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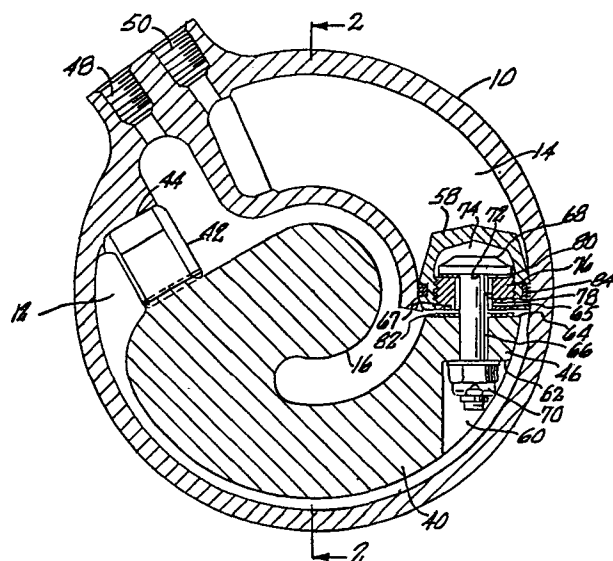
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**Rotary actuator.**

A rotary actuator having a cylindrical housing (10) in which an annular piston (40, 58) rotates through an arc within an annular chamber (14) in the housing (10) as a result of fluid pressure to produce rotary motion communicated from the piston (40, 58) to the drive shaft (16). The piston head (58) is capable of lateral or radial movement relative to the piston arm (40) so as to accommodate flexing of the piston arm (40) or variances in the shape of the chamber (14). Friction reduction washers (80, 82) are placed between the piston head (58) and the piston arm (40) to facilitate this movement. The overall effect is to reduce the friction encountered by the piston head (58) against the walls of the chamber (14) during movement, thereby improving overall performance of the actuator.



**EP 0 181 971 A1**

ROTARY ACTUATOR

The invention hereinafter described and claimed pertains to rotary actuators which are used to convert fluid pressure to mechanical movement. More particularly, this invention pertains to such actuators  
5 which produce rotary motion by means of an annular piston or pistons.

Rotary actuators are used to open and close doors or windows, raise and lower flaps on an airplane wing, turn switches or operate valves and any other device which  
10 must be moved in rotary fashion about a center point. Such actuators are generally fluid driven, meaning that a fluid, typically hydraulic or pneumatic, is used to cause the rotary movement.

One mechanism used to obtain this rotary movement  
15 utilizes one or more annular pistons. This is old in the art. For example, U.S. Patent No. 163,186, issued May 11, 1875, discloses an oscillating engine in which a pair of opposing annular pistons are utilized to generate motion. A similar arrangement of oscillating dual  
20 annular pistons is more recently disclosed in U.S. Patent No. 3,446,120, issued November 14, 1966, in an oscillating fluid-driven actuator.

Methods other than the annular piston arrangement have been used in the past to produce this rotary motion.  
25 A straight piston mechanism, in which the linear movement of the piston moves a rack gear across a gear shaft, imparting rotary motion to the gear shaft, has been used. The annular piston arrangement, however, produces greater torque and is more compact and light weight.

30 Actuators may be single acting or double acting. In a single acting actuator, motion is produced in one direction only. For example, in a single piston mechanism, the piston is caused to travel in the piston chamber by the input of fluid pressure medium into the  
35 chamber. Once the pressure is released, the piston will be returned to its starting position, usually by the gravitational weight of the device which was originally

5 moved by the piston or by a spring. In a double acting actuator, rotary motion is produced in both the counter-clockwise and clockwise directions. This is shown, for example, in U.S. Patent No. 3,446,120, in which opposing annular segment shaped pistons, working in similarly opposing piston chambers, can be made to move in opposing directions by the oscillation of pressure to the opposing chambers. Obviously, there are many uses for an actuator where the double acting feature will be preferred, if not  
10 required.

