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Wagner et al.

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[54] **PRESSURE RESPONSIVE DEVICE HAVING STACKED DIAPHRAGM ASSEMBLY**

[75] Inventors: **Leland Burns Wagner; Russell Cripe,** both of Goshen, Ind.

[73] Assignee: **Penn Controls Inc.,** Oak Brook, Ill.

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Related U.S. Application Data

[63] Continuation of Ser. No. 175,071, Aug. 26, 1971, abandoned.

[52] **U.S. Cl.** ..... **92/34,** 92/40, 92/45, 200/83 C, 200/83 S

[51] **Int. Cl.** **F01b 19/00,** F16j 3/00

[58] **Field of Search** ..... 92/34, 40, 43, 45; 200/83 C, 83 S

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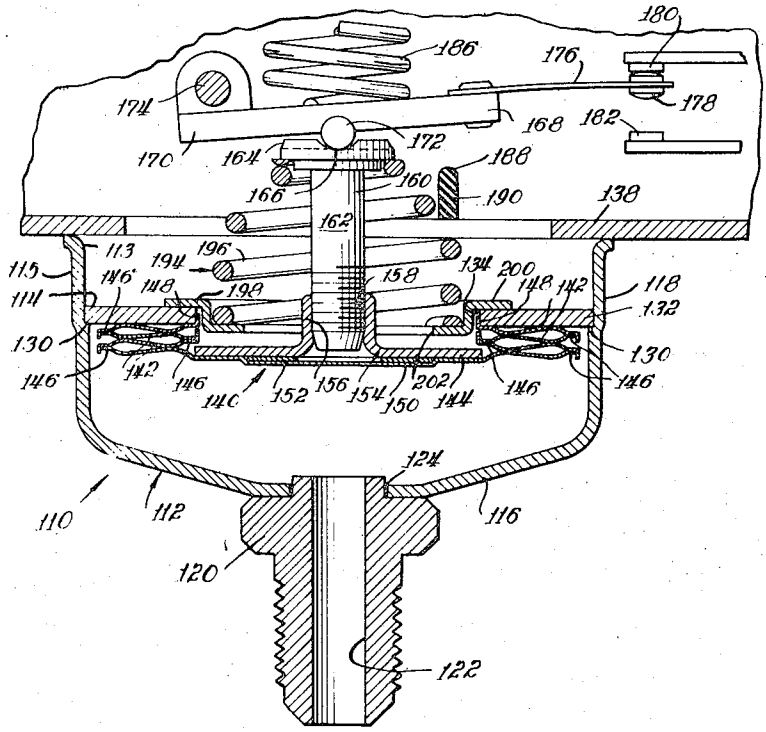
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Primary Examiner—Irwin C. Cohen
Assistant Examiner—Abraham Hershkovitz
Attorney, Agent, or Firm—Johnson, Dienner, Emrich & Wagner

[57] **ABSTRACT**

A pressure responsive device assembled in a cup-shaped housing, having a movable wall formed by a diaphragm assembly. The interior of the housing is interconnected to a pressurized system to cause movement of the stacked diaphragm assembly in response to variations in pressure. The stacked diaaphragm assembly includes a series of springy, wavy corrugated diaphragms connected together in accordian bellows-like fashion. A push-rod or operating stem is secured to and extends from the diaphragm assembly outwardly of the housing to actuate a controlled mechanism in accordance with movement of the diaphragm assembly in response to sensed pressure changes. Under over pressure conditions, the corrugated diaphragms of the diaphragm assembly close and come together, providing within the assembly itself, an automatic stop to further bellows movement, preventing the application of over stresses to the controlled mechanism. In addition, the diaphragms in their closed "over pressure" condition are capable of sustaining substantial over pressures because their unsupported spans are reduced. Thus, the diaphragms have a larger effective work area over prior art diaphragm assemblies, allowing the utilization of substantially thinner diaphragm material at lower cost and providing a lower spring rate.

