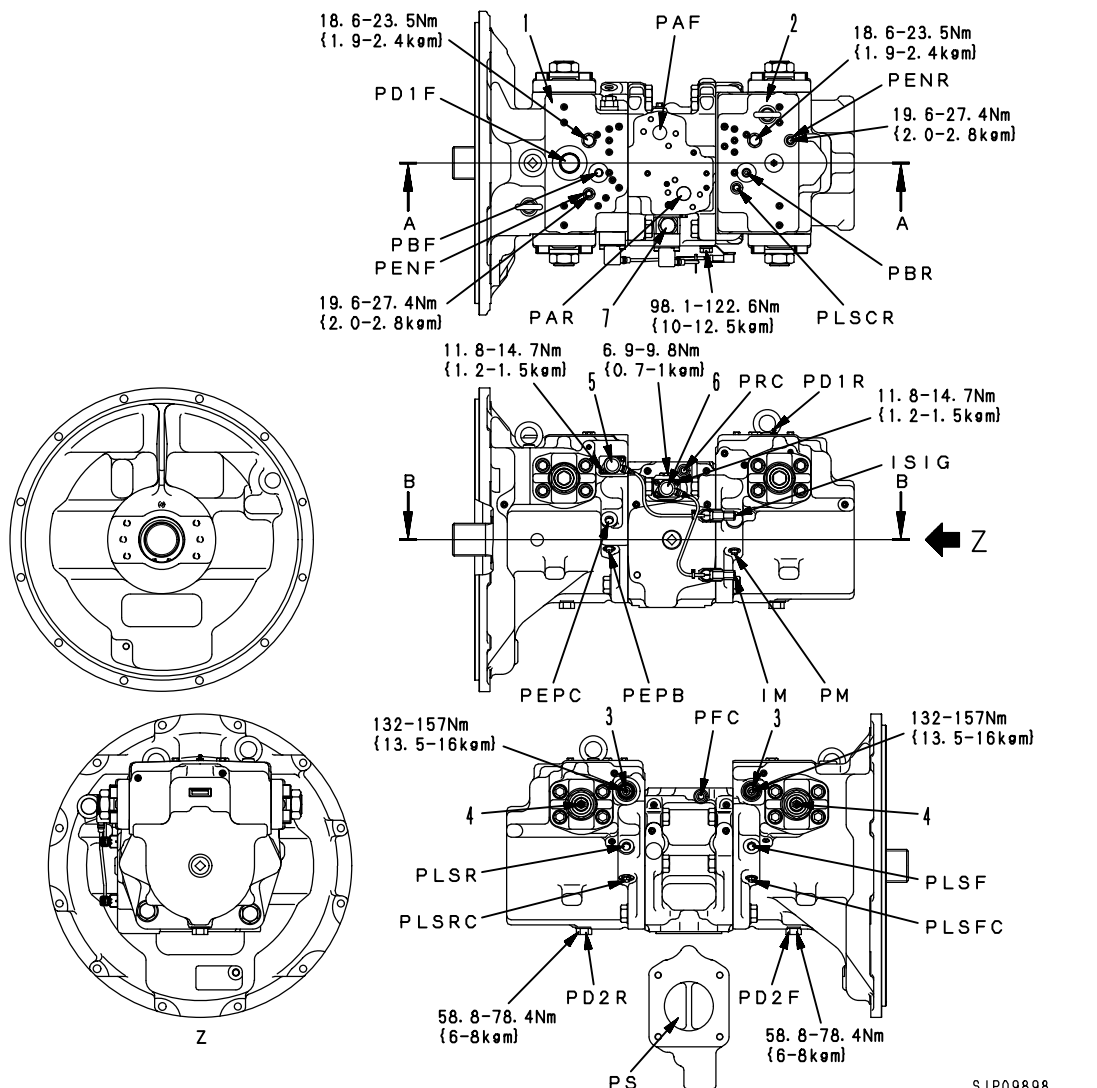


HYDRAULIC PUMP

HPV160+160 (190)



SJP09898

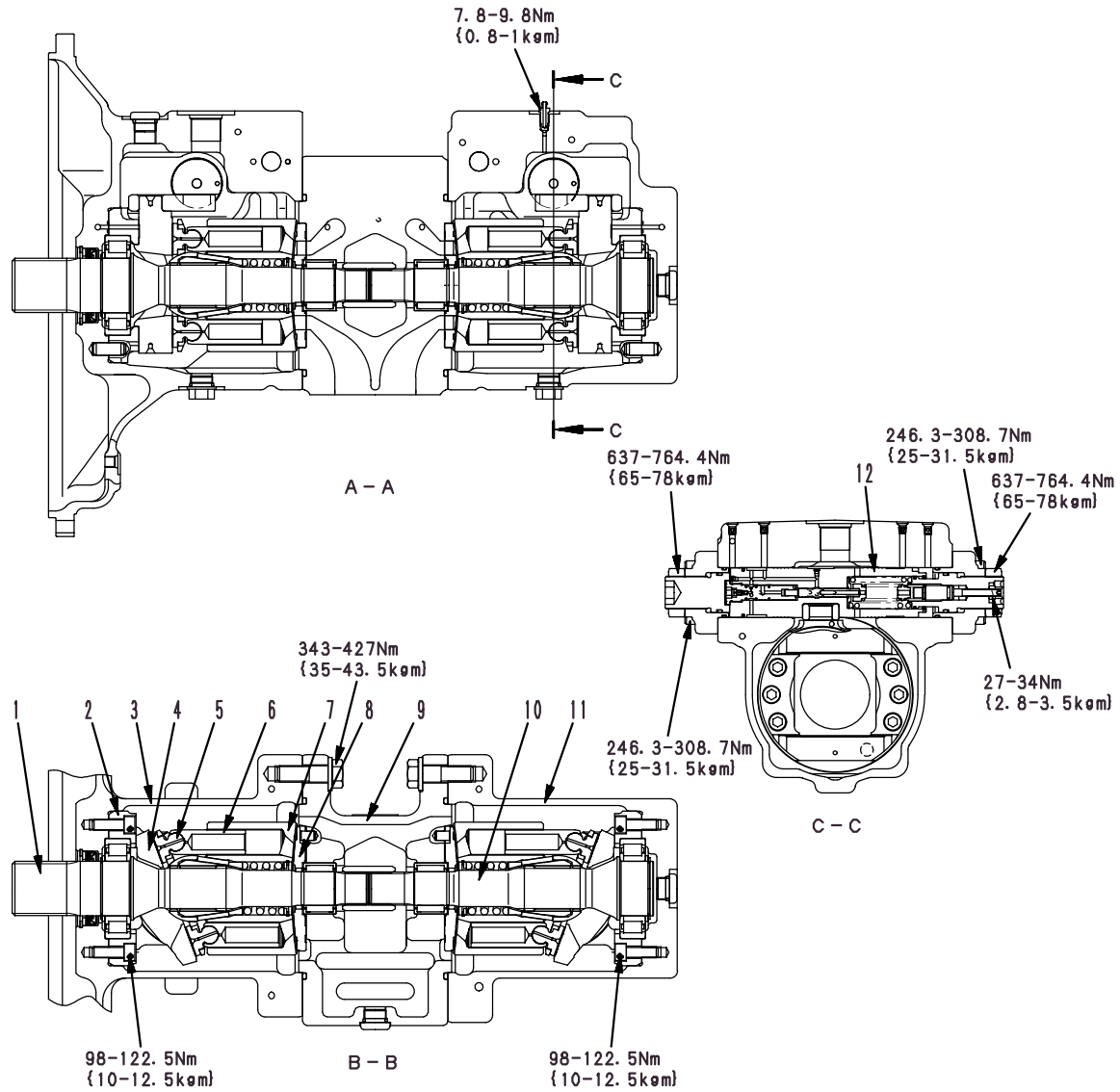
1. Front main pump
2. Rear main pump
3. LS valve
4. PC valve
5. LS-EPC valve
6. PC-EPC valve
7. Variable volume valve

IM : PC mode selector current
ISIG : LS set selector current
PAF : Front pump delivery
PFC : Front pump delivery pressure detection
PAR : Rear pump delivery
PRC : Rear pump delivery pressure detection
PBF : Front pump pressure input
PD1F : Case drain port
PENF : Front pump control pressure detection
PBR : Rear pump pressure input
PD2F : Drain plug
PD2R : Drain plug

PENR : Rear pump control pressure detection port
PLSF : Front load pressure input
PLSFC : Front load pressure detection port
PLSR : Rear load pressure input
PLSRC : Rear load pressure detection port
PS : Pump suction
PLSCR : LS set selector pressure detection port
PM : PC set selector pressure detection port
PEPC : EPC basic pressure input
PD1R : Air bleeder
PEPB : EPC basic pressure detection port

