United States Patent [19]

Ishii et al.

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[54] UNIDIRECTIONAL ROTATION ACTUATOR

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Sept. 27, 1972 Japan 47-96791

[52] **U.S. Cl.** **74/88**
[51] **Int. Cl.** **F16h 27/02**
[58] **Field of Search** 74/88

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Primary Examiner—Benjamin W. Wyche
Assistant Examiner—Wesley S. Ratliff, Jr.

[57] **ABSTRACT**

A unidirectional rotation actuator comprising a cylinder, a piston for undergoing sliding reciprocation within the cylinder, a cam groove formed in either the cylinder or piston in the surface thereof confronting the other, and a cam follower secured to the other confronting surface and engaged with the cam groove, the cam groove having a shape such that the piston, as it is driven by a working fluid in reciprocating motion, is simultaneously rotated intermittently in only one direction relative to the cylinder. For this purpose, the cam groove comprises a plurality of straight groove parts of alternately different inclinations in zigzag configuration and guide groove parts positioned at and forming junctures of adjacent straight groove parts, each guide groove part functioning to guide the cam follower which has relatively passed along one straight groove part into the succeeding straight groove part.

3 Claims, 16 Drawing Figures

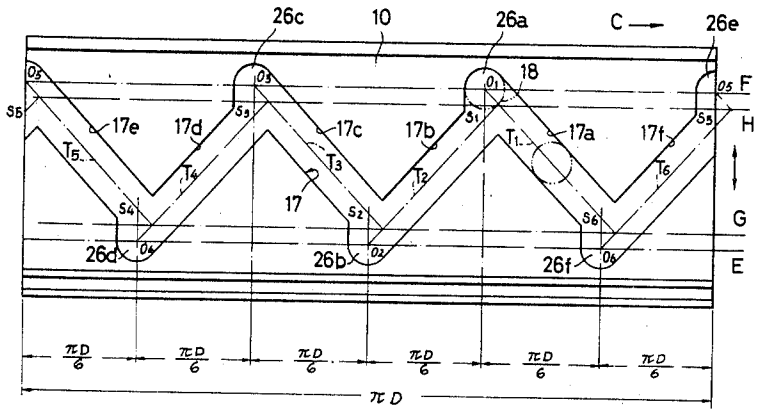


FIG. 1

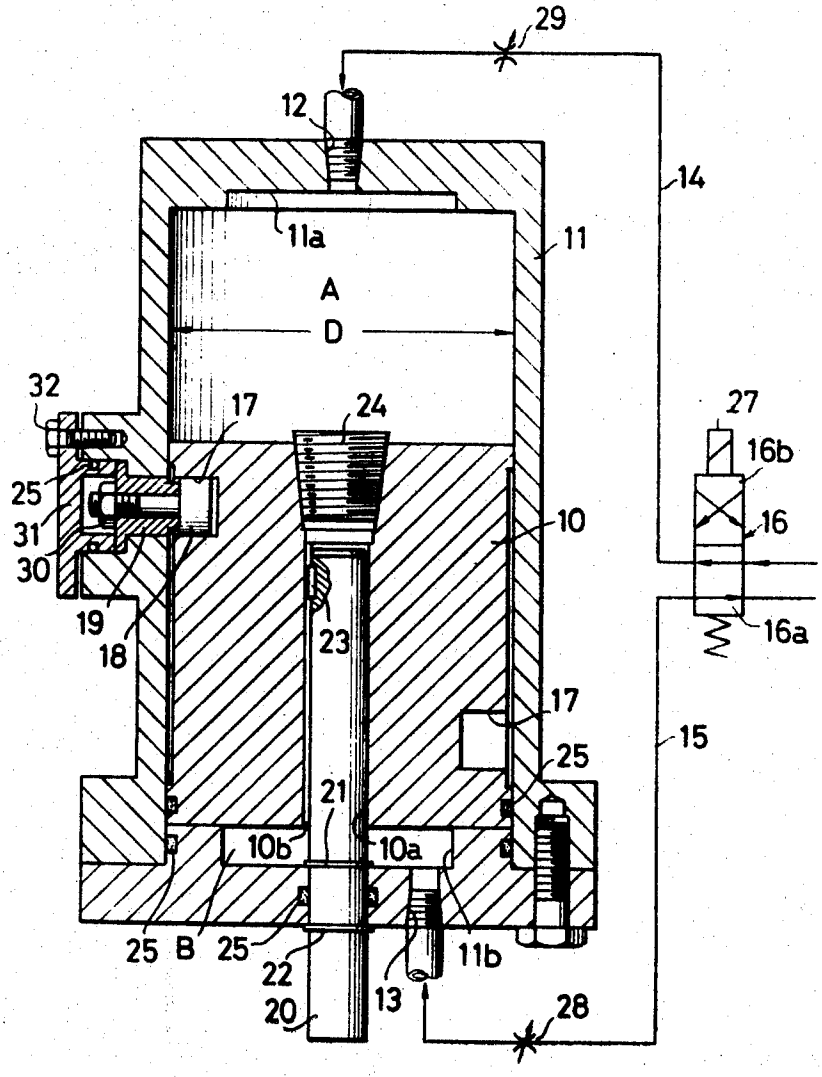

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FIG. 2

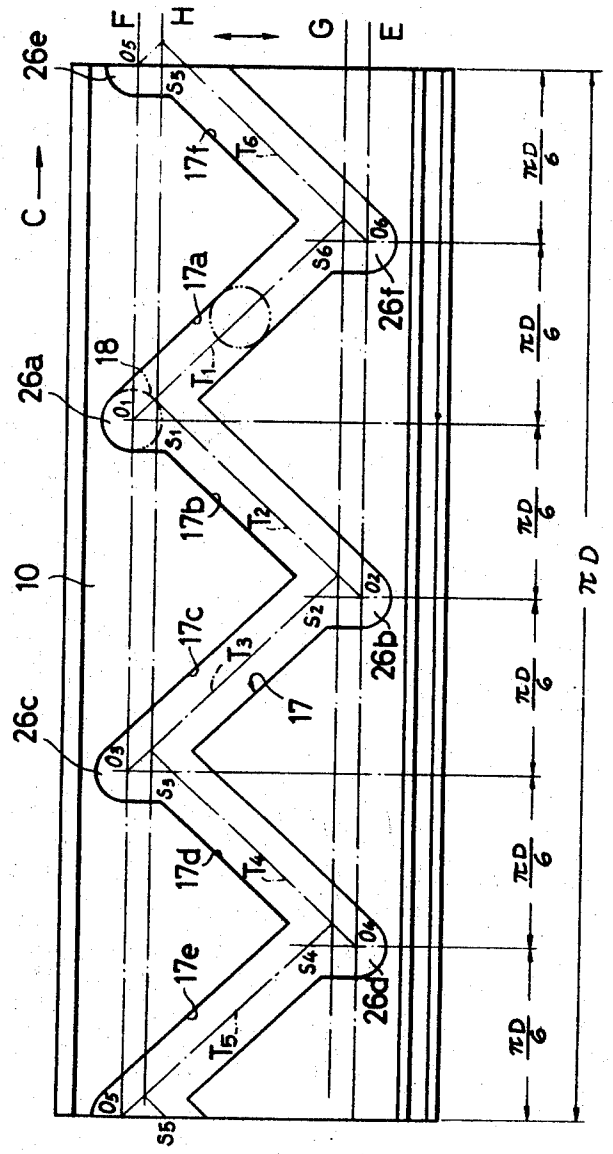

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FIG. 3

