

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
24 January 2008 (24.01.2008)

PCT

(10) International Publication Number
WO 2008/009950 A1

(51) International Patent Classification:
F15B 11/17 (2006.01) *F15B 11/16* (2006.01)

(21) International Application Number:
PCT/GB2007/002747

(22) International Filing Date: 19 July 2007 (19.07.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0614534.6 21 July 2006 (21.07.2006) GB

(71) Applicant (for all designated States except US):
ARTEMIS INTELLIGENT POWER LIMITED [GB/GB]; Sanderson Building, Mayfield Road, Edinburgh EH9 3JL (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **RAMPEN, William, Hugh, Salvin** [GB/GB]; 1 Merchiston Crescent, Edinburgh EH10 5AN (GB). **CALDWELL, Niall, James** [GB/GB]; 2F2 5 Balcarres Street, Edinburgh EH10 5JB (GB). **STEIN, Uwe, Bernhard, Pascal** [DE/GB]; 19 Hope Lane North, Edinburgh EH15 2PT (GB). **JOLY, Pierre** [FR/GB]; Flat 9, 5 Argyle Park Terrace, Edinburgh EH9 1JY (GB). **FIELDING, Michael, Richard** [GB/GB]; 6/5 Leamington Road, Edinburgh EH3 9PD (GB).

(74) Agent: **HANSON, William, Bennett;** BROMHEAD JOHNSON, 19 Buckingham Street, London WC2N 6EF (GB).

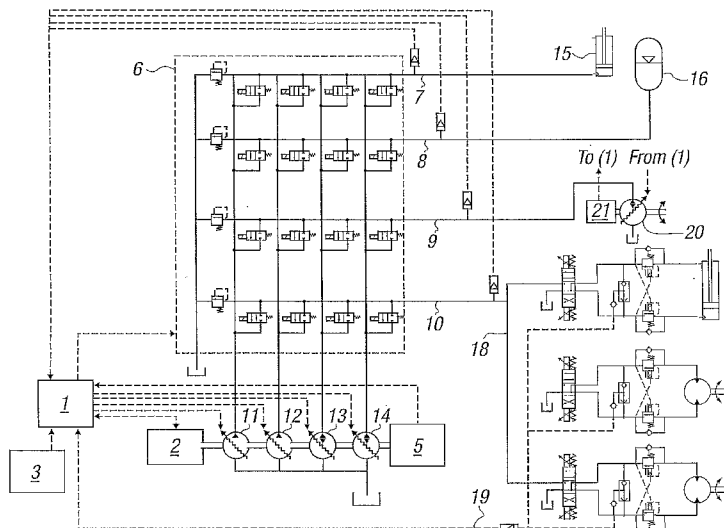
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, 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, MT, 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: FLUID POWER DISTRIBUTION AND CONTROL SYSTEM



(57) Abstract: A fluid power system comprises a pump with multiple independently variable outlets (11, 12, 13, 14), each of which is capable of delivering fluid in individually controllable volume units and a plurality of hydraulic loads (15, 16, 18, 20). A system of switching valves is configured to create fluid connections between the pump outlets and the loads. A control system commands both the pump and the switching valves, so as to create valve state combinations to satisfy load conditions as demanded by an operator. The number of pump outlets (11, 12, 13, 14) connected to one or more of the loads (15, 16, 18, 20) is changeable to satisfy the flow required of the load due to the operator demand, each pump outlet being commanded to produce a flow depending on the status of other outlets connected a load to which the outlet is connected and the operator demand for that load.

WO 2008/009950 A1



-
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*
- 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.*

FLUID POWER DISTRIBUTION AND CONTROL SYSTEM

Background to the Invention

[0001] This invention relates to a fluid power system.

[0002] In their most basic form, fluid power systems generally consist of a pressurised fluid source, a motion control valve and an actuator such as a ram or a motor. Systems are typically generalised by attaching further motion control valves in parallel to the first so that additional actuators can be moved with the power supplied by the fluid source. Because most actuators have a fixed linear or rotary movement per unit of fluid displacement, the force they exert is directly proportional to the pressure supplied. In systems with a single pump and multiple actuators there is always undesirable compromise given the practical impossibility of matching the instantaneous pressure requirements of all of the active actuators to the single pressure supply.

