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(54) Pressure switch apparatus.

(57) Pressure switch is shown which is accommodated in a pressure vessel (1) filled with a gas at a first pressure (P1), such as for a safety air bag in a road vehicle. The device comprises a pressure container (12) filled with a gas at a second pressure (P2), which container has at one side a flexible diaphragm (18) which reacts to the difference in the two pressures and interacts with an electrical circuit. The container is fitted with one side adjacent to and opposite a wall portion (14, 106, 214, 238, 256) of the pressure vessel and a magnetic element (16, 26, 240, 246/248) is operatively coupled to the diaphragm. The wall portion of the pressure vessel is made of non-magnetic material, and near the other side of the wall portion a magnetic field sensitive switching element (40) is mounted opposite the diaphragm magnetic element. A window element (13) of magnetic material may be placed in the wall portion of non-magnetic material, in line with the magnetic element and the switching element. An armature (232, 254) extending through the wall portion may be used to concentrate the magnetic flux path. The armature can be arranged to function in a head-on mode (232) or on a slide by mode (254). The magnetic curve of the system can be adjusted by using a bias magnet (216). A two part assembly permits attachment of the switch to the vessel without problems associated with the heat of welding from adversely affecting associated electronics and a circuit (222) is shown for providing a two wire output having voltage levels indicative of selected conditions.

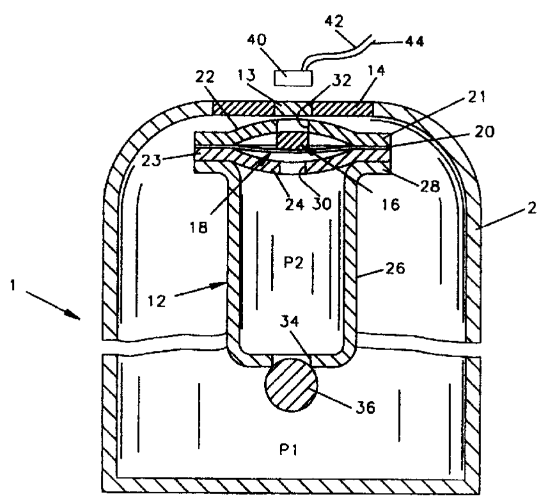

FIG. 2

EP 0 642 146 A2

Background of the Invention

This invention relates in general to condition sensors and more particularly to such sensors used to sense fluid pressure in a vehicular air bag safety system. In such a system, typically a pressure switch device is accommodated in a pressure vessel filled with a gas at a first pressure, such as for a safety air bag in a road vehicle, and which comprises a pressure container filled with a gas at a second pressure, which container has at one side a flexible diaphragm which reacts to the difference in the two pressures and interacts with an electrical circuit. Such a pressure device is shown in U.S. Patent No. 4,049,935.

In the case of this known device, the pressure of the pressure vessel must be monitored accurately so that the normal operation of the pressure vessel, for example, for the immediate deployment of a safety air bag in a road vehicle, is assured for an extended period of time. For this purpose, a pressure container filled with a gas at a second pressure is disposed inside the pressure vessel. The flexible diaphragm at one side of the pressure container will move or snap between opposite positions under the influence of the magnitude of the pressure differential between the first and second pressures. An element which is movable at right angles to the face surface and aligned with the center of the diaphragm will in this case carry along a movable arm of a two-way switch into engagement with one or the other stationary contact thereof. The pressure switch serves to monitor the pressure inside the main vessel, and any leakage thereof, and the pressure in the pressure container during the service life of the device. The pressure container with the diaphragm and the associated switching contacts are disposed inside the pressure vessel, and the electrical connections from the contacts run out through the wall of the pressure vessel and are connected outside the vessel to an associated electrical circuit, for example, to give off an alarm. The connections are generally passed through the wall of the pressure vessel by way of a glass or plastic seal. Since the pressure inside the pressure vessel lies in a range of 200 to 400 bar at temperatures between -40° and +130° C, and since the pressure inside the pressure container has to be maintained over a very long service life (at least 10 years), such seals are not found to be sufficiently reliable. Since the present switch device is used for activating the above mentioned air bag in a road vehicle, such a device must be capable of responding quickly and reliably at any time. Any loss in pressure from leakage through an unreliable seal in the wall is unacceptable.

An object of the invention is to overcome the above mentioned deficiency in the prior art.

