United States Patent [19]

Jacobellis

[11] **3,839,945**

[45] **Oct. 8, 1974**

[54] **ROTARY ACTUATOR**

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[73] Assignee: **Greer Hydraulics, Inc.,** Los Angeles, Calif.

[22] Filed: **July 9, 1973**

[21] Appl. No.: **377,565**

Related U.S. Application Data

[62] Division of Ser. No. 250,663, May 5, 1972, Pat. No. 3,783,746.

[52] **U.S. Cl.** **92/90,** 92/121, 92/125

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

[58] **Field of Search** 92/92, 121, 125; 46/87

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Primary Examiner—Irwin C. Cohen
Assistant Examiner—Abraham Hershkovitz
Attorney, Agent, or Firm—Arthur B. Colvin

[57] **ABSTRACT**

The invention relates to a rotary actuator of the type having a movable vane positioned in an arcuate chamber and secured to and extending radially outward from a shaft extending coaxially with the axis of said arcuate chamber. The arcuate chamber forms a central part of a substantially U-shaped chamber having a pair of legs open at their outer end, each chamber receiving a deformable bladder having a closed end adapted to react against opposed ends of the vane, means being provided to permit fluid under pressure to charge said bladders to effect expansion of one of the bladders for consequent movement of said movable vane and the shaft to which it is secured with resultant compression of the other bladder.

4 Claims, 15 Drawing Figures

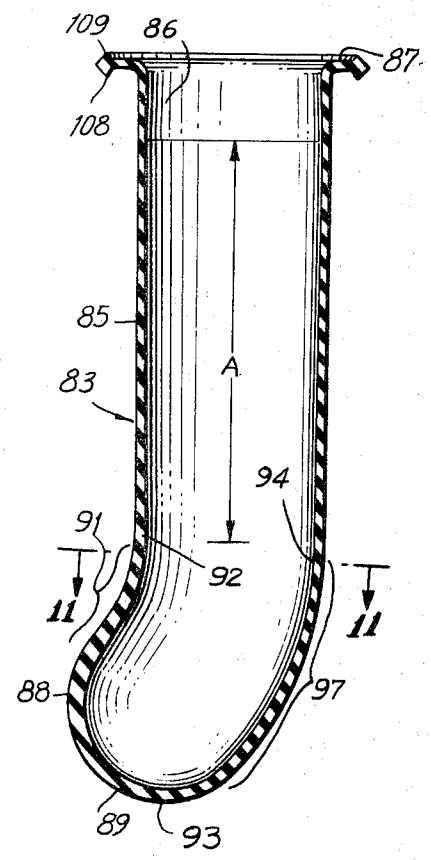


FIG. 1

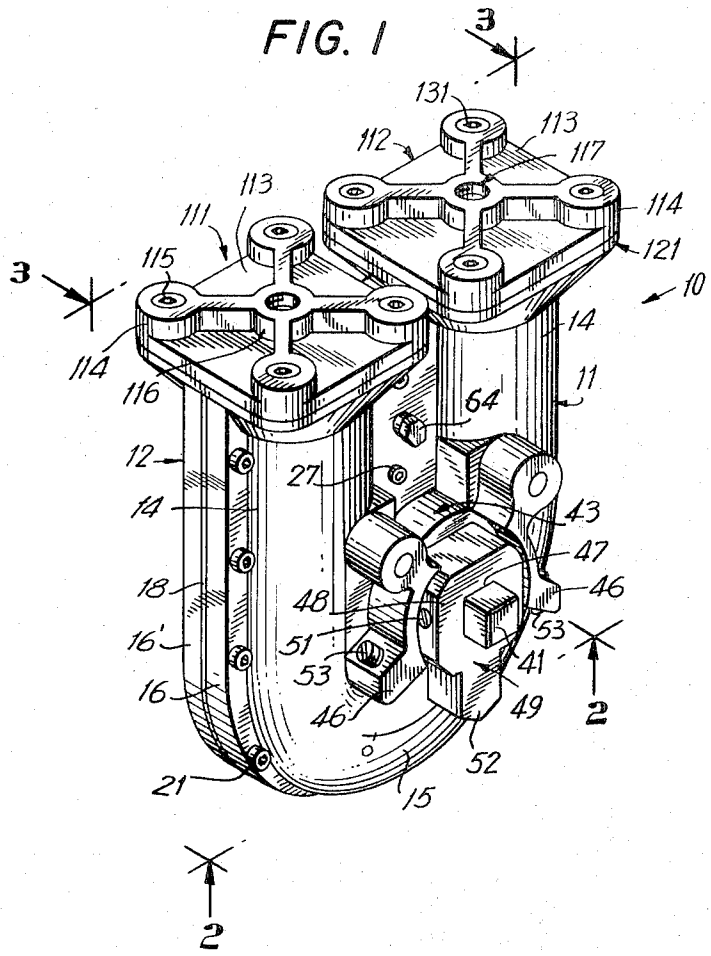

3
131
113
112
117
113
111
114
121
115
10
3
14
114
116
11
64
12
27
43
14
47
18
46
48
53
16'
51
41
53
16
46
49
2
52
21
15
2