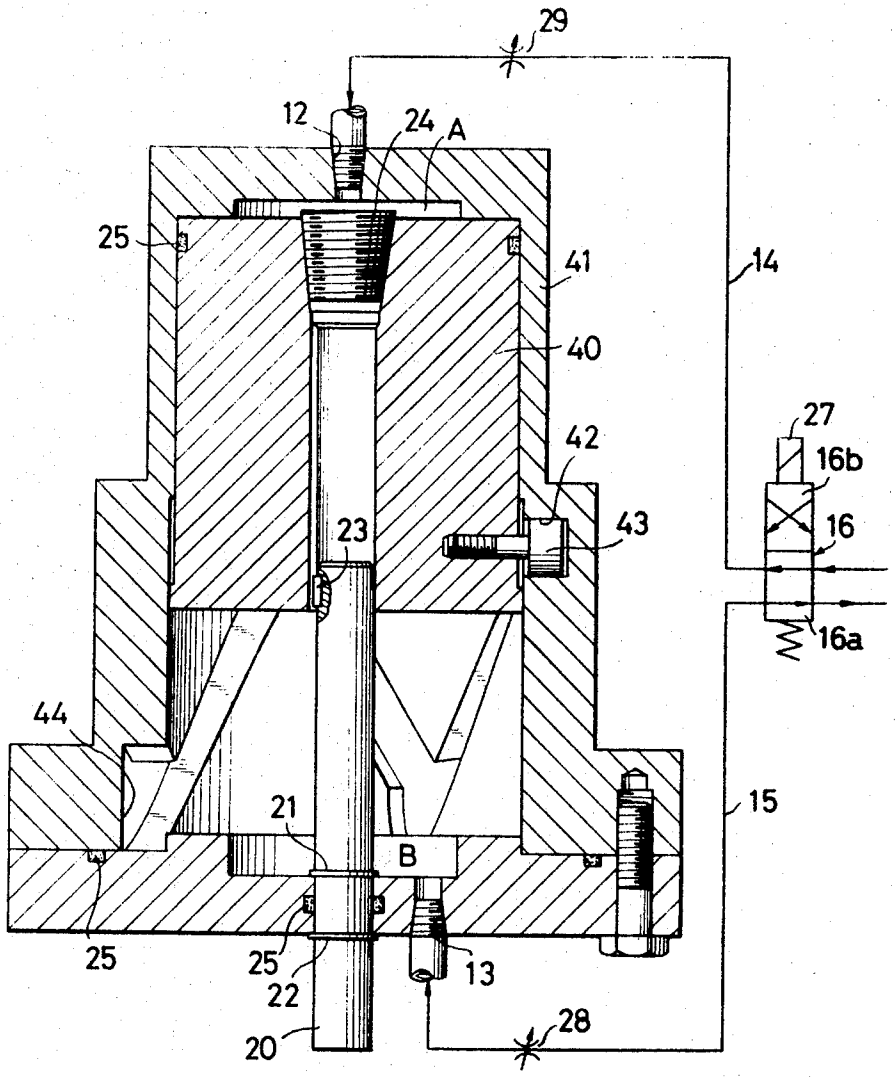

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FIG. 5

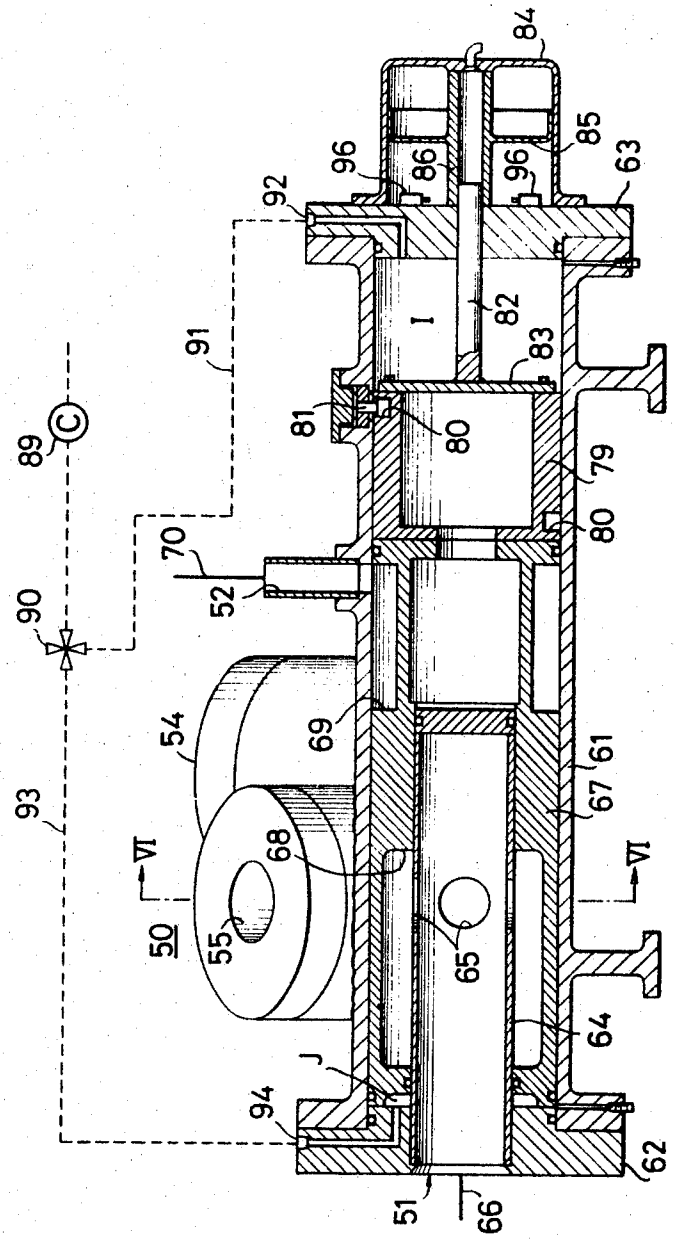

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FIG. 4A

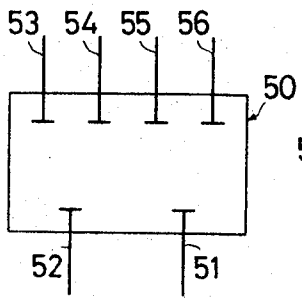


FIG. 4B

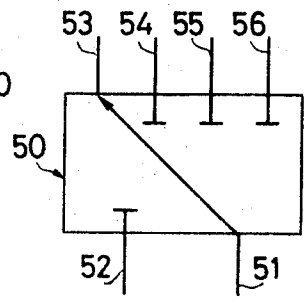


FIG. 4C

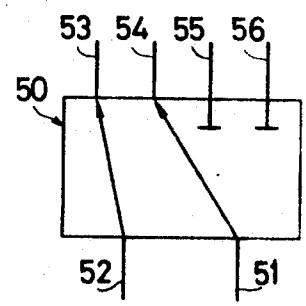


FIG. 4D

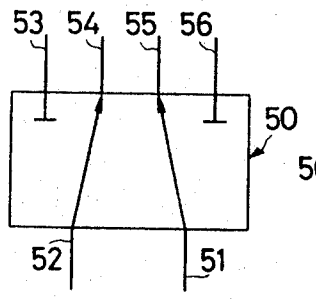


FIG. 4E

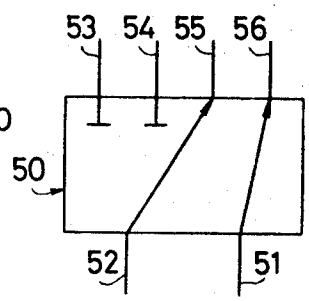


FIG. 4F

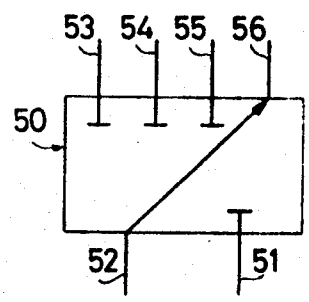


FIG. 6

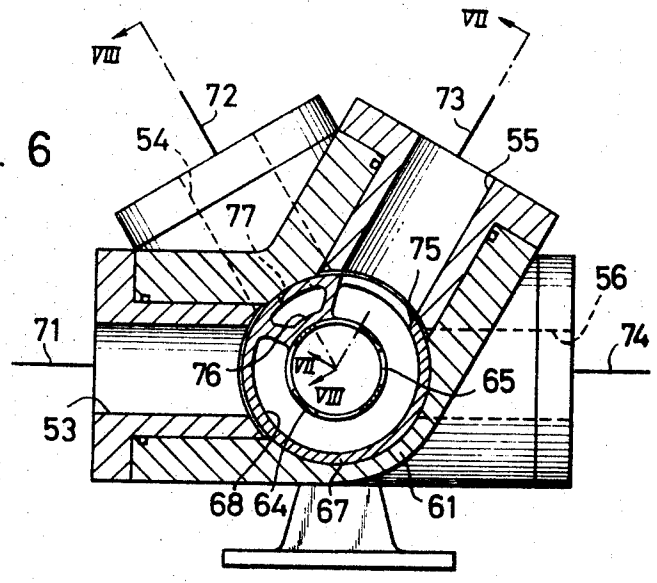


FIG. 7

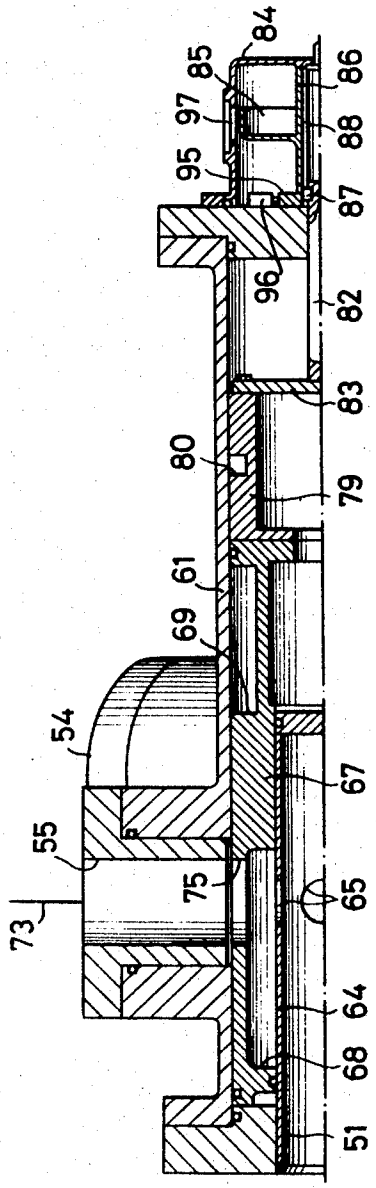

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FIG. 8

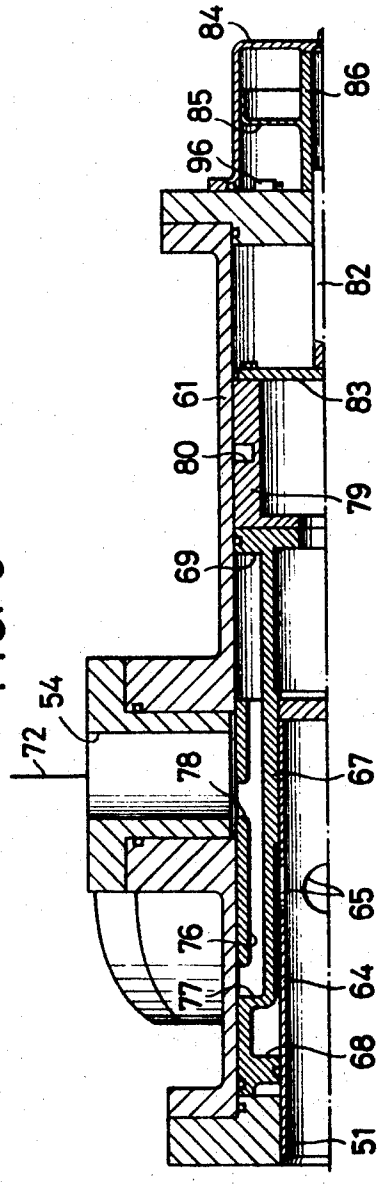

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FIG. 9A

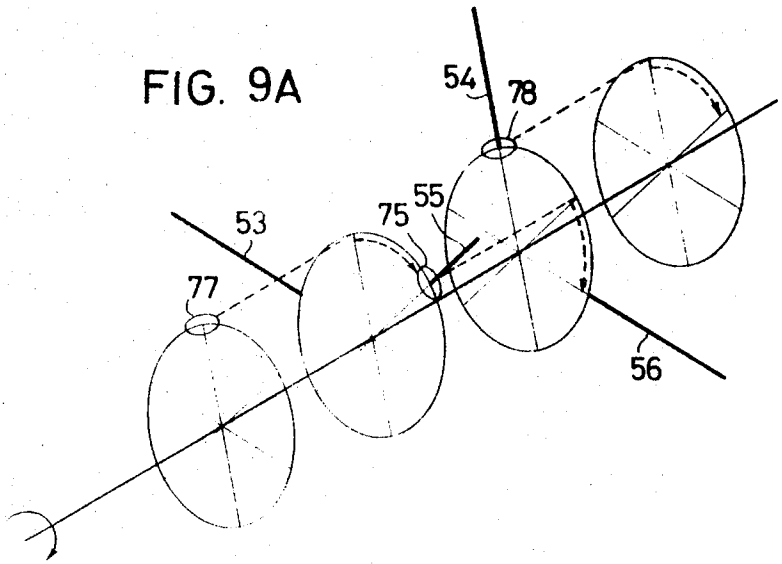
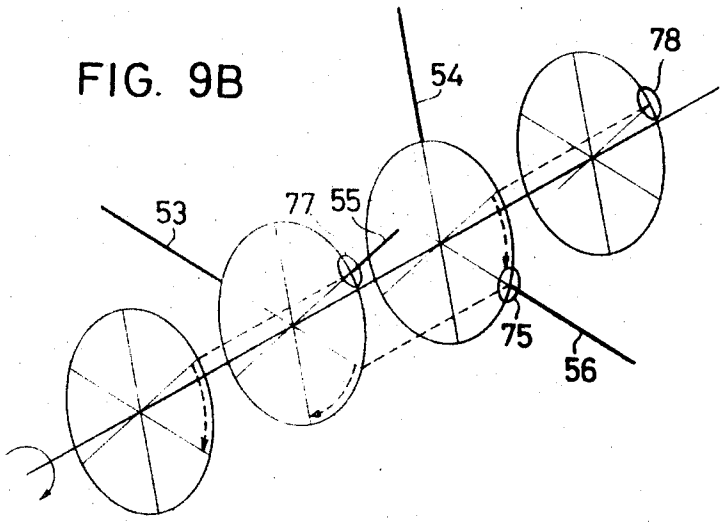