Summary of the Invention

Briefly in accordance with the invention, a pressure switch device of the type mentioned above is used with a container, also known as an accumulator, which is fitted with one side adjacent to and opposite a wall portion of the pressure vessel and a magnetic element is operatively connected to a movable diaphragm. The wall portion of the pressure vessel is made of non-magnetic material and a magnetic field sensitive switching element or transducer is fitted opposite the diaphragm's magnetic element on the other side of the wall portion.

In accordance with the invention, electrical leads passing through a seal in the wall of the pressure vessel is avoided. The switching action takes place directly adjacent the wall with the magnetic field from the diaphragm magnetic acting upon the magnetic field sensitive switching element or transducer on the outside of the pressure vessel wall.

In an advantageous embodiment, a window of magnetic material is placed in the wall portion of non-magnetic material, in line with the magnetic element and the switching element in order to obtain more sensitive switching action.

The wall portion of non-magnetic material and the window of magnetic material therein are preferably made of materials having essentially corresponding temperature expansion coefficients and which can readily be welded together. Preferred materials include austenitic steel for the non-magnetic material and ferritic steel for the magnetic material.

In one embodiment the magnetic element and the transducer are positioned in alignment with each other and with the south pole of the magnet facing the sensing face of the transducer to form a unipolar, head-on mode of operation.

In an advantageous embodiment of the invention the movable magnetic element is attached to a snap acting disc on an end of the accumulator container which is telescopically received in and suitably attached, as by welding, to a skirt depending from a wall portion which in turn is welded to the pressure vessel. The transducer and associated electrical circuitry providing either a digital or an analog output is then mounted on the opposite or outside face of the wall portion thereby avoiding any possible deleterious effects from heat associated with welding of the wall portion to the pressure vessel.

In another embodiment a fixed bias magnet of high coercivity is used to adjust the characteristics of the magnetic curve and is oriented with its poles coaxial with the poles of the moving magnet.

In yet another embodiment an armature extends through the wall portion with one end closely adjacent the movable magnet and another end contiguous with the transducer to concentrate the flux path. The armature comprises two L-shaped members with an L-shaped member aligned with each pole of the movable magnet.

In another embodiment an armature having two legs extends through the wall portion and the movable magnet comprises first and second magnets disposed on one another with their north and south poles alternated and with the magnets adapted to move between and past the legs of the armature to provide a bipolar, slide by mode of operation.

In an advantageous embodiment of the invention a circuit board is mounted on the wall portion outside the pressure vessel and converts a three lead output from a Hall effect transducer to a two lead output and provides respective voltage levels indicative of normal operation or a fault condition.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part thereof, wherein like numerals refer to like parts throughout.

Brief Description of the Drawings

Fig. 1 is a cross sectional view of a prior art device;

Fig. 2 is a cross sectional diagrammatic view of a pressure switch device made in accordance with a first embodiment of the invention;

Fig. 3 is a cross sectional view of an advantageous embodiment of the invention;

Fig. 4 is a cross sectional view of another embodiment of the invention;

Fig. 5 is a schematic diagram of an electrical circuit used in the Fig. 4 embodiment; and

Figs. 6 and 7 show additional embodiments of the invention.

Detailed Description of the Preferred Embodiments

In the prior art embodiment of a pressure switch referred to above and shown in Fig. 1, reference numeral 1 indicates in general a pressure vessel which is filled with a gas at a first pressure. The wall of the pressure vessel, made of steel for example, is indicated by 2. Reference numeral 3 indicates the pressure container acting as part of a pressure switch, which container is filled with a gas at a second pressure and which is mounted in a manner not shown in any further detail. The pressure container 3 is closed at one side by a flexible diaphragm 4, which can move between the solid and dashed lines under the influence of the above mentioned pressures. On the diaphragm rests a motion transfer element 5 which, through the movement of the diaphragm, can move a movable arm 6 of a switch from one position to the other into and out of engagement with stationary contacts 7 and 8. Contacts 7 and 8 are connected to leads which run out through bushings 9 in the wall of the pressure vessel and are connected to alarm or activation circuits not shown in any further detail. The bushings of the connections are generally of glass or plastic.

Such a vessel can be used to supply pressure for a safety air bag in a road vehicle. It operates in such a way that on the occurrence of a sudden great deceleration, measured by an acceleration sensor, the pressure vessel is pyrotechnically activated to release its pressure to the air bag, in order to rapidly inflate the latter and form a safety device for an occupant of the vehicle. The function of the pressure switch device is to constantly monitor the pressure in the main vessel and the pressure container.

