Oct. 6, 1959 J. W. YOWELL ET AL Re. 24,710

BELLOWS

Original Filed Dec. 26, 1952 2 Sheets-Sheet 1

Fig. 1

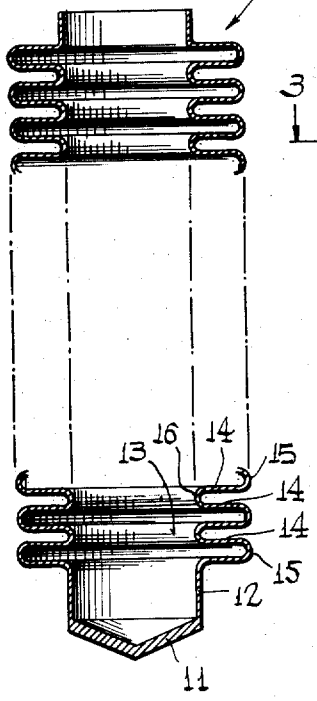


Fig. 2

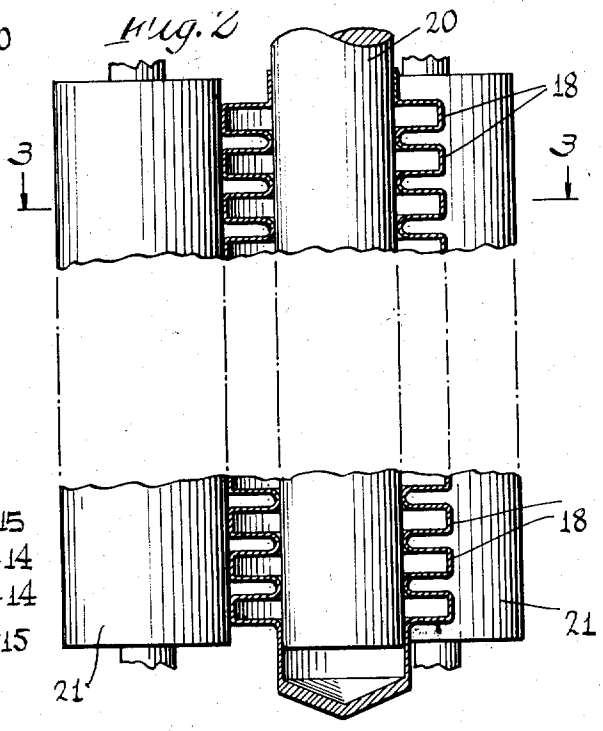
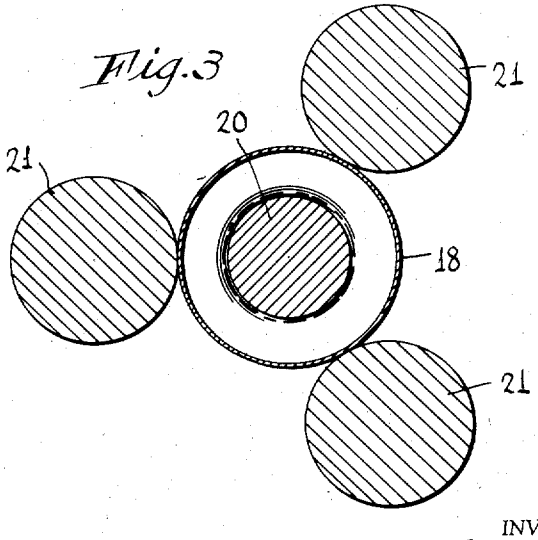


