March 6, 1962 B. E. O'CONNOR 3,023,741

SEALED ROTARY ACTUATOR

Filed April 29, 1960

Fig. 1

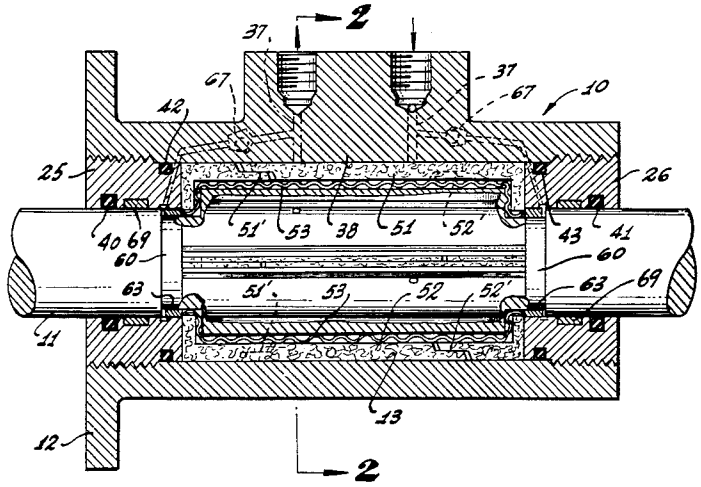


Fig. 2

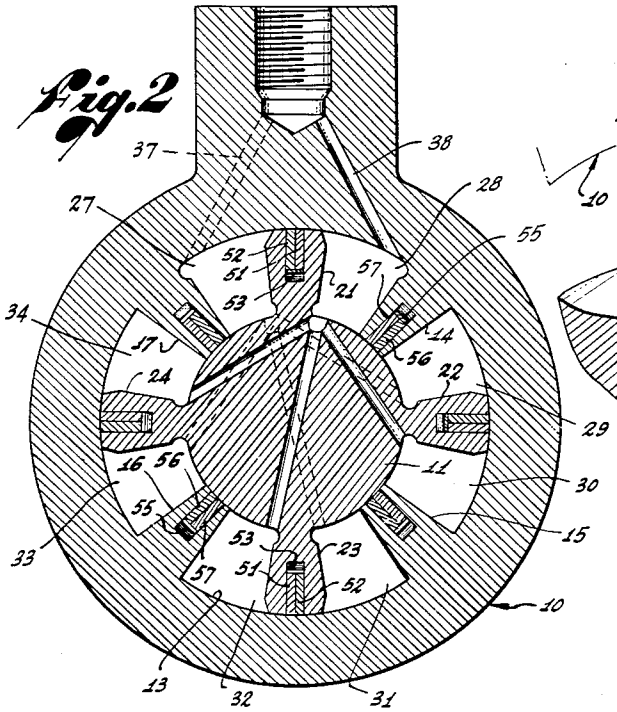


Fig. 3

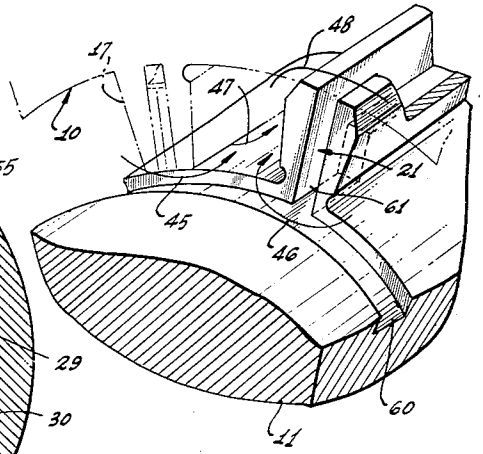
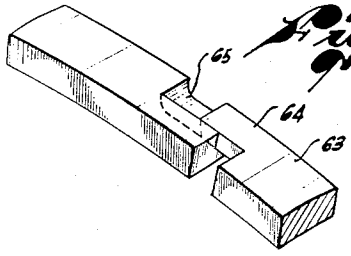


Fig. 4



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SEALED ROTARY ACTUATOR

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This invention relates to hydraulic actuator mechanisms, and more particularly to an improved sealed rotary actuator suitable for operation with pivotally adjustable devices in aircraft, such as elevators, ailerons, wingflaps, and the like.

A rotary actuator is the desired form of actuator for operation with a pivotally mounted device. In this connection, the shaft of a rotary actuator is located on the same axis as the pivotal mounting for the device. Thus, a given angular movement of the actuator shaft is directly converted into the same angular movement for the device that is pivotally mounted therewith. Therefore, the rotary actuator constitutes an extremely compact device for imparting angular movement to a pivotally mounted element. Such compactness cannot be attributed to linear actuators, wherein longitudinally slidable pistons necessarily require a considerable amount of space.