In a first embodiment of the pressure switch apparatus made according to the invention shown in Fig. 2, reference numeral 1 again indicates in general the pressure vessel filled with a gas at a pressure P1 and reference numeral 12 indicates the pressure container, also known as an accumulator assembly, filled with a gas at a pressure P2. The pressure container according to the invention is mounted close to a wall portion 14 of wall 2 of the pressure vessel. Wall portion 14 is made of non-magnetic or non-ferromagnetic material. A magnetic element 16 is operatively connected to a diaphragm 18 in any suitable manner as by being affixed thereto with adhesive material. Diaphragm 18 is preferably a disc movable with snap action between oppositely dished, concave and convex configurations. The outer marginal rim 20 of diaphragm 18 is sandwiched between flanges 21, 23 respectively of upper and lower support plates 22, 24 which are provided with outwardly dished central portions to provide space for diaphragm 18 to move between its opposite configurations. Plates 22, 24 and rim 20 are hermetically attached to each other in any suitable manner as by welding about the outer periphery of flanges 21, 23 and rim 20. Housing member 26, is generally cup shaped and formed with an outwardly extending flange 28 at an open end thereof which flange is also hermetically attached to lower support plate 24. Aperture 30 in support plate 24 permits the lower side of diaphragm 16 to be in communication with the pressure in accumulator assembly 12 while aperture 32 in upper plate 22 permits the upper side of diaphragm 18 to be in communication with the pressure in vessel 1 as well as permitting magnetic element 16 to move into a position closely adjacent wall portion 14. Housing member 26 is also formed with an aperture 34 through its bottom wall which allows infilling of the accumulator with a selected gas, preferably the same as that in vessel 1, at a selected pressure. Accumulator 12 is then hermetically sealed in a suitable manner as by welding closure element 36 to the bottom wall.

In general, the gas pressure P1 in the pressure vessel 1 will normally be a certain value higher than the gas pressure P2 in accumulator assembly 12. When this pressure difference (P1-P2) decreases to a level below a selected value, as a result of leakage in the pressure vessel and/or in the accumulator, the diaphragm 18 will move out of the solid line position to the position shown by dashed lines. The magnetic element 16 will then move closely adjacent to the wall portion 14.

A switch element 40 which is sensitive to magnetic fields, such as a Hall effect transducer, is provided at the other side of the wall portion outside the pressure vessel, aligned with and opposite the magnetic element 16. The switching element 40 is connected by means of connecting leads 42, 44 to suitable electrical circuits such as that shown in Fig. 5 to be discussed infra. The positioning and setting of the parts 16 and 40 is in this case such that when the magnetic element 16 moves along with disc 18 to the position shown by dashed lines, the switching element 40 will switch from an off condition to an on condition.

Magnetic element 16 is mounted on diaphragm 18 with its south pole facing wall portion 14 and moves toward and away from transducer 40 in a unipolar, head-on mode of operation. As the magnet moves closely adjacent wall portion 14 the gauss level increases above a threshold or switching point of the transducer thereby changing its output voltage. Although it is convenient to use a digital output, i.e. on/off, it should be realized that it is within the purview of the invention to use an analog output as well.

In an embodiment with greater sensitivity of the switch action, a core or window 13 of magnetic or ferro-magnetic material is provided in wall portion 14 in line with the magnetic element 16 and the transducer 40. In this embodiment, the magnetic field lines going out from the element 16 in the direction of the transducer will run in a more concentrated way through the window 13.

Wall portion 14 of non-magnetic material is preferably made of copper, aluminum or stainless steel. If the wall portion 14 is made, for example of austenitic steel, it is advantageous to make the window 13 of ferritic steel since both types of steel have virtually the same coefficient of heat expansion and can easily be welded together, for example, by laser welding.

As shown in Fig. 3, wall 2 of the vessel may be provided with an aperture 46 adapted to receive switch assembly 100. Switch assembly 100 comprises first and second subassemblies 102, 104 respectively. Subassembly 102 comprises the pressure sensing accumulator 12 mounted to the underside of base 106 as by spot welding in several places around the periphery of the flanges of plates 22, 24 and flange 28 to downwardly extending skirt 108, leaving a suitable passageway (not shown) between the interior of vessel 1 and bore 32 of upper support 22 to ensure equalization of pressure between the interior of vessel 1 and the upper face of diaphragm 18. Base or wall portion 106 is made of non-magnetic or non-ferromagnetic material in the same manner as wall portion 14 of the Fig. 2 embodiment. Base 106 is then hermetically connected to vessel 1 as by welding around its periphery as indicated at 110. The magnetically responsive transducer 40 and its associated electronics and mounting structure can then be conveniently placed on the top side of base 106 along with housing 112 to form subassembly 104. Subassembly 104 can be attached to base 106 by any convenient means, e.g., by using threaded fasteners, not shown. In this way excessive heat, associated with any welding of base 106 to wall 2 can be isolated from heat sensitive electronics.

