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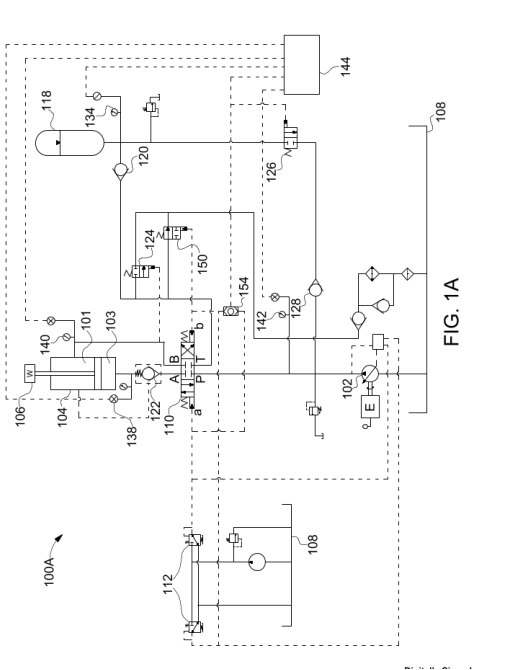
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(54) Title: METHOD AND SYSTEM FOR RECOVERING ENERGY FROM A LIFTED STRUCTURAL MEMBER OF AN OFF-HIGHWAY MACHINE

(57) Abstract: The present disclosure pertains to a system (100A-C, 200, 300) for recovering energy during vertical lifting/lowering of a structural member (106) of an off-highway machine. The system includes a pump (102), a hydraulic cylinder (104, 304) including the structural member (106, 306), an accumulator (118), a first direction control valve (110) operatively coupled to the hydraulic cylinder (104) and the accumulator (118). A first controller (112) is communicably coupled to the first direction control valve (110), a second directional control valve (150), and a shuttle valve (154) such that the first controller (112) generates a lowering/lifting actuation command to lower/lift the structural member (106) by operating the first direction control valve (110) to allow a fluid to flow from the hydraulic cylinder (104) to the accumulator (118) or from the hydraulic cylinder (104) to a tank (108) and vice versa.



FORM 2

THE PATENTS ACT 1970
(39 OF 1970)

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The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

**METHOD AND SYSTEM FOR RECOVERING ENERGY FROM A LIFTED
STRUCTURAL MEMBER OF AN OFF-HIGHWAY MACHINE**

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification describes the invention and the manner in which it is to be performed

DESCRIPTION

Technical Field

5 [001] This disclosure relates generally to energy conservation in off-highway hydraulic machines, and more particularly to energy recovery from lifted parts of an off-highway hydraulic machine.

BACKGROUND

10 [002] Traditionally, mechanical devices such as off-highway machines utilise hydraulic systems. Such off-highway machines may include earth movers, mining equipments, etc., and may be used for carrying and lifting heavy loads and other multiple tasks. Off-highway machines include equipments for construction, material handling, and agriculture, which lift heavy objects, along with a lifting structural member and associated parts such as, but not limited to, boom and parts fitted on the boom. In order to operate the lifting structural member a high pressure fluid may be supplied by the hydraulic system which in turn may be pumped using a pump. Accordingly, the energy required to operate the pump may be generated using fossil fuel run engines that would lead to a high carbon footprint. Further, in conventional off-highway machines, while lowering the lifting structural member that has been raised or elevated at a height, the hydraulic fluid from the hydraulic cylinder is generally supplied back to a tank. This may lead to wastage of the energy utilized by the pump while raising the lifting structural member.

[003] Therefore, there is a requirement to recover the energy utilized in lifting the lifted structural member while operating such off-highway machines in order to make them more efficient and less polluting.

SUMMARY OF THE INVENTION

25 [004] In an embodiment, a system for recovering energy during vertical lifting/lowering of a lifting structural member of an off-highway machine is provided. The system may include a pump, a hydraulic cylinder, an accumulator, a first direction control valve, a first controller and a second controller. In an embodiment, the hydraulic cylinder may include the lifting structural member. Further, the first direction control valve may be operatively coupled to the hydraulic cylinder and the accumulator. In an embodiment, a first controller may be communicably coupled to the first direction control valve, a second directional control valve, and a shuttle

