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(54) ACTUATOR ARRANGEMENT

(57) An actuator arrangement comprises a primary drive member 16 located within a housing 20 and defining, with the housing 20, a first chamber 22 and a second chamber 24, a controller 26 controlling the application of fluid under pressure to the first and second chambers 22, 24 to drive the primary drive member 16 for movement, an auxiliary drive member 36 moveable between a retracted position and an extended position under the control of an auxiliary controller 44, the auxiliary controller 44 being responsive to a control pressure applied, in use, to control the pressure applied to the first chamber 22.

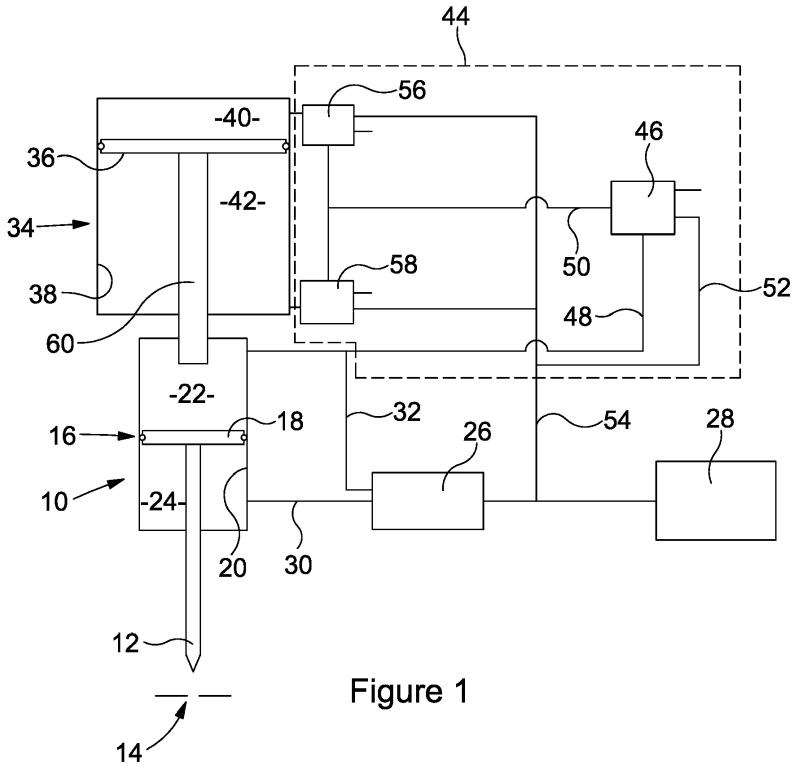

Figure 1

EP 3 012 462 A1

Description

[0001] This invention relates to an actuator arrangement, and in particular to a pneumatically or hydraulically operated actuator arrangement.

[0002] There are many applications in which actuator arrangements are used to drive components for movement. One such application is in controlling the operation of a valve such as an anti-surge valve. In such an application, a valve member is movable between a fully closed position in which it engages a seat so as to prevent fluid flow and a fully upon position in which the restriction to fluid flow past the seat is reduced. The valve member may further be capable of being held in a range of intermediate positions, thereby providing a greater degree of control over the flow of fluid past the seat.

[0003] The actuator arrangement used in controlling the operation of such a valve may be of pneumatic form, comprising a piston slidable within a cylinder so as to divide the cylinder into a pair of chambers, a control arrangement being operable to control the pressures applied to the chambers and thereby control the position occupied by the piston at any time. Movement of the piston is transmitted to the valve member by means of a connector member that interconnects the piston and the valve member.

[0004] In some applications, when the valve member engages the seat and so occupies its fully closed position, there is a need to ensure that the force maintaining the engagement between the valve member and the seat is held at a high level. This may be achieved by using a relatively large diameter piston to drive the valve member for movement, as the large effective area provided by such a piston results in the force applied to the valve member being relatively large. However, the use of a large diameter piston has the disadvantage that movement of the piston, in normal use, requires large volumes of air to be moved, the swept volume of the piston being large. As a consequence, not only does this solution involve the use of a large diameter piston but also many of the associated components of the actuator arrangement need to be large in order to accommodate the high gas flow rates required to drive such a piston for movement. Clearly, this impacts upon the weight, size, complexity and cost of the actuator arrangement.

[0005] Whilst described in relation to an anti-surge valve, it will be appreciated that the actuator arrangement may be employed in a range of other applications.

[0006] It is an object of the invention to provide an actuator arrangement in which this functionality is present and in which at least some of the disadvantages associated with known arrangements are overcome or are of reduced effect.

[0007] According to the present invention there is provided an actuator arrangement comprising a primary drive member located within a housing and defining, with the housing, a first chamber and a second chamber, a controller controlling the application of fluid under pressure to the first and second chambers to drive the primary drive member for movement, an auxiliary drive member moveable between a retracted position and an extended position under the control of an auxiliary controller, the auxiliary controller being responsive to a control pressure applied, in use, to control the pressure within the first chamber.

[0008] The auxiliary drive member may engage the primary drive member when the auxiliary drive member occupies its extended position.

[0009] In some arrangements, the controller may be operable to supply fluid under pressure to the first chamber, in which case the control pressure used by the auxiliary controller may be the pressure within the first chamber. Alternatively, the controller may control the operation of volume boosters or the like which serve to control the pressures in, for example, the first chamber. In such an arrangement, the control pressure may be the pressure applied to the volume booster associated with the first chamber controlling the operation thereof.

