

APPARATUS FOR GENERATING RECIPROCATORY MOTION

This invention relates to apparatus for generating linear or more usually reciprocatory motion. It is of particular application to devices for actuating fluid control valves in which operation of the valve between its open and closed positions requires a 90° turn of a shaft

in one direction or the other, but is of application in other situations where a limited stroke reciprocatory drive is required.

Valve actuators are known of the kind in which an hydraulically or pneumatically activated piston is used to drive a shaft in either one direction or the other through an operative stroke of, say, 90°, via a rack and pinion mechanism. It is usual to employ a double-ended arrangement using two racks working on opposite sides of a common pinion so as to provide a balanced driving couple. Such devices are made in a variety of sizes and are expensive to produce because of the high grade components needed to deal with the hydraulic or pneumatic pressures and torques involved. It is an object of this invention to provide an actuator which can be produced at less cost by employing a system of construction using fewer parts and parts of a nature lending themselves to ease of manufacture by repetition techniques and a simplified system of assembly. By "repetition techniques" in this context are meant plastic moulding, die casting, pressing and the like processes.

Such actuators may be of the so-called double acting kind, in which hydraulic or pneumatic pistons are used to drive the mechanism in both directions or of the kind sometimes called "fail safe" in which the mechanism is driven in one direction hydraulically or pneumatically but is driven in the other direction by spring return means. This invention is applicable to both such kinds as will appear hereinafter.

According to the invention there is provided apparatus for generating linear motion comprising a body, at least one cylinder mounted on and projecting from one side of said body, a piston in said cylinder, an actuating beam extending from said piston into said body and having movable surfaces in sliding contact with fixed surfaces in said body to define a bearing by which said piston and

actuating beam are guided in linear motion, and means for introducing pressure fluid into said cylinder to actuate said piston, said means including:

(a) a fixed port opening through a fixed surface of said linear bearing and communicating within a duct formed within said body by which pressure fluid may be supplied;

(b) a movable port opening through a movable surface of said linear bearing and communicating through a duct formed within said actuating beam and through the crown of said piston with the space in said cylinder above said piston; and

(c) a resilient sealing member between said fixed and moving surfaces of said linear bearing which member is arranged to maintain a fluid-tight communication between the fixed port and the movable port over their range of relative movement.

According to a preferred form of the invention, the actuating beam carries a rack gear, said central body carries an output shaft and a pinion on said output shaft engages with said rack gear to provide a reciprocatory rotational output from said shaft in response to reciprocating movements of said actuating beam. Said rack gear and said pinion are preferably housed within said central body. In a preferred arrangement said rack gear is mounted on a face of said actuating beam with the pitch line of said gear substantially coincident with the axis of said piston.

In a preferred form of mechanism according to the invention there is provided a central body, and a second cylinder is located on the opposite side of said body from said one cylinder, a piston is provided within each of said cylinders and a common actuating beam extends through said body and rigidly interconnects said pistons, ducts extend in opposite directions within said actuating beam and each communicate through a respective piston crown with the cylinder space above the respective piston, said

ducts each communicating through a respective port with a fluid supply zone, whereby supply of fluid to one cylinder and then the other reciprocates said pistons and actuating beam. The ducts may be divided from one another by an
5 intervening wall within the actuator beam and movable ports located on opposite sides of the actuator beam lead to the ducts which extend from the intervening wall in opposed directions to the crowns of their respective pistons. Where a spring return means is fitted it
10 may comprise a multiple spring pack housed in a cylinder mountable on said central body in opposition to the cylinder containing said piston.

In a preferred arrangement according to the preceding paragraph said spring return means includes spring
15 retraction means for holding said spring means retracted from its normal working position. Said retraction means may comprise cam means mounted on the outer end of the cylinder housing said spring pack and rotatable to withdraw the inner end of said spring pack and hold it in
20 an inoperative position.