valve. Further, the first controller may generate a lowering actuation command to lower the lifting structural member by operating the first direction control valve, that may enable a fluid to flow from either the hydraulic cylinder to the accumulator, or from the hydraulic cylinder to a tank. Further, the first controller may generate a lifting actuation command to lift the lifting structural member by operating the first direction control valve that may enable the fluid to flow from either the tank to the hydraulic cylinder via the pump, or from the accumulator to the hydraulic cylinder. In an embodiment, upon determination of the lowering actuation command from the first controller, the first controller may close the second directional control valve in order for the fluid to flow from the hydraulic cylinder to the accumulator. Further, upon determination of the lifting actuation command by the shuttle valve from the first controller and a lifting fluid pressure that may be required to lift the lifting structural member, the first controller may configure the pump to pump or supply the fluid from the tank to the hydraulic cylinder. Further, a second controller that may be communicably coupled to the shuttle valve, may open a third direction control valve or a pilot-operated check valve or a proportional direction control valve to enable the flow of the fluid from the accumulator to the hydraulic cylinder based on an accumulator fluid pressure level.

[005] In an embodiment, the fluid from the hydraulic cylinder may be configured to flow to the tank via a fourth direction control valve while lowering the lifting structural member in case the accumulator fluid pressure level is determined to be greater than the threshold level.

[006] In an embodiment, the hydraulic cylinder may be either a single-acting hydraulic cylinder, or a double-acting hydraulic cylinder.

[007] In an embodiment, the accumulator fluid pressure level and the the lifting pressure may be determined through a pressure transducer, or a pressure gauge.

[008] In an embodiment, an amount of the fluid that may be pumped from the tank to the hydraulic cylinder may be offset based on the flow of the fluid from the accumulator into the hydraulic cylinder through the third direction control valve.

[009] In an embodiment, the proportional direction control valve may control an amount of the fluid that may flow from the accumulator to the hydraulic motor. Further, the hydraulic motor may be coupled to an alternator such that alternator may generate an electrical energy based on a rotation of the hydraulic motor utilizing the amount of the fluid that may flow from the accumulator onto the hydraulic motor.

[010] In an embodiment, pumping electrical energy that may be required by the electric motor to the to pump for supply the fluid from the tank to the hydraulic cylinder may be offset based on the electrical energy generated by the alternator.

5 [011] Various objects, features, aspects, and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing figures in which like numerals represent like components.

BRIEF DESCRIPTION OF THE DRAWINGS

10 [012] The accompanying drawings, which are incorporated in, and constitute a part of this disclosure, illustrate exemplary embodiments, and together with the description, serve to explain the disclosed principles.

[013] **FIG. 1A, FIG. 1B** and **FIG. 1C** illustrate hydraulic circuit diagram of exemplary systems for recovering energy from a lifted structural member of an off-highway machine, in accordance with an embodiment of the present disclosure.

15 [014] **FIG 2** illustrates another exemplary hydraulic circuit diagram of the system for recovering energy from a lifted structural member of an off-highway machine, in accordance with an embodiment of the present disclosure.

[015] **FIG 3** illustrates yet another exemplary hydraulic circuit diagram of the system for recovering energy from a lifted structural member of an off-highway machine, in accordance
20 with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE DRAWINGS

[016] The foregoing description has broadly outlined the features and technical advantages of the present disclosure in order that the detailed description of the disclosure that follows may be better understood. Additional features and advantages of the disclosure will be described
25 hereinafter which forms the subject of the claims of the disclosure. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying other devices, systems, assemblies, and mechanisms for carrying out the same purposes of the present disclosure. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the scope of the

disclosure as set forth in the appended claims. The novel features which are believed to be characteristics of the disclosure, to its device or system, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present disclosure.

[017] The terms “comprises”, “comprising”, or any other variations thereof, are intended to cover a non-exclusive inclusion, such that a system or a device that comprises a list of components or steps does not include only those components or steps but may include other components or steps not expressly listed or inherent to such setup or device. In other words, one or more elements in a system or apparatus preceded by “comprises... a” does not, without more constraints, preclude the existence of other elements or additional elements in the system or apparatus.

[018] References will now be made to exemplary embodiments of the disclosure, as illustrated in the accompanying drawings. Wherever possible, same numerals have been used to refer to the same or like parts. The following paragraphs describe the present disclosure with reference to **FIGs. 1A, 1B, 1C, 2 and 3**.

