Jan. 3, 1956 J. A. SENN 2,729,243

CATENATED MULTIPLE ANEROID CAPSULE

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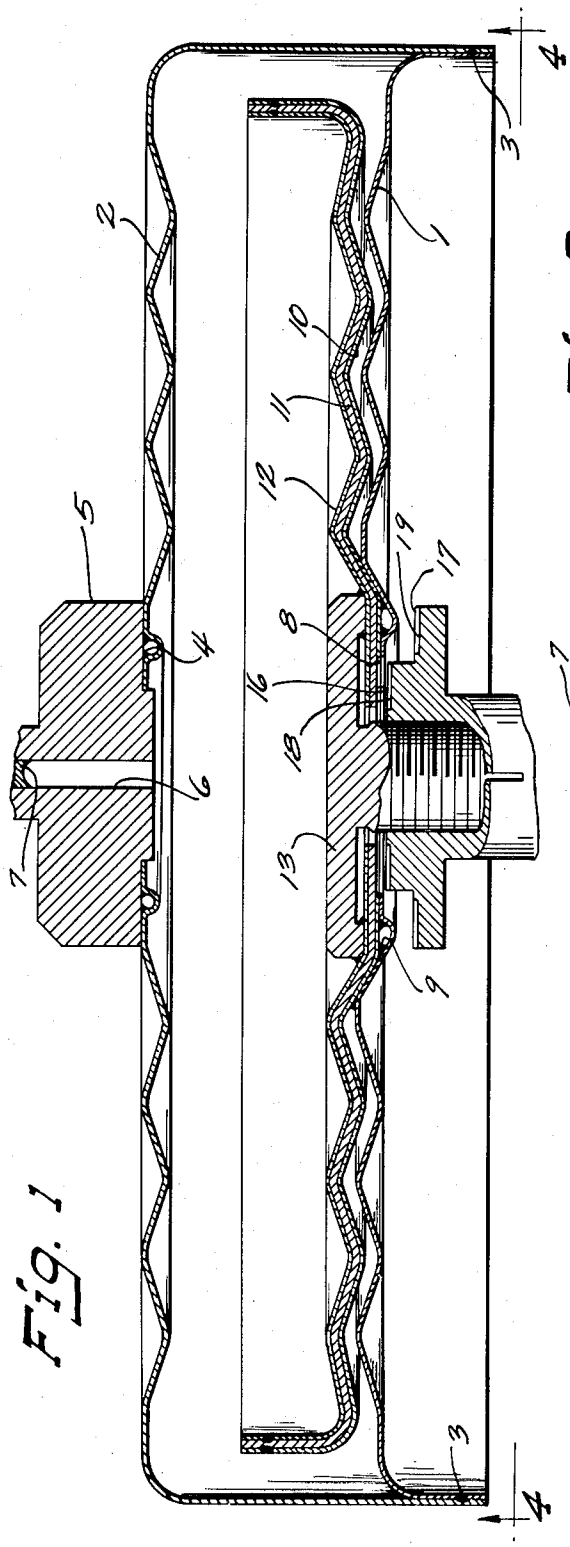


