(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 April 2007 (05.04.2007)

PCT

(10) International Publication Number
WO 2007/035997 A1

(51) International Patent Classification:
*B60K 6/12* (2006.01) *F15B 1/027* (2006.01)
*B60W 10/24* (2006.01) *B60W 10/04* (2006.01)
*F15B 21/14* (2006.01) *F15B 1/033* (2006.01)
*B60K 25/00* (2006.01)

(21) International Application Number:
PCT/AU2006/001426

(22) International Filing Date:
28 September 2006 (28.09.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2005905345 28 September 2005 (28.09.2005) AU

(71) Applicant *(for all designated States except US)*: **PERMO-DRIVE RESEARCH AND DEVELOPMENT PTY LTD** [AU/AU]; 203 Southern Cross Drive, Ballina, NSW 2478 (AU).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **THOMPSON, John, Graham** [AU/AU]; 75 Montwood Drive, Lennox Head, NSW 2478 (AU). **MARSHALL, Christopher, Scott** [AU/AU]; 5 Maple Drive, Alstonville, NSW 2477 (AU). **COOKE, Bradley, James** [AU/AU]; 2-6 Arlington Crt, Munruben, QLD 4125 (AU).

(74) Agent: **SPRUSON & FERGUSON**; GPO Box 3898, Sydney, NSW 2001 (AU).

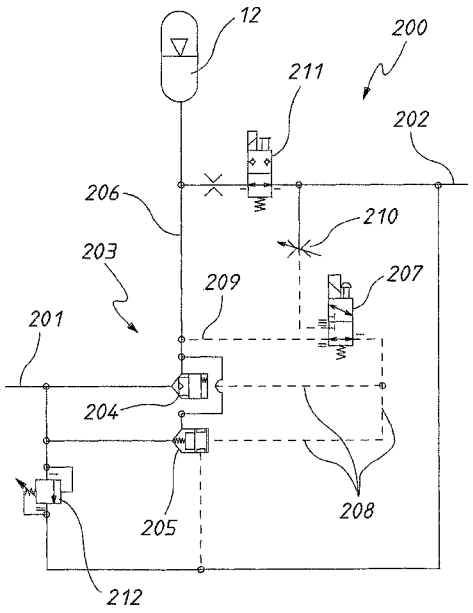
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*

*[Continued on next page]*

(54) Title: HYDRAULIC CIRCUIT FOR A ENERGY REGENERATIVE DRIVE SYSTEM




(57) Abstract: A circuit (200) for a regenerative drive system including a motor/pump apparatus (10) coupled to an accumulator (12) via a primary valve device (203). The valve (203) includes parallel valves (204, 205) via which hydraulic fluid under pressure from the apparatus (10) is delivered to the accumulator (12). When the apparatus (10) is operate as a motor, the valves (204, 205) are opened providing for flow from the accumulator (12) to the apparatus (10). Opening of the valves (204, 205) is governed so as to minimize shock loading the apparatus (10).

WO 2007/035997 A1

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# HYDRAULIC CIRCUIT FOR A ENERGY REGENERATIVE DRIVE SYSTEM

## Technical Field

The present invention relates to hydraulic circuits used to deliver hydraulic fluid under pressure to a motor/pump device to have the device act as a motor.

## Background of the Invention

Described in specification of USA Patent 6712166 is a regenerative drive system including a positive displacement pump/motor assembly that co-operates with an accumulator to receive hydraulic fluid under pressure from the assembly when the assembly is acting as a pump, and to deliver hydraulic fluid under pressure to the assembly when the assembly is to act as a motor. The assembly is inserted in the drive shaft of a vehicle. For example, under deceleration energy can be taken from the drive shaft and stored in the accumulator. This energy can then be extracted with the assembly operating as a motor so as to deliver energy to the drive shaft.

A disadvantage of the above discussed regenerative drive system is that when hydraulic fluid under pressure is delivered to the pump/motor from the accumulator, the apparatus "jolts" the drive train of the vehicle. This causes undesirable noise and vibration.

A further disadvantage of the above described system is that there is a delay between selecting operation of the apparatus as a motor and when it actually commences operation.

A still further disadvantage is that portion of the hydraulic circuit can be subjected to excessive pressure if portions of the hydraulic circuit fail. In particular failure can result in the uncontrolled release of hydraulic fluid from the accumulator to the reservoir through one of the return lines.

## Object of the Invention

It is the object of the present invention to overcome or substantially ameliorate at least one of the above disadvantages.

## Summary of the Invention

There is disclosed herein a hydraulic circuit including:

an accumulator to store hydraulic fluid under pressure;

a hydraulic pump/motor apparatus that when driven is operable as a pump to provide hydraulic fluid under pressure for delivery to the accumulator, while when receiving hydraulic fluid under pressure from the accumulator is operable as a motor;

a primary valve device connecting the apparatus to said accumulator to provide for the flow of the hydraulic fluid to said accumulator and operable to prevent flow from said accumulator to said apparatus to thereby have said accumulator store the hydraulic fluid under pressure; and

a control mechanism to control said device, said mechanism causing operation of said device to regulate the rate of change of flow from said accumulator to said apparatus.

Preferably, said device includes a control valve connected to said accumulator and said primary valve, the control valve being operable to deliver hydraulic fluid under pressure from the accumulator to said primary valve to cause operation of said primary valve to provide for the flow of hydraulic fluid from said accumulator to said apparatus.

Preferably, said circuit includes a tank to receive said hydraulic fluid, and a relief valve operable to deliver hydraulic fluid to said tank when said accumulator reaches a desired charged state.

Preferably, said circuit includes a pressure operated valve operatively associated with said relief valve and said tank, and wherein upon a predetermined pressure being applied to said pressure operated valve said pressure operated valve operates said relief valve to drain hydraulic fluid to said tank.

Preferably, said primary valve and relief valve are included in a valve assembly, said valve assembly including a valve chamber having a first, second and third port, and a first movable valve member movable between an open position providing for communication between said first and second ports and a closed position blocking flow between the first and second ports, and a second movable valve member movable between a closed position blocking communication between said first port and said third

port, and an open position providing for the flow of hydraulic fluid from said first port to said third port, with said first movable valve member providing portion of said primary valve, and said second movable valve member providing portion of said relief valve.

Preferably, primary valve device includes a first valve and a second valve, the first and second valves being arranged in parallel between said apparatus and said accumulator.

Preferably, said primary valve device is maintained closed in respect of fluid flow from said accumulator to said apparatus by control of hydraulic fluid under pressure from said accumulator.

Preferably, said control device includes a valve operable to vent said control hydraulic fluid to tank at a controlled rate.

Preferably, said circuit includes a dump valve operable to drain said accumulator.

Preferably, said circuit includes a relief valve operable to deliver hydraulic fluid to tank should hydraulic fluid under pressure being delivered to said primary valve device exceed a predetermined pressure.

## Brief Description of the Drawings

A preferred form of the present invention will now be described by way of example with reference to the accompanying drawings wherein:

Figure 1 is a schematic hydraulic circuit for a regenerative drive system;

Figure 2 is a further illustration of the hydraulic circuit of Figure 1 highlighting portions of the circuit used in a "propulsion" mode;

Figure 3 is an illustration of the hydraulic circuit of Figure 1 highlighting portions of the circuit used in a "retard" mode;

Figure 4 is an illustration of the hydraulic circuit of Figure 1 highlighting portions of the circuit used in a further "retard" mode:

Figure 5 is an illustration of the hydraulic circuit of Figure 1 highlighting portions of the circuit used in a "dump" mode;

Figure 6 is an illustration of the hydraulic circuit of Figure 1 highlighting portions of the circuit used in a "stand by" mode;

Figure 7 is a schematic sectioned side elevation of a valve assembly employed in the circuit of Figure 1; and

Figure 8 is a further schematic hydraulic circuit for a regenerative drive system.

