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(54) **Title:** ENERGY RECOVERY METHOD AND SYSTEM

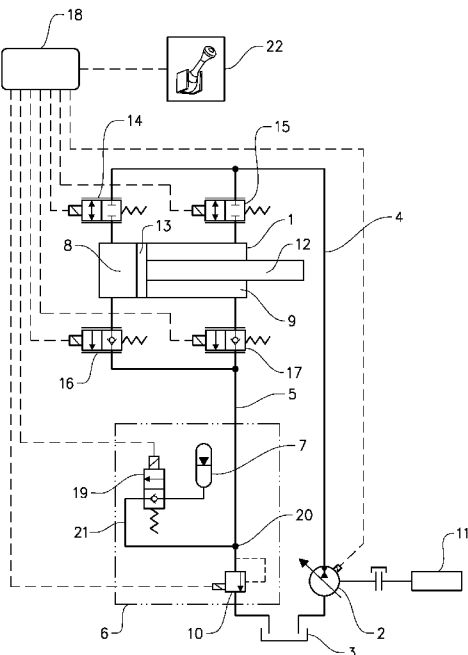


FIG. 1

(57) **Abstract:** The object of the present invention is to provide an inventive energy recovery method for a hydraulic system comprising a hydraulic cylinder (1), a pump (2), a tank (3), a supply conduit (4), a return conduit (5), and a hydraulic accumulator (7), the method comprises the steps of charging said hydraulic accumulator (7), and storing fluid in said hydraulic accumulator (7), wherein said energy recovery method comprises the step of directing fluid from said hydraulic accumulator (7) into an expanding chamber (8, 9) of said hydraulic cylinder (1) during an overrunning load condition.

TITLE

Energy recovery method and system

TECHNICAL FIELD

- 5 The present invention relates to an energy recovery method for a hydraulic system comprising a hydraulic cylinder, a pump, a tank, a supply conduit, a return conduit, and a hydraulic accumulator, wherein the method comprises the steps of charging said hydraulic accumulator, and storing fluid in said hydraulic accumulator. The present invention further relates to a
- 10 corresponding system.

BACKGROUND ART

- Hydraulic systems are frequently used for powering construction machines, such an excavator, which has a boom assembly comprising a boom, an arm
- 15 and a bucket pivotally coupled to each other. A hydraulic cylinder assembly is used control and operate the boom assembly, wherein the hydraulic cylinder assembly comprises a plurality of hydraulic cylinders, each having a piston therein which defines two chambers in the cylinder.
- 20 During powered extension and retraction of a hydraulic cylinder, pressurized fluid from a pump is usually applied by a valve assembly to one cylinder chamber and all the fluid exhausting from the other cylinder chamber flows through the valve assembly into a return conduit that leads to the system tank. Under some conditions, an external load or other force acting on the
- 25 machine enables extension or retraction of the cylinder assembly without significant fluid pressure from the pump. This is often referred to as an overrunning load. In an excavator for example, when the bucket is filled with heavy material, the boom can be lowered by the force of gravity alone. To save energy, it is desirable to recover the energy of that exhausting fluid,
- 30 instead of dissipating it in the valve assembly. Some prior hydraulic systems operate in several different operating modes, of which one for example is said powered extension and retraction, and another is an energy recovery

mode, in which pressurised exhausting fluid from an hydraulic actuator is sent to an accumulator, where it is stored under pressure for later use in powering the machine. Prior art documents US 2008/0110165 and US 2007/0074509 shows examples of energy recovery systems using such
5 accumulators. These prior art systems are however not optimized and further improvements with respect to energy saving are possible.

There is thus a need for an improved energy saving system for recovering and reusing energy in a hydraulic system.

10

SUMMARY

The object of the present invention is to provide an inventive energy recovery method where the previously mentioned problem is partly avoided. This object is achieved by the features of the characterising portion of claim 1,
15 wherein said energy recovery method comprises the step of directing fluid from said hydraulic accumulator into an expanding chamber of said hydraulic cylinder during an overrunning load condition.

The object of the present invention is further to provide an inventive hydraulic
20 system where the previously mentioned problem is partly avoided. This object is achieved by the features of the characterising portion of claim 10, wherein the hydraulic system is configured to direct fluid from said hydraulic accumulator into an expanding chamber of said hydraulic cylinder during an overrunning load condition.

25

The control of hydraulic systems often comprises several different operating modes. The controller is fed with a speed reference signal from the operator for each load. The controller subsequently determines which operating mode to use, and which valves of the hydraulic system to use, such that throttle
30 losses in the system are minimised, and maximal level of energy recovery is obtained.

Some of the operating modes are:

Normal operating mode involves feeding an expanding chamber of a hydraulic actuator with pressurised fluid from the pump and the return oil is
5 fed to the tank.

Recuperative operation mode is applied during an overrunning load where the potential energy of the load should be recovered by another hydraulic device of the hydraulic system. The load itself is the source of motion of the
10 hydraulic actuator and pressurises fluid in a contracting chamber of the hydraulic actuator. The pressurised fluid exciting the hydraulic actuator is for example directed to another load of the system, and/or to an accumulator for storing the energy, and/or to the pump of the hydraulic system, which temporarily will operate as a hydraulic motor. It does not matter if the
15 hydraulic actuator performs a positive stroke or negative stroke, and the potential energy of the load will be recovered.

Energy neutral operation mode is similar to recuperative operation mode and also applied during an overrunning load but without the level of potential
20 energy required to operate another hydraulic actuator of the system, or to save the energy in an accumulator. The load itself is the source of motion of the hydraulic actuator and pressurises fluid in a contracting chamber of the hydraulic actuator. The pressurised fluid of the contracting chamber of the hydraulic actuator is thus simply directed to the tank. It does not matter if the
25 hydraulic actuator performs a positive stroke or negative stroke. Hence, the load will be lowered substantially without the use of additional pump energy.

