **61**. Extraneous vibrations originating outside the body such as vibrations due to movement of the individual or vibrations conducted through the surface **62**, for example, due to the movement of other people or due to the operation of equipment in the vicinity of the surface **62,** are essentially not detected by the microphones in the matrix since the microphone assemblies are connected to the housing or frame by a material that is not acoustically conducting.

The ability to apply the microphone matrix of the invention to a body region without the need for any fastening devices such as straps or vacuum, allows the microphone matrix to be applied to a body over a prolonged period of time. The system of the invention may thus be used for continuously monitoring and recording body sounds over a substantially unlimited period of time. In particular,

the system may be used to continuously monitor body sounds such as reparatory tract sounds or cardiac sounds in an individual in an intensive care unit.

A cable **68** is connected to signal processing circuiting **70** for processing signals obtained by the microphones **44**, as required in any application. The wires in the cable **68** provide each microphone **44** with a voltage that may be used for activating a preamplifier in the microphone, and also serve for transmitting a voltage signal to recording or analyzing circuitry when wires connected to a microphone are connected at another end to recording or analyzing circuitry, as described below. If the microphones **44** are wireless, the electronic circuitry **70** includes a receiver for receiving signals from the microphone transmitters.

Fig. 10 shows exemplary electronic circuitry **70** that may be used in the system **65** of the invention. Any method for analyzing body sounds may be used in the system of the invention. For example, the electronic circuitry for processing acoustic signals obtained from two or more microphones, as disclosed in U.S. Patent No. 6,394,967 to Murphy, Kompis *et al.* supra, or U.S. Patent 6,887,208 may be used in the system of the invention. In the circuitry shown in Fig. 10, the analog signals are digitized by a multi-channel analog to digital converter **72**. The digital data signals **74**, are input to a memory **76**. Data input to the memory **76** are accessed by a processor **78** configured to process the data signals **74**. The signals **74** may be denoised by filtering components having frequencies outside of the range of body sounds in the body region, for example, vibrations due to movement of the individual. Each signal **74** may also be individual to band pass filtering so that only frequency components in the signal within a range of interest are analyzed. An input device such as a computer keyboard **80** or mouse **82** is used to input relevant information relating to the examination such as personal details of the individual **64**. A display screen **84** is used to display the signals **74** or the results of the processing.

CLAIMS:

1. A microphone matrix for recording body sounds, comprising:

(a) a frame having one or more recesses or openings on a surface of the housing or frame; and

(b) one or more microphone assemblies, each microphone assembly comprising a microphone, and each microphone assembly being disposed in a recess or opening in the frame, and wherein each microphone assembly is movable from an extended, spring biased position in which at least a portion of the microphone assembly protrudes beyond the surface of the frame to a retracted position in which the microphone assembly is deeper inside the recess.

2. The matrix according to Claim 1 wherein the housing or frame is formed from an acoustically dampening material.

3. The matrix according to Claim 1 or 2 wherein at least one microphone assembly is attached to the housing or frame by an acoustically dampening material.

4. The matrix according to any one of the previous claims wherein at least one microphone assembly includes a spacer formed from an acoustically conducting material.

5. The matrix according to any one of the previous claims further comprising one or more housings, each housing having a recess, wherein each microphone assembly is disposed in the recess of one of the housings and is supported by a tongue extending from a wall of the housing.

6. The matrix according to Claim 5 wherein the frame has a plurality of apertures each aperture configured to receive a housing.

7. The matrix according to Claim 5 wherein the frame is formed from a flexible material.

8. The matrix according to Claim 1 wherein the frame has a surface contoured to receive a body portion.

9. The matrix according to Claim 8 wherein the body surface includes at least a portion of a back.

10. The matrix according to Claim 7 wherein channels are formed in the frame and microphone leads pass through the channels.

11. The matrix according to any one of the previous claims wherein the microphones are wireless.

12. The matrix according to any one of Claims 1 to 10 wherein microphone leads are incorporated into a cable extending from the housing.

13. A method for recording body sounds comprising :

(a) providing a microphone matrix for recording body sounds, the matrix comprising:

(i) a frame having one or more recesses or openings on a surface of the housing or frame; and

(ii) one or more microphone assemblies, each microphone assembly comprising a microphone, and each microphone assembly being disposed in a recess or opening in the frame, and wherein each microphone assembly is movable from an extended, spring biased position in which at least a portion of the microphone assembly protrudes beyond the surface of the frame to a retracted position in which the microphone assembly is deeper inside the recess.