[019] Referring now to **FIG. 1A, FIG. 1B and FIG. 1C**, which illustrate a hydraulic circuit diagram of exemplary systems 100A, 100B and 100C for recovering energy from a structural member 106 of an off-highway machine (not shown), in accordance with an embodiment of the present disclosure. The illustrated diagrams of the 100A, 100B and 100C are of a hydro-mechanical machine such as, but not limited to, an excavator, a truck-mounted crane, a rough terrain crane, a slewing crane, a knuckle boom crane, a crawler crane, a pipe layers, a boom lift, an aerial work platform, etc. The systems 100A, 100B and 100C may include a pump 102 and a hydraulic cylinder 104 which may be a double acting type hydraulic cylinder. Accordingly, the hydraulic cylinder 104 may include a rod-end side 101 which may be mechanically coupled with the structural member 106. In an embodiment, the pump 102 may be, but not limited to, a variable displacement pump or a fixed displacement pump or a combination of both. In an embodiment, the structural member 106 may include, but not limited to, a bucket, an excavator, a hook, etc.

[020] Further, the systems 100A, 100B and 100C may include an accumulator 118 and a first direction control valve 110 that may be operatively coupled with the hydraulic cylinder 104 and the accumulator 118. Further, the systems 100A, 100B and 100C may include a first controller 112 that may be communicably coupled with the first direction control valve 110, a second direction control valve 150, and a shuttle valve 154. Further, the systems 100A, 100B and 100C may include a tank 108 that may store hydraulic fluid also interchangeably referred to as fluid herein.

[021] In an embodiment, the first controller 112 may be a joystick which may generate a lifting actuation command to lift the structural member 106 by moving the joystick to actuate the solenoid operated first direction control valve 110 to position “a” as shown in **FIG. 1A**. Further, the first controller 112 in form of a joystick may generate a lowering actuation command to lower the already lifted structural member 106 by actuating the solenoid operated first direction control valve 110 to position “b”. In an embodiment, initially to lift the structural member 106 based on a lifting actuation command generated by the first controller 112, the hydraulic fluid stored in the tank 108 may be pumped by the pump 102 through the first direction control valve 110 and a pilot operated check valve 122 which may be opened to allow the fluid to enter the hydraulic cylinder 104 in the piston side 103 simultaneously making the fluid from the rod-side 101 to flow out and move to the tank 108 through a second direction control valve 150 that is always open and closes on detection of the lowering actuation command from the first controller 112.

[022] Further, as shown in **FIG. 1A** a fourth direction control valve 124 is provided in a parallel line with the second direction control valve 150. In another embodiment, as shown in **FIG. 1B**, the system 100B may include a fifth directional valve 146 instead of the fourth direction control valve 124.

[023] It should be noted that the fourth direction control valve 124 or the fifth directional valve 146 may be operated based on detection of excess accumulator pressure level above threshold level during the lowering operation. During the lifting operation, the fourth direction control valve 124 or the fifth directional valve 146 may be closed to allow for the fluid to pass through the second direction control valve 150 into the tank 108. The systems 100A, 100B and 100C further include a second controller 144 which may be communicably connected to the shuttle valve 154, a check valve 120. In an embodiment, the systems 100A and 100B include a third direction valve 126 and the system 100C includes a pilot operated check valve 148 which may

connect the accumulator 118 to a parallel fluid supply line through a check valve 128. Further, the second controller 144 may monitor the rod-side pressure in the hydraulic cylinder 104, the non rod-side pressure in the hydraulic cylinder 104, pressure in the accumulator 118, pressure of fluid pumped by the pump 102, etc. via pressure transducers or pressure gauges 140, 138, 134, 142 respectively attached in respective lines transmitting the fluid in the systems 100A, 100B and 100C. In an embodiment, various valves of the systems 100A, 100B and 100C may be manually/pilot controlled or electrically controlled based on one or more control commands generated by the first controller 112 and/or the second controller 144.

[024] In an embodiment, the first direction control valve 110 may be, but not limited to, a four-way direction control valve. Once the structural member 106 has been elevated to a desired height and there is no actuation command received from the first controller 112, the first direction control valve 110 may be in a neutral condition and may stop flow of the fluid into or out of the hydraulic cylinder 104. In an embodiment, the pressure of the fluid while entering the hydraulic cylinder 104 may be measured using a pressure transducer or a pressure gauge 138.

