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(54) **WORK MACHINE**

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E02F 9/20 (2006.01)

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(2013.01); **F15B 11/042** (2013.01);
(Continued)

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F15B 11/042

See application file for complete search history.

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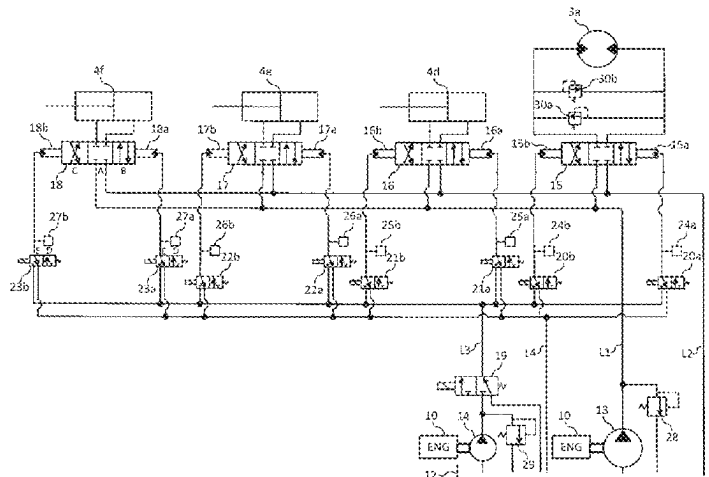
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(57) **ABSTRACT**

Provided is a work machine capable of appropriately switching between prevention of the degradation in a ride quality caused by an inertial force generated in braking of a hydraulic actuator and a work using the inertial force. In the work machine, under a condition where an operation device has been operated from an operation position toward a neutral position, in a case where an actual operation speed of the operation device is less than a quick operation threshold (S21: Yes), a spool is made moved from a supply and discharge position toward a blocking position at a first speed that is slower than a reference speed corresponding to the operation speed (S25, S27 to S29), and at a second speed that is faster than the first speed (S26 to S29) in a case where the operation speed is equal to or more than the quick operation threshold (S21: No).

4 Claims, 15 Drawing Sheets



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F15B 11/042 (2006.01)
F15B 11/044 (2006.01)
F15B 11/08 (2006.01)
- (52) **U.S. Cl.**
CPC *F15B 11/044* (2013.01); *F15B 11/08*
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9/2292 (2013.01)

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FIG. 1

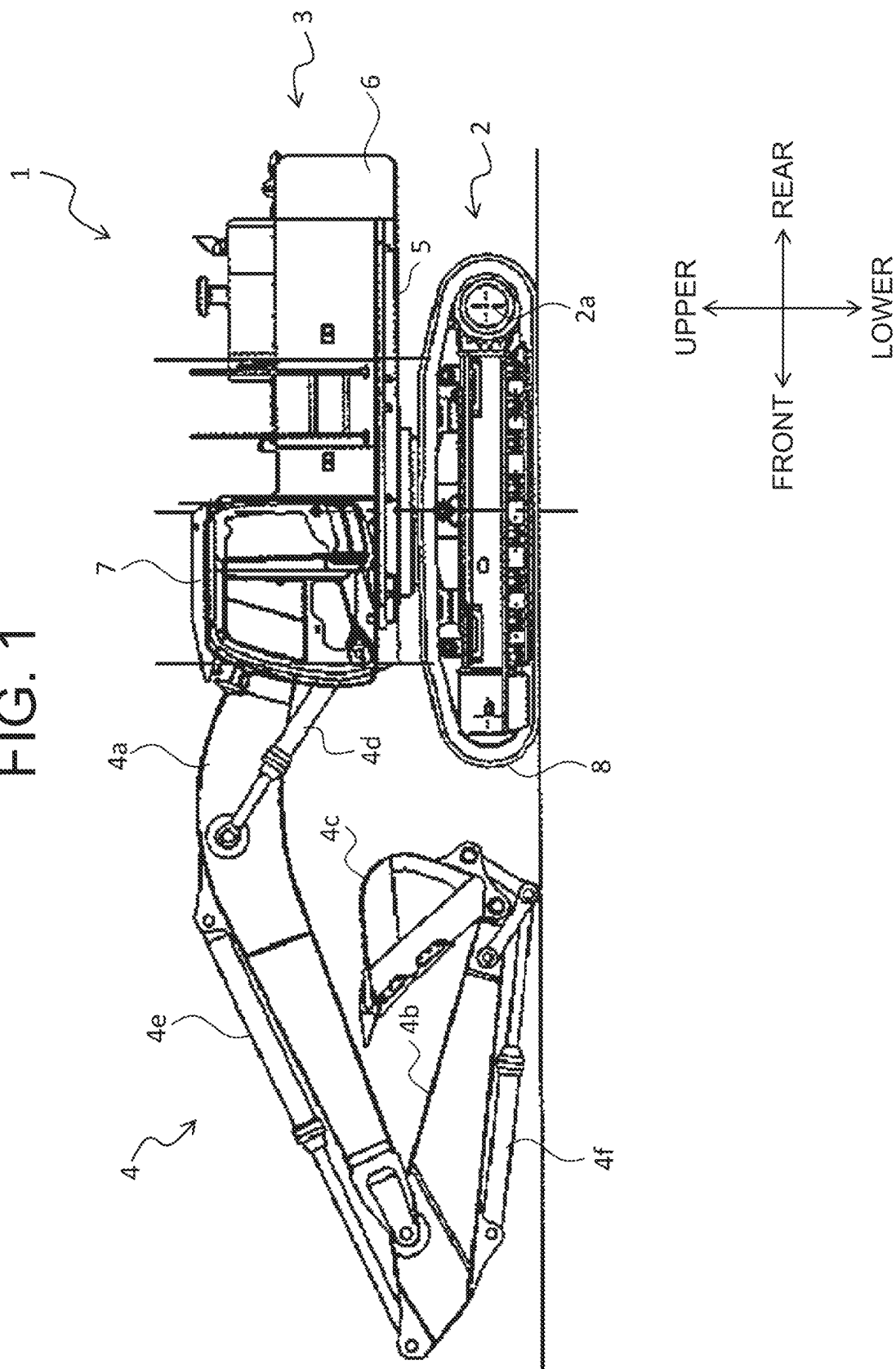
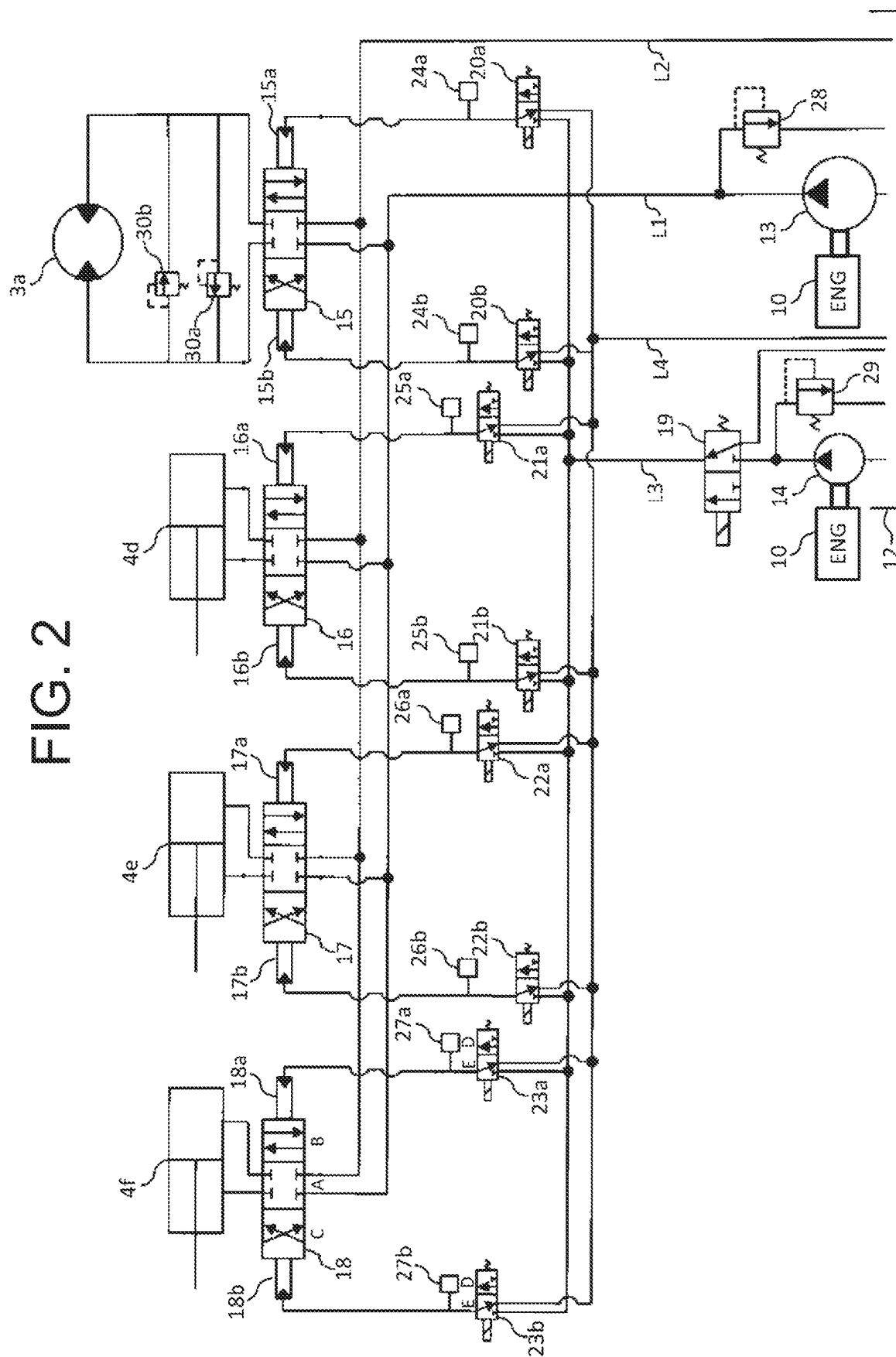