(b) placing the microphone matrix on a surface; and

(c) applying a body surface of an individual to the surface of the frame.

14. The method according to Claim 13 wherein at least a portion of the weight of the individual is transferred to one or more of the microphone assembly spacers.

15. The method according to Claim 14 wherein at least one microphone assembly moves from the extended spring biased position towards the retracted position when the weight of an individual is transferred to the microphone assembly.

16. The method according to any one of Claims 13 to 15 further comprising analyzing signals obtained by the one or more microphones.

17. The method according to any one of Claims 13 to 16, comprising continuously monitoring body sounds.

18. A system for analyzing body sounds comprising:

(a) a microphone matrix for recording body sounds, the matrix comprising:

(i) a frame having one or more recesses or openings on a surface of the housing or frame; and

(ii) one or more microphone assemblies, each microphone assembly comprising a microphone, and each microphone assembly being disposed in a recess or opening in the frame, and wherein each microphone assembly is movable from an extended, spring biased position in which at least a portion of the microphone assembly protrudes beyond the surface of the frame to a retracted position in which the microphone assembly is deeper inside the recess.; and

(b) electronic circuitry for analyzing signals obtained by the one or more microphones.

19. A microphone assembly for use in a microphone matrix according to any one of Claims 1 to 12.

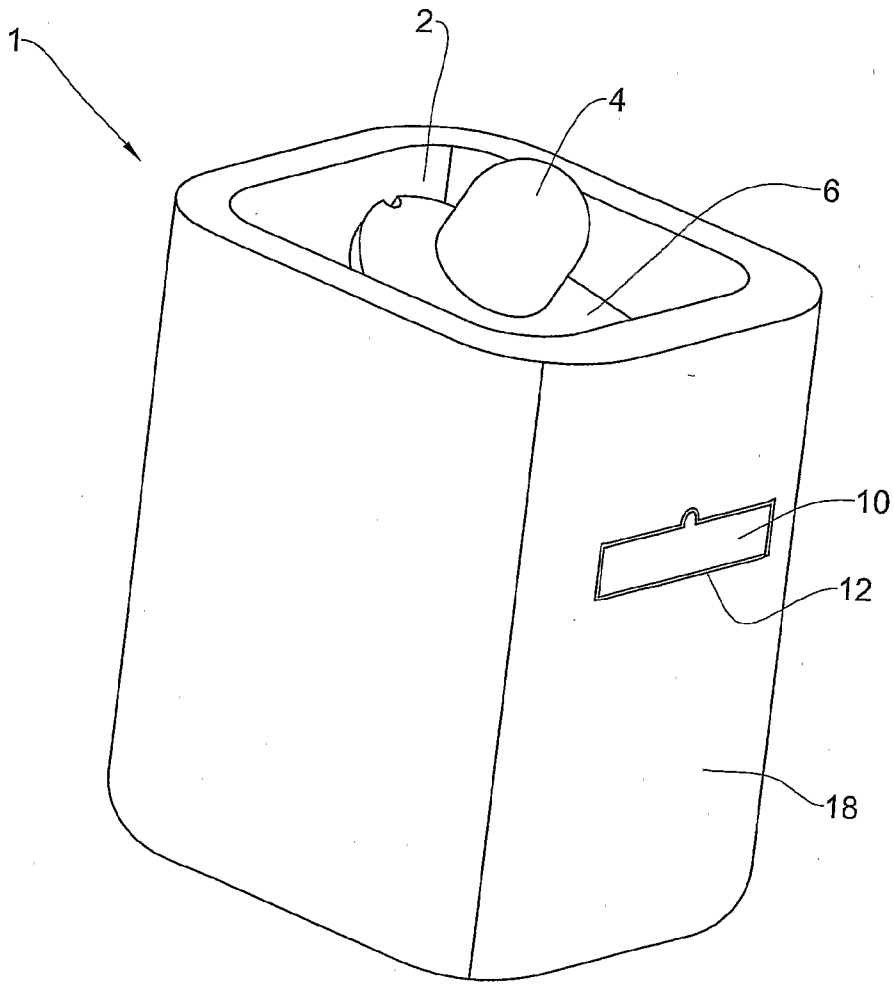

FIG. 1

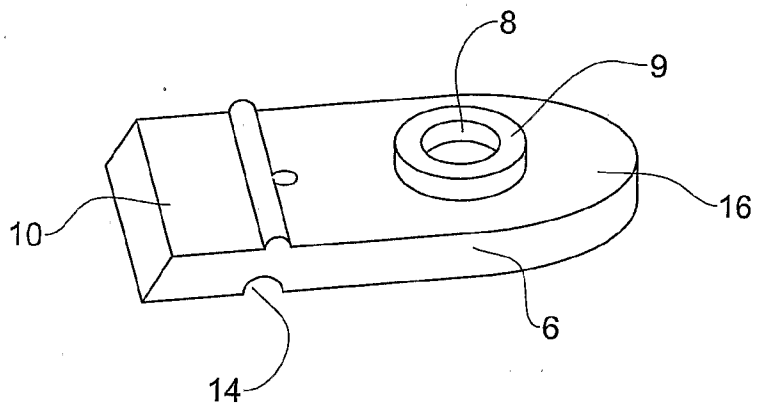

FIG. 2

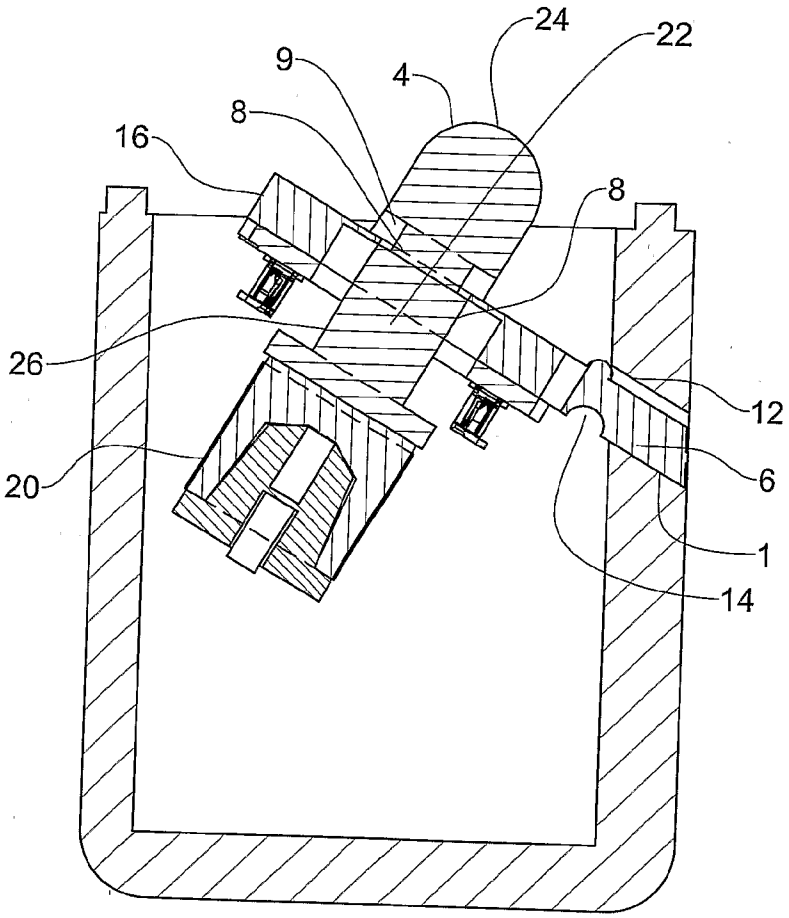