Another embodiment of the invention is shown in Figs. 4 and 5. In this embodiment pressure assembly 200 comprises a housing 202 formed of non-magnetic material, such as stainless steel, having a lower chamber 204 in which is disposed a spring 206 mounting a magnetic element 26 thereon in any suitable manner. A connecting pin 208 is operatively connected to magnetic element 26 in any suitable manner so that it is movable with the magnetic element. If desired, pin 208 could be integrally formed with magnetic element 26 but in any event it extends into engagement with diaphragm 18 of accumulator assembly 12 also received in chamber 204. Pressure sensing accumulator assembly 12 is telescopically received in chamber 204 and seated against annular ledge 210 and locked thereon by suitable means as by crimping the lower wall portion 212 of housing 202. An aperture 205 is provided in the side wall of housing 202 to permit equalization of pressures between the top face of diaphragm 18 and the pressure in the pressure vessel. Spring 206 maintains magnet 26 separated from wall portion 214 until diaphragm 18 moves to its upwardly convex configuration (not shown). If desired, annular ledge 210 can be omitted so that accumulator assembly 12 can be telescopically inserted to any desired position in order to locate movable magnetic element 26 at its optimum position relative to magnetic responsive switch 40 and the assembly 12 can be fixed to housing 202 in the same manner as in the Fig. 3 embodiment.

Magnetically responsive switch 40, such as a Hall effect transducer described above, is placed on the upper side of wall portion 214 longitudinally aligned with magnetic element 26 and its movement towards and away from wall 214. Magnetic element 26 is disposed so that its south pole faces magnetic responsive switch 40.

In the embodiments of the invention thus far described, the magnetic element is adapted to move directly toward and away from a sensing face of the magnetically responsive switch. As described above, in this mode of operation the relation between gauss and distance between the magnetic element and the switch is similar to a decaying exponential curve. In order to utilize the steeper levels of the gauss vs distance curves a second or bias magnetic element 216 is placed on the opposite side of switch 40 relative to magnetic element 26 with its south pole aligned with and facing switch 40. This reverse orientation of the magnets subtracts from the field of the moving magnet resulting in a bipolar mode so that the switch is operating on the steep portion of the curve where relatively small movement results in relatively large changes in field strength. When using a bias magnet it is preferred to use magnets having high coercivity, i.e. rare earth magnets, to avoid having problems of partial demagnetization.

Housing 202 is hermetically attached to the wall 2 of the vessel as by welding around its periphery as indicated at 218. Preferably after housing 202 has been mounted to the vessel, housing subassembly 220 is attached. Subassembly 220 includes, along with transducer 40 and bias magnet 216, circuit board 222.

A typical Hall effect transducer such as those available from Microswitch, a Division of Honeywell, is a three lead device. Although the pressure sensing apparatus can be used with three leads it is preferred to provide a two wire device to lower the cost of installation in a vehicle. Circuit board 220 comprising the circuit shown in Fig. 5 converts the three leads of such transducers to a two lead device.

Circuit board 220 comprises output current set resistor 224, bias current adjustment resistor 226, input filter capacitor 228, and if desired, a reverse voltage blocking diode 230 to prevent damage in the event of connecting the device to the wrong battery terminal of the vehicle. With particular reference to Fig. 5, the Hall effect transducer shown is used in a current sinking output mode of operation having an open collector NPN transistor Q1. Resistor 224 connected to the output of the device minimizes the effect of small leakage currents from the output or from any electronics with which the device is interfaced. Capacitor 226 connected in parallel with resistor 226 is used to filter any noise appearing on the battery line while resistor 226 is used to adjust the bias current level. When magnetic field is removed from the transducer its output will be at its quiescent, normally high state and current will not flow through the output transistor Q1 (except for minimal leakage current). When the transducer is subjected to a magnetic field above its actuation point current will flow through transistor Q1 and the output voltage, measured between the collector of Q1 and the negative terminal, will drop to ground potential, neglecting the saturation voltage of transistor Q1.

Other advantageous modified embodiments of the invention are shown in Figs. 6 and 7. In Fig. 6 an armature 232 is used to concentrate field flux. Armature 232 comprises first and second legs 234, 236 respectively, placed on either side of magnetic responsive switch 40, each leg extending through an aperture in non-magnetic wall 238 and hermetically attached thereto. Legs 234, 236 each has a distal free end placed adjacent a magnet 240 operatively connected to diaphragm 18 through motion transfer member 244.