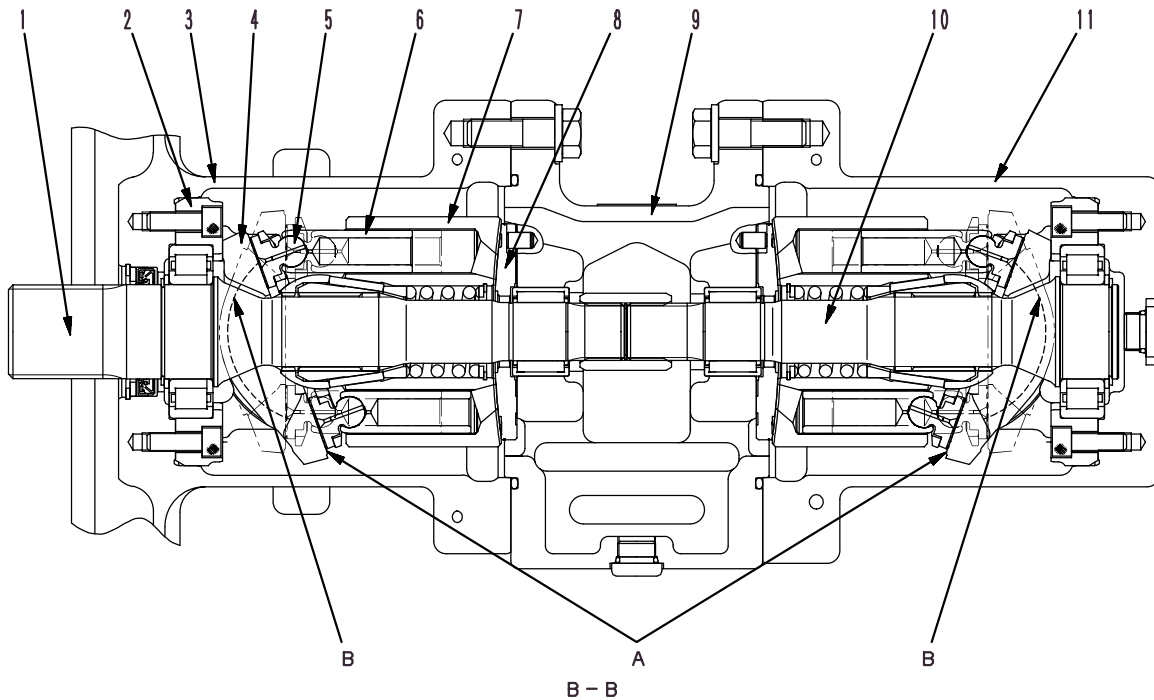
Outline

- This pump consists of 2 variable capacity swash plate piston pumps, PC valve, LS valve, and EPC valve.



SJP09899

- | | |
|------------------|-------------------|
| 1. Shaft (Front) | 7. Cylinder block |
| 2. Cradle | 8. Valve plate |
| 3. Case (Front) | 9. End cap |
| 4. Rocker cam | 10. Shaft (Rear) |
| 5. Shoe | 11. Case (Rear) |
| 6. Piston | 12. Servo piston |



SJP09900

Function

- The rotation and torque transmitted to the pump shaft are converted into hydraulic energy, and pressurized oil is discharged according to the load.
- It is possible to change the discharge amount by changing the swash plate angle.

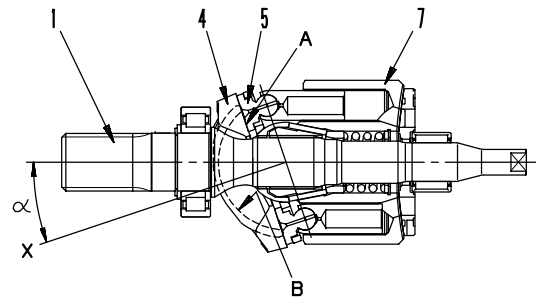
Structure

- Cylinder block (7) is supported to shaft (1) by a spline, and shaft (1) is supported by the front and rear bearings.
- The tip of piston (6) is a concave ball, and shoe (5) is caulked to it to form one unit. Piston (6) and shoe (5) form a spherical bearing.
- Rocker cam (4) has flat surface **A**, and shoe (5) is always pressed against this surface while sliding in a circular movement. Rocker cam (4) brings high pressure oil at cylinder surface **B** with cradle (2), which is secured to the case, and forms a static pressure bearing when it slides.
- Piston (6) carries out relative movement in the axial direction inside each cylinder chamber of cylinder block (7).
- The cylinder block seals the pressure oil to valve plate (8) and carries out relative rotation. This surface is designed so that the oil pressure balance is maintained at a suitable level. The oil inside each cylinder chamber of cylinder block (7) is sucked in and discharged through valve plate (8).

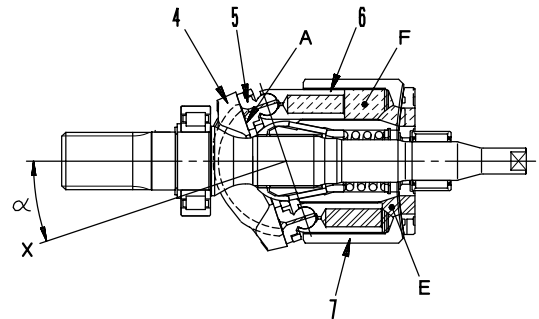
Operation

1) Operation of pump

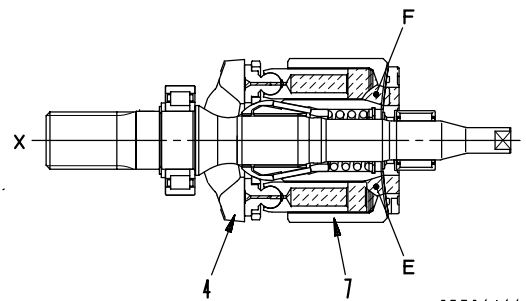
- i Cylinder block (7) rotates together with shaft (1), and shoe (5) slides on flat surface **A**. When this happens, rocker cam (4) moves along cylindrical surface **B**, so angle α between center line **X** of rocker cam (4) and the axial direction of cylinder block (7) changes. (Angle α is called the swash plate angle.)
- ii Center line **X** of rocker cam (4) maintains swash plate angle α in relation to the axial direction of cylinder block (7), and flat surface **A** moves as a cam in relation to shoe (5). In this way, piston (6) slides on the inside of cylinder block (7), so a difference between volumes **E** and **F** is created inside cylinder block (7). The suction and discharge is carried out by this difference **F** – **E**. In other words, when cylinder block (7) rotates and the volume of chamber **E** becomes smaller, the oil is discharged during that stroke. On the other hand, the volume of chamber **F** becomes larger, and as the volume becomes bigger, the oil is sucked in.
- iii If center line **X** of rocker cam (4) is in line with the axial direction of cylinder block (7) (swash plate angle = 0), the difference between volumes **E** and **F** inside cylinder block (7) becomes 0, so the pump does not carry out any suction or discharge of oil. (In actual fact, the swash plate angle never becomes 0.)



