April 11, 1961

H. M. GEYER
HYDRAULIC ACTUATOR WITH LOAD PROPORTIONAL LOCKING MEANS

2,979,034

Filed Feb. 18, 1959

3 Sheets-Sheet 1

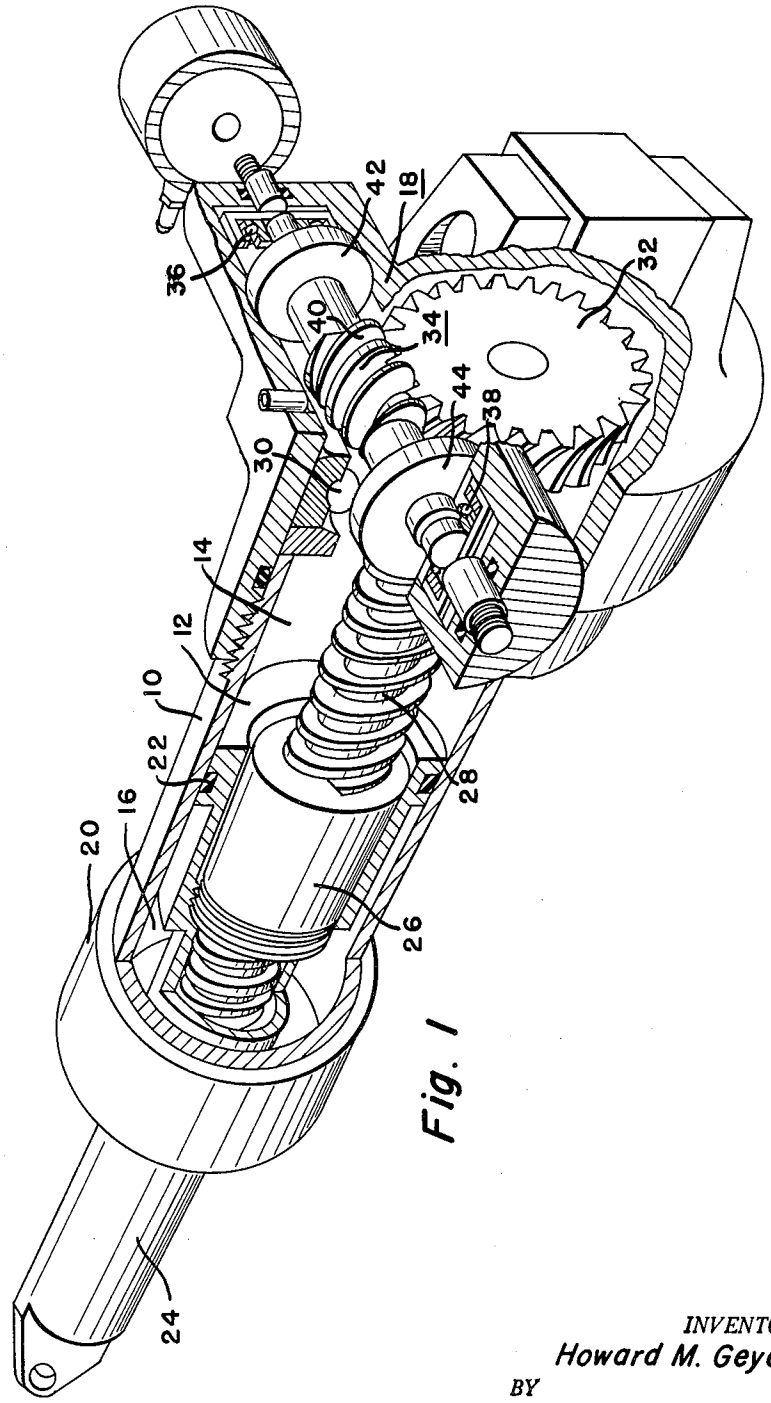


Fig. 1

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3 Sheets-Sheet 2

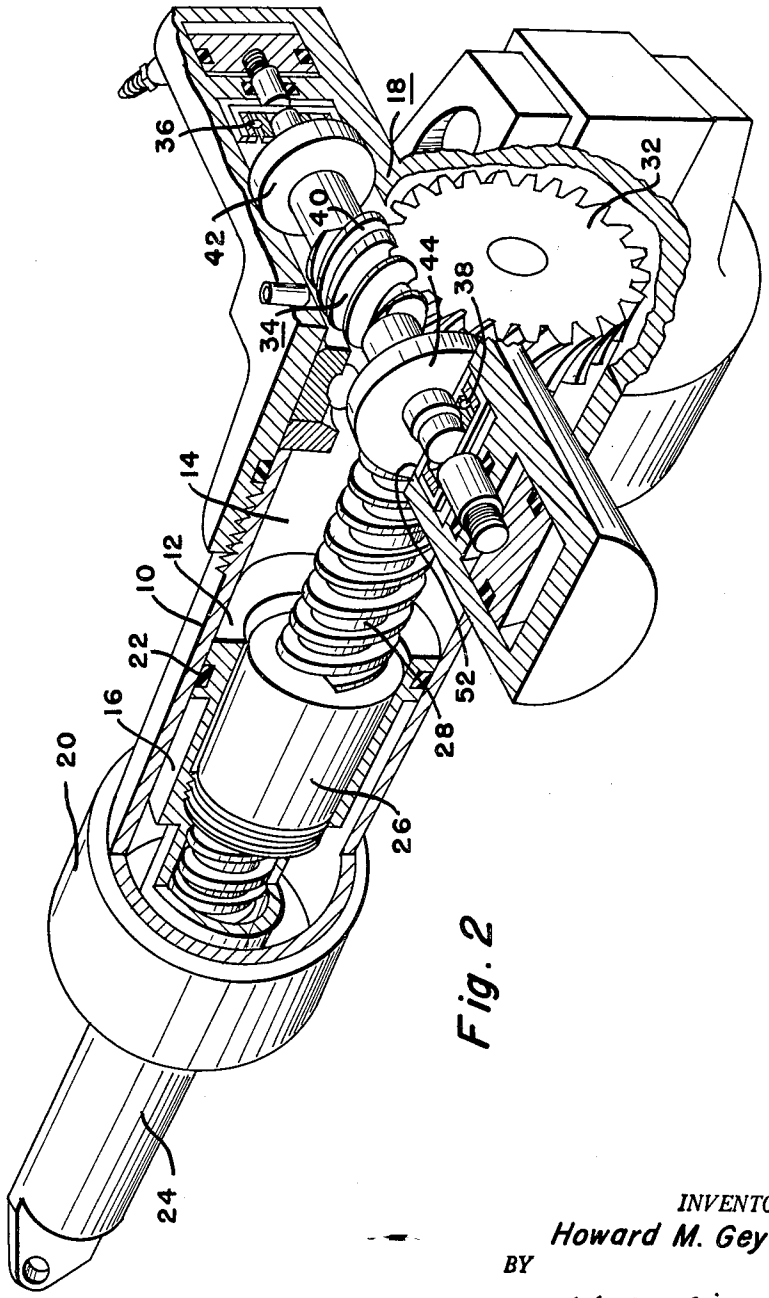


Fig. 2

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3 Sheets-Sheet 3

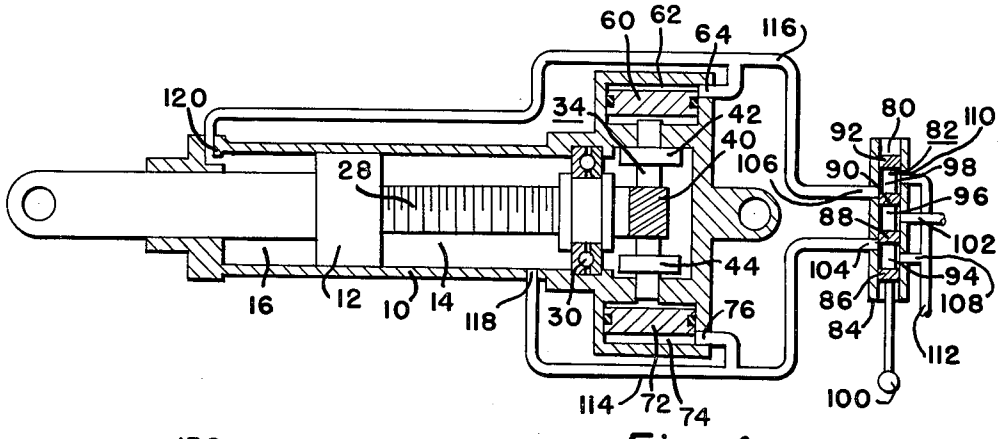


Fig. 4

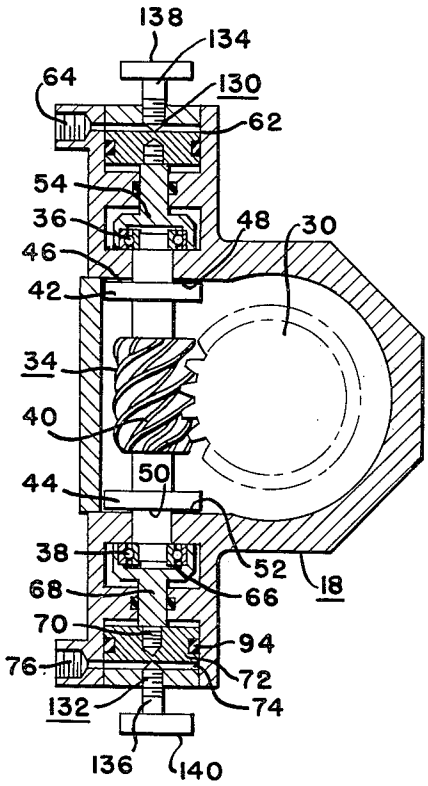


Fig. 5

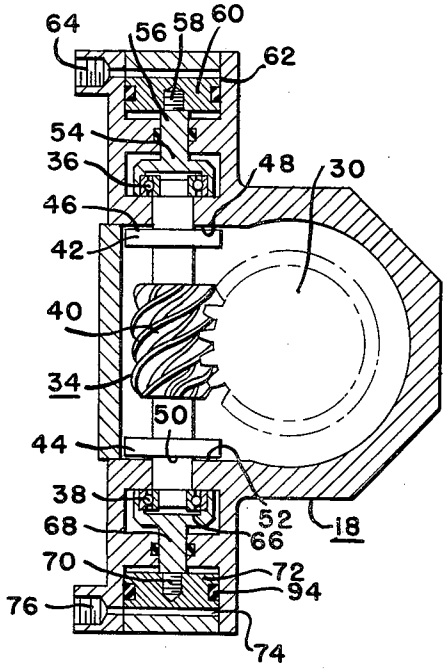


Fig. 3

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HYDRAULIC ACTUATOR WITH LOAD PROPORTIONAL LOCKING MEANS

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20 Claims. (Cl. 121—40)

This invention pertains to fluid pressure operated actuators, and particularly to a linear actuator having bidirectional load sensitive locking means.

Heretofore, actuators have been designed including unidirectional load sensitive locking means of the manually engageable type, for preventing actuator movement in one direction due to external loading. An actuator of this type is shown in my Patent 2,859,640. In addition, actuators have been designed wherein the unidirectional load sensitive locking means are automatically released by servo mechanism simultaneously with the application of pressure fluid to the actuator cylinder in opposition to the external load, such an actuator being shown in copending application Serial No. 551,801, filed December 8, 1955, in the name of Howard M. Geyer et al. and assigned to the assignee of this invention, now Patent No. 2,879,746. The present invention relates to an actuator construction including load sensitive bidirectional locking means which can be released by either a servo mechanical or manual means, together with an "inching" control system for controlling the rate of actuator movement.

