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(71)(72) Applicant and Inventor: FUZZELL, Joe, E. [US/US]; 2721 W. Gilbert, Peoria, IL 61604 (US).

(74) Agents: PHILLIPS, Richard F. et al.; 100 Northeast Adams Street, Peoria, IL 61629 (US).

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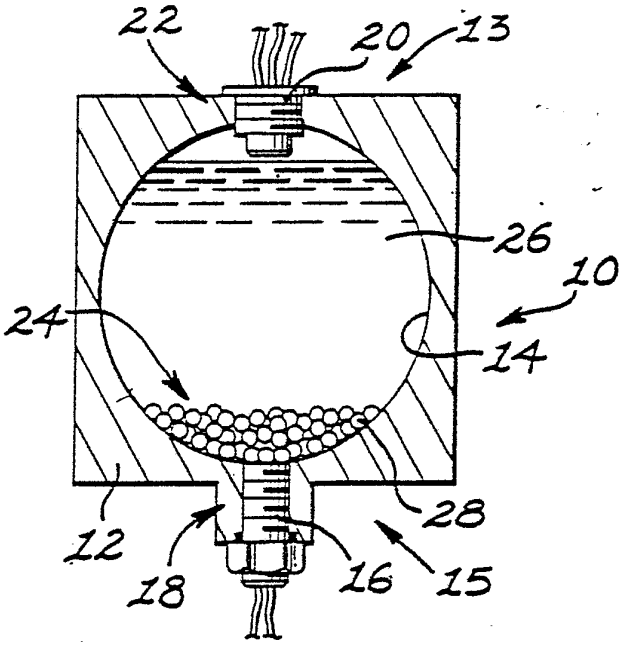
(54) Title: MOTION RESPONSIVE SENSOR AND SWITCH

(57) Abstract

A motion responsive sensor (10) having a housing (12) defining a chamber (14). A fluid substance (26) and a relatively more opaque second substance (28) occupy the chamber (14). Means (16) for emitting radiant energy and means (20) for detecting radiant energy are placed adjacent first and second portions (18, 22) of the chamber (14). Vibration of the sensor (10) serves to render the path intermediate the two means (16, 20) of lesser or greater opaqueness. This effect is used to advantage to change the state of the means for detecting (20) in response to preselected vibration of the sensor (10).



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Description

Motion Responsive Sensor and Switch

Technical Field

This invention relates generally to systems for detecting motion and more specifically to motion responsive sensors and switches.

Background Art

Sensors responsive to motion have long been in existence and have come into wide use. In the typical embodiment, such sensors include a support frame and a movable element pivotably attached to the support frame such that motion of the body to which the housing is attached results in relative motion between the support frame and the movable element.

This relative motion can be detected in numerous manners. U.S. Patent 4,214,238 issued to Adams et al. on July 22, 1980, details a seismic trigger in which motion between a support frame and an element suspended from the support frame serves to interrupt a light beam. This interruption is detected by an electrical circuit which activates an alarm in response to the detected motion.

U.S. Patent 4,131,020 issued to Hugli et al. on December 26, 1978, details an accelerometer having a support frame which includes a pair of capacitor plates. An element supported by the support frame bears a third capacitor plate intermediate the pair of capacitor plates thereby forming a pair of capacitors. In response to the support frame being subjected to motion, the capacitance of the capacitors varies. This variance is detected and may be utilized as a measure of the motion. Other principles are utilized in other motion sensing devices for detecting this relative motion.

Existing motion responsive sensors suffer an inherent defect. Suspending the movable element from the support frame requires the use of bearings. Often, as in the invention of U.S. Patent 4,214,238, jeweled pivoted bearings are required. This increases the complexity of the motion responsive switch and renders it somewhat prone to damage if exposed to severe shock. Similarly, deterioration of the bearings, misalignment of the parts, stacking of tolerances and the like can affect the sensitivity of the sensor.

The present invention is directed to overcoming one or more of the problems as set forth above.

