SERVICE MANUAL

HYDRAULIC EXCAVATOR

ViO80-1A

YANMAR

FOREWORD

This service manual outlines procedures for servicing YANMAR construction machinery. It contains specifications, servicing instructions and handling cautions. To obtain the maximum life and performance from YANMAR construction machinery, read this manual carefully and follow its instructions.
Please note that all dimensions and numerical values in this manual are for service reference, and are not inspection standards. Descriptions and specifications in this manual are subject to change without notice due to design improvements, etc.

⚠ WARNING

California
Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects and other reproductive harm.

⚠ WARNING

California
Proposition 65 Warning

Battery posts, terminals and related accessories contain lead and lead compounds, chemicals known to the State of California to cause cancer and reproductive harm.
Wash hands after handling.

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GENERAL CAUTIONS FOR MAINTENANCE WORK

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1. GENERAL CAUTIONS FOR MAINTENANCE WORK

1. General Cautions for Maintenance Work

1-1 Correct Work

Correct work means the quickest possible completion of according to the correct procedures and the specified standards.

It is important when conducting certain operations always to bear in mind the equipment, tools, gauges, materials, oil and grease, etc. that you must have ready, as well as items to be checked, adjusted, or disassembled, and cautions to watch out for.

1-2 Safety Precautions

(1) Never attempt servicing while engine is running or immediately after stopping operation.
(2) Wear work cloths, safety shoes and helmet.
(3) Check the equipment and tools before use. Especially, be sure to check the crane, lifting equipment and tools.
(4) When working together with other persons, allocate everyone's share of job, arrange the signals and act in concert with the other persons.
(5) The operation of the crane and slinging work must be performed by qualified persons.
(6) Do not enter or pass under the raised load.
(7) Lift and support the massive parts by crane before removing the installation bolts.
(8) Disconnect cables from battery before repairing the electric system.
(9) Remove the battery when welding the machine.

1-3 Preparations

(1) Check the service record of the machine. (That is, check how many months or hours the machine has been used since the preceding overhaul, what was the trouble then and what parts were replaced.)
(2) Have all servicing tools ready, i.e., tools, measuring devices (which have received periodic maintenance), containers, oil & grease, etc.
(3) Have the service literature (operation manual, parts catalog, etc.) ready.

1-4 Cautions for Disassembly and Reassembly

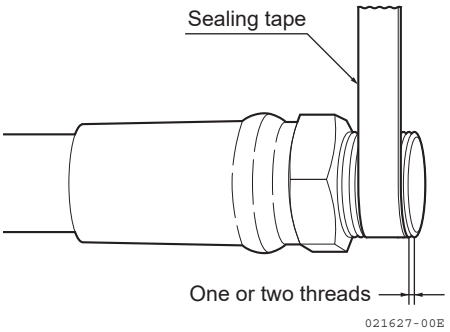
(1) Clean the machine before disassembly.
(2) Check and record the condition of the machine before disassembly :
  • Model, machine number, operation hours
  • Reasons for repair, history of repair
  • Contamination of filters
  • Fuel and oil condition
  • Damage to parts, etc.
(3) Place alignment marks on the necessary parts to facilitate reassembly.
(4) Clean all the removed parts and new replacement parts and put them in order.
(5) Use new seals, split pins, etc. for reassembly.

(6) Keep the parts apt to be damaged by water or oil apart from the oily or wet parts.
e.g.: Electrical parts, rubber parts, V-belts, etc.

(7) Use the jig for press-fitting the bearings, bushes and oil seals. When using a hammer, use a pad block.

(8) Clean the joint surface of all parts and keep them free from dust.

(9) Wind the sealing tape securely, leaving a space of one or two threads from the tip of the male screw. The tape should have an overlap of about 0.4 in. (10 mm).



1-5 Cautions for Removal and Installation of Hydraulic Equipment

(1) Check that the hydraulic oil temperature is low enough.

(2) Release air from the hydraulic tank to prevent the hydraulic oil from flowing out.

(3) Be sure to plug open the ends of hydraulic components to prevent dust from entering.

(4) Be sure to wipe hydraulic oil from the hydraulic components so that it will not be mistaken for an oil leak.

(5) Take care not to damage the plating on the cylinder rod.

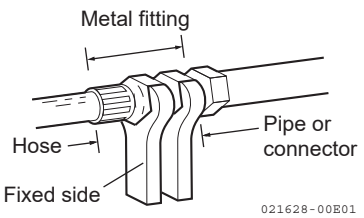
(6) Remove or install cylinders with rods fully retracted.

(7) Be sure to release air after installing the hydraulic cylinders.
- Run the engine at a low speed. Extend and retract the cylinders 4 to 5 times up to 2.0 to 3.9 in. (50 to 100 mm) from the end of the stroke. Then, fully extend and retract.

(8) Be sure to pressurize the hydraulic tank after installing the hydraulic components (in the case of the sealed hydraulic tank). Otherwise, hydraulic pumps might suffer cavitation and their life will be shortened.
- To pressurize the hydraulic tank, fully extend each cylinder and tighten the oil filter port plugs.

1-6 Cautions for Removal and Installation of Hydraulic Piping

(1) Installation of hydraulic hose
Take care not to twist the hoses. (Judge whether or not the hose is twisted by the hose mark.) For hoses with a metal fitting, use two wrenches to prevent twisting.
Use one to fix the hose, and the other to tighten the fitting to the specified tightening torque. Carefully check that the hoses do not come in contact after tightening. If any contact is found, correct it or use tubes.



(2) When installing hoses, first tighten to the specified torque and then loosen them a little. Then retighten to the specified torque.
- Break in the installed parts before tightening (except those using seal tapes).

(3) When installing pipes, turn the nuts more 1/4 to 1/2 turn after they reach the sharp torque rise point.

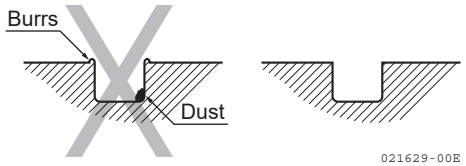
(4) When installing or removing hoses, use two wrenches, one to fasten the hose and the other to tighten or loosen the hose to prevent twisting.

(5) Check for oil leakage by applying max. pressure 5 to 6 times after attaching hydraulic hoses or pipes.

1. GENERAL CAUTIONS FOR MAINTENANCE WORK

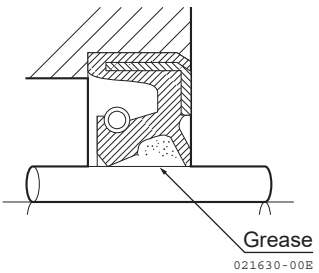
1-7 Cautions for Handling Seals

(1) Clean out grooves of O-rings. Remove burrs or dust if any.



(2) Take care not to twist O-rings. Correct by your finger if it is twisted.
(3) Take care not to damage seals when inserting.
(4) Handling of floating seals :
- Completely wipe off all the oil from the O-ring and housing after detaching the floating seals.
- Before installing, apply a little gear oil to the matching face of the housing.
- Turn the seals two or three times after installation to break them in.

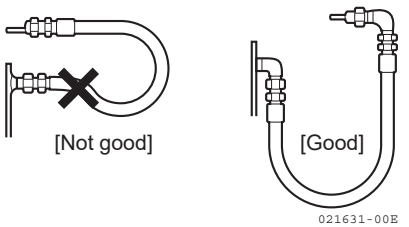
(5) Apply grease to the lip of the oil seals to prevent wear.



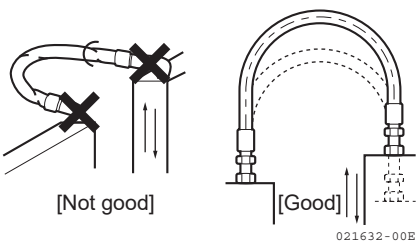
1-8 Correct Installation of Hydraulic Hose

In order to mount the hydraulic hose most effectively and economically, observe the following cautions.

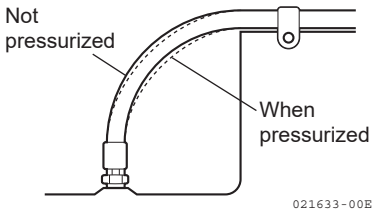
(1) When a hose is used at the minimum bending radius, use elbows to avoid sharp bending.



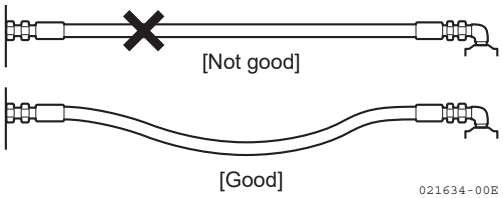
(2) To prevent twisting, the hose should be bent in the same direction as it moves.



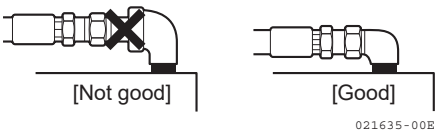
(3) When the hose is pressurized, the hose length varies slightly at the bend. Allow this change to occur and do not try to fasten the bend.



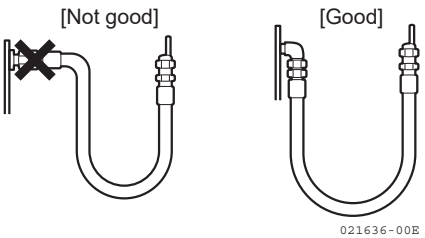
(4) It is necessary for the hose to have ample slackness for elongation and contraction, because its length will change by +2 % to -4 % when used at high pressure.



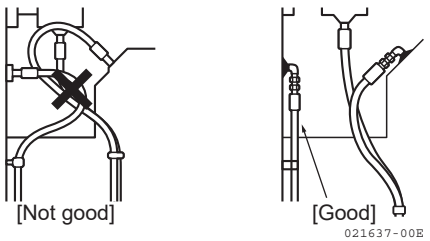
(5) Use the proper adapters, not pipes, in order to reduce the number and length of joints and improve the external appearance.



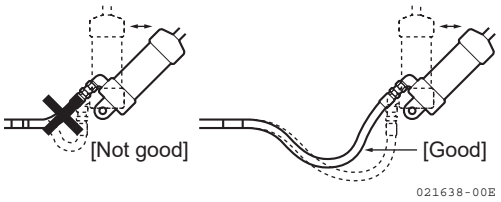
(6) Use an elbow to prevent excessive twisting or bending of the hose.



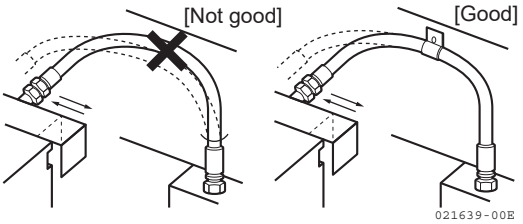
(7) Use adapters to make the hose as straight as possible. The outside appearance can be improved by avoiding the use of hoses that are too long.



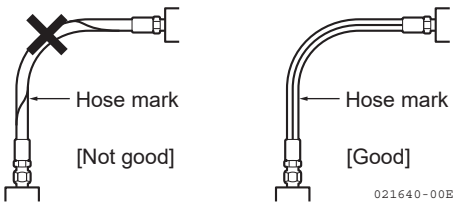
(8) The hose should be slightly longer than is absolutely necessary. The extra allows smoother movement of the hose and prevents sharp bending.



(9) When a bent hose is attached to two different planes, fix as shown in the diagram to prevent twisting.



(10) Use the marking on the hose as a guide to prevent twisting during installation.
Twisting of metal fitting with union nuts should be with a wrench on the hexagonal parts.



1. GENERAL CAUTIONS FOR MAINTENANCE WORK

1-9 Specifications of Hydraulic Hose

Specifications of the hydraulic hoses can be known by the code number or part descriptions as explained below. (For the parts number, please refer to our Parts Catalog.)

Description ..... Hose P 2 06 AB 075 W —
1 2 3 4 5 6 7 8

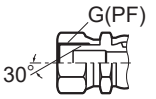
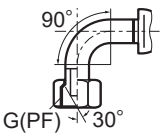
1 Part name

2 Hose material
- Rubber hose ..... G
- Wear-resistant high pressure rubber hose ..... H
- Plastic hose ..... P
- Wear-resistant plastic hose..... F

3 Recommended working pressure PSI(Mpa)
- Over 2986 (20.6) 1
- 2489 to 2986 (17.2 to 20.6) 2
- 1991 to 2489 (13.7 to 17.2) 3
- 1564 to 1991 (10.8 to 13.7) 4
- 995 to 1564 (6.9 to 10.8) 5
- 427 to 995 (2.9 to 6.9) 6
- 213 to 427 (1.5 to 2.9) 7
- Below 213 (1.5) 8

4 Nominal dia. (inch)
- 1 / 8” 02
- 3 / 16” 03
- 1 / 4” 04
- 3 / 8” 06
- 1 / 2” 08
- 5 / 8” 10
- 3 / 4” 12
- 1” 16

5 Combination of fitting

Fitting type	Code
Taper pipe thread R (PT)	A
 Straight pipe thread G (PF) with male 30 degrees seat	B
 90 degrees bent type. Straight pipe thread G (PF) with male 30 degrees seat	C
Without fitting	Y

* For the combination of fitting, refer to the list on the following page.

6 Total length (Unit : cm)

7 Hose protector
- Coil spring ..... W
- Coil tube ..... S
- Wire braid ..... B
- Tube (Rubber) ..... R
- Tube (Vinyl) V
- Sponge rubber ..... P
- Hose cover ..... K
- No protection ..... Blank

8 Other accessories
- No accessories...Blank
- O-ring 1

List of pipe threads

Symbol	Name
G (PF)	Straight pipe thread
R (PT)	Male taper pipe thread
Rc (PT)	Female taper pipe thread

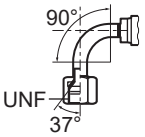
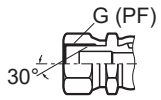
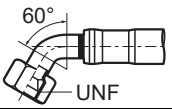
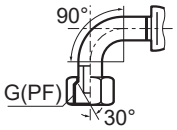
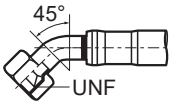
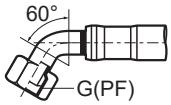
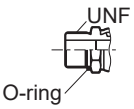
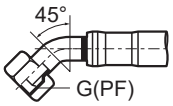
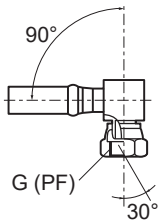
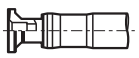
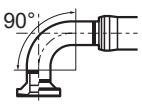
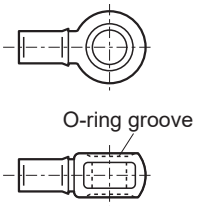
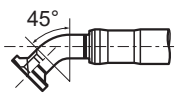
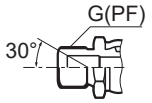
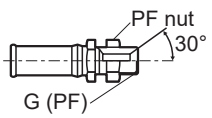
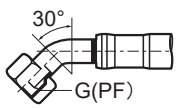
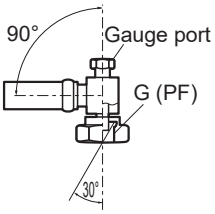
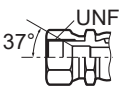
029292-00E

The example hose, P 2 06 AB 075 W stands for :
2 3 4 5 6 7

2 Material : Plastic
3 Working pressure : 2489 to 2986 PSI (17.2 to 20.6 MPa)
4 Nominal dia. : 3 / 8"
5 Fitting type : Taper pipe thread R (PT) and straight pipe thread G (PF) with male 30 degrees seat.
6 Length : 29.5 in. (75 cm)
7 Hose protector : Coil spring

1. GENERAL CAUTIONS FOR MAINTENANCE WORK

5 Combination of fitting

Fitting type		Code	Fitting type		Code
	Taper pipe thread R (PT)	A		90 degrees bent type. UNF thread with female 37 degrees seat	P
	Straight pipe thread G (PF) with male 30 degrees seat	B		60 degrees bent type. UNF thread with female 37 degrees seat	Q
	90 degrees bent type. Straight pipe thread G (PF) with male 30 degrees seat	C		45 degrees bent type. UNF thread with female 37 degrees seat	R
	60 degrees bent type. Straight pipe thread G (PF) with male 30 degrees seat	D		UNF, thread with O-ring groove	S
	45 degrees bent type. Straight pipe thread G (PF) with male 30 degrees seat	E		One-touch fitting (male)	T
	Straight pipe thread G (PF) with male 30 degrees seat	F		90 degrees elbow straight pipe thread male 30 degrees seat	V
	O-ring flange type	G			
	90 degrees bent O-ring flange type	H		Eyejoint with O-ring groove	W
	45 degrees bent O-ring flange type	J			
	Straight pipe thread, female 30 degrees seat with O-ring groove	K		Straight pipe thread with jam nut female 30 degrees seat	X
	30 degrees bent type. Straight pipe thread G (PF) with male 30 degrees seat	L		90 degrees elbow straight pipe thread with gauge port plug male 30 degrees seat	Z
	Taper pipe thread NPTF	M			
	UNF, thread with female 37 degrees seat	N	Without fitting		Y

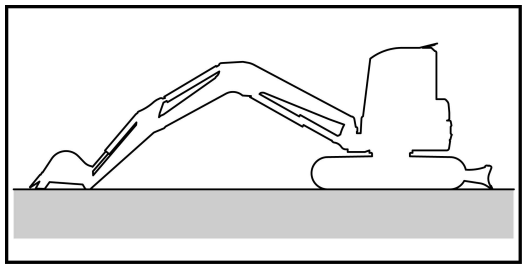
Note :

According to the combination of bending or elbow fittings, some hoses require drawings or original hoses to locally manufacture.

1-10 Air Release of Hydraulic Equipment

When operating the machine after disassembly or parts replacement of the hydraulic equipment, piping, etc., be sure to release air from the hydraulic system. This is necessary to prevent seizure and cavitation of the hydraulic equipment. If the air is left in the hydraulic system, the air is compressed or expanded depending on the load, having an adverse effect on the smooth operation of the hydraulic equipment and shortening the service life.

Attention
Before every oil or component change, if possible, set the machine at the oil level check position:
Blade back and lowered to the ground, equipment parallel to the tracks, boom cylinder half out, arm cylinder retracted to the end of its run, bucket teeth on the ground.



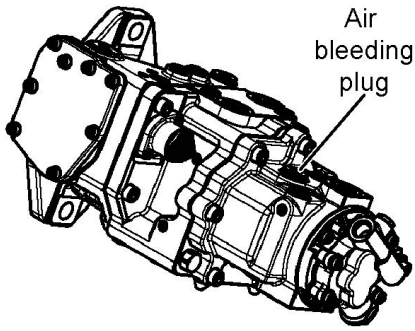
1. Air Release of Variable Displacement Piston Pumps

1) Make sure that all joints and fitting are not loosened.

2) Put a specified quantity of hydraulic oil into the hydraulic oil tank.
Note :

1. Refer to the hydraulic oil supply procedure for how to put hydraulic oil into the tank.
2. Keep the oil supply cap of the hydraulic oil tank removed.

3) Loosen the air bleeding plug of the pump to allow the air to escape in order to bleed it.



4) When the pump is fully bled, tighten the air bleed plug.

Air bleeding plug	G1/2-19
Tightening torque	79.7 ft·lbf (108 N·m)

5) Check the oil level and supply the hydraulic oil to the specified level if necessary. Then install the oil supply cap.

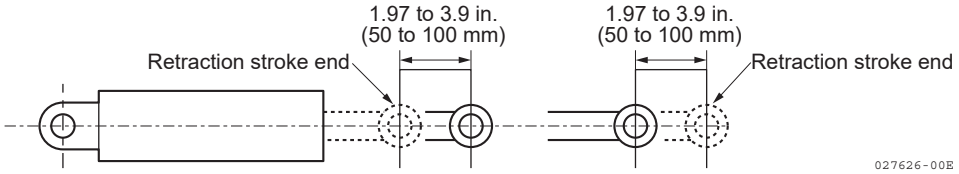
2. Air Release of Each Hydraulic Component

1) Run the engine at medium idling speed and activate the respective circuits for about 10 to 15 minutes.

2) Check the oil level and supply the hydraulic oil to the specified level if necessary.

3. Air Release of Hydraulic Cylinders

1) Set the Engine at low idling speed.
2) Extend and Retract the Cylinder Up to 1.97 to 3.9 in. (50 to 100 mm) from Each Stroke End Slowly 4 or 5 Times.



Note :

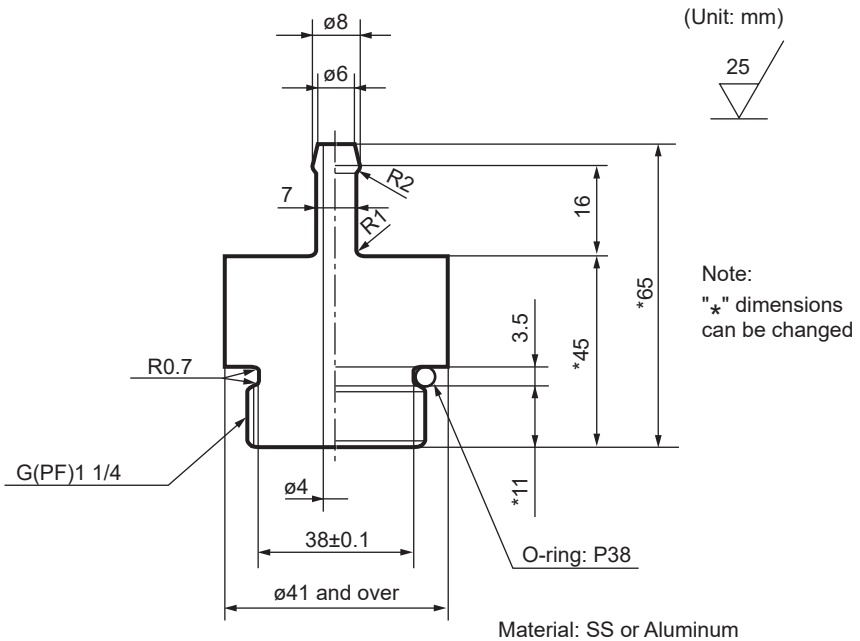
The extension and retraction stroke is up to 1.97 in. (50 mm) from each stroke end for the blade cylinder.

3) Then, Fully Extend and Retract the Cylinder 3 or 4 Times.
4) Check the oil level and supply the hydraulic oil to the specified level if necessary.

4. Air Release of Hydraulic Oil Tank

Replace the oil supply cap of the hydraulic tank with the vacuuming cap.

Connect the vacuuming cap to the vacuum compressor, vacuum the air in the hydraulic oil tank.



Vacuuming Cap

CHAPTER 2

TECHNICAL DATA

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2. TECHNICAL DATA

2. Technical Data

2-1 Specifications

Item				Unit	ViO80-1A	
					With standard arm	With long arm
Main specifications of machine						
Dimensions						
Overall length (Transportation position)				in. (mm)	252.4 (6410)	
Cabin	Overall height	Transportation position		in. (mm)	105.5 (2680)	
		Traveling position		in. (mm)	105.5 (2680)	
	Overall width	Full machine width		in. (mm)	89.4 (2270)	
Canopy	Overall height	Transportation position		in. (mm)	-	
		Traveling position		in. (mm)	-	
	Overall width	Full machine width		in. (mm)	-	
Tumbler center distance (steel / rubber)				in. (mm)	89.6 (2277) / 90.1 (2288)	
Track gauge				in. (mm)	73.6 (1870)	
Minimum ground clearance				in. (mm)	15.4 (390)	
Traveling performance						
Travel speed	Steel crawler	Low speed (Forward/Reverse)		MPH (km/hr)	1.4 (2.3)	
		High speed (Forward/Reverse)		MPH (km/hr)	2.6 (4.1)	
	Rubber crawler	Low speed (Forward/Reverse)		MPH (km/hr)	1.6 (2.5)	
		High speed (Forward/Reverse)		MPH (km/hr)	2.8 (4.5)	
Permissible water depth limit				in. (mm)	19.7 (500)	
Work performance						
Bucket	Width (Standard) *including side cutter			in. (mm)	29.53 (750)	
	[Standard. JIS heaped capacity]			cu.ft. (cu.m)	9.89 (0.28)	
	Number of teeth / Installation method			pcs.	4 / rubber pin lock type	
Maximum digging depth	With blade raised			in. (mm)	163.4 (4150)	177.2 (4500)
	With blade on the ground			in. (mm)	174.8 (4440)	188.6 (4790)
Maximum depth of vertically digging				in. (mm)	149.6 (3800)	162.6 (4130)
Maximum dumping height				in. (mm)	148.3 (4680)	193.3 (4910)
Minimum front swing radius (with boom in front)		Cabin		in. (mm)	97.2 (2470)	99.2 (2520)
		Canopy		in. (mm)	-	
Minimum front swing radius (with boom in front)		Cabin		in. (mm)	83.9 (2130)	85.4 (2170)
		Canopy		in. (mm)	-	
Rear end swing radius				in. (mm)	44.7 (1135)	
Boom swing angle	Cabin	Left		degrees	57	
		Right		degrees	60	
	Canopy	Left		degrees	-	
		Right		degrees	-	
Maximum digging force		Bucket		lbs. (k•N)	14286 (63.5)	
		Arm		lbs. (k•N)	9171 (40.8)	
Maximum tractive force		steel		lbs. (k•N)	14320 (63.7)	
		rubber		lbs. (k•N)	14230 (63.3)	
Maximum swing inclination angle (with standard bucket)				degrees	17.7	

2. TECHNICAL DATA

Item				Unit	ViO80-1A	
					With standard arm	With long arm
Main specifications of machine						
Work performance						
Swing speed				rpm	9	
Fuel consumption in practical operation			Maximum idling speed	Gals/h (L/h)	2.1 (8.1)	
			Eco mode	Gals/h (L/h)	1.8 (6.7)	
Blade						
Blade			Width × Height	in. (mm)	89.0 (2260) × 17.7 (450)	
			Capacity	cu.ft. (cu.m)	16.24 (0.46)	
			Lift above ground level	in. (mm)	18.1 (460)	
			Digging depth	in. (mm)	18.9 (480)	
Mean contact pressure						
JIS		Steel crawler	Cabin	PSI (KPa)	5.15 (35.5)	
			Canopy	PSI (KPa)	-	
		Rubber crawler	Cabin	PSI (KPa)	5.09 (35.1)	
			Canopy	PSI (KPa)	-	
Mass						
Operating mass		Steel crawler	Cabin	lbs. (kg)	17916 (8125)	
			Canopy	lbs. (kg)	-	
		Rubber crawler	Cabin	lbs. (kg)	17783 (8065)	
			Canopy	lbs. (kg)	-	
Base machine dry mass		Steel crawler	Cabin	lbs. (kg)	13230 (6000)	
			Canopy	lbs. (kg)	-	
		Rubber crawler	Cabin	lbs. (kg)	13098 (5940)	
			Canopy	lbs. (kg)	-	
Hydraulic equipment						
Hydraulic pump						
Drive method				-	Engine → Coupling →Pump (Direct drive)	
Type of pump				-	Variable piston pumps + gear pump	
Number of pumps				pcs.	4	
Theoretical discharge volume				cu.in./rev (cu.cm/rev)	2.26 (37)×2, 1.71 (28)×1, 0.61 (10)×1	
Maximum P.T.O. discharge volume			P.T.O.1	GPM (L/min)	31.7 (120)	
			P.T.O.2	GPM (L/min)	18.5 (70)	
Control valve						
Number of connected valves				pcs.	13	
System relief set pressure			P1, P2	PSI (MPa)	3698 (25.5)	
			P3	PSI (MPa)	3481 (24.0)	
			P4	PSI (MPa)	421 (2.9)	

2. TECHNICAL DATA

Item			Unit	ViO80-1A	
				With standard arm	With long arm
Hydraulic equipment					
Control valve					
	Circuit relief set pressure	Boom (at rod end)	PSI (MPa)	4134 (28.5)	
		Boom (at bottom end)	PSI (MPa)	4279 (29.5)	
		Arm (at rod end)	PSI (MPa)	4134 (28.5)	
		Arm (at bottom end)	PSI (MPa)	4134 (28.5)	
		Bucket (at rod end)	PSI (MPa)	4134 (28.5)	
		Bucket (at bottom end)	PSI (MPa)	4134 (28.5)	
		Boom swing (at rod end)	PSI (MPa)	4134 (28.5)	
		Boom swing (at bottom end)	PSI (MPa)	4134 (28.5)	
		Blade (at rod end)	PSI (MPa)	2176 (15)	
		Blade (at bottom end)	PSI (MPa)	-	
Cylinder					
	Boom	Stroke	in. (mm)	32.7 (831)	
		Inside diameter	in. (mm)	Ø4.53 (Ø115)	
		Piston rod diameter	in. (mm)	Ø2.56 (Ø65)	
		Speed: Up (Ground → Max.)	sec.	2.8	
		Speed: Down (Max. → Ground)	sec.	3	
	Arm	Stroke	in. (mm)	36.4 (924)	
		Inside diameter	in. (mm)	Ø3.94 (Ø100)	
		Piston rod diameter	in. (mm)	Ø2.56 (Ø65)	
		Speed: Full stroke for digging	sec.	3.3	
		Speed: Full stroke for dumping	sec.	2.8	
	Bucket	Stroke	in. (mm)	27.8 (705)	
		Inside diameter	in. (mm)	Ø3.74 (Ø95)	
		Piston rod diameter	in. (mm)	Ø2.36 (Ø60)	
		Speed: Full stroke for digging	sec.	2.3	
		Speed: Full stroke for dumping	sec.	1.9	
	Blade	Stroke	in. (mm)	6.69 (170)	
		Inside diameter	in. (mm)	Ø5.12 (Ø130)	
		Piston rod diameter	in. (mm)	Ø2.56 (Ø65)	
		Speed: Up (Ground → Max.)	sec.	1.1	
		Speed: Down (Max. → Ground)	sec.	1.2	
	Boom swing	Stroke	in. (mm)	23.8 (604)	
		Inside diameter	in. (mm)	Ø4.72 (Ø120)	
		Piston rod diameter	in. (mm)	Ø2.36 (Ø60)	
		Speed: Full stroke to the right	sec.	6.7	
		Speed: Full stroke to the left	sec.	6.0	

2. TECHNICAL DATA

Item				Unit	ViO80-1A	
					With standard arm	With long arm
Hydraulic equipment						
Swivel joint						
Swivel joint port diameter X Number				inch×pcs.	1/2 × 4, 3/8 × 4, 1/4 × 2	
Motor						
	Swing motor	Type		-	Fixed displacement piston motor	
		Displacement		cu.in./rev (cu.cm/rev)	2.42 (39.7)	
		Brake valve	Type		Cross relief valve	
			Relief set pressure	PSI (MPa)	3481 (24)	
	Travel motor	Type		-	Variable displacement piston motor	
		Displacement (Low/High)		cu.in./rev (cu.cm/rev)	3.41 (55.8) / 1.92 (31.5)	
		Brake valve	Type	-	Counter balance valve	
			System pressure	PSI (MPa)	3698 (25.5)	
		Type of reduction gear		-	Planetary gear (with double-reduction mechanism)	
Hydraulic oil tank						
	Tank capacity			Gals (L)	29.6 (112) [tank: 15.8 (60), others: 13.8 (52)]	
	Suction filter	Type		-	Wire gauze	
		Filtration area		sq.in. (sq.cm)	338 (2180)	
		Filtration accuracy		u	105	
	Return filter	Type		-	Filter paper	
		Filtration area		sq.in. (sq.cm)	1411 (9100)	
		Filtration accuracy		u	10	
		By-pass valve opening pressure		PSI (MPa)	21.3 (0.147)	
Locking device						
	Lever lock			-	Oil pressure controlled	
	Boom swing lock			-	Pedal guard	
	Swing lock			-	Mechanical brake	
Swing device						
	Swing bearing			-	Planetary gear (with reduction mechanism)	
	Power transmission			-	Swing motor shaft → Swing gear	
	Type of brake			-	Oil pressure controlled mechanical brake	
	Brake mounting position			-	Swing motor	

2. TECHNICAL DATA

Item				Unit	ViO80-1A	
					With standard arm	With long arm
Undercarriage						
	Steel crawler	Shoe width		in. (mm)	17.7 (450)	
		Grouser	Type	-	Triple grouser	
			Height	in. (mm)	0.79 (20)	
		Shoe and link mounting method		-	Bolt on	
		Link pitch		in. (mm)	6.06 (154)	
		Number of shoes (One side)		pcs.	39	
		Crawler drive method		-	Link driving	
	Rubber crawler	Shoe width		in. (mm)	17.7 (450)	
		Lug height		in. (mm)	1.18 (30)	
		Core metal pitch		in. (mm)	3.29 (83.5)	
	Carrier roller (Upper roller)	Manner of support		-	Overhang type	
		Quantity (One side)		pcs.	1	
		Bearing		-	Bearing	
		Sealing		-	Shaft seal	
	Number of shoe slide plates (One side)			pcs.	-	
	Track roller (Lower roller)	Quantity (One side)		pcs.	5	
		Bearing		-	Bush	
		Sealing		-	Floating seal	
	Idler	Quantity (One side)		pcs.	1	
		Bearing		-	Bush	
		Sealing		-	Floating seal	
	Number of sprocket teeth	Steel crawler		pcs.	19	
		Rubber crawler		pcs.	19	
	Crawler tension adjustment			-	Grease adjuster	
Engine						
	Main specifications					
		Engine model		-	4TNV98C-WBV	
		Type		-	Vertical 4 cylinder water-cooled direct injection diesel engine	
		Combustion system		-	Direct injection	
		Number of cylinders - Bore × Stroke		pcs. - in.×in. (mm×mm)	4 - 3.86 × 4.33 (98 × 110)	
		Total displacement		cu.in. (cu.cm)	202.5 (3318)	
		Rated output / engine speed		HP/rpm (kW/rpm)	(Gross) 56.9 / 2000 (42.4 / 2000)	
		Maximum output at maximum idling speed		HP/rpm (kW/rpm)	(Gross) 55.7 / 1900 (41.5 / 1900)	
		Maximum torque / engine speed		ft•lbf/rpm (N•m/rpm)	168.9 to 177.8 / 1300 (229 to 241 / 1300)	
		Specific fuel consumption		lbs./HP•h (g/kW•h)	0.373 (227) or less	
		Maximum idling speed		rpm	1875 to 1925	
		Minimum idling speed		rpm	1175 to 1225	
		Engine dry mass (excluding air cleaner and silencer)		lbs. (kg)	659 (299)	

2. TECHNICAL DATA

Item				Unit	ViO80-1A	
					With standard arm	With long arm
Engine						
Main specifications						
	Lubricating method			-	Forced lubrication by trochoid pump	
	Specific lubricating oil consumption			lbs./HP•h (g/kW•h)	0.00008 to 0.00037 (0.05 to 0.23)	
	Compression pressure			PSI (MPa)	493 (3.4) at 250 rpm	
Cylinder head						
	Intake valve	Open	bTDC	degrees	14	
		Close	aBDC	degrees	46	
	Exhaust valve	Open	bBDC	degrees	50	
		Close	aTDC	degrees	14	
	Intake valve clearance (Cold engine)			in. (mm)	0.0079 (0.2)	
	Exhaust valve clearance (Cold engine)			in. (mm)	0.0079 (0.2)	
	Intake valve seat angle			degrees	120	
	Exhaust valve seat angle			degrees	90	
Piston						
	First compression ring	Ring shape		-	Half keystone	
		Ring quantity		pcs.	4	
	Second compression ring	Ring shape		-	Rectangular	
		Ring quantity		pcs.	4	
	Oil-ring	Ring shape		-	Bevel V groove (with coil expander)	
		Ring quantity		pcs.	4	
Governor						
	Name			-	BOSCH ECU	
	Type			-	EDC17CV54 type	
Fuel feed system						
	Fuel filter			-	Filter paper with automatic air release device	
	Fuel filter filtration area			sq.in. (sq.cm)	310 (2000)	
	Oil/water separator			-	Float type	
	Feed pump			-	Plunger type (+ electric type)	
Lubrication system						
	Lubrication pump			-	Trochoid pump	
	LO pressure regulating valve opening pressure			PSI (MPa)	42.1 to 56.6 (0.29 to 0.39)	
	LO filter			-	Full flow filter	
	LO filter filtration area			sq.in. (sq.cm)	180 (1160)	
	Filter valve opening pressure			PSI (MPa)	11.4 to 17.1 (0.08 to 0.12)	
	Operating pressure of alarm switch			PSI (MPa)	5.69 to 8.53 (0.04 to 0.06)	
Cooling device						
	Cooling system			-	Water-cooling (Radiator)	
	Fan belt size			-	A44	
	Thermostat opening temperature			ºF (ºC)	159.8 (71)	
	Thermostat full-open temperature			ºF (ºC)	179.6 (82)	

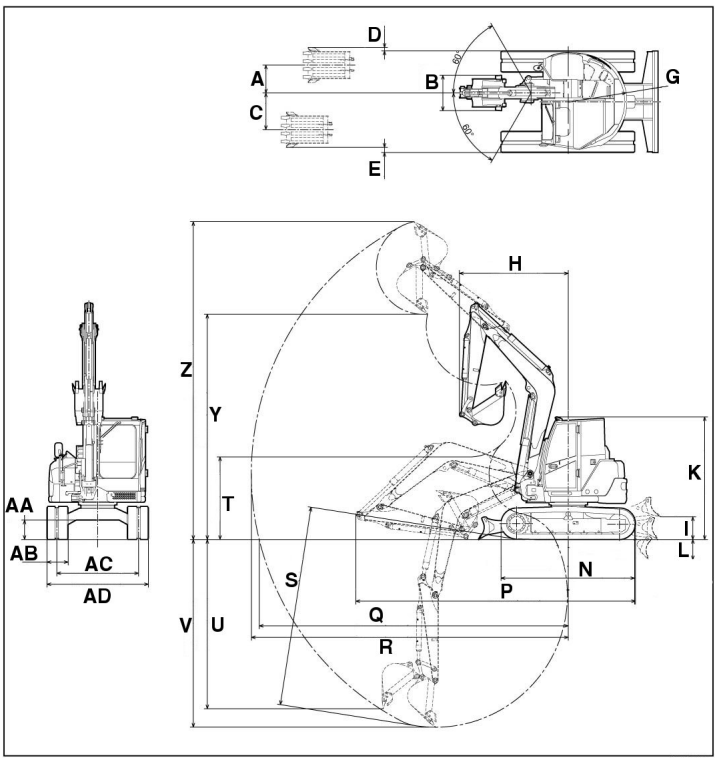
2. TECHNICAL DATA

Item			Unit	ViO80-1A	
				With standard arm	With long arm
Engine					
Cooling device					
	Radiator cap pressure		PSI (MPa)	12.80 (0.09)	
	Radiator fan		pcs.×Øin. (mm)	6 × Ø16.9 (Ø430)	
	Operating temperature of water temperature alarm switch		ºF (ºC)	224.6 to 235.4 (107 to 113)	
Air cleaner					
	Type		-	Cyclone type	
	Filtration area		sq.ft. (sq.m)	20.8 (1.93)	
Fuel injection pump					
	Injection pump type		-	Common rail system	
	Injection pump plunger diameter		in. (mm)	Ø0.26 (Ø6.5)	
	Injection pump cam lifting height		in. (mm)	0.26 (6.5)	
	Fuel injection timing (FIT)		degrees	bTDC 3.5	
	Firing order		-	1-3-4-2-1	
Nozzle					
	Type			BOSCH CR12.2	
	Nozzle hole diameter × Number of holes		Øin. (mm)×pcs.	Ø0.006 (Ø0.150) × 6	
	Spray angle		degrees	156	
	Fuel injection pressure		PSI (MPa)	- (Solenoid valve type)	
Turbocharger					
	Type		-	-	
	Revolution speed		rpm	-	
Starting device					
	Cold starting aids		-	Glow plug	
	Starting aids capacity		V-W	12-77	
	Battery type		-	130E41R-MF	
	Battery voltage - 5 hrs rate capacity		V-Ah	12-92	
Electrical equipment					
	Alternator	Type	-	AC generator	
		Nominal output	V-A	12-80	
		Rated speed	rpm	6000	
	Regulator	Type	-	IC type	
		Regulation voltage	V	14.3 to 14.7	
	Starter motor	Type	-	Reduction type	
		Nominal output	V-kW	12-3.0	
		Engagement	-	Magnet shift	
	LCD monitor		V-A	12-0.45	
	Horn		V-W	12 - 30	
	Fuse	Blade fuse	A×pcs.	30 × 3, 20 × 5, 10 × 2, 5 × 8	
		Slow blow fuse	A×pcs.	120 × 1, 100 × 1, 80 × 1, 60 × 1	

2. TECHNICAL DATA

Item		Unit	ViO80-1A	
			With standard arm	With long arm
Electrical equipment				
	Headlight	V-W	12-55 (Halogen type) × 2	
	Boom light	V-W	12-55 (Halogen type)	
	Room lamp (for cabin)	V-W	12-3	
	Wiper motor (for cabin)	V-W	12-48	

2-2 Outline Drawing and Working Area

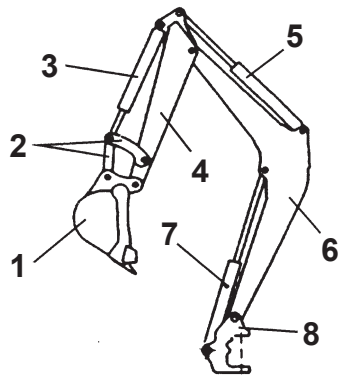
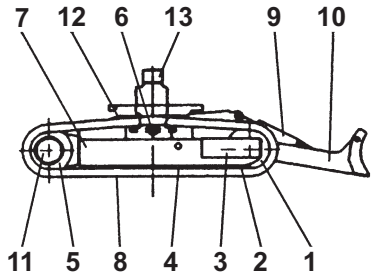
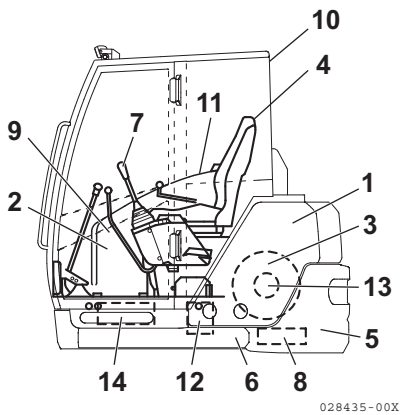


Unit : mm		L++			L++
A	620		Q	6820	7160
B	750		R	6960	7290
C	840		S	4440	4790
D	60		T	1940	1590
E	120		U	3800	4130
G	1135	1265 [8]	V	4150	4500
H / swing	2470/2130	2520 / 2170	Y	4680	4910
I	460		Z	6790	7020
K	2710		AA	390	
L	480		AB	450	
N	2890		AC	1870	
P	6410	6450	AD	2270	

8. with rear counterweight

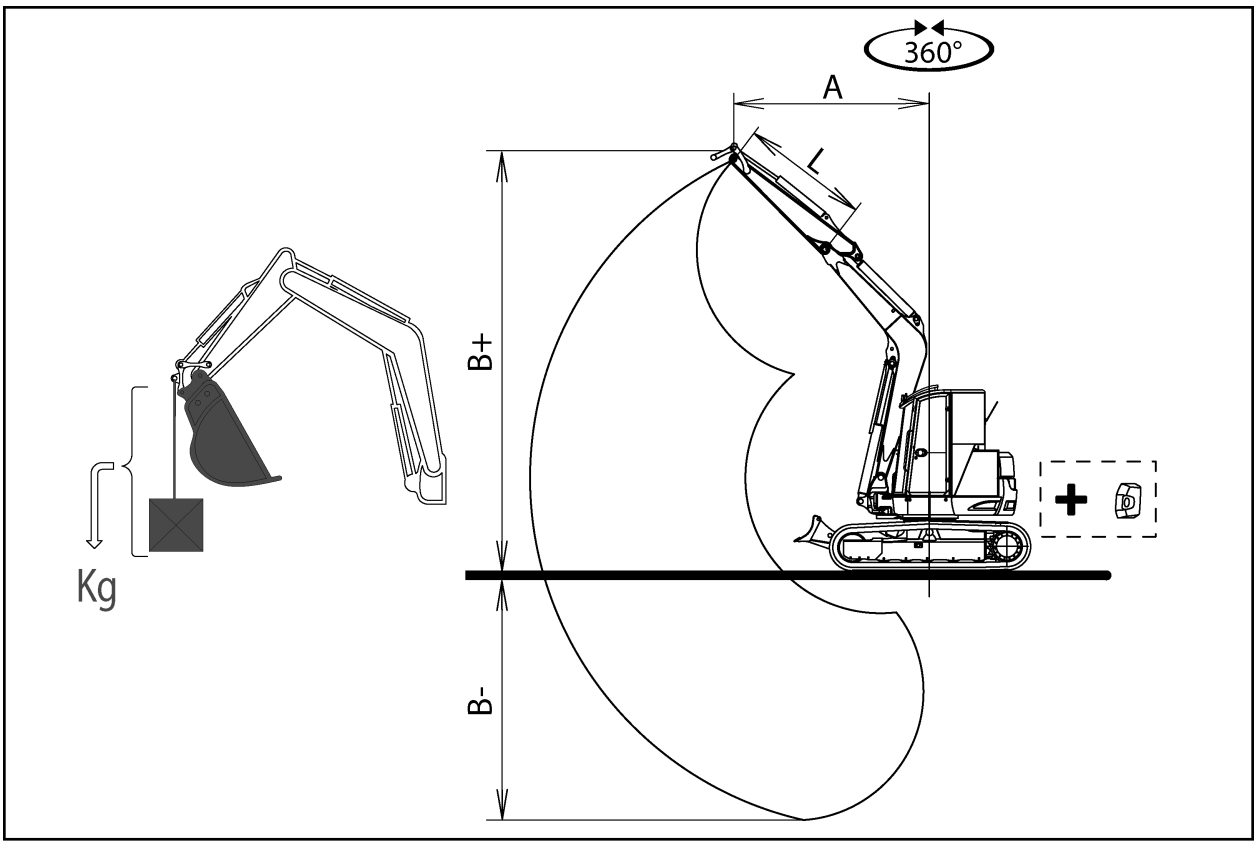
2-3 Weight List of Main Parts

[Unit : lbs. (kg)]

Equipment	No.	Part		ViO80-1A Cabin	
				Steel crawler	Rubber crawler
Front implement					
	1	Bucket	Ass'y	434.3 (197)	
	2	Bucket arm & link	Ass'y	77.2 (35)	
	3	Bucket cylinder	Ass'y	127.9 (58)	
	4	Arm	Ass'y	348.3 (158)	
	5	Arm cylinder	Ass'y	183.0 (83)	
	6	Boom	Ass'y	875.2 (397)	
	7	Boom cylinder	Ass'y	220.5 (100)	
	8	Boom bracket	Ass'y	392.4 (178)	
Undercarriage					
	1	Idler	Ass'y	116.8 (53) × 2	
	2	Crawler guard	Ass'y	24.3 (11) × 2	-
	3	Crawler adjuster	Ass'y	83.8 (38) × 2	
	4	Track roller	Ass'y	39.7 (18) × 10	
	5	Sprocket	Ass'y	41.9 (19) × 2	
	6	Carrier roller	Ass'y	15.9 (7.2) × 2	
	7	Track frame	Ass'y	2072.3 (940)	
	8	Steel crawler & Rubber crawler	Ass'y	903.9 (410) × 2	917.1 (416) × 2
	9	Blade cylinder	Ass'y	130.1 (59)	
	10	Blade	Ass'y	886.3 (402)	
	11	Travel motor	Ass'y	191.8 (87) × 2	
	12	Swing bearing	Ass'y	220.5 (100)	
	13	Swivel & hose or fitting	Ass'y	99.2 (45)	
Upperstructure					
	1	Engine hood	Ass'y	33.1 (15)	
	2	Hydraulic oil tank with filter	Ass'y	156.5 (71)	
	3	Engine	Ass'y	793.7 (360)	
	4	Operator's seat & mount	Ass'y	319.7 (145)	
	5	Counter weight	Ass'y	1929.0 (875)	
	6	Turning frame	Ass'y	1918.0 (870)	
	7	Controls (Lever stands and pedals)	Ass'y	88.2 (40)	
	8	Battery	Ass'y	63.9 (29)	
	9	Fuel tank & piping	Ass'y	35.3 (16)	
	10	Cabin	Ass'y	606.3 (275)	
	11	Covers, steps and panels		209.4 (95)	
	12	Swing motor	Ass'y	187.4 (85)	
	13	Pump & mount and hoses	Ass'y	165.3 (75)	
	14	Control valve & fitting and hoses	Ass'y	264.6 (120)	
	15	Cabin mount	Ass'y	189.6 (86)	
	16	Boom swing cylinder	Ass'y	160.9 (73)	

2-4 Lifting Capacity List

2-4-1 Without additional counterweight



L = 1650mm					
B \ A	Max	5m	4m	3m	2m
5m	*1720	-	*1720	-	-
4m	1090	1190	*1750	-	-
3m	950	1200	1720	*2480	-
2m	870	1190	1730	2460	-
1m	860	1140	1620	2190	-
0m	890	1100	1560	2180	-
-1m	970	1100	1560	2340	-
-2m	1190	-	1570	2600	-
-3m	*1350	-	-	*1550	-

L = 2000mm					
B \ A	Max	5m	4m	3m	2m
5m	*1610	-	*1530	-	-
4m	1050	1240	*1570	-	-
3m	890	1210	*1810	-	-
2m	820	1160	1640	2520	-
1m	790	1120	1530	2250	-
0m	800	1060	1450	2140	-
-1m	820	1050	1410	2150	-
-2m	1000	1040	1420	2140	-
-3m	-	-	-	-	-

Machine with cab and rubber tracks.