Fig. 3



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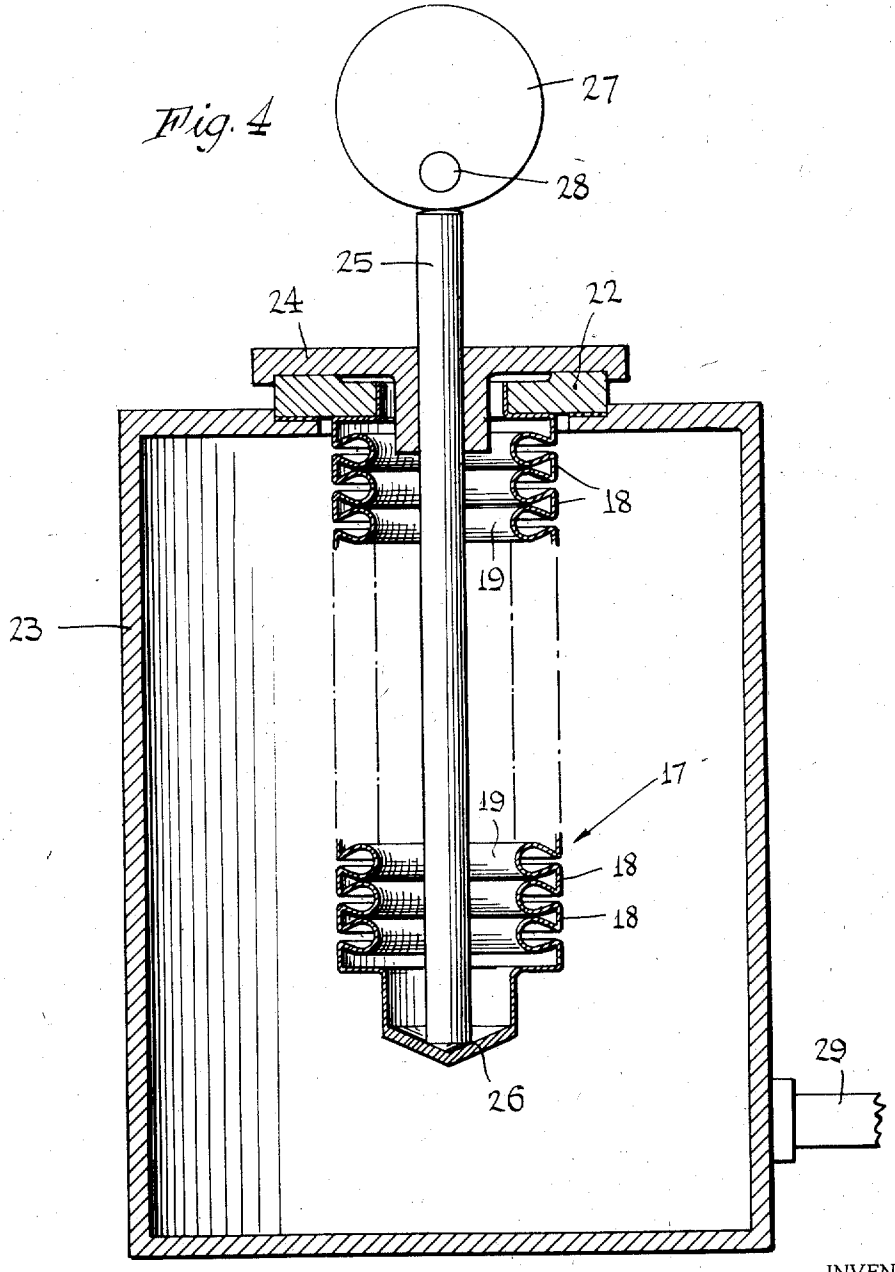
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BELLOWS

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Fig. 4



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BELLOWS

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10 Claims. (Cl. 137—796)

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This invention relates to bellows, and more particularly to metal bellows, including bellows adapted to be operated by fairly high fluid pressures in the range of fifty atmospheres or more.

Bellows of this class are commonly used in pressurized fluid systems involving control of hydraulic apparatus, fuel lines of jet aircraft engines and the like.

An object of the invention is to provide an improved metal bellows which is sensitive in its response to changes in fluid pressures and which is so organized and arranged that it can withstand pressures greatly in excess of those presently considered limiting for metal bellows of this class.

Another object of the invention is to provide an improved, sensitive metal bellows in which there is less likelihood of fatigue of the metal developing when the bellows is used with both moderate and high pressures.

Still another object of the invention is to provide an improved metal bellows as above set forth, which is simple and compact in its construction, and economical to fabricate.

A feature of the invention is the provision of an improved bellows as above set forth, in which the likelihood of permanent deformation and misadjustment of the bellows is minimized if not completely eliminated should the bellows be inadvertently subjected to over pressures above the intended operating range.

Other features and advantages will hereinafter appear.