Fig. 1

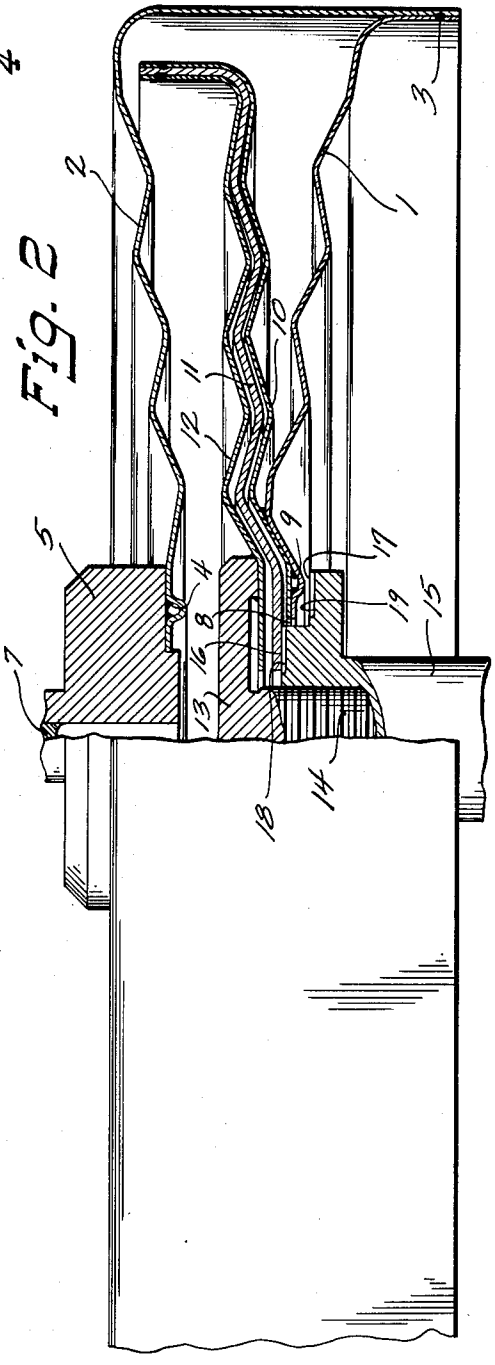


Fig. 2

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Fig. 3

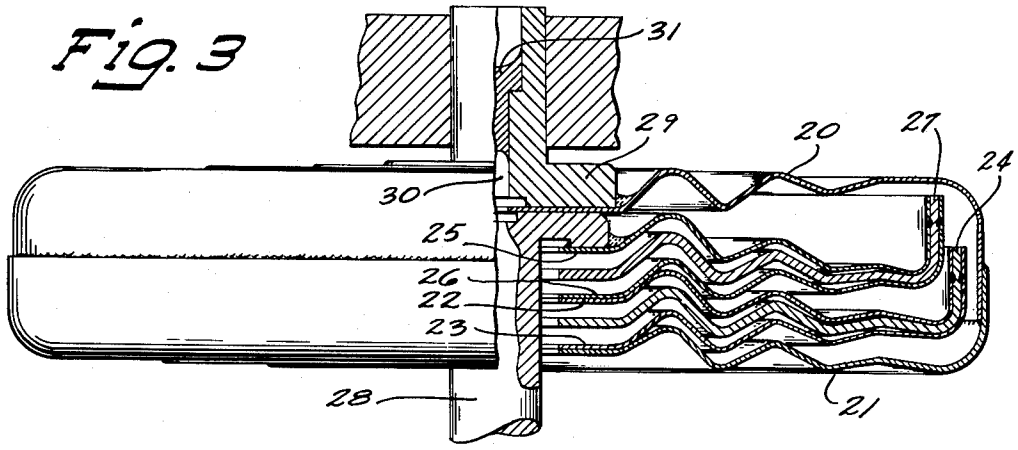
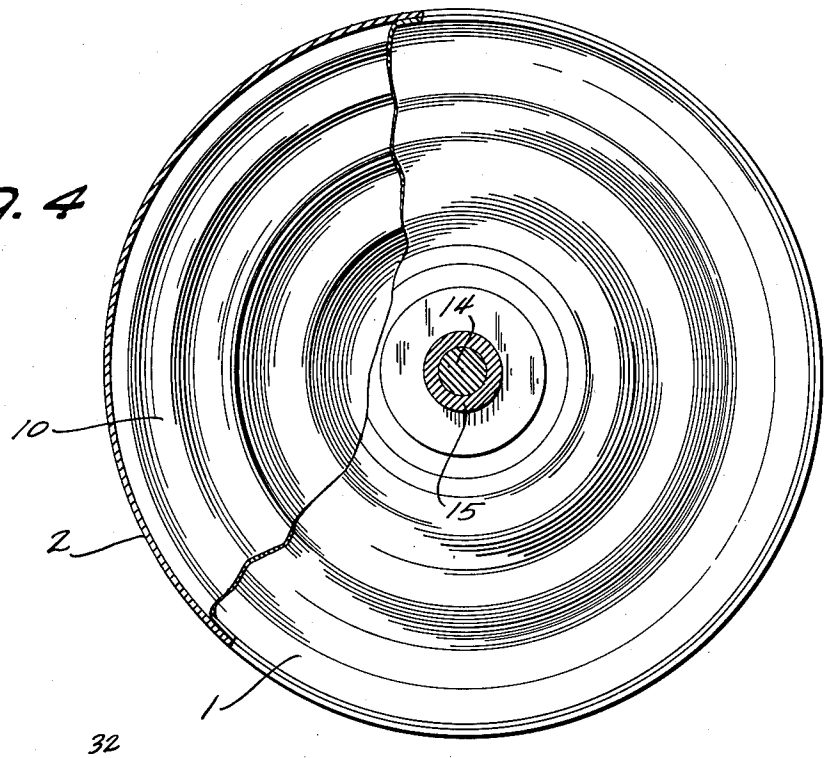