[025] Accordingly, when it is required to lower the lifted structural member 106, the first controller 112 may be moved to the position “b” in order to generate a lowering actuation command to lower the lifted structural member 106 by operating the first direction control valve 110 such that the fluid passes through the first direction control valve 110 into the hydraulic cylinder 104. Accordingly, the fluid from the first direction control valve 110 may flow into a rod-end side 101 of the hydraulic cylinder 104 which may increase the fluid pressure in the rod end side 101. Based on detection of the increase of fluid pressure in the rod-end side 101, the pilot operated check valve 122 may open and the first direction control valve 110 may allow the fluid to flow in A-T direction through a check valve 120 to the accumulator 118. Simultaneously, the lowering actuation command may be sensed by a second direction control valve 150 which may be closed in order to prevent the flow of fluid from the hydraulic cylinder 104 to the tank 108.

[026] Accordingly, the accumulator 118 may store the fluid under pressurized condition. In an embodiment, in case the accumulator 118 capacity to store fluid is reached and the accumulator pressure level is greater than a threshold pressure level, the fourth direction control valve 124 or the fifth directional valve 146 may open, thus allowing the fluid to flow from the hydraulic cylinder 104 to the tank 108.

[027] Further, when a subsequent lifting actuation command is generated by the first controller 112 to lift the structural member 106 the fluid may be supplied from the accumulator 118 as it may be storing the fluid at a high pressure/pressurized condition. Accordingly, based on the supply of the high pressurized fluid from the accumulator 118, an amount of a fluid required to be pumped by the pump 102 may be offset or compensated by the fluid supplied by the accumulator 118.

[028] In an embodiment, in a case pressure of the fluid contained in the accumulator 118 is greater than the lifting fluid pressure required to lift the structural member 106, then the fluid from the accumulator 118 may be supplied to the hydraulic cylinder 104 through the third direction control valve 126. This may offset or compensate the flow of fluid to be pumped from the pump 102.

[029] Accordingly, the energy required by the pump 102 to pump the fluid from the tank 108 may be reduced. It is to be noted that the based on the fluid supplied from the accumulator 118 the systems 100A, 100B and 100C may allow recovery of the energy by utilizing the potential energy of the fluid stored in the accumulator 118.

[030] In an embodiment, the shuttle valve 154 which may sense or receive the lifting or lowering actuation command for lifting or lowering of the structural member 106 from the first controller 112. Accordingly, the first controller 112 may configure the pump 102 to pump/supply the required amount of fluid to lift or lower the structural member 106 to the hydraulic cylinder 104 from the tank 108. Further, the second controller 144 may be communicably coupled with the shuttle valve 154, such that while lifting or lowering the structural member 106, the second controller 144 may configure the shuttle valve 154 to open the third direction control valve 126 or the pilot operated check valve 148. This may enable the flow of the fluid from the accumulator 118 to the hydraulic cylinder 104 through the third direction control valve 126 or the pilot operated check valve 148 depending upon fluid pressure level of the accumulator 118 to offset the fluid flow to be pumped by the pump 102.

[031] In an embodiment, the accumulator 118 may be pre-charged with an inert gas, such as but not limited to nitrogen, and may store fluid such as oil at high pressure. Further, the accumulator 118 may be, but not limited to, a rubber bladder type or a piston type accumulator.

[032] In an embodiment, the first controller 112 and the second controller 144 may be communicably connected to an input/output device (not shown) that may be configured to

receive inputs, and transmit outputs from/to a user(s) in form of, but not limited to, a touch, a gaze, a gesture, and voice commands, etc. In an embodiment, the input/output device may be configured to provide an output to the user in a form of a visual indication, an alarm or a voice notification or a combination of all. In an embodiment, the input/output device may be wirelessly connected to the first controller 112 through a communication protocol such as for example, CAN, CAN FD, PSI5, LIN, FlexRay, Common Industrial Protocol (CIP), Open Platform Communication (OPC) protocols, etc.

[033] The system 100B of FIG. 1B includes a fifth direction control valve 146 in place of the fourth direction control valve 124 as shown in system 100A of **FIG. 1A**. Accordingly, in case the accumulator 118 capacity to store fluid is reached while lowering the lifting structural member 106, the fifth direction control valve 146 may open based on detection of the accumulator pressure being above a threshold level, thus allowing the fluid to flow from the hydraulic cylinder 104 to the tank 108.