[0003] In the case of the state-of-the-art "load sensing" system, the displacement of a variable displacement pump is controlled such as to maintain its output pressure to a fixed margin above the maximum pressure required of any of the loads. The difference between this pressure and the actual pressure required of any one of the loads is throttled in a proportional valve, creating energy losses. When only one actuator is moved at a time these systems can be reasonably efficient. However when multiple actuators must be moved simultaneously at different pressures then the efficiency becomes poor - depending on the duty cycle, these losses can cause the overall efficiency of such a system to reduce to 30%.

[0004] The pump/motor described in EP 0494236 B1 and sold under the trade mark Digital Displacement is a positive-displacement fluid pump/motor in

which the working volumes are commutated not by mechanical means but by electronically-controlled solenoid-actuated poppet valves. Control of flow is achieved by varying the time-averaged proportion of working volumes which are commutated such as to pump fluid from the low pressure port to the high pressure port ("pump enabled"), or which are commutated such as to motor fluid from the high pressure port to the low pressure port ("motor enabled"), to the proportion which are connected in both expansion and contraction strokes to the low pressure port and thus do no fluid work ("idled"). A controller, synchronised to the position of the shaft by means of a position sensor, supplies pulses to the solenoid coils at the appropriate times such as to commutate each working volume as desired. Because the commutation of each stroke of the working volume is independently controllable, the pump/motor is capable of supplying fluid to or absorbing fluid from a port, in individual discrete volume units, each corresponding to a single stroke or part of a stroke (see WO 2004/025122) of a single working volume. The high pressure port of each working volume may be connected to a different fluid circuit. Thus a single pump/motor composed of many working volumes may provide multiple independent fluid supplies or sinks, the flow to or from each of which is independently variable.

[0005] WO 2006/011836 describes a system in which two separate pumps can be connected to first and second load outlet points in different configurations.

Summary of the Invention

[0006] The present invention provides a system that couples independent services from a pump, e.g. a pump according to EP 0361 927 B1 or a pump/motor according to EP 0494236 B1, to a multiplicity of different actuators, or loads, in a way that provides complete decoupling of the different load pressures, such that interactions between load responses are

avoided, and so that each service works only at the pressure required by its actuator. (References to a "pump" in this description and in the claims include the possibility of a pump/motor unless the context requires otherwise. References to a "hydraulic motor" also include the possibility of a pump/motor.) The invention allows additional pump/motor services to be both switched into and out of a single load while the load is in motion.

[0007] The system uses the ability of pumps according to EP 0361 927 B1 or pump/motors according to EP 0494236 B1 to provide a number of independent and fully controllable fluid supplies from one compact package with a single input shaft. By coupling combinations of these supplies to the loads, the control of multiple independent loads can be achieved at higher energy efficiency.

[0008] The invention thus provides a fluid power system according to claim 1, preferred or optional features of the invention being set out in the dependent claims.

[0009] The system comprises:

[0010] a fluid working machine with a plurality of ports each capable of supplying (pumping) or absorbing (motoring) pressurised fluid in individually commandable fluid units, such that the time averaged flow to or from each port is independent, which when working as a pump efficiently converts mechanical shaft energy into fluid power at the port, and when working as a motor efficiently converts fluid power at the port to shaft power;

[0011] a plurality of hydraulic loads, each consisting of an actuator such as a ram or a fluid motor, provided with one or more fluid ports such that the actuator may be moved by supplying pressurised fluid to or absorbing

pressurised fluid from the port(s), and a mechanical load such as a wheel in contact with the ground or an arm which does mechanical work such as digging the earth, and (optionally) load control valves such as overcentre ("counterbalance") valves such that the position of the ram or motor may be controlled by delivering fluid into either of the two fluid ports regardless whether the direction of force on the actuator is against or with the direction of motion;

[0012]a system of switching valves configured to create fluid connections between pump/motor ports and loads, each valve having a number of discrete states, whereby certain combinations of valve states serve selectively to supply fluid to one or more of the load ports from one or more of the pump/motor ports in one or more distinct and separate fluid paths;