Fig. 7 shows another variation wherein a pair of magnets 246, 248 are placed on each other with the poles oppositely aligned with each other and adapted to move in a direction which parallels end portions 250, 252 of armature 254 in a slide by bipolar mode. This arrangement provides an advantage that less expensive magnets can be employed since partial demagnetization is not a problem.

The foregoing is considered as illustrative of the principles of the invention. Since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the precise construction and operation snown and described, and accordingly, all suitable modifications and equivalents falling within the scope of the claims are intended to be included. For example, although the switch apparatus as described in terms of a pressure responsive device it will be appreciated that the disc could be formed of bimetal so that it can be actuated to move between opposite concave, convex configurations in response to selected changes in temperature with the same magnetic field sensitive switch arrangement being employed.

Claims

1. Pressure switch apparatus adapted for accommodation in a pressure vessel filled with a gas at a first pressure, such as for a safety air bag in a road vehicle, and which comprises a pressure container filled with a gas at a second pressure, which container has at one side a flexible diaphragm movable between two opposite configurations which reacts to the difference in the two pressures and interacts with an electrical circuit, characterized in that the container is fitted with one side adjacent to and opposite a wall portion of the pressure vessel, that a movable magnet is operatively connected to the diaphragm so that it is movable therewith, that the wall portion of the pressure vessel is made of non-magnetic material, and that near the other side of the wall portion a magnetic field sensitive switching element is disposed opposite the movable magnetic element.

2. Pressure switch apparatus according to claim 1 in which a window element of magnetic material is placed in the wall portion of non-magnetic material, in line with the movable magnetic element and the switching element.

3. Pressure switch apparatus according to claim 2 in which the wall portion is made of non-ferritic material and the wall element is made of ferritic material.

4. Pressure switch apparatus according to claim 3 in which the non-ferritic material is austenitic steel.

5. Pressure switch apparatus according to claim 3 in which the ferritic material is ferritic steel.

6. Pressure switch apparatus according to claim 1 in which the switching element is a Hall effect transducer.

7. Pressure switch apparatus according to claim 1 further including a stationary bias magnet disposed adjacent the magnetic field sensitive switching element on a side thereof remote from the movable magnetic element.

8. Pressure switch apparatus according to claim 7 in which the movable magnetic element and the stationary magnet are formed of rare earth material.

9. Pressure switch apparatus according to claim 1 in which the movable magnetic element is attached to the diaphragm.

10. Pressure switch apparatus according to claim 1 further including a motion transfer member disposed intermediate the movable magnetic element and the diaphragm.

11. Pressure switch apparatus according to claim 1 further including an armature extending through the wall portion between the magnetic field sensing switching element and the movable magnetic element.

12. Pressure switch apparatus according to claim 1 in which the pressure vessel is formed with an aperture and in which the apparatus comprises first and second subassemblies, the first subassembly including the pressure container mounted on a lower side of the wall portion, the wall portion formed with a flange adapted to fit over the aperture in the pressure vessel for hermetic attachment to the pressure vessel, the second subassembly including the magnetic field sensitive switching element and a housing attachable to an upper side of the wall portion to complete the assembly.

13. Pressure switch apparatus according to claim 1 in which the pressure vessel is formed with an aperture and in which the wall portion is formed with a flange adapted to fit over the aperture in the pressure vessel for hermetic attachment thereto, the wall portion having a downwardly extending member and the pressure container being attached to the downwardly extending member at a selected location relative to the wall portion.

14. Pressure switch apparatus according to claim 1 including an armature extending through the wall portion, the armature having opposite end portions, one end portion disposed closely adjacent the magnetic field sensitive switching element and another end disposed adjacent the movable magnetic element, the movable magnetic element adapted to move in a direction which parallels the another end of the armature.