FIG. 2



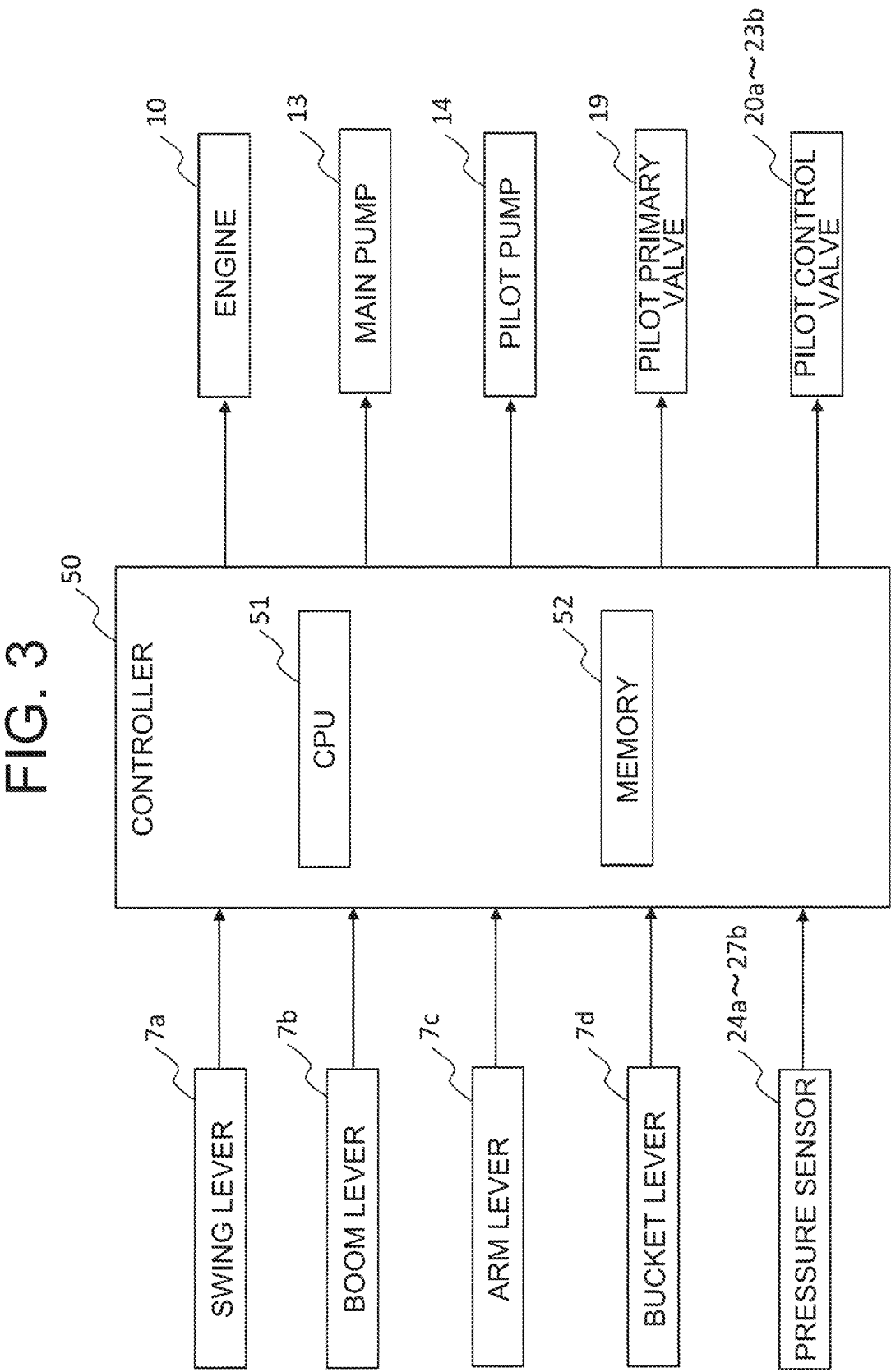


FIG. 4A

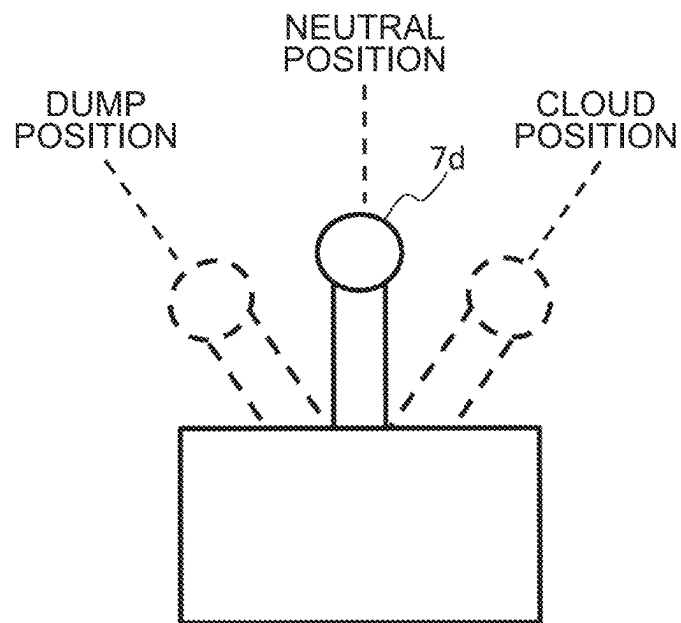


FIG. 4B

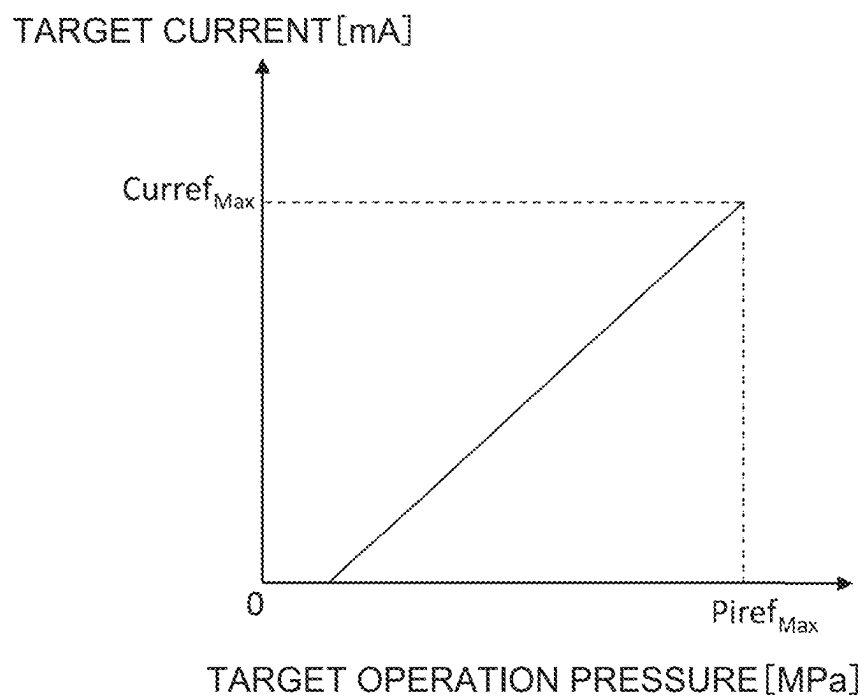


FIG. 5

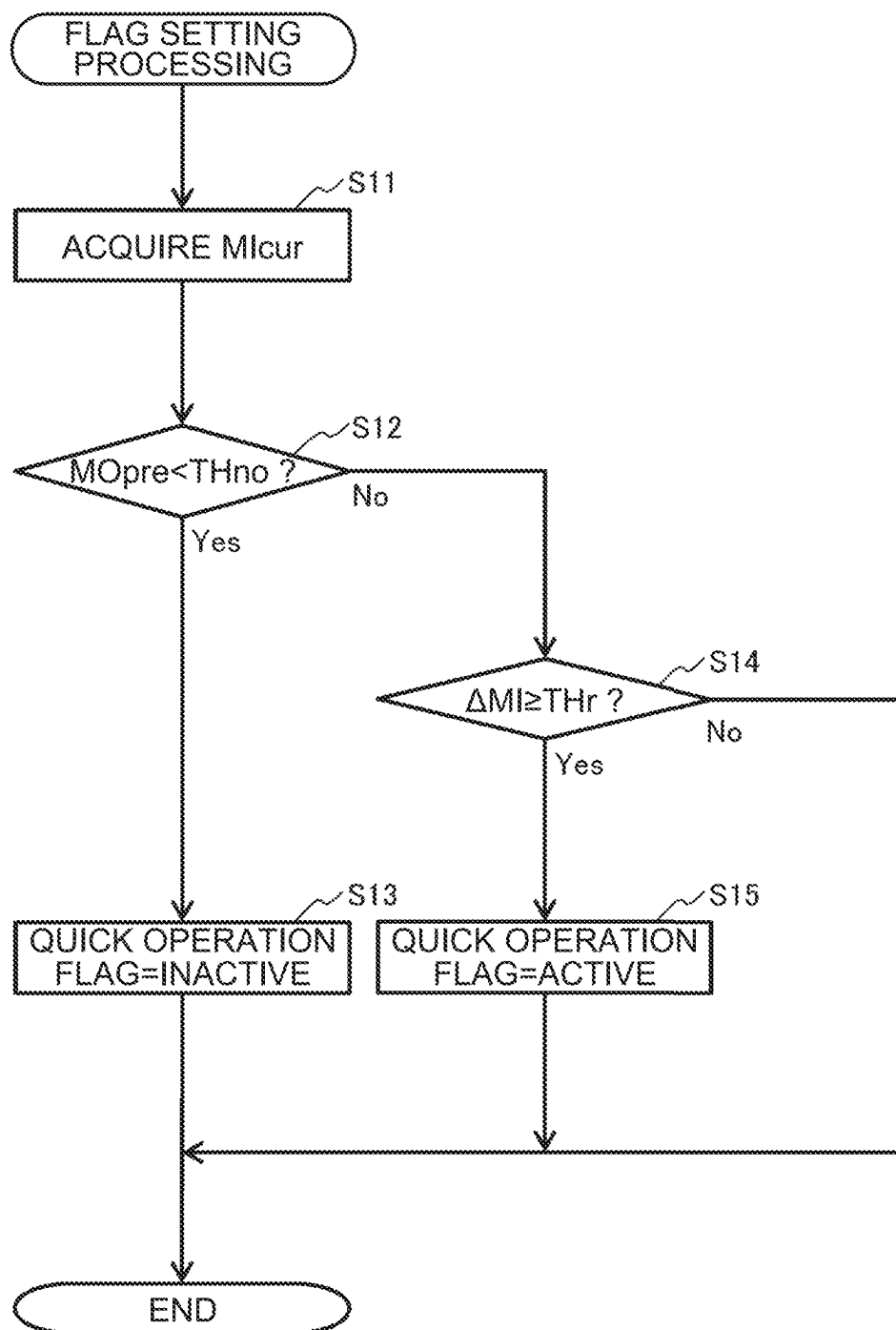


FIG. 6

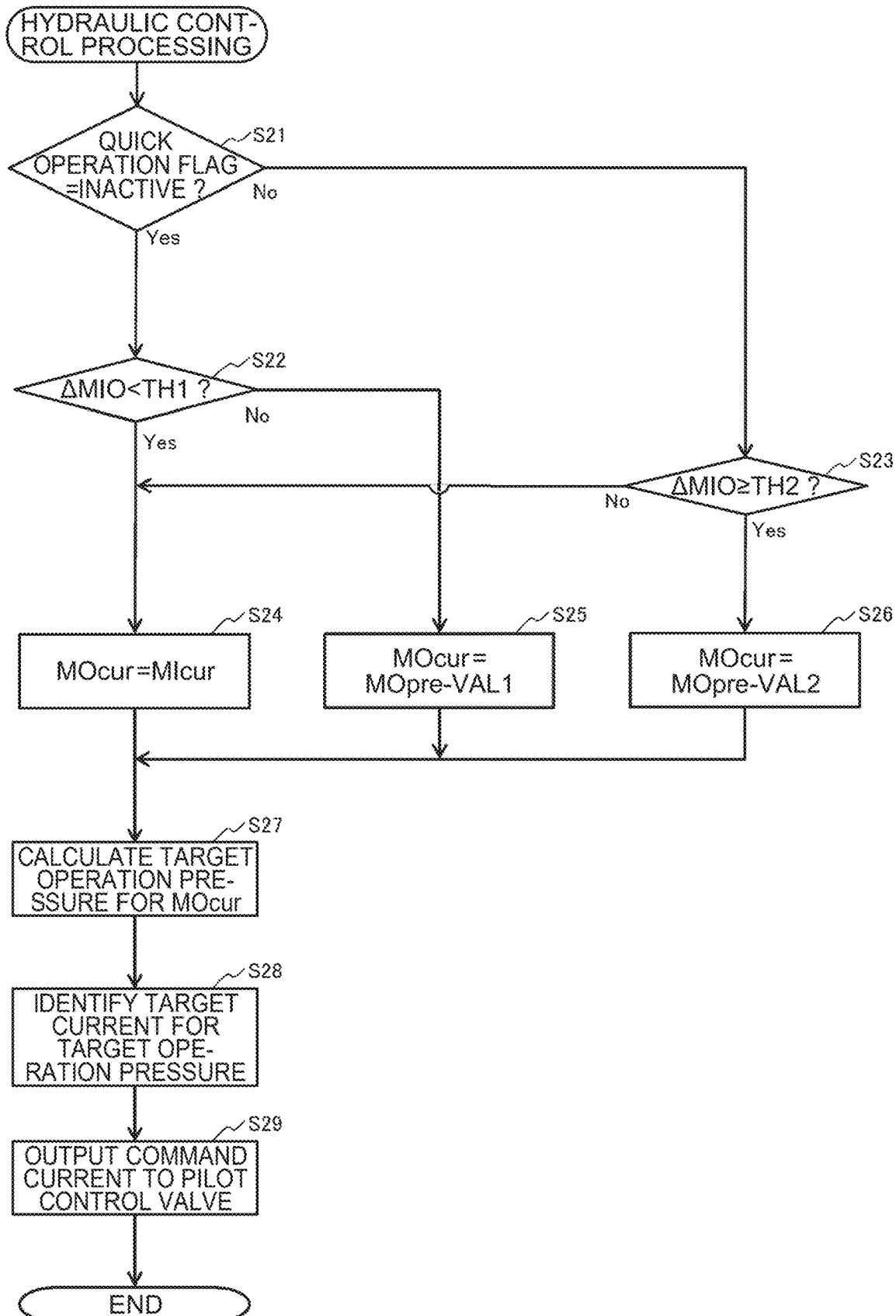


FIG. 7

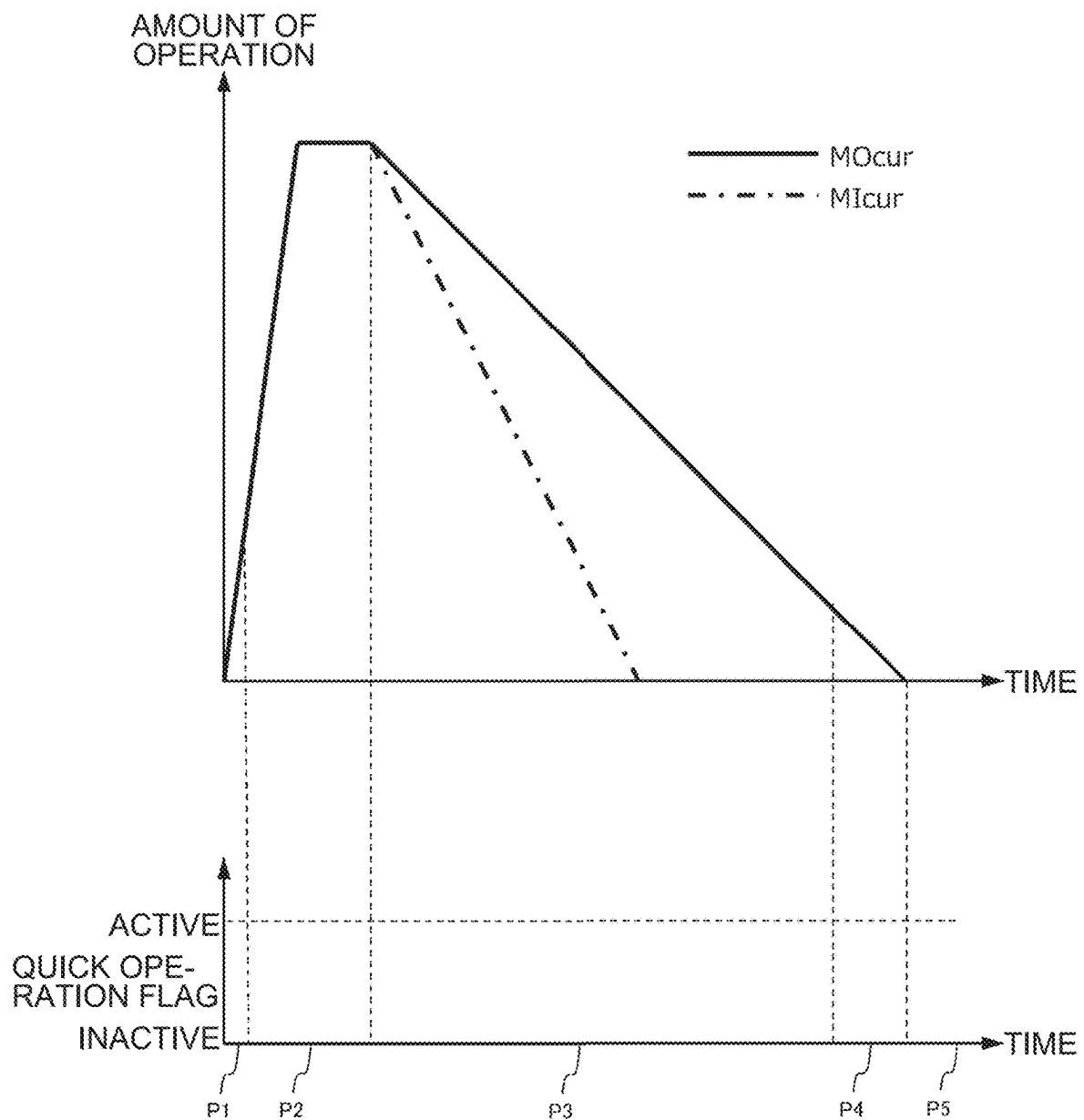


FIG. 8

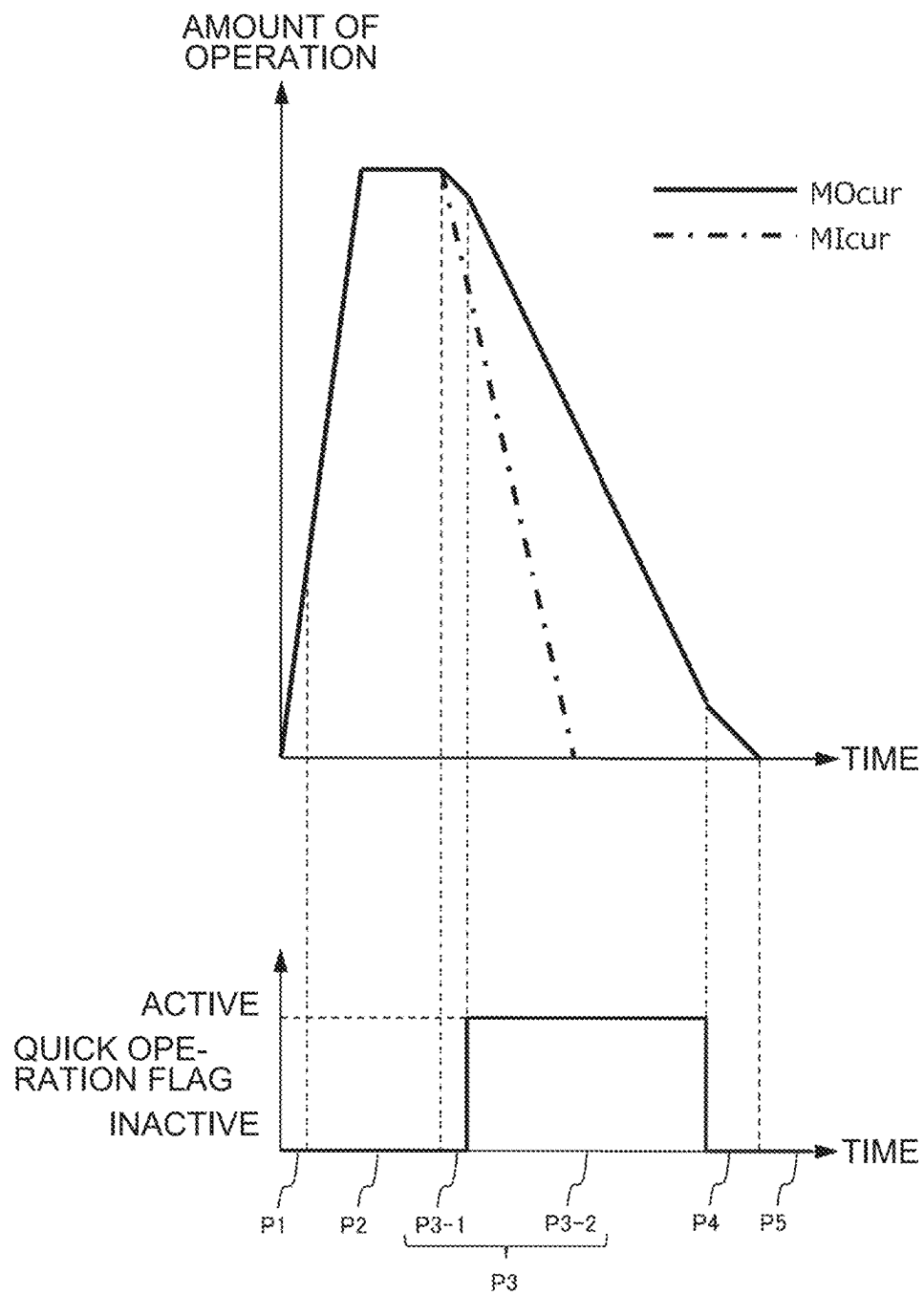


FIG. 9

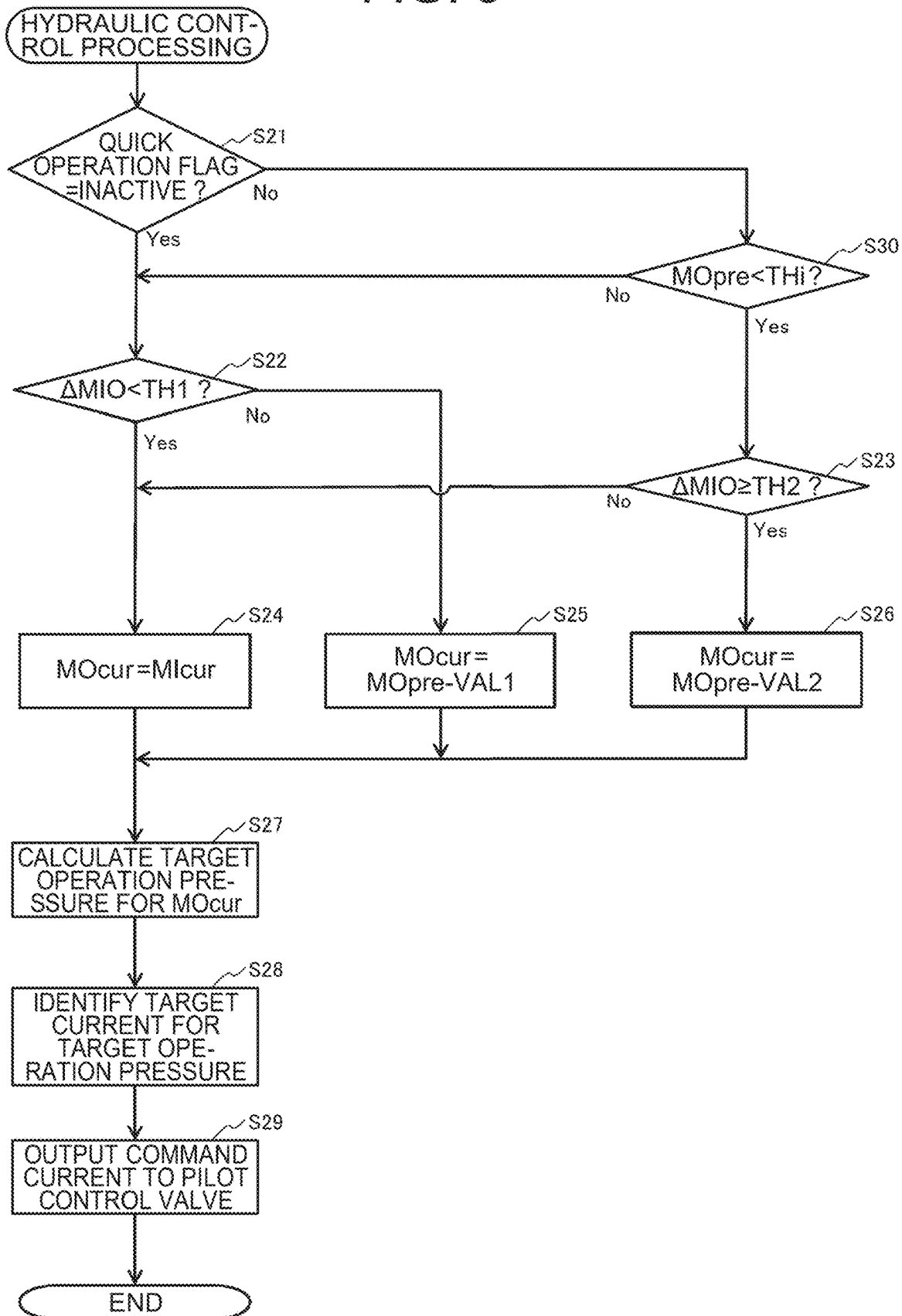


FIG. 10

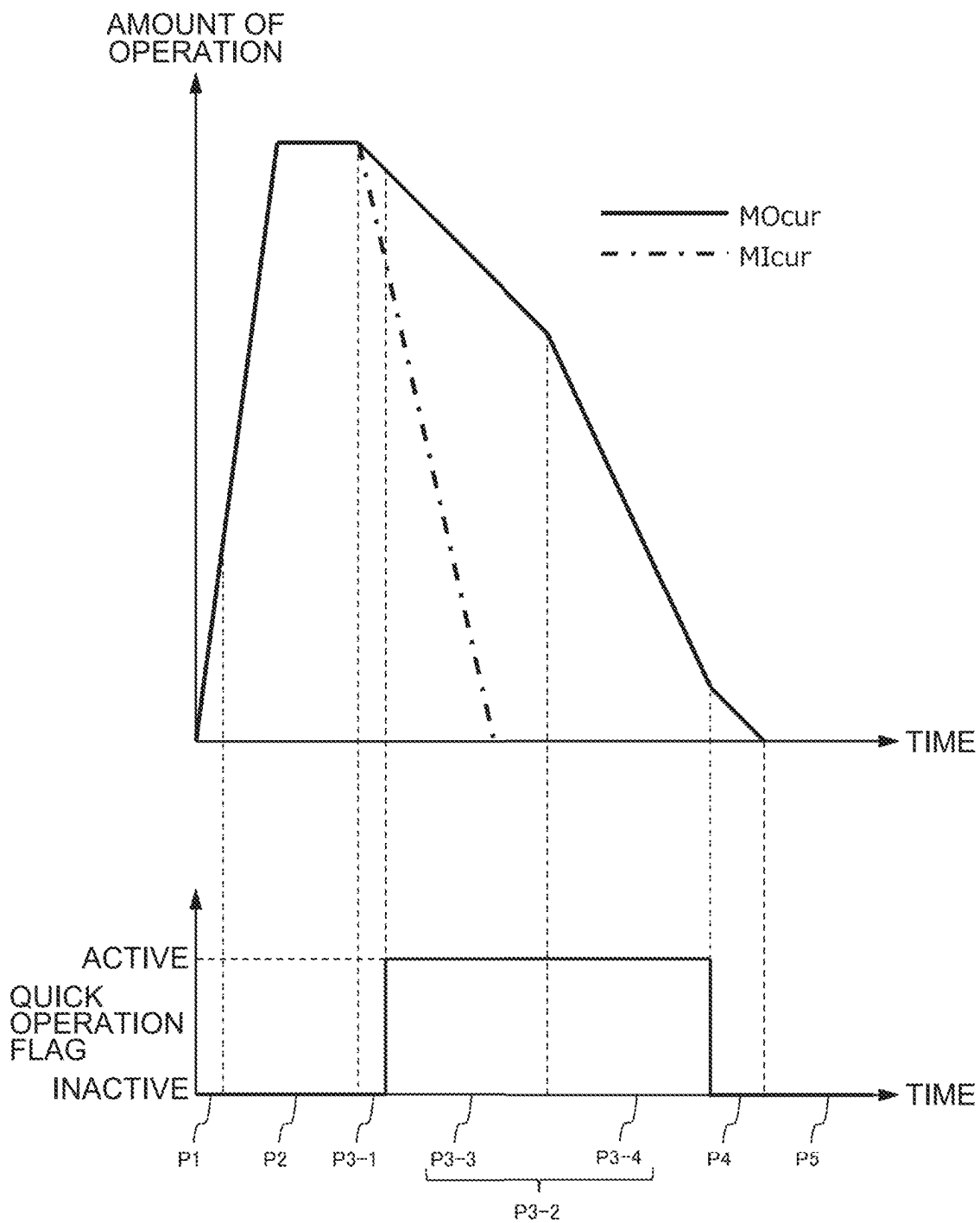


FIG. 11

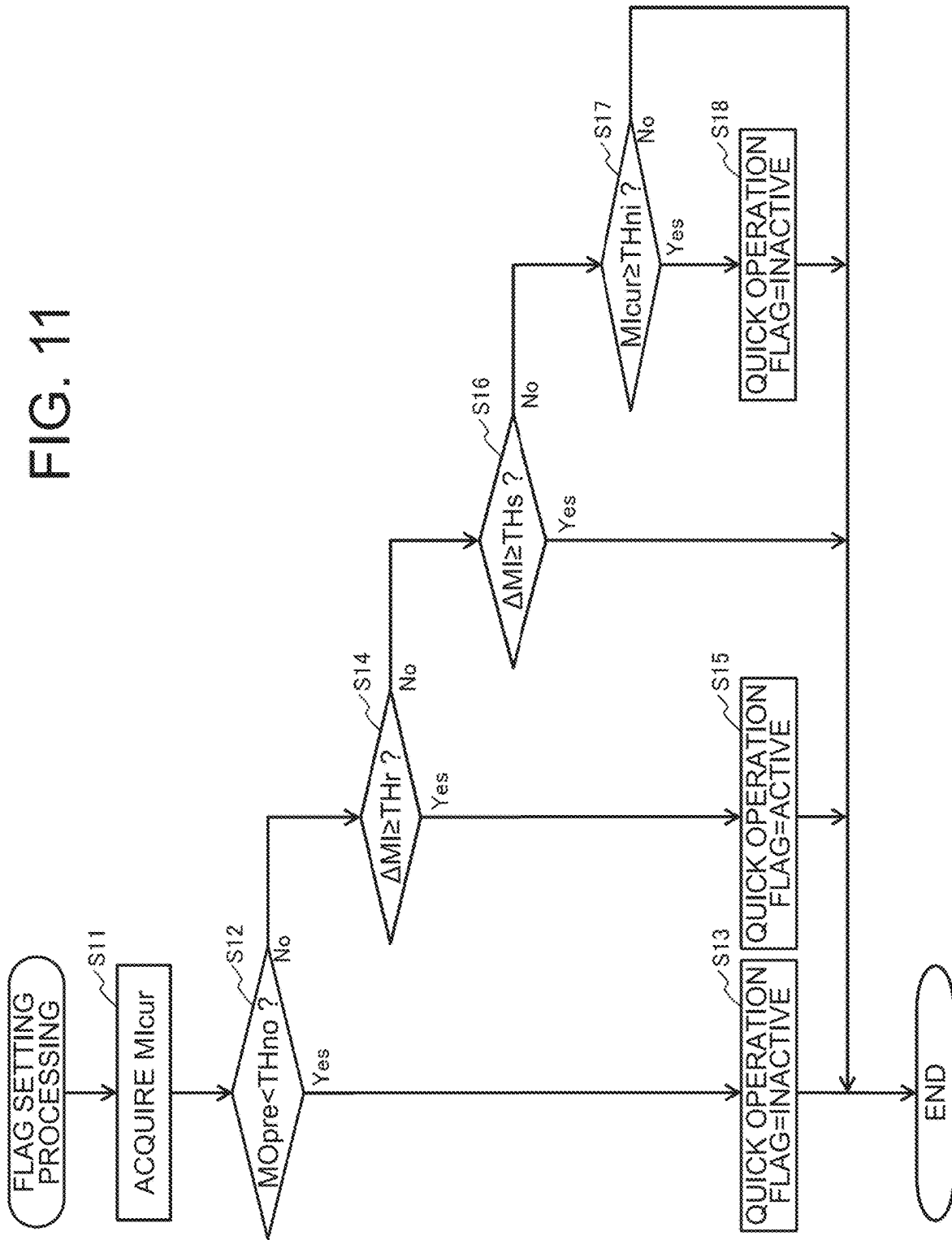


FIG. 12

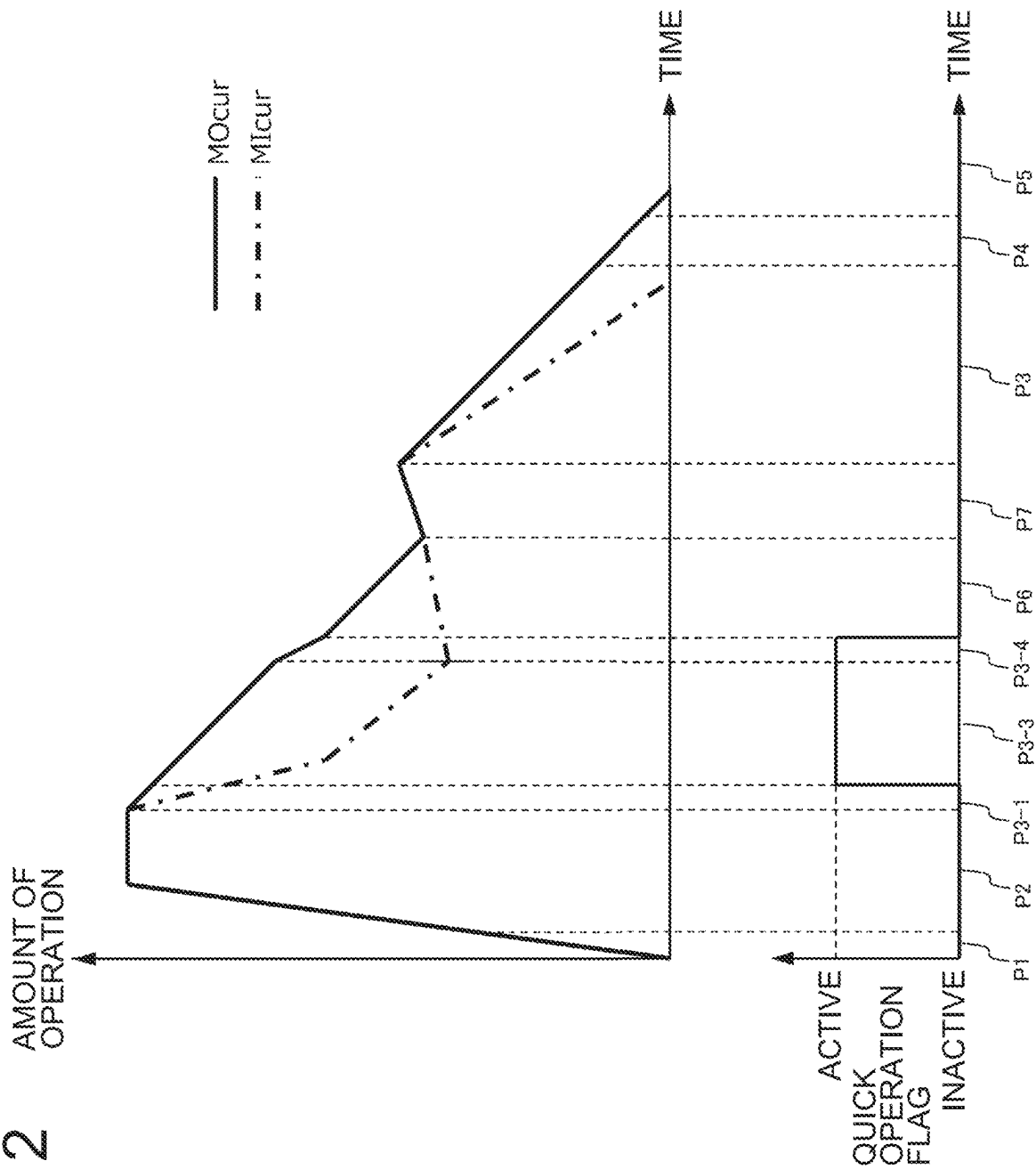


FIG. 13

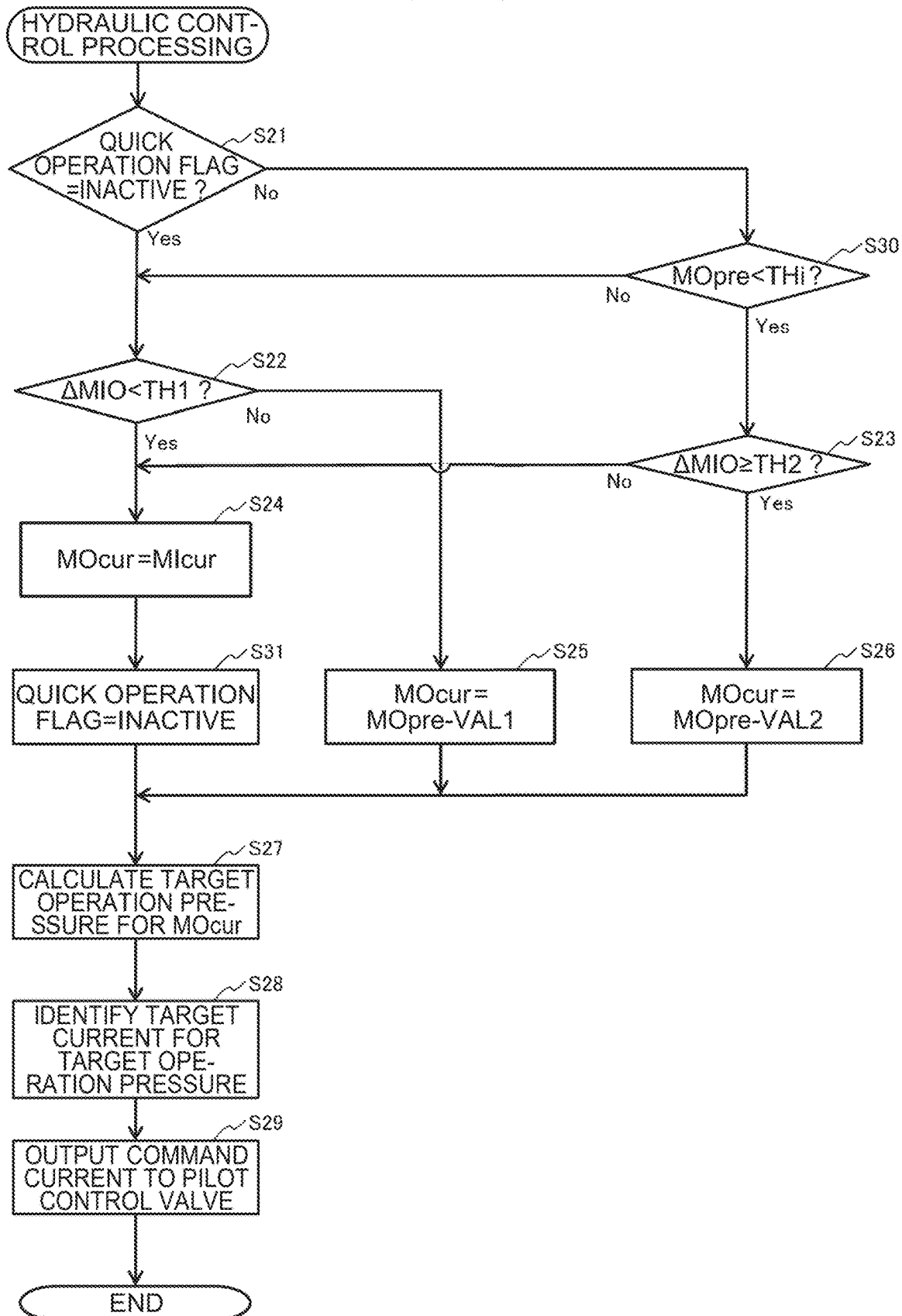


FIG. 14

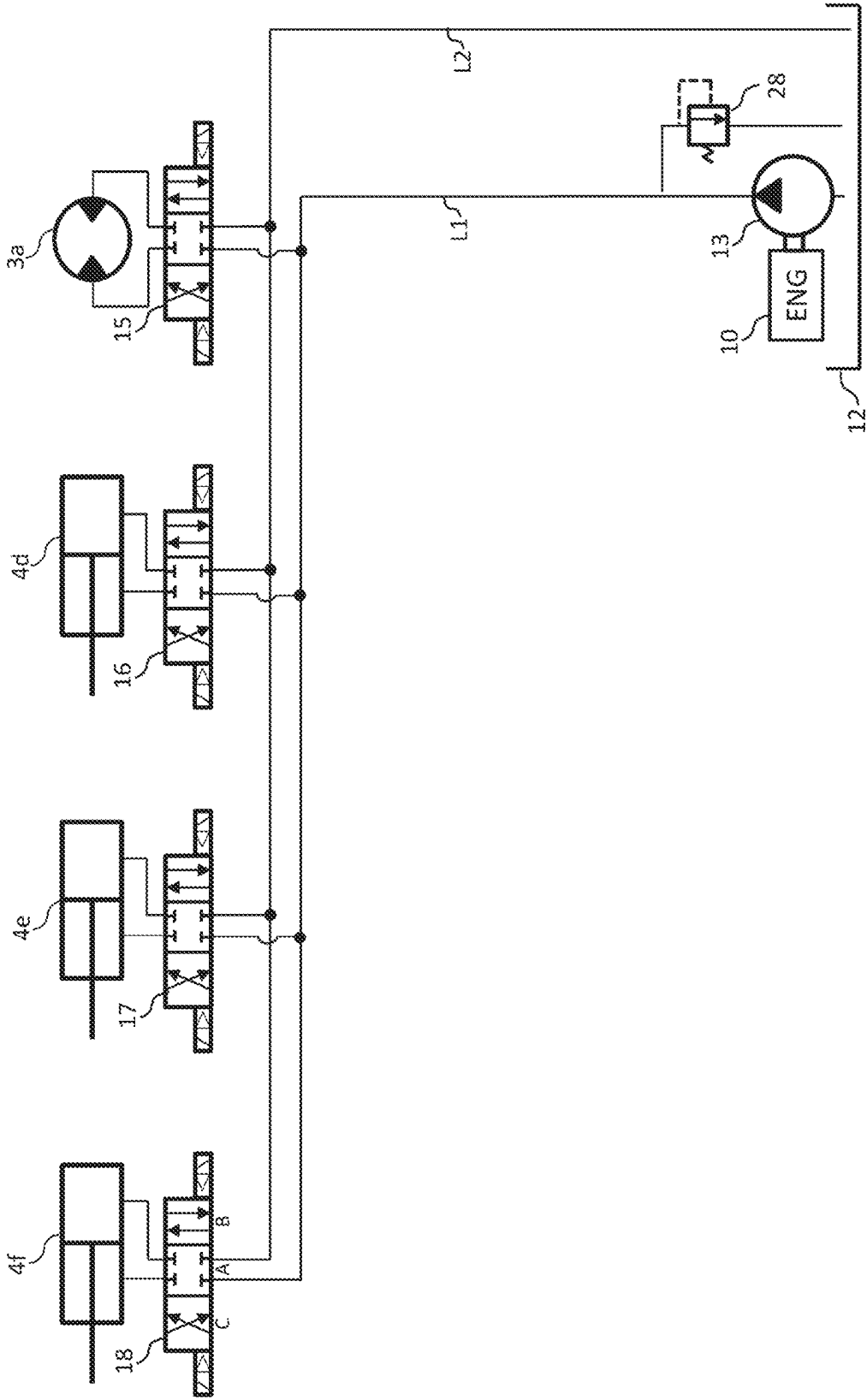
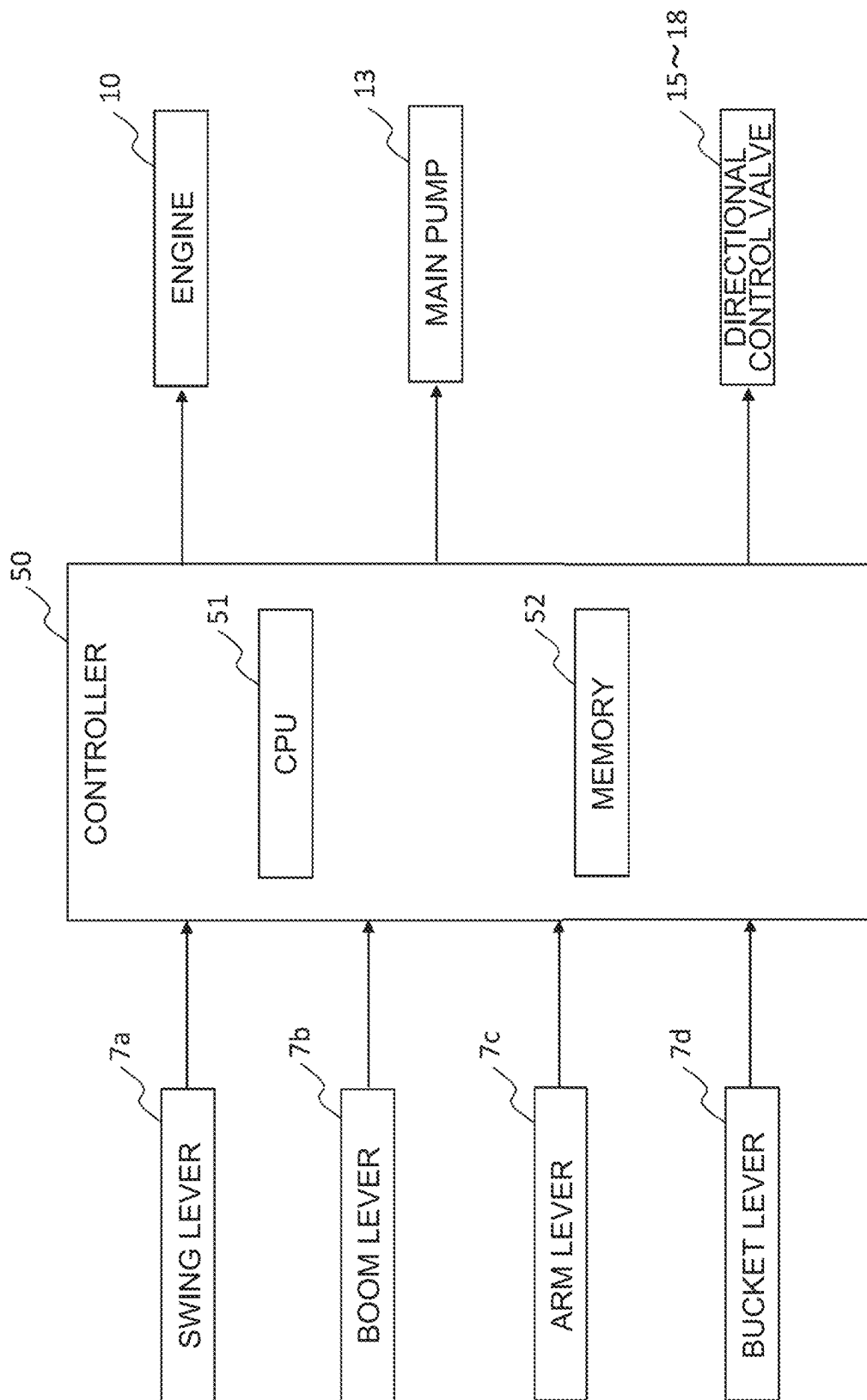


FIG. 15



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WORK MACHINE**TECHNICAL FIELD**

The present invention relates to a work machine equipped with a hydraulic actuator.

BACKGROUND ART

In a conventional work machine, various hydraulic actuators such as a traveling motor for making a vehicle body travel, a swing motor for making an upperstructure swing, hydraulic cylinders for raising and lowering a front working device, and the like are mounted.

In such a work machine, an operation of braking of a hydraulic actuator causes the vehicle body to vibrate due to an inertial force, which degrades a ride quality. For this problem, Patent Literature 1 discloses a technique of reducing an inertial force generated in braking of a hydraulic actuator to prevent degradation in a ride quality.

CITATION LIST**Patent Literature**

Patent Literature 1: WO2014/013877

SUMMARY OF INVENTION**Technical Problem**

On the other hand, the works that a work machine performs include such a work that uses a large inertial force generated in braking of a hydraulic actuator while forcing an operator to tolerate the degradation in a ride quality, such as a work of dropping mud in the bucket. However, in the technique of Patent Literature 1, the work of dropping mud in the bucket as described above cannot be performed due to a reduced inertial force.

The present invention has been made in view of the circumstances described above, and an object thereof is to provide a work machine capable of appropriately switching between prevention of the degradation in a ride quality caused by an inertial force generated in braking of a hydraulic actuator and a work using the inertial force.

Solution to Problem

In order to achieve the object described above, the present invention provides a work machine comprising: a prime mover; a hydraulic pump configured to pump a hydraulic oil upon being driven by the prime mover; a hydraulic actuator configured to operate upon being supplied with or discharging the hydraulic oil; a supply flow path for supplying the hydraulic oil pumped by the hydraulic pump to the hydraulic actuator; a return flow path for bringing the hydraulic oil discharged from the hydraulic actuator to a hydraulic oil tank; a directional control valve having a spool that moves between a supply and discharge position and a blocking position, the supply and discharge position being a position for opening the supply flow path and the return flow path to cause the hydraulic oil to be supplied to and discharged from the hydraulic actuator, and the blocking position being a position for blocking the supply flow path and the return flow path to stop the hydraulic oil to be supplied to and discharged from the hydraulic actuator; an operation device configured to be operated between an operation position

