May 29, 1956 K. L. TATE 2,747,615

PRESSURE RESPONSIVE DEVICE HAVING A SLOTTED METAL DIAPHRAGM

Filed Feb. 25, 1953 2 Sheets-Sheet 1

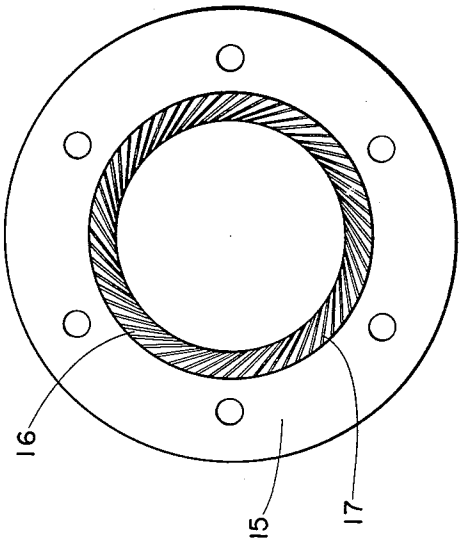


FIG. 4

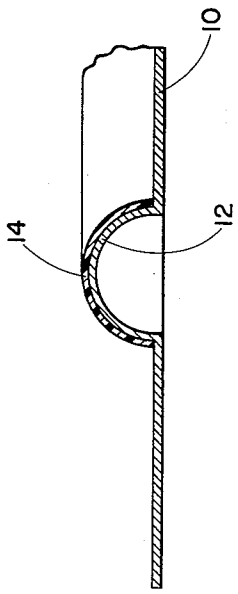


FIG. 3

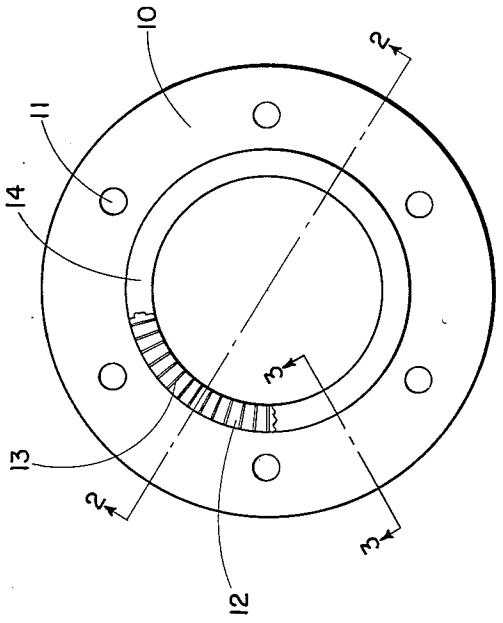


FIG. 1

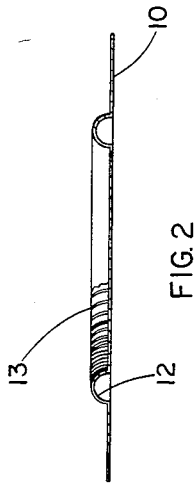


FIG. 2

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PRESSURE RESPONSIVE DEVICE HAVING A SLOTTED METAL DIAPHRAGM

Filed Feb. 25, 1953 2 Sheets-Sheet 2

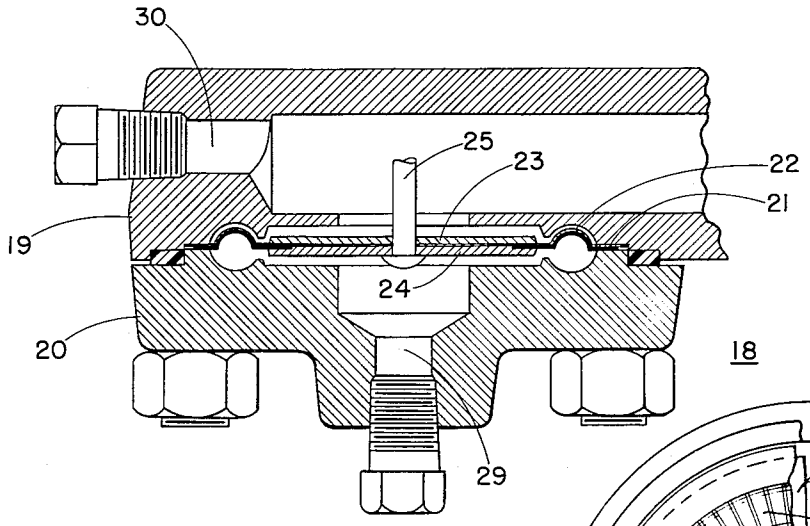


FIG. 5

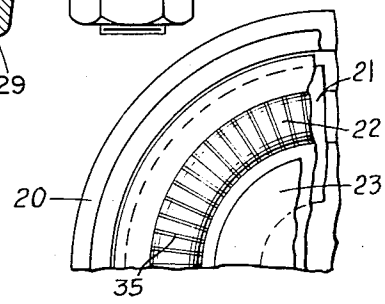


FIG. 7

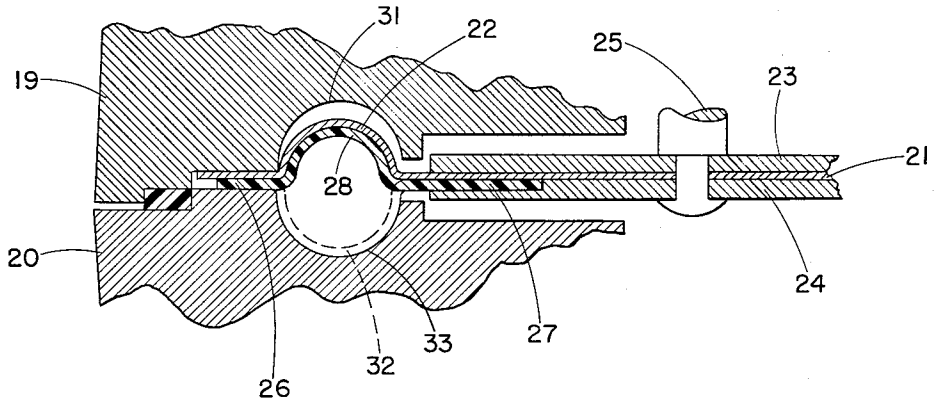


FIG. 6

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United States Patent Office 2,747,615 Patented May 29, 1956

2,747,615

PRESSURE RESPONSIVE DEVICE HAVING A SLOTTED METAL DIAPHRAGM

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Application February 25, 1953, Serial No. 338,658

3 Claims. (Cl. 137—784)

This invention generally relates to diaphragms for fluid pressure responsive devices and more particularly to diaphragms employed in connection with air operated devices or instruments of the force balance type.

For dependable operation of such instruments it is usually quite important that the effective area of the diaphragm remain constant for a travel of as much as 0.030 inch. It is even more important that for a given deflection the effective area remain constant over a long period of time and after having been subjected to a fairly wide range of temperatures and pressures. In other words, the diaphragm must be highly repeatable to perform the exacting function which is demanded of it.

In an effort to improve the conventional diaphragm made of fabric stock impregnated or covered with a coating of plastic material, it has been a common practice to form or mold a corrugation in the unsupported area of the diaphragm. Such a deeply formed corrugation tends to improve the constant area characteristic of the the diaphragm although the repeatability has not been improved to any substantial extent thereby inasmuch as the tendency to stretch still remains as an inherent characteristic of this type of material.

Insofar as repeatability is concerned, this objective could be obtained by the employment of a metallic sheet instead of a plastic coated fabric. To obtain a constant area characteristic and have the diaphragm linear with travel, it would again be necessary to introduce a deep corrugation of approximate semicircular configuration in the metallic sheet. However, when a metal diaphragm is so constructed, a new problem is introduced since it has been found that the diaphragm thereby becomes exceedingly stiff and unsuitable for this reason. The stiffness apparently arises largely from the fact that hoop stresses are set up in the corrugation when deflection occurs. Nevertheless because of the desirable repeatability characteristic, a metallic type diaphragm would usually be employed if the objectional stiffness characteristic could somehow be eliminated without the sacrifice of a good constant area characteristic.