Regenerative operation mode involves connecting the meter-in and meter-out of the hydraulic actuator. If pressurised fluid is supplied to the
30 interconnected inlet and outlet ports of the hydraulic actuator, the piston will extend due to the difference in cross-sectional area of the rod end and cap end side of the piston in the hydraulic cylinder. The fluid exciting the rod-end

chamber will enter the cap-end chamber and thus increase extension speed. An overrunning load in combination with a negative piston stroke will in this mode result in pressurised fluid exciting the contracting cap-end chamber and flow partly to the expanding rod-end chamber and part of the pressurised
5 fluid may be directed to the supply conduit and/or return conduit for recovering the energy thereof. For example, the fluid may be directed to the pump for driving the pump as a hydraulic motor, or the fluid may be directed to the accumulator or to another hydraulic load of the system.

10 The problem with the recuperative operation mode, energy neutral operation mode, and regenerative operation mode is that hydraulic fluid must in certain situations be supplied to the expanding chamber of the hydraulic actuator for refill thereof. Otherwise, the expanding chamber of the hydraulic actuator will exhibit cavitation and insufficient hydraulic actuator speed, because throttle
15 losses in the hydraulic system prevents refill of the expanding chamber merely by drawing fluid from the tank. A solution to this problem is to refill the expanding chamber of the hydraulic actuator with pressurised fluid from the pump during an overrunning load condition in said recuperative operation mode, energy neutral operation mode, and regenerative operation mode, but
20 this requires operation of the pump and is therefore not energy saving. Furthermore, this solution prevents using the pump as hydraulic motor in a recuperative operation mode. Another solution is to direct pressurised fluid exciting another hydraulic actuator to the expanding chamber of the hydraulic actuator. This solution is however only applicable in certain special
25 circumstances, as it requires simultaneous motion of another hydraulic actuator, as well as sufficient amount of fluid thereof.

The solution according to the invention uses a low pressure accumulator, which is controlled by means of a controller and a suitable valve arrangement
30 to feed the expanding chamber of said hydraulic actuator with pressurised fluid during an overrunning load condition. This can be referred to as a low pressure refill energy recovery mode.

The inventive solution leads to several advantages, such as allowing utilisation of hydraulic system operation modes where refill fluid is otherwise missing, increasing energy saving level by feeding the hydraulic cylinder with
5 fluid from the accumulator instead of using pressurised fluid from the pump, avoiding cylinder cavitation, and increasing speed of hydraulic actuator.

Further advantages are achieved by implementing one or several of the features of the dependent claims. The hydraulic cylinder may be a double
10 acting hydraulic cylinder that comprises a rod end chamber and a cap end chamber, and said fluid from said hydraulic accumulator may be directed into an expanding cap end chamber of said hydraulic cylinder during said overrunning load condition.

15 The expanding cap end chamber and said rod end chamber may be fluidically connected during said step of directing fluid from said hydraulic accumulator into an expanding chamber of said hydraulic cylinder.

The hydraulic cylinder may be a double acting hydraulic cylinder that
20 comprises a rod end chamber and a cap end chamber, and in that fluid from said hydraulic accumulator is directed into an expanding rod end chamber of said hydraulic cylinder during said overrunning load condition.

The inventive method may additionally involve directing fluid from said pump
25 into said expanding chamber of said hydraulic cylinder during said overrunning load condition, such that a relatively smooth transition from a overrunning load condition to a resistive load condition is obtainable.

The inventive method may additionally involve additionally directing fluid
30 exiting another hydraulic actuator of said hydraulic system into said expanding chamber of said hydraulic cylinder during said overrunning load condition.

The fluid forced out from said hydraulic cylinder may be directed at least partly to said pump for recuperative operation of said hydraulic system.

- 5 Charging said hydraulic accumulator may involve directing fluid exiting said hydraulic cylinder or another hydraulic actuator of said hydraulic system into said hydraulic accumulator during an overrunning load condition thereof, and/or directing fluid from said pump into said hydraulic accumulator.
- 10 The step of directing fluid from said hydraulic accumulator into an expanding chamber of said hydraulic actuator may further be based on detected fluid pressure within said expanding chamber. Thereby, hydraulic actuator cavitation is reduced or avoided, and reduced amount of fluid delivered by said pump is required.
- 15 The hydraulic accumulator may be fluidly connected to said return conduit at an accumulator coupling point, and a counter pressure valve may be arranged at said return conduit between said accumulator coupling point and said tank for regulating the charging pressure of said hydraulic accumulator.
- 20 The hydraulic accumulator may be arranged on the tank side of the hydraulic cylinder, in particular between any hydraulic cylinder metering valves of said hydraulic system and said tank.
- 25 The hydraulic system may further comprise a first control valve arranged to control the flow of hydraulic fluid between at least said pump and said cap end chamber of the hydraulic cylinder, a second control valve arranged to control the flow of hydraulic fluid between at least said pump and said rod end chamber of the hydraulic cylinder, a third control valve arranged to
- 30 control the flow of hydraulic fluid between at least said cap end chamber of said hydraulic cylinder and said tank, and a fourth control valve arranged to

control the flow of hydraulic fluid between at least said rod end chamber of the hydraulic cylinder and said tank.

The hydraulic system may further comprise a control unit, and in that each of
5 said first, second, third and fourth control valves may be individually controlled by said control unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in detail with reference to the
10 figures, wherein:

Figure 1 shows the hydraulic system according to the invention;
Figure 2 shows an excavator performing a motion;
Figure 3 shows the inventive hydraulic system of fig.1 including another
15 hydraulic actuator.

DETAILED DESCRIPTION

Mobile fluid power systems comprising hydraulic systems are commonly used in working machines, such as excavators, wheel loaders, forest
20 harvester, and the like, and mostly comprises a plurality of hydraulic actuators, a valve arrangement and at least one hydraulic pump. The hydraulic pump is driven by a power source, such as an internal combustion engine. The hydraulic actuators may be hydraulic pistons for operating an arm of an excavator, or a hydraulic motor for propulsion of a vehicle. An
25 electronic control system received control input from an operator of the system, and controls a plurality of hydraulic valves of the valve arrangement, which directs fluid between the systems components. The control unit operates the hydraulic system in different operating modes dependent on the specific situation, load, operator input, etc.

