

[54] **ROTARY ACTUATOR**

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

[51] Int. Cl. **F01c 9/00**

[58] Field of Search..... **92/121, 92**

[56] **References Cited**

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[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.

20 Claims, 15 Drawing Figures

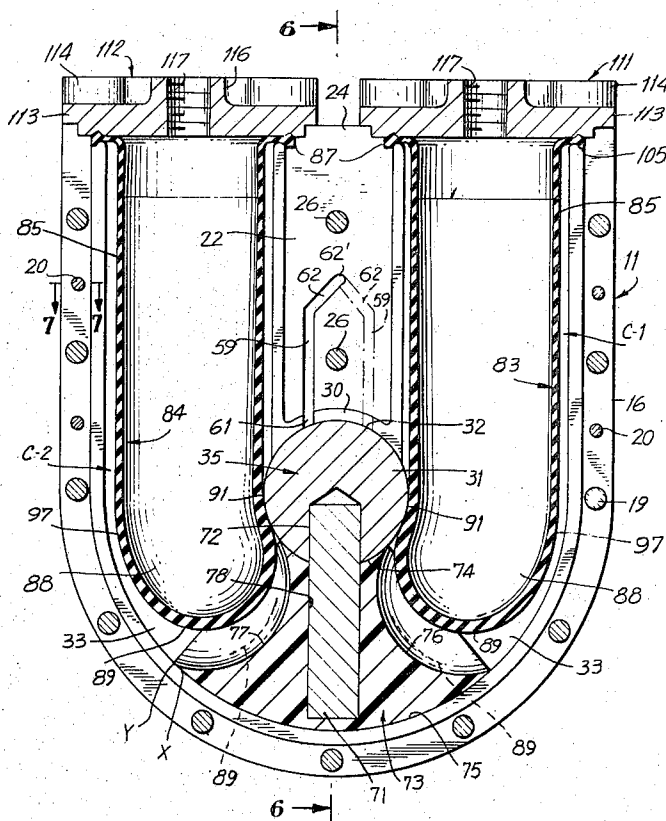


FIG. 3

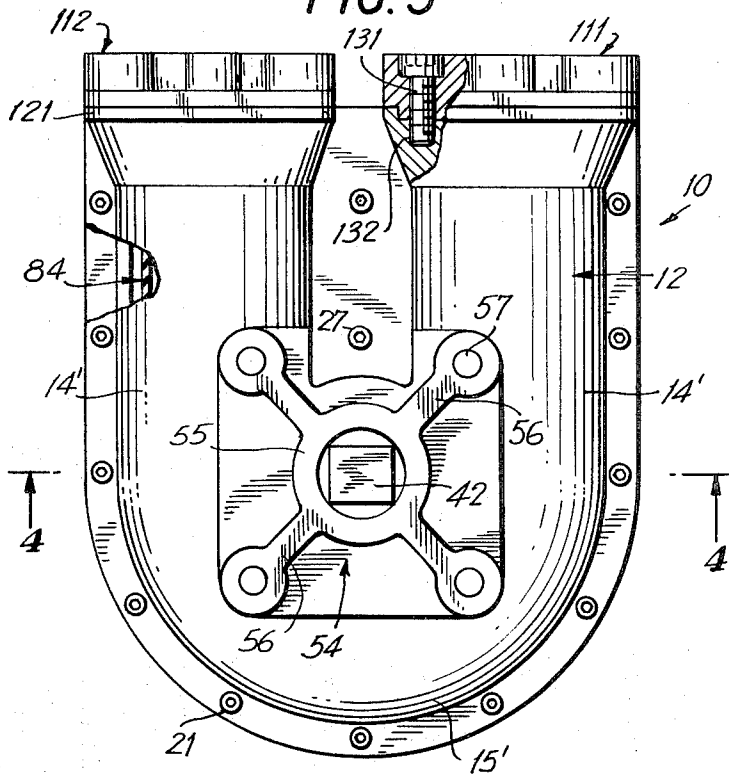
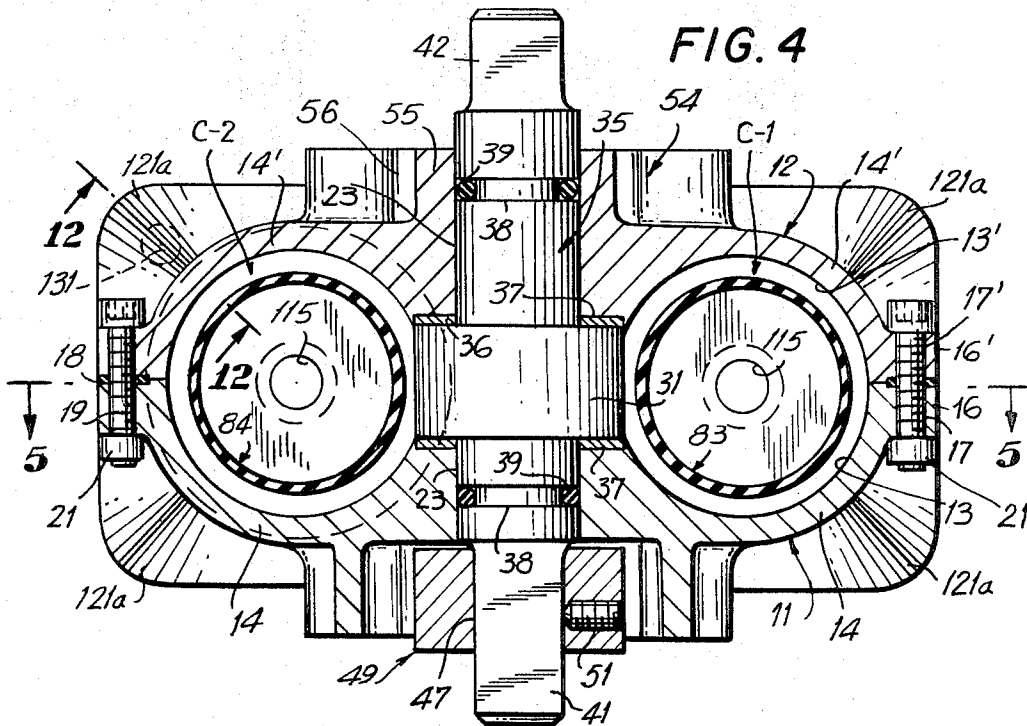