Disclosure of the Invention

In one aspect of the present invention, a motion responsive sensor has a housing which defines a chamber. Means for emitting radiant energy is positioned at one portion of said chamber. Means for detecting said electromagnetic radiation is positioned at a second portion of said chamber. A substance is contained within said chamber which, in response to motion of said sensor, alters the absorption coefficient for said radiant energy intermediate said means for emitting and said means for detecting.

Several types of sensors responsive to motion are extant. Typically these include a support frame and an element mechanically attached to and pivotable with respect to the support frame. The operation of sensors of this type can be affected by imperfect tolerancing, corrosion, bearing wear, extreme shock and the like.

The present invention avoids these problems by decreasing the need for bearing or mechanical connections. This provides an extremely rugged and long lasting motion responsive sensor requiring little maintenance.

Brief Description of the Drawings

Fig. 1 shows a diagrammatic cross-sectional view of a first embodiment of the present invention;

Fig. 2 shows a diagrammatic cross-sectional view of a second embodiment of the present invention;

Fig. 3 shows a diagrammatic cross-sectional view of a third embodiment of the present invention; and

Fig. 4 shows a schematic use of one aspect of the present invention;

Fig. 5 shows in greater detail an assembly containing a means for emitting and a means for detecting as utilized in the embodiment shown in Fig. 2.

It is to be understood that the drawings are not intended as a definition of the invention but are provided for the purpose of illustration only.

Best Mode for Carrying Out the Invention

Referring to the drawings, a motion responsive sensor embodying certain of the principles of the present invention is generally indicated by the reference numeral 10.

The motion responsive sensor 10 has a housing 12 which defines a central chamber 14. The housing 12 has a gravitational top and bottom 13,15, the positions of which vary, of course, with the orientation of said sensor 10. Means 16 for emitting electromagnetic radiation is positioned adjacent or abutting a first portion 18 of the chamber 14. This means for emitting 16 is, in the best mode, a light emitting diode (LED) providing a visible light source. For most

applications the sensor 10 can incorporate means for emitting 16 which emits either infrared, visible, or ultraviolet light; that is, electromagnetic radiation having a frequency in the range of between about $1x10^{12}$ and $5.5x10^{16}$ Hz. Alternatively, the means for emitting 16 may be an infrared light source, an ultraviolet light source, a klystron, or other source of electromagnetic radiation.

Means 20 for detecting electromagnetic radiation is positioned adjacent or abutting a second portion 22 of the chamber 14. The detecting means 20 is preferably a photodiode sensitive to electromagnetic radiation of the wavelength of that emitted by the emitting means 16. Those skilled in the art will recognize many electromagnetic radiation responsive elements that can be successfully utilized for the various possible means for emitting 16. It is the function of the detecting means 20 to change states, for example, to go from an "on" to an "off", or "open" to "closed" condition in response to the reception of a sufficient quantum of energy from the means for emitting 16.

The chamber 14 contains an assemblage of material 24 which, in response to the chamber 14 being exposed to vibration or other acceleration, causes at least a portion of the chamber 14 to undergo an alteration in opaqueness to that frequency of electromagnetic radiation emitted by the emitting means 16. Specifically, this alteration in opaqueness occurs intermediate the first and second portions 18,22 of the housing 12. Preferably, this assemblage of material 24 includes a first fluid substance 26 which is substantially transparent to the specific electromagnetic radiation and a second substance 28 which is relatively less transparent to the electromagnetic radiation. For the purposes of the

present application, a material of which a 1 millimeter thickness will attenuate at least 50% of the radiant energy of interest, shall be spoken of as "opaque". A material which is relatively less transparent than another material will be spoken of as being more opaque than said other material. The second substance 28 can be either a solid or a liquid and is preferably neither miscible nor soluble in the fluid substance 26. Additionally, the second substance 28 should be of a different density than that of the first fluid substance 26 such that the second substance 28 will collect at the gravitational top or bottom of the chamber 14 in response to the housing 12 being maintained substantially free from acceleration.