[034] Referring now to **FIG. 2**, another exemplary hydraulic circuit diagram of the system 200 for recovering energy from a lifted structural member 106 of an off-highway machine is illustrated. The system 200 is described in conjunction with the description of **FIGS. 1A-1C**. Accordingly, the system 200 includes a hydraulic motor 202, an alternator 204, a check valve 206 and a proportional direction control valve or flow control valve 252 which may be controlled by electrical solenoid or other possible means by second controller 144 instead of the third direction control valve 126 as shown in **FIGS. 1A-1C**. Accordingly, while lowering the lifted structural member 106 based on the generation of a lowering actuation command by the first controller 112, the fluid may flow from the hydraulic cylinder 104 to the accumulator 118. However, in case the pressure level of the accumulator 118 becomes greater than the threshold pressure level, the fluid from the accumulator 118 may flow to the tank 108 through the proportional direction control valve or flow control valve 252 which may allow a controlled quantity of fluid to pass through the hydraulic motor 202 which may be variable displacement or fixed displacement type. The hydraulic motor 202 in turn may be operationally coupled with the alternator 204 that may generate electrical energy based on a rotation of the hydraulic motor 202 based on the amount and pressure of the fluid flowing onto the hydraulic motor 202 through the proportional direction control valve or flow control valve 252. It is to be noted that the proportional direction control valve or flow control valve 252 may be operated by the second controller 144 by electrical signal or other electromechanical means, such as, but not limited

to solenoid actuation, etc. based on accumulator pressure level being monitored using the pressure transducer/pressure gauge 134. Further, the electrical energy generated by the alternator 204 may be stored in one or more batteries (not shown) which may be used to power the pump 102 for pumping the fluid in subsequent lifting or lowering operations leading to recovery of energy by using the fluid stored in the accumulator 118.

[035] Reference now to **FIG. 3**, another exemplary hydraulic circuit diagram of the system 300 for recovering energy from a lifted structural member 106 of an off-highway machine is illustrated. The system 300 is described in conjunction with the description of **FIGs. 1A-1C** and **FIG. 2**. The system 300 includes a single acting piston hydraulic cylinder 304 as compared to double acting piston hydraulic cylinder 104 as shown in **FIGs. 1A-1C** and **FIG. 2**. Accordingly, when the structural member 106 is to be lifted based on a lifting actuation command generated by the first controller 112, the first direction control valve 110 may allow the fluid to flow from the tank 108 to the hydraulic cylinder 304 into the piston side 103. Whereas, in case a lowering actuation command is generated by the first controller 112, the direction control valve 110 may allow the fluid to flow from the piston side 103 of the hydraulic cylinder 304 to the accumulator 118 via the check valve 120. The fluid from the accumulator 118 may flow to the tank 108 through the proportional direction control valve or flow control valve 252 which in turn may allow the controlled quantity of fluid to pass through the hydraulic motor 202 based on electrical command or other means by second controller 144. The hydraulic motor 202 may be coupled to the alternator 204 may then generate electrical energy which may be stored in batteries and utilized to power the pump 102 in subsequent lifting operations to be performed.

[036] It is to be noted that for the systems 200 and 300, the shuttle valve 154 may detect the lifting actuation command or the lowering actuation command from the first controller 112. The second controller 144 may be actuated based on the detection by the shuttle valve 154 which in turn may control the proportional direction control valve or flow control valve 252 electrically or electromechanically using a solenoid, etc. or pneumatically using pilot pressure mechanism, etc. or by other means. The proportional direction control valve or flow control valve 252 may be controlled in order to control the amount of fluid to flow to the hydraulic motor 202. Further, pressure of the fluid contained in the accumulator 118 also referred as accumulator fluid pressure interchangeably, may be determined by the pressure transducer or pressure gauge 134 and a pressure of the fluid required in the hydraulic cylinder 304 to lift the

lifting structural member 306 also referred as lifting fluid pressure, may be determined through a pressure transducer or a pressure gauge 138. The second controller 144 may accordingly control the flow of the fluid from the accumulator 118 to the hydraulic motor 202 which may be variable displacement or fixed displacement type through the proportional direction control valve or flow control valve 252 in order for the alternator to generate enough electrical power to power the pump 102 such that it could pump the fluid based on the lifting fluid pressure required.

[037] It may be noted that the present invention may be applicable to any type of lifting/ lowering bodies of machines where potential energy is lost while lowering the lifted object and the hydraulic circuit diagram shown here is only for illustration purposes.

[038] Thus, the hydraulic system recovers the energy, which is wasted during lifting and lowering of a lifting structural member in a hydro-mechanical machine, by converting the energy into hydraulic potential energy. This energy is then reused to improve productivity and fuel efficiency of the hydro-mechanical machine. The one or more accumulators may be used to store the pressurized fluid draining from the hydraulic cylinder, which may be used later by the boom cylinder or the other actuators for useful work.