5 Claims, 8 Drawing Figures



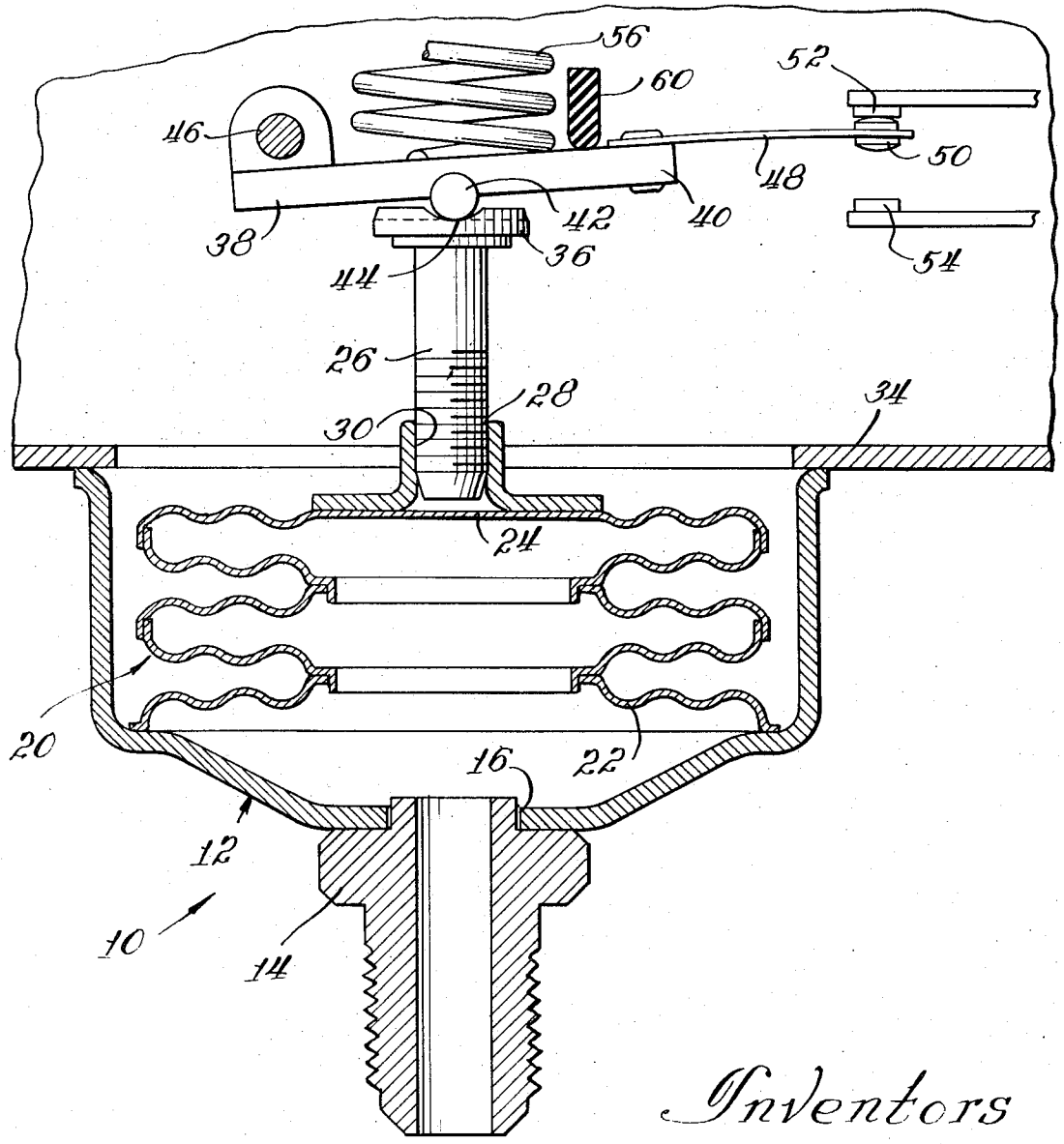
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SHEET 1 OF 3

Fig. 1

PRIOR ART



Inventors
Leland Burns Wagner
and
Russell Cripe
By
Johnson Dunner Emrich Vorbeck - Wagner
Atty's.

Fig. 2

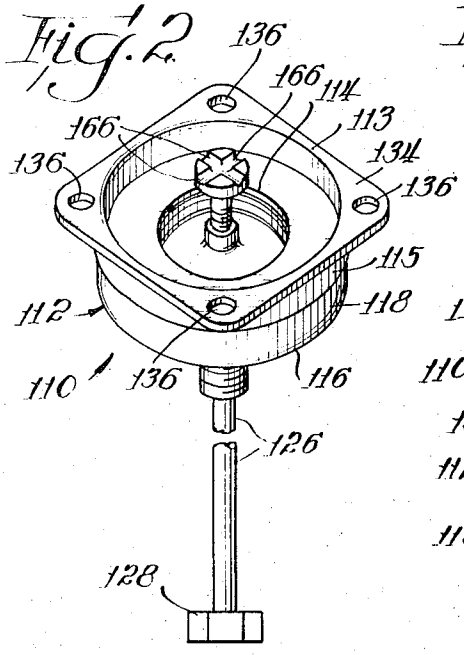
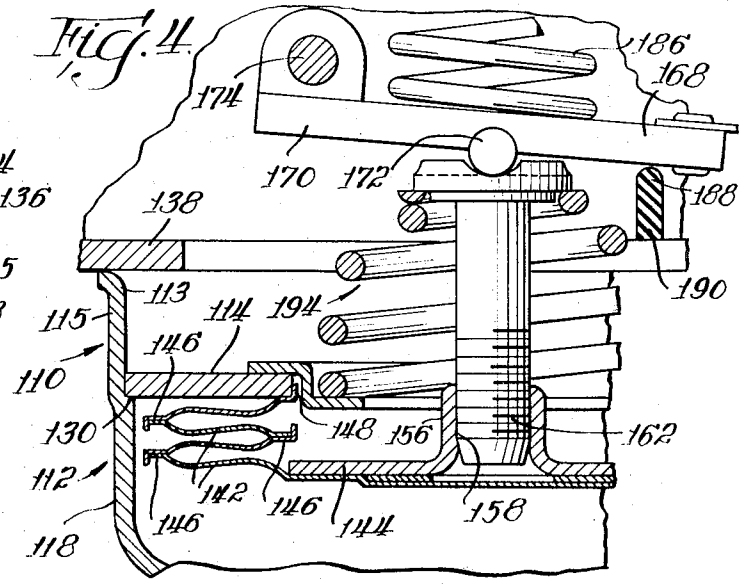