The first and second portions 18,22 are preferably located one at the gravitational top 13 and one at the gravitational bottom 15 of the chamber 14. The relatively less transparent second substance 28 will then collect adjacent one of the means for emitting 16 and the means for collecting 20.

The chamber 14 has a non-uniform cross section being, in the preferred embodiment, a sphere. As a consequence, the effective absorption cross section of the second substance 28 is smaller when vibration induces a suspension of the second substance 28 into the first fluid substance 26 than it is when lack of vibration results in a settling of the second substance 28. This is in part a result of the fact that the average cross-sectional area of that portion of the chamber 14 into which the second substance 28 settles is smaller than the average cross-sectional area of the entire chamber 14. Hence, in response to vibration of the motion responsive sensor 10, an increased amount of electromagnetic radiation reaches the detecting means 20.

Alternatively, the first and second housing portions 18,22 may be located at positions intermediate the top and bottom of the chamber 14. In this embodiment, as best shown in Fig. 3, the second substance 28 will collect at a position, either the top 13 or bottom 15 of the chamber 14, removed from the path intermediate the emitting means 16 and the detecting means 20. Acceleration of the motion responsive sensor 10 suspends the second substance 28 and causes a portion of it to occupy a position intermediate the emitting means 16 and the detecting means 20. This serves to decrease or eliminate the transmitted electromagnetic radiation in response to vibration of the sensor 10. The means for detecting 20 is selected to change states in response to this decrease in transmitted electromagnetic radiation. The chamber 14 of this embodiment can be of a constant cross section, such as a cube or cylinder, or it may be of a non-constant cross section, such as a sphere.

The relative densities of the first fluid substance 26 and the second substance 28 can be selected to achieve a given degree of suspension of the second substance 28 in the fluid substance 26 for a given degree of vibration of the sensor 10. Similarly, the strength of the emitting means 16, the sensitivity of the detecting means 20, the opaqueness of the second substance 28, and the viscosity of the first fluid substance 26 may be selected to provide a change in the output condition of the means for detecting 20 at a preselected level of sensor 10 vibration. One skilled in the art could select an appropriate combination of a first fluid substance 26, second substance 28, emitting means 16, and detecting means 20 to achieve the requisite change in output condition of the sensor 10 at a preselected level of vibration.

The housing 12 can be made of a substance substantially transparent to the electromagnetic radiation. The sensor 10 may then be manufactured with the chamber 14 totally sealed by the housing 12. The emitting means 16 and the detecting means 20 can then be set into the housing 12 adjacent, but not in physical contact with the chamber 14. Leakage problems are thereby avoided.

The housing 12 in this embodiment is coated with a substance preventing external electromagnetic radiation of the critical wavelength from entering the chamber 14 from a source external to the sensor 10. For example, in an embodiment having a source of visible light as the emitting means 16, the housing could be made of plexiglass externally coated with a non-reflective opaque paint.

The configuration of the chamber 14 can, as previously stated, take many forms. That shown in Fig. 1 is best suited for applications in which the sensor 10 will remain substantially level. That shown in Fig. 2 is relatively less sensitive to alterations in orientation, being capable of functioning correctly even if oriented at an angle of about 40° from the upright condition. The embodiment shown in Fig. 3, in which a blockage rather than an establishment of the electromagnetic path that serves as an indication of the sensor 10 being in a vibrating condition, is quite insensitive to orientation. If the two means 16,20 of the embodiment shown in Fig. 3 project sufficiently far from the walls of the chamber 14, the resulting sensor 10 will function correctly in any orientation.

Shown in Fig. 2 is an additional embodiment of the present invention. The emitting means 16 and the detecting means 20 are positioned such that an electromagnetic radiation emitting portion 34 of the emitting means 16 is adjacent an electromagnetic

radiation collecting portion 36 of the detecting means 20. Preferably, this is accomplished by including in such means 16,20 a fiber-optic bundle 38 for transmitting the electromagnetic radiation between the chamber 14 and the active or electronic portion of each means 16,20. The first and second portions of the housing 18,22 are, in this embodiment, adjacent one another; the first and second portions 18,22 containing, respectively, the emitting and collecting portions 34,36 of the emitting and detecting means 16,20. The first and second portions of the housing 18,22 are positioned, as shown in Fig. 2, at a location adjacent that portion of the chamber 14 where the second substance 28 settles. The second substance 28 is preferably a plurality of small opaque reflective balls such that in response to vibration the balls lift from the fiber-optic bundles and reflect electromagnetic radiation from one to the other.