It is therefore an object of this invention to provide a diaphragm having both desirable constant area and repeatability characteristics.

It is a further object of this invention to provide a diaphragm of metallic material having these characteristics but without the objectional stiffness characteristic in the direction in which it deflects.

It is also an object of the invention to provide a diaphragm having a desirable constant area characteristic introduced by virtue of a corrugation formed therein.

For a better understanding of my invention attention is now directed to the following description taken in connection with the accompanying drawings and to the appended claims, in which the features of my invention believed to be novel are more particularly set forth. In the drawings, Fig. 1 is a plan or top view partly broken away of a diaphragm incorporating the features of my invention; Fig. 2 is a sectional view taken on the line

2—2 of Fig. 1; Fig. 3 is an enlarged sectional view taken on the line 3—3 of Fig. 1; Fig. 4 is a plan view similar to Fig. 1 illustrating a modification of the invention; Fig. 5 is a partial cross sectional view through a fluid pressure responsive device between portions of which is employed a diaphragm representing a further modification of my invention; Fig. 6 is an enlarged cross sectional view through a portion of the device shown in Figure 5 better to illustrate the details of the modified diaphragm of the invention employed therein and Fig. 7 is a top plan view of a fragment of the Figs. 5 and 6 diaphragm as seen with a top portion of the Figs. 5 and 6 device removed.

Referring to Figures 1, 2 and 3 of the drawings, I have illustrated a diaphragm comprising a relatively thin circular shaped disk **10** of a suitable metallic material such as carbon steel, copper, stainless steel or any other metallic material which will withstand the corrosive action of fluids to which it may be subjected. Openings or holes **11** spaced circumferentially around and adjacent the outer edge of the disk are provided therein for passage of bolts or cap screws employed to sealingly clamp the peripheral portions of the disk between abutting members of the device or instrument within which the disk may be incorporated. In addition, a substantially U-shaped annular fold or corrugation **12** is also formed in the disk adjacent the periphery thereof but within the peripheral portion which will be clamped within an instrument.

In accordance with the invention and to considerably reduce the hoop stresses in or stiffness of the disk which would otherwise be a characteristic thereof, I provide a plurality of spaced slots **13** extending transversely through and across the fold or corrugation **12**. These slots may be of varying widths and spacing therebetween but usually are of the order of hundredths of an inch. In any event, the width of each slot is usually relatively small or narrow. For example, I have employed slots with a width as small as 0.010 inch with a spacing between slots of approximately 0.030 inch.

Although slotting of the corrugation solves the problem of increased stiffness which is introduced into the disk by incorporation of the annular corrugation therein, another and new problem is created thereby inasmuch as the diaphragm must be impervious or constitute a perfect seal through which fluids under pressure cannot pass.

Therefore, in accordance with a further feature of the invention and to prevent passage of fluid through the slots, the slots are sealingly covered with a layer or layers of a flexible and impervious or fluid impermeable material which will resist attack of any fluid which might be used and will change in stiffness as little as possible with change in temperature. For example, in the embodiment shown in Figures 1, 2 and 3, I have illustrated the employment of a thin layer or coating **14** of a plastic material such as Teflon, a polyvinyl resin or dental dam bonded to the convex surface of the corrugation **12**. The method of bonding varies dependent upon the plastic material employed as the coating. For example, in the case of a polyvinyl resin, a suitably shaped mold is coated with a commercial mold release and a polyvinyl resin such as Stanley 7 x 216 black Pastisol is applied to each half of the mold by brushing. The slotted and formed metallic disk freed from oxide, degreased and primed is then placed in the coated mold, the mold closed and its contents heated to approximately 350° F. for about a five to ten minute interval whereby the resin is cured to form a tough film securely bonded to the disk. In the case of Teflon, the metallic disk is cleaned, degreased, de-oxized and primed. Then a silicone rubber adhesive is applied to a surface of the metallic blank and a thin film of Teflon is