The prior art rotary actuators have suffered from a number of drawbacks. The first drawback arises as a result of the difficulty in providing for a sufficiently durable seal between the piston head and the annular  
15 chamber. Because of the variances in the dimensions of the annular chamber which can arise during manufacture, difficulty was encountered in designing a piston head which would provide a sufficiently durable seal against the walls of the annular chamber during operation,  
20 without creating excessive friction between the piston head and the wall. From a design standpoint it is the ultimate goal to produce the maximum torque from the rotary actuator for a given chamber pressure. It will be easily understood that any excess friction between the  
25 piston head and the walls of the annular chamber will greatly reduce the resultant torque from a given chamber pressure.

A further drawback encountered with the annular piston arrangement was that under any substantial  
30 pressure, the annular piston arm will undergo some flexing as the direction of the force exerted on the piston arm by the fluid pressure against the piston head is linear and is tangential to the axis of the piston arm. Any slight flexing of the piston arm would cause  
35 increased friction between the piston head and the wall of the annular chamber thereby reducing performance of the actuator.

One method which has been utilized to attempt to

neutralize this friction buildup resulting from deformations of the chamber wall and of the piston arm is to allow the piston head to "float" relative to the piston arm. This is shown, for example, in Sneen, U.S. Patent No. 3,446,120 (see Figure 11) and in Mehm, U.S. Patent No. 2,649,077 (see Figure 2). This method aided in the reduction of friction, but there was still considerable friction generated in these devices by the friction of the piston head against the piston arm. In other words, when the piston head is under substantial pressure, it is forced, under that great pressure, against the piston arm. Accordingly, there will be great friction between the piston head and the piston arm should the piston head attempt to move laterally relative to the piston arm. Therefore, the fact that the piston head is designed to "float" in the prior art devices does not improve the performance of the actuator as well as it might because the friction between the piston head and the piston arm will tend to hold the piston head against the chamber wall with greater force, thereby producing unnecessary friction between the piston head and the chamber wall.

Another method used to reduce sidewall friction has been the installation of slide pads of antifriction material on the exterior side of the piston arm which abuts the chamber wall. See Sneen, U.S. Patent No. 3,444,788, issued May 20, 1969. This method also does not address the problem of piston head/piston arm friction.

Another drawback inherent in the prior art devices resulted from the cumbersome and often complex design and relationship of the component parts resulting in higher costs of manufacture and maintenance and lower performance.

The rotary actuator herein described and claimed overcomes the drawbacks of the prior art in an actuator which utilizes only one annular chamber integrally formed in a housing and a piston operating in that single

annular chamber, and which provides friction reduction means between the piston head and piston arm to improve performance.

5 A novel design for the actuator provides a single annular chamber formed integrally within a cylindrical cavity in the housing. A single piston head, attached to a single arm, is caused to travel in the annular chamber, in both directions, by providing for the pressurization of the larger cavity in which the piston arm resides, and  
10 allowing that pressure to act on the underside of the piston head to drive the piston into the annular chamber, and providing the conventional pressurizing means to pressurize the annular chamber ahead of the piston head to force the piston arm out of the annular chamber,  
15 thereby providing for the oscillating or double-acting rotary motion required for most applications of the actuator in a very simple, inexpensively manufactured embodiment.

20 Additionally, friction reduction means are provided between the piston head and the piston arm to allow for freer movement of the piston head relative to the piston arm, so that the piston head may float within the annular chamber, thereby allowing the piston head to accommodate any flexing of the piston arm under load and any  
25 variances in the dimensions of the annular chamber.

Accordingly, it is the object of this invention to provide a simplified rotary actuator, which actuator has improved performance characteristics.

30 The present invention will be more particularly described with reference to the accompanying drawings, in which:-

35 Figure 1 is a top view of a preferred embodiment of a rotary actuator according to the present invention, in cross-section taken along line 1-1 in Figure 2. This figure shows an annular chamber and a single piston which operates therein, and a larger chamber in a cylindrical housing in which a piston arm resides. Also shown in this figure is friction reduction means between the

piston head and the piston arm.