In order that the invention may be better understood and carried into effect one construction thereof will now be described with reference to the accompanying drawings, in which:

25 Figure 1 is an exploded view of a double-acting valve actuator according to the invention;

Figure 2 is a side elevation of the valve actuator of Figure 1;

Figure 3 is a view of the actuator of Figure 1 but with one half of the central body removed and the cylinders in section;

Figure 4 is a cross-section on the centre line of Figure 3;

Figure 5 is a sectional view of a portion of the device illustrated in Figures 1 to 4;

Figure 6 is a diagram of the operational sequence of the actuator with one half of the central body removed and the piston and actuating beam in section;

Figure 7 is a sectional view of a spring return assembly for an actuator of the kind shown in Figures 1 to 6;

Figure 8 is an exploded view of the spring return assembly of Figure 7; and

Figure 9 is an operational sequence diagram similar to Figure 6 but with a spring return assembly fitted.

The actuator as seen in Figures 1 and 2 comprises a central body 1 on which are mounted two opposed cylinders 3A and 3B. Passing through the central body and journaled in it is an actuating shaft 4. In the end of the shaft 4 there is a male or female drive member 4A of suitable size and shape to engage a corresponding drive member on the valve with which the actuator is to be used. It is an advantage of the invention that male or female ended drive pinions may be used as the customer application may require. The shaft 4 emerges through a squared boss 1A moulded integrally with the central body 1. The central body 1 is moulded in two symmetrical halves which are held together by clamping screws 5A and 5B and corresponding screws inserted from the other side and located in the diagonally opposite corners.

Looking now at Figures 3 and 4 it will be seen that within the central body 1 and the cylinders 3A and 3B

there is located an actuator beam 2 which terminates at its ends in pistons 2A and 2B which are located in the respective cylinders 3A and 3B. The pistons are grooved and within the grooves are sealing rings 7A and 7B which
5 form a sliding fluid-tight fit within their respective cylinders.

It will be noted that the actuating beam 2 which is of generally rectangular cross section is set eccentrically with respect to the cylinder bores in
10 cylinders 3A and 3B. On its upper face as viewed in Figures 1 and 3 it carries a rack gear 8 and the eccentricity of beam 2 enables the pitch line of this rack gear to coincide with the axis through the pressure centres of the pistons, ie. the central axis through the
15 pistons. There is thus no turning moment in the pistons and no tendency therefore for the pistons to jam in their cylinders when under load.

The rack gear 8 engages a sequential gear 9 on the output drive shaft 4. Thus movement of the actuator beam
20 2 from its extreme position on the left, as seen in Figure 2 to its extreme position on the right will turn the output shaft through one quarter turn. Such a movement is required to turn a valve from its "on" position to its
"off" position or vice versa.

25 It will be seen from Figure 4 that the shaft 4 is journaled on either side of the pinion 9 at 10A and 10B in each of the two halves of which the central body 1 is constructed.

It will also be seen from Figure 4 that the actuator
30 beam 2 is supported in a linear bearing whose stationary surface is defined by a channel formed between the two component halves of the central body 1. Its lower surface contacts the floor of the channel which is made of a shallow "V" profile, the surface of the actuator beam
35 being of corresponding cuneiform profile. This configuration facilitates the manufacture of the mechanism

by die-casting techniques to a high standard of accuracy. Furthermore, in use the component of thrust on the rack gear 8 normal to the axis of the pistons 7A, 7B opposes lateral thrust on the actuating beam 2 at fluid supply zones (described below) to maintain the actuating beam in correct alignment.

Within the beam 2 two bores 11A and 11B (Figure 5) are provided extending from an intervening wall in the centre of the beam in opposite directions to the respective piston crowns. These bores are tapered off towards the centre of the beam in an overlapping manner so as each to communicate with a port 12A and 12B on a side wall of the beam on the opposite sides thereof which face the side walls of the channel housing beam 2. The arrangement will be better understood from Figure 5 which is a cross-sectional view of the centre portion of beam 2 on the line IV-IV of Figure 3.

At their other ends the bores 11A and 11B communicate through ports in the crowns of the respective pistons with the cylinder spaces above the pistons.