FIG. 2

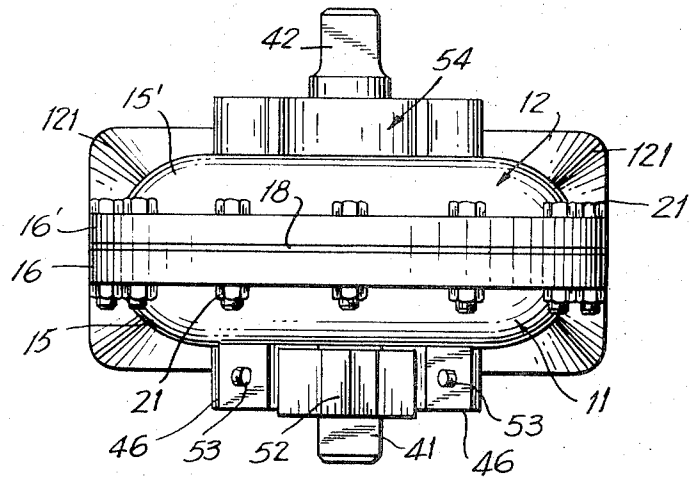

42
54
15'
12
121
121
18
21
16'
16
15
21
11
46
53
52
41
53
46

FIG. 3

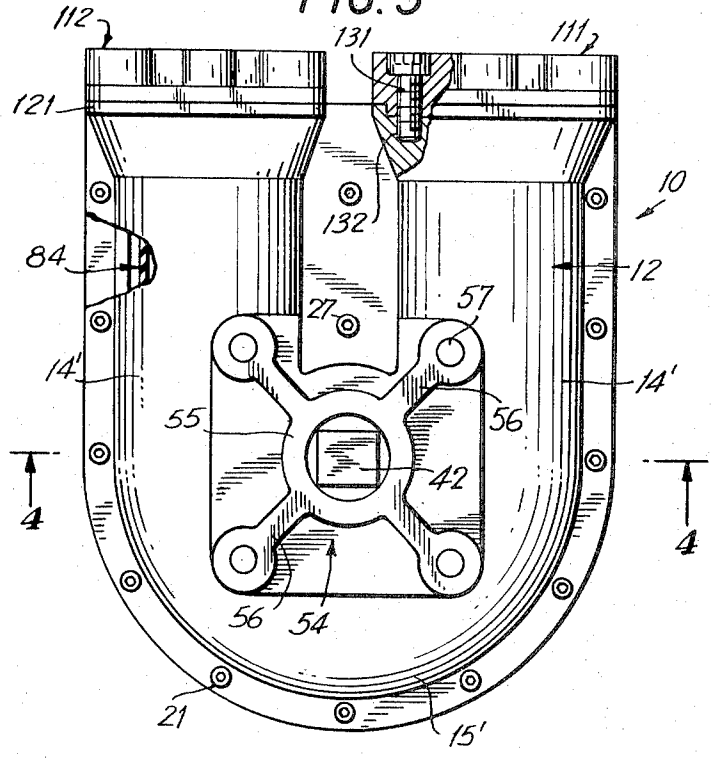

112
131
111
121
10
132
84
12
27
57
14'
14'
55
56
42
4
4
56
54
21
15'

FIG. 4

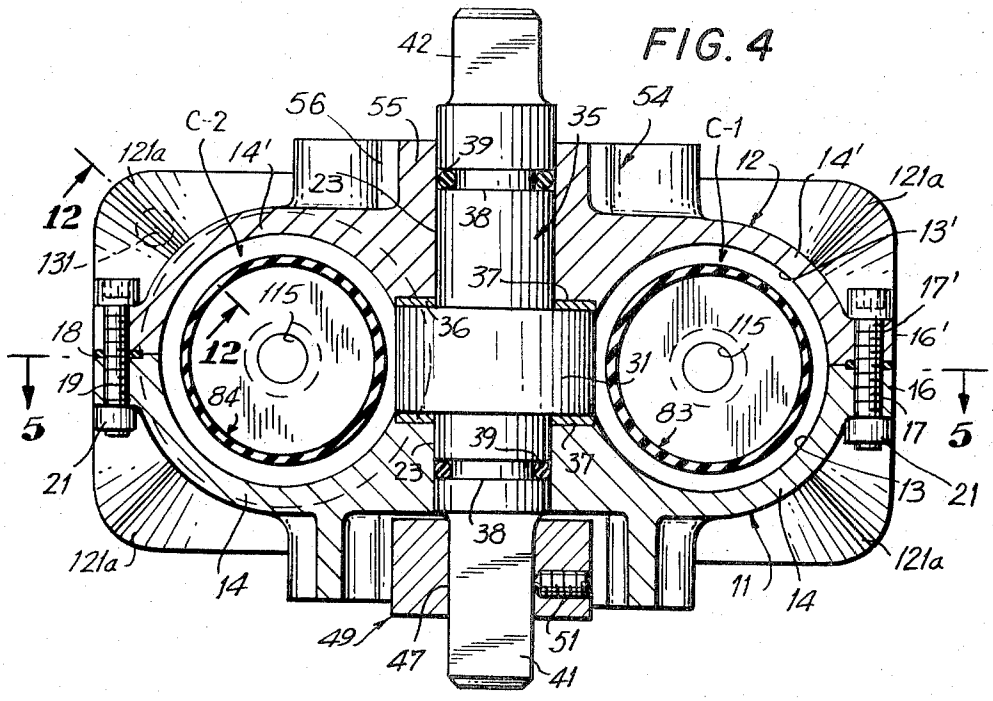

42
56
55
54
C-2
35
C-1
121a
14'
39
12
14'
121a
12
23
38
13'
131
37
17'
115
16'
18
36
115
12
31
16
19
84
83
5
5
39
17
21
23
37
13
21
38
121a
14
11
14
121a
49
47
51
41