## Detailed Description of the Preferred Embodiment

In the accompanying drawing there is schematically depicted a variable angle swash pump/motor apparatus 10. Typically the apparatus 10 would co-operate with the drive train of a motor vehicle to extract energy from the drive train when the vehicle is de-accelerating, and to deliver energy to the drive train for the purposes of aiding in propelling the vehicle. The apparatus 10 is part of a hydraulic circuit 11. The circuit 11 includes an accumulator 12 which stores hydraulic fluid under pressure. Connecting the apparatus 10 with the accumulator 12 is a high pressure line 13. Within the high pressure line 13 is a primary valve device in the form of primary valve 14 that provides for the flow of hydraulic fluid under pressure from the apparatus 10 to the accumulator 12 when the apparatus 10 is being driven, that is, when the apparatus 10 is acting as a pump. The primary valve 14 acts to retain the hydraulic fluid under pressure in the accumulator 12. However, the primary valve 14 is operable to provide for the flow of hydraulic fluid under pressure from the reservoir 12 to the apparatus 10 so that the apparatus 10 acts as a motor.

Operatively associated with the valve 14 is a control mechanism 15 that is a hydraulic sub-circuit 16 that causes the valve 14 to open so that there is flow from the accumulator 12 to the apparatus 10.

The hydraulic circuit 16 includes a control line 17 to which hydraulic fluid under pressure is delivered to cause actuation of the valve 14 to provide for the flow of hydraulic fluid from the accumulator 12 to the apparatus 10. In the line 17 is a one-way valve (restrictor) 18, with the line 17 extending to a line 19 having a pressure operated one-way valve 20. The line 19 extends to a control line 22 terminating at the valve 23.

The valve 23 has an input that communicates with the line 13 so as to receive hydraulic fluid under pressure therefrom. The valve 23 is operated by pressure in the line 22 and has an output to deliver fluid to the line 24. The line 24 via a one-way valve 25 communicates with the apparatus 10, with the line 24 receiving fluid from the apparatus 10 when the apparatus 10 is acting as a motor. The line 22 has in it a one-way valve 67. The valve 67 has a threshold pressure level of 20 bar before it will permit flow to the line 19.

The valve 23 communicates with the line 13 via a line 26. The line 26 is provided with a valve 27 and a further valve 28. The line 26 extends to a boost pump assembly 29 that provides hydraulic fluid under pressure to the line 24 for delivery to the apparatus 10 when the apparatus 10 is acting as a pump. The pump boost assembly 29 addresses any issues in respect of the apparatus 10 cavitating. The valve 28 limits pressure in the line 65 to 170 bar by venting excess pressure to line 64.

The pump assembly 29 includes a motor 30 that drives a pump 31. The pump 31 draws hydraulic fluid from a reservoir 32 and delivers hydraulic fluid under pressure to the line 24, via a one way valve 68 extending to the apparatus 10.

A restriction device 71 and one-way valve 72 provide the restricted flow of fluid from the pump 31 to the motor 30 to inhibit cavitation of the motor 30.

The line 24 between the valve 23 and valve 25 is also connected to the tank 32 via a heat exchanger assembly 34 that includes motor driven fans 35. A filter 36 is downstream of the assembly 34. The filter 36 has operatively associated with it a one-way pressure relief valve 37. The assembly 34 also includes a one-way pressure release valve 38.

The tank 32 is provided with a breather pipe 39.

Extending from a position between the valve 14 and the accumulator 12 is a line 40 that includes a restriction 41 and a valve 42. The valve 42 communicates with a line 43 that connects with the line 24 and extends to the heat exchanger assembly 34. The valve 42 is electrically operated.

Also communicating with the line 13 between the valve 14 and accumulator 12 is a further line 44 that includes a restriction 45 and a valve 46. The valve 46 is connected to the line 17.

The line 19 extends to a valve 47 that communicates with a return line 48 extending to the tank 32. The valve 47 is electrically operated.

Associated with the apparatus 10 is a clutch assembly not illustrated. The clutch assembly is operated by a control mechanism 49 integrated with the circuit 11. The mechanism 49 includes an actuator 50 including a cylinder 51 having a piston 52. One end of the cylinder 51 communicates with a line 53 via a restriction 54. Hydraulic fluid under pressure from the cylinder 51 is delivered to the line 53 so as to activate the clutch of the apparatus 10. To cause this fluid flow air under pressure is delivered to the chamber 55 via a pneumatic valve 56. The valve 56 receives air under pressure through a line 57. A vent line 58 also extends from the valve 56. When air under pressure is delivered to the chamber 55 by operation of the valve 56, the piston 52 moves to reduce the volume of the chamber 59 so fluid is forced through the line 53 to activate the clutch. When the chamber 55 is communicating with the vent line 58, the piston 52 is returned by means of the spring 60 so that fluid is drawn into the chamber 59 to again activate the clutch. The chamber 59 is "topped-up" with hydraulic fluid via the line 48.

A pressure relief valve 62 is provided in the line 19. The valve 62 essentially governs operation of the safety valve 23. If pressure in the line 22 is excessive fluid is drained to the line 64 so as to cause operation of the valve 23 to drain fluid to the line 24.

The following is a description of the various operating phases of the above described circuit 11.

The valve 46 is operable to connect the accumulator 12 to the valve 14 and to drain line 115 to tank 32.

**PROPULSION**

Effectively energy stored in the accumulator 12 is delivered to the apparatus 10 so that the apparatus 10 acts as a motor and at least aids in driving, for example, the vehicle or piece of machinery having the apparatus 10.

Hydraulic fluid under pressure is delivered from the accumulator 12 to the valve 14. The valve 14 is opened by the delivery thereto of hydraulic fluid under pressure through the line 17. The line 17 receives this hydraulic fluid under pressure via operation of the valve 46. The valve 46 is electrically operated and would be connected to a control panel incorporating a computer. When the valve 46 is operated to connect lines 44 and 61, the hydraulic fluid under pressure flows through the one-way valve 18 to the valve 14 to open the valve 14. Hydraulic fluid under pressure is then delivered to the line 13 from the accumulator 12. This hydraulic fluid from the line 13 then operates the apparatus 10.

When the hydraulic fluid under pressure is delivered to the line 61, this pressure closes the valve 20. At this time the valve 47 is also closed.

Operatively associated with the line 13 is the valve 23. The valve 23 operates as a safety valve and relieves pressure in the line 13 should it become excessive. This relief pressure is determined by the valve 62 as the valves 20 and 47 are closed. The valve 62 is set at 355 bar. Accordingly if pressure in the line 22 raises above 355 bar, the valve 62 will vent to the line 64 and cause operation of the valve 23 so as to vent excess pressure to the line 43 extending to the tank 32.

The return line 24 from the apparatus 10 also delivers the hydraulic fluid to the line 43. Hydraulic fluid passing through the line 43 is cooled by the heat exchanger assembly 34 prior to the delivery to the tank 32.

The one-way valve 18 also acts as a restriction and provides for build up of hydraulic fluid under pressure in the line 61 to close the valve 20.

As the valves 20 and 47 are closed, pressure in the line 22 is governed by the valve 62.

The valve 27 is also closed and like the valves 42 and 47 is electrically operated.

**RETARD**

When the accumulator 12 is to be charged, that is when the apparatus 10 is operating as a pump so as to retard operation of the associated vehicle or piece of machinery, fluid under pressure is delivered to the line 13 by the apparatus 10. This fluid under pressure passes through the valve 14 for delivery to the accumulator 12. In this

arrangement part of the hydraulic fluid under pressure in the line 13 is delivered to the motor 30 that drives the pump 31 to deliver fluid to the line 24 to be used by the apparatus 10, now acting as a pump. The pump 31 communicates with the tank 32 via a line 69. The motor 30 exhausts to the tank 32 via a line 70.

The motor 30 receives hydraulic fluid from the line 65. Hydraulic fluid is delivered to the line 65 upon operation of the valve 27. Again the valve 27 is electrically operated and will be controlled in a similar manner to the valves 42, 46 and 47.

Flow in the line 65 is governed by the valve 28. In this embodiment, the valve 28 is set at 170 bar. When there is a pressure drop across the valve 28 of 170 bar, the valve 28 allows flow to line 65 and therefore operates the motor 30.