A circuit for detecting and indicating excessive vibration is shown in Fig. 4. A motion responsive sensor 10, such as that of Fig. 1, utilizes an LED as the emitting means 16 and utilizes a photodiode as the detecting means 20. The photodiode is placed in series with an annunicator 30 and a voltage source 32.

Industrial Applicability

In the operation the embodiments described heretofore, the assemblage of material 24 contained within the chamber 14 contains a relatively opaque second substance 28 which tends to settle toward the top or bottom of the chamber 14 in response to the sensor 10 being free from significant vibration. Vibration of the sensor 10 tends to disperse the second substance 28 more evenly throughout the chamber 14 rendering the assemblage of material 24 intermediate

the two means 16,20 less opaque. The resulting increase in the amount of electromagnetic radiation reaching the detecting means 20 serves to change the state of the means for detecting 20. In the case of a photodiode, vibration of the sensor serves to place the photodiode in a state of conductance.

Alternatively, the emitting means and detecting means 20 can be positioned, as shown in Fig. 3, such that vibration of the sensor 10 effects a decrease in the transmitted radiation. Suitable electronics is provided to detect this decrease in transmitted radiation.

The motion responsive sensor 10 has numerous applications. In Fig. 4 a use is diagrammed in which sufficient vibration of the sensor 10 serves to activate the photodiode and close a power circuit through an annunciator 30. This embodiment provides a signal that the object to which the sensor 10 is attached is undergoing a certain degree of vibration. Alternatively, the motion responsive sensor 10 may be utilized to activate an hourmeter and electrical monitoring system of an engine in response to the engine being in a running condition. Those skilled in the mechanical arts will recognize numerous other applications for the motion responsive sensor 10 For example, the sensor 10 could be utilized with the use of suitable electronics, to deactivate a washing machine in response to excessive vibration thereof.

Other aspects, objects, advantages and uses of this invention can be obtained from a study of the drawings, the disclosure and the appended claims. It should be understood that the motion responsive sensor 10 can assume many other embodiments without departing from the following claims.

Claims

1. A motion responsive sensor (10), comprising:

a housing (12), said housing (12) defining a chamber (14) having first and second portions (18,22);

means (16) for emitting electromagnetic radiation, said emitting means (16) being positioned adjacent said first portion (18);

means (20) for detecting said electromagnetic radiation, said detecting means (20) being positioned adjacent said second portion (22), and spaced from said emitting means 16;

a first fluid substance (26) contained within said chamber (14); and

a second substance (28) contained within said chamber (14), said second substance (28) being immiscible and insoluble in said first fluid substance (26) and of a different opaqueness to said electromagnetic radiation than to said first fluid substance (26).

2. The sensor (10), as set forth in claim 1, wherein the second substance (28) is more opaque to said electromagnetic radiation than is said fluid substance (26).

3. The sensor (10), as set forth in claim 2, wherein the second substance (26) is substantially opaque to said electromagnetic radiation.

4. The sensor (10), as set forth in claim 2, wherein said second substance (28) is a plurality of solid elements.

5. The sensor (10), as set forth in claim 1, wherein said detecting means (20) is a radiant energy sensitive semiconductor.

6. The sensor (10), as set forth in claim 1, wherein said detecting means (20) includes a switch having an open and a closed condition, said switch being responsive to said electromagnetic radiation.

7. The sensor (10), as set forth in claim 6, wherein said switch is in said open condition in response to being free from exposure to said electromagnetic radiation.

8. The sensor (10), as set forth in claim 1, wherein at least one of said emitting means (16) and said detecting means (20) is free from abutment with said chamber (14), there being at least a portion of said housing (12) intermediate said one of said means (16,20) and said chamber (14).