FIG. 5

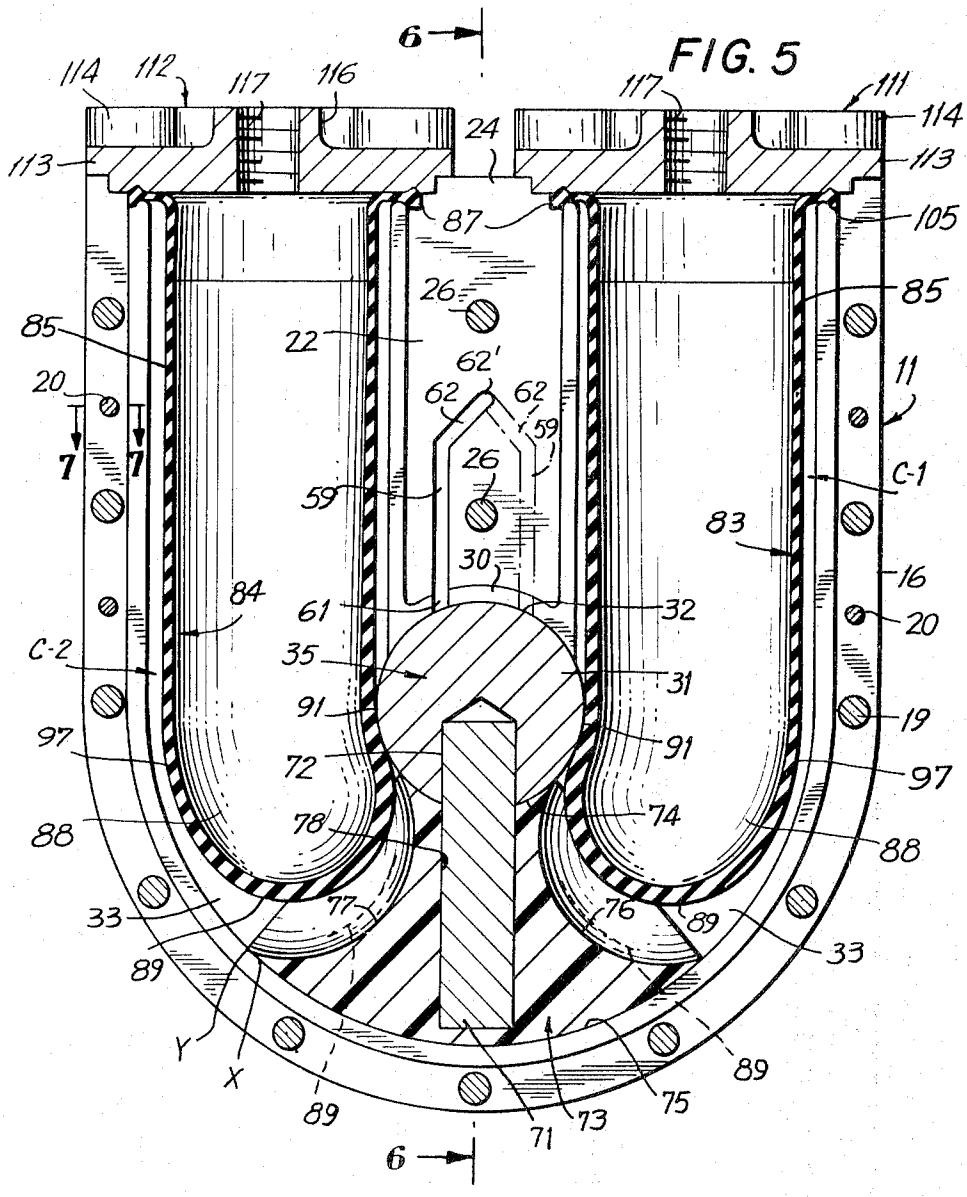
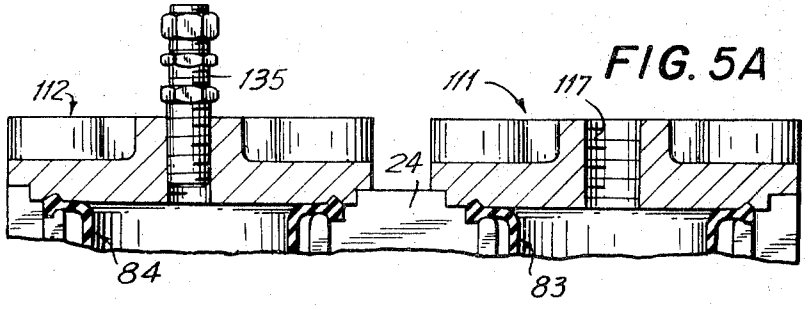

6
114
112
117
116
24
117
111
114
113
113
87
105
26
85
85
22
62'
62
62
20
11
59
7
7
26
C-1
59
83
30
16
84
61
32
20
C-2
35
31
91
19
91
97
72
97
74
78
88
88
33
77
76
89
33
89
Y
X
89
89
75
73
71
6

