Aug. 26, 1930. O. W. HEISE 1,774,437

EXPANSIBLE COLLAPSIBLE ELEMENT

Filed Aug. 26, 1925

Fig. 1

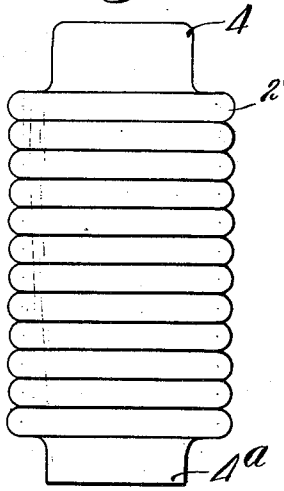


Fig. 3

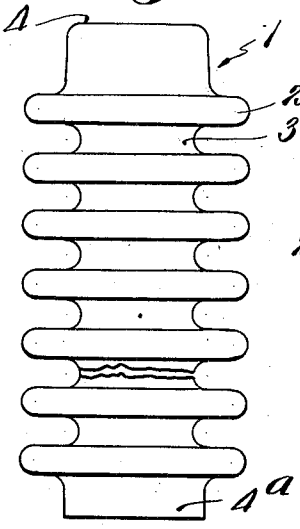


Fig. 2

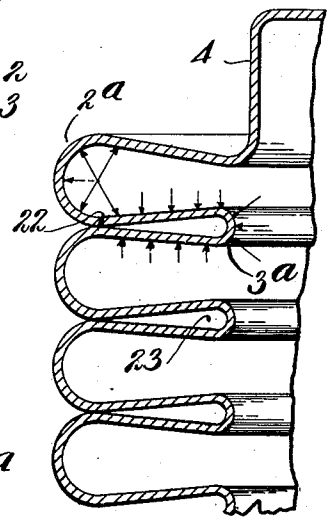


Fig. 7

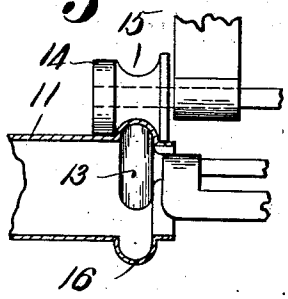


Fig. 5

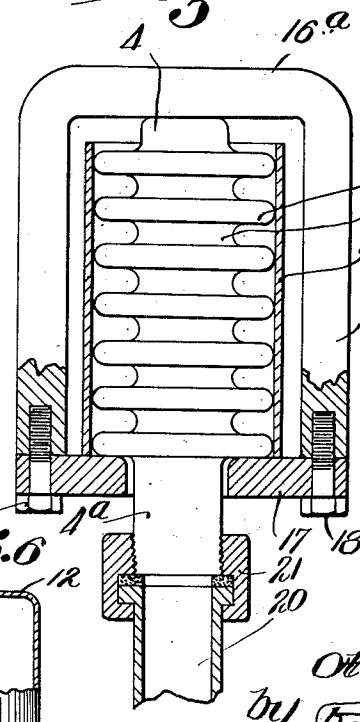


Fig. 4

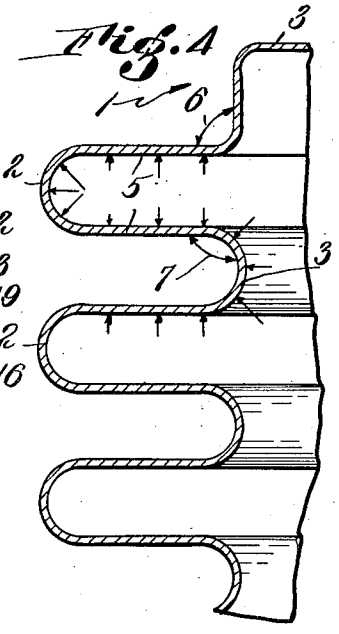


Fig. 8

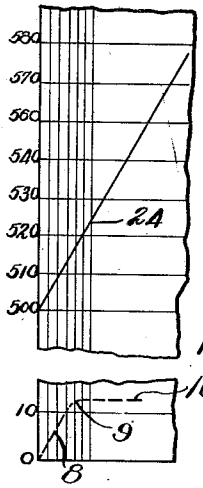


Fig. 6

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Patented Aug. 26, 1930

1,774,437

UNITED STATES PATENT OFFICE

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EXPANSIBLE COLLAPSIBLE ELEMENT

Application filed August 26, 1925. Serial No. 52,705.