30

The invention will be described in detail with reference to a small part of a hydraulic system for a mobile fluid power system, as illustrated in Figure 1.

The inventive hydraulic system comprises a hydraulic pump 2 for supplying pressurised hydraulic fluid to a double acting hydraulic cylinder that comprises a rod end chamber 9 and a cap end chamber 8. A sliding rod 12 is attached to a sliding piston 13, which divides a housing of the hydraulic
5 cylinder into said rod end chamber 9 and cap end chamber 8. The pump 2 draws fluid from a tank 3 and feeds pressurised fluid to a supply conduit 4. The pump is driven by a power source 1, such as an internal combustion engine. Only a single hydraulic pump 2 and hydraulic cylinder 1 is illustrated for sake of clarity.

10

Pressurised fluid from the supply conduit 4 is directed to the cap end chamber 8 via a first control valve 14, and to the rod end chamber 9 via a second control valve 15. Hydraulic fluid exiting the cap end chamber 8 is directed to the tank 3 via a third control valve 16, and hydraulic fluid exiting
15 the rod end chamber 9 is directed to the tank 3 via a fourth control valve 17. Each of said first to fourth control valves 14 – 17 is individually controlled by a control unit 18, and together they form a so called individual metering system. The control valves 14 - 17 of the individual metering system may be realised by spool valves or poppet valves, and they are preferably
20 proportionally controlled to allow good position control of the piston 13. The first and second control valves 14, 15 are bi-directional control valves that are proportionally operable in both flow directions. Thereby, the first and second control valves 14, 15 can accurately control the motion and speed of the piston, as well as controlling for example recuperation level during
25 recuperation operating mode. The third and fourth control valves 16, 17 are uni-directional control valves that are proportionally operable in flow direction from the hydraulic cylinder 1 to the tank 3, and acting as check valves in the opposite flow direction.

30 The hydraulic accumulator 7 is arranged on the tank side of the hydraulic cylinder 1, and fluidly connected to the return conduit 5 at an accumulator coupling point 20 by means of an accumulator conduit 21. Fluid flowing from

the hydraulic accumulator 7 to any of the cap end or rod end chambers 8, 9 is proportionally controlled by an accumulator control valve 19 that is arranged on the accumulator conduit 21 connecting the hydraulic accumulator 7 with the return conduit 5. Alternatively, the accumulator may be a simple on-off control valve and the third and fourth control valves 16, 17 may be bi-directional control valves that are proportionally operable in both flow directions.

The energy recovery system 6 comprises except for the hydraulic accumulator 7 and accumulator control valve 19 also a counter pressure valve 10 arranged on the return conduit 5 between the accumulator coupling point 20 and the tank 3. The counter pressure valve 10 controls charging of the hydraulic accumulator 7. The counter pressure valve 10, which raises the fluid pressure in the return conduit 5 and the accumulator conduit 21, is placed at the inlet of the tank 3. The counter pressure valve 10 is preferably pilot operated by means of an electrical signal from the control unit 18, such as to give counter pressure only when a signal is received from the control unit 18.

The control unit 18 is normally configured to, while using as little energy as possible from the pump 2, controlling the valve arrangement of the hydraulic system such that the hydraulic cylinder 1 follows the reference speed given by the operator of the system, for example inputted by means of a joystick 22. The control unit 18 determines, based on system information such as position, speed and acceleration of the hydraulic cylinder 1, and fluid pressure in cap end chamber 8, rod end chamber 9, supply conduit 4, return conduit 5, hydraulic accumulator 7, what operation mode is most suitable for the present situation. Said system information is acquired mainly by means of non-shown sensors positioned at suitable locations in the system. The control unit 18 is further configured to control charging of the hydraulic accumulator 7.

Charging of the hydraulic accumulator 7 is primarily performed by directing pressurised fluid into the accumulator 7 that would otherwise have been directed to the tank 3. This type of charging thus falls under energy recovery charging. Directing pressurised fluid into the accumulator is realised by

5 limiting flow through the counter pressure valve 10, thus leading to increased fluid pressure at accumulator coupling point 20. As soon as the fluid pressure at the accumulator coupling point 20 exceeds the fluid pressure within the accumulator 7, the check valve of the accumulator control valve opens and fluid is directed into the accumulator 7. Should the control unit 18

10 subsequently detect that the hydraulic cylinder 1 risk no longer being able to follow the reference speed of the hydraulic accumulator 1 set by the operator, then the flow through the counter pressure valve 10 is allowed to increase. In general however, first, second, third and fourth control valves 14, 15, 16, 17 determine the motion of the hydraulic cylinder 1, in combination with the

15 pump 2. Pressurised fluid exciting the hydraulic cylinder 1 may be occur in several different operation modes and cylinder modes, during for example an overrunning load condition or an inertial load condition. Charging of the accumulator 7 may also occur when the pump displacement is not variable to an extent required by the control unit 18 and pressurised fluid from the pump

20 otherwise would have been directed to the tank 3. A non-illustrated additional pump – accumulator - conduit could for example be included in the system for the purpose of direct charging of the accumulator 7. Charging of the accumulator 7 may also be performed by feeding pressurised fluid to the accumulator 7 exciting other hydraulic actuators of the hydraulic system,

25 such as other hydraulic cylinders or hydraulic motors.

Below, the energy recovery method for a hydraulic system will be explained in detail with reference to a few exemplary specific operation situations. Operation of the low pressure refill energy recovery mode according to the

30 invention is particularly advantageous in the following three cylinder modes:

1. Recuperative operation mode in combination with a positive piston stroke, wherein the expanding cap-end chamber 8 is refilled by means of fluid from the accumulator 7.