Figure 2 is a side view of the actuator of this invention in cross-section taken along line 2-2 in Figure 1. The relationship between a central drive shaft, the  
5 annular piston and the annular chamber is shown. Also shown is the general construction of the actuator.

Figure 3 is a bottom view of the actuator.

Figure 4 is a top view of the actuator.

Figure 5 is a view in isolation of an alternative  
10 embodiment of the piston head of the actuator and of an alternative embodiment of the manner in which the piston head is attached to the piston arm.

Figure 6 is a view in isolation of an alternative embodiment of the piston head.

15 The actuator of this invention has an outer housing 10. In the preferred embodiment, the housing 10 is of a circular configuration for greater compactness. The housing 10 is constructed from steel. The interior of housing 10 is a hollow cylinder containing a first  
20 chamber 12 and a second chamber 14. The second chamber 14 is annular in configuration and in the preferred embodiment is in the shape of a toroid arc segment. To obtain greater precision, thereby reducing dimensional tolerances in the second chamber 14, the toroid segment  
25 is preferably cut, rather than cast.

The housing 10 has a small opening at one end through which is inserted a drive shaft 16. The other end of housing 10 is open. A diaphragm 18, having a central opening to fit over the end of drive shaft 16,  
30 fits into the housing 10 to enclose chamber 12.

It will be appreciated that housing 10 is generally a cylinder, closed at one end, and open at the other. Annular chamber 14 is formed at the bottom edge of the closed end of this cylinder. The remaining volume of the  
35 cylinder is open, defining a void space. This large void space becomes first chamber 12 after diaphragm 18 is inserted, but provides important advantages relating to the construction of the actuator. For example, it will

be appreciated that this configuration allows a piston arm 40 and the drive shaft 16 to be of unitized construction, rather than the splined attachment means typically utilized between the piston and drive shaft in other actuators.

Thrust bearings 20 and 22 fit around the drive shaft 16 and in the apertures in the housing 10 and diaphragm 18, respectively, to hold the drive shaft 16 in place and to allow the drive shaft 16 to rotate. Two sets of packing and retainer rings 24 and 26 seal thrust bearing 20 against housing 10 and drive shaft 16 respectively; and two sets of packing and retainer rings 28 and 30 provide the same function between thrust bearing 22 and diaphragm 18 and drive shaft 16. Another packing and retainer ring set 32 seals the exterior circumference of the diaphragm 18 against housing 10. A metal split ring 34 is inserted into an appropriately sized aperture formed by corresponding grooves in housing 10 and diaphragm 18 to hold diaphragm 18 in place against housing 10. An access slot 36 (Figure 4) is provided in the exterior of housing 10 to allow the split ring 34 to be fed into position. A set screw 38 keeps the diaphragm 18 from turning in place relative to the housing 10.

Looking at Figure 1, it will be seen that piston arm 40 is formed integrally with drive shaft 16 as they are of unitized construction. It will be understood that conventional attachment means could be used. It also will be appreciated that the first chamber 12 is of sufficient size to accommodate therein the piston arm 40 and a portion of the drive shaft 16.

On the heel of piston arm 40 is attached a rubber stop 42. A shoulder 44 is formed on the interior of housing 10 against which rubber stop 42 abuts to stop movement of the piston arm 40.

Piston arm 40 is also formed as an arc segment of a toroid having an arc radius equal to that of second chamber 14. The cross-sectional diameter of piston arm 40 is appreciably less than the interior cross-section

diameter of second chamber 14 so that piston arm 40 may move freely into second chamber 14. It will be appreciated that in order for piston arm 40 to be able to move completely into second chamber 14, the center point  
5 for the arc radius of piston arm 40 must be the same as the center point for the arc radius for second chamber 14. It will further be appreciated that for improved compactness, when piston arm 40 is in the fully retracted position with rubber stop 42 against shoulder 44, the  
10 distal end 46 of piston arm 40 is at or near the entrance to second chamber 14.

Charging ports 48 and 50 provide the means whereby fluid under pressure can be introduced into first chamber 12 and second chamber 14, respectively. Threaded holes  
15 52, 53, 54 and 55 are provided in the exterior portion of housing 10 for ease of attachment of the actuator to another surface.