A = Tilt from the rotation axis

B = Attachment point height

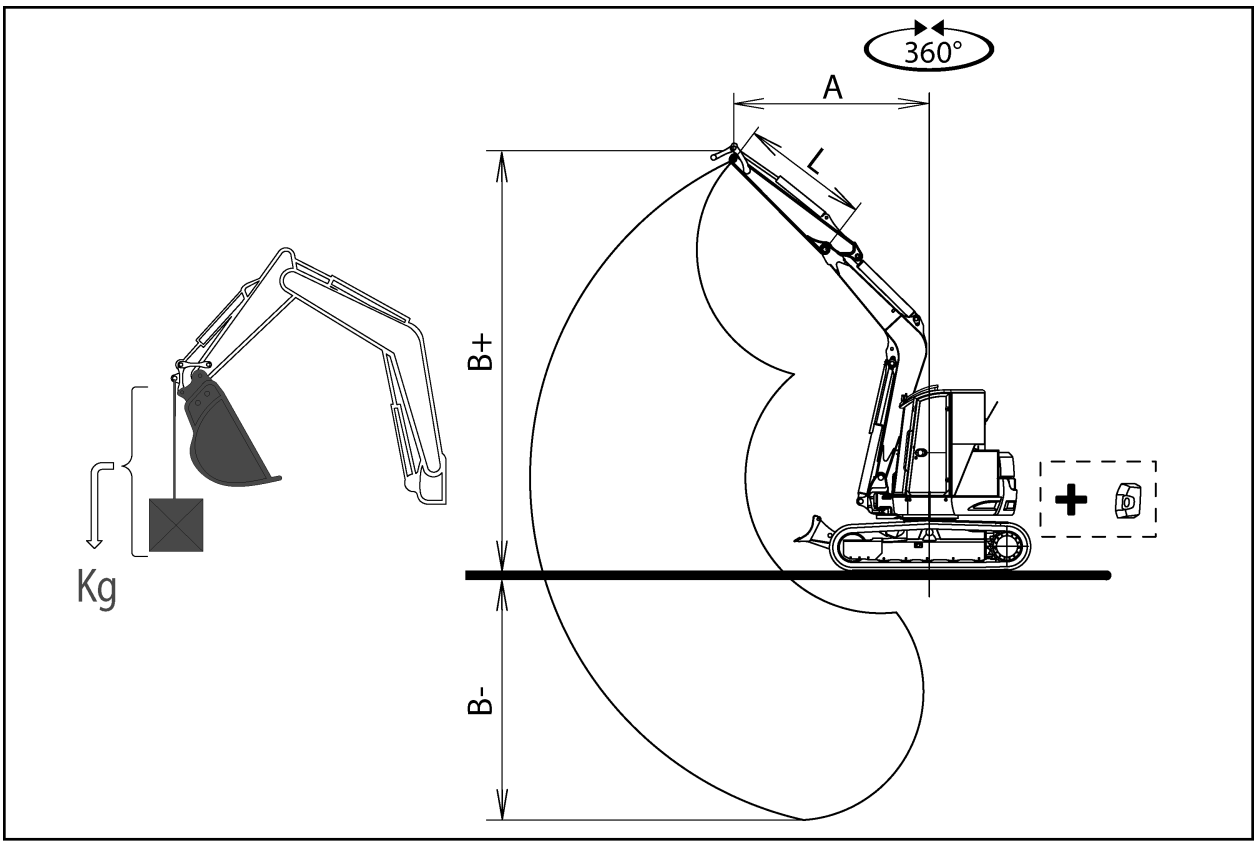
L = Arm length

* = Hydraulic capacity limits of the lifting force

■ = Maximum load raised by the machine

■ = Housing overload alarm value setting

2-4-2 With additional counterweight



L = 1650mm						
B \ A	Max	5m	4m	3m	2m	
5m	*1720	-	*1720	-	-	
4m	1250	1350	1750	-	-	
3m	1090	1360	1940	*2480	-	+ 394kg
2m	1000	1350	1940	2790	-	
1m	990	1300	1840	2520	-	
0m	1030	1260	1780	2510	-	
-1m	1120	1260	1780	2670	-	
-2m	1370	-	1780	2930	-	
-3m	*1350	-	-	*1550	-	

L = 2000mm						
B \ A	Max	5m	4m	3m	2m	
5m	*1610	-	*1530	-	-	
4m	1200	1410	*1570	-	-	
3m	1030	1380	*1810	-	-	+ 394kg
2m	950	1320	1850	2860	-	
1m	920	1280	1760	2570	-	
0m	930	1220	1680	2470	-	
-1m	1010	1210	1630	2470	-	
-2m	1160	1200	1640	2470	-	
-3m	-	-	-	-	-	

Machine with cab and rubber tracks.

A = Tilt from the rotation axis

B = Attachment point height

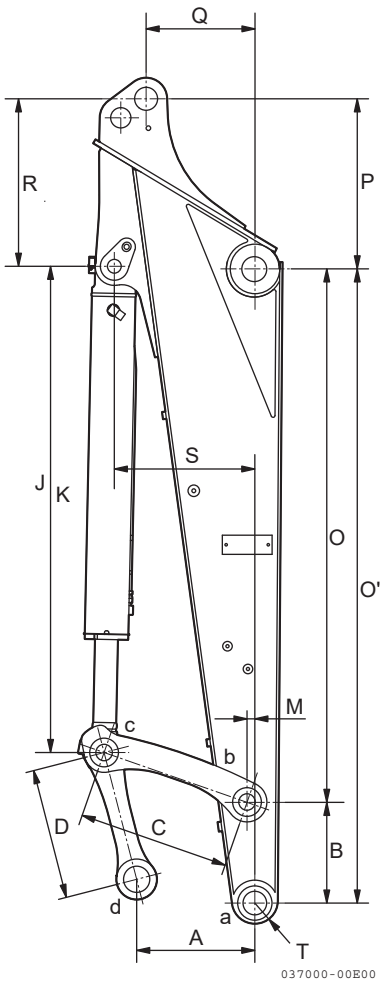
L = Arm length

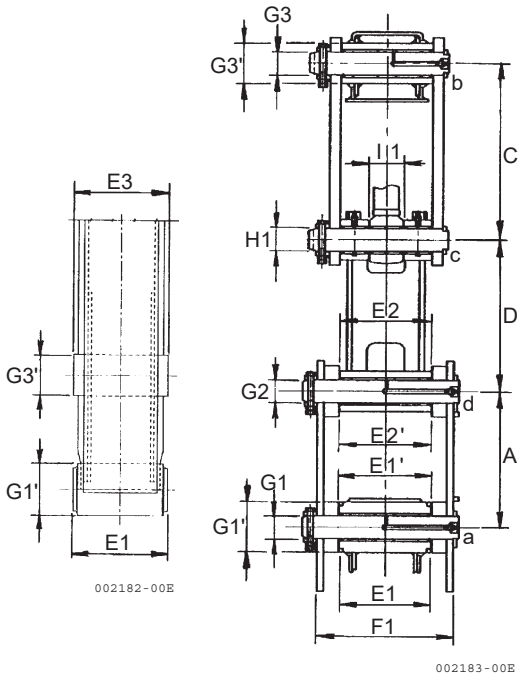
* = Hydraulic capacity limits of the lifting force

■ = Maximum load raised by the machine

□ = Housing overload alarm value setting

2-5 Specifications for Attachment





Unit : in. (mm)

Model			ViO80-1A
Dimensions			
	A		12.29 (312.2)
	B		10.16 (258)
	C		15.55 (395)
	D		13.46 (342)
	E 1	; External width of arm end boss	7.87 (200)
	E 1'	; Internal width of bucket pin boss	7.91 (201)
	E 2	; External width of bucket link boss	7.87 (200)
	E 2'	; Internal width of bucket pin boss	7.91 (201)
	E 3	; External width of bucket arm pivot pin boss	7.32 (186)
	F 1	; External width of bucket arm	12.28 (312)
	G 1	; Bucket pin diameter	ø1.97 (ø50)
	G 1'	; Arm end boss diameter	ø4.13 (ø105)
	G 2	; Bucket pin diameter	ø1.97 (ø50)
	G 3	; Bucket arm pivot pin diameter	ø1.97 (ø50)
	G 3'	; Bucket arm pivot pin boss diameter	ø3.54 (ø90)
	H 1	; Bucket cylinder rod end pin diameter	ø2.36 (ø60)
	I 1	; Bucket cylinder rod end boss thickness	2.76 (70)
	H 2	; Bucket cylinder bottom boss thickness	ø1.97 (ø50)
	I 2	; Bucket cylinder bottom boss thickness	2.36 (60)
	J	; Cylinder length when it is fully retracted	42.80 (1087)
	K	; Cylinder length when it is fully extended	70.55 (1792)
	M		0.75 (19)
	O		54.8 (1392)
	O'		64.96 (1650)
	P		17.52 (445)
	Q		11.12 (282.5)
	R		17.22 (437.5)
	S		14.39 (365.5)
	T		R2.07 (R52.5)
Oil pressure specifications			
	Hydraulic pump discharge volume GPM (L/min)	P1	18.6 (70.3)
		P2	18.6 (70.3)
		P3	14.1 (53.2)
		P4	5.0 (19)
	Total oil flow for P.T.O. GPM (L/min)		31.7 (120)
	Set pressure of system relief valve [PSI (MPa)] P1, P2		3698 (25.5)
	Set pressure of system relief valve [PSI (MPa)] P3		3481 (24)
	Set pressure of bucket circuit relief valve [PSI (MPa)]		4134 (28.5)

2-6 Periodic Inspection and Servicing

Check/Adjust/Supply ◇ Clean □ Oil and grease ■ Replace ● Oil sample ♦ + = and / = or

Check & Service items			Daily	Every 50h	Every 100h	Every 250h	Every 500h *	Every 1000h *	Every 2000h **
General	Missing or broken parts		◇						
	Tightening of nuts and bolts		◇						
	Engine condition, exhaust and inlet hoses		◇						
	Machine overall		□						
	Operation manual			◇(1)			◇	◇	◇
Greasing	Greasing points		■						
	Swing gear and crown			■	■	■	■	■	■
	Bearing rollers and bearings, idler wheels		◇			■(2)	■	■	■
Engine	Diesel filter			●(1)			●	●	●
	Water separator	Drain	◇						
		Pre fuel filter					●	●	●
		Bowl (if equipped)					□	□	□
	Oil		◇	♦(1)			♦	♦	♦
	Oil filter			●(1)			●	●	●
	Cooling fluid & leakage		◇						●
	Radiator fins		◇+□						
	Belt			◇	◇	◇	◇	◇	●
	Fuel hose, coolant hose								◇/●
	Performance of engine control and engine speed			◇(1)			◇	◇	◇
	Governor lever and accelerator device			◇(1)			◇	◇	◇
	Air cleaner	External air cleaner element	□(3)			●(3)	●	●	●
		Safety cartridge element (if equipped)					●	●	●
	Intake and exhaust valves								◇
	Injectors and injection pressure								□+◇
	Crankcase breather system								◇
	Engine silent-bloc & bracket			◇	◇	◇	◇	◇	◇
Exhaust	EGR valve							□+◇	□+◇
	Diesel Particulate Filter							□+◇	□+◇
Travel	Oil for travel gears			●(1)	◇(2)	◇/●(2)	●	●	●
	Tracks, rubber tracks & pads		◇						
	Track tension		◇						
	Play of travel lever			◇(1)			◇	◇	◇
	Performance of travel			◇(1)			◇	◇	◇
Hydraulic	Oil		◇	♦(1)			♦/●(4)	♦	♦
	Aspiration filter			□(1)			□/●(4)	□/●(4)	□/●(4)
	Ventilation filter							●	●
	Hydraulic oil return filter			●(1)		●(4)	●	●	●
	Other filter					●(4)	●	●	●
	Accumulator			◇(1)			◇	◇	◇
	Pump pressure			◇(1)			◇	◇	◇
	Play of control lever			◇(1)			◇	◇	◇
	Low pressure			◇(1)			◇	◇	◇
	Blade control			◇(1)			◇	◇	◇
	Boom swing			◇(1)			◇	◇	◇
	Boom			◇(1)			◇	◇	◇
	Arm			◇(1)			◇	◇	◇
	Bucket			◇(1)			◇	◇	◇
	Options			◇(1)			◇	◇	◇
Electric	Time counter		◇	◇	◇	◇	◇	◇	◇
	Wire breakage, short circuits, loosened terminals		◇	◇	◇	◇	◇	◇	◇
	LCD monitor		◇	◇	◇	◇	◇	◇	◇
	Battery			◇(1)			◇	◇	◇
Cabin	Cab filters					●(3)	●	●	●
	Air conditioning						◇	◇	◇
Final	Sign inspection card and return to YANMAR			◇ (1)		◇ (2) (3) (4)	◇	◇	◇

* or annualy first time occurs

** or two years

(1) First time 50-80h visit

(2) If machine does lot of digging line during one day (fiber, drop pipe, drainage…).

(3) If machine is used at dusty worksites.

(4) If a hydraulic hammer is used more than 30% of the machine operating time.

♦ Collect oil sample and keep analysis report. According to result replace oil if necessary.

2-7 Fuel, Lube Oil and Grease Recommended

Cooling fluid

Temperatures °C								Quantity prescribed (L)
-40	-20	0	20	40	60	80	100	
Long-life cooling fluid **YANMAR POWER COOLANT B-6**								8,9 Radiator 0,4 the expansion flask

Engine oil

Temperatures °C								Quantity prescribed (L)
-30	-20	-10	0	10	20	30	40	
5W30								11,2
10W30								
15W40								

Fuel

Temperatures °C							Quantity prescribed (L)
-20	-10	0	10	20	30	40	
No. 1-D / No. 2-D							115

Hydraulic oil

Temperatures °C							Quantity prescribed (L)
-20	-10	0	10	20	30	40	
VG46							60 in the tank
VG68							52 the rest

Gear oil

Temperatures °C							Quantity prescribed (L)
-20	-10	0	10	20	30	40	
75W90LS							1,1 by reducer
80W90LS							

2-7 Fuel, Lube Oil and Grease Recommended

Fuel oil

Temperatures °C							Quantity prescribed (L)
-20	-10	0	10	20	30	40	
No. 1-D / No. 2-D							115

Engine oil

Temperatures °C								Quantity prescribed (L)
-3	-20	-10	0	10	20	30	40	
5W30								11,2
10W30								
15W40								

Hydraulic oil

Temperatures °C							Quantity prescribed (L)	
-20	-10	0	10	20	30	40		
VG46							60	in the tank
VG68							52,0	the rest

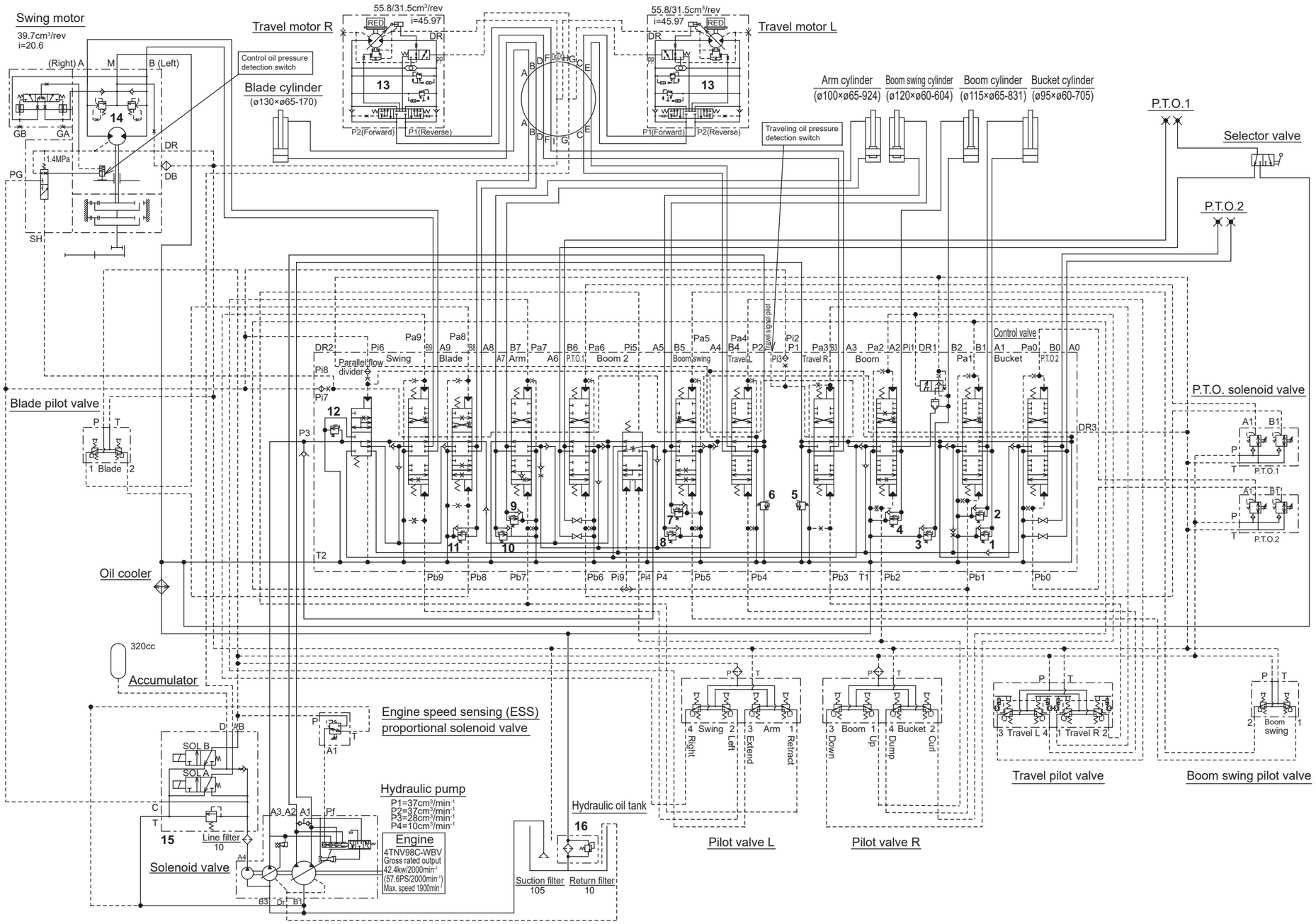
Mixture ratio of cooling water and antifreeze

Lowest temperature		°F (°C)	5 (-15)	-4 (-20)	-13 (-25)	-22 (-30)	-31 (-35)	-40 (-40)
ViO80-1A	Amount of anti-freeze	Gals. (L)	2.94 (2.8)	3.43 (3.3)	3.92 (3.7)	4.41 (4.2)	4.90 (4.65)	5.39 (5.1)
	Amount of water	Gals. (L)	6.86 (6.5)	6.37 (6.0)	5.88 (5.6)	5.39 (5.1)	4.90 (4.65)	4.41 (4.2)

Note :

At the delivery, water and antifreeze are mixed at the ratio for -31 °F (-35 °C) temperature above.

2-8 Hydraulic Circuit Schematic



Relief valve set pressure

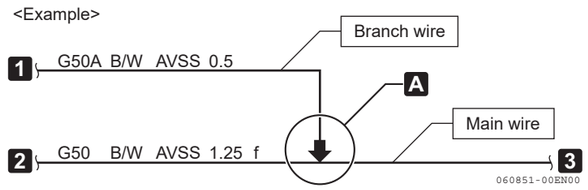
No.	PSI	MPa
1	4134	28.5
2	4134	28.5
3	4279	29.5
4	4134	28.5
5	3698	25.5
6	3698	25.5
7	4134	28.5
8	4134	28.5
9	4134	28.5
10	4134	28.5
11	2176	15
12	3481	24
13	3698	25.5
14	3481	24
15	421	2.9
16	21	0.147

2. TECHNICAL DATA

2-9 Wiring Diagram

■ How to Read Wiring Diagrams

● Intersections and Wire Connections

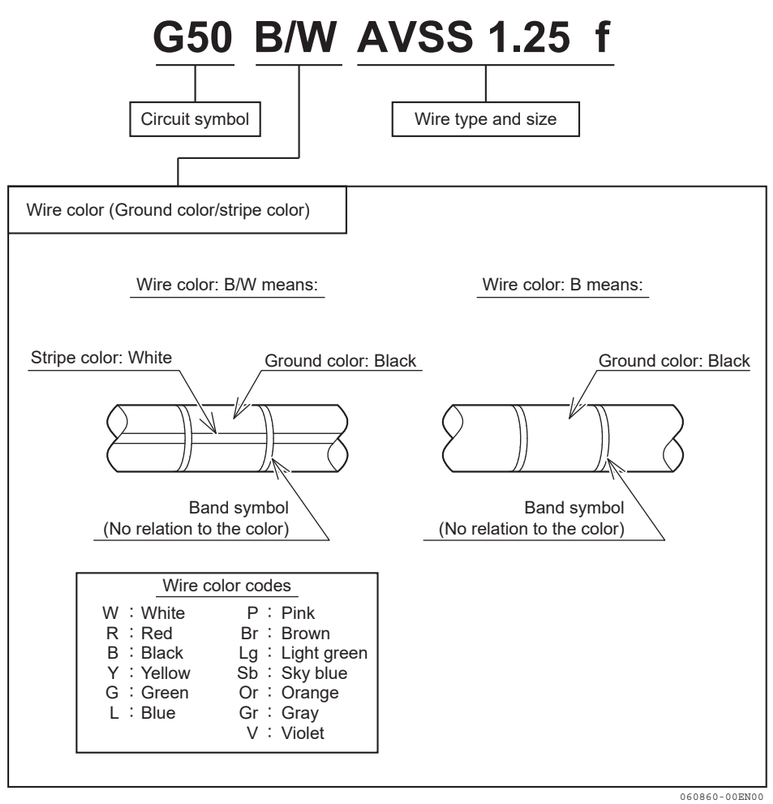


The point of arrow **A** on the main wire shown in the figure above represents an intersection of the branch wire and the main wire.
The direction of the arrow indicates which one is the branch wire (the arrowed line represents the branch wire) and also shows the division between the branch wire and the main wire.

In the example above, the wires are divided as follows.

1 to the point of arrow **A**	: Branch wire	G50A B/W AVSS 0.5 f
2 to **3**	: Main wire	G50 B/W AVSS 1.25 f

● How to Read Wiring Symbols

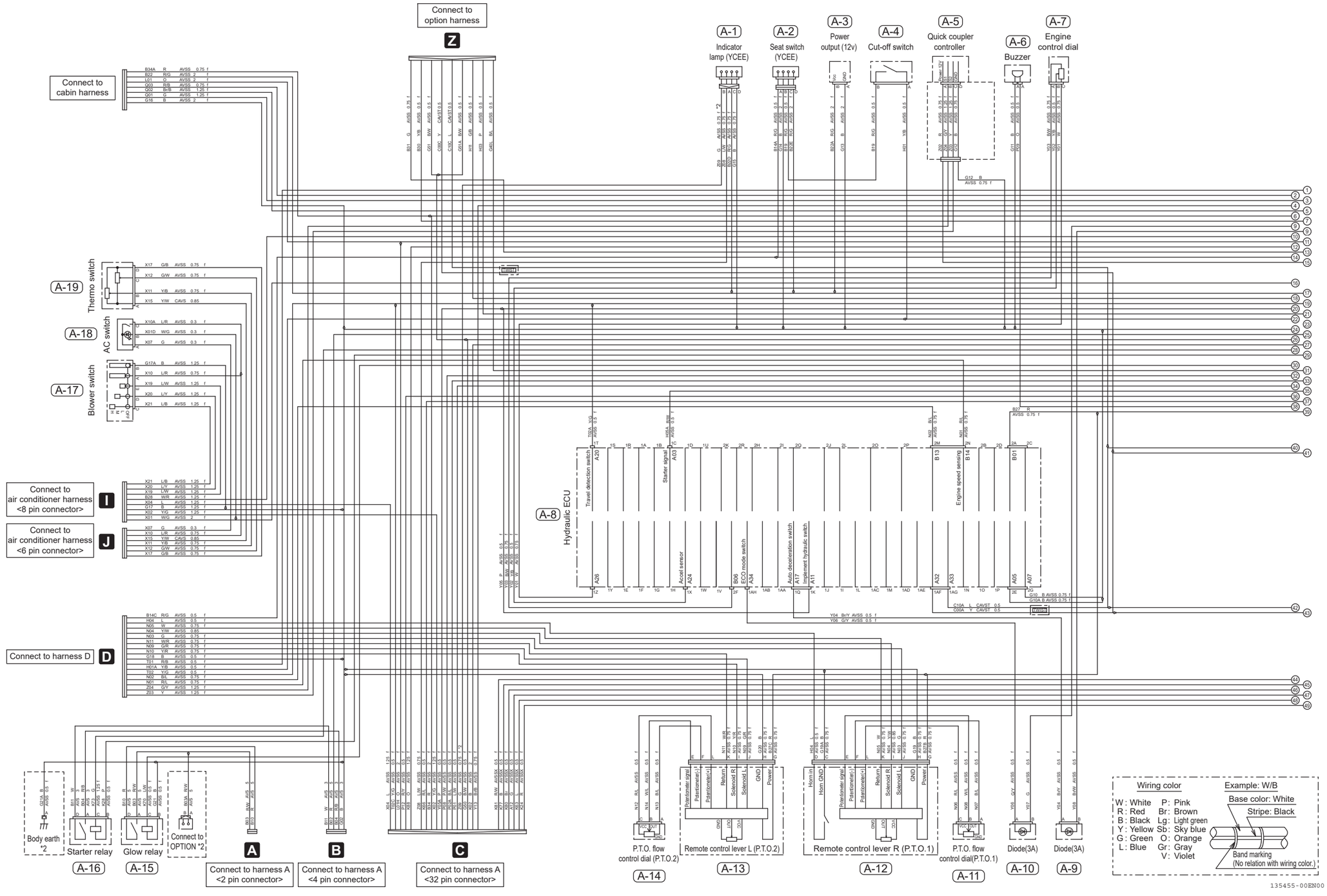


1) Harness B

*1: Applicable S/N: 1B259 and above

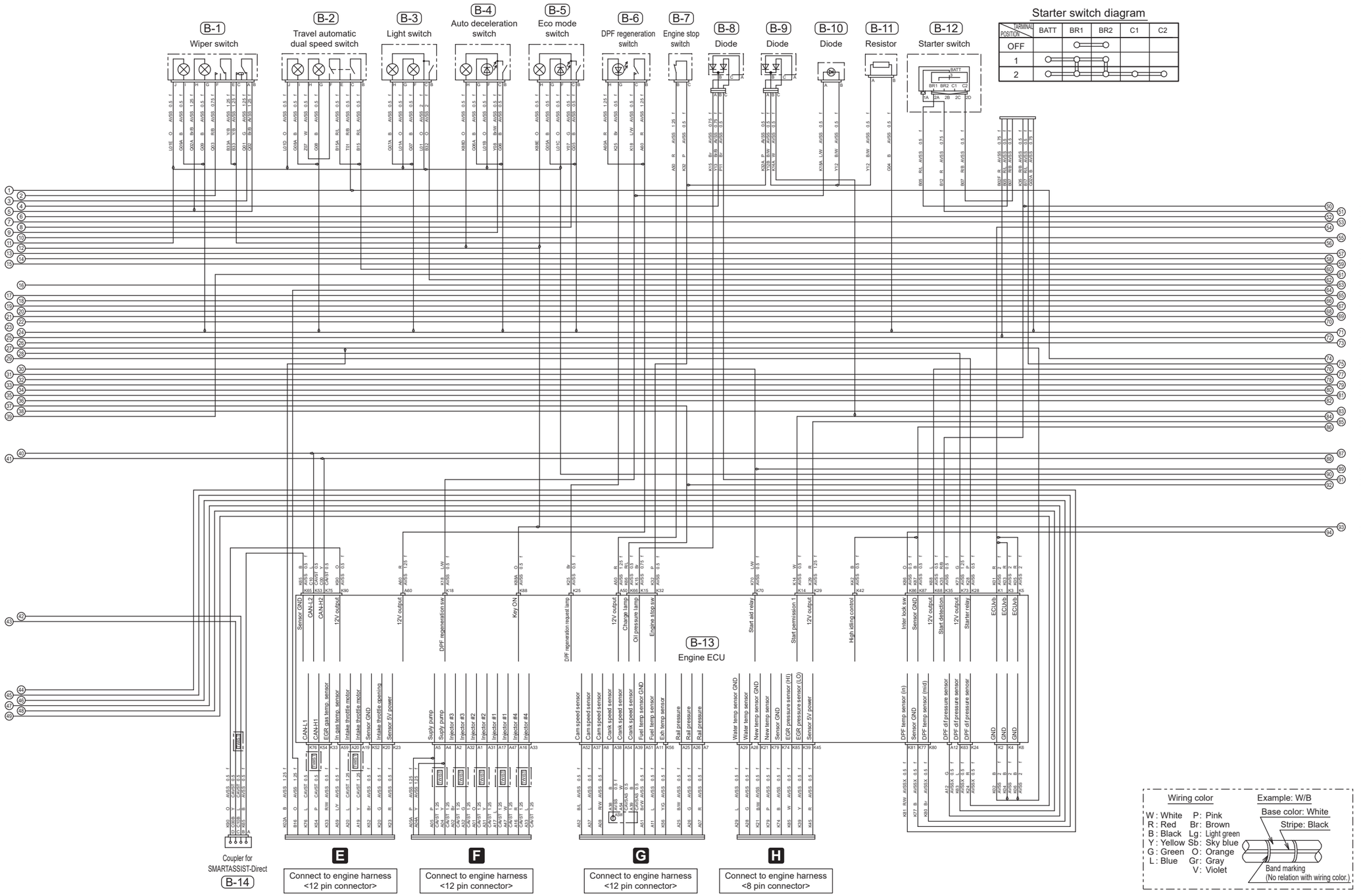
*2: Applicable S/N: 1B605 and above

1/3

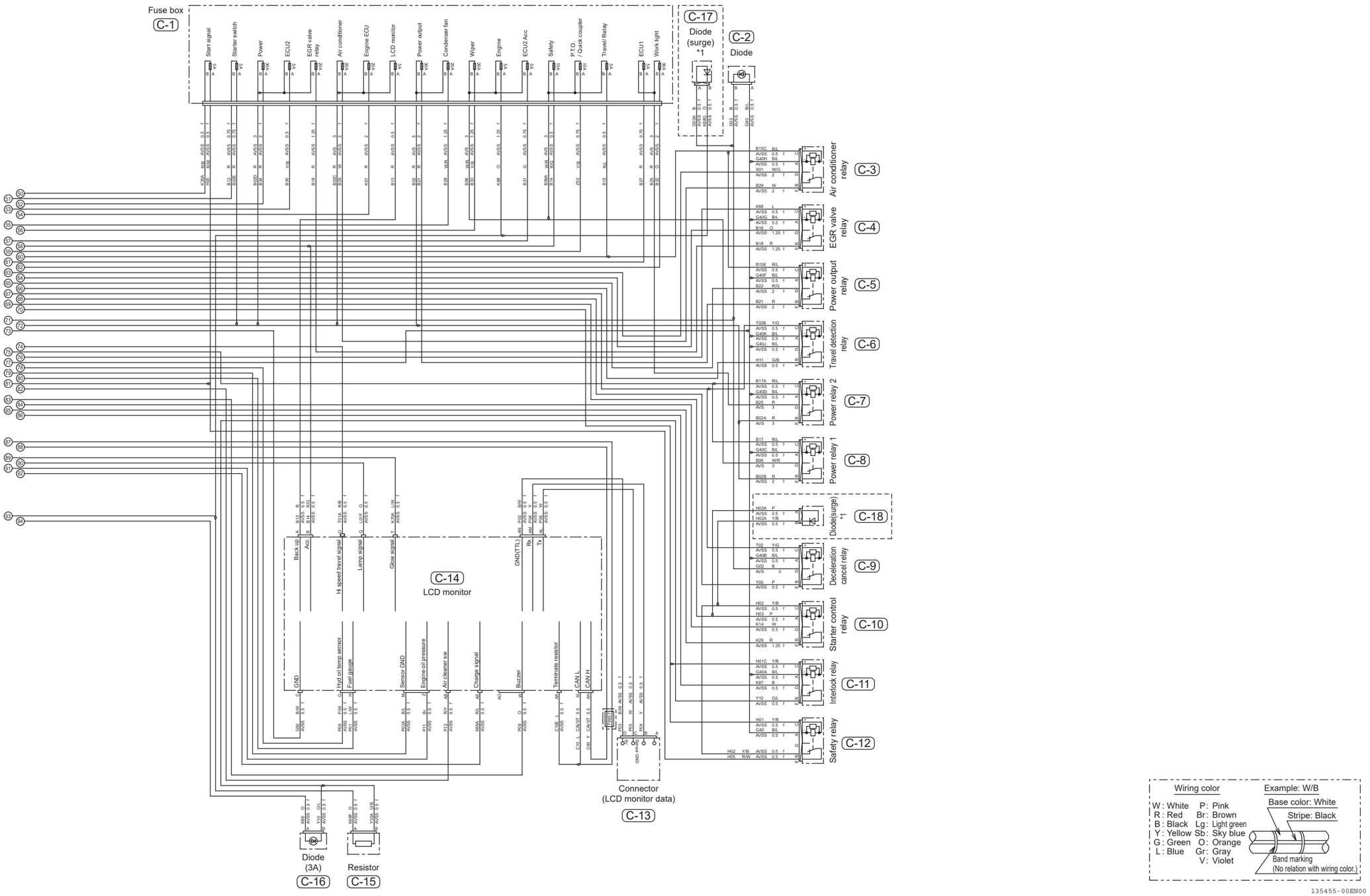


2. TECHNICAL DATA

2/3



2. TECHNICAL DATA



Wiring color

W : White P : Pink
R : Red Br : Brown
B : Black Lg : Light green
Y : Yellow Sb : Sky blue
G : Green O : Orange
L : Blue Gr : Gray
V : Violet

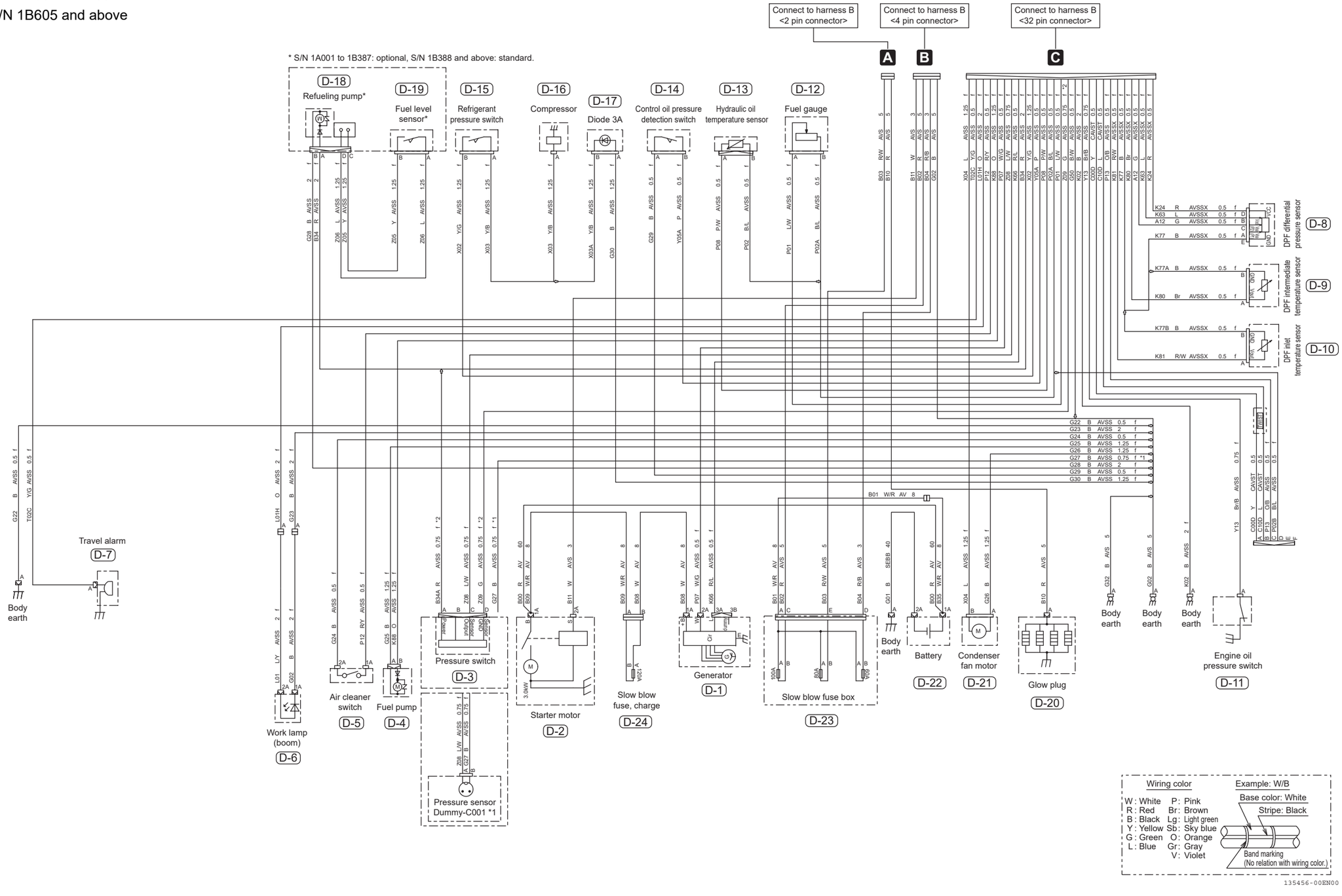
Example: W/B

135455-00EN00

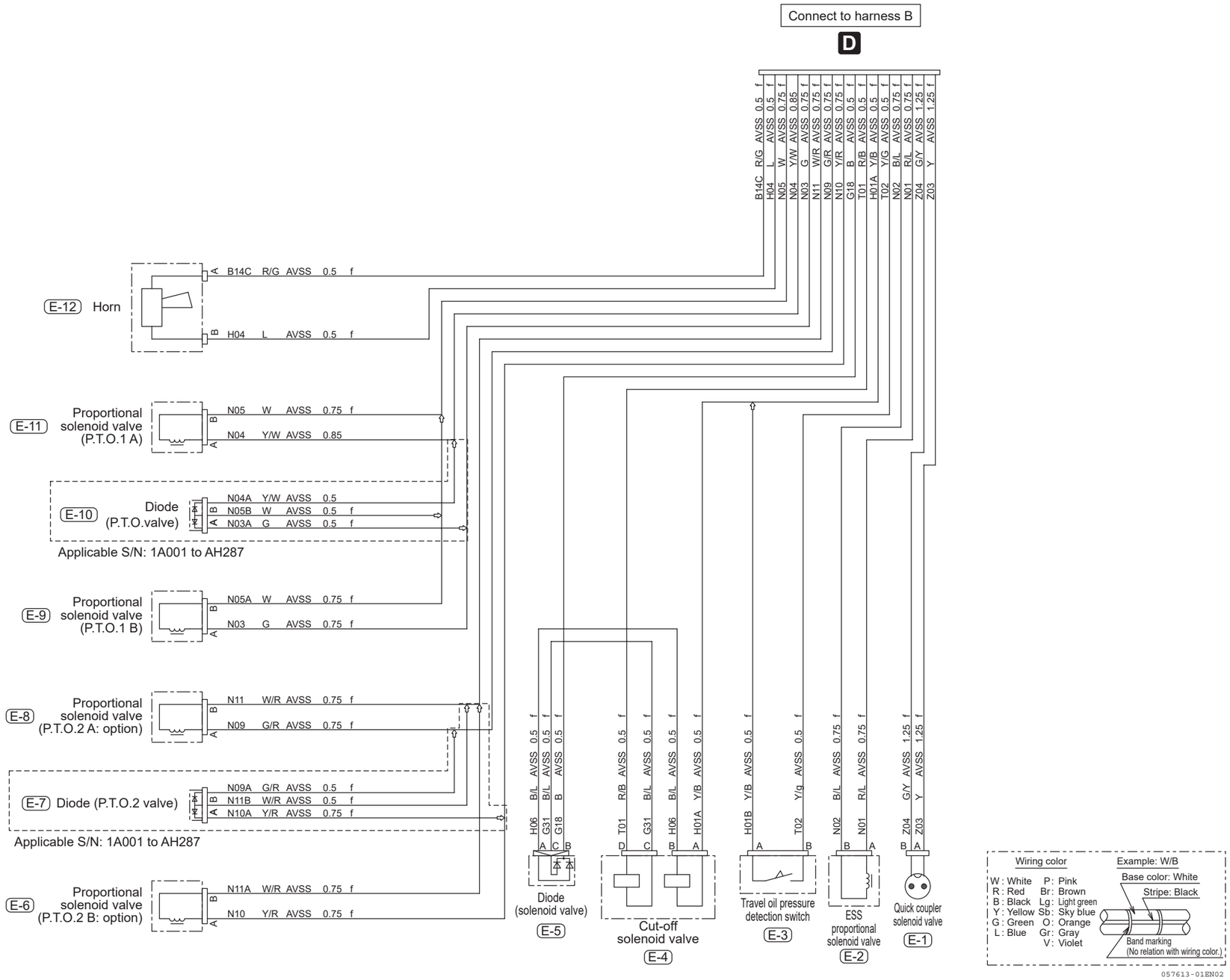
2) Harness A

*1: Applicable S/N 1A001 to 1B604

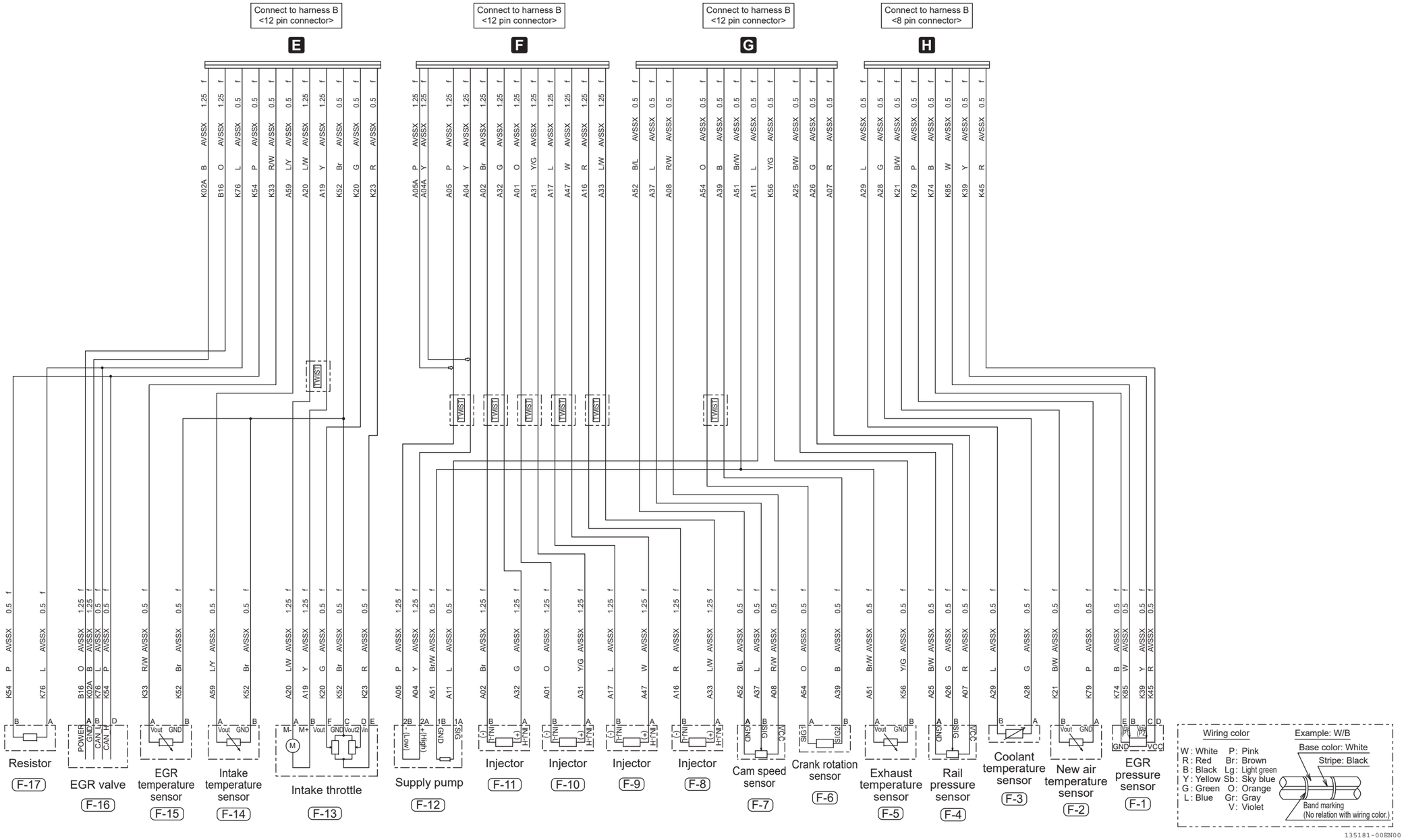
*2: Applicable S/N 1B605 and above



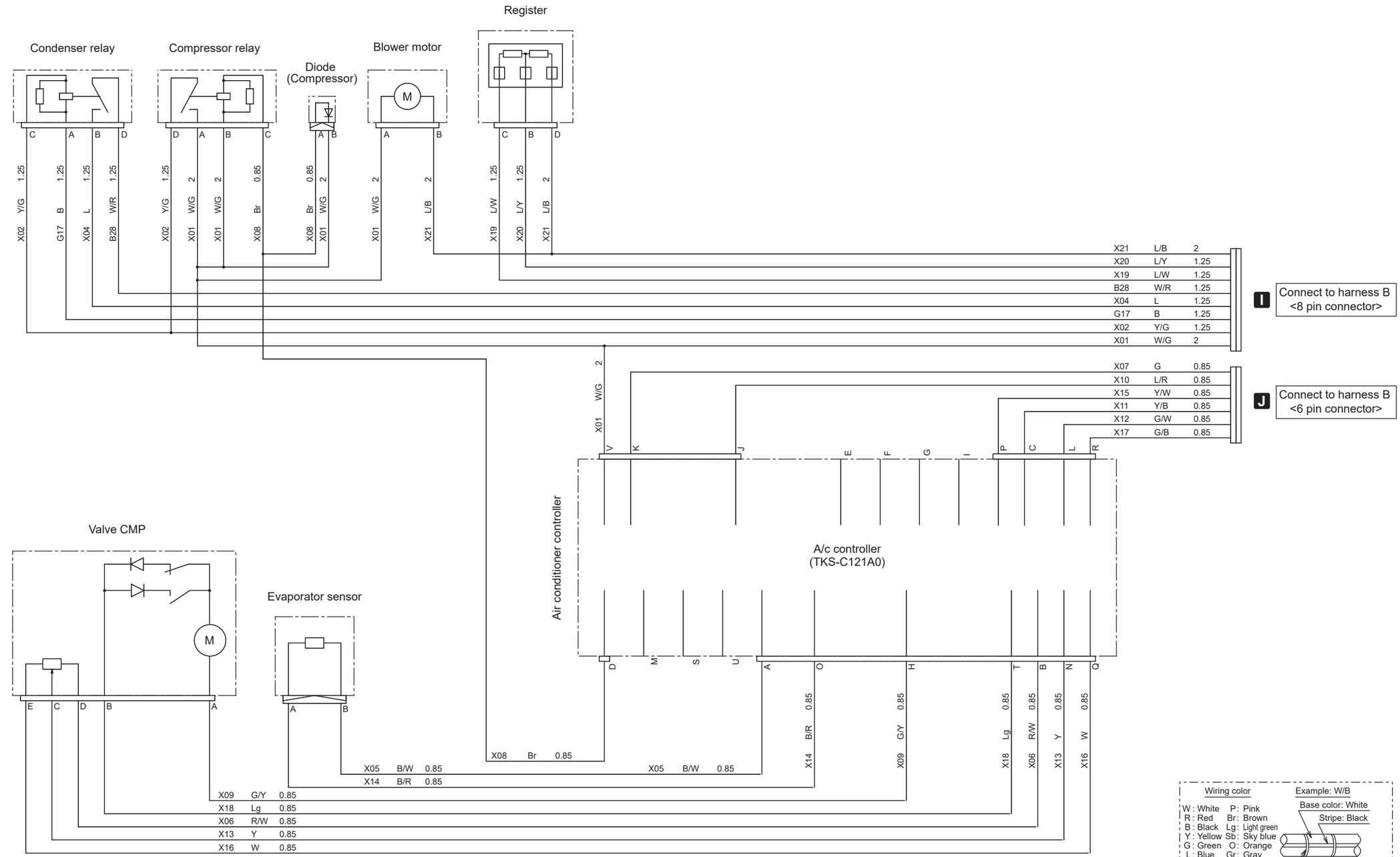
3) Harness D


Connect to harness B
D
B14C R/G AVSS 0.5 f
H04 L AVSS 0.5 f
N05 W AVSS 0.75 f
N04 Y/W AVSS 0.85
N03 G AVSS 0.75 f
N11 W/R AVSS 0.75 f
N09 G/R AVSS 0.75 f
N10 Y/R AVSS 0.75 f
G18 B AVSS 0.5 f
T01 R/B AVSS 0.5 f
H01A Y/B AVSS 0.5 f
T02 Y/G AVSS 0.5 f
N02 B/L AVSS 0.75 f
N01 R/L AVSS 0.75 f
Z04 G/Y AVSS 1.25 f
Z03 Y AVSS 1.25 f
E-12 Horn
A B14C R/G AVSS 0.5 f
B H04 L AVSS 0.5 f
E-11 Proportional solenoid valve (P.T.O.1 A)
B N05 W AVSS 0.75 f
A N04 Y/W AVSS 0.85
E-10 Diode (P.T.O.valve)
N04A Y/W AVSS 0.5
N05B W AVSS 0.5 f
N03A G AVSS 0.5 f
Applicable S/N: 1A001 to AH287
E-9 Proportional solenoid valve (P.T.O.1 B)
B N05A W AVSS 0.75 f
A N03 G AVSS 0.75 f
E-8 Proportional solenoid valve (P.T.O.2 A: option)
B N11 W/R AVSS 0.75 f
A N09 G/R AVSS 0.75 f
E-7 Diode (P.T.O.2 valve)
N09A G/R AVSS 0.5 f
N11B W/R AVSS 0.5 f
N10A Y/R AVSS 0.75 f
Applicable S/N: 1A001 to AH287
E-6 Proportional solenoid valve (P.T.O.2 B: option)
B N11A W/R AVSS 0.75 f
A N10 Y/R AVSS 0.75 f
H06 B/L AVSS 0.5 f
G31 B/L AVSS 0.5 f
G18 B AVSS 0.5 f
A C B
Diode (solenoid valve)
E-5
T01 R/B AVSS 0.5 f
G31 B/L AVSS 0.5 f
H06 B/L AVSS 0.5 f
H01A Y/B AVSS 0.5 f
D C B A
Cut-off solenoid valve
E-4
H01B Y/B AVSS 0.5 f
T02 Y/g AVSS 0.5 f
A B
Travel oil pressure detection switch
E-3
N02 B/L AVSS 0.75 f
N01 R/L AVSS 0.75 f
B A
ESS proportional solenoid valve
E-2
Z04 G/Y AVSS 1.25 f
Z03 Y AVSS 1.25 f
B A
Quick coupler solenoid valve
E-1
Wiring color
W : White
R : Red
B : Black
Y : Yellow
G : Green
L : Blue
P : Pink
Br : Brown
Lg : Light green
Sb : Sky blue
O : Orange
Gr : Gray
V : Violet
Example: W/B
Base color: White
Stripe: Black
Band marking
(No relation with wiring color.)
057613-01EN02