[0013]a control system, which commands both the fluid working machine and the switching valves, so as to both create valve state combinations to satisfy load conditions as demanded by an operator, the valve state combination being changeable such as to change the number of pump/motor outlets, connected to one or more of the loads, to satisfy the flow required of the load due to the operator demand, each pump/motor being commanded to produce or absorb a flow depending on which load port it is connected to and the status of other pump/motor ports connected to that load and the operator demand for that load, such that when the flow demand of a load port increases beyond the capability of a single pump/motor to supply it, another pump/motor is connected to the load by changing the state of the switching valve system, the sequence of valve switching events and commanded outlet flows being such as to continuously maintain the load flow demanded by the operator.

[0014] Individual fluid supplies from a Digital Displacement pump can be switched quickly from being controlled by a flow demand to being controlled by a pressure demand, the latter being achieved using a control loop with feedback from a pressure transducer.

[0015] Fluid supplies which are provided with feedback by means of a hydraulic pressure signal can also be controlled to maintain a certain power output. Such power control mode may be entered when the power demanded by the operator exceeds the power limit which is imposed on that particular load.

[0016] Prime movers such as diesel engines have a maximum power limit. If all loads are provided with pressure sensors which send signals to the controller, then it is possible for the controller to sum the power absorbed by each load and to compare this power with the power limit of the prime mover. In case the total power demanded by the loads would exceed the power limit, the controller reduces the flow commands to the pump services such that the total power is less than the power limit. Such reduction may be done according to a priority algorithm such that less important loads are reduced in preference to more important loads.

[0017] It is also possible for the controller to infer the power load on the engine by measuring the speed of the prime mover shaft. By means of the controller having an internal model of the relationship between prime mover load and speed, and a signal giving the controller information about the speed of the shaft, it is possible for the controller to measure the power imposed upon the prime mover by the pump by measuring the speed. If the power measured by this means exceeds the power limit of the prime mover, then the flow commands to the pump services may be reduced as mentioned in the previous paragraph.

[0018] Additionally the control system may be adapted to control one or more of the fluid outlets capable of working as a pump/motor, such that energy is delivered to or absorbed from a gas-filled accumulator, so as to buffer the torque load exerted on the prime mover, such that a smaller prime mover may be fitted than would normally be the case if the instantaneous peak torques of the duty cycle had to be supplied by the engine alone.

[0019] In the most general case the valve circuit allows any of the pump supplies to be connected to any of the loads; however in some cases it may be desirable to reduce the cost of the system by eliminating some of these possible connections. In this case the controller must have the information of which fluid connections are possible.

Brief Description of the Drawing

[0020] The invention will now be described in more detail, by way of example only, with reference to the accompanying drawing, the single figure of which schematically shows a system according to an embodiment of the invention

Detailed Description of a Particular Embodiment

[0021] The drawing shows a pump/motor with four independent fluid supplies, two of which 11, 12 are pump outlets, two of which 13, 14 are pump/motor outlets, and each of which is controlled by a controller 1. Mechanical power comes into the pump/motor unit via its shaft from a prime mover 2, which may take a speed demand signal from the controller 1.

[0022] The switching circuit 6 in this embodiment consists of digital solenoid valves in a matrix arrangement such that any of the fluid outlets of the

pump/motor 11, 12, 13, 14 may be coupled to any of the load ports 7, 8, 9, 10. These valves are controlled by the controller 1. Each of the load ports 7, 8, 9, 10 is protected from overpressure by a safety relief valve.

[0023] The first load port 7 is connected to a single acting ram 15. The pressure supply has a pressure sensor feeding a signal to the controller. The operator demands a certain pressure be maintained on the ram, however the system is also capable of controlling the flow to the ram, for instance if the flow required to meet the pressure demand exceeds a preset flow limit. In the case of a double-acting ram or a bi-directional fluid motor, a directional control valve may be provided to allow bi-directional movement of the ram, and load-control valves such as overcentre valves may be provided such that the ram may be moved in both directions regardless of the direction of force on the ram.