9. The sensor (10), as set forth in claim 1, wherein at least one of said emitting and detecting means (16,20) includes a fiber optic transmitter (38).

10. The sensor (10), as set forth in claim 9, wherein the fiber-optic transmitter (38) abuts one of the first and second portions (18,22) and is adjacent the other of the first and second portions (18,22).

11. A motion responsive sensor (10), comprising:

a housing (12), said housing (12) defining a chamber (14) having first and second portions (18,22) and a gravitational top and bottom (13,15);

means (16) for continuously emitting radiant energy having a frequency in the range of between about $1x10^{12}$ and $5.5x10^{16}$ Hz, said continuously emitting means (16) being positioned adjacent said first portion (18);

means (20) for detecting said radiant energy, said detecting means (20) being positioned adjacent said second portion (22);

a first fluid substance (26) contained within said chamber (14); and

a second substance (28) contained within said chamber (14), said second substance (28) being more opaque than said first fluid substance (26) and of a material adapted to settle adjacent one of said gravitational top and bottom (13,15) of the housing (12) in response to said sensor (10) being maintained substantially free from vibration.

12. The sensor (10), as set forth in claim 11, wherein said second substance (28) is a plurality of solid elements.

13. The sensor (10), as set forth in claim 12, wherein said second substance (28) is substantially reflective of the radiant energy emitted by said emitting means (16).

AMENDED CLAIMS

(received by the International Bureau on 12 August 1981 (12.08.81))

(amended) 1. A motion responsive sensor (10), comprising:

a housing (12), said housing (12) defining a chamber (14) having first and second portions (18,22);

means (16) for emitting electromagnetic radiation, said emitting means (16) being positioned adjacent said first portion (18);

means (20) for detecting the presence of a preselected quanta of said electromagnetic radiation, said detecting means (20) being positioned adjacent said second portion (22), and spaced from said emitting means 16;

a first fluid substance (26) contained within said chamber (14); and

a second substance (28) contained within said chamber (14), said second substance (28) being immiscible and insoluble in said first fluid substance (26) and being of a different opaqueness to said electromagnetic radiation than said first fluid substance (26).

2. The sensor (10), as set forth in claim 1, wherein the second substance (28) is more opaque to said electromagnetic radiation than is said fluid substance (26).

3. The sensor (10), as set forth in claim 2, wherein the second substance (26) is substantially opaque to said electromagnetic radiation.

4. The sensor (10), as set forth in claim 2, wherein said second substance (28) is a plurality of solid elements.

5. The sensor (10), as set forth in claim 1, wherein said detecting means (20) is a radiant energy sensitive semiconductor.

(amended) 6. The sensor (10), as set forth in claim 1, wherein said detecting means (20) includes a switch having an open and a closed condition, said switch being responsive to said detection of said preselected quanta of electromagnetic radiation.

(amended) 7. The sensor (10), as set forth in claim 6, wherein said switch is in said open condition in response to being free from exposure to said preselected quanta of said electromagnetic radiation.

8. The sensor (10), as set forth in claim 1, wherein at least one of said emitting means (16) and said detecting means (20) is free from abutment with said chamber (14), there being at least a portion of said housing (12) intermediate said one of said means (16,20) and said chamber (14).

9. The sensor (10), as set forth in claim 1, wherein at least one of said emitting and detecting means (16,20) includes a fiber optic transmitter (38).

10. The sensor (10), as set forth in claim 9, wherein the fiber-optic transmitter (38) abuts one of the first and second portions (18,22) and is adjacent the other of the first and second portions (18,22).