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corresponding to the supply and discharge position of the spool and a neutral position corresponding to the blocking position of the spool; and a controller configured to bring the spool closer to the supply and discharge position as the operation device approaches the operation position to increase a volume of the hydraulic oil to be supplied to and discharged from the hydraulic actuator, and bring the spool closer to the blocking position as the operation device approaches the neutral position to reduce the volume of the hydraulic oil to be supplied to and discharged from the hydraulic actuator, wherein in a case where the operation device has been operated from the operation position toward the neutral position, the controller is configured to: move the spool from the supply and discharge position toward the blocking position at a first speed that is slower than a reference speed in a case where an operation speed of the operation device is less than a quick operation threshold; and move the spool from the supply and discharge position toward the blocking position at a second speed that is faster than the first speed in a case where the operation speed is equal to or more than the quick operation threshold.

Advantageous Effects of Invention

According to the present invention, it is possible to obtain a work machine capable of appropriately switching between prevention of the degradation in a ride quality caused by an inertial force generated when a hydraulic actuator is braked and a work using the inertial force. The problems, arrangements, and advantageous effects other than those described above will be clarified by explanation of the embodiments below.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a side view of a hydraulic excavator.

FIG. 2 illustrates a drive circuit of a hydraulic excavator according to the present embodiment.

FIG. 3 is a control block diagram of a hydraulic excavator according to the present embodiment.

FIG. 4A is a schematic diagram of a bucket lever.

FIG. 4B illustrates a relation between a target operation pressure and a target current.

FIG. 5 illustrates a flowchart of flag setting processing according to the present embodiment.

FIG. 6 illustrates a flowchart of hydraulic control processing according to the present embodiment.

FIG. 7 illustrates changes with time in a current input operation amount and a current output operation amount in the case where a bucket lever has been slowly operated toward a neutral position.

FIG. 8 illustrates changes with time in a current input operation amount and a current output operation amount in the case where a bucket lever has been quickly operated.

FIG. 9 illustrates a flowchart of hydraulic control processing according to the first modification.

FIG. 10 illustrates changes with time in a current input operation amount and a current output operation amount in the case where a bucket lever has been quickly operated in the first modification.