Fig. 4



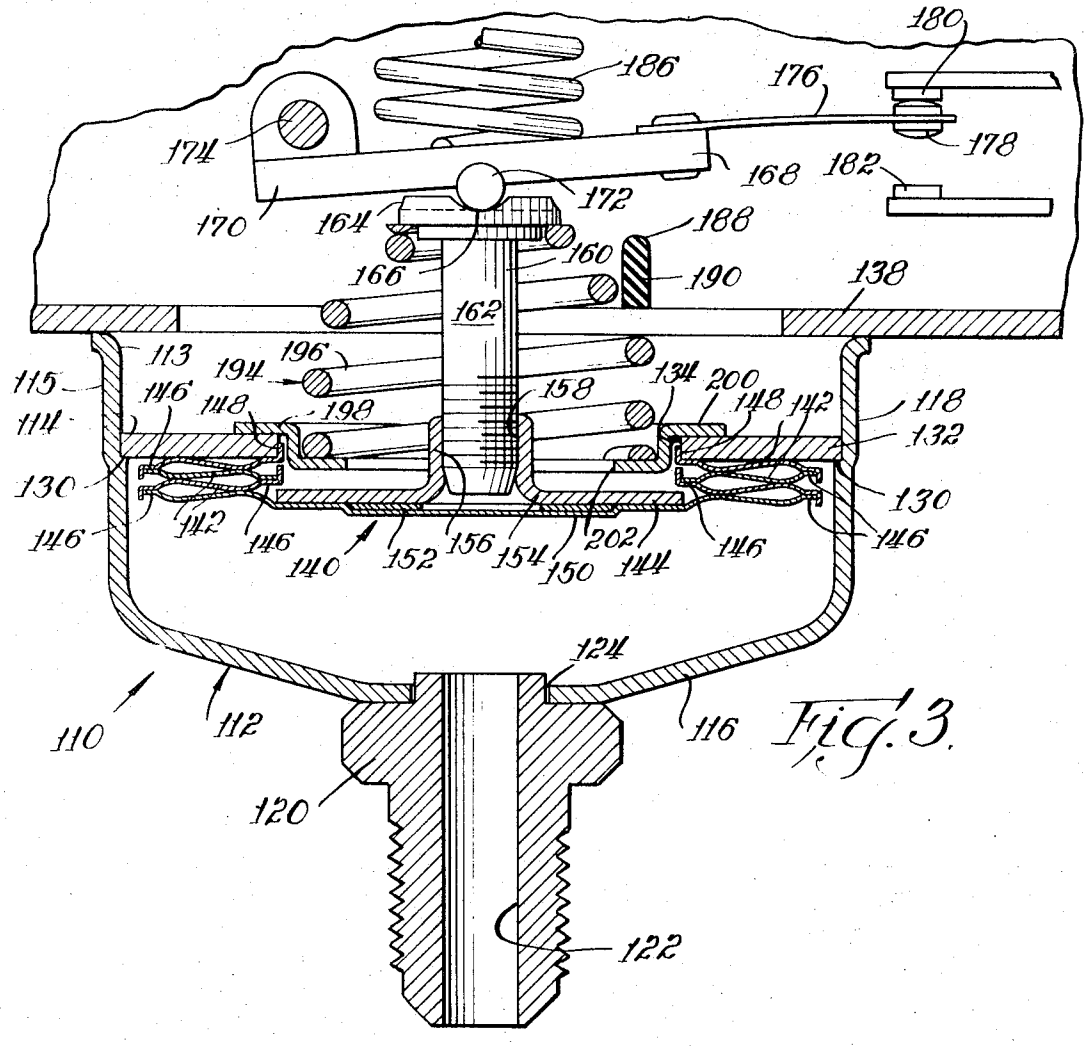


Fig. 3

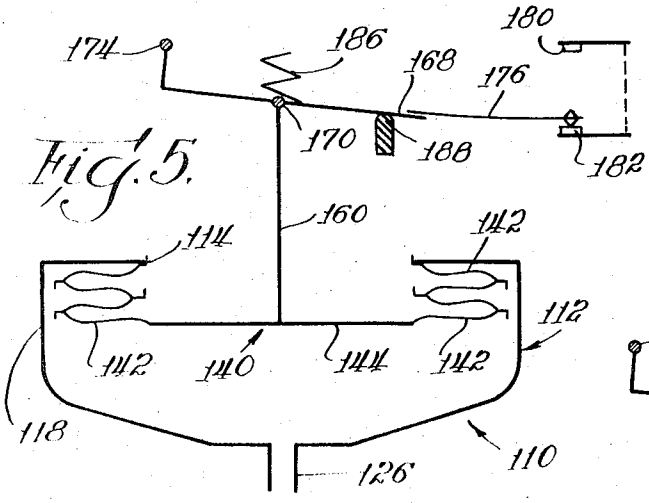


Fig. 5.

LOW PRESSURE
(AGAINST LOW PRESSURE STOP)

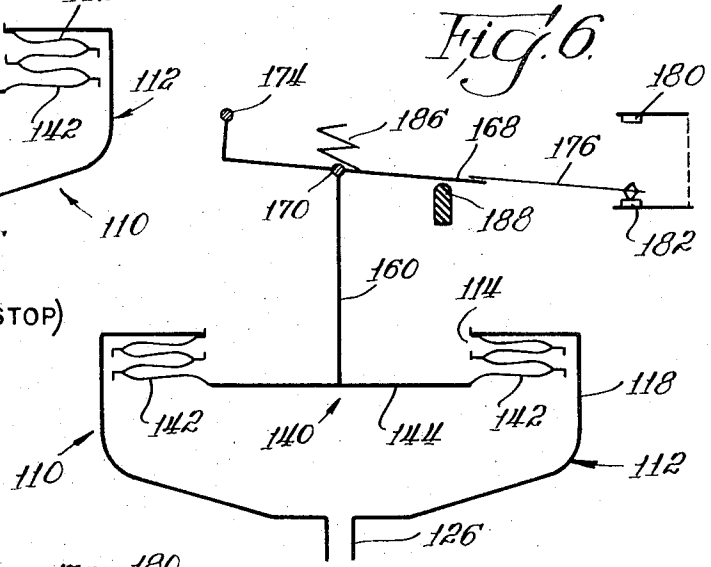


