United States Patent

Cusveller

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[45] **Sept. 5, 1972**

[54] **FLUID OPERATED ACTUATOR FOR MOVABLE MEMBERS**

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[73] Assignee: **Sperry Rand Australia Limited,** Maribymong, Victoria, Australia

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[21] Appl. No.: **73,508**

[30] **Foreign Application Priority Data**

Sept. 25, 1969 Australia 61,402/69

[52] **U.S. Cl.** **91/420,** 91/422, 91/437

[51] **Int. Cl.**.....**F15b 13/042**

[58] **Field of Search**.....91/170, 401, 422, 222, 400, 91/420, 437; 92/65; 137/596.12, 596.13

[56] **References Cited**

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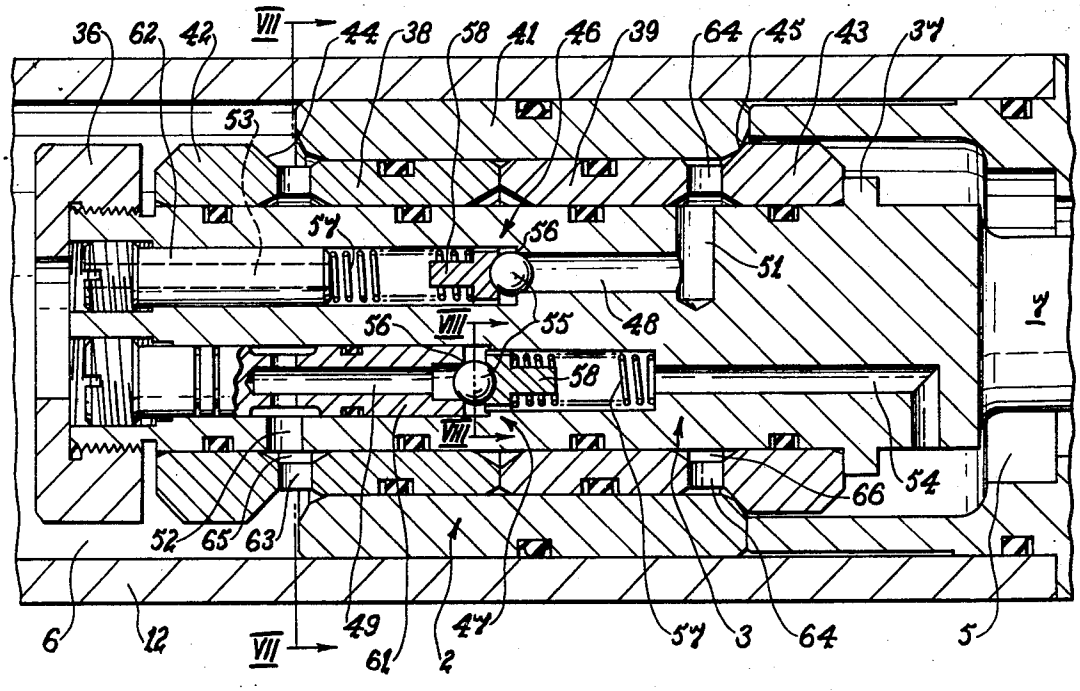
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Primary Examiner—Martin P. Schwadron
Assistant Examiner—Irwin C. Cohen
Attorney—Diller, Brown, Ramik & Holt

[57] **ABSTRACT**

A fluid operated actuator for controlling the movement of a member such as a valve and being connectable into a fluid circuit including pressure operated means for indicating extreme operative positions of the aforementioned member. The actuator including a piston-cylinder assembly, the piston of which is connectable to the aforementioned member, and pressure relief means operative to prevent the pressure acting on the piston reaching a predetermined level which is below that necessary to operate the indicating means. Cut-out means is provided within the piston-cylinder assembly to render the relief means inoperative when the piston reaches or approaches positions corresponding to the aforementioned extreme operative positions of the associated member, so that the pressure acting on the piston is able to rise sufficiently to operate the indicating means.

40 Claims, 24 Drawing Figures



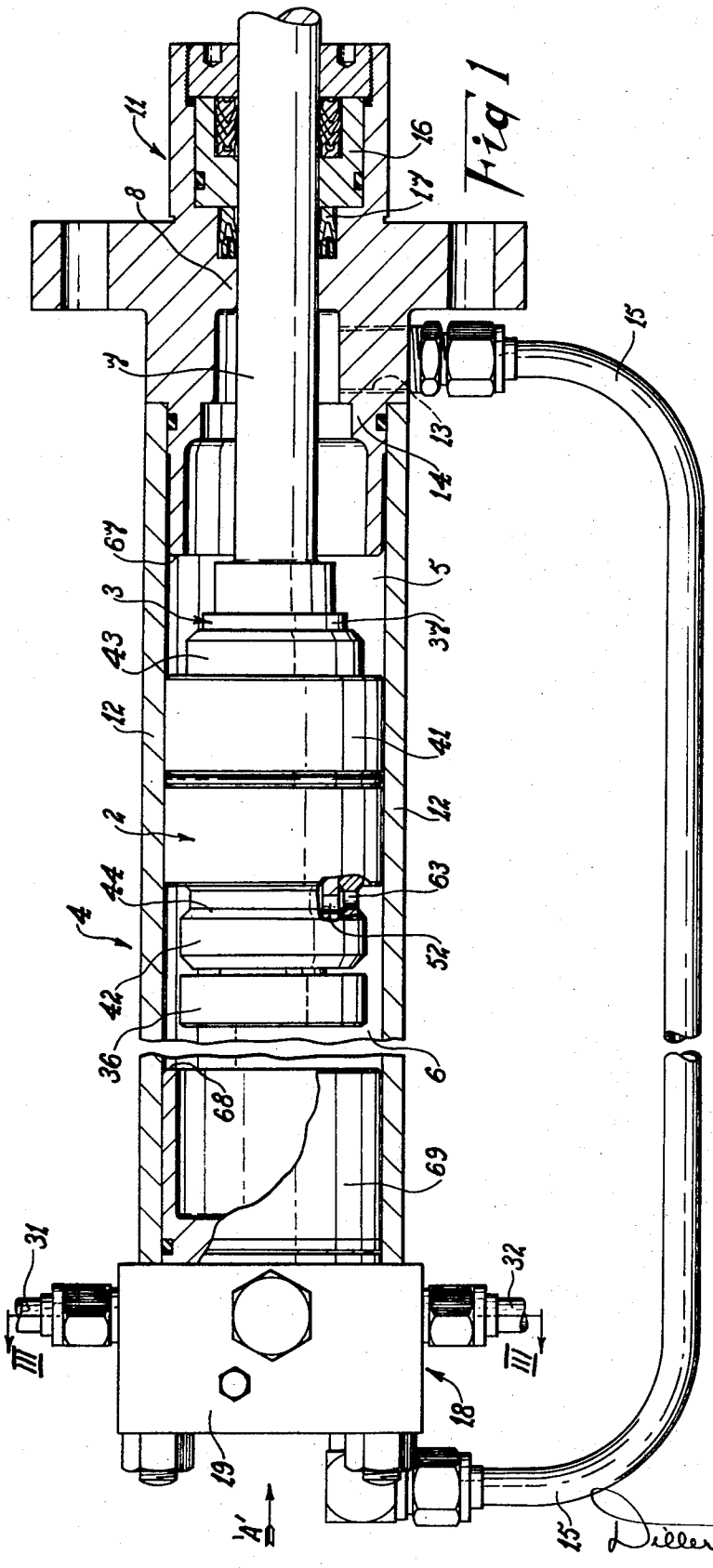


Fig 1

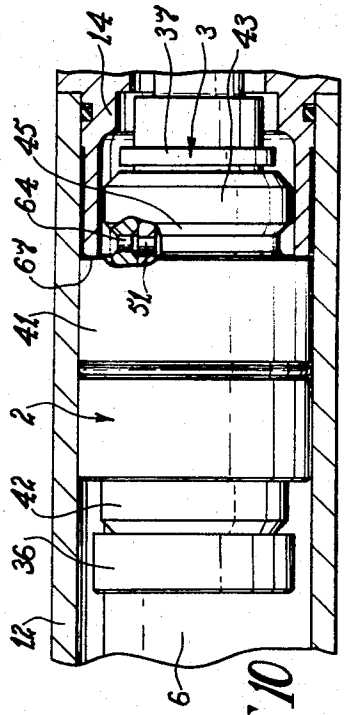


Fig 10

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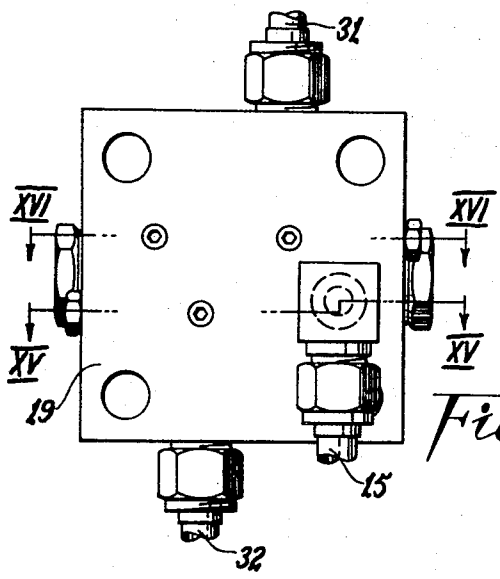


Fig 2

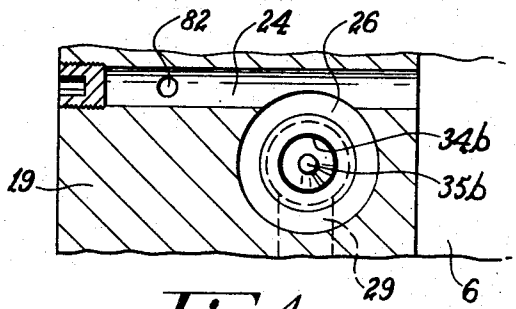


Fig 4

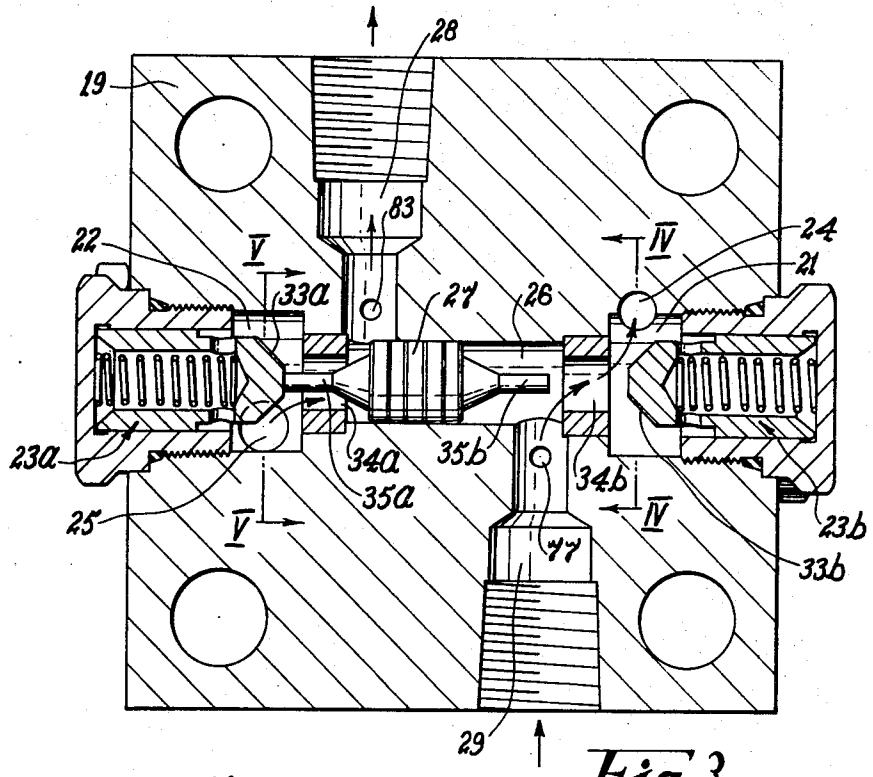


Fig 3

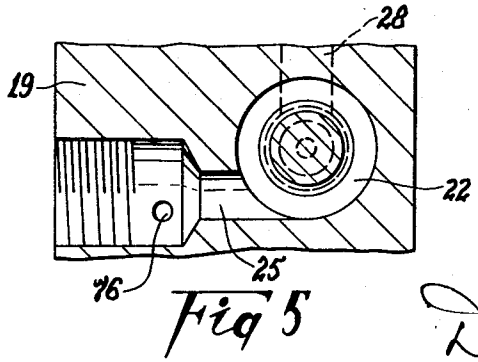


Fig 5

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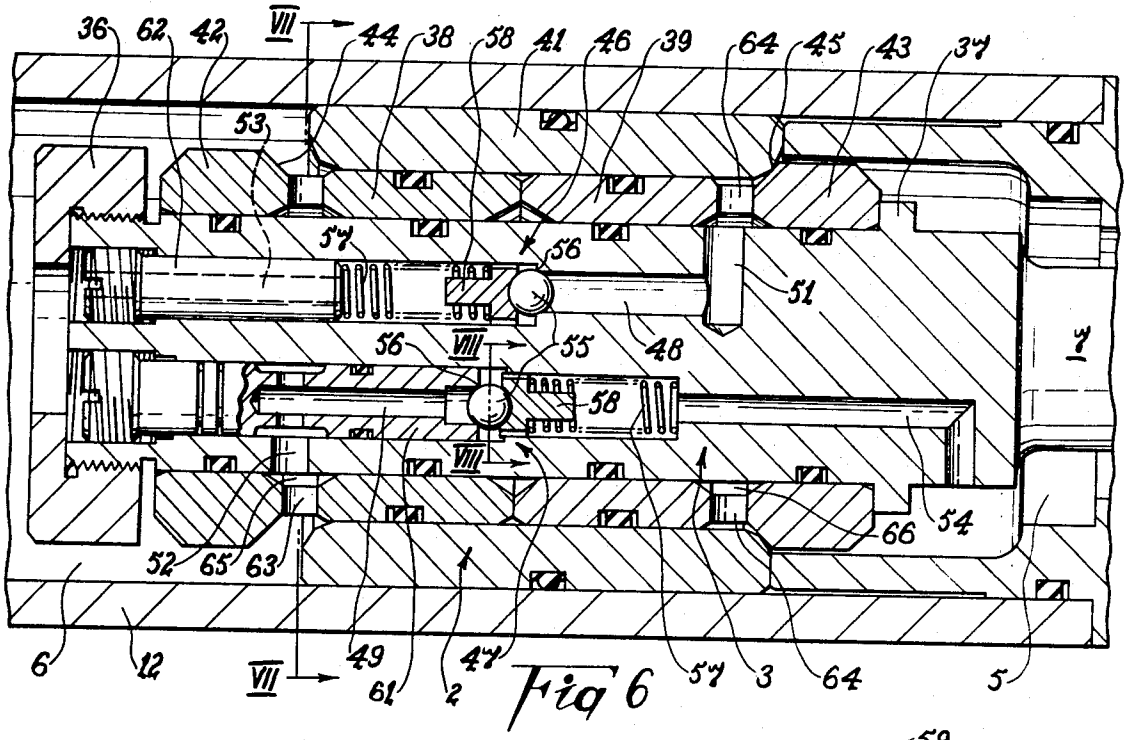


Fig 6

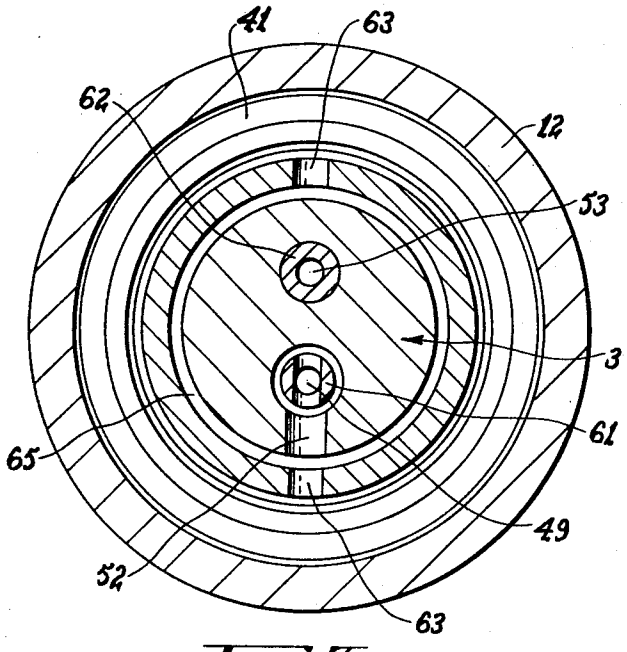


Fig 7

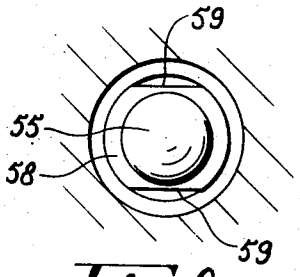


Fig 8

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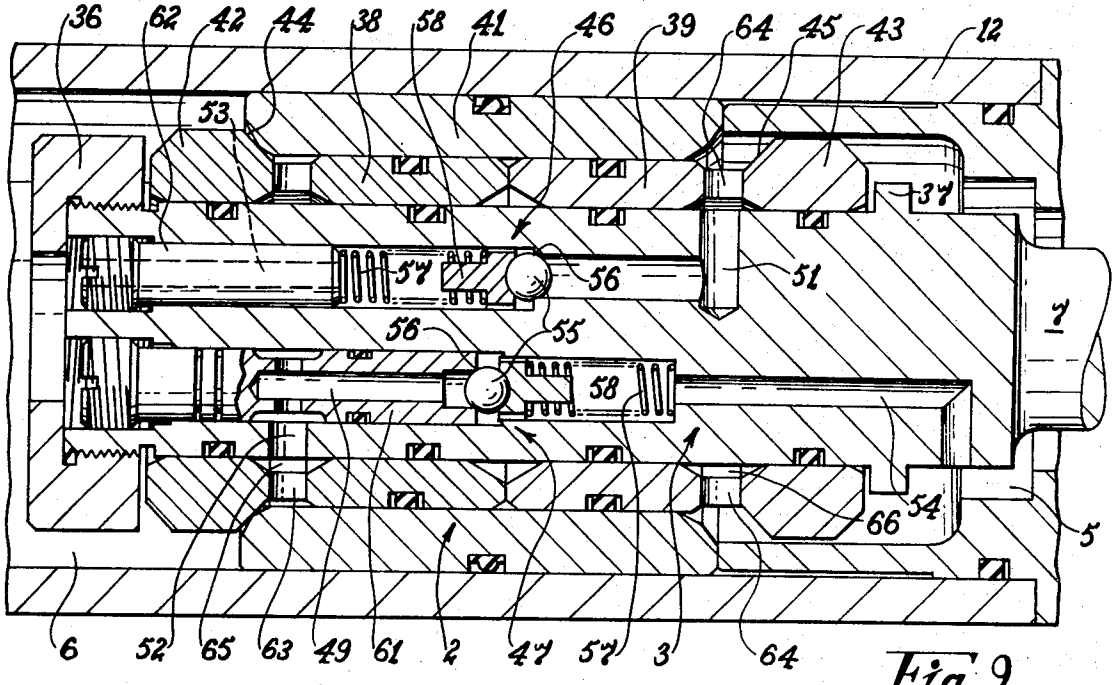


Fig 9

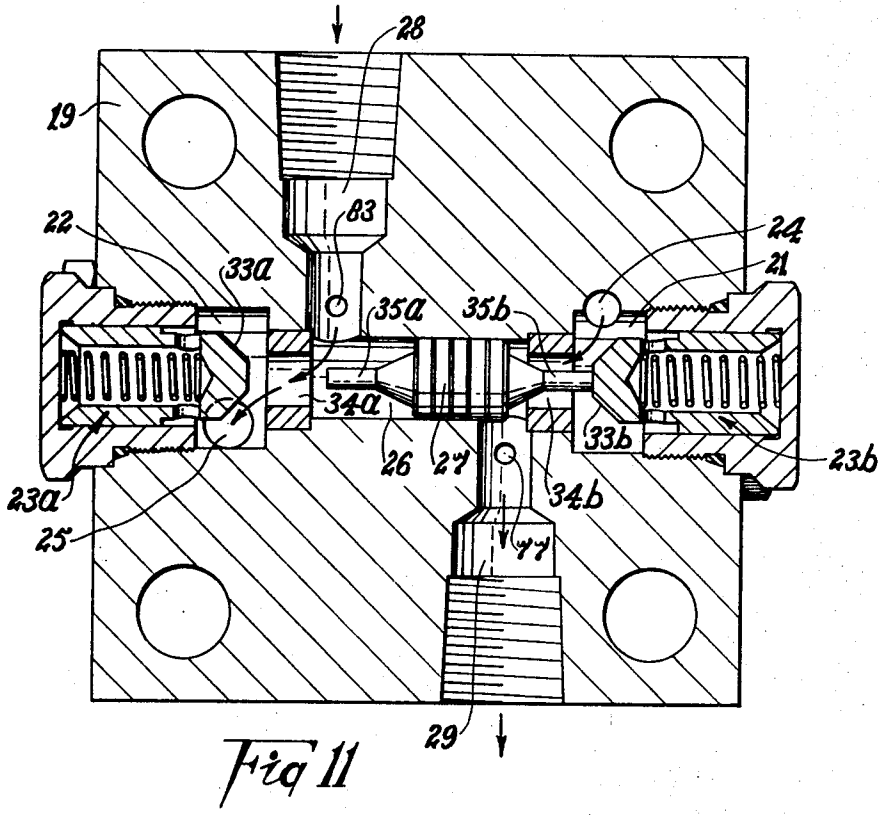


Fig 11

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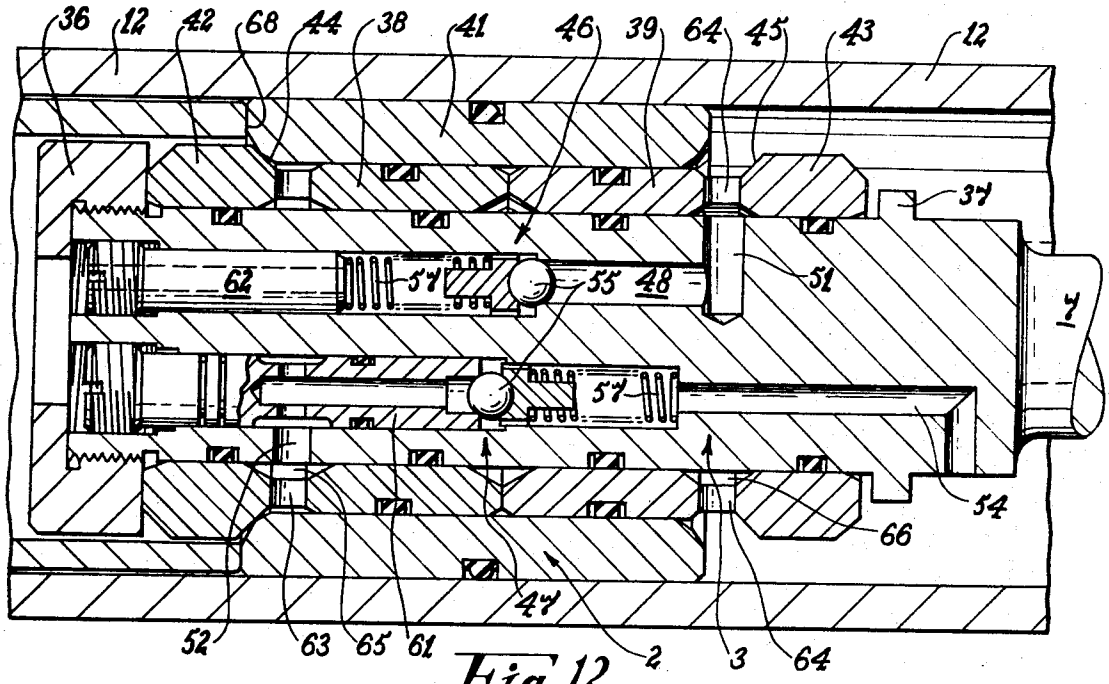


Fig 12

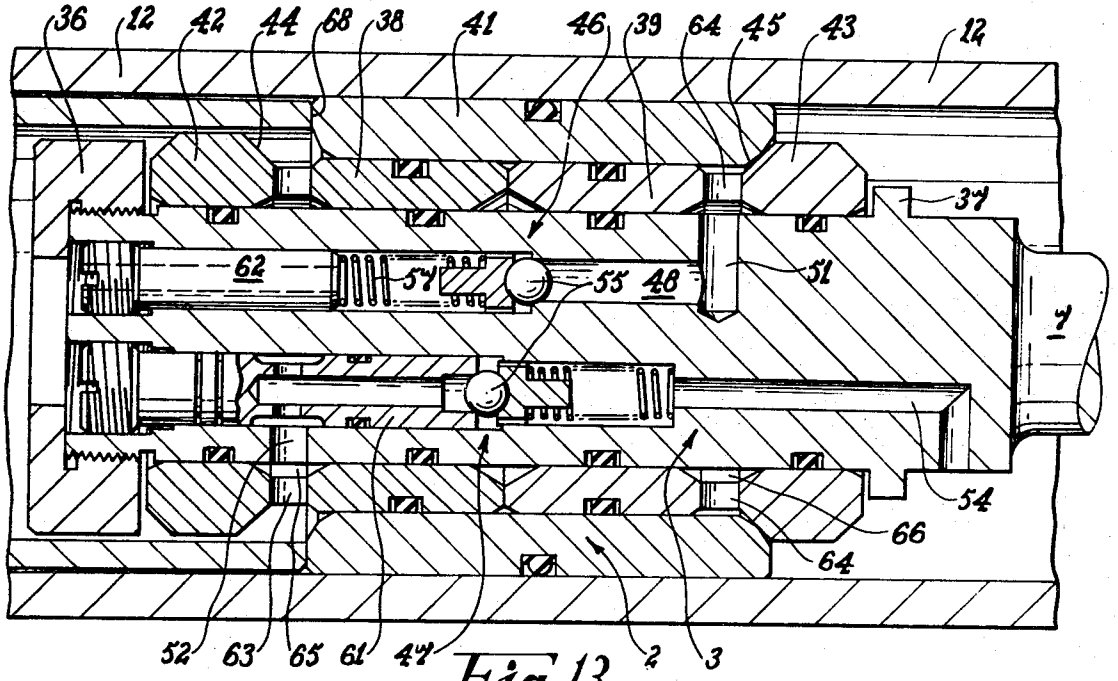


Fig 13

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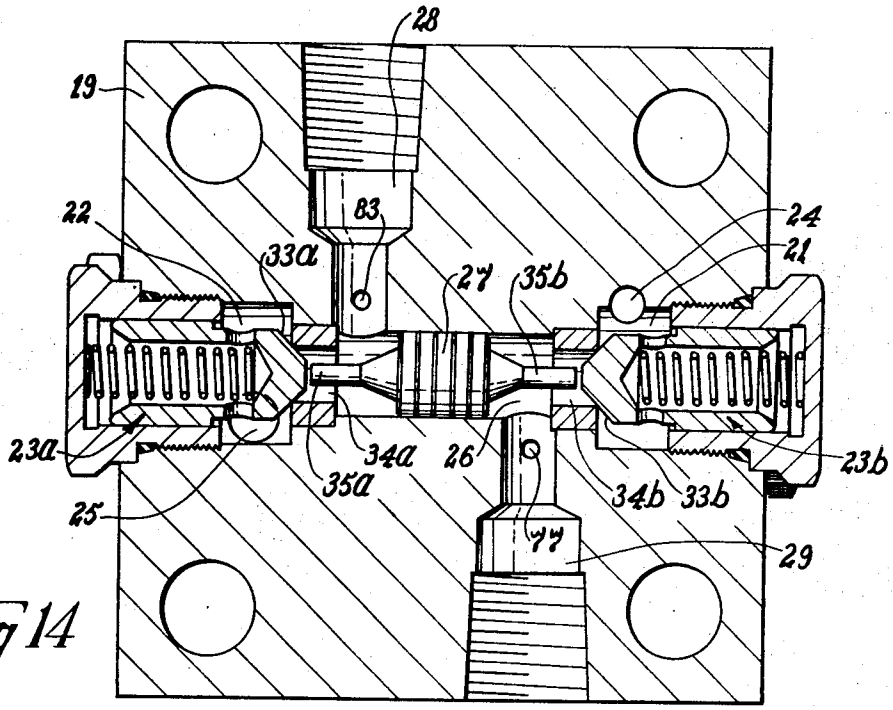


Fig 14

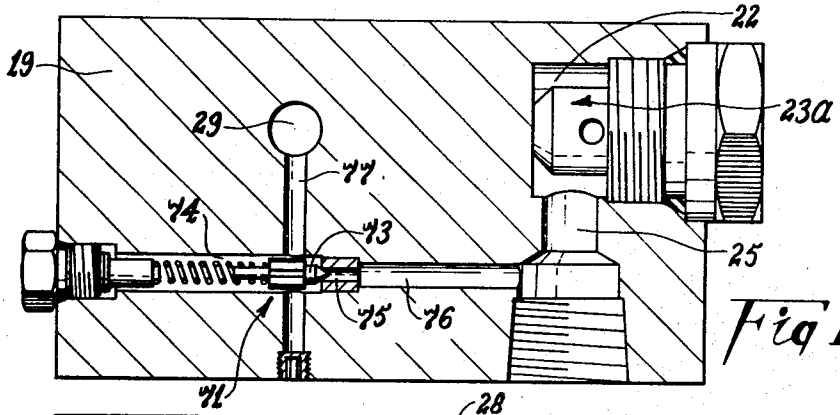


Fig 15

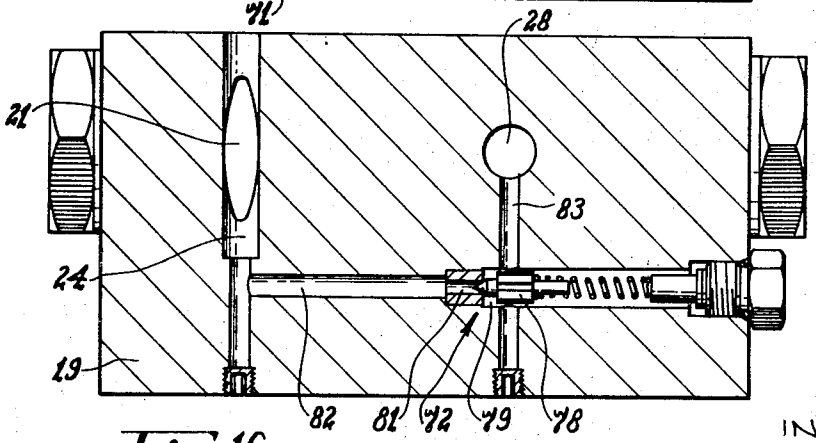


Fig 16

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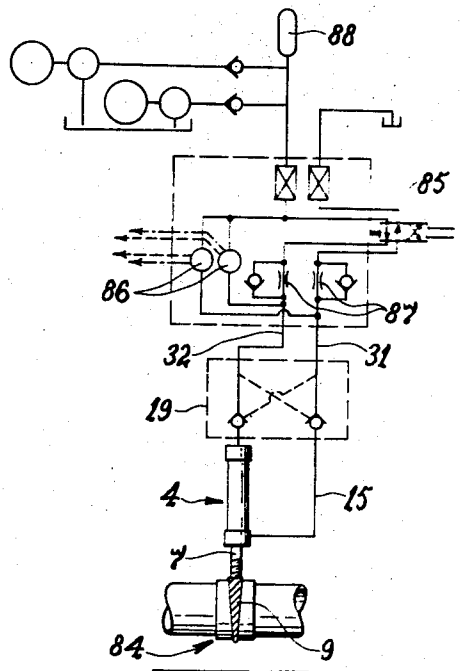


Fig 17

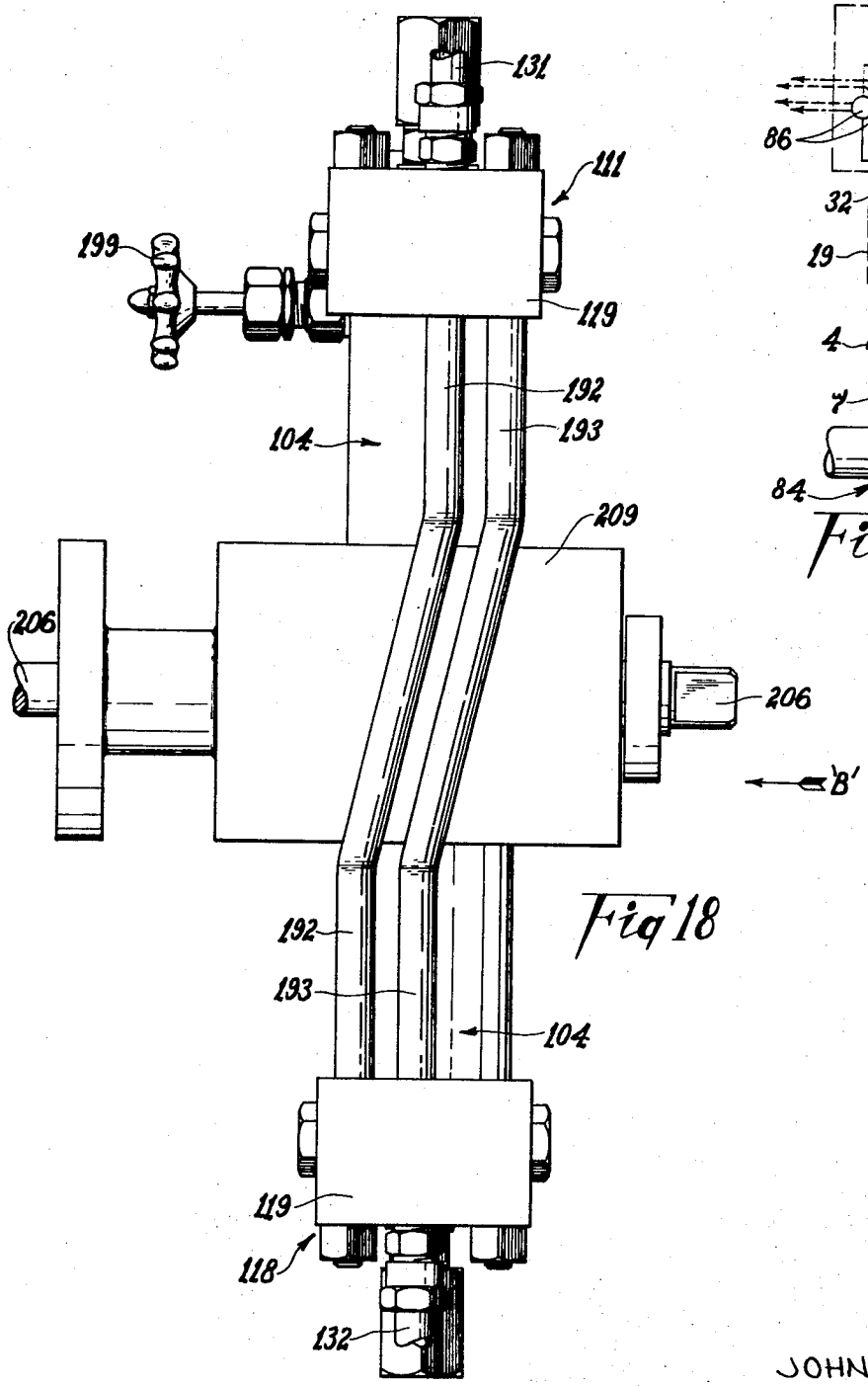


Fig 18

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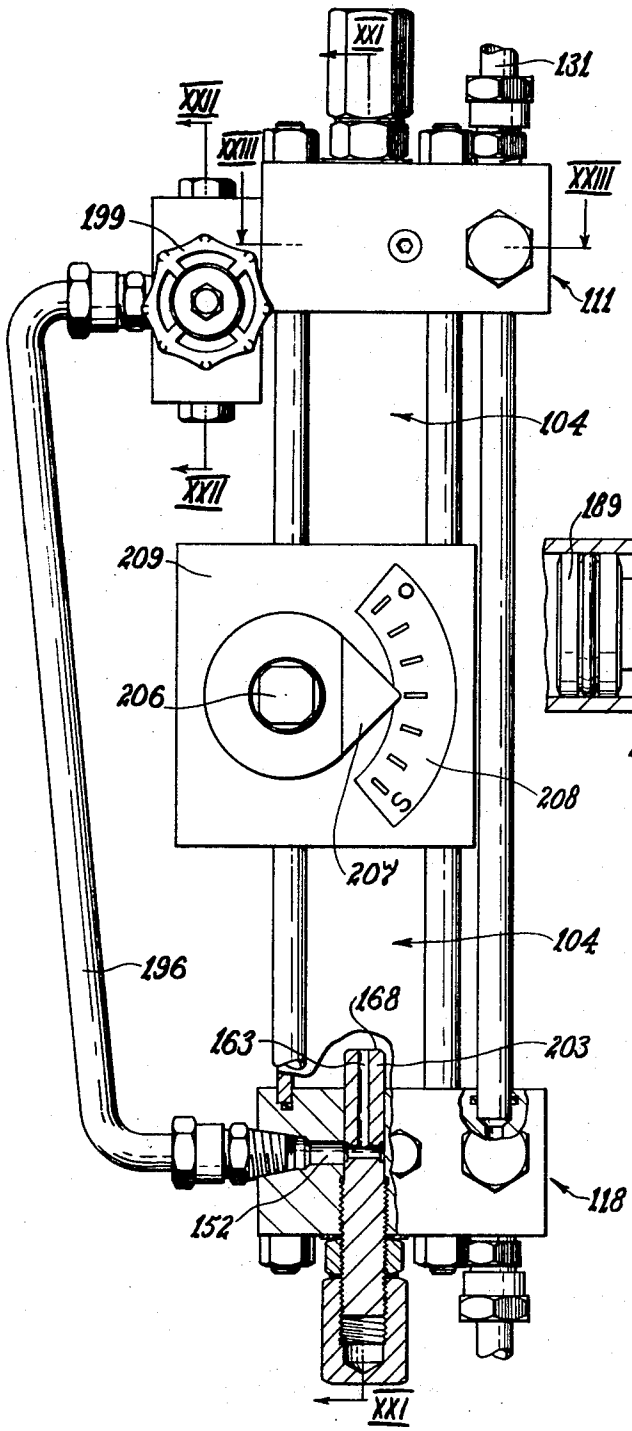


Fig 19

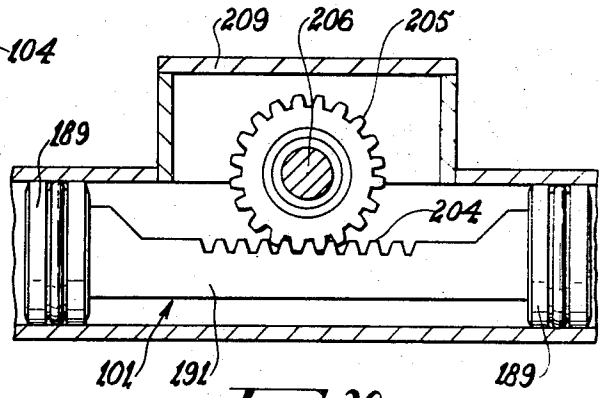


Fig 20

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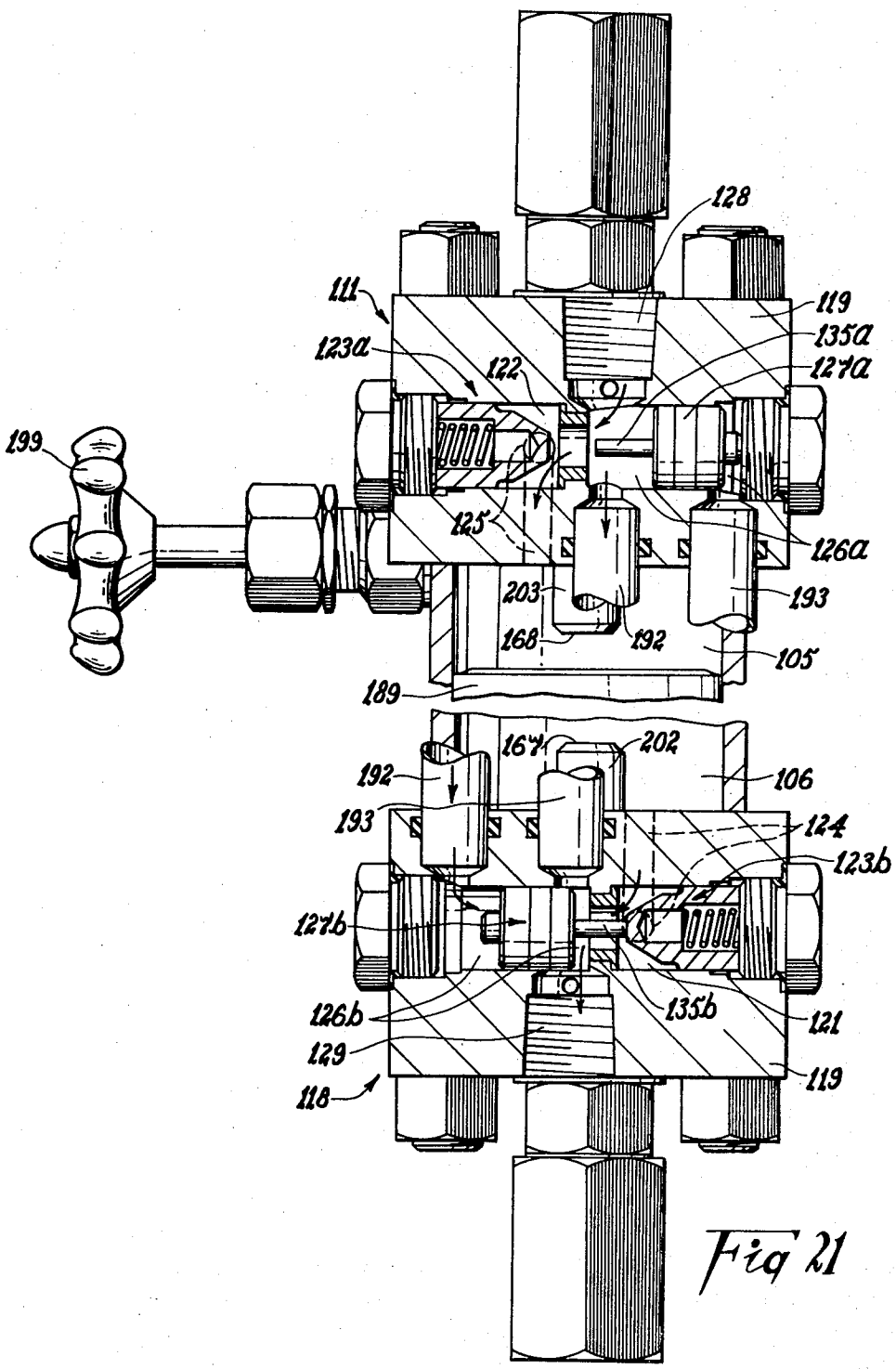


Fig 21

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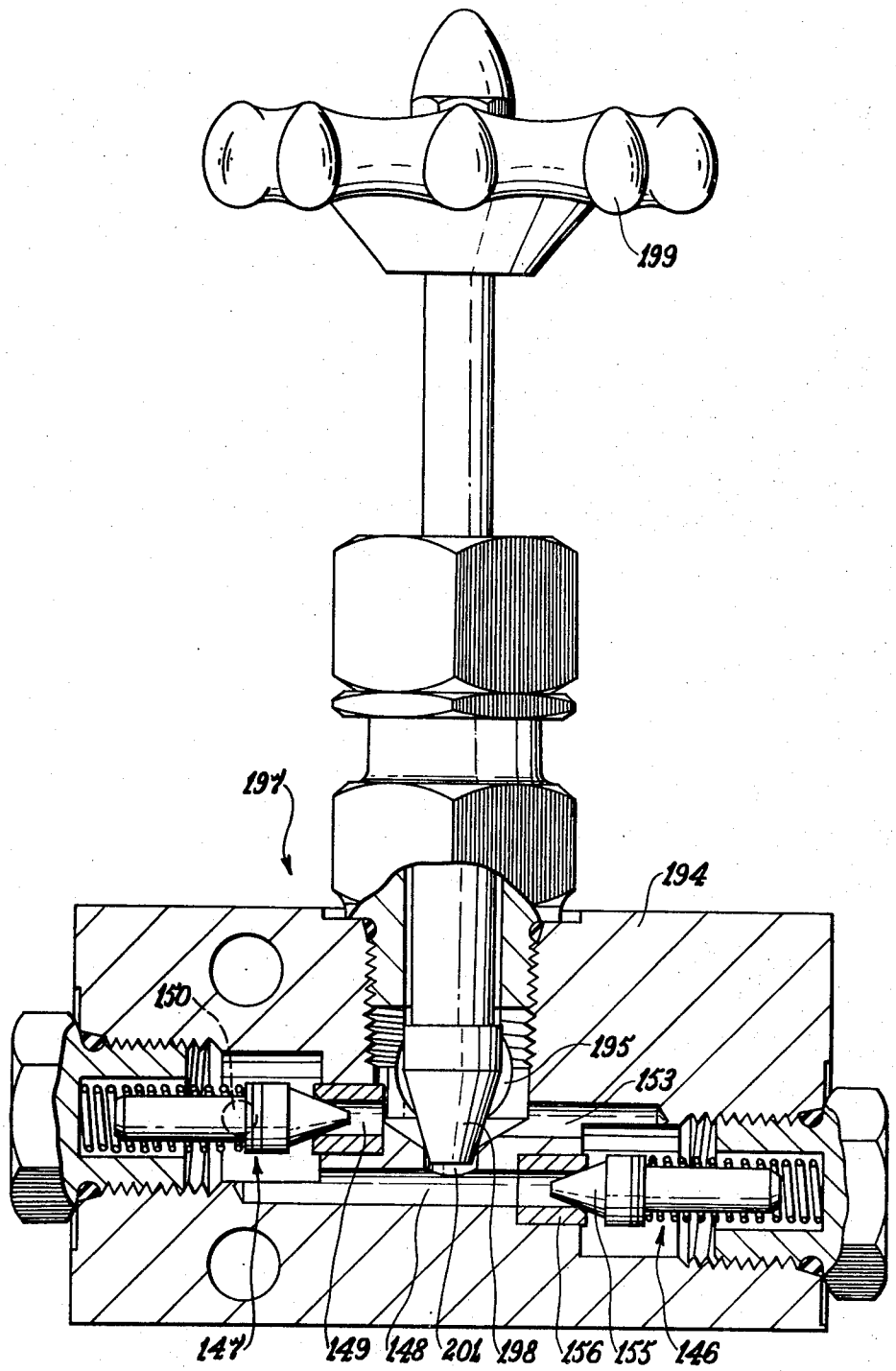


Fig 22

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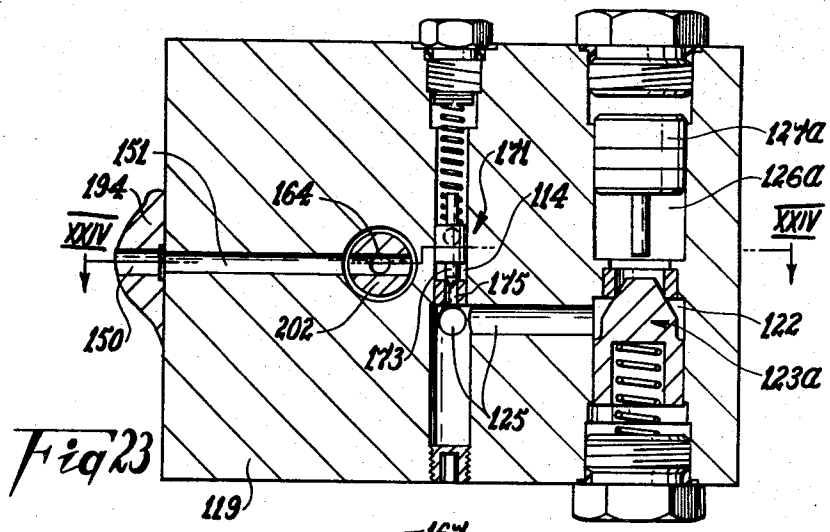


Fig 23

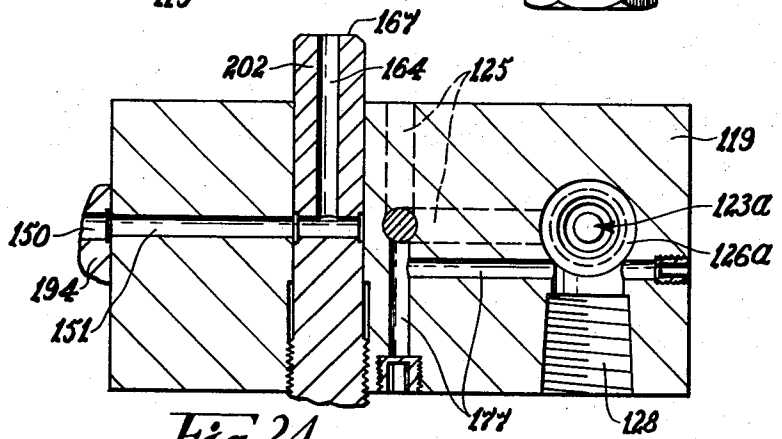


Fig 24

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FLUID OPERATED ACTUATOR FOR MOVABLE MEMBERS

This invention relates to fluid operated actuators for movable members, and is particularly concerned with such actuators for use in actuator systems which include means for indicating when the connected member approaches or reaches a desired position.

There are numerous movable member installations in which the member is either hidden or remotely located such that means is required to indicate whether the actuator has moved that member into or towards a particular position. An example installation requiring such indicator means is a valve installation on board a boat or ship, and it will be convenient to hereinafter describe the invention in relation to such an installation.

In view of the remote location of numerous valves on board ships, it is desirable if not essential to have some means for indicating whether each valve is in its open or closed position. It is common to control the movement of such valves through fluid pressure operated actuators, and the indicator system is usually formed separate to the actuator system although it may also be fluid controlled. The result is a complex and expensive maze of pipe-work, conduit, and ancillary equipment. In addition, known indicator systems employing fluid pressure are often adversely affected by temperature changes, and may give an incorrect indication if the associated valve is stuck or encounters abnormal resistance between the open and closed positions.

It is a principal object of the present invention to provide a movable member actuator which is operated by fluid pressure and can be incorporated into a system having means for indicating whether the actuator has reached or is approaching a particular operative condition. It is a further object of the invention to provide such an actuator which is relatively simple in construction and capable of being used with indicator means which is not susceptible to normal temperature variations. Yet another object of the invention is to provide such an actuator system incorporating indicator means which provides a positive indication only when the actuator adopts a predetermined operative condition.

In an actuator system including an actuator according to the invention, the pressurized fluid causing operative movement to the actuator is also utilized to operate the indicator means. As a result, an installation including such an actuator is much simpler than similar installations incorporating conventional actuators and indicator means. Basically the actuator includes pressure relief means which is operative to prevent the fluid pressure in at least part of the actuator system reaching a predetermined "indicator" pressure, and cut-out means for rendering the relief means inoperative when the actuator adopts a particular operative condition.

When an actuator according to the invention is applied to a marine valve, it is generally convenient to have the actuator arranged to indicate both the open and closed positions of that valve. The following particular embodiments of the actuator will be described as so arranged, but it is to be realized that in some cases indication of a single position will be sufficient. Furthermore, it must be understood that the invention is not restricted to actuation of valves, but is applicable to actuation of almost any other movable member such as doors, gates and hoists, to name but a few.

The following description refers in more detail to these essential features and further optional features of the invention. To facilitate an understanding of the invention, reference is made to the accompanying drawings where these features are illustrated in preferred form. It is to be understood however, that the essential and optional features of the invention are not limited to the specific forms of these features as shown in the drawings.

In the drawings:

FIG. 1 is a partially sectioned side elevational view of an actuator according to the invention, showing the actuator between its two extreme operative positions;

FIG. 2 is an end view of the actuator shown in FIG. 1 in the direction of arrow A;

FIG. 3 is an enlarged transverse cross-sectional view taken along line III—III of FIG. 1, with parts omitted for convenience of illustration, and showing the control valves as positioned during closing movement of the actuator;

FIG. 4 is a cross-sectional view taken along line LV—LV of FIG. 3;

FIG. 5 is a cross-sectional view taken along line V—V of FIG. 3;

FIG. 6 is an enlarged longitudinal cross-sectional view of the piston assembly of the actuator of FIG. 1, showing that assembly approaching the position in which a connected valve member is almost closed;

FIG. 7 is a transverse cross-sectional view taken along line VII—VII of FIG. 6;

FIG. 8 is a sectional view taken along line VIII—VIII of FIG. 6;

FIG. 9 is a view similar to FIG. 6 but showing the piston assembly location when the connected valve member is closed;

FIG. 10 is a view similar to part of FIG. 1, but showing the piston assembly location when return movement of the assembly is initiated to cause opening movement of the connected valve member;

FIG. 11 is a view similar to FIG. 3 but showing the control valves as positioned during opening movement of the actuator;

FIG. 12 is a view similar to FIG. 6 but showing the piston assembly as located when the connected valve member is approaching its fully open position;

FIG. 13 is a view similar to FIG. 9 but showing the piston assembly location when the connected valve member is fully opened;

FIG. 14 is a view similar to FIG. 3 but showing the control valves in the closed position as adopted when the actuator is inoperative;

FIG. 15 is an enlarged cross-sectional view taken along line XV—XV of FIG. 2;

FIG. 16 is an enlarged cross-sectional view taken along line XVI—XVI of FIG. 2;

FIG. 17 is a diagrammatic view of an actuator according to FIG. 1 connected into a fluid circuit;

FIG. 18 is a side elevational view of an alternative embodiment of an actuator according to the invention;

FIG. 19 is a side elevational view of the actuator shown in FIG. 18 taken in the direction of arrow B, and partially sectioned for convenience of illustration;

FIG. 20 is a cross-sectional view taken along line XX—XX of FIG. 18;

FIG. 21 is a cross-sectional view taken along line XXI—XXI of FIG. 19, parts being omitted for convenience of illustration;

FIG. 22 is a cross-sectional view taken along line XXII—XXII of FIG. 19;

FIG. 23 is a cross-sectional view taken along line XXIII—XXIII of FIG. 19; and

FIG. 24 is a cross-sectional view taken along line XXIV—XXIV of FIG. 23.

FIGS. 1 to 16 of the drawings show one particular embodiment of the invention for use with slidable gate or other linear movement valves, in which the actuator includes a primary piston 2 and a secondary piston 3, both of which are mounted within a single cylinder 4 for axial movement relative thereto. The primary piston 2 divides the cylinder 4 transversely into two chambers 5 and 6, and for convenience those chambers will be hereinafter called opening and closing chambers respectively. A piston rod 7 is secured to the secondary piston 3 for movement therewith and extends through end wall 8 of the cylinder 4 for connection to a valve member 9 (see FIG. 17), and it is preferred that the opening chamber 5 is defined between the end wall 8 and the primary piston 2.

The end wall 8 may form part of an end cap 11 secured to the cylinder body 12 and having a fluid passageway 13 through a barrel portion 14 thereof and connecting at one end with the opening chamber 5. Alternatively however, the fluid passageway 13 may be formed through the side wall of the cylinder body 12. A conduit 15 may be connected to the fluid passageway 13 and connected into a fluid circuit of the actuator as hereinafter described. The bore of the cap 11 through which the piston rod 7 passes is preferably defined in part by a removable bush 16 having any suitable means 17 therein to form a substantially fluid-tight seal with the piston rod 7 whilst allowing axial movement of that rod.

A cap member 18 may also close the opposite end of the cylinder 4, and that member preferably has a control valve block 19 formed integral therewith (see FIGS. 2 to 5), although the block 19 may be formed as a separate element and connected to any other appropriate part of the actuator as desired. In the example arrangement shown, the valve block 19 includes two valve compartments 21 and 22, each of which contains a spring influenced one-way valve 23. The compartment 21 is in direct communication with the cylinder chamber 6 through a passage 24, and compartment 22 communicates with the conduit 15 through a passage 25 and is thereby connected with the cylinder chamber 5. It will be appreciated that the external conduit 15 may be substituted by some other means such as a passage formed within the wall of the cylinder body 12.

An intermediate compartment 26 may be formed within the block 19 and contains an axially slidable spool element 27 arranged to open either valve 23 as hereinafter described. Ports 28 and 29 communicate with the compartment 26 on opposite sides respectively of the spool element 27 as shown in FIG. 3, and each serves as inlet and outlet means for a respective one of the chambers 5 and 6. When the actuator is connected into a fluid system, a supply-exhaust conduit 31 is connected to port 28, and a similar conduit 32 is connected to the port 29. The spool element 27 serves as a fluid seal between the ports 28 and 29.

Each valve 23 preferably includes a conical nose section 33 which normally projects into and closes a valve orifice 34. The spring setting of each valve 23 is such that the valve may be opened by the normal operating pressure of the fluid used to operate the actuator. A stem 35 extends axially from each of the two opposite ends of the spool element 27 to engage and open a respective valve 23 as hereinafter described. For convenience of description, identifying reference numerals of the valves 23 and associated parts connected to chambers 5 and 6 will be hereinafter suffixed *a* and *b* respectively.

The primary piston 2 may be axially movable relative to the secondary piston 3 and the piston rod 7 between two limit stops each of which is preferably secured to the secondary piston 3. In the arrangement shown in FIGS. 1 and 6, one such stop is formed by an annular nut 36 secured to the terminal end portion of the secondary piston 3, and the other stop is formed by a collar 37 secured to the secondary piston 3 adjacent the piston rod 7. It is convenient to form the collar 37 integral with the secondary piston 3. Although the secondary piston 3 is shown integral with the piston rod 7, it will be appreciated that those two parts may be formed separate and attached by a screw thread or other connection.

As shown particularly in FIG. 6, the primary piston 2 includes an inner sleeve formed of two parts 38 and 39 which are slidable on the secondary piston 3 between nut 36 and collar 37, and an outer sleeve 41 which is slidable on the inner sleeve parts 38 and 39. The inner sleeve is made in two parts as a matter of convenience for assembly with the outer sleeve 41, and each part 38 and 39 has an enlarged end portion 42 and 43 respectively which defines an annular shoulder 44 and 45 respectively. The two shoulders 44 and 45 are opposed and each provides a combined stop and sealing surface for cooperation with the outer sleeve 41 as hereinafter described.

The pressure relief means preferably includes a pair of relief valves 46 and 47 which are arranged to prevent the fluid pressure within the cylinder chambers 5 and 6 respectively from reaching the aforementioned "indicator" pressure — that is, when the relief means is not rendered inoperative by the cut-out means. Although the relief valves 46 and 47 may be located externally of the cylinder 4, it is preferred to locate them within a respective relief passage 48 and 49 formed within the secondary piston 3. Each relief passage 48 and 49 may extend axially of the piston rod 7, and have laterally extending entrance portions 51 and 52 respectively through which communication is made with the respective chambers 5 and 6. The valve 46 exhausts to chamber 6 through a passage 53, and valve 47 exhausts to chamber 5 through passage 54. Obviously, an arrangement may exist in which the two relief valves 46 and 47 are located within a single relief passage.

Each of the relief valves 46 and 48 may include a valve member 55 movable axially relative to the associated relief passage, and a cooperable valve seat 56. In one form as shown in FIG. 6, each valve member 55 is a ball which is locatable within an orifice 56 defining its respective valve seat, and the valve member is preferably biased by a spring 57 towards that seat. Each spring 57 acts on its respective valve ball 55 through a slide member 58 which is provided with flat surfaces 59 (see FIG. 8) or other clearance means or apertures to allow passage of fluid thereby.

The seat 56 of valve 47 may be formed by the bore of a bush 61 mounted within the secondary piston 3, and the axial position of the bush 61 is preferably adjustable to enable variation of the compression of valve spring 57 and consequently the valve closing force. The seat 56 of valve 46 may be formed by one end of the relief passage 48, and the passage 53 is preferably formed as the bore of a bush 62 adjustably mounted in the secondary piston 3 to enable variation of the compression of the spring 57 for the valve 46.

The pressure relief means may also include a pair of passages 63 and 64 formed through respective parts 38 and 39 of the primary piston inner sleeve, and they are located to communicate with the lateral passages 52 and 51 respectively. That communication may be maintained over the length of movement of the primary piston 2 relative to the secondary piston 3, through internal grooves 65 and 66 of the inner sleeve parts 38 and 39 respectively (see FIG. 7).

Cut-out means for the arrangement so far described preferably includes a pair of abutments 67 and 68 (see FIG. 1) which limit axial movement of the primary piston 2 with the secondary piston 3. The abutments 67 and 68 are located adjacent respective opposite ends of the cylinder body 12, and each is arranged to stop movement of the primary piston 2 towards that end whilst allowing continued movement of the secondary piston 3. In one form, the abutment 67 is defined by the axially inner end face of the barrel portion 14 of the end cap 11, and abutment 68 is defined by the axially inner end face of a barrel portion 69 of the end cap 18. The secondary piston is receivable within the bore of each of the barrel portions 14 and 69 to allow the aforementioned continued movement. Obviously, any other suitable abutment may be used such as a simple pin projecting radially inwardly from the side wall of the cylinder 4, or the cross-sectional area of the cylinder body 12 may be reduced to form appropriate stop shoulders.

Safety means is preferably provided within the valve block 19 to prevent the pressure within either chamber 5 and 6 reaching a predetermined upper safe limit. In this regard, the control valves 23a and 23b remain closed when the actuator is not in operation, as shown in FIG. 14, and consequently fluid is trapped in both chambers 5 and 6. That fluid may expand with a rise in ambient temperature, and the resulting increase in pressure may cause damage to the actuator if not relieved. One such safety means is two spring influenced one-way valves 71 and 72 (see FIGS. 15 and 16) which communicate with the chambers 5 and 6 respectively.

Safety valve 71 includes a valve element 73 contained within a chamber 74 and biased to normally close the orifice 75. The orifice 75 communicates direct with the port 25 through a passage 76 to allow fluid under pressure to be exhausted from the chamber 5 by way of conduit 15. The valve chamber 74 communicates with the port 29 through a passage 77, whereby fluid exhausted through the valve 71 is able to drain to a tank or reservoir by way of conduit 32.

The safety valve 72 also comprises a valve element 78 contained within a chamber 79 and biased to normally close an orifice 81. The orifice 81 communicates direct with the passage 24 through a passage 82 to allow fluid under pressure to be exhausted from the chamber 6 by way of the passage 24. The valve chamber 79 communicates with the port 28 through a passage 83, whereby fluid exhausted through the valve 72 is able to drain to a tank or reservoir by way of the conduit 31.

In an example installation including the previously described actuator as shown diagrammatically in FIG. 17, the end portion of the piston rod 7 located outside the cylinder 4 is secured to the slide 9 of a gate valve 84, and means is preferably provided whereby the axial position of the slide 9 may be adjusted relative to the piston rod 7.

One or both of the primary piston abutments 67 and 68 may be adjustable in the axial direction of the cylinder 4 to enable variation of the stop position or positions of the piston 2. Conduits 31 and 32 are selectively connectable to a source of pressurized fluid through a directional control valve 85. In one position of the valve 85, conduit 31 serves to supply fluid to chamber 5, and conduit 32 functions as a drainpipe for chamber 6. In another position of the valve 85, conduit 32 feeds chamber 6, and conduit 31 drains chamber 5. Alternatively, a separate feed and drainpipe may be connected to each chamber and controlled by appropriate valving as required.

A pressure sensitive switch 86 is preferably connected to each of the conduits 31 and 32, and each of the switches 86 may be operatively connected to a suitable indicator device (not shown). Each indicator device may be arranged to produce a visual and/or audible signal, but it is generally convenient to employ simple incandescent lamps as the indicator devices. Chokes 87 and an accumulator 88 may be provided in the circuit as required according to known procedures and techniques.

The actuator may be hydraulically or pneumatically operated, but hydraulic operation is generally preferred.

Assuming the gate valve 84 is in an open position, the slide 9 may be moved towards the closed position by causing pressurized fluid to enter the actuator circuit through conduit 32 which feeds that fluid into the cylinder chamber 6 through port 29. Fluid passing through port 29 enters the intermediate compartment 26, and the pressure thereof opens the valve 23*b* (FIG. 3) so that the fluid is then able to pass from valve compartment 21 to the chamber 6 through passage 24. That same fluid pressure urges the spool element 27 to open the valve 23*a* by engagement between the stem 35*a* and nose section 33*a* as shown in FIG. 3, and consequently chamber 5 is able to exhaust through conduit 15 to port 28 and conduit 31. In normal operation, that fluid pressure is insufficient to open the relief valve 47 so that the fluid functions to urge the primary and secondary pistons 2 and 3 towards the end cap 11 of the cylinder 4. When the fluid is first introduced into the chamber 6 however, the primary piston 2 moves relative to the secondary piston 3 away from the end cap 18 and subsequently engages the stop collar 37 (see FIG. 1), after which the two pistons 2 and 3 move together with the piston rod 7 thereby progressively closing the gate valve 84.

During such closing movement, the relief passage 49 is in communication with the chamber 6 through the lateral entrance 52 and the passage 63 as shown in FIGS. 1 and 6. If the gate valve slide 9 sticks or encoun-

ters an obstacle such as to increase the resistance to further closing movement, or prevent such further movement, a build-up of pressure will naturally occur within the chamber **6**. The relief valve **47** is arranged to open before that pressure reaches the aforementioned "indicator" pressure which is effective to operate the pressure sensitive switch **86** connected to the conduit **32**. Thus, fluid is able to escape from the chamber **6** through the passages **49** and **54** to the chamber **5**, from where it is discharged through the conduits **15** and **31**.

Assuming closing movement of the actuator continues, a condition is eventually achieved in which the outer sleeve **41** of the primary piston **2** engages and is stopped by the abutment **67** as shown in FIG. **6**. The inner sleeve parts **38** and **39** and secondary piston **3** are able to continue moving together towards the end cap **11**, until the shoulder **44** engages the adjacent end of the sleeve **41** as shown in FIG. **9**. In this position, communication between chamber **6** and the relief valve **47** is closed, and the pressure within the chamber **6** acts on the secondary piston **3** alone so that the piston rod **7** continues to move in the closing direction and the stop collar **37** is progressively moved into the bore of the barrel portion **14**. Thus, when the valve slide **9** closes, pressure is built up within the chamber **6**, and consequently the conduit **32**, beyond the "indicator" pressure thereby resulting in operation of the associated indicator device.

When it is desired to open the gate valve **84**, the directional control valve **85** is operated so that pressure fluid is introduced to the chamber **5** through the conduit **31**, and the conduit **32** connects the chamber **6** to drain. It will be appreciated that the closing force of the actuator during the last part of the closing movement is dependent upon the axial end area of the secondary piston **3**, since both sleeves of the primary piston **2** are held by the abutment **67**, and that area is preferably substantially less than the combined end face area of the primary and secondary pistons which is subjected to fluid pressure within the chamber **5**. Thus, for the same fluid pressure, the opening force of the actuator is greater than the final closing force thereby ensuring effective operation of the actuator.

When pressurized fluid is fed into the valve block compartment **26** by way of conduit **31** and port **28**, valve **23*a*** opens as shown in FIG. **11** to allow the fluid to enter port **25** from where it passes to the chamber **5** by way of the conduit **15**. The fluid pressure in compartment **26** also moves the spool element **27** into a position such that the stem **35*b*** engages the valve nose section **33*b*** and causes the valve **23*b*** to open as shown in FIG. **11**, and thereby allow the chamber **6** to exhaust through passage **24** to the port **29** and connected conduit **32**.

Initial entry of pressurized fluid into the chamber **5** causes the primary piston **2** to adopt the position shown in FIG. **10** in which the inner sleeve part **38** engages the nut **36** and the outer sleeve **41** engages the shoulder **44**. After that position has been reached, the primary and secondary pistons move together towards the end cap **18** thereby causing the connected valve **84** to open. Also in this position of the pistons **2** and **3**, the relief passage **48** is in communication with the chamber **5** through the lateral entrance **51** and the passage **64** as shown in FIGS. **10** and **12**.

During opening movement, pressure build-up within the chamber **5** is relieved in the same manner as described in relation to the chamber **6** during the closing movement, except that the pressure relief is effected through opening of the relief valve **46** with consequent discharge of fluid to the chamber **6** through the passage **53**. Fluid escapes from the chamber **6** through the passage **24** and port **29** to the conduit **32** which is connected to drain during this particular operation, as previously described. It will be appreciated that under normal conditions, the pressure in the chamber **5** will not rise to the relief pressure unless abnormal resistance to the opening movement of the valve slide **9** is encountered.

As the valve slide **9** approaches the fully opened position, the outer sleeve **41** of the primary piston **2** engages the abutment **68** as shown in FIG. **12**, and is thereby held against further movement in the opening direction. The inner sleeve parts **38** and **39** and secondary piston **3** however, continue to move in that direction as fluid pressure within the chamber **5** acts against their combined effective end area. The shoulder **45** of the inner sleeve part **39** is thereby moved into engagement with the adjacent end of the sleeve **41** as shown in FIG. **13**, after which the secondary piston **3** continues to move alone and is progressively moved deeper into the bore of the barrel section **69**. Engagement between the outer sleeve **41** and the abutment **68** results in closing of communication between the entrance **51** of the relief passage **48** and the chamber, and that occurs as the valve slide **9** arrives at or approaches its fully opened position. Thus, build-up of pressure in the chamber **5** is caused by cessation of movement of the piston rod **7** and fluid cannot escape through the relief passage **48** so that the actuator device associated with the conduit **31** is subsequently actuated.

When pressurized fluid is not being fed through either of the conduits **31** or **32** — i.e., the actuator is static — the control valves **23*a*** and **23*b*** assume closed positions as shown in FIG. **14**. Thus, fluid is trapped in both of the chambers **5** and **6** and the escape means previously described enables relief of pressure from those chambers if the pressure therein becomes excessive because of fluid expanding under increased temperature. If the pressure increase occurs in chamber **5**, that increase will be also present in the conduit **15** because of its constant connection with the chamber **5**, and the conduit **15** is also in constant communication with safety valve **71** through port **25** and passage **76** as shown in FIG. **15**. The valve **71** is arranged to open when the pressure reaches a predetermined limit, and thereby allows exhaust of fluid to conduit **32** by way of passage **77** and port **29**.

If the pressure increase occurs in the chamber **6**, safety valve **72** will open because it is in constant communication with the chamber **6** through interconnecting passages **24** and **82**. Exhaust of fluid from the valve chamber **79** to conduit **31**, occurs through passage **83** and port **28** as shown in FIG. **16**.

The construction described may be modified in numerous ways to achieve the basic requirements of the invention. For example, a single relief valve may serve both chambers **5** and **6** of the cylinder **4** if the associated relief passages are appropriately arranged.

Also, the actuator may be constructed to provide a positive indication in one position only, in which case the relief means and cut-out means are suitably modified. Still further, the stop collar **37** may be contained within or enveloped by the primary piston **2** so as to be capable of only limited axial movement relative thereto. Also, the primary piston **2** may consist of a single sleeve section, in which case the relief means within the piston assembly is arranged to suit.

Yet another embodiment of the invention is shown in FIGS. **18** and **24**, and that embodiment is particularly suitable for use with a rotary or semi-rotary valve such as a butterfly valve. For convenience, components of this embodiment which correspond to components of the first described embodiment will be identified by like reference numerals, except that those numerals will form part of the series **101** to **200**.

According to this embodiment, the cylinder **104** contains a piston assembly **101** having a pair of cylindrical end portions **189** which are joined by an intermediate portion **191** as shown in FIG. **20**. Each end portion **189** forms a movable end wall of a respective one of the cylinder chambers **105** and **106**, and end caps **111** and **118** are secured to opposite ends of the cylinder **104** substantially as in the previous embodiment. It is preferred in this embodiment however, that a separate valve block **119** be formed integral with or attached to each of the end caps **111** and **118**, and each of those blocks **119** contains a control valve **123** as shown in FIG. **21**, which is operative to control passage of fluid into and out of the adjacent cylinder chamber. Control valves **123*a*** and **123*b*** are associated with chambers **105** and **106** respectively.

Each control valve **123** preferably includes the same basic components as the valves **23** described in relation to the first embodiment, and functions in the same manner. The principal advantages are that each spool element **127** includes a single stem **135**, and the compartments **126** communicate through two conduits **192** and **193** as shown in FIGS. **18** and **21**. The conduit **192** connects the front side of compartment **126*a*** to the rear side of compartment **126*b*** so that pressurized fluid entering the compartment **126*a*** from the conduit **131** and through port **128** is effective to cause valve **123*b*** to open through the medium of the spool element **127*b*** and thereby allow the chamber **106** to exhaust through port **129** to conduit **132**. The conduit **193** connects the front side of the compartment **126*b*** to the rear side of the compartment **126*a*** to enable both valves **123*b*** and **123*a*** to open when the conduits **132** and **131** function as feed and drain lines respectively.

The valve compartment **122** of valve **123*a*** communicates with the chamber **105** through a passage **125** as shown in FIGS. **21**, **23** and **24**, and a passage **124** connects the compartment **121** of the valve **123*b*** to the chamber **106** as also shown in FIG. **21**. FIG. **21** shows the valves **123*a*** and **123*b*** positioned as when fluid is fed to the chamber **105** through the conduit **131** and is drained from the chamber **106** through the conduit **132**.

Relief means is preferably located externally of the cylinder **104** and in the particular arrangement shown includes a valve block **194** containing relief valves **146** and **147** which function substantially the same as the corresponding valves **46** and **47** of the previously described embodiment. Relief valve **146** includes a member **155** arranged to close an orifice **156** of a relief passage **148** which communicates with the chamber **105** through a passage **150** of the block **194** and interconnected passages **151** and **164** of the adjacent block **119**, as shown in FIG. **23**. The valve **146** exhausts to the chamber **106** through a passage **153** and connecting port **195** of the valve block **194**, and a conduit **196** (see FIG. **19**) which connects the port **195** to interconnected passages **152** and **163** of the other valve block **119** (i.e., that containing valve **123*b***) as shown in FIG. **19**. The passages **152** and **163** communicate direct to the chamber **106** and correspond to passages **151** and **164** respectively of the other block **119**. In this regard, the passage arrangement in both of the valve blocks **119** is substantially identical.

The relief valve **147** receives high pressure fluid from the chamber **106** through conduit **196**, port **195** and a passage **149** of the valve block **194**. It is exhausted to the chamber **105** through the interconnected passages **150**, **151** and **164**.

A manually operable by-pass valve **197** is preferably connected to the relief valve assembly to enable the valves **146** and **147** to be by-passed when desired. For example, such by-pass allows manual movement of the piston assembly **101** during maintenance of the actuator. The valve **197** includes a closure member **198** which is operable by a hand wheel **199** to open and close a by-pass orifice **201** which extends between and connects the port **195** and passage **148** as shown in FIG. **22**.

Cut-out means for this embodiment preferably includes a pair of stop elements **202** and **203** which contain the passages **164** and **163** respectively. The axially inner end face of the element **202** forms the abutment **167** and the corresponding end face of the element **203** forms the abutment **168**. Both the elements **202** and **203** may be adjustably mounted within the respective valve blocks **119** as shown in FIG. **19**, to allow variation of the axial position of the respective end faces **167** and **168**, and consequently the two stop positions of the piston assembly **101**.

It will be appreciated from the foregoing that the relief valve **146** is rendered ineffective when an end portion **189** of the piston assembly **101** engages the abutment face **168** of the stop element **203**. In that position of the piston assembly **101**, the passage **163** is closed and high pressure fluid is unable to escape from the chamber **105** into chamber **106**, even though the relief valve **146** may be open and connects the conduit **196** to the chamber **105**. Thus, under such conditions, the pressure within chamber **105**, and consequently conduit **131**, progressively increases until the "indicator" pressure is reached. During operation of the actuator between the stop positions of the piston assembly, the chamber **106** remains in communication with the relief valve assembly through the passage **163**, but as with the previously described embodiment, the relief valve **146** is arranged so as to remain closed under normal operating pressure conditions.

The abutment face **167** and relief valve **147** function in the same manner as described for abutment face **168** and relief valve **146**, when pressurized fluid is introduced to the chamber **106** for moving the piston assembly **101** in the opening direction.

Safety means similar to that described in relation to the first embodiment is also preferably provided in each valve block **119**. For convenience, only the safety means in the block **119** containing the valve **123***a* will be described, and it is to be understood that identical means is provided in the other block **119**.

Referring to FIGS. **23** and **24**, a safety valve **171** includes a valve member **173** contained with a compartment **174** and spring influenced to normally close an orifice **175**. The orifice **175** communicates direct with the chamber **105** through passage **125**, and the compartment **174** communicates with the port **128** through a passage **177**. Thus, when valves **123***a* and **123***b* are closed, excessive pressure within the chamber **105** causes the valve **171** to open and exhaust fluid to the conduit **131** through the port **128**. The corresponding safety valve of the block **119** containing control valve **123***b*, functions in the same way to exhaust chamber **106** to the conduit **132**.

In the arrangement particularly shown in the drawings, the piston assembly **101** is connectable to the valve element of a butterfly or similar semi-rotary valve, and that connection may be effected through a rack and pinion. The rack **204** may be formed on the intermediate portion **191** of the piston assembly **101** as shown in FIG. **20**, and the pinion **205** is secured to a rotatable drive shaft **206** adapted to be operatively connected to the butterfly valve. The shaft **206** may be rotatably mounted in a housing **209** formed integral with or connected to the cylinder **104**.

A visual indicator may be associated with the actuator in addition to an indicator device of the kind described in relation to the previous embodiment. Such an additional indicator may include a pointer **207** secured to the shaft **206**, and a scale **208** secured to the cylinder **104**, as shown in FIG. **19**. In FIG. **19** the indicator shows the piston assembly **101** to be in its intermediate position in which a connected valve member is located between its open and closed positions.

It will be clear that an actuator construction according to FIGS. **18** to **24**, may be connected into a fluid system to operate in basically the same manner as the construction first described. That is, in operation the actuator of FIGS. **18** to **24** may be included in a fluid circuit as shown in FIG. **17**. If desired, the two piston end portions **189** may be of a different size to produce a difference in the closing and opening forces for the same fluid pressure.

The basic actuator construction last described may be also applied to linear movement valves, but for such an application it may be more convenient to have each piston end portion **189** contained within respective spaced cylinders rather than a single cylinder as shown and described. Any of the relief and cut-out means described may be used with such a construction, and the connection of each piston end portion **189** to the valve slide may take any convenient form.

Although the specific embodiments of the actuator described have included a piston or pistons as the force transmitting element of the actuator, it is to be understood that other types of elements may be used. For example, the force transmitting element may be a diaphragm, bellows, or any other element adapted to translate fluid pressure into mechanical movement.

It will be appreciated that an actuator as described has considerable potential because of its simple yet effective construction. In a marine application as described for example, the expense and complexity of the actuator and indicator installations are both significantly reduced. Furthermore, the actuator is not susceptible to giving false indications because of leakage in the fluid system, and it is substantially fail-safe in that all valves return to a closed position if the fluid system fails.

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the preferred constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A fluid operated actuator including an actuator element movable under the influence of fluid pressure and being connectable to a member to be actuated, pressure relief means operable to prevent the pressure acting on said actuator element reaching a predetermined level, and cut-out means operable to render said relief means inoperative when said actuator element adopts a particular axial position, said actuator element being defined by a piston assembly which is slidable axially within a cylinder and divides the interior of that cylinder transversely into two chambers, and said pressure relief means communicates with at least one of said chambers when said cut-out means is inoperative, said cut-out means including valve means forming at least part of said piston assembly for closing communication between said one chamber and said relief means when said actuator element is in said particular axial position.

2. An actuator according to claim **1**, wherein said cylinder includes inlet means for both said chambers whereby pressurized fluid may be introduced to either of said chambers according to the desired direction of movement of the piston assembly; and said pressure relief means is operable to relieve pressure from whichever of said chambers is subjected to said pressurized fluid, so long as said cut-out means remains inoperative.

3. An actuator according to claim **1**, wherein said relief means includes at least one relief valve.

4. An actuator according to claim **2**, wherein said relief means includes two relief valves, each of which is operatively connected to a respective one of said chambers.

5. An actuator according to claim **1**, wherein said piston assembly has a first said particular operative position in which said part thereof closes communication between one of said chambers and said pressure relief means, and is positioned adjacent the end of the cylinder remote from that chamber; and a second said particular axial position in which said part thereof closes communication between the other said chamber, and is positioned adjacent the end of said cylinder opposite said firstmentioned end thereof.

6. An actuator according to claim **1**, wherein means is provided to reduce the effective end surface area of the piston assembly to which pressurized fluid is applied to cause movement of the piston assembly in one direction, said means being arranged to cause said area

reduction when said piston assembly is at or adjacent the said particular axial position; and the opposite effective end surface area of the piston assembly in which pressurized fluid is applied for initially moving the piston assembly in the opposite direction, is greater than said reduced area.

7. An actuator according to claim 1, wherein said piston assembly has a first said particular operative position in which a first part of said piston assembly closes communication between one of said chambers and said pressure relief means, and is positioned adjacent the end of the cylinder remote from that chamber; and a second said particular operative position in which a second part of said piston assembly closes communication between the other said chamber and said pressure relief means, and is positioned adjacent the end of said cylinder opposite said firstmentioned end thereof.

8. A fluid operated actuator including, a cylinder, a piston assembly slidable axially within said cylinder and dividing the interior thereof transversely to define two variable volume chambers, inlet means to allow introduction of pressurized fluid to one of said chambers, connecting means projecting through a wall of said cylinder for connecting said piston assembly to a member to be actuated, pressure relief means connected to said one chamber and being operable to prevent the fluid pressure therein reaching a predetermined level, and cut-out means operable to render the relief means inoperative when the piston assembly adopts a particular axial position relative to said cylinder, said cut-out means including valve means forming part of said piston assembly for closing communication between said one chamber and said pressure relief means when said piston assembly adopts said particular axial position.

9. An actuator according to claim 8, wherein fluid inlet and outlet means is provided for both said chambers so that pressurized fluid may be introduced to either of said chambers according to the desired direction of movement of the piston assembly, and said pressure relief means is connected to both said chambers to control the pressure within whichever of said chambers is subjected to said pressurized fluid.

10. An actuator according to claim 9, wherein a single port defines both the inlet means and the outlet means for each said chamber, said ports communicating with their respective chambers through a pressure operated control valve arranged to open both said ports to their respective chambers in response to pressurized fluid being fed into either one of said ports, whereby the port receiving said pressurized fluid functions as inlet means for its respective chamber and the other said port functions as outlet means for its chamber.

11. An actuator according to claim 10, wherein said control valve has biasing means to normally close communication between both said ports and their respective chambers, and safety valve means is connected to both said chambers to prevent the pressure therein exceeding a predetermined upper limit.

12. An actuator according to claim 8, wherein said pressure relief means includes a relief valve operatively connected to at least one of said chambers.

13. An actuator according to claim 8, wherein said pressure relief means includes two relief valves, each of which is operatively connected to a respective one of said chambers.

14. An actuator according to claim 13, wherein each said relief valve is contained within said piston assembly.

15. An actuator according to claim 8, wherein said piston assembly includes a secondary piston which is connected to an end portion of a piston rod which forms at least part of said connecting means, and a primary piston which is slidably mounted on said secondary piston for limited axial movement relative thereto; said piston rod projecting through an end wall of said cylinder and being movable axially relative to the cylinder with said secondary piston; said pressure relief means includes a passage formed through said secondary piston to provide communication between said chambers; and said valve means includes at least part of said primary piston which is arranged to open or close said communication according to its axial position relative to said secondary piston.

16. An actuator according to claim 13, wherein said relief means passage has an entrance portion which extends laterally through the surface of said secondary piston over which said primary piston slides, said primary piston part being located over said entrance portion and closing same when in said particular axial position.

17. An actuator according to claim 16, wherein; said primary piston includes an inner sleeve section slidable on said secondary piston, and an outer sleeve section which is slidable on said inner sleeve section; stop means is provided on said secondary piston to limit axial movement of said inner sleeve section relative to the secondary piston; and said outer sleeve section is located between opposed annular shoulders of said inner sleeve section and is engageable therewith to limit its axial movement relative to said inner sleeve section.

18. An actuator according to claim 17, wherein an opening extends radially through said inner sleeve section and remains in communication with said passage entrance portion in all axial positions of said inner sleeve section relative to said secondary piston, and communication between said entrance portion and the adjacent cylinder chamber is closed by engagement between said outer sleeve section and one of said annular shoulders.

19. An actuator according to claim 17, wherein an abutment is provided within said cylinder for engagement by said outer sleeve section to limit axial movement of said outer sleeve section relative to the cylinder in one direction; and said inner sleeve section and secondary piston are able to move further in said one direction after said outer sleeve section and said abutment engage, whereby said outer sleeve section is located relative to said secondary piston to close said relief passage.

20. An actuator according to claim 19, wherein said relief passage is closed when said outer sleeve section engages both the said abutment and the said annular shoulder located remote from said abutment; and in that position of the piston assembly the effective end area thereof which is engageable by pressurized fluid to move the said secondary piston further in said one direction, is smaller than the effective opposite end

area of the piston assembly which is engageable by pressurized fluid to move said assembly in the direction opposite to said one direction.

21. An actuator according to claim 15, wherein said relief means includes a one-way valve located in said relief passage.

22. An actuator according to claim 15, wherein two said passages are formed through said secondary piston, and said primary piston part is movable axially relative to the secondary piston between two positions in each of which said part closes a respective said passage.

23. An actuator according to claim 17, wherein two said passages are formed through said secondary piston, said primary piston part is movable axially relative to the secondary piston between two positions in each of which said part closes a respective said passage, two openings extend radially through said inner sleeve section and each remains in communication with the entrance portion of a respective one of said passages in all axial positions of said inner sleeve section relative to said secondary piston, and communication between each said entrance portion and the adjacent cylinder chamber is closed by engagement between said outer sleeve section and a respective one of said annular shoulders.

24. An actuator according to claim 18, wherein two said passages are formed through said secondary piston; said primary piston part is movable axially relative to the secondary piston between two positions in each of which said part closes a respective said passage; a pair of spaced abutments are provided within said cylinder for engagement by said outer sleeve section to limit axial movement of said outer sleeve section relative to the cylinder in two opposite directions; and said inner sleeve section and secondary piston are able to move further in each said direction after said outer sleeve section and the respective said abutment engage, whereby said outer sleeve section is located relative to said secondary piston to close the respective said relief passage.

25. An actuator according to claim 24, wherein said outer sleeve section engages a respective said abutment in each of said two positions, and a reduction in the said effective end area of the piston assembly occurs in each of said positions, the said end area reduced being opposite for each of said positions.

26. An actuator according to claim 22, wherein said relief means includes a one-way relief valve located in each said passage, and said valves are arranged to allow passage of fluid in respective opposite directions.

27. An actuator according to claim 15, wherein a combined inlet and outlet port is provided for each said chamber, each said port communicating with its respective said chamber through a pressure-operated control valve arranged to open both said ports to their respective chambers in response to pressurized fluid being fed into either one of said ports, whereby the port receiving said pressurized fluid functions as inlet means for its respective chamber and the other said port functions as outlet means for its chamber.

28. An actuator according to claim 27, wherein said control valve has biasing means to normally close communication between both said ports and their respective chambers, and safety valve means is connected to both said chambers to prevent the pressure therein exceeding a predetermined upper limit.

29. An actuator according to claim 27, wherein said control valve is contained in a valve block secured to one end of said cylinder; said block including two valve compartments, one of which communicates directly with the adjacent said cylinder chamber, and the other communicates with the remote said cylinder chamber through a conduit; and each said port is connected to a respective said valve compartment when said control valve is opened.

30. An actuator according to claim 29, wherein said control valve includes two one-way valve elements which are biased by spring means towards each other into closed positions in which each closes communication between a respective said port and valve compartment, and an axially slidable spool element disposed between said valve elements and providing a fluid seal between said ports; said spool being operative to open one said valve element in response to fluid pressure in the port of the other said valve element.

31. An actuator according to claim 8, wherein: said piston assembly includes two cylindrical end portions, an intermediate portion joining said end portions, and a rack formed on said intermediate portion and drivably engageable with a pinion projecting through an aperture in a side wall of said cylinder, said rack and pinion forming at least part of said connecting means; said relief means includes a main relief passage providing a communication between said chambers; and said valve means includes at least one of said end portions of the piston assembly which is arranged to open or close said communication between said chambers according to the axial position of the piston assembly relative to said cylinder.

32. An actuator according to claim 31, wherein said main relief passage is defined by a conduit located externally of said cylinder and which communicates with each said chamber through a respective passage extending axially of the cylinder and arranged to be closed by the adjacent end surface of the piston assembly.

33. An actuator according to claim 32, wherein each said axial passage is formed in a stop element which projects axially into said cylinder from a respective end wall thereof, the end surface of each stop element which is located within said cylinder serving as an abutment for the adjacent end of said piston assembly and having the respective said axial passage opening therethrough.

34. An actuator according to claim 33, wherein each said stop element is adjustably mounted in the respective cylinder end wall to enable variation of the axial position of the said end surface thereof.

35. An actuator according to claim 31, wherein said relief means include relief valve means connected to said main relief passage and operable to open and close communication between said chambers through said main passage, according to the fluid pressure existing in said chambers.

36. An actuator according to claim 35, wherein said relief valve means includes a valve housing having a compartment therein, said main passage communicating direct with said compartment and with one of said cylinder chambers, and compartment inlet and outlet

passages each of which communicates with the other said cylinder chamber and is controlled by a respective one-way valve, the two said one-way valves being arranged to respectively allow fluid into and out of said compartment.

37. An actuator according to claim **32**, wherein said relief means include relief valve means connected to said main relief passage and operable to open and close communication between said chambers through said main passage, according to the fluid pressure existing in said chambers; said relief valve means including a valve housing having a compartment therein, said main passage communicating direct with said compartment and with one of said cylinder chambers, and compartment inlet and outlet passages each of which communicates with the other said cylinder chamber and is controlled by a respective one-way valve, the two said one-way valves being arranged to respectively allow fluid into and out of said compartment, said compartment inlet passage communicating with one of said axial passages, and said conduit communicating direct with the other said axial passage.

38. An actuator according to claim **37**, wherein said relief valve means includes a manually operable by-pass valve which is operable to open direct communication between said conduit and said one axial passage.

39. An actuator according to claim **31**, wherein each of the opposite end walls of said cylinder is defined by a valve block which includes: a combined fluid supply and exhaust port, a pressure operable one-way valve which is normally biased into a closed position and controls fluid flow through said port, and an axially slidable spool element which is pressure operable to open said one-way valve; and respective drain passage means connects the said port of each said valve block to a rear side of the said spool element of the other said valve block, whereby pressurized fluid supplied to one said chamber through the adjacent said valve block is operative to cause the said spool element of the other said valve block to open its respective said one-way valve and thereby allow said other chamber to exhaust.

40 An actuator according to claim **39**, wherein safety valve means is provided within each said valve block and communicates with the adjacent said chamber to prevent the pressure therein exceeding a predetermined upper limit.

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