FIG. 11 illustrates a flowchart of flag setting processing according to the second modification.

FIG. 12 illustrates changes with time in a current input operation amount and a current output operation amount in the case where a bucket lever is quickly operated toward a neutral position after reaching a target position, temporarily

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stopped with the operation speed gradually being reduced, and slowly operated again toward the neutral position.

FIG. 13 illustrates a flowchart of hydraulic control processing according to the third modification.

FIG. 14 illustrates a drive circuit of a hydraulic excavator according to the fourth modification.

FIG. 15 is a control block diagram of a hydraulic excavator according to the fourth modification.

DESCRIPTION OF EMBODIMENTS

An embodiment of a hydraulic excavator 1 (work machine) according to the present invention will be described with reference to the drawings. It should be noted that a specific example of the work machine is not limited to the hydraulic excavator 1, but may be a wheel loader, a crane, a dump truck, or the like. It should be also noted that, the front, rear, left, and right are mentioned herein based on the viewpoint of an operator who rides on to operate the hydraulic excavator 1 unless otherwise specified.

FIG. 1 is a side view of the hydraulic excavator 1. As illustrated in FIG. 1, the hydraulic excavator 1 includes an undercarriage 2 and an upperstructure 3 supported by the undercarriage 2. The undercarriage 2 and the upperstructure 3 are examples of a machine body. The undercarriage 2 includes a pair of left and right crawlers 8 that are continuous tracks. Driving a traveling motor 2a causes the pair of right and left crawlers 8 to rotate independently. This makes the hydraulic excavator 1 travel. However, the undercarriage 2 may include wheels instead of the crawlers 8.

The upperstructure 3 is supported on the undercarriage 2 so as to be made swung by a swing motor 3a (see FIG. 2). The upperstructure 3 mainly includes a swing frame 5 serving as a base, a front working device 4 (working device) mounted to the center of the front of the swing frame 5 so as to be rotatable in the vertical direction, a cab (operator's seat) 7 placed on the left side of the front of the swing frame 5, and a counterweight 6 placed on the rear of the swing frame 5.

The front working device 4 includes a boom 4a supported on the upperstructure 3 so as to raise and lay down, an arm 4b supported on the distal end of the boom 4a so as to be rotatable, a bucket 4c supported on the distal end of the arm 4b so as to be rotatable, boom cylinders 4d for driving the boom 4a, an arm cylinder 4e for driving the arm 4b, and a bucket cylinder 4f for driving the bucket 4c. The counterweight 6 is a heavy object having an arc shape as viewed from the above, which is provided to adjust the weight balance with the front working device 4.