[0010] In such an arrangement, when the control pressure controlling the pressure within the first chamber is high so that the first chamber is pressurised to drive the primary drive member to a predetermined position, the application of the high control pressure causes operation of the auxiliary controller to drive the auxiliary drive member towards its extended position.

[0011] Where used in conjunction with, for example, an anti-surge valve, it will be appreciated that if the control pressure is high such that high pressure is applied to the first chamber to drive the primary drive member to a position in which the valve member of the anti-surge valve engages its seat, the auxiliary controller will respond to the application of the high control pressure, driving the auxiliary drive member to a position in which it engages the primary drive member and so supplements or augments the load serving to drive the valve member towards and/or maintain the valve member in engagement with its seat.

[0012] By way of example, the auxiliary drive member may comprise a relatively large diameter piston to which fluid under pressure may be applied under the control of the auxiliary controller. In such an arrangement, the auxiliary controller may comprise a switching valve responsive to the control pressure to control the operation of a pair of spool valves controlling the application of fluid under pressure to the large diameter piston. Whilst such an arrangement makes use of a large diameter piston to supplement the load applied by the primary drive member, it will be appreciated that the large diameter piston is only driven for movement occasionally, and so the quantity of fluid that has to be supplied for normal operation of the actuator arrangement is lower than is the case with conventional arrangements.

[0013] In an alternative arrangement, the auxiliary drive member may be of relatively small dimensions and may be driven for movement by a higher pressure fluid. By way of example, a pump may be provided to pressu-

rise fluid applied to the auxiliary drive member. The fluid may comprise a hydraulic fluid derived from a source independent of the pneumatic supply to the primary drive member. The pump may be a pneumatically powered pump.

[0014] Alternatively the auxiliary drive member may control the operation of a valve forming part of a hydraulic intensifier which in turn controls movement of the primary drive member.

[0015] The invention will further be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of an actuator arrangement in accordance with one embodiment of the invention;

Figure 1 a illustrates a modification to the arrangement of Figure 1; and

Figures 2 to 5 are views similar to Figure 1 illustrating alternative embodiments.

[0016] Referring firstly to Figure 1, an actuator arrangement 10 is illustrated for use in driving a valve member 12 for movement relative to a seat 14 to control the flow of fluid past the seat 14. The valve member 12 may comprise part of, for example, an anti-surge valve. The actuator arrangement 10 comprises a primary drive member 16 in the form of a piston 18 to which the valve member 12 is connected and moveable within a cylinder 20, dividing the cylinder into a first chamber 22 and a second chamber 24. A positioner or controller 26 controls the position occupied by the piston 18 by controlling the supply of fluid under pressure, for example compressed air, from a reservoir 28 to the first and second chambers 22, 24. By way of example, if it is determined that the valve member 12 should be lifted further away from its seat 14, then in order to achieve this fluid is supplied to the second chamber 24 along line 30 increasing the pressure within the second chamber 24, a quantity of fluid from the first chamber 22 being vented therefrom along the line 32. Conversely, if the valve member 12 is to be driven towards its seat then fluid is supplied to the first chamber 22 via line 32 to increase the pressure within the first chamber 22, a quantity of fluid being vented from the second chamber 24 along the line 30. The changes in pressure result in the piston 18 being driven to a new equilibrium position, the valve member 12 moving along with the piston 18.

[0017] Figure 1 a illustrates a variant to the arrangement of Figure 1 in which the controller 26, instead of directly controlling the application of fluid under pressure from the reservoir 28 to the chambers 22, 24, instead outputs control pressures via lines 30b, 32b to control the operation of volume boosters 30a, 32a to control the supply of fluid under pressure from the reservoir 28 to the chambers 22, 24 and thereby control the position of the piston 18. It will be appreciated that in this arrangement, the control pressures need not be the same as the pressures within the chambers 22, 24, but are merely representative of desired pressures thereof.

[0018] Regardless as to the manner in which the piston 18 is controlled, in accordance with the invention an auxiliary drive member 34 in the form of a second piston 36 is provided, the piston 36 being movable within an associated cylinder 38. The piston 36 and cylinder 38 together define third and fourth chambers 40, 42, and an auxiliary controller 44 is operable to control the supply of fluid to the third and fourth chambers 40,42.

[0019] As illustrated, the auxiliary controller 44 comprises a pneumatic switching valve 46 operable, depending upon the control pressure applied thereto from a control line 48. In the arrangement of Figure 1, the control line 48 is connected to the first chamber 22, and so the control pressure will substantially match the pressure within the first chamber 22. In the arrangement of Figure 1 a, the control line 48 is connected to the line 32b controlling the operation of the volume booster 32a. The control pressure thus may vary from the actual pressure within the first chamber 22, but will be indicative of a desired pressure for the first chamber 22. The control pressure within the control line 48 is used to control whether a second control line 50 is supplied with fluid at high pressure or is instead at a lower pressure. The manner in which the switching valve 46 operates is such that when the applied control pressure exceeds a predetermined level, then the second control line 50 is supplied with fluid at high pressure via the lines 52, 54 providing flow connections to the reservoir 28. When the applied control pressure is lower than the predetermined level, then the second control line 50 is exposed to a lower pressure, for example it may communicate with the line 48 and so be exposed to substantially the lower pressure within the first chamber 22. Alternatively, it may be connected to a low pressure reservoir during this phase in the operation of the system.