In this mode of operation, the valve 47 is closed as is the valve 20. Accordingly the valve 62 governs the pressure at which the valve 23 will relieve pressure in the line 13. Should the pressure exceed 355 bar, then the valve 62 will allow flow to the line 64 thereby causing operation of the valve 23 to vent excess pressure to the line 24. This will generally occur when the accumulator 12 is fully charged.

In respect of the valve 23 it should be appreciated that it provides for flow to the line 22 at all times. However that flow is restricted.

When the accumulator 12 is fully charged, pressure in the line 13 builds to the extent that pressure in the line 22 triggers the valve 62. This causes the valve 23 to open and deliver the excess fluid to the line 24. This hydraulic fluid is vented to the tank 32 via the line 43.

The valve 145 enables fluid to be drawn into line 140 during operation of the valve 14.

When suction in the line 24 is detected as too high, valve 27 is opened to deliver fluid to line 65. Motor 30 is then operated to drive pump 31.

**DUMP**

When the vehicle or piece of machinery is to be idle, the reservoir 12 needs to be relieved in respect of pressure. This is achieved by dumping the pressure from the accumulator 12 to the tank 32.

This dumping of the pressure from the accumulator 12 is achieved by operation of the valve 42. When the valve 42 is electrically operated so as to be opened, the fluid in the reservoir 12 is drained to the tank 32 via the line 43.

**STAND BY**

The circuit 11 also has a "standby" configuration.

The standby configuration is employed when for example, the vehicle is being operated so as not to be accelerating or de-accelerating but with the apparatus 10 acting as a pump. That is, the vehicle is in a steady state.

In the standby mode, the valve 47 is opened, with the valve 20 open as there is no pressure in line 61 to open valve 20. Also in the standby mode, the valve 27 can be actuated so as to enable operation of the motor 30 as previously described.

In the standby mode the valves 42 and 46 are closed.

With the valve 47 open and pressure in the line 22 above 20 bar, hydraulic fluid flows through the valve 67, valve 20 and valve 47 to be delivered to the tank 32. This flow operates the valve 23 so that hydraulic fluid is delivered from the line 26 via the valve 23 to the line 24 wherefrom it is delivered to the line 43 extending to the tank 32. Accordingly the apparatus 10 can be operated at maximum pump output without raising pressure excessively in the circuit 11.

**CLUTCH**

Hydraulic fluid under pressure from the circuit 11 is employed by the clutch assembly 49. When the apparatus 10 is to be disconnected, air under pressure is delivered to the chamber 55 causing hydraulic fluid to flow along the line 53 to cause actuation of the clutch to disconnect the apparatus 10 so that it is no longer operative.

In respect of the abovementioned hydraulic circuit 11, operation of the valve 14 substantially ameliorates the problems associated with "jolting" (shock loading) of the hydraulic circuit 11 and drive train of the vehicle. That is, there is greater control of the rate of change of flow from the accumulator 12 to the apparatus 10.

The above described hydraulic circuit 11 has the further advantage of the safety valve 23. The valve 23, by being governed by the valve 62, controls the pressure in the line 13.

The abovementioned circuit 11 has the further advantage of being able to react quicker. Operation of the valve 14 ameliorates problems associated with delay in operation of the apparatus 10 by using pressure from the accumulator 12 to operate the valve 14.

**VALVE ASSEMBLY**

In Figure 7 there is schematically depicted in sectioned side elevation a valve assembly 143. The assembly 143 incorporates valves 14, 23, 62 and 67. The valve assembly 143 is adapted to provide for the delivery of fluid under pressure to the accumulator 12 while allowing fluid under pressure from the accumulator 12 to pass to the apparatus 10. However in particular when delivering hydraulic fluid under pressure from the accumulator 12 to the apparatus 10, the valve assembly 143 by including the valve 14 is configured to control the flow from the accumulator 12 so that there is no surge delivered to the remainder of the circuit 11.

By incorporating the valve 23, the valve assembly 143 provides for the venting of hydraulic fluid to the tank 32.

The valve assembly 143 includes a port 111 that is connected to the accumulator 12 by means of hydraulic line 114. The port 112 is attached to the line 13 while the port 113 is attached to the line 22 extending to the valve 62. A further port 116 also vents to the tank 32 via the line 115. The port 112 acts as an input for the valve 23 while the port 113 acts as an output for the valve 23.

The valve assembly 143 has a central chamber 142 including a first sub chamber 118 having a movable valve member 119, and a second sub chamber 117 having a movable valve member 120.

The chamber 118 is stepped so as to have a first portion 121 of smaller diameter than a second portion 122, with the valve member 119 being stepped so as to have a first piston portion 123, and a second portion 124 of larger diameter than the portion 123.

Seals 125 are provided to sealingly connect the valve member 119 with the walls of the chamber 118. A spring 126 urges the valve member 119 in the direction of the arrow 127. At one end of the piston 119 there is provided a seal 128 that engages a seat 129.

The chamber 142 has surrounding it a sleeve 130 that includes an annular cavity 131 communicating with radially extending apertures 132 that intern communicate with the port 112. The port 112 extends to the sub chamber 117 while the port 111 extends to the sub chamber 118.

Slidably mounted in the sleeve 130 is the valve member 120. The valve member 120 is urged in the direction of the arrow 133 by a spring 134. The movable valve member 120 has a seal 135 that engages a seat 136, with the port 113 communicating with the sub chamber 117.

One end of the chamber 117 is provided with the valve 67 and pressure relief valve 62 that communicates with the port 116.

In the above discussed valve assembly 143, the spring 126 is relatively weak. For example, the movable valve member 119 may be moved to displace the seal 128 from the seat 129 upon pressure in the sub chamber 117 reaching 3 bar. The spring 134 is also relatively weak, with the movable valve member 120 moving the seal 135 from the seat 136 when there is pressure differential across the movable valve member 120 of about 3 bar. The pressure relief valve 137 is operated when pressure in the chamber 142 exceeds 355 bar. In that respect it should be appreciated there is a passage 138 extending through the movable valve member 120 so that the pressure relief valve 67 is subjected to the pressure within the chamber 142.

The movable valve member 119 is provided with a passage 144 that communicates via a passage 145 with the port 111. This provides for the delivery of hydraulic fluid under pressure from the reservoir to the rear chamber 146 to urge the piston 119 to close the seat 129 when pressure in the port 112 is less than the port 111. When pressure in the port 112 is greater than the port 111 the piston 119 is moved to open the seat 129.

The valve assembly 143 includes a further port 139 that communicates with the line 140.

In operation of the above valve assembly 143, during "retard" pressure delivered to the line 13 causes hydraulic fluid under pressure to enter the port 112 and causes movement of the movable valve member 120 to move the seal 124 away from the seat 129. Hydraulic fluid under pressure is then delivered to the port 111 and therefore the line 142 leading to the accumulator 12. This will continue until the accumulator 12 is essentially charged. During this phase of operation, the movable valve member 120 maintains the seal 125 in contact with the seat 136 as there is essentially no pressure drop across the movable valve member 120. However once the accumulator 12 is fully charged and pressure rises to 355 bar in the chamber 142, the valve 137 is operated to vent hydraulic fluid to tank 32. This causes a pressure drop across the movable valve member 120 and movement of the valve member 120 so that the seal 135 moves away from the seat 136. Accordingly hydraulic fluid is bled to tank 32 through the port 113 and line 115.

During the "dump" phase the movable valve members 119 and 120 remain seated effectively closing the ports 111 and 113.

When "propulsion" is initiated, the valve assembly 143 is operated to deliver hydraulic fluid under pressure from the accumulator 12 to the port 139 via the line 140. However due to restrictions 45 and 18, flow to the sub chamber 118 is relatively slow and therefore movement of the valve member 119 is relatively slow, that is the seal 128 is moved slowly away from the seat 129 thereby eliminating or at least substantially reducing any shock loading of the circuit 11. In the "propulsion" mode the valve 67 remains closed and therefore the valve member 120 maintains the seal 135 against the seat 136.

In the accompanying drawings Figure 7 shows the valve assembly 143 in the "propulsion" mode of operation with hydraulic fluid going from the line 114 to the line 13 through the ports 111 and 112, as well as in the "retard" mode of operation with hydraulic fluid being delivered to the accumulator 12 by passing from the port 112 to the port 111.