One of the strongest arguments heretofore advanced against the acceptance of rotary actuators for the above-mentioned purposes is the difficulty in suitably sealing such actuators against leakage of fluid between the working chambers thereof. Such chambers are formed by providing the actuator shaft with elongated radial shoulders or ribs that extend into spaces between circumferentially spaced, inwardly projecting ribs of the surrounding housing. The outer surface of a rib on the shaft is in sliding engagement with the inner wall of the housing, and the inner surface of a rib of the housing is in sliding engagement with the lateral surface of the shaft. Thus, there is an elongated chamber on both sides of the radial surfaces of each rib.

The direction of movement of the shaft relative to its housing is determined by the difference in fluid pressure on the opposite sides of a rib of the shaft. It is of utmost importance that there be no leakage of fluid from the high-pressure chamber to the low-pressure chamber. One way to minimize leakage is to make all abutting surfaces carefully machined, highly polished surfaces. However, such precautions still result in an undesirable quantity of fluid leakage between chambers. Such minimum leakage is too much to be permitted in many hydraulic actuators.

It is an object of this invention to provide an improved rotary actuator that eliminates the above and other disadvantages of prior-art rotary actuators.

It is another object of this invention to provide an improved rotary actuator which effectively minimizes leakage of hydraulic fluids between chambers containing fluids at different pressures.

A further object of this invention is to provide an improved rotary actuator construction, in which sealing elements are cooperatively arranged to substantially prevent the leakage of fluid from a high-pressure chamber to a low-pressure chamber around any part of the shaft or its housing.

Yet another object of this invention is to provide an improved rotary actuator having a minimum number of component parts of simple design and rugged construction.

The above and other objects and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawing of an illustrative embodiment thereof, in which:

FIGURE 1 is a longitudinal sectional view of a rotary

actuator in accordance with my invention, showing the shaft grooved at the ends of the ribs thereon, and expansible seals disposed in such grooves and abutted by the ends of respective spring elements that extend lengthwise of the ribs;

FIGURE 2 is a sectional view taken along the line 2—2 of FIGURE 1, showing the relative positions of the actuator parts intermediate the ends of the shaft;

FIGURE 3 is an enlarged, fragmentary perspective view of the shaft of the actuator of FIGURE 1, showing the overlying portion of the housing in phantom, to aid in explaining the leakage paths that have heretofore existed in rotary actuators, and which are avoided in the actuator construction of my invention; and

FIGURE 4 is a fragmentary perspective view of the ends of the expansible sealing elements used in my improved actuator.

Referring to FIGURE 1, there is shown a housing **10** in which a shaft **11** is rotatably mounted, for connection to respective elements (not shown) wherein one rotates relative to the other. Such connections may be made by suitably keying the shaft **11** to the shaft on which one device is mounted, and by securing the housing **10**, as by a flange **12** thereon, to the other device.

Referring to FIGURE 2 along with FIGURE 1, the housing **10** is provided internally with a central bore **13**, from which a number of circumferentially spaced ribs **14**, **15**, **16**, and **17** extend. As shown, the ribs **14**, **16** and **15**, **17** are diametrically opposed. The distance between the diametrically opposed ribs is the diameter of the shaft **11**.

Within the housing **10**, and coextensive with the ribs **14—17** thereof, the shaft **11** is provided with circumferentially spaced ribs **21**, **22**, **23**, and **24**. The radial dimensions of the ribs **21—24** and the ribs **14—17** are the same, whereby to permit the inner surfaces of the ribs **14—17** of the housing to engage the lateral surface of the shaft **11**, and the outer surfaces of the ribs **21—24** to engage the wall of the bore **13**.

With the shaft **11** located in the housing **10** so that the ribs **21—24** thereof are coextensive with the ribs **14—17** of the housing, a pair of nut elements **25**, **26** are placed over the shaft **11** and threadedly secured in the housing. As shown in FIGURE 1, the ends of the ribs **21—24** are in abutment with the elements **25**, **26**. With this arrangement, it will be seen that the ribs **21—24** (together with the adjacent pairs of ribs **17—14**, **14—15**, **15—16**, and **16—17**, and the end elements **25**, **26** define pairs of chambers **27—28**, **29—30**, **31—32**, and **33—34**. From these pairs of chambers, respective chambers **28**, **30**, **32**, and **34** are in fluid communication with each other. Similarly, the remaining chambers **27**, **29**, **31**, and **33** are in fluid communication with each other.