Fig. 4



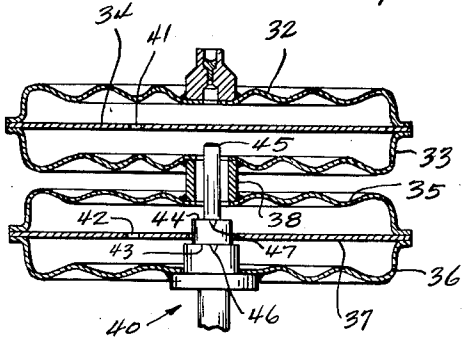




Fig. 5

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2,729,243

# CATENATED MULTIPLE ANEROID CAPSULE

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4 Claims. (Cl. 137—787)

This invention relates to so called capsule pressure motors for use in aneroid altimeters and barometers or other pressure responsive devices and it resides more particularly in improvements in such capsules, wherein the effective area and scope of displacement are large relative to the overall external dimensions of the capsule and in which an external inwardly collapsible member houses and is joined to one or more internal outwardly expandable members to form a multiple capsule with a single void in which the displacements of the several members are additive. The invention at times includes the use of idle reenforcing diaphragms to assure precise positioning and travel of the internal capsules within the limited space available therefor and at times includes abutments positioned to interfere with displacements of the idle diaphragms and the external capsule to cause displacements to approximate logarithmic or other functions of the pressure differentials applied.

Heretofore, pressure responsive motors employed for sensitive altimeters, including those employed in radio sonde instruments and the like, have consisted of a plurality of diaphragm capsules housing separate voids which capsules are joined to one another in multiple to provide the necessary large effective area and the substantial displacement which the sensitive forms of such instruments require. A bank of such diaphragms, in multiple, has an overall longitudinal dimension several times the scope of the displacement range. Multiple capsules of this type furthermore are often lacking in radial stability and have a response such that complex linkages and adjusting systems are required if an even scale instrument is to be provided.

It is an object of this invention to provide an aneroid pressure motor of greater compactness.

It is another object of this invention to provide an aneroid pressure motor in which the thickness of material employed may be chosen to limit maximum fibre stress without loss of radial stability.

It is another object of this invention to provide an aneroid pressure motor having a response such that adjustment is simplified and such that an altimeter instrument with even scale deflection may be more easily constructed therefrom.

The foregoing and other objects and advantages of this invention will appear from the description following which is set forth by reference to the accompanying drawings forming a part hereof, in which there is set forth, by way of illustration and not of limitation, specific forms in which the apparatus of this invention may be embodied.

In the drawings:

Fig. 1 is a side view in elevation and in section of one form of altimeter capsule of this invention including motion hindering means, the capsule being shown in a condition of minimum stress corresponding to exposure to maximum altitude,

Fig. 2 is a side view in elevation and partly in section of the capsule shown in Fig. 1 the parts being shown



in a condition of maximum stress corresponding to exposure to minimum altitude,

Fig. 3 is a side view in elevation and partly in section of another form of capsule constructed in accordance with this invention in which two internal outwardly expandable members are housed within and contribute their displacements to an external inwardly collapsible member,

Fig. 4 is a top plan view of the capsule shown in Figs. 1 and 2, parts being shown broken away, and

Fig. 5 is a side view in elevation and in section of a capsule entirely inwardly collapsible in which the motion hindering apparatus of this invention is embodied.