SDP01409



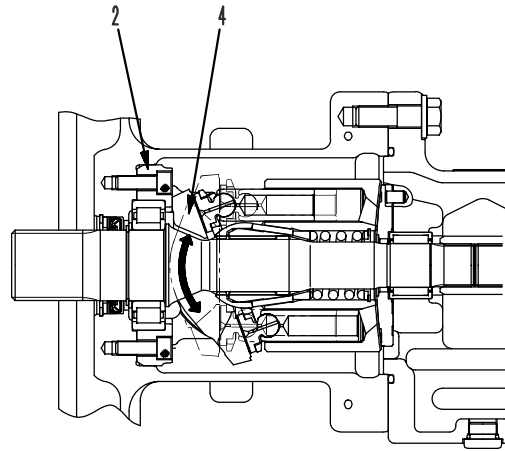
SDP01410



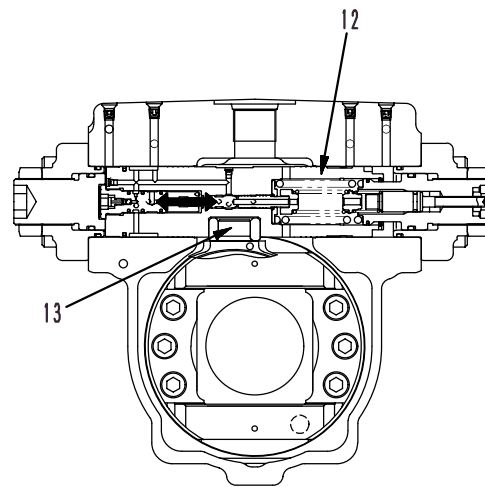
SDP01411

2) Control of discharge amount

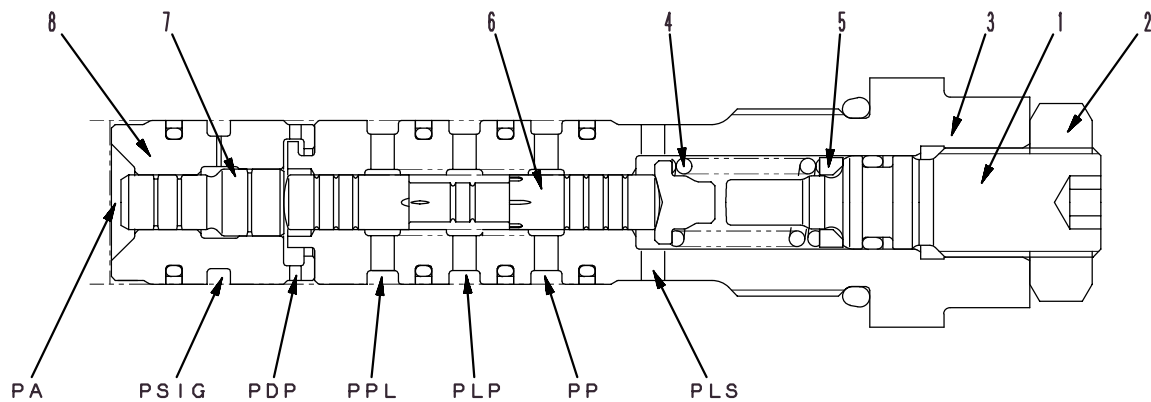
- If the swash plate angle α becomes larger, the difference between volumes **E** and **F** becomes larger and discharge amount **Q** increases.
- Swash plate angle α is changed by servo piston (12).
- Servo piston (12) moves in a reciprocal movement (\leftrightarrow) according to the signal pressure from the PC and LS valves. This straight line movement is transmitted through rod (13) to rocker cam (4), and rocker cam (4), which is supported by the cylindrical surface to cradle (2), slides in a rotating movement in direction of arrow.
- With servo piston (12), the area receiving the pressure is different on the left and the right, so main pump discharge pressure (self pressure) **PP** is always brought to the chamber receiving the pressure at the small diameter piston end.
- Output pressure **Pen** of the LS valve is brought to the chamber receiving the pressure at the large diameter end. The relationship in the size of pressure **PP** at the small diameter piston end and pressure **Pen** at the large diameter end, and the ratio between the area receiving the pressure of the small diameter piston and the large diameter piston controls the movement of servo piston (12).



SJP09901



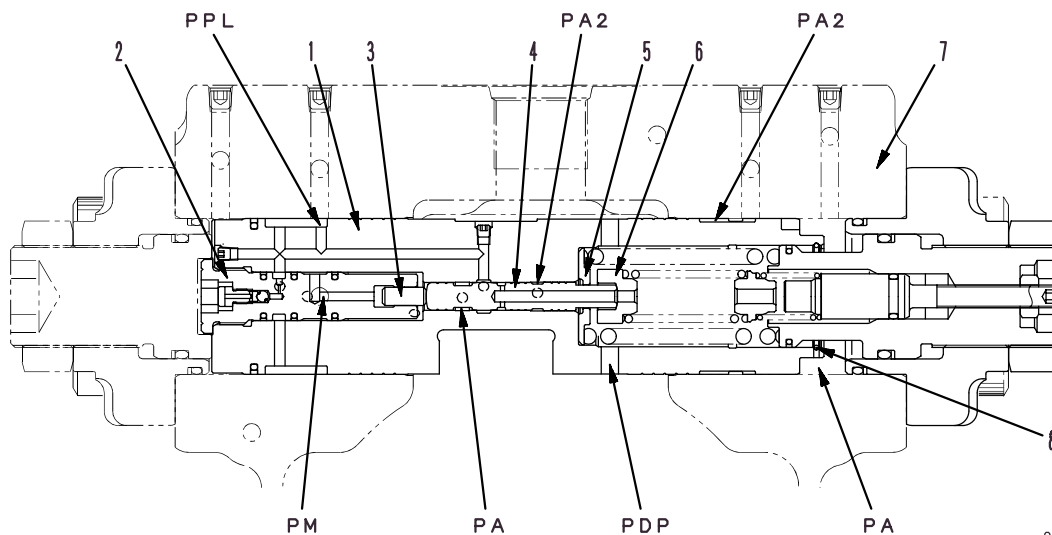
SJP09902

LS VALVE

SJP09041

1. Plug
2. Locknut
3. Sleeve
4. Spring
5. Seat
6. Spool
7. Piston
8. Sleeve

PA : Pump port
PP : Pump port
PDP : Drain port
PLP : LS control pressure output port
PLS : LS pressure input port
PPL : PC control pressure input port
PSIG : LS mode selection pilot port

PC VALVE

SJP09903

1. Servo piston assembly
2. Plug
3. Pin
4. Spool
5. Retainer
6. Seat
7. Cover
8. Wiring

PA : Pump port
PA2 : Pump pressure pilot port
PDP : Drain port
PM : PC mode selector pressure pilot port
PPL : PC control pressure output port

Function

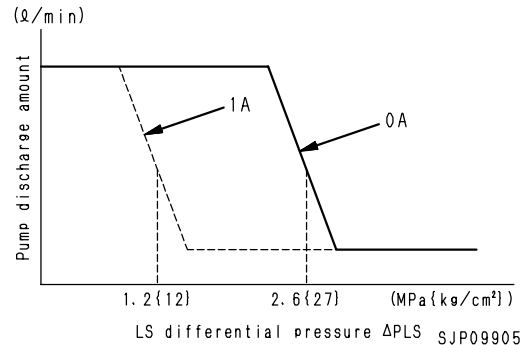
(1) LS valve

The LS valve detects the load and controls the discharge amount.

This valve controls main pump discharge amount **Q** according to differential pressure ΔPLS ($=\text{PP} - \text{PLS}$) [called the LS differential pressure] (the difference between main pump pressure **PP** and control valve outlet port pressure **PLS**).

Main pump pressure **PP**, pressure **PLS** {called the LS pressure} coming from the control valve output, and pressure **PSIG** {called the LS selector pressure} from the proportional solenoid valve enter this valve. The relationship between discharge amount **Q** and differential pressure ΔPLS , (the difference between main pump pressure **PP** and LS pressure **PLS**) ($= \text{PP} - \text{PLS}$) changes as shown in the diagram at the right according to LS pressure selector current **PSIG** of the LS-EPC valve.

When **PSIG** changes between 0 and 1A, the set pressure of the spring changes according to this, and the selector point for the pump discharge amount changes at the rated central valve between 1.2 ↔ 2.6 MPa {12 ↔ 27 kg/cm²}.

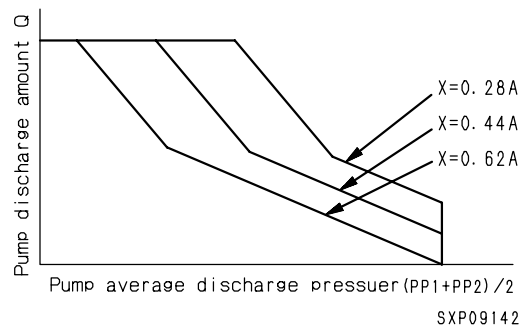


(2) PC valve

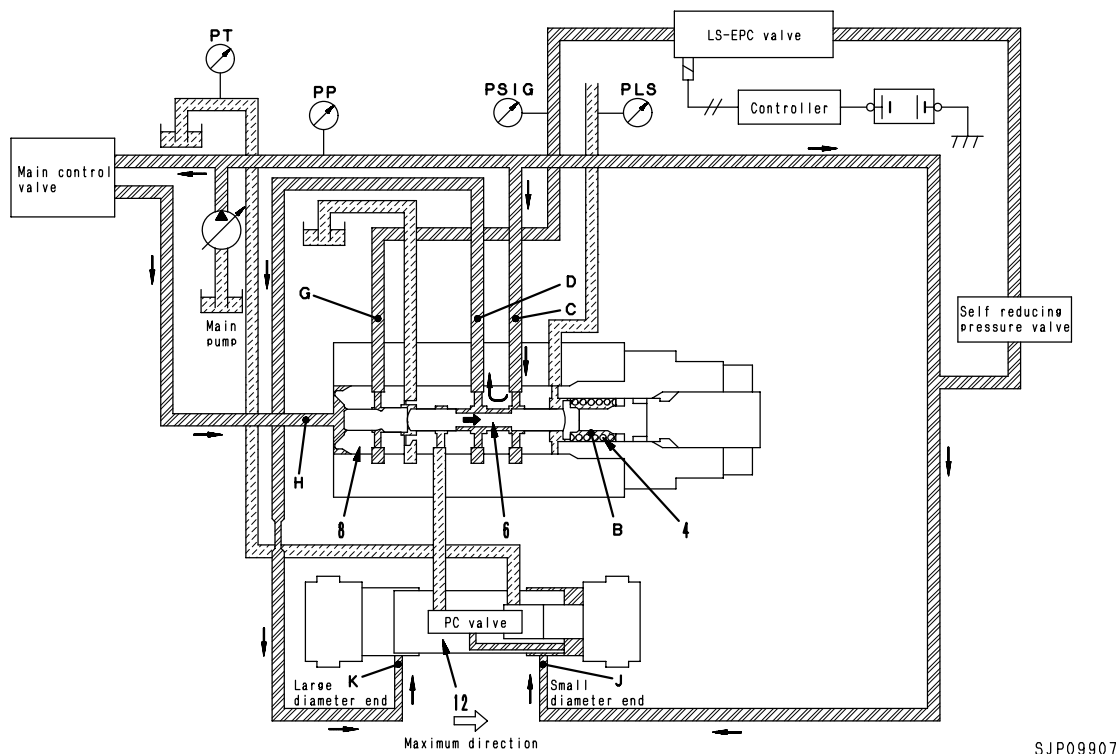
When the pump discharge pressure **PP1** (self-pressure) and **PP2** (other pump pressure) are high, the PC valve controls the pump so that no more oil than the constant flow (in accordance with the discharge pressure) flows even if the stroke of the control valve becomes larger. In this way, it carries out equal horsepower control so that the horsepower absorbed by the pump does not exceed the engine horsepower.