5 2. Recuperative operation mode in combination with a negative piston stroke, wherein the expanding rod-end chamber 9 is refilled by means of fluid from the accumulator 7.

3. Regenerative operation mode in combination with a positive piston stroke,
10 wherein the expanding cap-end chamber 9 is refilled by means of fluid from the accumulator 7.

In the first cylinder mode described above, potential energy of the load and moving machine equipment is recovered and transmitted to other hydraulic
15 consumers of the hydraulic system, or used to operate the pump 2 as hydraulic motor. The fluid required to refill the expanding cap-end chamber 8 of the hydraulic cylinder is taken at least partly from the hydraulic accumulator 7, and the present cylinder mode is thus realisable as soon the accumulator 7 is sufficiently charged. No pressurised fluid is required from
20 the pump 2.

The second cylinder mode described above is similar to the first cylinder mode, and potential energy of the load and moving machine equipment is also here recovered and transmitted to other hydraulic consumers of the
25 hydraulic system, or used to operate the pump 1 as hydraulic motor. The fluid required to refill the expanding rod-end chamber 9 of the hydraulic cylinder 1 is taken at least partly from the hydraulic accumulator 7, and the present cylinder mode is thus realisable as soon the accumulator 7 is sufficiently charged. No pressurised fluid is required from the pump 2.

30

The third cylinder mode uses fluid at least partly from the low pressure accumulator 7 for refill of the expanding cap-end chamber 8. Additional refill

fluid is required during this cylinder more due to the the difference in cross-sectional area of the rod end and cap end side of the piston 13 in the hydraulic cylinder 1, whereby the amount of fluid expelled from the rod-end chamber 9 is not sufficient for completely refilling the expanding cap-end chamber 8. Without refill fluid from the accumulator 7, fluid would have been required from other sources, such as the pump 2, or other hydraulic actuators of the hydraulic system that are simultaneously moving and able to provide the necessary refill fluid. No substantial amount of pressurised fluid is required from the pump 2.

10

Operation of the low pressure refill energy recovery mode according to the invention is particularly advantageous in the above described three cylinder modes, but the low pressure refill energy recovery mode is advantageous also in other cylinder modes. For example, refill of the expanding chamber is equally required in the neutral operation mode, and due to the invention, said refill may be accomplished by means of fluid from accumulator 7 instead of fluid from the pump 2 or other non-reliable fluid sources.

The hydraulic system is configured to use the hydraulic accumulator 7 for storing hydraulic fluid for refill purpose. Since the fluid of the accumulator 7 is not adapted to be the sole or supplemental power source for powered extension and retraction of a hydraulic cylinder, there is no need to store high pressure fluid within the accumulator. Hence, only low pressure fluid will be stored in the accumulator 7. For example, the accumulator 7 may typically be adapted to store hydraulic fluid having a fluid pressure between 0 – 50 bar, preferably 0 - 30 bar. This can be compared with a fluid pressure of around 300 bar for hydraulic accumulators arranged on the pump side of the hydraulic actuators, i.e. the fluid high potential side, and which are adapted to be used for powered extension and retraction of the hydraulic accumulators.

30

The control unit 18 will frequently change between the different operating modes during operation of the hydraulic system. For example, in a typical

modern excavator application of the invention as illustrated in fig. 2, a hydraulically operated boom assembly comprising a boom 23 pivotally attached to the house 26 of the vehicle, a stick 24 pivotally attached to the boom 23, and a bucket 25 pivotally attached to the stick 24. In a situation
5 where the hydraulic cylinder 1 is associated with the stick 24 of the boom assembly, and where the stick 24 starts a motion from a near horizontal orientation, pivots downwards as indicated by the arrow in fig.2 in an overrunning load condition to reach a vertical orientation, and then continues the same motion in a resistive load condition to reach a final position where
10 the stick 24 has an inclined configuration again, the control unit 18 may for example select to initially operate the hydraulic system in a recuperative or regenerative operation mode during lowering of the load for the purpose of recovering the potential energy of the load in the bucket 25 and stick 24. Upon approaching the vertical orientation of the stick 24, the control unit 18
15 may select the neutral operation mode due to the reduced level of potential energy available, and when the speed of the stick 24 risks falling below the speed reference set by the operator, the control unit 18 will select the normal operation mode to keep the required speed and subsequently to raise the load again as the stick 24 passes the vertical position and approaches the
20 house 26 of the excavator. Without refill fluid from the accumulator 7, neither the recuperative nor the regenerative operation modes would have been possible, and pressurised fluid from the pump 2 would have been required for refill purpose, given that no refill fluid was available from another fluid
actuator.

25

During the initial motion from the horizontal orientation to the near vertical orientation, fluid from the accumulator 7 is directed to the expanding cap end chamber 8 of the hydraulic cylinder 1 associated with the motion of the stick 24 for the purpose of refilling said chamber 8. At a certain time instant, a
30 transition from the overrunning load condition to the resistive load condition is required. For the purpose of providing a relatively smooth transition from said overrunning load condition to said resistive load condition, a small amount of

fluid may during certain advantageous operation modes be directed from said pump 2 into said expanding chamber 8 of said hydraulic cylinder 1 already during said overrunning load condition, in addition to the fluid from the accumulator 7. Since the first and second control valves 14, 15 are

5 proportionally controlled, it is easy to control the level of fluid supply from the pump 2. The hydraulic system is however normally configured to supply the main part of the fluid from the accumulator 7 and only a small part from the pump 2 for the purpose of accomplishing high energy recovery level.