[0020] The fluid pressure within the second control line 50 is used to control the operation of a pair of pilot spool valves 56, 58 to control the fluid pressures within the third and fourth chambers 40, 42. Specifically, when the fluid pressure within the second control line 50 is high, the pilot spool valve 56 occupies a position in which it permits fluid flow to the third chamber 40 from the line 54, the pilot spool valve 58 venting the fourth chamber 42. Accordingly, the piston 36 will move in a downward direction in the orientation illustrated. When the second control line 50 is at a reduced pressure, then the pilot spool valves 56, 58 switch positions so that the third chamber 40 is vented whilst the fourth chamber 42 is exposed to high pressure. As a result, upward movement of the piston 36 occurs.

[0021] In essence, therefore, when the controller 26 drives the system to apply full or high pressure to the chamber 22, the control unit 44 operates to positively drive the piston 36 in the downward direction.

[0022] A rod 60 is coupled to the piston 36 for movement therewith, the rod 60 projecting from the cylinder 38 and into the cylinder 20 so that, depending upon the positions occupied by the pistons 18, 36, the rod 60 may engage the piston 18.

[0023] In normal use, the controller 26 controls the supply of fluid to the first and second chambers 22, 24 as described hereinbefore, the auxiliary controller 44 operating to apply fluid under pressure to the fourth chamber 42 whilst the third chamber 40 is vented with the result that the piston 36 occupies a retracted position and the rod 60 is not engaged with the piston 18, as the pressure within the chamber 22 will normally be below the predetermined threshold.

[0024] In the event that the valve member 12 is to be moved into engagement with the seat 14, then this is achieved by applying high pressure to the first chamber 22 whilst the second chamber 24 is vented to low pressure. The application of high pressure to the first chamber 22 not only serves to commence movement of the piston 18 and valve member 12 to drive the valve member 12 towards its seat 14 as outlined hereinbefore, but also results in the application of a high control pressure to the switching valve 46 of the auxiliary controller 44 causing it to switch position to result in the application of fluid under pressure to the second control line 50. The application of high pressure to the second control line 50 causes switching of the pilot spool valves 56, 58 with the result that the third chamber 40 becomes pressurised whilst the fourth chamber 42 is vented. As a result, the piston 36 moves downward, in the orientation illustrated, to its extended position driving the rod 60 with it to bring the rod 60 into engagement with the piston 18. Once such engagement has been established, it will be appreciated that the force resulting from the application of fluid under pressure to the third chamber 40 is transmitted to the piston 18 and valve member 12, supplementing the load applied by the fluid pressure within the first chamber 22 in ensuring that the valve member 12 is moved to and held in engagement with the seat 14.

[0025] As illustrated, the piston 36 is of relatively large diameter and so whilst the fluid pressure applied thereto in use is derived from the reservoir 28 and so is substantially the same as that applied to the first chamber 22 when the valve is to be closed, the force resulting from the application of the pressure to piston 36 is relatively large.

[0026] When the valve member 12 is to be lifted away from its seat 14, the controller 26 operates to reduce the pressure within the first chamber 22 and so to lower the control pressure applied to the switching valve 46. This reduction rapidly results in switching of the switching valve 46 and hence in switching of the pilot spool valves 56, 58, with the result that the piston 36 is rapidly returned to its retracted position. Such movement separates the rod 60 from the piston 18 leaving the piston 18 free to move under the control of the controller 26 as described hereinbefore.

[0027] It will be appreciated that the arrangement of Figure 1 is advantageous in that the piston 18 and cylinder 20 can be of relatively small size, requiring relatively small volumes of fluid to be supplied thereto in use, whilst still allowing a sufficiently large force to be applied to hold the valve member 12 in engagement with the seat 14 when required.

[0028] Whilst in Figure 1 the pressure within the chamber 42 controls return movement of the piston 36, a spring or other resilient bias means may be used, alone or in conjunction with fluid pressure, to drive the piston 36 for return movement if desired.

[0029] Turning to the arrangement of Figure 2, in which like elements to those of the arrangement of Figure 1 are denoted by like numerals, the fluid used to drive the piston 36 for movement is not derived from the reservoir 28 but rather is derived from an auxiliary reservoir 62 and is pressurised to a level higher than the output from the reservoir 28 by a pump 64. Conveniently, in this embodiment, the fluid used to drive the piston 36 is a hydraulic fluid rather than compressed air as in the arrangement of Figure 1. The pump 64 may be a pneumatically powered pump, for example powered using compressed air from the reservoir 28. Supply of the pressurised fluid from the pump 64 to the third chamber 40 is controlled by a pilot valve 66 responsive to the fluid pressure within the first chamber 22 such that when the pressure within the first chamber 22 is high, the valve 66 operates to supply high pressure fluid from the pump 64 to the third chamber 40, and when the first chamber pressure is low, the third chamber 40 communicates via the valve 66 and a check valve 68 with the reservoir 62 to permit the venting of fluid therefrom

[0030] In use, the position occupied by the piston 18 and valve member 12 is controlled as outlined hereinbefore with reference to Figure 1. In this mode of operation the pressure within the first chamber 22 normally remains sufficiently low that the valve 66 occupies its position in which the third chamber 40 is vented via the check valve 68 to the reservoir 62. In the event that the valve member 12 is to be moved into engagement with the seat 14, the first chamber 22 is pressurised to a high level. This results both in the piston 18 being urged to drive the valve member 12 as described hereinbefore and also results in switching of the valve 66, interrupting the venting of the third chamber 40 and instead applying the output from the pump 64 to the third chamber 40. As a result, the piston 36 is driven downwards in the orientation illustrated, establishing contact between the piston 36 and the piston 18 so that the force arising from the pressure within the third chamber 40 is transmitted to the piston 18 and valve member 12, holding the valve member 12 against its seat 14.