FIG. 4



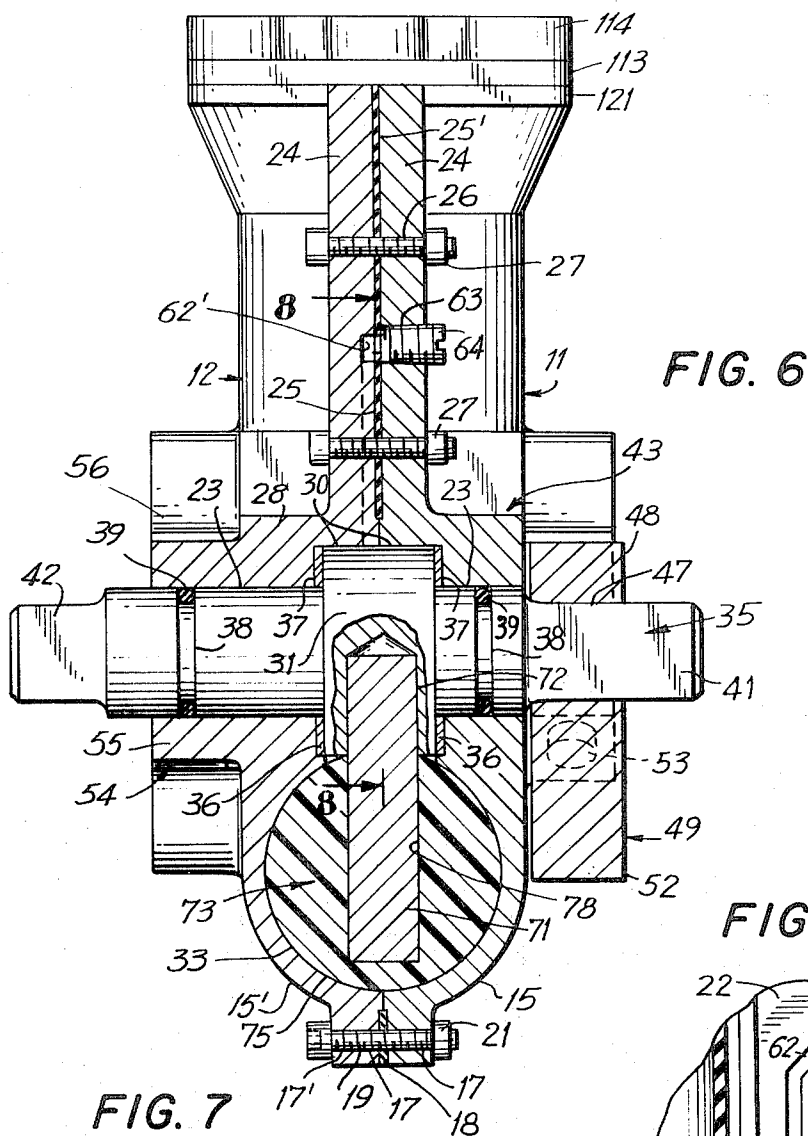
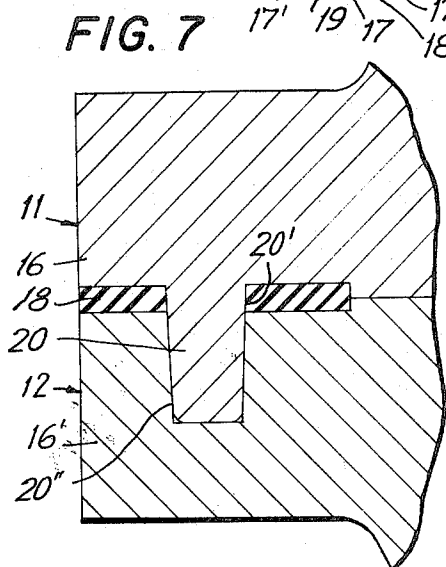
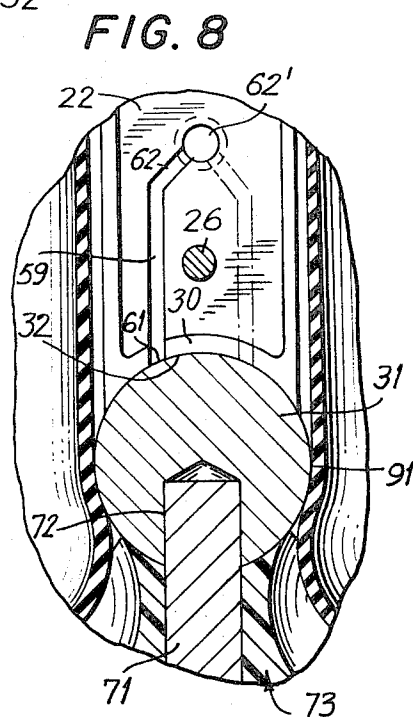