FIG. 9B



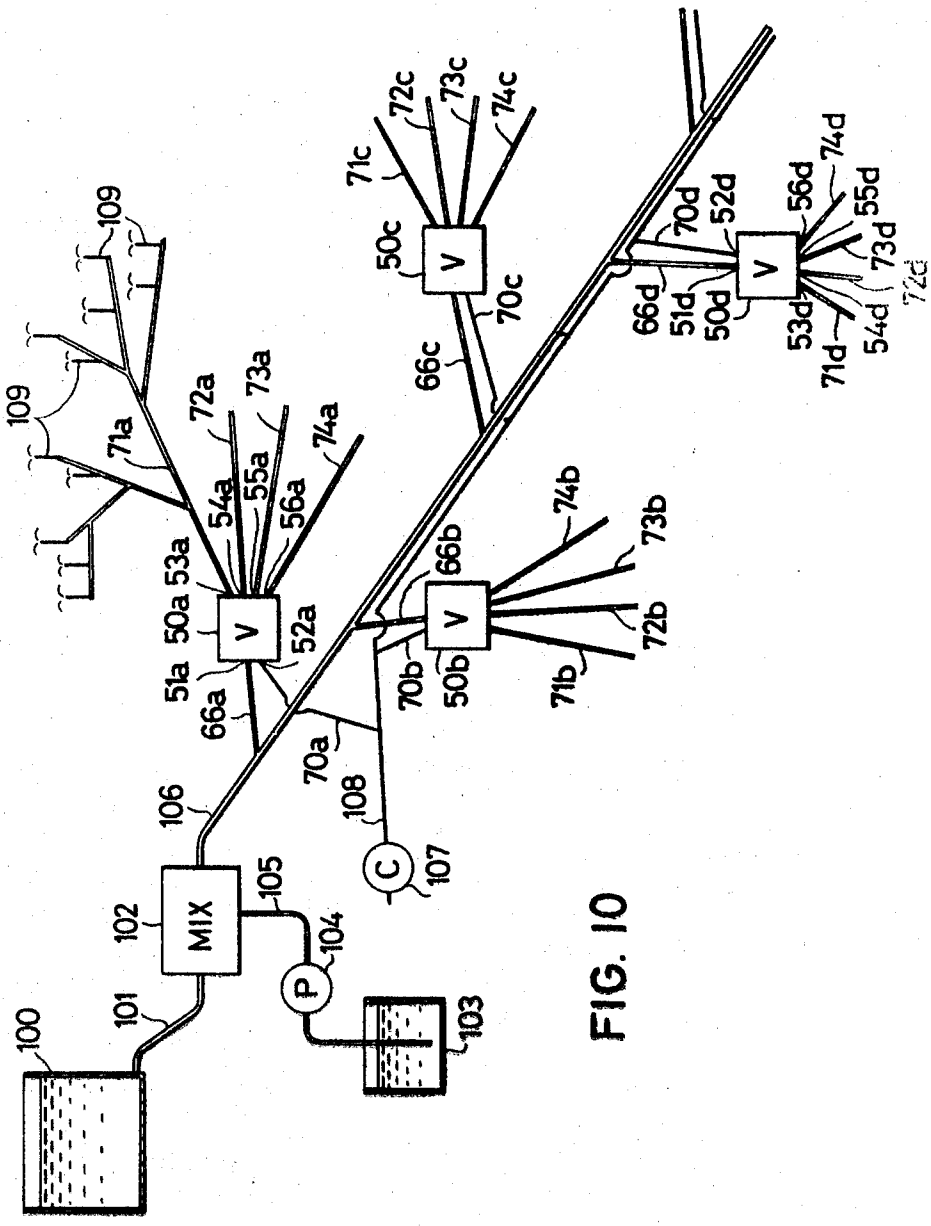

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55a
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73a
74a
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109
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FIG. 10

UNIDIRECTIONAL ROTATION ACTUATOR

BACKGROUND OF THE INVENTION

The present invention relates generally to a unidirectional rotation actuator and more particularly to an actuator having a piston driven by a working fluid to undergo reciprocating motion and, as caused by a cam mechanism, to rotate in a single direction interrelatedly with its reciprocating motion, this rotation being utilized as the output of the actuator.

Among unidirectional rotation actuators known heretofore in which working fluids are utilized as motive power source, there is a device in which the reciprocating motion of a piston driven by a working fluid is converted by a crank mechanism into a unidirectional rotation.

This known actuator undergoes a movement corresponding to a sine curve, however, whereby variations in the rotational torque of the output shaft disadvantageously occur. Another problem accompanying this known device is that, since a braking device has been used for stopping the rotation output shaft at a specific position for each intermittent rotation, it has been difficult to stop the output shaft at the specific position.

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a new and useful unidirectional rotation actuator in which the above described difficulties have been overcome.

A specific object of the invention is to provide a unidirectional rotation actuator which produces a rotational output intermittently in only one direction. In accordance with the invention, the rotation stopping position after each intermittent rotation of a rotating structure is determined with high precision.

Another object of the invention is to provide a indirectional rotation actuator in which, by use of a mechanism comprising a cam groove of zigzag shape made up of a plurality of straight groove parts continuously joined end-to-end with alternately different inclinations and a cam follower engaged with this cam groove, an intermittent rotational output is produced each time the cam follower moves along one of the straight groove parts. As the cam follower reaches each bend in the zigzag cam groove, that is, the junction of two adjacent straight groove parts, the intermittent rotation is temporarily stopped. For this reason, a braking device is not necessary for stopping the intermittent rotation. Furthermore, since the elemental parts of the cam groove are straight, the rotational torque is always constant.

Still another object of the invention is to provide a unidirectional rotation actuator which is suitable for application in a selector valve, control valve, or changeover valve for carrying out valve changeover or switching with each intermittent rotation.

Further objects and features of the invention will be apparent from the following detailed description with respect to preferred embodiments of the invention when read in conjunction with the accompanying drawings, throughout which like parts are designated by like reference numerals and characters.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a longitudinal section of a first embodiment of a unidirectional rotation actuator according to the present invention;

FIG. **2** is a developed plan view indicating the shape of a cam groove formed around the outer cylindrical surface of the piston of the actuator shown in FIG. **1**;

FIG. **3** is a longitudinal section of a second embodiment of a unidirectional rotation actuator according to the invention;

FIGS. **4**A through **4**F are diagrams respectively indicating the valve changing over operation of a changeover or selector valve to which the actuator of the invention is applied;

FIG. **5** is a longitudinal section of one embodiment of specific structure of the changeover valve indicated in FIGS. **4**A through **4**F;

FIG. **6** is a cross section taken along the line VI—VI in FIG. **5**;

FIG. **7** is a longitudinal section taken along the line VII—VII in FIG. **6**;

FIG. **8** is a longitudinal section taken along the line VIII—VIII in FIG. **6**;

FIGS. **9**A and **9**B are diagrammatic perspective views for a description of the operation of the changeover valve device illustrated in FIGS. **5** through **8**; and

FIG. **10** is a schematic diagram showing the general organization of a system for sprinkling or spreading agricultural chemicals in which changeover valve mechanisms utilizing the actuator of the invention are employed.

DETAILED DESCRIPTION

With reference to FIGS. **1**, **2**, and **3**, first and second embodiments of the unidirectional rotation actuator according to the invention will first be described.

FIGS. **1** and **2** illustrate on embodiment of the actuator of the invention.

A piston **10** is slidably and rotatably fitted in a fixed cylinder **11**, the displacement of the piston **10** in its axial direction being limited at positions where the two end surfaces of the piston abut against the corresponding head or end wall surfaces of the cylinder **11**. The end walls of the cylinder are respectively provided with ports **12** and **13**, which communicate with recesses **11***a* and **11***b* formed in the inner sides of the end walls. Pipe lines **14** and **15** are respectively connected at their ends on one side to the ports **12** and **13** and at their other ends to an electromagnetic four-way valve **16**.

The piston **10** is provided around its outer cylindrical surface with a continuous cam groove **17** of zigzag shape as shown in a developed view in FIG. **2**. A cylindrical cam follower **18** projects into the interior of the cylinder **11** to enter and engage with the cam groove **17** and is thus fixedly held by means such as a holder **19** disposed within the cylindrical side wall of the cylinder **11** at substantially the midpoint position in the axial direction of the cylinder.

This cam follower **18** is secured by a nut **30** to the holder **19**, which is held fixedly in place by a cover **31** secured to the cylinder **11** by bolts **32**.

An output shaft **20** extends through and is rotatably held by one end wall of the cylinder **11** and extends at its inner end to a position which is substantially at the midpoint of the cylinder **11** in the axial direction thereof. This output shaft **20** is prevented from being displaced in its axial direction by rings **21** and **22** engaged with the inner and outer parts of the cylinder end

wall through which the shaft extends. Furthermore, the inner end of the output shaft **20** extending into the cylinder **11** is slidably engaged with a central through bore **10***a* formed through the piston **10**, and a slide key **23** fixed to the output shaft near its inner end is slidably engaged in a key groove **10***b* formed in the wall of the bore **10***a* in the longitudinal direction thereof. Accordingly, the piston **10** can slide axially within the cylinder **11** independently of the output shaft **20** but is caused to rotate unitarily with the shaft **20** about its axis.

A screw plug **24** is screwed into the piston **10** at its end near the inner end of the output shaft **20** thereby to close the end of the bore **10***a* and thereby to completely isolate from each other the cylinder chambers A and B on opposite sides of the piston **10** within the cylinder **11**. In addition, packings such as O-rings **25** are provided at appropriate parts to ensure tightness against leakage of the working fluid supplied into the cylinder **11**.

The shape of the aforementioned cam groove **17** formed in the outer cylindrical surface of the piston **10** will now be described in conjunction with FIG. **2**, which is a development into a plan view of the cylindrical outer surface of the piston **10**. The cam groove **17** is made up of straight grooves **17***a* through **17***f* consecutively joined in zigzag formation at bends spaced apart by $\pi D/6$ around the outer circumference πD of the piston **10**.

The above mentioned groove parts **17***a* through **17***f* are respectively of straight form, and the cam groove **17** is of zigzag configuration made up of groove parts **17***a*, **17***c*, and **17***e* inclined in one direction and groove parts **17***b*, **17***d*, and **17***f* inclined in an opposite direction, these groove parts of different inclination being alternately disposed in continuously joined arrangement. At the bends in this zigzag groove formation, there are formed guide groove parts **26***a* through **26***f* into which the cam follower **18** is introduced for the purpose of causing the piston **10** to rotate in the same direction. The part of the outer cylindrical surface of the piston **10** in which the groove parts are formed is of somewhat smaller diameter then the parts thereof near the upper and lower ends thereof in contact with the inner wall surface of the cylinder **11**.

The configuration of the cam groove parts **17***a* through **17***f* and the guide groove parts **26** will now be considered in detailed with reference to FIG. **2**. Points **02**, **04**, and **06**, on line E and points *o***1**, *o***3**, and *o***5** on line F indicate the relative center positions of the cam follower **18** when the piston **10** is at its highest position and at its lowest position (as viewed in FIG. **1**), respectively. Lines G and H are imaginary lines positioned at a specific distance above and below the lines E and F, respectively.

Lines T**1** through T**6** are respectively the centerlines of the zigzag grooves **17***a* through **17***f*, which have widths slightly greater than the diameter of the cam follower **18**. The intersections with the line E or F of the extensions of the centerlines T**1** through T**6** in the direction opposite to the direction (arrow C direction in FIG. **2**) for causing the piston **10** to rotate are here designated by reference characters *o***1** through *o***6**. Furthermore, the intersections with the centerlines T**2**, T**3**, ... T**1**, T**6** of vertical lines drawn toward the centerlines T**2**, T**3**, ... T**6**, T**1** from the intersections *o***1** through *o***6** are here designated by reference characters *s***1**, *s***2**, ... *s***5**, *s***6**.

The guide groove part **26***a* between the groove parts **17***a* and **17***b* has a contour determined by the envelope line of the movement of the cam follower **18** as it is caused to move along the centerline T**1** to the point *o***1** and further caused to descend vertically to the point *s***1**. The groove parts **17***a* and **17***b* are contiguously joined to and communicate with this guide groove part **26***a*. The contours of the guide groove parts **26***b*, **26***c*, ... **26***f* are similarly determined. The points o**1** and o**6** are at positions dividing the outer circumference of the piston **10** into six equal divisions, these positions being offset respectively to the left of the points at which the nearest pair of groove parts intersect.

Next, the operation of the actuator of the above described construction will be described. In FIG. **1**, the solenoid **27** is deenergized, and a port **16***a* of the four-way valve **16** is connected to the pipe lines **14** and **15**. Accordingly, the working fluid such as compressed air or oil is supplied through the pipe line **14**, a throttle valve **29**, and port **12** to the chamber A of the cylinder **11**, and the piston **10** descends under the guidance of the cylinder **11** and the output shaft **20**. When the piston **10** is at its lowest position, the cam follower **18** is positioned within the guide groove part **26***a*.

When the solenoid **27** is energized, the four-way valve **16** operates to connect its port **16***b* to the pipe lines **14** and **15**. Accordingly, the working fluid is conducted through the pipe line **15** and, passing by a throttle valve **28**, is supplied through the port **13** into the cylinder chamber B. Consequently, the piston **10** starts to ascend. On one hand, as the piston **10** rises, the working fluid filling the chamber A is discharged through the port **12** and the pipe line **14**. The velocity of movement of the piston **10** can be suitably set by adjusting the variable throttling valves **28** and **29**.

Assuming that the cam follower **18** starts its operation from the point o**1**, the vertical surface of the guide groove part **26***a* being guided the cam follower **18**. Since the point o**1** is offset to the left (as viewed in FIG. **2**) from the intersection of the centerlines T**1** and T**2**, the cam follower **18** always contacts and presses against the inclined wall surface of the groove part **17***b* as a result of the rise of the piston **10**. Consequently, as the piston **10** continues to rise, it rotates in the arrow C direction, its inclined groove part **17***b* being guided by the cam follower **18**.

As the piston **10** reaches its highest position determined by the cylinder **11**, the cam follower **18** slides along the groove part **17***b* and enters the guide groove part **26***b*, at which position the piston **10** has rotated 60° from its position indicated in FIG. **1**. This rotation of the piston **10** is transmitted by way of the slide key **23** to the output shaft **20**, whereby the output shaft **20** rotates **60** degrees together with the piston **10**.

When, with machine in this operational state, the solenoid **27** is again deenergized, the direction of flow of the working fluid within the pipe lines **14** and **15** is reversed, and working fluid is supplied to the chamber A to impart a force urging the piston **10** to move downward. The piston descends vertically, the vertical surface of the guide groove part **26***b* being guided by the cam follower **18**, which then comes into pressing contact with the inclined wall surface of the groove part **17***c* adjacent to the groove part **17***b*.

Accordingly, as the piston **10** continues to descend, it rotates in the same direction as in the above described case, its inclined groove part **17***c* being guided

by the cam follower **18.** When the piston **10** reaches its lowest position determined by the cylinder **11,** the cam follower **18,** guided along the groove part **17***c*, enters into the guide groove part **26***c*, whereupon the piston **10** has been rotated a further 60 degrees from its rotational position corresponding to its highest position.

As is apparent from the above description, by repeatedly rendering the solenoid **27** into energized and deenergized states, the flow direction of the working fluid through the pipe lines **14** and **15** is alternately reversed, and the piston undergoes a repetition of a rising stroke and a descending stroke and, at the same time, is rotated through a constant 60° of angle in the same direction for each stroke. The rotation of the piston **10** is transmitted to the output shaft **20,** which thereby is rotated intermittently in the same direction through a constant angle each time, that is, as highly precise indexing is carried out.

In the above described embodiment of the invention, the guide groove parts **26***a* through **26***f* are provided at positions dividing the circumference of the piston **10** into six equal intervals, and the output shaft **20** is caused to rotate in the same direction by increments of **60** degrees of angle as the piston **10** undergoes repeated ascending and descending strokes. The number of these guide groove parts is not necessarily limited to six, however. That is, by using *n* guide groove parts disposed at equally spaced intervals, it is possible to make the rotational angle of the output shaft **20** resulting form one stroke of the piston **10** equal to 360°/n.

Furthermore, by disposing the guide groove parts at positions, not with equal spacing, but with unequal spacing, the output shaft **20** can be caused to undergo intermittent rotation strokes varying angles as a result of the stokes of the piston **10.** It will be observed that since the cam groove **17** is formed continuously around the outer peripheral surface of the piston **10,** the number of the guide groove parts, that is, the number of bends in the cam groove, is always an even number.

In the case where, in forming the guide groove parts at the bends in the cam groove **17,** the direction of extension of the inclined groove part is made opposite to that in the above described embodiment, the output shaft **20** is rotated through constant angle intervals only in directions opposite to that mentioned above as the piston **10** undergoes ascending and descending strokes. Furthermore, since each stroke of the piston **10** is restricted between the lines E and F in FIG. **2** by the longitudinal dimension of the cylinder **11,** the forming of each guide groove part **26** with a further elongation of the extension part of the inclined groove part will have no deleterious effect whatsoever on the operation of the actuator.

A second embodiment of the unidirectional rotation actuator according to the invention will now be described in conjunction with FIG. **3,** in which parts which are the same as those in FIG. **1** are designated by like reference numerals and characters. Detailed description of these parts will not be repeated.

In this second embodiment, a cam groove **42** of the same or similar contour as the cam groove **17** in the first embodiment is formed in the inner wall surface of the lower half part of a cylinder **41.** A cam follower **43** engaged with this cam groove **42** is embeddedly fixed at its root end to the outer cylindrical surface of a piston **40** near the lower end thereof, this piston **40** being slidably provided within the cylinder **41.**

A guide groove part **44** at the lower side of the cam groove **42** is extended to the lower end of the cylinder **41** in order to facilitate the forming of the cam groove **42** and to facilitate the engagement of the cam follower **43** with the cam groove **42** at the time the piston **40** is fitted into the cylinder **41.**

The operation of the actuator in this second embodiment thereof is similar to that in the preceding first embodiment. That is, a solenoid is repeatedly energized and deenergized to changeover the four-way valve **16** thereby the repeatedly reverse the direction of flow of a working fluid through pipe lines **14** and **15.** As a result, the piston **40** undergoes repeated ascending and descending strokes relative to an output shaft **20** and the cylinder **41,** whereby the output shaft **20** is rotated intermittently in one direction through a constant angle for each piston stroke.

While, in the above described first and second embodiments, the cylinder **11** (or **41**) is stationary, and the piston **10** (or **40**) is driven in up-and-down movement to drive the output shaft **20** in intermittent rotation, it is also possible to provide an actuator in which the shaft **20** is stationary, and the cylinder **11** (or **41**) is caused by the reciprocating motion of the piston **10** (or **40**) to undergo intermittent rotation through specific angular increments.

One embodiment of a changeover valve device in which the actuator of the invention is applied will now be described, the fundamental operation of this device being first considered in conjunction with FIGS. **4A** through **4F.** This changeover valve device **50** is provided with two flow inlets **51** and **52** and four flow outlets **53, 54, 55** and **56.**

Initially, this device **50** is in the state indicated in FIG. **4A,** that is, the state wherein the flow inlets **51** and **52** are shut off from the flow outlets **53, 54, 55** and **56.** Next the device **50** assumes the state indicated in FIG. **4B** wherein the flow inlet **51** is communicated with the flow outlet **53,** and the first fluid entering through the inlet **51** is discharged through the outlet **53.** Then the device **50** assumes the state indicated in FIG. **4C** wherein it is changed over so that the inlet **51** is communicated with the outlet **54,** and, at the same time, the inlet **52** communicates anew with the outlet **53.** Through the outlet **54,** the first fluid entering through the inlet **51** is discharged, while through the outlet **53,** a second fluid entering through the inlet **52** is discharged.

Similarly, when the changeover valve device is in the state indicated in FIG. **4D,** the inlet **51** is communicated with the outlet **55,** and the inlet **52** is communicated with the outlet **54.** In the state indicated in FIG. **4E.** the inlet **51** is communicated with the outlet **56,** while the inlet **52** is communicated with the outlet **55.** Further, in the state indicated in FIG. **4F,** only the inlet **52** is communicated with the outlet **56.**

In this manner, the changeover valve device **50** is successively changed over in the sequence indicated in FIGS. **4A** through **4F,** whereby the flow inlet **51** is switched and successively communicated with the flow outlets **53, 54, 55,** and **56** in that order, while, at the same time but with a lag of one step, the flow inlet **52** is switched and successively communicated with the flow outlets **53, 54, 55,** and **56.** When the valve device in the state indicated in FIG. **4F** is further changed over, the device assumes the original state indicated in

FIG. 4A, and the inlets 51 and 52 are both cut off from the outlets 53, 54, 55, and 56.

A specific embodiment of structure of the valve device 50 for accomplishing the above described changeover operation will now be described, reference being made to FIGS. 5 through 8, in which parts which have the same functions as those of FIGS. 1 and 4A through 4F are designated by the same reference numerals and letters. The valve device 50 has a valve casing structure 61 of substantially the shape of a hollow cylinder with open ends closed by cover members 62 and 63 secured thereto. A tubular member 64 is fixed at one end to the cover member 62 and extends coaxially into the interior of the valve casing structure 61. This tubular member 62 has a number of holes 65 in its cylindrical wall and has a closed inner end. A pipe line 66 for supplying a first fluid communicatively connected to the other outer end of this tubular member 64.

A valve member 67, in which the tubular member 64 is fitted, is fitted in turn in the valve casing structure 61 in a manner permitting it to slide and rotate freely relative to the casing structure 61 and the tubular member 64. This valve member 67 at its middle portion facing the tubular member 64 has an internal annular recess 68 and, furthermore, at its right end (as viewed in FIG. 5) facing the valve casing 61 has an external annular recess 69. The recess 68 communicates with a flow inlet 51 by way of the holes 65 in the tubular member 64 unrelatedly to the sliding position described hereinafter of the valve member 67, while the recess 69 is communicating with a flow inlet 52 provided in the valve casing 61. To the inlet 52, there is connected a pipe line 70 for supplying a second fluid.

Around the outer peripheral part of the valve casing structure 61, there are provided four flow outlets 53, 54, 55, and 56 with respective centerlines spaced apart by 60 degrees of angle as shown in FIG. 6. The outlets 53 and 55 are disposed on the same circumference of the casing structure 61, while the outlets 54 and 56 are disposed on the same circumference of the casing 61 at a position offset in the axial direction of the casing by a sliding distance described hereinafter of the valve member 67 from the positions of the outlets 53 and 55. Pipe lines 71, 72, 73, and 74 are respectively connected to these outlets 53, 54, 55, and 56.

The valve member 67 further has a port 75 for communicating with the recess 68. When the valve member 67 is in the position indicated in FIG. 5, the port 75 is coincident with the outlet 55 as indicated in FIGS. 6 and 7, and the pipe line 66 and the inlet 51 are communicating with the outlet 55 and the pipe line 73. In the valve member 67, furthermore, there is formed a communication passage 76 extending in the longitudinal direction of the valve member 67 for the purpose of communicating with the recess 69 but avoiding the recess 68 as shown in FIGS. 6 and 8. In addition, holes 77 and 78 are formed to provide communication between the outer periphery of the valve member 67 and the communication passage 76.

These holes 77 and 78 are provided on the centerline of the valve member 67 and are spaced apart by a specific distance in the longitudinal direction of the valve casing structure 61. As indicated in FIG. 8, one of the holes, 77, is tightly closed by the inner peripheral surface of the valve casing 61, but the other hole 78, coincides with the outlet 54, and the pipe lines 70 and 72 are communicative. That is, in the state of the valve device shown in FIG. 8, the inlet 51 is communicative with the outlet 55, while the inlet 52 is communicative with the outlet 54, the changeover valve device being in the state indicated in FIG. 4D.

To the right end part of the valve member 67, there is fixed a piston 79 corresponding to the piston 10 shown in FIG. 1. The piston 79 is slidably and rotatably fitted in the valve casing structure 61 corresponding to the cylinder 11 in FIG. 1 and has around its outer cylindrical surface a zigzag groove 80 similar to that indicated in FIG. 2, and a cam follower 81 embeddedly secured to and projecting inward from the inner wall surface of the valve casing 61 is engaged with this groove 80. To the right end (as viewed in FIG. 8) of the piston 79, there is fixed a disc 83, to the center of which, there is fixed one end of a rod 82 coaxially alined with the valve casing 61 and passing rotatably and slidably through a center hole in the cover member 63. A cap cover 84 is secured to the cover member 63 and houses a hollow shaft 86 supporting integrally a ring-shaped member 85, the hollow shaft 86 being rotatably supported and coaxially alined with the rod 82. A key 87 secured to the other end of the rod 82 is engaged with a key slot 88 formed in the hollow shaft 86 in the longitudinal direction thereof, whereby the rod 82 can slide axially relative to the hollow shaft 86 but rotates unitarily therewith.

With the various parts of this valve in the state described above and indicated in the figures, compressed air is supplied from an air compressor 89 by way of a four way electromagnetic valve 90 into a pipe line 91 and then through a passageway 92 in the cover member 63 into a chamber I to the right (as viewed in FIG. 5) of the piston 79 in the casing 61. The valve member 67, the piston 79, and other parts are then in a state wherein they have rotated to a certain angular position and have moved to their most left ward positions relative to the valve casing 61 and the tubular member 64.

With the various parts in the above described states, in the above described states, the valve device 50 is in the state indicated in FIG. 4D, that is, in FIG. 9A, wherein the port 75 communicating with the inlet 51 is coincidently alined with the outlet 55, and the port 78 communicating with the other inlet 52 is coinciding with the outlet 54. Consequently, a first fluid being supplied through the pipe line 66 is being discharged through the pipe line 73, while a second fluid being supplied through the pipe line 70 is being discharged through the pipe line 72.

When the above mentioned four-way electromagnetic valve is changed over, the compressed air from the air compressor 89 this time is conducted through a pipe line 93 and, passing through a passageway 94 in the cover member 62, is supplied into a chamber J to the left of the valve member 67 in the valve casing 61, while the pipe line 91 is opened to the outside atmosphere. Consequently, as compressed air is thus supplied into the chamber J, the valve member 67, the piston 79, and like parts are moved toward the right. During this movement, the piston 79 rotates in the clockwise direction as viewed in FIG. 6, its cam groove 80 being guided by the cam follower 81, and thus rotates through 60° of angle, as described hereinbefore, while the valve member 67 and the piston 79 move to their most right positions.

During this operation, the port 75 communicating with the inlet 51 and the ports 77 and 78 communicat-

ing with the inlet **52** move along the intermittent line in FIG. **9A** (in which, for the sake of convenience, the intermittent line is drawn to trace a movement once in the longitudinal direction and then in rotation through 60° of angle). As a consequence, the ports **75, 77** and **78** reach the positions indicated in FIG. **9B**, where the port **75** coincides with the outlet **56,** and the port **77** coincides with the outlet **55.** Accordingly, the first fluid from the pipe line **66** is discharged through the pipe line **74,** while the second fluid from the pipe line **70** is discharged through the pipe line **73,** through which the first fluid was being discharged until now. That is, the valve device assumes the state indicated in FIG. **4E.**

Thereafter, when the four-way electromagnetic valve **90** is further changed over to supply compressed air through the pipe line **91** to the chamber I and simultaneously to oen the pipe line **93** to the atmosphere, the valve member **67,** the piston **79,** and the like are forced to move leftward and, at the same time, are rotated through 60° of angle in the same direction, the cam groove **80** being guided by the cam follower **81.** During this movement, the ports **75, 77,** and **78** move as indicated by intermittent line in FIG. **9B**, and only the port **78** coincides with the outlet **56.** Consequently, from the valve device **50,** only the second fluid is discharged through the pipe line **74,** through which the first fluid was being discharged until now, and the first fluid is shut off by the valve device. That is, the valve device assumes the state indicated in FIG. **4F.**

Thereafter, by changing over the four-way electromagnetic valve **90,** the valve member **67** is moved alternately toward the right and left and, moreover, rotated clockwise by increments of a constant angle thereby to change over the positions of the ports **75, 77,** and **78** relative to the outlets **53, 54, 55,** and **56,** the valve device thereby being changed over successively into the states indicated in FIGS. **4A, 4B, 4C,** . . . . . .