The ports 12A and 12B communicate with fluid supply ducts 14A and 14B provided in the respective halves of the central body 1 by way of connecting zones formed between the side faces of the actuator beam and the opposed walls of the channel in which the beam operates. These zones are defined by sealing rings seated into the walls of the channel as shown in Figure 4 at 15A and 15B and in dotted outline in Figure 2. The sealing rings, which are shown as of circular section plastics materials but may be of any suitable material and cross section are seated in grooves formed in the channel walls in an elongated oval configuration and surround an area equivalent to or slightly greater than that swept by the ports 12A and 12B in moving over their operative strokes. They form a seal between the respective channel wall and the corresponding side face of the actuator beam, the face of the actuator

beam making sliding contact therewith. A shallow chamber is thus formed between the face of the actuator beam and the inner wall of the channel from which the face of the actuator beam has a small clearance.

5 It will now be seen that the introduction of hydraulic or pneumatic pressure fluid through say duct 14A (solid arrows in Figure 6) will supply the connecting zone within sealing ring 15A and thus through port 12A and bore 11A to the space above piston head 2A in cylinder 3A, thus
10 forcing the piston and actuator beam 2 to the left (as seen in Figure 6) thus turning the pinion 9 clockwise through one quarter turn. Air from cylinder 2B vents through passage 11B and through duct 14B (dotted arrows in Figure 6). The drive in the reverse direction is
15 obviously achieved by introducing pressure fluid through duct 14B and venting air through duct 14A.

It will further be seen that the only access to the spaces above the piston heads in cylinders 3A and 3B for pressure fluid is through the ports and bores in the
20 piston heads and actuator beam. Thus the cylinders themselves can be made without connecting ports or valves and lend themselves to manufacture by simple methods. As shown in the construction illustrated the cylinders are made as drawn sheet metal cups. They are held in place by
25 lips retained in grooves formed in the central body. Thus the lip 16B formed on cylinder 3B is held within a groove formed by the inturned flange 17B formed on the central body. An "O" ring 18 provides a resilient support between the central body and the lip 16B. However, it will be
30 noticed that this support is not required to withstand the pressure of actuating fluid. The cylinder 3A is similarly mounted. This arrangement has the advantage that the interior of the body containing the rack and pinion is not pressurised with working fluid and so there are no
35 problems of fluid leakage as the rack and pinion wear in service and no reason for the pinion to become ejected.

Furthermore, the arrangement is inherently safe against dismantling the halves of the body by withdrawing the bolts connecting them because if this is attempted the pressure at the connecting zone and within the cylinder will be relieved before the cylinders are released from their captive position within the body.

The arrangement so far described is a so-called double acting valve actuator since actuation is carried out by hydraulic or pneumatic pressure in both directions. A spring return system can, however, be substituted for one of the hydraulic cylinders as will now be described with references to Figures 7, 8 and 9.

The spring pack is housed in a cylinder 20 provided at its open end with a folded lip 21, corresponding to the lips 16A and 16B on the cylinders 3A and 3B, and by which it may be mounted in the assembly in the same manner as has been described above. However, the cylinder 20 is deeper than cylinders 3A and 3B so as to accommodate compression springs of a suitable length. A group, in this case of six such springs 22 is provided grouped around a central stem to be described later. At one end the springs bear upon the closed end of the cylinder 20. At their other end they bear upon a pressure plate 23 which, in operation will bear upon the end face of a piston head (2A or 2B according to which end of the assembly the spring pack is fitted) at one end of actuator beam 2. The ends of the springs are located on bosses 24, 25 etc., spaced around the pressure plate. Their ends may also be guided between the pins of a spider which may be made of plastics material, the central core of which is fitted over a central boss 28 set up on the pressure plate 23. The number of springs is not material but should be such as to provide a balanced force on pressure plate 23.

Set in the closed end of cylinder 20 and located against turnout eg., by a key and keyway is a bush 30 through which passes a central tubular stem 31. Outwardly

of bush 30 is a cam 32, the cam face 32A of which bears on a cam face 30A formed on the outer face of bush 30. Cam 32, the purpose of which will be described later is held beneath the head 31A of the central stem 31 and is located on the stem by means of a keyway (not shown) engaging on a key formed on the central stem so that when the cam 32 turns, the stem turns with it. A conical spring 34, which is located at its inner end in a groove 35 formed on the central stem by means of a washer and circlip, and at its outer end on the end face of cylinder 20 maintains the cam faces 30A and 32A in contact.