A piston head 58 is attached to piston arm 40 by means which allow the piston head 58 to "float" in a  
20 lateral, or in the preferred embodiment, a radial manner relative to piston arm 40. These attachment means comprise a corner notch 60 formed in piston arm 40 which presents a shoulder 62 which is parallel to the face 64 of the piston arm 40. A hole is formed between the face  
25 64 and shoulder 62. The hole is situated at the center point of face 64. A bolt 66 having an enlarged head 68 extends through that hole and is secured by nut 70 against shoulder 62. The length of bolt 66 is such that it extends an appreciable distance beyond the face 64 of  
30 piston arm 40. The enlarged head 68 of bolt 66 presents a shoulder 72 which is parallel to face 64.

The piston head 58, which is preferably constructed of an aluminum-nickel-bronze alloy, is cup-shaped such that it has an interior cavity 74 of sufficient size to  
35 fit over the enlarged head 68 of bolt 66. A portion of the interior surface of cavity 74 is threaded so as to receive a threaded insert 76 which retains the piston head 58 upon enlarged head 68 of bolt 66. It will be

appreciated that the hole in piston arm 40 between shoulder 62 and face 64 has an interior diameter equal to the exterior diameter of bolt 66 such that there is no lateral or radial movement by bolt 66 in that hole. On the other hand, the interior diameter of hole 78 in threaded insert 76 is appreciably larger than the exterior diameter of bolt 66. Similarly, the interior diameter of cavity 74 is appreciably larger than the exterior diameter of enlarged head 68. Accordingly, piston head 58 is capable of lateral or radial movement relative to bolt 66 and hence, relative to piston arm 40. It will further be appreciated that to provide for this lateral or radial movement, there must be some free space provided between piston head 58 and piston arm 40. This free space is obtained by making the interior cavity 74 and piston head 58 appreciably deeper than the distance bolt 66 extends away from face 64 of piston arm 40. A lock pin 65 is inserted into corresponding holes in piston head 58 and insert 76 to prevent insert 76 from turning after it has been inserted. Wrenching hole 67 is added to insert 76 to aid in its insertion and removal.

Even though these provisions have been made to allow for radial or lateral movement of piston head 58 relative to piston arm 40, it will be readily understood after having read the preceding material that if second chamber 14 is subjected to high pressure, a tremendous force will be exerted against piston head 58 pushing it against the face 64 of piston arm 40. The resultant friction between piston head 58 and insert 76 against the face 64 of piston arm 40 will virtually preclude the free lateral movement of piston 58. This completely vitiates the beneficial results expected by allowing piston head 58 to float in the first instance. To counteract this phenomena, a low friction thrust washer 80 is placed between shoulder 72 of enlarged head 68 and threaded insert 76, and another low friction thrust washer 82 is placed between face 64 of piston arm 40 and the threaded insert 76. Suitable thrust washers have a coating of a

polytetrafluoroethylene-lead mixture which provides for exceptionally low friction. Therefore, even under substantial loads, the piston head 58 will be able to float relative to the piston arm 40. Therefore, during the travel of the piston arm 40 through its arc in second chamber 14, as the piston arm 40 may flex during surges in pressure, or as the piston head 58 encounters variances in the configurations of the walls of second chamber 14, the piston head 58 will more readily and with less friction float relative to piston arm 40 so that the piston head 58 will adjust its position to seek the path of least resistance, thereby minimizing friction between it and the walls of second chamber 14, producing maximized performance for the actuator.

In Figure 1, one of several embodiments for the configuration of the piston head 58 is shown. Here it will be noted that the exterior configuration of piston head 58 is such that it contacts the walls of second chamber 14 at one circumferential point only. At that point, a sealing ring 84 is fitted into an appropriately sized groove formed in piston head 58. The best performance is obtained by using a sealing ring 84 which is resistant to extrusion under high pressure.