A projection **95** provided on the hollow shaft **86** rotating intermittently together with the rod **82** as the valve device is changed over activates limit switches **96** mounted at equally spaced (60°) positions on the cover member **63,** whereby the changeover positions thereof are verified. In addition, through an open window **97** provided in the cover cap **84,** the rotational position of the ring-shaped member **85,** that is, the rotational position of the valve member **67,** can be verified by visual observation.

By intercoupling the limit switches **96** and the four-way electromagnetic valve **90** and setting the four-way valve **90** so that it is automatically changed over after a specific constant time from the instant of activation of each switch **96,** the above described valve device can be automatically changed over successively and continuously to the six states indicated in FIGS. **4A** through **4F.**

Furthermore, by changing the construction of the valve member **67,** and valve casing **61** housing this valve member, it is possible to provide a valve mechanism accomplishing the same operation described above merely by rotating the valve member **67** by increments of a constant angle or merely by causing it to slide by increments of a constant distance.

As described above, by using the unidirectional rotation actuator of the invention, it is possible to realize changeover valve devices capable of cyclically effecting various valve changing over modes of operation in prescribed sequences.

A changeover valve mechanism of the above described character can be advantageously applied to wide variety of uses, one embodiment of which is a liquid chemical sprinkling system for sprinkling a large-scale agricultural farm as described below with reference to FIG. **10.** In FIG. **10,** parts which are the same or similar to those in FIGS. **5** and **6** are designated by like reference numerals.

In this system, water stored in a water tank **100** is supplied by way of a pipe line **101** to a mixing device **102.** Separately, a liquid chemical stored in a liquid chemical tank **103** is pumped by a pump **104** to the mixing device **102,** where the liquid chemical and the water are mixed with a prescribed constant ratio. The resulting liquid mixture is sent through a main line **106** and then conducted from the main line **106** to a plurality of branched pipe lines **66***a* through **66***d*, being supplied to first flow inlets **51***a* through **51***d* of changeover valve devices **50***a* through **50***d* shown in FIG. **5.**

On one hand, compressed air from an air compressor **107** is supplied through a main line **108** and further through a plurality of branch lines to the second flow inlets **52***a* through **52***d* of the valve devices **50***a* through **50***d*. At this time, these valve devices **50***a* through **50***d* are in the state indicated in FIG. **4B**, and diluted chemical liquid conducted through pipe lines **66***a* through **66***d* to first flow inlets **51** (as shown in FIG. **5**) is conducted by way of outlets **53** to pipe lines **71***a* through **71***d* to be sprinklers **109** connected to the outer ends of these pipe lines **71***a* through **71***d*.

After a specific sprinkling time, the valve devices **50***a* through **50***d* are switched to the state indicated in FIG. **4C**, whereupon pipe lines **66***a* through **66***d* are communicated with pipe lines **72***a* through **72***d*, while pipe lines **70***a* through **70***d* are communicated with pipe lines **71***a* through **71***d*. Consequently, the diluted chemical liquid is sprinkled by sprinklers (not shown) connected to the pipe line **72***a* through **72***d*. On one hand, compressed air is introduced into the interior of the pipe lines **71***a* through **71***d*, and the chemical solution remaining within these pipe lines **71***a* through **71***d* is discharged and sprinkled toward the outside by way of sprinklers **109.** Thus, undesirable occurrences such as the dripping of residual chemical solution within the pipe lines **71***a* through **71***d* onto the areas around the sprinklers **109** and the resulting supply of the chemical solution in large quantity to cause crop damage are prevented.

Furthermore, after sprinkling for a specific time through sprinklers connected to the pipe lines **72***a* through **72***d*, the valve devices **50***a* through **50***d* are changed over to the state indicated in FIG. **4D**. As a result of this valve switching, the pipe lines **66***a* through **66***d* are communicated with pipe line, **73***a* through **73***d*, and pipe lines **70***a* through **70***d* are communicated with pipe lines **72***a* through **72***d*. Accordingly, sprinkling of the chemical solution is started anew through sprinklers connected to the pipe lines **73***a* through **73***d*, and residual solution within the pipe lines **72***a* through **72***d* is discharged by compressed air.

In this manner, the valve devices **50***a* through **50***d* are changed over successively from the state indicated in FIG. **4B** to that indicated in FIG. **4F**, whereby the chemical solution conducted to the pipe lines **66***a* through **66***d* is switched and supplied in the sequence through pipe lines **71***a* through **71***d*, **72***a* through **72***d*, **73***a* through **73***d*, and **74***a* through **74***d* and sprinkled by

sprinklers connected to these pipe lines. At the same time, compressed air introduced through pipe lines **70***a* through **70***d* is supplied to the pipe lines immediately after the supply of the chemical solution is shut off, and residual solution within the pipe lines **71** through **74** is disposed of by discharging and spreading.

When the valve devices **50***a* through **50***d* in the state indicated in FIG. **4F** are further switched, the valve devices **50***a* through **50***d* assume the state indicated in FIG. **4A**, and the pipe lines **66***a* through **66***d* and **70***a* through **70***d* are both fully shut off from communication with the pipe lines **71** through **74**.

By stopping both the pump **104** and the compressor **107**, the operation of sprinkling the chemical solution is completed.

By the use of the above described system for sprinkling chemical liquids, the piping for discharging and disposing of residual chemical liquid remaining within the pipe lines to which supply of chemical liquid has been shut off can be remarkable simplified.

Further, this invention is not limited to these embodiments but various variations and modifications may be made without departing from the scope and spirit of the invention.

What we claim is:

1. A unidirectional rotation actuator comprising:

a cylinder of hollow cylindrical shape;

a piston fitted within the cylinder so as to be rotatable about and slidable along the axis of the cylinder relative thereto;

means for driving the piston in reciprocating sliding motion relative to the cylinder in the axial direction thereof;

said piston having an outer cylindrical surface facing the inner cylindrical surface of the cylinder, one of said surfaces having a cam groove therein of a zigzag shape including in continuous alternate combination, substantially straight groove parts of the same inclination in respectively different directions joined end-to-end at bends in the zigzag shape; and

a cam follower member fixed to and projecting from the other of said surfaces into engagement in the cam groove,

said cam groove having guide groove portions respectively provided at said bends, each of said guide groove portions being so shaped that, in concurrence with sliding in one direction of the piston relative to the cylinder, the cam follower member is permitted to advance further along the centerline of one straight groove part of the cam groove beyond the intersection of said centerline and the centerline of the succeeding adjacent straight groove part and, then, in concurrence with sliding of the piston in the direction opposite to said one direction, is permitted to undergo displacement in said sliding direction thereby to abut relatively against one wall surface of said adjacent straight groove part, and

said piston being intermittently rotated in each sliding motion in one direction and the reverse direction.

2. A unidirectional rotation actuator as set forth in claim **1**, further comprising a rotatable shaft mounted centrally in said piston and extending axially thereof such that the rotatable shaft rotates unitarily with said piston and is slidable relative to the piston but not slidable relative to the cylinder.

3. A unidirectional rotation actuator as set forth in claim **1**, further comprising a valve structure fixed to the piston and having a specific number of valve ports, fluid outlets with which at least one of said specific valve ports communicates in concurrence with unitary rotation through a specific angle of the valve structure with the piston, and means for supplying a fluid to be distributed to the fluid valve ports.

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