FIG. 13

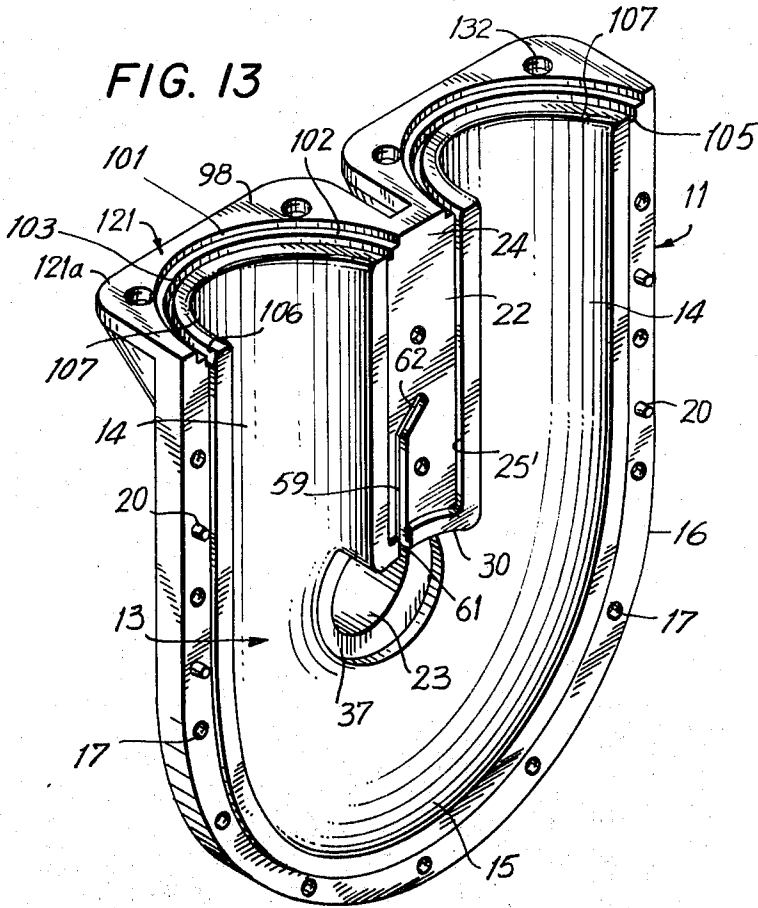
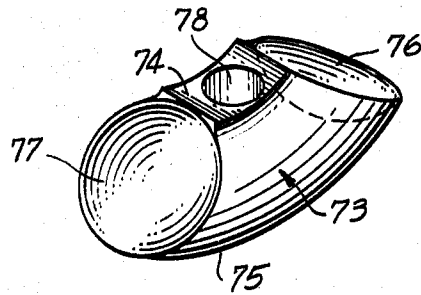


FIG. 14



ROTARY ACTUATOR

This application is a continuation-in-part of copending application Ser. No. 120,656, filed May 3, 1971, now U.S. Pat. No. 3,680,982.

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 the unit 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 are semi-circular in cross section and are joined 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 the vane 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°.

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 its entire circumference from substantially the mouth of the bladder to the arcuate portion 88 is 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, positined 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 121a shown in FIG. 13.

The undersurface 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 compressed 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 actuator 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 cup 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 move 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 bladder 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 accomplished by merely removing the end caps 111, 112 and then releasing 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 the bladders, 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 pressure 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. A rotary actuator comprising a casing having a substantially U-shaped cavity therein, the mid-portion of said U-shaped cavity being substantially arcuate, said U-shaped cavity having a pair of legs positioned respectively on each side of said arcuate portion of said

U-shaped cavity and in substantially the same plane, each of said legs being open at its outer end, and defining chambers substantially circular in cross section, a shaft extending through said casing coaxial with the axis of said arcuate portion, a vane movably mounted in said arcuate portion defining a chamber on each side of said vane, said chambers forming part of the chambers defined by said legs, said vane being operatively connected to said shaft and extending radially therefrom, a pair of bladders positioned respectively in said chambers, each of said bladders having an end portion with a closed end associated respectively with opposed surfaces of said vane, each of said bladders being conformed to effect movement of each of said end portions thereof in an arcuate path in said arcuate portion of said U-shaped cavity, for reaction of the closed end of the bladders against the opposed surfaces of said vane, means to close the open end of each of said chambers defined by said legs and to secure the end of said bladder adjacent thereto in fixed position and means selectively to charge each of said bladders, thereby to effect rotation of said shaft when the associated bladder is charged with fluid under pressure.

2. A rotary actuator comprising a casing having a substantially arcuate cavity therein, a shaft extending through said casing coaxial with the axis of said arcuate cavity, a vane in the form of a segment of a toroid, having the ends of the segment defining reaction seats, said vane being movably mounted in said cavity defining a chamber on each side of said vane, said vane being operatively connected to said shaft and extending radially therefrom, a pair of bladders positioned respectively in said chambers, each of said bladders having an end portion with a closed end associated respectively with the reaction seats defined by the opposed end surfaces of said vane, each of said bladders being conformed to effect movement of each of said end portions thereof in an arcuate path in said arcuate cavity, for abutment of the closed end of the bladders against said reaction seats defined by the opposed surfaces of said vane to effect rotation of said shaft when the associated bladder is charged with fluid under pressure.