In the accompanying drawings:

Figure 1 is an axial sectional view of a usual or conventional bellows having a wall contour characterized by reverse bends and by spaced coaxial wall sections connecting the bends, said wall sections lying generally in spaced radial planes.

Fig. 2 is a fragmentary axial sectional view of the bellows of Fig. 1 mounted on a mandrel and subjected to rollers for flattening the outer bends of the wall.

Fig. 3 is a transverse section taken on line 3—3 of Fig. 2.

Fig. 4 is a fragmentary axial view of the bellows of Fig. 3 mounted in a pressure chamber and having its radial walls bulged inward as provided by the invention to make it more sensitive and pressure-resistant.

The improved bellows and method of making the same, forming the subject matter of this invention, have particular utility in the control of fluid systems, particularly high pressure systems such as are encountered in aircraft and the like. Several such controls are illustrated and described in our copending application Serial No. 211,936, filed February 20, 1951, entitled Fluid Pressure Operated Control. The bellows used in the controls described in our aforesaid application and those which are disclosed by the instant invention are operative under variations if pressure is applied to the exterior of the bellows walls.

The method of the present invention contemplates re-

forming or working bellows having the conventional wall contour shown in Fig. 1, such bellows being at present commonly incorporated in fluid pressure operated controls and the like. The conventional bellows **10** shown in Fig. 1 is constituted all of one piece, having a closed end portion comprising a conical end wall **11** and a cylindrical wall **12** joining the wall **11** and the corrugated wall **13** of the bellows. The corrugated wall **13** comprises a plurality of spaced coaxial wall sections **14** lying in equispaced radial planes and joined together by reverse bends or outer and inner circular connector portions **15** and **16**, the bends **15** being outermost and the bends **16** innermost. The bellows **10** may be made in any suitable manner well known to those skilled in the art.

In accordance with this invention the bellows **10** is re-worked or reformed to provide an improved bellows **17**, Fig. 4, which retains the sensitivity of the bellows **10** but at the same time is adapted to withstand much greater working pressures. For example, if the working pressure of the bellows **10** is in the neighborhood of nine hundred pounds per square inch, the working pressure of the bellows **17** formed from the bellows **10** would be in the neighborhood of thirty-five hundred pounds per square inch.

It will be observed that the wall contour or section of the bellows **17** is quite different from that of the bellows **10**, since it has a plurality of spaced, narrow flat juxtaposed annular bands **18** each band constituting a section of a cylinder and being aligned and coaxial with the other bands. The bands **18** may be thought of, and are hereinafter referred to, as wall portions having a radial depth equal to the wall thickness, since obviously they constitute segments of the bellows forming narrow sections of a cylinder wherein the radial depth of each section is actually the thickness of the cylinder wall. *It will be appreciated that in a cylinder having a wall of constant thickness that the radial depth of the wall is equal to the wall thickness and hence by defining a wall thickness as being equal to a radial depth, a cylinder having a wall which is of equal thickness throughout and which, of course, is cylindrical is thereby defined. In cones, for example, the wall thickness is less than the radial thickness in view of the wall being oblique to the axis of the cone.* The corrugated wall of the bellows **17** has other annular portions **19** integral with, disposed within and connecting adjacent bands **18**, each portion **19** having a cross section which is substantially circular and extends through an arc materially greater than 180 degrees. *By being substantially circular the cross-section constitutes a smooth curve free from reversed curvatures or undulations.*

In the bellows **10** each of the inner bends **16** of the corrugated wall **13** has a circular cross section extending through an arc of only 180 degrees, which is very materially less than the arc covered by the wall portions **19** of the bellows **17**.