4) Engine harness

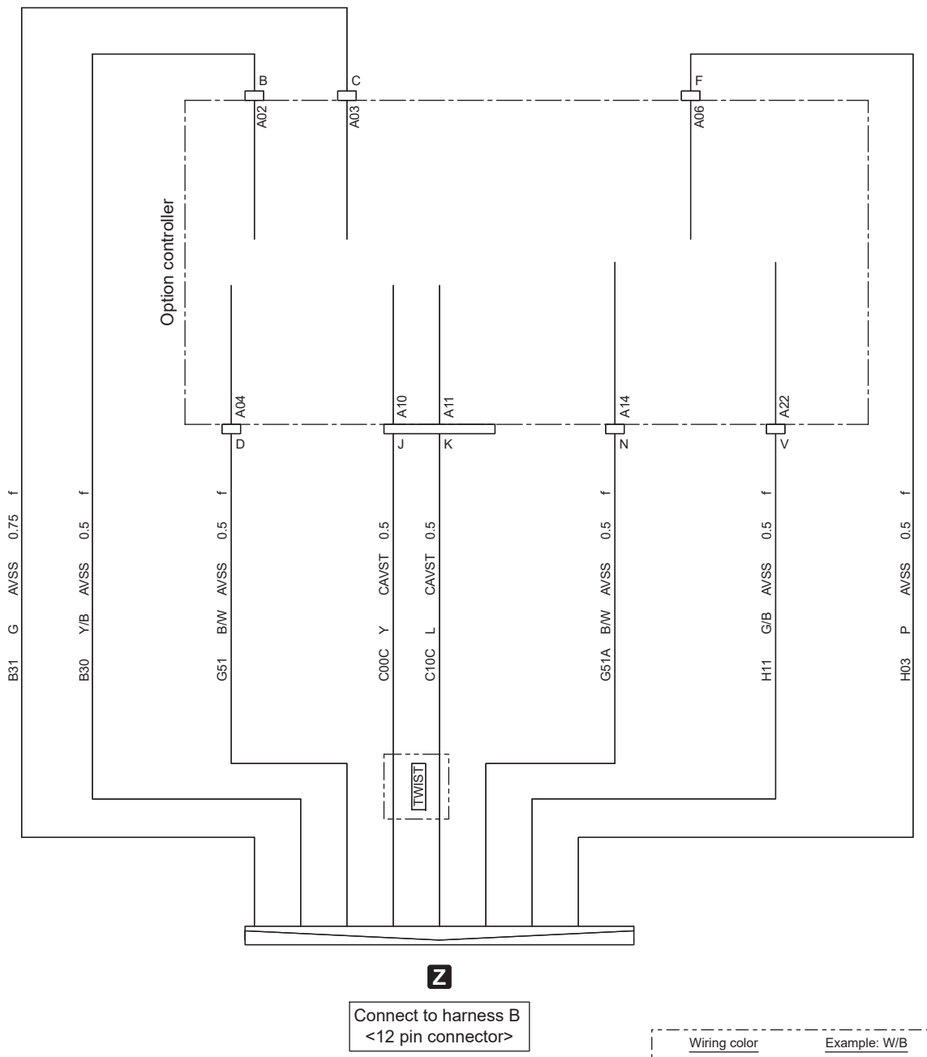


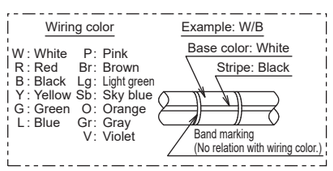
5) Air conditioner harness



6) Option harness

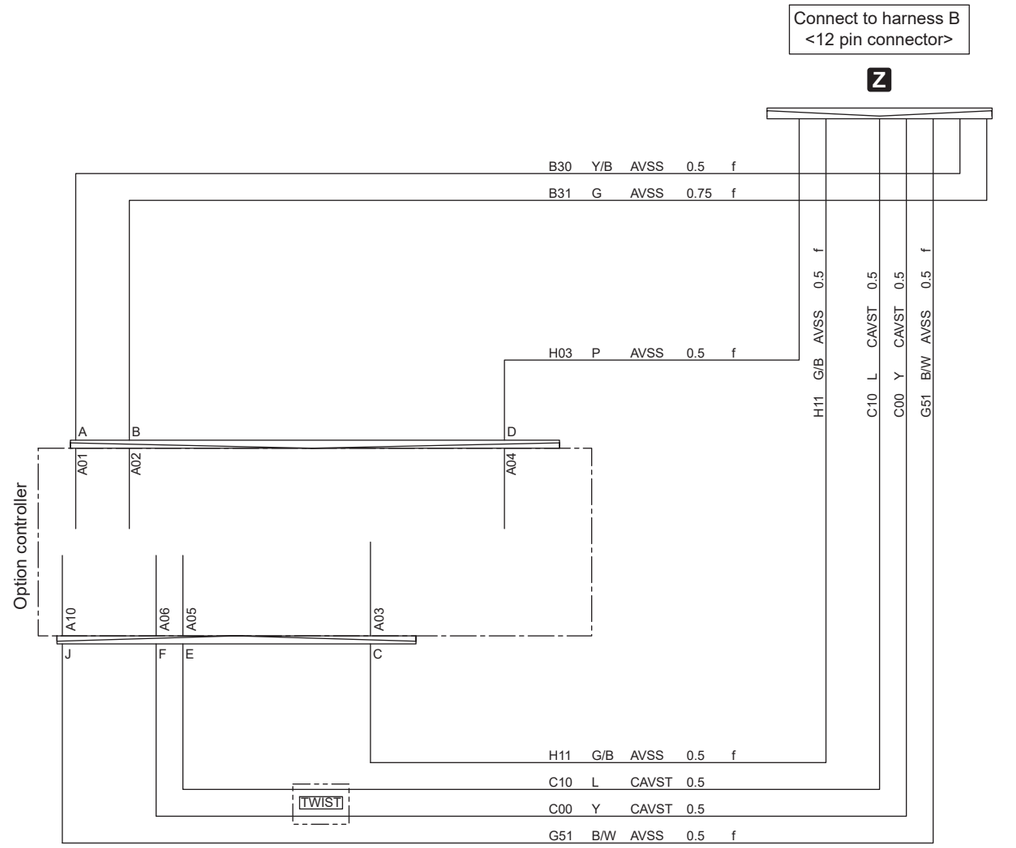
Applicable S/N 1A001 to AG976

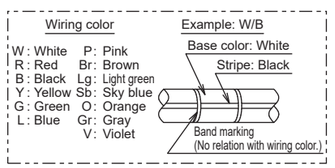




135142-00EN00

Applicable S/N AG977 and above





135143-00EN00

CHAPTER 3

SERVICE STANDARDS

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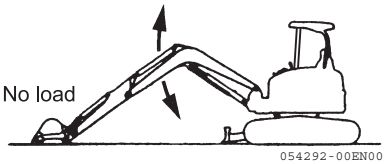
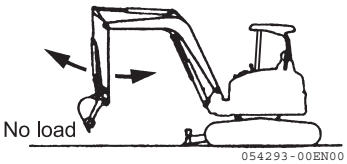
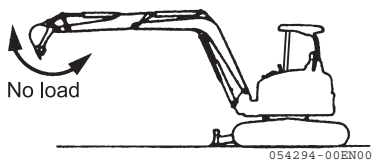
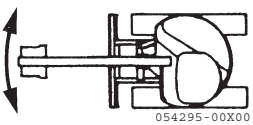
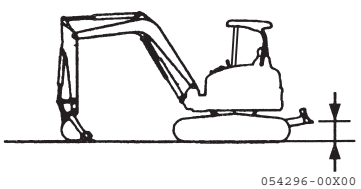
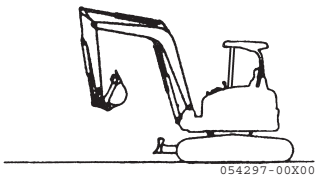
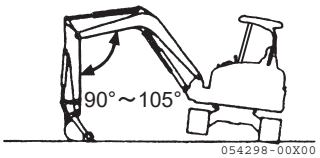
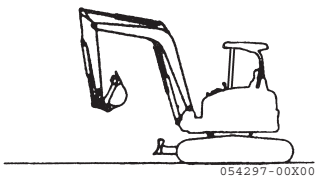
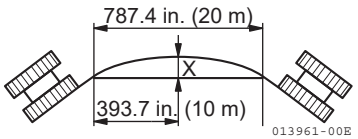
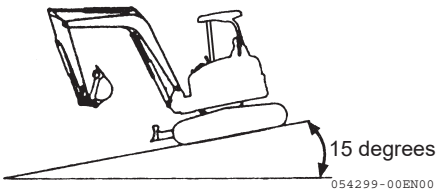
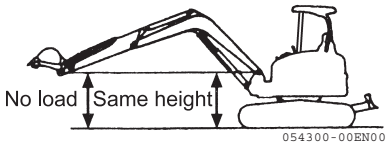
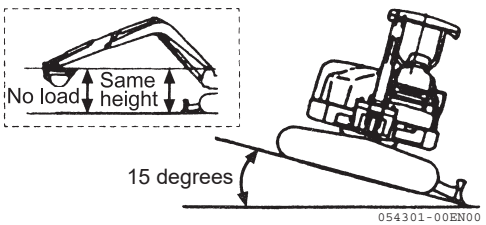
3. Service Standards

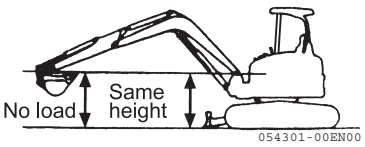
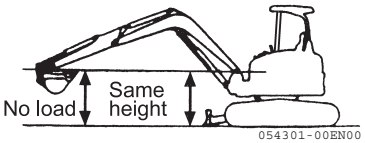
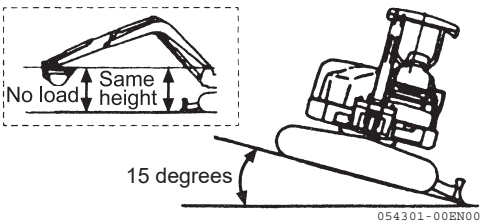
3-1 Machine Performance

Applicable model				ViO80-1A	
Item	Measuring condition		Unit	Standard	Allowance
Machine performance					
Working speed					
Boom speed Max. cylinder extension Bucket teeth grounded	Machine position  • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Excluding cushion	Up	sec.	2.8	3.1
		Down		3.0	3.3
Arm speed Max. cylinder retraction Max. cylinder extension	Machine position  • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground	Extend	sec.	2.8	3.1
		Retract		3.3	3.6
Bucket speed Max. cylinder retraction Max. cylinder extension	Machine position  • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground	Dump	sec.	1.9	2.2
		Curl		2.3	2.6
Boom offset speed Max. cylinder retraction Max. cylinder extension	Machine position  • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Full stroke	Right swing	sec.	6.7	7.0
		Left swing		6.0	6.3
Blade speed Max. cylinder retraction Blade grounded	Machine position  • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground	Up	sec.	1.1	1.4
		Down		1.2	1.5

3. SERVICING STANDARDS

Applicable model			ViO80-1A	
Item	Measuring condition	Unit	Standard	Allowance
Machine performance				
Travel speed	Machine position  054297-00X00 • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Traveling time for 787.4 in. (20 m) after an approach run of 196.9 in. (5 m) or more.	sec.	High speed 15.6	18.6
			Low speed 27.0	30.0
Track speed	Machine position  054298-00X00 • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Travel lever : Full throttle (Floating crawler side) • Float one side of the crawler. Make a mark on the crawler. After turning the floating crawler side more than once, measure the time needed for 3 turns of the crawler.	sec.	High speed 15	17
			Low speed 26	28
Track deviation	Machine position  054297-00X00 • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Measure the deviation (χ) in a travel distance of 787.4 in. (20 m) after an approach run of 196.9 in. (5 m) or more.  013961-00E	in. (mm)	11.8 (300) or less	14.2 (360) or less

Applicable model			ViO80-1A	
Item	Measuring condition	Unit	Standard	Allowance
Machine performance				
Traveling drift	Machine position  • Engine : stopped • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Drift of the machine after 5 min. on a slope with an inclination of 15 degrees.	in. (mm)	0 (0) or less	0 (0) or less
Drift of cylinders				
Boom drift (Cylinder rod retraction)	Machine position  • Engine : stopped • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Make the boom and bucket pins the same height. • Measure the retraction or extension of each cylinder rod after leaving the machine at the above position for 10 min. • Lift the blade to the highest position, and measure the cylinder rod extension after 10 min.	in. (mm)	0.16 (4) or less	0.24 (6) or less
Arm drift (Cylinder rod extension)			0.39 (10) or less	0.59 (15) or less
Bucket drift (Cylinder rod extension)			0.39 (10) or less	0.51 (13) or less
Blade drift (Cylinder rod extension)			0.24 (6) or less	0.35 (9) or less
Boom swing drift (Cylinder rod extension)	Machine position  • Engine : stopped • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Make the boom and bucket pins the same height. • Park the machine on a slope with an inclination of 15 degrees and turn the upperstructure 90 degrees to the crawler and engage the swing lock. • Measure the cylinder rod extension after 10 min.	in. (mm)	0.24 (6) or less	0.35 (9) or less

Applicable model			ViO80-1A	
Item	Measuring condition	Unit	Standard	Allowance
Machine performance				
Swing drift at stopping	Machine position  • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Make the boom and bucket pins the same height. • Make match marks on the outer race and the inner race of the swing bearing (or the track frame). • Measure shifted distance between both marks after making one turn with no load.	in. (mm)	8.66 (220) or less, 30 degrees or less	12.60 (320) or less, 45 degrees or less
Swing time	Machine position  • Engine : Maximum speed • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Site : Firm, flat ground • Make one idling turn with no load, then measure the time necessary to make 5 turns.	sec.	33	38
Swing drift	Machine position  • Engine : stopped • Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C) • Make the boom and bucket pins the same height. • Park the machine on a slope with an inclination of 15 degrees and turn the upperstructure 90 degrees to the crawler. • Make match marks on the outer race and the inner race of the swing bearing (or the track frame). • Measure shifted distance or angle between both marks after 5 min.	in. (mm)	0 (0)	

3. SERVICING STANDARDS

3-2 Engine

1) Nominal and Allowable Values

Applicable model			4TNV98C-WBV	
Item		Unit	Standard	Allowable limit
Cylinder head				
Adjustment of valve clearance		in. (mm)	0.006 to 0.010 (0.15 to 0.25)	-
Cylinder head distortion (Flatness)		in. (mm)	0.0020 (0.05) or less	0.0059 (0.15)
Valve sinkage	Intake	in. (mm)	0.0197 to 0.0276 (0.50 to 0.70)	0.0315 (0.8)
	Exhaust	in. (mm)	0.0236 to 0.0315 (0.60 to 0.80)	0.0315 (0.8)
Valve seat angle	Intake	degrees (°)	120	-
	Exhaust	degrees (°)	90	-
Valve seat correction angle		degrees (°)	40, 150	-
Intake valve	Guide inside diameter	in. (mm)	0.0316 to 0.3161 (8.015 to 8.030)	0.3181 (8.08)
	Valve stem outside diameter	in. (mm)	0.3136 to 0.3141 (7.965 to 7.980)	0.3110 (7.90)
	Valve stem bend	in. (mm)	0.0016 to 0.0028 (0.040 to 0.070)	0.0067 (0.17)
Exhaust valve	Guide inside diameter	in. (mm)	0.0316 to 0.3161 (8.015 to 8.030)	0.3181 (8.08)
	Valve stem outside diameter	in. (mm)	0.3132 to 0.3138 (7.955 to 7.970)	0.3110 (7.90)
	Valve stem bend	in. (mm)	0.0018 to 0.0030 (0.045 to 0.075)	0.0067 (0.17)
Valve guide	Projection from cylinder head	in. (mm)	0.5791 to 0.5905 (14.71 to 15.00)	-
	Insertion method	in. (mm)	Cold-fitted	-
Vavle stem seal projeciton from cylinder head		in. (mm)	0.736 to 0.748 (18.7 to 19.0)	-
Push rod bend		in. (mm)	Less than 0.0012 (0.03)	0.0012 (0.03)
Rocker arm and shaft	Arm shaft hole diameter	in. (mm)	0.7283 to 0.7291 (18.500 to 18.520)	0.7311 (18.57)
	Shaft outside diameter	in. (mm)	0.7272 to 0.7280 (18.470 to 18.490)	0.7260 (18.44)
	Oil clearance	in. (mm)	0.0004 to 0.0020 (0.010 to 0.050)	0.0051 (0.13)
Valve spring	Free length	in. (mm)	1.8701 (47.5)	1.8504 (47.0)
	Squareness	in. (mm)	-	0.0472 (1.2)

3. SERVICING STANDARDS

Applicable model					4TNV98C-WBV	
Item				Unit	Standard	Allowable limit
Cam shaft and timing gear train						
	Cam shaft	End play		in. (mm)	0.0020 to 0.0079 (0.05 to 0.20)	0.0118 (0.030)
		Bend (1/2 the dial gauge reading)		in. (mm)	0 to 0.0008 (0 to 0.02)	0.0020 (0.05)
		Cam lobe height		in. (mm)	1.6707 to 1.6758 (42.435 to 42.565)	1.6608 (42.185)
		Gear end	Bush inside diameter	in. (mm)	1.9681 to 1.9707 (49.990 to 50.055)	1.9736 (50.130)
			Cam shaft outside diameter	in. (mm)	1.9655 to 1.9665 (49.925 to 49.950)	1.9642 (49.890)
			Oil clearance	in. (mm)	0.0016 to 0.0051 (0.040 to 0.130)	0.0094 (0.240)
		Intermedi-ate	Bore inside diameter	in. (mm)	1.9685 to 1.9695 (50.000 to 50.025)	1.9724 (50.100)
			Cam shaft outside diameter	in. (mm)	1.9650 to 1.9659 (49.910 to 49.935)	1.9636 (49.875)
			Oil clearance	in. (mm)	0.0026 to 0.0045 (0.065 to 0.115)	0.0089 (0.225)
		Flywheel end	Bore inside diameter	in. (mm)	1.9685 to 1.9695 (50.000 to 50.025)	1.9724 (50.100)
			Cam shaft outside diameter	in. (mm)	1.9655 to 1.9665 (49.925 to 49.950)	1.9642 (49.890)
			Oil clearance	in. (mm)	0.0020 to 0.0039 (0.50 to 0.100)	0.0083 (0.210)
	Idler gear shaft	Idler gear A	Shaft outside diameter	in. (mm)	1.8091 to 1.8100 (45.950 to 45.975)	1.8071 (45.900)
			Bush inside diameter	in. (mm)	1.8110 to 1.8120 (46.000 to 46.025)	1.8140 (46.075)
			Oil clearance	in. (mm)	0.0010 to 0.0030 (0.025 to 0.075)	0.0068 (0.175)
		Idler gear B	Shaft outside diameter	in. (mm)	1.8091 to 1.8100 (45.950 to 45.975)	1.8071 (45.900)
			Bush inside diameter	in. (mm)	1.8110 to 1.8120 (46.000 to 46.025)	1.8140 (46.075)
			Oil clearance	in. (mm)	0.0010 to 0.0030 (0.025 to 0.075)	0.0068 (0.175)
	Timing gear backlash		Crank gear, cam gear, idler gear, fuel injection pump drive gear and P.T.O. gear	in. (mm)	0.0031 to 0.0055 (0.08 to 0.14)	0.0063 (0.16)

3. SERVICING STANDARDS

Applicable model				4TNV98C-WBV	
Item			Unit	Standard	Allowable limit
Crank shaft and piston					
	Crank shaft	Bend (1/2 the dial gauge reading)	in. (mm)	-	0.0008 (0.02)
		Connecting rod journals: Journal outside diameter	in. (mm)	2.2816 to 2.2820 (57.952 to 57.962)	2.2796 (57.902)
		Connecting rod journals: Bearing inside diameter	in. (mm)	2.2835 to 2.2845 (58.000 to 58.026)	-
		Connecting rod journals: Bearing insert thickness	in. (mm)	0.0587 to 0.0591 (1.492 to 1.500)	-
		Connecting rod journals: Oil clearance	in. (mm)	0.0015 to 0.0029 (0.038 to 0.074)	0.0059 (0.150)
		Main bearing journal: Journal outside diameter	in. (mm)	2.5572 to 2.5576 (64.952 to 64.962)	2.5552 (64.902)
		Main bearing journal: Bearing inside diameter	in. (mm)	2.5590 to 2.5598 (65.000 to 65.020)	-
		Main bearing journal: Bearing insert thickness	in. (mm)	0.0785 to 0.0791 (1.995 to 2.010)	-
		Main bearing journal: Oil clearance	in. (mm)	0.0015 to 0.0027 (0.038 to 0.068)	0.0059 (0.150)
	Thrust bearing	Crank shaft end play	in. (mm)	0.0051 to 0.0091 (0.13 to 0.23)	0.0110 (0.28)
	Piston	Piston outside diameter (measured at 90° to the piston pin)	in. (mm)	3.8559 to 3.8563 (97.940 to 97.950)	3.8545 (97.905)
		Piston diameter measure location (upward from the bottom of the piston)	in. (mm)	0.8661 (22)	-
		Piston pin: Hole inside diameter	in. (mm)	1.1811 to 1.1815 (30.000 to 30.009)	1.1826 (30.039)
		Piston pin: Pin outside diameter	in. (mm)	1.1809 to 1.1811 (29.995 to 30.000)	1.1797 (29.965)
		Piston pin: Oil clearance	in. (mm)	0.0000 to 0.0006 (0.000 to 0.014)	0.0029 (0.074)
	Piston ring	Top ring: Ring groove width	in. (mm)	0.0803 to 0.0811 (2.040 to 2.060)	-
		Top ring: Ring width	in. (mm)	0.0764 to 0.0772 (1.940 to 1.960)	0.0756 (1.920)
		Top ring: Side clearance	in. (mm)	0.0031 to 0.0047 (0.080 to 0.120)	-
		Top ring: End gap	in. (mm)	0.0098 to 0.0177 (0.250 to 0.450)	0.0213 (0.540)
		Second ring: Ring groove width	in. (mm)	0.0819 to 0.0825 (2.080 to 2.095)	0.0864 (2.195)
		Second ring: Ring width	in. (mm)	0.0776 to 0.0783 (1.970 to 1.990)	0.0768 (1.950)
		Second ring: Side clearance	in. (mm)	0.0035 to 0.0049 (0.090 to 0.125)	0.0096 (0.245)
		Second ring: End gap	in. (mm)	0.0177 to 0.0256 (0.450 to 0.650)	0.0287 (0.730)

3. SERVICING STANDARDS

Applicable model					4TNV98C-WBV	
Item				Unit	Standard	Allowable limit
Crank shaft and piston						
	Piston ring	Oil ring	Ring groove width	in. (mm)	0.1187 to 0.1193 (3.015 to 3.030)	0.1232 (3.130)
			Ring width	in. (mm)	0.1169 to 0.1177 (2.970 to 2.990)	0.1161 (2.950)
			Side clearance	in. (mm)	0.0010 to 0.0024 (0.025 to 0.060)	0.0071 (0.180)
			End gap	in. (mm)	0.0098 to 0.0177 (0.250 to 0.450)	0.0217 (0.550)
	Connect-ing rod	Connecting rod small end	Wrist pin bush inside diameter	in. (mm)	1.1821 to 1.1826 (30.025 to 30.038)	1.1838 (30.068)
			Wrist pin outside diameter	in. (mm)	1.1809 to 1.1811 (29.995 to 30.000)	1.1797 (29.965)
			Oil clearance	in. (mm)	0.0010 to 0.0017 (0.025 to 0.043)	0.0040 (0.101)
		Connecting rod big end	Side clearance	in. (mm)	0.0079 to 0.0157 (0.20 to 0.40)	-
	Tappet		Tappet bore (block) inside diameter	in. (mm)	0.4724 to 0.4731 (12.000 to 12.018)	0.4739 (12.038)
			Tappet stem outside diameter	in. (mm)	0.4715 to 0.4720 (11.975 to 11.990)	0.4707 (11.955)
			Oil clearance	in. (mm)	0.0004 to 0.0017 (0.010 to 0.043)	0.0033 (0.083)
Cylinder block						
	Cylinder inside diameter			in. (mm)	3.8583 to 3.8594 (98.000 to 98.030)	3.8634 (98.130)
	Cylinder bore		Roundness	in. (mm)	0.0004 (0.01) or less	0.0012 (0.03)
			Taper			
Lubricating oil pump						
	Outer rotor outside clearance			in. (mm)	0.0039 to 0.0061 (0.100 to 0.155)	0.0098 (0.25)
	Outer rotor side clearance			in. (mm)	0.0020 to 0.0039 (0.05 to 0.10)	0.0059 (0.15)
	Outer rotor to inner rotor tip clearance			in. (mm)	-	0.0063 (0.16)
	Rotor shaft clearance		Gear case bearing inside diameter	in. (mm)	0.5110 to 0.5126 (12.980 to 13.020)	0.5138 (13.050)
			Rotor shaft outside diameter	in. (mm)	0.5100 to 0.5104 (12.955 to 12.965)	0.5096 (12.945)
			Rotor clearance	in. (mm)	0.0006 to 0.0026 (0.015 to 0.065)	0.0041 (0.105)
Others						
	Intake/Exhaust valve clearance			in. (mm)	0.006 to 0.010 (0.15 to 0.25)	-
	Compression pressure at 250 rpm			PSI (MPa)	483 to 513 (3.33 to 3.53)	384 to 414 (2.65 to 2.85)
	Deviation between cylinders			PSI (MPa)	29 to 43 (0.2 to 0.3)	-
	Oil pressure switch operating pressure			PSI (MPa)	5.8 to 8.8 (0.04 to 0.06)	-

3. SERVICING STANDARDS

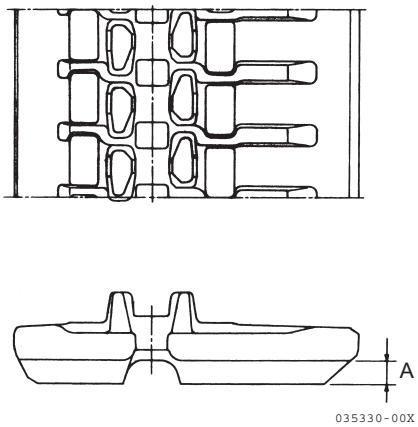
Applicable model				4TNV98C-WBV	
Item			Unit	Standard	Allowable limit
Others					
	Thermostat	Valve opening temperature	degree F (degree C)	157 to 163 (70 to 73)	-
		Full opening lift temperature	in. (mm)	0.32 (8) or above [at 185 degree F (85 degree C)]	-

3. SERVICING STANDARDS

3-3 Undercarriage

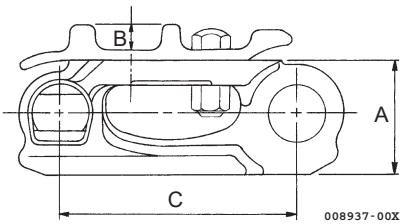
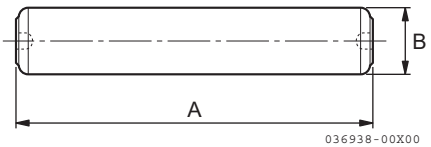
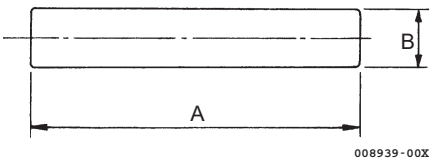
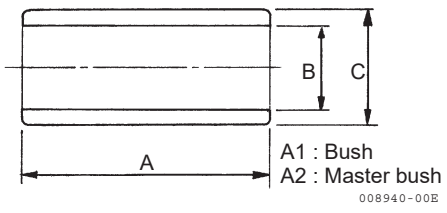
3-3-1 Rubber Crawler Specifications

[Unit : in. (mm)]

Applicable model	ViO80-1A		
Part	Measuring position	Standard	Wear limit
Rubber crawler specifications			
(1) Rubber crawler 	A	1.18 (30)	0.20 (5)

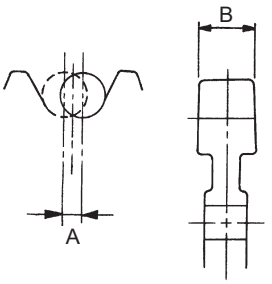
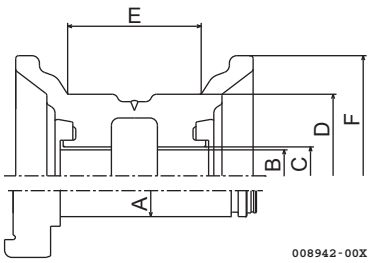
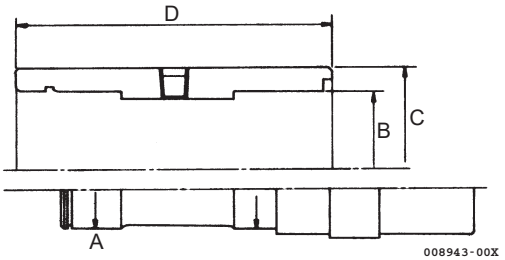
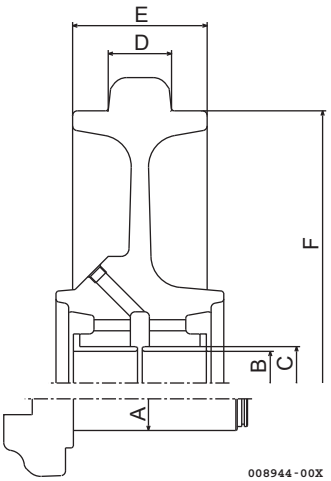
3-3-2 Steel Crawler Specifications

[Unit : in. (mm)]

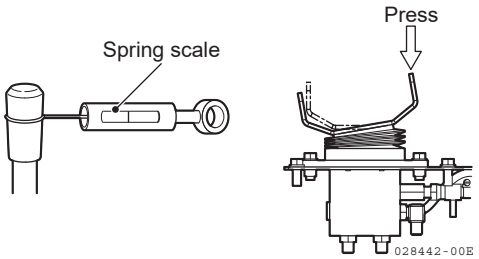
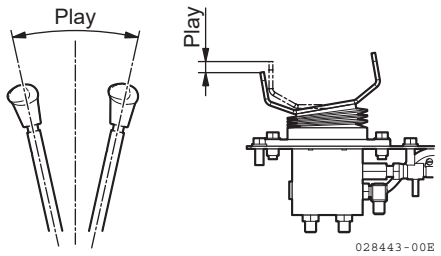
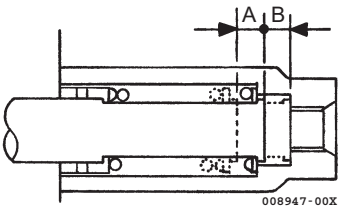
Applicable model		ViO80-1A		
Part		Measuring position	Standard	Wear limit
Steel crawler specifications				
(1) Crawler link (Triple grouser)  ***Note :*** *For the link pitch, measure 5 links at three places and obtain the average value.*		A	2.91 (74)	2.76 (70)
		B	0.79 (20)	0.47 (12)
		C	6.06 (154)	6.18 (157)
(2) Master pin  		A	5.16 (131)	-
		B	Ø0.94 (Ø24.00)	Ø0.87 (Ø22)
(3) Pin  		A	5.16 (131)	-
		B	Ø0.95 (Ø24.075)	Ø0.87 (Ø22)
(4) Bush & master bush  	A	A1	3.18 (80.8)	-
		A2	2.93 (74.5)	-
	B		Ø0.97 (Ø24.6)	Ø1.02 (Ø26)
	C		Ø1.62 (Ø41.26)	Ø1.47 (Ø37.3)

3-3-3 Common Specifications of Steel & Rubber Crawlers

[Unit : in. (mm)]

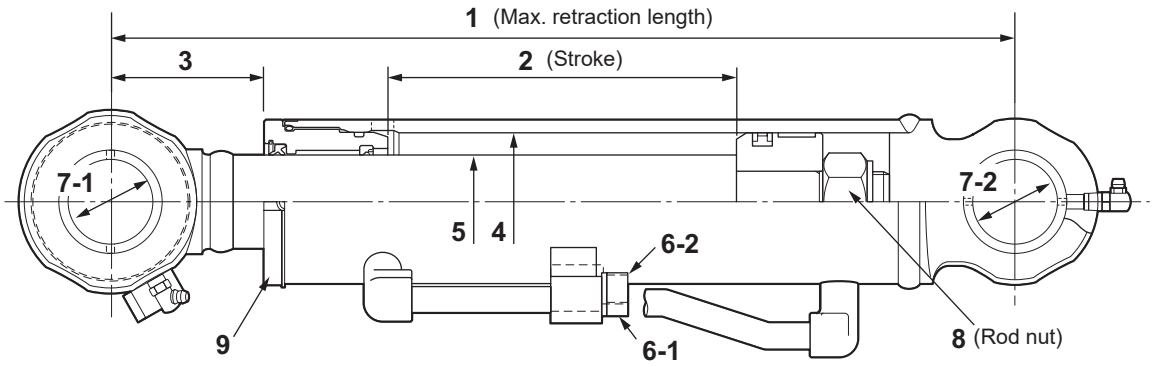
Applicable model		ViO80-1A		
Part		Measuring position	Standard	Wear limit
Common specifications of steel & rubber crawlers				
(1) Sprocket 		A	0.31 (7.96)	-
		B	1.50 (38)	1.30 (33)
(2) Track roller & shaft 		A	Ø1.57 (Ø40)	Ø1.56 (Ø39.5)
		B	Ø1.57 (Ø40)	Ø1.59 (Ø40.4)
		C	Ø1.73 (Ø44)	-
		D	Ø4.72 (Ø120)	Ø4.57 (Ø116)
		E	4.25 (108)	4.49 (114)
		F	Ø6.93 (Ø176)	Ø6.77 (Ø172)
(3) Carrier roller & shaft 		A	Ø1.38 (Ø35)	-
		B	Ø2.83 (Ø72)	-
		C	Ø3.54 (Ø90)	Ø3.39 (Ø86)
		D	4.61(117)	-
(4) Idler & shaft 		A	Ø1.73 (Ø44)	Ø1.71 (Ø43.5)
		B	Ø1.73 (Ø44)	Ø1.75 (Ø44.4)
		C	Ø1.97 (Ø50)	-
		D	1.69 (43)	1.46 (37)
		E	3.94 (100)	3.62 (92)
		F	Ø14.76 (Ø375)	Ø14.53 (Ø369)

3-4 Controls

<table>
<tr><td colspan="3">Applicable model</td><td colspan="3">ViO80-1A</td></tr>
<tr><td colspan="3">Item</td><td>Measuring conditions</td><td>Unit</td><td>Standard</td><td>Allowable limit</td></tr>
<tr><td colspan="7">Controls</td></tr>
<tr><td></td><td colspan="6">Operating force</td></tr>
<tr><td></td><td></td><td>Right control lever (Boom & Bucket)</td><td rowspan="8">• Engine : stopped
• Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C)
• Lever operating force : Measure the force by hanging the spring scale on the lever grip.
• Pedal operating force : Measure the force by applying load as shown below.
  </td><td rowspan="8">lbs. (N)</td><td>2.63 (11.7)</td><td>3.75 (16.7)</td></tr>
<tr><td></td><td></td><td>Left control lever (Arm & Swing)</td><td>2.63 (11.7)</td><td>3.75 (16.7)</td></tr>
<tr><td></td><td></td><td>Blade lever</td><td>4.41 (19.6)</td><td>5.53 (24.6)</td></tr>
<tr><td></td><td></td><td rowspan="2">Travel levers</td><td>Forward
3.53 (15.7)</td><td>Forward
4.65 (20.7)</td></tr>
<tr><td></td><td></td><td>Reverse
3.53 (15.7)</td><td>Reverse
4.65 (20.7)</td></tr>
<tr><td></td><td></td><td>-</td><td>-</td><td>-</td></tr>
<tr><td></td><td></td><td>Boom swing pedal</td><td>16.55 (73.6)</td><td>17.67 (78.6)</td></tr>
<tr><td></td><td></td><td>-</td><td>-</td><td>-</td></tr>
<tr><td></td><td colspan="6">Play of control lever & pedal</td></tr>
<tr><td></td><td></td><td>Right control lever (Front & rear / left & right)</td><td rowspan="6">• Engine : stopped
• Hydraulic oil temp. : 122 to 140 °F (50 to 60 °C)
• Play of each control lever and pedal : Measure the total play (front & rear and left & right) at the lever grip end or the pedal end.
  </td><td rowspan="6">in. (mm)</td><td>0.2 (5)
or less</td><td>-</td></tr>
<tr><td></td><td></td><td>Left control lever (Front & rear / left & right)</td><td>0.2 (5)
or less</td><td>-</td></tr>
<tr><td></td><td></td><td>Blade lever</td><td>0.2 (5)
or less</td><td></td></tr>
<tr><td></td><td></td><td>Travel levers</td><td>0.2 (5)
or less</td><td></td></tr>
<tr><td></td><td></td><td>Boom swing pedal</td><td>0.2 (5)
or less</td><td>-</td></tr>
<tr><td></td><td></td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="7">Control valve</td></tr>
<tr><td></td><td colspan="6">Spool stroke</td></tr>
<tr><td></td><td></td><td>Boom</td><td rowspan="12">  </td><td rowspan="12">in. (mm)</td><td rowspan="11">0.31 (8.0)</td><td rowspan="12">-</td></tr>
<tr><td></td><td></td><td>Bucket</td></tr>
<tr><td></td><td></td><td>Arm</td></tr>
<tr><td></td><td></td><td>Swing</td></tr>
<tr><td></td><td></td><td>Parallel-flow divider</td></tr>
<tr><td></td><td></td><td>Inlet</td></tr>
<tr><td></td><td></td><td>Right travel</td></tr>
<tr><td></td><td></td><td>Left travel</td></tr>
<tr><td></td><td></td><td>Blade</td></tr>
<tr><td></td><td></td><td>Boom swing</td></tr>
<tr><td></td><td></td><td>-</td><td>-</td></tr>
</table>

3-5 Hydraulic Equipment

3-5-1 Hydraulic Cylinders



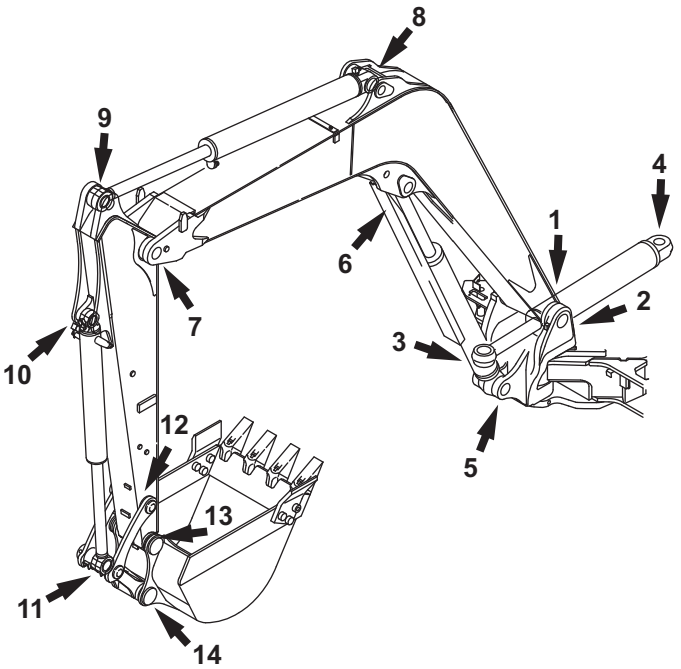
Unit: in. (mm)

No. \ Cylinder		Boom	Arm	Bucket	Boom swing	Blade
1		51.4 (1306)	53.6 (1361)	42.8 (1087)	42.2 (1071)	32.7 (831)
2		32.7 (831)	36.4 (924)	27.8 (705)	23.8 (604)	6.69 (170)
3		4.02 (102)	5.47 (139)	4.41 (112)	5.77 (146.5)	14.4 (365.5)
4		Ø4.53 (Ø115)	Ø3.94 (Ø100)	Ø3.74 (Ø95)	Ø4.72 (Ø120)	Ø5.12 (Ø130)
5		Ø2.56 (Ø65)	Ø2.56 (Ø65)	Ø2.36 (Ø60)	Ø2.36 (Ø60)	Ø2.56 (Ø65)
6-1 (Rod side)		G1/2	G1/2	G1/2	G3/8	G3/8
6-2 (Bottom side)		G1/2	G1/2	G1/2	G3/8	G1/2
7-1	Standard	Ø2.76 (Ø70)	Ø2.36 (Ø60)	Ø2.36 (Ø60)	Ø2.36 (Ø60)	Ø2.36 (Ø60)
	Allowable limit	Ø2.80 (Ø71)	Ø2.40 (Ø61)	Ø2.40 (Ø61)	Ø2.40 (Ø61)	Ø2.40 (Ø61)
7-2	Standard	Ø2.76 (Ø70)	Ø2.36 (Ø60)	Ø1.97 (Ø50)	Ø2.36 (Ø60)	Ø2.36 (Ø60)
	Allowable limit	Ø2.80 (Ø71)	Ø2.40 (Ø61)	Ø2.01 (Ø51)	Ø2.40 (Ø61)	Ø2.40 (Ø61)
8	Thread size (mm)	M45	M48	M42	M42	M48
	Width across flat	2.76 (70)	2.95 (75)	2.56 (65)	2.56 (65)	2.95 (75)
	Tightening torque ft•lbf (N•m)	2098 to 2171 (2845 to 2943)	2124 (2880)	1773 to 1845 (2403.5 to 2501.6)	1773 to 1845 (2403.5 to 2501.6)	2605 to 2677 (3532 to 3630)
	Screw locking agent	Three Bond 1324	–	Three Bond 1324	Three Bond 1324	Three Bond 1324
9	Thread size (mm)	M120	M107	M100	M125	M135
	Tightening torque ft•lbf (N•m)	885 to 929 (1200 to 1260)	701 (951)	738 to 774 (1000 to 1050)	1033 to 1048 (1400 to 1470)	1180 to 1239 (1600 to 1680)
	Screw locking agent	–	Three Bond 1901	–	–	–

Symbol	Name
G (PF)	Straight pipe thread
R (PT)	Taper pipe thread (male)
Rc (PT)	Taper pipe thread (female)

3-6 Implement

3-6-1 Front Attachments

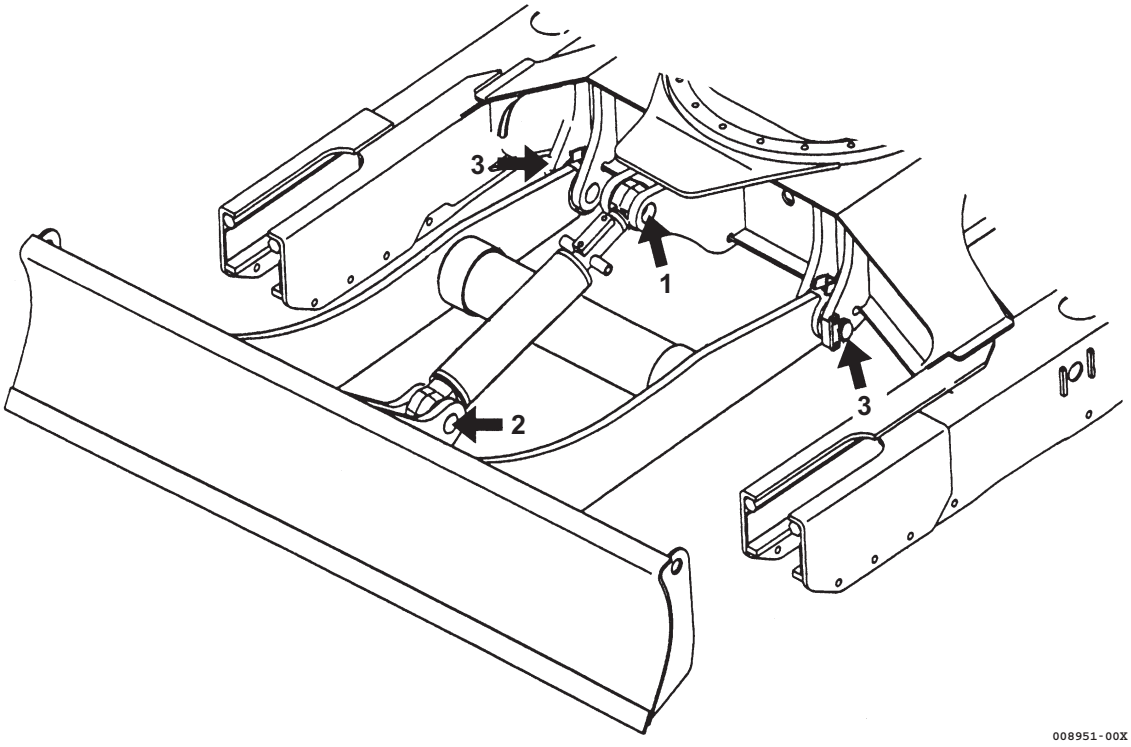


Unit : in. (mm)