Each of the traveling motor 2a, the swing motor 3a, the boom cylinders 4d, the arm cylinder 4e, and the bucket cylinder 4f is an example of a hydraulic actuator that operates upon being supplied with and discharging hydraulic oil. However, specific examples of the hydraulic actuators are not limited thereto. Hereinafter, these actuators may be collectively referred to as "hydraulic actuators 2a, 3a, 4d to 4f" and the like.

The cab 7 has an internal space allowing an operator who operates the hydraulic excavator 1 to ride therein. In the internal space of the cab 7, a seat on which the operator sits and an operation device to be operated by an operator who has sit on the seat are placed.

The operation device accepts an operation for operating the hydraulic excavator 1 from an operator. An operation which has been made to the operation device by the operator causes the undercarriage 2 to travel, the upperstructure 3 to swing, and the front working device 4 to work. Specific

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examples of the operation device include a lever, a steering wheel, an accelerator pedal, a brake pedal, a switch, and the like. As illustrated in FIG. 3, the operation device includes a traveling pedal (not illustrated), a swing lever 7a, a boom lever 7b, an arm lever 7c, and a bucket lever 7d.

The traveling pedal accepts an operation for instructing to cause the traveling motor 2a to rotate from the operator. The swing lever 7a accepts an operation for instructing to cause the swing motor 3a to rotate from the operator. The boom lever 7b accepts an operation for instructing to cause the boom cylinders 4d to expand and contract from the operator. The arm lever 7c accepts an operation for instructing to cause the arm cylinder 4e to expand and contract from the operator. The bucket lever 7d accepts an operation for instructing to cause the bucket cylinder 4f to extend and contract from the operator. The levers 7a to 7d do not have to be provided independently, but first and second levers may be provided and set such that the front and rear direction of the first lever corresponds to the swing lever 7a, the left and right direction of the first lever corresponds to the boom lever 7b, the front and rear direction of the second lever corresponds to the arm lever 7c, and the left and right direction of the second lever corresponds to the bucket lever 7d.

FIG. 2 illustrates a drive circuit of the hydraulic excavator 1 according to the present embodiment. As illustrated in FIG. 2, the hydraulic excavator 1 mainly includes an engine 10, a hydraulic oil tank 12, a main pump 13 (hydraulic pump), a pilot pump 14, directional control valves 15, 16, 17, 18, a pilot primary valve 19, pilot control valves 20a, 20b, 21a, 21b, 22a, 22b, 23a, 23b, and pressure sensors 24a, 24b, 25a, 25b, 26a, 26b, 27a, 27b.

The engine 10 is a prime mover that generates power for driving the hydraulic excavator 1. The hydraulic oil tank 12 stores the hydraulic oil therein. The main pump 13 is rotated by the power of the engine 10, and pumps the hydraulic oil stored in the hydraulic oil tank 12 to a hydraulic oil supply flow path L1. The pilot pump 14 is rotated by the power of the engine 10 also serving as the power source of the main pump 13, and pumps the hydraulic oil stored in the hydraulic oil tank 12 to a pilot supply flow path L3 as pilot pressure oil.