(amended) 11. A motion responsive sensor (10), comprising:

a housing (12), said housing (12) defining a chamber (14) having first and second portions (18,22) and a gravitational top and bottom (13,15);

means (16) for emitting radiant energy having a frequency in the range of between about $1x10^{12}$ and $5.5x10^{16}$ Hz, said continuously emitting means (16) being positioned adjacent said first portion (18);

means (20) for detecting said radiant energy, said detecting means (20) being positioned adjacent said second portion (22);

a first fluid substance (26) contained within said chamber (14); and

a second substance (28) contained within said chamber (14), said second substance (28) being more opaque than said first fluid substance (26) and of a material adapted to settle adjacent one of said gravitational top and bottom (13,15) of the housing (12) in response to said sensor (10) being maintained substantially free from vibration.

12. The sensor (10), as set forth in claim 11, wherein said second substance (28) is a plurality of solid elements.

13. The sensor (10), as set forth in claim 12, wherein said second substance (28) is substantially reflective of the radiant energy emitted by said emitting means (16).

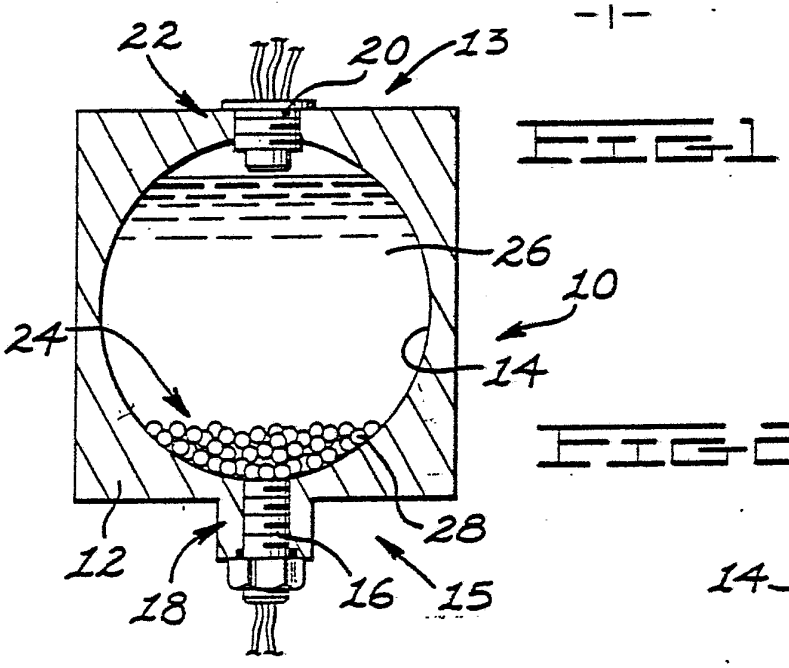


FIG 1

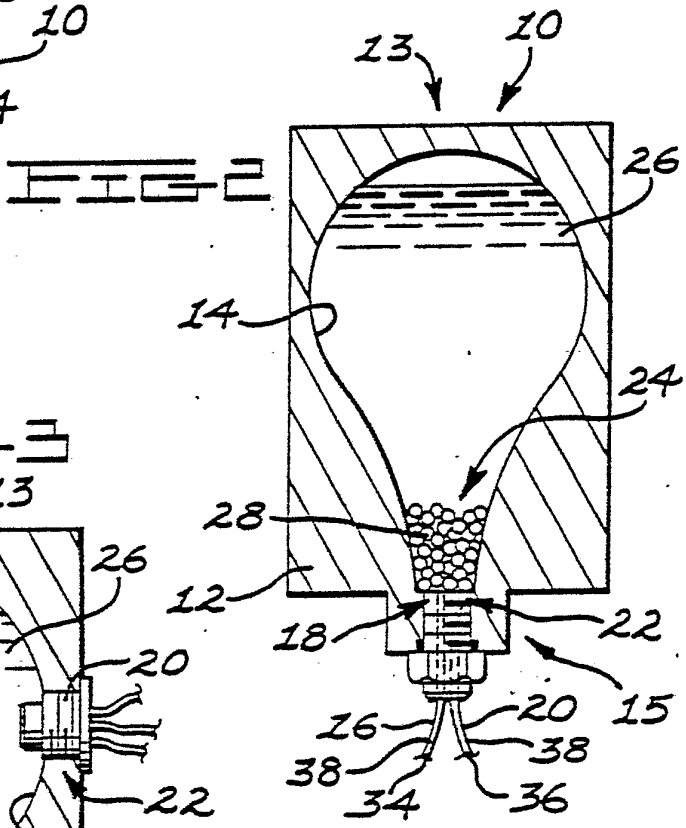


FIG 2

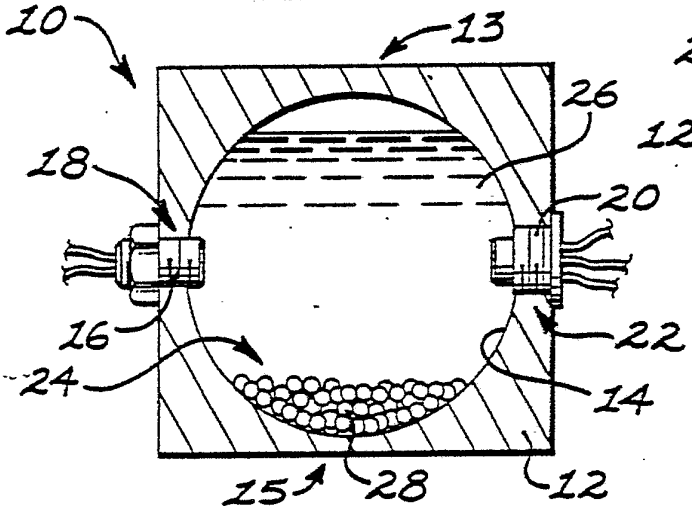


FIG 3

FIG 4

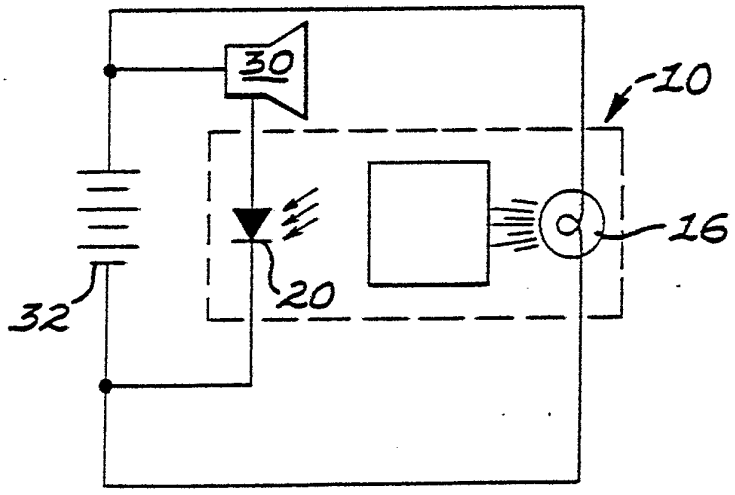
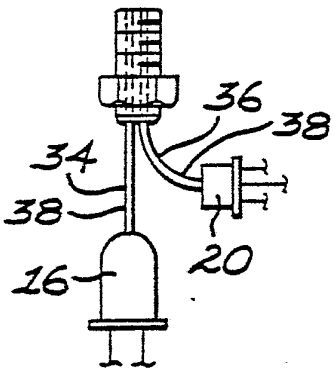


FIG 5



INTERNATIONAL SEARCH REPORT

International Application No PCT/US81/00797

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[3] G01D 5/34

U.S. CL. 250/231 R

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US	250/222, 231R, 573-575 356/337-343 73/57, 653-657

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 4,155,065 Published 15 May 1979, Stimler	1-13
A	US, A, 3,961,185 Published 1 June 1976, Brokenshire et al.	1-13
A	US, A, 4,123,944 Published 7 November 1978, Mezrich et al.	1-13
A	US, A, 4,028,933 Published 14 June 1977, Lemons et al.	1-13
A	US, A, 3,990,795 Published 9 November 1976, Parker	1-13

* Special categories of cited documents: [15]

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"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
21 July 1981	30 JUL 1981
International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	Gulmo