No.	Applicable model: ViO80-1A	Standard	Wear limit	
	Measuring point		Pin	Bore of bush or hole
1	Boom swing fulcrum	Ø3.94 (Ø100)	-0.02 (-0.5)	+0.02 (+0.5)
2	Boom fulcrum	Ø3.15 (Ø80)		
3	Boom swing cylinder, rod	Ø2.36 (Ø60)		
4	Boom swing cylinder, bottom	Ø2.36 (Ø60)		
5	Boom cylinder, bottom	Ø2.76 (Ø70)		
6	Boom cylinder, rod	Ø2.76 (Ø70)		
7	Arm fulcrum	Ø2.76 (Ø70)		
8	Arm cylinder, bottom	Ø2.36 (Ø60)		
9	Arm cylinder, rod	Ø2.36 (Ø60)		
10	Bucket cylinder, bottom	Ø1.97 (Ø50)		
11	Bucket cylinder, rod	Ø2.36 (Ø60)		
12	Link “A” arm	Ø1.97 (Ø50)		
13	Bucket fulcrum	Ø1.97 (Ø50)		
14	Bucket “link A”	Ø1.97 (Ø50)		

Note : *Allowable clearance is 0.04 in. (1.0 mm).*

3-6-2 Blade Moving Device



Unit : in. (mm)

No.	Applicable model : ViO80-1A	Standard	Wear limit	
	Measuring point		Pin	Bore of bush or hole
1	Blade cylinder, rod	Ø2.36 (Ø60)	-0.02 (-0.5)	+0.02 (+0.5)
2	Blade cylinder, bottom	Ø2.36 (Ø60)		
3	Blade fulcrum	Ø2.36 (Ø60)		

Note : *Allowable clearance between pin and bore of bush or hole is 0.04 in. (1.0 mm).*

3-7 List of Tightening Torque

3-7-1 Machine

Applicable model			ViO80-1A		
Equipment			Thread size	Tightening torque ft•lbf (N•m)	Adhesive
	No	Tightening part			
Engine / Electrical equipment					
	1	Engine mount vibroisolating rubber	M16 × 130	195.3 to 224.2 (264.8 to 304)	Three Bond 1324
	2	Engine × Engine mount F (Radiator side)	M10 × 35 (11T)	61.4 (83.3)	Three Bond 1324
	3	Engine × Engine mount R (Flywheel side)	M12 × 30 (10.9)	79.7 to 94.4 (108 to 128)	Three Bond 1324
	4	Air cleaner	M8 × 20	14.5 to 16.7 (19.6 to 22.6)	-
	5	Air cleaner intake hose (Engine and Air cleaner side)	Hose clip 80	1.8 to 2.5 (2.5 to 3.4)	-
	6	Air cleaner intake hose (Air cleaner intake side)	Hose clip 90	0.9 to 1.1 (1.2 to 1.5)	-
	7	Cooling water hose	Hose clip 48	1.8 to 2.5 (2.5 to 3.4)	-
	8	Fuel gauge unit	M5×12 (Pan-head machine screw)	0.87 to 1.08 (1.18 to 1.47)	-
	9	Fuel tank × Bracket SWP × Clamp	M8 × 16	9.4 to 12.3 (12.8 to 16.7)	-
	10	Fuel drain valve	R3/8	14.5 to 21.7 (19.6 to 29.4)	Sealing tape Loctite 577
	11	Fuel tank holding band (Tank holding (upper) side)	Nut 10	1.8 to 2.1 (2.5 to 2.9)	-
	12	Fuel tank holding band (Lock nut (lower) side)	Nut 10	18.1 to 23.9 (24.5 to 32.4)	-
	13	Fuel tank bracket L × Frame	M10 × 30	32.5 to 43.4 (44.1 to 58.9)	Three Bond 1324
	14	Battery holding rod (Battery holding side)	Nut 8	2.2 (2.94)	-
	15	Battery holding rod (Lock nut side)	Nut 8	9.4 to 12.3 (12.8 to 16.7)	-
	16	LCD monitor × Panel	M5 × 20	1.88 to 2.43 (2.55 to 3.3)	-
	17	Knob (Thermo blower)	M4 × 5	0.22 to 0.37 (0.3 to 0.5)	-
	18	Engine × Compressor bracket	M8 × 50	-	Three Bond 1324
	19	Engine × Pulley bracket	M10 × 20	-	Three Bond 1324
	20	Air conditioner hose × Condenser (Condenser lower side)	M16 × 1.5 (Hose joint)	8.9 to 11.1 (12 to 15)	-
	21	Air conditioner hose × Compressor	M8 × 25	14.8 to 18.4 (20 to 25)	-
	22	Air conditioner hose × Condenser (Condenser upper side)	M22 × 1.5 (Hose joint)	14.8 to 18.4 (20 to 25)	-
	23	Air conditioner hose × Condenser (Condenser lower side)	M16 × 1.5 (Hose joint)	8.9 to 11.1 (12 to 15)	-
	24	Air conditioner hose × Compressor	M8 × 25	14.8 to 18.4 (20 to 25)	-

3. SERVICING STANDARDS

Applicable model			ViO80-1A		
Equipment			Thread size	Tightening torque ft•lbf (N•m)	Adhesive
	No	Tightening part			
Engine / Electrical equipment					
	25	Safety switch (Cut-off lever)	Nut 18 (Fine thread)	21.7 to 25.3 (29.4 to 34.3)	-
	26	Engine control dial	Nut 9 (Fine thread)	1.08 or less (1.47 or less)	-
	27	Mount × Air conditioner bracket	Nut 8	9.37 to 12.3	-

3. SERVICING STANDARDS

Applicable model			ViO80-1A		
Equipment			Thread size	Tightening torque ft•lbf (N•m)	Adhesive
	No	Tightening part			
Engine / Electrical equipment					
	25	Exhaust pipe × Clamp	M10 × 65	32.5 (44.1)	-
Travel device					
	1	Nipple valve	M16	36.1 (49)	-
	2	Sprocket (Boron steel bolt)	M14 × 35	137.2 to 151.9 (186 to 206)	Loctite 262 or K-965
	3	Idler seal cover × Crawler adjust spring	M14 × 60	87.0 to 108.4 (118 to 147)	Loctite 262 or K-965
	4	Track roller	M20 × 40	325.4 to 361.6 (441.2 to 490.2)	Loctite 262 or K-965
Controls					
	1	Grip (L, R) × Travel lever (L, R)	M4 × 12 (Binding head screw)	1.3 to 1.9 (1.77 to 2.55)	Three Bond 1324
	2	Blade lever × Blade valve	M8 × 16	11.2 to 13.4 (15.2 to 18.2)	-
Frame					
	1	Swing bearing × Lower frame	M16 × 90 (10.9T)	231.4 to 245.8 (313.7 to 333.3)	Loctite 262 or K-965
	2	Swing bearing × Turning frame	M16 × 85 (10.9T)	231.4 to 245.8 (313.7 to 333.3)	Loctite 262 or K-965
	3	Counter weight × Turning frame (Boron steel bolt)	M24 × 140	354.5 to 441.4 (480.7 to 598.4)	Three Bond 1324
	4	Crawler guard × Lower frame (Steel crawler)	M16 × 40	195.3 to 224.2 (264.8 to 304)	Loctite 262 or K-965
Rigging					
	1	Cabin mount × Turning frame	M16 × 45 (11T)	195.3 to 224.2 (264.8 to 304)	Three Bond 1324
	2	Slide frame × Slide assembly	Hexagon socket heed bolt M8 × 16	16.7 to 21.0 (22.6 to 28.4)	Three Bond 1324
	3	Slide assembly × Seat mount	Hexagon socket heed bolt M8 × 16	16.7 to 21.0 (22.6 to 28.4)	Three Bond 1324
	4	Key lock plate × Key cylinder	U nut M10	5.8 to 8.7 (7.8 to 11.8)	-
	5	Cabin/Seat mount × Vibroisolating rubber (Double Nut)	Nut M20	195.3 to 217 (264.8 to 294.2)	-
	6	Rearview mirror	Nut M10	16.7 to 21.7 (22.6 to 29.4)	-
	7	Side mirror	Nut M10	32.5 to 43.4 (44.1 to 58.9)	-
Hydraulic equipment					
	1	CF coupling	Hexagon socket heed bolt M14 × 50	108.4 to 123.2 (147 to 167)	Three Bond 1324
	2	Flange 40.5 × Hydraulic pump	M10 × 30	28.8 to 43.4 (39.1 to 58.8)	-
	3	Hydraulic pump mount × Hydraulic pump	M18 × 55	216.8 to 239 (294 to 324)	-
	4	Swivel joint × Track frame	M12 × 40	57.9 to 72.4 (78.5 to 98.1)	Loctite 262 or K-965
	5	Travel motor × Track frame	M16 × 45	123.2 to 151.9 (167 to 206)	Loctite 262 or K-965

Applicable model			ViO80-1A		
Equipment	No	Tightening part	Thread size	Tightening torque ft•lbf (N•m)	Adhesive
Hydraulic equipment					
	6	Swing motor × Turning frame	M16 × 50	195.3 to 224.2 (264.8 to 304)	Three Bond 1324
	7	Hydraulic oil tank × Turning frame	M16 × 35	123.2 to 151.9 (167 to 206)	Three Bond 1324
	8	Oil level gauge × Hydraulic oil tank	M10 × 30	10.8 to 11.6 (14.7 to 15.7)	-
	9	Drain plug × Hydraulic oil tank	M24	79.6 (107.9)	-
	10	Temperature sensor × Hydraulic oil tank	M12 × 1.5 (Fine thread)	14.8 to 17.7 (20 to 24)	-
	11	Hose clip 13 (Drain)	-	1.6 to 1.8 (2.16 to 2.45)	-
	12	Hose clip 16 (Drain)	-	1.6 to 1.8 (2.16 to 2.45)	-
	13	Hose clip 35 (Hyd. oil tank return)	-	2.9 to 3.6 (3.9 to 4.9)	-
	14	Hose clip 41 (Oil cooler - Hyd. oil tank)	-	2.9 to 3.6 (3.9 to 4.9)	-
	15	Hose clip 54 (Suction hose)	-	3.6 to 4.4 (4.9 to 5.9)	-
	16	Hose clip 80 (Suction hose)	-	3.6 to 4.4 (4.9 to 5.9)	-
	17	Hose clip 90 (Suction hose)	-	3.6 to 4.4 (4.9 to 5.9)	-
	18	Control valve × Turning frame	M10 × 45	14.5 to 18.8 (19.6 to 25.5)	Three Bond 1324
	19	Hose clamp A1, A2	M10 × 55	35.5 to 43.4 (44.1 to 58.9)	Three Bond 1324
	20	Hose clamp B	M10 × 50	35.5 to 43.4 (44.1 to 58.9)	Three Bond 1324
	21	Hose clamp 1/2	M12 × 40	57.9 to 72.4 (78.5 to 98.1)	Three Bond 1324
	22	Hose clamp 3/4	M12 × 55, 70	57.9 to 72.4 (78.5 to 98.1)	Three Bond 1324
	23	Quick tube × Arm	M8 × 25	28.9 to 33.3 (39.2 to 45.1)	-
	24	Hose clamp	M12 × 60	(78.5 to 98.0)	-
	25	90 degrees elbow check × Control valve conflux	G1/2	72.3 to 86.7 (98 to 117.6)	-
Implement					
	1	Boom fulcrum pin lock plate	M14 × 35	87.0 to 108.4 (118 to 147)	Three Bond 1324
	2	Boom fulcrum pin retaining plate	M14 × 25	87.0 to 108.4 (118 to 147)	Three Bond 1324
	3	Arm fulcrum pin lock plate	M14 × 25	87.0 to 108.4 (118 to 147)	Three Bond 1324
	4	Arm fulcrum pin retaining plate	M14 × 25	87.0 to 108.4 (118 to 147)	Three Bond 1324
	5	Boom cylinder rod pin lock plate	M14 × 35	87.0 to 108.4 (118 to 147)	Three Bond 1324

Applicable model			ViO80-1A		
Equipment			Thread size	Tightening torque ft•lbf (N•m)	Adhesive
	No	Tightening part			
Implement					
	6	Boom swing cylinder bottom pin lock plate	M12 × 30	57.9 to 72.4 (78.5 to 98.1)	Three Bond 1324
	7	Boom swing cylinder rod pin lock plate	M14 × 35	87.0 to 108.4 (118 to 147)	Three Bond 1324
	8	Arm cylinder bottom pin lock plate	M14 × 35	87.0 to 108.4 (118 to 147)	Three Bond 1324
	9	Arm cylinder rod pin lock plate	M14 × 35	87.0 to 108.4 (118 to 147)	Three Bond 1324
	10	Bucket cylinder bottom pin lock plate	M12 × 30	57.9 to 72.4 (78.5 to 98.1)	Three Bond 1324
	11	Blade fulcrum pin lock plate	M12 × 30	57.9 to 72.4 (78.5 to 98.1)	Three Bond 1324
	12	Blade cylinder pin lock plate	M14 × 35	87.0 to 108.4 (118 to 147)	Three Bond 1324

3-7-2 Engine

1) Tightening torque for major bolts and nuts

No.	Item	Thread size × Pitch (mm)	Tightening torque [ft•lbf (N•m)]	Lubricating oil
1	Cylinder head bolt	M11 × 1.25	76 to 83 (103.1 to 112.9)	Yes
2	Connecting rod bolt	M10 × 1.0	40 to 43 (53.9 to 58.8)	Yes
3	Flywheel bolt	M14 × 1.5	137 to 152 (186.2 to 205.8)	Yes
4	Main bearing cap bolt	M11 × 1.25	80 to 87 (108.1 to 117.9)	Yes
5	Crankshaft pulley bolt	M14 × 1.5	80 to 94 (107.9 to 127.5)	Yes
6	Flywheel speed sensor	M6 × 1.0	4.4 to 7.4 (6.0 to 10.0)	No
7	Camshaft speed sensor	M6 × 1.0	5.5 to 6.3 (7.5 to 8.5)	No
8	EGR valve pipe	M10 × 1.5	43.3 to 47.0 (58.7 to 63.7)	No
9	Fresh air temperature sensor	M6 × 1.0	2.2 to 3.0 (3.0 to 4.0)	No
10	Intake air temperature sensor	M14 × 1.5	8.1 to 12.5 (11.0 to 17.0)	No
11	Exhaust temperature sensor	M12 × 1.25	18.4 to 29.5 (25.0 to 40.0)	No
12	EGR pressure sensor	M6 × 1.0	4.1 to 6.2 (5.6 to 8.4)	No
13	DPF temperature sensor (Inlet)	M14 × 1.5	25.8 to 33.2 (35.0 to 45.0)	No
14	DPF temperature sensor (Intermediate)	M12 × 1.25	18.4 to 29.5 (25.0 to 40.0)	No
15	DPF differential pressure sensor	M6 × 1.0	4.1 to 6.2 (5.6 to 8.4)	No
16	Bolt, DPF differential pressure sensor pipe joint	M12 × 1.25	33.2 to 40.5 (45.0 to 55.0)	Burning prevention medicine
17	Valve cover nut	M8 × 1.5	8.9 to 11.0 (12.0 to 15.0)	No
18	Glow plug	M10 × 1.25	11.1 to 14.8 (15 to 20)	No
19	Glow connector nut	M4 × 0.7	0.7 to 1.1 (1 to 1.5)	No

2) Tightening torque for fuel system

No.	Item	Thread size × Pitch (mm)	Tightening torque Unit: ft•lbf (N•m)	Lubricating oil
1	Fuel injector bolt	M8 × 1.25	18.0 to 20.9 (24.4 to 28.4)	No
2	Supply pump drive gear nut	M18 × 1.5	55 to 63 (75 to 85)	No
3	High-pressure fuel line nut (common rail)	M12 × 1.5	21.7 to 25.3 (29.4 to 34.3)	No
4	High-pressure fuel line nut (injector)	M12 × 1.5	21.7 to 25.3 (29.4 to 34.3)	No
5	High-pressure fuel line nut (supply pump)	M16 × 1.0	21.7 to 25.3 (29.4 to 34.3)	No

3-7-3 Tightening Torque for General Bolts and Nuts

Item		Thread size × Pitch	Tightening torque [Unit: ft•lbf (N•m)]	Remarks
Hexagon head bolt (7T) Nut	Coarse screw thread	M6 × 1	7.23 to 8.70 (9.8 to 11.8)	1) Apply 80% of tightening torque when tightened to aluminum. 2) Apply 60% of tightening torque for 4T bolts and lock nuts. 3) Use fine screw threads for engine only.
		M8 × 1.25	16.67 to 20.95 (22.6 to 28.4)	
		M10 × 1.5	32.53 to 43.44 (44.1 to 58.9)	
		M12 × 1.75	57.90 to 72.36 (78.5 to 98.1)	
		M14 × 2	86.82 to 108.50 (117.7 to 147.1)	
		M16 × 2	123.03 to 151.95 (166.8 to 206.0)	
		M18 × 2.5	173.70 to 209.85 (235.5 to 284.5)	
		M20 × 2.5	238.83 to 296.66 (323.8 to 402.2)	
	Fine screw thread	M14 × 1.5	94.0 to 108.5 (127.5 to 147.1)	
		M16 × 1.5	155.56 to 177.25 (210.9 to 240.3)	
PT plug		1/8	7.23 (9.8)	
		1/4	14.46 (19.6)	
		3/8	21.69 (29.4)	
		1/2	43.44 (58.9)	
Pipe joint bolt		M8	9.40 to 12.32 (12.7 to 16.7)	
		M10	14.46 to 18.73 (19.6 to 25.4)	
		M12	18.07 to 25.30 (24.5 to 34.3)	
		M14	28.91 to 36.14 (39.2 to 49.0)	
		M16	36.22 to 43.44 (49.1 to 58.9)	

3-7-4 Hydraulic Fitting

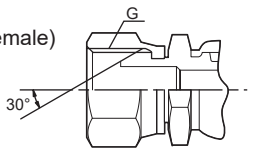
(1) Tightening torque of parallel pipe thread

For 30° sheet type joint and the O-ring sheet type joint.

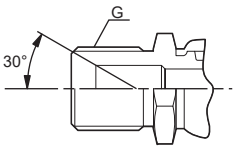
Unit: ft•lbf (N•m)

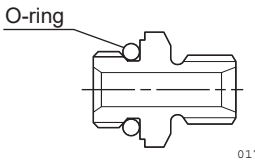
Nominal designation of screw thread G (PF)	Tightening torque
	Material: Steel, Cast iron
1/8	10.1 to 12.3 (13.7 to 16.7)
1/4	16.6 to 20.3 (22.6 to 27.5)
3/8	32.5 to 39.8 (44.1 to 53.9)
1/2	39.1 to 47.7 (53.0 to 64.7)
3/4	78.1 to 95.5 (106 to 129)
1	91.1 to 111.4 (124 to 151)
1 1/4	110.7 to 135.3 (150 to 183)
1 1/2	137.4 to 166.4 (186 to 226)

Example
Parallel pipe thread (female)
(male 30° sheet)



Parallel pipe thread (female)





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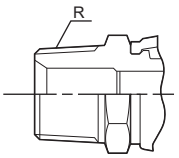
(2) Tightening torque of taper pipe thread

Apply seal tape

Unit: ft•lbf (N•m)

Nominal designation of screw thread R (PT)	Tightening torque
	Material: Steel, Cast iron
1/8	5.1 to 6.5 (6.9 to 8.8)
1/4	7.2 to 10.8 (9.8 to 14.7)
3/8	21.7 to 28.9 (29.4 to 39.2)
1/2	28.9 to 36.2 (39.2 to 49.0)
3/4	36.2 to 47.0 (49.0 to 63.7)
1	50.6 to 65.1 (68.6 to 88.3)
1 1/4	72.3 to 86.8 (98.1 to 118)

Example
Parallel pipe thread (female)



017501-00E

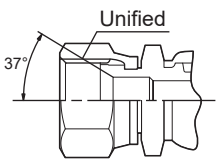
(3) Tightening torque of unified screw thread

For 30° sheet type joint and the O-ring sheet type joint.

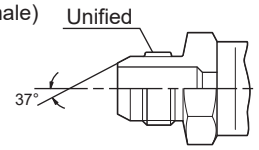
Unit: ft•lbf (N•m)

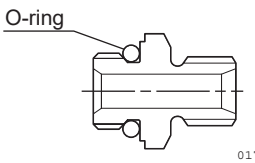
Nominal designation of screw thread G (PF)	Tightening torque
	Material: Steel, Cast iron
7/16-20UNF	13.0 to 15.9 (17.7 to 21.6)
9/16-18UNF	26.0 to 31.8 (35.3 to 43.1)
3/4-16UNF	32.5 to 39.8 (44.1 to 53.9)
7/8-14UNF	39.1 to 47.7 (53 to 64.7)
1 1-16-12UN	78.1 to 95.5 (106 to 129)
1 5/16-12UN	91.1 to 111.4 (124 to 151)
1 5/8-12UN	110.7 to 135.3 (150 to 183)

Example
Unified screw thread (female)
(male 37° sheet)



Example
Unified screw thread (female)
(male 37° sheet)





017502-00E

3-8 Pressure Adjustment

3-8-1 Relief Valves

1) Conditions

(1) Engine: maximum speed
(2) Hydraulic oil temperature: 122 to 140 °F (50 to 60 °C)
(3) Pressure gauge capacity: 7252 PSI (50 MPa), 5076 PSI (35 MPa)

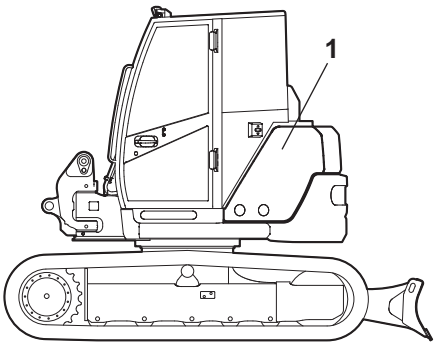
2) Relief Valve Specification

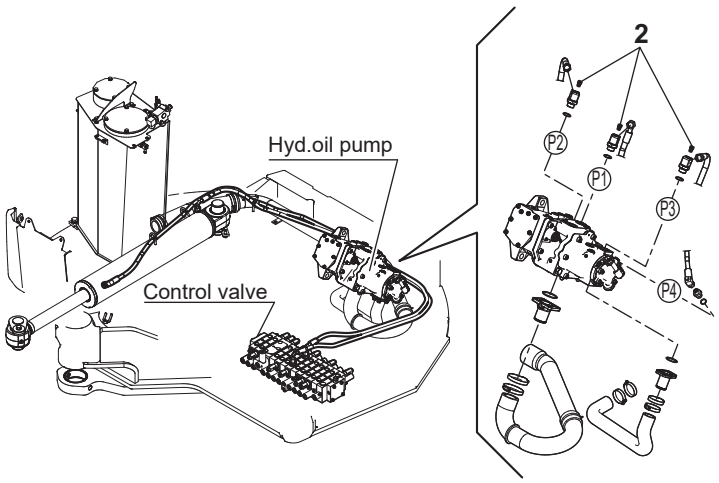
[Unit: PSI (MPa) at GPM (L / min)]

Valve		Pump	Set pressure
			ViO80-1A
System relief valve	No.1	Piston pump P1	3727 (25.7) at 7.9 (30)
	No.2	Piston pump P2	3727 (25.7) at 7.9 (30)
	No.3	Piston pump P3	3510 (24.2) at 7.9 (30)
Circuit relief valve	Boom (rod end)	Piston pump P1	4134 (28.5) at 13.2 (50)
	Boom (bottom end)	Piston pump P1	4279 (29.5) at 13.2 (50)
	Arm (rod end)	Piston pump P2	4134 (28.5) at 13.2 (50)
	Arm (bottom end)	Piston pump P2	4134 (28.5) at 13.2 (50)
	Bucket (rod end)	Piston pump P1	4134 (28.5) at 13.2 (50)
	Bucket (bottom end)	Piston pump P1	4134 (28.5) at 13.2 (50)
	Boom swing (rod end)	Piston pump P2	4134 (28.5) at 13.2 (50)
	Boom swing (bottom end)	Piston pump P2	4134 (28.5) at 13.2 (50)
	Blade (rod end)	Gear pump P3	2176 (15) at 13.2 (50)

3) Measurement Procedure

(1) Remove cover B **1**.
(2) Remove plugs R (PT) 1/8 **2** from the output port of the variable displacement piston pumps and the gear pump and install the oil pressure gauge.



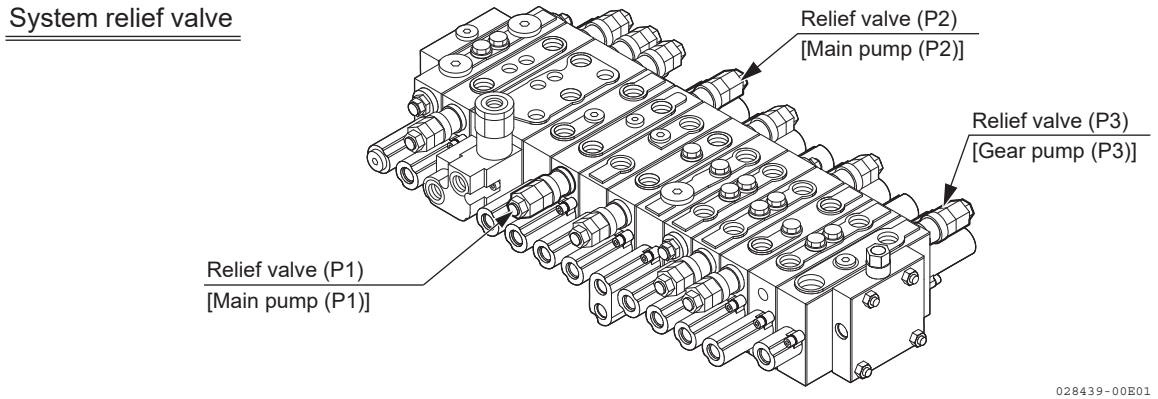


4) Adjustment Procedure

(1) To check the pressure of the system relief valve (for the piston pump P1) in the control valve, retract the bucket cylinder to its stroke end, hold the lever and read the gauge. Adjust the pressure if necessary.

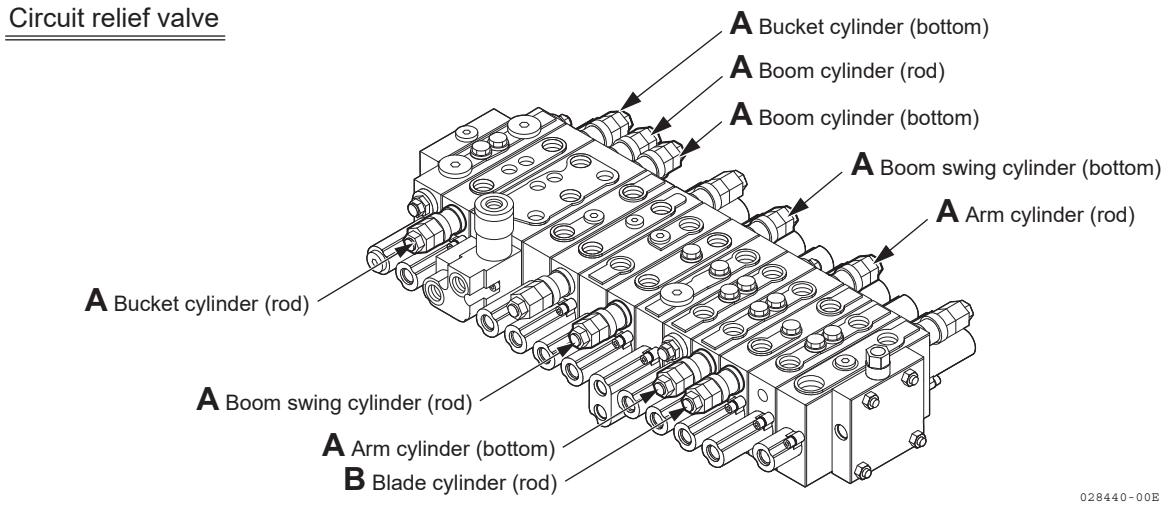
(2) To check the pressure of the system relief valve (for the piston pump P2), retract or extend the arm or boom swing cylinder to its stroke end, hold the lever and read the gauge. Adjust the pressure if necessary.

(3) To check the pressure of the system relief valve (for the gear pump P3), extend the blade cylinder to its stroke end, hold the lever and read the gauge. Adjust the pressure if necessary.



(4) To adjust the pressure of each circuit relief valve, extend or retract the cylinder to its stroke end, hold the lever and read the gauge. Whether the pressure of the circuit relief valve is lower than that of the system relief valve can be read on the gauge.

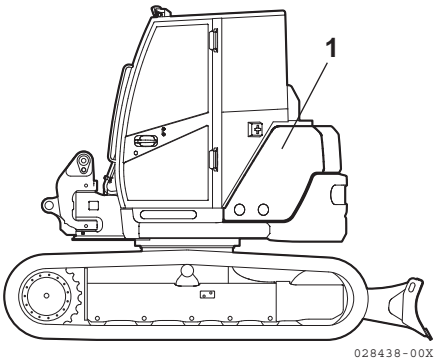
Increase the pressure of the system relief valve and that of the circuit relief valve by turns, and lock the adjust screw when the specified pressure of the circuit relief valve is obtained. Then lower the pressure of the system relief valve to the specified pressure and lock the adjust screw.



5) Pressure Change by One Turn of Adjust Screw

	Pressure change PSI (MPa)	Number of adjust screw turns
System relief valve (P1, P2, P3)	2582 (17.8)	1/1
Circuit relief valve **A**	4119 (28.4)	1/1
Circuit relief valve **B**	2582 (17.8)	1/1

3-8-2 Swing Brake Valve

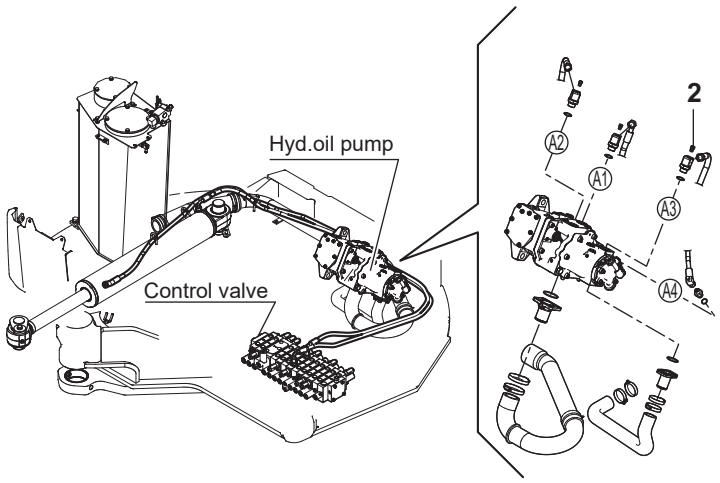


1) Conditions

(1) Engine: low idling speed
(2) Hydraulic oil temperature: 122 to 140 °F (50 to 60°C)
(3) Pressure gauge capacity: 4977.1 PSI (34.3 MPa)
(4) Set pressure: 3481 PSI (24.0 MPa)

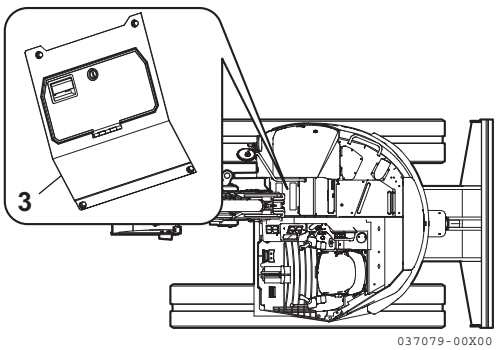
2) Measurement Procedure

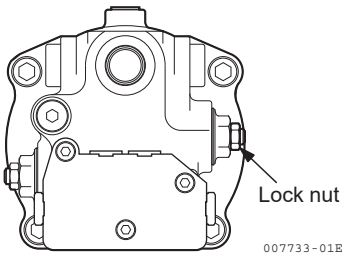
(1) Remove cover **1**.
(2) Remove plug R (PT) 1/8 **2**.
(3) Install the pressure gauge.
(4) Fix the front implement.
(5) Move the swing control lever to the right and the left, hold the lever with relief pressure applied and read the gauge.

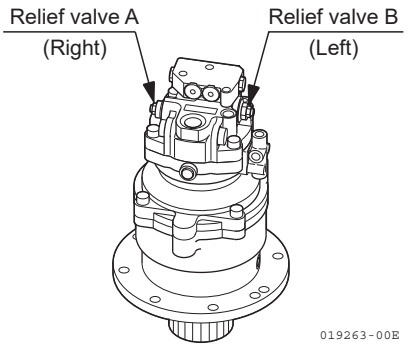


3) Adjustment Procedure

(1) Remove center cover **3**.
(2) Loosen the lock nut of the relief valve and adjust the pressure with the adjust screw.



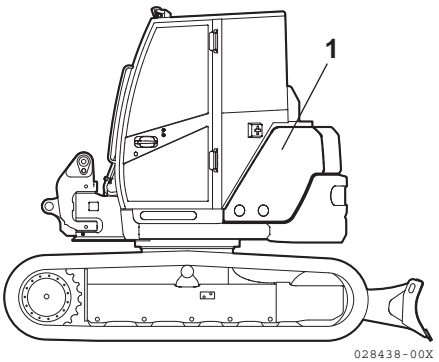




Pressure change / one turn of adjust screw

	Relief valve
Pressure change / one turn	1398 PSI (9.7 MPa)

3-8-3 Cut-off Valve

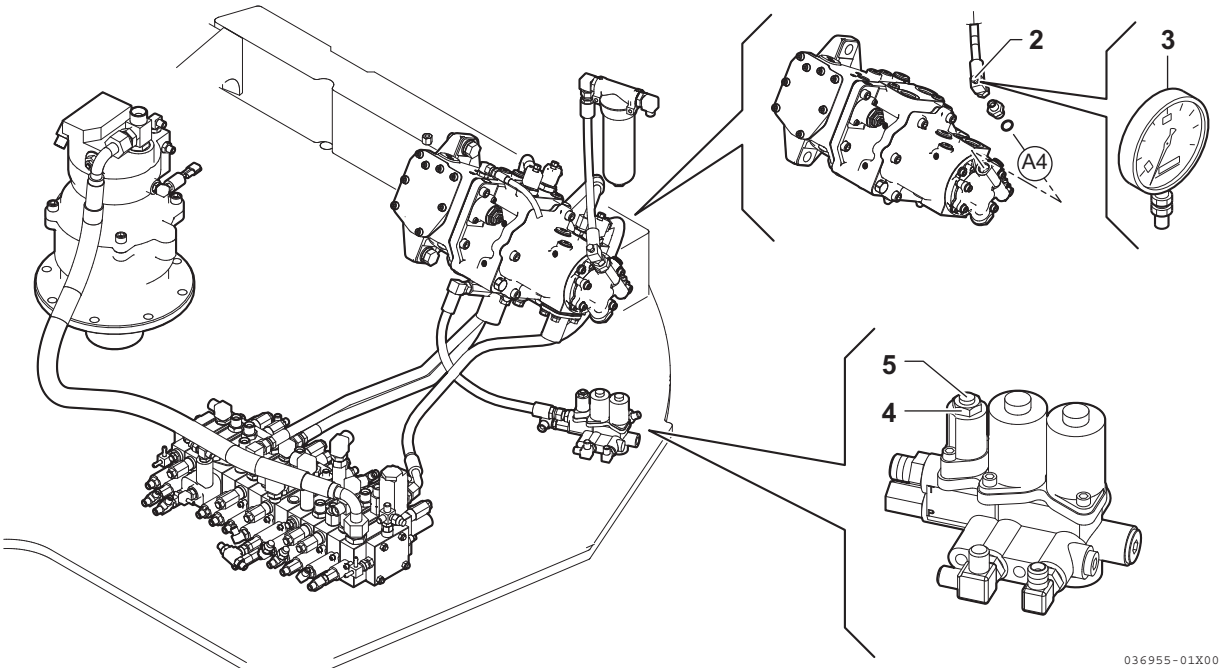


1) Conditions

(1) Engine: low idling speed
(2) Hydraulic oil temperature: 122 to 140 °F (50 to 60 °C)
(3) Pressure gauge capacity: 1422 PSI (9.8 MPa)
(4) Set pressure: 421 PSI (2.9 MPa)

2) Measuring Procedure

(1) Remove cover **1**.
(2) Remove plug R (PT)1/8 **2** and install pressure gauge **3**.
(3) Move the lock lever to the "Unlock" position, and read gauge **3**.
(4) Disengage the lock lever and read the pressure gauge.



3) Adjustment Procedure

(1) Loosen the lock nut **4**.
(2) Adjust the pressure with the adjust screw **5**.
(3) Tighten the lock nut **4** to fix the adjust screw **5**.

CHAPTER 4

ENGINE

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4. Engine

4-1 Safety

4-1-1 Safety Statements

Yanmar is concerned for your safety and your machine's condition. Safety statements are one of the primary ways to call your attention to the potential hazards associated with Yanmar TNV engine operation. Follow the precautions listed throughout the manual before operation, during operation and during periodic maintenance procedures for your safety, the safety of others and to protect the performance of your engine. Keep the labels from becoming dirty or torn and replace them if they are lost or damaged. Also, if you need to replace a part that has a label attached to it, make sure you order the new part and label at the same time.

This safety alert symbol appears with most safety statements. It means attention, become alert, your safety is involved! Please read and abide by the message that follows the safety alert symbol.

⚠ DANGER

DANGER indicates a hazardous situation which, if not avoided, *will* result in death or serious injury.

⚠ WARNING

WARNING indicates a hazardous situation which, if not avoided, *could* result in death or serious injury.

⚠ CAUTION

CAUTION indicates a hazardous situation which, if not avoided, *could* result in minor or moderate injury.

NOTICE

NOTICE indicates a situation which can cause damage to the machine, personal property and/or the environment or cause the equipment to operate improperly.

4-1-2 Safety Precautions

During Operation and Maintenance

⚠ DANGER

High Pressure Hazard!

- **This engine uses a high-pressure common rail system. For disassembly of the high pressure parts (e.g. the high-pressure pipe) in particular, be sure to wait approximately 10 to 15 minutes before performing disassembly.**
- **Do not loosen the high pressure pipe while the engine is running, even in low idle. This is dangerous because fuel under high pressure will blow out.**
- **Failure to comply will result in death or serious injury.**

⚠ DANGER

Scald Hazard!

- **Never remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.**
- **Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.**
- **Always check the level of the engine coolant by observing the reserve tank.**
- **Failure to comply will result in death or serious injury.**

⚠ DANGER

Explosion Hazard!

- **Keep the area around the battery well-ventilated. While the engine is running or the battery is charging, hydrogen gas is produced which can be easily ignited.**
- **Keep sparks, open flame and any other form of ignition away while the engine is running or battery is charging.**
- **Never check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.**
- **If the electrolyte is frozen, slowly warm the battery before you recharge it.**
- **Failure to comply will result in death or serious injury.**
- **ply will result in death or serious injury.**

⚠ DANGER

Crush Hazard!

- **When you need to transport an engine for repair, have a helper assist you to attach it to a hoist and load it on a truck.**
- **Never stand under a hoisted engine. If the hoist mechanism fails, the engine will fall on you, causing death or serious injury.**
- **Failure to comply will result in death or serious injury.**

⚠ DANGER

Fire and Explosion Hazard!

- **Diesel fuel is flammable and explosive under certain conditions.**

- **When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.**
- **Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.**
- **Wipe up any spills immediately.**
- **Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.**
- **Only use the key switch to start the engine.**
- **Never jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.**
- **If the unit has an electric fuel pump, when you prime the fuel system, turn the key switch to the ON position for 10 to 15 seconds to allow the electric fuel pump to prime the system.**
- **If the unit has a mechanical fuel pump, when you prime the fuel system, operate the fuel priming lever of the mechanical fuel pump several times until the fuel filter cup is filled with fuel.**
- **Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.**
- **Never refuel with the engine running.**
- **Keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.**
- **Never overfill the fuel tank.**
- **Fill the fuel tank. Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.**

⚠ DANGER (Continued)

- **Be sure to place the diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.**
- **Never place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.**
- **Before you operate the engine, check for fuel leaks. Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.**
- **Never remove the fuel cap with the engine running.**
- **Never use diesel fuel as a cleaning agent.**
- **Place an approved container under the air bleed port when you prime the fuel system. Never use a shop rag to catch the fuel. Wipe up any spills immediately. Always close the air bleed port after you complete priming the system.**
- **Wear eye protection. The fuel system is under pressure and fuel could spray out when you open the air bleed port.**
- **If the unit has an electric fuel pump, turn the key switch to the ON position for 10 to 15 seconds, or until the fuel coming out of the air bleed port is free of bubbles, to allow the electric fuel pump to prime the system.**
- **If the unit has a mechanical fuel pump, operate the fuel priming pump several times until the fuel coming out of the air bleed port is free of bubbles.**
- **Failure to comply will result in death or serious injury.**

⚠ WARNING

Sever Hazard!

- Keep hands and other body parts away from moving/rotating parts such as the cooling fan, flywheel or PTO shaft.
- Wear tight-fitting clothing and keep your hair short or tie it back while the engine is running.
- Remove all jewelry before you operate or service the machine.
- Never start the engine in gear. Sudden movement of the engine and/or machine could cause death or serious personal injury.
- Never operate the engine without the guards in place.
- Before you start the engine make sure that all bystanders are clear of the area.
- Keep children and pets away while the engine is operating.
- Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.
- Failure to comply could result in death or serious injury.

⚠ WARNING

Exhaust Hazard!

- Never operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.
- Never block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.
- Make sure that all connections are tightened to specifications after repair is made to the exhaust system.
- Failure to comply could result in death or serious injury.

⚠ WARNING

Alcohol and Drug Hazard!

- Never operate the engine while you are under the influence of alcohol or drugs.
- Never operate the engine when you are feeling ill.
- Failure to comply could result in death or serious injury.

⚠ WARNING

Exposure Hazard!

- **Wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.**
- **Never wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving/rotating parts such as the cooling fan, flywheel or PTO shaft.**
- **Always tie back long hair when you are working near moving/rotating parts such as a cooling fan, flywheel, or PTO shaft.**
- **Never operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the alert signals.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Burn Hazard!

- **If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.**
- **Always wear eye protection.**
- **Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.**
- **Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Burn Hazard!

- **Batteries contain sulfuric acid. Never allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. Always wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and/or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

High-Pressure Hazard!

- **Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.**
- **Never check for a fuel leak with your hands. Always use a piece of wood or cardboard. Have your authorized YANMAR industrial engine dealer or distributor repair the damage.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Shock Hazard!

- **Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.**
- **Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. Always keep the connectors and terminals clean.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Entanglement Hazard!

- **Stop the engine before you begin to service it.**
- **Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.**
- **If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Sudden Movement Hazard!

- **Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

To prevent possible eye injury, always wear safety glasses while servicing the engine.

⚠ WARNING

Fume/Burn Hazard!

- **Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Never apply over 40 psi (2.8 kgf/cm) to the waste gate actuator.

⚠ WARNING

- **Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.**
- **Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.**

⚠ WARNING

- **Never use the E-ECU for other purposes than intended or in other ways than specified by YANMAR. Doing so could result in the violation of emission control regulations and will void the product warranty.**
- **Improper use or misuse of the E-ECU may result in death or serious injury due to an abrupt and unexpected increase in engine speed.**

⚠ WARNING

- **Be sure to use the E-ECU in conjunction with the engines whose models or serial numbers are specified by YANMAR.**
  Other E-ECU/engine combinations than specified will void the engine warranty.
- **Improper use or misuse of the E-ECU may result in death or serious injury due to an abrupt and unexpected increase in engine speed.**

⚠ WARNING

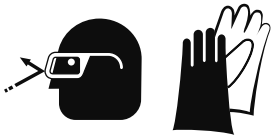
- **Replacing the fuel injector involves rewriting the injector trim data in the E-ECU.**
  Be sure to contact your local YANMAR dealer before replacing the fuel injector.
  Failure to rewrite the injector trim data before replacing the fuel injector will void the engine warranty.
- **Improper use or misuse of the E-ECU may result in death or serious injury due to an abrupt and unexpected increase in engine speed.**

⚠ WARNING

- **Replacing the E-ECU involves migrating the fuel injection data to the existing E-ECU to the new unit.**
  Be sure to contact your local YANMAR dealer before replacing the E-ECU.
  Failure to migrate the fuel injection data before replacing the E-ECU will void the engine warranty.
- **Improper use or misuse of the E-ECU may result in death or serious injury due to an abrupt and unexpected increase in engine speed.**

⚠ CAUTION

Coolant Hazard!



- **Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.**
- **Failure to comply may result in minor or moderate injury.**

⚠ CAUTION

Flying Object Hazard!

- **Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.**
- **Failure to comply may result in minor or moderate injury.**

⚠ CAUTION

Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.

⚠ CAUTION

Pinch Hazard!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

⚠ CAUTION

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.

NOTICE

- Only use diesel fuels recommended by Yanmar for the best engine performance, to prevent engine damage and to comply with EPA/ARB warranty requirements.
- Only use clean diesel fuel.
- Never remove the primary strainer (if equipped) from the fuel tank filler port. If removed, dirt and debris could get into the fuel system causing it to clog.

NOTICE

Never attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the machine and shorten its life. If adjustment is ever required, contact your authorized YANMAR industrial engine dealer or distributor.

NOTICE

If any problem is noted during the visual check, the necessary corrective action should be taken before you operate the engine.

NOTICE

Never hold the key in the START position for longer than 15 seconds or the starter motor will overheat.

NOTICE

If the engine start fails, wait 30 seconds before you start the engine again.

NOTICE

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than (30°) in any direction or if an engine runs for short periods of time (less than three minutes) at an angle greater than (35°) in any direction, engine oil may enter the combustion chamber causing excessive engine speed and white exhaust smoke. This may cause serious engine damage.

NOTICE

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

- Avoid operating in extremely dusty conditions.
- Avoid operating in the presence of chemical gases or fumes.
- Avoid operating in a corrosive atmosphere such as salt water spray.
- Never install the engine in a floodplain unless proper precautions are taken to avoid being subject to a flood.
- Never expose the engine to the rain.

NOTICE

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

- The standard range of ambient temperatures for the normal operation of YANMAR engines is from +5 °F (-15 °C) to +113 °F (+45 °C).
- If the ambient temperature exceeds +113 °F (+45 °C) the engine may overheat and cause the engine oil to break down.
- If the ambient temperature is below +5 °F (-15 °C) the engine will be hard to start and the engine oil may not flow easily.
- Contact your authorized YANMAR industrial engine dealer or distributor if the engine will be operated outside of this standard temperature range.

NOTICE

The illustrations and descriptions of optional equipment in this manual, such as the operator's console, are for a typical engine installation. Refer to the documentation supplied by the optional equipment manufacturer for specific operation and maintenance instructions.

NOTICE

If any indicator illuminates during engine operation, stop the engine immediately. Determine the cause and repair the problem before you continue to operate the engine.

NOTICE

- Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and/or shorten engine life.
- Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap/dipstick and the surrounding area before you remove the cap.
- Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.
- Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

NOTICE

- Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and/or shorten engine life.
- Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.
- Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

NOTICE

- Never overfill the engine with engine oil.
- Always keep the oil level between the upper and lower lines on the oil cap/dipstick.

NOTICE

For maximum engine life, YANMAR recommends that when shutting the engine down, you allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.

NOTICE

Never use an engine starting aid such as ether. Engine damage will result.