In Figure 8, the valve assembly 143 is shown in a configuration in which hydraulic fluid under pressure is being vented to the tank 32 by having hydraulic fluid pass from the port 112 to the port 113.

The primary valve 14 is provided by the valve body 144 of the assembly 143 and the movable valve member 119 while the valve 23 is provided by the body 144 and the movable valve member 120.

The valve 145, as previously mentioned, allows fluid to be drawn into line 140 and then line 139 to provide for rapid movement of valve member 119 in the direction opposite to arrow 127.

In Figure 8 there is schematically depicted an hydraulic circuit 200. The circuit 200 is an alternative to the circuit 11 of the previous embodiment. In this embodiment the circuit 200 communicates with the variable angle swash pump/motor apparatus 10 via the line 201, while the line 202 communicates with the tank 32.

In this embodiment, the primary valve device includes a first check valve 204 and a second check valve 205. The valves 204 and 205 are arranged in series so that hydraulic fluid under pressure delivered to them from the line 201 is delivered to the line 206 extending to the accumulator 12.

When the reservoir 12 is approaching or is at full capacity, the apparatus 10 is operated so as to produce minimum flow, by adjusting the angle of the swash plate.

When the apparatus 10 is to operate as a motor (that is when it is receiving hydraulic fluid under pressure from the accumulator 12) the valves 204 and 205 are opened by operation of a valve 207. The valves 204 and 205 are configured so that they are maintained in the closed position by hydraulic fluid under pressure from the line 206. As can be seen control lines 208 extend from the valve 207, with the valve 207 receiving hydraulic fluid under pressure from the line 206 through the control line 209. When the valve 207 connects the lines 208 and 209, hydraulic fluid under pressure from the accumulator 12 maintains the valves 204 and 205 closed. However when the valve 207 is operated so as to connect the lines 208 to the line 202 extending to the tank 32, this pressure relief allows the valves 204 and 205 to open thereby providing for flow from the

accumulator 12 to the apparatus 10. The valve 207 is electrically operated and communicates with line 202 via a resistance valve 210. Preferably the resistance valve 210 is adjustable and can therefore be manipulated to determine the rate of flow passing from the line 208 to the line 202. By limiting the flow rate from the line 208 to the line 202, the valves 204 and 205 open at a desired rate so that the apparatus 10 (acting as a motor) starts at a controlled rate. Preferably the valve 205 is opened later than the valve 204 when flow is initiated from the accumulator 12 to the apparatus 10.

A dump valve 211 is operable to drain the accumulator 12.

A safety valve 212 is provided to vent pressure in the line 201 to tank via the line 202 should the pressure in the line 201 exceed a predetermined pressure.

**CLAIMS:**

1. A hydraulic circuit including:

an accumulator to store hydraulic fluid under pressure;

a hydraulic pump/motor apparatus that when driven is operable as a pump to provide hydraulic fluid under pressure for delivery to the accumulator, while when receiving hydraulic fluid under pressure from the accumulator is operable as a motor;

a primary valve device connecting the apparatus to said accumulator to provide for the flow of the hydraulic fluid to said accumulator and operable to prevent flow from said accumulator to said apparatus to thereby have said accumulator store the hydraulic fluid under pressure; and

a control mechanism to control said device, said mechanism causing operation of said device to regulate the rate of change of flow from said accumulator to said apparatus.

2. The circuit of claim 1, wherein said device includes a control valve connected to said accumulator and said primary valve, the control valve being operable to deliver hydraulic fluid under pressure from the accumulator to said primary valve to cause operation of said primary valve to provide for the flow of hydraulic fluid from said accumulator to said apparatus.

3. The circuit of claim 1 or 2, further including a tank to receive said hydraulic fluid, and a relief valve operable to deliver hydraulic fluid to said tank when said accumulator reaches a desired charged state.

4. The circuit of claim 3, further including a pressure operated valve operatively associated with said relief valve and said tank, and wherein upon a predetermined pressure being applied to said pressure operated valve said pressure operated valve operates said relief valve to drain hydraulic fluid to said tank.

5. The circuit of claim 3 or 4, wherein said primary valve and relief valve are included in a valve assembly, said valve assembly including a valve chamber having a first, second and third port, and a first movable valve member movable between an open position providing for communication between said first and second ports and a closed position blocking flow between the first and second ports, and a second movable valve

member movable between a closed position blocking communication between said first port and said third port, and an open position providing for the flow of hydraulic fluid from said first port to said third port, with said first movable valve member providing portion of said primary valve, and said second movable valve member providing portion of said relief valve.

6. The circuit of claim 1, wherein said primary valve device includes a first valve and a second valve, the first and second valves being arranged in parallel between said apparatus and said accumulator.

7. The circuit of claim 1 or 6, wherein said primary valve device is maintained closed in respect of fluid flow from said accumulator to said apparatus by control of hydraulic fluid under pressure from said accumulator.

8. The circuit of claim 1, 6 or 7, wherein said control device includes a valve operable to vent said control hydraulic fluid to tank at a controlled rate.

9. The circuit of any one of claims 1, 6, 7 or 8, further including a dump valve operable to drain said accumulator.

10. The circuit of any one of claims 1, or 6 to 9, further including a relief valve operable to deliver hydraulic fluid to tank should hydraulic fluid under pressure being delivered to said primary valve device exceed a predetermined pressure.