FIG. 5A


135
112
111
117
24
84
83

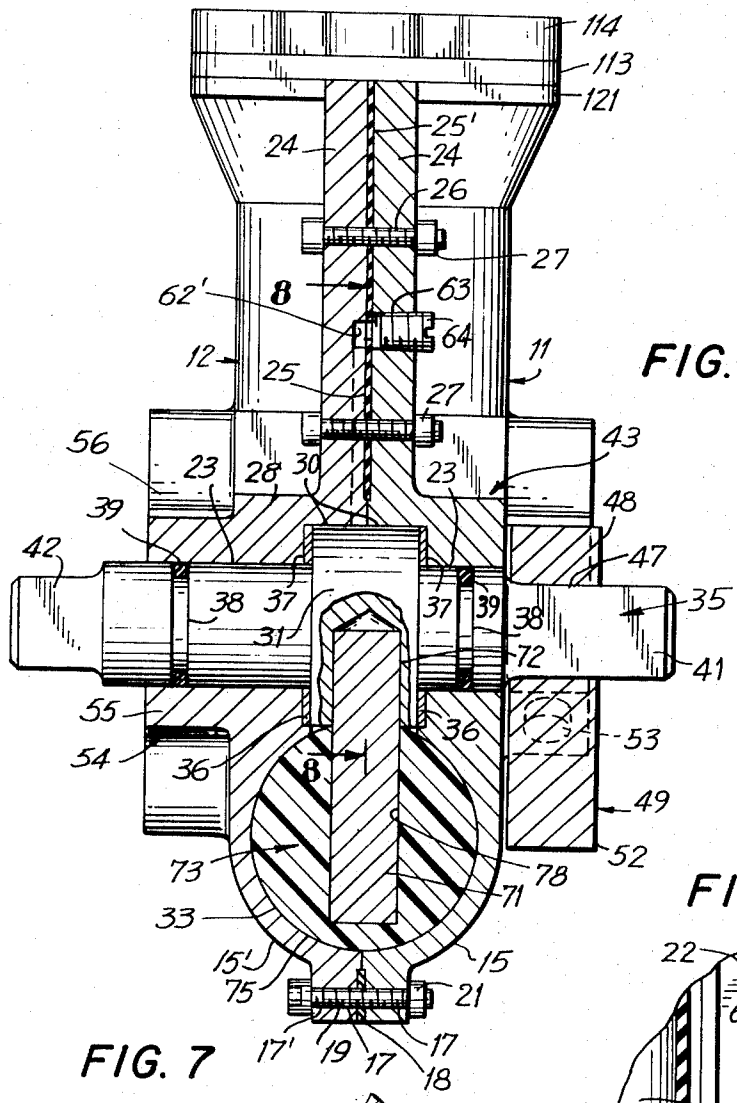


FIG. 6

FIG. 7

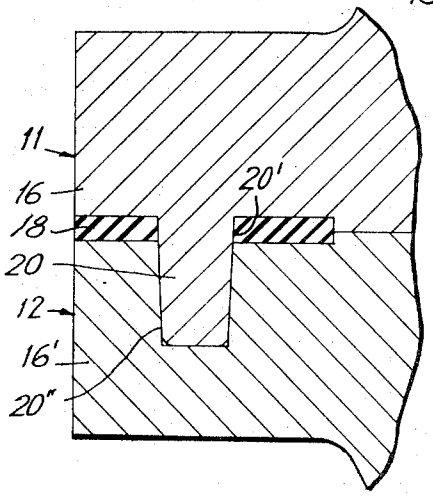


FIG. 8

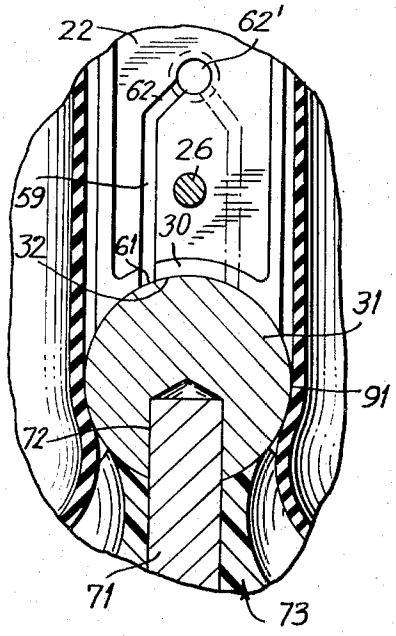


FIG. 9

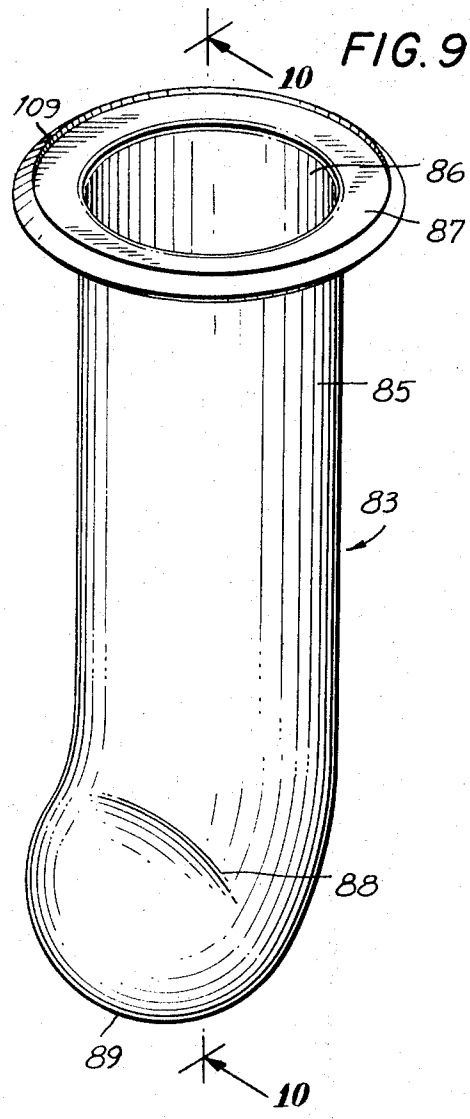


FIG. 10

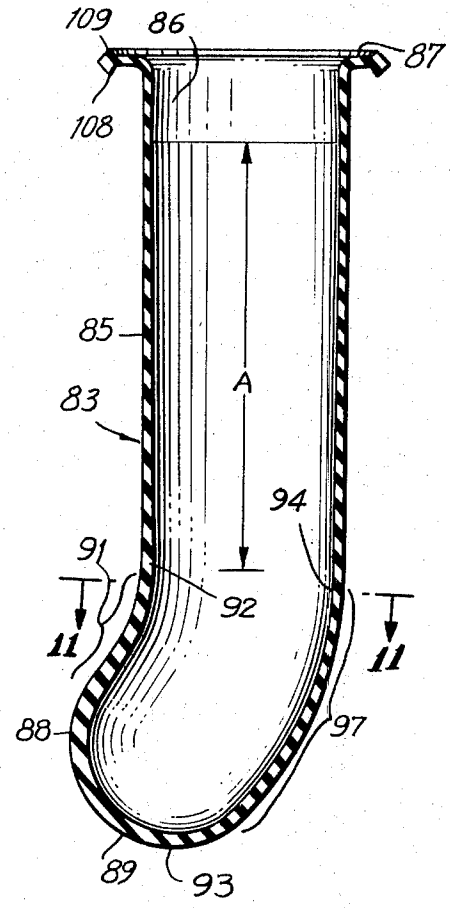


FIG. 11

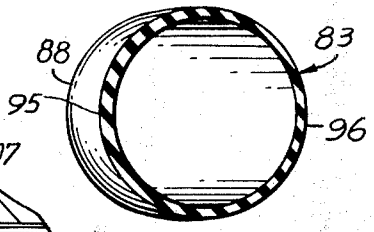


FIG. 12

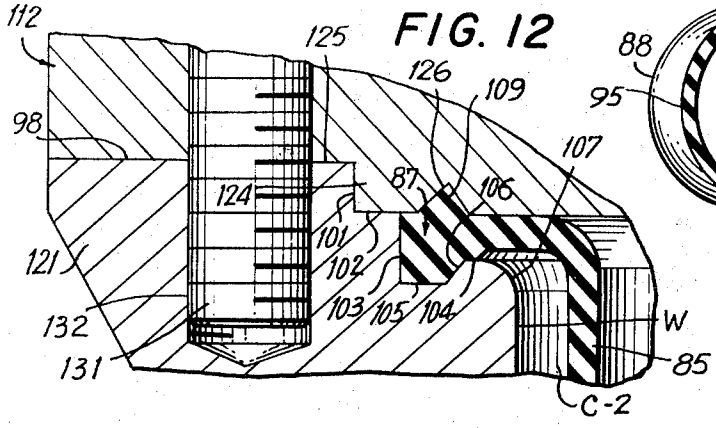


FIG. 13

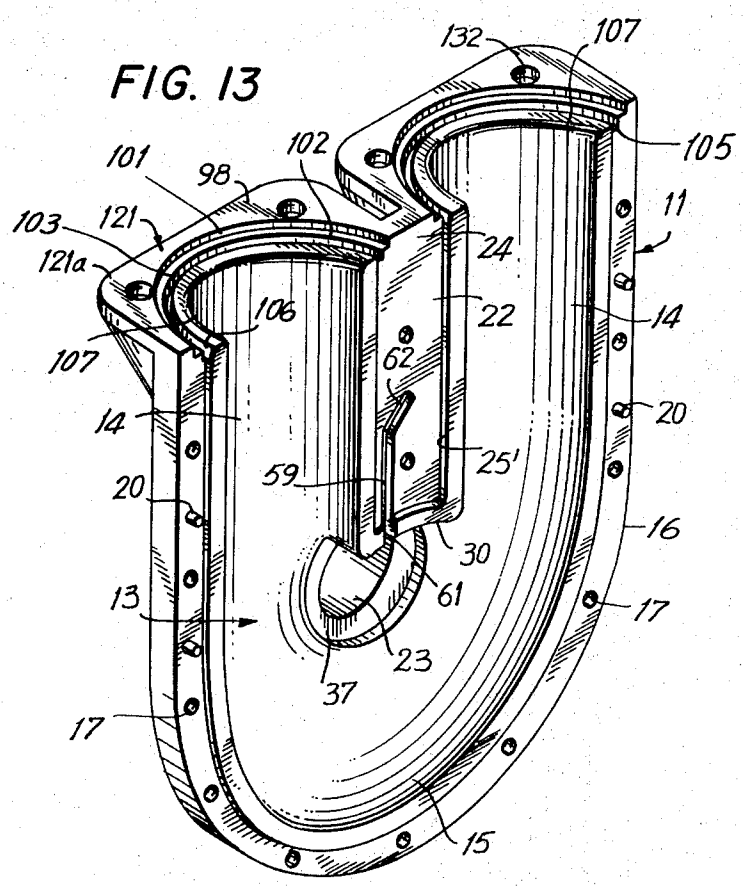
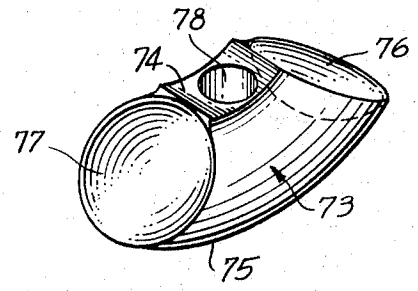

132
107
105
101
98
102
11
103
121
24
121a
106
22
14
107
62
20
14
25'
59
20
16
30
61
13
17
23
37
17
15

FIG. 14


78
74
76
77
73
75

ROTARY ACTUATOR

This application is a division of copending application Ser. No. 250,663, filed May 5, 1972 now U.S. Pat. No. 3,783,746.

AS conducive to an understanding of the invention, it is noted that where an actuator utilizes a movable vane positioned in a casing and which is connected to and extends radially from a rotary shaft and which is subjected to the force imparted by the introduction of fluid such as liquid under pressure into a cavity defined on one side of the movable vane to effect rotary movement of the vane and the shaft, by causing the fluid in a cavity defined on the other side of the vane to be expelled from said cavity, leakage of fluid between the free end of the vane and the adjacent surface of the cylinder in which the vane is rotating, results in a high degree of inefficiency of the unit.

Where, to prevent leakage, close tolerances are established between the free edges of the vane and the associated surfaces of the casing in which it is rotating, the cost of machining the edges of the vane and the surface of the casing is extremely high and at best leakage still occurs due to the requirement that sufficient clearance be provided to permit free rotation of the vane.

Where, to prevent such leakage, bladders are provided on each side of the vane so that upon expansion of one of the bladders force will be exerted against the vane to move the latter, if the majority of the force exerted by the expanding bladder is not against the vane but is applied to the side wall of the casing in which the bladder is positioned, inefficiency of operation will result.