NOTICE

- Always be environmentally responsible.
- Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.
- Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.
- Failure to follow these procedures may seriously harm the environment.

NOTICE

Never engage the starter motor while the engine is running. This may damage the starter motor pinion and/or ring gear.

NOTICE

New engine break-in:

- On the initial engine start-up, allow the engine to idle for approximately 15 minutes while you check for proper engine oil pressure, diesel fuel leaks, engine oil leaks, coolant leaks, and for proper operation of the indicators and/or gauges.
- During the first hour of operation, vary the engine speed and the load on the engine. Short periods of maximum engine speed and load are desirable. Avoid prolonged operation at minimum or maximum engine speeds and loads for the next four to five hours.
- During the break-in period, carefully observe the engine oil pressure and engine temperature.
- During the break-in period, check the engine oil and coolant levels frequently.

NOTICE

- Never attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the fuel injection quantity control.
- Failure to comply may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may affect the warranty coverage of your engine.

NOTICE

Protect the air cleaner, turbocharger (if equipped) and electric components from damage when you use steam or high-pressure water to clean the engine.

NOTICE

Never use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19686 mmAq) or a wire brush to clean the radiator fins. Radiator fins damage easily.

NOTICE

The tightening torque in the *Standard Torque Chart (see General Service Information section)* should be applied only to the bolts with a "7" head. (JIS strength classification: 7T)

- Apply 60 % torque to bolts that are not listed.
- Apply 80 % torque when tightened to aluminum alloy.

NOTICE

If any indicator fails to illuminate when the key switch is in the ON position, see your authorized YANMAR industrial engine dealer or distributor for service before operating the engine.

NOTICE

Establish a periodic maintenance plan according to the engine application and make sure you perform the required periodic maintenance at the intervals indicated. Failure to follow these guidelines will impair the engine's safety and performance characteristics, shorten the engine's life and may affect the warranty coverage on your engine.

NOTICE

If the fuel filter/water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter/water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter/water separator 2 - 3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.

NOTICE

- When the engine is operated in dusty conditions, clean the air cleaner element more frequently.
- Never operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.

NOTICE

The maximum air intake restriction, in terms of differential pressure measurement, must not exceed 0.90 psi (6.23 kPa; 635 mmAq). Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

NOTICE

It is important to perform daily checks.

Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.

NOTICE

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

NOTICE

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test.

NOTICE

Do not short-circuit the charging system between alternator terminals IG and L. Damage to the alternator will result.

NOTICE

Do not connect a load between alternator terminals L and E. Damage to the alternator will result.

NOTICE

Do not remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.

NOTICE

Do not turn the battery switch OFF while the engine is operating. Damage to the alternator will result.

NOTICE

Do not operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

NOTICE

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.

NOTICE

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.

NOTICE

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

NOTICE

After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel supply pump to become misaligned.

NOTICE

Do not use a high-pressure wash directly on the alternator. Water will damage the alternator and result in inadequate charging.

NOTICE

Do not reverse the positive (+) and negative (-) ends of the battery cable. The alternator diode and stator coil will be damaged.

NOTICE

When the battery indicator goes out, it should not come on again. The battery indicator only comes on during operation if the alternator fails. However, if an LED is used in the battery indicator, the LED will shine faintly during normal operation.

NOTICE

Using a non-specified V-belt will cause inadequate charging and shorten the belt life. Use the specified belt.

NOTICE

Agricultural or other chemicals, especially those with a high sulfur content, can adhere to the IC regulator. This will corrode the conductor and result in battery over-charging (boiling) and charging malfunctions. Consult YANMAR before using the equipment in such an environment or the warranty is voided.

NOTICE

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated on the wiring diagram. The starter motor will malfunction or break down if the resistance is higher than the specified value.

NOTICE

The starter motor is water-proofed according to JIS D 0203, R2 which protects the motor from rain or general cleaning. Do not use high-pressure wash or submerse the starter motor in water.

NOTICE

Use a specialized battery charger to recharge a battery with a voltage of 8 volts or less. Booster starting a battery with a voltage of 8 volts or less will generate an abnormally high voltage and destroy electrical equipment.

NOTICE

Removing the battery cables or the battery while the engine is operating may cause damage to the current limiter depending on the electrical equipment being used. This situation could cause loss of control of output voltage. The continuous high voltage of 23 - 24 volts (for 5000 min^{-1} (rpm) dynamo) will damage the current limiter and other electrical equipment.

NOTICE

Reversing the battery cable connections at the battery or on the engine will destroy the SCR diode in the current limiter. This will cause the charging system to malfunction and may cause damage to the electrical harnesses.

NOTICE

Avoid damage to the turbocharger or the engine. Do not spray blower wash fluid or water too quickly.

Use short strokes from a spray bottle to inject blower wash fluid or water into the turbocharger.

Spraying too much wash fluid or water, or spraying too quickly will damage the turbocharger.

NOTICE

Do not allow any material to fall into the oil lines or the oil inlet and outlet ports of the turbocharger.

NOTICE

If the waste valve does not meet specifications, replace the turbocharger or have it repaired by a qualified repair facility.

NOTICE

- Never attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the diesel fuel injection quantity control.
- Modifications may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may void its warranty. Be sure to use Yanmar genuine replacement parts.

NOTICE

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

NOTICE

Each pressure adjusting shim removed or added changes the pressure threshold by approximately 275 psi (1.9 MPa, 19 kgf/cm^2). Adding adjusting shims increases the threshold pressure. Removing adjusting shims reduces the pressure threshold.

NOTICE

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.

NOTICE

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

NOTICE

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

NOTICE

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

NOTICE

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

NOTICE

Allow the engine to warm-up for at least five minutes and the idle speed of the engine to return to normal before engaging the transmission or any PTOs. Engaging the transmission or PTO at an elevated engine speed could result in an unexpected movement of the equipment.

NOTICE

Shut down the engine if the fault indicator comes on.

Continuing running the engine with the fault indicator being on may result in a serious malfunction of or damage to the engine, and will void the engine warranty.

NOTICE

Do not energize the starter for a period of longer than 15 seconds.

Take a pause of at least 30 seconds between energization of the starter.

Otherwise the starter could suffer damage.

NOTICE

- High-pressure washing not recommended.
- Avoid using high-pressure washing for electronic or electric devices installed in, on or around the engine, including the E-ECU, relays and harness couplers.

Otherwise such devices may suffer malfunction due to water ingress into them.

NOTICE

Always check the battery for proper charge.

Otherwise the electronically controlled engines may fail to start.

NOTICE

- Do not plug or unplug the E-ECU for a period of at least 6 seconds after power to the unit has been turned on or off.
- Do not touch connector pins of the E-ECU with bare hands. Doing so may result in corrosion of the connector pins and/or damage to the internal circuits of the E-ECU due to static electricity.
- Do not force a measuring probe into the female coupler. Doing so may cause contact failure of the connector pins, resulting in malfunction of the E-ECU.
- Take care to prevent water from entering the couplers when plugging or unplugging the connector. Water inside the couplers may cause corrosion, resulting in malfunction of the E-ECU.
- Avoid plugging/unplugging the connector more than approx. 10 times.
  Frequent plugging/unplugging of the connector may cause contact failure of the connector pins, resulting in malfunction of the E-ECU.
- Do not use the E-ECU that has ever suffered drop impact.

NOTICE

- Never permit anyone to operate the engine or driven machine without proper training.

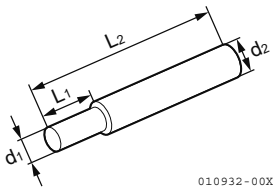
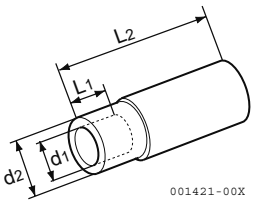
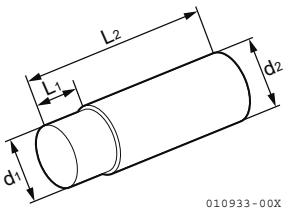
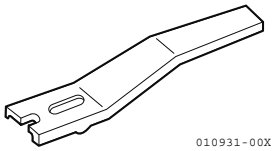
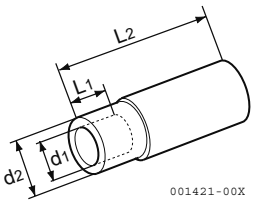
- Read and understand this Operation Manual before you operate or service the machine to ensure that you follow safe operating practices and maintenance procedures.
- Machine safety signs and labels are additional reminders for safe operating and maintenance techniques.
- See your authorized YANMAR industrial engine dealer or distributor for additional training.

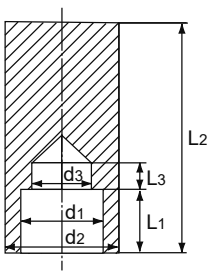
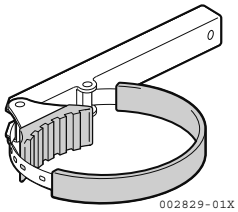
4-2 Engine

4-2-1 Before You Begin Servicing

Before performing any service procedures within this section, read the following safety information and review the *Safety Statements* section on page *4-1-1*.

4-2-2 Special Service Tools

<table>
<tr><th>No.</th><th>Tool name</th><th>Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>1</td><td>Valve guide tool (for removing valve guide)</td><td>
<table>
<tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr>
<tr><td>All models</td><td>0.787 in. (20 mm)</td><td>2.953 in. (75 mm)</td><td>0.295 in. (7.5 mm)</td><td>0.433 in. (11 mm)</td></tr>
</table>
Locally manufactured</td><td> 
</td></tr>
<tr><td>2</td><td>Valve guide tool (for installing valve guide)</td><td>
<table>
<tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr>
<tr><td>All models</td><td>0.591 in. (15 mm)</td><td>2.559 in. (65 mm)</td><td>0.551 in. (14 mm)</td><td>0.787 in. (20 mm)</td></tr>
</table>
Locally manufactured</td><td> 
</td></tr>
<tr><td>3</td><td>Connecting rod bushing replacer (for removal/ installation of connecting rod bushing)</td><td>
<table>
<tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr>
<tr><td>4TNV98C, 4TNV98CT</td><td>0.787 in. (20 mm)</td><td>3.937 in. (100 mm)</td><td>1.181 in. (30 mm)</td><td>1.299 in. (33 mm)</td></tr>
</table>
Locally manufactured</td><td> 
</td></tr>
<tr><td>4</td><td>Valve spring compressor (for removal/ installation of valve spring)</td><td>YANMAR Part No. 129100-92630</td><td> 
</td></tr>
<tr><td>5</td><td>Stem seal installer (for installing valve stem seal)</td><td>
<table>
<tr><th>Model</th><th>d1</th><th>d2</th><th>d3</th><th>L1</th><th>L2</th><th>L3</th></tr>
<tr><td>All models</td><td>0.638 in. (16.2 mm)</td><td>0.866 in. (22 mm)</td><td>0.531 in. (13.5 mm)</td><td>0.740 in. (18.8 mm)</td><td>2.559 in. (65 mm)</td><td>0.157 in. (4 mm)</td></tr>
</table>
Locally manufactured</td><td> 


</td></tr>
<tr><td>6</td><td>Filter wrench (for removal/ installation of engine oil filter)</td><td>Available locally</td><td> 
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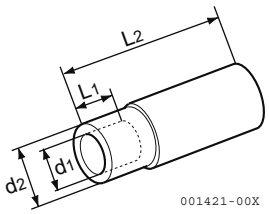
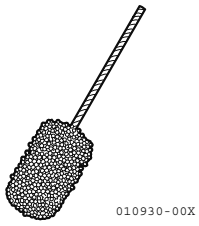
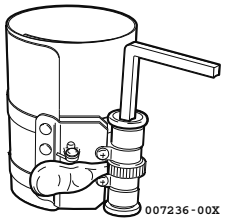
</table>

<table>
<tr><th>No.</th><th>Tool name</th><th colspan="2">Applicable model and tool size</th><th>Illustration</th></tr>
<tr><td>7</td><td>Camshaft bushing tool (for extracting camshaft bushing)</td><td colspan="2"><table><tr><th>Model</th><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr><tr><td>4TNV98C, 4TNV98CT</td><td>0.709 in. (18 mm)</td><td>2.756 in. (70 mm)</td><td>1.968 in. (50 mm)</td><td>2.087 in. (53 mm)</td></tr></table>Locally manufactured</td><td> 
</td></tr>
<tr><td>8</td><td>Flex-hone (for preparation of cylinder walls)</td><td colspan="2"><table><tr><th>Model</th><th>YANMAR Part No.</th><th>Cylinder bore</th></tr><tr><td>4TNV98C, 4TNV98CT</td><td>129400-92440</td><td>3.504 - 3.976 in. (89 - 101 mm)</td></tr></table></td><td> 
</td></tr>
<tr><td>9</td><td>Piston ring compressor (for installing piston)</td><td colspan="2">YANMAR Part No. 95550-002476
The piston insertion tool is applicable for
2.362 - 4.921 in. (60 - 125 mm) diameter pistons</td><td> 
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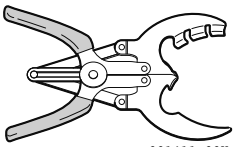
<tr><td>10</td><td>Piston ring expander (for removal/ installation of piston ring)</td><td colspan="2">Available locally</td><td> 
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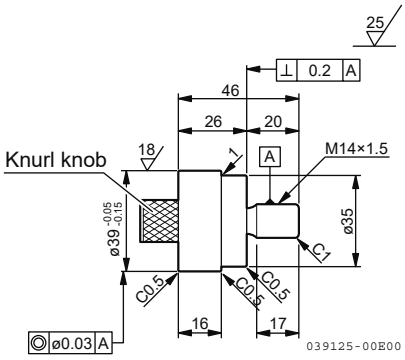
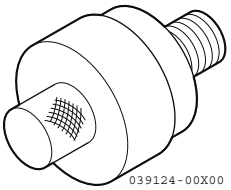
<tr><td>11</td><td>Crankshaft pulley installing tool (for taper pilot)</td><td>Locally manufactured (4TNV98C, 4TNV98CT series)</td><td> 
</td><td> 
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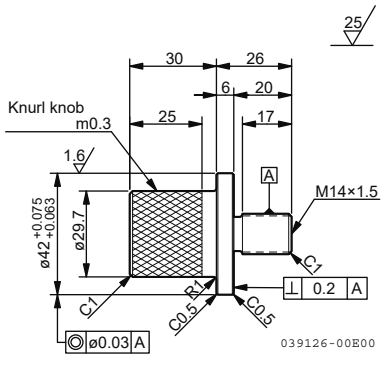
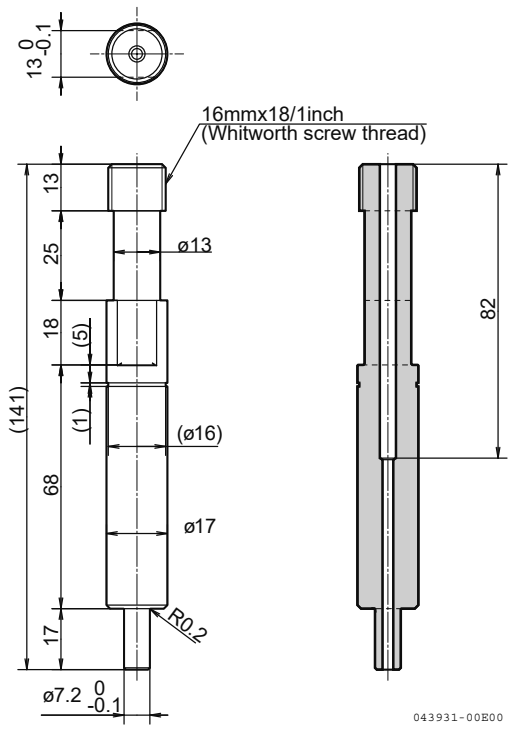
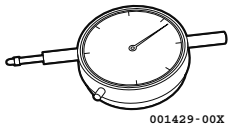
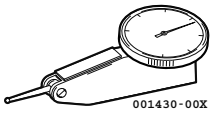
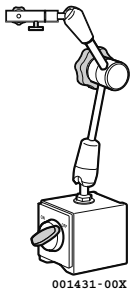
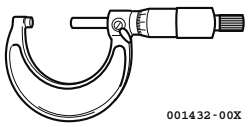
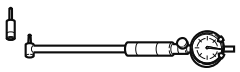
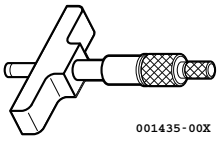
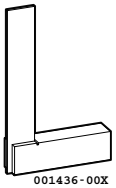
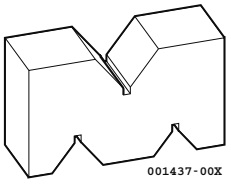
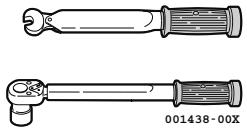
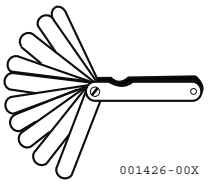
<tr><td>12</td><td>Crankshaft pulley installing tool (for straight pilot)</td><td>Locally manufactured (4TNV98C, 4TNV98CT series)</td><td> 
</td><td></td></tr>
</table>

No.	Tool name	Applicable model and tool size	Illustration
14	Compression gauge adapter (129A00-92950)		

4-2-3 Measuring Instruments

No.	Instrument name		Application	Illustration
1	Dial Indicator	Locally available	Measure shaft bend and end play.	 001429-00X
2	Test indicator	Locally available	Measurements of narrow or deep portions that cannot be measured by dial gauge.	 001430-00X
3	Magnetic stand	Locally available	For holding the dial gauge when measuring.	 001431-00X
4	Micrometer	Locally available	For measuring the outside diameters of crankshaft, pistons, piston pins, etc.	 001432-00X
5	Cylinder bore gauge	Locally available	For measuring the inside diameters of cylinder liners, bearing bores, etc.	 001433-00X
6	Calipers	Locally available	For measuring outside diameters, depth, thickness and width.	001434-00X
7	Depth micrometer	Locally available	For measuring of valve recession.	 001435-00X
8	Square	Locally available	For measuring valve spring inclination and straightness of parts.	 001436-00X
9	V-block	Locally available	For measuring shaft bend.	 001437-00X

No.	Instrument name		Application	Illustration
10	Torque wrench	Locally available	For tightening nuts and bolts to the specified torque.	
11	Feeler gauge	Locally available	For measuring piston ring gaps, piston ring clearance, and valve adjustment clearance.	

4-2-4 Cylinder Head

Cylinder Head Components

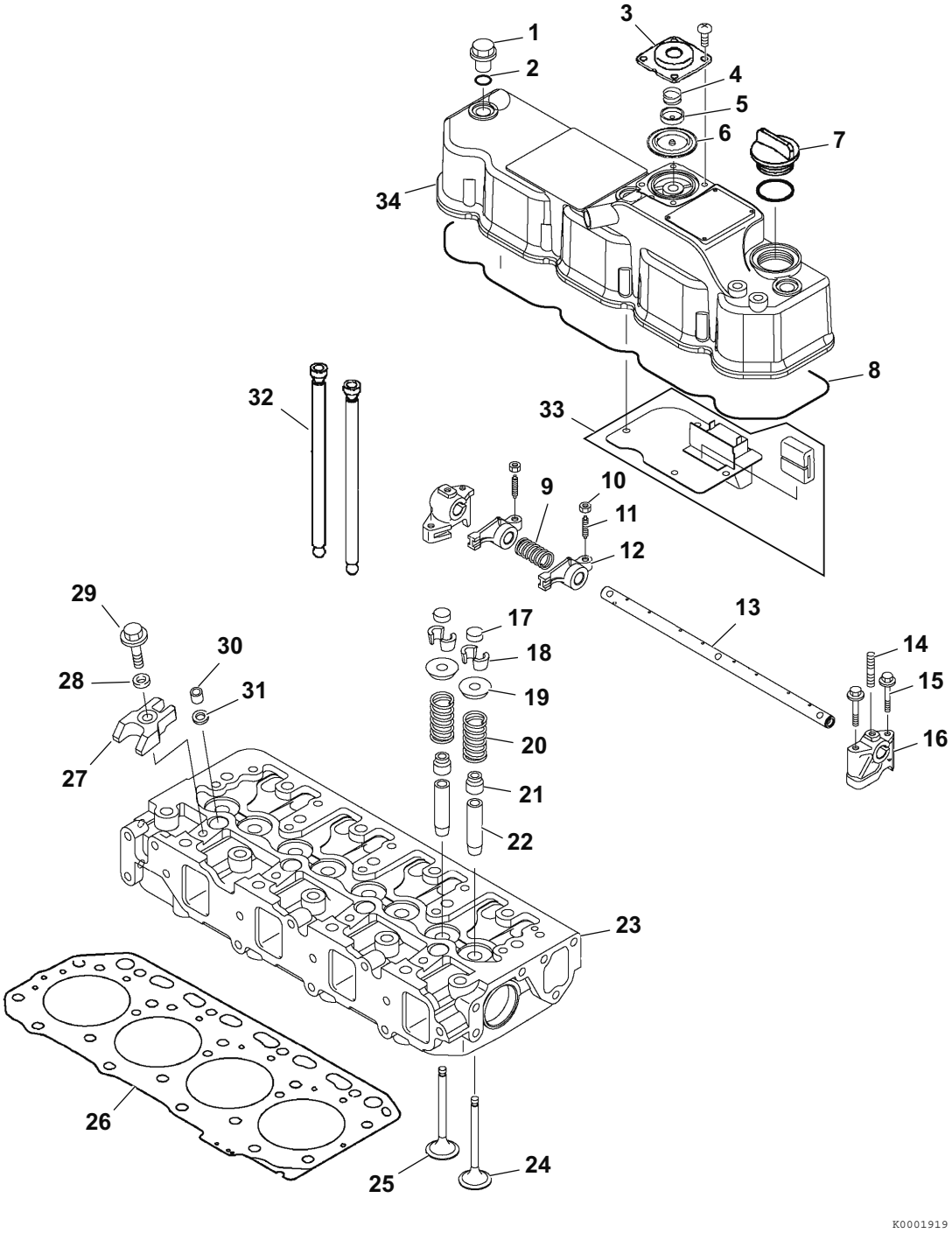
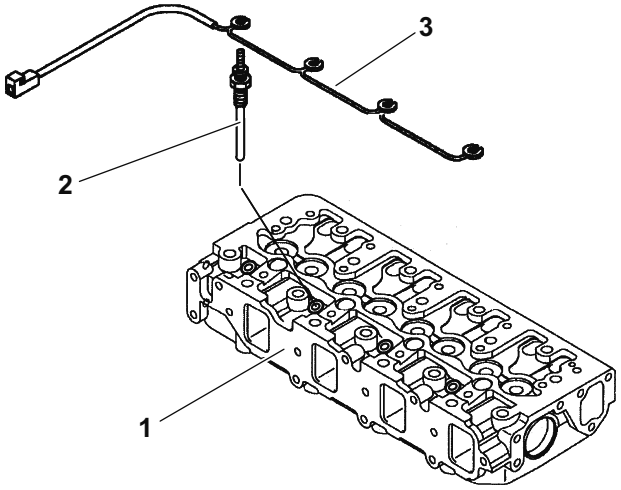


Figure 4-2-1

1 – Valve cover nut
2 – Valve cover nut O-ring
3 – Crankcase breather cover
4 – Diaphragm spring
5 – Diaphragm plate
6 – Crankcase breather diaphragm (non-turbocharged engines only)
7 – Oil fill cap
8 – Valve cover gasket
9 – Rocker arm shaft spring
10 – Valve adjusting screw lock nut
11 – Valve adjusting screw
12 – Rocker arm
13 – Rocker arm shaft
14 – Rocker arm shaft aligning stud
15 – Support bolt
16 – Rocker arm shaft support
17 – Valve cap
18 – Valve keepers
19 – Spring retainer
20 – Valve spring
21 – Valve stem seal
22 – Valve guide
23 – Cylinder head
24 – Intake valve
25 – Exhaust valve
26 – Cylinder head gasket
27 – Fuel injector retainer
28 – Washer
29 – Fuel injector retainer bolt
30 – Fuel injector nozzle protector
31 – Fuel injector nozzle seat
32 – Push rod
33 – Crankcase breather components
34 – Valve cover

Components of a Cylinder Head

Cylinder head with glow plugs applicable to all models.



1 – Cylinder head
2 – Glow plug
3 – Harness, glow plug

Figure 4-2-2

Disassembly of Cylinder Head

Prepare a clean, flat working surface on a workbench large enough to accommodate the cylinder head assembly. Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of the cylinder head.

1. Drain the coolant from the engine into a suitable container.

NOTICE

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

2. Disconnect the electrical wire from the glow plug, injector, intake throttle, EGR valve and sensors **(Figure 4-2-3, (1))**.

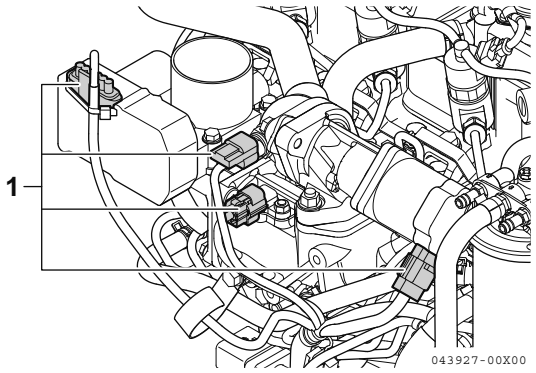


Figure 4-2-3

3. Disconnect the fuel pipes from the fuel filter, if the fuel filter is mounted on the intake manifold.
4. Remove the intake throttle, EGR valve and fuel filter on the intake manifold if required (discard the all gasket).
5. Remove the intake manifold bolts **(Figure 4-2-4, (1))**. Remove the intake manifold **(Figure 4-2-4, (2))**. Discard the intake manifold gasket **(Figure 4-2-4, (3))**.

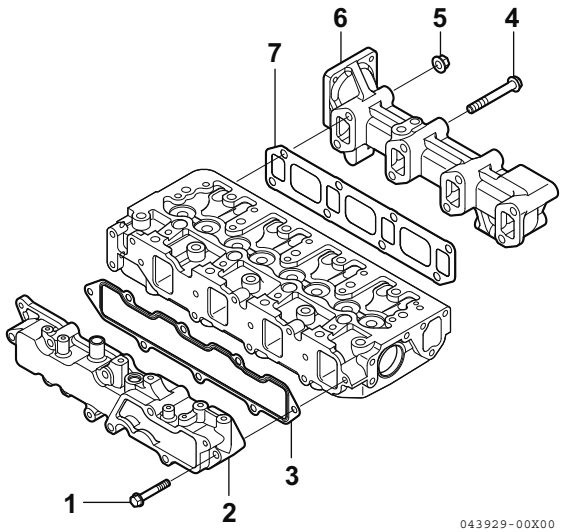


Figure 4-2-4

6. Disconnect the electrical wire from the diesel particulate filter if mounted.
7. Remove the diesel particulate filter from the engine (discard the all gasket).
8. Remove the exhaust manifold bolts **(Figure 4-2-4, (4))** and nuts **(Figure 4-2-4, (5))**. Remove the exhaust manifold **(Figure 4-2-4, (6))** and the exhaust manifold gasket **(Figure 4-2-4, (7))**.
9. Remove the coolant pump. *See Disassembly of Engine Coolant Pump on page 4-4-6.*
10. Remove the high-pressure lines and fuel injectors from the cylinder head. *See Removal of Injector on page 4-3-8.*

■ Removing the glow plugs

1. Remove the glow plug harness **(Figure 4-2-5, (2))** from each glow plug **(Figure 4-2-5, (1))**.
2. Remove the glow plug from the cylinder head.

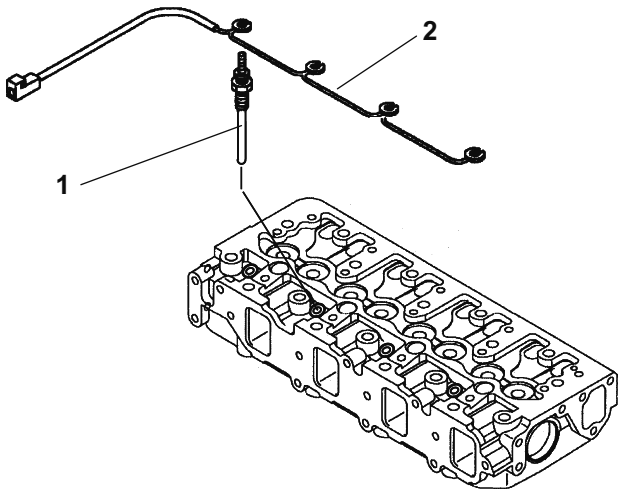


Figure 4-2-5

Note: Removing the cylinder head from the engine requires that the glow plugs be removed in advance.
Failure to remove the glow plugs in advance could result in damages to the glow plugs because their tips are protruding from the cylinder head combustion chamber surface.

■ Removal of valve cover

1. Disconnect the electrical wire from sensors on the valve cover.
2. Remove the valve cover nuts **(Figure 4-2-6, (1))**.
3. Remove the O-ring **(Figure 4-2-6, (2))** on each valve cover nut.

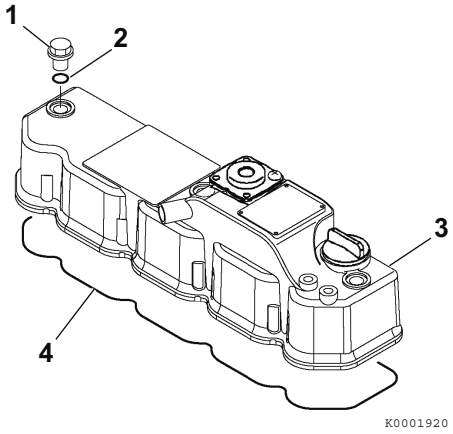


Figure 4-2-6

4. Remove the valve cover **(Figure 4-2-6, (3))** and the valve cover gasket **(Figure 4-2-6, (4))**.

■ Removal of rocker arm assembly

1. Remove the bolts **(Figure 4-2-7, (1))** that retain the rocker arm shaft supports.
2. Remove the rocker arm shaft assembly from the cylinder head.

   Note: Identify the push rods so they can be reinstalled in their original locations.

3. Remove the push rods and identify for installation.

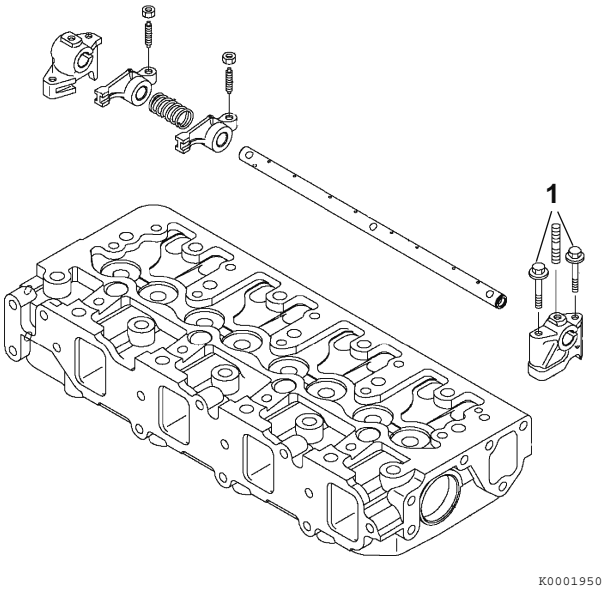


Figure 4-2-7

■ Disassembly of rocker arm assembly

1. Remove the rocker arm shaft alignment stud **(Figure 4-2-8, (4))** from support **(Figure 4-2-8, (5))**.

   Note: The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise. Twist and pull out on the rocker arm shaft to remove. Reverse this process when you reinstall the rocker arm shaft into the supports.

2. Slide the rocker arm shaft **(Figure 4-2-8, (3))** out of the rocker arm supports **(Figure 4-2-8, (5))**, springs **(Figure 4-2-8, (1)),** and rocker arms **(Figure 4-2-8, (2))**.

   Note: Mark the rocker arms so they can be reinstalled with the original matching valve and pushrod.

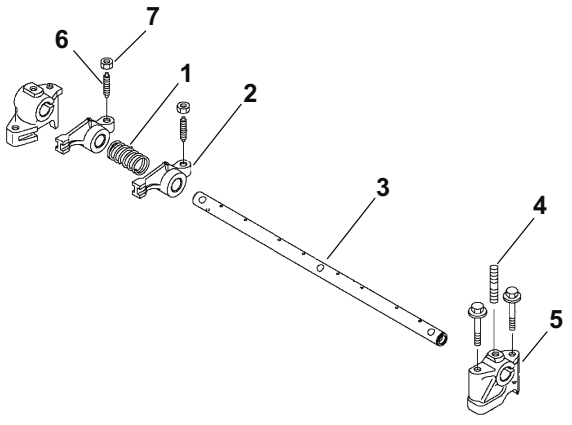
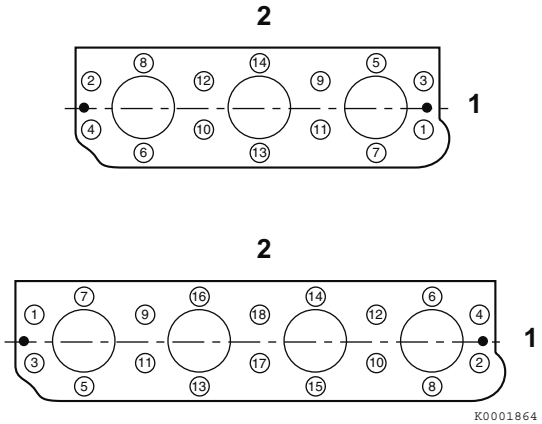


Figure 4-2-8

3. Remove the valve adjusting screw **(Figure 4-2-8, (6))** and the lock nut **(Figure 4-2-8, (7))** from the rocker arms.

■ Removal of cylinder head

1. Loosen the cylinder head bolts following the sequence shown in **(Figure 4-2-9)**.



1 – Cooling fan end
2 – Camshaft side

Figure 4-2-9

2. Remove the cylinder head bolts **(Figure 4-2-10, (1))**.
3. Lift the cylinder head away from the cylinder block. Discard the cylinder head gasket **(Figure 4-2-10, (2))**. Position the cylinder head on the work bench to prevent damage to the combustion surface.

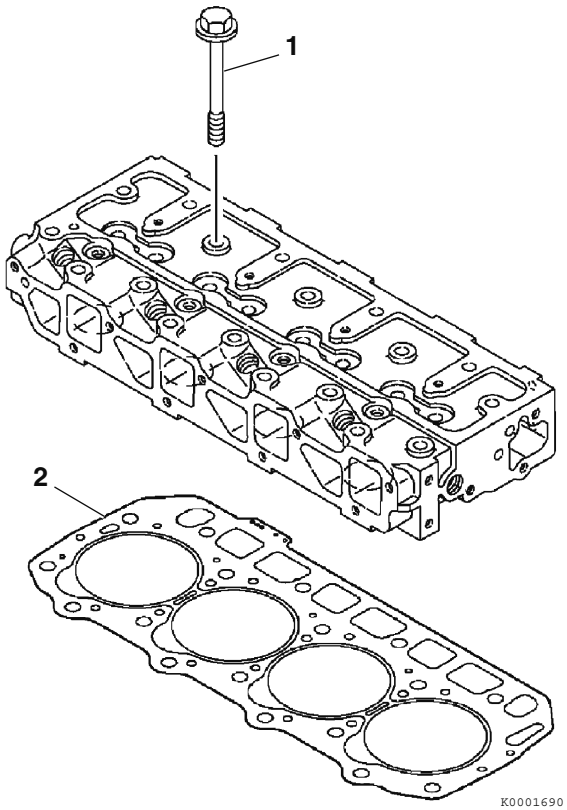


Figure 4-2-10

■ Removal of intake/exhaust valves

1. Place the cylinder head on the work bench with the combustion side down.
2. Remove the valve cap **(Figure 4-2-12, (1))** and keep with the valve it was installed on.
3. Using the valve spring compressor tool, compress one of the valve springs **(Figure 4-2-11)**.

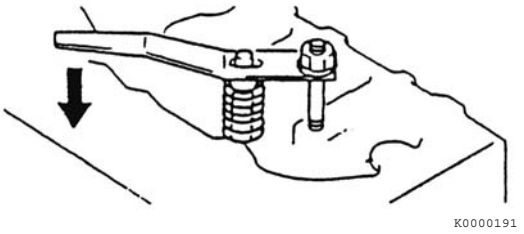


Figure 4-2-11

4. Remove the valve keepers **(Figure 4-2-12, (2))**.
5. Slowly release the tension on the valve spring.
6. Remove the spring retainer **(Figure 4-2-12, (3))** and valve spring **(Figure 4-2-12, (4))**.

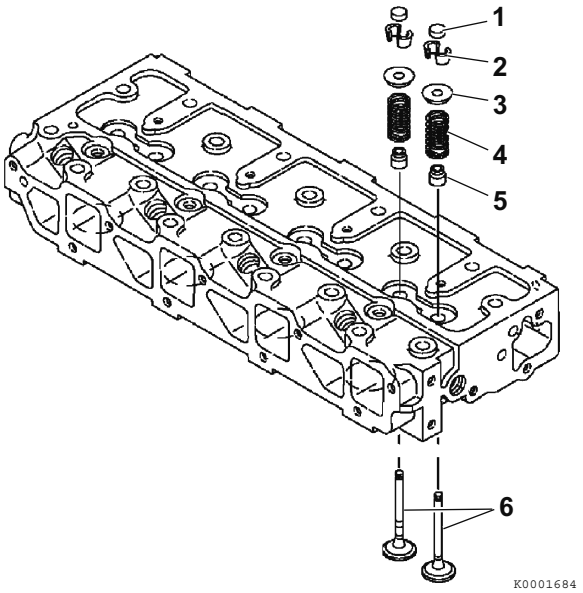


Figure 4-2-12

7. Repeat the procedure with all remaining valves.

   Note: If the valves are to be reused, identify them so they can be installed in their original location.

8. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves **(Figure 4-2-12, (6))** from the cylinder head.
9. Remove the valve stem seals **(Figure 4-2-12, (5))**.

■ Removal of valve guides

Note: Removal of the valve guides should be postponed until inspection and measurement procedures have been performed. See Inspection of valve guides on page 4-2-15.

1. If the valve guides were not within specifications, use a drift pin and hammer to drive the valve guides **(Figure 4-2-13, (1))** out of the cylinder head.

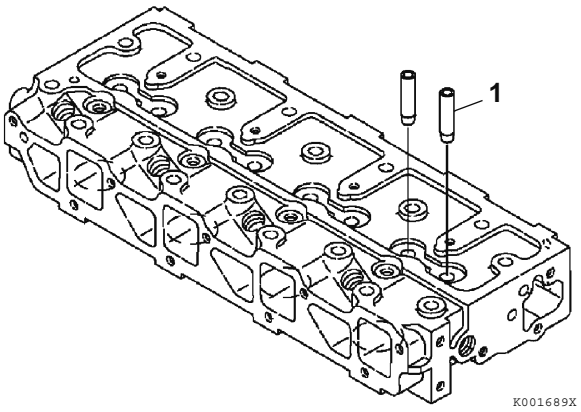


Figure 4-2-13

Cleaning of Cylinder Head Components

⚠ WARNING

Fume/Burn Hazard!

- **Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.**
- **Failure to comply could result in death or serious injury.**

Thoroughly clean all components using a non-metallic brush and an appropriate solvent. Each part must be free of carbon, metal filings and other debris.

Inspection of Cylinder Head Components

Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted or otherwise damaged. Discard any parts that do not meet its specified limit.

NOTICE

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

NOTICE

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

■ Inspection of push rods

Push rod bend

Determine if the bend of the push rods are within the specified limit.

1. Place the push rods on a flat inspection block or layout bed.
2. Roll the push rods until a gap can be observed between a portion of the push rod and the surface of the block or layout bed.
3. Use a feeler gauge to measure the gap **(Figure 4-2-14)**. *See "3-2 Engine Service Standard" section for the service limit.*

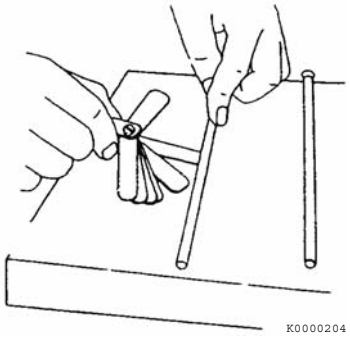


Figure 4-2-14

■ Inspection of rocker arm assembly

Rocker arm shaft hole diameter

Use a test indicator and micrometer to determine if the inside diameter of all the rocker arm support brackets and the rocker arms **(Figure 4-2-15)** are within the specified limits. *See "3-2 Engine Service Standard" section for the service limit.*

Inspect the contact areas **(Figure 4-2-15, (1))** for excessive wear or damage**.**

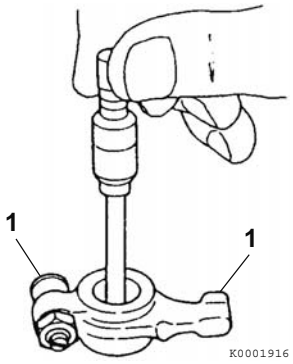


Figure 4-2-15

Rocker arm shaft outside diameter

Use a micrometer to measure the rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart **(Figure 4-2-16)**. *See "3-2 Engine Service Standard" section for the service limit.*

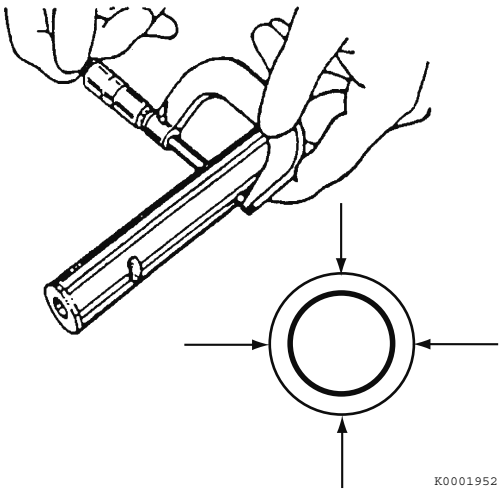


Figure 4-2-16

■ Inspection of valve guides

Visually inspect the valve guides for distortions, scoring or other damage.

Note: Measure the valve guides while they are installed in the cylinder head.

Use a telescoping gauge and micrometer to measure the inside diameter at each end of the valve guide. Measure in three places and 90° apart **(Figure 4-2-17)**. *See "3-2 Engine Service Standard" section for the service limit.* Replace valve guides if not within specification.

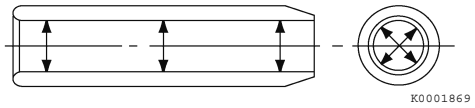


Figure 4-2-17

■ Inspection of cylinder head

Cylinder head distortion

Place the cylinder head flat and inverted (combustion side up) on the bench. Use a straight edge and a feeler gauge to measure cylinder head distortion **(Figure 4-2-18)**. Measure diagonally and along each side. *See "3-2 Engine Service Standard" section for the service limit.*

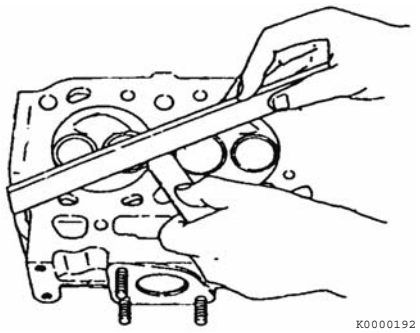


Figure 4-2-18

If distortion exceeds the service limit, resurface or replace the cylinder head. Remove only enough material to make the cylinder head flat, but do not remove more than 0.008 in. (0.20 mm).

■ Inspection of intake and exhaust valves

Visually inspect the intake and exhaust valves. Replace any valves that are obviously discolored, heavily pitted or otherwise damaged.

Valve stem diameter

Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end **(Figure 4-2-19, (1))**. *See "3-2 Engine Service Standard" section for the service limit.*

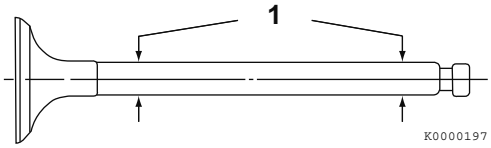


Figure 4-2-19

Valve stem bend

Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the block or bed. Use a feeler gauge to measure the gap **(Figure 4-2-20)**. *See "3-2 Engine Service Standard" section for the service limit.*

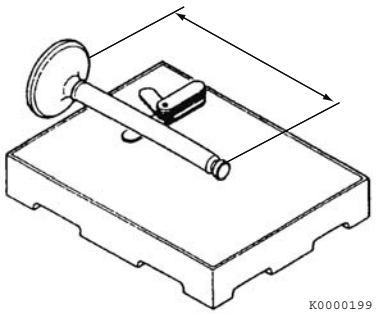


Figure 4-2-20

Valve recession

Note: The valve guides must be installed to perform this check.

Insert the valves into their original locations and press them down until they are fully seated. Use a depth micrometer **(Figure 4-2-21)** to measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve **(Figure 4-2-22)**. *See "3-2 Engine Service Standard" section for the service limit.*

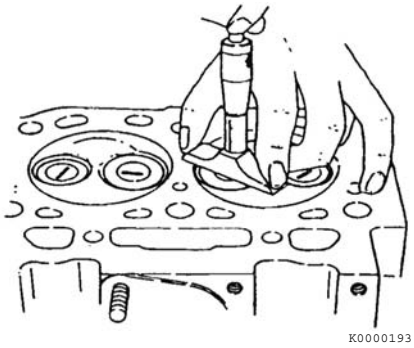


Figure 4-2-21

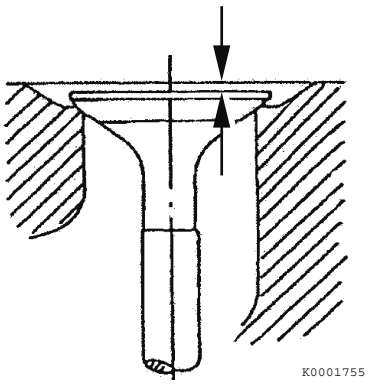


Figure 4-2-22

Valve face and valve seat

Always check the clearance between the valve and valve guide before grinding or lapping the valve seats. *See "3-2 Engine Service Standard" section for the service limit.* If the clearance exceeds the limit, replace the valve and/or valve guide to bring the clearance within the limit.

Roughness or burrs will cause poor seating of a valve. Visually inspect the seating surfaces of each valve and valve seat to determine if lapping or grinding is needed.

Visually inspect all valve faces and valve seats for pitting, distortion, cracking, or evidence of overheating. Usually the valves and the valve seats can be lapped or ground to return them to serviceable condition. Severely worn or damaged components will require replacement.

Coat the valve seat with a thin coat of bluing compound. Install the valve and rotate it to distribute bluing onto the valve face **(Figure 4-2-23, (1))** and even in width.

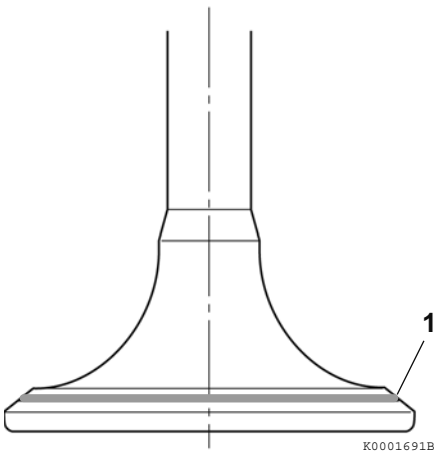


Figure 4-2-23

Also visually inspect the valve seat for even contact.

Light cutting can be performed by the use of a hand-operated cutter **(Figure 4-2-24, (3)).**

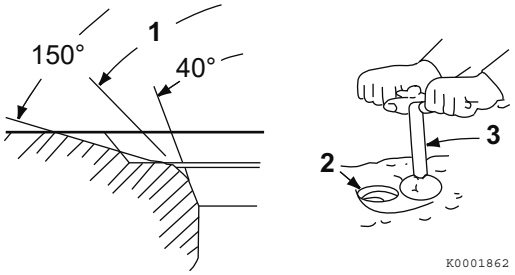


Figure 4-2-24

The valve seat diameter can be adjusted by top-grinding with a 150° stone to make the seat diameter smaller, and bottom-grinding using a 40° stone to make the seat diameter larger. Once the seat location has been corrected, grind and lap the seat angle **(Figure 4-2-24, (1))** to specification. *See "3-2 Engine Service Standard" section for the service limit.*

Grind the valve face and/or valve seat only enough to return them to serviceable condition. Grinding is needed if the valve and the valve seat do not contact correctly. Check the recession after grinding.