Fig. 6.

LOW PRESSURE
(NORMAL)

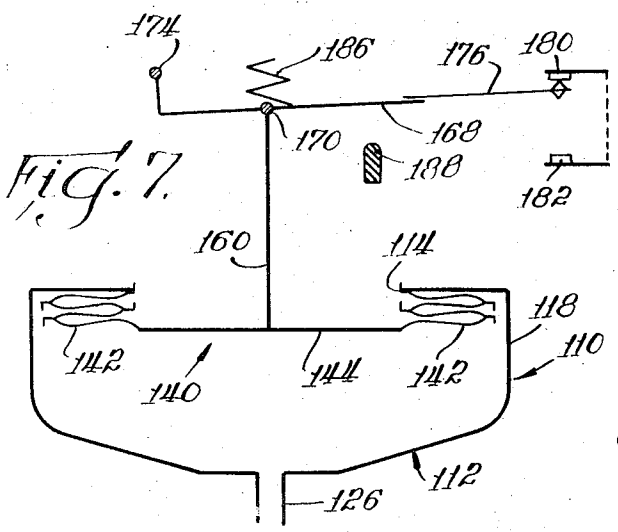


Fig. 7.

HIGH PRESSURE
(NORMAL)

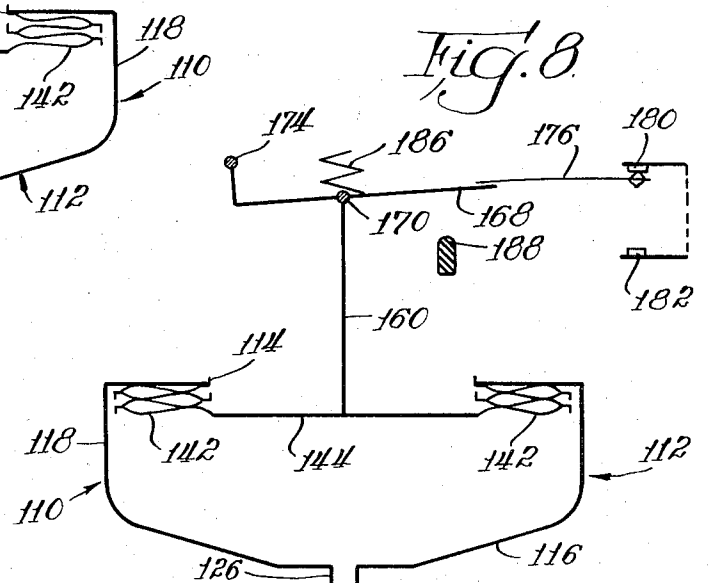


Fig. 8.