In other words, If the load during the operation becomes larger and the pump discharge pressure rises, it reduces the discharge amount from the pump; and if the pump discharge pressure drops, it increases the discharge amount from the pump. The relationship between the average of the front and rear pump discharge pressures (average discharge amount of F, R pumps (**PP1** + **PP2**)/2) and pump discharge amount **Q** is shown on the right, with the current given to the PC-EPC valve solenoid shown as a parameter. The controller senses the actual speed of the engine, and if the speed drops because of an increase in the load, it reduces the pump discharge amount to allow the speed to recover. In other words, when the load increases and the engine speed drops below

the set value, the command current to the PC-EPC valve solenoid from the controller increases according to the drop in the engine speed to reduce the pump swash plate angle.



OPERATION



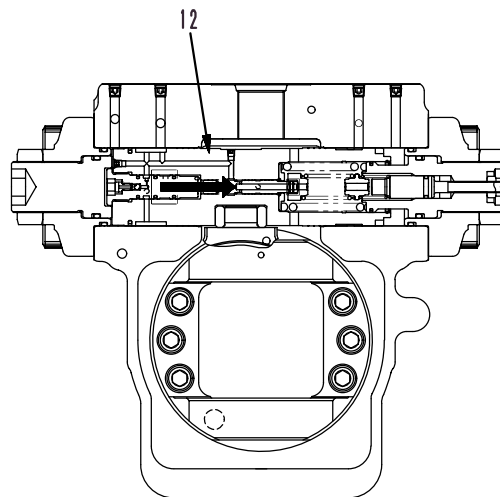
(1) LS valve

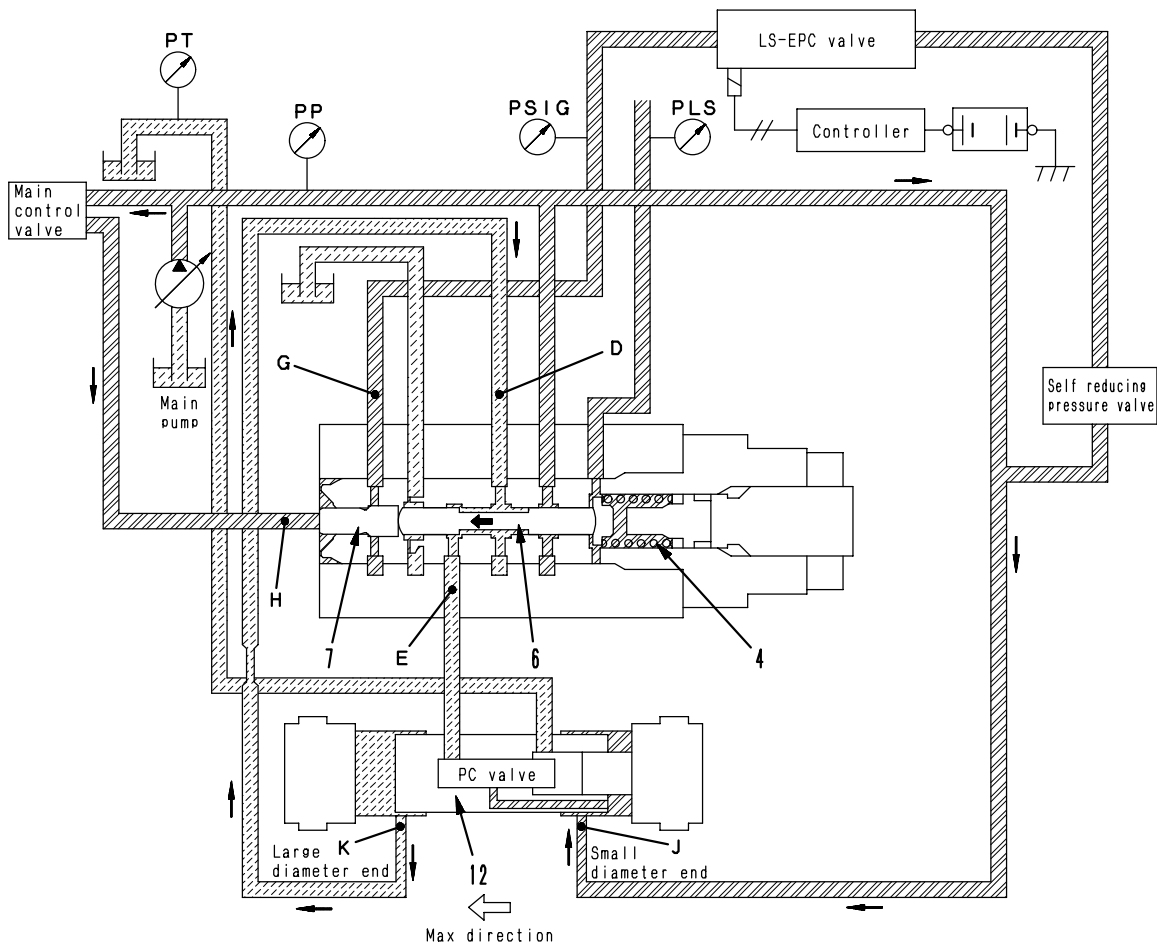
1) When control valve is at neutral position

- The LS valve is a three-way selector valve, with pressure **PLS** (LS pressure) from the inlet port of the control valve brought to spring chamber **B**, and main pump discharge pressure **PP** brought to port **H** of sleeve (8). The size of this LS pressure **PLS** + force **Z** of spring (4) and the main pump pressure (self pressure) **PP** determines the position of spool (6). However, the size of the output pressure **PSIG** (the LS selection pressure) of the EPC valve for the LS valve entering port **G** also changes the position of spool (6). (The set pressure of the spring changes).
- Before the engine is started, servo piston (12) is pushed to the right. (See the diagram on the right)
- When the engine is started and the control lever is at the neutral position, LS pressure **PLS** is 0 MPa {0 kg/cm²}. (It is interconnected with the drain circuit through the control valve spool.)

At this point, spool (6) is pushed to the right, and port **C** and port **D** are connected. Pump pressure **PP** enters the large diameter end of the piston from port **K** and the same pump pressure **PP** also enters port **J** at the small diameter end

of the piston, so the swash plate is moved to the minimum angle by the difference in the area of the piston (12).