The inner end of stem 31 is internally screw threaded at 36 and a screw 37 is inserted through the inner face of the boss 28 to retain the pressure plate 23 within the assembly. A clearance hole 38 allows freedom for the pressure plate 23 to move inwardly with the inner end face of boss 28 riding over a reduced diameter end portion on stem 31. Thus when the spring pack is in use the pressure plate 23 can be moved against the pressure of springs 24, 25 etc., to permit actuation of the valve actuator and can be returned by the pressure of the springs when the hydraulic actuating pressure is released or fails.

The purpose of the cams 30, 32 is to facilitate assembly of the spring pack in an actuator assembly of the kind described above.

The assembly of a "double acting" actuator is carried out as follows. First the piston rings 7A and 7B are mounted on the piston heads 2A and 2B. The sealing rings 18 and 19 are mounted on the end flanges of cylinders 3A and 3B and the cylinders are engaged over the piston heads. The assembly thus formed is then set into one half of the central body 1 with the sealing rings 18 and 19 engaged in the grooves provided for them. The sealing ring 15B will have been previously located in its groove. The shaft 4 is then introduced through bearing 10A, the teeth of segmental gear 9 being in engagement with the teeth of

rack gear 8 in the appropriate location according to the position of actuator beam 2. For this to be done correctly the beam is preferably placed at one end of its travel, ie. with one piston head at the top of its stroke, so that the gear 9 may be placed at its corresponding starting point. The other half of the central body, with its sealing ring 15A already in position is then engaged over the assembly so far brought together, the bearing 10B engaging over the shaft 4 and the cylinder, flanges 16A and 16B being received into the grooves of the central body part. Bolts 5A and 5B can then be inserted and the structure bolted together by bolts from both sides as above described.

For this operation to be carried out without difficulty when a spring pack as above described is substituted for one of the cylinders 3A, 3B the cams 30 and 32 are brought into use. By turning the stem head 31A by the appropriate amount, say half a turn, the cams are brought to their high level so that the stem 31 is drawn up (to the left as seen in Figure 6) and the springs are compressed so that the piston head at that end of the device can enter the cylinder 20 by an appropriate amount and without load. When the assembly has been completed the cam 32 can then be returned to its original position, thus releasing the spring assembly into its normal working position. The cam 32 is likewise used to withdraw the springs when the device is disassembled.

The operational diagram is shown in Figure 9 and it will be noted that supply of working fluid through port 12A causes the beam 2 to be moved through its working stroke. Release of the air pressure allows springs 22 acting through thrust plate 23 to return beam 2 to its rest position.

Hydraulic or pneumatic connections can be made to the device by means of nipples provided at 40 and 41 (Figure 4) which, it will be noted are included one on each body

half. Dowels may be provided, suitably placed to locate the body halves together one such being shown at 42 (Figure 4).

It will be appreciated that the construction described and illustrated is in virtually all respects symmetrical so that production by die-casting and moulding techniques involves a minimum of tooling. Thus the two halves of the central body are entirely alike so that only one die is required. Similarly the actuator beam/piston item is a single moulding which may be made in suitable plastics material. The rack gear 8 is preferably metallic and attached to the actuator beam in any suitable manner, it may be moulded integrally therewith. Again, the same central body and actuator beam/piston parts may be used even though a spring return assembly is to be employed. Furthermore, since the arrangement provides access to both ends of the actuating shaft 4 different drive sockets or male connections may be provided at either end to adapt the device to a variety of valves which it is required to operate.