HIGH PRESSURE (OVERPRESSURE)
(CORRUGATIONS ACTING AS HIGH PRESSURE STOP)

PRESSURE RESPONSIVE DEVICE HAVING STACKED DIAPHRAGM ASSEMBLY

This is a continuation, of application Ser. No. 175,071, filed Aug. 26, 1971 now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to pressure responsive devices used to actuate controlled mechanisms, such as electric switches or valves, and in particular, to pressure responsive devices employing stacked diaphragm assemblies.

In pressure responsive devices of the above type, one of the inherent problems is that they are often thrown off calibration and even damaged permanently when subjected to over pressures. This happens because such devices are designed to operate over a relatively small given pressure range for the controlling conditions. For example, when set for use in a pressurized refrigeration system, when the system is not used in hot weather, the pressure responsive devices often encounter excessive pressure due to high ambient temperatures acting on the pressurized refrigerant. This is the usual condition during shipping and summer installation of such pressurized refrigerated systems.

Accordingly, one object of this invention is to provide a pressure responsive device that incorporates a built-in high pressure stop to prevent calibration errors and damage occurring when the unit is exposed to over pressures.

Another object of this invention is to provide a pressure responsive device having a stacked diaphragm assembly actuated by pressure where the effective work area of each diaphragm in the stacked diaphragm assembly is greater than prior art devices for a given radium of the device housing.

A further object of this invention is to provide a pressure responsive device having a stacked diaphragm assembly actuated by pressure where the stacked diaphragm assembly has a lower spring rate and is less expensive to manufacture than prior art similar devices.

SUMMARY OF THE INVENTION

A pressure responsive device comprising a housing or chamber, one wall of which is in the form of a stacked diaphragm assembly for movement in response to pressure within the housing. The stacked diaphragm assembly comprises a series of springy, wavy corrugated diaphragms connected together in accordion bellows-like arrangement with the outermost diaphragm secured about the margin of enlarged opening in the housing. Movement of the diaphragm assembly is utilized to effect actuation of controlled mechanism. Under the application of over pressures internal to the housing, the diaphragms come together automatically stopping further movement of the bellows assembly, thereby preventing further stresses being transmitted to the controlled mechanism and allowing the use of relatively thinner diaphragm material with a consequent cost saving and lower spring rate of the assembly than similar prior art devices.

DESCRIPTION OF DRAWINGS

For a better understanding of this invention, reference may be had to the accompanying drawings in which:

FIG. 1 is a partial cross sectional view of a pressure responsive device representative of the prior art devices;

FIG. 2 is a perspective view of the preferred embodiment of this invention;

FIG. 3 is an enlarged cross sectional view showing the preferred embodiment of FIG. 2 supported from a switch housing under a high pressure condition;

FIG. 4 is a partial enlarged view identical to FIG. 3 except the position of parts is shown under a low pressure condition; and

FIGS. 5 through 8 are schematic diagrams of the present invention showing the position of parts, respectively, in a low over-pressure condition, low normal pressure condition, high normal pressure condition, and high over-pressure condition.

DESCRIPTION OF PRIOR ART

Referring to FIG. 1 there is shown a prior art stacked diaphragm device generally designated by the reference numeral **10**, and having a cup-shaped housing **12**. A plug or connector **14** extends through an opening **16** in the lowermost portion of housing **12**. A capillary tube is connected between a pressurized refrigeration system and plug **14**.

A stacked diaphragm assembly **20** is supported inwardly of the open end of the cup-shaped housing **12**, and comprises a plurality of wavy-shaped diaphragms **22** having an annular ring shape and connected in series together in a corrugated fashion, and an actuator plate **24**. The wavy diaphragms **22** are formed of a springy material, such as stainless steel, and the ends of adjacent diaphragms are secured together. A push rod **26** is supported by the actuator plate **24** by virtue of its threaded end **28** being screwed into the threaded bore **30** to mount the push rod **26** in a perpendicular relationship with respect to actuator plate **24**.