FIG. 3

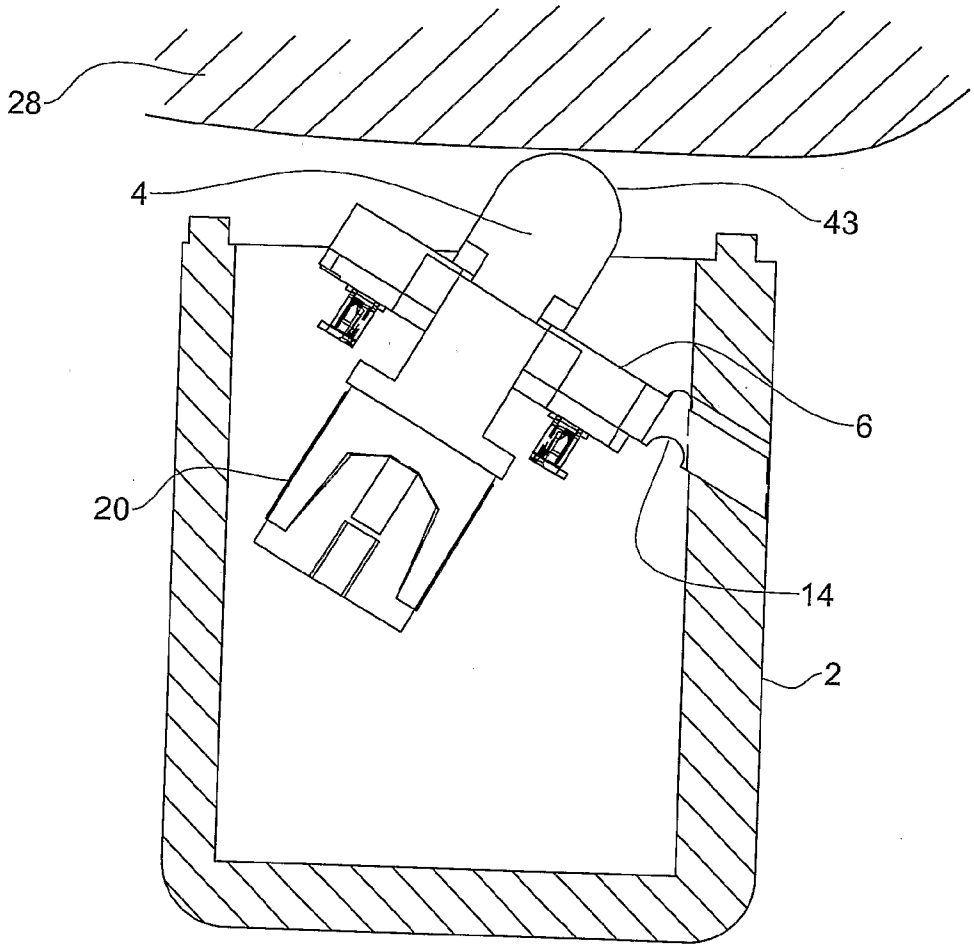

FIG. 4

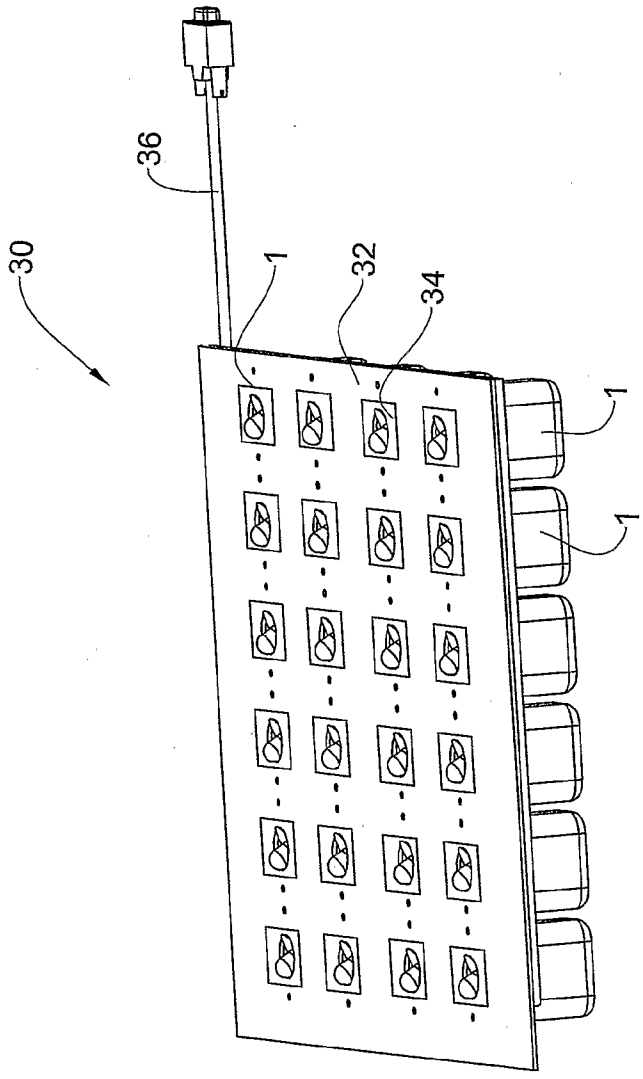

FIG. 5

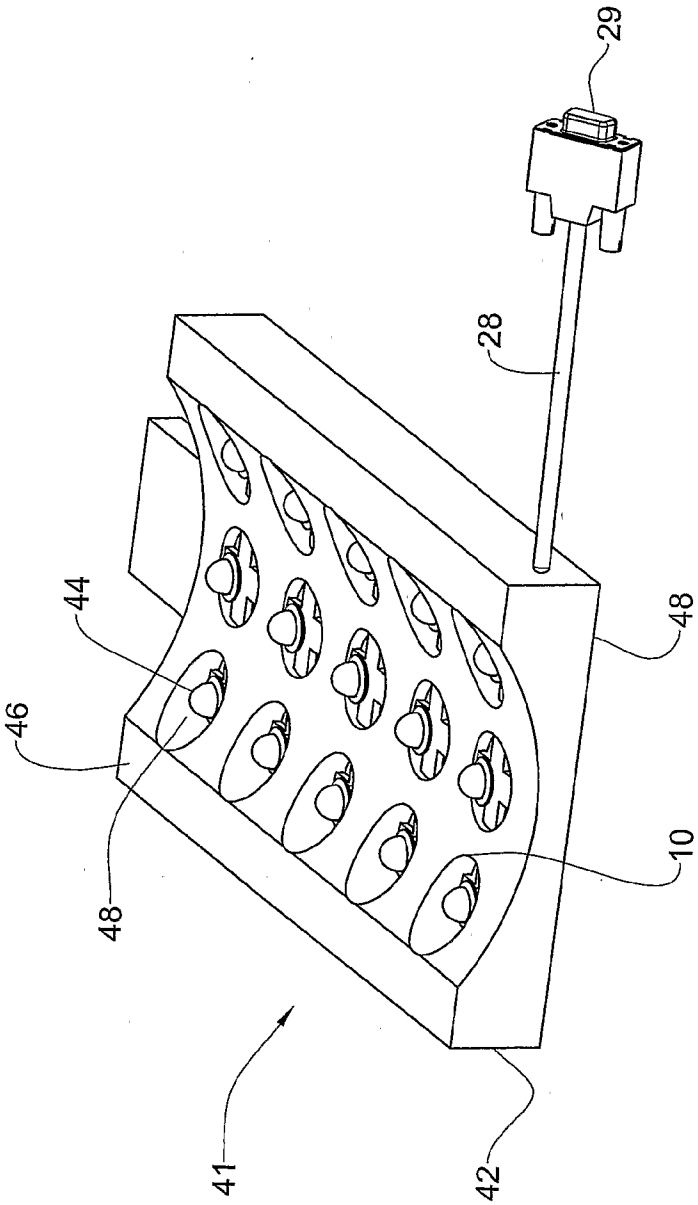

FIG. 6

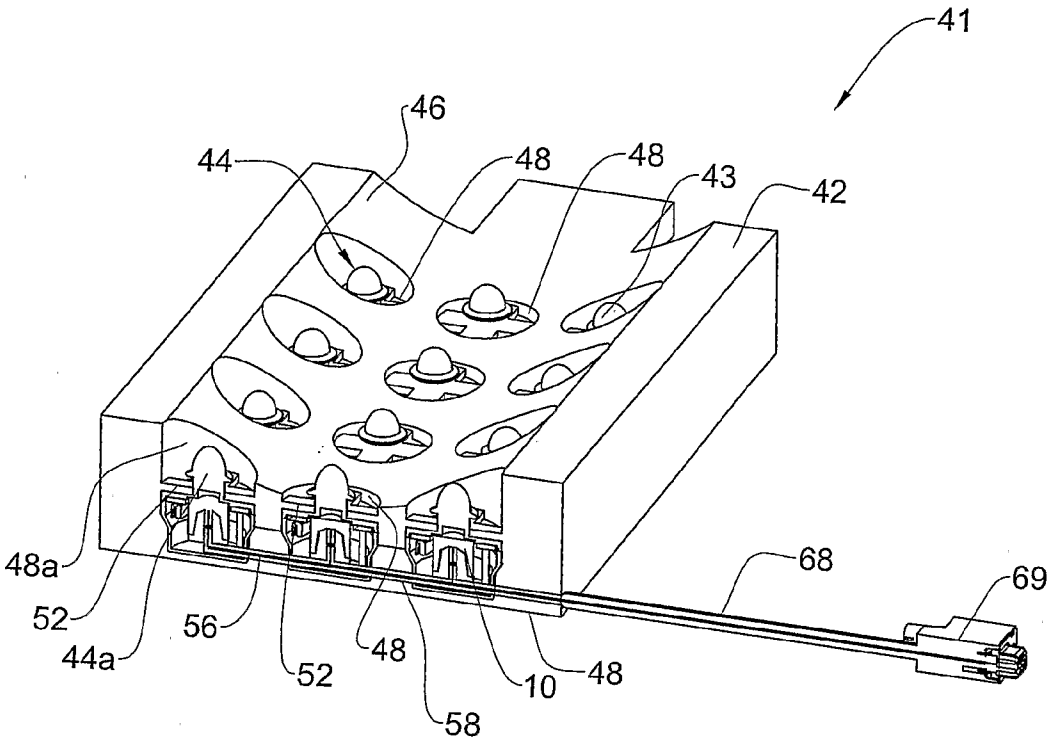

FIG. 7

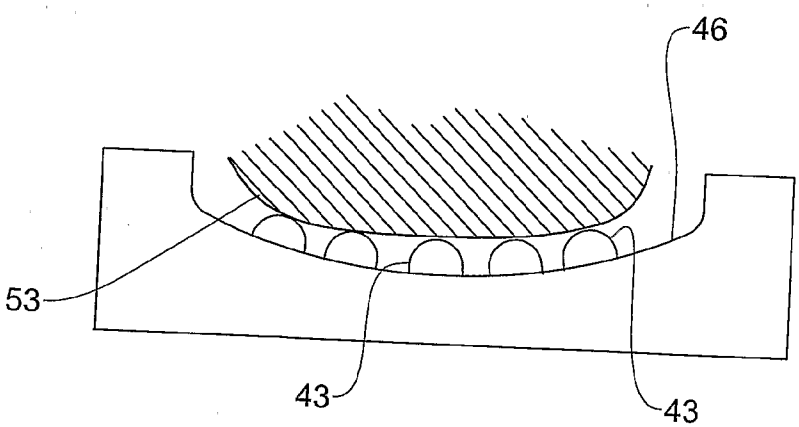

FIG. 8

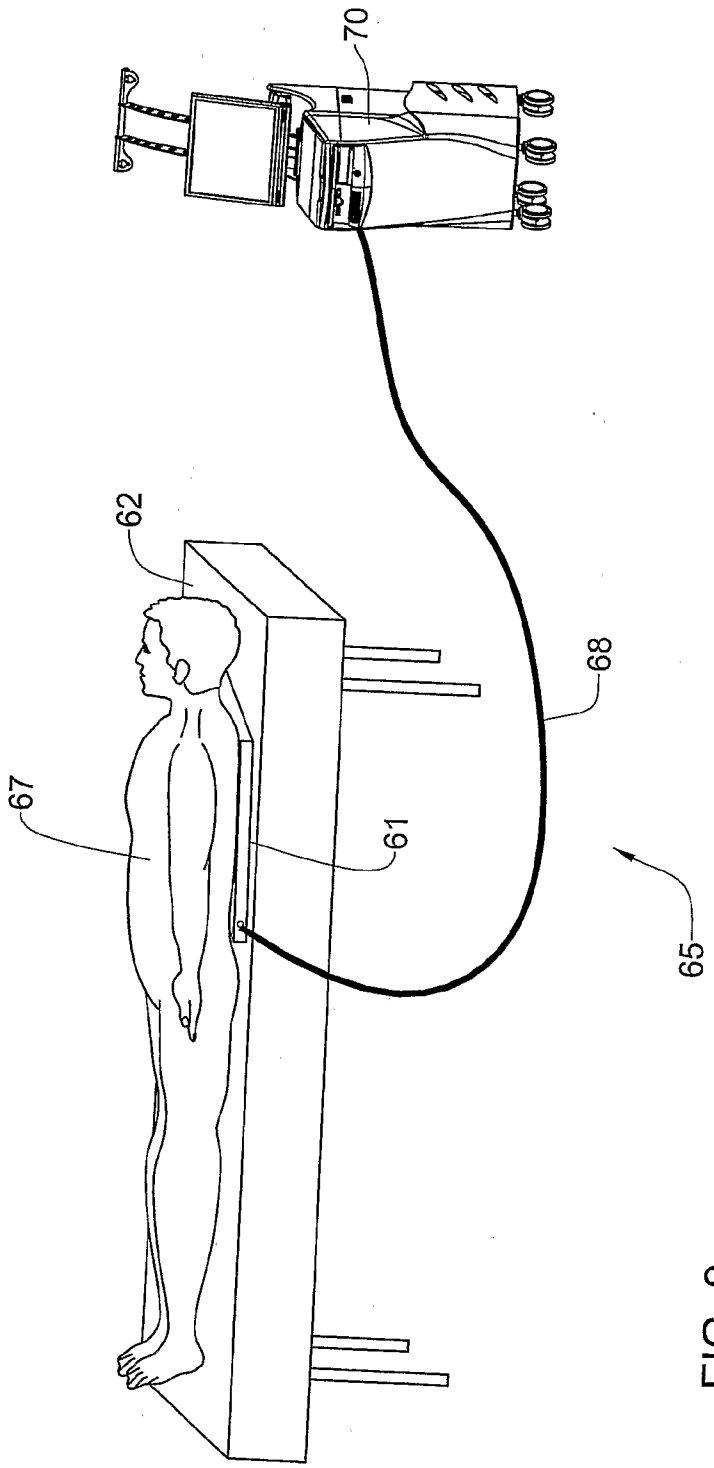

FIG. 9

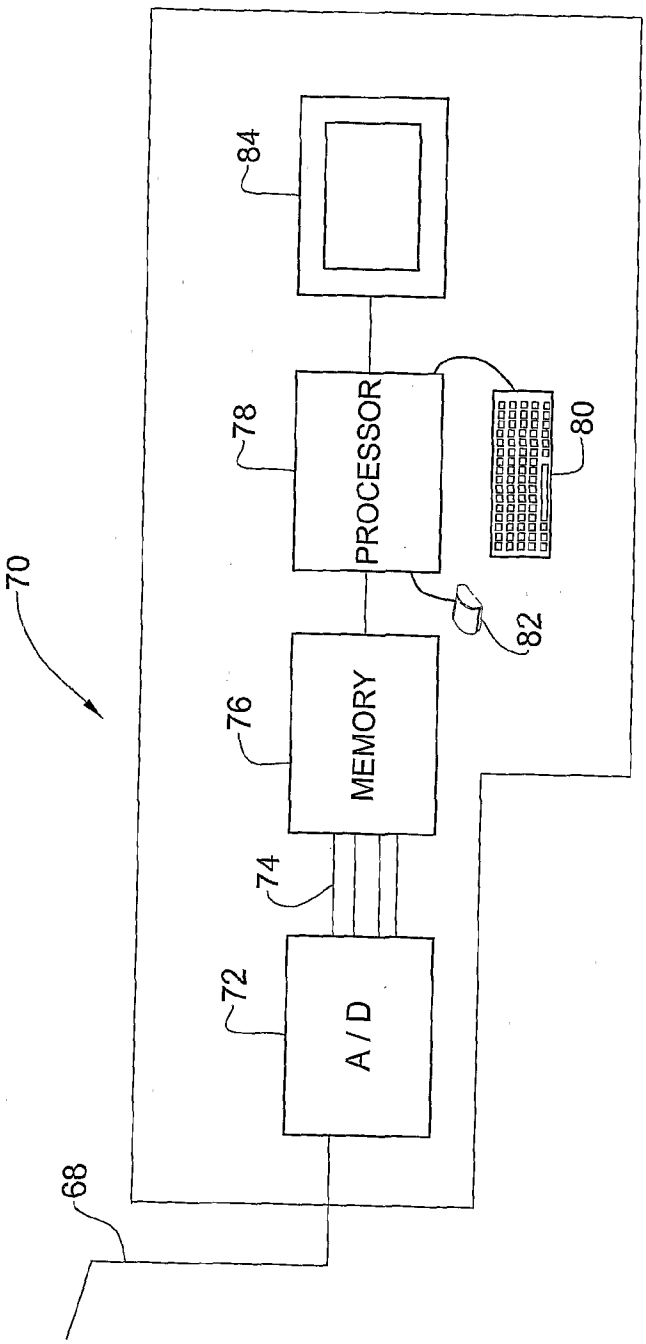

FIG. 10