[0024] The second load port 8 is connected to a gas-charged accumulator. This is capable of storing energy as gas pressure and returning it back as fluid energy at a later time.

[0025] The third port 9 is connected to a hydraulic motor 20 . The operator demands a certain flowrate with a certain direction be supplied to the motor, however the system is also capable of controlling the pressure to the motor, for instance if the pressure required to meet the flow demand exceeds a preset pressure limit.

[0026] In this example, the hydraulic motor 20 is a "Digital Displacement" pump/motor and the controller 1 sends pulses to the commutating valves of the motor, synchronised with the position of the motor shaft by means of a motor shaft position sensor 21. The direction of the rotation of this

pump/motor is determined by the phasing of the commutating pulses relative to the shaft as implemented by the controller.

[0027]The fourth load port 10 is connected to a pressure supply 18 to three separate flow-compensated proportional valves with a load sensing arrangement, each of which controls the flow to a separate hydraulic work function, each of which is provided with load-control valves. The operator controls the proportional valves, and an arrangement of shuttle and check valves feeds the highest pressure required of any of the loads back to the controller via a transducer. The pump is controlled to maintain the pressure in the supply line some margin above the pressure in the load sense line, however the system is also capable of controlling the flow to the valves, for instance if the flow required to meet the pressure demand exceeds a preset flow limit. It is also possible for one of the load ports to supply a network of open-centre valves, in which case the flow output of this load port may be adjusted according to the setting of the proportional valves such that the minimum excess flow is created.

[0028]The controller 1 receives commands from the operator interface 3, receives the feedback from the shaft position sensor 5, receives a pressure signal from sensors connected to each of the load ports 7, 8, 9, 10, receives a pressure feedback signal from the load sense pressure line 19, sends commands to the digital valves which need to be activated inside the valve circuit 6 to connect the fluid supplies 11, 12, 13, 14 to the loads ports 7, 8, 9, 10, and sends pulses to the fluid working machines 11, 12, 13, 14 such that the load ports 7, 8, 9, 10 produce or absorb the fluid flow required by the operator through the interface 3 and the load sensing pressure feedback sensor 19, subject to limitation when the pressure in each of the load ports approaches the maximum pressure allowed on each of the load ports 7, 8, 9, 10 or when the total shaft power taken from the prime mover 2 exceeds the maximum

which it can provide. The controller may also supply commands to directional control valves associated with one or more of the loads.

[0029]The controller 1 can choose to transfer fluid energy from the accumulator 16 to the shaft of the pump/motor for the purposes of buffering the load on the engine such that the sum of the fluid power supplied to the other load ports 7, 9, 10 can temporarily exceed the maximum power output of the prime mover 2, and can provide fluid energy to the accumulator 16 to store energy when the fluid power demands on the other loads 7, 9, 10 are lower than maximum power output of the engine.

[0030]In addition, the controller 1 must coordinate the commands to both the valves within the switching block 6 and the fluid working machines 11, 12, 13, 14. If the operator demands dictate that zero flow is required from the load ports 7, 9, 10 then the switching valves inside the block 6 may disconnect the load ports 7, 9, 10 from the fluid working machines 11, 12, 13, 14. When the operator demand dictates that fluid be either sourced from or absorbed to one of the load port 7, 9, 10 then the minimum number of fluid machines capable of fulfilling the flow demand is connected to that load port. As the operator demand changes then the number of fluid working machine ports which are connected to the load port can change depending on the instantaneous demand. In the case that the valves in the block 6 take significant time to change state, then optionally a forecast demand may be used in addition to the instantaneous demand, this forecast demand being based on an extrapolation of the trend of the operator demand or other knowledge which the controller has of the likely future demand, such that the future demand can be met without interruption.

[0031]In addition, the controller 1 must balance the requirements of the operator against the limitations of the pump/motor and the switching circuit.

The single-acting ram 15 can be supplied with fluid from any of the pump/motor ports 11, 12, 13, 14 via the switching circuit 6, but only certain of the pump/motor ports 13, 14 are capable of absorbing fluid from it.