The pressure responsive device **10** is mounted on the under surface of a base wall **34** for a switch housing. The enlarged head **36** of the push rod **26** projects upwardly into the housing, and the base portion **38** of a switch actuator lever **40** has a circular pin **42** disposed intermediate its ends in a crosswise direction which bears against slot **44**. One end of base portion **38** is pivotally mounted on a stationary pivot pin **46**, which is supported horizontally (not shown) by the switch housing. A contact lead **48** extends from the free end of base portion **38** and its outer end is provided with a contact button **50**, which is disposed between a pair of spaced electrical contacts **52** and **54**. The stacked diaphragm assembly acts against the force of a range spring **56** to cause the switch actuator lever **40** to move between the high pressure contact **52** and the low pressure contact **54**, depending on the condition sensed.

To limit the movement of the switch actuator lever **40** in the high pressure direction, a high pressure stop **60** hangs downwardly from the switch housing **34** in the path of lever **40**. In a high over-pressure condition, the stacked diaphragm assembly **20** expands outwardly and the high perssure stop **60** stops the movement of switch actuator lever **40**. If the ambient temperature is significantly beyond the relatively narrow temperature range of the pressure responsive device **10**, the relatively large outward expansion of the diaphragm assembly **20** will often throw off the calibration of the device and even become permanently damaged.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to FIG. 2 there is shown a pressure responsive device, which embodies the principles of this invention and is generally designated by the reference numeral **110.** Pressure responsive device **110** has a cup-shaped housing **112** having an open end **114,** a closed end **116** and rounded side walls **118.**

A plug or connector **120** (FIG. 3) having a cylindrical bore **122** is seated in an opening **124** formed in the lowermost portion of the closed end **116,** and this connector **120** couples a capillary tube **126** with the closed end **116** of the housing **112** so that the capillary tube is in communication with the interior of the housing. Capillary tube **126** is provided with a flared nut **128** (FIG. 3) for connection to a pressurized system (not shown) (such as a refrigeration system) which the pressure responsive device **110** monitors.

The cup-shaped housing **112** includes a mounting portion **113** comprising a cylindrical wall portion **115** that extends upwardly from and is integrally formed with the side wall **118,** and out-turned integral mounting flange **134** at the upper edge of cylindrical wall portion **115.** The mounting flange **134** has a square shape and has mounting apertures **136** at each corner for the purpose of supporting the pressure-responsive device **110.** For example, in FIGS. **2** and **3,** the pressure-responsive device **110** is fastened to the under surface of the base wall **138** of a housing of a controlled mechanism. For convenience, the controlled mechanism has been shown as a switch.

At the juncture of the cylindrical wall portion **115** and rounded side wall **118,** an annular shoulder **130** is formed in the interior of housing **112.** A circular cover plate **132** is seated on its annular shoulder and has an enlarged central opening **133** which defines the open end **114.**

The stacked diaphragm assembly **140** is supported inwardly of the open end **114** of the cup-shaped housing **112,** and comprises a plurality of wavy-shaped, corrugated diaphragms **142** having an annular ring shape and connected in series together in an accordion bellows-like fashion, and an actuator plate **144.** The wavy diaphragms **142** are formed of a springy material, such as stainless steel, and the ends of adjacent diaphragms are secured together as by brazing at **146.** The free end **148** of the outermost diaphragm **142** is secured about the periphery of the central opening **134** of cover plate **132** as by brazing or welding. The innermost diaphragm **142** is integrally formed with a circular shaped disk **150** which is staked to the lower surface of the actuator plate **144** as by welding, such that the integral diaphragm extends radially outwardly of the actuator plate **144.**

The actuator plate **144** has a circular configuration and comprises a pair of integrally formed plate portions **152** and **154,** where the upper plate portion **154** is formed at its center with a hollow upstanding leg **156** having an internal threaded bore **158.**

A push rod or operating stem **160** is supported by the actuator plate **144** by virtue of its threaded end **162** being screwed into the threaded bore **158** to mount the push rod **160** in a perpendicular relationship with respect to actuator plate **144.** The push rod **160,** which is in the form of a threaded bolt, has an enlarged head **164** provided at its upper end crosswise to the threaded portion **162** and a pair of criss-cross slots **166** are formed in the enlarged head **164** for the purpose of providing a pair of alternate bearing surfaces for a switch actuator lever **168.**

As previously mentioned, the pressure-responsive device **110** is mounted on the under surface of a base wall **138** for a switch housing. The enlarged head **164** of the push rod **160** projects upwardly into the housing, and the base portion **170** of switch actuator lever **168** has a circular pin **172** disposed intermediate its ends in a crosswise direction which bears against one of the two slots **166.** One end of base portion **170** is pivotally mounted on a stationary pivot pin **174,** which is supported horizontally (not shown) by the switch housing. A contact leaf **176** extends from the free end of base portion **170** and its outer end is provided with a contact button **178,** which is disposed between a pair of spaced electrical contacts **180** and **182.** The stacked diaphragm assembly acts against the force of a range spring **186** to cause the switch actuator lever **168** to move between the high pressure contact **180** and the low pressure contact **182,** depending on the pressure applied to the interior of housing **112.**