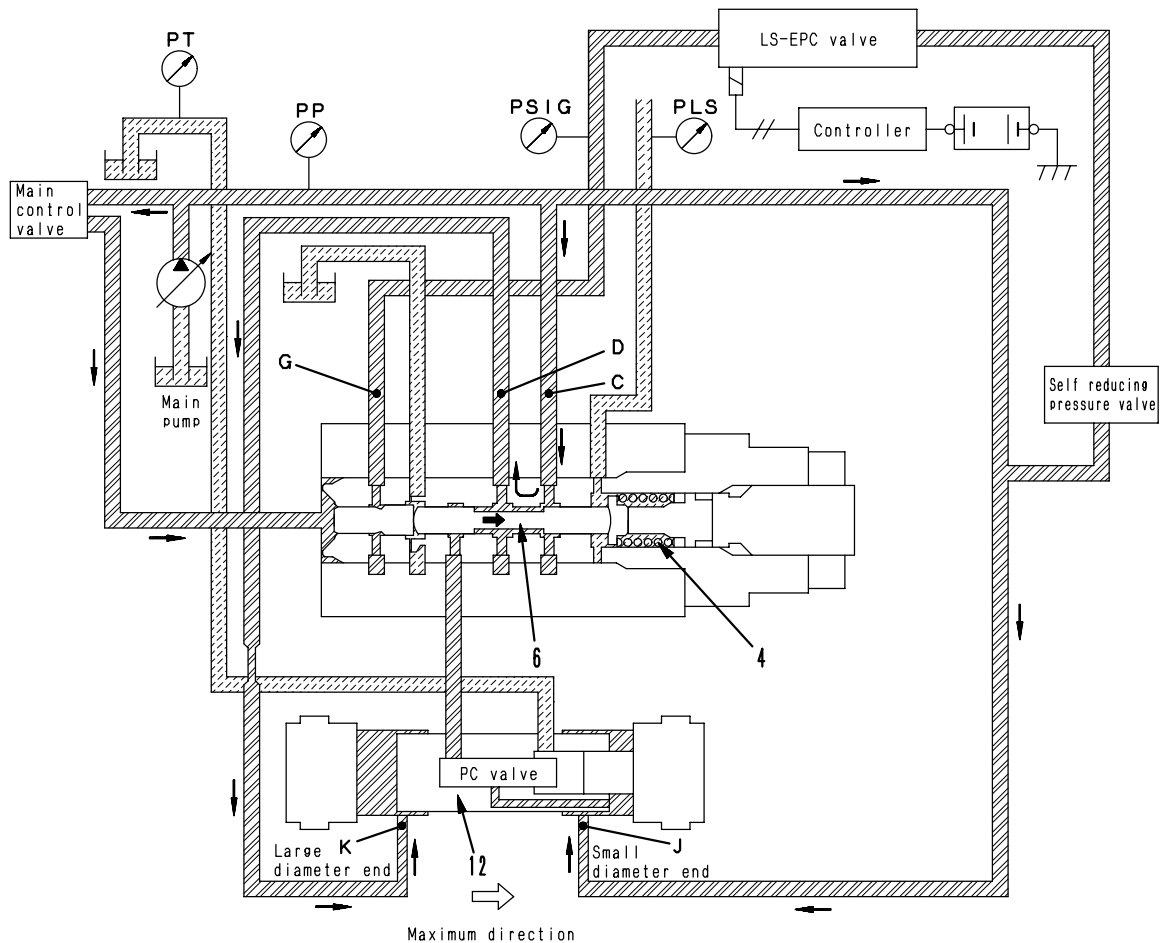




SJP09910

2) Operation in increase direction for pump discharge amount

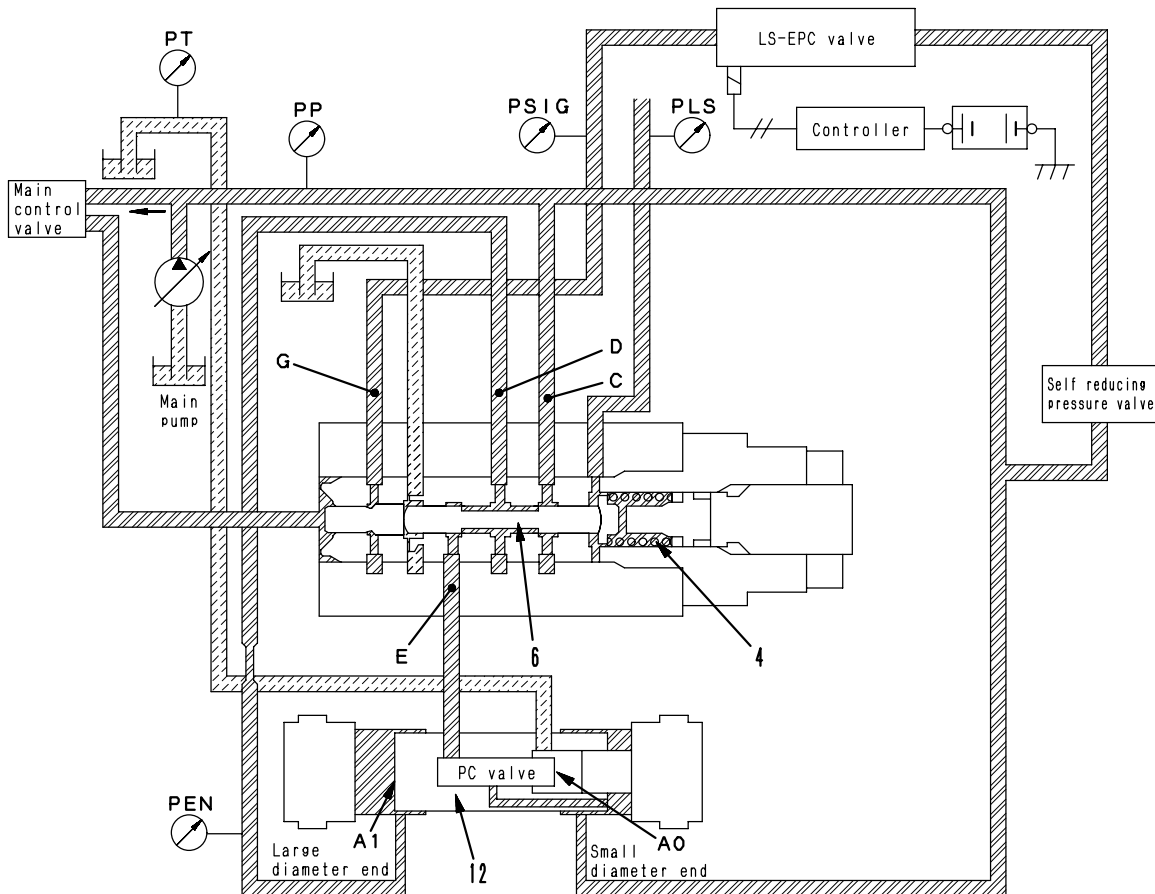
- When the difference between the main pump pressure **PP** and LS pressure **PLS**, in other words, LS differential pressure ΔPLS , becomes smaller (for example, when the area of opening of the control valve becomes larger and pump **PP** drops), spool (6) is pushed to the left by the combined force of LS pressure **PLS** and the force of spring (4).
- When spool (6) moves, port **D** and port **E** are joined and connected to the **PC valve**. When this happens, the **PC valve** is connected to the drain port, so circuit **D – K** becomes drain pressure **PT**. (The operation of the **PC valve** is explained later).
- For this reason, the pressure at the large diameter end of servo piston (12) becomes drain pressure **PT**, and pump pressure **PP** enters port **J** at the small diameter end, so servo piston (12) is pushed to the right. Therefore, the swash plate moves in the direction to make the discharge amount larger. If the output pressure of the **EPC valve** for the **LS valve** enters port **G**, this pressure creates a force to move piston (7) to the right. If piston (7) is pushed to the right, it acts to make the set pressure of spring (4) weaker, and the difference between **PLS** and **PP** changes when ports **D** and **E** of spool (6) are connected.