10 Fig. 3 schematically illustrates the inventive energy recovery method and system of fig. 1 but here schematically including also another hydraulic actuator 27 in form of a double acting hydraulic cylinder, which is connected in parallel with the hydraulic cylinder 1. The hydraulic system may of course include many more non-illustrated hydraulic actuators, which are fluidly

15 connected to the pump 2 and hydraulic accumulator 7. Note also that the control unit 18, joystick 22 and associated control lines are not illustrated in fig. 3. The cap and rod end chambers of the other hydraulic actuator 27 are preferably connected to the pump 2 via a fifth and sixth control valve 28, 29 respectively, and cap and rod end chambers of the other hydraulic actuator

20 27 are preferably connected to the tank 3 and hydraulic accumulator 7 via the seventh and eighth control valves 30, 31 respectively. The fifth and sixth control valves 28, 29 being essentially identical to the first and second control valves 14, 15, and seventh and eighth control valves 30, 31 being essentially identical to the third and fourth control valves 16, 17. It is clear from the fig. 1

25 and 3 that the energy recovery system 6 including the hydraulic accumulator 7 is arranged on the fluid low potential side of the hydraulic system, close to the tank 3. Hence, fluid exciting the hydraulic cylinder 1 or the other hydraulic actuator 27 may be directed to the hydraulic accumulator via said third, fourth, seventh or eighth control valves 16, 17, 30, 31 for charging said

30 accumulator 7, and fluid may be discharged from the hydraulic accumulator 7 and supplied to the hydraulic cylinder 1 and/or other hydraulic actuator 27 for refill purpose via said third, fourth, seventh or eighth control valves 16, 17, 30,

31. Said third, fourth, seventh or eight control valves 16, 17, 30, 31 are thus arranged between the hydraulic actuators and the energy recovery system 6.

5 The term other hydraulic actuator as used herein, generically refers to any device, such as a cylinder-piston arrangement or a rotational motor for example, that converts hydraulic fluid flow into mechanical motion, and oppositely.

10 The term resistive load is considered to define a load that opposes the direction of motion of the actuator. The direction of the load reaction is opposite of the direction of motion of the actuator, or a component of the direction of motion.

15 The term overrunning load, sometimes called a negative load, is considered to define a load that has the same direction as the motion of the actuator, or a component of the direction of motion.

20 The term inertial load is considered to define a load in which the load reaction on the actuator is essentially characterized by Newton's Second Law of Motion.

25 Reference signs mentioned in the claims should not be seen as limiting the extent of the matter protected by the claims, and their sole function is to make claims easier to understand. As will be realised, the invention is capable of modification in various obvious respects, all without departing from the scope of the appended claims. Accordingly, the drawings and the description thereto are to be regarded as illustrative in nature, and not restrictive.

Table of reference signs

	1	Hydraulic cylinder
	2	Pump
	3	Tank
5	4	Supply conduit
	5	Return conduit
	6	Energy recovery system
	7	Hydraulic accumulator
	8	Cap end chamber
10	9	Rod end chamber
	10	Counter pressure valve
	11	Power source
	12	Sliding rod
	13	Piston
15	14	First control valve
	15	Second control valve
	16	Third control valve
	17	Fourth control valve
	18	Control unit
20	19	Accumulator control valve
	20	Accumulator coupling point
	21	Accumulator conduit
	22	Joystick
	23	Boom
25	24	Stick
	25	Bucket
	26	House
	27	Another hydraulic actuator
	28	Fifth control valve
30	29	Sixth control valve
	30	Seventh control valve
	31	Eight control valve

CLAIMS

1. An energy recovery method for a hydraulic system comprising a hydraulic cylinder (1), a pump (2), a tank (3), a supply conduit (4), a return conduit (5), and a hydraulic accumulator (7), the method comprises the steps of charging said hydraulic accumulator (7), and storing fluid in said hydraulic accumulator (7), **characterised in that** said energy recovery method further comprises the step of directing fluid from said hydraulic accumulator (7) into an expanding chamber (8, 9) of said hydraulic cylinder (1) during an overrunning load condition.
2. The method according to claim 1, **characterised in that** said hydraulic cylinder (1) is a double acting hydraulic cylinder that comprises a rod end chamber (9) and a cap end chamber (8), and in that said fluid from said hydraulic accumulator (1) is directed into an expanding cap end chamber (8) of said hydraulic cylinder (1) during said overrunning load condition.
3. The method according to claim 2, **characterised in that** said expanding cap end (8) chamber and said rod end chamber (9) are fluidically connected during said step of directing fluid from said hydraulic accumulator (7) into an expanding chamber (7, 8) of said hydraulic cylinder (1).
4. The method according to claim 1, **characterised in that** said hydraulic cylinder (1) is a double acting hydraulic cylinder that comprises a rod end chamber (9) and a cap end chamber (8), and in that fluid from said hydraulic accumulator (7) is directed into an expanding rod end chamber (9) of said hydraulic cylinder during said overrunning load condition.

5. The method according to any of the previous claims 1 to 4,
characterised by additionally directing fluid from said pump (2) into
said expanding chamber (8, 9) of said hydraulic cylinder (1) during
said overrunning load condition, such that a relatively smooth
5 transition from a overrunning load condition to a resistive load
condition is obtainable.
6. The method according to any of the previous claims 1 to 5,
characterised by additionally directing fluid exiting another hydraulic
10 actuator (27) of said hydraulic system into said expanding chamber (8,
9) of said hydraulic cylinder (1) during said overrunning load condition.
7. The method according to any of the previous claims 1 to 6,
characterised in that said fluid forced out from said hydraulic cylinder
15 (1) is directed at least partly to said pump (2) for recuperative
operation of said hydraulic system.
8. The method according to any of the previous claims 1 to 7,
characterised in that said step of charging said hydraulic
20 accumulator (7) involves directing fluid exiting said hydraulic cylinder
(1) or another hydraulic actuator (27) of said hydraulic system into said
hydraulic accumulator (7) during an overrunning load condition, and/or
directing fluid from said pump (2) into said hydraulic accumulator (7).
- 25 9. The method according to any of the previous claims 1 to 8,
characterised in that said hydraulic accumulator (7) is fluidly
connected to said return conduit (5) at an accumulator coupling point
(20), and in that a counter pressure valve (10) is arranged at said
return conduit (5) between said accumulator coupling point (20) and
30 said tank (3) for regulating the charging pressure of said hydraulic
accumulator (7).