[039] In the drawings and specification there has been set forth preferred embodiments of the invention, and although specific terms are employed, these are used in a generic and descriptive sense only and not for purposes of limitation. Changes in the form and the proportion of parts, as well as in the substitution of equivalents, are contemplated as circumstances may suggest or render expedient without departing from the scope of the invention.

[040] The illustrated steps are set out to explain the exemplary embodiments shown, and it should be anticipated that ongoing technological development will change the manner in which particular functions are performed. These examples are presented herein for purposes of illustration, and not limitation. Alternatives (including equivalents, extensions, variations, deviations, etc., of those described herein) will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. Such alternatives fall within the scope and spirit of the disclosed embodiments.

It is intended that the disclosure and examples be considered as exemplary only, with a true scope of disclosed embodiments being indicated by the following claims.

WE CLAIM:

1. A system for recovering energy during vertical lifting/lowering of a structural member (106) of an off highway machine, comprising:

a pump (102);

a hydraulic cylinder (104, 304) comprising the structural member (106);

an accumulator (118);

a first direction control valve (110) operatively coupled to the hydraulic cylinder (104, 304) and the accumulator (118); and

a first controller (112) communicably coupled to the first direction control valve (110), a second directional control valve (150) and a shuttle valve (154), wherein the first controller (112) is configured to generate:

a lowering actuation command to lower the structural member (106) by operating the first direction control valve (110) to configure a fluid to flow from:

the hydraulic cylinder (104, 304) to the accumulator (118), or

the hydraulic cylinder (104, 304) to a tank (108); or

a lifting actuation command to lift the structural member (106) by operating the first direction control valve (110) to configure the fluid to flow from:

the tank (108) to the hydraulic cylinder (104, 304) via the pump (102), or

the accumulator (118) to the hydraulic cylinder (104, 304),

wherein, upon determination of the lowering actuation command from the first controller (112), the first controller (112) is configured to close the second directional control valve (150) to configure the fluid to flow from the hydraulic cylinder (104, 304) to the accumulator (118), and

wherein, upon determination of the lifting actuation command by the shuttle valve (154) from the first controller (112) and a lifting fluid pressure required to lift the structural member (106):

the first controller (112) is configured to configure the pump (102) to pump the fluid from the tank (108) to the hydraulic cylinder (104, 304), and

a second controller (144), communicably coupled to the shuttle valve (154), is configured to open a third direction control valve (126) or a pilot-operated check valve (148) or a proportional direction control valve or a flow control valve (252) to

enable the flow of the fluid from the accumulator (118) to the hydraulic cylinder (104, 304) based on an accumulator fluid pressure level.

2. The system as claimed in claim 1, wherein in case the accumulator fluid pressure level is greater than a threshold level, the fluid from the hydraulic cylinder (104, 304) flows to the tank (108) via a fourth direction control valve (124) or a fifth direction control valve (146) while lowering the structural member (106).

3. The system as claimed in claim 1, wherein the hydraulic cylinder (104, 304) is a single acting hydraulic cylinder (304) or a double acting hydraulic cylinder (104).

4. The system as claimed in claim 1, wherein the accumulator fluid pressure level is determined through a pressure transducer or pressure gauge (134, 142).

5. The system as claimed in claim 1, wherein the lifting fluid pressure is determined through a pressure transducer or pressure gauge (138).

6. The system as claimed in claim 1, wherein an amount of the fluid pumped from the tank (108) to the hydraulic cylinder (104, 304) is offset based on the flow of the fluid from the accumulator (118) into the hydraulic cylinder (104, 304) through the third direction control valve (126).

7. The system as claimed in claim 6, wherein the proportional direction control valve or the flow control valve (252) is configured to control an amount of the fluid flowing from the accumulator (118) to the hydraulic motor (202),

wherein the hydraulic motor (202) is coupled to an alternator (204), and

wherein the alternator (204) is configured to generate electrical energy based on a rotation of the hydraulic motor based on the amount of the fluid flowing from the accumulator (118) onto the hydraulic motor (202).

8. The system as claimed in claim 7, wherein pumping electrical energy required by the pump (102) to pump the fluid from the tank (108) to the hydraulic cylinder (104, 304) is offset based on the electrical energy generated by the alternator (204).

9. The system as claimed in claim 7, wherein the hydraulic motor (202) and the pump (102) are a variable displacement type and/or a fixed displacement type.

10. The system as claimed in claim 1, wherein the proportional direction control valve or flow control valve (252) is electronically controlled, electromechanically actuated, or pneumatically controlled by the second controller (144).