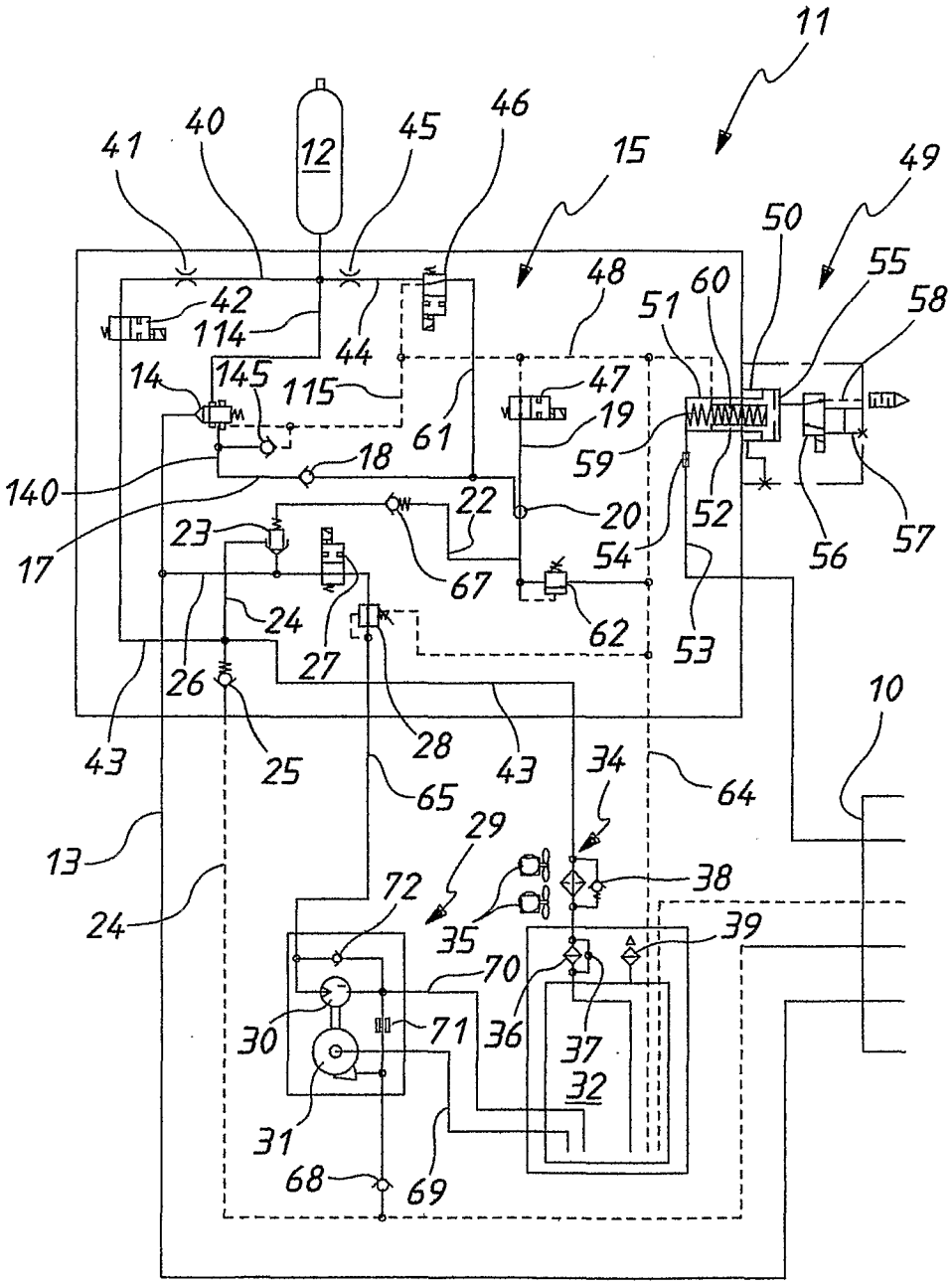

11
41
40
12
45
46
15
49
50
55
58
42
114
44
48
51
60
14
145
115
61
47
19
59
18
140
22
20
52
57
23
54
56
17
67
24
62
53
27
26
10
43
25
28
43
34
64
65
13
29
72
38
24
35
39
70
30
71
36
37
32
31
68
69