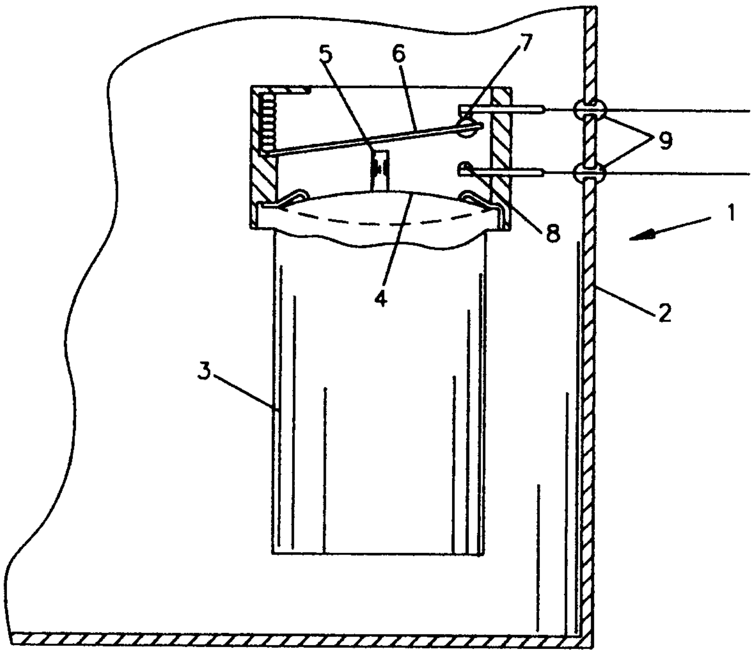
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FIG. 1

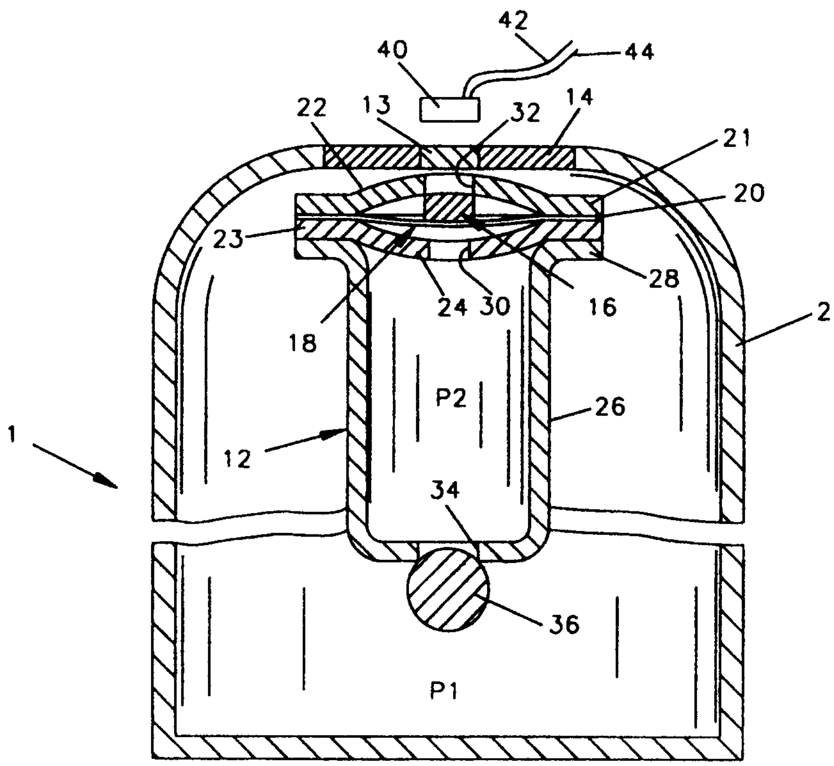
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FIG. 2