Another method of attachment of the piston head 58 to the piston arm 40 is shown in Figures 5 and 6. Here, the piston head 58' and 58" does not have an interior cavity. Rather, the piston head has a centrally located aperture through which bolt 66 is inserted. Another modification is made to face 64 of piston arm 40. The end of piston arm 40 is reduced in size to create a shoulder 100 and a neck portion 102. The piston head 58' and 58" has a small cavity which fits over the neck portion 102. To provide for movement of the piston head 58' and 58" relative to the piston arm in this arrangement, the aperture 104 between face 64 and shoulder 62 is made appreciably larger than the size of bolt 66. A spacer 106 extends between nut 70 and the underside of the piston head 58' and 58" to allow for

pretensioning of the bolt 66. This pretensioning of the bolt 66 increases its fatigue life, and also permits precise looseness between the piston head 58' and 58" and the piston arm 40. In this embodiment, the thrust washers 80 and 82 are placed between the piston 58' and 58" head and face 64 and between shoulder 62 and nut 70. It will also be understood that because the aperture in the piston head is now exposed to fluid under pressure, packing and retainer ring 108 must be utilized.

10        Figures 5 and 6 also display alternative embodiments for the configuration of the piston head. Looking first to Figure 5, piston head 58' is in the shape of a toroid segment so that the sealing contact between the piston head 58' and the walls of second chamber 14 is increased. 15 This configuration finds its greatest utility in those applications where extremely high pressures are experienced. Although this configuration of piston head 58' presents a potential for greater friction between the piston head and the wall of second chamber 14, the 20 precision with which the toroidal bore of second chamber 14 is machined, and the provision for low friction float of the piston head 58' during movement of the piston arm 40, minimizes the increased frictional problems.

      In Figure 6, another embodiment of piston head 58" 25 is shown. Here, the exterior piston surface is generated by a radius equal to that of the interior surface 110 of the exterior wall portion of second chamber 14.

30

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CLAIMS:

1. A rotary actuator characterised in comprising a housing (10) having a closed first end, and an open second end, said housing (10) defining a cylindrical hollow space (12) except for an annular chamber (14) in the shape of an arc segment of a toroid in said housing (10) against said closed end, said annular chamber (14) opening into said hollow space (12) in said housing; a centrally located aperture in said closed first end of said housing (10); a drive shaft (16) rotatably mounted in said housing (10) and extending exteriorly of said housing (10) through said aperture in said closed end; an annular piston attached to said drive shaft (16), such that said piston rotates in said housing (10) coaxially with and into said annular chamber (14), said piston having a piston arm (40), and piston head means (58) attached to said piston arm (40) for providing sealing contact with said annular chamber (14) during the movement of said piston therein; diaphragm means (18) for closing said second end of said housing and port means (48,50) for introducing fluid under pressure into said annular chamber (14) and into said hollow space (12) in said housing (10).

2. A rotary actuator according to Claim 1, further comprising attachment means (66,68,70) for attaching said piston head (58) to said piston arm (40) such that said piston head (58) may move laterally relative to said piston arm (40).

3. A rotary actuator according to Claim 2, further comprising friction reduction means (80,82) between said piston head (58) and said piston arm (40) for reducing friction when said piston head (58) moves relative to said piston arm (40).

4. A rotary actuator according to Claim 3, wherein said friction reduction means comprises at least one thrust washer (80,82).

5. A rotary actuator according to Claim 4, wherein said thrust washer (80,82) has a coating of friction

reduction material.

6. A rotary actuator according to Claim 5, wherein said friction reduction coating contains polytetrafluoroethylene.

5 7. A rotary actuator according to any one of claims 3 to 6, wherein said attachment means comprises:-

10 (a) bolt means (66) attached to and extending longitudinally from said piston arm (40), said bolt (66) having an enlarged portion (68) at its end distal from said piston arm (40);

15 (b) an interior cavity (74) defining the width space in said piston head (58), said interior cavity (74) being of a size substantially greater than said enlarged portion (68) of said bolt means (66); and

20 (c) insert means (76) attached to said piston head (58) for attaching said piston head (58) to said bolt means (66), said insert means (76) having an aperture (78) through which said bolt means (66) passes, said aperture (78) being appreciably larger than the diameter of said bolt means (66).