3. The combination set forth in claim 2 in which the reaction seat defined by each of the ends of said segment is in the form of a cup-shaped recess.

4. The combination set forth in claim 2 in which the segment of a toroid defining said vane is substantially circular in cross section, said arcuate cavity is substantially circular in cross section, the end surfaces of said vane extend substantially radially with respect to the axis of said toroid.

5. A rotary actuator comprising a casing having a substantially arcuate cavity therein, a shaft extending through said casing coaxial with the axis of said arcuate cavity, a vane movably mounted in said cavity defining a chamber on each side of said vane, said vane being operatively connected to said shaft and extending radially therefrom, said casing having a pair of parallel chambers therein, each substantially circular in cross section having an open outer end and an open inner end, said inner ends being in communication respectively with the ends of the chambers defined by said vane in said arcuate cavity, whereby said parallel chambers and the chambers in said arcuate cavity define a substantially U-shaped chamber extending in a plane perpendicular to the axis of said shaft, a pair of bladders positioned respectively in said chambers, each of

said bladders having a body portion positioned respectively in one of said pair of parallel chambers, each of said bladders having an end portion with a closed end extending respectively into the ends of said arcuate cavity and associated respectively with opposed surfaces of said vane, each of said bladders being conformed to effect movement of each of said end portions thereof in an arcuate path in said arcuate cavity, for reaction of the closed end of the bladders against the opposed surfaces of said vane, means retaining the end of each of the bladders remote from the closed end thereof in fixed position in each of said pair of chambers and means selectively to charge each of said bladders with fluid under pressure, to effect rotation of said shaft when the associated bladder is charged.

6. The combination set forth in claim 5 in which means are provided to close the open outer ends of each of said chambers.

7. The combination set forth in claim 5 in which each of said bladders has a mouth remote from the closed end thereof, each mouth having a radially extending annular flange, and means closing the open outer end of each of said chambers and clamping the flange of each of said bladders in a fixed position.

8. The combination set forth in claim 5 in which each of said bladders has a mouth remote from the closed end thereof, each mouth having a radially extending annular flange, a cap associated with each of the open outer ends of each chamber, means to secure said caps in fixed position and to clamp the flange of an associated bladder against said outer end, each of said caps having a port to which a source of fluid under pressure may be connected.

9. The combination set forth in claim 8 in which one of said ports has a fitting to which a source of liquid under pressure may be connected and the other of said ports has a fitting to which a source of gas under pressure may be connected.

10. The combination set forth in claim 5 in which the body portion of each of said bladders is substantially cylindrical and is positioned respectively in each of said pair of parallel chambers substantially coaxial with the longitudinal axis thereof, each of the end portions of said bladders being bent inwardly with respect to the longitudinal axis of the body portion in a plane parallel to the plane of said U-shaped chamber, with the axis of each end portion being substantially aligned with the axis of the arcuate cavity, the wall thickness of at least the major portion of the body portion being substantially uniform and the wall thickness of the end portion being greater at its inner side than its outer side, whereby when said bladders are charged with fluid under pressure, the body portion will elongate in direction substantially parallel to the longitudinal axis of the body portion and the end portion will elongate in an arcuate path, the outer side of the end portion stretching at a faster rate than the inner side.

11. A rotary actuator comprising a casing having a substantially arcuate cavity therein, a shaft extending through said casing coaxial with the axis of said arcuate cavity, said cavity having a bore through which said shaft extends, an arcuate seat is provided in said casing coaxial with the axis of said shaft, said shaft has a coaxial hub rigid therewith, the ends of said shaft extending in opposed directions from said hub, the latter resting on said seat, a vane in the form of a segment of a toroid having its axis coaxial with said shaft, said vane being

movably mounted in said cavity defining a chamber on each side of said vane, said vane being operatively connected to said shaft and extending radially therefrom, a pair of bladders positioned respectively in said chambers, each of said bladders having an end portion with a closed end associated respectively with opposed surfaces of said vane, each of said bladders being conformed to effect movement of each of said end portions thereof in an arcuate path in said arcuate cavity, for reaction of the closed end of the bladders against the opposed surfaces of said vane to effect rotation of said shaft when the associated bladder is charged with fluid under pressure.