This invention pertains to pressure responsive devices in the form of an expansible-collapsible element of metal or other desired material and to a mode of making the same. Such an element will be referred to as a metallic bellows throughout the specification but it should be understood that this is not intended to limit the material or structure of the device.

This type of apparatus is a bellows-like, axially expansible, and usually collapsible tube commonly of copper or brass and which changes its length when subjected to fluid pressure. Such devices are in general old and well known, and have a wide range of utility, as, for example, for automatically controlling the operation of valves, etc.

Various methods of making metallic bellows have been employed, a common mode of procedure being to roll a single cylindrical tube between a pair of intermeshing ribbed rolls, one roll being disposed within the tube and the other outside of it, thus forming circumferentially extending hollow ribs or corrugations, alternate ribs being directed outwardly and inwardly, respectively. Usually these ribs or folds are of equal axial width and have substantially parallel straight side walls.

In order to obtain the desired variation in length when the bellows is subjected to pressure it is usual to make its walls of very thin copper or brass which flex easily, are readily worked, and do not rust nor corrode when exposed to moisture. Since the materials employed are relatively weak and have a low elastic limit the usual metallic bellows has a rather limited range. In other words if the expansion curve of an ordinary metallic bellows be plotted it will be found to be linear for pressures varying within a limited range only, and if such range be exceeded, the metallic bellows, being stressed beyond the elastic limit of the metal, takes a permanent set and no longer expands or contracts in direct ratio to the pressure changes to which it is subjected. Usually when so overloaded the metallic bellows buckles or becomes otherwise deformed since the walls apparently do not stretch at exactly the same rate.

Since the pressure range of an ordinary metallic bellows is relatively small for the reasons just stated, it is necessary to design the metallic bellows with reference to the particular use to which it is to be put and if made strong enough to withstand a high pressure it is no longer sensitively responsive to low pressures or to slight variations in pressure.

For the above reasons metallic bellows have not heretofore, so far as is known to me, been successfully employed under conditions where a long range of pressures is met with, for example in steam pressure gauges, which are at times called upon to register pressures ranging from 1 to 600 lbs. or more.

In the course of a series of experiments conducted with the object of developing a metallic bellows for use in high pressure gauges I have discovered that when a metallic bellows is externally loaded, as for example by means of a weight applied to its movable end, it shows no substantial change in length until the pressure substantially equals the loading weight, whereupon it responds to further increments in pressure with substantially the same degree of sensitiveness and accuracy as it would do at a much lower pressure range if unloaded. This principle and its practical application I have more fully discussed in a co-pending application, Serial No. 52,703, filed August 26, 1925.

In experimenting with such a loaded metallic bellows I found that when the pressure was increased beyond a certain point the walls of the metallic bellows, particularly if it were of considerable length, tended to bulge or buckle in spite of the load, probably due to slight irregularities in thickness or hardness of the metal. Extending my experiments and using very high pressures of the order of 800 lbs. per square inch, I found that when a metallic bellows of usual type and intended for a pressure range having an upper limit of the order of 10 lbs. for example was externally loaded to prevent axial expansion and then subjected internally to this very high fluid pressure its outwardly directed ribs or corrugations would eventually dilate or bulge until their outer parts

became nearly circular in radial section and their outer surfaces were brought substantially into engagement. The metal being stressed beyond the elastic limit retained this new shape so that when the pressure was released the outwardly projecting ribs or corrugations still substantially touched each other.

Upon subsequently subjecting this modified metallic bellows under external load to pressure I found that it was as sensitively responsive as before to pressure variations but capable of withstanding substantially any internal pressure short of that which would actually burst the metal without further permanent deformation, although expanding or contracting at a regular rate and in direct ratio to the pressure applied.

This modified metallic bellows provides the long range heretofore sought for in vain in devices of this character, and is admirably adapted for use in pressure gauges or other devices subject to great pressure variations.

While I have thus far evolved no incontrovertible theory in explanation of the reason for the improved results obtainable by the use of this modified metallic bellows just described, I apprehend that such improved results may be due in part at least to the contact of the outwardly extending ribs with one another so that they mutually support each other and in effect form a continuous column until the loaded metallic bellows begins to elongate. Secondly, to the almost circular contour of the outer parts of the outwardly directed ribs which necessarily increases their resistance to deformation when subjected to internal pressure, and thirdly, to the initial overstressing of the metal and to actual shaping by the high pressure to which it is subjected in making it.