25 8. A rotary actuator according to Claim 7, wherein said friction reduction means (80,82) are placed between said insert means (76) and said enlarged portion (68) of said bolt means (66), and between said insert means (76) and said piston arm (40).

30 9. A rotary actuator according to any one of claims 3 to 6, wherein said attachment means comprises:-

35 (a) an aperture (104) in said piston arm (40);  
(b) bolt means (66) extending through said aperture (104), said bolt means (66) having a diameter appreciably less than said aperture (104);

(c) an aperture in said piston head (58',58") through which said bolt means (66) extend, said piston head aperture being equal in

size to said bolt means (66);

(d) nut means (70) for securing said bolt (66) to said piston arm (40); and

5 (e) spacer means (106) between said piston head (58',58") and said nut means (70).

10. A rotary actuator according to Claim 9, wherein said friction reduction means (80,82) are placed between said piston head (58',58") and said piston arm (40), and between said piston arm (40) and said nut means (70).

10 11. A rotary actuator according to any one of the preceding claims wherein said piston head (58) has a convex radial exterior configuration, and exterior circumferential groove formed at the point of the piston head's maximum exterior diameter, and sealing means (84)  
15 in said groove for sealing against fluid bypass in said annular chamber (14).

12. A rotary actuator according to any one of the preceding claims, wherein said piston head (58) has an exterior surface configuration of a toroid segment.

20 13. A rotary actuator having a housing (10), an annular chamber (14) in said housing, an annular piston arm (40) mounted in said housing (10) and rotatable through an arc coaxially within said annular chamber (14), and a piston head (58) attached by attachment means  
25 (66) to said piston arm (40), said attachment means for allowing lateral movement of said piston head (58) relative to said piston arm (40), characterised in comprising friction reduction means (80,82) between said piston head (58) and said piston arm (40) for reducing  
30 friction between said piston head (58) and said piston arm (40) during lateral movement of said piston head (58) relative to said piston arm (40).

14. A rotary actuator according to Claim 13, wherein said friction reduction means comprise of at least one  
35 thrust washer (80,82) having a coating of friction reduction material.