If the valve or seat require grinding, lap the valve after grinding. Lap the valve face to the valve seat using a mixture of valve lapping compound and engine oil.

Be sure to thoroughly wash all parts to remove all grinding powder or compound.

■ Inspection of valve springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.

Fractures

Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the valve spring.

Corrosion

Check for corrosion of the spring material caused by oxidation.

Squareness

Use a flat surface and a square to check each spring for squareness **(Figure 4-2-25)**. *See "3-2 Engine Service Standard" section for the service limit.*

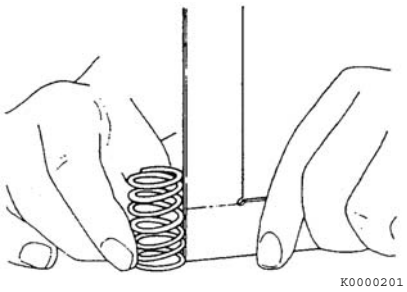


Figure 4-2-25

Free length

Use a caliper to measure the length of the spring **(Figure 4-2-26)**. *See "3-2 Engine Service Standard" section for the service limit.*

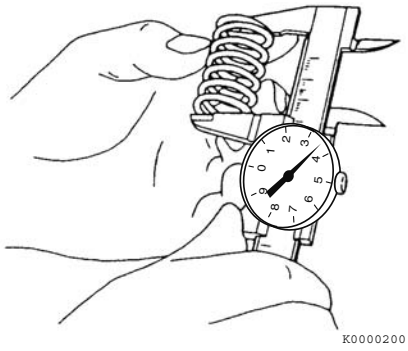


Figure 4-2-26

Reassembly of Cylinder Head

Use new gaskets, O-rings and seals for the reassembly of the cylinder head.

NOTICE

Liberally oil all components during reassembly to prevent premature wear or damage.

■ Reassembly of valve guides

1. The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in a freezer for at least twenty minutes This will cause the valve guides to contract, making it easier to install the valve guides into place.
2. Immediately after removing the valve guides from the freezer, insert the valve guides **(Figure 4-2-27, (1))** in their proper positions.

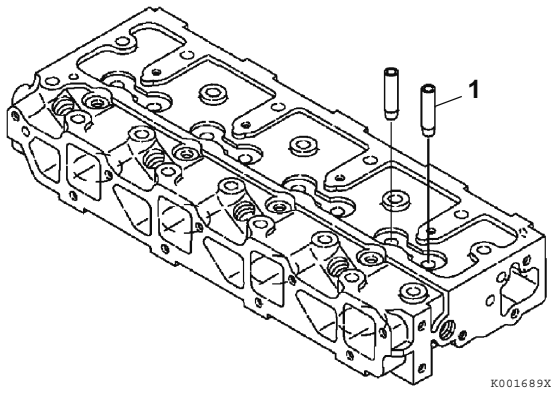


Figure 4-2-27

3. Finish installing the valve guides **(Figure 4-2-28, (1))** into the cylinder head to the proper height **(Figure 4-2-28, (3))** using the valve guide installation tool **(Figure 4-2-28, (2))**. *See "3-2 Engine Service Standard" section for the service limit.*

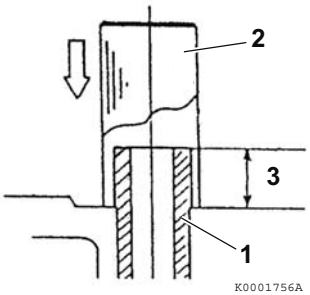


Figure 4-2-28

■ Reassembly of intake and exhaust valves

NOTICE

Always install new valve stem seals.

The exhaust valve stem seals are different than the intake valve stem seals and can be identified by either the paint marks on the outside of the seals or by the color of the seal spring. Ensure they are installed in the correct locations.

Engine model	Marking	
	Intake	Exhaust
All models	None	White (Paint on outside of seal)

1. Oil the lip of the valve stem seal **(Figure 4-2-29, (2)).** Using the valve stem seal installation tool **(Figure 4-2-29, (1))**, install a new valve stem seal on each of the valve guides **(Figure 4-2-29, (3))**.

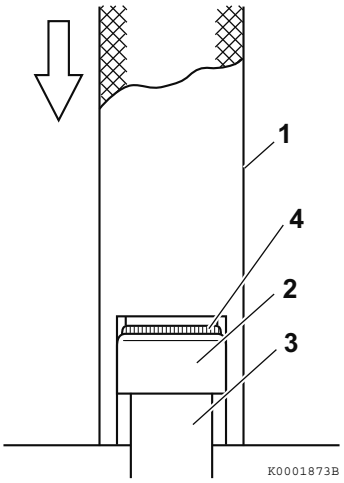


Figure 4-2-29

2. Measure the distance **(Figure 4-2-30, (1))** from the cylinder head to valve stem seal to ensure proper clearance **(Figure 4-2-30, (2))** between the guide and the seal. *See "3-2 Engine Service Standard" section for the service limit.*

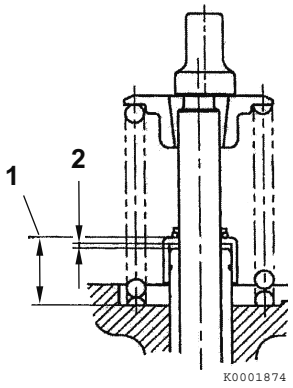


Figure 4-2-30

3. Place the cylinder head assembly on its exhaust port side.
4. Place all the valves **(Figure 4-2-31, (6))** in their proper location in the cylinder head.

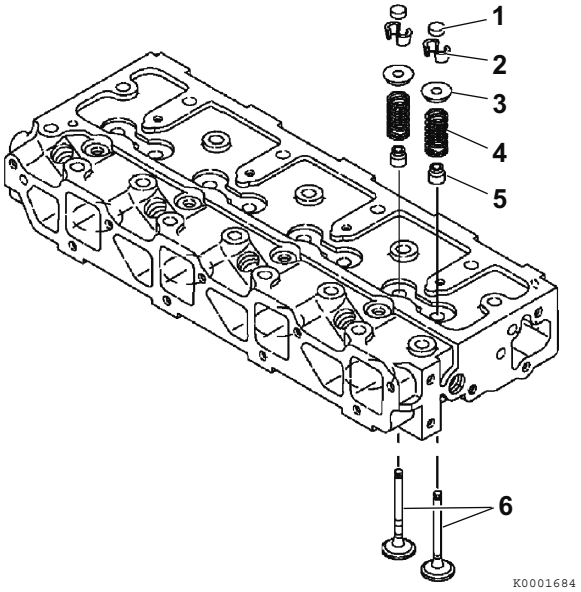


Figure 4-2-31

5. Place the cylinder head on the workbench with the combustion side down to install the valve springs. Install the valve spring **(Figure 4-2-31, (4))** and the spring retainer **(Figure 4-2-31, (5))**.
6. Using the valve spring compressor tool, compress the valve spring.
7. Insert the valve keepers **(Figure 4-2-31, (2))** and slowly release the tension on the valve spring. Install the valve cap **(Figure 4-2-31, (1)).** Repeat the steps on all the remaining valves.

■ Reassembly of cylinder head

1. Carefully clean both the combustion surface of the cylinder head and the top surface of the cylinder block. Then place a new cylinder head gasket **(Figure 4-2-32, (2))** on the cylinder block.
2. Position the cylinder head on the cylinder head gasket.

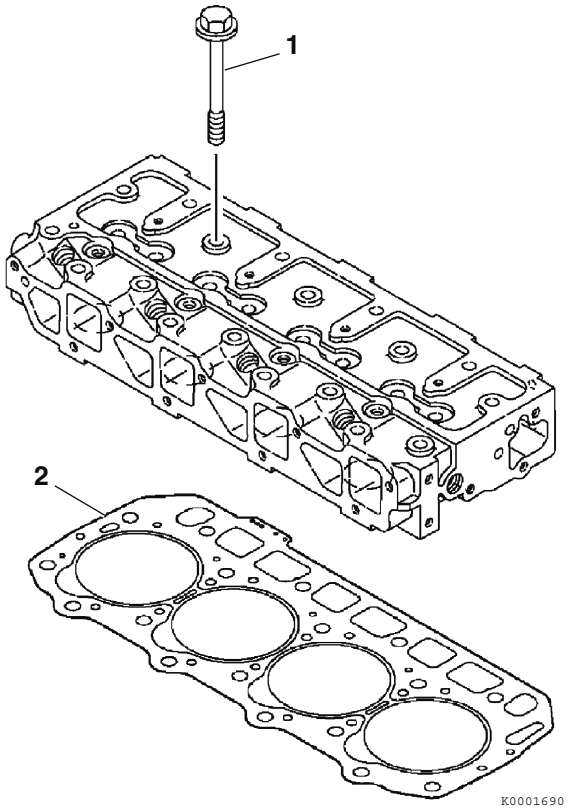
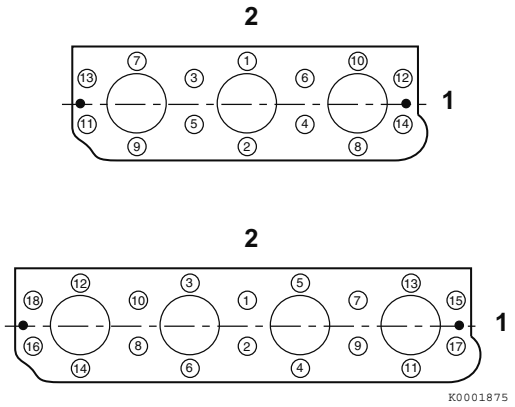


Figure 4-2-32

3. Lightly oil the threads of the cylinder head bolts **(Figure 4-2-32, (1))**. Tighten the bolts to the specified torque in two steps as shown in the chart below. Tighten in the sequence shown in **(Figure 4-2-33)**. *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

First step	1/2 of final torque
Second step	Final torque

4. Insert the push rods in their respective positions.



1 – Fan end
2 – Camshaft side

Figure 4-2-33

■ Reassembly of rocker arm reassembly

NOTICE

Ensure the lubrication holes **(Figure 4-2-34, (1))** in the rocker arm shaft are oriented correctly with respect to the rocker arms **(Figure 4-2-34, (2))**.

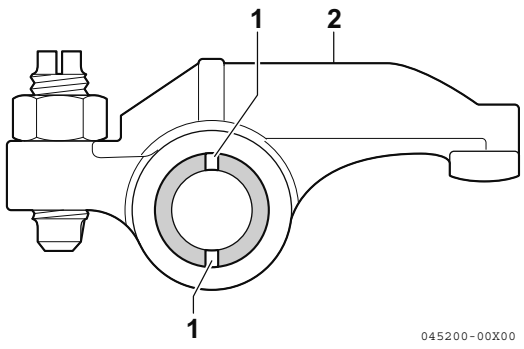


Figure 4-2-34

1. Lubricate the rocker arm shaft. Slide the rocker arm supports **(Figure 4-2-35, (5))**, springs **(Figure 4-2-35, (1))** and rocker arms **(Figure 4-2-35, (2))** onto the shaft.

   Note:

   - *The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise. Twist and push on the rocker arm shaft to reinstall.*
   - *To properly align the rocker arm shaft with the rocker arm shaft supports, first reinstall a rocker arm support **(Figure 4-2-35, (5))** having a hole for the shaft alignment stud **(Figure 4-2-35, (4))**. Align the hole in the rocker arm shaft and the hole in the rocker arm support. Reinstall the alignment stud.*

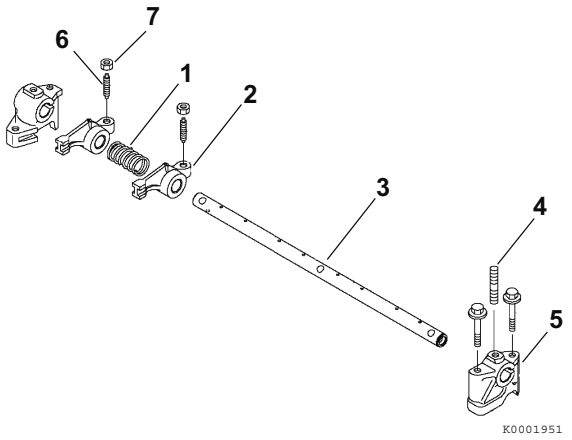


Figure 4-2-35

*Note: **Figure 4-2-35** shows components for one cylinder. Components for all remaining cylinders are assembled in the same order.*

2. Place the rocker arm shaft assembly onto the cylinder head.
3. If removed, reinstall the valve adjusting screws **(Figure 4-2-35, (6))** and the lock the nuts **(Figure 4-2-35, (7))**.
4. Align the push rods with their respective rocker arms.
5. Reinstall and tighten the rocker arm shaft retaining bolts (M10 × 65) to the specified torque.
6. Tighten the rocker arm shaft alignment studs.
7. Adjust the valve clearance. *See Measuring and Adjusting Valve Clearance on page 4-2-22.*

■ Reassembly of the valve cover

1. Lightly grease a new valve cover gasket **(Figure 4-2-36, (4))**. Place the gasket in the groove of the valve cover **(Figure 4-2-36, (3))**.
2. Place the valve cover on the cylinder head.
3. Be sure new O-rings **(Figure 4-2-36, (2))** are installed on the valve cover nuts. Reinstall and tighten the valve cover nuts **(Figure 4-2-36, (1))**.
4. Reinstall the exhaust manifold using a new gasket. Tighten the bolts to the specified torque.

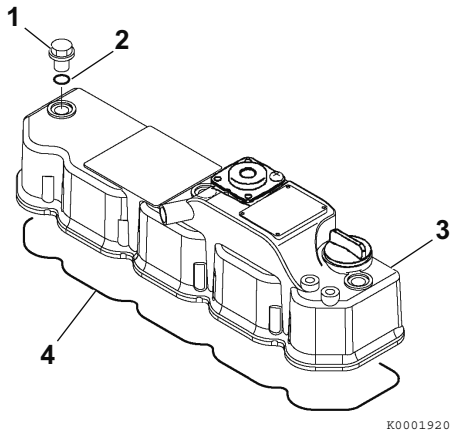


Figure 4-2-36

5. Reinstall the intake manifold using a new gasket. Tighten the bolts to the specified torque.
6. Install each glow plug **(Figure 4-2-37, (1))**, and tighten it with the specified torque. Install each electrical harness **(Figure 4-2-37, (1))**, and tighten it with the specified torque.

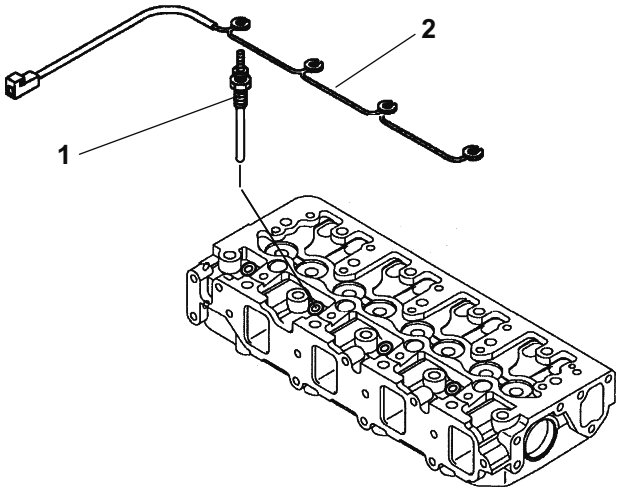


Figure 4-2-37

7. Reinstall the fuel injectors. *See Reassembly of injector on page 4-3-9.*
8. Reinstall the high pressure and the return fuel injection lines. *See Removal of Common Rail on page 4-3-6*
9. Reinstall the engine coolant pump. *See Reassembly of Engine Coolant Pump on page 4-4-8.*

⚠ CAUTION

For high-pressure pipe, use a new one. If you reuse it, the displacement of the working face may occur, causing the fuel leaks.

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10. Reinstall the coolant hoses on the cold start device on the fuel injection pump.
11. Reinstall the alternator. *See Installation of Alternator on page 4-7-11.*

4-2-5 Measuring and Adjusting Valve Clearance

Measure and adjust while the engine is cold.

Note:

- *The No. 1 piston position is on the flywheel end of the engine, opposite the radiator. The firing order is 1-3-2 for 3-cylinder engines and 1-3-4-2 for 4-cylinder engines.*
- *3-cylinder engines fire every 240° of crankshaft rotation.*
- *4-cylinder engines fire every 180° of crankshaft rotation.*
- *Valve clearance of both the intake and exhaust valves can be checked with the piston for that cylinder at top dead center (TDC) of the compression stroke. When a piston is at TDC of the compression stroke, both rocker arms will be loose and the cylinder TDC mark on the flywheel will be visible in the timing port of the flywheel housing.*
- *If there is no valve clearance, and the cylinder is at TDC of the compression stroke, extreme wear, or damage to the cylinder head or valves may be possible.*
- *If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top dead center after turning. Make adjustment for the remaining cylinders in the order of firing by turning the crankshaft each time.*
- *To decrease the number of rotations required to check all cylinders, other cylinders can also be checked as indicated in the chart below.*

Example: On a 3-cylinder engine, with the No. 1 piston at TDC on the compression stroke (both valves closed), the valves indicated on the top line of the chart can be adjusted without rotating the crankshaft. To adjust the remaining two valves, rotate the crankshaft until the No. 1 piston is at TDC on the exhaust stroke (exhaust valve only open).

■ 3-cylinder engines

Cylinder No.	**1**		**2**		**3**	
Valve	**Intake**	**Exhaust**	**Intake**	**Exhaust**	**Intake**	**Exhaust**
No. 1 cylinder at TDC compression	•	•	•			•
No. 1 cylinder at TDC exhaust				•	•	

■ 4-cylinder engines

Cylinder No.	**1**		**2**		**3**		**4**	
Valve	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
No. 1 cylinder at TDC compression	•	•	•			•		
No. 4 cylinder at TDC compression				•	•		•	•

1. Remove the valve cover. *See Removal of valve cover on page 4-2-10*.

   Note: If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top dead center after turning, and make adjustment for other cylinders in the order of firing by turning the crankshaft.

2. Rotate the crankshaft clockwise as seen from the coolant pump end, to bring No. 1 piston to TDC on the compression stroke while watching the rocker arm motion and timing grid on the flywheel. (Position where both the intake and exhaust valves are closed.)
3. Insert a feeler gauge **(Figure 4-2-38, (1))** between the rocker arm and valve cap, and record the measured valve clearance. (Use the data for estimating the wear.)

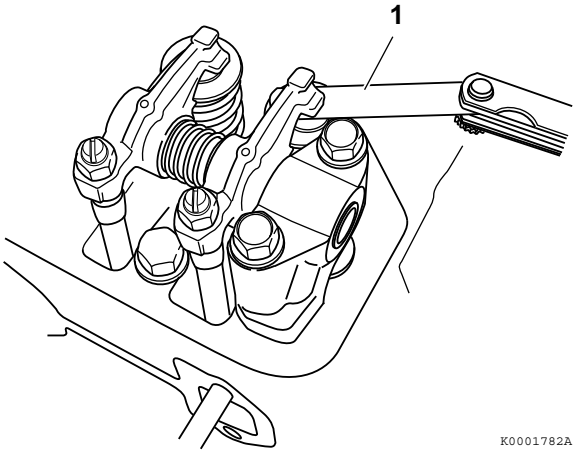

Figure 4-2-38

4. If adjustment is required, proceed to the next step.
5. Loosen the valve adjusting screw lock nut **(Figure 4-2-39, (1))** and valve adjusting screw **(Figure 4-2-39, (2))** on the rocker arm and check the valve for inclination of the valve cap, entrance of dirt, or wear.

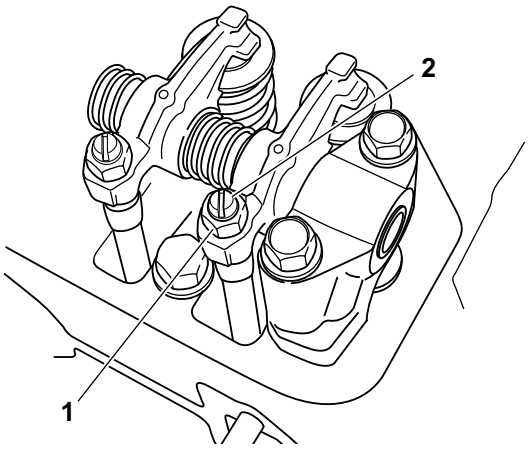

Figure 4-2-39

6. Insert a feeler gauge of the correct thickness **(Figure 4-2-40, (1))** *(See "3-2 Engine Service Standard" section for the service limit.)* between the rocker arm and valve cap. Turn the valve adjustment screw to adjust the valve clearance so there is a slight “drag” on the feeler gauge when sliding it between the rocker arm and the valve cap. Hold the adjusting screw while tightening the valve adjusting screw lock nut **(Figure 4-2-39, (1))**. Recheck the clearance.

   Note: There is a tendency for the clearance to decrease slightly when the lock nut is tightened. It is suggested that you make the initial clearance adjustment slightly on the “loose” side before tightening the lock nut.

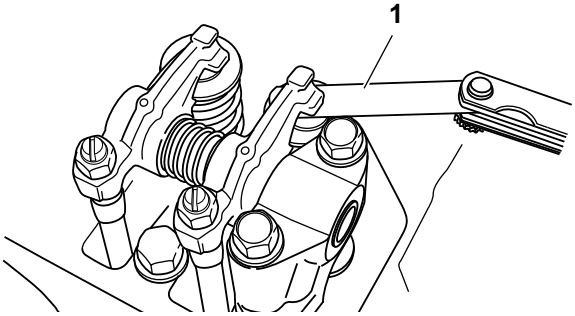

Figure 4-2-40

7. Apply oil to the contact surface between the adjusting screw and push rod.
8. Rotate the crankshaft. Measure and adjust the valves on the next cylinder. Continue until all the valves have been measured and adjusted.

4-2-6 Crankshaft and Camshaft Components

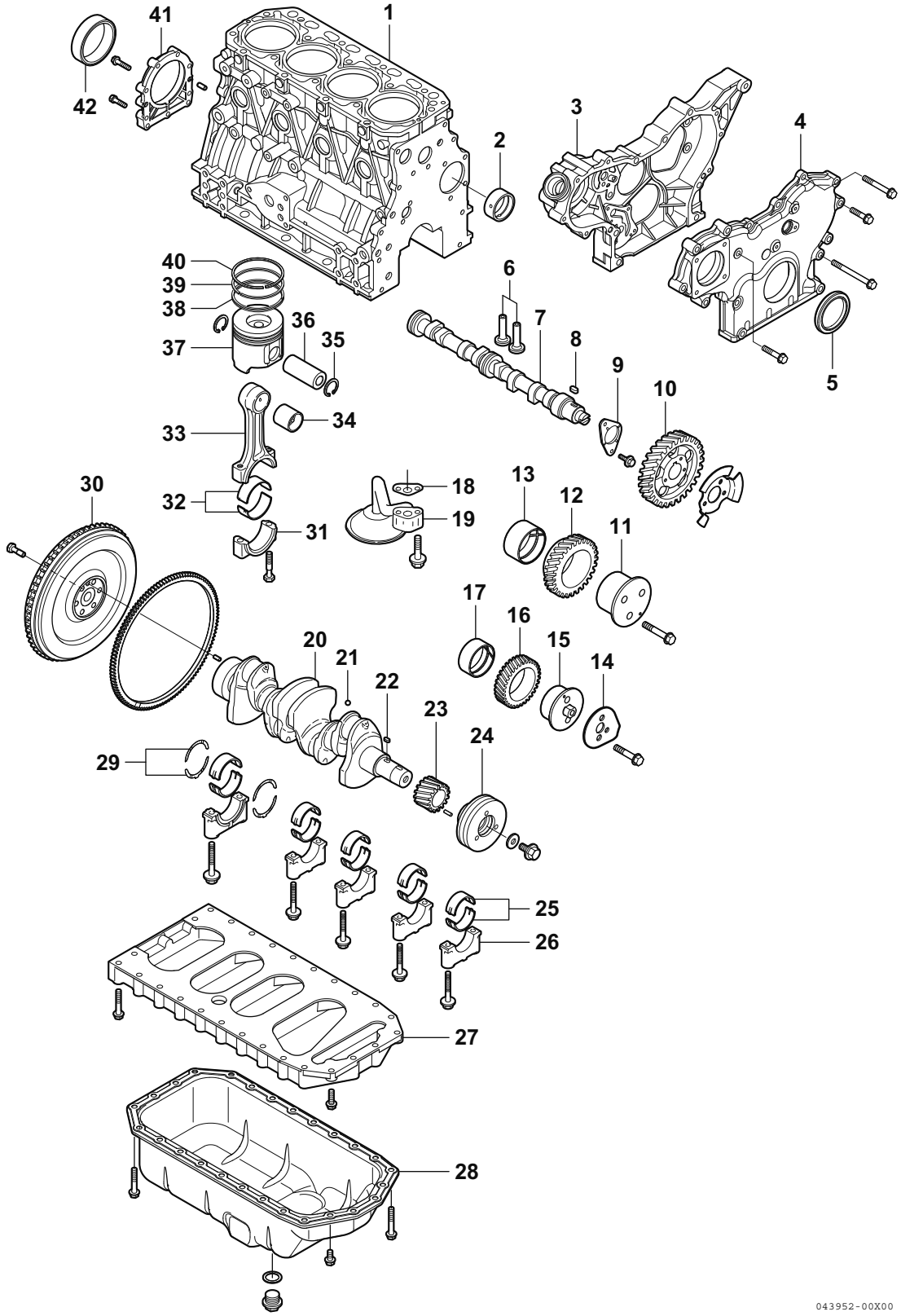

Figure 4-2-41

1 – Cylinder block
2 – Camshaft bushing
3 – Gear case
4 – Gear case cover
5 – Front crankshaft seal
6 – Tappets
7 – Camshaft
8 – Camshaft gear key
9 – Camshaft end plate
10 – Camshaft gear
11 – Idler gear shaft (A)
12 – Idler gear (A)
13 – Idler gear bushing (A)
14 – Idler gear plate (B)
15 – Idler gear shaft (B)
16 – Idler gear (B)
17 – Idler gear bushing (B)
18 – Oil pickup gasket
19 – Oil pickup
20 – Crankshaft
21 – ball
22 – Crankshaft gear key
23 – Crankshaft gear
24 – Crankshaft pulley
25 – Main bearing inserts
26 – Main bearing cap
27 – Oil pan spacer
28 – Oil pan
29 – Thrust bearings
30 – Flywheel
31 – Connecting rod cap
32 – Connecting rod bearing inserts
33 – Connecting rod
34 – Wrist pin bushing
35 – Circlip
36 – Wrist pin
37 – Piston
38 – Oil ring
39 – Second compression ring
40 – Top compression ring
41 – Crankshaft rear seal housing
42 – Crankshaft rear seal

Disassembly of Engine

Prepare a clean, flat working surface on a workbench large enough to accommodate the engine components. Discard all used gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of engine.

NOTICE

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

If the engine will be completely disassembled, the following preliminary steps should be performed:

1. Disconnect the battery cables at the battery. Always disconnect the negative (-) cable first.
2. Remove the throttle cable, electrical connections, intake and exhaust system connections, and fuel supply lines from the engine.
3. Remove the alternator. *See Removal of Alternator on page 4-7-7.*
4. Drain the engine coolant from the radiator and cylinder block. Remove the cooling system components from the engine.
5. Remove the engine from the machine. Mount the engine to a suitable engine repair stand having adequate weight capacity.

   NOTICE

   Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.

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6. Clean the engine by washing with solvent, air or steam cleaning. Carefully operate so as to prevent any foreign matter or fluids from entering the engine or any fuel system or electrical components remaining on the engine.
7. Drain the engine oil into a suitable container. Remove the oil filter.
8. Remove the cylinder head. *See Cylinder Head on page 4-2-7*.

9. Remove fuel supply pump if necessary. *See Removal of Supply Pump on page 4-3-10 if necessary.*
10. Remove the starter motor. *See Removal of Starter Motor on page 4-6-5.*

Disassembly of Camshaft and Timing Components

Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of the camshaft and timing components.

■ Removal of timing gear case cover

1. Remove the bolt and washer retaining the crankshaft pulley.

NOTICE

Use care not to damage the threads in the end of the crankshaft when removing the crankshaft pulley.

2. Remove the crankshaft pulley using a gear puller.
3. Remove the bolts that retain the gear case cover to the cylinder block and oil pan.
4. Remove the gear case cover **(Figure 4-2-42, (1))**.

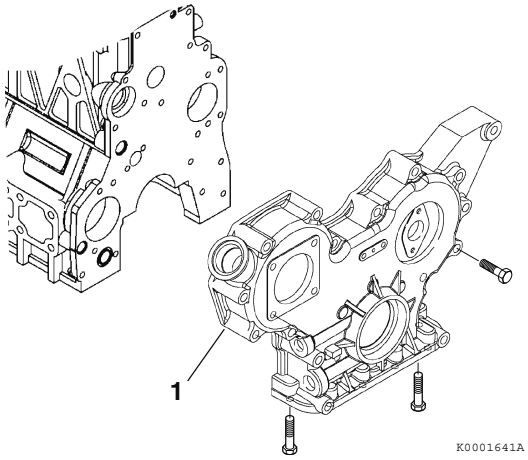


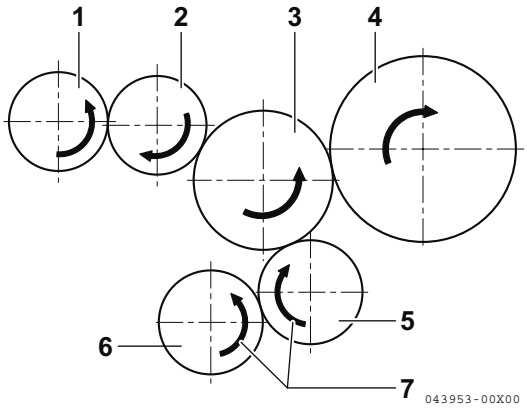
Figure 4-2-42

■ Checking timing gear backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of mating gears **(Figure 4-2-43)**. If not within specification, replace both mating gears. *See "3-2 Engine Service Standard" section for the service limit.*

Note: Do not allow the gear being checked to move axially as excess end play could cause a false reading.

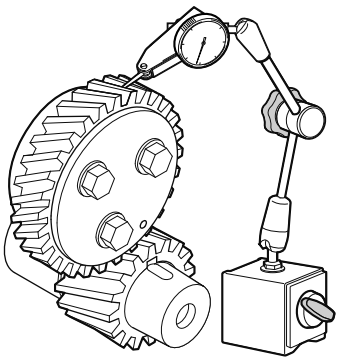


1 – Supply pump gear
2 – Idler gear (B)
3 – Idler gear (A)
4 – Camshaft gear
5 – Crankshaft gear
6 – Lubricating oil pump gear
7 – Direction of rotation

Figure 4-2-43

■ Measuring idler gear-to-crankshaft gear backlash

1. Install a dial indicator as shown in **Figure 4-2-44**.



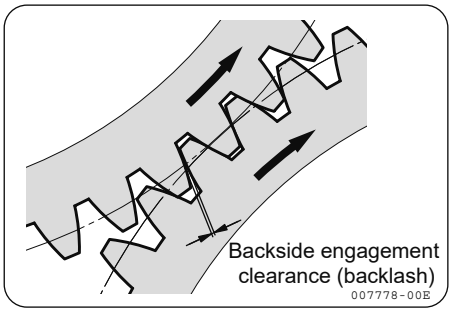


Figure 4-2-44

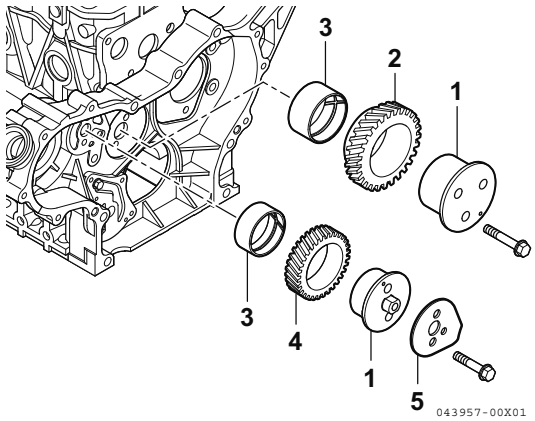
2. Rotate the idler gear back and forth to check the idler gear-to-crankshaft gear backlash. The total indicator reading is the backlash. Record the measurement.

■ Measuring idler gear-to-camshaft gear backlash

1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.
2. Install the dial indicator to read the camshaft gear backlash. Rotate the camshaft drive gear against the idler gear to measure the backlash. Record the measurement.
3. Check the idler gear-to-fuel injection pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

■ Removal of timing gears

1. Remove the bolts from the idler gear shaft **(Figure 4-2-45, (1))**. Remove the idler gear shaft, idler gear **(Figure 4-2-45, (2))** and bushing **(Figure 4-2-45, (3)).**



1 – Idler gear shaft
2 – Idler gear (B)
3 – Idler gear bushing
4 – Idler gear (A)
5 – Plate, idle shaft

Figure 4-2-45

2. Do not remove the crankshaft gear unless it is damaged and requires replacement. If the gear must be removed, remove it using a gear puller.
3. Removal of the camshaft gear requires the camshaft be removed and placed in a press. Do not remove the camshaft gear unless it or the camshaft is damaged and requires replacement. *See Removal of camshaft on page 4-2-28.*
4. Remove the supply pump drive gear using a gear puller.

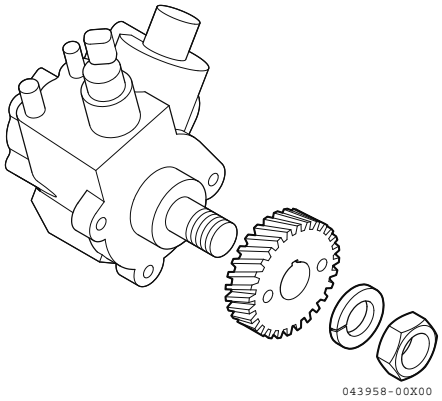


Figure 4-2-46

■ Removal of oil pan

1. Invert the engine (oil pan up) on the engine stand.
2. Remove the oil pan **(Figure 4-2-47, (1))**.

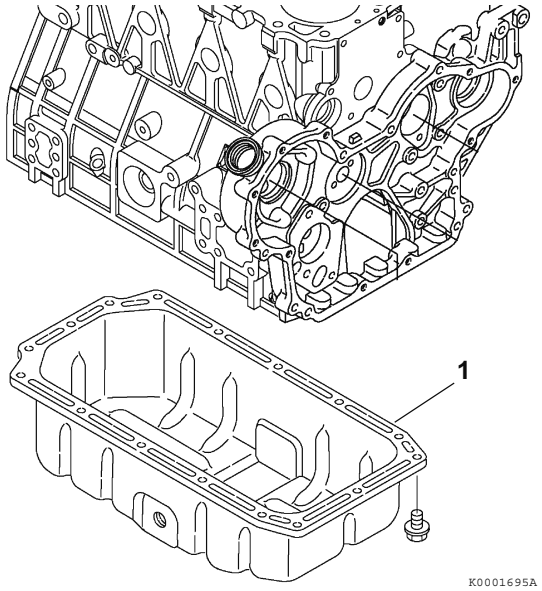


Figure 4-2-47

3. Remove the oil pickup tube **(Figure 4-2-48, (1))** and O-ring **(Figure 4-2-48, (2))**.

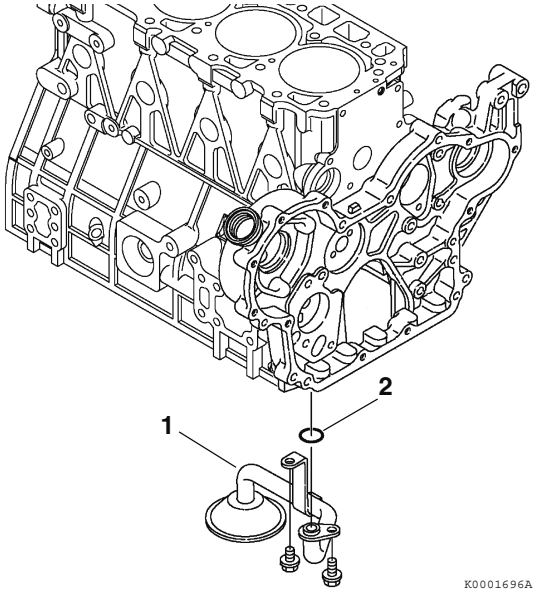


Figure 4-2-48

■ Removal of camshaft

1. Before removing the camshaft, check the camshaft end play.
   - **Method A:** Install a dial indicator **(Figure 4-2-49, (1))** on the cylinder block. Move the camshaft **(Figure 4-2-49, (2))** back and forth to measure the end play. Record the measurement. *See "3-2 Engine Service Standard" section for the service limit.*

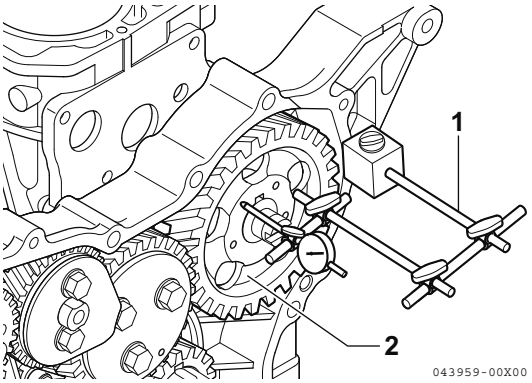


Figure 4-2-49

   - **Method B:** Use a feeler gauge to measure the clearance between the thrust plate **(Figure 4-2-50, (1))** and front camshaft bearing **(Figure 4-2-50, (2))**. *See "3-2 Engine Service Standard" section for the service limit.*

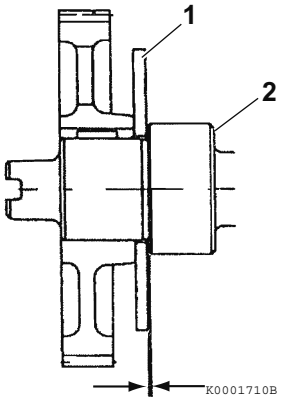


Figure 4-2-50

2. Remove the two bolts **(Figure 4-2-51, (3))** retaining the camshaft thrust plate **(Figure 4-2-51, (1))**.

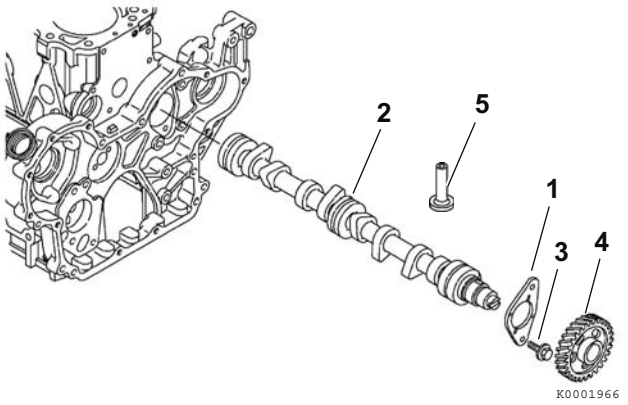


Figure 4-2-51

3. Rotate the engine in the engine stand so that gravity causes the tappets **(Figure 4-2-51, (5))** to drop away from the camshaft lobes.

   Note: Rotate the camshaft at least two turns to "bump" any sticking tappets away from the camshaft.

4. Slowly pull the camshaft **(Figure 4-2-51, (2))** assembly out of the engine being careful not to damage the front camshaft bushing.

   Note:

   - *If the engine is not installed on an engine repair fixture, stand the engine upright on the flywheel end mounting flange. Rotate the camshaft at least two turns to bump the tappets out of the way to prevent the tappets from interfering with the removal of the camshaft.*
   - *The tappets are "mushroom" shaped and must be removed from inside the engine crankcase.*

5. Remove the tappets. Mark the tappets so they can be reinstalled in the same location.
6. Remove the camshaft drive gear **(Figure 4-2-51, (4))** only if the gear or camshaft require replacement. Use a knife-edge puller and a press to remove the gear. The gear is a shrink-fit and will need to be heated to 356 - 392 °F (180 - 200 °C) to remove.

■ Removal of gear case or front plate

Note: The camshaft must be removed before the gear case can be removed. See Inspection of camshaft on page 4-2-38.

1. Remove the oil pump.

   Note: It is not necessary to remove the fuel supply pump from the gear case to remove the gear case. If the fuel supply pump does not need to be repaired, leaving it mounted to the timing gear case will eliminate the need to re-time it during assembly. See Removal of Supply Pump on page 4-3-10.

2. Remove the bolts **(Figure 4-2-52, (4))**.
3. Remove the gear case **(Figure 4-2-52, (1))** from the cylinder block. Thoroughly clean all old sealant from the mating surfaces.
4. Inspect and measure the camshaft bushing. *See "3-2 Engine Service Standard" section for the service limit.* If damaged or worn beyond service limits, remove the camshaft bushing **(Figure 4-2-52, (3))**.
5. **4TNV98C, 4TNV98CT:** Remove two O-rings **(Figure 4-2-52, (2))**.

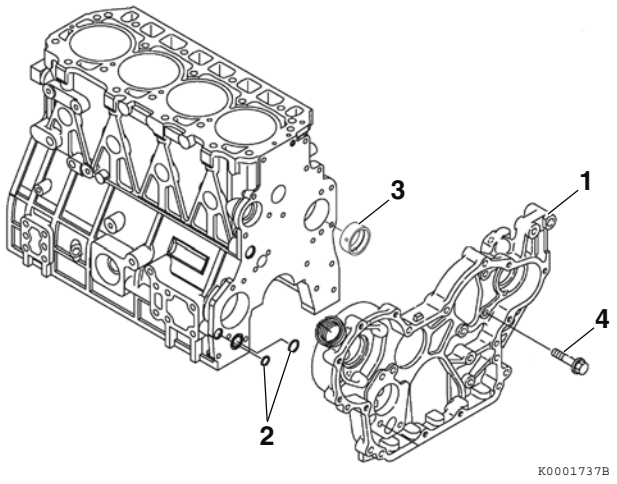


Figure 4-2-52

Disassembly of Crankshaft and Piston Components

■ Removal of pistons

NOTICE

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.

NOTICE

Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

Note: Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Using a feeler gauge, measure the connecting rod side clearance as shown **(Figure 4-2-53)**. *See "3-2 Engine Service Standard" section for the service limit.*
   If the measurement is out of specification, replace the crankshaft, connecting rod, or both.

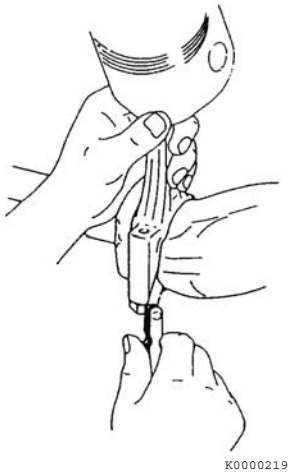


Figure 4-2-53

2. Measure bearing oil clearance prior to removing the pistons and connecting rods to determine extent of wear. Record the measurements.

NOTICE

Mark the connecting rod caps and connecting rods so the caps and connecting rods stay together.

1- Remove the bearing cap. Do not remove the bearing inserts at this time.

2- Wipe oil from the bearing insert and crankshaft journal surfaces.

3- Place a piece of PLASTIGAGE® **(Figure 4-2-54, (1))** along the full width of the bearing insert.

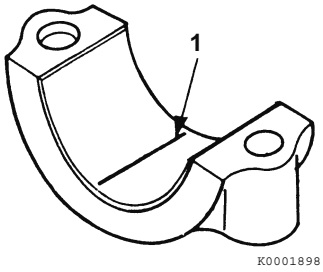


Figure 4-2-54

NOTICE

Do not rotate the crankshaft when using PLASTIGAGE. A false reading may result.

4- Reinstall bearing cap and tighten to specification. *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

5- Remove bearing cap.

6- Compare the width of the flattened PLASTIGAGE to the graduation marks on the package **(Figure 4-2-55, (1))**. The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance.

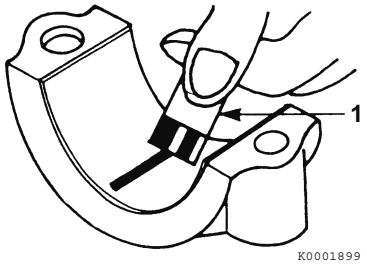


Figure 4-2-55

7- Repeat with remaining connecting rods.

NOTICE

Do not allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

---

3. Use a wooden dowel against the connecting rod and tap the piston/connecting rod assembly out of the cylinder.
4. Mark the cylinder number on the piston and connecting rod.
5. Remove the bearing inserts **(Figure 4-2-56, (2))**.
6. Remove the compression rings **(Figure 4-2-56, (3))** from the piston using a piston ring expander.
7. Remove the oil ring **(Figure 4-2-56, (4))** from the piston using a piston ring expander.

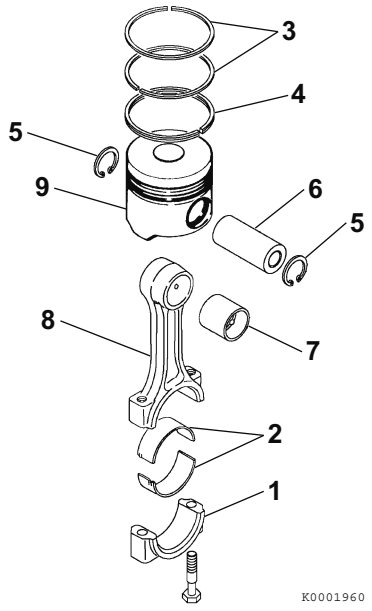


Figure 4-2-56

8. Remove the circlips **(Figure 4-2-56, (5))** from the wrist pin.
9. Remove the wrist pin **(Figure 4-2-56, (6))** and connecting rod **(Figure 4-2-56, (8))** from the piston **(Figure 4-2-56, (9))**.
10. Repeat the steps until all pistons are removed and dissembled.

■ Removal of crankshaft

1. Remove the flywheel **(Figure 4-2-57, (1))** from the crankshaft.
2. Remove the bolts from the rear oil seal assembly **(Figure 4-2-57, (2-3))**. Remove the assembly from the engine.

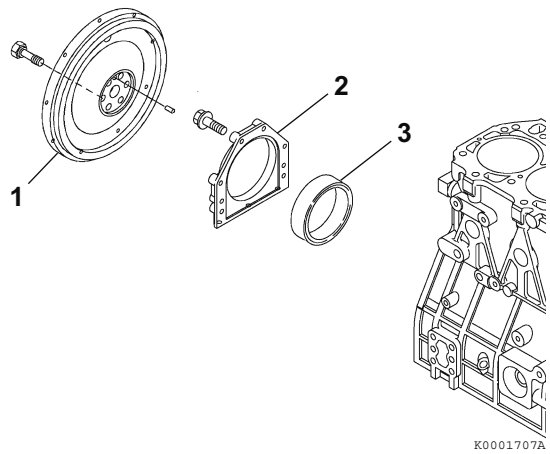


Figure 4-2-57

3. Before removing the main bearing caps, measure the crankshaft end play. Use either of the following two methods.
   - **Method A:** Install a dial gauge **(Figure 4-2-58, (1))** on the cylinder block. Move the crankshaft **(Figure 4-2-58, (2))** in and out to measure the end play. Record the measurement.

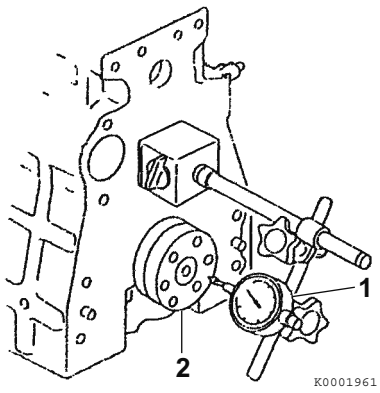


Figure 4-2-58

   - **Method B:** Use a feeler gauge to measure the clearance **(Figure 4-2-59, (3))** between the thrust bearing **(Figure 4-2-59, (1))** and crankshaft **(Figure 4-2-59, (2))**. Record the measurement. *See "3-2 Engine Service Standard" section for the service limit.*

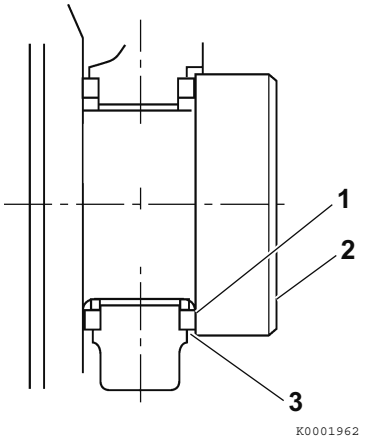


Figure 4-2-59

4. Remove the main bearing caps **(Figure 4-2-60, (3))**. Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same order as they were removed. Do not remove the bearing inserts at this time.