SJP09912

3) Operation in decrease direction for pump discharge amount

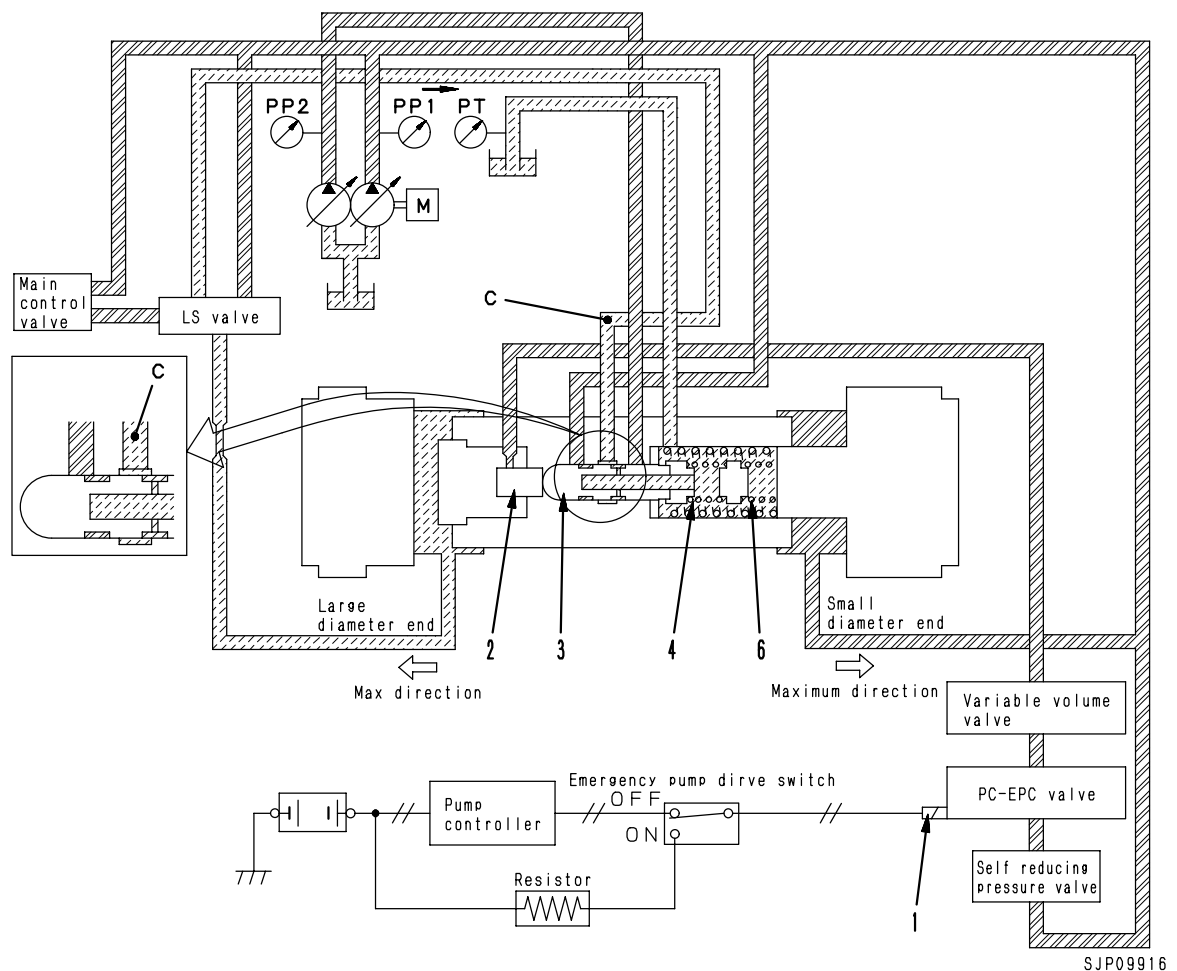
- The following explains the situation if the servo piston (12) moves to the right (the discharge amount becomes smaller). When LS differential pressure ΔPLS becomes larger (for example, when the area of opening of the control valve becomes smaller and pump pressure **PP** rises), pump pressure **PP** pushes spool (6) to the right.
- When spool (6) moves, main port pressure **PP** flows from port **C** and port **D** and from port **K**, it enters the large diameter end of the piston.
- Main pump pressure **PP** also enters port **J** at the small diameter end of the piston, but because of the difference in area between the large diameter end and the small diameter end of servo piston (12), servo piston (12) is pushed to the right.
- As a result, the swash plate moves in the direction to make angle smaller.
- If LS selection pressure **PSIG** enters port **G**, it acts to make the set pressure of spring (4) weaker.



SJP09914

4) When servo piston is balanced

- Let us take the area receiving the pressure at the large diameter end of the piston as **A1**, the area receiving the pressure at the small diameter end as **A0**, and the pressure flowing into the large diameter end of the piston as **Pen**. If the main pump pressure **PP** of the LS valve and the combined force of force **Z** of spring (4) and LS pressure **PLS** are balanced, and the relationship is **A0 × PP = A1 × Pen**, servo piston (11) will stop in that position, and the swash plate will be kept at an intermediate position. (It will stop at a position where the opening of the throttle from port **D** to port **E** and from port **C** to port **D** of spool (6) is approximately the same.)
- At this point, the relationship between the area receiving the pressure at both ends of piston (12) is **A0 : A1 = 1:2**, so the pressure applied to both ends of the piston when it is balanced becomes **PP : Pen = 2:1**.
- The position where spool (6) is balanced and stopped is the standard center, and the force of spring (4) is adjusted so that it is determined when **PP – PLS = 2.6 MPa {27 kg/cm²}**. However, if **PSIG** (the output pressure of 0 ↔ 2.9 MPa {0 ↔ 30 kg/cm²} of the EPC valve of the LS valve) is applied to port **G**, the balance stop position will change in proportion to pressure **PSIG** between **PP – PLS = 2.6 ↔ 1.2 MPa {27 ↔ 12 kg/cm²}**.



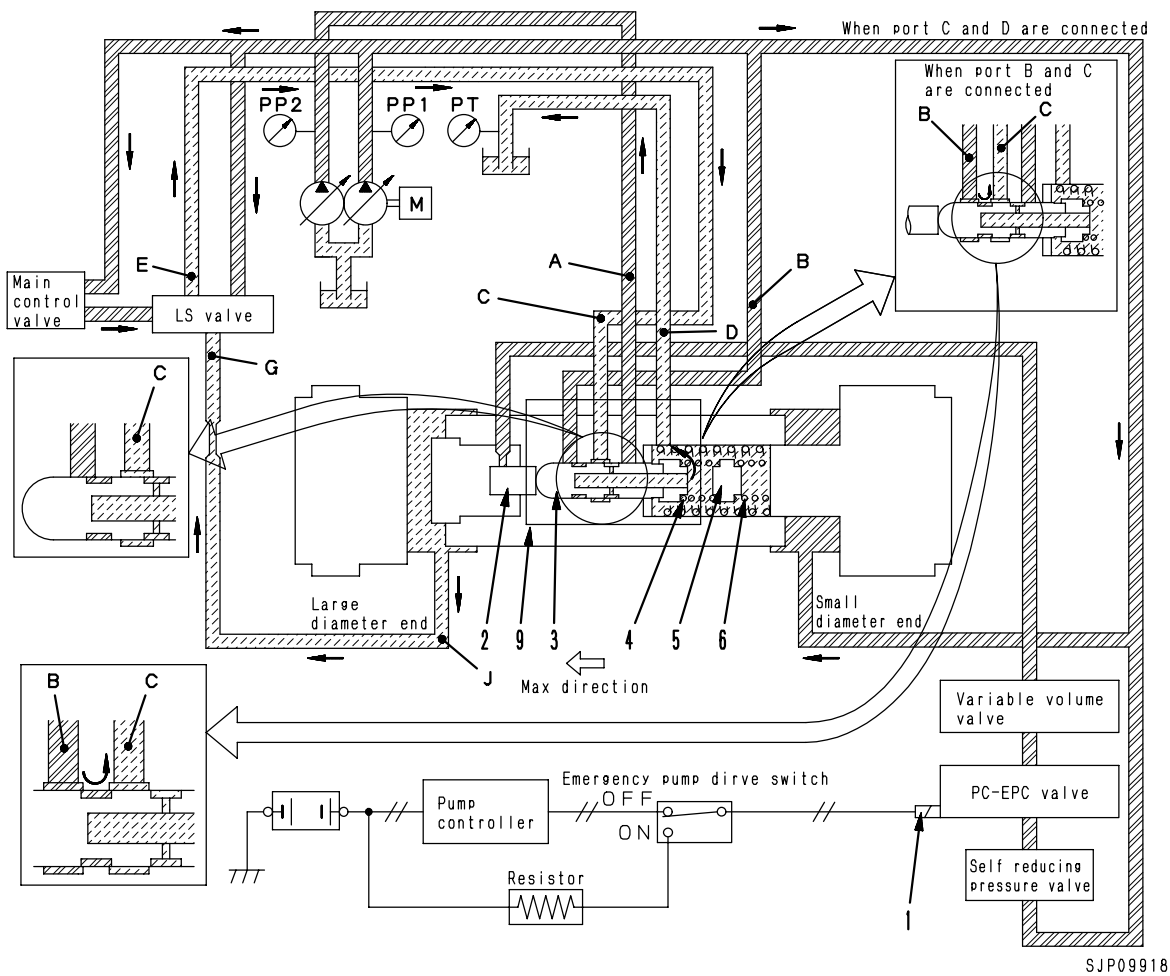
(2) PC Valve

1) When pump controller is normal

a. When the load on the actuator is small and pump pressures PP1 and PP2 are low

i) Movement of PC-EPC solenoid (1)