Whatever may be the true explanation of the observed results, I regard my modified metallic bellows as constituting a distinct improvement over metallic bellows as ordinarily constructed, and have fully demonstrated its high utility as a pressure responsive device.

In the accompanying drawings I have illustrated my improved metallic bellows and also certain steps which I prefer to follow in the process of making it, although these illustrations are to be considered merely by way of example and not as constituting limitations of the invention disclosed.

In the drawings,

Fig. 1 is a side elevation of my improved metallic bellows;

Fig. 2 is a fragmentary radial section to larger scale of the metallic bellows shown in Fig. 1;

Fig. 3 is a side elevation of a metallic bellows of usual construction and which by suitable manipulation may be modified to produce my improved metallic bellows;

Fig. 4 is a radial section of the metallic bellows of Fig. 3;

Fig. 5 is an elevation partly in section illustrating apparatus useful in making my improved metallic bellows;

Fig. 6 is a fragmentary side elevation, partly in section, showing a tubular cup from which the metallic bellows may be made;

Fig. 7 is a fragmentary view showing mechanism useful in performing the initial steps in making the improved metallic bellows; and

Fig. 8 is a diagram in which the action of the ordinary metallic bellows is graphically compared with that of my improved metallic bellows.

Referring to the drawings, the numeral 1 (Fig. 3) designates a metallic bellows of usual type consisting of a tubular thin walled hollow metallic body having a series of peripheral folds forming alternating outwardly and inwardly directed hollow ribs, the outwardly directed ribs being indicated by the numerals 2 and the inwardly directed ribs by the numeral 3.

Commonly this tubular body is formed from a seamless tubular cup and has one end 4 permanently closed. The opposite end 4^a provides a tubular shank by means of which the metallic bellows is attached in any suitable fluid tight manner to the pipe or conduit which is to supply the pressure to act upon the interior of the metallic bellows.

Referring to Fig. 4, the usual type of metallic bellows is shown to large scale in section and in such usual form of metallic bellows the side walls 5 of the ribs are usually substantially parallel, the inwardly and outwardly directed ribs being of substantially equal axial width and radial depth.

When a metallic bellows of ordinary type is subjected to internal pressure, such pressure bears with substantially equal force in opposite directions against the inner surfaces of the parallel walls 5 and thus tends to separate these walls. Since the walls are connected at their outer curved ends, the movement of these walls under pressure is substantially confined to their inner ends, the walls swinging away from each other and thereby increasing the angles 6 and 7 between the inner ends of the walls and the adjacent parts. A metallic bellows thus elongates axially to an amount which constitutes the summation of the increase in width of the several ribs.

Since metallic bellows are usually made of very thin metal, commonly brass or copper, so that they may be sensitively responsive to slight pressure variations, they are incapable of resisting pressures above a very moderate amount. When the pressure is increased beyond this point the metal at the angles 6 and 7 is stressed beyond the elastic limit so that the metallic bellows acquires a permanent set

and does not reassume its normal length when the pressure is removed.

When the expansion curve of such a metallic bellows is plotted, it assumes more or less the form indicated by the dotted line 8 in Fig. 8, it being assumed that the metallic bellows under test is intended to respond to pressure variations ranging from zero to 10 lbs. When such a metallic bellows is tested, the deflection, corresponding to the abscissæ of the diagram of Fig. 8 increases in substantially direct ratio to the increase in pressure, indicated by the ordinates in said figure, up to a point perhaps but slightly beyond the upper limit of the range for which the metallic bellows is designed, whereupon the elastic limit of the metal being exceeded the deflection curve rapidly falls off as indicated, beginning at some point such as 9 and following a line 10 which bears no definite ratio to the increase in pressure. Such a metallic bellows is manifestly not suitable for use in measuring pressures beyond its normal range.