   Note: The "arrows" on the main bearing caps point to the flywheel end of the engine.

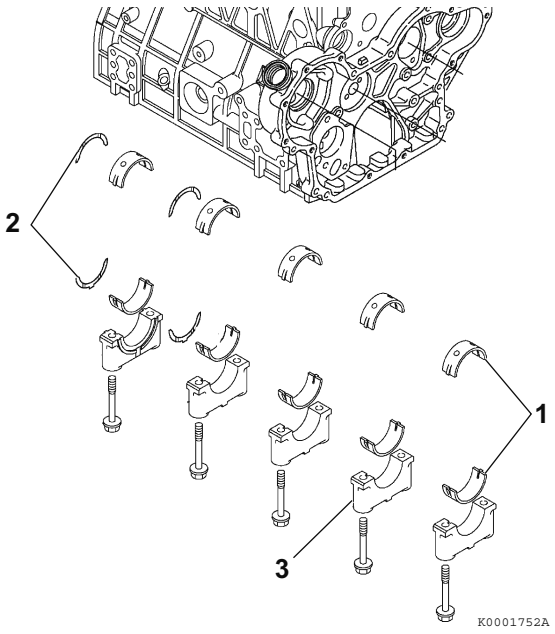


Figure 4-2-60

5. Measure bearing oil clearance prior to removing the crankshaft to determine extent of wear. Record the measurements.

   1- Wipe oil from the bearing insert and crankshaft journal surfaces.

2- Place a piece of PLASTIGAGE **(Figure 4-2-61, (1))** along the full width of each bearing insert.

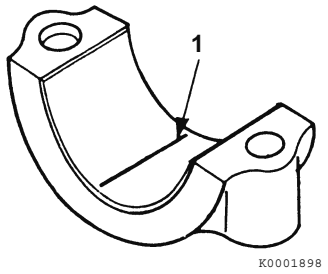


Figure 4-2-61

NOTICE

Do not rotate the crankshaft when using PLASTIGAGE. A false reading may result.

3- Reinstall bearing caps and tighten to specification. *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

4- Remove bearing caps.

5- Compare the width of the flattened PLASTIGAGE to the graduation marks on the package **(Figure 4-2-62, (1))**. The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance.

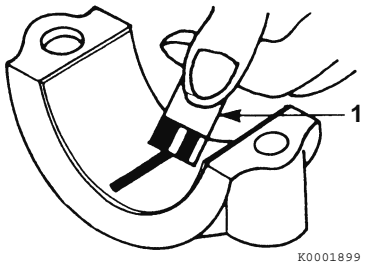


Figure 4-2-62

6. Remove the crankshaft from the engine.
7. Remove the bearing inserts **(Figure 4-2-60, (1))** and thrust bearings **(Figure 4-2-60, (2))**.

   Note: Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

8. If necessary, remove the crankshaft gear **(Figure 4-2-63, (1)),** parallel pin **(Figure 4-2-63, (2))** and key **(Figure 4-2-63, (3))**. If using a gear puller, be careful not to damage the threads in the end of the crankshaft.

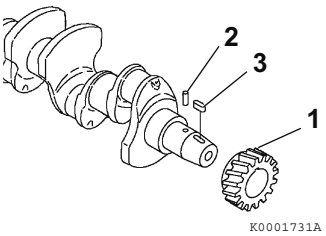


Figure 4-2-63

Inspection of Crankshaft and Camshaft Components

⚠ WARNING

Fume/Burn Hazard!

- **Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.**
- **Failure to comply could result in death or serious injury.**

Thoroughly clean all components using a brush and appropriate solvent. Each part must be free of carbon, gasket material, metal filings and other debris.

■ Replacement of crankshaft oil seals

1. Remove the seal **(Figure 4-2-64, (2))** from the cover **(Figure 4-2-64, (1))**.
2. Apply a continuous bead of ThreeBond Liquid Gasket No. 1207F, YANMAR Part No. 977770-1207F to the outside diameter of a new oil seal **(Figure 4-2-64, (2)),** and install in the gear case cover**.** Apply lithium grease to the lip of the seal.

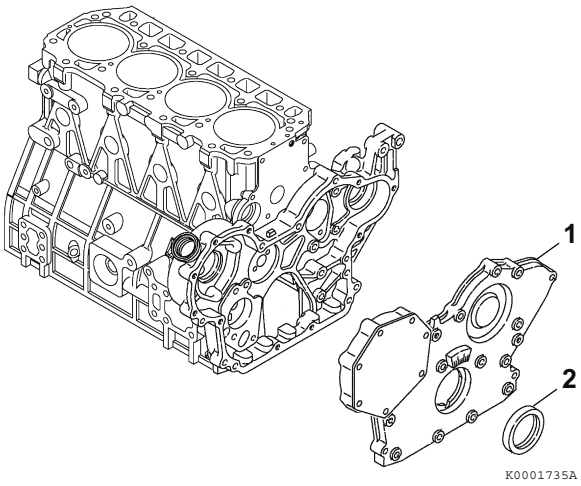


Figure 4-2-64

3. Remove the rear oil seal **(Figure 4-2-65, (3))** from the seal housing **(Figure 4-2-65, (2))**.
4. Apply a continuous bead of ThreeBond Liquid Gasket No. 1207F, YANMAR Part No. 977770-1207F to the outside diameter of a new oil seal **(Figure 4-2-65, (3)),** and install in the housing**.** Apply lithium grease to the lip of the seal.

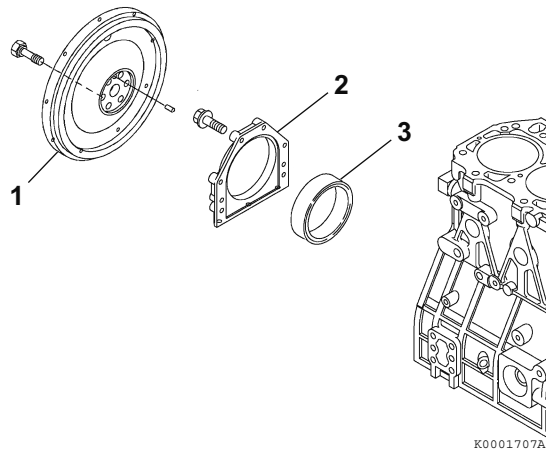


Figure 4-2-65

■ Measure crankshaft bearing oil clearance

Oil clearance should be checked during disassembly to determine the extent of wear, and during assembly to ensure long engine life. The same procedure is done for both connecting rods and main bearings.

■ Inspection of cylinder block

1. Ensure that oil passages are clear and unobstructed.
2. Check for discoloration or evidence of cracks. If a fracture is suspected, use the color check method or the Magnaflux method to determine if the cylinder block is fractured.
3. Inspect cylinders for roundness, taper, or evidence of scoring. Collect and record the measurements. Consider honing, reboring or replacing the cylinder block if the measurements are not within specification.
   - Take measurements at three places **(Figure 4-2-66,** (a, b, c), and in two directions (d and e) in each cylinder.

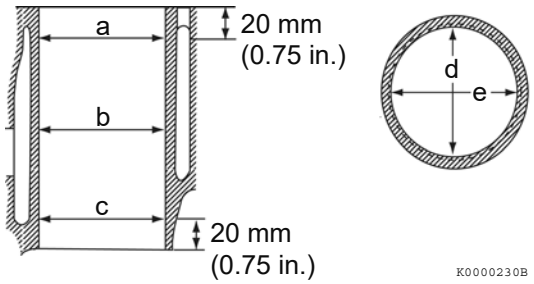


Figure 4-2-66

■ Inspection of pistons, piston rings and wrist pin

Note:

- *On an engine with low hours, the pistons, piston rings may be reused if they are found to be within specifications. The pistons and piston rings must be reinstalled in the same cylinders from which they were originally removed.*
- *On an engine with high hours, the pistons rings should be replaced and the cylinder honed (See Honing and Boring on page 4-2-39) or replaced. The piston should be replaced as necessary.*

1. Clean piston ring grooves using a piston ring groove cleaning tool. Follow manufacturer's instructions for correct operation.
2. Wash the pistons in an appropriate solvent using a soft brush.
3. Visually inspect each piston for cracks. Pay particular attention to the ring lands between the piston ring grooves.
4. Measure the diameter of the piston skirt at 90° to the wrist pin bore as shown **(Figure 4-2-67)**. Measurements must be taken at a specified distance **(Figure 4-2-67, (1))** from the bottom of the piston, based on engine model. Record the measurements. *See "3-2 Engine Service Standard" section for the service limit.*

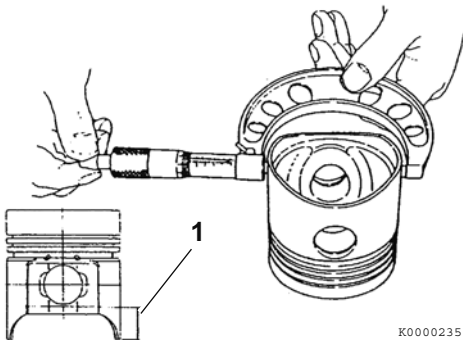


Figure 4-2-67

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection *(see Inspection of cylinder block on page 4-2-34)* to obtain piston-to-cylinder clearance. Record the measurements. *See "3-2 Engine Service Standard" section for the service limit.*
6. Measure the diameter of the wrist pin bore on both sides of the piston **(Figure 4-2-68)**. *See "3-2 Engine Service Standard" section for the service limit.* Record the measurements.

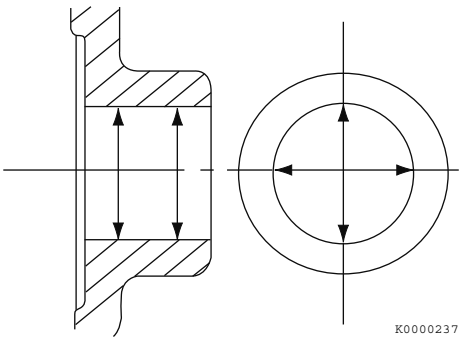


Figure 4-2-68

7. Measure the outside diameter of the wrist pin in three places and at 90° **(Figure 4-2-69)**. *See "3-2 Engine Service Standard" section for the service limit.* Record the measurements.

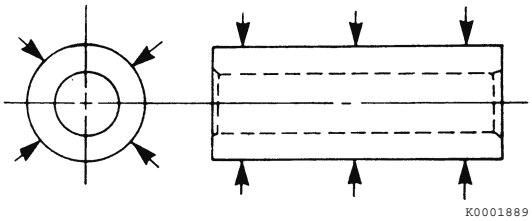


Figure 4-2-69

8. Using a micrometer, measure the thickness of each piston ring. *See "3-2 Engine Service Standard" section for the service limit.* Record the measurements.

   Note:

   - *On an engine with low hours, the pistons, piston rings and cylinders may be reused if they are found to be within specifications.*
   - *On an engine with high hours, the pistons rings should be replaced and the cylinder honed (see Honing and Boring on page 4-2-39) or replaced. The piston should be replaced as necessary.*
9. Place each compression piston ring in the groove as shown **(Figure 4-2-70)**. Use a feeler gauge to measure the clearance between the piston ring and the piston ring land. Record the measurements. *See "3-2 Engine Service Standard" section for the service limit.* Replace the piston if not within specification.

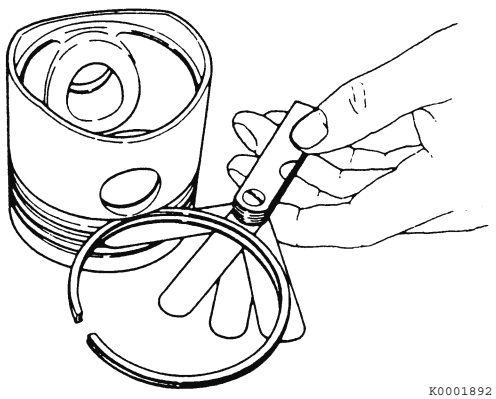


Figure 4-2-70

10. To measure piston ring end gap, insert each compression piston ring **(Figure 4-2-71, (1))**, one at a time, into the cylinder. Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 1.18 in. (30 mm) **(Figure 4-2-71, (2))** from the bottom of the bore. Remove the piston. Measure the end gap **(Figure 4-2-71, (3))** of each piston ring. Record the measurements. *See "3-2 Engine Service Standard" section for the service limit.*

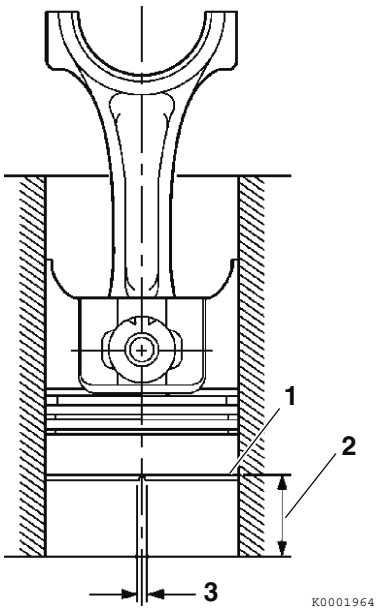


Figure 4-2-71

Note: Always check the piston ring end gap when installing new piston rings. See "3-2 Engine Service Standard" section for the service limit. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

11. Repeat the above steps for each cylinder and piston assembly.

■ Inspection of connecting rod

1. Measure the wrist pin bushing bore using a bore gauge **(Figure 4-2-72, (1))**. Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end **(Figure 4-2-72, (2))**. *See "3-2 Engine Service Standard" section for the service limit.*

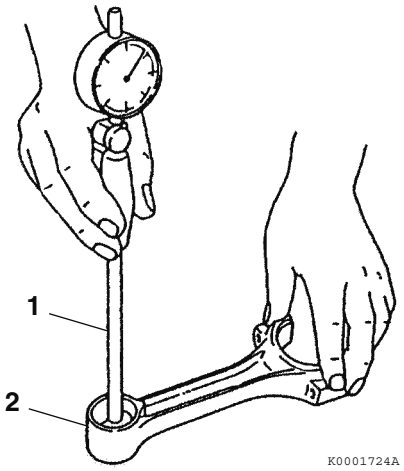


Figure 4-2-72

2. Place the connecting rod bearing inserts into the connecting rod and connecting rod cap. Install the rod cap and tighten the bolts to the specified torque.
3. Measure the inside diameter. *See "3-2 Engine Service Standard" section for the service limit.*

■ Inspection of tappets

1. Inspect the tappet contact surfaces for abnormal wear **(Figure 4-2-73, (1))**. Normal wear will be even as shown in **(Figure 4-2-73, (2)).** Slight surface defects can be corrected using an oilstone.

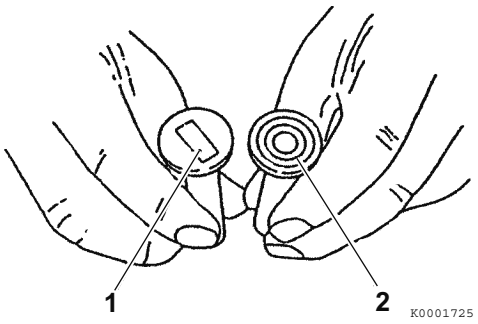


Figure 4-2-73

2. Measure the outside diameter of the tappet stem **(Figure 4-2-74, (1))**. *See "3-2 Engine Service Standard" section for the service limit.*

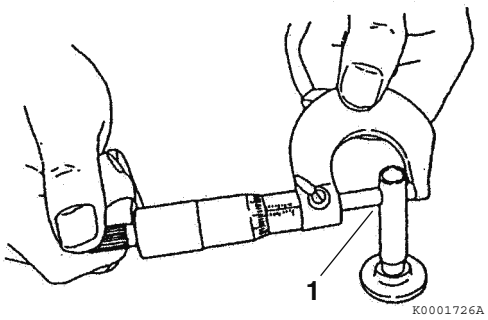


Figure 4-2-74

3. Measure the tappet bores in the cylinder block. *See "3-2 Engine Service Standard" section for the service limit.*

■ Inspection of crankshaft

1. Place the crankshaft end journals **(Figure 4-2-75, (4))** on V-blocks.
2. Place a dial indicator **(Figure 4-2-75, (3))** on a center main bearing surface.

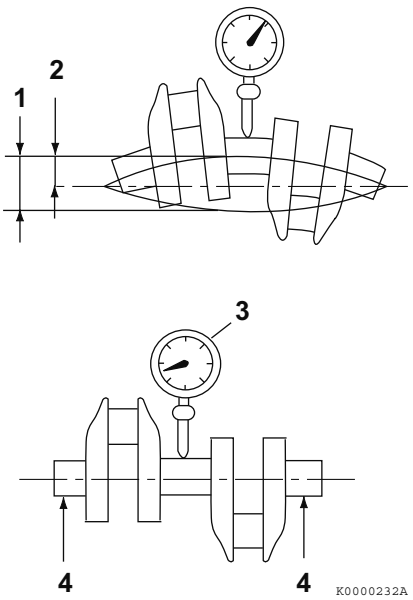


Figure 4-2-75

3. Rotate the crankshaft and observe runout. *See "3-2 Engine Service Standard" section for the service limit.*
4. Use the color check method or Magnaflux® to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.
5. Measure the outside diameter of each crankpin **(Figure 4-2-76, (2))** and main bearing journal **(Figure 4-2-76, (1))**. *See "3-2 Engine Service Standard" section for the service limit.* Take measurements at several places around each bearing surface. If not within specification, grind the journals and install undersize bearings, or replace the crankshaft.

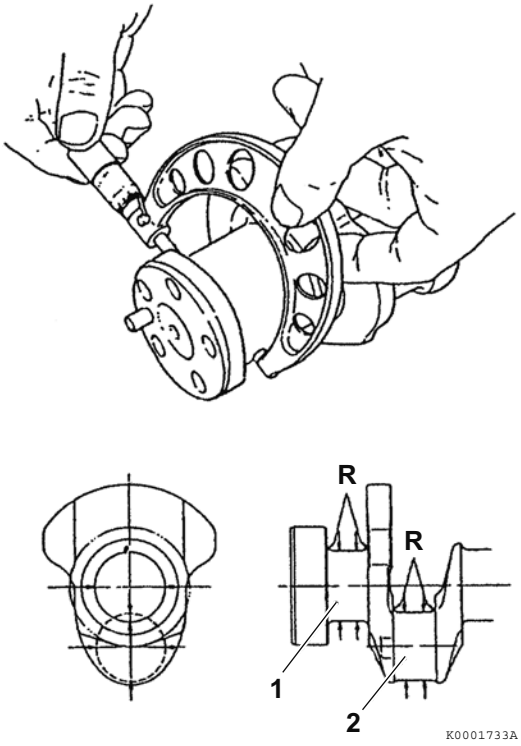


Figure 4-2-76

■ Inspection of camshaft

1. Use V-blocks and a dial indicator to check camshaft bend **(Figure 4-2-77)**. Place the indicator on the center bearing journal.

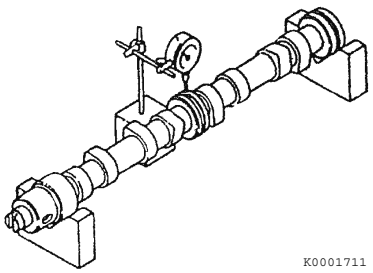


Figure 4-2-77

2. Rotate the camshaft and observe the runout. *See "3-2 Engine Service Standard" section for the service limit.*
3. Measure the height of each lobe **(Figure 4-2-78, (1))**. *See "3-2 Engine Service Standard" section for the service limit.*

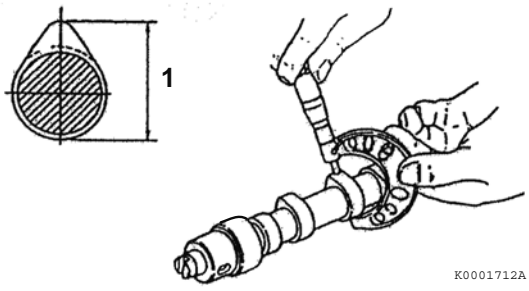


Figure 4-2-78

4. Measure the diameter of the gear end **(Figure 4-2-79, (1))**, intermediate **(Figure 4-2-79, (2)),** and flywheel end **(Figure 4-2-79, (3))** bearing journals. *See "3-2 Engine Service Standard" section for the service limit.*

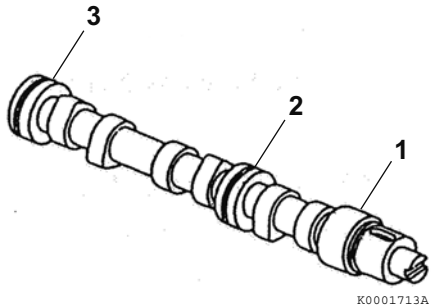


Figure 4-2-79

■ Inspection of camshaft bushing and bores

1. Measure the I.D. of the front bushing and the remaining bores in the cylinder block. *See "3-2 Engine Service Standard" section for the service limit.*
2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no bearing inserts used.

■ Inspection of idler gear and shaft

1. Measure the outside diameter **(Figure 4-2-80, (1))** of the idler gear shaft **(Figure 4-2-80, (2))**. *See "3-2 Engine Service Standard" section for the service limit.*
2. Measure the inside diameter **(Figure 4-2-80, (3))** of the idler gear bushing **(Figure 4-2-80, (4))**. *See "3-2 Engine Service Standard" section for the service limit.*

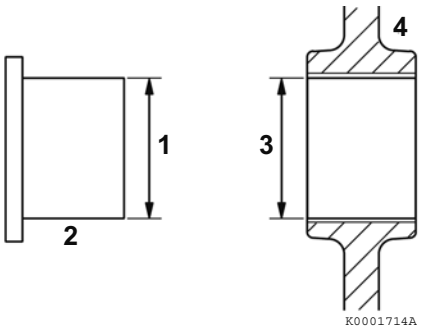


Figure 4-2-80

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out-of-round, or tapered beyond specifications, rebore and hone to restore cylinders to usable condition. Slight imperfections can be corrected by honing alone.

1. **Boring** - Significant cylinder damage may be corrected by boring the cylinder to an oversize dimension. Refer to the appropriate parts catalog for available oversize pistons and piston rings.
   - Boring a cylinder should always be done in a properly equipped machine shop.
   - A bored cylinder should always be finished with a hone to properly prepare the cylinder surface so the new piston rings will seat properly.
   - After the cylinder has been bored and honed, install the appropriate oversize pistons and piston rings.
2. **Honing** - Minor cylinder imperfections may be corrected by using a rigid cylinder hone **(Figure 4-2-82, (1))**. Be sure not to exceed the maximum cylinder bore specification.

   Deglazing - A used cylinder that did not require boring or honing, should always be deglazed with a ball hone **(Figure 4-2-82, (2))** before installing new piston rings. This will properly prepare the cylinder surface to allow new piston rings to seat properly.

   Note: When honing a cylinder, with either a ridged hone or a ball hone **(Figure 4-2-81, *(1)*)***, move the rotating hone up and down in the cylinder bore to accomplish a 30° to 40° crosshatch pattern* ***(Figure 4-2-81)****. This will provide the ideal surface for the proper seating of new piston rings.*

NOTICE

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

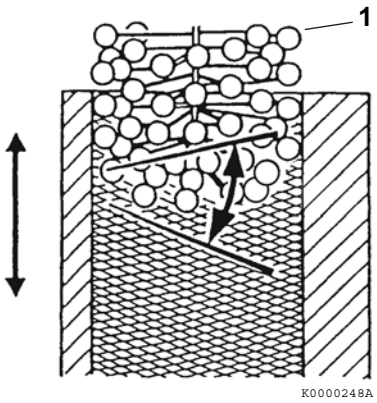


Figure 4-2-81

- Use a 50:50 mixture of diesel fuel and engine oil as a honing fluid.
- Use a 300-grit hone at 300 - 1200 min^{-1} (rpm) **(Figure 4-2-82)**.

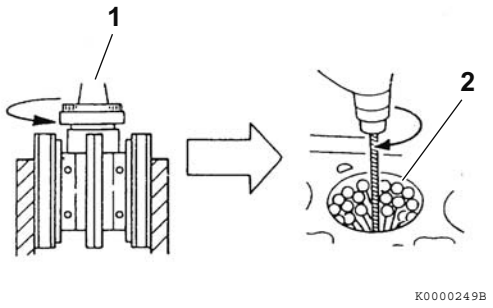


Figure 4-2-82

NOTICE

Solvents will not adequately remove honing residue, resulting in premature piston and ring wear. Always wash cylinders using hot, soapy water.

- When honing is completed, wash the cylinder block with hot water and soap. The cylinder wall is adequately cleaned when a white rag wiped in cylinder comes out clean. Use brushes to clean all passages and crevices. Rinse with hot water and dry with compressed air. Apply clean engine oil to all steel surfaces to prevent rusting.

Reassembly of Crankshaft and Piston Components

Note:

- *Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.*
- *Use new gaskets, seals and O-rings during assembly.*
- *Liberally apply clean engine oil to all internal parts during assembly.*
- *All fasteners should be tightened to a given torque. If a special torque is not provided in the Special Torque. See "3-7-2 Engine Tightening Torque" section for tightening torque.*

■ Reassembly of pistons

1. Select the parts needed to reassemble the piston and connecting rod for one cylinder.
2. If removed, install a new wrist pin bushing **(Figure 4-2-83, (7))** using a press and the appropriate service tool. Be sure to align the oil holes.

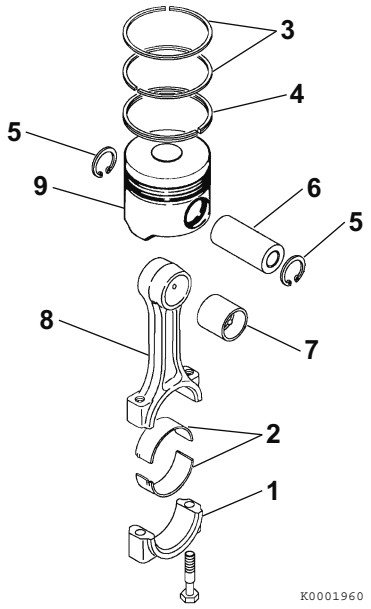


Figure 4-2-83

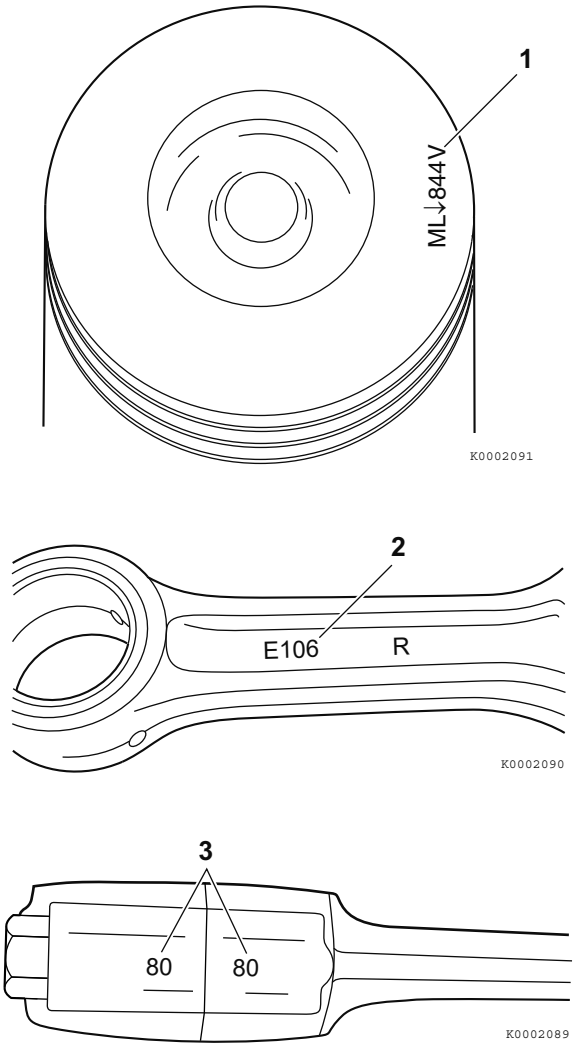
3. Reinstall one circlip **(Figure 4-2-83, (5))** into the piston. Ensure the circlip is securely seated in the groove.

NOTICE

The piston and connecting rod must be assembled together in the correct orientation. The orientation of the piston and connecting rod are different depending on engine model.

Piston to connecting rod orientation - by model
Orient the piston identification mark stamped on top of the piston on the same side as the rod and cap match marks stamped on the connecting rod.

Note: The actual appearance of the match marks on the piston and connecting rod may vary, but they will always be in the same locations.



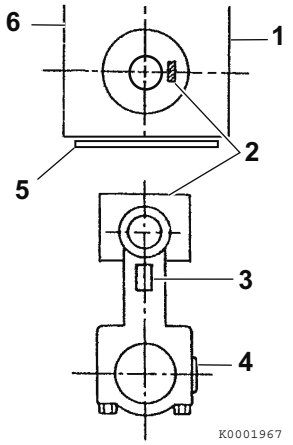
1 – Piston identification mark
2 – Embossed mark on connecting rod
3 – Rod and cap match marks

Figure 4-2-84

Piston assembly - all TNV models

When correctly assembled, the piston identification mark **(Figure 4-2-85, (2))** stamped into the top of the piston will be on the same side of the connecting rod as the match marks **(Figure 4-2-85, (4))** stamped into the connecting rod and connecting rod cap.

When installed in the cylinder, the piston identification mark **(Figure 4-2-85, (2))** stamped on the top of the piston must face the fuel injection pump side **(Figure 4-2-85, (1))** of the engine and the embossed mark on the connecting rod **(Figure 4-2-85, (3))** must face the flywheel end **(Figure 4-2-85, (5))** of the engine.



1 – Fuel injection pump side of engine
2 – Piston identification mark
3 – Embossed mark on connecting rod
4 – Rod and cap match marks
5 – Flywheel end of engine
6 – Camshaft side of engine

Figure 4-2-85

4. Lubricate and reinstall the wrist pin **(Figure 4-2-86, (6))** through the piston and connecting rod.
5. Reinstall the second circlip **(Figure 4-2-86, (5))** and ensure it is securely seated in the groove.

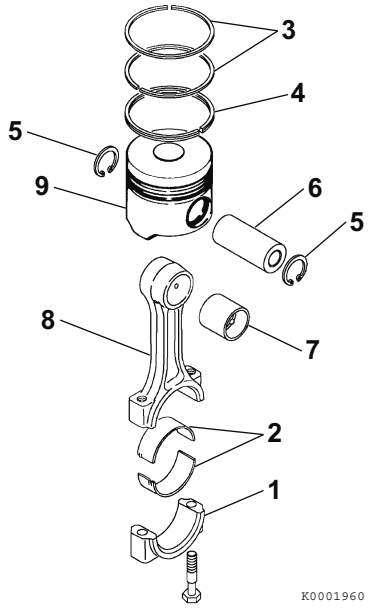


Figure 4-2-86

Note:

- *If installing new piston rings the end gap must be checked and adjusted as necessary. See Inspection of pistons, piston rings and wrist pin on page 4-2-34 for specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.*
- *Reinstall the top and second piston rings with the stamped "makers mark" **(Figure 4-2-88, (1))** facing the top of the piston. The "makers mark" may vary in appearance but will always be located on the top surface of the piston ring adjacent to the piston ring gap. The oil ring and oil ring expander can be installed either side up.*

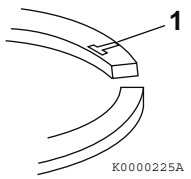


Figure 4-2-87

NOTICE

Always use a piston ring installation tool (expander) when installing piston rings. Never attempt to install piston rings by hand.

6. Reinstall the oil ring expander **(Figure 4-2-89, (4))**. Reinstall the oil ring **(Figure 4-2-89, (3))** with the end gap at 180° from the expander end gap**.**
7. Reinstall the second compression ring **(Figure 4-2-89, (2)).** This ring is identified by its dark color and tapered face profile**.**
8. Reinstall the top compression ring **(Figure 4-2-89, (1))**. This ring is identified by its silver color and barrel-shaped face profile.

NOTICE

The oil ring expander **(Figure 4-2-89, (4))** end gap must be located 180° from the oil ring **(Figure 4-2-89, (3))** end gap.

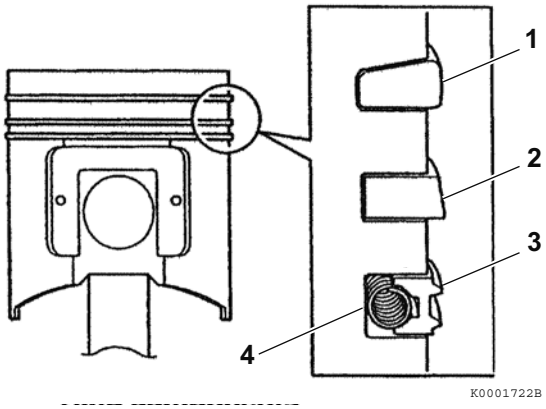
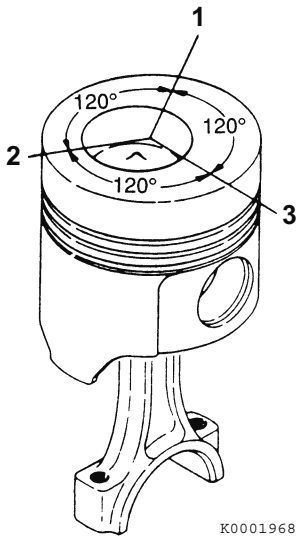


Figure 4-2-88

9. Stagger the piston ring end gaps at 120° intervals **(Figure 4-2-90, (1, 2, 3))**. Do not position the top piston ring end gap in line with the wrist pin.



1 – Top compression ring end gap
2 – Second compression ring end gap
3 – Oil ring end gap

Figure 4-2-89

■ Installation of crankshaft

1. If removed, reinstall the keys and timing gear on the crankshaft.
2. Reinstall new bearing inserts **(Figure 4-2-90, (1))** and thrust bearing **(Figure 4-2-90, (2))** in the cylinder block and main bearing caps. Apply a liberal coat of clean engine oil to the bearings and crankshaft journals.
3. Place the crankshaft into the engine.

NOTICE

The main bearing caps are numbered and have arrows for proper positioning. The No. 1 cap is at the flywheel end. The arrows point toward the flywheel end of the engine.

4. Reinstall the main bearing caps **(Figure 4-2-90, (3))**.

5. Apply a light coat of clean engine oil to the bearing cap bolts and tighten the bolts to the specified torque in two stages (1/2 then full torque). *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

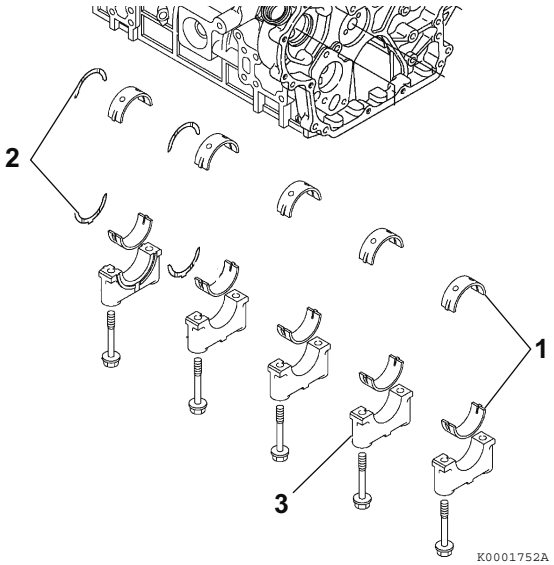


Figure 4-2-90

6. Rotate the crankshaft to assure it turns freely.
7. Apply ThreeBond Liquid Gasket No. 1207F, YANMAR Part No. 977770-1207F to the mounting flange of the seal housing **(Figure 4-2-91, (2))**.
8. Align the seal housing with the two dowel pins.
9. Reinstall seal housing and seal assembly.
10. Reinstall the flywheel **(Figure 4-2-91, (1))** and tighten the bolts to the specified torque. *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

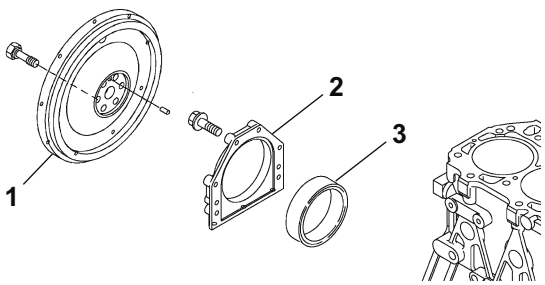


Figure 4-2-91

■ Installation of pistons

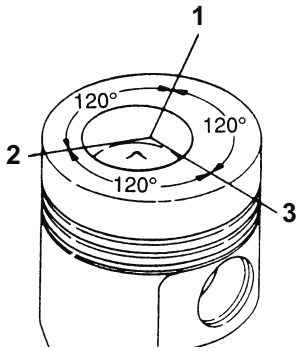
NOTICE

Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft bearing journal may result.

1. Lubricate the piston, piston rings, and cylinder with clean engine oil or assembly lubricant.
2. Rotate the crankshaft so the crankpin for the piston being installed is near bottom dead center.

NOTICE

Ensure the piston ring gaps are located correctly **(Figure 4-2-92)**.



1 – Top compression ring end gap
2 – Second compression ring end gap
3 – Oil ring end gap

Figure 4-2-92

3. Using a piston ring compressor, compress the piston rings.

NOTICE

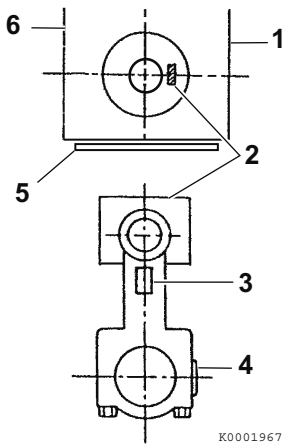
The piston and connecting rod must be installed in the correct orientation.

Piston orientation to cylinder	
All TNV models	Orient the piston identification mark stamped on top of the piston on the fuel injection pump side of the engine

Piston installation - all TNV models

When correctly assembled, the piston identification mark **(Figure 4-2-93, (2))** stamped into the top of the piston will be on the same side of the connecting rod as the match marks **(Figure 4-2-93, (4))** stamped into the connecting rod and connecting rod cap.

When installed in the cylinder, the piston identification mark **(Figure 4-2-93, (2))** stamped on the top of the piston must face the fuel injection pump side **(Figure 4-2-93, (1))** of the engine and the embossed mark on the connecting rod **(Figure 4-2-93, (3))** must face the flywheel end **(Figure 4-2-93, (5))** of the engine.



1 – Fuel injection pump side of engine
2 – Piston identification mark
3 – Embossed mark on connecting rod
4 – Rod and cap match marks
5 – Flywheel end of engine
6 – Camshaft side of engine

Figure 4-2-93

4. Reinstall the bearing inserts **(Figure 4-2-94, (1))** in the connecting rod and cap.
5. Apply a liberal coat of clean engine oil to the bearing inserts and crankshaft journal.
6. Apply a light coat of clean engine oil to the rod cap bolts. Reinstall the connecting rod cap **(Figure 4-2-94, (2))**. Tighten the connecting rod bolts to the specified torque in two stages (1/2 then full torque). *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

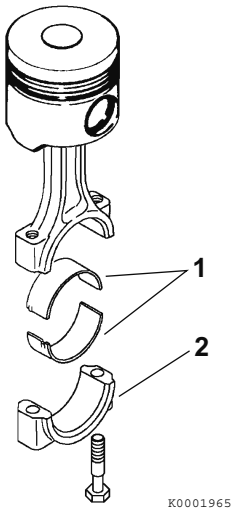


Figure 4-2-94

7. Reinstall the remaining pistons in their respective cylinders.

Reassembly of Camshaft and Timing Components

■ Installation of gear case

1. If removed, install a new camshaft bushing **(Figure 4-2-95, (3))** using the appropriate service tool.
2. Apply a continuous bead of ThreeBond Liquid Gasket No. 1207F, YANMAR Part No. 977770-1207F to the mounting area of the gear case. Be sure to circle each bolt hole.
3. **4TNV98C, 4TNV98CT:** Install two new O-rings **(Figure 4-2-95, (2))** in the cylinder block.

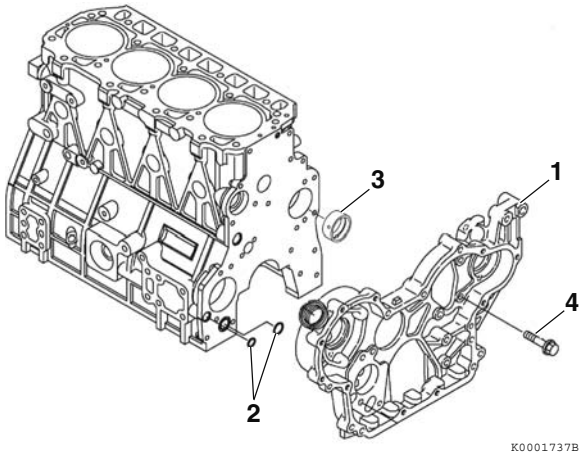


Figure 4-2-95

4. Reinstall the gear case **(Figure 4-2-95, (1))**. Tighten the bolts to the specified torque.

■ Installation of camshaft

Note: The gear housing or front plate must be reinstalled prior to installing the camshaft. See Installation of gear case on page 4-2-46.

1. If removed, reinstall the camshaft end plate **(Figure 4-2-96, (1))**, key, and timing gear **(Figure 4-2-96, (4))** onto the camshaft using a press.

   Note: Heat the gear to 356 - 392 °F (180 - 200 °C) and press onto the end of the camshaft.

2. Rotate the cylinder block so that gravity will keep the tappets **(Figure 4-2-96, (5))** in place and out of the way of the camshaft lobes when the camshaft is being reinstalled.

   Note:

   - *If the engine is not installed on an engine repair fixture, stand the engine upright on the flywheel end mounting flange.*
   - *The tappets are "mushroom" shaped and must be installed from inside the engine crankcase.*

3. Lubricate the tappets with clean oil or assembly lube. Reinstall the tappets in their respective locations in the cylinder block. Push the tappets fully into the tappet bores so they will not interfere with the installation of the camshaft.
4. Lubricate the camshaft **(Figure 4-2-96, (2))** with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine.
5. Reinstall and tighten the cap screws **(Figure 4-2-96, (3))**.

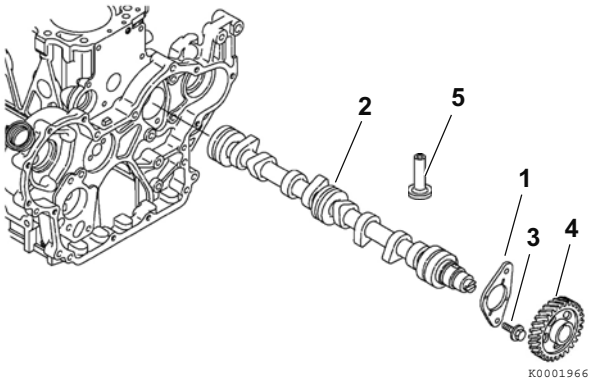
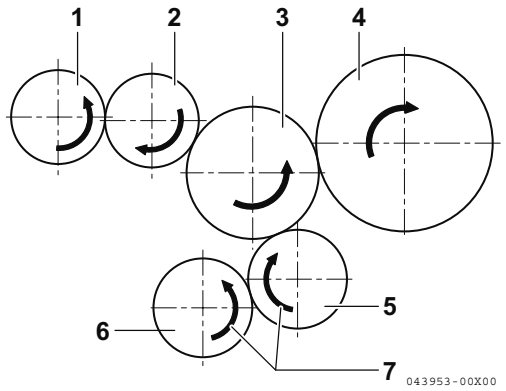


Figure 4-2-96

■ Installation of timing gears

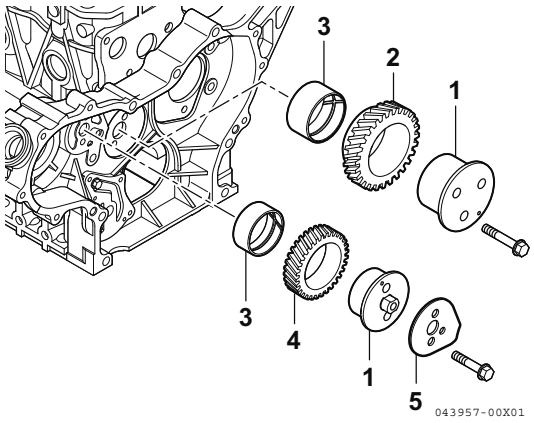
1. Set the No. 4 piston to top dead center.
2. Rotate the camshaft until the mark **(Figure 4-2-97, (C))** is approximately at the 9 o'clock position**.**



1 – Supply pump gear
2 – Idler gear (A)
3 – Idler gear (B)
4 – Camshaft gear
5 – Crankshaft gear
6 – Lubricating oil pump gear
7 – Direction of rotation

Figure 4-2-97

3. Lubricate the idler gear **(Figure 4-2-98, (2))**, bushing **(Figure 4-2-98, (3))** and idler gear shaft **(Figure 4-2-98, (1))** with clean engine oil.



1 – Idler gear shaft
2 – Idler gear (A)
3 – Idler gear bushing
4 – Idler gear (B)
5 – Plate, idle shaft

Figure 4-2-98

4. Align the timing gears as shown in **(Figure 4-2-97)**.
5. Reinstall the idler gear and idler gear shaft. Be sure the oil hole in the bushing is facing toward the top of the engine.
6. Ensure all three timing marks on idle gear A and two timing marks on idle gear B **(Figure 4-2-97, (A, B, C))** are aligned**.**
7. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque. *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

■ Installation of gear case cover

1. Apply a continuous bead of ThreeBond Liquid Gasket No. 1207F, YANMAR Part No. 977770-1207F to the mounting area of the gear case cover **(Figure 4-2-99, (1))**. Be sure to circle the bolt holes.
2. Reinstall and tighten the gear case cover bolts.

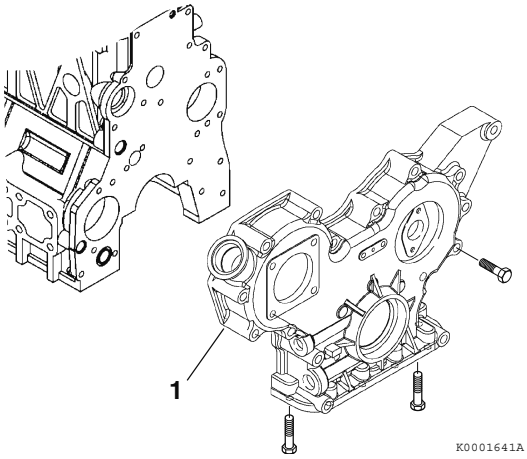


Figure 4-2-99

3. Reinstall the crankshaft pulley.

NOTICE

Use the crankshaft pulley installation tool **(Figure 4-2-100, (3))** when reinstalling the pulley **(Figure 4-2-100, (1))**. The tool will guide the pulley hub and protect the front seal **(Figure 4-2-100, (2))** from damage.