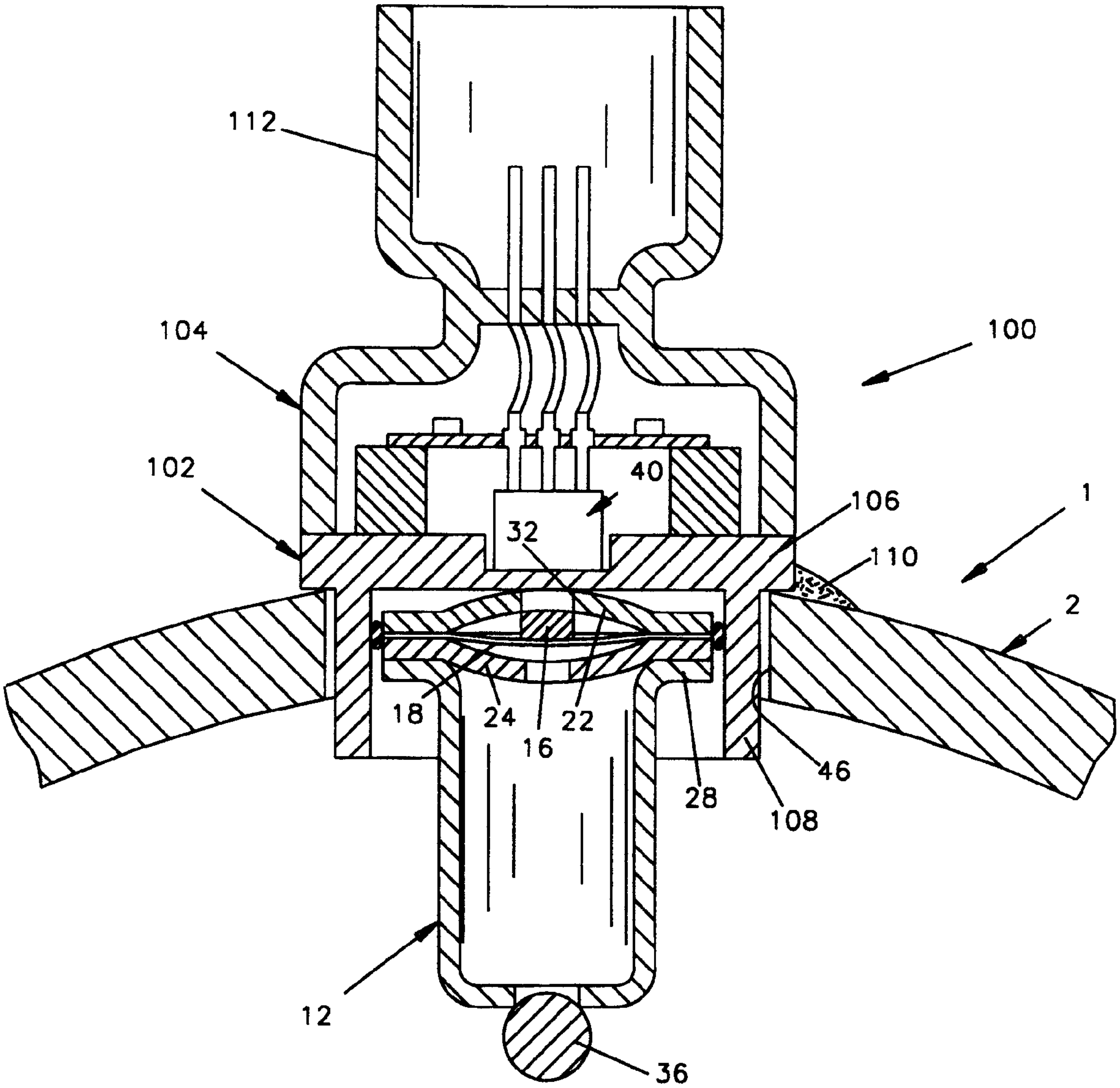
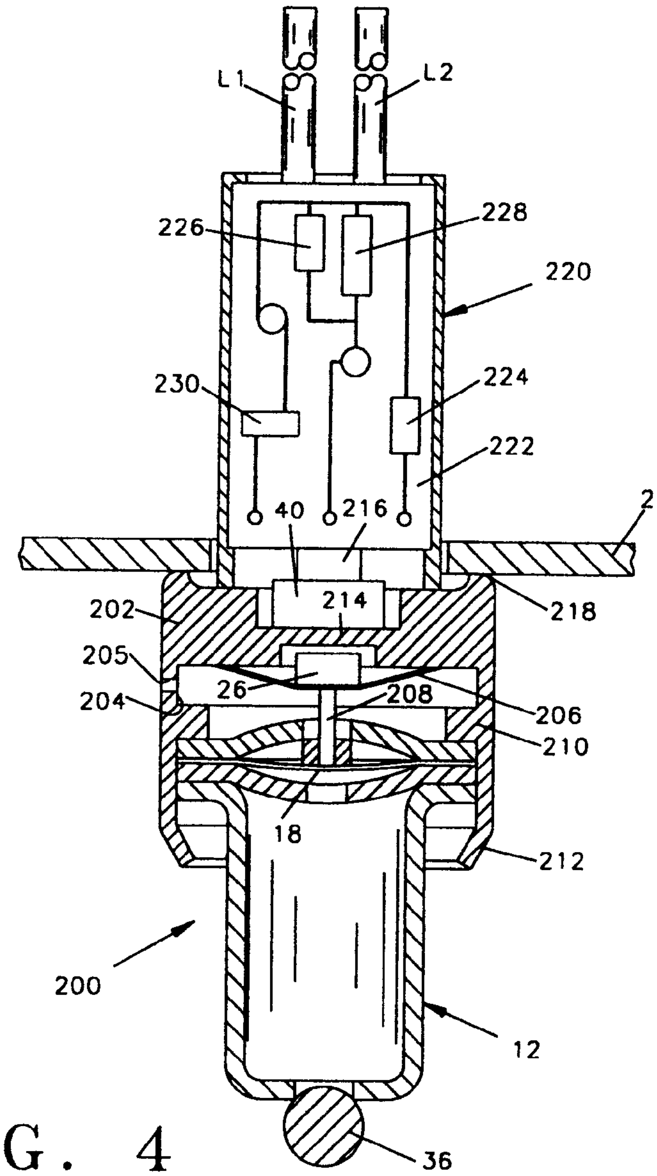