The hydraulic oil supply flow path L1 is a flow path for the hydraulic oil, which extends from the hydraulic oil tank 12 to the hydraulic actuators 3a, 4d to 4f via the main pump 13 and the directional control valves 15 to 18 (in FIG. 3, the driving motor 2a is not illustrated). That is, the hydraulic oil supply flow path L1 is a supply flow path for supplying the hydraulic oil pumped by the main pump 13 to the hydraulic actuators 3a, 4d to 4f.

The hydraulic actuators 3a, 4d to 4f are connected to the hydraulic oil tank 12 through a hydraulic oil return flow path L2. The hydraulic oil return flow path L2 is a flow path extending from the hydraulic actuators 3a, 4d to 4f to the hydraulic oil tank 12 via the directional control valves 15 to 18. That is, the hydraulic oil return flow path L2 is a return flow path for bringing the hydraulic oil discharged from the hydraulic actuators 3a, 4d to 4f back to the hydraulic oil tank 12.

A pilot supply flow path L3 is a flow path for the pilot pressure oil, which extends from the hydraulic oil tank 12 to pilot ports 15a to 18b of the directional control valves 15 to 18 via the pilot pump 14, the pilot primary valve 19, and the pilot control valves 20a to 23b. That is, the pilot supply flow path L3 is a flow path for supplying the pilot pressure oil pumped by the pilot pump 14 to the pilot ports 15a to 18b.

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The pilot ports **15a** to **18b** are connected to the hydraulic oil tank **12** through a pilot return flow path **L4**. The pilot return flow path **L4** is a flow path extending from the pilot ports **15a** to **18b** to the hydraulic oil tank **12** via the pilot control valves **20a** to **23b**. That is, the pilot return flow path **L4** is a flow path for bringing the pilot pressure oil discharged from the pilot ports **15a** to **18b** back to the hydraulic oil tank **12**.

The directional control valves **15** to **18** are placed on the hydraulic oil supply flow path **L1** and the hydraulic oil return flow path **L2**. The directional control valves **15** to **18** control the volume and direction of the hydraulic oil supplied to the hydraulic actuators **3a**, **4d** to **4f** through the hydraulic oil supply flow path **L1** and the volume of the hydraulic oil discharged from the hydraulic actuators **3a**, **4d** to **4f** through the hydraulic oil return flow path **L2**.

More specifically, the directional control valve **15** controls the supply and discharge of the hydraulic oil to and from the swing motor **3a**, the directional control valve **16** controls the supply and discharge of the hydraulic oil to and from the boom cylinders **4d**, the directional control valve **17** controls the supply and discharge of the hydraulic oil to and from the arm cylinder **4e**, and the directional control valve **18** controls the supply and discharge of the hydraulic oil to and from the bucket cylinder **4f**. The directional control valves **15** to **18** have the structures which are common to each other, and thus, in the following, the directional control valve **18** will be described in detail.

The directional control valve **18** includes a spool that moves between a blocking position A, a dump position B, and a cloud position C. The blocking position A is a position for blocking the hydraulic oil supply flow path **L1** and the hydraulic oil return flow path **L2** to stop the supply and discharge of the hydraulic oil to and from the bucket cylinder **4f**. The dump position B and the cloud position C are positions for opening the hydraulic oil supply flow path **L1** and the hydraulic oil return flow path **L2** to allow the hydraulic oil to be supplied to and discharged from the bucket cylinder **4f**. The dump position B and the cloud position C are located opposite to each other across the blocking position A.

More specifically, the dump position B is a position for causing the hydraulic oil to be supplied to a rod chamber of the bucket cylinder **4f** and to be discharged from a bottom chamber so as to make the bucket cylinder **4f** contract. The cloud position C is a position for causing the hydraulic oil to be supplied to the bottom chamber of the bucket cylinder **4f** and to be discharged from the rod chamber so as to make the bucket cylinder **4f** extend. As the spool approaches the blocking position A, the volume of hydraulic oil supplied to and discharged from the bucket cylinder **4f** decreases. On the other hand, as the spool approaches the dump position B or the cloud position C, the volume of hydraulic oil supplied to and discharged from the bucket cylinder **4f** increases.

The spool of the directional control valve **18** is initially at the blocking position A. In the directional control valve **18**, the pilot pressure oil is supplied to the pilot port **18a** and discharged from the pilot port **18b**, whereby the spool moves from the blocking position A toward the dump position B. Furthermore, in the directional control valve **18**, the pilot pressure oil is supplied to the pilot port **18b** and discharged from the pilot port **18a**, whereby the spool moves from the blocking position A toward the cloud position C.

The pilot primary valve **19** is placed on the pilot supply flow path **L3** at a position closer to the pilot pump **14** than the pilot control valves **20a** to **23b**. The pilot primary valve **19** controls the volume of pilot pressure oil supplied from

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the pilot pump **14** to the pilot control valves **20a** to **23b**. The pilot primary valve **19** is a directional solenoid valve that controls the volume of supply in accordance with the control by the controller **50**.

The pilot control valves **20a** to **23b** are placed on the pilot supply flow path **L3** and the pilot return flow path **L4** at positions closer to the pilot ports **15a** to **18b** than the pilot primary valve **19**. The pilot control valves **20a** to **23b** control the volume of hydraulic oil supplied to the pilot ports **15a** to **18b** through the pilot supply flow path **L3** and the volume of hydraulic oil discharged from the pilot ports **15a** to **18b** through the pilot return flow path **L4**. The pilot control valves **20a** to **23b** are directional solenoid valves that control the volume of supply in accordance with the control by the controller **50**. The pilot control valves **20a** to **23b** have the structures which are common to each other, and thus, in the following, the pilot control valves **23a**, **23b** will be described in detail.

The pilot control valve **23a** is placed between the pilot port **18a** and the pilot pump **14**, and, between the pilot port **18a** and the hydraulic oil tank **12**. The pilot control valve **23a** includes a spool that moves between a supply position D and a return flow position E. The supply position D is a position for supplying the pilot pressure oil pumped from the pilot pump **14** to the pilot port **18a**. The return flow position E is a position for bringing the pilot pressure oil discharged from the pilot port **18a** back to the hydraulic oil tank **12**. The spool of the pilot control valve **23a** is initially at the return flow position E. The spool approaches the supply position D from the return flow position E as a command current output from the controller **50** increases.

The pilot control valve **23b** is placed between the pilot port **18b** and the pilot pump **14**, and, between the pilot port **18b** and the hydraulic oil tank **12**. The pilot control valve **23b** includes a spool that moves between the supply position D and the return flow position E. The spool moves in accordance with the magnitude of the command current, whereby the pilot control valve **23b** is switched to the supply position D or the return flow position E.

The pressure sensors **24a** to **27b** are placed between the pilot control valves **20a** to **23b** and the pilot ports **15a** to **18b**. The pressure sensors **24a** to **27b** detect the pressure of pilot pressure oil (hereinafter, referred to as "pilot pressure") supplied from the pilot control valves **20a** to **23b** to the pilot ports **15a** to **18b**. Then, the pressure sensors **24a** to **27b** output pressure signals indicating the pilot pressure as detected to the controller **50**.

In the hydraulic oil supply flow path **L1A**, a main relief valve **28** for bringing the hydraulic oil flowing through the hydraulic oil supply flow path **L1** back to the hydraulic oil tank **12** is mounted in the case where the discharge pressure of the main pump **13** exceeds a predetermined pressure. In the pilot supply flow path **L3**, a pilot relief valve **29** for bringing the pilot pressure oil flowing through the pilot supply flow path **L3** back to the hydraulic oil tank **12** is mounted in the case where the discharge pressure of the pilot pump **14** exceeds a predetermined pressure. Furthermore, between the directional control valve **15** and the swing motor **3a**, swing relief valves **30a**, **30b** that open in the case where the driving pressure or braking pressure of the swing motor **3a** exceeds a predetermined pressure to prevent the driving pressure or the braking pressure from excessively increasing are mounted.

FIG. 3 is a control block diagram of the hydraulic excavator **1** according to the present embodiment. FIG. 4A

is a schematic diagram of the bucket lever **7d**. FIG. **4B** illustrates a relation between a target operation pressure and a target current.

As illustrated in FIG. **3**, the hydraulic excavator **1** is provided with the controller **50** including a CPU **51** (Central Processing Unit) and a memory **52**. The memory **52** is configured with, for example, a ROM (Read Only Memory), a RAM (Random Access Memory), an HDD (Hard Disk Drive), or a combination thereof. The CPU **51** reads and executes program codes stored in the memory **52**, whereby the controller **50** implements the processing which will be described later.

However, a specific configuration of the controller **50** is not limited thereto, but may be implemented with hardware such as an ASIC (Application Specific Integrated Circuit), an FPGA (Field-Programmable Gate Array), or the like.

The controller **50** controls the operations of the whole of the hydraulic excavator **1**. The controller **50** causes the engine **10**, the main pump **13**, and the pilot pump **14** to rotate based on operation signals output from the various levers **7a** to **7d** and pressure signals output from the pressure sensors **24a** to **27b**, and also causes the pilot primary valve **19** and the pilot control valves **20a** to **23b** to open or close (outputs command currents).

As illustrated in FIG. **4A**, the bucket lever **7d** is designed to be fallen down (operated) by an operator between the dump position and the cloud position across the neutral position. Hereinafter, a fallen amount (operation amount) of the bucket lever **7d** at the neutral position is expressed as the ratio of 0%, and that at the dump position (or cloud position) is expressed as the rate of 100%. Then, the bucket lever **7d** outputs an operation signal indicative of the fallen amount (operation amount) to the controller **50**. The neutral position corresponds to the blocking position A of the spool of the directional control valve **18**. The dump position corresponds to the dump position B of the spool of the directional control valve **18**. The cloud position corresponds to the cloud position C of the spool of the directional control valve **18**. The positions other than the neutral position of the bucket lever **7d** are examples of operation positions.

The controller **50** calculates a target operation pressure of the pilot pressure oil to be supplied to the pilot ports **18a**, **18b** based on the operation amount of the bucket lever **7d** (more specifically, a current output operation amount **MOcur**, which will be described later). More specifically, the controller **50** increases the target operation pressure for the pilot port **18a** as the fallen amount of the bucket lever **7d** toward the dump position increases. Furthermore, the controller **50** increases the target operation pressure of the pilot port **18b** as the fallen amount of the bucket lever **7d** toward the cloud position increases.

As illustrated in FIG. **4B**, in the memory **52**, a correlation between a target operation pressure and a target current is stored. The correlation stored in the memory **52** expresses that a target current increases as the target operation pressure increases. The controller **50** reads the target current for the target operation pressure as calculated from the memory **52**. Then, the controller **50** outputs the target current as read to the pilot control valves **23a**, **23b** as a command current. This causes the spool of the directional control valve **18** to move. The levers **7a** to **7d** have the structure which are common to each other, and thus the repetitive explanation thereof will be omitted.

FIG. **5** illustrates a flowchart of the flag setting processing according to the present embodiment. FIG. **6** illustrates a flowchart of the hydraulic control processing according to the present embodiment. The flag setting processing is the

processing of determining whether the operator has quickly operated the bucket lever **7d** toward the neutral position. The hydraulic control processing is the processing of supplying command currents to the pilot control valves **23a**, **23b** to control the pilot pressure to be supplied to the pilot ports **18a**, **18b** of the directional control valve **18** (that is, control the position of the spool of the directional control valve **18**). The controller **50** alternately and repeatedly executes the flag setting processing and the hydraulic control processing.

A previous input operation amount **MIpre** is an operation amount indicated in an operation signal output from the bucket lever **7d** in the previous flag setting processing and hydraulic control processing (that is, an actual operation amount). A previous output operation amount **MOpre** is an operation amount corrected in the previous hydraulic control processing (that is, an operation amount for a command current). A current input operation amount **MIcur** is an operation amount indicated in an operation signal output from the bucket lever **7d** in the current flag setting processing and hydraulic control processing (that is, an actual operation amount). A current output operation amount **MOcur** is an operation amount corrected in the current hydraulic control processing (that is, an operation amount for a command current). The previous input operation amount **MIpre** and the previous output operation amount **MOpre** are stored in the memory **52**.

As illustrated in FIG. **5**, the controller **50** acquires the current input operation amount **MIcur** from the bucket lever **7d** (**S11**). Next, the controller **50** compares the previous output operation amount **MOpre** with a neutral output threshold **THno** stored in the memory **52** (**S12**). The neutral output threshold **THno** is set to a value allowing the bucket lever **7d** to be evaluated as being located near the neutral position (for example, 0% to 5%). Furthermore, as described above, the position of the spool of the directional control valve **18** is controlled in accordance with a command current determined based on the previous output operation amount **MOpre**. In other words, it can be said that the previous output operation amount **MOpre** corresponds to the present position of the spool of the directional control valve **18**, and the neutral output threshold **THno** corresponds to a value allowing the spool of the directional control valve **16** to be evaluated as being located near the blocking position A.

Then, in response to the previous output operation amount **MOpre** being less than the neutral output threshold **THno** (**S12**: Yes), the controller **50** sets "inactive (first value)" in a quick operation flag stored in the memory **52** (**S13**), and ends the flag setting processing. The previous output operation amount **MOpre** being less than the neutral output threshold **THno** refers to the case that the bucket lever **7d** has been pulled back in vicinity of the neutral position (in other words, the spool of the directional control valve **18** has moved near the blocking position A). The quick operation flag is a flag indicating that the bucket lever **7d** has been quickly operated toward the neutral position. The "inactive" is indicative of the case that the bucket lever **7d** has not been quickly operated toward the neutral position.