12. The combination set forth in claim 11 in which the inner periphery of said vane has an arcuate surface of curvature complementary to that of the peripheral surface of the hub, said two surfaces being juxtaposed and means securely to retain said vane in fixed position with respect to said hub.

13. The combination set forth in claim 11 in which the hub and the arcuate surface of the vane each has an aligned radial bore and a pin secured by force fit in said bores securely retains the vane in fixed position with respect to said hub.

14. A rotary actuator comprising a casing comprising two substantially identical sections defining a front and rear section, each of said sections having a pair of parallel cavities and an arcuate cross member each substantially semicircular in cross section, said pair of parallel cavities and the associated arcuate cavity defining a substantially U-shaped cavity, each of said sections having an outwardly extending perimeter flange and an abutment section between the pair of parallel cavities, said sections when juxtaposed defining a substantially U-shaped chamber substantially circular in cross section, with an arcuate cavity being defined by the juxtaposed cross members, a gasket interposed between the juxtaposed perimeter flanges, and an additional gasket interposed between said abutment sections, means clamping said sections together, the lower ends of said abutment sections being arcuate and defining a seat, a bore coaxial with the arcuate cavity defined by said arcuate cross members extending through said front and rear sections and aligned with said seat, a shaft extending through said bores coaxial with the axis of said arcuate cavity and having a portion resting on said seat, a vane movably mounted in said arcuate cavity defining a chamber on each side of said vane, said vane being operatively connected to said shaft and extending radially therefrom, a pair of bladders positioned respectively in said chambers, each of said bladders having an end portion with a closed end associated respectively with opposed surfaces of said vane, each of said bladders being conformed to effect movement of each of said end portions thereof in an arcuate path in said arcuate cavity, for reaction of the closed end of the bladders against the opposed surfaces of said vane to effect rotation of said shaft when the associated bladder is charged with fluid under pressure.

15. The combination set forth in claim 14 in which each of the inner surfaces of said bore extending through said front and rear sections has an annular recess coaxial with said bore, said shaft has an enlarged diameter hub between its ends resting on said arcuate seat, a pair of thrust washers encompass said shaft and straddle said hub, said washers being seated respectively in said annular recesses.

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16. The combination set forth in claim 14 in which complementary pins and recesses are provided in said perimeter flanges to align said front and rear sections when they are juxtaposed.

17. The combination set forth in claim 14 in which said abutment sections each has a recess therein and the additional gasket is positioned in said recess.

18. The combination set forth in claim 14 in which one end of said shaft protrudes beyond the outer surface of an associated plate, a hub is secured to said protruding end of said shaft, said hub having a radially extending stop finger and abutment means positioned on the other surface of said plate to limit the arcuate movement of said stop finger and said shaft.

19. A rotary actuator comprising a casing having a substantially U-shaped cavity therein, said U-shaped cavity having a pair of legs and an arcuate cross member connecting one end of each of said legs, each of said legs being open at its other end, said arcuate cavity being substantially circular in cross section and said legs defining cylindrical chambers substantially circular in cross section, a shaft extending through said casing coaxial with the axis of said arcuate cross member, a

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vane movably mounted in the chamber defined by said arcuate cross member, said vane being operatively connected to said shaft and extending radially therefrom, a pair of bladders positioned respectively in the cylindrical chambers defined by each of said legs, each of said bladders having an end portion with a closed end associated respectively with opposed surfaces of said vane for reaction of the closed ends of the bladders against the opposed surfaces of said vane to effect rotation of said shaft when the associated bladder is charged with fluid under pressure.

20. The combination set forth in claim 19 in which each of said bladders has a mouth remote from the closed end thereof, each mouth having a radially extending annular flange, a cap associated with each of the open outer ends of each of the chambers defined by said legs, means to secure said caps in fixed position and to clamp the flange of an associated bladder against said outer end, each of said caps having a port to which a source of fluid under pressure may be connected.

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