Referring now to the drawings, the capsule of this invention, in the form appearing in Figs. 1, 2 and 4, is housed within an inwardly collapsible external housing made up of a lower corrugated cup diaphragm **2**. The diaphragms **1** and **2**, for convenience, are referred to herein as a free diaphragm and a reference diaphragm respectively. The reference diaphragm **2** is soldered at **4** to a sealing boss **5** having an access channel **6** which is closed by low melting solder **7** after the gas contained has been reduced to the quantity desired. The boss **5** also constitutes one of two relatively movable attachment members through which displacement of the motor may be communicated to parts intended to be moved thereby.

The center of free diaphragm **1** is open as indicated at **8**, where it meets and is joined by solder **9**, with the open center of an internal corrugated cup diaphragm **10**. Cup diaphragm **10** is of reduced diameter small enough to be entirely housed within the cup diaphragm **2**. The outer upturned rim of diaphragm **10** receives in nested relation and is welded to the rim of an idle stiffening member **11**, the rim of which receives in turn and is welded to the nested rim of internal corrugated cup diaphragm **12**.

The center of diaphragm **12** is soldered to and closed by the head **13** of a threaded stem **14** which threadingly engages the internally threaded bore of an adjustable sleeve **15** having a collar bearing step flanges **16** and **17**. Flange **16** is indented with a vent groove **18** and flange **17** by a vent groove **19** to ensure free access of the atmosphere at all times to the space above and below the idle member **11**. Stem **14** and sleeve **15** constitute the second attachment member which is relatively movable with respect to the attachment member provided by boss **5**.

The assembly of diaphragms **1**, **2**, **10** and **12** is such as to provide an enclosure for a single connected void which is evacuated to an appropriate degree through the channel **6** and sealed by solder **7** as previously indicated. When so evacuated and when subjected to a pressure corresponding with a low altitude, environmental pressure, acting on the diaphragms **1** and **2** deflects the same inwardly as indicated in Fig. 2. At the same time, the environmental pressure acting on the diaphragms **10** and **12** causes them to separate from the idle member **11** as shown in the same figure. The displacements of all four of the diaphragms mentioned thus act additively to produce a combined relative displacement of the members **5** and **15**.

Diaphragms **1** and **2** are preferably made of a diameter large enough so that metal of sufficient thickness to have the requisite radial strength may be employed without harmful maximum fibre stress occurring under the displacements demanded. The diaphragms **10** and **12**, being smaller in diameter than the diaphragms **1** and **2** are preferably made of thinner metal in order that they may be capable of the substantial displacement required without harmful maximum fibre stress occurring. The diaphragms **10** and **12**, being made thin enough to

comply with the above requirements, are weakened radially, but the reenforcing effect of the thicker idle member **11** lends adequate radial strength to the assembly.

As the capsule is carried to higher altitudes the members relax resiliently toward a configuration such as is illustrated in Fig. 1. In traveling to and from extreme operating positions the step flanges **16** and **17** engage with and separate from elements disposed in the path of their movement. As indicated in Fig. 2, in going from an environment of lower pressure to higher pressure the flange **16** comes into engagement with the stiffening member **11**. As pressure is further increased deflection of diaphragm **12** ceases to occur since the spacing between it and the stiffening member **11** is thereafter held constant. Resistance to deformation of the assembly as a whole is therefore increased.

As environmental pressure continues to rise the flange **17** eventually comes into contact with diaphragm **1**. Further pressure rise then occurs without alteration of the spacing between diaphragm **10** and the stiffening member **11** and the resilient properties of the assembly as a whole are characterized by the stiffer action of diaphragms **1** and **2** which are the only members functioning as free members under such conditions. Resistance to displacement is thus further increased.

As a result of the action above, a plurality of pressure displacement functions are brought successively into play. These successive functions may be chosen to closely approximate any desired pressure displacement relationship such as a logarithmic function or otherwise.