15. A rotary actuator according to Claim 14, wherein said coating contains polytetrafluoroethylene.



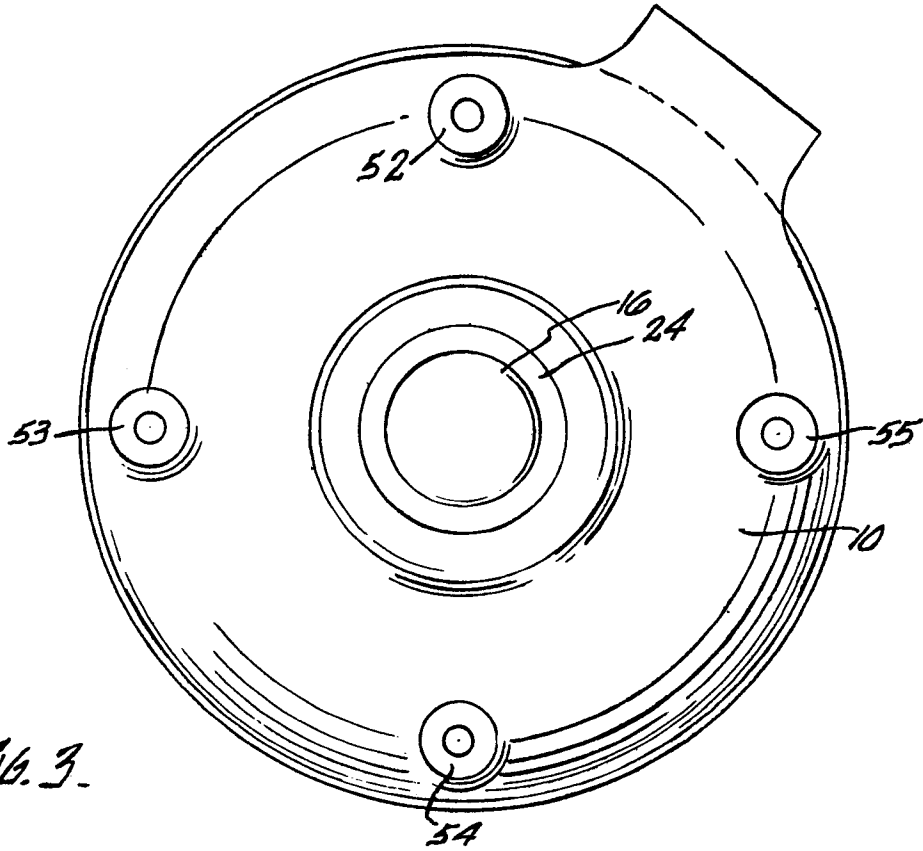


FIG. 3.

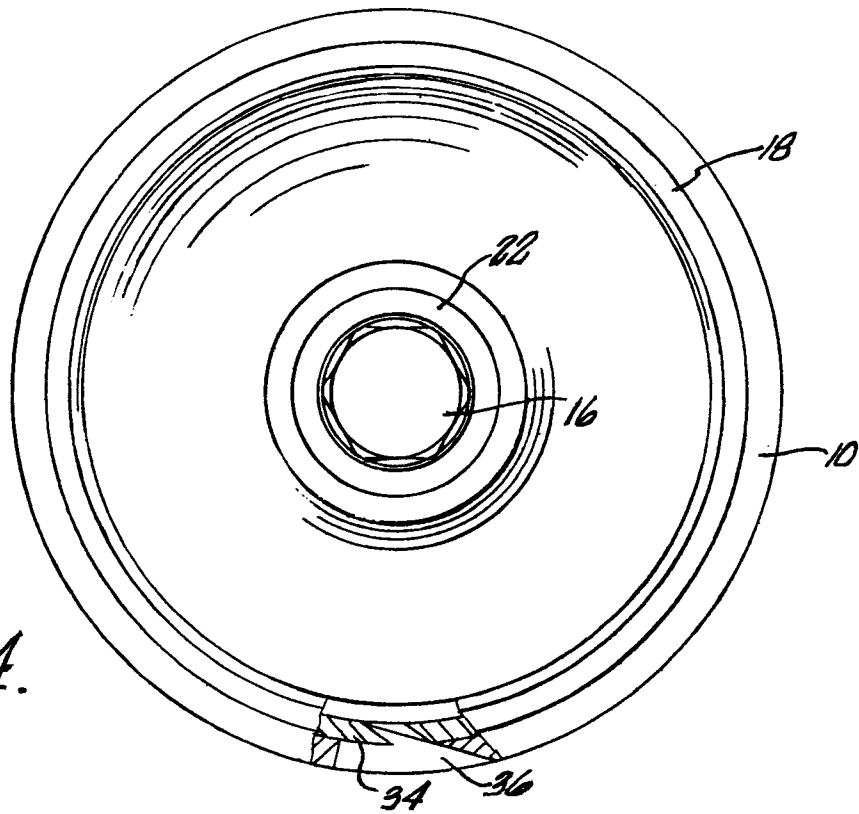


FIG. 4.