Where bladders are used and in the event of failure it is necessary to completely disassemble theunit for replacement, the resultant "down time" may have serious consequences.

It is accordingly among the objects of the invention to provide a bladder operated rotary actuator which is relatively simple to fabricate at relatively low cost and which will positively avoid leakage from one side of the movable vane to the other without need for machining or close tolerances being maintained and which may readily be disassembled for replacement of the bladders in a minimum period of time.

According to the invention these objects are accomplished by the arrangement and combination of elements hereinafter described and more particularly recited in the claims.

In the accompanying drawings in which are shown one or more of various possible embodiments of the several features of the invention.

FIG. 1 is a perspective view of the actuator.

FIG. 2 is a bottom plan view thereof taken along line 2—2 of FIG. 1.

FIG. 3 is a rear view taken along line 3—3 of FIG. 1.

FIG. 4 is a sectional view on an enlarged scale taken along line 4—4 of FIG. 3.

FIG. 5 is a sectional view taken along line 5—5 of FIG. 4.

FIG. 5A is a sectional view with parts broken away similar to FIG. 5 of another embodiment of the invention.

FIG. 6 is a sectional view taken along line 6—6 of FIG. 5.

FIG. 7 is a fragmentary detail view on an enlarged scale taken along line 7—7 of FIG. 5.

FIG. 8 is a fragmentary detail view on an enlarged scale taken along line 8—8 of FIG. 6.

FIG. 9 is a perspective view of one of the bladders used in the actuator.

FIG. 10 is a longitudinal sectional view on a slightly smaller scale taken along line 10—10 of FIG. 9.

FIG. 11 is a transverse sectional view taken along line 11—11 of FIG. 10.

FIG. 12 is a fragmentary detail view on an enlarged scale taken along line 12—12 of FIG. 4.

FIG. 13 is a perspective view of the front section of the actuator, and

FIG. 14 is a perspective view of the movable vane of the actuator.