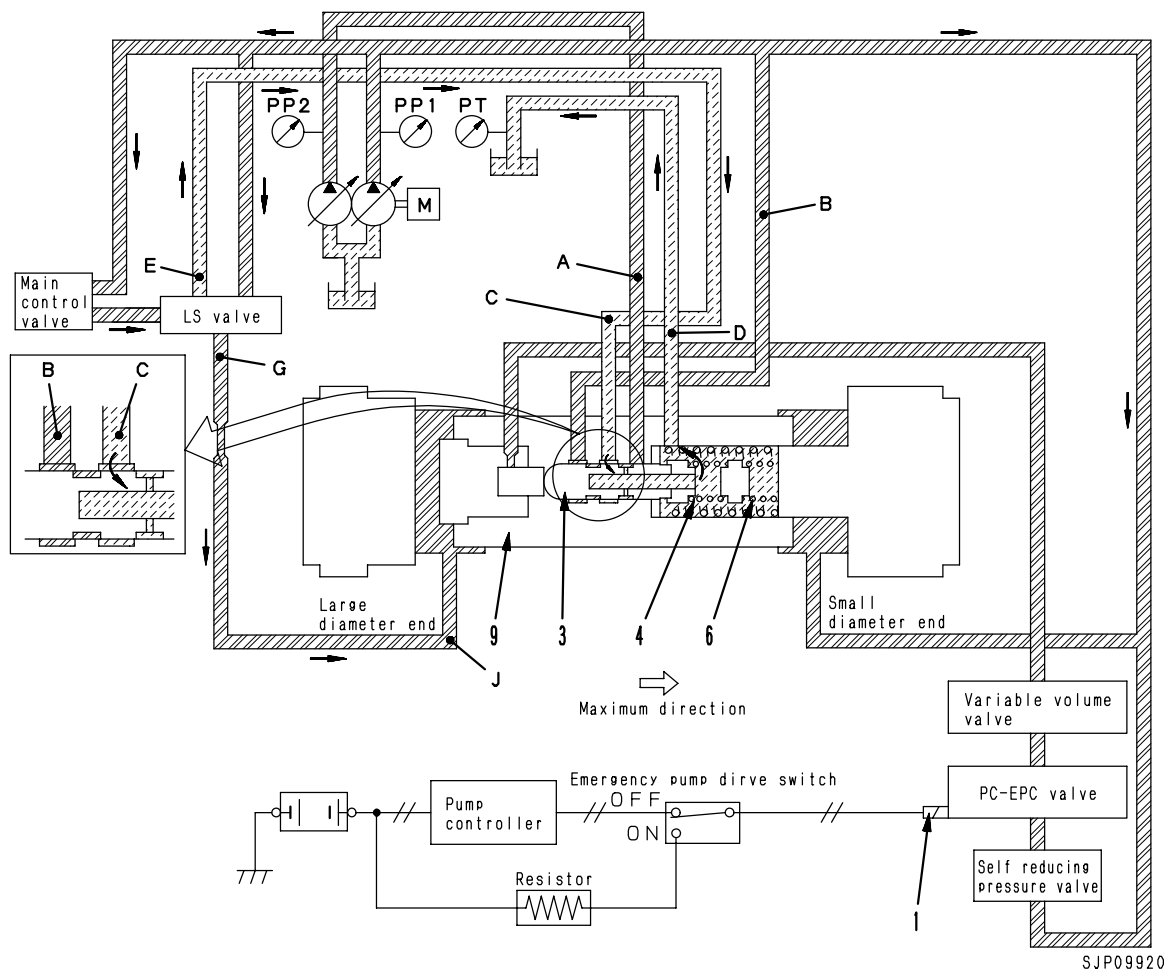
- The command current from the pump controller flows to PC-EPC solenoid (1). This command current acts on the PC-EPC valve and outputs the signal pressure. When this signal pressure is received, the force pushing piston (2) is changed.
- On the opposite side to the force pushing this piston (2) is the spring set pressure of springs (4) and (6) and pump pressure **PP1** (self pressure) and **PP2** (other pump pressure) pushing spool (3). Piston (2) stops at a position where the combined force pushing spool (3) is balanced, and the pressure (pressure of port **C**) output from the PC valve changes according to this position.
- The size of command current X is determined by the nature of the operation (lever operation), the selection of the working mode, and the set value and actual value for the engine speed.
- ★ Other pump pressure
This is the pressure of the pump at the opposite end.
For the F pump, it is the R pump pressure
For the R pump, it is the F pump pressure



ii) Action of spring

- The spring load of springs (4) and (6) in the PC valve is determined by the swash plate position.
- If piston (9) moves to the right, spring (6) is compressed, and if it moves further to the right, spring (6) contacts seat (5) and is fixed in position. In other words, the spring load is changed by piston (9) extending or compressing springs (4) and (6).
- If the command circuit input to PC-EPC valve solenoid (1) changes further, the force pushing piston (2) changes, and the spring load of springs (4) and (6) also changes according to the valve of the PC-EPC valve solenoid command current.

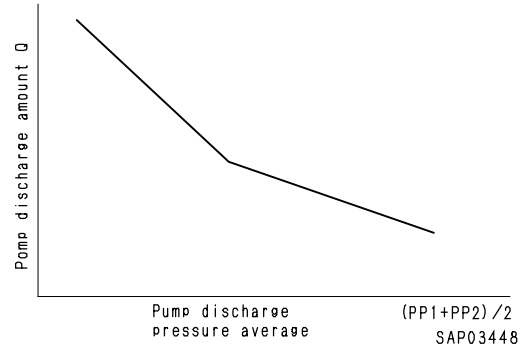
- Port **C** of the PC valve is connected to port **E** of the LS valve (see (1) LS valve). Self pressure **PP1** enters port **B** and the small diameter end of servo piston (9), and other pump pressure **PP2** enters port **A**.
- When pump pressures **PP1** and **PP2** are small, spool (3) is on the left. At this point, port **C** and **D** are connected, and the pressure entering the LS valve becomes drain pressure **PT**. If port **E** and port **G** of the LS valve are connected (see (1) LS valve), the pressure entering the large diameter end of the piston from port **J** becomes drain pressure **PT**, and servo piston (9) moves to the left. In this way, the pump discharge amount moves in the direction of increase.
- As servo piston (9) moves further, springs (4) and (6) expand and the spring force becomes weaker. When the spring force becomes weaker, spool (3) moves to the right, so the connection between port **C** and port **D** is cut, and the pump discharge pressure ports **B** and **C** are connected. As a result, the pressure at port **C** rises, and the pressure at the large diameter end of the piston also rises, so the movement of piston (9) to the left is stopped.
- In other words, the stop position for piston (9) (= pump discharge amount) is decided at the point where the force of springs (4) and (6) and the pushing force from the PC-EPC valve solenoid and the pushing force created by the pressures **PP1** and **PP2** acting on the spool (3) are in balance.



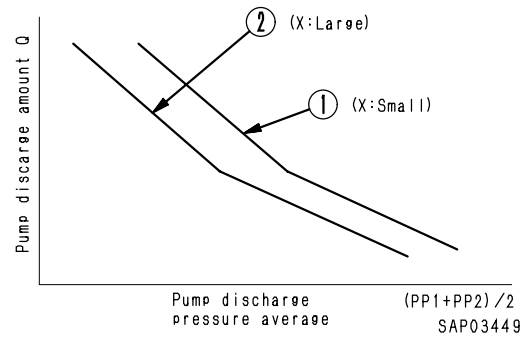
b. When load on actuator is large and pump discharge pressure is high