FIG. 3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L2
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228
220
230
224
222
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218
205
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212
200
12
36

FIG. 4

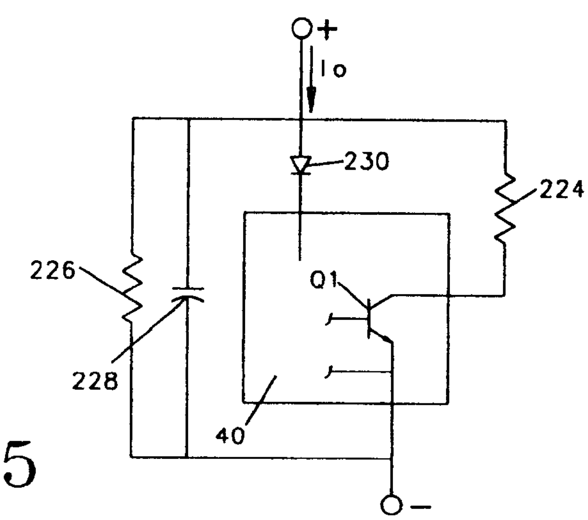
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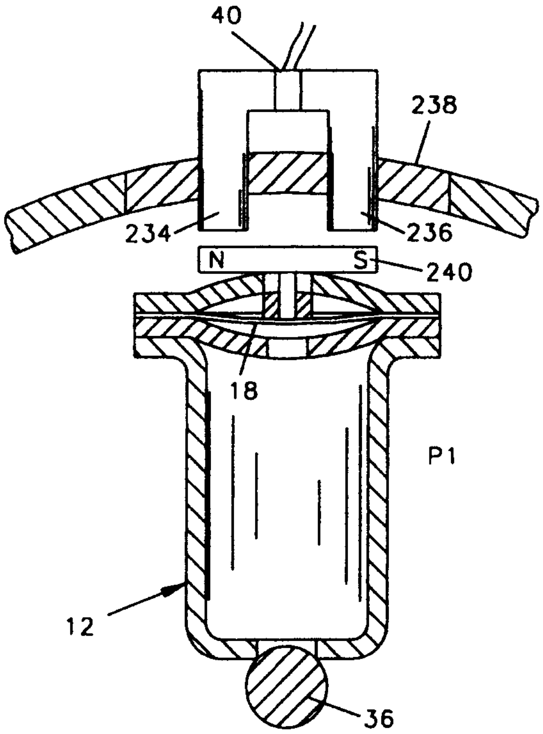
FIG. 5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36

FIG. 6

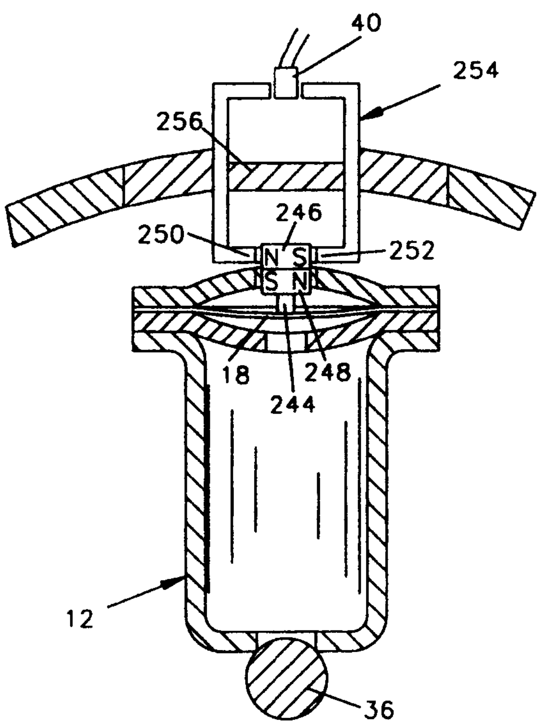
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FIG. 7