FIG. 1

Propulsion

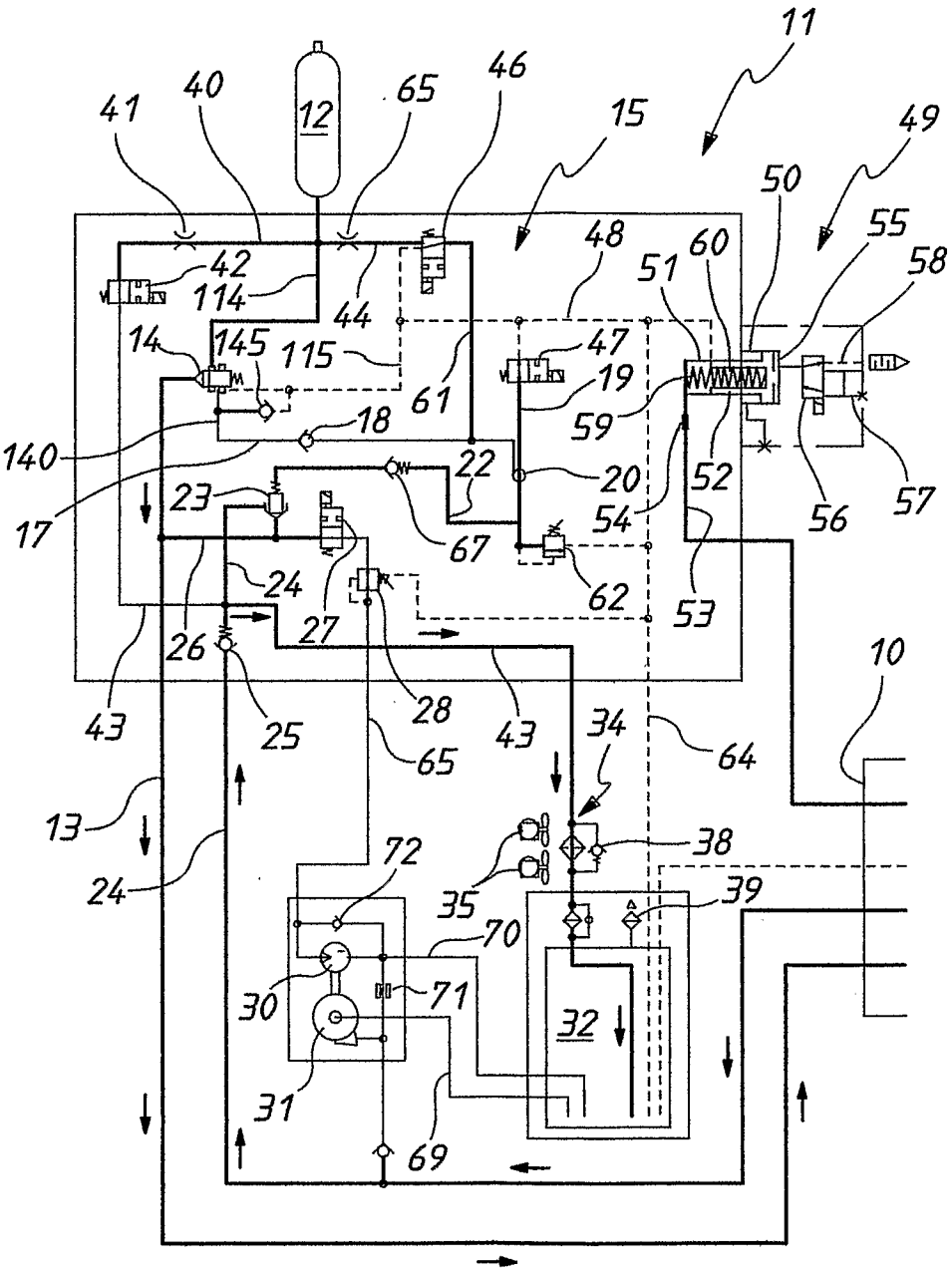



FIG.2

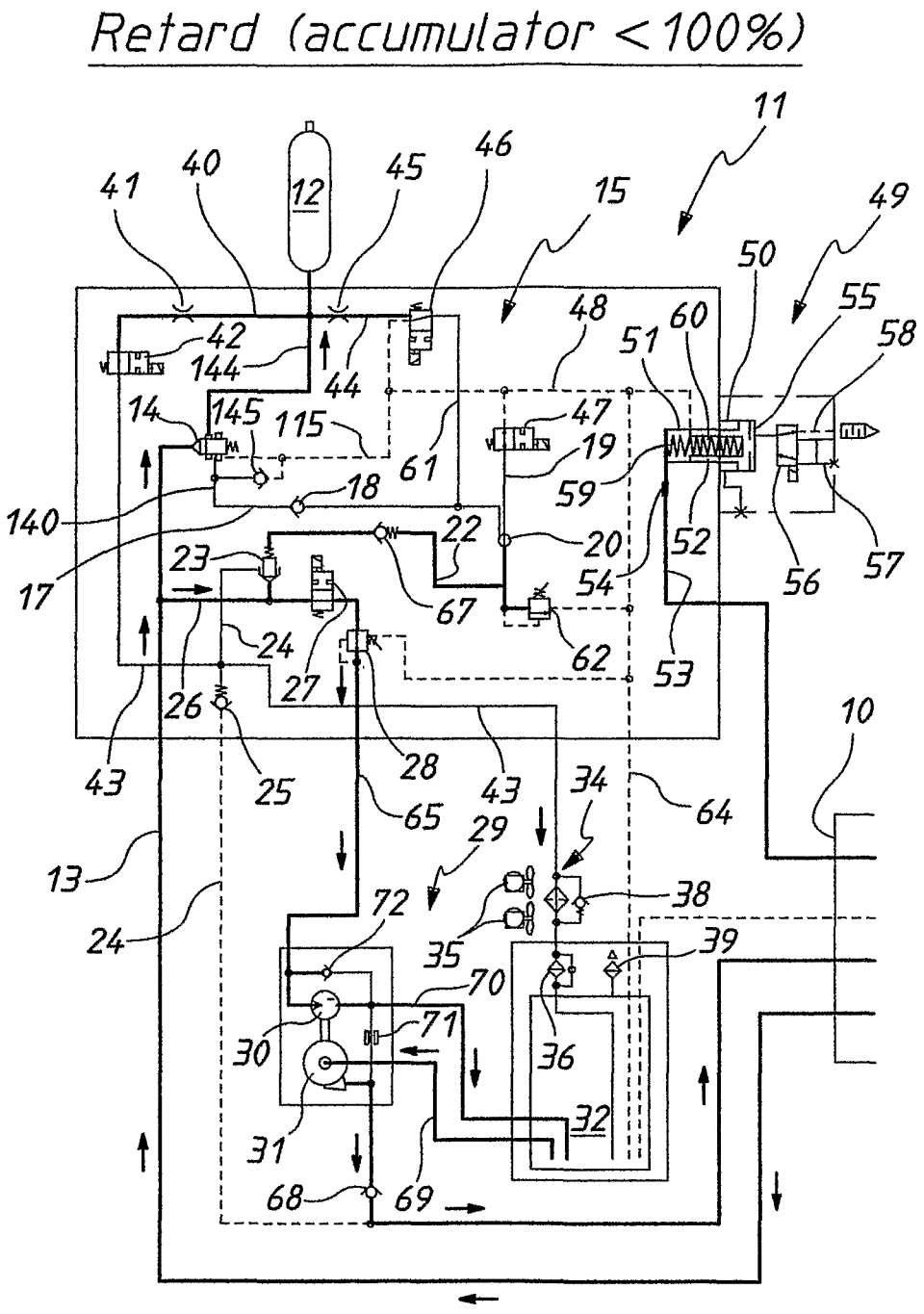

Retard (accumulator <100%)
11
41
40
12
45
46
15
49
50
55
58
42
144
44
48
51
60
14
145
115
61
47
19
59
18
140
22
20
52
57
23
54
56
17
67
24
62
53
26
27
10
43
25
28
43
34
64
65
29
13
72
38
24
35
39
70
71
30
36
32
31
68
69

FIG.3

Standby

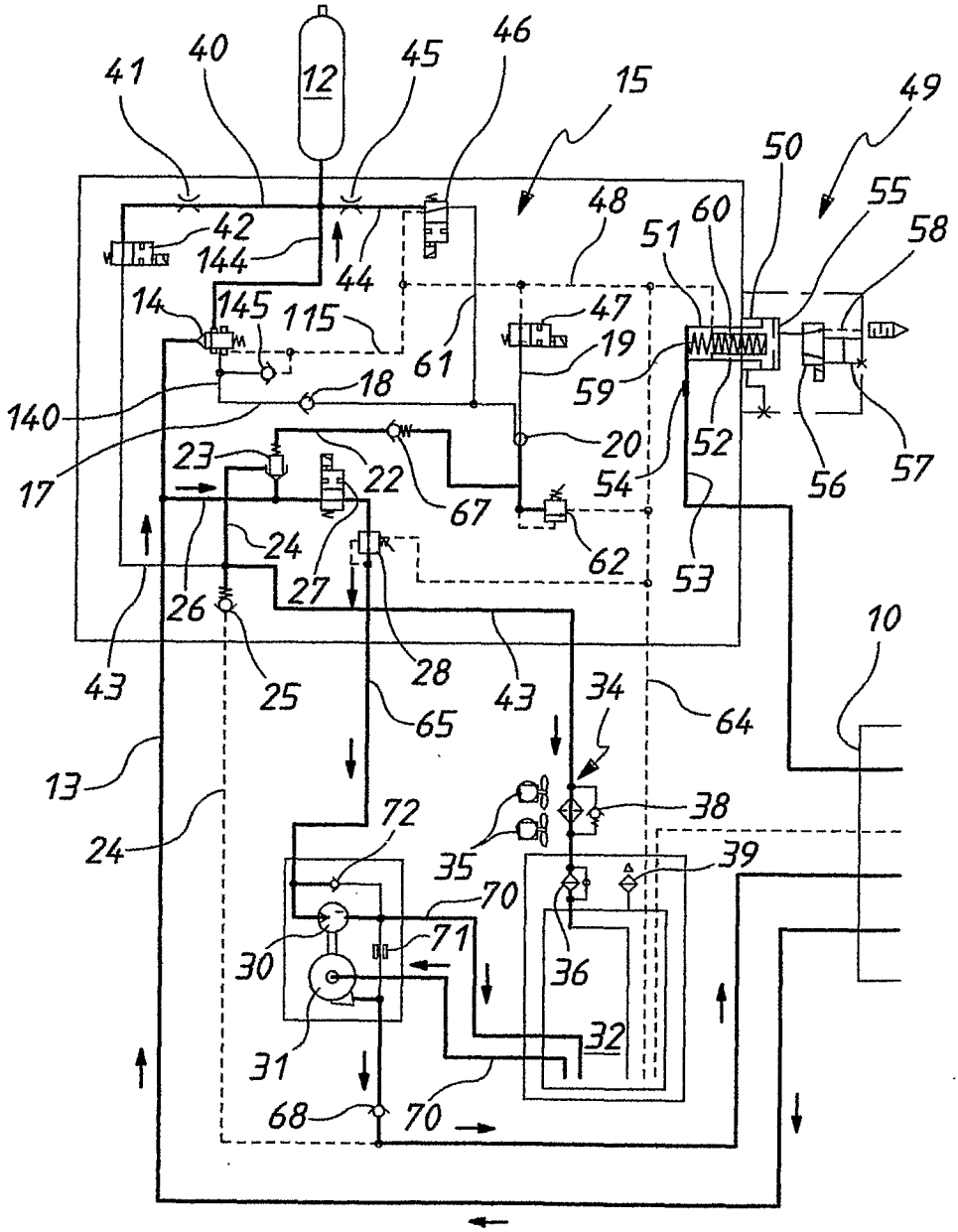



FIG.4

Retard (accumulator >=100%)