As shown, the chambers **27** and **28** are connected through respective port connections **37**, **38** to the exterior of the housing **10**, such port connections **37**, **38** being adapted for connection to a hydraulic-fluid source (not shown). As will be apparent, the positions of the ribs **21—24**, and hence the angular position of the shaft **11**, is dependent upon the difference between the fluid pressures in the chambers on the opposite sides of such ribs.

To insure that no hydraulic fluid will escape from the housing **10** in the axial direction, conventional O-ring seals **40**, **41** are provided around the shaft **11** and suitable grooves formed in the end elements **25**, **26**, and by O-rings **42**, **43** surrounding the end elements **25**, **26**. The O-rings **40—43** represent conventional means for preventing leakage of fluid between two concentric surfaces.

With the axial leakage avoided, this leaves the problems of leakage of fluid between the high-pressure chambers and the low-pressure chambers. The possible paths for

such leakage between chambers are around the outer surfaces of the ribs **21—24**, around the inner surfaces of the ribs **14—17**, and around the ends of these ribs. This is shown more clearly in FIGURE 3 wherein arrows **45, 46** illustrate leakage paths around the ends of the ribs **17, 21**, and arrows **47, 48** illustrate the leakage paths, respectively, between the inner surface of the rib **17**, and the shaft **11**, and between the outer surface of the rib **21** and the housing **10**.

To avoid the possibility of leakage of fluid along the paths **47, 48**, I utilize a slotted construction for the ribs **14—17** and **21—24**, the ribs being slotted longitudinally as indicated more clearly in FIGURE 3, and I employ elongated strips of packing material in the slots that are spring-biased to abut the confronting surface with which the rib is in abutment. Referring to FIGURE 1, such sealing for the ribs **21—24** on the shaft **11** is effected by elements **51, 52** of packing material in the shape of an elongated U to conform to the slot formed in the ribs **21—24**. At the bottom of the slots in the ribs **21—24**, there are provided respective spring elements **53**. As shown, the springs **53** are elongated, ribbon-like elements, the vertical legs of which terminate in horizontal end portions against which the ends of the legs of the packing elements **51, 52** are located. The packing elements **51, 52**, which are placed side by side in the slots in each of the ribs **21—24**, are each split along their lengths so that the two parts thereof can be separated longitudinally. However, the splits **51'** in the elements **51** are longitudinally spaced from the split portions **52'** in the elements **52**. As will be seen, such arrangement of the split portions of these packing elements avoids the formation of a leakage path through the bodies of these elements.

When the springs **53** and the packing elements **51, 52** are initially assembled in the ribs **21—24** as illustrated, the springs **53** are normally flexed so as to bow outwardly along their lengths. Then, when the shaft **11** is inserted in the housing, so that the ribs **21—24** are located intermediate the ribs **14—17** on the housing, the packing elements **51, 52** and the springs **53** are forced inwardly along their lengths. In this manner, the packing elements **51, 52** are biased outwardly by the springs **53** into engagement with the inner wall of the bore **13**, such bias being sufficient to insure constant engagement of the packing elements **51, 52** with the inner wall of the bore, so as to prevent the possibility of hydraulic fluid leaking around the ribs **21—24** past the packing elements, i.e., along the paths **48**.

As indicated in FIGURES 2 and 3, the ribs **14—17** of the housing are slotted in the same manner as the ribs **21—24**, and similar springs **55** and packing elements **56, 57** are located in the ribs **14—17**, the arrangement of the slots and the elements **55—57** being reverse to the arrangement in the ribs **21—24**, so that the springs **55** bias the packing elements **56, 57** inwardly into engagement with the lateral surface of the shaft **11**. In this manner, it will be seen that my actuator is effectively sealed against leakage along the paths **47, 48** indicated in FIGURE 3.

To avoid the possibility of leakage along the paths **45, 46** indicated in FIGURE 3, i.e., around the ends of the ribs **14—17** and **21—24**, I provide circumferential grooves **60** in the surface of the shaft **11** immediately adjacent the ends of the ribs **21—24**. Also, I provide short axial slots **61** in the shaft **11** at the centers of the ribs **21—24**, such slots **61** being coextensive with the ends of the legs of the slots in the ribs **21—24**. As shown, the axially extending ends of the legs of the springs **53** (see FIGURE 1) are located in the main body of the shaft in such axial slot portions, and extend to the extreme ends of the ribs **21—24**.