On the other hand, in response to the previous output operation amount **MOpre** being equal to or more than the neutral output threshold **THno** (**S12**: No), the controller **50** compares an input operation variation amount ΔMI with a quick operation threshold **THr** stored in the memory **52** (**S14**). The input operation variation amount ΔMI is the amount of change expressed with a difference of the current input operation amount **MIcur** relative to the previous input operation amount **MIpre** ($MIpre - MIcur$), or is the ratio of the current input operation amount **MIcur** relative to the

previous input operation amount M_{ipre} (M_{icur}/M_{ipre}). The quick operation threshold THr is a threshold relating to the speed of an operation (referred to as an “operation speed” herein) expressed as the amount of change in an operation per unit time, and is set to a value allowing the bucket lever $7d$ to be evaluated as having been quickly operated toward the neutral position (for example, the value set based on the difference of the current input operation amount M_{icur} relative to the previous input operation amount M_{ipre} or the ratio of the current input operation amount M_{icur} relative to the previous input operation amount M_{ipre} is 10% to 50% or the like).

In response to the input operation variation amount ΔMI being equal to or more than the quick operation threshold THr (S14: Yes), the controller 50 sets “active (second value)” in the quick operation flag (S15), and ends the flag setting processing. “Active” is indicative of the case that the bucket lever $7d$ has been quickly operated toward the neutral position. On the other hand, in response to the input operation variation amount ΔMI being less than the quick operation threshold THr (S14: No), the controller 50 ends the flag setting processing without changing the value of the quick operation flag.

Next, as illustrated in FIG. 6, the controller 50 determines the value of the quick operation flag set in the most recent flag setting processing (S21). In response to the quick operation flag being set to the “inactive” (S21: Yes), the controller 50 compares an input and output difference ΔMIO with a first limit threshold $TH1$ stored in the memory 52 (S22). On the other hand, in response to the quick operation flag being “active” (S21: No) the controller 50 compares the input and output difference ΔMIO with a second limit threshold $TH2$ stored in the memory 52 (S23).

The input and output difference ΔMIO is the amount of variation of the previous output operation amount M_{opre} relative to the current input operation amount M_{icur} ($M_{icur}-M_{opre}$ or M_{opre}/M_{icur}). The first limit threshold $TH1$ and the second limit threshold $TH2$ are set to values allowing the previous output operation amount M_{opre} to be evaluated as having reached the current input operation amount M_{icur} (for example, 0% to 5%). The first limit threshold $TH1$ and the second limit threshold $TH2$ may be the same values or different values.

In response to the input and output difference ΔMIO being less than the first limit threshold $TH1$ (S22: Yes), the controller 50 sets the current output operation amount M_{ocur} to a value which is the same as the current input operation amount M_{icur} (S24). That is, in the case where the bucket lever $7d$ has not been quickly operated toward the neutral position (S21: Yes) and also the previous output operation amount M_{opre} has reached the current input operation amount M_{icur} (S22: Yes), the controller 50 sets the current input operation amount M_{icur} to the current output operation amount M_{ocur} without correcting the current input operation amount M_{icur} (S24).

In response to the input and output difference ΔMIO being equal to or more than the first limit threshold $TH1$ (S22: No), the controller 50 corrects the previous output operation amount M_{opre} with a first correction value $VAL1$ (for example, $M_{opre}-VAL1$) and sets it to the current output operation amount M_{ocur} (S25). That is, in the case where the bucket lever $7d$ has not been quickly operated toward the neutral position (S21: Yes) and also the previous output operation amount M_{opre} has not reached the current input operation amount M_{icur} (S22: No), the controller 50 subtracts the first correction value $VAL1$ from the previous output operation amount M_{opre} and sets it to the current

output operation amount M_{ocur} regardless of the value of the current input operation amount M_{icur} (S25).

In response to the input and output difference ΔMIO being less than the second limit threshold $TH2$ (S23: No), the controller 50 sets the current output operation amount M_{ocur} to a value which is the same as the current input operation amount M_{icur} (S24). That is, in the case where the bucket lever $7d$ has been quickly operated toward the neutral position (S21: No) and also the previous output operation amount M_{opre} has reached the current input operation amount M_{icur} (S23: No), the controller 50 sets the current input operation amount M_{icur} to the current output operation amount M_{ocur} without correcting the current input operation amount M_{icur} (S24).

In response to the input and output difference ΔMIO being equal to or more than the second limit threshold $TH2$ (S23: Yes), the controller 50 corrects the previous output operation amount M_{opre} with a second correction value $VAL2$ (for example, $M_{opre}-VAL2$) and sets it to the current output operation amount M_{ocur} (S26). That is, in the case where the bucket lever $7d$ has been quickly operated toward the neutral position (S21: No) and also the previous output operation amount M_{opre} has not reached the current input operation amount M_{icur} (S23: Yes), the controller 50 subtracts the second correction value $VAL2$ from the previous output operation amount M_{opre} and sets it to the current output operation amount M_{ocur} regardless of the value of the current input operation amount M_{icur} (S26).

Next, the controller 50 calculates a target operation pressure for the current output operation amount M_{ocur} set in steps S24 to S26 (S27).

Subsequently, the controller 50 identifies a target current for the target operation pressure calculated in step S27, based on the correlation illustrated in FIG. 4B (S28). Then, the controller 50 outputs the target current identified in step S28 to the pilot control valves $23a$, $23b$ as a command current (S29). This varies the pilot pressure to be supplied to the pilot ports $18a$, $18b$ of the directional control valve 18, whereby the spool of the directional control valve 18 moves.

The second correction value $VAL2$ is set to a value which is greater than the first correction value $VAL1$. That is, the difference between the previous output operation amount M_{opre} and the current output operation amount M_{ocur} in step S25 is smaller than the difference between the previous output operation amount M_{opre} and the current output operation amount M_{ocur} in step S26. Accordingly, the speed of movement of the spool of the directional control valve 18 based on the current output operation amount M_{ocur} set in step S25 is slower than that of the spool of the directional control valve 18 based on the current output operation amount M_{ocur} set in step S26. As a result, the braking of the bucket cylinder $4f$ in the case where the process in step S25 has been executed is limited more than that in the case where the process in step S26 has been executed.

Referring to FIG. 5 to FIG. 8, the processing to be carried out in the case where the bucket lever $7d$ is pulled down from the neutral position toward a target position on the side of the dump position and then pulled back from the target position to the neutral position will be described. The controller 50 alternately executes the flag setting processing and the hydraulic control processing about 10 to 100 times until the bucket lever $7d$ is pulled down from the neutral position to the target position and then pulled back to the neutral position. The target position may be the dump position or any position between the neutral position and the dump position. The same processing is applied to the case

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that the bucket lever 7d is pulled down toward the cloud position. The same processing is also applied to the cases that the levers 7a to 7c other than the bucket lever 7d are operated.

FIG. 7 illustrates the changes with time in the current input operation amount M_{Icur} and the current output operation amount M_{Ocur} in the case where the bucket lever 7d is slowly operated toward the neutral position (the speed of an operation for the bucket lever 7d is less than the quick operation threshold THR). FIG. 8 illustrates the changes with time in the current input operation amount M_{Icur} and the current output operation amount M_{Ocur} in the case where the bucket lever 7d is quickly operated (the speed of an operation for the bucket lever 7d is equal to or more than the quick operation threshold THR).

A period P1 illustrated in FIG. 7 is the period of time in which the bucket lever 7d starts to be pulled down from the neutral position toward the target position. In the flag setting processing and the hydraulic control processing during this period of time, the processes are executed in order of S11→S12: Yes→S13→S21: Yes→S22: Yes→S24→S27 to S29. That is, the controller 50 sets “inactive” in the quick operation flag (S13) and sets a value which is the same as the current input operation amount M_{Icur} to the current output operation amount M_{Ocur} (S24).

A period P2 illustrated in FIG. 7 is the period of time in which the bucket lever 7d continues to be pulled down until it reaches a target position. In the flag setting processing and the hydraulic control processing during this period of time, the processes are executed in order of S11→S12: No→S14: No→S21: Yes→S22: Yes→S24→S27 to S29. That is, the controller 50 sets a value which is the same as the current input operation amount M_{Icur} to the current output operation amount M_{Ocur} without changing the value of the quick operation flag (S24).

As described above, in the periods P1 and P2, a value which is the same as the current input operation amount M_{Icur} is set to the current output operation amount M_{Ocur}, whereby the spool of the directional control valve 18 moves from the blocking position A toward the dump position B (the bucket cylinder 4f contracts) at the speed following the speed of an actual operation of the bucket lever 7d (the amount of an operation per unit time).

A period P3 illustrated in FIG. 7 is the period of time in which the bucket lever 7d is pulled back from the target position to the vicinity of the neutral position. In the flag setting processing and the hydraulic control processing during this period of time, the processes are executed in order of S11→S12: No→S14: No→S21: Yes→S22: No→S25→S27 to S29. That is, the controller 50 subtracts the first correction value VAL1 from the previous output operation amount M_{Opre} and then sets it to the current output operation amount M_{Ocur} without changing the value of the quick operation flag (S25).

A period P4 illustrated in FIG. 7 is the period of time in which the bucket lever 7d reaches the vicinity of the neutral position. In the flag setting processing and the hydraulic control processing during this period of time, the processes are executed in order of S11→S12: Yes→S13→S21: Yes→S22: No→S25→S27 to S29. That is, the controller 50 sets “inactive” in the quick operation flag (S13), subtracts the first correction value VAL1 from the previous output operation amount M_{Opre}, and sets it to the current output operation amount M_{Ocur} (S25).

A period P5 illustrated in FIG. 7 is the period of time after the bucket lever 7d reaches the neutral position. In the flag setting processing and the hydraulic control processing

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during this period of time, the processes are executed in order of S11→S12: Yes→S13→S21: Yes→S22: Yes→S24→S27 to S29. That is, the controller 50 sets “inactive” in the quick operation flag (S13) and sets a value which is the same as the current input operation amount M_{Icur} to the current output operation amount M_{Ocur} (S24).

In the periods P3 to P4 illustrated in FIG. 7, the spool of the directional control valve 18 moves toward the blocking position A (that is, the bucket cylinder 4f is braked). The variation in speed (decrease in speed) of the current output operation amount M_{Ocur} in the periods P3 to P4 is less than the variation in speed of the current input operation amount M_{Icur}. Accordingly, the speed of movement of the spool of the directional control valve 18 in the periods P3 to P4 (hereinafter, referred to as “first movement speed”) is slower than the speed of movement for the current input operation amount M_{Icur} (hereinafter, referred to as “reference speed”). That is, in the periods P3 to P4, the braking of the bucket cylinder 4f is limited.

On the other hand, in FIG. 8, the variation in speed of the current input operation amount M_{Icur} while the bucket lever 7d moves from the target position toward the neutral position is more than that illustrated in FIG. 7. Accordingly, in FIG. 8, the period P3 of FIG. 7 is divided into periods P3-1 and P3-2. In the period P3-1 in FIG. 8, the processes which are the same as those in the period P3 of FIG. 7 are executed. In both FIG. 7 and FIG. 8, the same processes are executed in the periods P1, P2, P4, P5.

In the flag setting processing and the hydraulic control processing during the period P3-2 of FIG. 8, the processes are executed in order of S11→S12: No→S14: Yes→S15→S21: No→S23: Yes→S26 to S29. That is, the controller 50 sets “active” in the quick operation flag (S15), subtracts the second correction value VAL2 from the previous output operation amount M_{Opre}, and sets it to the current output operation amount M_{Ocur} (S26).

The variation in speed (decrease in speed) of the current output operation amount M_{Ocur} in the period P3-2 of FIG. 8 is less than that of the current input operation amount M_{Icur}. Accordingly, the speed of movement of the spool of the directional control valve 18 in the period P3-2 of FIG. 8 (hereinafter, referred to as “second movement speed”) is slower than the speed of movement for the current input operation amount M_{Icur} (hereinafter, referred to as “reference speed”). That is, in the period P3-2 of FIG. 8, the braking of the bucket cylinder 4f is limited.

In the period P3 of FIG. 7, the current output operation amount M_{Ocur} is set using the first correction value VAL1, while, in the period P3-2 of FIG. 8, the current output operation amount M_{Ocur} is set using the second correction value VAL2 which is greater than the first correction value VAL1. Accordingly, the second movement speed in the period P3-2 of FIG. 8 is faster than the first movement speed in the period P3 of FIG. 7. That is, in the period P3-2 of FIG. 8, the limitation for the braking of the bucket cylinder 4f is relaxed as compared with that in the period P3 of FIG. 7.

According to the embodiment described above, for example, the following advantageous effects can be obtained.

According to the embodiment described above, in the case where the speed of an operation for the bucket lever 7d toward the neutral position is less than the quick operation threshold THR, the spool of the directional control valve 18 is made moved at the first speed which is slower than the reference speed. This enables prevention of the degradation in a ride quality caused by an inertial force generated in braking of the bucket cylinder 4f.

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On the other hand, according to the embodiment described above, in the case where the speed of an operation for the bucket lever 7d toward the neutral position is equal to or more than the quick operation threshold THr, the spool of the directional control valve 18 is made moved at the second speed which is slower than the reference speed and faster than the first speed. This enables an operation using an inertial force generated in braking of the bucket cylinder 4f (for example, a work of dropping mud) to be performed.

As described above, according to the embodiment described above, adjusting the speed in operating the bucket lever 7d toward the neutral position enables appropriate switching between prevention of the degradation in a ride quality caused by an inertial force and a work using the inertial force.

In the embodiment described above, the example in which the second speed is set slower than the reference speed has been described, however, the second speed may be set to a value which is the same as the reference speed. That is, the process of step S26 may be replaced with that of step S24. This enables use of a larger inertial force in the work of dropping mud or the like.

[First Modification]

Next, referring to FIG. 9 and FIG. 10, the hydraulic control processing according to the first modification will be described. FIG. 9 illustrates a flowchart of the hydraulic control processing according to the first modification. FIG. 10 illustrates the changes with time in the current input operation amount Mlcur and the current output operation amount MOcur in the case where the bucket lever 7d has been quickly operated in the first modification. In the following, the features which are common to those of the embodiment described above will not be described while mainly describing the differences therefrom. The hydraulic control processing according to the first modification differs from the hydraulic control processing illustrated in FIG. 6 in that it further includes step S30, while the other features are the same as those illustrated in FIG. 6.