The pressure displacement relationship of a corrugated disc diaphragm is nearly linear when the diaphragm is in a relatively unstressed condition. As stress increases displacement for a given increment of pressure becomes smaller as an inherent property of such a diaphragm, but not to an extent sufficient to approximate a logarithmic relationship. A nearly logarithmic relationship, however, can be closely approached as noted by correlating the state of stress of the diaphragms with the engagement and disengagement of the interfering members referred to, taking advantage of the inherent departure from a linear relationship to ease the transition between successive integral members of free diaphragms.

In the apparatus shown in Figs. 1, 2 and 4, a nearly smooth transition occurs from a capsule having the characteristics of four free members to one having the characteristics of three free members and finally to one having the characteristics of two free members. By the use of a larger number of diaphragm members and a larger number of transitions even closer approximation to any desired pressure displacement relationship may be achieved.

In the case of an altimeter it is desirable that the dial or scale of successive elevations be evenly divided or nearly so, such being called an even scale instrument. The pressure altitude relationship, however, roughly approximates a logarithmic function. In accordance with this invention a capsule may be provided in which increments of displacements are linearly related to altitude rather than pressure. This being the case, multiplying linkage in the instrument may be greatly simplified and initial adjustment and calibration of the instrument can be reduced to a single simple adjustment. For example, the adjustable actuating sleeve **15** may be turned on the threaded stem **14** to bring about a very close approximation of the pressure displacement relationship which the capsule unit is intended to exhibit in spite of inevitable variations in manufacture. Diaphragm assemblies as heretofore constructed have not been adjustable in this sense, a factor which has caused the rejecting or discarding of a very high proportion of diaphragm capsules manufactured for use in altimeters.

In the apparatus shown in Figs. 1 and 2, it may be desirable to close the juncture, held and sealed by solder **9**, by means of a weld, in which event the only soldered junctions remaining are those formed by solder **4** and the solder joining the member **13** to the diaphragm **12**. These two junctures are so related that thermostatic effects, unavoidable where solder is employed, are opposed and substantially equal, thus rendering the capsule self-compensating in this regard. If proper known alloys having exceptionally low temperature coefficients of change of physical properties are employed, a capsule having overall properties of exceptional thermal stability may thus be constructed in accordance with this invention. This is true to a surprising degree even when solder **9** is employed since such introduces but a single uncompensated juncture.

In the event that compactness is sought but the features of adjustability and modification of pressure displacement ratios, above described, are not desired, the apparatus of this invention can be constructed as appears in Fig. 3. In the apparatus here shown a pair of inwardly collapsible diaphragm members **20** and **21** are joined at their outer rims by solder as shown. The free diaphragm **21** is open at the center and is joined by solder with a set of internal outwardly expandable diaphragms **22** and **23** which meet at their outer rims and are welded to a radial stiffening member **24**.

The members **22**, **23** and **24** are open at their centers and diaphragm **22** is joined at its center with a second set of internal outwardly expandable diaphragm members **25** and **26**. The diaphragms **25** and **26** meet at their outer rims and are welded to a radial stiffening member **27**. The members **25**, **26** and **27** are likewise open at their centers and the center of diaphragm **25** is joined with and closed by the head of an actuating stem **28**.

The center of external reference diaphragm **20** is closed by a mounting sleeve **29** having a channel **30** which is closed by solder **31** after evacuation. The capsule assembly shown in Fig. 3 thus is possessed of six members, the deflections of which are additive, although they house but a single void. The several diaphragm elements furthermore are closely nested and occupy a total space not greatly in excess of that of the well known two element diaphragm. The total displacement available, without subjecting the metal to harmful maximum stresses, is approximately three times that available with the well known two element diaphragm. These results are achieved, moreover, without sacrifice of radial stiffness since the stiffening members **24** and **27** adequately supplement any deficiency in this regard which would otherwise arise from the use of adequately yieldable diaphragms **22**, **23**, **25** and **26**.

The displacements of the external collapsible housing and the internal expandable assembly are rendered additive in the forms of this invention above described by means of a junction between the internal and external parts which junction surrounds a central opening and by means of an actuating member movable through the central opening, the actuating member engaging a remote part of the internal expandable assembly.