Referring now to the drawings, the actuator **10** comprises a housing formed from a front section **11** and a rear section **12.**

As is clearly shown, the sections **11** and **12** are similar in configuration and for simplicity, front section **11** will be described in detail with corresponding elements of rear section **12** having the same reference numerals primed.

Thus, front section **11,** referring to FIG. **13,** has a substantially U-shaped concavity **13,** the parallel legs **14** of which are1semi-circular in cross section and are oined by a cross member **15** which is arcuate both in-cross section and in plan view.

The section **11** has an outstanding flange **16** through which a series of spaced openings **17** extend. Thus, when the flanges **16, 16'** of sections **11** and **12** are placed into juxtaposition with a gasket **18** intervening, and bolts **19** are passed through the aligned openings **17, 17'** in flanges **16, 16'** and through associated openings in gasket **18,** and nuts **21** are screwed on the ends of the bolts **19** and tightened, the sections **11** and **12** will be securely retained together as shown in FIG. **4** for example with the juxtaposed semi-circular concavities **13, 13'** of sections **11, 12** defining a U-shaped housing that has two parallel chambers C–**1,** C–**2** defined by the associated pairs of juxtaposed legs **14, 14'** joined by arcuate cross members **15, 15'** all of which are substantially circular in cross section.

In order to align the front and rear sections **11** and **12,** as shown in FIGS. **5** and **7,** the flange **16** of section **11** has a plurality of outstanding pins **20** rigid therewith which extend through aligned openings **20'** in gasket **18** into associated sockets **20''** in section **12.**

As shown in FIGS. **4, 6** and **13,** each section **11** and **12** has a bore **23** therethrough, said bores being longitudinally aligned when the sections are secured together as above described.

The inner surfaces **22** of the upper central portion **24** (FIGS. **5, 6** and **13**) of each of the sections **11, 12** are in juxtaposition with a gasket **25** therebetween, the latter being positioned in a recess **25'** in such inner surface **22,** said upper portions **24** being securely retained together clamping the gasket **25** therebetween, by bolts **26** with nuts **27** screwed thereon.

The lower end **30** of each of the upper central portions **24** is arcuate as shown in FIGS. **6** and **13** and when such central portions **24** are juxtaposed, said lower ends **30** define an arcuate seat **32** for a hub **31.**

As shown in FIGS. **4** and **6,** a shaft **35** extends through the aligned bores **23** and through a hub **31,** the

latter being secured to the shaft as by pinning or being formed integrally with said shaft.

A pair of thrust washers **36** encompass shaft **35**, straddling hub **31** as shown in FIG. **4**, the washers being seated in annular recesses **37** coaxial with bores **23** (FIG. **6**).

The shaft **35** has a pair of annular grooves **38** positioned respectively on each side of hub **31** (FIG. **4**) each groove **38** mounting an "O" ring **39** to provide a rotary seal.

The ends of shaft **35** which protrude beyond sections **11, 12** are rectangular in cross section as at **41, 42.** As shown in FIG. **1**, the front section **11** has a central boss **43** formed integrally therewith, having four radiating legs, two of which, designated by the numeral **46**, defining stop legs.

Referring to FIGS. **1, 4** and **6**, the end **41** of shaft **35** extends through the rectangular bore **47** of the hub **48** of a stroke indicator and detent **49** the hub **48** being secured to end **41** by set screw **51.** Rotation of shaft **35**, in the manner hereinafter described, is limited by the abutment of the finger **52** of detent **49** against adjustable set screws **53** screwed through the stop legs **46.**

The rear section **12** as shown in FIGS. **3, 4** and **6** also has a central boss **54** formed integrally therewith, the latter having a central arcuate hub **55** through which the end **42** of shaft **35** extends and four radiating mounting legs **56** each with a threaded opening **57** to facilitate mounting of the actuator **10** to the casing of a valve (not shown), for example, which is to be operated by the actuator.

In order to lubricate the hub **31**, with respect to its seat **32**, as shown in FIGS. **5, 6, 8** and **13** for example, the inner surface **22** of each of the upper central portions **24** of sections **11** and **12** has a vertical groove **59**, the lower end **61** of each of which is in communication with the arcuate seat **32** for hub **31.**

The upper end **62** of each groove **59** is inclined and meet at **62'** so that both grooves **59** are in communication with a transverse threaded filling bore **63** extending through section **11**, said bore **63** having a removable plug **64** screwed therein.

Rigid with hub **31** and extending radially therefrom is a torque arm **71** which as illustratively shown in FIG. **6** is cylindrical in cross section and has one end positioned as by force fit into a radial bore **72** in the hub **31.**

The torque arm mounts a follower member or vane **73** which, as shown in FIGS. **6** and **14**, is a segment of a toroid and is substantially cylindrical in cross section conforming to the cross section of the arcuate cavity **33** (FIG. **6**) defined by the juxtaposed cross members **15, 15'** of the U-shaped concavities **14, 14'.**

Thus, the vane **73** is of diameter just slightly smaller than that of the arcuate cavity **33** as shown in FIG. **6** so that although the vane will move freely in said cavity **33** there will be a minimum clearance between thevane and the wall of cavity **33.**

The vane **73** when viewed in vertical cross section with respect to shaft **35**, as shown in FIG. **5**, has an arcuate inner end **74** of curvature complementary to that of hub **31** so that said inner end **74** may fit snugly against the hub.

The outer end **75** of the vane **73** (FIG. **5**) is also arcuate, of curvature complementary to that of the inner surface of arcuate cavity **33** and occupies an arc of approximately **85** degrees.

More particularly the ends **76, 77** of the toroidal segment defining the vane are cup-shaped and define reaction seats as will hereinafter be described.

Although the vane **73** could be of any suitable rigid material, in the illustrative embodiment shown it is molybdenum disulfide filled nylon and has a bore **78** extending radially with respect to the axis of the toroid and of diameter substantially the same as that of torque arm **71** which is force fitted into bore **78.**

Positioned in each of the chambers **C–1, C–2** defined by the juxtaposed sections **11, 12** on each side of the vane **73** is a bladder **83, 84** of resilient deformable material such as rubber or other material having like characteristics.

Since the bladders **83, 84** are identical, only bladder **83** will be described.