10. A hydraulic system comprising a hydraulic cylinder (1), a pump (2) configured to supply fluid to at least said hydraulic cylinder (1), a tank (3), a supply conduit (4) connecting said pump (2) and said hydraulic cylinder (1), a return conduit (5) connecting said hydraulic cylinder (1) and said tank (3), and a hydraulic accumulator (7), **characterised in that** said hydraulic system is configured to direct fluid from said hydraulic accumulator (7) into an expanding chamber (8, 9) of said hydraulic cylinder (1) during an overrunning load condition.
11. A hydraulic system according to claim 10, **characterised in that** said hydraulic cylinder (1) is a double acting hydraulic cylinder that comprises a rod end chamber (9) and a cap end chamber (8), and in that said hydraulic system is configured to direct fluid from said hydraulic accumulator (7) into an expanding cap end chamber (8) or expanding rod end chamber (9) of said hydraulic cylinder (1) during said overrunning load condition.
12. A hydraulic system according to any of claim 10 or 11, **characterised in that** said hydraulic accumulator (7) is arranged on the tank side of the hydraulic cylinder (1), in particular between any hydraulic cylinder metering valves (16, 17, 30, 31) of said hydraulic system and said tank (3).
13. A hydraulic system according to any of the previous claims 10 to 12, **characterised in that** said hydraulic accumulator (7) is fluidly connected to said return conduit (5) at an accumulator coupling point (20), and in that said hydraulic system further comprising a counter pressure valve (10) arranged at said return conduit (5) between said accumulator coupling point (20) and said tank (3) for regulating the charging pressure of said hydraulic accumulator (7).

14. A hydraulic system according to any of the previous claims 10 to 13,
characterised in that said hydraulic system further comprising a first
control valve (14) arranged to control the flow of hydraulic fluid
between at least said pump (2) and said cap end chamber (8) of the
5 hydraulic cylinder (1), a second control valve (15) arranged to control
the flow of hydraulic fluid between at least said pump (2) and said rod
end chamber (9) of the hydraulic cylinder (1), a third control valve (16)
arranged to control the flow of hydraulic fluid between at least said cap
end chamber (8) of said hydraulic cylinder (1) and said tank (3), and a
10 fourth control valve (17) arranged to control the flow of hydraulic fluid
between at least said rod end chamber (9) of the hydraulic cylinder (1)
and said tank (3).
15. A hydraulic system according to any of the previous claims 10 to 14,
15 **characterised in that** said hydraulic system further comprising a
control unit (18), and in that each of said first, second, third and fourth
control valves (14, 15, 16, 17) is individually controlled by said control
unit (18).

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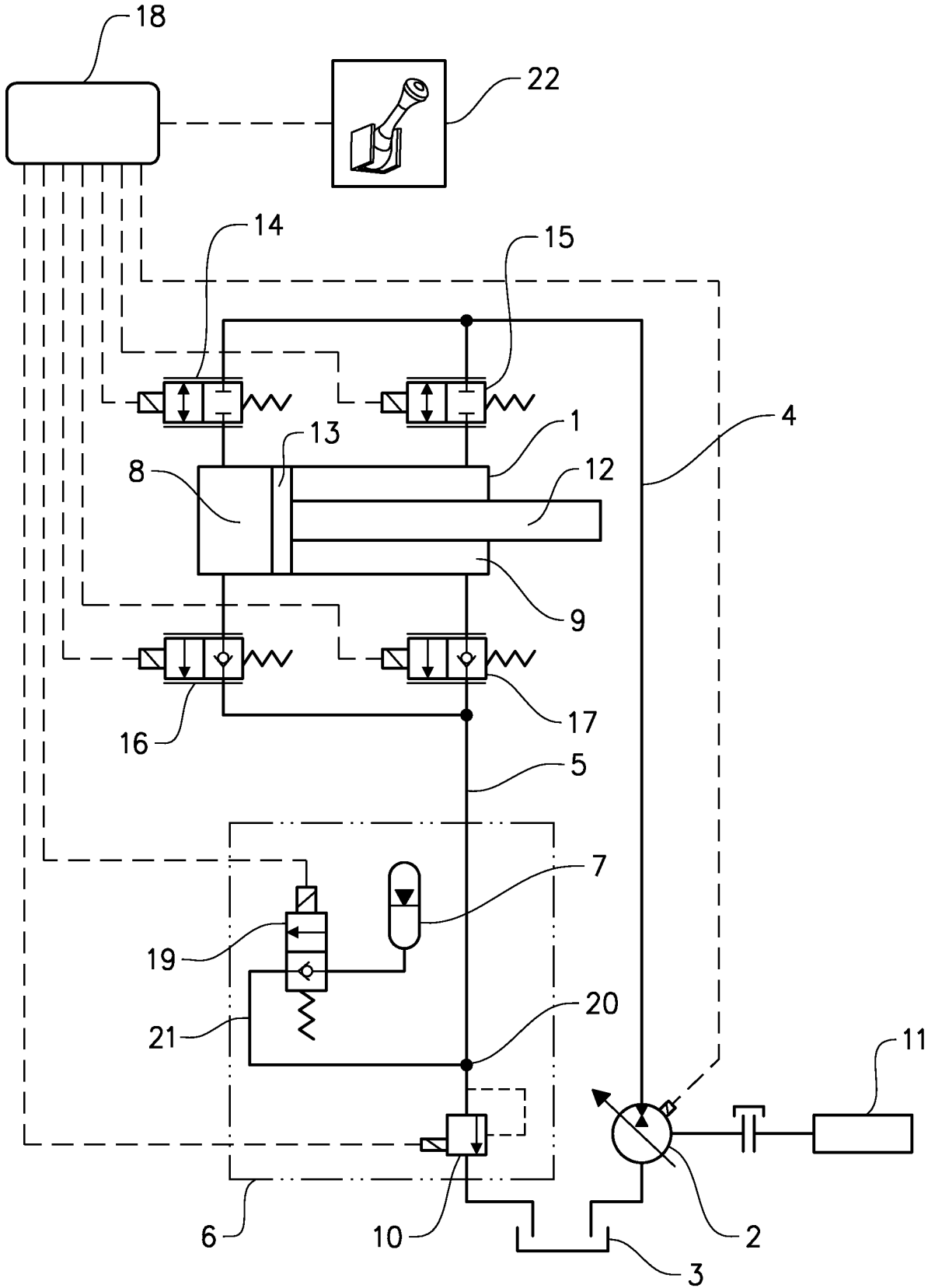