In accordance with my present process I may proceed to construct a metallic bellows of the type shown in Fig. 3 in the usual manner by starting with a tubular cup 11 closed at one end as indicated at 12, Fig. 6. I then insert in the open end of this cup a roller 13, Fig. 7, and apply a second roller 14 to the outside surface of the cup, the latter roller having a concave portion 15 complemental to the peripheral edge of the roll 13. These rolls are brought forcibly together and at the same time rotated and thus press the metal of the tubular cup to form a curved outwardly projecting rib 16. This or a similar process may be repeated until the entire length of the cup has been provided with such ribs suitably spaced apart. These ribs may be deepened by successive operations in which rolls of greater diameter are employed until the tubular cup finally assumes the form shown in Fig. 3. I lay no claim to this process of forming the ordinary type of metallic bellows since this is a method common and well understood in the art. Having produced a metallic bellows of the form shown in Fig. 3 in the above manner or in any other suitable way, I next prefer to mount this metallic bellows in a device such as shown in Fig. 5. This device comprises a substantially U-shaped frame having parallel legs 16 united by a cross bar 16^a and a removable yoke 17 which may be secured to the ends of the legs 16 by means of bolts 18.

The yoke 17 is first removed and the metallic bellows is placed within the frame with its closed end 4 bearing against the inner surface of the cross bar 16^a. The yoke 17 is furnished with an opening for the passage of the neck or shank 4^a of the metallic bellows, the latter fitting loosely within this opening, and the yoke 17 is then secured to the U-shaped frame by means of the bolts 18, the dimensions of the parts being such that upon tightening the bolts a slight initial load or compressive stress may be imposed upon the metallic bellows if desired. This initial load is unnecessary, however, since as soon as pressure is applied the metallic bellows first tends to elongate and immediately comes into contact with opposite ends of the frame which thus in effect apply an axial load to the metallic bellows.

Preferably before introducing the metallic bellows into the frame I slip a heavy sleeve 19 over the metallic bellows, such sleeve having an internal diameter substantially equal to the maximum external diameter of the metallic bellows. This sleeve prevents any radial buckling or distortion of the metallic bellows when pressure is applied, but is not necessary particularly in treating metallic bellows of relatively short length.

After the metallic bellows has been arranged within the frame as described, the neck 4^a of the metallic bellows is connected to a pressure supply pipe 20, as for example by means of a suitable fluid tight joint or union 21. I now admit fluid at very high pressure through the pipe 20 to the interior of the metallic bellows. I have found that an internal pressure of the order of 800 lbs. is sufficient for my purpose when treating metallic bellows of the type which would ordinarily be employed in connection with a pressure range of the order of 10 lbs. or thereabouts.

When this pressure is admitted, the outwardly extending ribs of the metallic bellows immediately begin to swell or bulge and assume a more or less bulbous contour in radial section as indicated in Fig. 2. At the same time the inwardly directed ribs commence to collapse or flatten and may in the extreme case collapse entirely so that their side walls are substantially in contact, thus forming solid ribs. On the other hand, the outwardly extending ribs as above stated bulge or swell until their outer parts become more or less circular in radial section and eventually touch each other as indicated at 22. This high pressure stresses the metal far beyond its elastic limit so that when the pressure is now removed the metallic bellows retains the shape imparted to it and exhibits the external appearance shown in Fig. 1 where the bulbous or swollen outwardly extending ribs 2^a touch each other normally even when the metallic bellows is not subjected to internal pressure beyond that of the atmosphere.

When a metallic bellows, modified in accordance with this process is now employed as the pressure responsive element in a pressure gauge or the like, and is externally loaded, it shows itself capable of withstanding a wide range of pressure variation without exhibiting eccentricities in behavior and

without buckling or becoming deformed, and as the metallic bellows is normally collapsed, external load may be applied without substantially changing its shape. If such metallic bellows be externally loaded, for example by means of a weight of 500 lbs. bearing against its closed end, the curve of deflection will be substantially as indicated in Fig. 8. Under these circumstances, no substantial deflection will be observed until a pressure of 500 lbs. has been admitted to the interior of the metallic bellows, thereupon the metallic bellows begins to elongate or deflect, following a substantially linear equation as represented by the straight line 24, in Fig. 8, the elongation or deflection bearing a constant ration to the increase in pressure although the pressure extends through a long range above the starting point, far beyond the range for which the metallic bellows before modification was intended. Furthermore during this expansion under high pressures the metallic bellows responds apparently with the same degree of sensitiveness as would the unmodified metallic bellows have responded to pressures of a much lower range, that is to say, as indicated in Fig. 8 the line 24 is substantially parallel to the line 8.