Referring to FIGS. **9** and **10**, the bladder **83** has a cylindrical body portion **85**, having an open mouth **86** with an annular flange **87** extending radially outward therefrom. The lower end portion **88** of the bladder has a rounded closed end **89** and such lower end portion **88** is bent or curved to extend arcuately with respect to the longitudinal axis of the body portion **85.** More particularly, the axis of such end portion **88** extends at substantially an obtuse angle with respect to the longitudinal axis of said body portion.

As is clearly shown in FIGS. **5, 10** and **11**, the wall of the cylindrical body portion **85** of the bladder is of substantially uniform thickness around it entire circumference from substantially the mouth of the bladder to the arcuate portion **88** as designated by the letter A.

The inner or concave side **91** of the wall of the bladder defined by the concavity of the lower portion **88** of the bladder is of progressively increasing thickness from the upper end **92** of such inner side to substantially the central portion **93** of the closed end of the bladder and then is of progressively reduced thickness until it merges with the wall of the body portion **85** as at **94.**

In addition, referring to FIG. **11**, the thickness of the wall of the arcuate portion **88** when viewed in cross section is maximum at the mid portion **95** of the concave side **91** and substantially progressively decreases along each side of said mid portion **95** of the concave side **91** from such mid portion **95** to the mid portion **96** of the opposed outer convex side **97.**

As a result of the foregoing construction of the bladder it is apparent that the wall of the closed end **89** is relatively thick so that it will withstand abrasion. Furthermore, since the wall thickness of the outer convex side **97** of the end portion **88** is less than that of the inner concave side **91**, when the bladder expands, the thinner wall of the outer side **97** will stretch at a faster rate than the thicker wall of the inner side **91** so that the closed end **89** of the lower portion **88** of the bladder will tend to move in an arcuate path against the seats defined by the cup-shaped ends **76, 77** of vane **73.**

The bladders **83, 84** are mounted in the chambers **C–1, C–2** as shown in FIG. **5** so that the arcuate lower end portions **88** of the bladder will be aligned with the portions of the arcuate cavity **33** on each side of vane **73.**

To this end, as shown in FIG. **12**, the top surface **98** of each of the parallel legs of the U-shaped housing defined by the juxtaposed substantially semi-circular concavities **13, 13'** has an annular recess **101** positioned inwardly of the outer periphery thereof defining an an-

nular shoulder 102. A second annular recess 103 is provided in said top surface, positioned inwardly of shoulder 102 and of greater depth than recess 101 and defining an annular shoulder 104 which has an annular groove 105 therein, the inner edge 106 of which is beveled outwardly as shown. The mouth 107 of each chamber C–1, C–2 defined by the juxtaposed concavities 13, 13′ is rounded as shown.

The flange 87 of each bladder has a thickened outer periphery, the lower surface of which is triangular in cross section as at 108 as shown in FIG. 10, with the apex of the triangle directed downwardly. The upper surface of the thickened outer periphery is also triangular in cross section as at 109 with the apex of the triangle directed upwardly.

A bladder 83, 84 is positioned in each of the chambers C–1, C–2 as shown in FIG. 5 with the inner or concave side 91 of each of the bladders positioned adjacent the inner side of each chamber so that the arcuate bottom or end portion 88 of each bladder will be aligned with the arcuate cavity 33 of the U-shaped chamber. The flange 87 is positioned so that the triangular lower surface 108 thereof is positioned in annular groove 105 as shown in FIG. 12.

Means are provided to clamp the flanges 87 of each of the bladders against the top surface 98 of each chamber. Thus, a pair of identical cap plates 111, 112 are provided. Referring to FIG. 1 for example, each cap plate has a base 113 which is substantially square in plan and has four bosses 114 rising from each corner thereof, each having a bore 115 therethrough. In addition, the base 113 has a central hub 116 which has a threaded bore 117 therethrough.

The square base 113 is of dimension corresponding to the dimension of a flange 121 extending outwardly from the mouth 107 of each chamber C–1, C–2, the top surface of said flanges 121 defining the top surface 98 above referred to. More particularly the rectangular flange 121 is formed by the juxtaposition of the two half flanges 121*a* shown in FIG. 13.

The underface of each base 113 (FIG. 12) has a cylindrical hub 124 depending therefrom defining an annular shoulder 125 which seats on top surface 98 when the cylindrical hub 124 is positioned in annular recess 101 with the periphery of the hub 124 seated on shoulder 102. The undersurface of hub 124 adjacent the periphery thereof has an annular groove 126 in the form of an inverted triangle, to accommodate the upper triangular portion 109 of flange 87.

The thickness of the periphery of the flange 87 is greater than the distance between the aligned recess 105 and groove 126, so that when the cap 112 for example, is in seated position as shown in FIG. 12, the periphery of the flange 87 will be conpressed to fill the region between annular recess 105 and groove 126, the body portion 85 of each bladder being spaced inwardly from the wall W of each chamber C–1, C–2.

To clamp the caps 111, 112 against flanges 121, a screw 131 is passed through each of the openings 115 in bosses 114, into an associated aligned threaded opening 132 in flange 121 as shown in FIG. 12.

The actuator above described may be utilized to operate a three way valve for example, which has a neutral position and two operating positions on each side of the neutral position.

The actuator may be secured to the casing of the valve by securing the hub 54 to a mounting plate on the valve by means of screws (not shown) extending into the threaded openings 57. When so mounted, the end 42 of shaft 35 would be coupled to the shaft of the valve.

When the vane 73 is in the position shown in FIG. 5, the valve will be in its neutral position. Assuming that both of the bladders 83, 84 are fully charged with a fluid such as oil through the ports 117 of caps 111, 112 so that the bladders are expanded and stretched and completely fill the associated chambers C–1, C–2.

Under such fully charged condition of the bladders the closed ends 89 thereof will have moved against the cup-shaped seats 76, 77 of the vane 73 as shown in broken lines in FIG. 5.

The acutator is now ready for operation. Assuming that it is desired to rotate the shaft 35 in a counterclockwise direction from the neutral position shown in FIG. 5, a source of oil under pressure is applied to the port 117 of cap 112 and the port 117 of cap 111 is connected to a reservoir.