CLAIMS:

1. Apparatus for generating linear motion comprising a body, at least one cylinder mounted on and projecting from one side of said body, a piston in said cylinder, an actuating beam extending from said piston into said body and having movable surfaces in sliding contact with fixed surfaces in said body to define a bearing by which said piston and actuating beam are guided in linear motion, and means for introducing pressure fluid into said cylinder to actuate said piston, said means including:

(a) a fixed port opening through a fixed surface of said linear bearing and communicating within a duct formed within said body by which pressure fluid may be supplied;

(b) a movable port opening through a movable surface of said linear bearing and communicating through a duct formed within said actuating beam and through the crown of said piston with the space in said cylinder above said piston; and

(c) a resilient sealing member between said fixed and moving surfaces of said linear bearing which member is arranged to maintain a fluid-tight communication between the fixed port and the movable port over their range of relative movement.



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2. Apparatus according to claim 1, wherein said actuating beam carries a rack gear, said body carries an output shaft and a pinion on said output shaft meshes with said rack gear to provide a rotational output to said shaft in response to linear movement of said actuating beam.

3. Apparatus according to claim 2, wherein said rack gear and pinion are housed within said body.

4. Apparatus according to claim 3, wherein said rack gear is mounted on said actuating beam with the pitch line of said rack gear substantially coincident with the axis of said piston.

5. Apparatus according to claim 4, wherein said actuating beam is generally rectangular in cross-section and has an upper face to which the rack gear is fixed, and first and second side faces and a lower face each constituting moving surfaces of said linear bearing, said movable port being formed in one of said side faces.

6. Apparatus according to claim 5, wherein the lower face of said actuating beam is cuneiform and slides over a correspondingly grooved face forming part of said fixed surface of the linear bearing whereby the separating force at the rack gear normal to the axis of the piston produces a reaction on the lower face of the beam that opposes the



lateral thrust on said actuating beam at said fluid supply zone to maintain said actuating beam in correct alignment.

7. Apparatus according to any preceding claim wherein said sealing means is supported in a recess in said fixed surface of said linear bearing and makes wiping contact with said moving surface.

8. Apparatus according to any preceding claim, wherein a peripheral sealing member of resilient material secured to the piston maintains a fluid-tight seal between the piston and the cylinder and urges the cylinder into alignment with the piston.

9. Apparatus according to claim 8, wherein the cylinder is a metal cup having a formation on its rim which mates with a formation in the body to locate the cylinder relative to the body, and a resilient annular support between the cylinder and the body permits mechanical movement therebetween within a range of float but is not exposed to fluid pressure.

10. Apparatus according to any preceding claim, wherein a second cylinder is located on the opposite side of said body from said one cylinder, a piston is provided within each of said cylinders and a common actuating beam extends through said body and rigidly interconnects said pistons, ducts extend in opposite directions within said actuating beam and each communicate through a respective piston crown with the cylinder space above the respective piston, said ducts each communicating through a respective port with a fluid supply zone, whereby supply of fluid to one cylinder and then the other reciprocates said pistons and actuating beam.



- 11. Apparatus according to claim 10, wherein the ducts are divided from one another by an intervening wall within the actuator beam and movable ports located on opposite sides of the actuator beam lead to the ducts which extend from the intervening wall in opposed directions to the crowns of their respective pistons.
- 12. Apparatus according to any of claims 1 to 9, further comprising spring return means mounted on said body in a position opposed to said cylinder said spring return means providing a return stroke for said actuating beam.
- 13. Apparatus according to claim 12, wherein said spring return means comprises a multiple spring pack housed in a second cylinder mountable on said body in opposition to the cylinder containing said piston.
- 14. Apparatus according to claim 13, wherein a piston is provided within each cylinder and said actuating beam extends through said body and rigidly interconnects said pistons, said spring pack including a thrust plate which



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locates in force-transmitting relationship with a piston in the second cylinder.

15. Apparatus according to claim 12, wherein said spring return means includes spring retraction means for holding said spring means retracted from its normal working position.

16. Apparatus according to claim 15, wherein said retraction means comprises cam means mounted on the outer end of the cylinder housing said spring pack and rotatable to withdraw the inner end of said spring pack and hold it in a position clear of the piston withdrawal datum position.

17. A fluid operated piston-rack rotary actuator substantially as hereinbefore described with reference to and as illustrated in Figures 1 - 5 of the accompanying drawings.

18. Apparatus according to claim 14 provided with a spring pack substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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