[0032] In addition, in the case of a variable speed prime mover, the controller can send a speed demand signal to the prime mover. This speed demand can be chosen such that the prime mover will at this speed be at its optimum operating point for energy consumption, given the load on the prime mover, but may be overridden under some operating conditions. If the flow demand from the operator for one of loads exceeds the ability of the system to satisfy, and all of the pump/motor units are already committed, then the speed setpoint may be increased above what would be optimum for fuel consumption. The torque on the prime mover and the maximum available torque can either be calculated from the outlet pressures and flows of all the pump/motor units which is known by the controller, or in the case of an electronically-controlled prime mover can be fed back to the controller from the prime mover electronic control unit.

[0033] It may be that the variable speed prime mover does not include a speed governor; in this case the controller must supply to the prime mover a torque demand signal, and a feedback control loop is necessary within the controller to maintain the prime mover at the demanded speed. The speed of the prime mover is known to the controller by means of the shaft position sensor 5 or electronic feedback provided by the prime mover electronic control unit.

[0034] The controller can operate according to different algorithms, e.g having different ramp times, hysteresis, delay etc. depending on the nature of the load. For example, in a mobile work platform (manlift) a main lift cylinder

can be controlled gently to avoid exciting the bounciness of the boom, whilst the auxiliary hydraulic cylinders can be more responsive.

[0035] The functions of the controller 1 may be shared across several hardware microcontrollers. For instance, the function of generating the pulses to the commutating valves in the pump/motor, synchronised to the shaft by use of the position sensor signal, may be executed by a first controller. The function of controlling the overall system to the demands of the operator may be executed by a second controller, which may be asynchronous to the shaft. In this case the second controller may send to the first controller a flow rate demand or pressure demand, the generation of the pump/motor commutating valve pulses synchronised with shaft position being left to the first microcontroller. In this way the second controller may execute the overall system control function at regular fixed time steps asynchronous to the shaft position, facilitating rapid development of the system control software.

Claims

1. A fluid power system, comprising
 - a. a pump with multiple independently-variable outlets, each of which is capable of delivering fluid in individually-controllable volume units;
 - b. a plurality of hydraulic actuators or loads, and any associated directional switching and load control valves;
 - c. a system of switching valves configured to create fluid connections between the pump outlets and the actuators or loads, each valve having discrete states, whereby certain combinations of states of the valves serve selectively to supply fluid to one or more of the loads from one or more of the pump outlets in one or more distinct and separate fluid paths; and
 - d. a control system, which commands both the pump and the switching valves, so as to create valve state combinations to satisfy load conditions as demanded by an operator, the valve state combination being changeable such as to change the number of pump outlets connected to one or more of the loads to satisfy the flow required of the load due to the operator demand, each pump outlet being commanded to produce a flow depending on the status of other outlets connected a load to which the outlet is connected and the operator demand for that load, the sequence of valve switching events and commanded outlet flows being such as to continuously maintain the load flow demanded by the operator.

2. A system according to claim 1, wherein the pump has a drive shaft, each outlet comprises one or more working chambers of the pump, each working chamber has one or more commutating valves and the control

system is arranged to supply pulses to the commutating valves, synchronised to the position of the shaft by means of a position sensor.

3. A system according to claim 1 or 2, wherein at least one of the loads is a hydraulic motor having a motor shaft, and the control system is arranged to supply pulses to commutating valves of said hydraulic motor, synchronised to the position of the motor shaft by means of a motor shaft position sensor.
4. A system according to claim 1, 2 or 3, wherein the control system is arranged to operate such that when the flow demand of a load increases beyond the capability of a single outlet to supply it, another pump outlet is connected to the load by changing the state of the switching valve system.
5. A system according to claim 1, 2 or 3, wherein the control system is arranged to command one or more of the pump outlets to maintain a set pressure rather than a set flowrate, that set pressure being maintained by a feedback control system involving sensing the pressure of the outlet and modulating the flow of the pump such as to maintain a load to which it is connected at the desired pressure.
6. A system according to claim 5 wherein said one or more pump outlets switch between pressure or flow control modes depending on whether they are connected to a pressure-controlled- or flow-controlled load by the switching valves.
7. A system according to any preceding claim, wherein one or more of the pump outlets is capable of being commanded to maintain a set hydraulic power output, that power output being maintained by a feedback control system involving sensing the pressure of the outlet and modulating the

flow of the pump such as to maintain the product of outlet pressure and flow at the load to which it is connected, or by inferring the load on an engine driving the pump by measuring the speed of the engine and knowledge of the response of an engine speed controller.