Accordingly, among my objects are the provision of an actuator assembly including bidirectional load sensitive locking means; the further provision of an actuator assembly including bidirectional load sensitive locking means and servo means for releasing the locking means; the further provision of an actuator assembly of the aforesaid type including manual means for releasing the bidirectional locking means; and the still further provision of a control system for an actuator of the aforesaid type including means for controlling the rate of actuator movement by controlling the pressure in the servo actuated lock releasing means.

The aforementioned and other objects are accomplished in the present invention by incorporating a rotatable and axially movable worm shaft assembly which carries a pair of friction locking elements that are engageable with brake surfaces so as to lock the actuator against movement in both directions due to external loading of the actuator. Since the braking force of the locking means is proportional to the load, the locking means operate as a self-energizing brake. Specifically, the actuator includes a cylinder having a reciprocable piston disposed therein capable of fluid pressure actuation in both directions. The piston divides the cylinder into an extend chamber and a retract chamber, and includes an extending rod portion adapted for connection to any suitable load device. The piston, by virtue of its connection to the load device, is restrained against rotation, and carries a nut. The nut threadedly engages a reversible Acme screw that is rotatably journalled within the cylinder. Accordingly, it is apparent that piston reciprocation is dependent upon and effects rotation of the screw shaft, and therefore if rotation of the screw shaft is prevented, the actuator piston will be locked against movement.

The locking means include the rotatable and axially movable worm shaft alluded to hereinbefore, the worm portion of which meshes with a worm wheel attached to

the screw shaft. The worm shaft assembly includes a pair of spaced flanges, or collars, constituting friction brakes, the outer surfaces of which are engageable with shoulders of the actuator cylinder assembly. The worm shaft is bearing mounted adjacent its end within the actuator cylinder. The outer races of the bearing for rotatably journalling the worm shaft assembly with the cylinder are connected to brake release pistons disposed within brake release cylinders in the cylinder assembly.

Each brake releasing cylinder is connected to a conduit through which fluid under pressure is supplied to one of the actuator chambers. The supply and drain of fluid under pressure to the actuator chambers is controlled by a four-way valve. Accordingly, whenever fluid under a pressure potential sufficient to exceed the external load is applied to an actuator chamber in opposition to the external load, the load on the worm shaft assembly will be removed by the pressure in the actuator chamber.

To control the rate of actuator movement when the actuator is externally loaded, either in tension or compression, the pressure potential of the operating fluid is slowly increased so as to relieve the locking means proportional to the lock releasing pressure. In instances when the actuator is to be moved in assistance of the external load, when the braking force of the locking means has been reduced so that the brake torque is less than that necessary to restrain the worm shaft assembly against rotation, the actuator will begin to move. Thus, by controlling the lock releasing pressure, the rate at which the actuator moves can be regulated.

In a modified embodiment, the brake releasing cylinders embody manually operable screw devices which can engage the lock releasing pistons so as to center the worm shaft assembly in the absence of fluid pressure application to the lock releasing cylinders.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein preferred embodiments of the present invention are clearly shown, and wherein like numerals denote like parts throughout the several views.

In the drawings:

Figure 1 is a perspective view, partly in section and partly in elevation, depicting an actuator constructed according to one embodiment of the present invention.

Figure 2 is a view similar to Figure 1 with the locking means engaged due to a tension load.

Figure 3 is a transverse sectional view of the actuator locking means.

Figure 4 is a schematic view of the novel actuator control system of the present invention.

Figure 5 is a sectional view, depicting a modified actuator construction.

With particular reference to Figure 1, an actuator is shown including a cylinder 10 having disposed therein a reciprocable piston 12. The piston 12 divides the actuator cylinder into an extend chamber 14 and a retract chamber 16. One end of the cylinder 10 is closed by a head cap assembly 18 connected thereto by a screw threaded coupling, the other end of the cylinder 10 being closed by a tail cap 20, likewise connected thereto by a screw threaded coupling. The piston 12 includes sealing means 22 engageable with the inner periphery of the cylinder 10 and also includes an integral axially extending hollow piston rod 24 which projects through the tail cap 20. The outer end of the piston rod 24 is closed, and is adapted for connection to a movable load device, not shown, which load device prevents rotation of the piston. The head cap assembly 18 of the cylinder is designed for attachment to a suitable fixed support which precludes movement thereof.