[0031] When the valve is to be reopened, the fluid pressure within the first chamber 22 is reduced. This results in switching of the valve 66 so that the third chamber 40 is vented via the check valve 68 to the reservoir 62. The force holding the valve member 12 in engagement with

the seat 14 is thus reduced. As the piston 18 is driven upwards, in the orientation illustrated, it will be appreciated that the piston 36 is also moved upwards, expelling fluid from the third chamber 40 via the check valve 68 to the reservoir.

[0032] As this arrangement makes use of higher pressures in driving the piston 36 for movement, the piston 36 may be of reduced diameter as shown. Consequently, additional size reductions can be made whilst maintaining the required levels of functionality.

[0033] It will be appreciated that the modification of Figure 1 may be applied to the arrangement of Figure 2 with the result that the control pressure applied to the valve 66 may differ from the pressure within the first chamber 22.

[0034] In the arrangements of Figures 1 and 2, potentially there may be a short delay between the controller 26 pressurising the first chamber 22 to drive the valve member 12 to its closed position and the auxiliary drive member 34 operating to supplement the closing load applied to the valve member 12, the delay arising from the valve switching times, the time taken to pressurise the third chamber 40 and the time taken from the piston 36 to reach the position in which it engages the piston 18. In many applications this short delay will be acceptable, but there may be applications in which a faster operation is required.

[0035] Figure 3 illustrates an arrangement in which a faster operating speed may be attained. In Figure 3 like reference numerals are used to denote parts similar in function to those of the arrangements of Figures 1 and 2.

[0036] In the arrangement of Figure 3, a hydraulic pressure intensifier arrangement is provided. The piston 18 includes a projection 18a which extends from the cylinder 20 into a housing 70, the housing 70 and the end of the projection 18a together defining a volume 72 which communicates with an oil reservoir 74. It will be appreciated that as the piston 18 moves under the control of the controller 26 the capacity of the volume 72 will vary, and oil will flow back and forth between the volume 72 and the reservoir 74 to keep the volume 72 filled with oil.

[0037] The arrangement comprises an auxiliary drive member 34 in the form of a piston 36 slidable within a cylinder 38. The piston 36 carries a valve member 76 engageable with a seat 78 defined by a movable part 70a of the housing 70 to control the flow of oil between the volume 72 and the reservoir 74. It will be appreciated that when the piston 36 occupies a position in which oil is able to flow between the reservoir 74 and the volume 72 then the piston 18 is free to move under the control of the controller 26. When the piston 36 is moved to bring the valve member 76 into engagement with the seat 78 and so terminates the flow of oil, further piston movement will pressurise the oil within the volume 72, the pneumatic pressure applied to the piston 36 being intensified by the intensifier arrangement such that the pressure applied to the projection 18a is significantly higher than the pressure applied to the piston 36. As a result, the piston 18 and valve member 12 are held positively with the valve member 12 engaging the seat 14.

[0038] Movement of the piston 36 is controlled by a switching valve 80 operable to control the pressure within the third chamber 40 by controlling the supply of fluid thereto and by controlling the operation of a quick exhaust valve 82 to vent compressed air from the third chamber 40.

[0039] In normal use, therefore, when the valve member 12 is not in engagement with the seat 14, the first chamber 22 will be at a pressure below the pressure at which the valve 80 operates. Accordingly, fluid under pressure is not supplied to the third chamber 40 and the valve 82 will be open. As a result, the valve member 76 will not be held in engagement with its seat 78. The piston 18 and valve member 12 are thus free for movement under the control of the controller 26, such movement resulting in oil being displaced between the reservoir 74 and the volume 72.

[0040] When the valve member 12 is to engage the seat 14, the first chamber 22 is pressurised to a high pressure. As mentioned above, this results in the piston 18 and valve member 12 moving in the downward direction as shown. It further results in the valve 80 operating to cause an increase in the pressure within the third chamber 40, and in the valve 82 closing to prevent exhaust flow from the third chamber 40. As a result, the piston 36 is urged in the downward direction bringing the valve member 76 into engagement with the seat 78. This engagement interrupts the flow of oil between the volume 72 and the reservoir 74 and so further movement of the piston 36 serves to raise the pressure within the volume 72, applying a large, intensified load to the projection 18a and piston 18 to maintain the engagement of the piston 18 with the seat 14.

[0041] In order to subsequently allow the valve member 12 to lift from its seat 14, the pressure within the first chamber 22 is reduced. This reduction in pressure causes switching of the valve 80 so that compressed air is no longer supplied to the third chamber 40, and the valve 82 is switched to allow the rapid exhaust of air from the third chamber 40. As a result, the pressure within the third chamber 40 quickly falls and so the valve member 76 can lift from its seating to allow oil flow to and from the volume 72 to recommence, for example under the action of a spring.