We have found that our improved bellows **17** shown in Fig. 4 has substantially the same sensitivity to changes in fluid pressure as the bellows **10** shown in Fig. 1, but is able to withstand pressures greatly in excess of the pressure considered the upper limit for the bellows **10**. Thus, if as above mentioned the operating pressure of the bellows **10** is under nine hundred pounds per square inch, the operating pressure for the bellows **17** may be almost four times this value or up to thirty-five hundred pounds per square inch. This increase in the fluid pressure to which the bellows **17** may be safely subjected is attributed to the shape of the wall section, incorporating the flat cylindrical wall portions **18** and the circular wall portions **19**. When the bellows **17** is subjected to external fluid pressure this pressure will be distributed in

the folds of the bellows and will result in a tensile stress being set up in the wall portions **19**. Such stress can be readily withstood by said wall portions as it is well known that resilient metal formations usually have their greatest strength in tension. When the bellows **17** shortens or elongates in response to the force of fluid pressure, the flexing accompanying said action will occur mainly in the inner wall sections **19** and will be uniform therein, and since said wall sections have a relatively great length, considering the section contour, the amount of actual flexing of any one small portion will not be materially greater than the flexing of the other portions. Accordingly there is less likelihood of fatigue of the material when the bellows is in operation, since the flexing will be well within the elastic limits of the material.

The points of small radii in the wall section, namely the junctions of the wall portions **18** and **19**, will have less bending than the large radius portions **19** due to work hardening and stiffening of the material where the small radii occur. Instead, a bending of the wall portions **18** will be effected in response to high pressures, due mainly to the stiffening of the metal where the sharp bends are. Thus these portions will bulge or bow slightly outward when the bellows contracts.

It will be noted that the outer wall portions **18**, being in alignment with each other, are enabled to touch and provide a buttressing effect which utilizes the strength of a column. This occurs prior to any permanent deformation of the bellows occurring, and accordingly the bellows is able to withstand considerable over pressures without loss of calibration or permanent deformation.

If a stop is used in conjunction with the bellows, to become operative when a determinately large pressure is experienced, the stop is preferably adjusted so that the adjacent convolutions of the bellows wall will not be brought into contact with each other, since we have found that the improved wall contour of the bellows of Fig. 4 is well able to withstand over pressures without relying on the buttressing effect above mentioned.

In following the method of the invention the bellows **10** shown in Fig. 1 may be placed on a mandrel **20** which closely fits the inside portions of the bellows wall **13**. Rollers **21** are then advanced radially against the exterior of the bellows, to cause a flattening of the outer wall portions thereof, thus forming the narrow cylindrical bands **18**. The bellows is then removed from the mandrel **20** and the open end soldered to a ring **22** which preferably constitutes the mounting for the bellows in the device of ultimate use. The ring **22** is clamped to the mouth of a container **23**, with the bellows extending into the interior of the container. This may be advantageously done by means of a circular plate **24**, said plate also constituting a bearing for a rod **25** which is extended into the bellows and engages the lowermost end wall **26** thereof. Engaging the outer end of the rod **25** is an eccentric or cam **27** carried on a shaft **28**. The container **23** has a fluid connection **29** by which fluid may be introduced into the container under pressure. Prior to the introduction of pressure in the container **23** the bellows will be elongated and the rod **25** in a position lower than that shown, the cam **27** being correspondingly rotated from the position shown. Fluid is then introduced in the container **23** under pressure and the pressure increased, meanwhile the cam **27** being slowly rotated to enable the rod **25** to raise as the bellows **17** contracts. With a proper correlation between the pressure in the container **23** and the movement of the cam **27** the circular wall portions **19** will be formed by the fluid pressure and will retain the circular shape shown after the pressure is relieved. The bellows **17** may then be removed from the container **23** and installed permanently in the device of ultimate use.

Variations and modifictions may be made within the scope of the claims and portions of the improvements may be used without others.

We claim:

1. An external overpressure resistant *metallic* bellows comprising a resilient, tubular one-piece body having walls provided with annularly-extending corrugations, said corrugated walls having outer portions comprising narrow, flat, juxtaposed, annular bands, each band constituting substantially a section of a cylinder and being aligned and coaxial with the other bands, and having other annular portions integral with, disposed inside of and connecting adjacent bands, said other portions having a cross section which is substantially circular and normally extends through an arc materially greater than 180 degrees.

2. An external overpressure resistant *metallic* bellows comprising a resilient, tubular, one-piece body having walls provided with annularly-extending corrugations, the radially outermost portions of said walls having a radial depth substantially equal to the wall thickness, and said walls having annular portions disposed inwardly of and joined to said outermost portions and characterized by a cross section which is substantially circular and extends through an arc materially greater than 180 degrees, said inwardly-disposed portions being free of reverse curvatures.