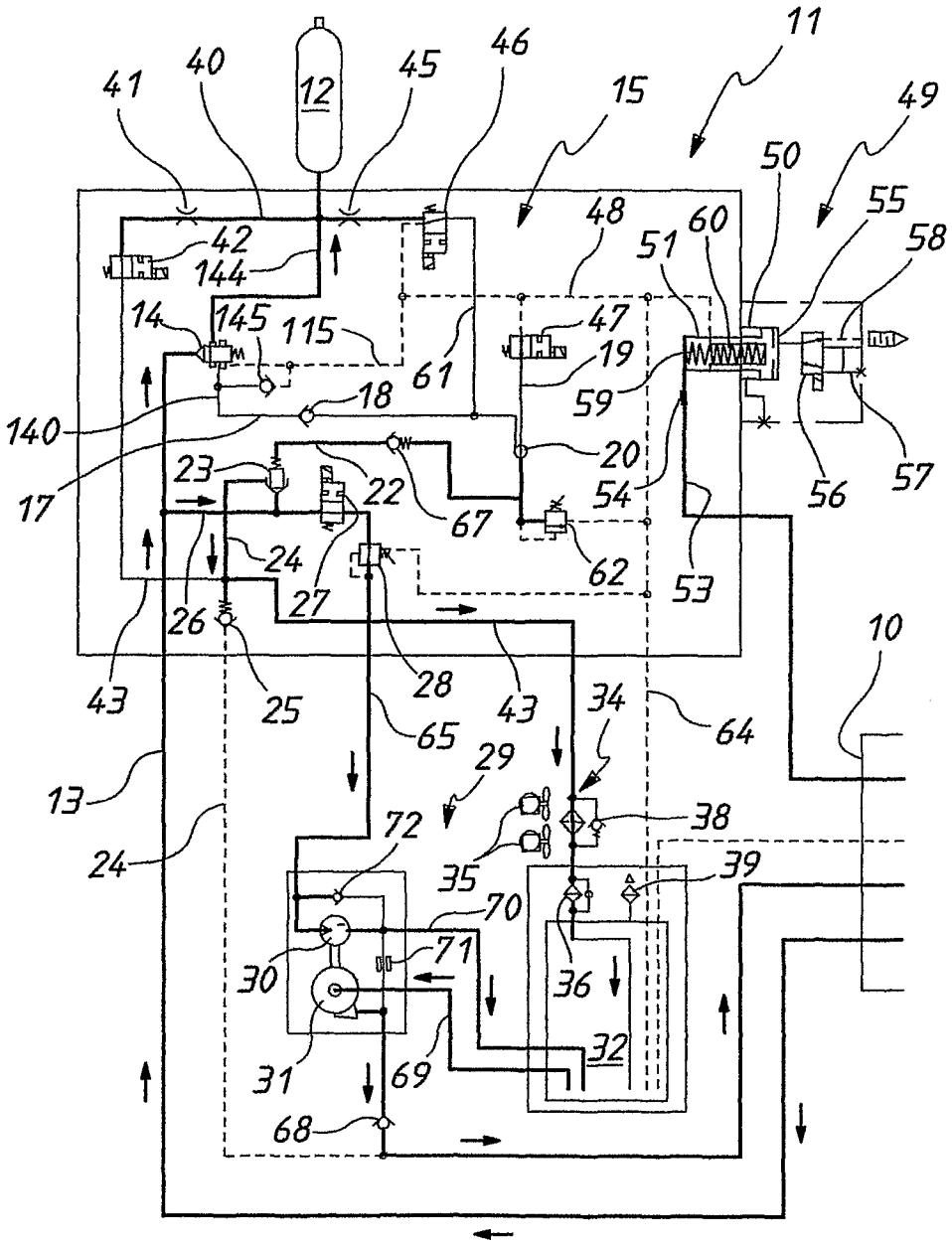



FIG.5

Dump

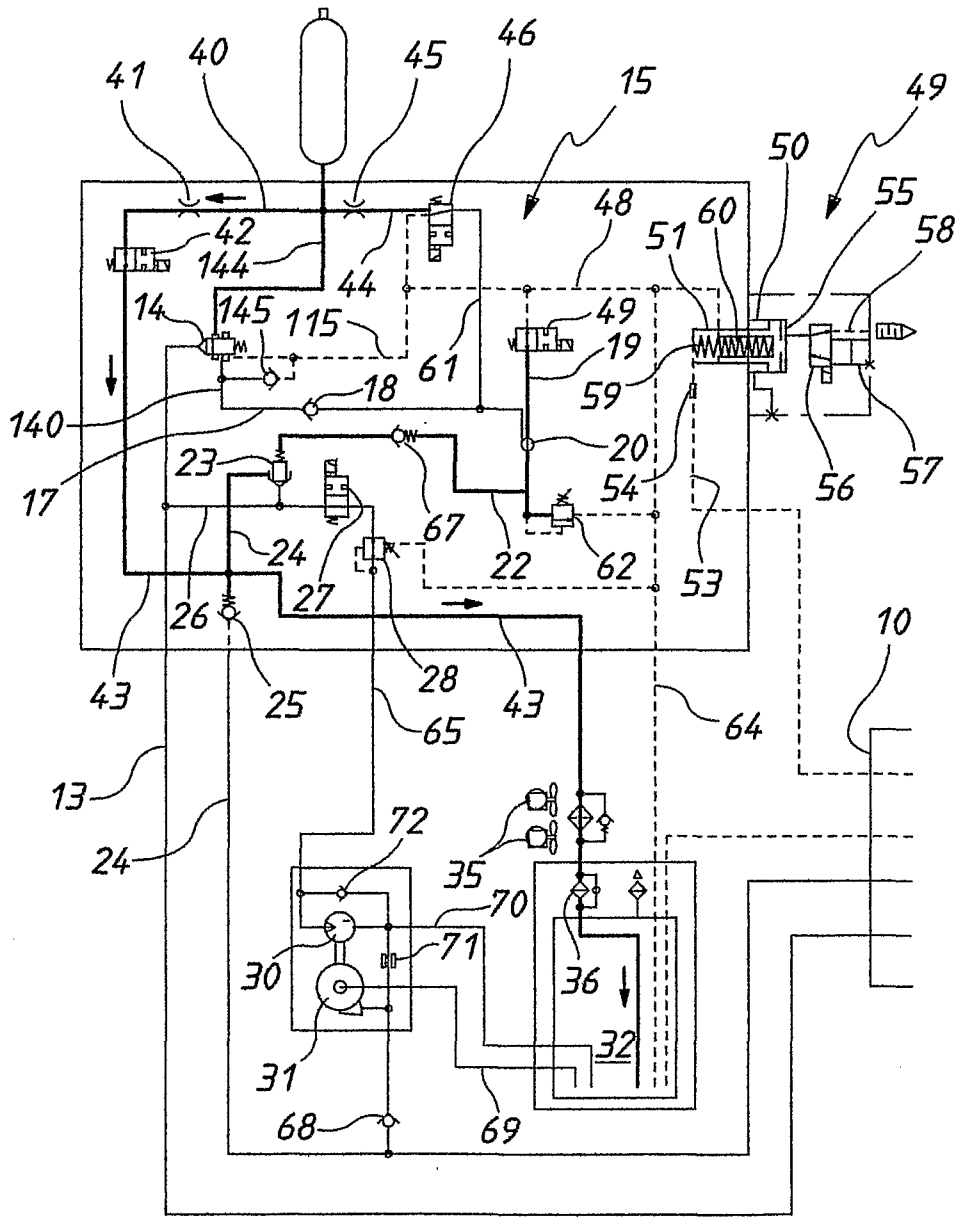

41
40
45
46
15
49
50
55
58
48
60
51
42
144
44
14
145
115
61
49
19
59
18
140
17
20
23
67
54
56
57
24
22
62
53
26
27
43
25
28
43
65
64
10
13
24
72
35
70
71
30
36
32
31
68
69

FIG.6

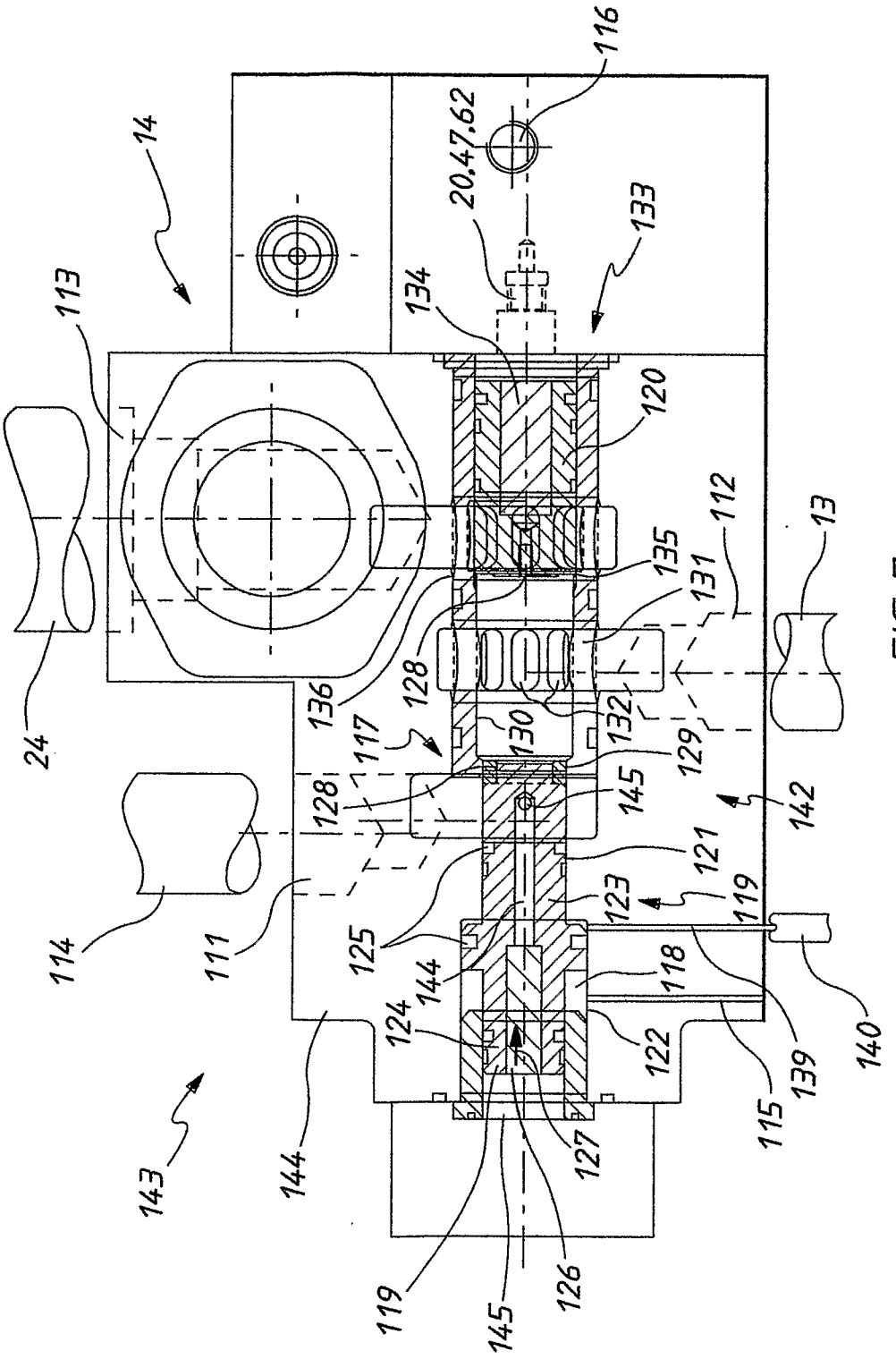

116
20,47,62
14
133
113
134
120
112
13
135
131
24
128
136
130
132
117
129
128
145
142
121
123
119
114
111
125
144
118
124
122
139
140
115
143
144
127
119
145
126