While I have referred to a pressure gauge as an example of devices in which my modified metallic bellows may be found particularly useful I do not wish to limit myself in any way to the use of my metallic bellows in such surroundings but believe that it may find wide utility in other apparatus and in other environments.

I claim:

1. As an article of manufacture a hollow thin walled resilient metallic body having outwardly projecting peripheral ribs alternating with inwardly directed ribs, the inwardly directed ribs being always so spaced as to permit free access of pressure fluid into the outwardly projecting ribs, said body being so constructed and arranged that when externally loaded it does not substantially decrease in length, and when so loaded and subjected to internal pressure it shows substantially no increase in length until the pressure substantially equals the load and thereafter elongates in substantially direct ratio to slight increments of pressure with substantially the same degree of sensitiveness that it would at a lower range if unloaded.

2. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said device comprising a thin walled tubular substantially cylindrical metallic body having a series of outwardly projecting annular hollow ribs alternating with inwardly directed ribs, a portion of each outwardly projecting rib normally contacting with adjacent outwardly projecting ribs but the inwardly directed ribs being spaced from one another, said device when externally loaded being sensitively responsive in direct ratio to successive slight changes of pressure throughout a range of pressures exceeding said load.

3. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said device comprising a thin walled tubular substantially cylindrical metallic body having a series of outwardly projecting ribs alternating with inwardly projecting ribs, said outwardly projecting ribs normally being of bulbous contour in radial section and having their outer surfaces normally in contact, the inwardly directed ribs normally being spaced apart, said device when externally loaded and subjected to pressure showing substantially no change in length until the pressure substantially equals the load and thereafter responding with substantially the same degree of sensitiveness and accuracy as it would do at a low pressure range, if unloaded.

4. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said device comprising a thin walled hollow metallic body provided with alternating inwardly and outwardly directed annular ribs, the outwardly extending ribs being of larger area in radial section than the inwardly directed ribs, said device when externally loaded being sensitively responsive in direct ratio to successive slight increments of pressure throughout a pressure range whose lower limit substantially equals said load.

5. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said device comprising a hollow thin walled metallic tubular body having a series of peripheral hollow ribs, alternate ribs projecting inwardly and outwardly respectively, the inwardly projecting ribs being axially flattened as compared with the outwardly projecting ribs, and the outer surfaces of adjacent outwardly projecting ribs being normally substantially in contact, said device when externally loaded being sensitively responsive in direct ratio to successive slight increments of pressure above a pressure equaling the load.

6. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said

device comprising a hollow thin walled peripherally corrugated cylindrical metallic body having outwardly and inwardly directed series of ribs, said device being normally collapsed substantially to its shortest dimensions with its outwardly directed ribs in contact and with its inwardly directed ribs spaced apart, said device being axially expansible when subjected to internal pressure and when externally loaded responding sensitively in direct ratio to successive slight increments of pressure throughout a pressure range whose lower limit substantially equals said load.

7. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said device comprising a hollow thin walled peripherally corrugated tubular metallic body having outwardly and inwardly directed ribs, one set of ribs normally being in contact so that it will sustain an external force acting in an axial direction without substantial dimunition in length but will increase in length when subjected to internal pressure, the other set of ribs normally being spaced apart, said device when externally loaded being sensitively responsive in substantially direct ratio to successive slight increments of pressure throughout a pressure range whose lower limit substantially equals said load.

8. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said device comprising a hollow metallic body having a thin ribbed wall, said wall having alternating inwardly and outwardly directed bends constituting annular ribs, the outwardly directed bends being bulbous in radial section and the inwardly directed bends being of less area in radial section than the outwardly directed bends said device when externally loaded and subjected to pressure responding sensitively in substantially direct ratio to successive slight increments of pressure throughout a pressure range whose lower limit substantially equals said load.

9. A resilient pressure responsive device of the class described which expands when subjected to internal pressure and which possesses inherent tendency to resume its normal length when the pressure is relieved, said device comprising a hollow metallic body having a thin peripheral wall, said wall comprising a series of outwardly directed bends forming hollow annular corrugations, said hollow corrugations being separated by inwardly directed bends forming axially narrow ribs, said device when externally loaded being sensitively responsive in substantially direct ratio to successive slight increments of pressure throughout a pressure range whose lower limit substantially equals said load.

Signed by me at Bridgeport, Connecticut, this 24 day of Aug. 1925.

OTTO W. HEISE.