3. The invention as defined in claim 2 in which said [inwardly] *outwardly* disposed annular portions are closely juxtaposed and engageable with each other during compression of the bellows effected by an overpressure, said engagement occurring prior to the bellows becoming permanently deformed.

4. An external overpressure resistant *metallic* bellows comprising a resilient, tubular, one-piece body having annularly-extending corrugations, said corrugations including a series of juxtaposed annular walls, the walls of each of said corrugations being connected together by an inwardly-disposed, curved connector wall portion and being normally and at all times convergent in the direction of the outside of the bellows, said curved connector wall portions comprising part of said corrugations and said corrugations further including at least one flat, annular, outwardly-disposed wall portion constituting a cylindrical section, connecting together adjacent annular walls of said pairs.

5. The method of forming an overpressure resistant bellows from a bellows which has corrugated side walls having a plurality of flat, spaced, coaxial portions lying generally in equispaced radial planes and inner and outer circular connector portions connecting together said flat portions, with the outer connector portions being substantially flat and the inner portions circular, which includes the step of subjecting the exterior of said corrugated walls of the bellows to a fluid pressure greatly in excess of the working pressure of said bellows and simultaneously supporting the ends of the bellows to prevent unrestrained contraction thereof, said excess pressure being sufficient to permanently curve inward the said flat portions of the walls and cause said permanently curved portions to constitute substantially continuations of the curves of the inner circular connector portions.

6. The method of forming an overpressure resistant bellows from a conventional bellows which has corrugated side walls having a plurality of flat, spaced, coaxial portions lying generally in equispaced radial planes and inner and outer circular connector portions connecting together said flat portions, which includes the steps of rolling flat the outer circular connector portions of the bellows, and subjecting the exterior of said corrugated walls of the bellows to a fluid pressure greatly in excess of the working pressure of said conventional bellows and simultaneously movably supporting the ends of the bellows to provide controlled contraction thereof, said excess pressure being sufficient to permanently curve inward the said radial portions of the walls and cause said permanently curved portions to constitute substantially continuations of the curves of the inner circular connector portions.

7. An overpressure resistant metallic bellows comprising a resilient, tubular one-piece body having walls provided with annularly-extending corrugations, said corrugated walls having portions comprising narrow, flat, juxtaposed, annular bands, each band constituting substantially a section of a cylinder and being aligned and coaxial with the other bands, and having other annular portions integral with and connecting adjacent bands, said other portions having a cross section which is substantially circular and normally extends through an arc materially greater than 180 degrees.

8. An overpressure resistant metallic bellows comprising a resilient, tubular, one-piece body having its wall formed with annular coaxial corrugations of substantially uniform thickness throughout the length of the body, said corrugations including radially offset integrally joined inner and outer annular wall portions of substantially equal thickness, one of said annular wall portions of such corrugations being characterized by a cross-section which is substantially circular through an arc materially greater than 180 degrees and is free of reverse curvature intermediate its junctions with the other said annular wall portions of such corrugation.

9. The method of forming an overpressure resistant bellows from a bellows which has corrugated side walls having a plurality of flat, spaced, coaxial portions lying generally in equispaced radial planes and inner and outer circular connector portions connecting together said flat portions, with one of the connector portions being substantially flat and the other portions circular, which includes the step of subjecting the corrugated walls of the bellows to a fluid pressure greatly in excess of the working pressure of said bellows and simultaneously supporting the ends of the bellows to prevent unrestrained variations in length thereof, said excess pressure being sufficient to permanently curve the said flat portions of the walls and cause said permanently curved portions to constitute substantially continuations of the curves of the other circular connector portions.

10. The method of forming an overpressure resistant bellows from a conventional bellows which has corrugated side walls having a plurality of flat, spaced, coaxial portions lying generally in equispaced radial planes and inner and outer circular connector portions connecting together said flat portions, which includes the steps of rolling flat the one of said circular connector portions of the bellows, and subjecting the corrugated walls of the bellows to a fluid pressure greatly in excess of the working pressure of said conventional bellows and simultaneously movably supporting the ends of the bellows to provide controlled variations in length thereof, said excess pressure being sufficient to permanently curve the said radial portions of the walls and cause said permanently curved portions to constitute substantially continuations of the curves of the other circular connector portions.

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