FIG. 1

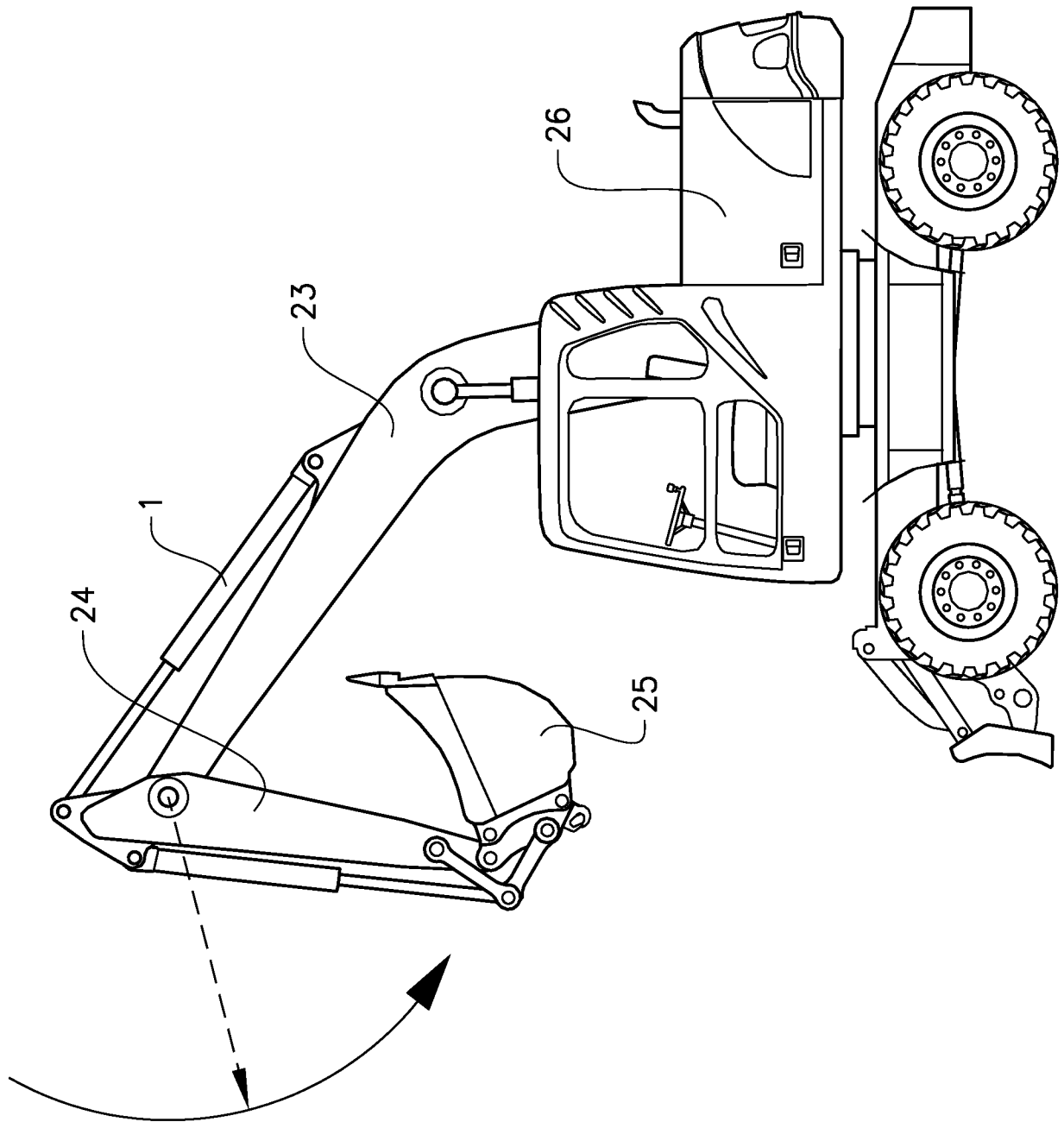


FIG. 2

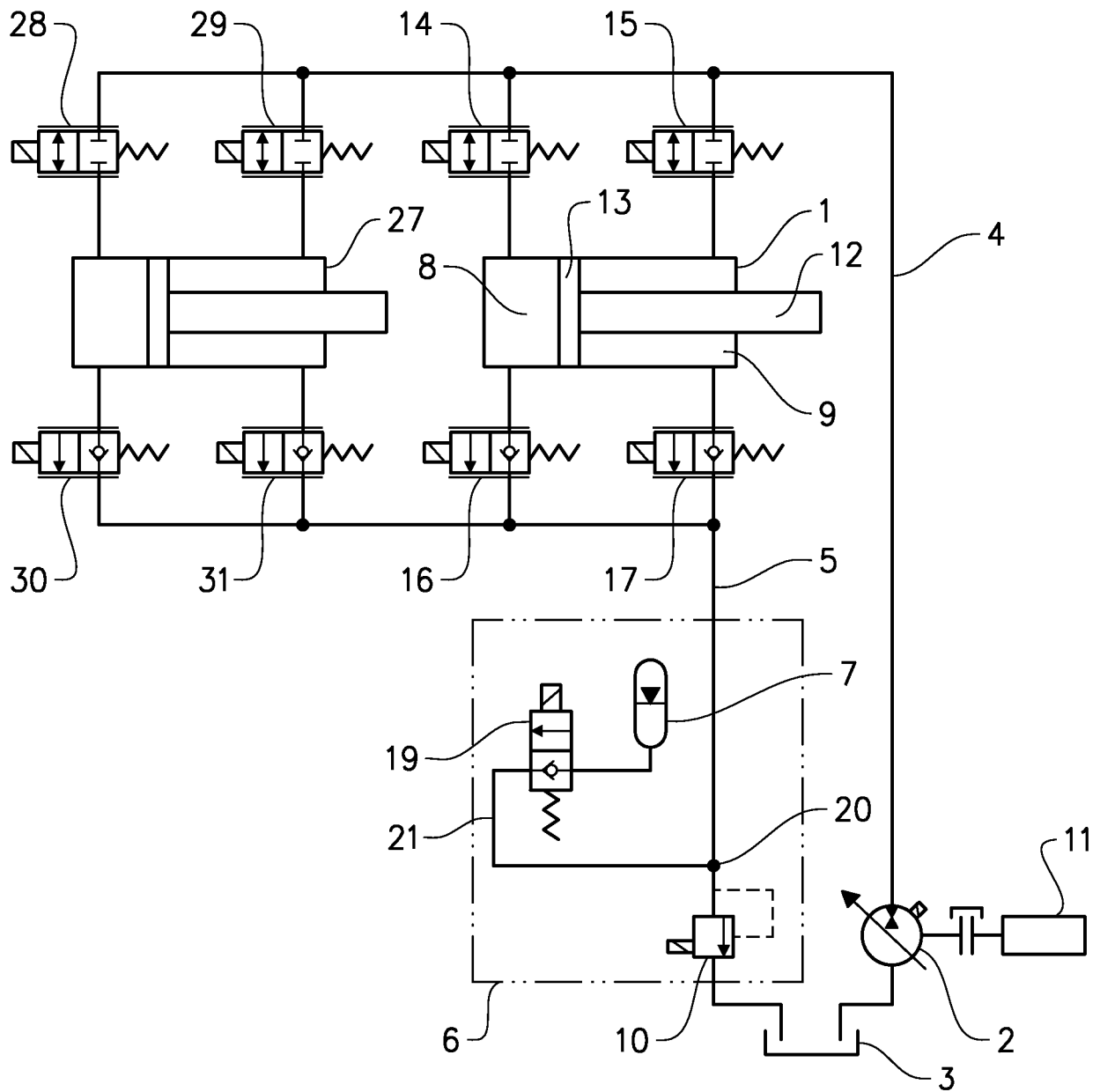


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2011/050641

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: E02F, F15B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6962050 B2 (HIRAKI HIKOSABURO ET AL), 29 May 2003 (2003-05-29); abstract; page 20, line 60 - page 21, line 12; figures 6-9,14-16 --	1-15
X	WO 9300515 A1 (CATERPILLAR INC), 7 January 1993 (1993-01-07); abstract; pages 1-2; page 16, line 10 - page 20, line 4; figure 1 --	1-15
X	US 20080072589 A1 (JACOBS GEORG ET AL), 27 March 2008 (2008-03-27); abstract; paragraphs [0023]-[0025]; figures --	1-15

 Further documents are listed in the continuation of Box C. See patent family annex.

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Date of the actual completion of the international search

09-02-2012

Date of mailing of the international search report

14-02-2012

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2011/050641

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20040107699 A1 (FALES ROGER CLAYTON ET AL), 10 June 2004 (2004-06-10); abstract; paragraph [0025]; figure 2 --	1-15
X	DE 4000185 A1 (KOMATSU DRESSER CO), 12 July 1990 (1990-07-12); column 2, line 26 - column 4, line 7; figure 1 --	1-15
X	US 20110030364 A1 (PERSSON BENGT-GORAN ET AL), 10 February 2011 (2011-02-10); abstract; paragraphs [0006]-[0008]; figure 1 --	1-15