Dated this 1st day of August 2023

-- Digitally Signed--

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ABSTRACT

METHOD AND SYSTEM FOR RECOVERING ENERGY FROM A LIFTED STRUCTURAL MEMBER OF AN OFF-HIGHWAY MACHINE

The present disclosure pertains to a system (100A-C, 200, 300) for recovering energy during vertical lifting/lowering of a structural member (106) of an off-highway machine. The system includes a pump (102), a hydraulic cylinder (104, 304) including the structural member (106, 306), an accumulator (118), a first direction control valve (110) operatively coupled to the hydraulic cylinder (104) and the accumulator (118). A first controller (112) is communicably coupled to the first direction control valve (110), a second directional control valve (150), and a shuttle valve (154) such that the first controller (112) generates a lowering/lifting actuation command to lower/lift the structural member (106) by operating the first direction control valve (110) to allow a fluid to flow from the hydraulic cylinder (104) to the accumulator (118) or from the hydraulic cylinder (104) to a tank (108) and vice versa.

[To be published with FIG. 1A]

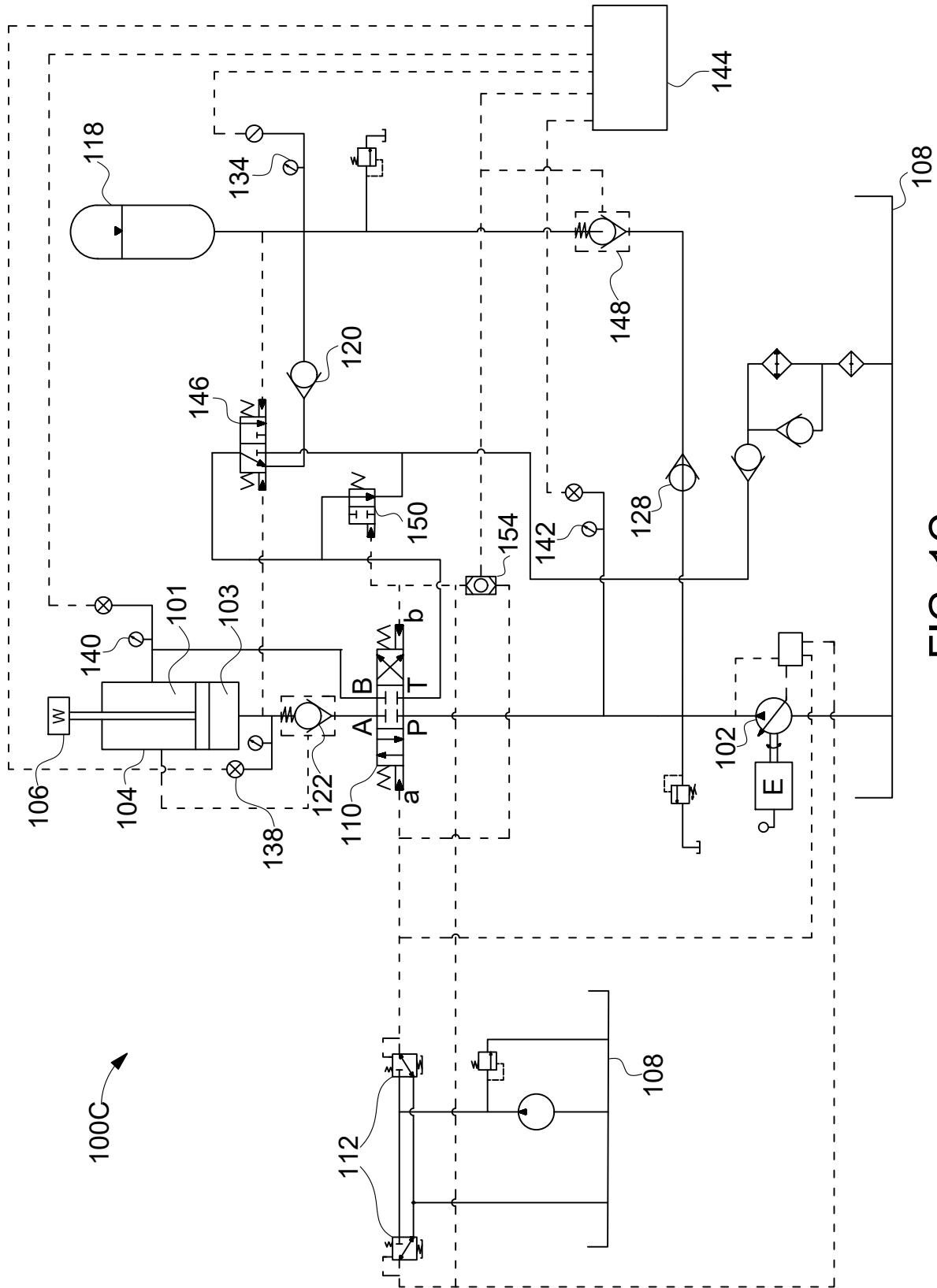


FIG. 1C

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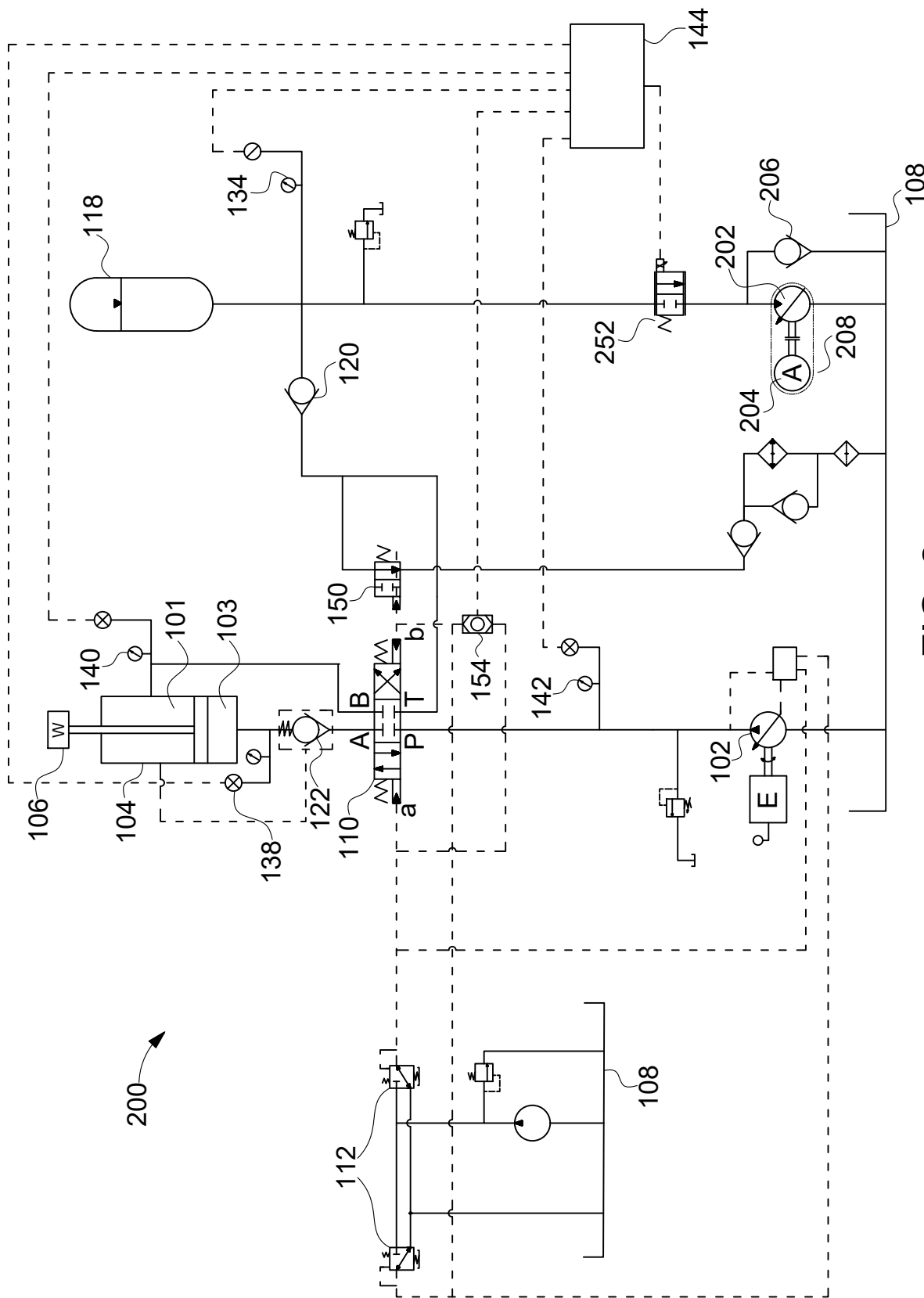


FIG. 2

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