Within the grooves **60** in the shaft **11**, I locate expansible ring elements **63**, which tend to expand radially and thereby provide a tight seal against the inner surfaces of the end elements **25, 26** and immediately adjacent the extreme ends of the ribs **14—17** and **21—24**. The rings are pressure loaded against the sides of the grooves **60** nearest the ends of the ribs, as by means of check valves indicated diagrammatically at **67** from the inlets **37**. Such pressure loading of the rings, together with the outward bias of the expansible seal elements **63** and the axial thrust by the springs **53** against the seals **51, 52**, prevents hydraulic fluids from leaking around the ends of the ribs **14—17** and **21—24**. Thus, my improved actuator provides effective sealing against leakage around the radial and circumferential surfaces of the ribs. This sealing is so effective as to permit the shaft to be supported for rotation in low friction bearings **69** located in the end elements.

One form of construction of expansible-ring seal element **63** is shown in FIGURE 4. The element **63** is a split ring element, wherein one end is notched and shaped to form a finger element **64**, and the other end is notched, as at **65**, to slidably receive the finger **64**. In the uncompressed condition of the ring **63**, the finger **64** is substantially removed, circumferentially, from the notched portion **65** in the opposite end of the ring. In assembling such a ring on the shaft **11**, the ring is compressed circumferentially to force the finger **64** into the notch **65**. Since the ring in the compressed condition is of the proper size to fit within the circumferential grooves **60** in the shaft **11**, the spring characteristics of the ring cause it to tend to expand radially. This expansion characteristic causes the lateral surface portions of the ring to be firmly biased against the inner surfaces of the end elements **25, 26**.

While I have illustrated and described a particular embodiment of my invention, it will be apparent that various modifications may be made without departing from the spirit and scope of my invention. For example, double rings, like the ring **63**, may be employed; also solid rings (e.g. metal, Teflon, etc.) may be used as by relatively expanding the ring and shrinking the shaft in order to assemble the ring in the groove. Accordingly, I do not intend that my invention be limited, except as by the appended claims.

I claim:

1. In a rotary actuator, the combination of: a shaft having spaced radial ribs; a housing surrounding said shaft having spaced inwardly projecting shoulders, a shoulder being located intermediate adjacent ribs, said shoulders being of the same radial dimension as said ribs, said shoulders and ribs being coextensive; sealing means for said ribs and said shoulders to prevent leakage of fluid along the circumferential surfaces of said ribs and shoulders; sealing means at the ends of the ribs and shoulders to prevent leakage of fluid around the ends of said ribs and shoulders, including ring elements surrounding said shaft at the ends of said ribs; and means for applying fluid under pressure to the outer radial surfaces of said ring elements and force them into sealing engagement with said ribs.

2. A rotary actuator comprising: a shaft having spaced radial ribs, said shaft having circumferential grooves at the ends of said ribs; a housing surrounding said shaft having spaced inwardly projecting shoulders, a shoulder being located intermediate adjacent ribs, said shoulders being of the same radial dimension as said ribs, said shoulders and ribs being coextensive; expansible ring seal elements in said grooves to prevent leakage of fluid along the end surfaces of said ribs and shoulders; and means to permit fluid under pressure to be applied against the outer radial surfaces of said ring seal elements, thereby causing the inner radial surfaces of said ring seal elements to sealingly abut the ends of said ribs.

3. A rotary actuator comprising: a shaft having spaced radial ribs, said ribs being slotted along their lengths, said shaft having a circumferential groove therein at each end of said ribs; a housing surrounding said shaft having spaced inwardly projecting shoulders, a shoulder being located intermediate adjacent ribs, said shoulders being of the same radial dimension as said ribs, said shoulders and ribs being coextensive, said shoulders being

slotted along their lengths, said housing being threaded adjacent the ends of said shoulders; nut elements threaded into said housing and abutting said shoulders and ribs; sealing elements in the slots; means biasing said sealing elements radially; expansible ring seal elements in said grooves to prevent leakage of fluid along the end surfaces of said ribs and shoulders, the width of each ring seal element being less than the width of the groove in which it is located; and means to pressure-load said ring seal elements inwardly, including fluid connections through said nut elements to the outer portions of said grooves, whereby fluid under pressure acts through said

connections to force said ring seal elements axially into sealing engagement with the inner faces of the grooves and the adjacent sealing elements.

References Cited in the file of this patent

UNITED STATES PATENTS

1,799,294	Gough	Apr. 7, 1931
2,060,804	Friedstedt	Nov. 17, 1936
2,164,876	Horlacher	July 4, 1939
2,778,338	Shafer	Jan. 22, 1957
2,870,748	Hemphill	Jan. 27, 1959