applied over the silicone rubber adhesive. The metal blank with the Teflon and silicone adhesive is assembled into a mold and cured at a suitable temperature and pressure to effect a secure bond. Inasmuch as the slots 13 are so narrow, such a coating would not be forced through the slots by the fluid pressures usually used. However, in the event that it is desired to increase the width of the slots or to employ a seal of lesser bond strength, the coating may be applied both to the convex and to the concave surface of the corrugation as well.

Although the slots 13 have been illustrated as extending transversely through the annular metallic corrugation in a radial direction, there may be an application or applications where a diaphragm must be used which has greater flexibility than would result by virtue of radial slots. Thus, I have illustrated in Figure 4, as a modification of my invention, a diaphragm comprising a metallic disk 15 having an annular corrugation 16 therein with spaced slots 17 extending transversely therethrough in a diagonal direction or obliquely at an angle with respect to the radius or radii of the corrugation. With the slots inclined to the radius at angles between 60 and 90 degrees, for example, the diaphragm stiffness is reduced several fold since the longer metal strips or spokes in the corrugation both bend and twist as the diaphragm deflects.

In so far as production procedure is concerned, the corrugation may be slotted by several methods. For example, after forming the diaphragm with the corrugation therein, a slitting punch may be employed together with a die having adequate backing and a stripper. On the other hand, a resist may be printed on the entire diaphragm with the exception of the portions of the corrugation to be slotted. Then, such portions, which would be unprotected by the resist, would be etched through. Subsequently, one or both surfaces of the corrugation may be sprayed with a coating material such as Teflon using suitable means to block off the peripheral portion of the diaphragm outside the corrugation which is usually clamped within an instrument or device and the inner area or portion within the corrugation which is usually interposed and clamped between a pair of relatively rigid push plates.

In Figure 5, I have illustrated a partial cross section through a differential pressure responsive device 18 having an internal space or compartment defined by a pair of abutting housing sections 19 and 20. The compartment is divided into a pair of chambers by a diaphragm representing another modification of my invention.

Like the previously described embodiment, the diaphragm of this modification comprises a metallic disk 21 of metallic material with an annular fold or corrugation 22 therein. As illustrated, the peripheral portion of the diaphragm outside the corrugation 22 is fixedly and sealingly clamped between the abutting housing sections 19 and 20 while the central portion of the diaphragm inside the corrugation is interposed and clamped between a pair of relatively rigid push plates 23 and 24 in accordance with common and well known practice. Flexure or movement of the diaphragm is transmitted from the push plates to a push rod 25 which in turn transmits the motion to a torque tube, for example, and thus to elements outside of the housing in a well known manner. While the annular corrugation 22 may be provided either with special radial slots as in the Figure 1 embodiment or with diagonal slots as illustrated in the Figure 4 embodiment, it is shown as being provided with spaced radial slots 35 as better illustrated by Figure 7. However, as distinguished from these embodiments and to prevent passage of fluid through the slots, I have employed an annular shaped strip of flexible and impermeable material having outer and inner peripheral portions 26 and 27, Fig. 6, clamped or maintained in sealing engagement with portions of metallic disk 21 respectively clamped between the housing sections and the push plates. The impermeable and flexible strip is not otherwise bonded or sealed to the disk 21 so that the intermediate portion 28 thereof between the clamped peripheral portions is flexibly movable with respect to and engageable with a surface of the corrugation 22 as better illustrated in Figure 6. In normal operation, the fluid pressure entering the device or instrument 18 through passage 29, for example, is greater than the pressure entering through the passage 30. If by chance the higher pressure greatly exceeds the lower pressure, the diaphragm corrugation is prevented from rupturing by resting against the surface of an annular groove 31 provided in housing section 19. In the event that a large overrange of pressure should occur in a reverse direction, intermediate portion 28 of the flexible strip of impermeable material will move away from the metallic corrugation 22 and assume the shape shown by the dotted lines 32 in Figure 6 where, it will be observed, the flexible material will not rupture since it will be supported by the surface defined by an annular groove 33 provided in housing section 20. The flexible strip of impermeable material may be made of any suitable material dependent upon the expected fluid pressure, temperature and corrosive characteristics such as a plastic, rubber, or a plastic or rubber impregnated fabric material.