8. A system according to any preceding claim, wherein operator demands which are beyond the capabilities of the system simultaneously to satisfy, are resolved by use of a priority control system such that certain loads are supplied in preference to certain other loads, those loads which are not preferred being connected to fewer pump outlets than those which are preferred, or being connected to no pump outlet.
9. A system according to any preceding claim, wherein a prime mover driving the pump has a power limit, and the control system acts to reduce the output power to the loads whenever the demands would cause this power limit to be exceeded, either by reducing the number of outlets connected to one or more of the loads or by reducing the flowrate or pressure applied to one or more of the loads so as to reduce the total power drawn from the prime mover by the pump.
10. A system according to any preceding claim, wherein at least one of the independently variable outlets has a motoring mode in which it absorbs fluid and transfers energy to a prime mover otherwise driving the pump.
11. A system according to any preceding claim, wherein the pump has a drive shaft driven by a prime mover and the control system commands the drive shaft to turn at an optimum speed for a power demand such as to minimise energy or fuel consumption of the prime mover, this optimum speed being overridden with a higher non-optimal speed whenever it is

required to increase the flow capacity of each pump outlet in order to satisfy demands from the operator.

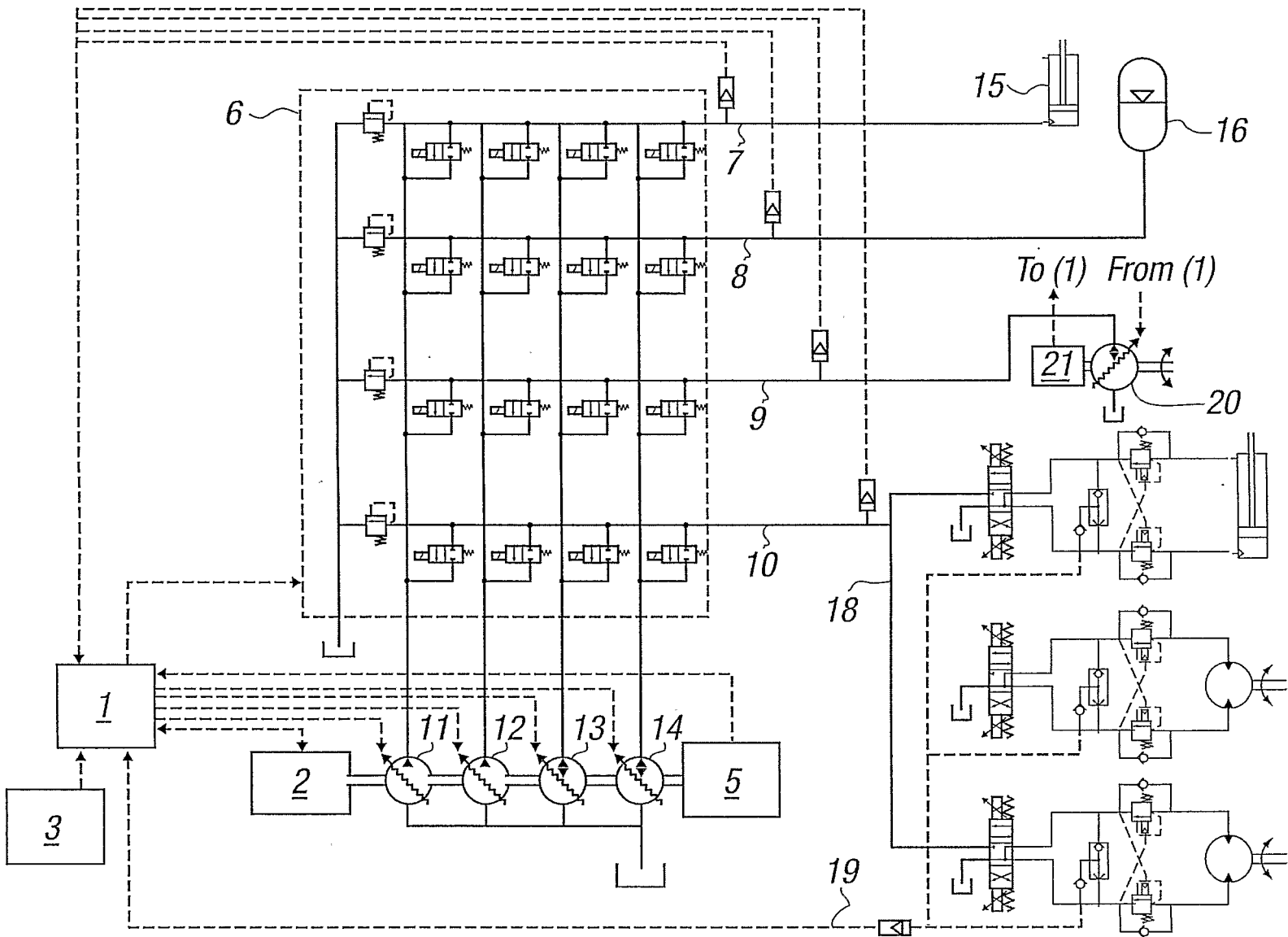


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/002747

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 494 236 A (UNIV EDINBURGH [GB] ARTEMIS INTELLIGENT POWER LTD [GB]) 15 July 1992 (1992-07-15) cited in the application	2,3