By having criss-cross slots **166** it is possible to accurately center the contact leaf **176** relative to contacts **180** and **182** since the pin **172** is in alignment with one of the slots every quarter turn of control lever **160.**

To limit the movement of the switch actuator lever **168** in the low pressure direction, a low pressure stop **188** in the form of an upstanding post **190** is supported on the supporting wall **138** directly below the outer free end of the lever portion **168.**

When the pressure-responsive device **110** is to be used in a vacuum, it is necessary to add to the above-described structure a counterbalancing spring assembly **194** comprising a spring **196** disposed about the stem portion **162** of the push rod **160** and acting between the enlarged head **164** and a spring retainer plate **198.** The spring retainer plate **198** has a circular shape with an offset peripheral flange **200** that is secured to the cover plate **132** on its outer surface about the opening **134** and which has an enlarged central opening **202** through which the push rod **160** and upstanding leg portion **156** extend. The spring assembly **194** functions to prevent the diaphragm assembly **140** from being pulled downward into the cup under a vacuum condition.

FIGS. **5** through **8** schematically depict the pressure-responsive device of this invention and show the relative position of its movable parts under four possible conditions. FIG. **5** represents the condition of lower than normal pressure, i.e., beyond the preselected controlled pressure range, and shows the switch actuator lever **168** abutting against the low pressure stop **188** and the contact leaf bowed upwardly. Under this condition, the series of springy wavy diaphragms **142** stretch to their outermost limit since the fluid's volume has contracted.

FIG. **6** represents the condition of normal low pressure where the electrical switch contact **176** has just made electrical contact with the low pressure contact **182.** FIG. **7** depicts the position of the movable parts of the FIG. **1** embodiment under the normal high pressure condition where the switch blade contact **176** has just engaged the high pressure electrical contact **180.**

FIG. **8** shows the over-pressure position of the parts in the high pressure direction. Under these conditions, the adjacent corrugations of the springy wavy diaphragms **142** abut against each other and provide an

inherent built-in high pressure stop. It will thus be appreciated that in the high over-pressure conditions, the automatic stopping action of the abutting diaphragms **142** prevents overstressing the electrical switch parts and consequently changes in setting of damage since excessive stresses on the switch mechanism are eliminated.

Also since in the abutting overstressed condition of the diaphragms **142**, their respective unsupported spans are reduced, and diaphragms are capable of sustaining substantial pressure, while using relatively thinner naterial tha prior art devices. It is possible to obtain more work output for a given diaphragm radius as compared with the prior art devices since each diaphragm has a large effective exposed area acted upon by the expanding or contracting fluid. The particular diaphragm assembly disclosed above enables the use of diaphragms of a much smaller thickness which results in both better actuation and substantial savings in the cost of material. It has been found, for example, that diaphragms having a 0.005 inch thickness when assembled in the above-described manner, operate satisfactorily at 500 pounds of pressure actuation as compared with prior art stacked diaphragm assemblies requiring a diaphragm thickness of 0.009 inches for operation at only 300 pounds of pressure actuation. Another inherent advantage of using thinner diaphragm material is that a lower spring rate for the stacked diaphragm assembly is obtained, yielding a smaller differential in the switching action.

One of the most important advantages of the stacked diaphragm assembly of this invention is that it inherently establishes an over-pressure limit within the sensing element itself, thus avoiding the prior art disadvantages of over-stressing the external mechanisms by bending the switching arm and supporting pins which cause misalignments and misoperations.

Although the invention has been described with respect to a preferred embodiment in which a chamber for receiving a pressurized fluid has a movable wall in the form of a bellows assembly which contracts and expands in response to variations in pressure, it is to be understood that the invention is not so limited and is applicable to other pressure responsive arrangements. For example, the invention is also applicable to a pressure charged chamber such as is usually provided with a remotely located sensing bulb interconnected to the chamber by a capillary tubing, the tubing, chamber and sensing bulb being filled with a charge of temperature responsive liquid, under pressure. Under such cases, in response to temperature variations in the vicinity of the sensing bulb, the fluid charge in the closed system expands and contracts actuating the bellows assembly in response to the pressure variations within the closed system. Under such conditions, high ambient temperatures often create over pressures within the sensing bulb and closed chambers which are prevented from being transmitted to the mechanism controlled by the movable bellows assembly, as has been explained hereinbefore for the preferred embodiment.