Thus I have provided for assembly in fluid pressure responsive devices, diaphragms having the desirable characteristics of low stiffness, minimum effective area change with travel, large travel and ability to withstand large overrange and reversal of pressures. Furthermore, the very objectional characteristic of a sustained deviation inherent in most diaphragms is not possessed by the diaphragms of my invention. In other words, my diaphragms possess much less drifting tendency with time, temperature and pressure inasmuch as the load is carried by metal rather than fabric or plastic. In short, the diaphragms of my invention possess all of the desirable characteristics only one or a few of which are possessed by any one prior art diaphragm known to applicant.

While I have, in accordance with the patent statutes, shown and described a particular embodiment of my invention and modifications thereof, it will be obvious that changes and modifications can be made without departing from the invention in its broader aspects and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a fluid pressure responsive device having an internal compartment defined by a pair of abutting housing sections, a diaphragm dividing said compartment into a pair of chambers and comprising a disk of metallic material having an annular corrugation therein, a peripheral portion of said diaphragm outside said corrugation being fixedly clamped between said housing sections with a central portion thereof inside said corrugation beng interposed and clamped between a pair of relatively rigid push plates, said corrugation having a plurality of spaced slots extending transversely therethrough and an annular strip of semi-flexible impermeable material having outer and inner peripheral portions maintained in sealing engagement with portions of said metallic diaphragm respectively clamped between said housing sections and said push plates, the intermediate portion of said annular strip between said peripheral portions thereof being flexibly movable with respect to and engageable with a surface of said corrugation.

2. In a pressure responsive device having an internal compartment defined by a pair of abutting housing sections, the combination of a diaphragm dividing said compartment into a pair of chambers and comprising a disk of metallic material having an annular corrugation therein, a peripheral portion of said diaphragm outside said corrugation being fixedly clamped between said housing sections with a central portion thereof inside said corrugation being interposed and clamped between a pair of relatively rigid push plates, an annular groove in one of

said housing sections, an annular groove in the other of said housing sections positioned opposite said first mentioned annular groove and defining an annular cavity therewith, the corrugated portion of said disk being disposed within said cavity with the convex surface thereof positioned adjacent the surface defining the groove in said one housing section, said corrugation having a plurality of spaced slots extending transversely therethrough and an annular strip of semi-flexible impermeable material having outer and inner peripheral portions maintained in sealing engagement with portions of said metallic diaphragm respectively clamped between said housing sections and said push plates, the intermediate portion of said annular strip between said peripheral portions thereof being positioned adjacent said corrugation and defining a seal to prevent passage of fluid through said slots and between said chambers, said intermediate portion being flexibly movable with respect to and engageable with the concave surface of said corrugation and with the surface defining the groove in said other housing section.

3. A diaphragm for a pressure responsive device comprising a disk of metallic material having an annular corrugation therein, said corrugation having a plurality of spaced slots extending transversely therethrough, an annular strip of semi-flexible impermeable material maintained in sealing engagement with peripheral portions of said disk outside said corrugation and with an annular portion of said disk inside said corrugation, an intermediate

portion of said annular strip between said portions thereof maintained in sealing engagement with said peripheral and annular portions of said disk being flexibly movable with respect to and engageable with a surface of said corrugation and support means spaced from and positioned opposite said surface for support of said intermediate portion of said flexible strip when disengaged from said corrugation.

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