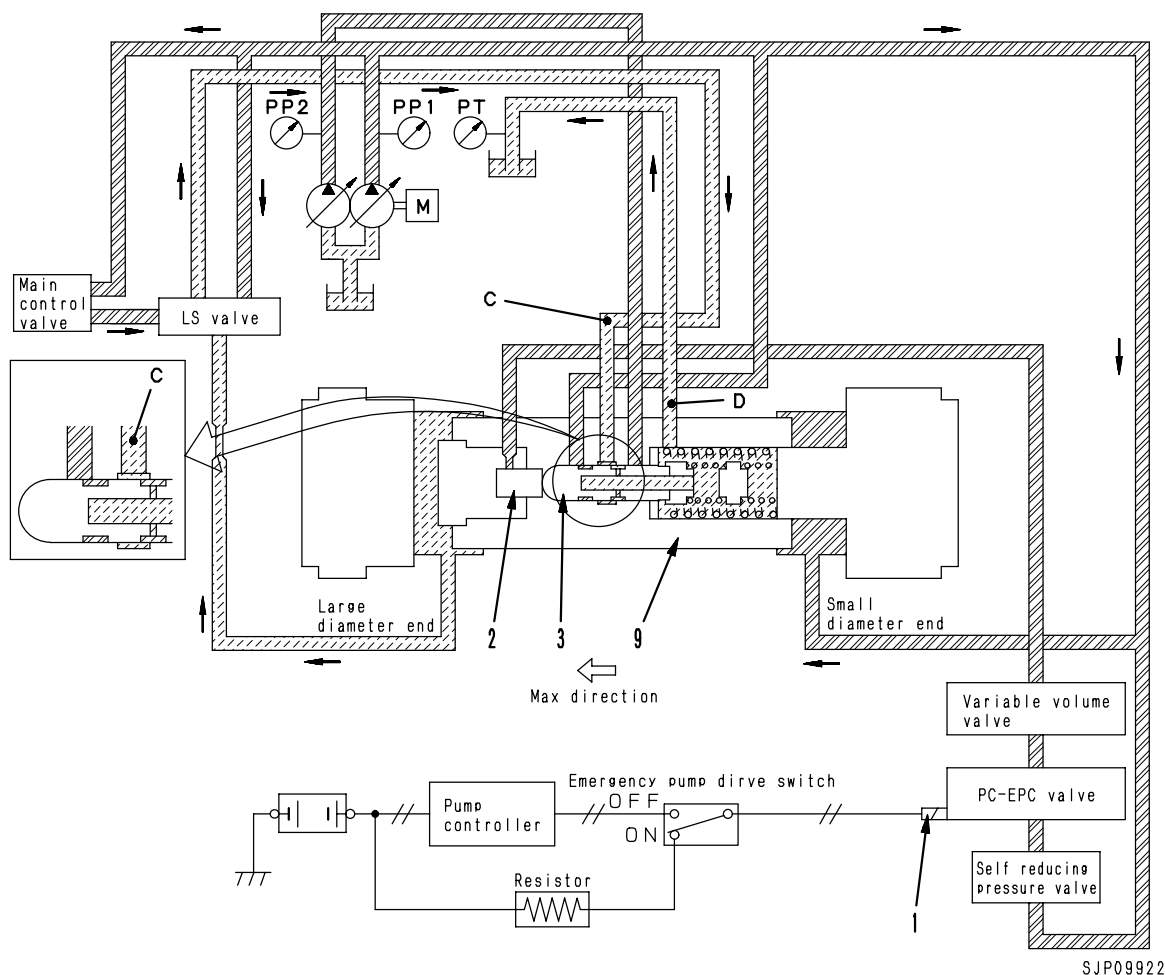
- When the load is large and pump discharge pressures **PP1** and **PP2** are high, the force pushing spool (3) to the right becomes larger and spool (3) moves to the position in the diagram above. When this happens, as shown in the diagram above, part of the pressurized oil from port **B** flows out through port **C** where the LS valve is actuated to port **D**, and the pressurized oil flowing from port **C** to the LS valve becomes approximately half of main pump pressure **PP**.
- When port **E** and port **G** of the LS valve are connected (see (1) LS valve), the pressure from port **J** enters the large diameter end of servo piston (9), and servo piston (9) stops.
- If pump discharge pressure **PP** and **PP2** increases further and spool (3) moves further to the right, main pump pressure **PP1** flows to port **C** and acts to make the discharge amount the minimum. When piston (9) moves to the right, springs (4) and (6) are compressed and push back spool (3). When spool (3) moves to the left, port **C** and port **B** are disconnected and port **C** and port **D** are interconnected. As a result, the pressure at port **C** (= **J**) drops, and piston (9) stops moving to the right.
- The position in which piston (9) stops when this happens is further to the right than the position when pump pressures **PP1** and **PP2** are low.

- The relation of average pump pressure ($PP1 + PP2)/2$ and the position of servo piston (9) forms a bent line because of the double-spring effect of springs (4) and (6). The relationship between average pump pressure ($PP1 + PP2)/2$ and pump discharge amount Q is shown in the figure at the right.



- If command voltage X sent to PC-EPC valve solenoid (1) increases further, the relationship between average pump pressure ($PP1 + PP2)/2$, and pump discharge amount Q is proportional to the pushing force of the PC-EPC valve solenoid and moves in parallel. In other words, the pushing force of PC-EPC solenoid (1) is added to the force pushing to the left because of the pump pressure applied to the spool (3), so the relationship between the average pump pressure ($PP1 + PP2)/2$ and Q moves from ① to ② in accordance with the increase in X .



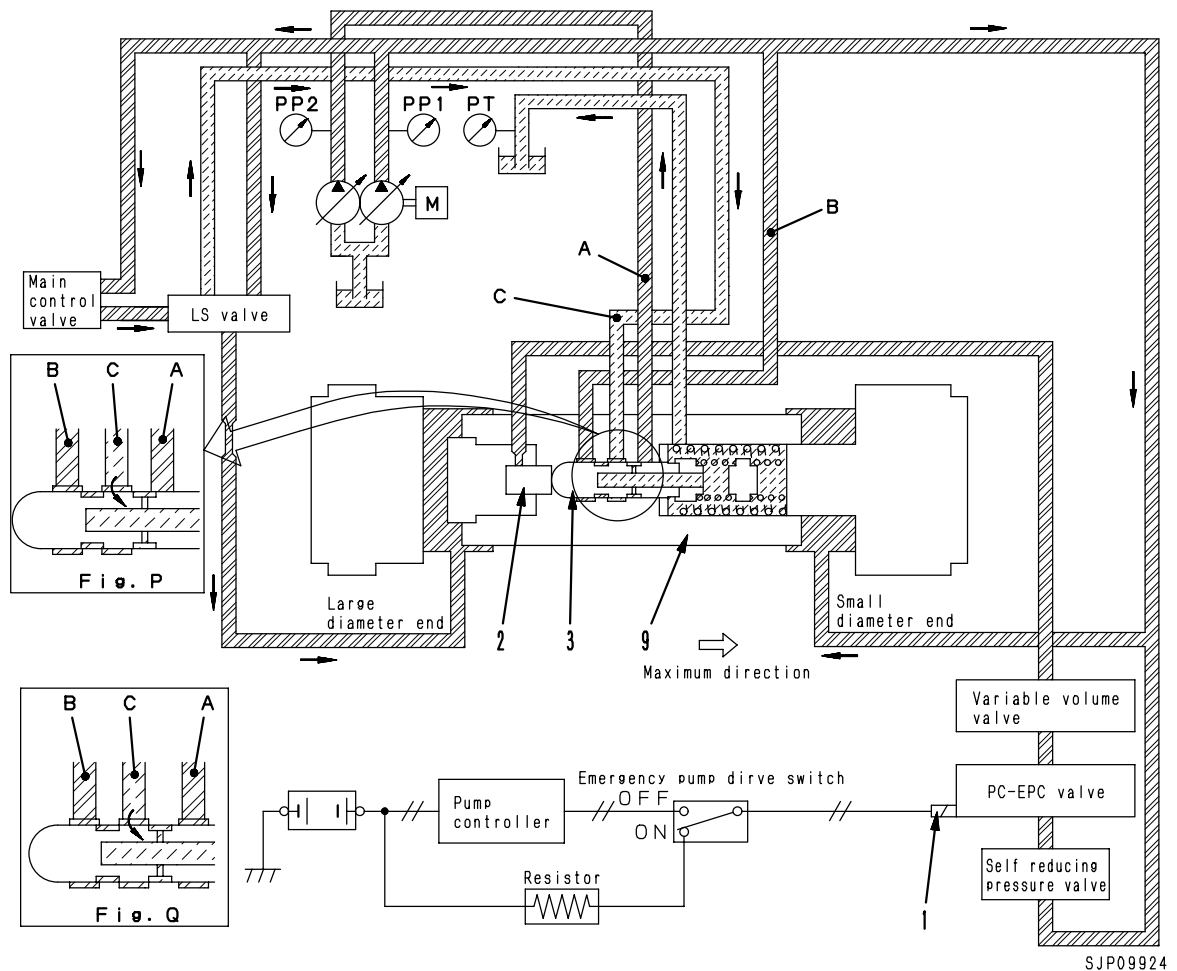


2) When pump controller is abnormal and emergency pump drive switch is ON

a. When load on main pump is light

- If there is a failure in the pump controller, turn emergency pump drive switch **ON** to switch to the resistor side. In this case, the power source is taken directly from the battery. But if the current is used as it is, it is too large, so use the resistor to control the current flowing to PC-EPC valve solenoid (1).
- When this is done, the current becomes constant, so the force pushing piston (2) is also constant.
- If the main pump pressure **PP1** and **PP2** are low, the combined force of the pump pressure and the force of PC-EPC valve solenoid (1) is weaker than the spring set force, so spool (3) is balanced at a position to the left.

- At this point, port **C** is connected to the drain pressure of port **D**, and the large diameter end of the piston of servo piston (9) also becomes the drain pressure **PT** through the LS valve. When this happens, the pressure at the small diameter end of the piston is large, so servo piston (9) moves in the direction to make the discharge amount larger.



b. When main pump load is heavy

- In the same way as in the previous item, when the emergency pump drive switch is **ON**, the command current sent to PC-EPC valve solenoid (1) becomes constant. For this reason, the force of piston (2) pushing spool (3) is constant.
- If main pump pressures **PP1** and **PP2** increase, spool (3) moves further to the right than when the main pump load is light, and is balanced at the position in the diagram above (See Fig. P).
- In this case, the pressure from port **B** flows to port **C**, so servo piston (9) moves to the right (to make the discharge amount smaller) by the same mechanism as explained in item 2)-b, and stops at a position to the right of the position when the load on the pump is light (See Fig. Q). In other words, even when the emergency pump drive switch is **ON**, the curve for the pump pressure **PP** and discharge amount **Q** is determined as shown in

the diagram for the valve of the current sent to the PC-EPC valve solenoid through the resistor.

The curve when the emergency pump drive switch is **ON** is curve ②, which is to the left of curve ① for when the pump controller is normal.