As illustrated in FIG. 9, the controller 50 according to the first modification compares the previous output operation amount MOp_{re} with an initial operation threshold TH_i stored in the memory 52 in response to the quick operation flag being set to "active" (S21: Yes) (S30). The initial operation threshold TH_i is a value that is set based on the current position and target position of the bucket lever 7d, and is set to a value allowing the current position of the bucket lever 7d to be evaluated as being near the target position (for example, 80% to 95% of the target position). Then, in response to the previous output operation amount MOp_{re} being equal to or more than the initial operation threshold TH_i (S30: No), the controller 50 executes the processes after step S22. On the other hand, in response to the previous output operation amount MOp_{re} being less than the initial operation threshold TH_i (S30: Yes), the controller 50 executes the processes after step S23.

In combination of the flag setting processing of FIG. 5 and the hydraulic control processing of FIG. 9, as illustrated in FIG. 10, the period P3-2 of FIG. 8 is divided into periods P3-3 and P3-4. On the other hand, in FIG. 10, the processes to be executed in the periods P1, P2, P3-1, P4, and P5 are substantially the same as those of FIG. 8.

In the flag setting processing and the hydraulic control processing during the period P3-3 of FIG. 10, the processes are executed in order of S11→S12: No→S14: No→S21: Yes→S15→S21: No→S30: No→S22: No→S25→S27 to S29. That is, the controller 50 sets "active" in the quick operation flag (S15), subtracts the first correction value

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VAL1 from the previous output operation amount MOp_{re}, and sets it to the current output operation amount MOc_{ur} (S25). That is, in the period P3-3 of FIG. 10, the braking of the bucket cylinder 4f is limited greatly more than that in the period P3-2 of FIG. 8.

In the flag setting processing and the hydraulic control processing in the period P3-4 of FIG. 10, the processes are executed in order of S11→S12: No→S14: No→S21: No→S30: Yes→S23: Yes→S26 to S29. That is, the controller 50 subtracts the second correction value VAL2 from the previous output operation amount MOp_{re} and sets it to the current output operation amount MOc_{ur} without changing the value of the quick operation flag (S26).

According to the first modification, in the case where the speed of an operation for the bucket lever 7d being equal to or more than the quick operation threshold THr, the spool of the directional control valve 18 is made moved at the first speed if the previous output operation amount MOp_{re} is less than the initial operation threshold TH_i (period P3-3 in FIG. 10), and the spool of the directional control valve 18 is made moved at the second speed if the previous output operation amount MOp_{re} is equal to or more than the initial operation threshold TH_i (period P3-4 in FIG. 10).

This makes the state in which the spool of the directional control valve 18 moves at the first speed (periods P3-1 and P3-3 in FIG. 10) longer in time than that in the period P3-1 in FIG. 8. That is, in the first half of the during in which the bucket lever 7d is made moved from the target position to the neutral position, the degradation in a ride quality caused by an inertial force generated in the braking of the bucket cylinder 4f can be prevented.

[Second Modification]

Next, referring to FIG. 11 and FIG. 12, the flag setting processing according to the second modification will be described. FIG. 11 illustrates a flowchart of the flag setting processing according to the second modification. FIG. 12 illustrates the changes with time in the current input operation amount Mlcur and the current output operation amount MOc_{ur} in the case where the bucket lever 7d is quickly operated toward the neutral position after reaching the target position, temporarily stopped with the operation speed gradually being reduced, and slowly operated again toward the neutral position. In the following, the features which are common to those of the embodiment described above will not be described while mainly describing the differences therefrom. The flag setting processing according to the second modification differs from the flag setting processing illustrated in FIG. 5 in that it further includes steps S16 to S18, while the other features are the same as those illustrated in FIG. 5.

The controller 50 according to the second modification compares the input operation variation amount ΔMI with a stop threshold TH_s stored in the memory 52 (S16) in response to the input operation variation amount ΔMI being less than the quick operation threshold THr (S14: No). The stop threshold TH_s is set to a value allowing the bucket lever 7d to be estimated as being stopped (for example, 0% to 2%). That is, in step S16, the controller 50 determines whether the bucket lever 7d being operated from the target position toward the neutral position has been stopped half-way, or whether an input operation for the bucket lever 7d has turned from decreasing to increasing.

Next, in response to the input operation variation amount ΔMI being less than the quick operation threshold THr and also equal to or more than the stop threshold TH_s (S14: No & S16: Yes), the controller 50 ends the flag setting processing without changing the value of the quick operation flag.

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On the other hand, in response to the input operation variation amount ΔMI being less than the stop threshold TH_s (S16: No), the controller 50 compares the current input operation amount MI_{cur} with a neutral input threshold TH_{ni} stored in the memory 52 (S17). The neutral input threshold

TH_{ni} is set to a value allowing the bucket lever 7d to be evaluated as being brought back to the neutral position (for example, 0% to 2%). That is, the controller 50 determines whether the bucket lever 7d has returned to the neutral position in step S17.

Next, in response to the current input operation amount MI_{cur} being equal to or more than the neutral input threshold TH_{ni} (S17: Yes), the controller 50 sets "inactive (second value)" in the quick operation flag (S18), and ends the flag setting processing. On the other hand, in response to the

current input operation amount MI_{cur} being less than the neutral input threshold TH_{ni} (S17: No), the controller 50 ends the flag setting processing without changing the value of the quick operation flag.

In combination of the flag setting processing of FIG. 11 and the hydraulic control processing of FIG. 9, as illustrated in FIG. 12, during the periods P3-4 and P4 of FIG. 10, periods P6, P7, in which an operation for the bucket lever 7d is started again after it is temporarily stopped, and a period P3, in which the bucket lever 7d is being slowly operated

toward the neutral position, are added. The processes to be executed in the periods P1, P2, P3-1, P3-3, P3-4, P4, and P5 of FIG. 12 are substantially the same as those of FIG. 10.

In the flag setting processing and the hydraulic control processing during the period P6 of FIG. 12, the processes are executed in order of S11→S12: No→S14: No→S16: No→S17: Yes→S18→S21: Yes→S22: No→S25→S27 to S29. That is, the controller 50 sets "inactive" in the quick operation flag (S18), subtracts the first correction value VAL_1 from the previous output operation amount MO_{pre} , and sets it to the current output operation amount MO_{cur} (S25). This causes the braking of the bucket cylinder 4f to be greatly limited in the period P6 of FIG. 12 as compared with that in the immediately preceding period P3-4.

In the flag setting processing and the hydraulic control processing during the period P7 of FIG. 12, the processes are executed in order of S11→S12: No→S14: No→S16: Yes→S21: Yes→S22: Yes→S24→S27 to S29. That is, the controller 50 sets a value which is the same as the current input operation amount MI_{cur} to the current output operation amount MO_{cur} without changing the value of the quick operation flag (S24). The same applies to the case where the lever operation turns to acceleration.

According to the second modification, "inactive" is set in the quick operation flag at the timing in which the bucket lever 7d quickly operated toward the neutral position has been temporarily stopped (period P6), and thus, thereafter, in the case where the bucket lever 7d is slowly operated toward the neutral position, the braking of the bucket cylinder 4f can be greatly limited. This results in prevention of the degradation in a ride quality caused by an inertial force generated in braking of the bucket cylinder 4f.

[Third Modification]

Next, referring to FIG. 13, the hydraulic control processing according to the third modification will be described. FIG. 13 illustrates a flowchart of the hydraulic control processing according to the third modification. In the following, the features which are common to those of the embodiment described above and the first modification will not be described while mainly describing the differences therefrom. The hydraulic control processing according to the third modification differs from the hydraulic control pro-

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cessing illustrated in FIG. 6 and FIG. 9 in that it further includes step S31, while the other features are the same as 6 illustrated in FIG. 5 and the hydraulic control processing illustrated in FIG. 9.

As illustrated in FIG. 13, in response to the input and output difference ΔMIO being less than the first limit threshold TH_1 (S22: Yes), the controller 50 according to the third modification sets the current output operation amount MO_{cur} to a value which is the same as the current input operation amount MI_{cur} (S24), and also sets "inactive" in the quick operation flag (S31). That is, according to the hydraulic control processing of FIG. 13, "inactive" is set in the quick operation flag in the period P7 of FIG. 12 (S31). This enables the actions and effects which are the same as those according to the second modification to be obtained in the combination of the flag setting processing of FIG. 5 and the hydraulic control processing of FIG. 13 as well.

[Fourth Modification]

Next, referring to FIG. 14 and FIG. 15, a drive circuit and a hardware configuration according to the fourth modification will be described. FIG. 14 illustrates a drive circuit of the hydraulic excavator 1 according to the fourth modification. FIG. 15 is a control block diagram of the hydraulic excavator 1 according to the fourth modification. In the following, the features which are common to those of the embodiment described above and will not be described while mainly describing the differences therefrom.

As illustrated in FIG. 14, in the drive circuit according to the fourth modification, the engine 10, the pilot pump 14, the pilot primary valve 19, the pilot control valves 20a, 20b, 21a, 21b, 22a, 22b, 23a, 23b, and the pressure sensors 24a, 24b, 25a, 25b, 26a, 26b, 27a, 27b are omitted. Furthermore, in the drive circuit according to the fourth modification, the directional control valves 15 to 18 are configured with directional solenoid valves having spools that move in accordance with the control by the controller 50. As illustrated in FIG. 15, the controller 50 outputs command currents to the directional control valves 15 to 18 in S29 of FIG. 6, FIG. 9, and FIG. 13.

According to the fourth modification, the processing according to the embodiment described above and the first to third modifications can be implemented with the drive circuit that is configured simply.

An engine has been exemplified as a prime mover so far, however, the prime mover is not limited thereto, but may be an electric motor, a fuel cell, or the like. Alternatively, a combination of these may be used as a prime mover.

The embodiment described above has been described as one of the examples of the present invention, and it is not intended that the scope of the present invention is limited to the embodiment described above. Those skilled in the art could implement the present invention in various other ways without making them depart from the concept of the present invention.

REFERENCE SIGNS LIST

- 1 hydraulic excavator
- 2 undercarriage
- 2 a traveling motor
- 3 upperstructure
- 3 a swing motor
- 4 front working device
- 4 a boom
- 4b arm
- 4c bucket
- 4d boom cylinder

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4e arm cylinder
 4f bucket cylinder
 5 swing frame
 6 counterweight
 7 cab
 7a swing lever
 7b boom lever
 7c arm lever
 7d bucket lever
 8 crawler
 10 engine (prime mover)
 12 hydraulic oil tank
 13 main pump
 14 pilot pump
 15, 16, 17, 18 directional control valve
 18a, 18b pilot port
 19 pilot primary valve
 20a, 20b, 21a, 21b, 22a, 22b, 23a, 23b pilot control valve
 24a, 24b, 25a, 25b, 26a, 26b, 27a, 27b pressure sensor
 28 main relief valve
 29 pilot relief valve
 30a, 30b swing relief valve
 50 controller
 51 CPU
 52 memory

The invention claimed is:

1. A work machine comprising:
 a prime mover;
 a hydraulic pump configured to pump a hydraulic oil upon
 being driven by the prime mover;
 a hydraulic actuator configured to operate upon being
 supplied with or discharging the hydraulic oil;
 a supply flow path for supplying the hydraulic oil pumped
 by the hydraulic pump to the hydraulic actuator;
 a return flow path for bringing the hydraulic oil dis-
 charged from the hydraulic actuator to a hydraulic oil
 tank;
 a directional control valve having a spool that moves
 between a supply and discharge position and a blocking
 position, the supply and discharge position being a
 position for opening the supply flow path and the return
 flow path to cause the hydraulic oil to be supplied to
 and discharged from the hydraulic actuator, and the
 blocking position being a position for blocking the
 supply flow path and the return flow path to stop the
 hydraulic oil to be supplied to and discharged from the
 hydraulic actuator;

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an operation device configured to be operated between an
 operation position corresponding to the supply and
 discharge position of the spool and a neutral position
 corresponding to the blocking position of the spool; and
 a controller configured to bring the spool closer to the
 supply and discharge position as the operation device
 approaches the operation position to increase a volume
 of the hydraulic oil to be supplied to and discharged
 from the hydraulic actuator, and bring the spool closer
 to the blocking position as the operation device
 approaches the neutral position to reduce the volume of
 the hydraulic oil to be supplied to and discharged from
 the hydraulic actuator, wherein
 in a case where the operation device has been operated
 from the operation position toward the neutral position,
 the controller is configured to:
 move the spool from the supply and discharge position
 toward the blocking position at a first speed that is
 slower than a reference speed in a case where an
 operation speed of the operation device is less than
 a quick operation threshold; and
 move the spool from the supply and discharge position
 toward the blocking position at a second speed that
 is faster than the first speed in a case where the
 operation speed is equal to or more than the quick
 operation threshold.
 2. The work machine according to claim 1, wherein
 the second speed is a speed that is slower than the
 reference speed.
 3. The work machine according to claim 2, wherein
 the controller is configured to:
 move the spool at the first speed in a case where the
 operation speed is equal to or more than the quick
 operation threshold and the operation device is
 located at a position that is less than an initial
 operation threshold set based on a current position
 and a target position of the operation device; and
 move the spool at the second speed in a case where the
 operation speed is equal to or more than the quick
 operation threshold and the operation device is
 located at a position that is equal to or more than the
 initial operation threshold.
 4. The work machine according to claim 2, wherein
 the controller is configured to cancel control of deceler-
 ating the spool in a case where the operation device has
 been stopped between the operation position and the
 neutral position.

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