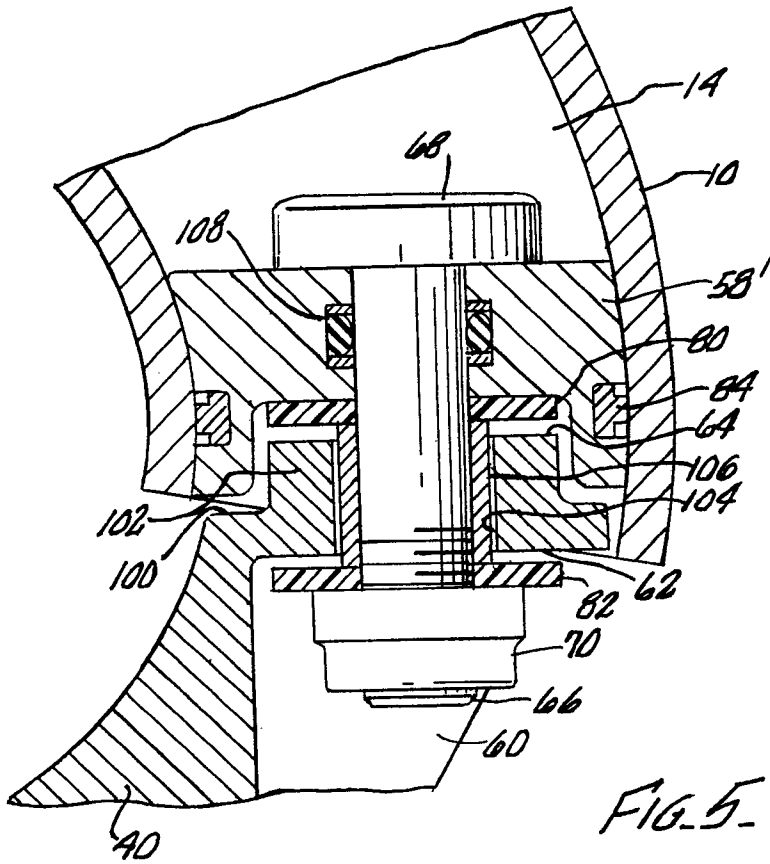


FIG. 5.

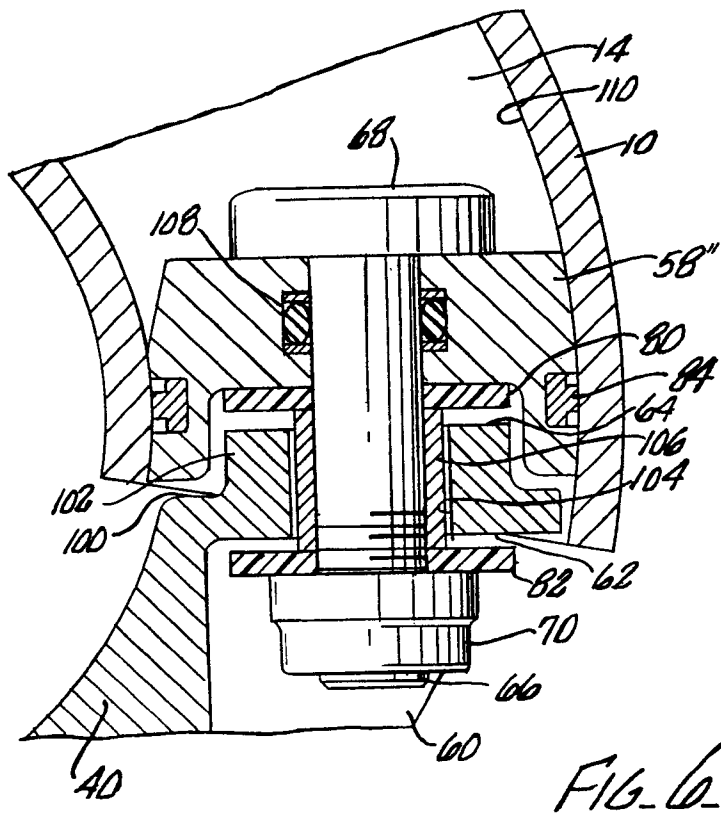


FIG. 6.



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	FR-A-2 253 159 (JOHAN TENFJORD) * Page 5, lines 21-36 *	1, 2, 9, 11, 12	F 15 B 15/12
X	FR-A-2 076 326 (SURA) * Page 2, line 33 - page 4, line 34; figure 3 *	1	
A	GB-A-1 140 283 (CARGO GEAR)		
A	FR-A- 522 037 (HAAS)		
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			F 15 B F 03 C F 16 J
Place of search THE HAGUE		Date of completion of the search 26-06-1985	Examiner KNOFS J.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone		T : theory or principle underlying the invention	
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A : technological background		D : document cited in the application	
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P : intermediate document		& : member of the same patent family, corresponding document	