X	JP 59170505 A (FUJI ELECTRIC CO LTD), 26 September 1984 (1984-09-26); (abstract) Retrieved from: EPODOC database; Original document: JP59170505 A; abstract; figure 2 --	1-15
E	JP 2011220390 A (KOBELCO CONSTR MACHINERY CO LTD), 4 November 2011 (2011-11-04); (abstract) Retrieved from: WPI database; Original document: JP2011220390 A; abstract; figures -- -----	1-15

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International Patent Classification (IPC)

E02F 9/22 (2006.01)

F15B 21/14 (2006.01)

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Information on patent family members

International application No.

PCT/SE2011/050641

US	6962050 B2	29/05/2003	DE	60126081 D1	08/03/2007
			EP	1288505 A1	05/03/2003
			JP	3862256 B2	27/12/2006
			US	20030097837 A1	29/05/2003
			WO	0188381 A1	22/11/2001
WO	9300515 A1	07/01/1993	EP	0559792 A4	13/04/1994
US	20080072589 A1	27/03/2008	CN	101065583 A	31/10/2007
			DE	102004061559 A1	29/06/2006
			EP	1828617 A1	05/09/2007
			JP	2008524535 A	10/07/2008
			KR	20070102490 A	18/10/2007
			US	7784278 B2	31/08/2010
			WO	2006066760 A1	29/06/2006
US	20040107699 A1	10/06/2004	US	6854268 B2	15/02/2005
DE	4000185 A1	12/07/1990	JP	2245573 A	01/10/1990
US	20110030364 A1	10/02/2011	EP	2252799 A2	24/11/2010
			KR	20100116664 A	01/11/2010
			WO	2009102740 A3	15/10/2009
JP	59170505 A	26/09/1984	NONE		
JP	2011220390 A	04/11/2011	NONE		