[0042] In this arrangement, as the projection 18a moves with the piston 18 and valve member 12, and such movement displaces oil between the volume 72 and the reservoir 74 to keep the volume 72 filled with oil, locking of the valve member 12 against movement occurs very rapidly, in use. Furthermore, the rapid exhausting of air from the chamber 40 when movement of the valve member 12 away from its seat 14 is to occur allows substantially instantaneous removal of the applied intensified pressure, thus allowing fast reopening of the valve.

[0043] If desired, a booster pump may be incorporated into the system to accelerate the rate of air flow into or

from the third chamber 40 at appropriate points in the operating procedure.

[0044] As with Figure 2, the modification shown in Figure 1 may be applied to the arrangement of Figure 3.

[0045] It will be appreciated that the embodiments described hereinbefore represent just examples, and that a number of modifications and alterations may be made to the arrangements described without departing from the scope of the invention. By way of example, whilst in the description hereinbefore the actuator arrangement is used to control the movement of a linearly displaceable valve member, it could be used in controlling, for example, a rotary moveable valve member or another device. Figure 4 illustrates, diagrammatically, one arrangement of this type. In the arrangement of Figure 4, the piston 18, instead of being coupled to a valve member 12, is instead coupled to a drive member 90. The drive member 90 includes a toothed section, the teeth of which mesh with a pinion 92 mounted upon a spindle 94 forming the drive input to a rotary valve. It will be appreciated that movement of the piston 18 causes axial displacement of the drive member 90 which, by virtue of the toothed coupling between the drive member 90 and the pinion 92, causes angular or rotary movement of the spindle 94 and operation of the rotary valve. In the arrangement illustrated, a spring 96 is used to cause return movement of the piston 18, but it could, if desired, be pressure driven in both directions. Whilst not illustrated in detail, any of the arrangements described hereinbefore may be employed to augment the load applied by the piston 18 to the drive member 90, in use, assisting in moving the rotary valve to and holding the rotary valve in a predetermined position, when required in response to the first chamber 22 being pressurised to a level exceeding a predetermined level. An arrangement of this type can be used to provide and allow operation of, for example, a rotary valve with a high breakout force.

[0046] Figure 5 illustrates an alternative scheme in which a pair of oppositely acting actuator arrangements 10 are provided. As with the arrangement of Figure 4, Figure 5 illustrates the actuator arrangements 10 in connection with a rotary valve arrangement, but the Figure 5 scheme could also be applied to linear arrangements. Rather than use a toothed arrangement to transmit drive between the drive member 90 and the spindle 94, the arrangement of Figure 5 makes use of a pin 98 carried by the drive member 90, the pin 98 being received within a slot 100 formed in a member 102 mounted upon the spindle 94. In this arrangement, movement of one of the auxiliary drive members 34, of any of the forms outlined hereinbefore, augments the load moving the drive member 90 in one direction, and movement of the other of the auxiliary drive members 34 augments the load driving the drive member 90 in the opposite direction. Where used with a valve, it will be appreciated that this arrangement allows the loads driving the valve member towards both of its extreme positions, or other positions, and maintaining the valve member in those positions, to be augmented in response to the application of a control pressure greater than a predetermined level to the associated first chamber 22. Accordingly, an actuator for a valve with a high sealing force and high break out force can be provided.

[0047] Whilst described hereinbefore in relation to the control of an anti-surge valve, the invention may be employed in a number of other applications, for example in ensuring that valve members which have a tendency to stick operate when required, or to augment the load required to open a valve. Although the description hereinbefore relates primarily to ensuring that a valve member, when instructed to occupy its closed position, is positively driven to and held in that position, the secondary drive member augmenting the loads applied to the valve member by the primary drive member 16, the arrangement may be modified for use in other applications for example to allow a valve member to be positively driven to and held in or driven from a fully open or other predetermined position.

Claims

1. An actuator arrangement comprising a primary drive member located within a housing and defining, with the housing, a first chamber and a second chamber, a controller controlling the application of fluid under pressure to the first and second chambers to drive the primary drive member for movement, an auxiliary drive member moveable between a retracted position and an extended position under the control of an auxiliary controller, the auxiliary controller being responsive to a control pressure applied, in use, to control the pressure within the first chamber.

2. An actuator arrangement according to Claim 1, wherein the auxiliary drive member engages the primary drive member when the auxiliary drive member occupies its extended position.

3. An actuator arrangement according to Claim 1, wherein a hydraulic intensifier arrangement is provided between the primary drive member and the auxiliary drive member.

4. An actuator arrangement according to any of the preceding claims, wherein the auxiliary drive member comprises a relatively large diameter piston to which fluid under pressure may be applied under the control of the auxiliary controller.

5. An actuator arrangement according to Claim 4, wherein the auxiliary controller comprises a switching valve responsive to the control pressure to control the operation of a pair of spool valves controlling the application of fluid under pressure to the large diameter piston.

6. An actuator arrangement according to any of Claims 1 to 3, wherein the auxiliary drive member is of relatively small dimensions and is driven for movement by a higher pressure fluid.

7. An actuator arrangement according to Claim 6, further comprising a pump operable to pressurise fluid applied to the auxiliary drive member.

8. An actuator arrangement according to Claim 7, wherein the fluid comprises a hydraulic fluid derived from a source independent of the supply to the primary drive member.