FIG.7

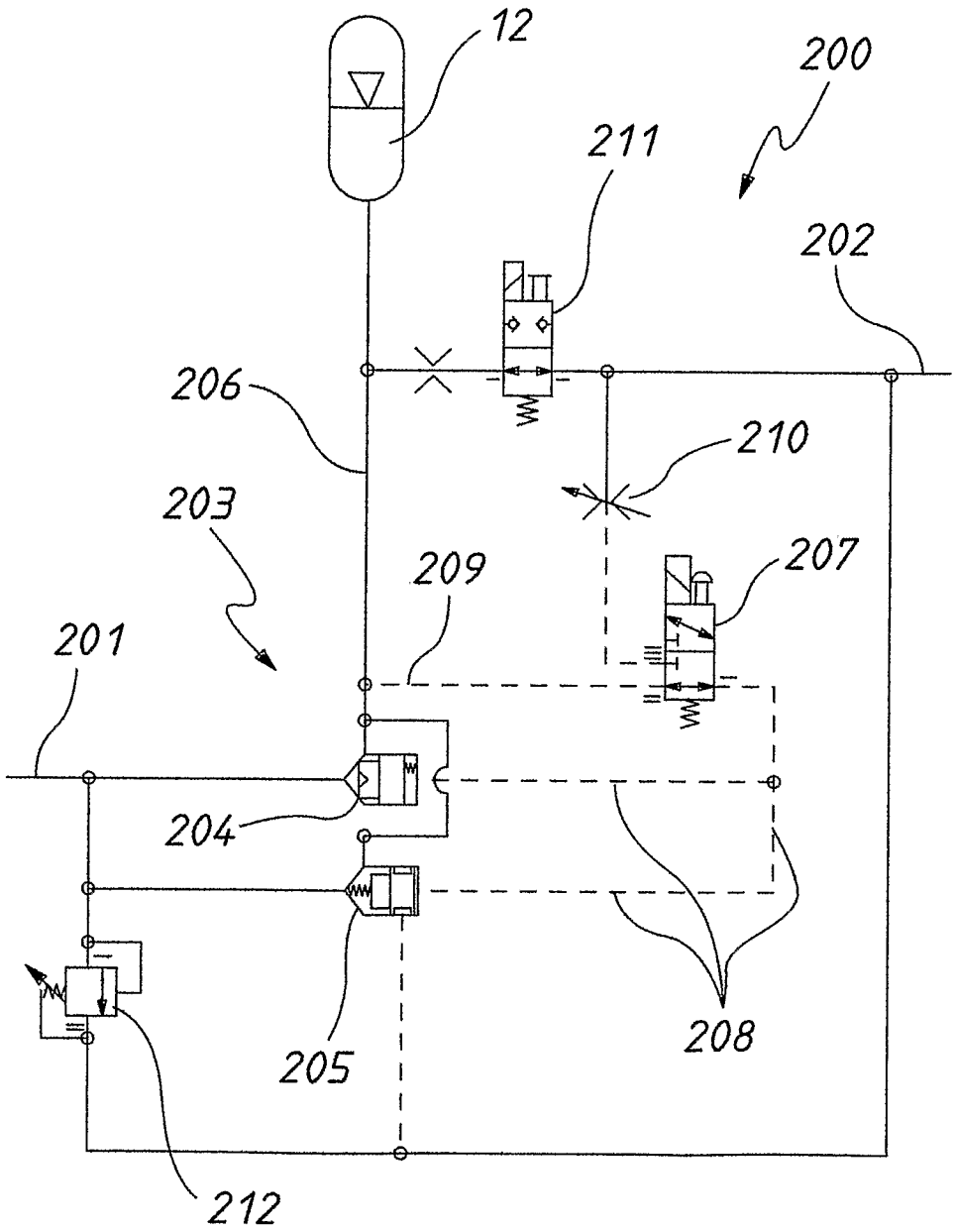



FIG.8

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/AU2006/001426

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

***B60K 6/12*** (2006.01) ***B60W 10/24*** (2006.01) ***F15B 21/14*** (2006.01) ***B60K 25/00*** (2006.01)***F15B 1/027*** (2006.01) ***B60W 10/04*** (2006.01) ***F15B 1/033*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See below under "Electronic database"

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU:IPC B60K 6/12

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI: IPC B60K/-, B60W/-, F15/- and key words like HYDRAULIC, PUMP, MOTOR, ACCUMULATOR, VALVE, REGENERATE, RELIEF and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 6170587 B1 (BULLOCK) 09 January 2001<br>See whole document | 1-4, 6-10 |
| X | US 4986383 A (EVANS) 22 January 1991<br>See whole document | 1-4, 6-10 |
| X | US 4813510 A (LEXEN) 21 March 1989<br>See whole document | 1-4, 6-10 |

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 01 November 2006 | 0 8 NOV 2006 |
| Name and mailing address of the ISA/AU<br>AUSTRALIAN PATENT OFFICE<br>PO BOX 200, WODEN ACT 2606, AUSTRALIA<br>E-mail address: pct@ipaustralia.gov.au<br>Facsimile No. (02) 6285 3929 | Authorized officer<br>**ASANKA PERERA**<br>Telephone No : (02) 6283 2373 |

**INTERNATIONAL SEARCH REPORT**

International application No.
**PCT/AU2006/001426**

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0047643 A1 (ADVANCED ENERGY SYSTEMS INC) 17 March 1982<br>See whole document | 1-4, 6-10 |
| X | US 5086865 A (TANAKA et al) 11 February 1992<br>See whole document | 1-4, 6-10 |
| X | US 5607027 A (PUETT JR) 04 March 1997<br>See whole document | 1, 2 |
| A | US 4760697 A (HEGGIE et al) 02 August 1988<br>See whole document | 1-10 |
| A | EP 0427409 B1 (SMITHS INDUSTRIES PLC) 15 May 1991<br>See whole document | 1-10 |
| A | JP 10071873 A (MITSUBISHI MOTORS CORP) 17 March 1998<br>See whole document | 1-10 |

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/AU2006/001426**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent Document Cited in Search Report | | Patent Family Member | | | | | |
|---|---|---|---|---|---|---|---|
| US | 6170587 | AU | 70134/98 | CA | 2286615 | EP | 0975480 |
| | | HK | 1026875 | NZ | 500627 | WO | 9847732 |
| US | 4986383 | | | | | | |
| US | 4813510 | DE | 3619187 | DK | 234287 | EP | 0248178 |
| EP | 0047643 | JP | 57077227 | | | | |
| US | 5086865 | EP | 0366087 | JP | 2117432 | JP | 2117436 |
| US | 5607027 | AU | 55530/96 | CA | 2219284 | EP | 0824416 |
| | | US | 6119802 | WO | 9633883 | | |
| US | 4760697 | | | | | | |
| EP | 0427409 | GB | 2239439 | US | 5065784 | | |
| JP | 10071873 | | | | | | |

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX