

## SECTION 5 STEERING SYSTEM

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# SECTION 5 STEERING SYSTEM

## GROUP 1 STRUCTURE AND FUNCTION

### 1. OUTLINE

The steering system of this machine consists of a variable displacement piston pump supplying a load sensing steering system and a closed center loader system.

This system offers faster response from the priority valve of flow amplifier and the pump. Also it offers advantages in connection with cold start up and improvements in system stability.

The components of the steering system are :

- Steering pump
- Flow amplifier
- Steering unit
- Accumulators
- Steering cylinders

The flow amplifier contains a directional valve, an amplification stage, a priority valve, a pilot pressure relief valve and shock and suction valve.

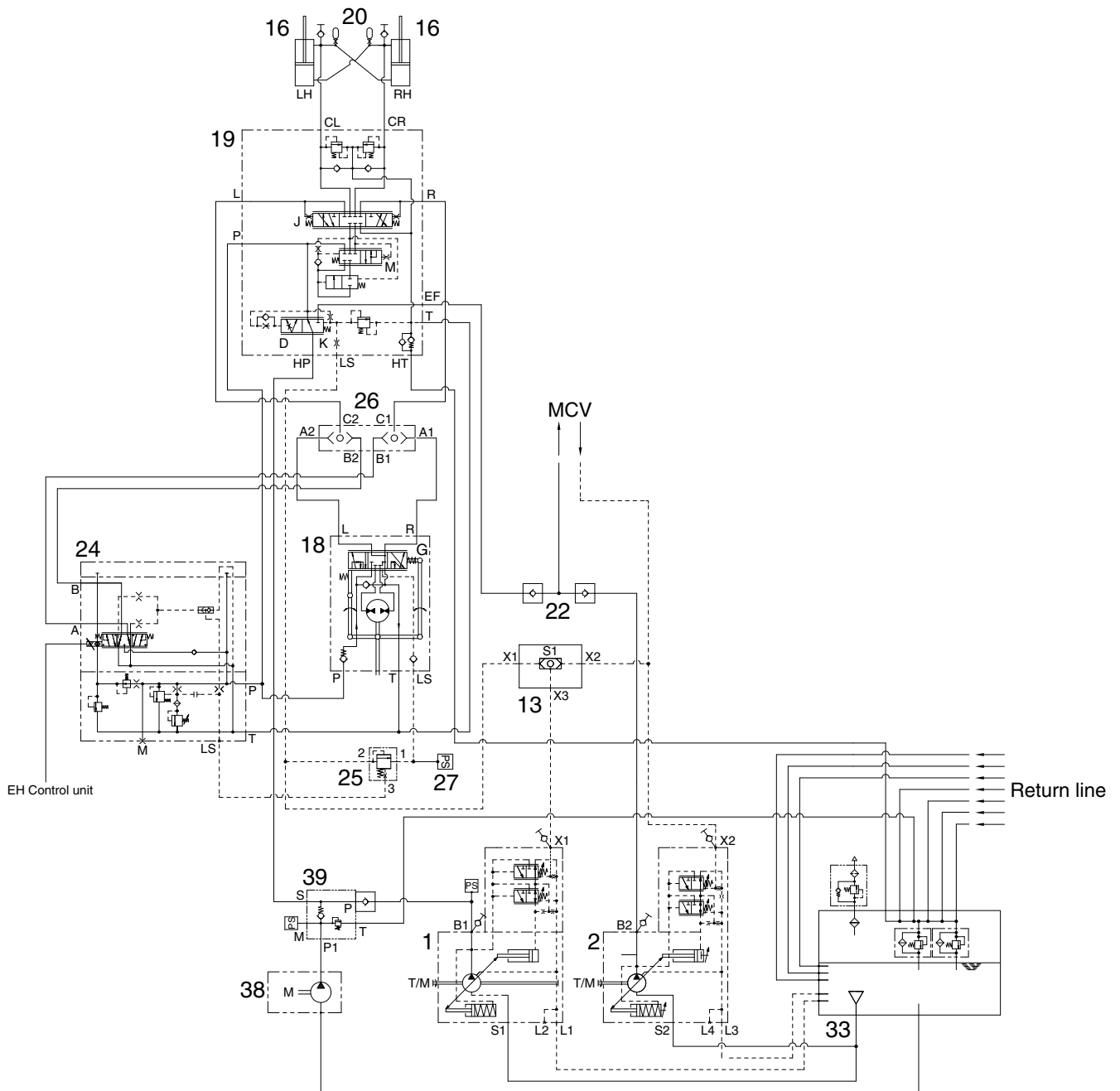
The steering pump draws hydraulic oil from the hydraulic tank.

Outlet flow from the pump flows to the priority valve of flow amplifier. The priority valve of flow amplifier preferentially supplies flow, on demand, to the steering unit. When the machine is steered, the steering unit routes flow to the steering cylinders to articulate the machine.

When the machine is not being steered, or if pump flow is greater than steering flow, the priority valve supplies flow to the loader system.

That is, output flow from the steering pump enters into the main control valve for the operation of the attachment.

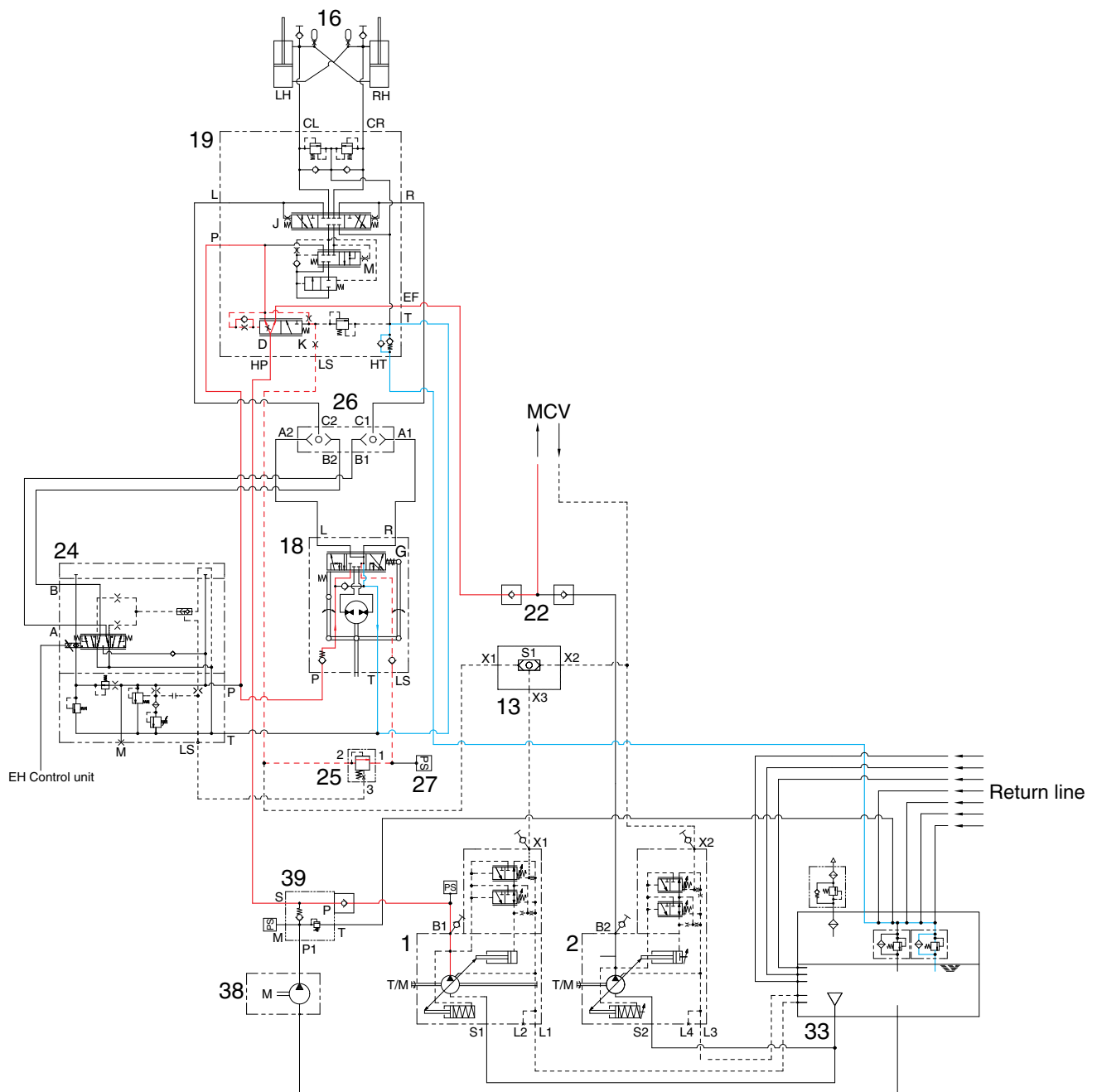
## 2. HYDRAULIC CIRCUIT



980A5SE01

- |                      |                                   |                         |
|----------------------|-----------------------------------|-------------------------|
| 1 Steering pump      | 20 Accumulator                    | 33 Hydraulic tank       |
| 2 Loader pump        | 22 Check valve                    | 38 Motor pump (option)  |
| 13 Shuttle valve     | 24 Proportional valve (option)    | 39 Check valve (option) |
| 16 Steering cylinder | 25 LS compensating valve (option) |                         |
| 18 Steering unit     | 26 Shuttle valve                  |                         |
| 19 Flow amplifie     | 27 Pressure sensor                |                         |

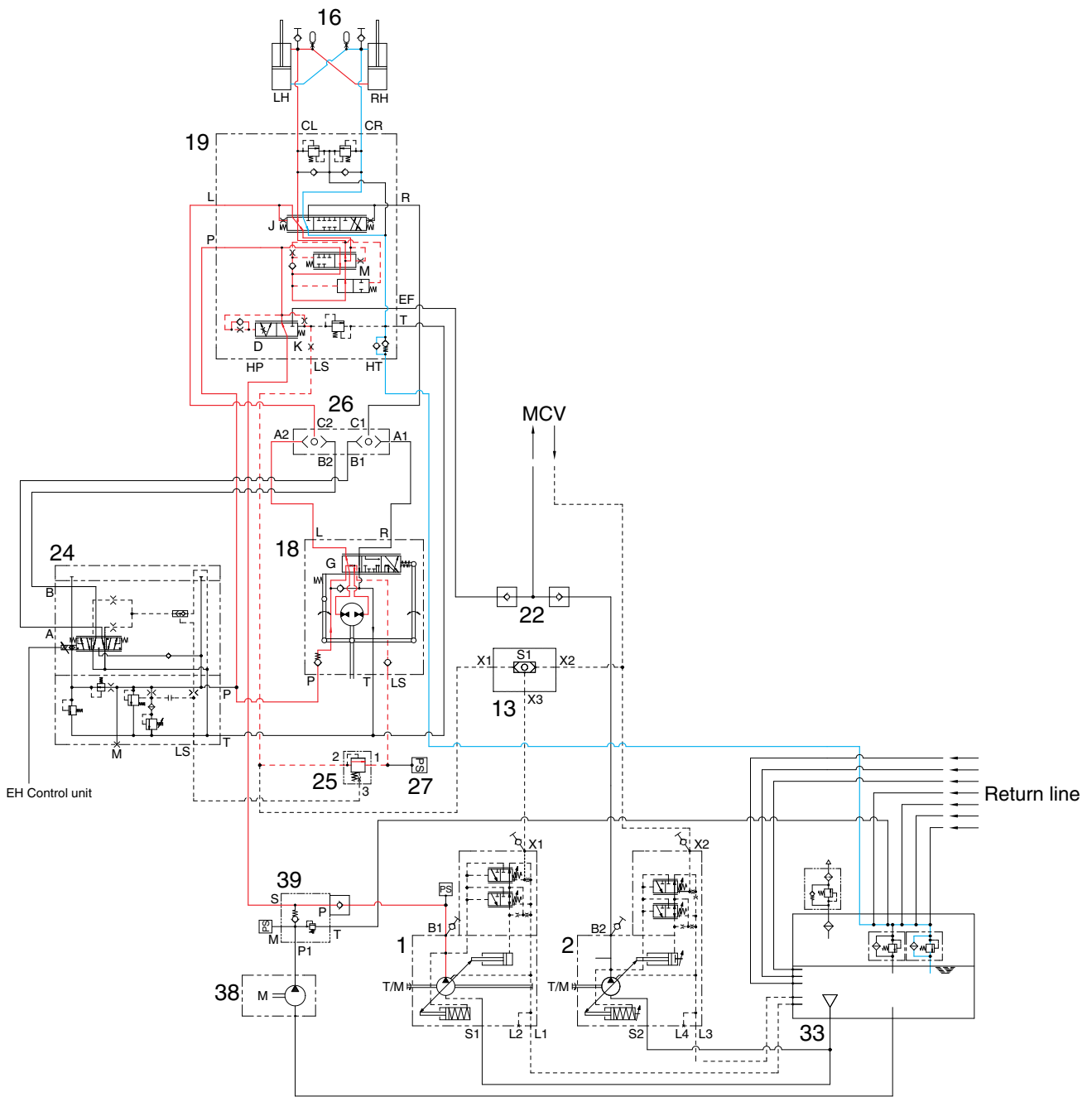
1) NEUTRAL



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- The steering wheel is not being operated so control spool (G) does not move.
  - The oil from the steering pump enters port HP of the priority valve of flow amplifier and the inlet pressure oil moves the spool (D) to the right.
  - Almost all of pump flow goes to the loader system (main control valve) through the EF port and partly flows into the hydraulic tank (33) through the control spool (G).
- This small flow is useful to prevent the thermal shock problem of the steering unit (18).

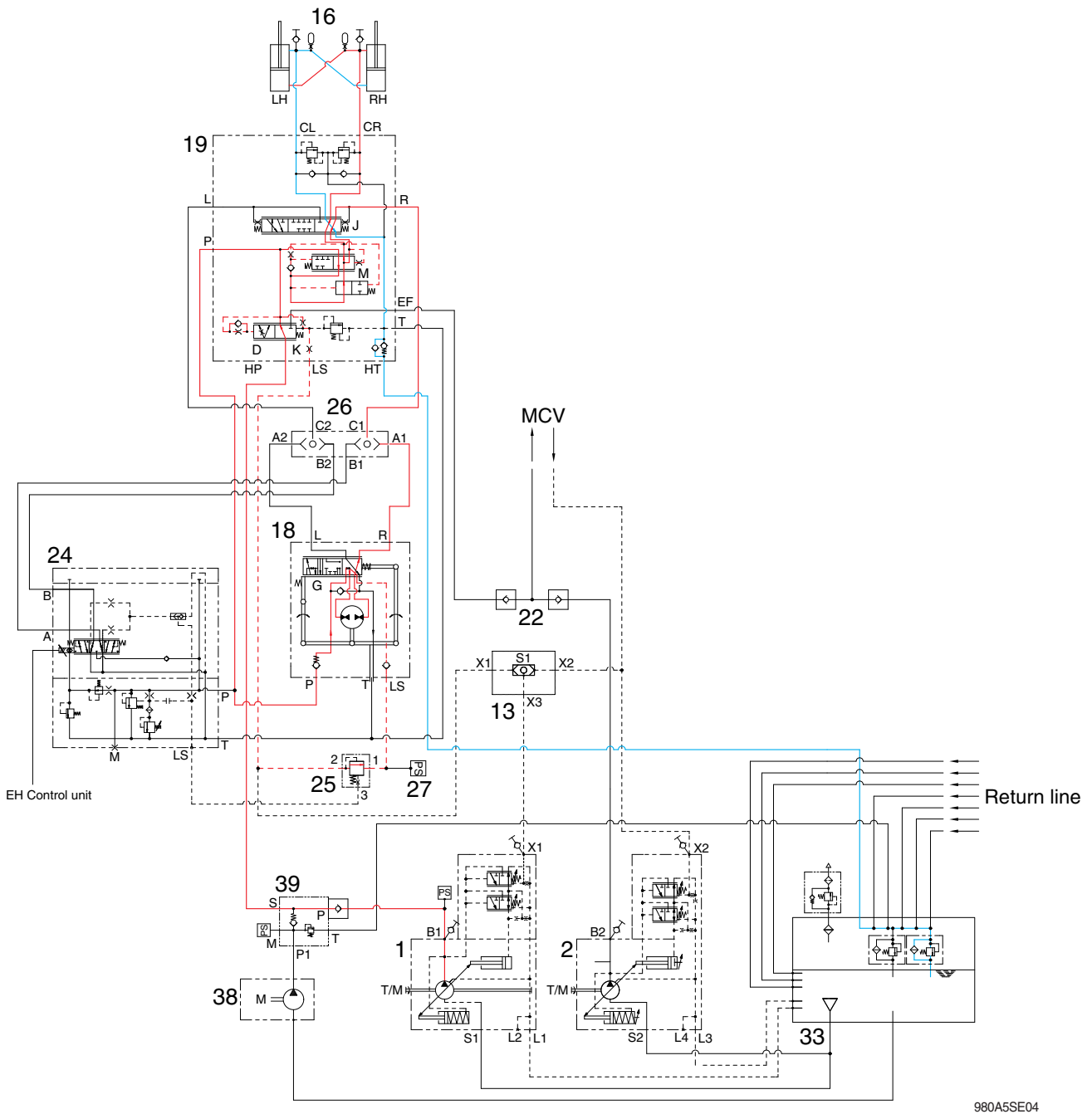
## 2) LEFT TURN



980A5SE03

- When the steering wheel is turned to the left, the spool (G) within steering unit (18) connected with steering column shaft is pushed to the right direction.
- The oil discharged from the pump flows into HP port of flow amplifier (19).
- The delivered oil passes through the main orifice of steering unit (8), through the priority valve spool (D) of flow amplifier (19). The position of priority spool (D) is determined when the pressure difference between front and rear of main orifice is balanced with control spring (K) force.
- The oil supplied through the directional spool (J) from the steering unit is combined with the direct oil from the priority valve spool (D) in the amplifier spool (M). The amplified oil flows into the small chamber of the left steering cylinder and large chamber of the right steering cylinder respectively.
- Oil returned from left and right cylinder returns to hydraulic tank through directional spool (J) of flow amplifier (19).
- When the above operation is completed, the machine turns to the left.

### 3) RIGHT TURN



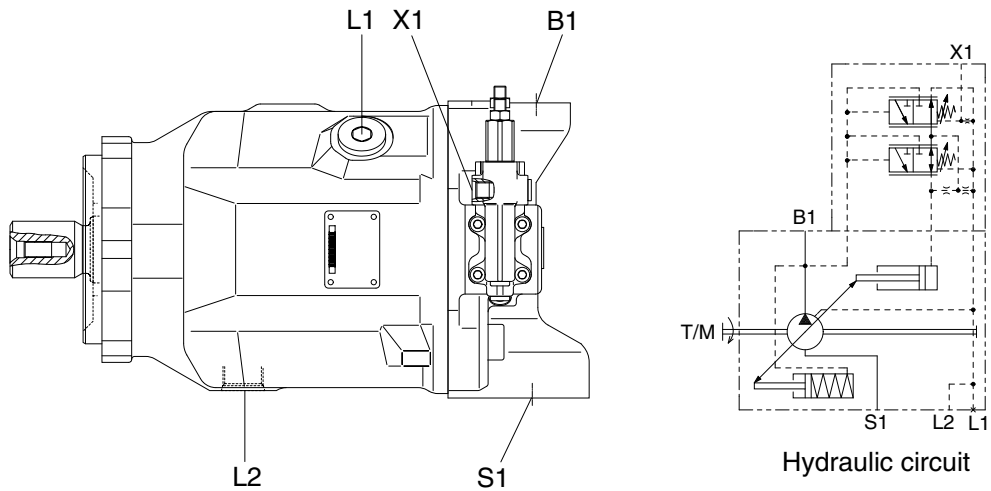
980A5SE04

- When the steering wheel is turned to the right, the spool (G) within steering unit (18) connected with steering column shaft is pushed to the right direction.
- The oil discharged from the pump flows into HP port of flow amplifier (19).
- The delivered oil passes through the main orifice of steering unit (8), through the priority valve spool (D) of flow amplifier (19). The position of priority spool (D) is determined when the pressure difference between front and rear of main orifice is balanced with control spring (K) force.
- The oil supplied through the directional spool (J) from the steering unit is combined with the direct oil from the priority valve spool (D) in the amplifier spool (M). The amplified oil flows into the small chamber of the right steering cylinder and large chamber of the left steering cylinder respectively.
- Oil returned from left and right cylinder returns to hydraulic tank through directional spool (J) of flow amplifier (19).
- When the above operation is completed, the machine turns to the right.

### 3. STEERING PUMP

#### 1) STRUCTURE (1/2)

This steering pump is variable displacement piston pump.

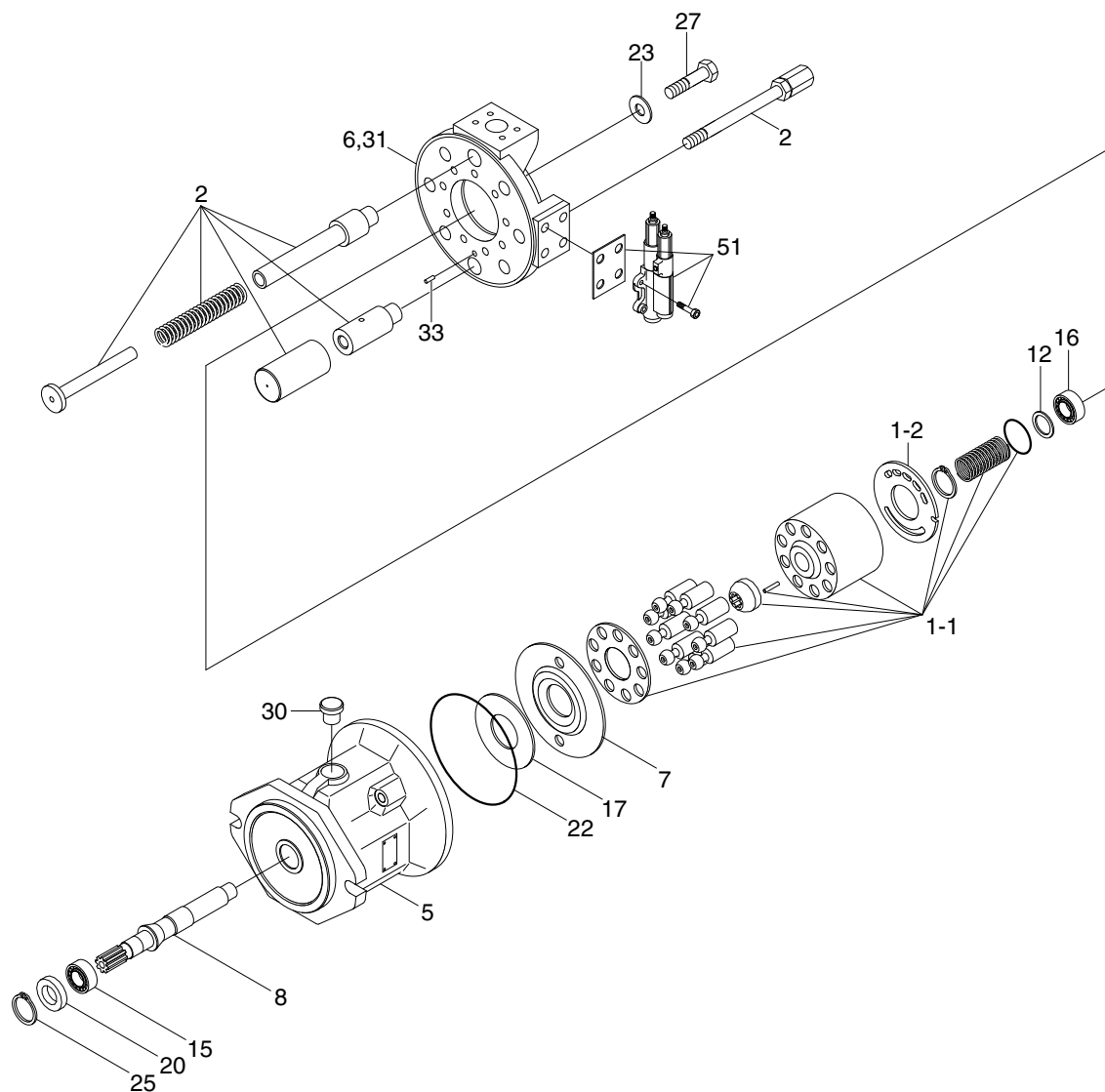


980T36WE88

Port	Port name	Port size
B1	Pressure port	SAE 1 1/4"
S1	Suction port	SAE 2 1/2"
L1, L2	Case drain port	1 5/16-12UN
X1	Pilot pressure port	7/16-20UNF

※ **Function, disassembly and assembly** : Refer to page 6-11~18 and 6-64~76.

## STRUCTURE (2/2)



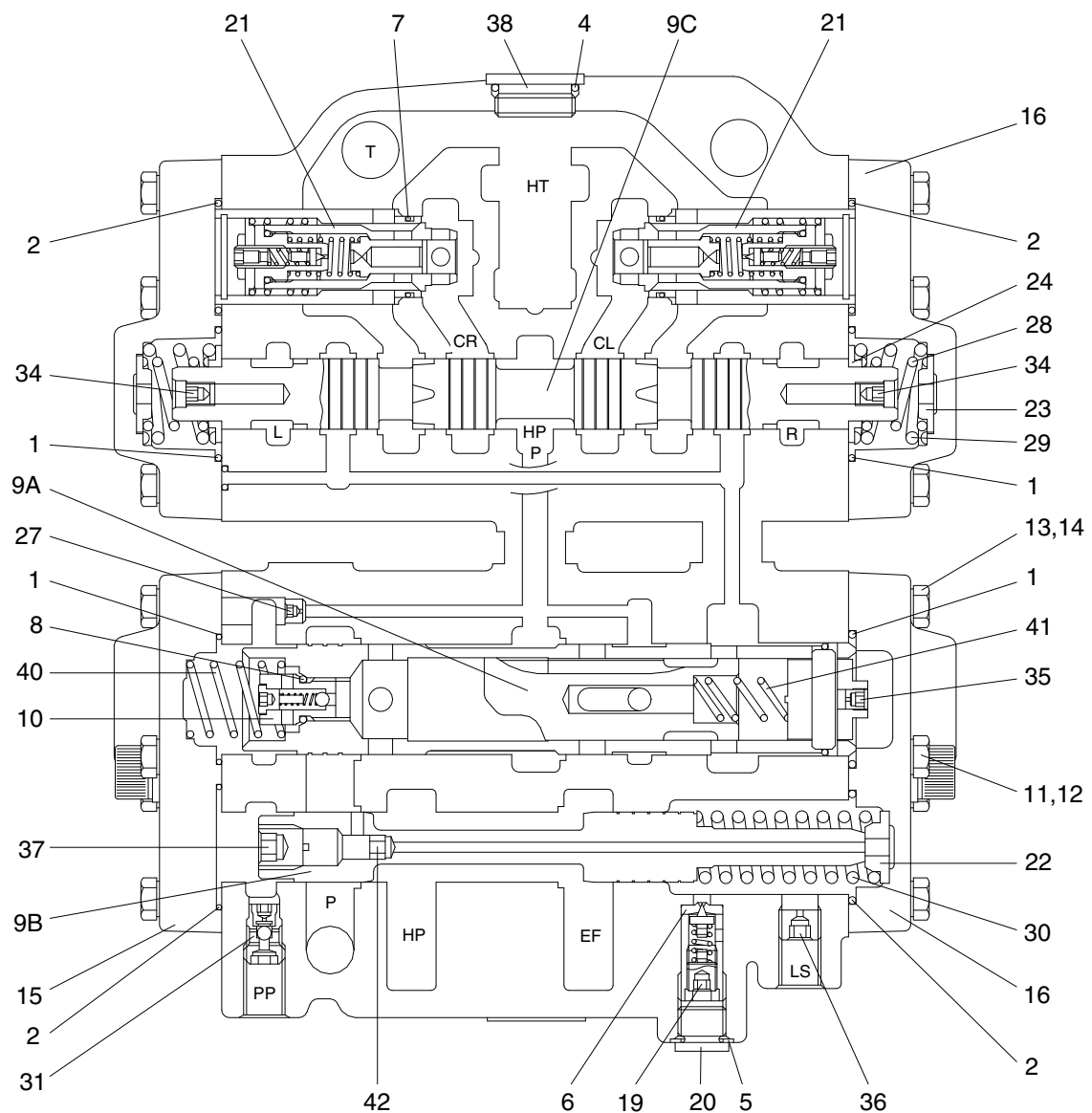
78096WE11

- |                             |                         |                         |
|-----------------------------|-------------------------|-------------------------|
| 1 Rotary group              | 8 Drive shaft           | 23 O-ring               |
| 1-1 High speed rotary group | 12 Adjustment shim      | 25 V-ring               |
| 1-2 Control plate           | 15 Taper roller bearing | 27 Socket screw         |
| 2 Adjusting piece           | 16 Taper roller bearing | 30 Locking screw        |
| 5 Pump housing              | 17 Bearing liner        | 31 Double break-off pin |
| 6 Port plate                | 20 Shaft seal ring      | 33 Cylinder pin         |
| 7 Swash plate               | 22 O-ring               | 51 Control valve        |



## 4. FLOW AMPLIFIER

### 1) STRUCTURE



(770-7) 5-6

1 O-ring	12 Spring washer	28 Spring
2 O-ring	13 Screw	29 Spring
4 O-ring	14 Spring washer	30 Spring
5 Washer	15 End cover	31 Throttle check valve
6 Washer	16 End cover	34 Orifice
7 O-ring	19 Relief valve	35 Orifice
8 O-ring	20 Plug	36 Orifice
9A Amplifier valve	21 Shock, suction valve	37 Plug
9B Priority valve	22 Spring seat	38 Plug
9C Directional valve	23 Spring seat	40 Spring
10 Check valve	24 Spring guide	41 Spring
11 Screw	27 Orifice	42 Orifice

## **2) OPERATION**

### **(1) Introduction**

The flow amplifier contains a directional valve, an amplification stage, a priority valve, a pilot pressure relief valve and shock and suction valves.

The flow amplifier amplifies the oil flow from the steering unit cylinder ports L or R by an amplification factor of 8. The amplified oil flow is directed from the flow amplifier ports CL or CR to the steering cylinder. The amplified flow is proportional to the rate of the steering wheel rotation. If the oil flow from the pump fails, the flow amplifier cuts off the amplification.

### **(2) Priority valve**

The priority valve is used in load sensing systems where the same pump supplies oil to both steering system and working hydraulics.

The steering system always has first priority.

The pressure on the LS connection is almost zero during measuring (steering unit in neutral position).

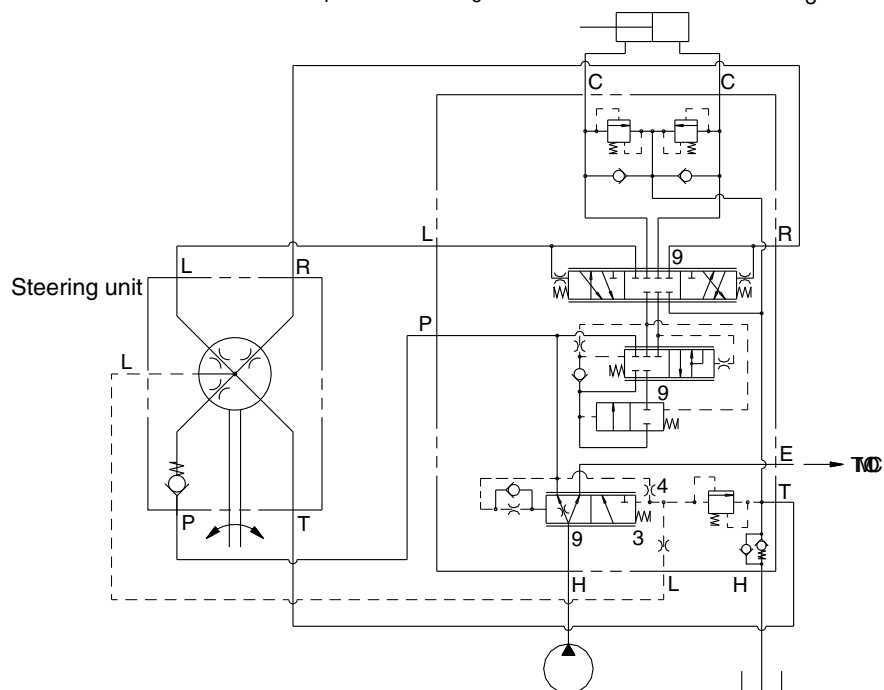
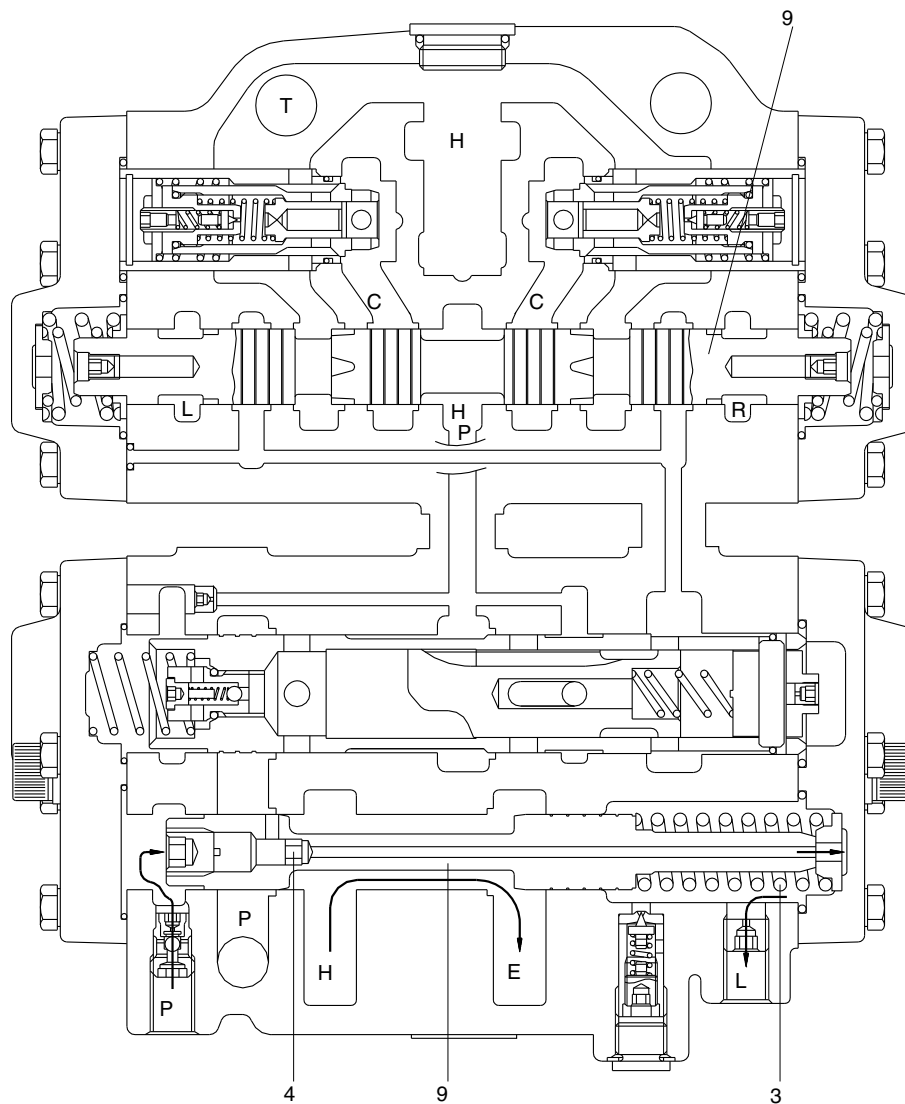
### **(3) Shock valves**

The shock valves protect the flow amplifier against shock from external forces on the steering cylinders. The shock valves in flow amplifier limit the maximum pressure drop from CL to HT and from CR to HT.

### **(4) HP-HT ports characteristic**

The pilot pressure relief valve protects the steering unit against excess pressure. The pilot pressure relief valve together with the priority valve limit the maximum steering pressure HP-HT.

# (5) Neutral



980A5SE100

In neutral position, the oil passes from the pump across the integrated priority valve (9B) in the flow amplifier for discharge through the EF port. With the steering unit in neutral, flow through it is blocked and all flow through the priority valve (9B) in flow amplifier is directed out the EF port to the loader control valve.

With the engine off, the priority valve spool (9B) is pushed to the left by the spring (30). The passage to the EF port is blocked while the passage to the P port is open.

When the machine is first started, all pump flow is routed to the steering unit which blocks the flow. With the flow blocked, the pressure increases.

Steering inlet pressure is supplied through the dynamic orifice (42) in the spool. This causes the priority valve spool (9B) to shift to the right against the spring (30) and open the EF port.

As long as the steering unit is in neutral, just enough pressure is maintained at the steering unit to keep the priority valve spool (9B) shifted to the right.

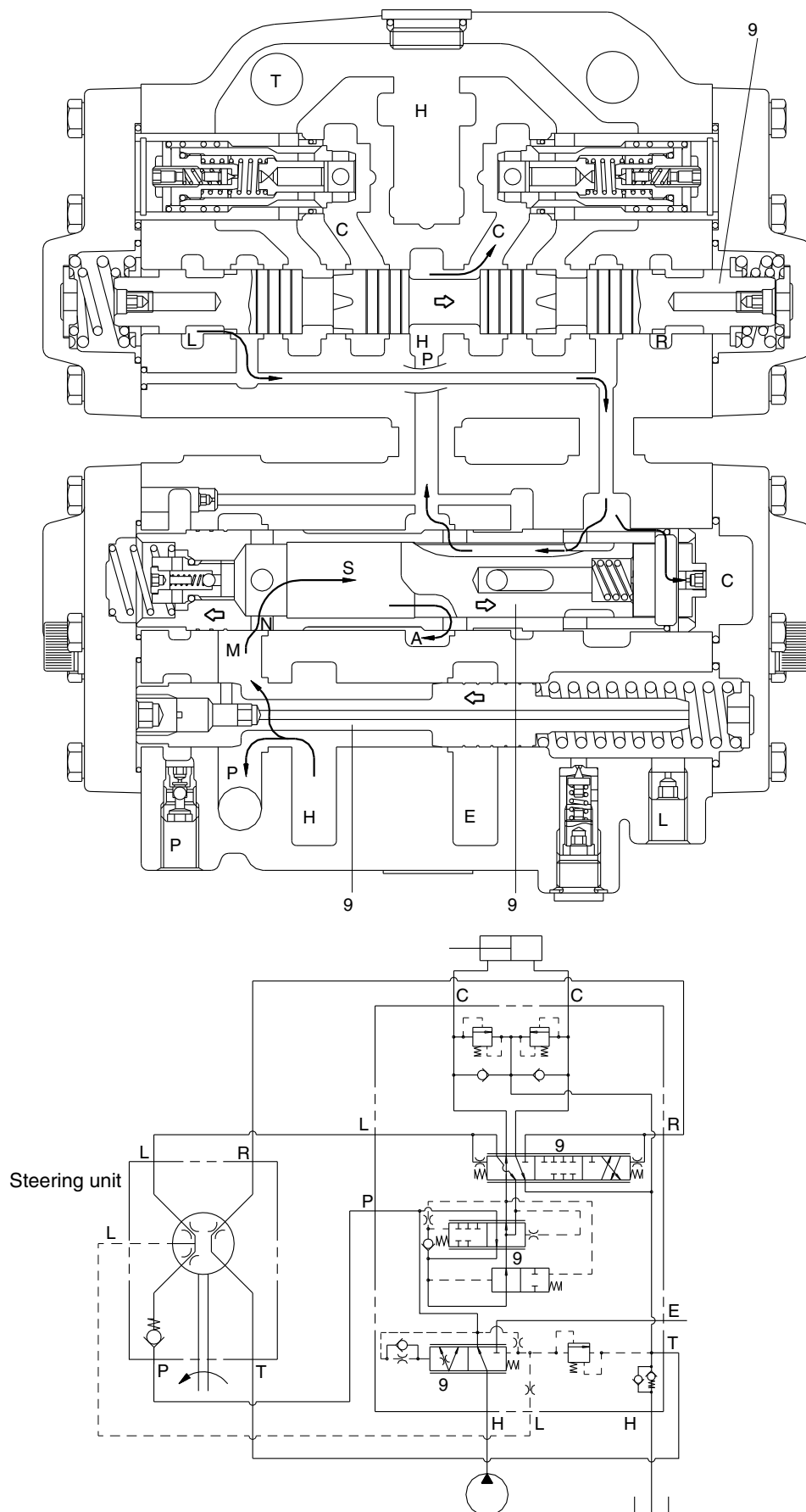
The operating pressure in the loader system has no effect on the operation of the priority valve (9B) of flow amplifier. With the loader actuated in relief, the priority valve (9B) will not shift until the machine is steered.

Flow through the priority valve spool (9B) passes from the P port through the orifice (42) and into the LS port. It flows through the steering unit LS passage which is routed to return when the steering unit is in neutral. This provides a warm-up circuit for the steering unit to prevent binding of the steering unit due to oil temperature extremes.

In neutral position, also the directional valve (9C) is in its center position.

This means that knock and impacts from the cylinder are not transmitted to the steering unit. The flow amplifier is thus of the non-reaction type.

## (6) Mid-turn



980A5SE101

If the steering wheel is turned to the left, a LS signal is passed to the priority valve (9B). The priority valve (9B) is reversed so that more oil is passed across the P port to the steering unit for discharge through the L port of the flow amplifier.

The directional valve (9C) is reversed through the pressure being transmitted across the boring in the spool whereby the spool is moved the right.

The opening shall allow connection between the pilot flow and the pressure control/amplifier valve (9A).

The pilot pressure from the orifice in chamber C moves the valve to the left and passage for the pilot flow therefore is possible out of hole F.

The main flow passes from the priority valve (9B) to the circular channel M. As the amplifier spool is moved to the left, the passage will now be open across the holes N to the chamber S.

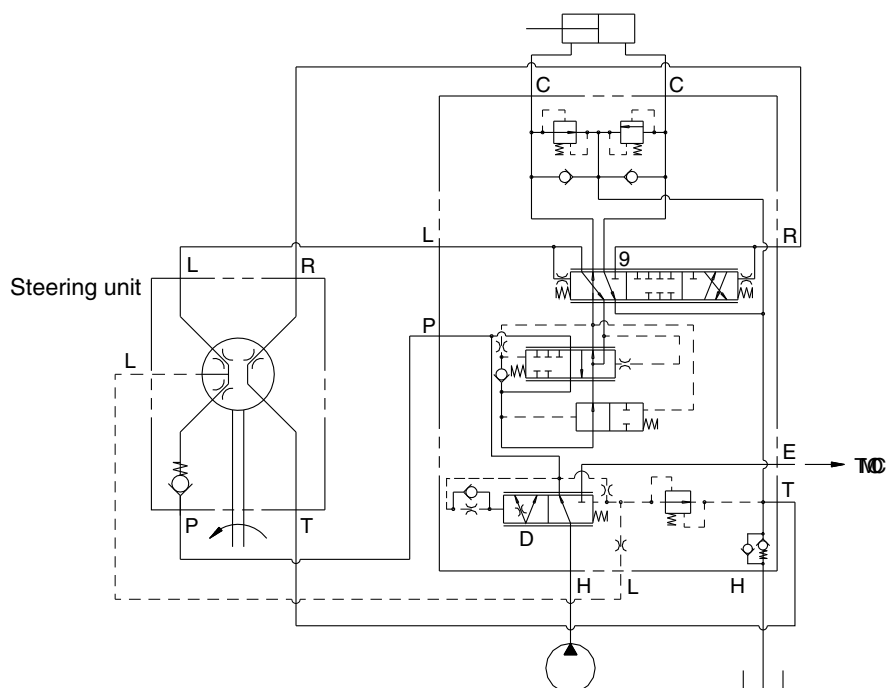
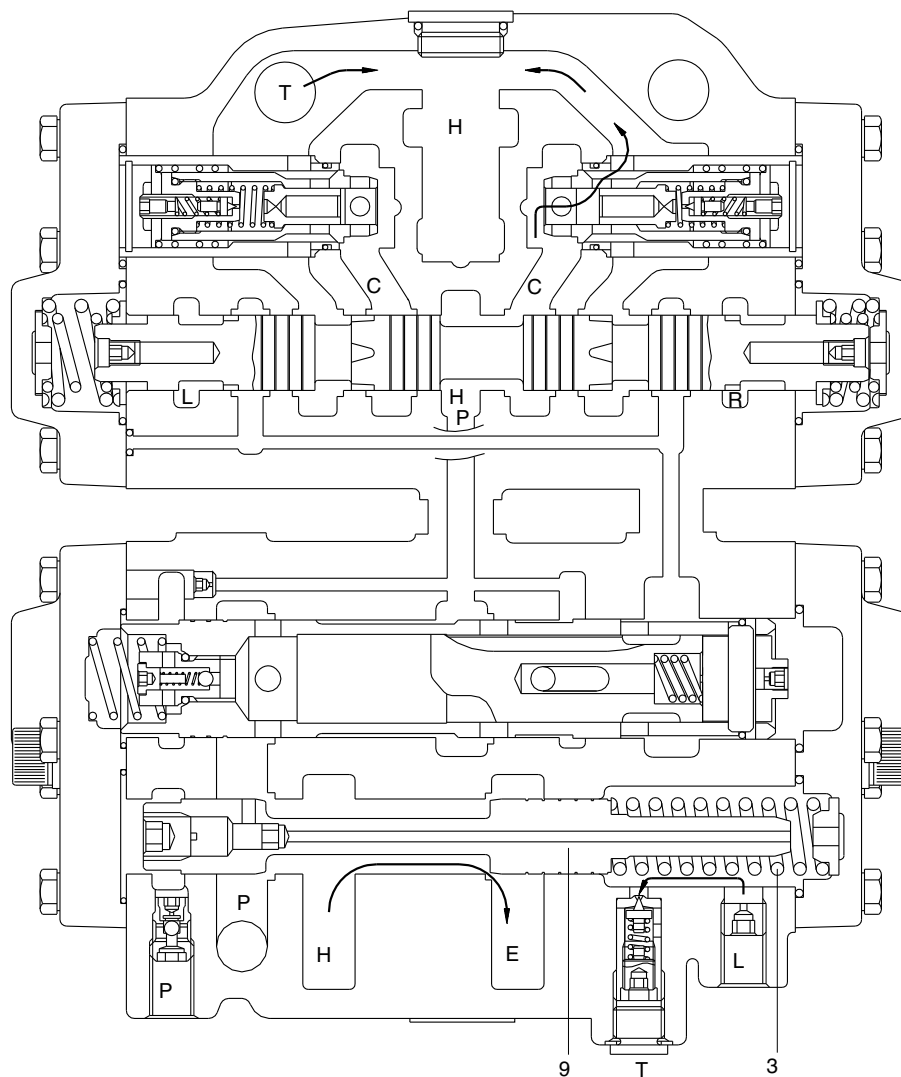
The spool goes to a position so that the pressure in chamber S equals the pressure in chamber C.

The passage is now open for the main flow through the priority valve (9B) across the holes A.

The main flow and pilot flow merge and is passed across the directional valve (9C) to the steering cylinder through CL port.

The return oil passes across the directional valve (9C) to the hydraulic tank.

# (7) Full turn



980A5SE102

When the machine is steered to a full turn, the frames bottom against the steering stops. To limit steering system pressure, a relief system is built into the priority valve assembly (9B).

When the frames bottom is stopped, the pressure in the steering cylinders increases. This pressure is sensed at the LS port. When the pressure in the LS port increases enough to push priority valve spool (9B) off its seat, oil in the load sensing circuit flows to return through the T port. Load sensing pressure is limited to the pressure setting of the relief valve.

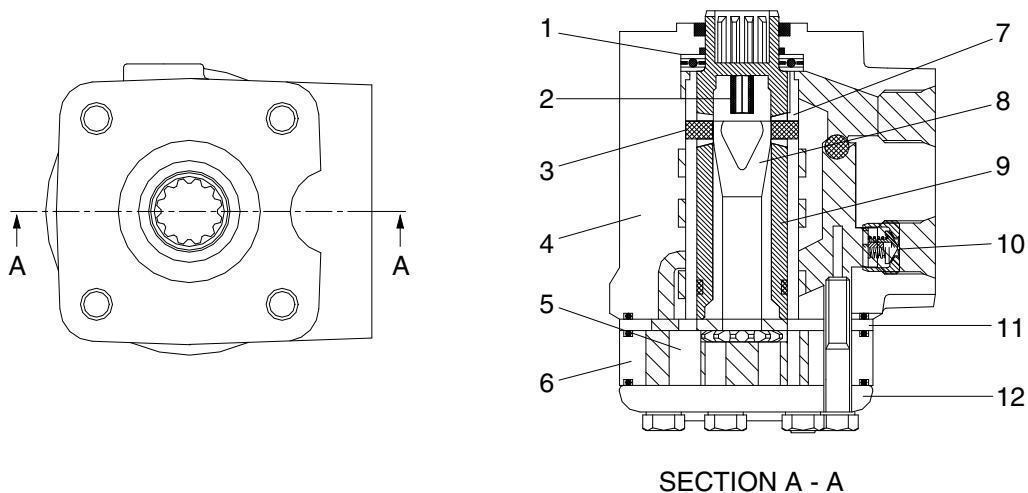
Pressure to the steering unit (pilot pressure), which is sensed at the left end of the priority valve spool (9B) in flow amplifier, continues to increase until it can move the spool to the right against the load sensing pressure plus spring (30) force. At this time, all oil flows out of the EF port to the loader control valve.

If the loader attachment is being operated while steering, the loader function will slow until the machine reaches the steering stops. At that time, the loader cycle speed will increase until the machine is steered again.



## 4. STEERING UNIT

### 1) STRUCTURE



7607SE17

1	Bearing	5	Gear wheel	9	Spool
2	Neutral position spring	6	Gear rim	10	Check valve
3	Cross pin	7	Sleeve	11	Distributor plate
4	Housing	8	Cardan shaft	12	End cover

### 2) OPERATION

The steering unit consists of a rotary valve and a rotary meter.

Via a steering column the steering unit is connected to the steering wheel of the machine.

When the steering wheel is turned, oil is directed from the steering system pump via the rotary valve (spool and sleeve) and rotary meter (gear wheel set) to the cylinder ports L or R, depending on the direction of turn. The rotary meter meters the oil flow to the steering cylinder in proportion to the angular rotation of the steering wheel.

Spool (9) is connected directly to the drive shaft of steering wheel. It is connected to sleeve (7) by cross pin (3) (not in contact with the spool when the steering wheel is at neutral) and neutral position spring (2).

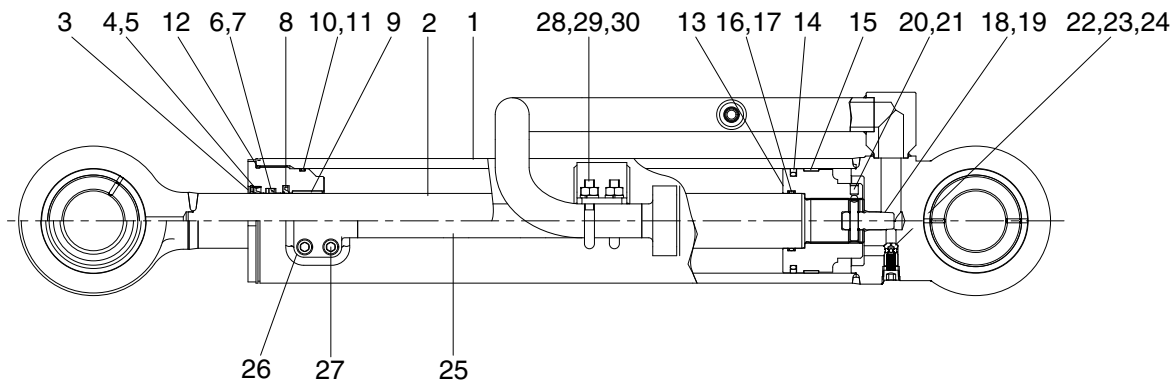
Cardan shaft(8) is meshed at the top with cross pin (3) and forms one unit with sleeve (7).

At the same time, it is meshed with gear rim (5) of the gerotor set by spline.

There are four ports in valve body. They are connected to the pump circuit, tank circuit, and the head, and left and right steering cylinder. In addition, the pump port and tank port are connected inside the body by the check valve. Therefore, if there is any failure in the pump of engine, oil can be sucked in directly from the tank through the check valve.

## 5. STEERING CYLINDER

### 1) STRUCTURE



9805SE05

1	Tube assembly	12	O-ring	23	Spring
2	Rod assy	13	Piston	24	Socket plug
3	Gland	14	Piston seal	25	Pipe assembly
4	Dust wiper	15	Wear ring	26	O-ring
5	Retaining ring	16	O-ring	27	Hexagon bolt
6	Rod seal	17	Back-up ring	28	U-bolt
7	Back-up ring	18	Cushion plunger	29	Hexagon nut
8	Buffer ring	19	Paraller pin	30	Spring washer
9	Bearing	20	Steel ball	31	Bearing
10	O-ring	21	Set screw	32	Retaining ring
11	Back-up ring	22	Check valve		

### 2) OPERATION

This machine use to cross connected cylinder for steering operation.

The steering cylinder use a gland (3) to remove piston and sealed seals. Dust wiper (4) located on the inside of the gland protects cylinder inner parts from dust. The piston (13) is fastened to the rod (2).

The piston uses a single wear ring (15) with a piston seal (14) to seal between the piston and tube. The gland seals against the tube with two O-rings. The rod is sealed against the gland with a rod seal (6).

## GROUP 2 OPERATIONAL CHECKS AND TROUBLESHOOTING

### 1. OPERATIONAL CHECKS

This procedure is designed so the service man can make a quick check of the steering system using a minimum amount of diagnostic equipment. If you need additional information, refer to structure and function in group 1.

A location will be required which is level and has adequate space to complete the checks.

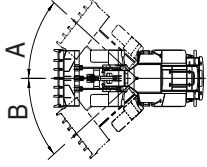
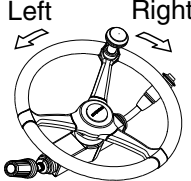
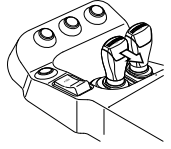
The engine and all other major components must be at operating temperature for some checks.

Locate system check in the left column and read completely, following this sequence from left to right. Read each check completely before performing.

At the end of each check, if no problem is found (OK), that check is complete or an additional check is needed. If problem is indicated (NOT OK), you will be give repair required and group location. If verification is needed, you will be give next best source of information :

- Chapter 2 : Troubleshooting
- Group 3 : Tests and adjustments

※Hydraulic oil must be at operating temperature for these checks (refer to page 6-54).

Item	Description	Service action
<b>Steering unit check</b>  	<p>Run engine at low idle.</p> <p>Turn steering wheel until frames are at maximum right (A) and then left (B) positions.</p> <p><b>LOOK</b> : Frames must move smoothly in both directions.</p> <p>When steering wheel is stopped, frames must stop.</p> <p><b>FEEL</b> : Excessive effort must not be required to turn steering wheel.</p> <p><b>NOTE</b> : It is normal for steering to drift from stops when steering wheel is released.</p>	<p><b>OK</b> Check completed.</p> <p><b>NOT OK</b> Go to next check.</p>
<b>Steering system leakage check</b> Heat hydraulic oil to operating temperature. Run engine at high idle.	 <p>Turn steering wheel rapidly until frames are against stop.</p> <p>Hold approximately 2 kg on steering wheel.</p> <p>Count steering wheel revolutions for 1 minute.</p> <p>Repeat test in opposite direction.</p> <p><b>LOOK</b> : Steering wheel should rotate less than 7 rpm.</p> <p><b>NOTE</b> : Use good judgment;</p> <p>Excessive steering wheel rpm does not mean steering will be affected.</p>	<p><b>OK</b> Check completed.</p> <p><b>NOT OK</b> Do steering system leakage test in group 3 to isolate the leakage.</p>
<b>Priority valve (in flow amplifier) low pressure check</b>	<p>Park machine on a hard surface.</p> <p>Hold brake pedal down.</p> <p>Run engine at high idle.</p> <p>Steer machine to the right and left as far as possible.</p> <p><b>LOOK</b> : Machine must turn at least half way to the right and left stops.</p>	<p><b>OK</b> Check completed.</p> <p><b>NOT OK</b> Do flow amplifier pressure test in group 3.</p>
<b>Priority valve (in flow amplifier) high pressure check</b>  Run engine at high idle.	 <p>Steer to steering stop and release steering wheel.</p> <p>Roll bucket back and hold over relief and observe engine rpm.</p> <p>Turn steering wheel to steering stop and hold, observe engine rpm.</p> <p><b>LOOK</b> : Steering stall engine rpm must be higher than hydraulic stall rpm.</p>	<p><b>OK</b> Check completed.</p> <p><b>NOT OK</b> Priority pressure is set too high. Do flow amplifier pressure test in group 3.</p>

## 2. TROUBLESHOOTING

※ Diagnose malfunction charts are arranged from most probable and simplest to verify, to least likely, more difficult to verify. Remember the following steps when troubleshooting a problem :

Step 1. Operational check out procedure (see group 3 in section 1)

Step 2. Operational checks (in this group)

Step 3. Troubleshooting

Step 4. Tests and adjustments (see group 3)

Problem	Cause	Remedy
<b>No steering</b>	Low oil level. Failed steering pump.  Failed main pump drive. Stuck priority valve spool. Broken priority valve spring. Relief valve in flow amplifier stuck open.	Add recommended oil.  Remove and inspect return filter for metal pump particles.  Do main pump flow test.  Remove and inspect priority valve spool.  Remove and inspect spring.  Do relief cartridge leakage test in group 3.
<b>No hydraulic functions steering normal</b>	Stuck open system relief valve. Locked safety valve. Plugged pilot line filter. Failed hydraulic pump. Low secondary pressure of RCV.	Replace relief valve.  Unlock safety valve.  Inspect and replace.  Remove and inspect the pump.  Check the pressure and replace if necessary.

Problem	Cause	Remedy
<b>Slow or hard steering</b>	Too much friction in the mechanical parts of the machine.  Cold oil.  Low priority valve pressure setting.  Worn hydraulic pump.  Sticking priority valve spool.  Broken priority valve spring.	Lubricate bearings and joints of steering column or repair if necessary. Check steering column installation.  Warm the hydraulic oil.  Do priority valve pressure test. Clean or replace cartridge in flow amplifier.  Do hydraulic pump performance check .  Remove and inspect.  Remove and inspect.
<b>Constant steering to maintain straight travel</b>	Air in system.  Leakage in steering system.  Worn steering unit.    Leaf spring without spring force or broken.  Spring in double shock valve broken.  Gear wheel set worn.  Cylinder seized or piston seals worn.	Check for foamy oil.  Do steering system leakage check.  Do steering system leakage check. Do steering unit neutral leakage test in group 3.  Replace leaf springs.  Replace shock valve.  Replace gear wheel set.  Replace defects parts.
<b>Slow steering wheel movement will not cause any frame movement</b>	Leakage in steering unit gerotor.  Worn steering unit gerotor.	Do steering system leakage check.  Do steering leakage check.
<b>Steering wheel can be turned with frames against steering stop</b>	Leakage in steering system.	Do steering system leakage check.
<b>Steering wheel turns with no resistance and causes no frame movement</b>	Broken steering column or splined coupling.  Lack of oil in steering unit.  Leakage in steering system.	Remove and inspect.  Start engine and check steering operation.  Do steering system leakage test in group 3.

Problem	Cause	Remedy
<b>Erratic steering</b>	Air in oil. Low oil level. Sticking priority valve spool. Loose cylinder piston. Damaged steering unit.	Check for foamy oil. Add recommended oil. Remove and inspect spool. Remove rod to inspect piston. Remove and inspect.
<b>Spongy or soft steering</b>	Air in oil. Low oil level.	Check for foamy oil. Add recommended oil.
<b>Free play at steering wheel</b>	Loose steering wheel nut. Worn or damaged splines on steering column or unit.	Tighten. Inspect.
<b>Steering unit binding or steering wheel does not immediately return to neutral when released</b>	Binding in steering column or misalignment of column. High return pressure. Contamination in steering unit. Large particles of contamination in steering unit.	Inspect. Check for a pinched or damaged return line. Inspect hydraulic filter for contamination. Repair cause of contamination. Flush hydraulic system. Inspect hydraulic filter for contamination. Repair cause of contamination. Flush hydraulic system.
<b>Steering unit locks up</b>	★ Thermal shock  Worn or damaged steering unit.	Do priority valve LS port flow test in group 5. This oil flow provides a warm -up flow to steering unit when not using the steering. Repair or replace steering unit.
<b>Abrupt steering wheel oscillation</b>	Improperly timed gerotor gear in steering unit.	Time gerotor gear.
<b>Steering wheel turns by itself</b>	Lines connected to wrong port.	Reconnect lines.
<b>Vibration in steering system or hoses jump</b>	High priority valve setting.	Do priority valve pressure test.
<b>Neutral position of steering wheel cannot be obtained, i.e. there is a tendency towards "motoring"</b>	Steering column and steering unit out of line. Too little or no play between steering column and steering unit input shaft. Pinching between inner and outer spools.	Align the steering column with steering unit. Adjust the play and, if necessary, shorten the splines journal. Contact the nearest service shop.

★ Thermal shock is caused by a large temperature differential(Approx. 30°C, 50°F) between the steering valve and hydraulic oil. If the steering is not operated for a long period of time and the orifice in the bottom of the priority valve spool is plugged, the steering valve may bind up when the steering is operated if the hydraulic oil is hot enough.

Problem	Cause	Remedy
<b>"Motoring" effect.</b> <b>The steering wheel can turn on its own.</b>	Leaf springs are stuck or broken and have therefore reduced spring force.	Replace leaf springs.
	Inner and outer spools pinch, possibly due to dirt.	Clean steering unit or contact the nearest service shop.
	Return pressure in connection with the reaction between differential cylinder and steering unit too high.	Reduce return pressure.
	Oil is needed in the tank.	Fill with clean oil and bleed the system.
	Steering cylinder worn.	Replace or repair cylinder.
	Gear wheel set worn.	Replace gear wheel set.
	Spacer across cardan shaft forgotten.	Install spacer.



Problem	Cause	Remedy
<b>Backlash</b>	Cardan shaft fork worn or broken. Leaf springs without spring force or broken. Worn splines on the steering column.	Replace cardan shaft. Replace leaf springs. Replace steering column.
<b>"Shimmy" effect. The steered wheels vibrate. (Rough tread on tires gives vibrations)</b>	Air in the steering cylinder.  Mechanical connections or wheel bearings worn. High priority valve setting pressure.	Bleed cylinder. Find and remove the reason for air collection. Replace worn parts. Set pressure as regular value.
<b>Steering wheel can be turned slowly in one or both directions without the steered wheels turning.</b>	One or both shock valves are leaky or are missing in steering valve.	Clean or replace defective or missing valves.
<b>Steering is too slow and heavy when trying to turn quickly.</b>	Insufficient oil supply to steering unit, pump defective or number of revolutions too low. Relief valve setting too low. Relief valve sticking owing to dirt. Spool in priority valve sticking owing to dirt. Too weak spring in priority valve.	Replace pump or increase number of revolutions. Adjust valve to correct setting. Clean the valve. Clean the valve, check that spool moves easily without spring. Replace spring by a stronger.
<b>"Kick back" in steering wheel from system. Kicks from wheels.</b>	Fault in the system.	Contact authorized man or shop.

Problem	Cause	Remedy
<b>Heavy kick-back in steering wheel in both directions.</b>	Wrong setting of cardan shaft and gear-wheel set.	Correct setting as shown in this manual.
<b>Turning the steering wheel activates the steered wheels opposite.</b>	Hydraulic hoses for the steering cylinders have been switched around.	Connect lines to correct ports.
<b>Hard point when starting to turn the steering wheel</b>	Spring force in priority valve too weak. Oil is too thick (cold).	Replace spring by a stronger. Let motor run until oil is warm.
<b>Too little steering force (possibly to one side only).</b>	Pump pressure too low. Too little steering cylinder. Piston rod area of the differential cylinder too large compared with piston diameter.	Correct pump pressure. Fit a larger cylinder. Fit cylinder with thinner piston rod or 2 differential cylinders.
<b>Leakage at either input shaft, end cover, gear-wheel set, housing or top part.</b>	Shaft defective. Screws loose. Washers or O-rings defective.	Replace shaft seal. Tighten screws. Replace.

## GROUP 3 TESTS AND ADJUSTMENTS

### 1. HYDRAULIC OIL CLEAN UP PROCEDURE USING PORTABLE FILTER CADDY

- ※ Service equipment and tool.
  - Portable filter caddy
  - Two 3658 mm (12 ft) × 1" I.D. 100R1 hoses with 3/4 M NPT ends
  - Quick disconnect fittings
  - Discharge wand
  - Various size fittings and hoses
- ※ Brake system uses oil from hydraulic oil tank. Flush all lines in the steering system.  
Disassemble and clean major components for steering system.  
Steering components may fail if steering system is not cleaned after hydraulic oil tank contamination.
- 1) If hydraulic system is contaminated due to a major component failure, remove and disassemble steering cylinders to clean debris from cylinders.
- 2) Install a new return filter element. Clean filter housing before installing new element.
- ※ For a failure that creates a lot of debris, remove access cover from hydraulic oil tank. Drain and clean hydraulic oil tank of fill the specified oil to hydraulic oil tank through upper cover.
- 3) To minimize oil loss, pull a vacuum in hydraulic oil tank using a vacuum pump. Connect filter caddy suction line to drain port at bottom of hydraulic oil tank using connector. Check to be sure debris has not closed drain port.
- 4) Put filter caddy discharge line into hydraulic oil tank filter hole so end is as far away from drain port as possible to obtain a through cleaning of oil.

- 5) Start the filter caddy. Check to be sure oil is flowing through the filters.  
Operate filter caddy approximately 10 minutes so oil in hydraulic oil tank is circulated through filter a minimum of four times.  
※ Hydraulic oil tank capacity 184 ℓ (48.6 U.S. gal).  
Leave filter caddy operating for the next steps.
- 6) Start the engine and run it at high idle.  
※ For the most effective results, cleaning procedure must start with the smallest capacity circuit then proceed to the next largest capacity circuit.
- 7) Operate all functions, one at a time, through a complete cycle in the following order: clam, steering, bucket, and boom. Also include all auxiliary hydraulic functions.  
  
Repeat procedure until the total system capacity has circulated through filter caddy seven times, approximately 30 minutes.  
Each function must go through a minimum of three complete cycles for a through cleaning for oil.  
  
※ Filtering time for machines with auxiliary hydraulic functions must be increased because system capacity is larger.
- 8) Stop the engine. Remove the filter caddy.
- 9) Install a new return filter element.
- 10) Check oil level in hydraulic oil tank ; Add oil if necessary.

## 2. TEST TOOLS

### 1) CLAMP-ON ELECTRONIC TACHOMETER INSTALLATION

- Service equipment and tools

Tachometer

A : Clamp on tachometer.

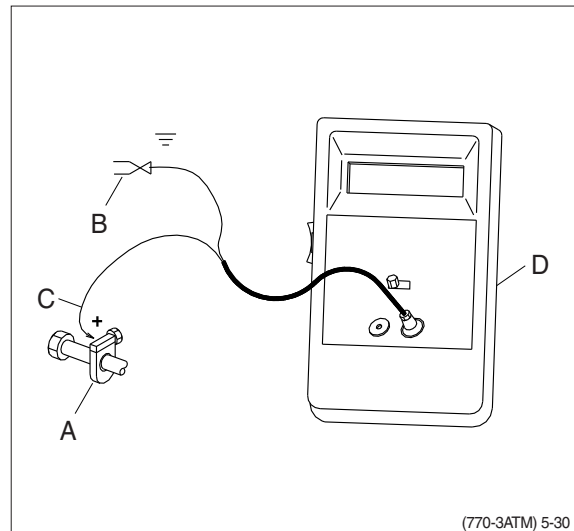
Remove paint using emery cloth and connect to a straight section of injection line within 100 mm (4in) of pump.

Finger tighten only-do not over tighten.

B : Black clip (-). Connect to main frame.

C : Red clip (+). Connect to transducer.

D : Tachometer readout. Install cable.



### 2) DIGITAL THERMOMETER INSTALLATION

- Service equipment and tools

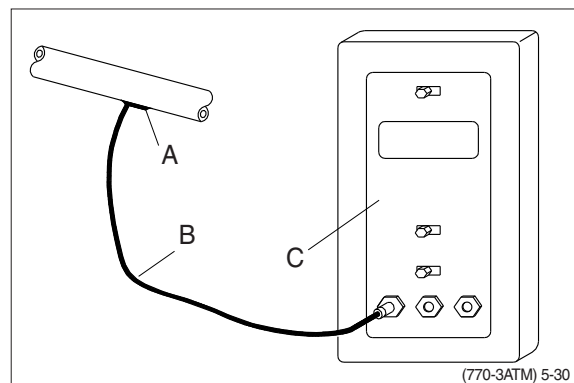
Digital thermometer

A : Temperature probe.

Fasten to a bare metal line using a tie band. Wrap with shop towel.

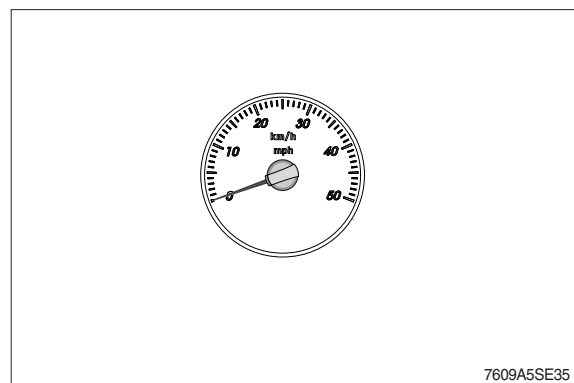
B : Cable.

C : Digital thermometer.



### 3) DISPLAY MONITOR TACHOMETER

The display monitor tachometer is accurate enough for test work.



### 3. STEERING SYSTEM RESTRICTION TEST

- **SPECIFICATION**

Oil temperature       $45 \pm 5^{\circ}\text{C}$  ( $113 \pm 9^{\circ}\text{F}$ )  
Engine speed          High idle  
Maximum pressure    2.1MPa (21 bar, 300psi)  
at flow amplifier

- **GAUGE AND TOOL**

Gauge 0~7 MPa (0~70 bar, 0~1000 psi) 2EA

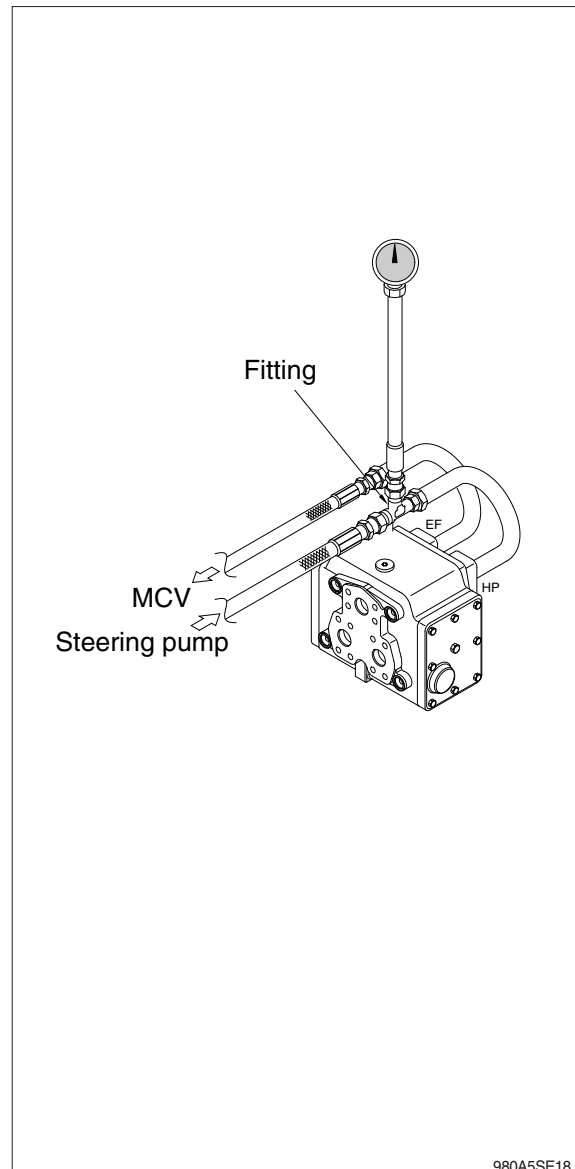
- This test will check for restrictions in the steering system which can cause overheating of hydraulic oil.

- 1) Install temperature reader.  
(see temperature reader installation procedure in this group).
- 2) Heat hydraulic oil to specifications.  
(see hydraulic oil warm up procedure at page 6-54).
- 3) Connect fitting and install gauge.

**⚠ Do not operate steering or loader functions or test gauge may be damaged.**

- 4) Run engine at specification and read pressure gauges.

If pressure is more than specification at the flow amplifier, inspect flow amplifier for a priority valve spool. Make sure orifice plugs installed in ends of priority valve spool. Check for plugged orifice in flow amplifier LS port.



#### 4. STEERING UNIT LEAKAGE TEST

- **SPECIFICATION**

Oil temperature  $45 \pm 5^{\circ}\text{C}$  ( $113 \pm 9^{\circ}\text{F}$ )

Engine speed High idle

Maximum leakage  $7.5 \text{ } \ell / \text{min}$  (2 gpm)

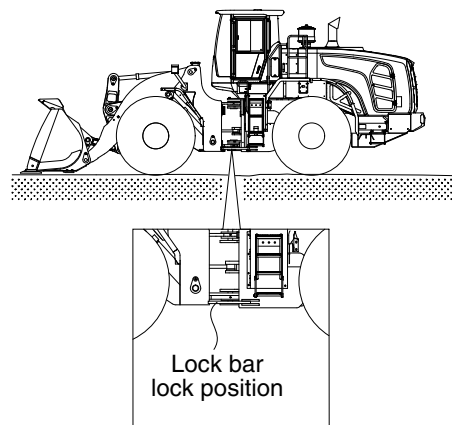
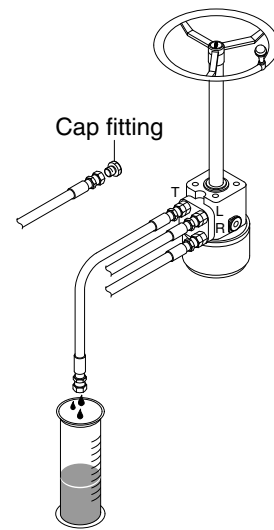
- **GAUGE AND TOOL**

Temperature reader

Measuring container (approx. 20  $\ell$  )

Stop watch

- 1) Install frame locking bar to prevent machine from turning.
- 2) Install temperature reader.  
(see temperature reader installation procedure in this group).
- 3) Heat hydraulic oil to specifications.  
(see hydraulic oil warm up procedure at page 6-54).
- 4) Disconnect return hose from fitting.  
Install cap fitting.
- 5) Run engine at specifications. Rotate steering wheel against locking bar using approximately  $1.2 \text{ kgf} \cdot \text{m}$  of force.  
Measure oil flow from return hose for 1 minute.
- 6) Leakage is greater than specifications,  
repair or replace steering unit.



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## 5. FLOW AMPLIFIER PRESSURE TEST

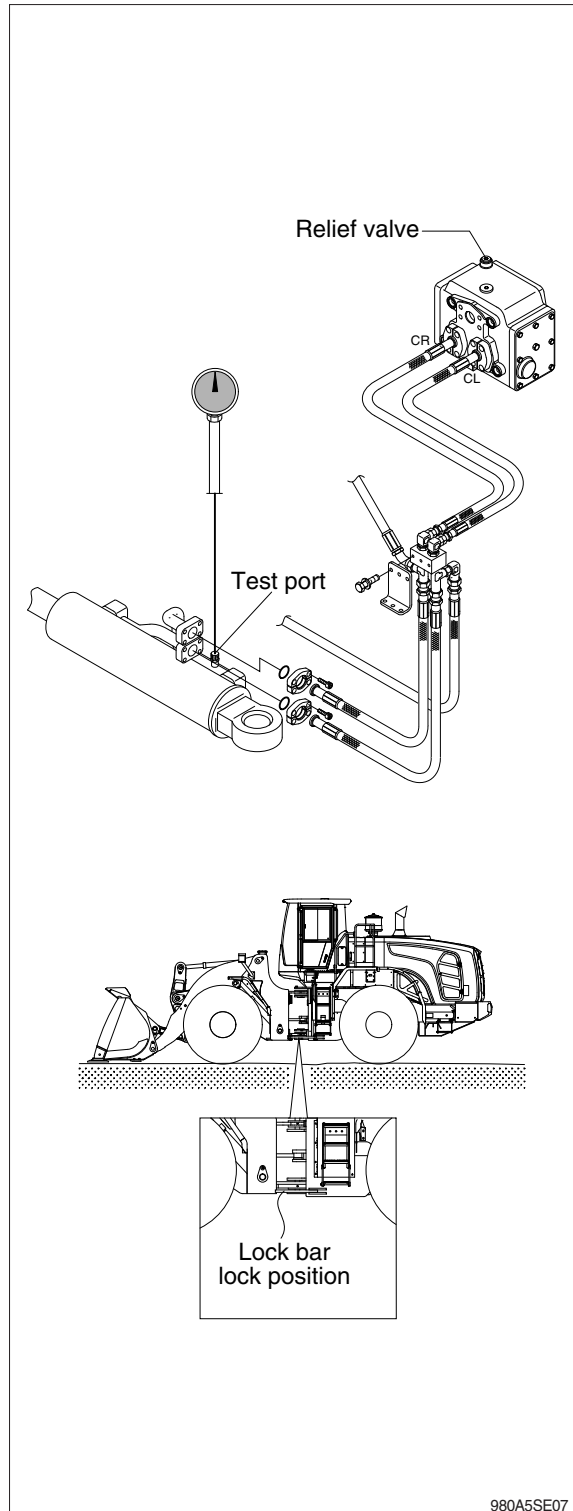
### · SPECIFICATION

Oil temperature	$45 \pm 5^{\circ}\text{C}$ ( $113 \pm 9^{\circ}\text{F}$ )
Engine speed	High idle
Oil pressure	20.1~21.1 MPa (205~215 bar, 2900~3100 psi)

### · GAUGE AND TOOL

Gauge 0~35 MPa (0~350 bar, 0~5000 psi)  
Temperature reader

- 1) Connect gauge to test port.
- 2) Install temperature reader (see installation procedure in this group).
- 3) Install frame locking bar.
- 4) Heat hydraulic oil to specifications.  
(see hydraulic oil warm up procedure at page 6-54)
- 5) Run engine at specifications and turn steering wheel rapidly hold approximately 22N (5lb force) pressure on wheel with frames locked.
  - ※ If steering wheel is turned slowly, it will continue to with the frames locked. This will give an incorrect pressure reading.  
If steering wheel continues to turn rapidly with the frames locked, steering system leakage is indicated.
- 6) Read pressure gauge. This is the flow amplifier relief pressure.
- 7) If pressure is not to specification, turn adjusting screw in relief cartridge using a hex head wrench to adjust pressure.  
  
If pressure cannot be adjusted to specification, disassemble and inspect flow amplifier.





## 6. FLOW AMPLIFIER LS PORT FLOW TEST

### · SPECIFICATION

Oil temperature  $45 \pm 5^{\circ}\text{C}$  ( $113 \pm 9^{\circ}\text{F}$ )  
Engine speed Low idle  
LS port flow (approx.) 1 mℓ/min

### · GAUGE AND TOOL

Temperature reader  
Measuring container  
Stop watch

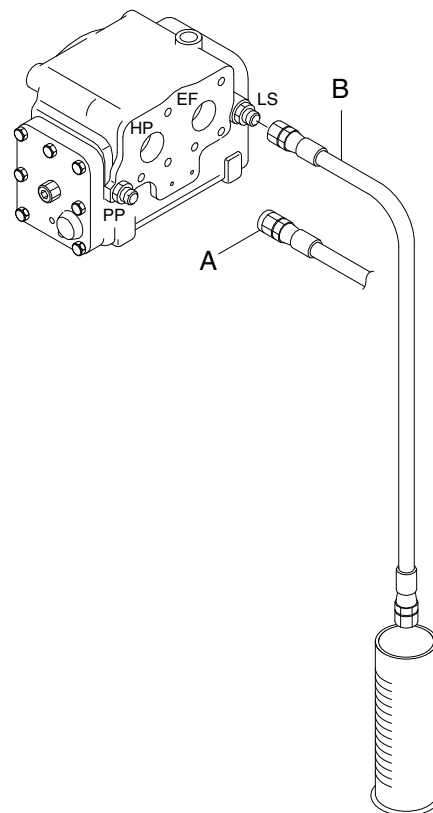
Flow amplifier LS port flow test will check for a plugged or missing orifice in the bottom of the priority valve spool. A plugged orifice will block warm up flow to the steering unit which can cause thermal shock (see for an explanation of thermal shock page 5-22).

A missing orifice can cause the pump to be loaded to high pressure at all times causing overheating.

- 1) Install temperature reader (see temperature reader installation procedure in this group.)
- 2) Heat hydraulic oil to specifications (see hydraulic oil warm up procedure at page 6-54).
- 3) Disconnect line from LS port and install plug (A).
- 4) Connect line (B) to flow amplifier.
- 5) Start engine and run at specification.
- 6) Measure flow from LS port for 1 minute.
- 7) If flow is low, low steering system neutral pressure or a plugged orifice in bottom priority valve spool is indicated.

If flow is high, remove priority valve spool and inspect for a missing orifice.

Do hydraulic system restriction test in this group.



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## 7. FLOW AMPLIFIER RELIEF CARTRIDGE LEAKAGE TEST

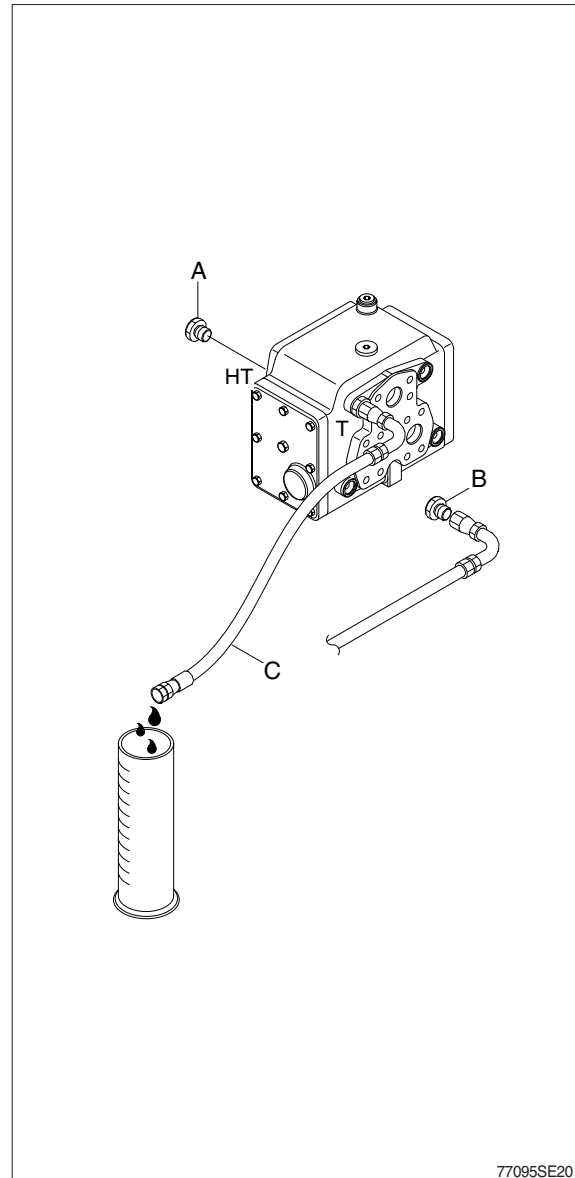
### · SPECIFICATION

Oil temperature  $45 \pm 5^{\circ}\text{C}$  ( $113 \pm 9^{\circ}\text{F}$ )  
Engine speed High idle  
Maximum leakage 1 mℓ/min (16 drops per min)

### · GAUGE AND TOOL

Temperature reader  
Measuring container  
Stop watch

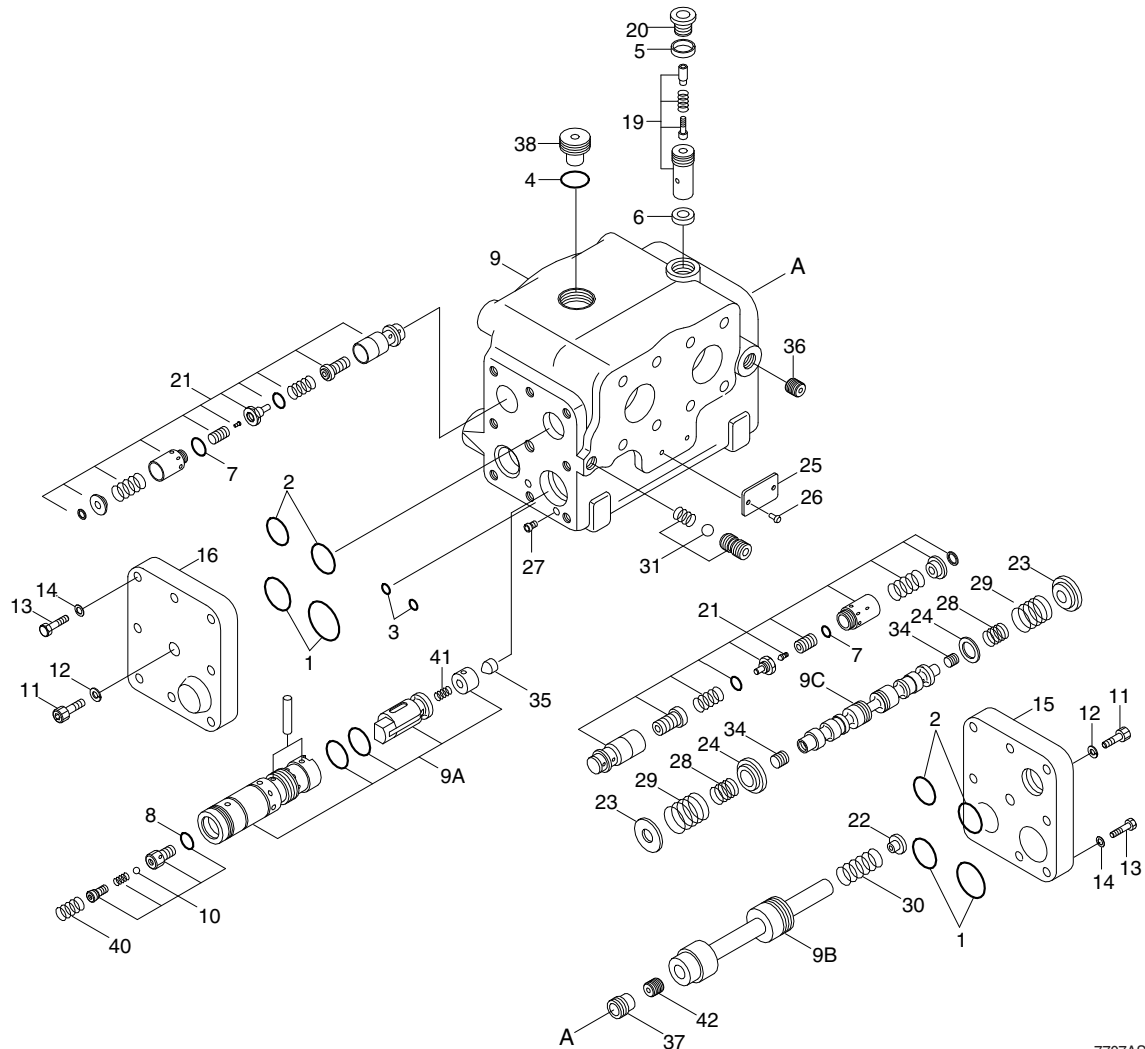
- 1) Install temperature reader.  
(see temperature reader installation procedure in this group).
- 2) Heat hydraulic oil to specifications.  
(see hydraulic oil warm up procedure at page 6-54).
- 3) Install plug (A) in HT port.  
Disconnect line from T port on flow amplifier. Install plug (B) in line.
- 4) Connect line (C) to flow amplifier.
- 5) Start engine and run at specification.
- 6) Measure oil leakage from T port.
- 7) If leakage is more than specification, disassemble and inspect cartridge for damage or debris.



## GROUP 4 DISASSEMBLY AND ASSEMBLY

### 1. FLOW AMPLIFIER

#### 1) STRUCTURE

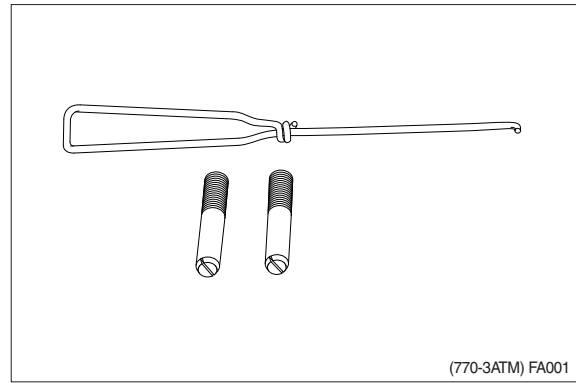


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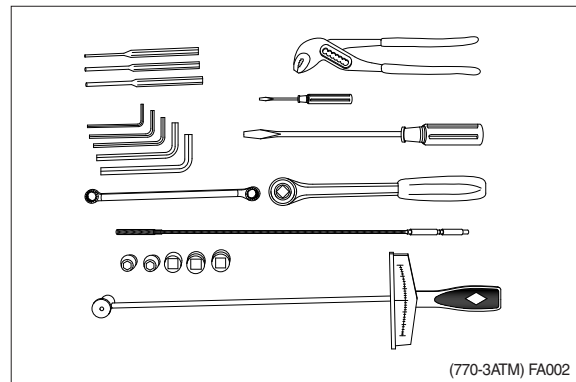
1	O-ring	12	Spring washer	28	Spring
2	O-ring	13	Screw	29	Spring
3	O-ring	14	Spring washer	30	Spring
4	O-ring	15	End cover	31	Throttle check valve
5	Washer	16	End cover	34	Orifice
6	Washer	19	Relief valve	35	Orifice
7	O-ring	20	Plug	36	Orifice
8	O-ring	21	Shock, suction valve	37	Plug
9	Housing	22	Spring seat	38	Plug
9A	Amplifier valve	23	Spring seat	40	Spring
9B	Priority valve	24	Spring guide	41	Spring
9C	Directional valve	26	Name plate	42	Orifice
10	Check valve	27	Orifice		
11	Screw				

## 2) TOOLS

- Guide screws : M8×1.0
- Hook : Wire



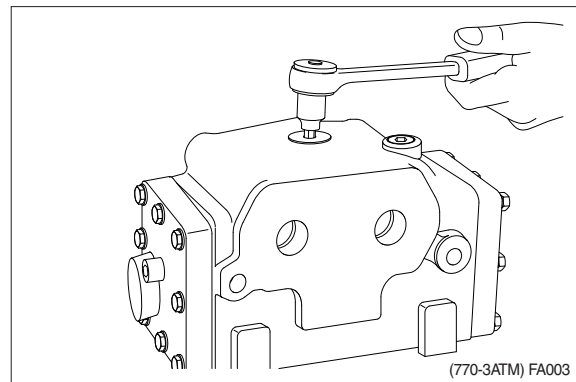
- Hexagon keys : 4, 5, 6, 8 and 10 mm
- Ratchet for socket spanners
- Hex socket for external : 13, 17 & 19 mm
- Hex socket for internal : 8 & 10 mm
- Multigrip pliers
- Ring spanner: 13 mm
- Screwdrivers : 3 and 10 mm
- Steel Mandrels : 3, 5 and 8 mm
- Torque wrench : 12.2 kgf · m (88 lbf · ft)
- Magnetic rod



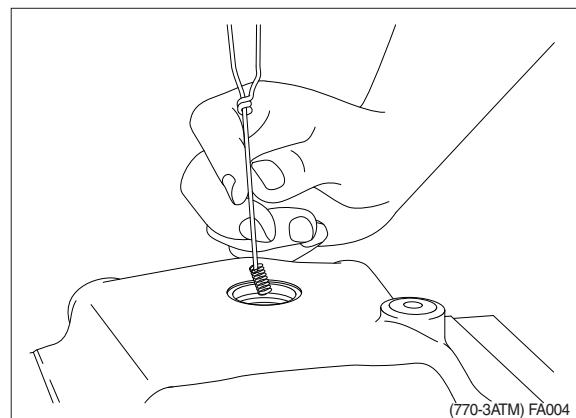
## 3) DISASSEMBLY

### (1) Disassembly counter pressure valve

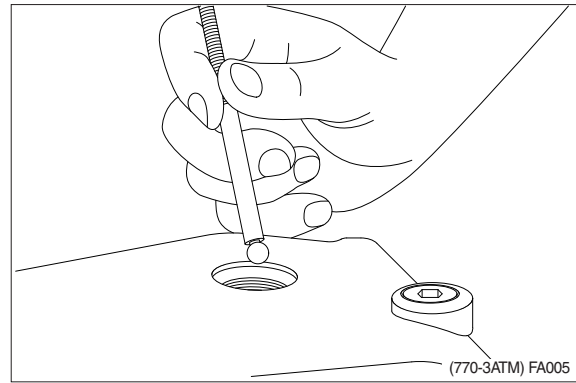
- ① Unscrew plug with O-ring (hexagon socket for 8 mm internal hexagon).



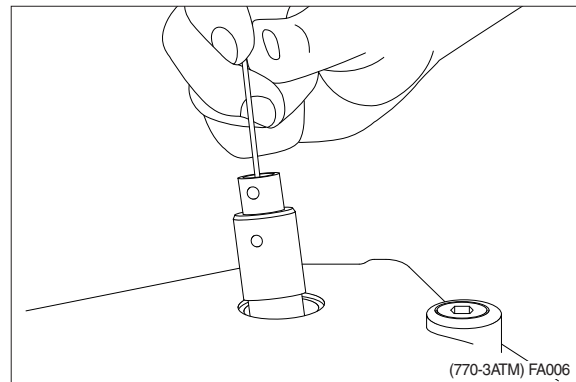
- ② Take out small spring (hook).



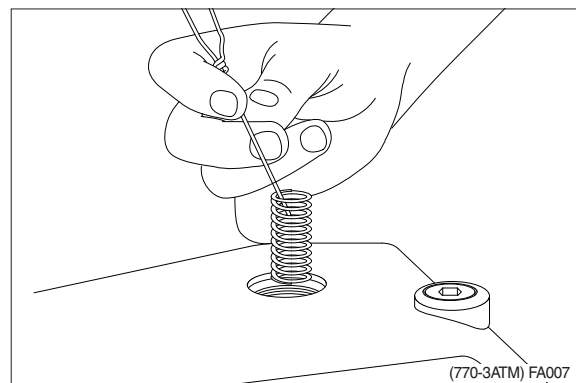
- ③ Take out ball (magnetic rod).



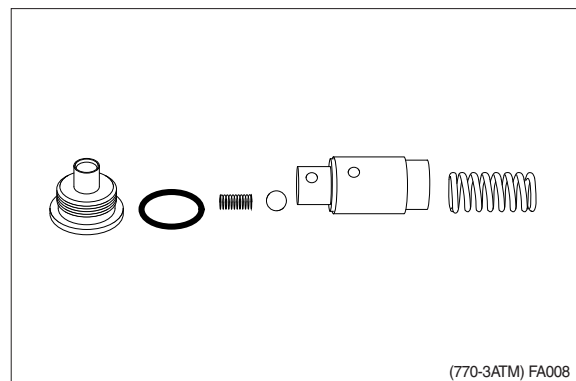
- ④ Take out piston.



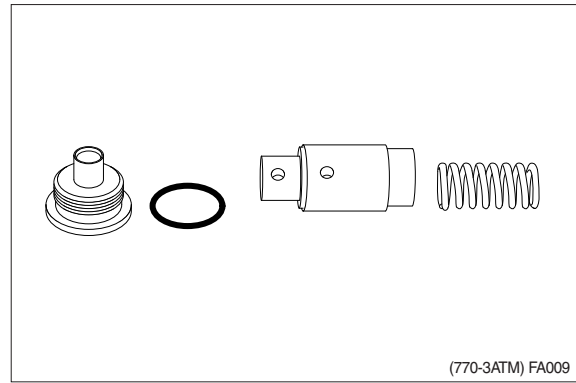
- ⑤ Take out spring.



- ⑥ Counter pressure valve shown disassembled.

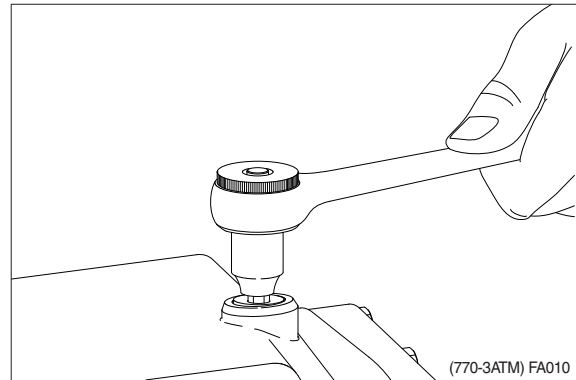


- ⑦ Counter pressure valve with orifice shown disassembled.

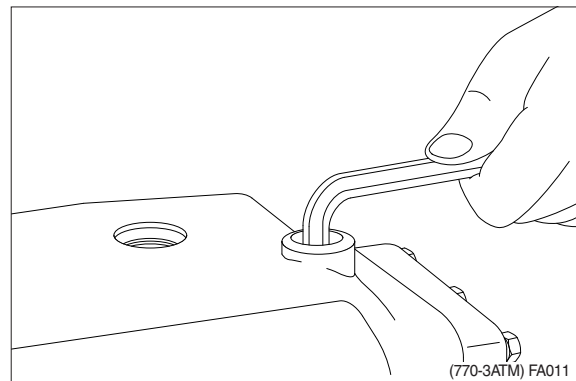


**(2) Removing pressure relief valve**

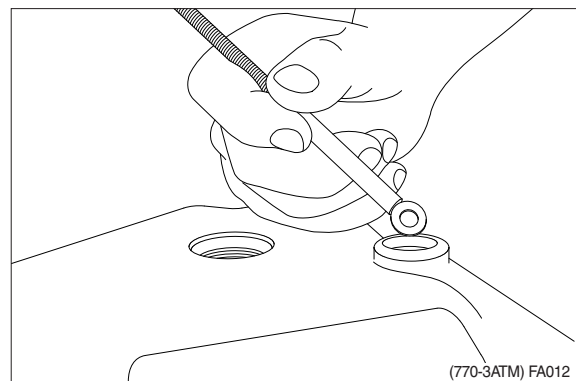
- ① Unscrew plug with washer (hexagon socket for 8 mm internal hexagon).



- ② Screw pressure relief valve out (10 mm hexagon key).

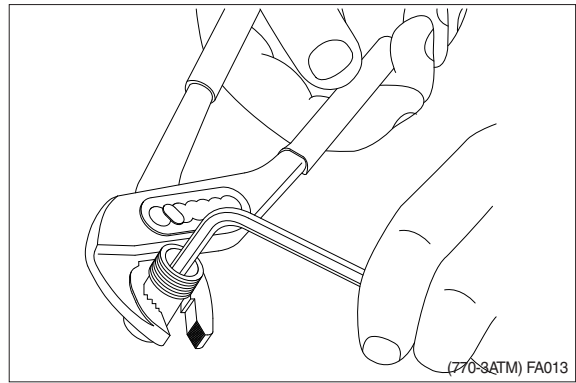


- ③ Take out washer (magnetic rod).

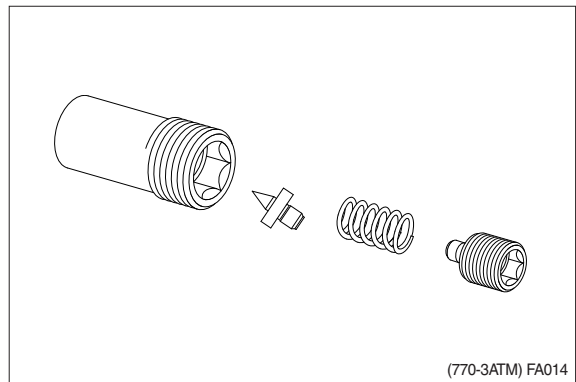


### (3) Disassembly pressure relief valve

- ① Hold cartridge (multigrip pliers) and screw the adjustment screw out (5 mm hexagon key).

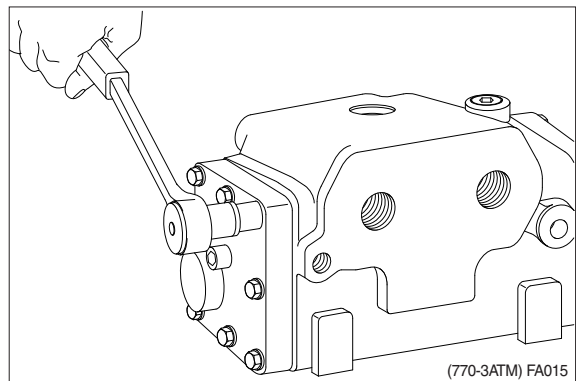


- ② Pressure relief valve shown disassembled.

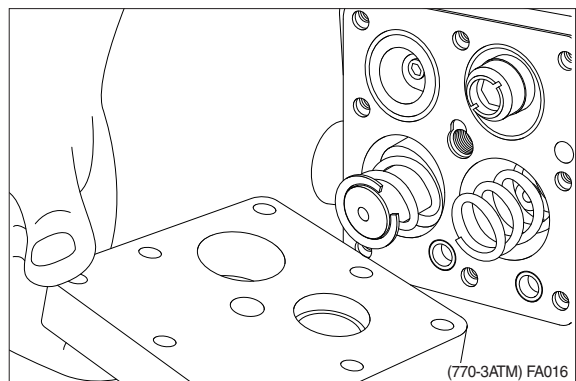


### (4) Removing end cover at PP-connection

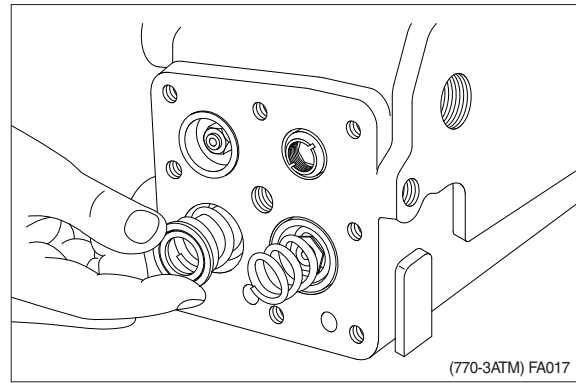
- ① Unscrew screws with spring washer using hexagon socket for 13 mm external hexagon and 10 mm internal hexagon.



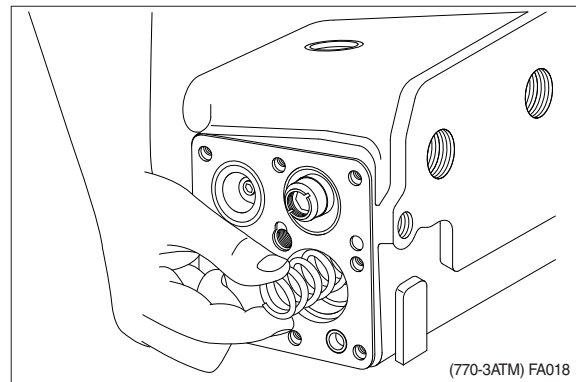
- ② Remove end cover.



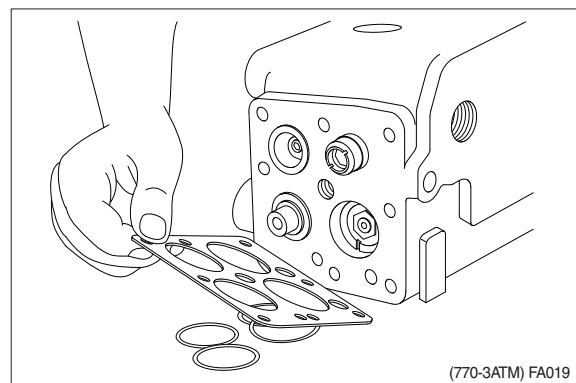
- ③ Remove stop and 2 springs.



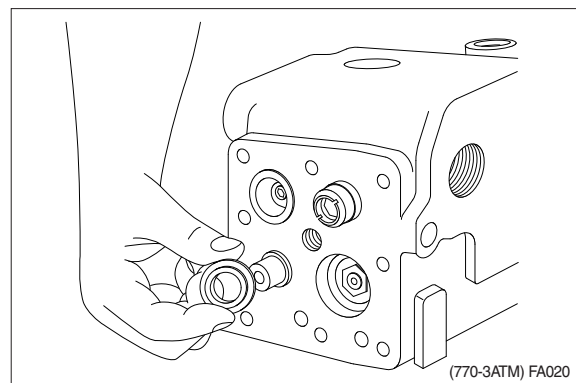
- ④ Remove spring.



- ③ Remove plate and 6 O-rings.



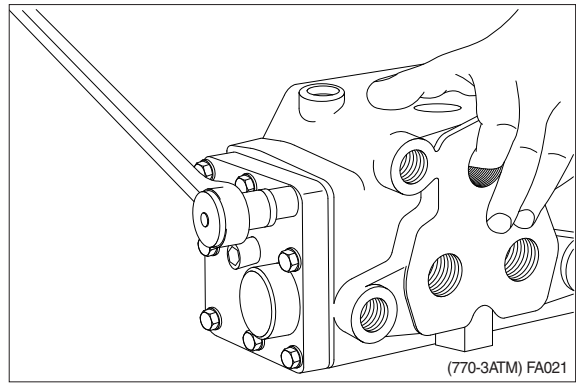
- ④ Remove spring guide.



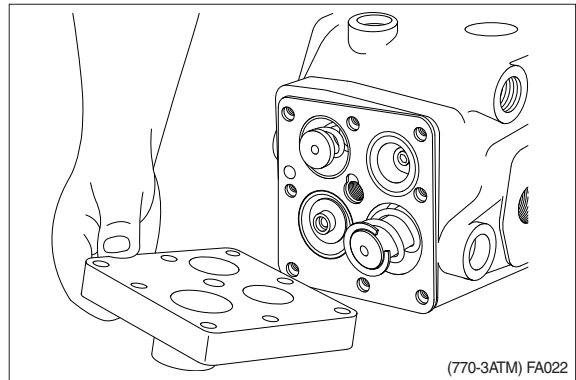


### (5) Removing end cover at LS-connection

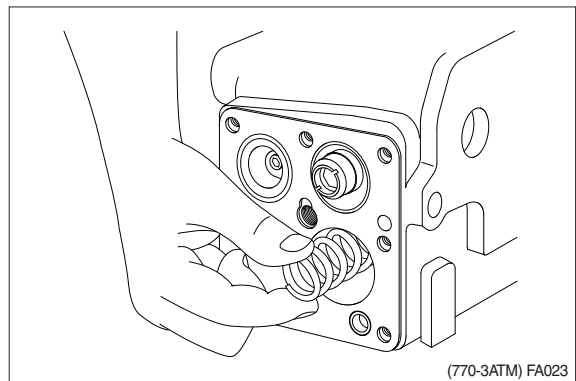
- ① Unscrew screws with spring washer using hexagon socket for 13 mm external hexagon and 10 mm internal hexagon.



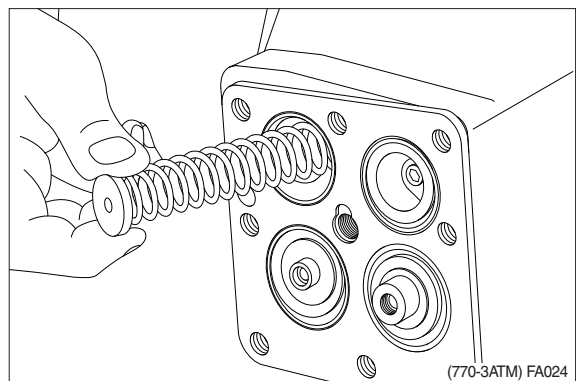
- ② Remove end cover.



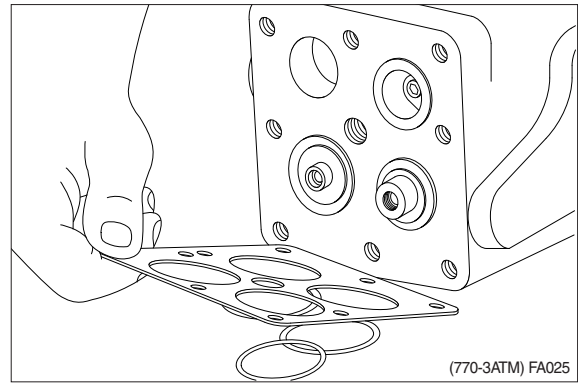
- ③ Remove stop and 2 springs.



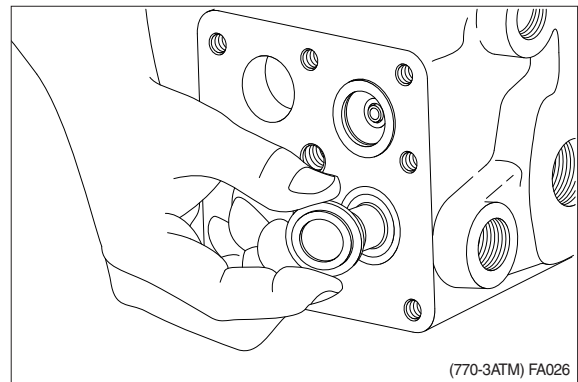
- ④ Remove stop and spring.



- ⑤ Remove plate and 4 O-rings.

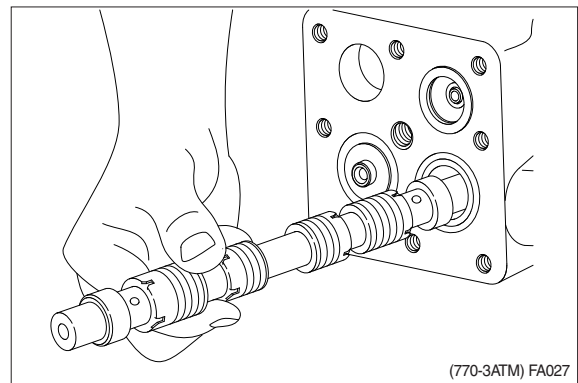


- ⑥ Remove spring guide.

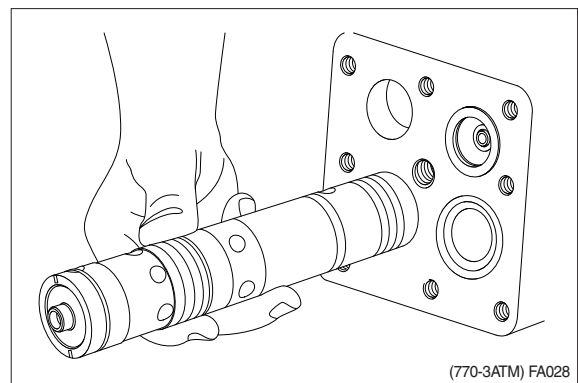


## (6) Removing spools

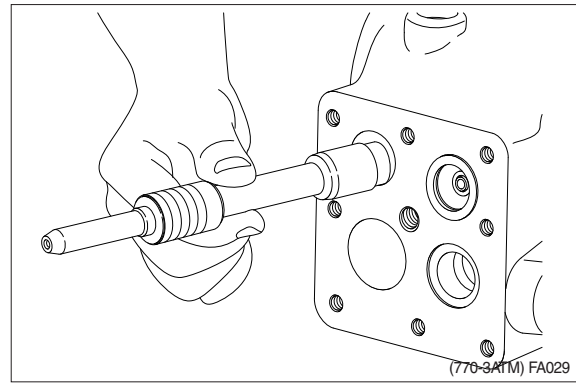
- ① Remove directional spool.



- ② Remove amplifier spool.

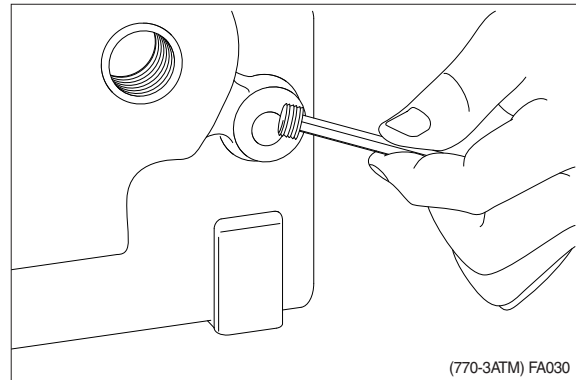


- ③ Remove priority valve spool.

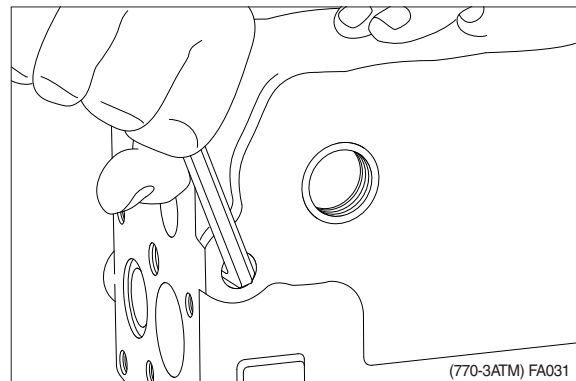


**(7) Removing orifices and throttle check valve**

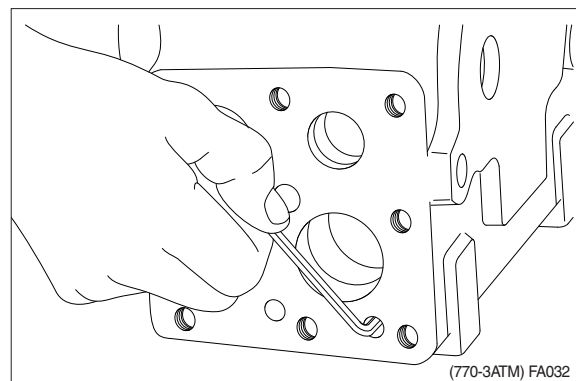
- ① Unscrew orifice in LS-connection with 6 mm hexagon key.



- ② Unscrew throttle check valve in PP-connection with 6mm hexagon key.

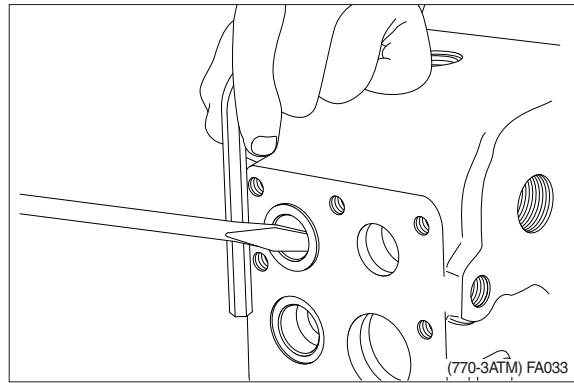


- ③ Unscrew orifice in housing with 4 mm hexagon key.



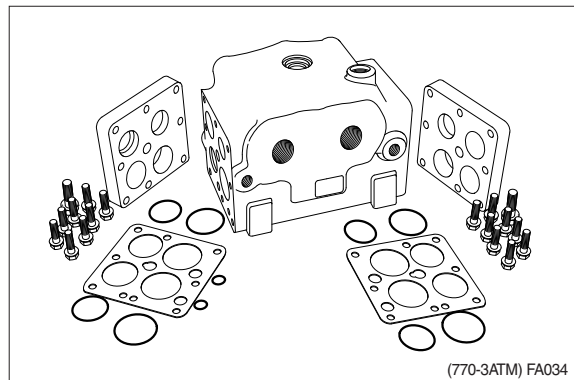
## (8) Removing shock valves

- ① Remove shock valve with screwdriver and hexagon key.

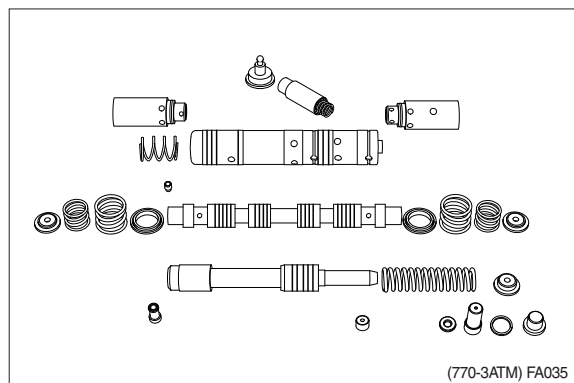


## (9) Overview of disassembled parts

- ① Housing and end cover with accessories.

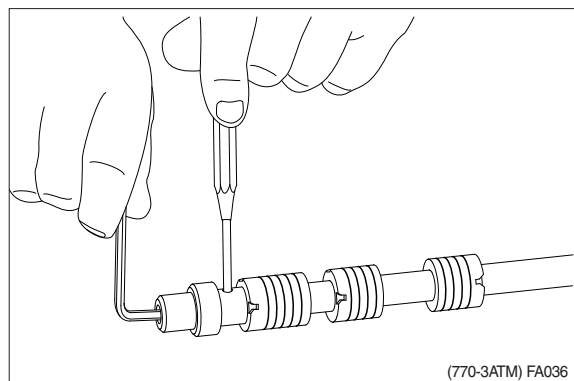


- ② Spool with accessories.

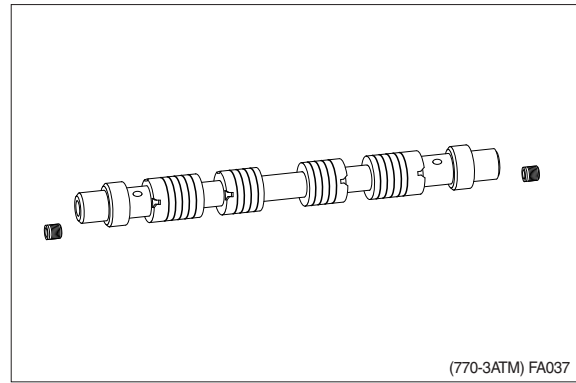


## (10) Disassembly of directional spool

- ① Unscrew orifice with 4 mm hexagon key. Use a mandrel.

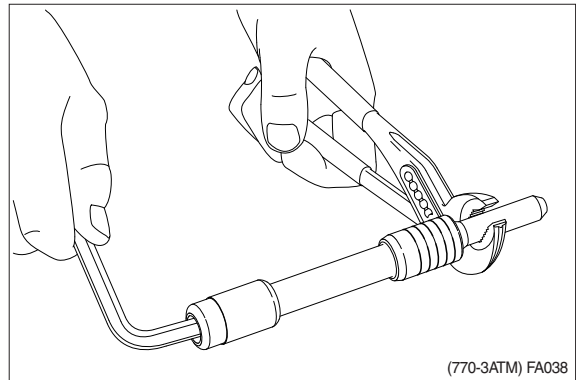


- ② Directional spool shown disassembled.

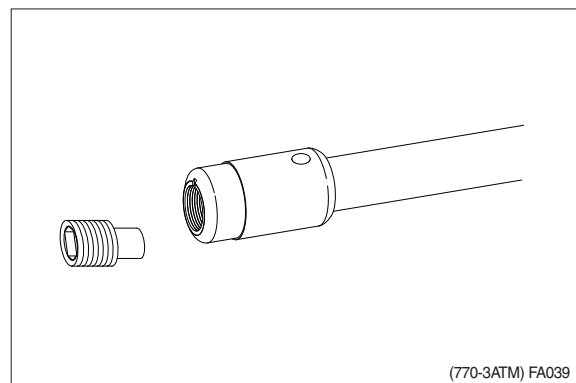


### (11) Disassembly of priority valve spool

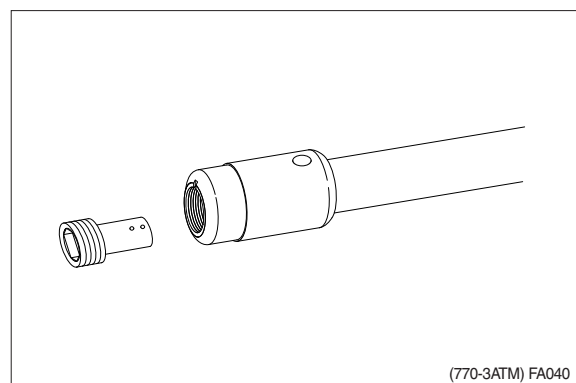
- ① Unscrew plug or throttle check valve with 8 mm hexagon key.



- ② Priority valve spool with plug for external PP shown disassembled.

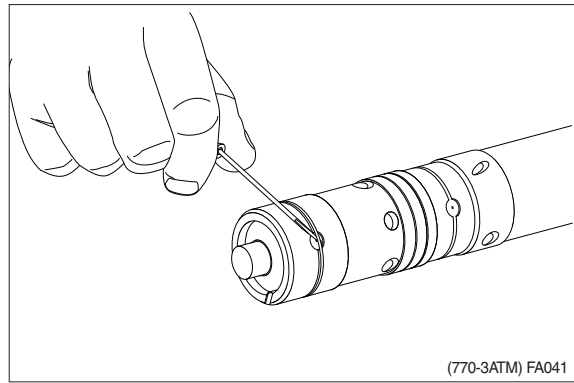


- ③ Priority valve spool with throttle check valve for internal PP shown disassembled.

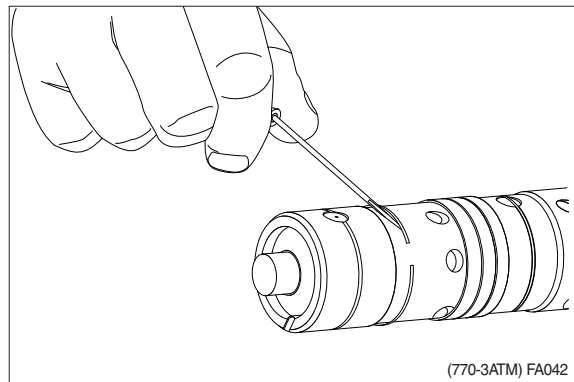


## (12) Disassembly of amplifier spool

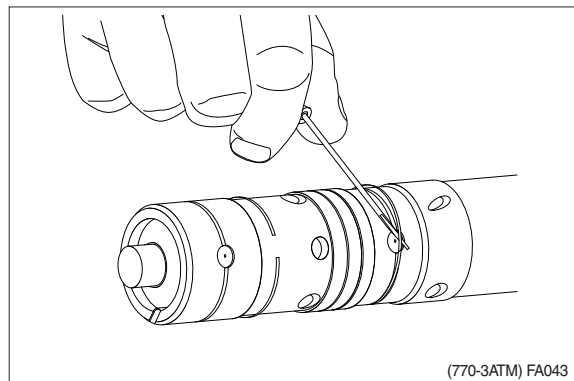
- ① Carefully remove the spring ring from the recess with 3mm screwdriver.
- ※ Avoid damage to the spring ring.



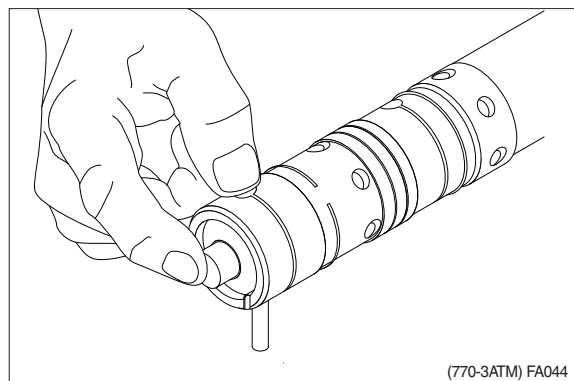
- ② Carefully guide the spring ring back.



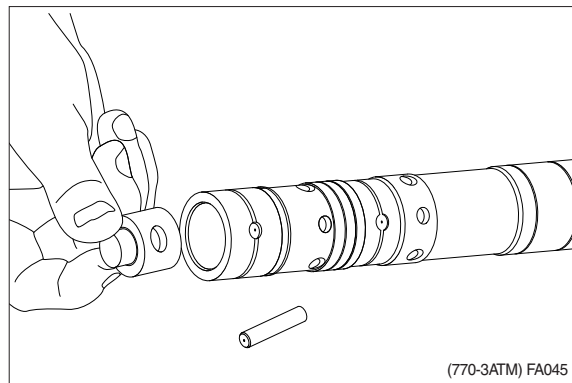
- ③ Carefully take the spring ring from the recess and guide it back with 3mm screwdriver.
- ※ Avoid damage to the spring ring.



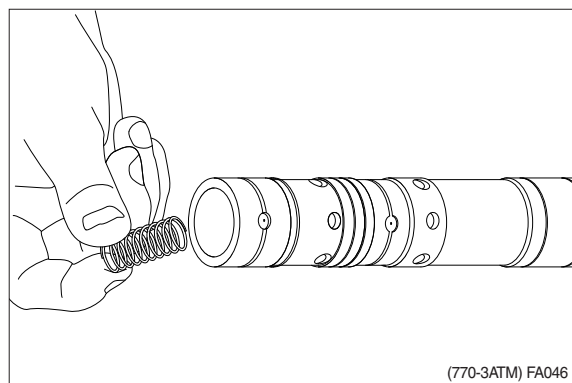
- ④ Press pin out gently with finger.



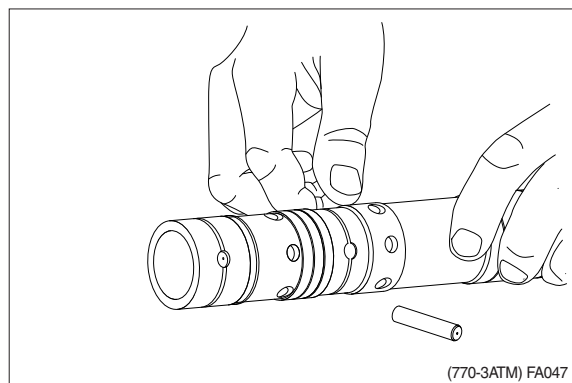
- ⑤ Take out plug.



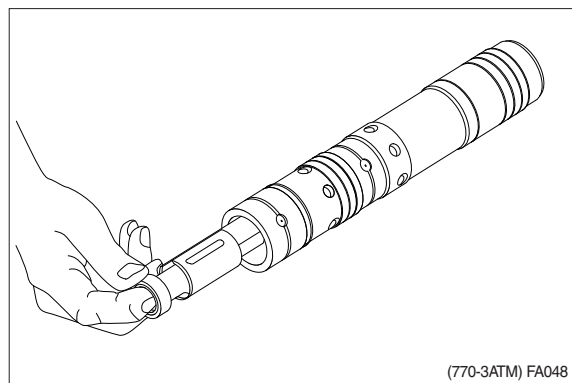
- ⑥ Take out spring.



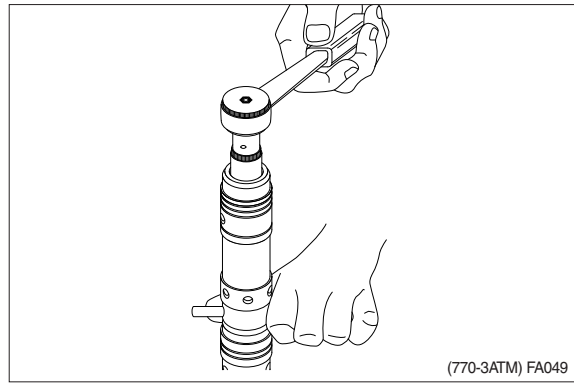
- ⑦ Take out pin 3mm screwdriver.



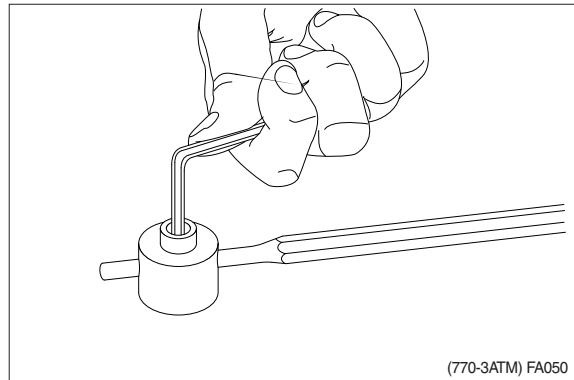
- ⑧ Take out inner spool.



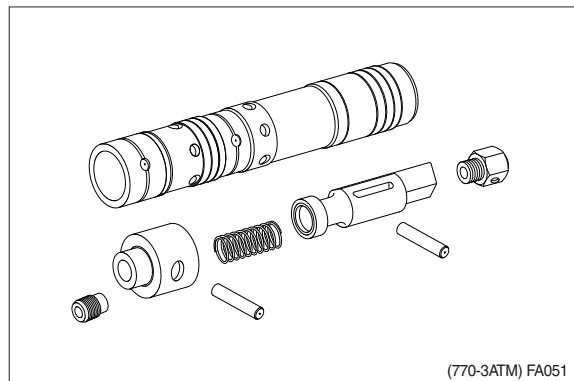
- ⑨ Unscrew check valve with hexagon socket for 17 mm external hexagon and mandrel in the pin hole.  
※ Avoid damaging the spool surface.



- ⑩ Unscrew orifice out of plug with 4 mm hexagon key. Use a mandrel.

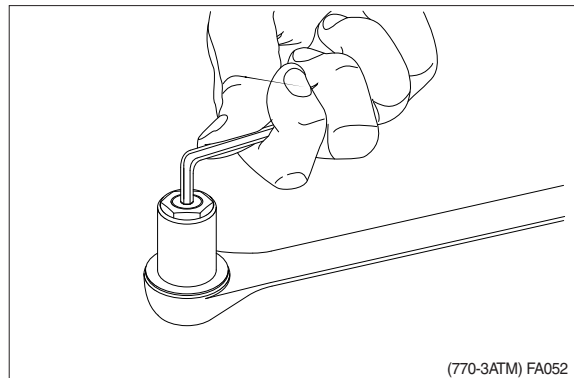


- ⑪ Amplifier spool shown disassembled.



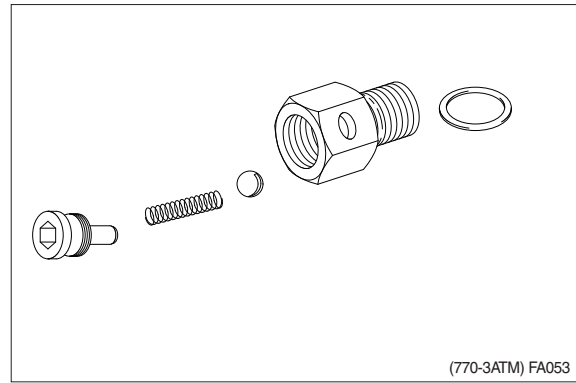
### (13) Disassembly of check valve

- ① Unscrew plug with 4 mm hexagon key and hexagon socket for 17 mm external hexagon.



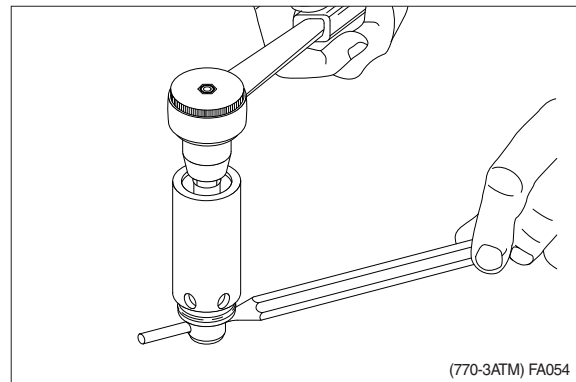


- ② Check valve shown disassembled.

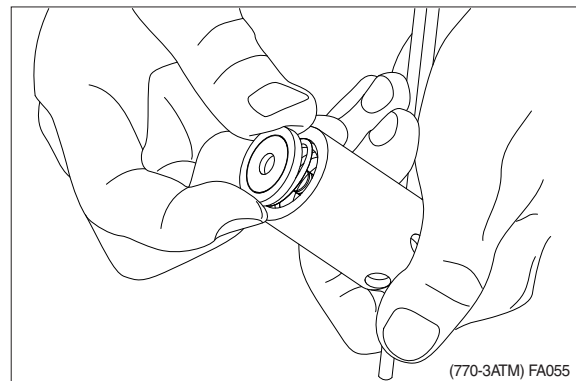


**(14) Disassembly of shock valve / suction valve**

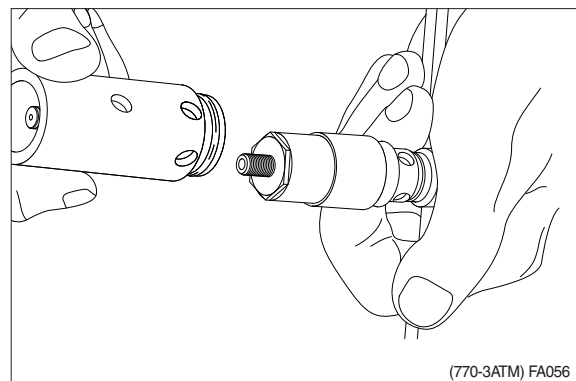
- ① Unscrew locknut with hexagon socket for 13 mm external hexagon. Use a mandrel.
- ※ When readjusting shock valve hold locknut with 13 mm ring spanner.



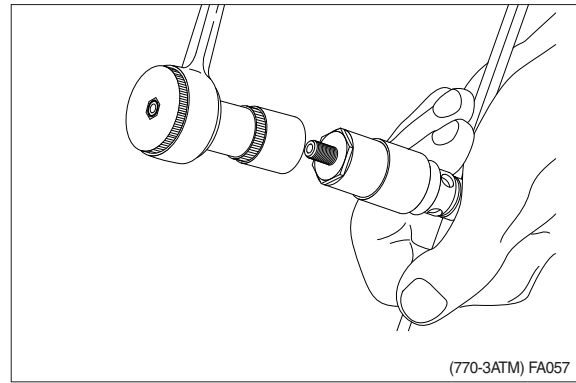
- ② Take out disc and spring.



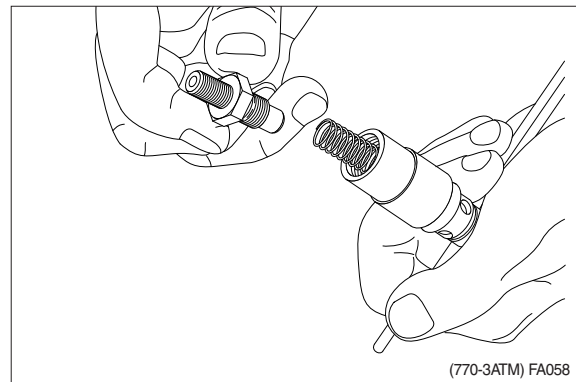
- ③ Take off housing.



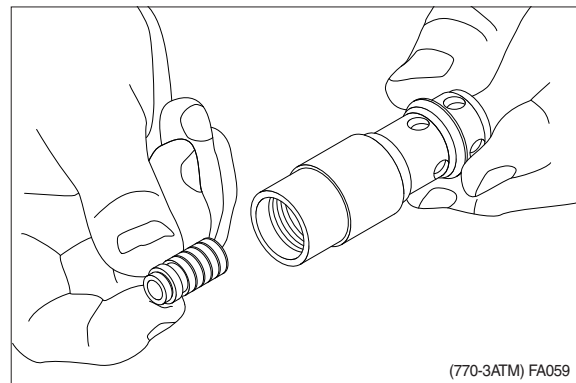
- ④ Unscrew pilot valve with hexagon socket for 19 mm external hexagon. Use a mandrel.



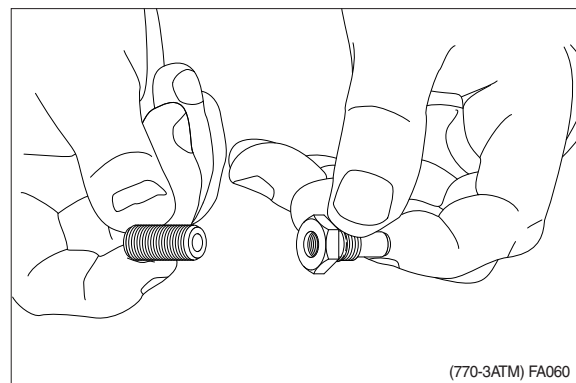
- ⑤ Take out pilot valve and spring.



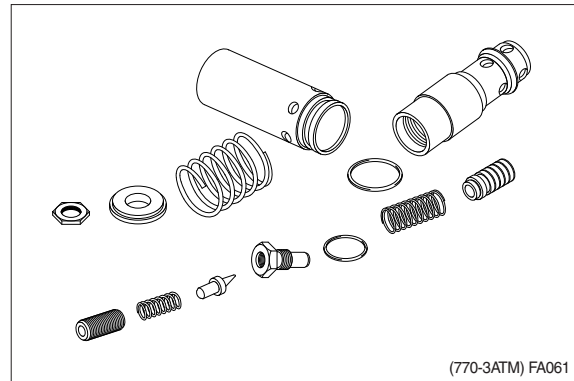
- ⑥ Take out spool.



- ⑦ Unscrew adjustment screw and take out spring and ball.



- ⑧ Shock valve / suction valve shown disassembled.



※ **Cleaning**

Clean all parts carefully with low aromatic kerosene.

※ **Inspection and replacement**

Replace all gaskets and sealing washers. Check all other parts carefully and replace if necessary.

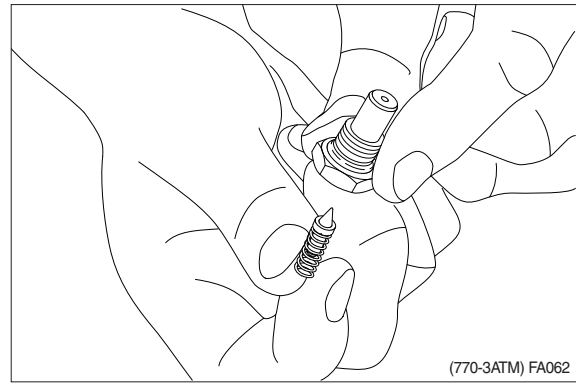
※ **Lubrication**

Before assembly, lubricate all parts with hydraulic oil.

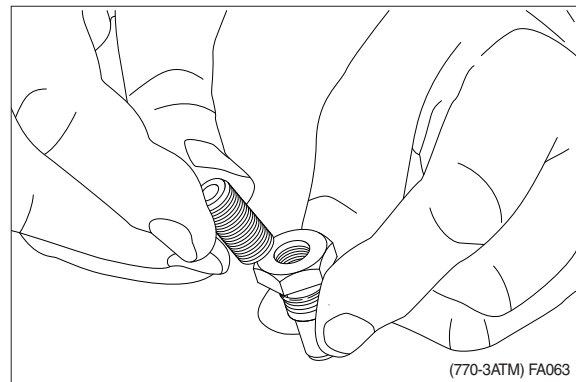
#### 4) ASSEMBLY

##### (1) Assembly of shock valve / suction valve

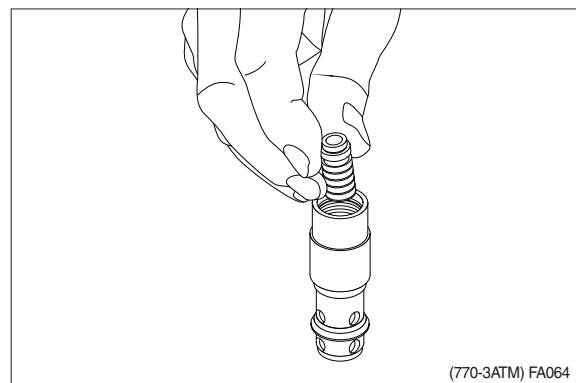
- ① Guide spring with cone into housing.



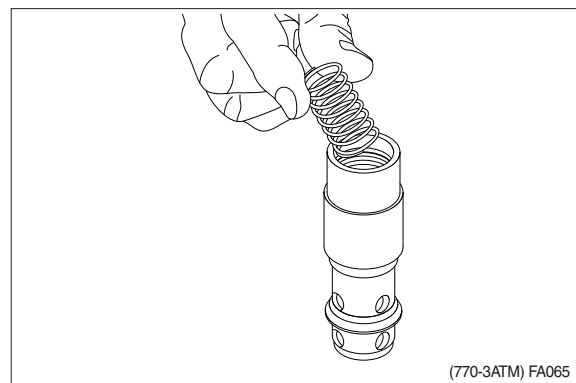
- ② Fit adjustment screw.



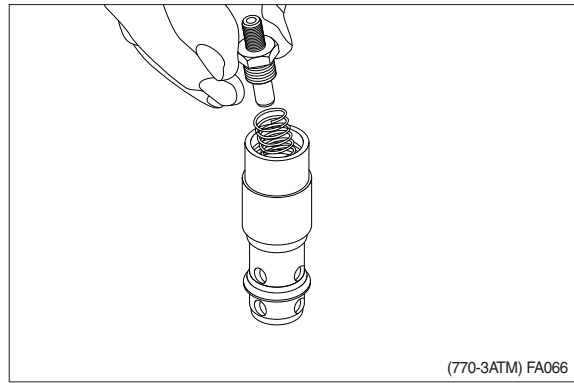
- ③ Fit spool.



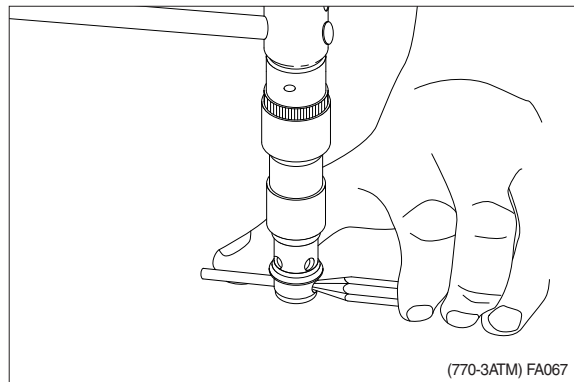
- ④ Fit spring.



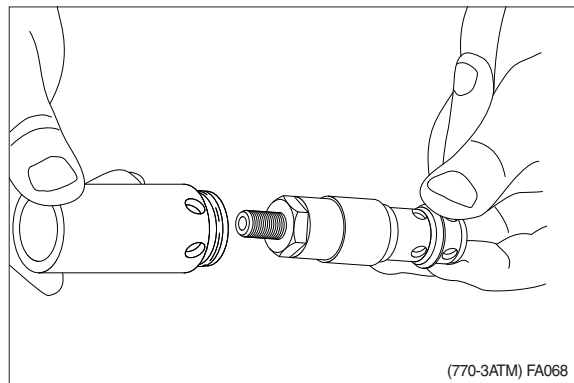
- ⑤ Fit pilot valve.  
Remember O-ring.



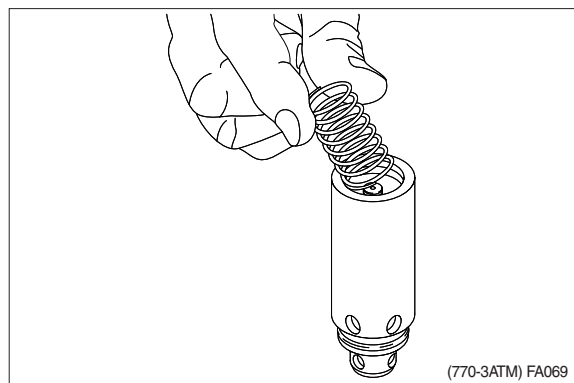
- ⑥ Tighten with torque wrench for 19 mm external hexagon. Use a mandrel.  
· Tightening torque :  $2 \pm 0.5 \text{ kgf} \cdot \text{m}$   
( $14.5 \pm 3.6 \text{ lbf} \cdot \text{ft}$ )



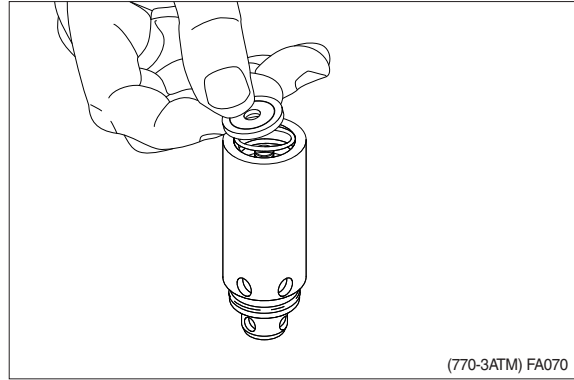
- ⑦ Fit housing.



- ⑧ Fit spring.

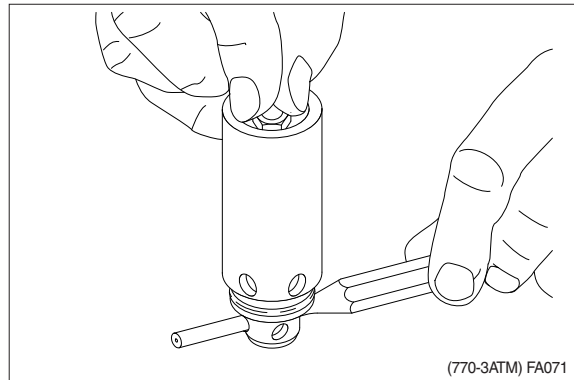


- ⑨ Fit disc.



- ⑩ Fit locknut.

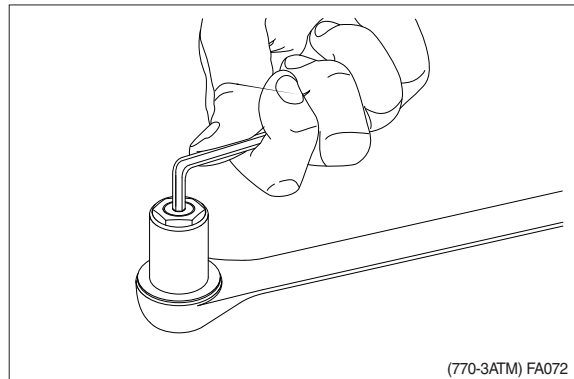
· Tightening torque :  $1.5 \pm 0.2 \text{ kgf} \cdot \text{m}$   
( $10.8 \pm 1.4 \text{ lbf} \cdot \text{ft}$ )



## (2) Assembly of check valve

- ① Fit ball, spring and plug.

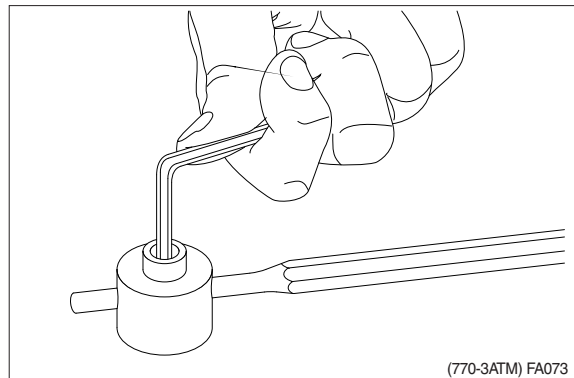
· Tightening torque :  $0.5 \pm 0.1 \text{ kgf} \cdot \text{m}$   
( $3.6 \pm 0.7 \text{ lbf} \cdot \text{ft}$ )



## (3) Assembly of amplifier spool

- ① Fit orifice in plug.

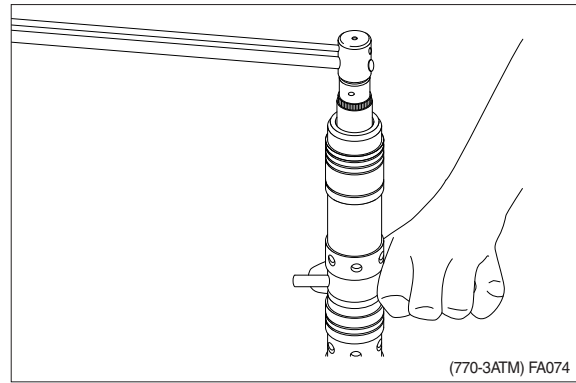
· Tightening torque :  $0.5 \pm 0.1 \text{ kgf} \cdot \text{m}$   
( $3.6 \pm 0.7 \text{ lbf} \cdot \text{ft}$ )



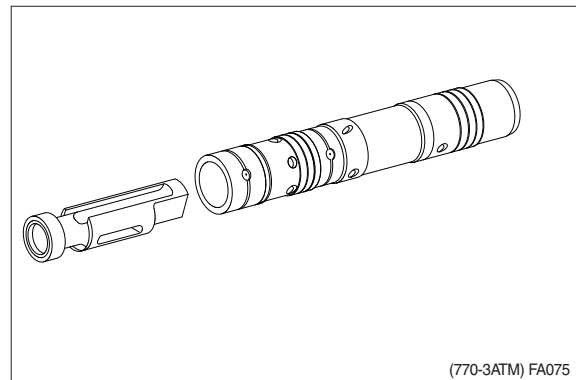
② Fit check valve.

- Tightening torque :  $2 \pm 0.3 \text{ kgf} \cdot \text{m}$   
( $14.5 \pm 2.2 \text{ lbf} \cdot \text{ft}$ )

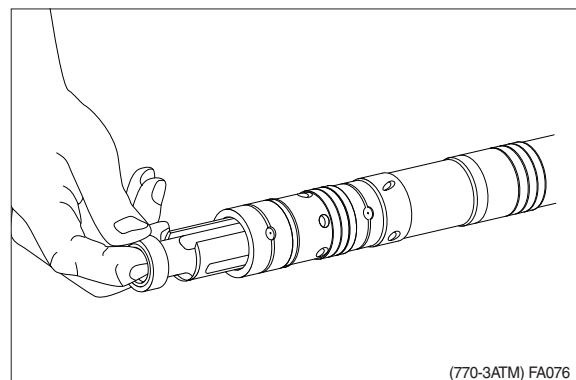
- ※ Avoid damaging spool surface.  
Remember O-ring.



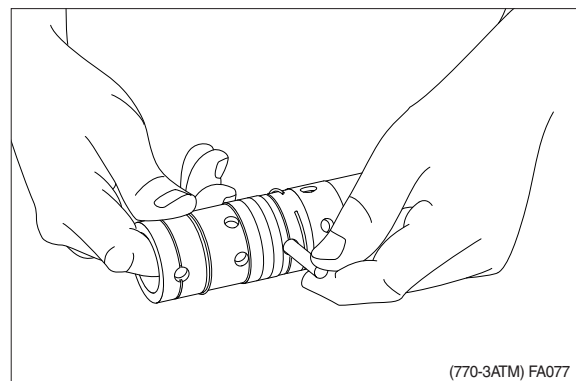
③ Place inner spool in the correct position.



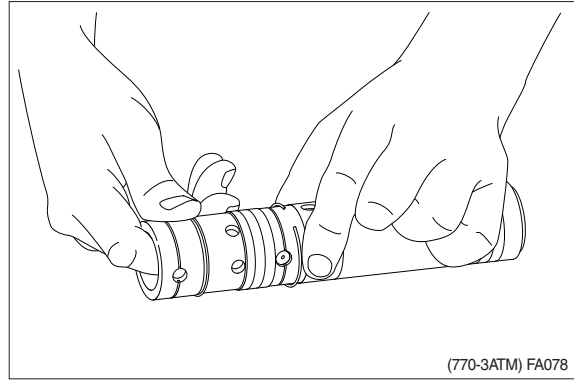
④ Guide inner spool in.



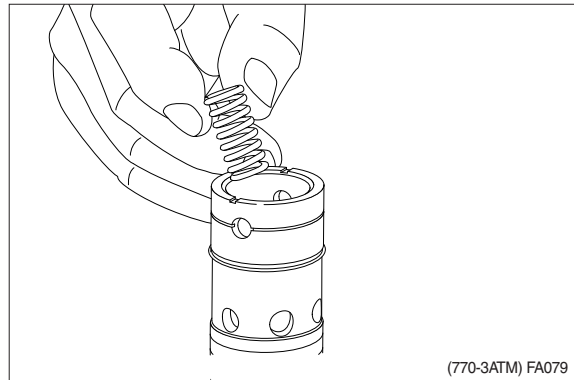
⑤ Fit pin.



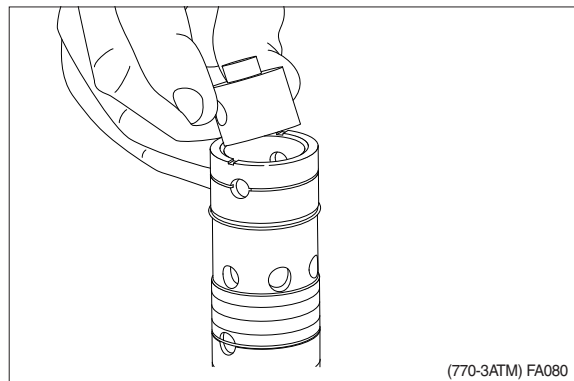
- ⑥ Push spring ring into position. Place spring ring into the recess with ends facing away from pin holes.



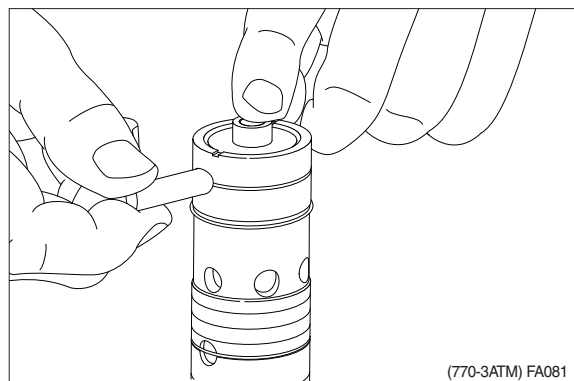
- ⑦ Fit spring.



- ⑧ Fit plug.

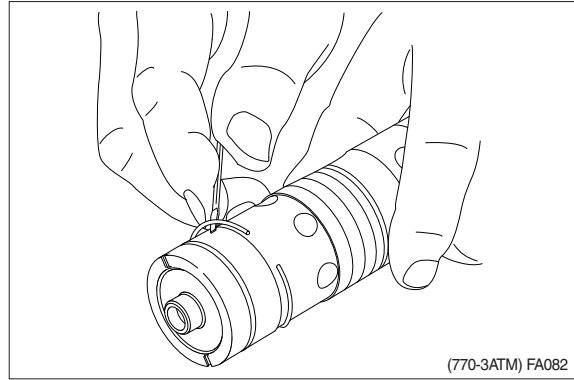


- ⑨ Fit pin.



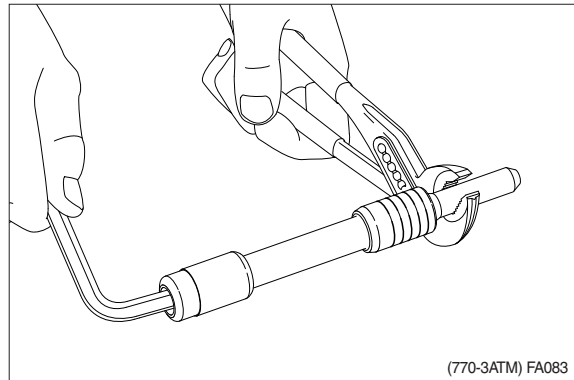


- ⑩ Push spring ring into position. Place spring ring into the recess with ends facing away from pin holes.



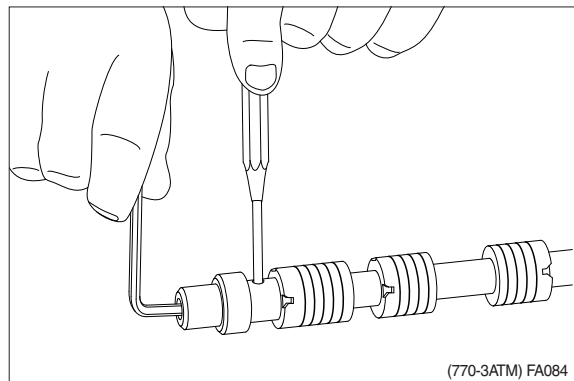
#### (4) Assembly of priority valve spool

- ① Fit plug or throttle check valve.  
External PP : Plug.  
Internal PP : Throttle check valve.  
· Tightening torque :  $1 \pm 0.3 \text{ kgf} \cdot \text{m}$   
( $7.2 \pm 2.2 \text{ lbf} \cdot \text{ft}$ )



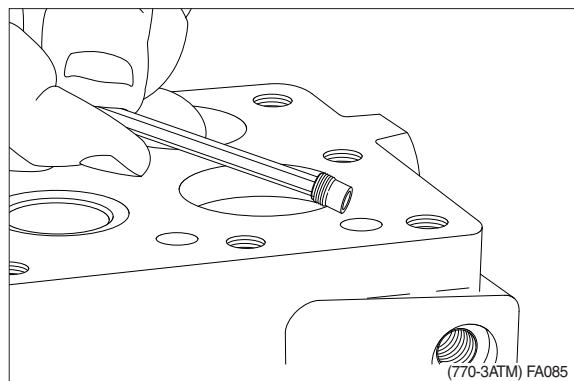
#### (5) Assembly of directional spool

- ① Screw in orifice.  
· Tightening torque :  $0.5 \pm 0.1 \text{ kgf} \cdot \text{m}$   
( $3.6 \pm 0.7 \text{ lbf} \cdot \text{ft}$ )



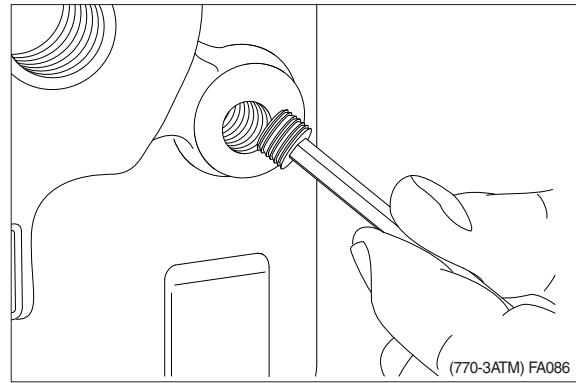
#### (6) Installation of orifice and throttle check valve

- ① Fit orifice in housing.  
· Tightening torque :  $0.5 \pm 0.1 \text{ kgf} \cdot \text{m}$   
( $3.6 \pm 0.7 \text{ lbf} \cdot \text{ft}$ )



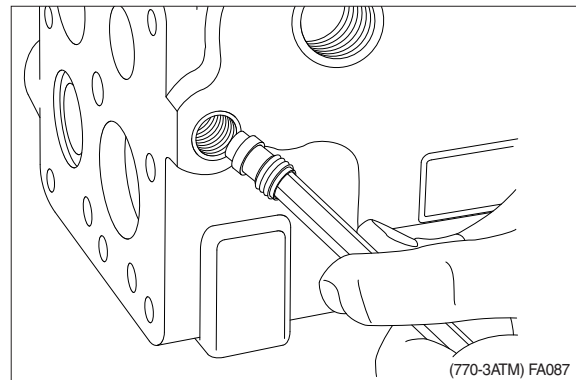
② Fit orifice in LS - connection.

- Tightening torque :  $1 \pm 0.3 \text{ kgf} \cdot \text{m}$   
( $7.2 \pm 2.2 \text{ lbf} \cdot \text{ft}$ )



③ Fit throttle check valve in PP - connection.

- Tightening torque :  $1 \pm 0.3 \text{ kgf} \cdot \text{m}$   
( $7.2 \pm 2.2 \text{ lbf} \cdot \text{ft}$ )



※ Comments on flow amplifiers with internal PP :

1. 1/4 BSP. F in PP - connection.

Fit washer and plug.

- Tightening torque :  $4.1 \pm 0.3 \text{ kgf} \cdot \text{m}$   
( $29.7 \pm 2.2 \text{ lbf} \cdot \text{ft}$ )

2. 7/16 - 20 UNF in PP - connection.

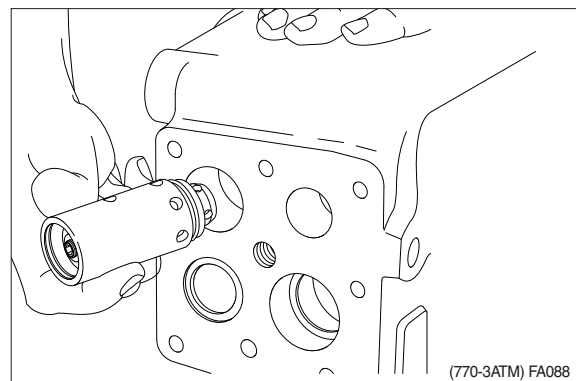
Fit O-ring and plug.

- Tightening torque :  $1.5 \pm 0.5 \text{ kgf} \cdot \text{m}$   
( $10.8 \pm 3.6 \text{ lbf} \cdot \text{ft}$ )

**(7) Installation of shock valves**

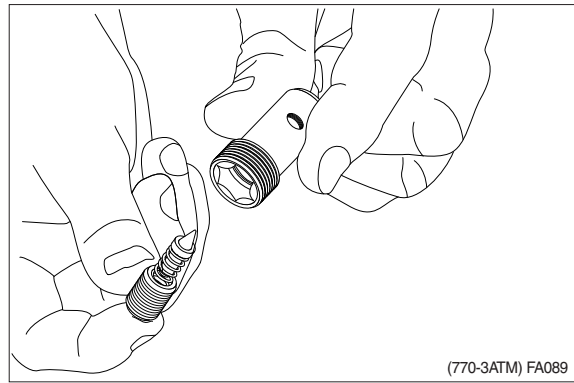
① Guide shock valve in and secure it by hand.

Remember O-ring.

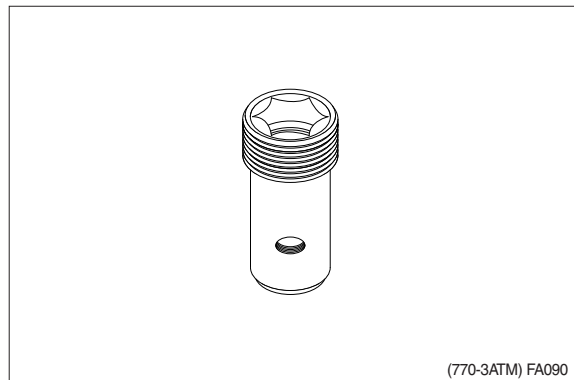


### (8) Assembly of pressure relief valve

- ① Guide adjustment screw, spring and cone up into the cartridge.

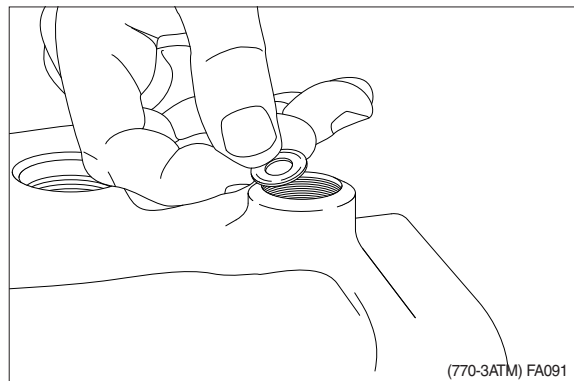


- ② Screw the adjustment screw so far in that the 10 mm hexagon key fully engages.

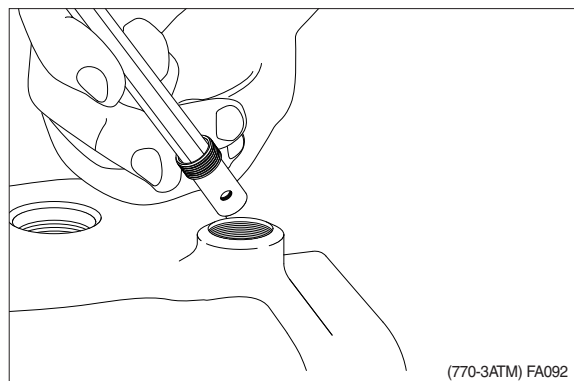


### (9) Installation of pressure relief valve

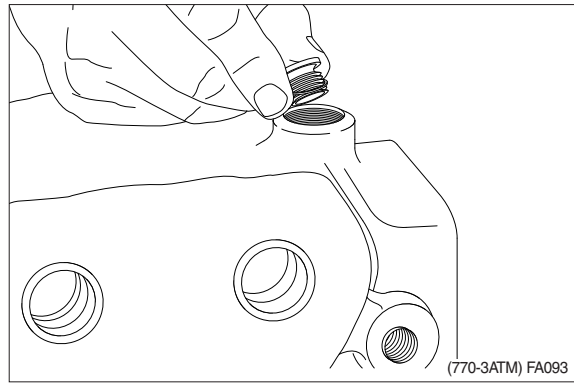
- ① Let the washer drop into the hole.



- ② Fit pressure relief valve.
  - Tightening torque :  $3.1 \pm 0.3 \text{ kgf} \cdot \text{m}$   
( $22.4 \pm 2.2 \text{ lbf} \cdot \text{ft}$ )

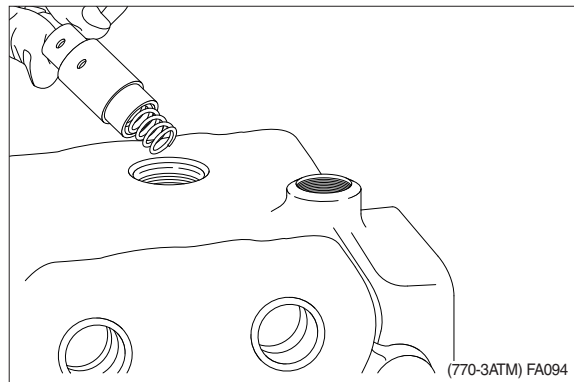


- ③ Fit plug with washer.  
 · Tightening torque :  $6 \pm 0.5 \text{ kgf} \cdot \text{m}$   
 ( $44.1 \pm 3.6 \text{ lbf} \cdot \text{ft}$ )

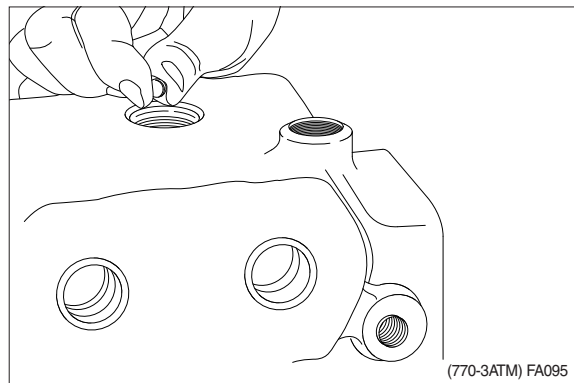


#### (10) Installation of back pressure valve

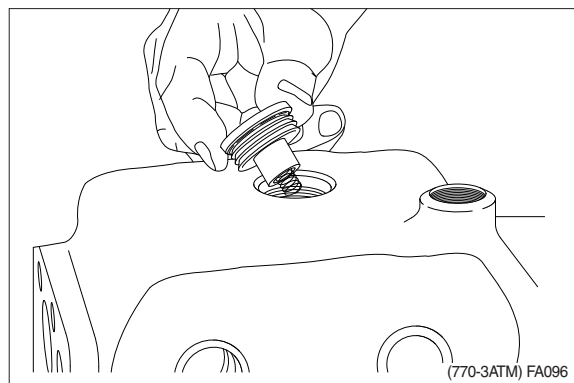
- ① First fit spring in piston with vaseline.  
 Fit assembled piston and spring.



- ② Let the ball drop down.

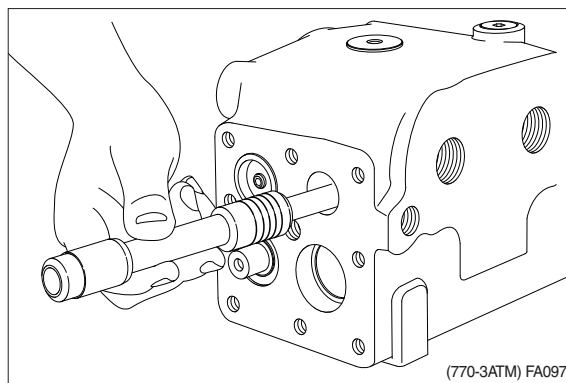


- ③ Fit spring in plug with vaseline.  
 Fit assembled plug and spring.  
 Remember O-ring.  
 · Tightening torque :  $2.6 \pm 0.3 \text{ kgf} \cdot \text{m}$   
 ( $18.8 \pm 2.2 \text{ lbf} \cdot \text{ft}$ )

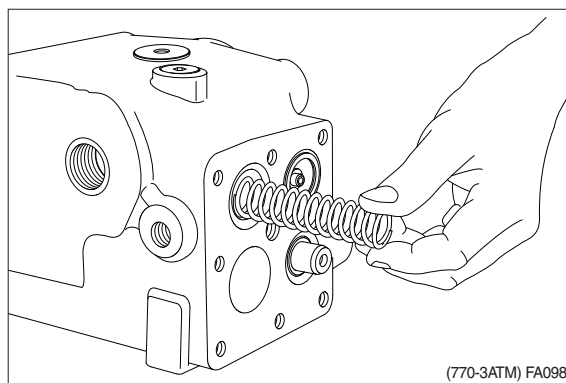


## (11) Installation of spools

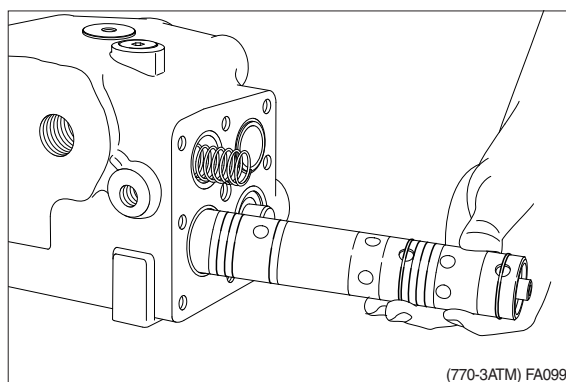
- ① Fit directional spool.  
Fit priority valve spool.
- ※ Spring control must be placed in correct position against LS - connection.



- ② Fit spring.
- ※ Spring must be by the LS - connection.

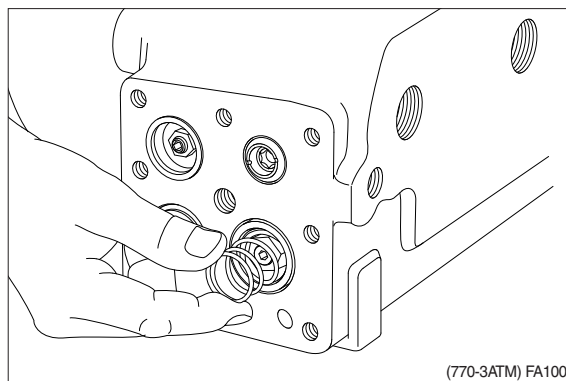


- ③ Fit amplifier spool.
- ※ The orifice must be placed in correct position against LS - connection.

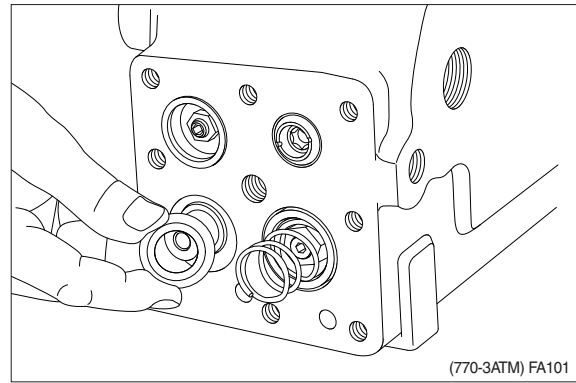


## (12) Installation of end cover at PP - connection

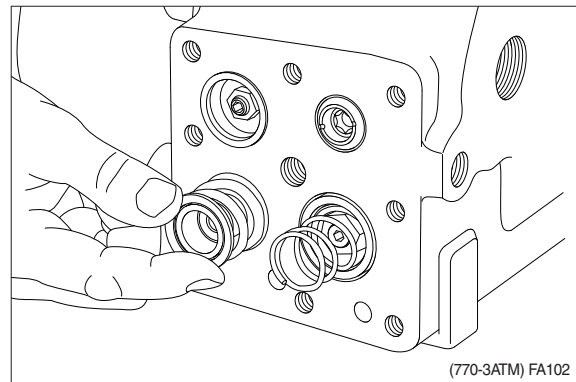
- ① Fit spring with vaseline on amplifier
- ※ spool.  
The spring must be fitted at the PP - connection.



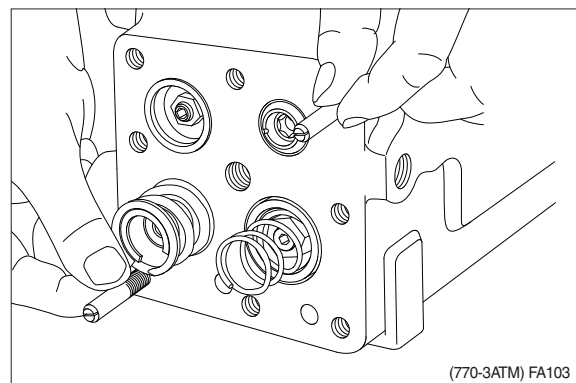
- ② Fit spring guide with vaseline.



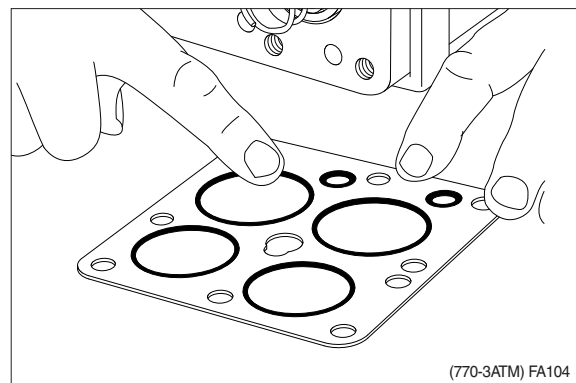
- ③ Fit large and small springs with vaseline.



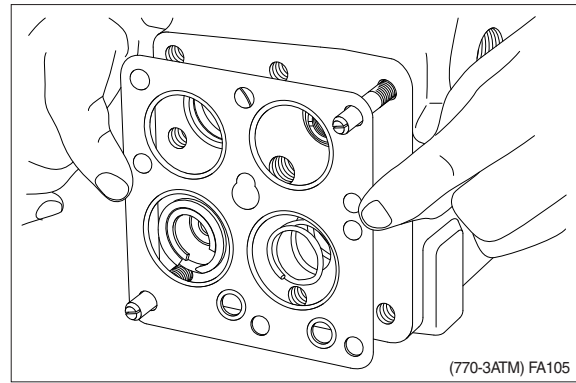
- ④ Fit guide screws.



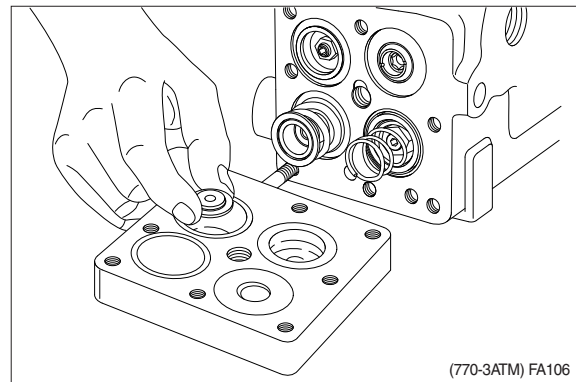
- ⑤ Fit 4 large and 2 small O-rings.



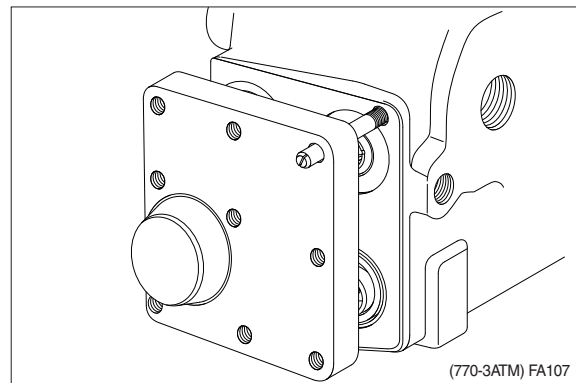
⑥ Guide plate in.



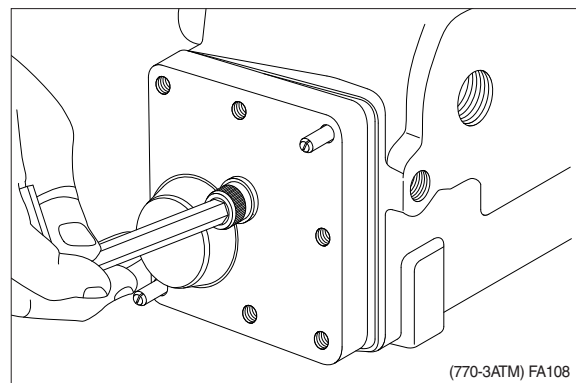
⑦ Fit stop (thickness : 5 mm) in end cover with vaseline.



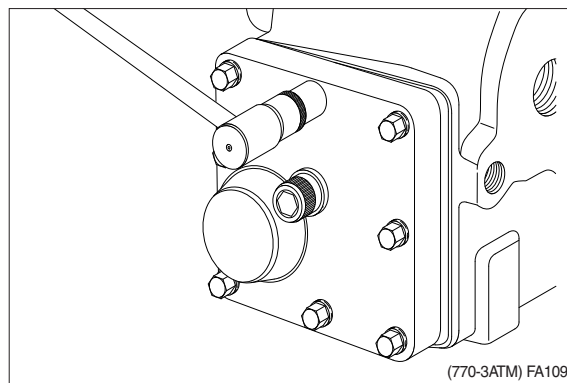
⑧ Guide end cover in.



⑨ Fit screw with spring washer.

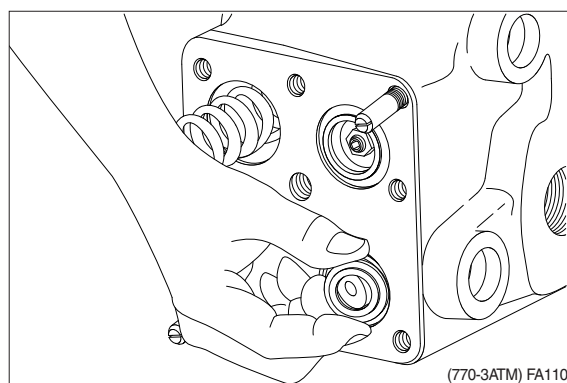


- ⑩ Fit screws with spring washer.
- Tightening torque :  $2.6 \pm 0.5 \text{ kgf} \cdot \text{m}$   
( $18.8 \pm 3.6 \text{ lbf} \cdot \text{ft}$ )
  - Tightening torque :  $8.2 \pm 1 \text{ kgf} \cdot \text{m}$   
for large screw ( $59.3 \pm 7.2 \text{ lbf} \cdot \text{ft}$ )

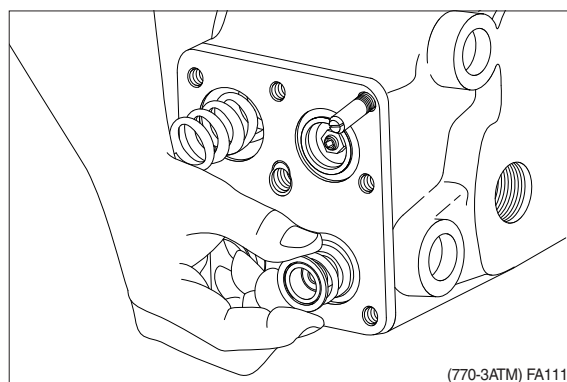


### (13) Installation of end cover at LS - connection

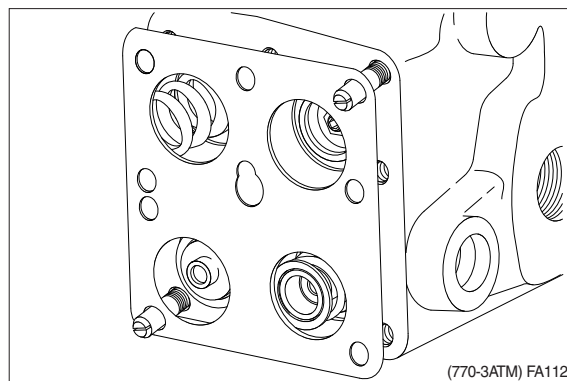
- ① Fit guide screws.  
Fit remote control with vaseline.



- ② Fit large and small springs with vaseline.

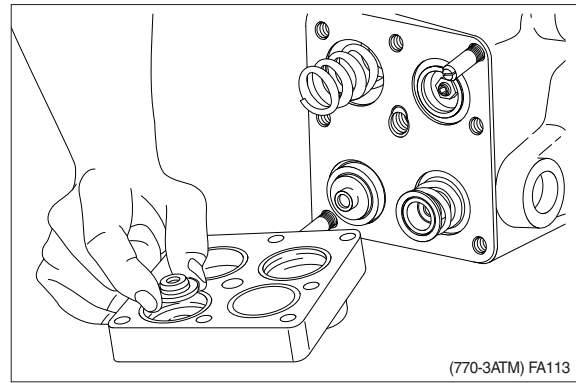


- ③ Guide in plate with 4 O-rings.

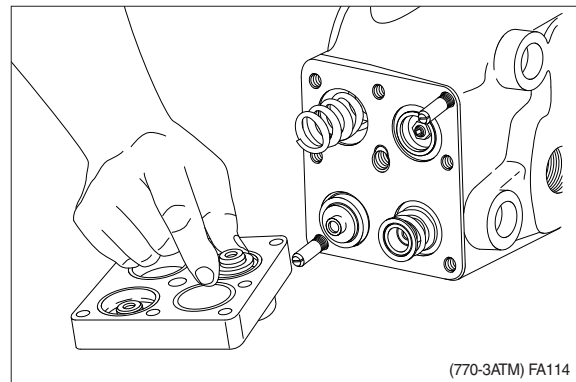




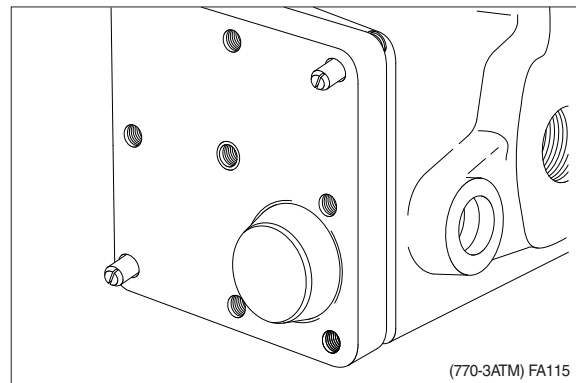
- ④ Fit stop for priority valve spool (thickness : 8 mm) with vaseline.



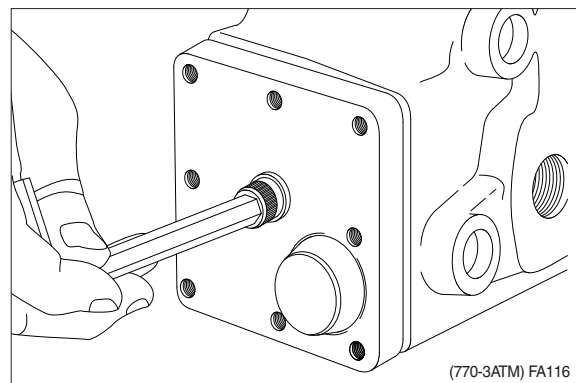
- ⑤ Fit stop for directional spool (thickness : 5 mm) with vaseline.



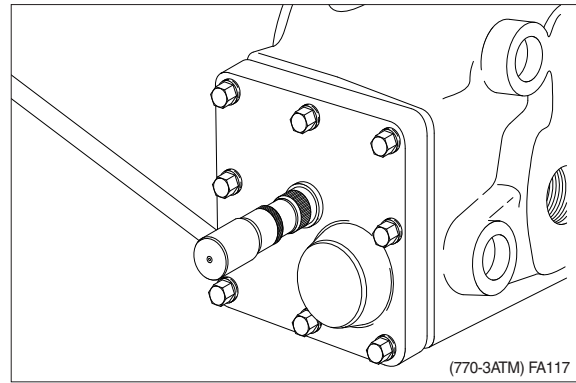
- ⑥ Guide in end cover.



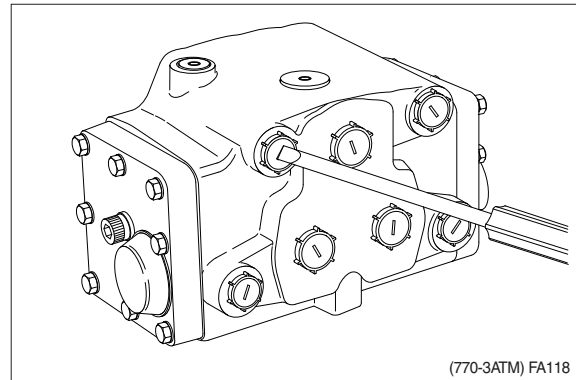
- ⑦ Fit large screw with spring washer.



- ⑧ Fit screws with spring washers.
- Tightening torque :  $2.6 \pm 0.5 \text{ kgf} \cdot \text{m}$   
( $18.8 \pm 3.6 \text{ lbf} \cdot \text{ft}$ )
  - Tightening torque :  $8.2 \pm 1 \text{ kgf} \cdot \text{m}$   
for large screw ( $59.3 \pm 7.2 \text{ lbf} \cdot \text{ft}$ )



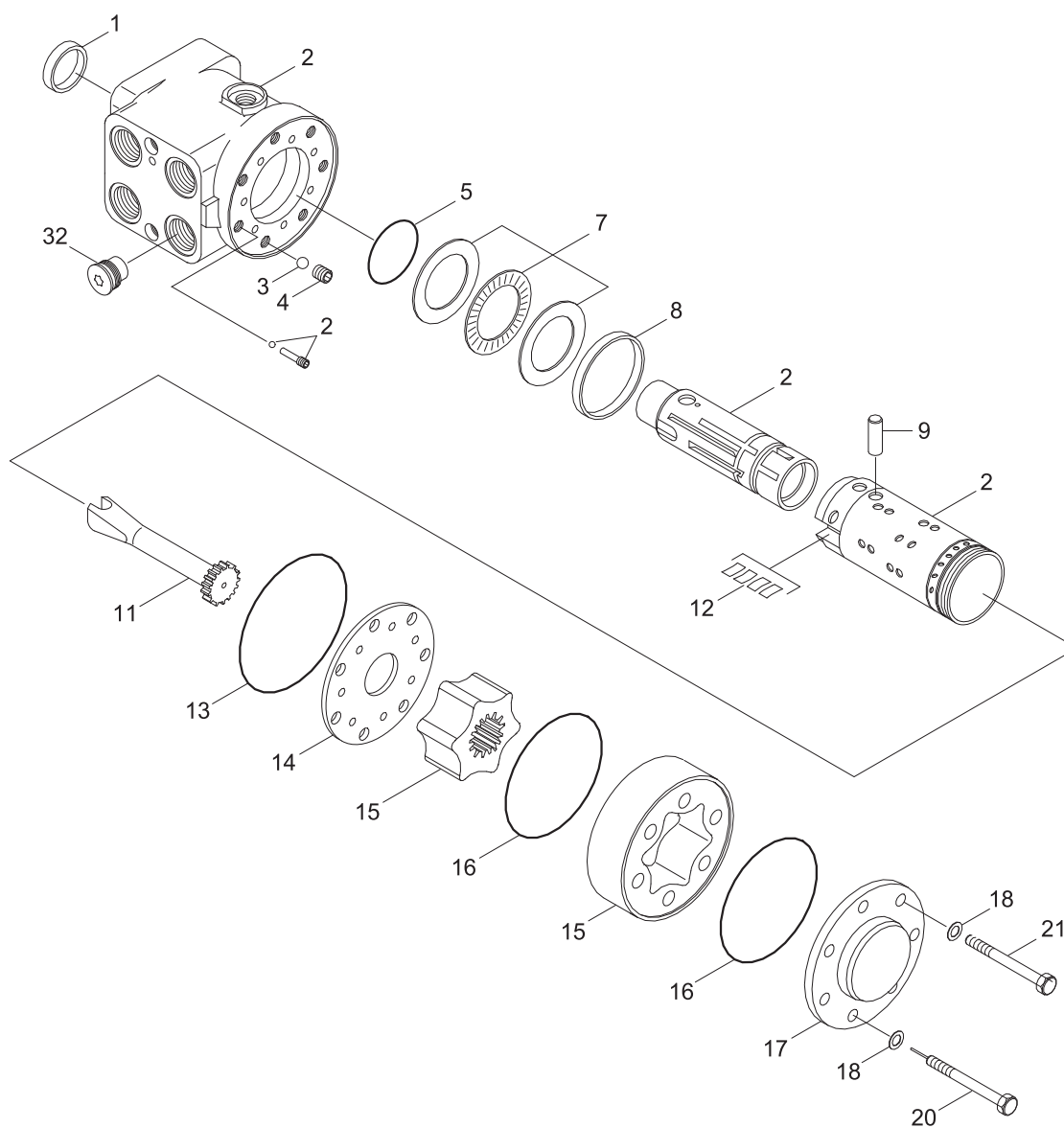
- ⑨ Fit plastic plugs.



This completes assembly.

## 2. STEERING UNIT

### 1) STRUCTURE

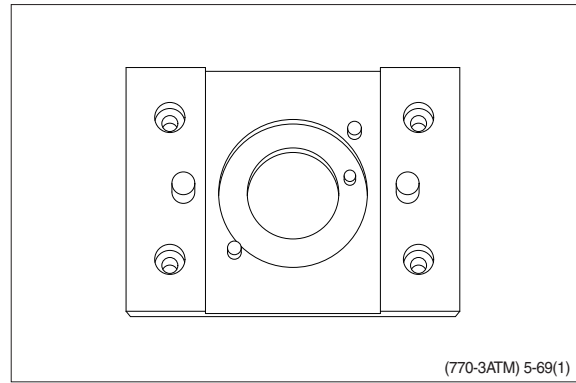


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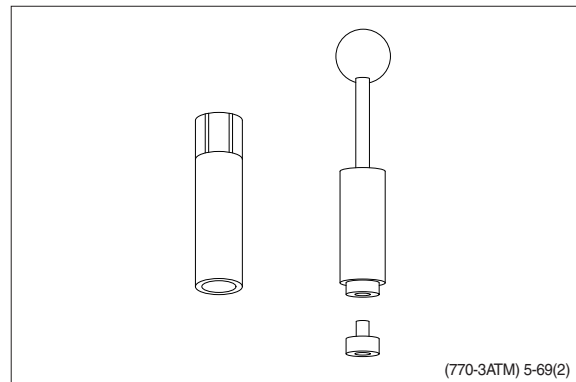
- |   |                        |    |                   |    |             |
|---|------------------------|----|-------------------|----|-------------|
| 1 | Dust seal ring         | 9  | Cross pin         | 17 | End cover   |
| 2 | Housing, Spool, sleeve | 11 | Shaft             | 18 | Washer      |
| 3 | Ball                   | 12 | Spring set        | 20 | Pin screw   |
| 4 | Bushing                | 13 | O-ring            | 21 | Screw       |
| 5 | Lip seal               | 14 | Distributor plate | 32 | Check valve |
| 7 | Bearing assy           | 15 | Gearwheel set     |    |             |
| 8 | Ring                   | 16 | O-ring            |    |             |

## 2) TOOLS

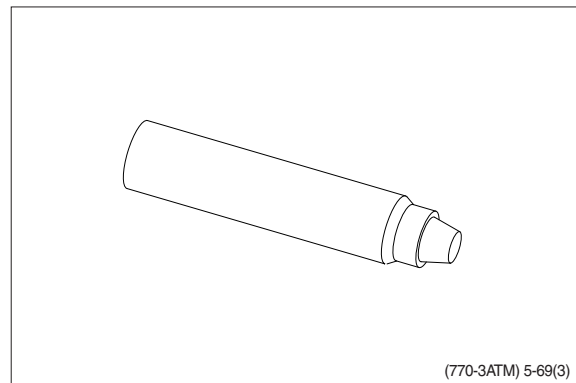
(1) Holding tool.



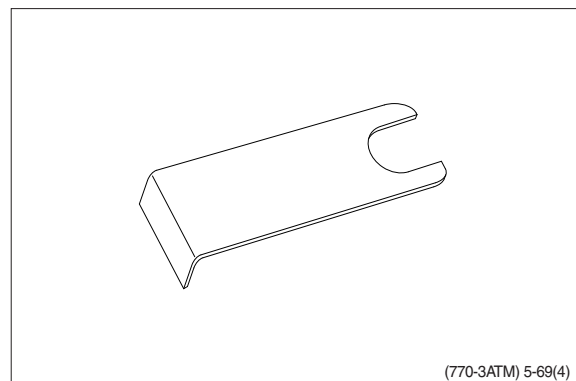
(2) Assembly tool for O-ring and kin-ring.



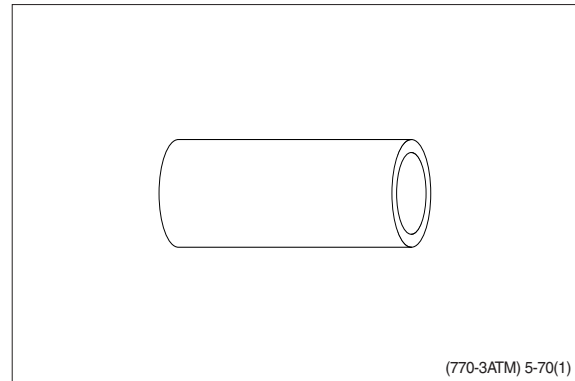
(3) Assembly tool for lip seal.



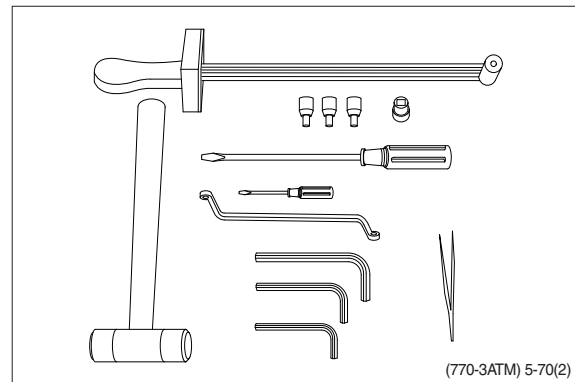
(4) Assembly tool for cardan shaft.



(5) Assembly tool for dust seal.

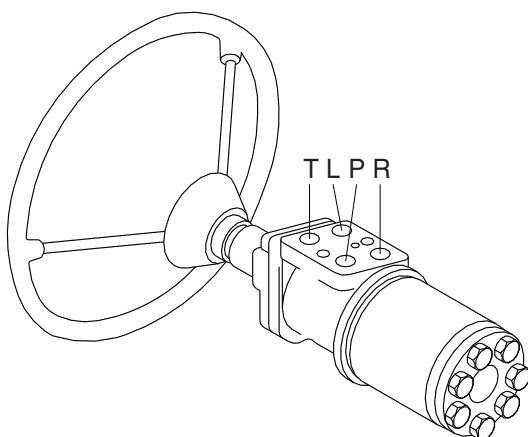


(6) Torque wrench 0~7.1 kgf · m  
(0~54.4 lbf · ft)  
13 mm socket spanner  
6, 8 mm and 12 mm hexagon sockets  
12 mm screwdriver  
2 mm screwdriver  
13 mm ring spanner  
6, 8 and 12 mm hexagon socket spanners  
Plastic hammer  
Tweezers



### 3) TIGHTENING TORQUE AND HYDRAULIC CONNECTIONS

#### (1) Hydraulic connections



L : Left port  
R : Right port  
T : Tank  
P : Pump

(770-3ATM) 5-71

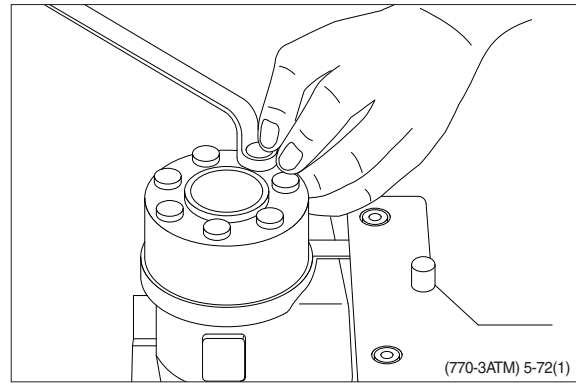
#### (2) Tightening torque

Screwed connection	Max. tightening torque [ kgf · m (lbf · ft) ]			
	With cutting edge	With copper washer	With aluminum washer	With O - ring
1/4 BSP.F	4.1 (29.7)	2.0 (14.5)	3.1 (22.4)	-
3/8 BSP.F	6.1 (44.1)	2.0 (14.5)	5.1 (36.9)	-
1/2 BSP.F	10.2 (73.8)	3.1 (22.4)	8.2 (59.3)	-
7/16-20 UNF	-	-	-	2.0 (14.5)
3/4-16 UNF	-	-	-	6.1 (44.1)
M 12×1.5	4.1 (29.7)	2.0 (14.5)	3.1 (22.4)	2.0 (14.5)
M 18×1.5	7.1 (51.4)	2.0 (14.5)	5.1 (36.9)	5.1 (36.9)
M 22×1.5	10.2 (73.8)	3.1 (22.4)	8.2 (59.3)	7.1 (51.4)

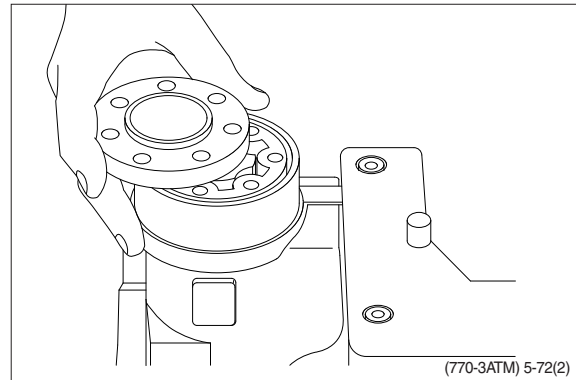
#### 4) DISASSEMBLY

- (1) Disassemble steering column from steering unit and place the steering unit in the holding tool.

Screw out the screws in the end cover(6-off plus one special screw).

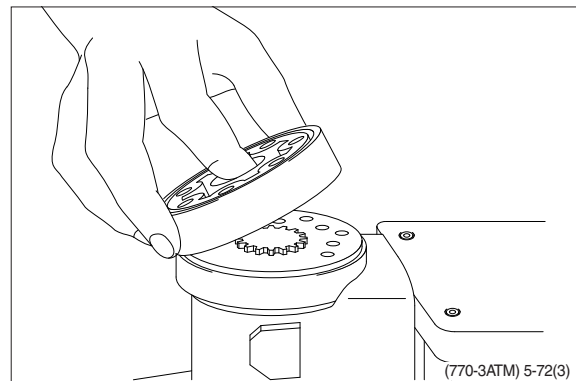


- (2) Remove the end cover, sideways.

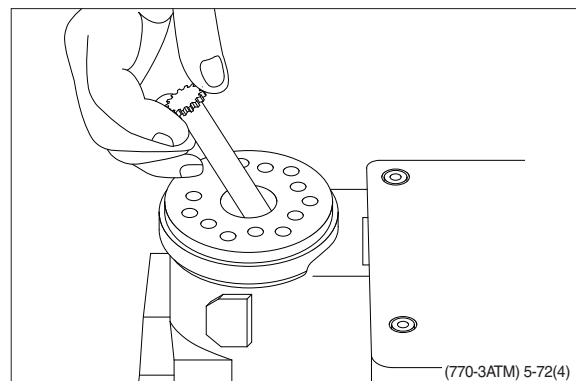


- (3) Lift the gearwheel set (with spacer if fitted) off the unit.

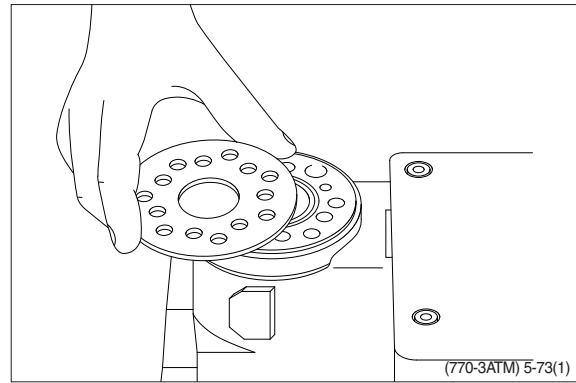
Take out the two O-rings.



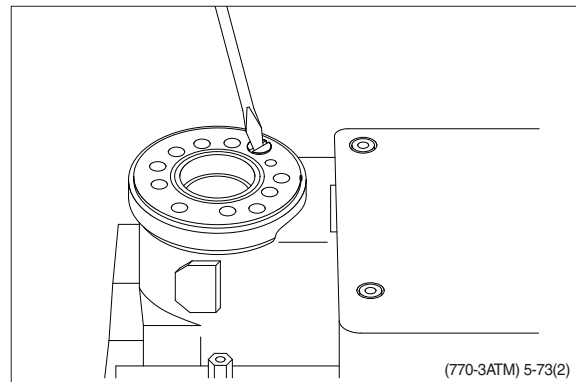
- (4) Remove cardan shaft.



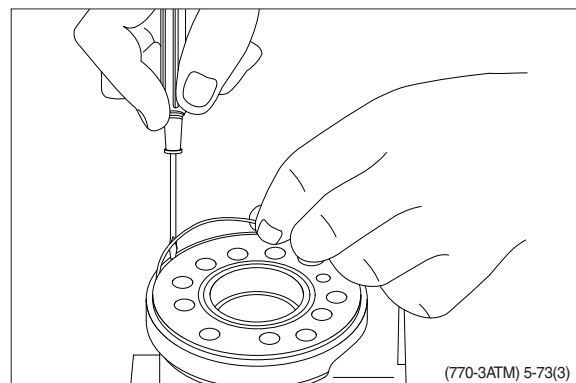
(5) Remove distributor plate.



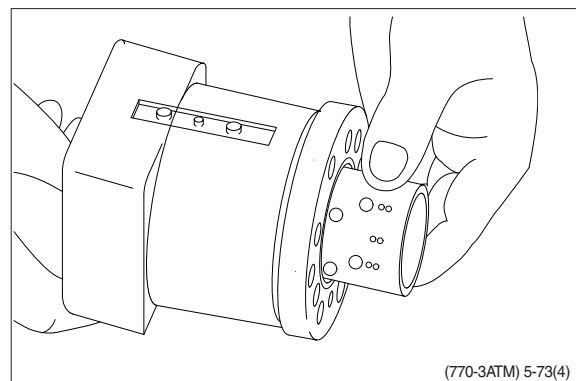
(6) Screw out the threaded bush over the check valve.



(7) Remove O-ring.

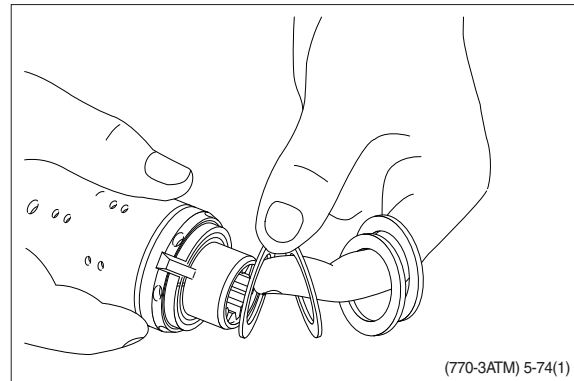


(8) Take care to keep the cross pin in the sleeve and spool horizontal. The pin can be seen through the open end of the spool. Press the spool inwards and the sleeve, ring, bearing races and needle bearing will be pushed out of the housing together.

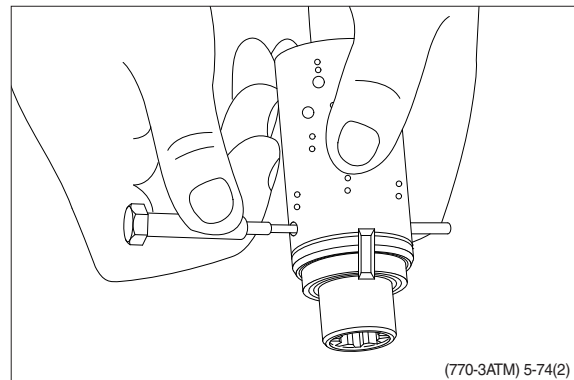




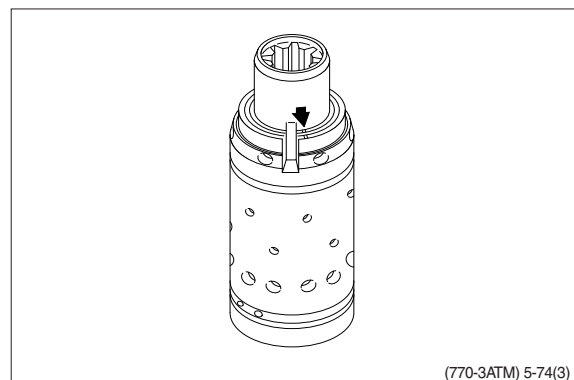
- (9) Take ring, bearing races and needle bearing from sleeve and spool. The outer (Thin) bearing race can sometimes "stick" in the housing, therefore check that it has come out.



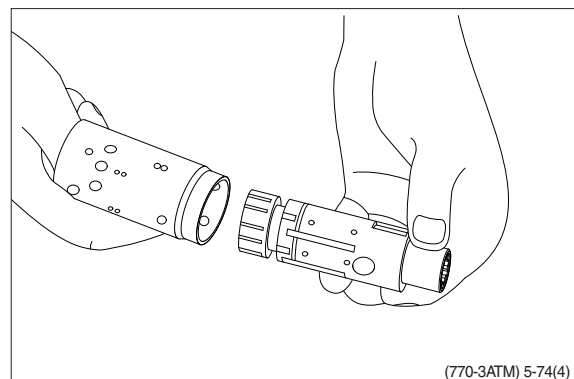
- (10) Press out the cross pin. Use the special screw from the end cover.



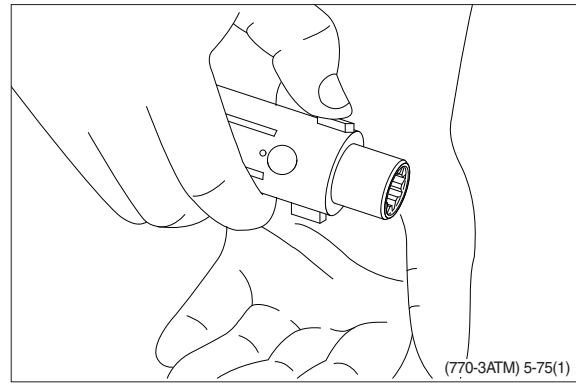
- ※ A small mark has been made with a pumice stone on both spool and sleeve close to one of the slots for the neutral position springs (see drawing). If the mark is not visible, remember to leave a mark of your own on sleeve and spool before the neutral position springs are disassembled.



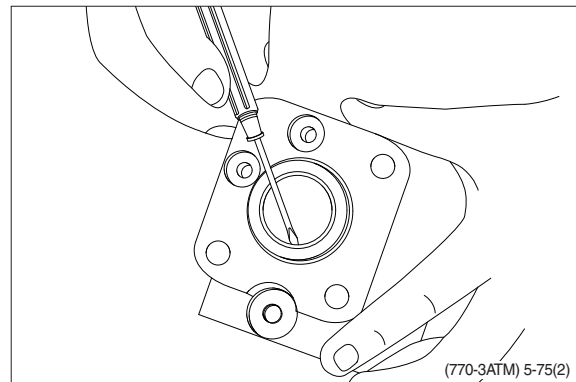
- (11) Carefully press the spool out of the sleeve.



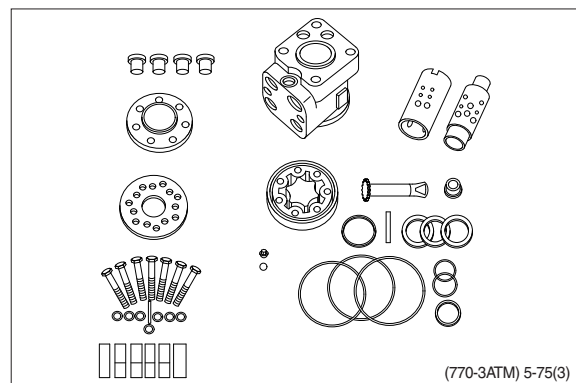
- (12) Press the neutral position springs out of their slots in the spool.



- (13) Remove dust seal and O-ring.



- (14) The steering unit is now completely disassembled.



※ **Cleaning**

Clean all parts carefully in Shellsol K or the like.

※ **Inspection and replacement**

Replace all seals and washers. Check all parts carefully and make any replacements necessary.

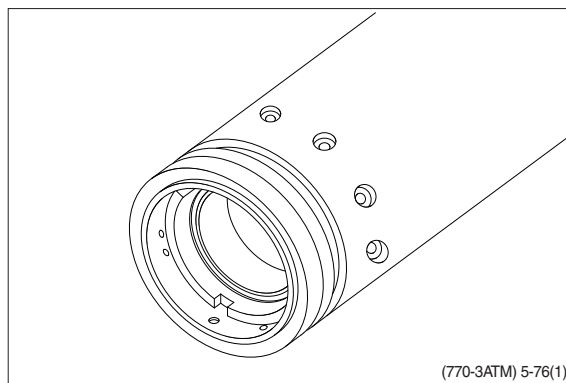
※ **Lubrication**

Before assembly, lubricate all parts with hydraulic oil.

## 5) ASSEMBLY

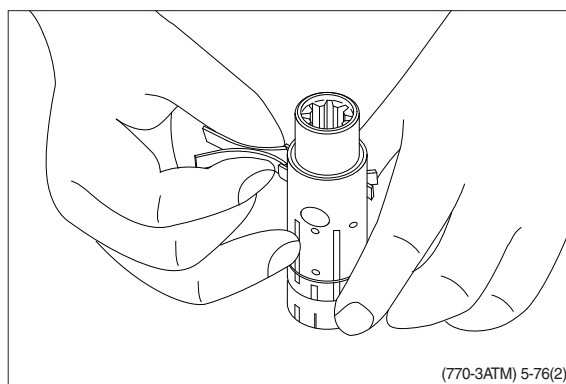
(1) Assemble spool and sleeve.

- ※ When assembling spool and sleeve only one of two possible ways of positioning the spring slots is correct. There are three slots in the spool and three holes in the sleeve in the end of the spool / sleeve opposite to the end with spring slots. Place the slots and holes opposite each other so that parts of the holes in the sleeve are visible through the slots in the spool.



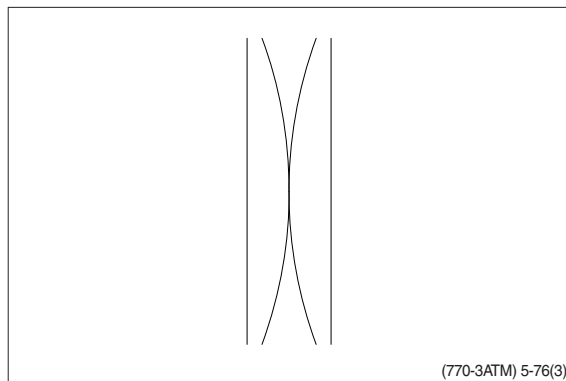
(2) Place the two flat neutral position springs in the slot.

Place the curved springs between the flat ones and press them into place (see assembly pattern).

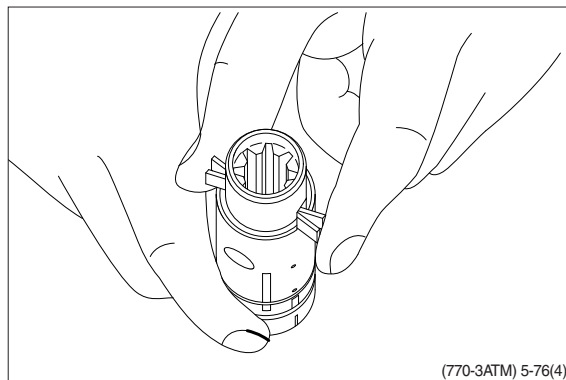


※ Assembly pattern.

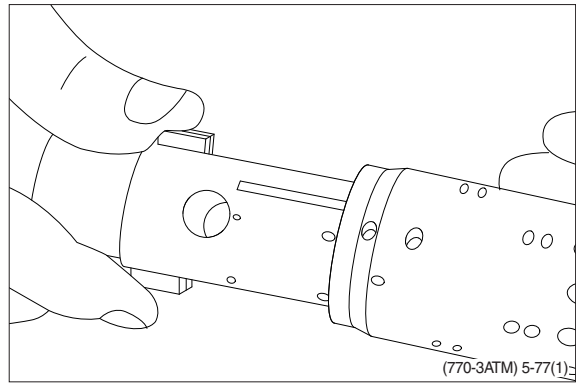
- Weak springs (blue)
  - 2 - off flat, blue : Part no. 150-0748
  - 2 - off curved, blue : Part no. 150-0749
- Blue set
  - Spare set : Part no. 150-4265



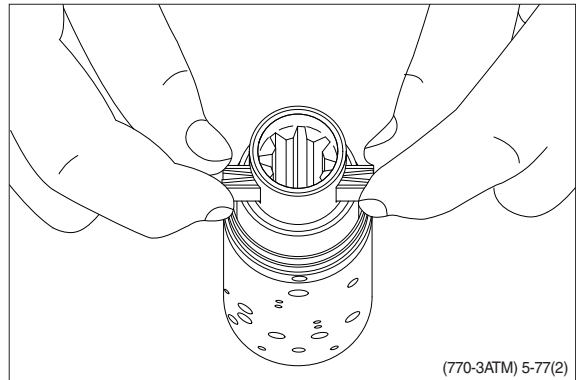
(3) Line up the spring set.



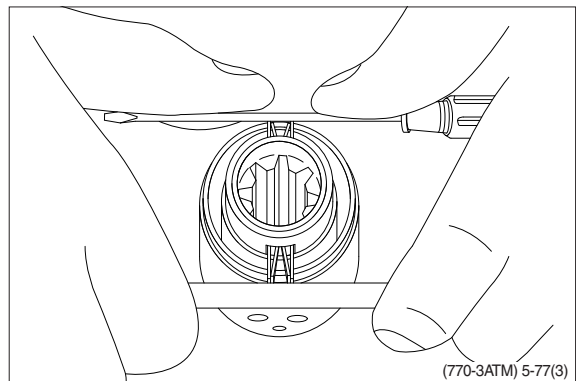
- (4) Guide the spool into the sleeve. Make sure that spool and sleeve are placed correctly in relation to each other (see page 3-76, No.(1)).



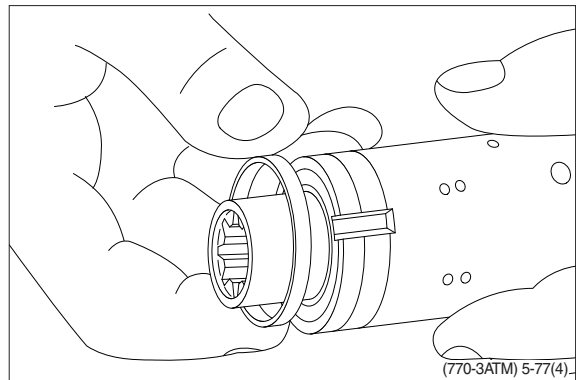
- (5) Press the springs together and push the neutral position springs into place in the sleeve.



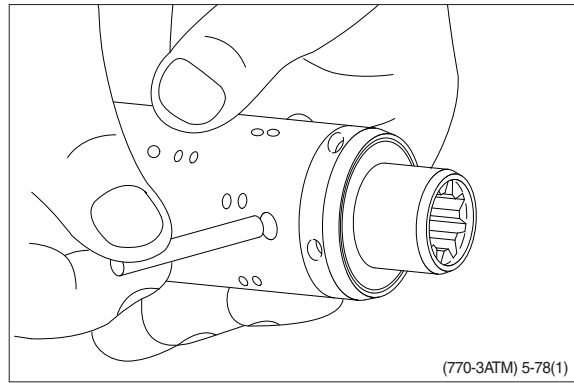
- (6) Line up the springs and center them.



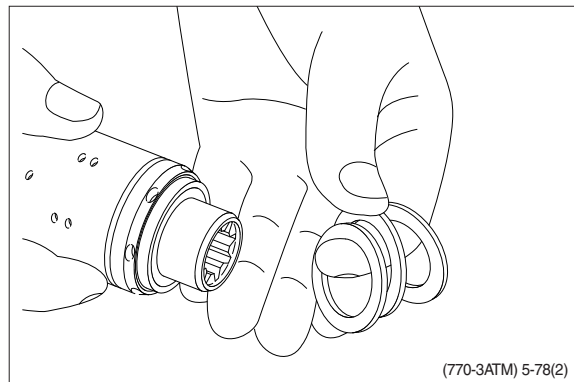
- (7) Guide the ring down over the sleeve.  
※ The ring should be able to rotate free of the springs.



(8) Fit the cross pin into the spool / sleeve.

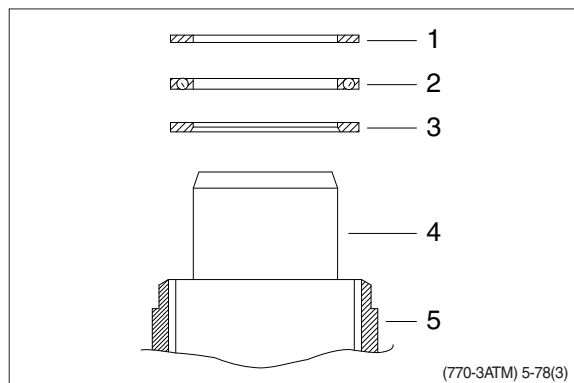


(9) Fit bearing races and needle bearing as shown on below drawing.



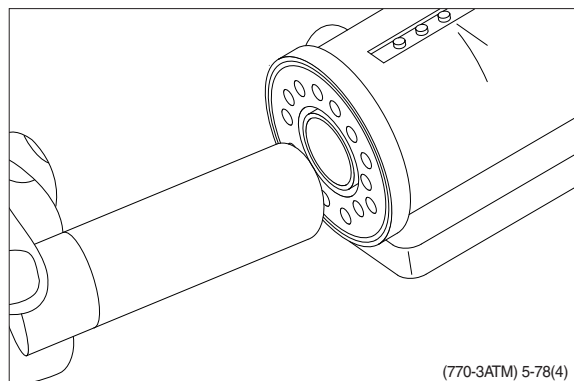
※ Assembly pattern for standard bearings

- 1 Outer bearing race
- 2 Needle bearing
- 3 Inner bearing race
- 4 Spool
- 5 Sleeve

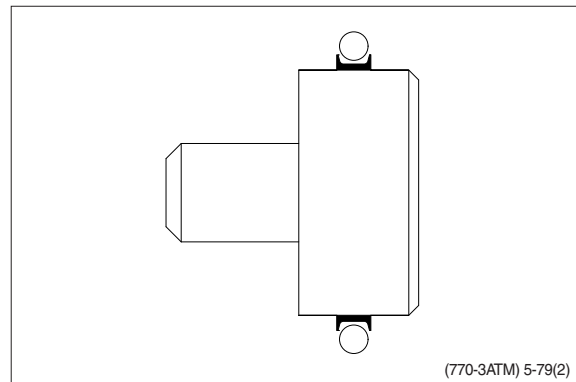
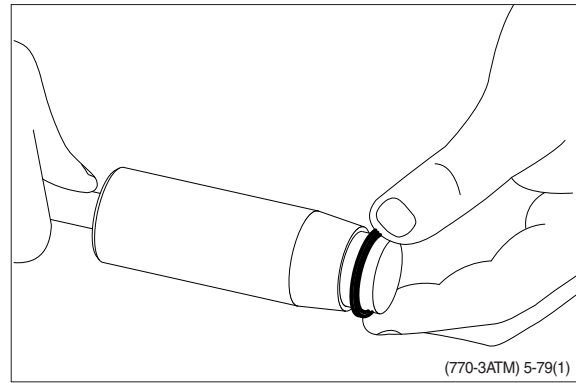


Installation instruction for O-ring

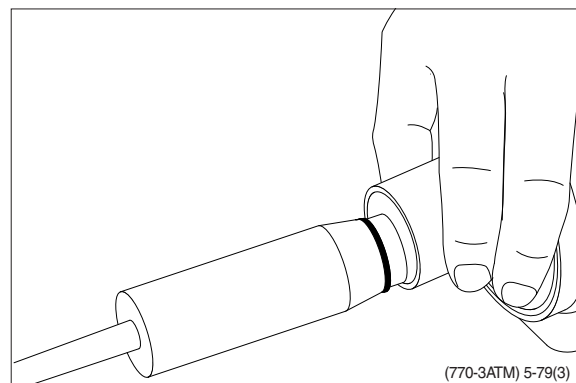
(10) Turn the steering unit until the bore is horizontal. Guide the outer part of the assembly tool into the bore for the spool / sleeve.



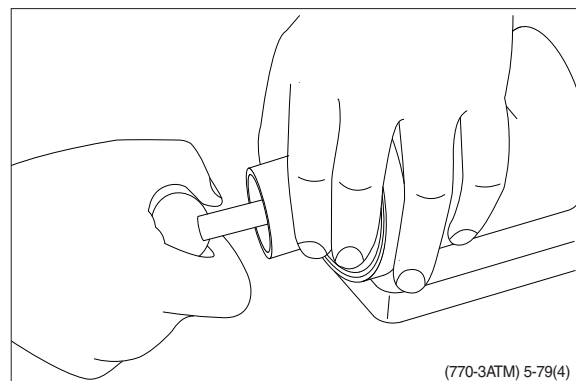
- (11) Grease O-ring with hydraulic oil and place them on the tool.



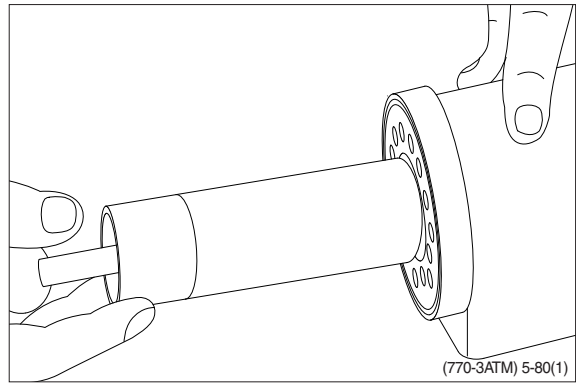
- (12) Hold the outer part of the assembly tool in the bottom of the steering unit housing and guide the inner part of the tool right to the bottom.



- (13) Press and turn the O-ring into position in the housing.

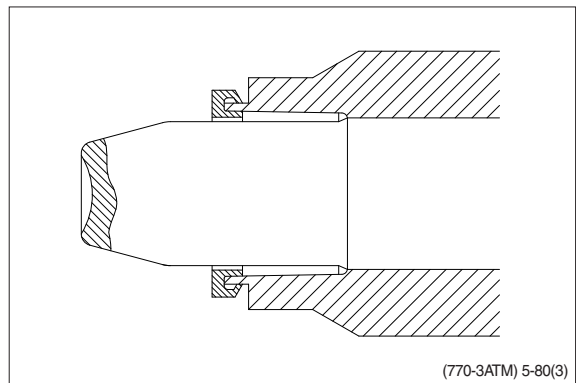
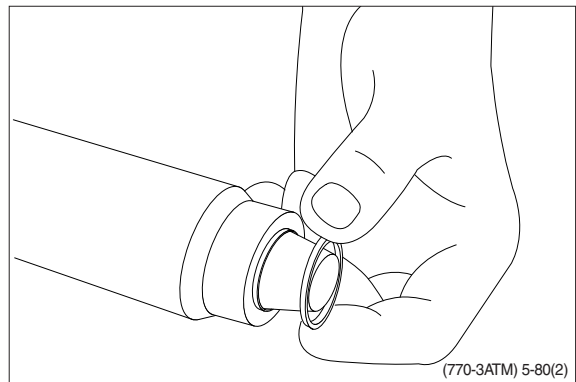


- (14) Draw the inner and outer parts of the assembly tool out of the steering unit bore, leaving the guide from the inner part in the bore.

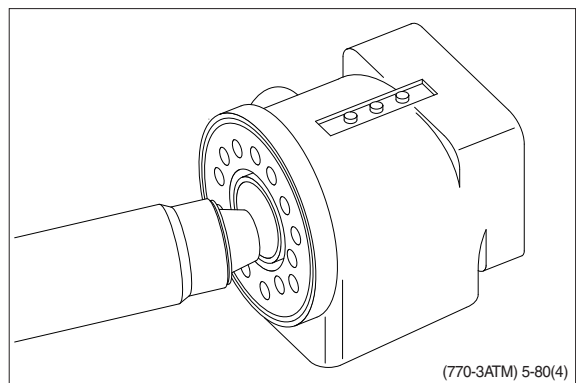


#### Installation instructions for lip seal

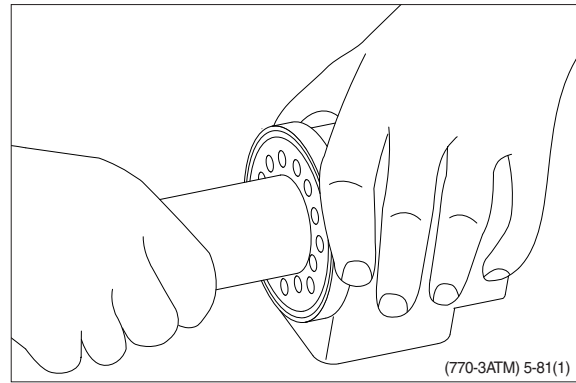
- (15) Lubricate the lip seal with hydraulic oil and place it on the assembly tool.



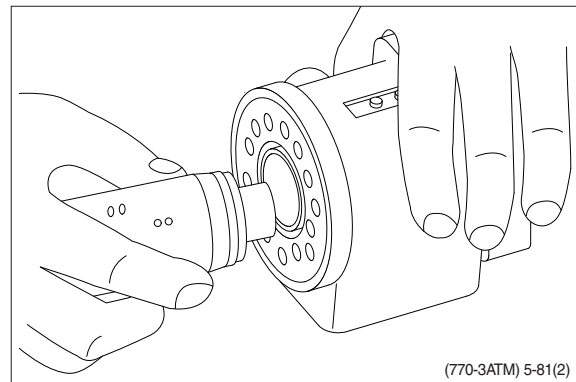
- (16) Guide the assembly tool right to the bottom.



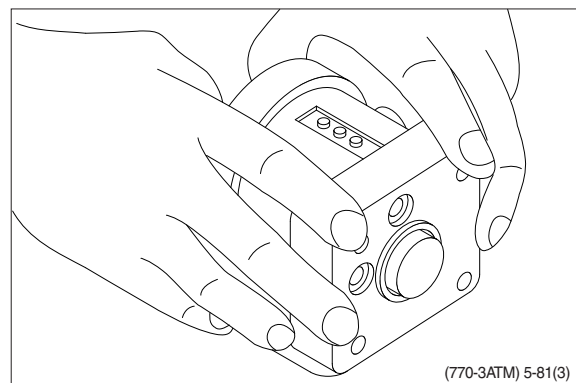
- (17) Press and turn the lip seal into place in the housing.



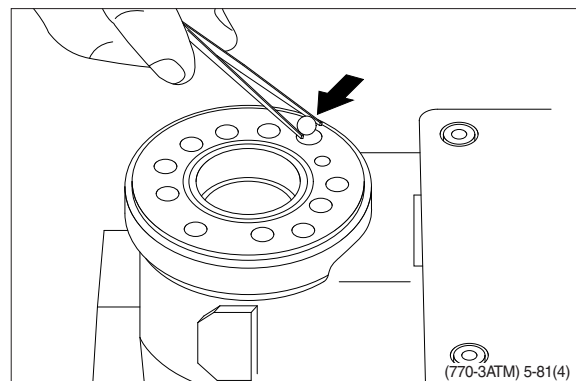
- (18) With a light turning movement, guide the spool and sleeve into the bore.  
※ Fit the spool set holding the cross pin horizontal.



- (19) The spool set will push out the assembly tool guide. The O-ring are now in position.

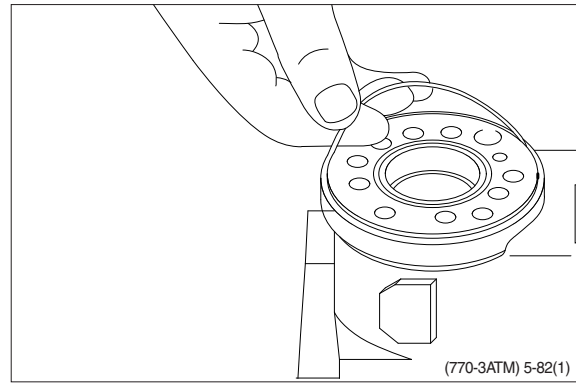


- (20) Turn the steering unit until the bore is vertical again. Put the check valve ball into the hole indicated by the arrow.

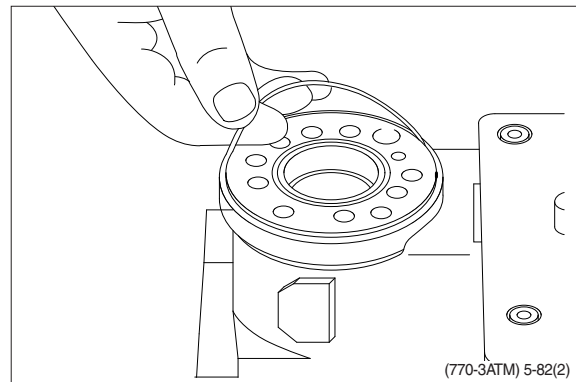




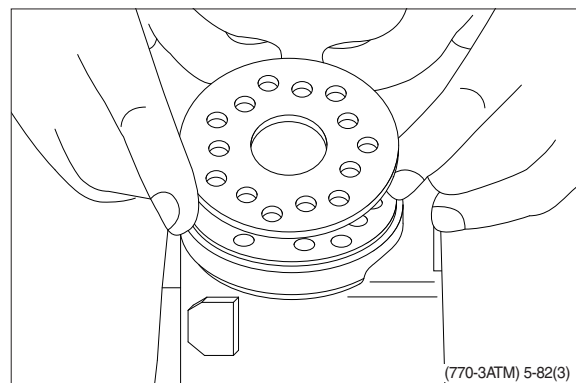
- (21) Screw the threaded bush lightly into the check valve bore. The top of the bush must lie just below the surface of the housing.



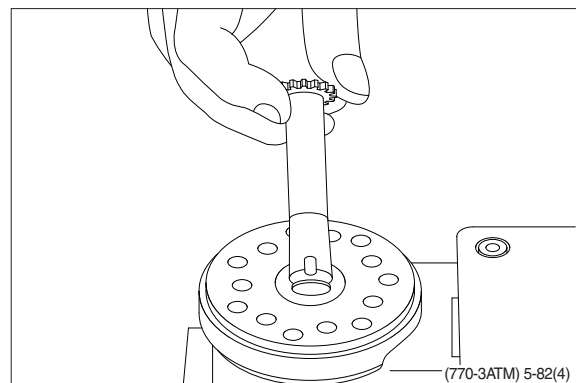
- (22) Grease the O-ring with mineral oil approx. viscosity 500 cSt at 20. C .



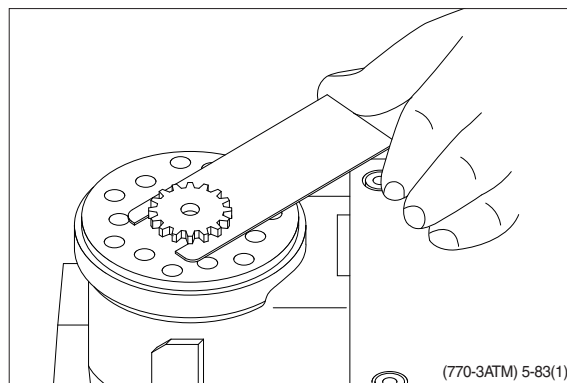
- (23) Place the distributor plate so that the channel holes match the holes in the housing.



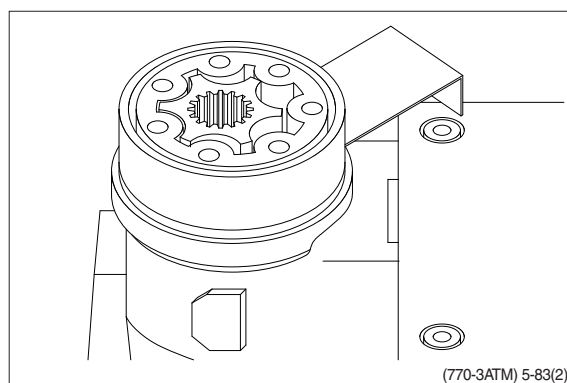
- (24) Guide the cardan shaft down into the bore so that the slot is parallel with the connection flange.



- (25) Place the cardan shaft as shown - so that it is held in position by the mounting fork.



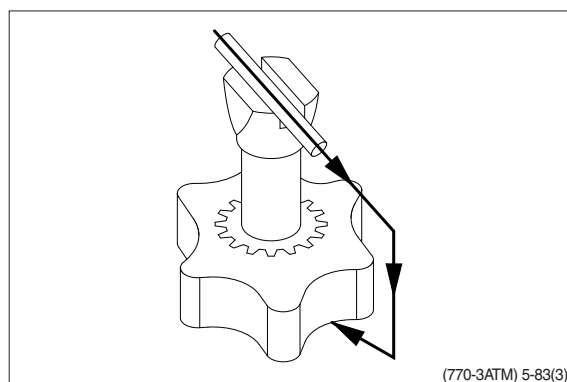
- (26) Grease the two O-rings with mineral oil approx. viscosity 500 cSt at 20° C and place them in the two grooves in the gear rim. Fit the gearwheel and rim on the cardan shaft.



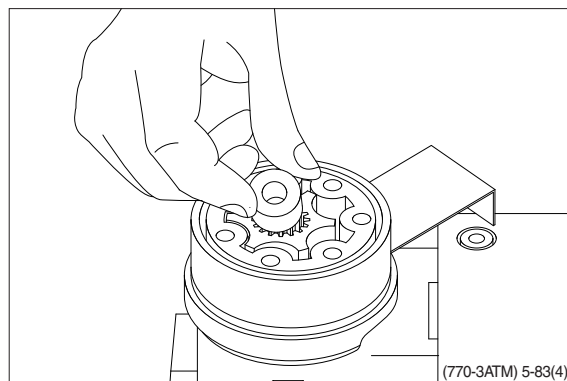
- (27) Important

Fit the gearwheel (rotor) and cardan shaft so that a tooth base in the rotor is positioned in relation to the shaft slot as shown.

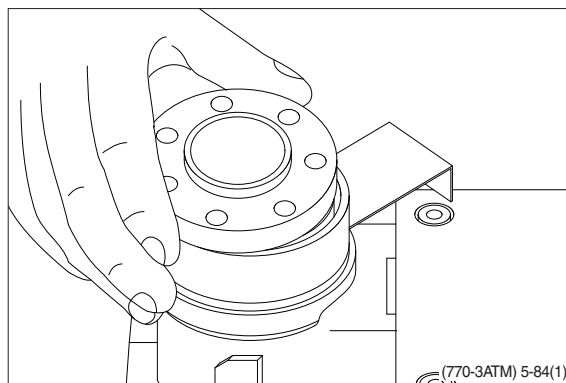
Turn the gear rim so that the seven through holes match the holes in the housing.



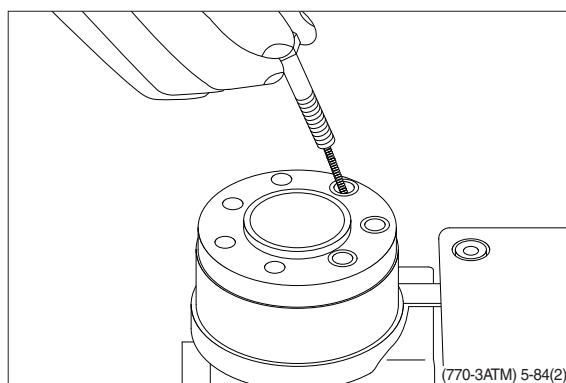
- (28) Fit the spacer, if any.



(29) Place the end cover in position.

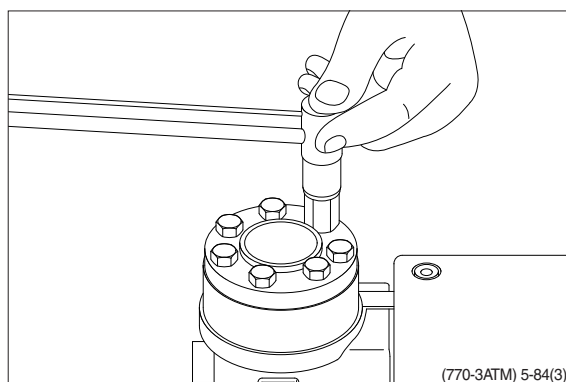


(30) Fit the special screw with washer and place it in the hole shown.

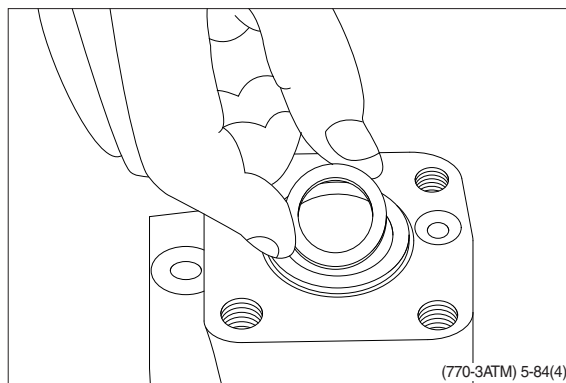


(31) Fit the six screws with washers and insert them. Cross-tighten all the screws and the rolled pin.

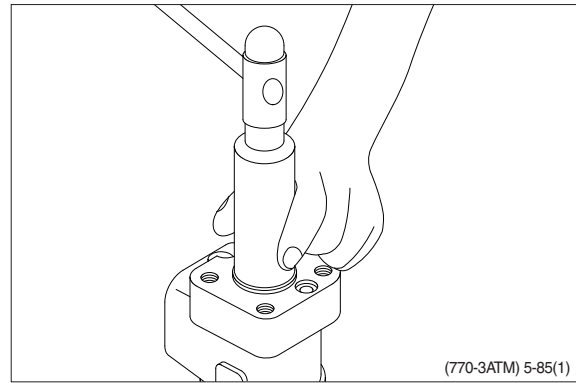
- Tightening torque :  $3.1 \pm 0.6 \text{ kgf} \cdot \text{m}$   
( $22.4 \pm 4.3 \text{ lbf} \cdot \text{ft}$ )



(32) Place the dust seal ring in the housing.

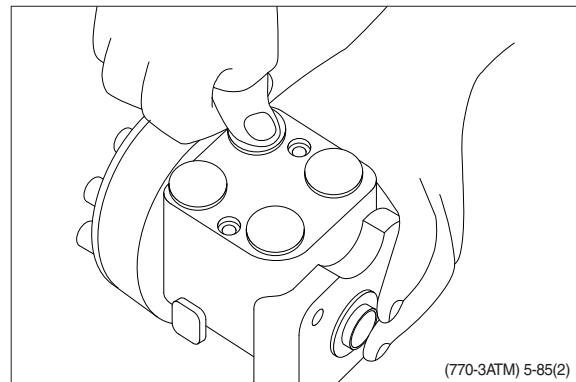


(33) Fit the dust seal ring in the housing.



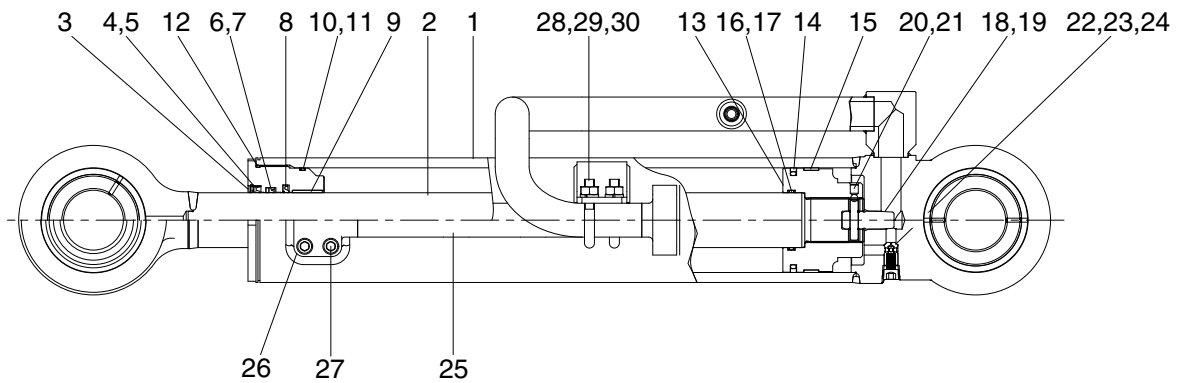
(34) Press the plastic plugs into the connection ports.

※ Do not use a hammer!



### 3. STEERING CYLINDER

#### 1) STRUCTURE

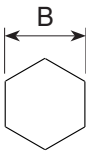


78095SE05

1	Tube assembly	12	O-ring	23	Spring
2	Rod assy	13	Piston	24	Plug
3	Gland	14	Piston seal	25	Pipe assy
4	Dust wiper	15	Wear ring	26	O-ring
5	Retaining ring	16	O-ring	27	Hexagon nut
6	Rod seal	17	Back-up ring	28	U-bolt
7	Back-up ring	18	Cushion plunger	29	Hexagon nut
8	Buffer ring	19	Parallel pin	30	Spring washer
9	Bushing	20	Steel ball	31	Spherical bearing
10	O-ring	21	Set screw	32	Retaining ring
11	Back-up ring	22	Check valve		

## 2) TOOLS AND TIGHTENING TORQUE

### (1) Tools

Tool name	B	Remark
L-wrench	5	
Spanner	70	
Wrench	For gland	
(-) Driver	Small and large sizes	
Torque wrench	Capable of tightening with the specified torques	

### (2) Tightening torque

Part name	Item	Size	Torque	
			kgf · m	lbf · ft
Gland	3	M110×2	88±9	637±65
Piston	13	M 45×2	75±8	542±58
Set screw	21	M 8×1.5	2.0±0.2	14.4±1.4
Plug	24	PT 3/8	7.0±0.7	50.6±5.06

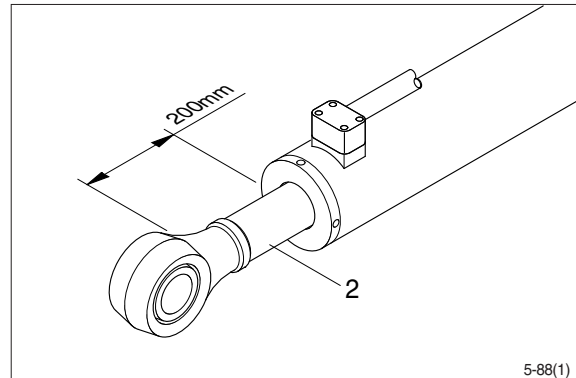
### 3) DISASSEMBLY

#### (1) Remove cylinder head and piston rod

① Hold the clevis section of the tube in a vise.

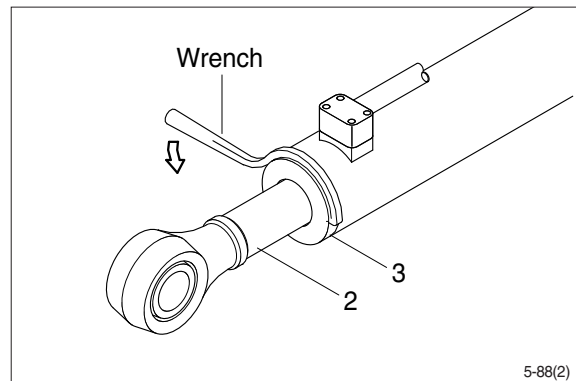
※ Use mouth pieces so as not to damage the machined surface of the cylinder tube. Do not make use of the outside piping as a locking means.

② Pull out piston rod (2) about 200 mm (7.8 in). Because the piston rod is rather heavy, finish extending it with air pressure after the oil draining operation.



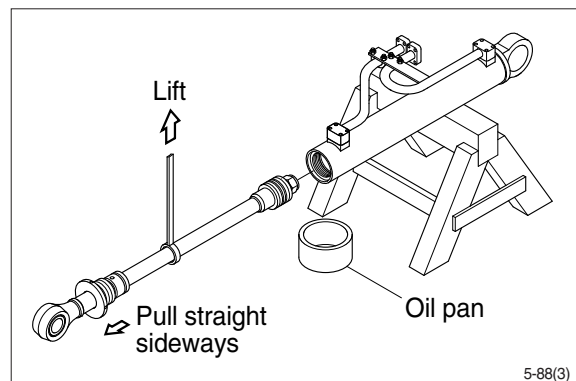
③ Loosen and remove the gland (3).

※ Cover the extracted piston rod (2) with rag to prevent it from being accidentally damaged during operation.



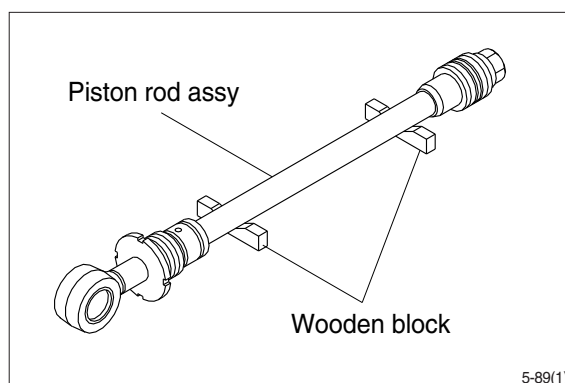
④ Draw out gland (3) and piston rod (2) assembly together from cylinder tube (1).

※ Since the piston rod assembly is heavy in this case, lift the tip of the piston rod (2) with a crane or some means and draw it out. However, when piston rod (2) has been drawn out to approximately two thirds of its length, lift it in its center to draw it completely.



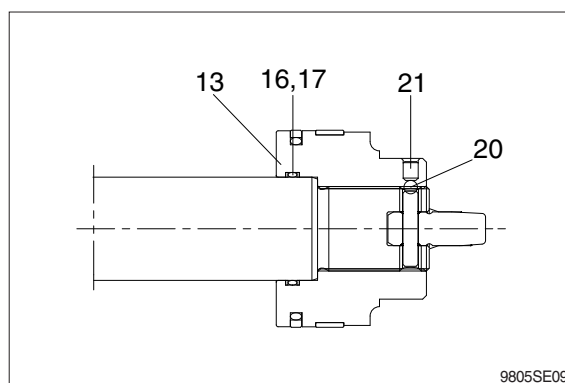
- ※ Note that the plated surface of piston rod (2) is to be lifted. For this reason, do not use a wire sling and others that may damage it, but use a strong cloth belt or a rope.

- ⑤ Place the removed piston rod assembly on a wooden V-block that is set level.
- ※ Cover a V-block with soft rag.

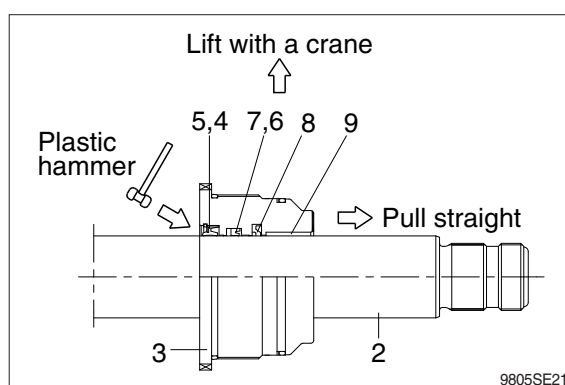


## (2) Remove piston and gland assembly

- ① Remove the set screw (21) and steel ball (20).
- ② Remove piston assembly (13), back up ring (17) and O-ring (16).



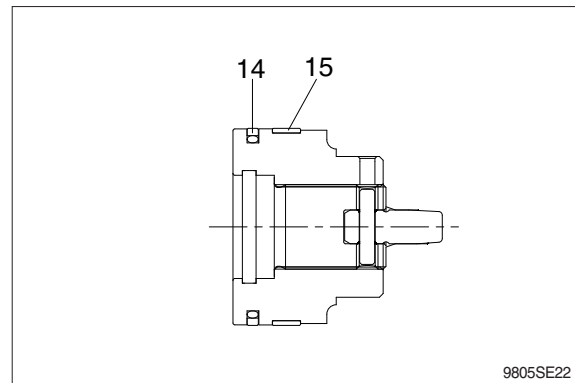
- ③ Remove the gland (3) assembly from piston rod (2).
  - ※ If it is too heavy to move, move it by striking the flanged part of gland (3) with a plastic hammer.
  - ※ Pull it straight with gland assembly lifted with a crane.
- Exercise care so as not to damage the lip of rod bushing (9) and packing (4,5,6,7,8) by the threads of piston rod (2).





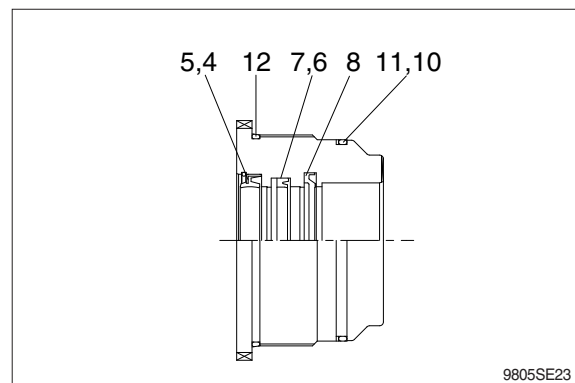
### (3) Disassemble the piston assembly

- ① Remove wear ring (15) and piston seal (14).
- ※ Exercise care in this operation not to damage the grooves.



### (4) Disassemble gland assembly

- ① Remove back up ring (11), and O-ring (10).
  - ② Remove O-ring (12).
  - ③ Remove retaining ring (5) and dust wiper (4).
  - ④ Remove back up ring (7), rod seal (6) and buffer ring (8).
- ※ Exercise care in this operation not to damage the grooves.
- ※ Do not remove seal and ring, if does not damaged.

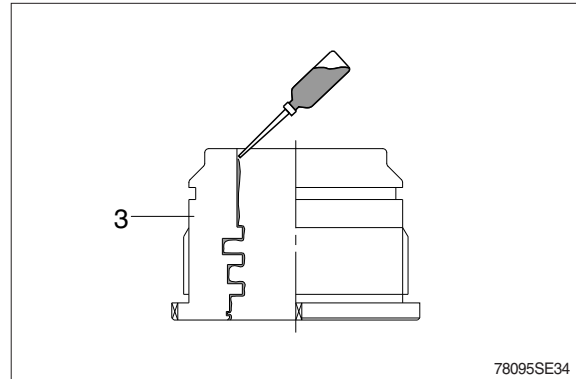


#### 4) ASSEMBLY

##### (1) Assemble gland assembly

※ Check for scratches or rough surfaces if found smooth with an oil stone.

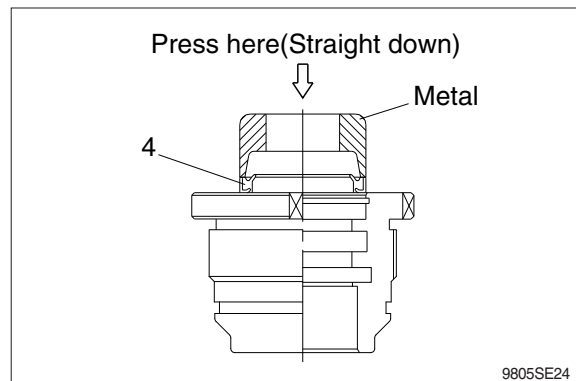
- ① Coat the inner face of gland (3) with hydraulic oil.



- ② Coat dust wiper (4) with grease and fit dust wiper (4) to the bottom of the hole of dust wiper.

At this time, press a pad metal to the metal ring of dust seal.

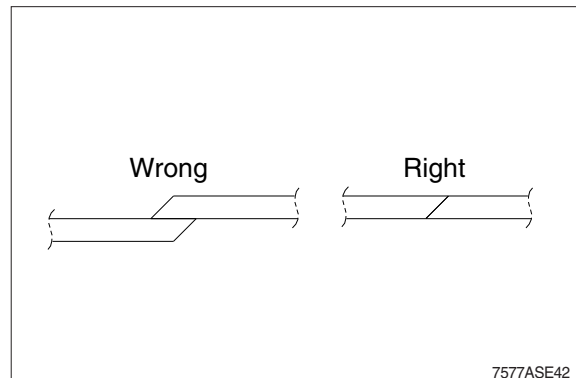
- ③ Fit retaining ring (5) to the stop face.



- ④ Fit back up ring (7) and rod seal (6), and buffer ring (8) to corresponding grooves, in that order.

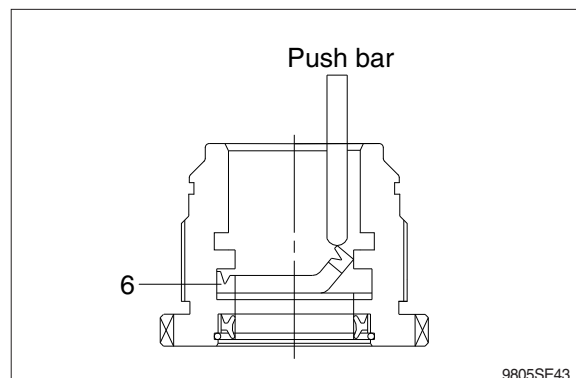
※ Coat each packing with hydraulic oil before fitting it.

※ Insert the backup ring until outside of it is inserted into groove.

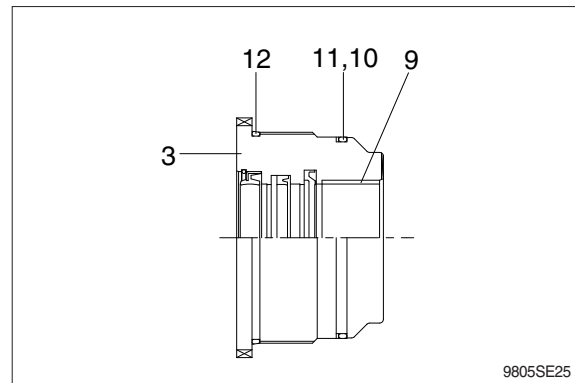


※ Rod seal (6) has its own fitting direction. Therefore, confirm it before fitting them.

※ Fitting rod seal (6) up side down may damage its lip. Therefore check the correct direction that is shown in figure.

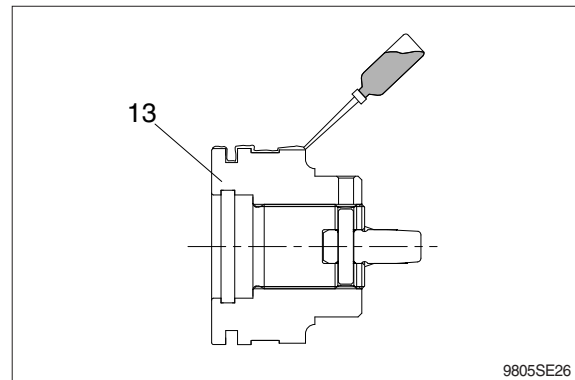


- ⑤ Fit back up ring (10) to gland (3).
- ※ Put the backup ring in the warm water of 30~50°C.
- ⑥ Fit O-ring (10,12) to gland (3).
- ⑦ Fit bushing (9) to gland (3).

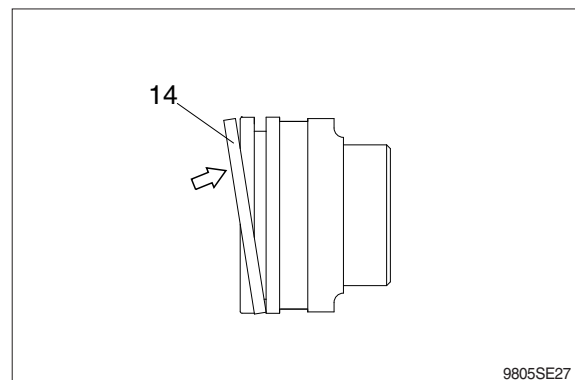


## (2) Assemble piston assembly

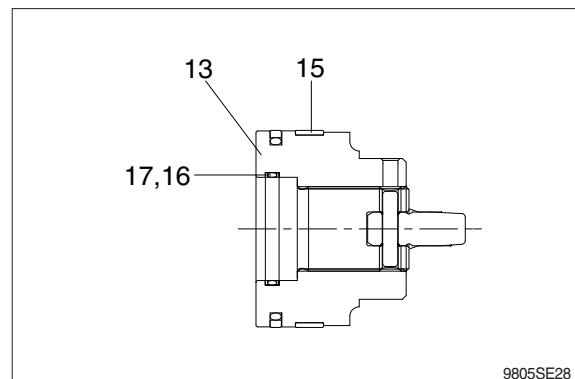
- ※ Check for scratches or rough surfaces.
- ① If found smooth with an oil stone.  
Coat the outer face of piston (13) with hydraulic oil.



- ② Fit piston seal (14) to piston
- ※ Put the piston seal in the warm water of 60~100°C for more than 5 minutes.
- ※ After assembling the piston seal, press its outer diameter to fit in.

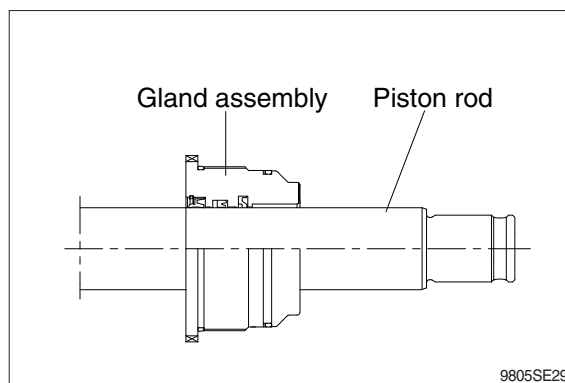


- ③ Fit wear ring (15) to piston (13).
- ④ Fit back up ring (17) and O-ring (16) to piston (13).

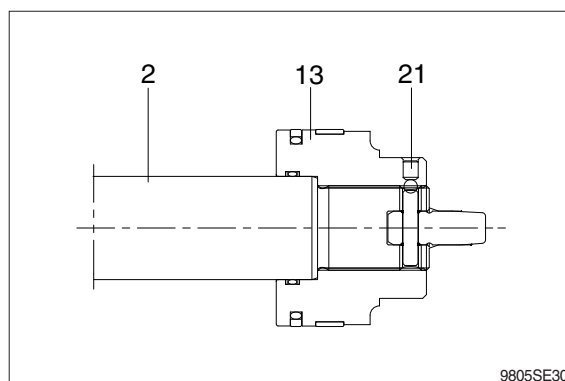


### (3) Install piston and gland assembly

- ① Fix the piston rod assembly to the work bench.
- ② Apply hydraulic oil to the outer surface of piston rod (2), the inner surface of piston and gland.
- ③ Insert gland assembly to piston rod (2).

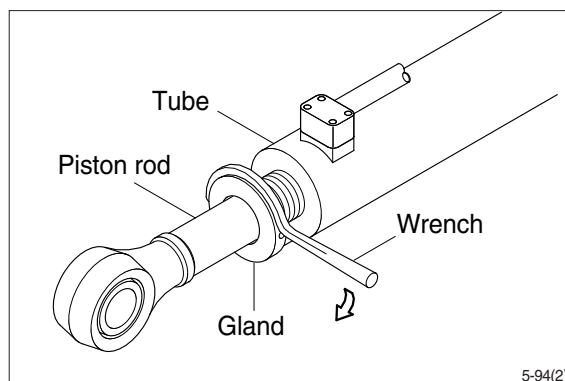
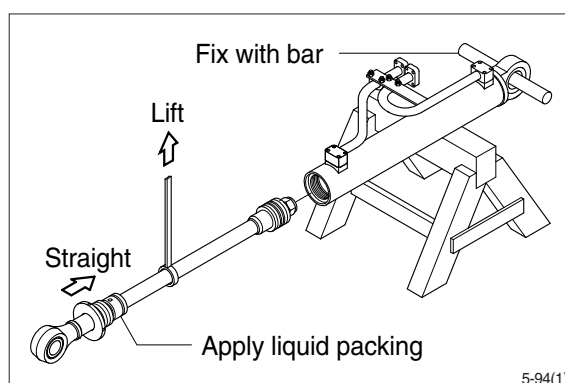


- ④ Fit piston assembly to piston rod.
- ⑤ Tighten piston (13) to piston rod (2).
  - Tightening torque :  $75 \pm 8 \text{ kgf} \cdot \text{m}$   
( $542 \pm 57.9 \text{ lbf} \cdot \text{ft}$ )
- ⑥ Tighten set screw (21) to piston (13).
  - Tightening torque :  $2.0 \pm 0.2 \text{ kgf} \cdot \text{m}$   
( $14.5 \pm 1.45 \text{ lbf} \cdot \text{ft}$ )



### (4) Overall assemble

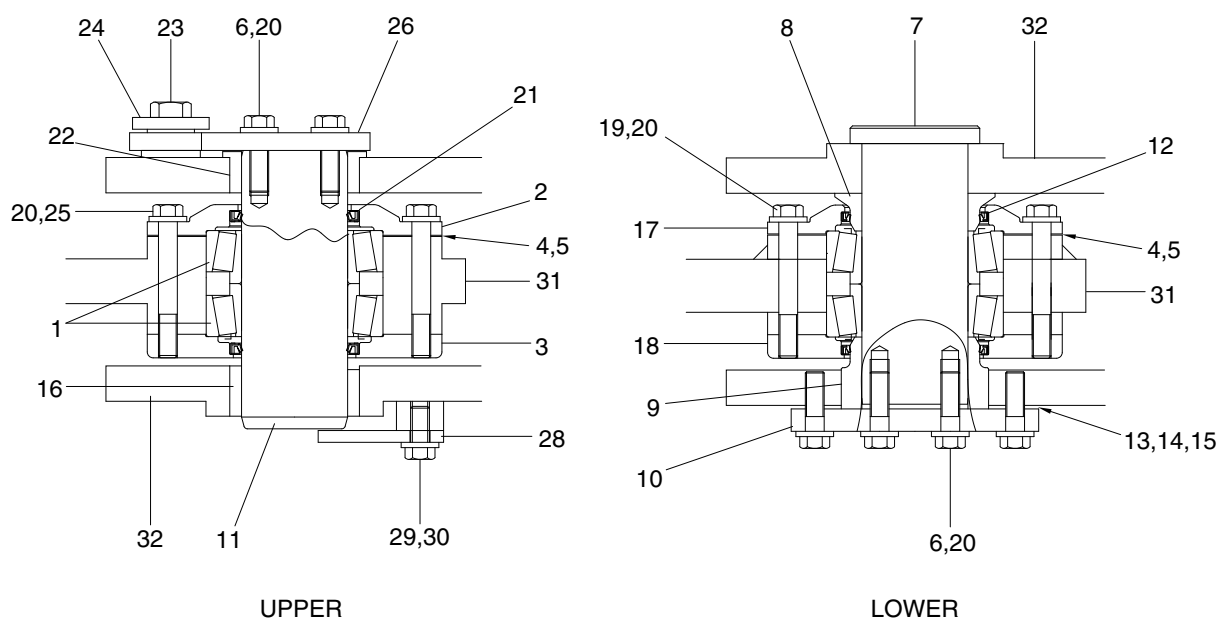
- ① Place a V-block on a rigid work bench. Mount the cylinder tube assembly on it and fix the assembly by passing a bar through the clevis pin hole to lock the assembly.
- ② Insert the piston rod assembly in to the cylinder tube assembly, while lifting and moving the piston rod assembly with a crane.
  - ※ Be careful not to damage piston seal by thread of cylinder tube.
- ③ Fit gland to the tube.
  - Tightening torque :  $88 \pm 9 \text{ kgf} \cdot \text{m}$   
( $637 \pm 65 \text{ lbf} \cdot \text{ft}$ )



## 4. CENTER PIVOT PIN

### 1) CONSTRUCTION

Figure shows the construction of the center pivot pin assembly. This assembly serves to connect the front frame with the rear frame; two sets of assemblies are provided, one each for the upper and lower parts. The numbers in parentheses following the parts name denote the item numbers shown in the figure in the disassembly and assembly procedures.



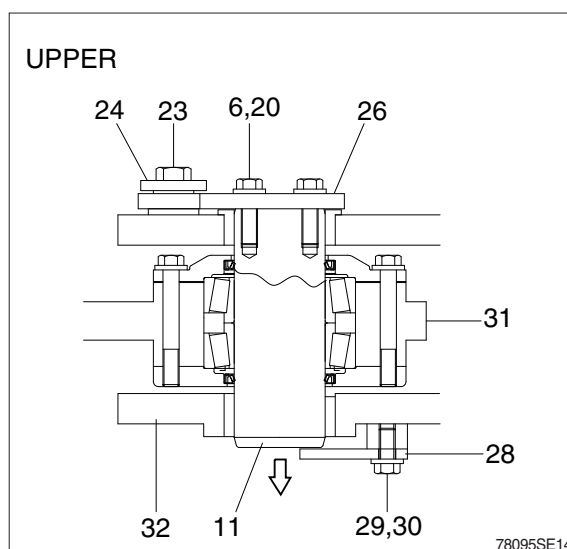
78095SE13

1	Bearing	12	Dust seal	23	Hexagon bolt
2	Cover	13	Shim (0.1 t)	24	Hardened washer
3	Cover	14	Shim (0.5 t)	25	Hexagon bolt
4	Shim (0.1 t)	15	Shim (2.0 t)	26	Plate
5	Shim (0.5 t)	16	Bushing	28	Plate
6	Hexagon bolt	17	Cover	29	Hexagon bolt
7	Pin	18	Cover	30	Hardened washer
8	Collar	19	Hexagon bolt	31	Front frame
9	Collar	20	Hardened washer	32	Rear frame
10	Plate	21	Dust seal		
11	Pin	22	Bushing		

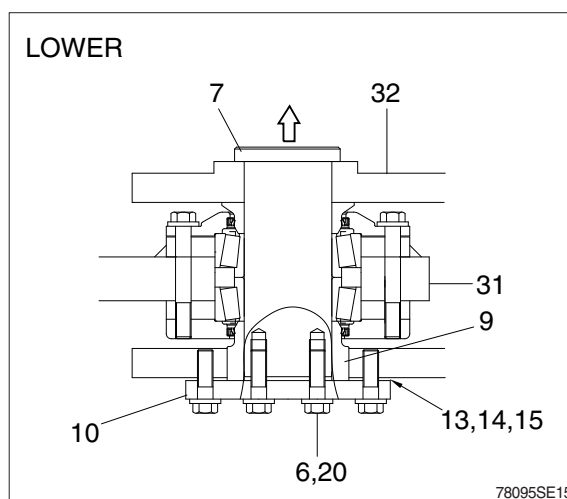
## 2) DISASSEMBLY

After supporting the front frame and the rear frame as horizontally as possible using wood blocks and jacks, disassemble as follows: In order to facilitate the disassembly/assembly of the center pivot pins, remove the drive shaft, hydraulic line and steering cylinder first.

- (1) Maintain the horizontal level of front frame (31) and rear frame (32), and then remove hexagon bolt (6, 23, 29), washer (20, 24) and plate (26, 28).
- (2) Take out upper pin (11) to the downside using a metal punch.



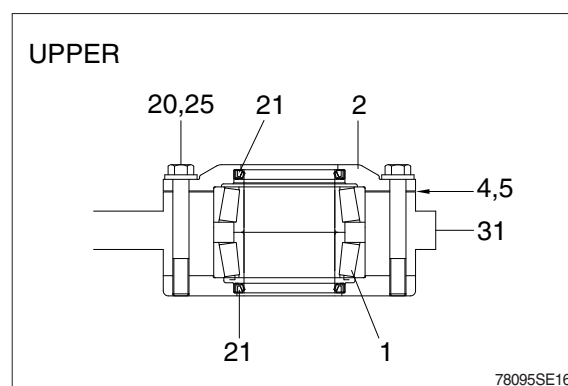
- (3) Maintain the front frame horizontal level, remove hexagon bolts (6) and then remove the plate (10) and shims (13, 14, 15).
- (4) Take out lower pin (7) to the upside using a metal punch carefully.
- (5) Jack up or lifting the front frame (31) slightly, the collar (9) protrudes over the rear frame. Remove the collar (9).
- (6) Lift the frame by passing the slinging wire rope at four positions of front frame, in order to separate it from the rear frame.
- (7) Support the front frame safely.



(8) Remove bolt (25), washer (20) and then take out cover (2) and shims (4, 5).

(9) Take out dust seal (21) from the cover (2).

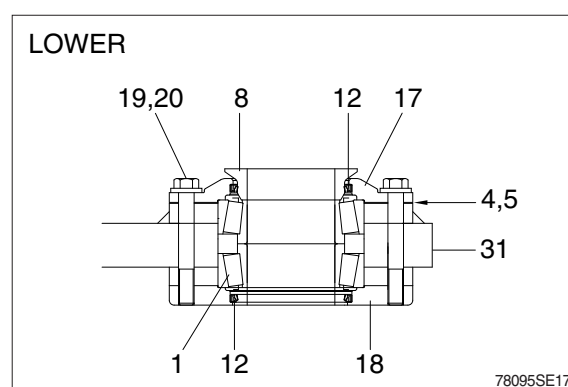
(10) Remove the bearing (1), and dust seal (21).



(11) Remove bolt (19), washer (20) and then take out cover (17, 18) and shims (4, 5).

(12) Take out the dust seal (12) from the cover (17, 18).

(13) Remove the bearing (1) and collar (8).



### 3) INSPECTION

(1) Check the bearing sliding surface for excessive wear, scorching or scratches; replace if necessary.

(2) Replace all dust seals (12, 21) with new ones.

(3) Grind any pins (7, 11) dented with an oilstone or replace any pins abrasive excessively.

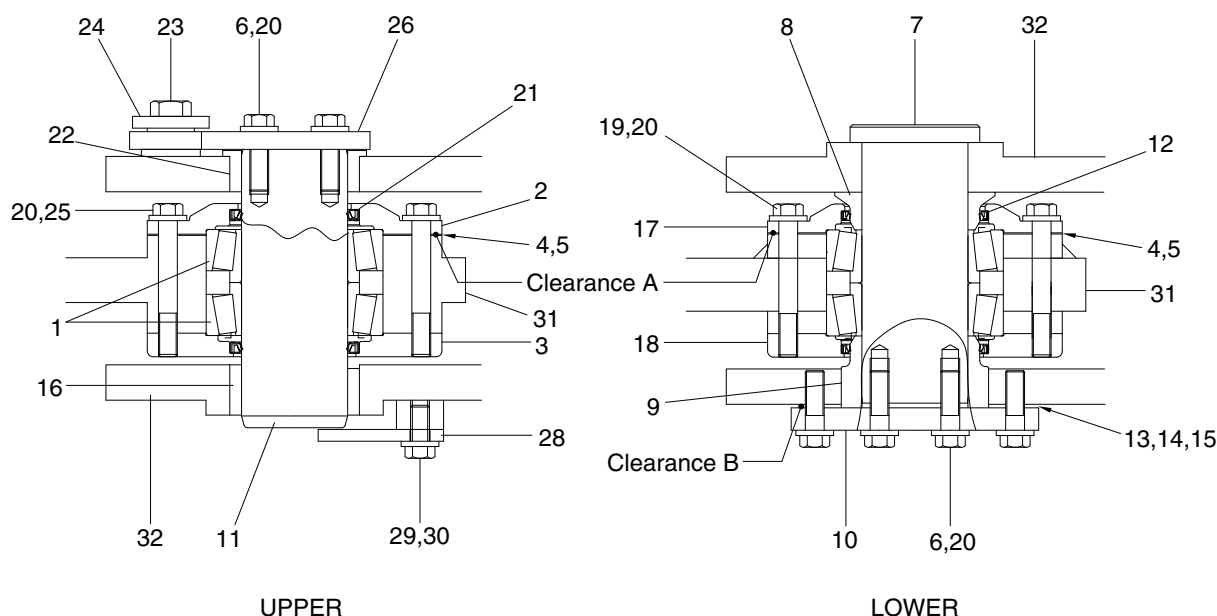
(4) Check inside cover (2, 3, 17, 18) and collar (8, 9) for dents or scratches; if any damage is found, correct with a grinder or replace.

(5) The serviceable limit of pins and bushings is shown in the table below.

Unit : mm

Item No.	Name	Std dimension	Serviceable limit			Remedy
			Outer dia	Inner dia	Clearance	
7, 11	Pin	Upper :100 Lower : 105	99.5/104.5		0.8	Replace
1	Tapered roller bearing			100.5/105.5		
8, 9	Collar			100.5/105.5		
12, 21	Dust seal	When removed				Replace

#### 4) ASSEMBLY



78095SE19

Assemble the center pivot group by reversing the order of disassembly while paying close attention to the following.

- (1) Put the dust seal (12,21) into cover (2, 3, 17, 18).
- ※ Apply grease to the lip of the dust seal. Insert the dust seal so that the dust seal lip faces out and punch four places on the outer circumference of the seal to lock it.
- (2) Lower the temperature of the lower bearing cup to  $-75 \pm 5^{\circ}\text{C}$  ( $-103 \pm 9^{\circ}\text{F}$ ) and install it to front frame until it contacts the bottom of the frame.
- (3) Place the cover (3, 18).
- (4) Coat lightly with oil and install lower bearing in bore in front frame. Coat lightly with oil and install upper bearing in bore in upper front frame.
- (5) Place the cover (2, 17) and hold in place with bolt (19, 25). At this time, adjust shims (4, 5) to press the shoulder of bearing (1) against retainer.
  - **Adjustment method of clearance A**
  - ① Install bearing (1) and cover (2, 17) without shim (4, 5)  
Install four of bolt (19, 25) so that each bolt is separated by 90 degrees.
    - Tightening torque :  $2.0 \sim 3.0 \text{ kgf} \cdot \text{m}$  ( $14.5 \sim 21.7 \text{ lbf} \cdot \text{ft}$ )
  - ② Adjust shims (4, 5) in order to control the clearance A.
    - Clearance A : Below 0.1 mm
    - Shim thickness : 0.1 mm, 0.5 mm
  - ③ Measure bearing preload and confirm the value.
    - Bearing preload :  $1.2 \sim 2.5 \text{ kgf} \cdot \text{m}$  ( $8.7 \sim 18.1 \text{ lbf} \cdot \text{ft}$ )



- (5) Apply grease to lower collar (8) and insert it to the lower of roller bearing.
- (6) After setting the bearing so that its upper surface is horizontal, tighten the all the bolt (19, 25).  
After tightening, confirm that tapered roller bearing moves lightly ; if does not move smoothly, add shims (4, 5).
- Tightening Torque : 35~43 kgf · m (253~311 lbf · ft)
  - Apply loctite #243.
- (7) Move the front frame and join it to the rear frame so that match the pin hole at the center.
- (8) Apply grease to pin (11), bushing (22) and insert it into tapered roller bearing (1).
- (9) Apply grease to lower collar (9) and insert it to the lower of roller bearing through rear frame (32).
- (10) Apply grease to pin (7) and insert it into tapered roller bearing (1).
- (11) Before tightening bolt (6), adjust shims (13, 14, 15) in order to control the clearance between the plate (21) and rear frame (32).
- **Adjustment method of clearance B**
- ① Install pin (7) and plate (10) without shim (13, 14, 15).  
Install four of bolt (6) so that each bolt is separated by 90 degrees.
    - Tightening torque : 2.0~3.0 kgf · m (14.5~21.7 lbf · ft)
  - ② Adjust shims in order to control the clearance B.
    - Clearance B : 0.1~0.2 mm
    - Shim thickness : 0.1 mm, 0.5 mm, 2.0 mm
- (12) Tighten the all the bolts (6).
- Tightening Torque : 35~43 kgf · m (253~311 lbf · ft)
  - Apply loctite #243.

## 5) TROUBLESHOOTING

Trouble	Probable cause	Remedy
Shock is felt when steering	Capscrew for fixing steering valve is loose	Retighten
	Faulty center pivot pin mounting bolts	Retighten
	Center pivot pins have worn out	Readjust or replace
	Faulty hydraulic system	See hydraulic system
Shock is felt when moving backward or forward	Fault fixing of connecting capscrews	Retighten
	Center pins have worn out	Readjust or replace
	Bearings of support unit have worn out	Retighten
	Drive shaft damaged	See drive system
	Faulty transmission	See transmission system