The piston 24 is threadedly connected to a nut 26, such

that the nut 26 reciprocates with the piston 12. An Acme screw shaft, or member, 28 is rotatably journalled within the head cap assembly 18 of the actuator by ball bearing means 30. A worm wheel 32 is rigidly attached to the inner end of the Acme screw shaft 26 within the head cap assembly 18. Since the piston 12 carries the nut 26, reciprocation of the piston 12 is dependent upon and effects rotation of the screw shaft 28. Moreover, since the worm wheel 32 is rigidly connected to the screw shaft 28, rotation of the screw shaft will impart rotation to the worm gear.

With reference to Figures 1 and 3, a worm shaft assembly 34, the axis of which is transverse to the axis of the screw shaft 28, is rotatably journalled within the head cap assembly 18 by ball bearing assemblies 36 and 38. The worm shaft assembly includes a worm 40 meshing with the worm wheel 32 and a pair of spaced thrust collars 42 and 44. The worm and worm wheel are reversible, that is, during rotation of the worm wheel 32 in the clockwise direction as viewed in Figure 1, the worm shaft assembly 34 will rotate in the clockwise direction, and during rotation of the worm wheel 32 in the counterclockwise direction as viewed in Figure 1, the worm shaft assembly 34 will rotate in the counterclockwise direction. Obviously, if the worm shaft assembly 34 is restrained against rotation, the worm wheel 32 cannot rotate, and hence the screw shaft 26 cannot rotate and the piston 12 cannot reciprocate.

With particular reference to Figure 3, the thrust collar 42 has a braking surface 46 engageable with surface 48 of a shoulder integral with a head cap assembly 18. The thrust collar 44 has a braking surface 50 engageable with a surface 52 of the shoulder integral with the head cap assembly 18. Counterclockwise rotation of the worm wheel 32 exerts an axial thrust on the worm shaft assembly 34 to the left as viewed in Figure 3, thereby tending to urge the braking surface 50 and the thrust collar 44 into engagemnet with the surface 52. Conversely, rotation of the worm wheel 32 in the clockwise direction exerts an axial thrust on the worm shaft assembly 34 to the right thereby tending to move the braking surface 46 of the collar 42 into engagement with the surface 48. Since the worm wheel 32 moves in the counterclockwise direction during extending movement of the piston, the thrust collar 44 constitutes the extend locking means, and the thrust collar 42 constitutes the retract locking means.

The outer race of the bearing 36, which is of the combined thrust and radial type, is carried by an annulus 54 having an integral rod portion 56 with a threaded end 58. The threaded end 58 is attached to a lock release piston 60 disposed within a lock release cylinder 62. The cylinder 62 communicates with a lock release port 64.

Similarly, the outer race of the combined thrust and radial bearing 38 is carried by an annulus 66 having an integral rod projection 68 with a threaded end 70, the threaded end 70 being connected to a lock release piston 72 disposed within a cylinder 74. The cylinder 74 is connected to a lock release port 76. If both of the cylinders 62 and 74 are subjected to hydraulic fluid under pressure, the worm shaft assembly 34 will be centered through the bearing assemblies 36 and 38 as depicted in Figure 3, in which position the bidirectional locking means are released. The cylinders 62 and 74 and the pistons 60 and 72, respectively, constitute servo means for releasing the locking means. that is, neither the extend locking collar 44 nor the retract locking collar 42 engages its braking surface 52 or 48, respectively. However, if neither lock release cylinder 62 or 74 is subjected to fluid under pressure, and the actuator is externally loaded, the worm shaft assembly will be moved axially to either the left or the right depending upon the direction of the load. Thus, for a tension load, as depicted in Figure 2, the worm shaft assembly 34 will move axially downward so that the surface 50 of the collar 44 engages the surface 52. The brake torque is directly proportional to the load, and since the area of the surfaces 50 and 52 in engagement with each other results in a braking torque that exceeds the torque due to the tension load, the actuator will be locked against movement. Conversely, if the actuator is subjected to a compression load, the worm shaft assembly 34 will move axially upward so that the surface 46 of the collar 42 engages the surface 48. The braking torque for locking the actuator against a compression load is likewise directly proportional to the applied load.

With particular reference to Figure 4, the control system for the actuator will be described. The control system includes a four-way valve 80 comprising a reciprocable plunger 82 disposed for movement within a valve casing 84. The plunger 82 is formed with spaced lands, 86, 88, 90 and 92, annular grooves 94, 96 and 98 being formed by the lands. The valve plunger 82 includes a rod portion 100 constituting a handle for manual operation.

The valve casing 84 is formed with an inlet port 102, a pair of control ports 104 and 106 and a pair of drain ports 108 and 110. The inlet port 102 is connected to a suitable source of hydraulic fluid under pressure, not shown, such as a pump. The drain ports 108 and 110 are connected to a drain conduit 112. The control port 104 is connected to an extend conduit 114 and the control port 106 is connected to retract conduit 116, the conduits 114 and 116 communicating with actuator ports 118 and 120, and to brake ports 76 and 64.

The lands 88 and 90 cooperate with control ports 104 and 106, respectively such that when the plunger 82 is moved upwardly, as viewed in Figure 4, the port 106 will be connected to the pressure supply port 102 while the port 104 is connected to drain. Conversely, when the plunger 82 is moved downwardly, as viewed in Figure 4, the control port 104 is connected to the pressure supply port 112 and the control port 106 is connected to drain. In the neutral position of the valve plunger 82, as depicted in Figure 4, both of the control ports 104 and 106 are connected to drain, and hence the brake release cylinders 62 and 74 are not subjected to pressure, whereupon if the actuator is subjected to an external load, the worm shaft assembly 34 will be moved axially in one direction or the other so as to lock the actuator piston against movement.

Assuming that the actuator is subjected to an external compression load, and is to be retracted, the valve plunger 82 is moved upwardly, as viewed in Figure 4, to connect port 106 to pressure port 102 and connect port 104 to drain. Accordingly, the brake release cylinder 62 will be subjected to pressure, the potential of which is determined by the degree of opening of the port 106 to the pressure port 102. When the pressure potential of the fluid supplied to the brake release cylinder 62 exceeds the external compression load, the worm shaft assembly, constituting the locking means, will be centered thereby permitting the actuator piston to be retracted. If the control valve plunger 82 is moved slowly upward from the neutral position with a compression load, as viewed in Figure 4, the brake release pressure is slowly increased so as to relieve the braking torque proportional to the brake release pressure. When the braking torque is less than that necessary to restrain the worm shaft against rotation the actuator begins to retract, so that by controlling the brake release pressure by throttling the flow through the control ports the rate at which the actuator piston moves can be regulated, and this type of operation is termed "inching."

Assuming that the actuator piston is subjected to an external tension load, if the actuator is to be extended the brake releasing pressure in cylinder 74 must exceed the brake torque imposed on the worm shaft assembly by the tension load. When the braking torque has been reduced to a value less than that necessary to restrain rotation of the worm shaft assembly, the actuator piston will

be extended at a rate determined by the flow of fluid to the control valve assembly.

To effect retract movement of the actuator under tension load, the control valve plunger 82 is moved upwardly so as to connect port 106 to pressure and connect port 104 to drain. The pressure in the retract chamber removes the load from the worm shaft assembly. If the actuator is subjected to compression load, the application of pressure to the extend chamber removes the load from the worm shaft assembly so as to release the locking means.

With reference to Figure 5, a modified actuator assembly is shown wherein each end wall of the brake releasing cylinders 62 and 74 has a threaded opening, 130 and 132 respectively. The threaded openings 130 and 132 receive threaded lock releasing members 134 and 136, respectively, having knurled external heads 138 and 140. In the modified embodiment, the worm shaft assembly 34 can be manually centered by proper adjustment of the threaded brake releasing members 134 and 136. As depicted in Figure 5, the manual lock releasing means are used in combination with the hydraulic lock releasing means so as to facilitate movement of the actuator due to external loads, if necessary, upon failure of the fluid pressure system.

While the embodiments of the invention as herein disclosed constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. An actuator assembly including, a cylinder, a reciprocable piston disposed in said cylinder, a member rotatably journalled in said cylinder and operatively connected to the piston such that piston movement is dependent upon and effects rotation of said member, and self-engageable, bidirectional, load sensitive locking means operatively connected with said member for preventing rotation thereof in either direction so as to prevent movement of said piston in either direction due to an external load.

2. An actuator assembly including, a cylinder, a reciprocable piston therein, a member rotatably journalled in said cylinder and operatively connected to the piston such that piston movement is dependent upon and effects rotation of said member, and releasable, self-engageable, bidirectional, load sensitive locking means operatively connected with said member for preventing rotation thereof in either direction so as to prevent movement of said piston in either direction due to an external load.

3. An actuator assembly including, a cylinder, a reciprocable piston therein, a member rotatably journalled in said cylinder and operatively connected to the piston such that piston movement is dependent upon and effects rotation of said member, self-engageable, bidirectional, load sensitive locking means operatively connected with said member for preventing rotation thereof in either direction so as to prevent movement of said piston in either direction due to an external load, and servo means engageable with said locking means to release said locking means to permit movement of said piston in either direction.

4. An actuator assembly including a cylinder, a reciprocable piston disposed therein, a member rotatably journalled in said cylinder and operatively connected to the piston such that piston movement is dependent upon and effects rotation of said member, self-engageable, bidirectional, load sensitive locking means operatively connected with said member for preventing rotation thereof in either direction so as to prevent movement of said piston in either direction due to an external load, and manual means engageable with said locking means to release said locking means to permit movement of said piston in either direction.

5. An actuator assembly including, a cylinder, a piston reciprocable therein, a screw shaft rotatably journalled in said cylinder and operatively connected to the piston

such that piston movement is dependent upon and effects rotation of said screw shaft, said screw shaft being restrained against axial movement relative to the cylinder, and self-engageable, bidirectional, load sensitive locking means operatively connected with said screw shaft for preventing rotation thereof in either direction so as to prevent movement of said piston in either direction due to an external load.

6. Self-engageable, bidirectional, load sensitive locking means for an actuator having a cylinder, a reciprocable piston disposed in said cylinder capable of fluid pressure actuation in both directions, and a member rotatably supported in said cylinder and operatively connected with said piston such that piston movement is dependent upon and effects rotation of said member, including, a rotatable and axially movable assembly engaging said member whereby rotation of said member in either direction will effect axial movement of said assembly in one direction or the other, said assembly including a pair of spaced thrust collars, and a pair of spaced braking surfaces of said cylinder engageable with said thrust collars when said assembly is moved axially in either direction from a centered position for preventing rotation of said assembly and said member in either direction to prevent movement of said piston in either direction due to an external load.

7. Self-engageable, bidirectional, load sensitive locking means for an actuator having a cylinder, a reciprocable piston disposed in said cylinder capable of fluid pressure actuation in both directions, and a member rotatably supported in said cylinder and operatively connected with said piston such that piston movement is dependent upon and effects rotation of said member, including, a rotatable and axially movable element engaging said member, the axis of said element being transverse to the axis of said member whereby rotation of said member in either direction will effect axial movement of said element in one direction or the other, a pair of spaced thrust collars attached to said element, a brake surface on said cylinder engageable with said thrust collars when said element is moved axially in either direction from a centered position for preventing rotation of said element and said member to prevent movement of said piston in either direction due to an external load.

8. Self-engageable, bidirectional, load sensitive locking means for an actuator having a cylinder, a reciprocable piston disposed in said cylinder capable of fluid pressure actuation in both directions, and a member rotatably supported in said cylinder and operatively connected with said piston such that piston movement is dependent upon and effects rotation of said member, including, a worm gear connected to rotate with said member, a worm shaft engageable with said worm gear, said worm shaft being supported for rotation and axial movement relative to said cylinder whereby upon rotation of said member said worm shaft will move axially in one direction or the other, a pair of spaced thrust collars attached to said worm shaft, and a cooperable braking surface of said cylinder engageable with each of said thrust collars upon axial movement of said worm shaft in either direction from a centered position to prevent rotation of said worm shaft and said worm gear to thereby prevent movement of said piston in either direction due to an external load.

9. The locking means set forth in claim 8 including a pair of spaced combined thrust and radial bearing assemblies for supporting said worm shaft.

10. The locking means set forth in claim 9 wherein each of said bearing assemblies includes inner and outer race members, and wherein the outer race member of each bearing assembly is supported by a reciprocable annulus whereby centering of said annuli will center said worm shaft and release said locking means.

11. A fluid pressure operated actuator including, a cylinder, a reciprocable piston disposed in the cylinder capable of fluid pressure actuation in either di-

rection, a member rotatably supported in the cylinder and operatively connected to the piston such that piston movement effects and is dependent upon rotation of said member, a rotatable and axially movable element engaging said member, and self-engaging, bidirectional, load sensitive locking means cooperable between said element and said cylinder for locking the element and the member against rotation in either direction to thereby lock the piston against movement in either direction due to an external load.

12. A fluid pressure operated actuator including, a cylinder, a reciprocable piston disposed in the cylinder capable of fluid pressure actuation in either direction, a member rotatably supported in the cylinder and operatively connected to the piston such that piston movement effects and is dependent upon rotation of said member, and releasable self-engageable, bidirectional, load sensitive locking means cooperable between said element and said cylinder for locking the element and the member against rotation in either direction to thereby lock said piston against movement in either direction due to an external load.

13. The actuator set forth in claim 12 including servo means engageable with said locking means for releasing said locking means.

14. The actuator set forth in claim 12 including manual means engageable with said locking means for releasing said locking means.

15. A fluid pressure operated actuator including, a cylinder, a reciprocable piston disposed in said cylinder capable of fluid pressure actuation in both directions, a member rotatably supported in said cylinder and operatively connected to the piston such that piston movement effects and is dependent upon rotation of said member, a worm gear attached to rotate with said member, brake means including a worm shaft engaging said worm gear, means supporting said worm shaft for rotation and axial movement relative to said cylinder, a pair of spaced thrust collars attached to said worm shaft, and a pair of spaced surfaces of said cylinder engageable with said thrust collars upon axial movement of said worm shaft in opposite directions from a centered position for restraining rotation of said worm shaft and said member in proportion to an external load acting in either direction on said piston.

16. The actuator set forth in claim 15 wherein the means for supporting said worm shaft for rotation and axial movement comprises a pair of spaced combined radial and thrust bearing assemblies.

17. The actuator set forth in claim 16 wherein said bearing assembly includes inner and outer races and wherein the outer race of each bearing assembly is carried by a reciprocable annulus whereby said brake means can be released to permit movement of the actuator piston in either direction by centering said worm shaft through said annuli.

18. The actuator set forth in claim 15 including a pair of fluid pressure operated brake releasing pistons for centering said worm shaft to release said brake means.

19. The actuator set forth in claim 15 including a pair of manually operable screw devices for centering said worm shaft to release said brake means.

20. A control system for a fluid pressure operated actuator having a cylinder, a reciprocable piston disposed therein, a member rotatably journalled in the cylinder and operatively connected to the piston such that piston movement is dependent upon and effects rotation of said member, self-engageable, bidirectional, load sensitive locking means operatively connected with said member for preventing rotation thereof in either direction so as to prevent movement of said piston in either direction due to an external load, and fluid pressure operated means for releasing said locking means, including, a source of fluid under pressure, and manually operable throttle valve means for controlling the application of pressure fluid to the lock releasing means and to the actuator cylinder whereby the rate of movement of said actuator piston can be regulated by controlling the pressure potential of the fluid applied to the lock releasing means.

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