If desired, the advantages of the successive hindering of multiple diaphragms, in accordance with this invention, may be obtained in apparatus which consists of externally collapsible members, as shown in Fig. 5. In this form of apparatus a pair of inwardly collapsible diaphragms **32** and **33** are joined and sealed at their rims to an intermediate idle member **34**. A similar pair of diaphragms **35** and **36** are assembled in like fashion against the opposite faces of an idle member **37** and this assembly is joined with diaphragm **33** by a sleeve **38** and solder as shown. Diaphragm **32** has a central opening closed by a sealing and attachment fitting **39** and by solder as shown. Diaphragm **36** is similarly closed by an actuating member **40**. Vents **41** and **42** in idle members **34** and **37** respectively join the several enclosures into a single connected void.

The apparatus as shown in Fig. 5 is in the configuration assumed when exposed to pressure corresponding with

maximum altitude. As pressure increases and the several diaphragms collapse, shoulder **43** of actuator **40** comes into contact with idle member **37** increasing the overall stiffness of the assembly. Further increase in pressure brings shoulder **44** of actuator **40** into contact with the central part of diaphragm **33** causing a further increase in stiffness of the assembly. A further rise in pressure then brings abutment **45** of actuator **40** into contact with idle member **34** with additional stiffness thereafter being exhibited by the assembly. Notches **46** and **47** in the shoulders **43** and **44**, ensure a connected void in cases where the capsule is not fully evacuated.

The diaphragms employed in the apparatus of this invention are preferably formed of a metal having a low temperature coefficient of change of elastic modulus. If not, temperature compensation may be obtained in the usual fashion by adjusting the gas content of the capsule or by the imposition of thermostatically controlled external loads or both.

The diaphragms themselves and particularly the assemblies making up the internal outwardly expandable portions of the apparatus may be formed in multiple layers in a die to produce a precisely interfitting relationship between the diaphragms themselves as well as with the idle stiffening members. For this purpose, it is desirable that a precipitation hardenable alloy be employed such as beryllium copper, Z-nickel and the like. These alloys can be readily formed in their soft state and may be subsequently hardened through moderate heat treatment without substantial distortion.

I claim:

1. In a resilient capsule pressure motor the combination comprising spaced external free and reference diaphragms joined and sealed to one another at their outer rims to surround an internal void, an attachment member engaging said external reference diaphragm, a central opening in said external free diaphragm, first and second closely adjacent internal outwardly expandable diaphragms disposed within the space surrounded by said external diaphragms joined and sealed to one another at their outer rims, said first internal diaphragm having a central opening adjacent the central opening in said external free diaphragm, means forming a sealed connection between said first internal diaphragm and said external free diaphragm adjacent the central openings thereof, and a second attachment member responsively connected with the second internal diaphragm extending outwardly therefrom through the openings in said internal and external diaphragms.



2. A resilient capsule pressure motor in accordance with claim 1 wherein an idle radial stiffening member is superimposed between and joined to the meeting rims of said first and second internal diaphragms.

3. In a resilient capsule pressure motor the combination comprising spaced external free and reference diaphragms joined and sealed to one another at their outer rims to surround an internal void, an attachment member engaging said external reference diaphragm, a central opening of said external free diaphragm, first and second closely spaced internal outwardly expandable diaphragms disposed within the space surrounded by said external diaphragms, an idle radial stiffening member having a central opening interposed between said internal diaphragms, said internal diaphragms being joined and sealed to one another and to said idle member at their outer rims, said first internal diaphragm having a central opening adjacent the central opening in said external free diaphragm, means forming a sealed connection between said first internal diaphragm and said external free diaphragm adjacent the central openings thereof, second attachment member responsively connected with the second internal diaphragm extending outwardly therefrom through the openings in said internal and external diaphragms, and motion hindering means connected to said second attachment member positioned to engage and hinder the motion of said free external diaphragm and said idle member successively at predetermined positions of movement of said second attachment member.

4. A capsule in accordance with claim 3 wherein the motion hindering means are adjustably connected to the second attachment means to adjustably alter the positions of engagement with the external free diaphragm and the idle member.

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