The foregoing disclosure relates only to a preferred, exemplary embodiment of the inventive pressure-responsive device, which is intended to include all changes and modifications, as well as additions to the example described and illustrated, and which are within the spirit and scope of the invention, as set forth in the appended claims.

We claim:

1. A pressure responsive device comprising an open-ended housing having a wall member with a central opening defining its open end, a stacked diaphragm assembly supported inwardly in said housing providing a movable wall closing said central opening and defining with the interior walls of said housing an expandable chamber therein, said diaphragm assembly including a series of springy, curved, corrugated diaphragms interconnected together in accordian bellow-like arrangement, each of said diaphragms extending radially away from said central opening and terminating a short distance from said interior walls of said housing, wherein one end of said series is secured about the margin of said central opening of said wall meber and the other end of said series terminates in a springy, curved, corrugated diaphragm having a closed wall underlying said central opening, inlet means for introducing a fluid into said expandable chamber, a push-rod coupled to said closed wall member and extending outwardly of said housing for actuating a controlled device in response to variations in pressure within said housing and wherein adjacent diaphragms of said series of curved diaphragms abut and become based against each other and the outermost diaphragm abuts and becomes based against said wall member of said housing under conditions of overpressure within said chamber to transmit further pressures to the walls of said housing and thereby significantly restrict the application of further forces to said push rod with the application of further pressure to said bellows to thereby provide an automatic high pressure stop for said pressure responsive device.

2. A pressure responsive device as set forth in claim **1** wherein spring means opposing said compressed movement of said diaphragm assembly are provided and wherein low pressure stop means are provided for limiting the movement of said push-rod when pressure within said housing is below a predetermined minimum.

3. A pressure responsive device for moving a switch actuator lever in response to changes of a sensed pressure condition comprising an open-ended housing having a wall member with a central opening defining its open end, a stacked diaphragm assembly supported inwardly in said housing closing said central opening and defining with the interior walls of said housing an expandable chamber therein, said diaphragm assembly including a series of springy, curved corrugated diaphragms connected together in an accordian bellow-like arrangement and an actuator plate disposed inwardly of said open end, each of said diaphragms extending radially away from said central opening and terminating a short distance from said interior walls, wherein one end of said series is secured about the margin of said central opening and the other end of said series terminates in a springy, curved, corrugated diaphragm having a closed wall underlying said central opening, said actuator plate being coupled to said closed wall member, a push-rod coupled to said actuator plate and extending outwardly of said open end, said push-rod being operatively connected to said switch actuator lever, spring means for normally biassing said switch actuator lever and said push-rod to urge said bellows to an expanded state, said bellows and said spring means being compressed with the occurrence of pressure of a predetermined value in said

chamber, said adjacent diaphragms of said series of springy, curved diaphragms being moved into abuttting relation with and becoming based against each other and the outermost diaphragm being moved into abutting relation with and becoming based against said wall member of said housing in response to overpressure conditions to significantly restrict the application of further operating forces to said push-rod and switch actuator member.

4. A pressure responsive device comprising an open-ended housing having a wall member with a central opening defining its open end, a stacked diaphragm assembly supported inwardly in said housing providing a movable wall closing said central opening and defining with the interior walls of said housing an expandable chamber therein, said diaphragm assembly icluding a series of springy, curved, corrugated diaphragms with the inner ends and the outer ends of the diaphragms alternately connected together in accordian bellows-like arrangement, each of said diaphragms extending radially away from said central opening and terminating a short distance from said interior walls of said housing, each of the outer peripheral portions of said diaphragms having a planar portion brazed to the corresponding planar peripheral portion of an adjacent diaphragm to minimize rupture stresses applied to the outer portions of the diaphragm during the application of compression forces to the diaphragm, and wherein one end of said series is secured about the margin of said central opening of said wall member and the other end of said series terminates in a springy, curved, corrugated diaphragm having a closed wall underlying said central opening, raised portions on the outer surface of each corrugated diaphragm being in aligned relation with the raised portion of the outer surface of the next adjacent diaphragm, inlet means for introducing a fluid into said expandable chamber, a push-rod coupled to said closed wall member and extending outwardly of said housing for actuating a controlled device in response to variations in pressure within said housing, the raised portion of the adjacent diaphragms of said series of curved diaphragms being moved into abutting relationship to cause the diaphragms to become based against said wall member of said housing under conditions of overpressure within said chamber to provide an automatic high pressure stop and thereby prevent further movement of said push-rod and controlled devices by said bellows in response to excessive pressure.

5. A pressure responsive device as set forth in claim **4** in which said outer ends of at least one diaphragm of each adjacent pair of diaphragms includes a portion bent at an angle to said planar portion to provide a nesting configuration for the end of the other diaphragm of said pair.

* * * * *