As the fluid under pressure enters port 117, the fully charged bladder 84 will stretch and expand. Since the bladder 84 is already engaging the wall of the chamber C–2 and the cup-shaped seat 77, the only portion of the force exerted by the expanding bladder that will have any effect will be that exerted by the end 89 thereof against seat 77 of vane 73. Consequently, such force will tend to cause the vane 73 and shaft 35 to rotate in a counterclockwise direction, the oil in bladder 83 being expelled from port 117 of cap 111 to the reservoir. As a result, the three way valve (not shown) controlled by shaft 35 will be moved from neutral position to an operating position. To either close the three way valve or more it to its other operating position, it is merely necessary to connect the source of fluid under pressure to port 117 of cap 111 and to connect the port 117 of cap 112 to the reservoir and reverse the operation previously described.

As above noted, since the thickness of the wall of cylindrical body portion 85 of the bladders is uniform, such body portion 85 will stretch or elongage and contract in a direction parallel to the longitudinal axis of the body portion 85.

As the wall thickness of the outer or convex side 97 of the end portion 88 of the bladder is less than that of the inner or concave side 91 thereof, the expansion of the bladder at the end portion 88 thereof will cause such end portion 88 to move in an arcuate path, i.e., the outer side 97 will stretch at a greater rate than the inner side 91.

As a result, the closed end 89 of the shoulder 84 will remain substantially centered on its seat 77 so that a substantial force will be exerted against the vane 73 to effect rotation of shaft 35 with consequent application of relatively great torque from shaft 35 to the valve being operated.

In the absence of the unique bladder above described, if the expansion of the bladder along its length was solely in a direction parallel to the longitudinal axis of the bladder, the majority of force exerted by the closed end 89 of the bladder would be against the wall of the chamber C–2 approximately at "X" (FIG. 5) rather than against the vane 73, with resultant inefficiency of the device.

Furthermore, due to such substantial force being exerted by the end 89 of the bladder both against the wall of the chamber as at "X" and the adjacent edge "Y"

of the vane, it would tend to restrain movement of the vane 73 further reducing the efficiency of the device.

By reason of the fact that the bladders 83, 84 form completely sealed chambers, in which the fluid under pressure is received, leakage of fluid past the movable vane 73 is completely eliminated and there is no need for precision machining of the interior of the housing or the portions of the vane 73 adjacent thereto.

In the event that after long use, the bladders must be replaced, this is readily accomplished by merely removing the caps 111, 112 and the old bladders and positioning a new set of bladders in the chambers C–1, C–2 and replacing the caps.

If for any reason it is necessary to completely disassemble the actuator, this may readily be accompished by merely removing the end caps 111, 112 and then relasing the nuts 21 on bolts 19.

In the embodiment above described, the bladders 83, 84 are both precharged with oil. However, it is within the scope of the invention to use a fluid such as gas under pressure to effect actuation of the vane, or as shown in the embodiment of FIG. 5A to have one of the1bladders, i.e., bladder 84, precharged with gas under pressure through valve 135 which is then retained closed and have oil under pressure forced into the port 117 of cap 111.

To ready the embodiment of the actuator shown in FIG. 5A for operation, the bladder 84 is precharged with gas under pressure and the bladder 83 with oil under presure so that the vane 73 will be set to the neutral position shown in FIG. 5.

To rotate the shaft 35 in a counterclockwise direction from the position shown in FIG. 5, where the bladder 84 is charged with gas under pressure, it is merely necessary to open a valve connecting port 117 of cap 111 to reservoir. As a result, the bladder 83 will expand and the end 89 thereof will move in an arcuate path reacting against seat 77 of vane 73. To rotate the shaft 35 in a clockwise direction from the position shown in FIG. 5, where the bladder 84 is charged with gas under pressure, it is merely necessary to connect port 117 of cap 111 to a source of oil under pressure greater than that in bladder 84. As a result, the end 89 of bladder 83 will move in an arcuate path reacting against seat 76 of vane 73 to rotate shaft 35 and the bladder 84 will be compressed by movement of seat 77 of vane 73 against end 89 of bladder 84 and end 89 will retract in an arcuate path.

It is apparent that the gas filled bladder 84 will act as a spring which will extend and retract depending upon conditions of operation.

It is further apparent with the constructions above described that by reason of the fact that the fluid used to react against the vane is wholly contained in the bladders, no contamination of the interior of the unit will occur so that corrosion of the side wall of the casing will be eliminated and in addition impurities in the oil used to charge the bladders will not clog the shaft of the actuator.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. An inflatable bladder for a rotary actuator, said bladder having a substantially cylindrical inflatable body portion with an open end mounting flange portion and an end portion having a closed end, said end portion in its uninflated state being preformed so that its axis extends at substantially an obtuse angle with respect to the longitudinal axis of said body portion, so that the outside walls on the opposite sides of said end portion are concave and convex respectively and the outside wall of the closed end thereof being convex, the wall thickness of the cylindrical body portion being substantially uniform along its entire length and the wall thickness of the convex side wall and closed end being less than that of the concave side wall; whereupon when said bladder is pressurized the thinner wall will stretch at a faster rate than the thicker wall so that the closed end of the bladder will tend to move in an arcuate path.

2. The combination set forth in claim 1 in which, the wall thickness is maximum at the mid portion of the concave side and substantially progressively decreases along each side of said mid portion of the concave side from such mid portion to the mid portion of the convex side.

3. The combination set forth in claim 1 in which the closed end of the bladder is rounded.

4. As an article of manufacture an inflatable bladder for a rotary actuator having a substantially cylindrical inflatable body portion with an open mouth and a radially extending annular mounting flange and an end portion having a closed rounded end, said end portion in its uninflated state being preformed so that its axis extends at substantially an obtuse angle with respect to the longitudinal axis of said body portion so that the outside walls on the opposite sides of said end portion are concave and convex respectively, the wall thickness of the cylindrical body portion being substantially uniform along its entire length, the wall thickness of the convex side wall being less tha that of the concave side wall, the wall thickness being maximum at a point approximately mid-way of the length of the end portion on the concave side and progressively decreasing circumferentially along each side of the midway point to a point approximately midway of the length of the end portion on the convex side, whereupon when said bladder is pressurized the thinner wall will stretch at a faster rate than the thicker wall so that the closed end of the bladder will tend to move in an arcuate path.

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