A	column 5, line 35 - column 7, line 34; figures 1,4	1,5
A	----- WO 2004/025122 A (ARTEMIS INTELLIGENT POWER LTD [GB]; STEIN UWE BERNHARD PASCAL [GB]; CA) 25 March 2004 (2004-03-25) cited in the application page 3, line 26 - page 4, line 20; figure 1	1-3,10
A	----- WO 2006/011836 A (VOLVO CONST EQUIP HOLDING SE [SE]; VIGHOLM BO [SE]) 2 February 2006 (2006-02-02) cited in the application page 4, line 19 - page 6, line 26; figures 1,2	1,4,5,8
A	----- EP 0 361 927 A (UNIV EDINBURGH [GB]) 4 April 1990 (1990-04-04) cited in the application column 5, line 39 - column 7, line 18; figure 2	1,2,4-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/GB2007/002747

Patent document cited in search report	A	Publication date	Patent family member(s)	Publication date
EP 1286058	A	26-02-2003	DE 10141351 A1 US 2003037545 A1	06-03-2003 27-02-2003
US 5471837	A	05-12-1995	NONE	
US 2006236688	A1	26-10-2006	JP 2006283784 A KR 20060106660 A	19-10-2006 12-10-2006
EP 0494236	A	15-07-1992	NONE	
WO 2004025122	A	25-03-2004	AT 330123 T AU 2003263356 A1 DE 60306169 T2 EP 1537333 A1 JP 2005538299 T US 2006039795 A1	15-07-2006 30-04-2004 31-05-2007 08-06-2005 15-12-2005 23-02-2006
WO 2006011836	A	02-02-2006	CN 1989039 A EP 1773644 A1 KR 20070043808 A SE 527434 C2 SE 0401938 A US 2007234718 A1	27-06-2007 18-04-2007 25-04-2007 07-03-2006 29-01-2006 11-10-2007
EP 0361927	A	04-04-1990	AU 639213 B2 AU 4499089 A AU 641438 B2 DE 68917066 D1 DE 68917066 T2 WO 9003519 A1 WO 9105163 A1 JP 4501294 T JP 5503335 T NZ 230801 A US 5190446 A US 5259738 A ZA 8907398 A	22-07-1993 18-04-1990 23-09-1993 01-09-1994 19-01-1995 05-04-1990 18-04-1991 05-03-1992 03-06-1993 25-06-1992 02-03-1993 09-11-1993 29-05-1991