9. An actuator arrangement according to Claim 7 or Claim 8, wherein the pump is a pneumatically powered pump.

10. An actuator arrangement according to Claim 3 or any of Claims 4 to 9 when dependent upon Claim 3, wherein the auxiliary drive member controls the operation of a valve forming part of the hydraulic intensifier.

11. An actuator arrangement according to any of the preceding claims, wherein the fluid applied to the first chamber comprises compressed air.

12. A valve arrangement comprising a valve member and an actuator arrangement according to any of the preceding claims operable to drive the valve member for movement.

13. A valve arrangement according to Claim 12, wherein the valve member is a linearly movable valve member or a rotatably movable valve member.

14. A valve arrangement according to Claim 12 or Claim 13, further comprising a second auxiliary drive member oriented oppositely to the first mentioned auxiliary drive member.

15. A valve arrangement according to any of Claims 12 to 14, wherein the valve arrangement forms part of an anti-surge valve.

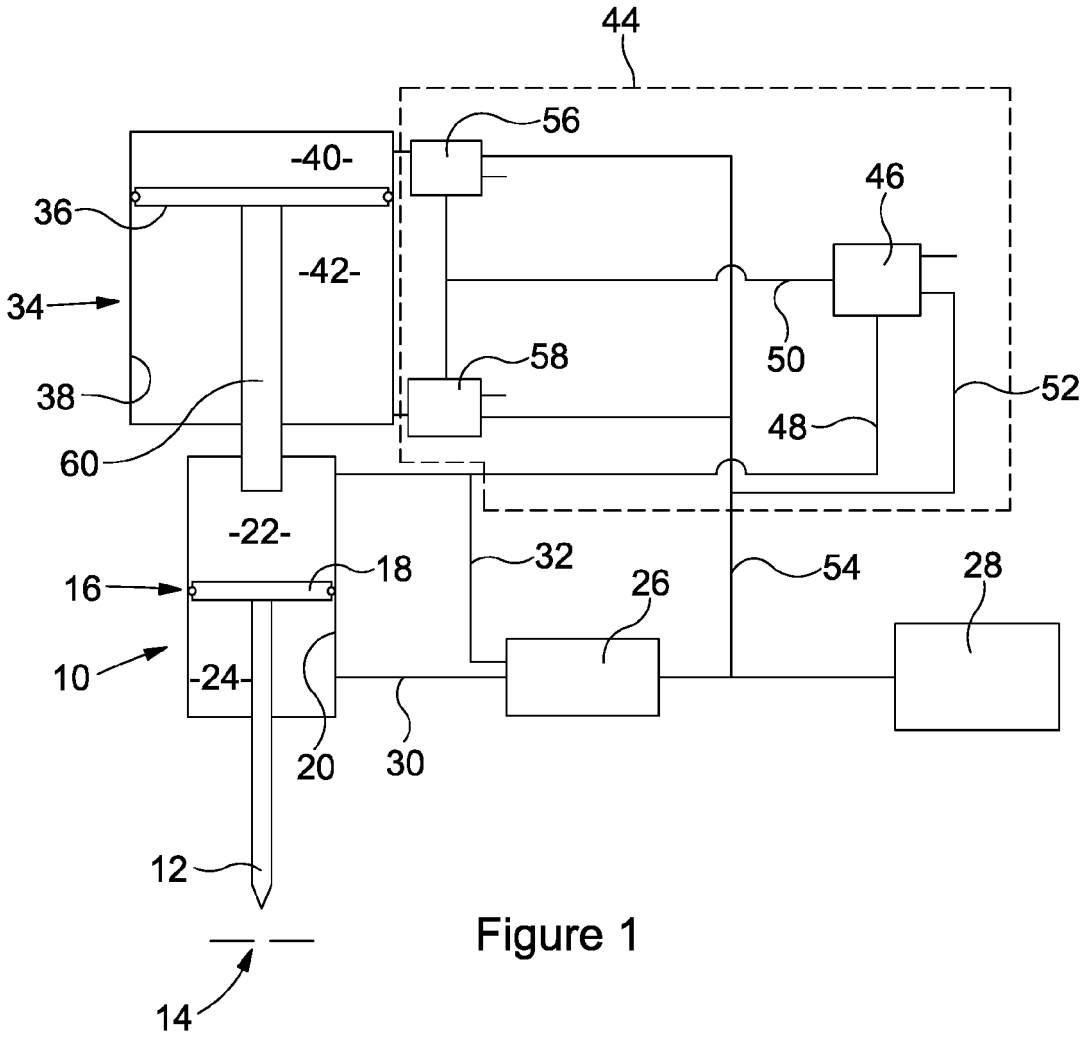

Figure 1

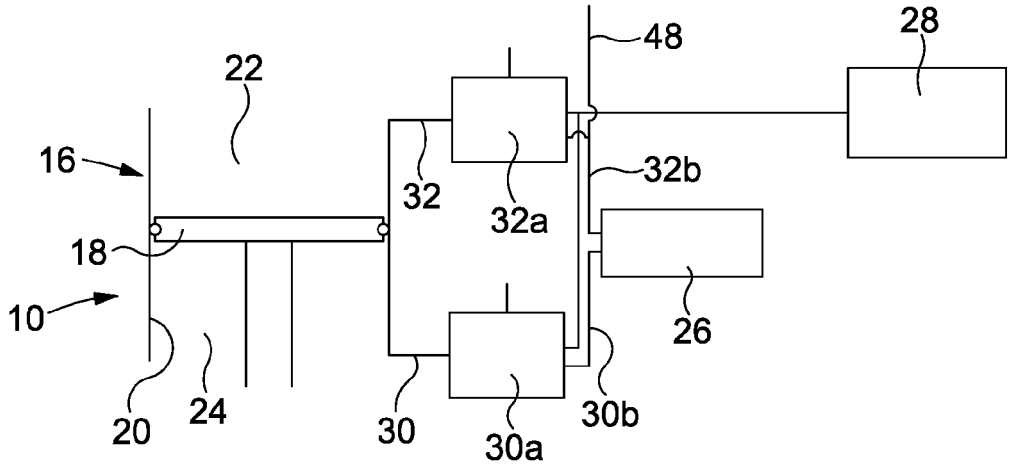

Figure 1a

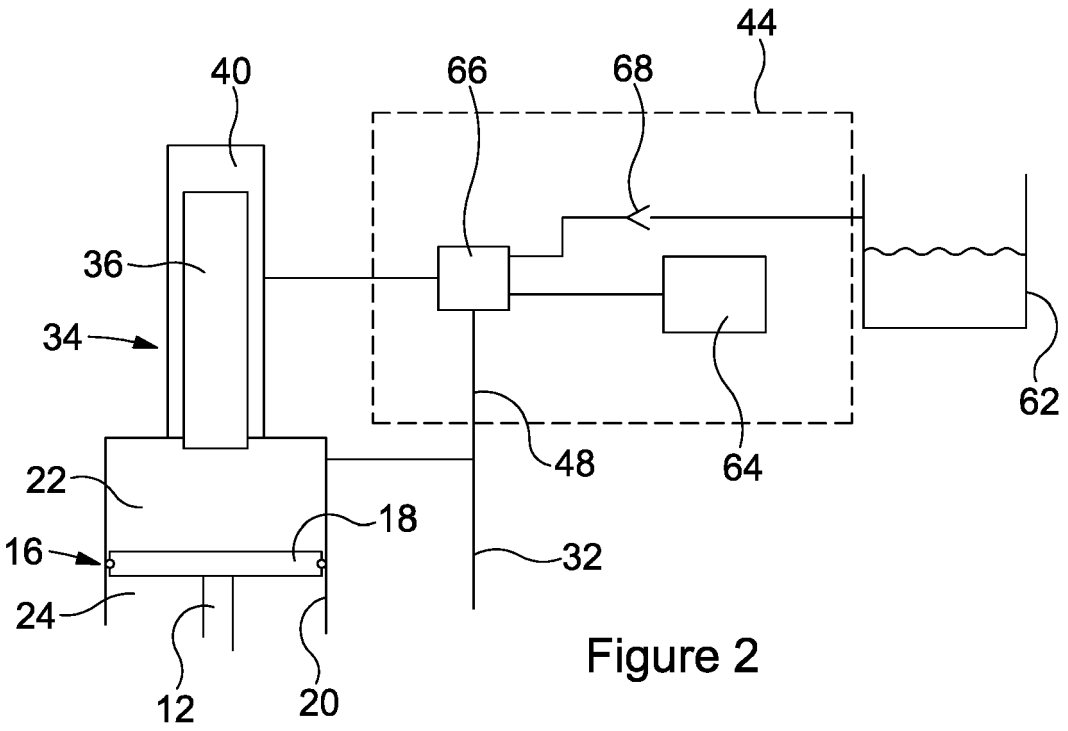

Figure 2

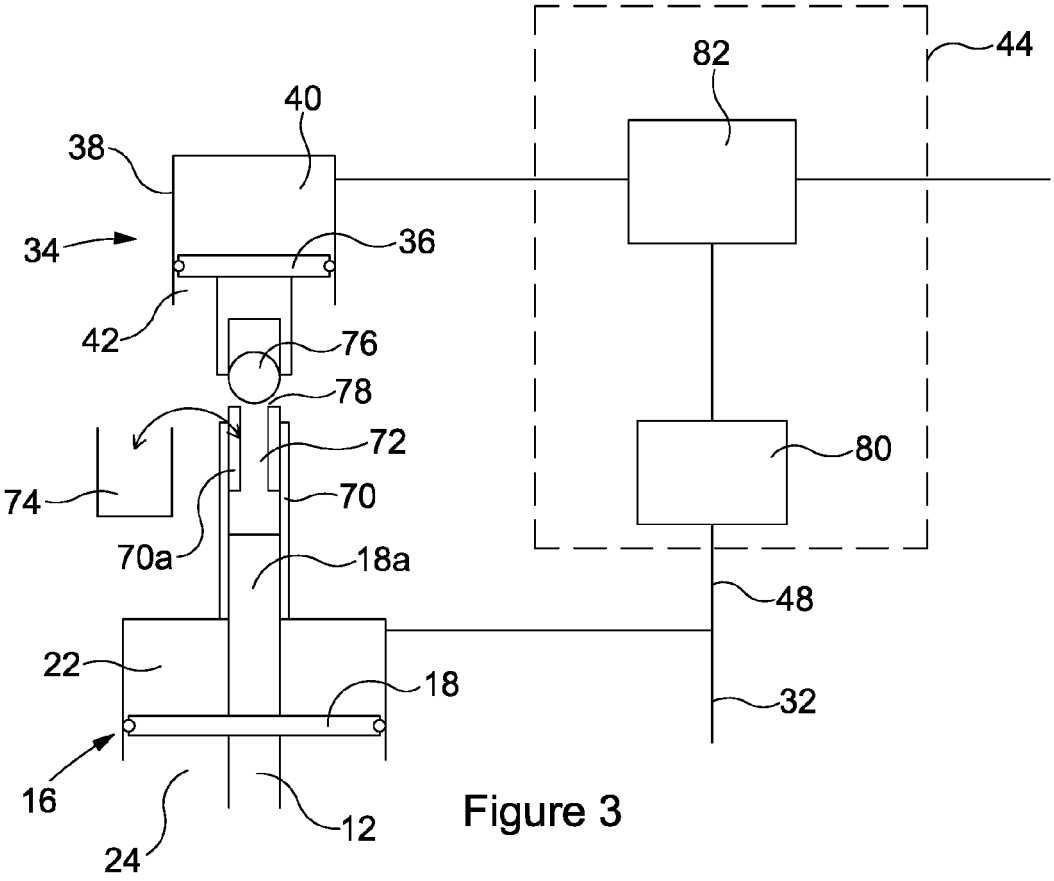

Figure 3

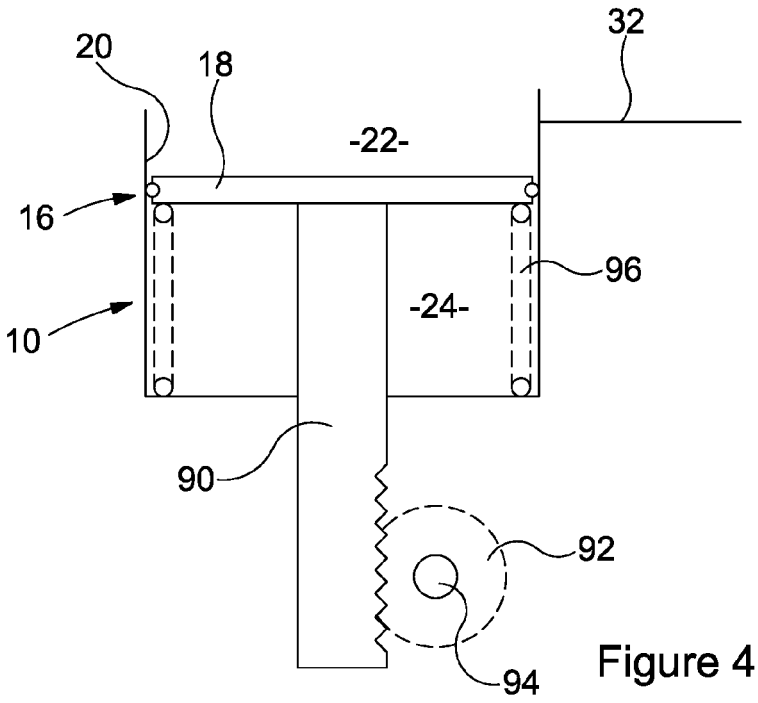

Figure 4

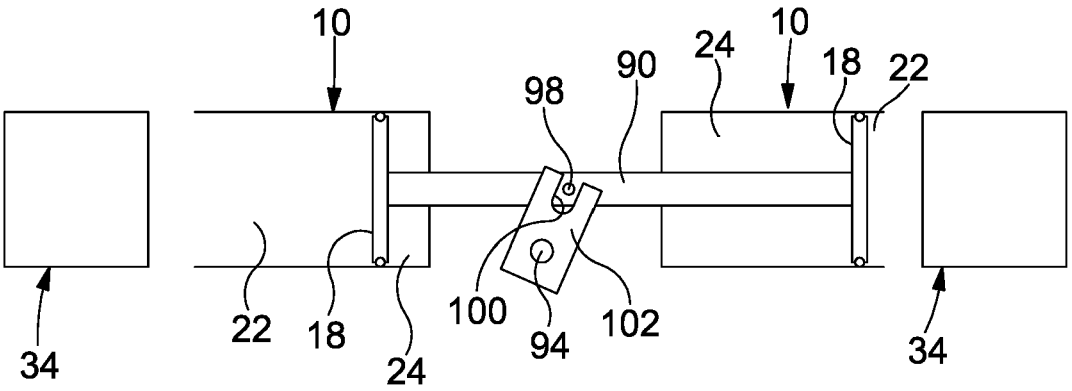

Figure 5

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European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 15 18 6613

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 955 195 A (JONES MARVIN R [US] ET AL) 11 September 1990 (1990-09-11) * column 4, lines 12-38 * * column 6, lines 15-49; figures 1-3 *	1-15	INV. F15B11/032 F15B11/036 F15B15/14
X	EP 2 327 884 A1 (CATERPILLAR WORK TOOLS BV [NL]) 1 June 2011 (2011-06-01) * paragraphs [0017] - [0019], [0021], [0028], [0029], [0032], [0037] - [0039]; figure 2 *	1-15	
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A	EP 2 067 911 A1 (SANY HEAVY IND CO LTD [CN]) 10 June 2009 (2009-06-10) * figures 2-10 *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 March 2016	Heneghan, Martin

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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