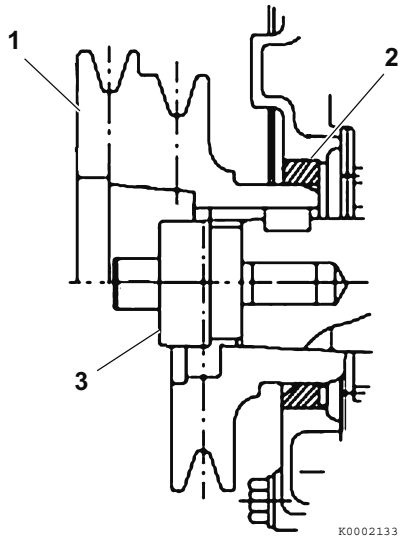


Figure 4-2-100

4. Reinstall the washer and bolt. Tighten the bolt to the specified torque. *See "3-7-2 Engine Tightening Torque" section for tightening torque.*

■ Installation of oil pan

1. Reinstall the oil pickup tube **(Figure 4-2-101, (1))** using a new O-ring **(Figure 4-2-101, (2)).**

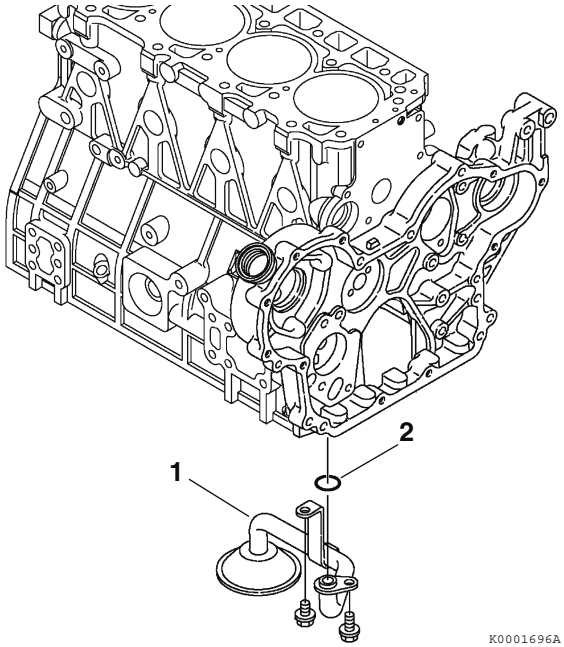


Figure 4-2-101

2. Apply a continuous bead of ThreeBond Liquid Gasket No. 1207F, YANMAR Part No. 977770-1207F to the mounting surface of the oil pan **(Figure 4-2-102, (1))**. Be sure to circle each bolt hole.
3. Reinstall the oil pan and tighten the bolts securely.

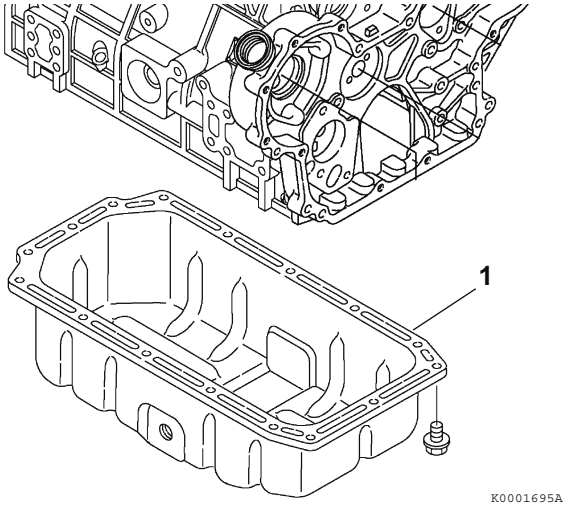


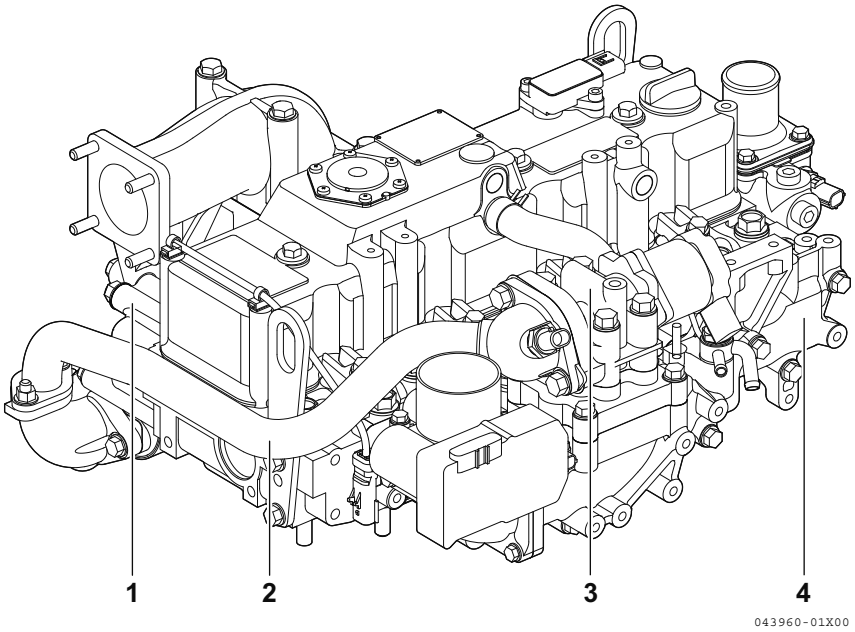
Figure 4-2-102

Final Reassembly of Engine

1. Reinstall the starter motor.
2. Reinstall the cylinder head. *See Removal of cylinder head on page 4-2-11.*
3. Reinstall the engine in the machine.
4. Reconnect the fuel and coolant lines.
5. Reinstall the alternator.
6. Reconnect all electrical connections.
7. Fill the engine with oil and coolant.
8. Reconnect the battery cables, negative (-) cable last.

4-2-7 EGR System

EGR System (Typical Model)



1 – Exhaust manifold
2 – EGR pipe
3 – EGR valve
4 – Intake manifold

Figure 4-2-103

■ Disassembly of EGR System

⚠ DANGER

Scald Hazard!

- **Never remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.**
- **Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.**
- **Always check the level of the engine coolant by observing the reserve tank.**
- **Failure to comply will result in death or serious injury.**

⚠ WARNING

Burn Hazard!

- **Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Entanglement Hazard!

- **Stop the engine before you begin to service it.**
- **Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.**
- **If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.**
- **Failure to comply could result in death or serious injury.**

⚠ WARNING

Fume/Burn Hazard!

- **Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.**
- **Failure to comply could result in death or serious injury.**

⚠ CAUTION

Flying Object Hazard!

- **Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.**

- **Failure to comply may result in minor or moderate injury.**

⚠ CAUTION

Coolant Hazard!

- **Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.**

- **Failure to comply may result in minor or moderate injury.**

NOTICE

When it is necessary to replace an EGR valve, be sure to replace the entire EGR valve assembly. Neither attempt to disassemble and repair the EGR valve, nor replace its individual components.

NOTICE

The EGR system uses steel gaskets at the joints between its components/parts. These steel gaskets are specific to the respective joints. When you remove the system's components/parts and reinstall them, replace the steel gaskets between them with new correct ones.

1. Remove the air cleaner if an air cleaner is equipped on the EGR valve.
2. EGR valve is in a closed state when the key switch is turned off. In order to clean the valve, ECU sends signals to EGR, and forcibly fully opens the EGR valve. Therefore, do not disconnect the wire harness when you remove the EGR valve from the engine. However, if it is difficult to remove the EGR valve from the engine with the wire harness being connected, disconnect the wire harness first and remove the EGR valve. After removing the EGR valve, reconnect the wire harness to the engine.
3. Use a special wire harness if you want to remove the EGR valve farther from the engine for efficient cleaning. *(See **(Figure 4-2-104)**)*

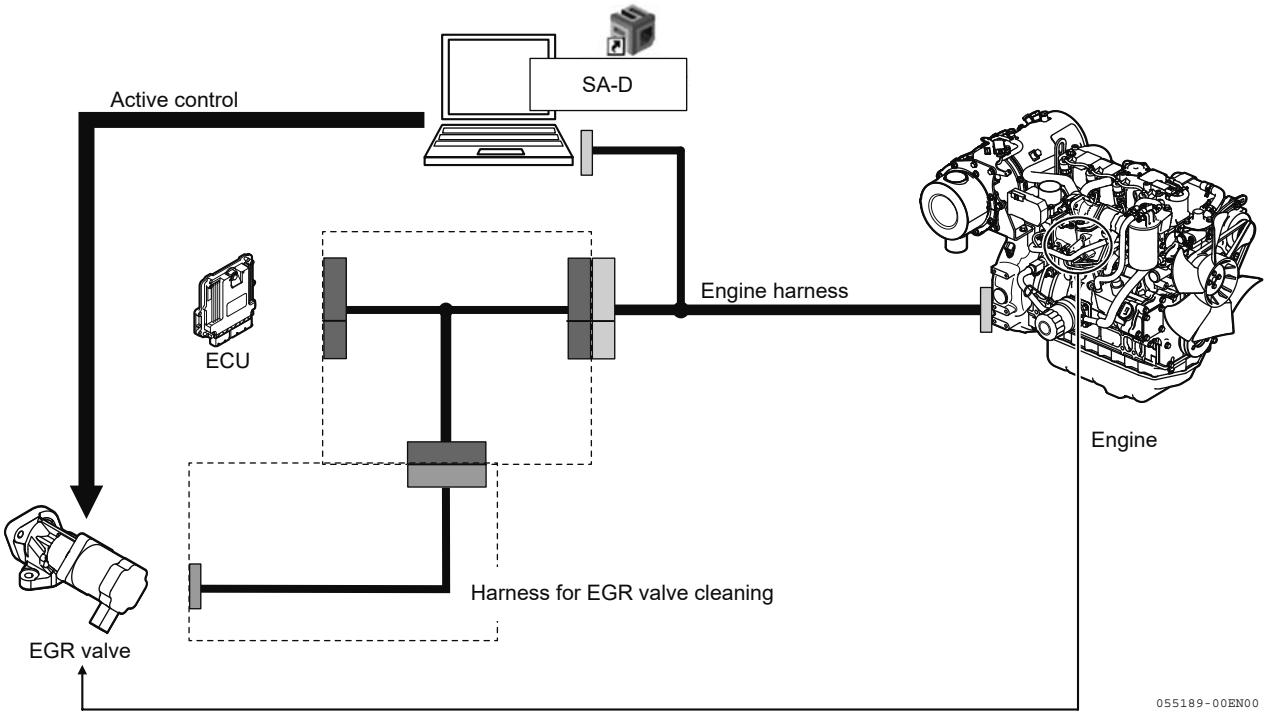
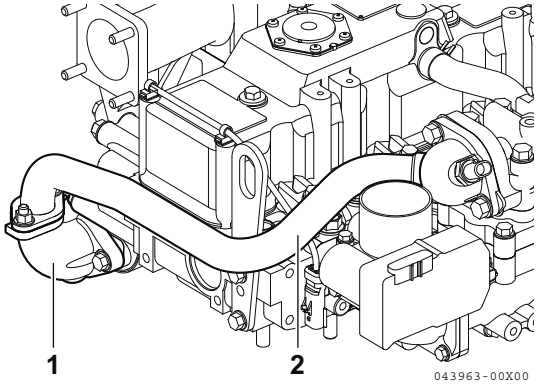


Figure 4-2-104

■ 4TNV98C

1. Loosen the nuts in the coupling flanges of the exhaust manifold and the EGR pipe.
2. Loosen the bolts in the coupling flanges of the EGR pipe and EGR valve, and remove the EGR pipe.



1 – Connecting pipe (EGR out)
2 – EGR pipe

Figure 4-2-105

3. Remove the EGR valve.

■ EGR active control

Connect the SMARTASSIST DIRECT (SA-D) to the engine wire harness.

- Before forcibly activating the EGR, check for errors that affect the fully closing process of the EGR.
  How to check: Press “Defect Display” and “Current Defect”. If the error is displayed, go to (1). If no error is displayed, go to (2).

(1)

- Select “Diagnostic Codes” and select “Defect History”
- Press “All Clear” button
- Error information is cleared from the “Defect History”

(2)

- Select “Diagnosis Tests” and select “Active Control”
- Press “Execute” button from “EGR Valve Opening Control”
- Enter the user ID and password
- When “EGR Valve Opening Control” is displayed, enter “106” in “Desired” and press “Set”
- Active control starts if no error is found
- Check that the desired value on the screen indicates the set target value. EGR valve opening control lamp comes on.

NOTICE

Do not end the SA-D while cleaning the EGR.

For details on how to operate the EGR Active Control, refer to the SMARTASSIST DIRECT (SAD) Operation Manual.

■ Cleaning the EGR valves

⚠ WARNING

Fume/Burn Hazard!

- **Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.**

- **Failure to comply could result in death or serious injury.**

⚠ CAUTION

Flying Object Hazard!

- **Always wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.**

- **Failure to comply may result in minor or moderate injury.**

Clean the EGR valve every 3000 hours of operation to prevent carbon deposits. This leads to deterioration of EGR performance. Blow the carbon deposits with the compressed air (0.19 MPa (2 kg/cm^2) or less). Use a soft brush with carbon cleaner or kerosene to clean the EGR valve if the EGR valve is excessively dirty. Be sure to remove all carbon deposits. **(Figure 4-2-106)** In this case, the motor portion and the coupler terminals should not be exposed to solvent or cleaner. This may result in a malfunction.

If the carbon deposits can not be removed by a brush, be sure to replace the entire EGR valve assembly.

Remove the remaining carbon deposits by blowing the compressed air. **(Figure 4-2-106)**

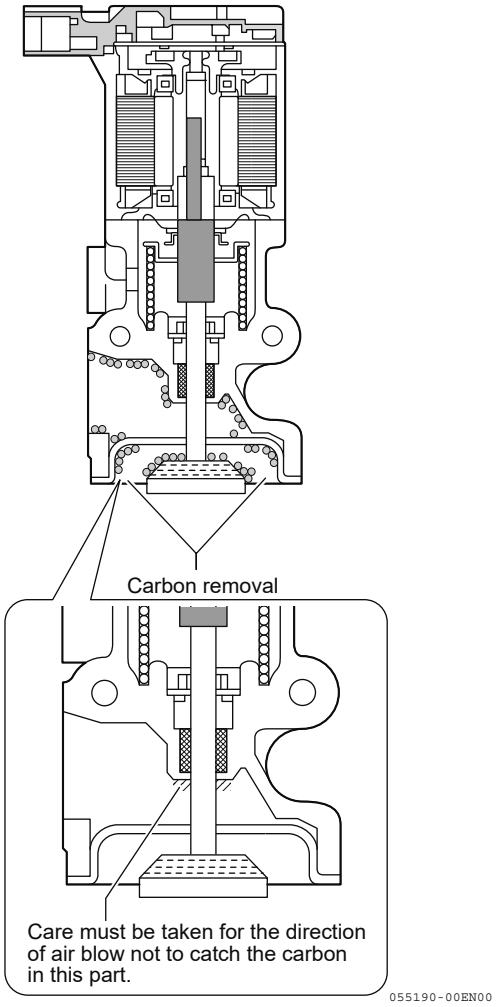


Figure 4-2-106

■ Exit the EGR active control

You can exit the EGR Active Control from the SMARTASSIST DIRECT screen.

- Press the “Stop” button from “EGR Valve Opening Control”.
- EGR valve opening control lamp goes off and EGR Active Control exits.

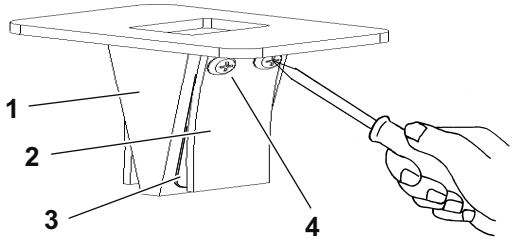
■ Precautions for cleaning

- Do not disassemble the EGR valve.
- Do not use wash fluid.
- Do not use a hard brush made of metal.
- Clean entire circumference of the valve and the valve seat, and blow with the compressed air.
- Do not put your fingers into the valve portion.

■ Lead valves

Similarly to the EGR valves, the lead valves must be periodically cleaned every 3000 hours because, as exhaust gas circulates through them for a prolonged time, carbon is deposited on their inner surfaces, possibly deteriorating the EGR ratio.

To remove carbon deposited inside the lead valves, disassemble and clean them.



1 – Case
2 – Stopper
3 – Valve
4 – Machine screw

Figure 4-2-107

To remove deposited carbon, use carbon cleaner, kerosene, or some other liquid capable of removing carbon as well as a soft brush or cloth to clean the valves, taking care not to damage their parts.

Upon completion of carbon removal, wipe off water and liquid, make sure that the case, valve, and stopper are free of foreign matter, and then reinstall the valve and related parts.

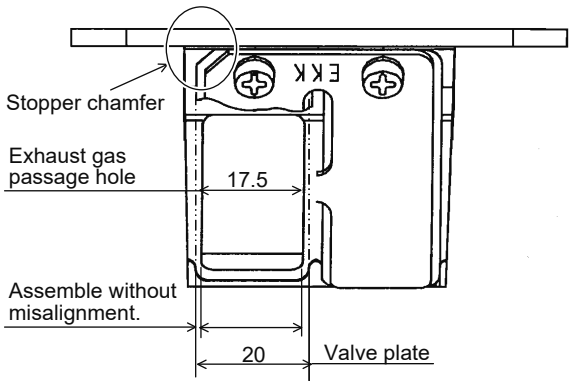


Figure 4-2-108

■ Precautions for installation

1. The valve and stopper must be installed in their specific orientations. As shown in the figure above, install the valve and stopper so that they are located on the left-hand side of the lead valve.
2. Install the valve by tightening the machine screw while ensuring that it is evenly positioned inside the case window.
3. The machine screw must be tightened with torque of 1.37 ± 0.2 N·m (14 ± 2 kgf·cm).
4. After tightening the machine screw, mark it with a marker to indicate that it has already been tightened.

■ EGR cooler

The EGR cooler must be periodically cleaned every 1500 hours because the exhaust gas passage is subject to carbon deposition and the cooling water transit portion to scale deposition and these depositions gradually deteriorate the cooling of recirculated gas, thus resulting in higher gas temperatures and lower effective circulation amounts (EGR ratio).

To remove deposited carbon from the gas passage, use compressed air (0.19 MPa (2 kg/cm^2) or lower). Then dip the gas passage in carbon cleaner, kerosene, or some other liquid capable of removing carbon; leave it dry and blow it with compressed air again.

To clean the water transit portion, dip it in a solution of descaling detergent diluted with water and wash it.

■ EGR pipe and other connecting elbows

The exhaust gas passage is subject to carbon deposition when used over time. To remove deposited carbon from the gas passage, use compressed air (0.19 MPa (2 kg/cm^2) or lower). If the exhaust gas passage is heavily fouled, clean it by dipping it in carbon cleaner, kerosene, or some other liquid capable of removing carbon.

NOTICE

•Always be environmentally responsible.

- Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.
- Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.
- Failure to follow these procedures may seriously harm the environment.

■ Installing EGR related components/parts

To install these components/parts, reverse the disassembly procedure described above: thus install the lead valve, spacer, EGR valve, EGR pipe, EGR cooler, elbow, cooler cooling water hose, and EGR cooling water hose exactly in this order.

The EGR system uses steel gaskets at the joints between its components/parts. When you remove the system's components/parts and reinstall them, replace the steel gaskets between them with new correct ones.

■ Intake Throttle

The intake throttle is a device that controls the amount of the engine air intake. The TNV series engines use it for the combustion of soot collected inside the DPF. The intake throttle is driven by the DC motor. The ECU controls the appropriate degree of opening of the throttle depending on the engine speed and load conditions. Accordingly, the engine takes in the minimum required amount of air to increase the exhaust temperature and burn soot inside the DPF.

Check the operation performance of the intake throttle every 3000 hours of operation. It is necessary to connect SMARTASSIST DIRECT for the EGR valve cleaning. For details, refer to the SMARTASSIST DIRECT Operation Manual.

Precautions for handling the intake throttle

- Do not use a throttle after you have dropped it. Even if it appears okay on the outside, it may have internal damage.
- Do not apply excessive impact or load to the throttle.
- Do not touch the stop screw part, as it has already been adjusted.
- Prevent any foreign matter including oil, dust, and water droplets from entering the air passage part.
- Do not remove the sensor cover installation rivet.
- Consider static electricity and prevent static electric charge of the human body when handling the throttle.
- Do not touch the sensor cover terminal directly.
- Do not touch the throttle valve with your hands when the throttle is energized.
  Your hands may get pinched in the valve and get injured.
- Do not check operation with the installation surface of the throttle unit pointing down, as the valve protrudes from the installation surface.
- Prevent water and foreign matter from entering the connector connection part.

Characteristics of the intake throttle

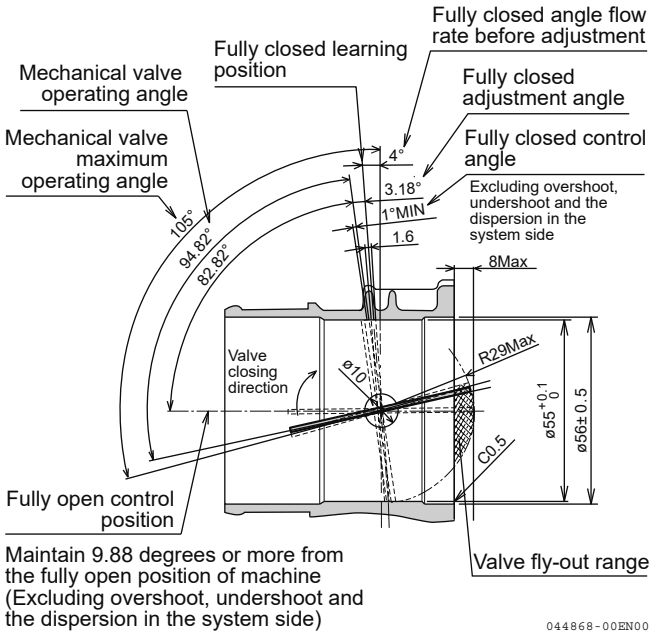


Figure 4-2-109

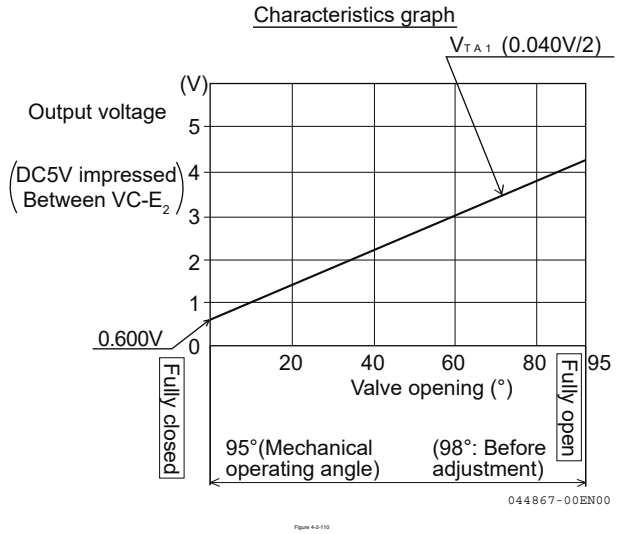


Figure 4-2-110

4. ENGINE

4-3 Fuel System

4-3-1 Before You Begin Servicing

Before performing any service procedures within this section, read the following safety information and review the *Safety Statements section on page 4-1-1*.

4-3-2 System Structure

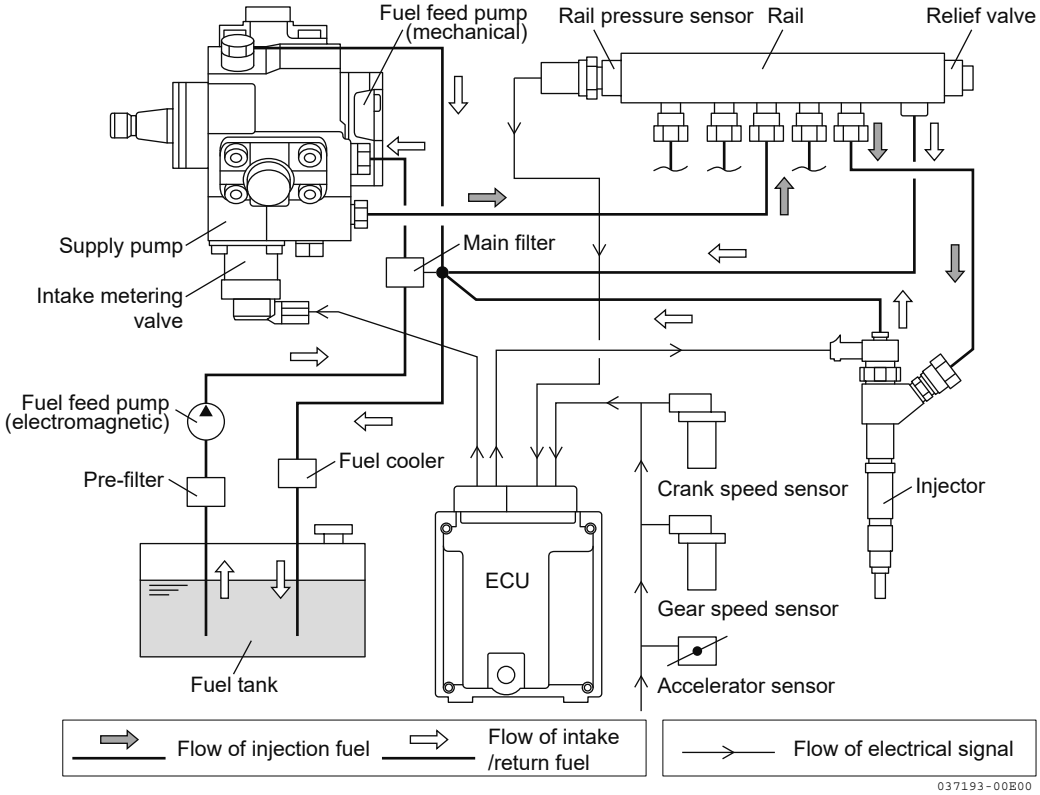


Figure 4-3-1

■ Supply pump

The fuel passes the pre-filter and is pressure-fed by a fuel feed pump to the main filter, then it arrives at the supply pump. The ECU controls the opening of the intake metering valve and adjusts the fuel intake volume so that the rail pressure is at the target value. The fuel pressurized in the supply pump is fed to the rail.

■ Rail

A pressure of up to 160 MPa is accumulated in the rail. The rail is equipped with a rail pressure sensor and it sends information to the ECU. In the case of an abnormal increase in the rail pressure, the mechanical relief valve opens to prevent the pressure increase.

■ Injector

The ECU controls the injector to maintain optimum injection volume and injection timing and injects the high pressure fuel accumulated in the rail into the cylinder.
Each injector has its unique correction data to optimize the injection volume. The correction data can be found on the top of the injectors. The correction data is written to the ECU, and the ECU corrects the injection volume based on the correction data. Therefore, it is necessary to write the correction data to the ECU when the injector or ECU is replaced. For details, refer to the SMARTASSIST DIRECT (SA-D) Operation Manual. Never touch the electric wiring with your hands when the key switch is in the “ON” position. High-voltage current flows in the injector.

■ Crank rotation sensor and gear speed sensor

The crank rotation sensor is equipped on the flywheel side and the gear speed sensor is equipped on the gear side. Based on these 2 sensor outputs, the ECU recognizes the engine speed and each piston position.

■ ECU

Based on the information from each sensor, ECU determines optimum injection volume, injection timing and rail pressure, and controls the intake metering valve of the supply pump and injector. It also monitors the occurrence of system abnormality at all times. If an abnormality is detected, it notifies the operator and controls the safe running condition of the system.

4-3-3 Fuel System Diagram

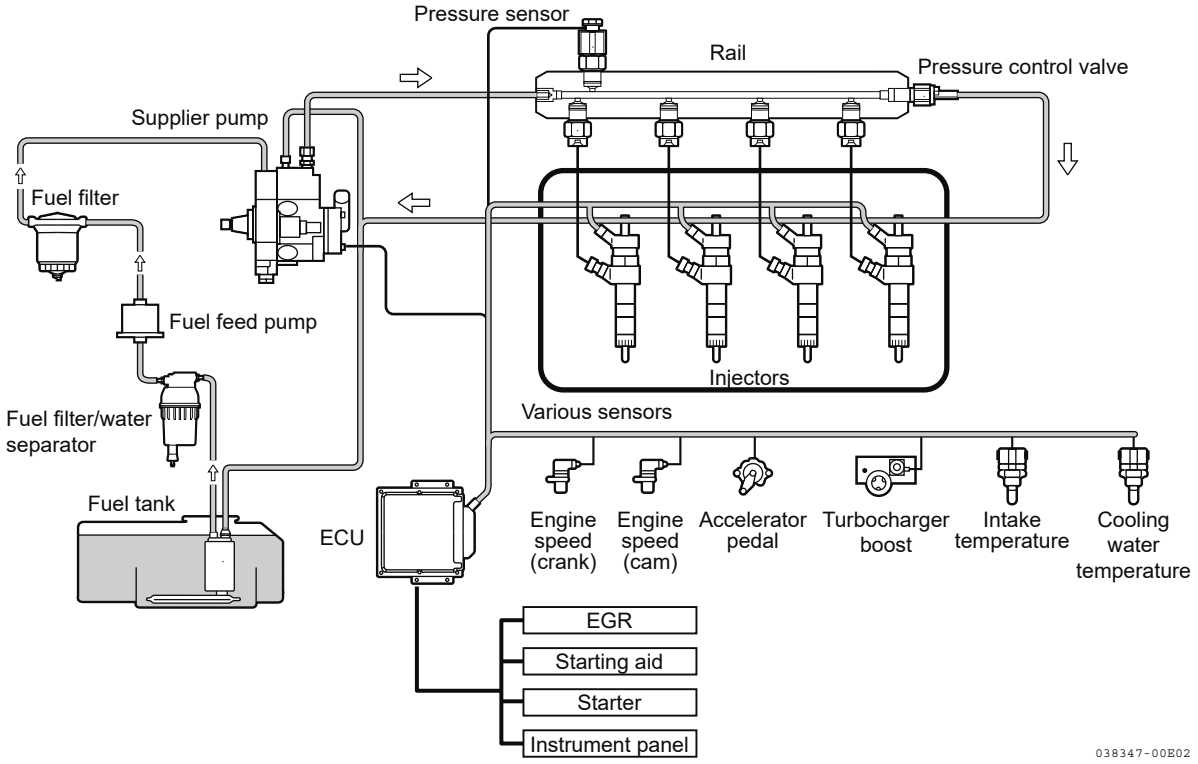
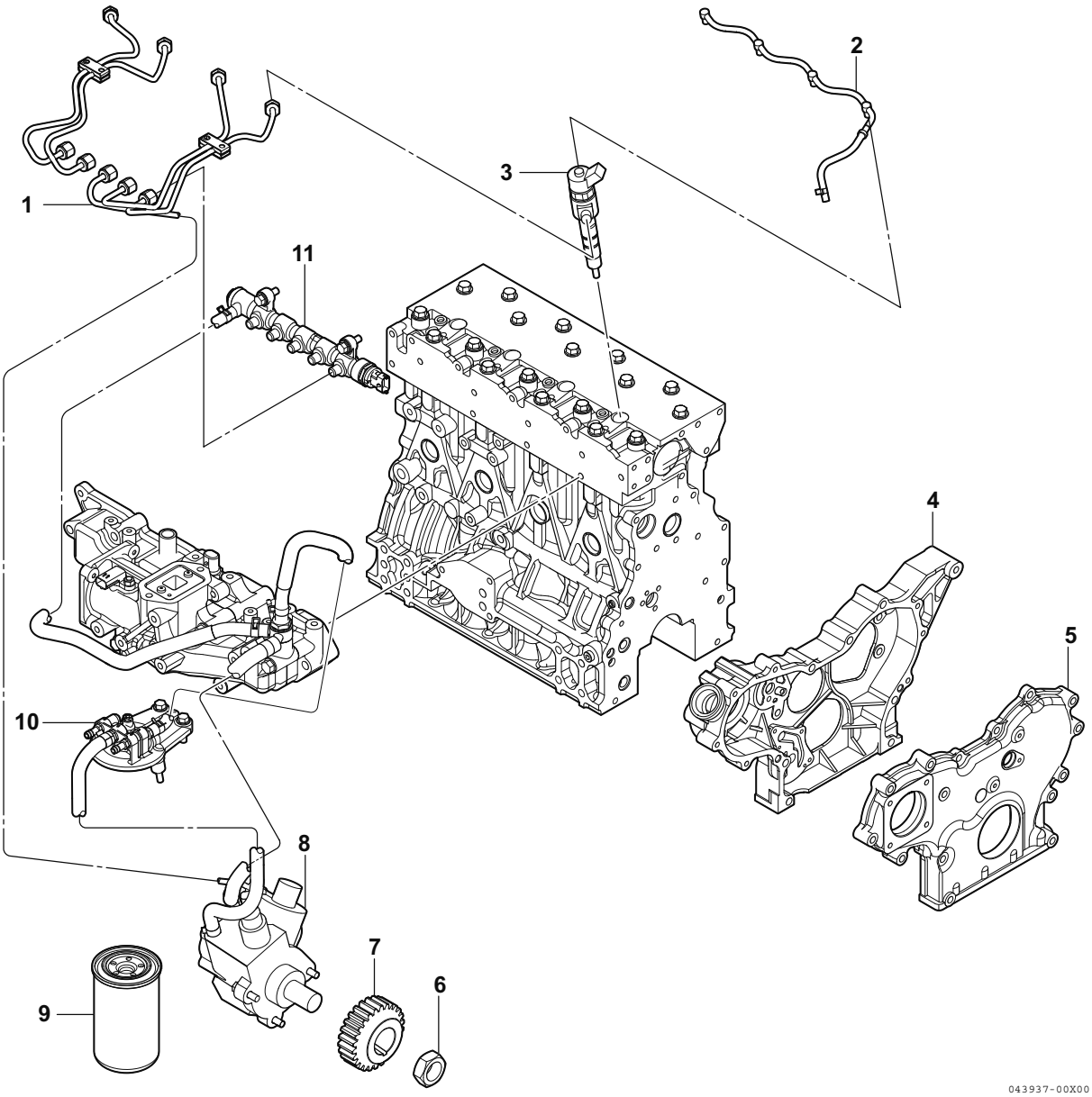


Figure 4-3-2

4-3-4 Fuel System Components



1 – High-pressure fuel injection lines
2 – Fuel return line
3 – Fuel injector
4 – Gear case
5 – Gear case cover
6 – Fuel supply pump drive gear nut
7 – Fuel supply pump drive gear
8 – Supply pump
9 – Fuel filter
10 – Fuel filter housing
11 – Common rail

Figure 4-3-3

Removal of Common Rail

1. Remove the wiring of the injector coupler on the injector.

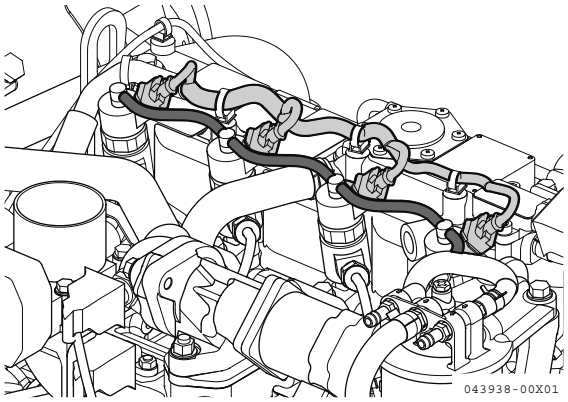


Figure 4-3-4

2. Remove the wiring coupler of the pressure sensor **(Figure 4-3-6, (3))**.

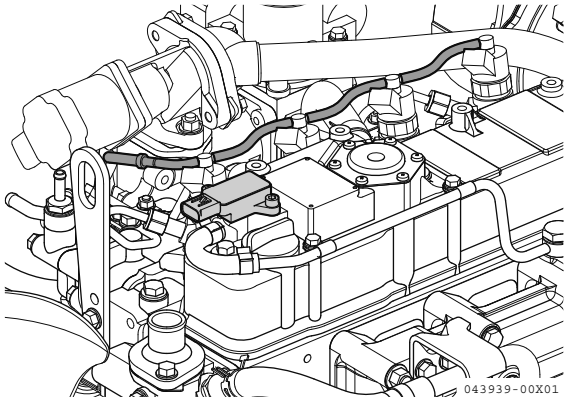


Figure 4-3-5

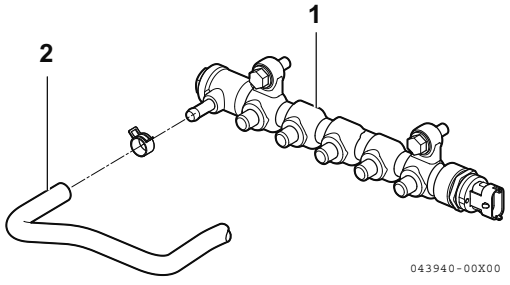


Figure 4-3-6

3. Remove the leak piping **(Figure 4-3-6, (2))** from the pressure limiter **(Figure 4-3-6, (1))**.

4. Remove the fuel return hose from the injector. Pull out the fuel return hose connector (back leak rail connector) **(Figure 4-3-7, (2))** vertically while fully pressing the retaining ring (clip) **(Figure 4-3-7, (1))** attached on the top of the injector in the direction of the arrow A **(Figure 4-3-7)**. Do not hold the hose. This may damage the hose. Do not reuse the removed clips.

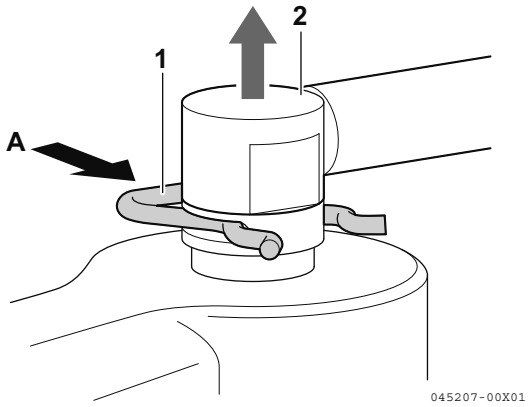


Figure 4-3-7

5. Removal of engine valve cover
Loosen the nuts and remove the engine valve cover.

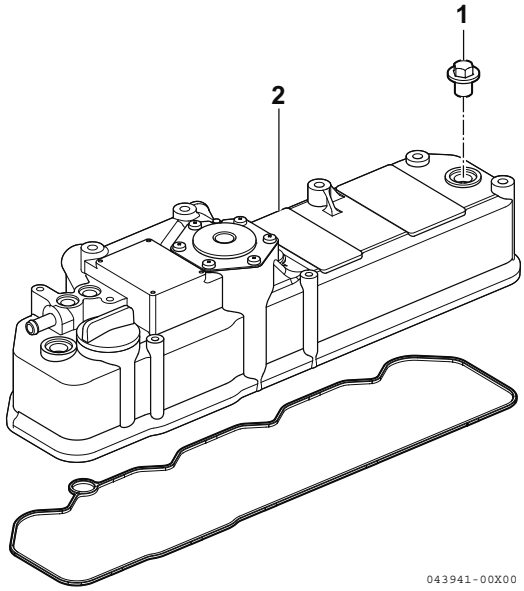


Figure 4-3-8

6. Removal of high-pressure pipe (1) (Common rail - injector)

   1- Clean around the cap nuts on both the injector and rail sides, using a brush or aspirator.

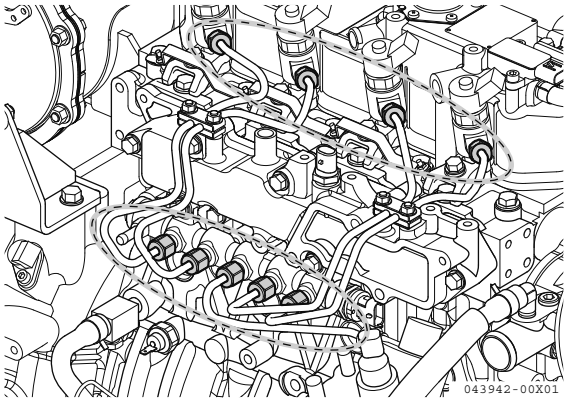


Figure 4-3-9

2- Press the pipe against the bearing surface by hand and loosen the cap nut while holding the pipe using a tool.

3- While pressing and holding the pipe against the bearing surface by hand, loosen and remove the cap nut by hand.

4- Remove the high-pressure pipe.

5- Clean the removed seat portions of the injector with an aspirator or the like and cover them with a vinyl bag.

7. Removal of high-pressure pipe (2)
(Supply pump - common rail)

1- Clean around the cap nuts on both the pump and rail sides, using a brush or aspirator.

2- Press the pipe against the bearing surface by hand and loosen the cap nut while holding the pipe using a tool.

3- While pressing and holding the pipe against the bearing surface by hand, loosen and remove the cap nut by hand.

4- Remove the high-pressure pipe.

5- Clean the removed seat portions of the rail inlet with an aspirator or the like and cover them with a vinyl bag.

8. Removal of common rail
Remove the 2 pieces of M8 bolts that attach the common rail, and remove the rail body.

NOTICE

- Loosen the bolts while securely holding the rail body by hand not to drop it.
- Hold the rail body without touching the sensors.

Reassembly of Common Rail

1. Reassembly of common rail body
Temporarily tighten the 2 pieces of M8 bolts by hand while securely holding the common rail body by hand. Then, tighten the bolts to specification.

Tightening torque for M8 bolts	16.7 - 20.9 ft·lb (22.6 - 28.4 N·m ; 2.3 - 2.9 kgf·m)

2. Reassembly of high-pressure pipe (1)
(Common rail - injector)

⚠ CAUTION

For high-pressure pipe, use a new one. If you reuse it, the displacement of the working face may occur, causing the fuel leaks.

1- Before reinstalling the high-pressure pipe, apply fuel to the cap nut thread portion.

2- Temporarily tighten the cap nuts (both the injector and rail sides) while pressing and fixing the seat portions.

3- Tighten the cap nuts to specification.

Tightening torque for cap nut (injector side)	19.5 - 23.2 ft·lb (26.5 - 31.4 N·m ; 2.7 - 3.2 kgf·m)
Tightening torque for cap nut (rail side)	21.7 - 25.3 ft·lb (29.4 - 34.3 N·m ; 3.0 - 3.5 kgf·m)

3. Reassembly of high-pressure pipe (2)
(Supply pump - common rail)

⚠ CAUTION

For high-pressure pipe, use a new one. If you reuse it, the displacement of the working face may occur, causing the fuel leaks.

1- Before reinstalling the high-pressure pipe, apply fuel to the cap nut thread portion.

2- Temporarily tighten the cap nuts (both the pump and rail sides) while pressing and fixing the seat portions.

3- Tighten the cap nuts to specification.

Tightening torque for cap nut (rail side)	21.7 - 25.3 ft·lb (29.4 - 34.3 N·m ; 3.0 - 3.5 kgf·m)
Tightening torque for cap nut (pump side)	

4. Be sure the new O-rings are installed on the valve cover nuts.
   Reinstall and tighten the valve cover nuts.
5. Press in the connector vertically from above while fully pressing the retaining ring of the injector in the direction of the arrow A. At this time, apply kerosene to the O-ring.

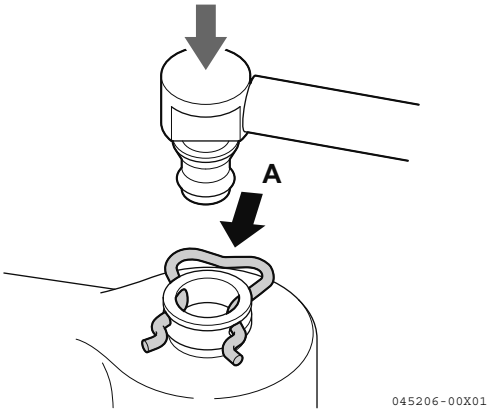


Figure 4-3-10

6. Reinstall the leak piping from the pressure limiter.

NOTICE

Do not reuse the gaskets.

---

7. Reinstall the wiring coupler of the pressure sensor.
8. Reinstall the injector wiring coupler.
9. Replace attached parts of the rail Spare parts for the rail pressure sensor **(Figure 4-3-11, (1))** and the pressure limiting valve **(Figure 4-3-12, (1))** are available for replacement. See the below table for the part number and the tightening torque.

Part name	Part No.	Tightening torque
Rail pressure sensor	129A00-57100	66.4 - 73.8 ft·lb (90 - 100 N·m ; 9.2 - 10.2 kgf·m)
Pressure limiting valve (with O-ring)	129A00-57200	70.1 - 77.4 ft·lb (95 - 105 N·m ; 9.7 - 10.7 kgf·m)
O-ring for pressure limiting valve	129A00-57210	–

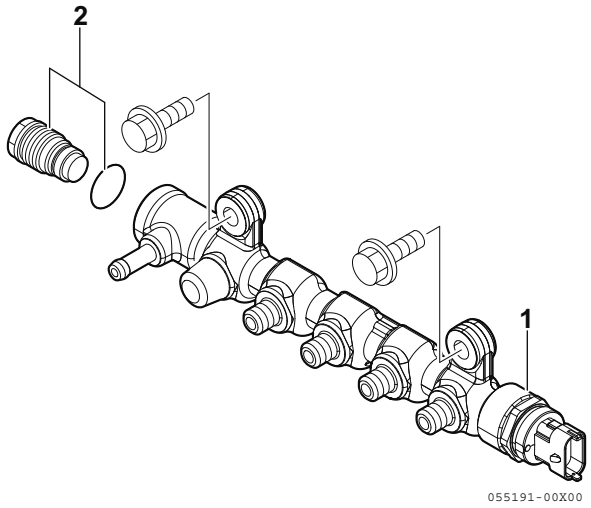


Figure 4-3-11

Removal of Injector

1. Remove the wiring of the injector coupler on the injector and move it to a place where it won't interfere the operation.
2. Remove the fuel return pipe.
   At this time, remove the fuel return pipe vertically while pressing the retaining ring.
3. Removal of high-pressure pipe (Common rail - injector)

⚠ CAUTION

For high-pressure pipe, use a new one. If you reuse it, the displacement of the working face may occur, causing the fuel leaks.

1- Clean around the cap nuts on both the injector and rail sides, using a brush or aspirator.

2- Press the pipe against the bearing surface by hand and loosen the cap nut while holding the pipe using a tool.

3- While pressing and holding the pipe against the bearing surface by hand, loosen and remove the cap nut by hand.

4- Remove the high-pressure pipe.

5- Clean the removed seat portions of the injector with an aspirator or the like and cover them with a vinyl bag.

4. Loosen the injector fixture retainer bolt (M8), and remove the retainer.
5. Remove the injector.

NOTICE

- Do not reuse the injector seats.
- Separate the injectors by each cylinder (mark them).
- Clean the removed injectors and cover them with a vinyl bag.
- Never disassemble the injector. If you change the injector to the new one must be changed with whole injector.

Reassembly of injector

1. Reassembly of injector
   Insert the injector into the head by using the new injector seat.

NOTICE

- If you reuse the injector, be sure to reinstall it to the original cylinder.
- When replacing the injector, replace it in the assembly.
- If you replace the injector, it is required to write the correction value of each injector to E-ECU.
- If rewriting is not correctly done, the engine performance cannot be guaranteed.
- Rewrite the correction value using SMARTASSIST DIRECT(SA-D).
- The correction value is written on the injector.

2. Reassembly of injector fixture retainer

1- Reinstall the injector fixture retainer. Temporarily tighten the bolt by hand at this time.

3. Reassembly of high-pressure pipe (Common rail - injector)

1- Before reinstalling the high-pressure pipe, apply fuel to the cap nut thread portion.

2- Temporarily tighten the cap nut (both the injector and rail sides) while pressing and fixing the seat portions.

4. Tighten the injector fixture retainer bolt to specification.

Tightening torque for M8 bolts	18.0 - 20.9 ft·lb (24.4 - 28.4 N·m ; 2.5 - 2.9 kgf·m)

5. Tighten the high-pressure pipe cap nut to specification.

Tightening torque for cap nuts (injector side)	19.5 - 23.2 ft·lb (26.5 - 31.4 N·m ; 2.7 - 3.2 kgf·m)
Tightening torque for cap nuts (rail side)	21.7 - 25.3 ft·lb (29.4 - 34.3 N·m ; 3.0 - 3.5 kgf·m)

6. Reinstall the fuel return pipe.

NOTICE

At this time, insert the fuel return pipe vertically while pressing the retaining ring. Apply light oil to the O-ring so that it does not roll up. (Do not use lubricating oil because alloys such as zinc are used.)

7. Reinstall the wire harness with the M4 nuts.

8. Reinstall the injector wiring coupler.

NOTICE

- If you replace the injector, it is required to write the correction value of each injector to E-ECU.
- If rewriting is not correctly done, the engine performance cannot be guaranteed.
- Rewrite the correction value using Yanmar Diagnostic Tool, SMARTASSIST DIRECT (SA-D).
- The correction value is written on the injector.
- Contact your authorized YANMAR dealer or distributor for replacement of the injector.
- If the correction value of the injector is not correctly written, not only the engine performance cannot be guaranteed, but the engine may also not comply with emission control regulations.

Removal of Supply Pump

1. Remove the wiring coupler of the fuel pressure sensor.
2. Remove the wiring coupler of the suction control valve (SCV).
3. Remove the fuel supply pipe (supply pump inlet) from the fuel filter (supply pump intake).

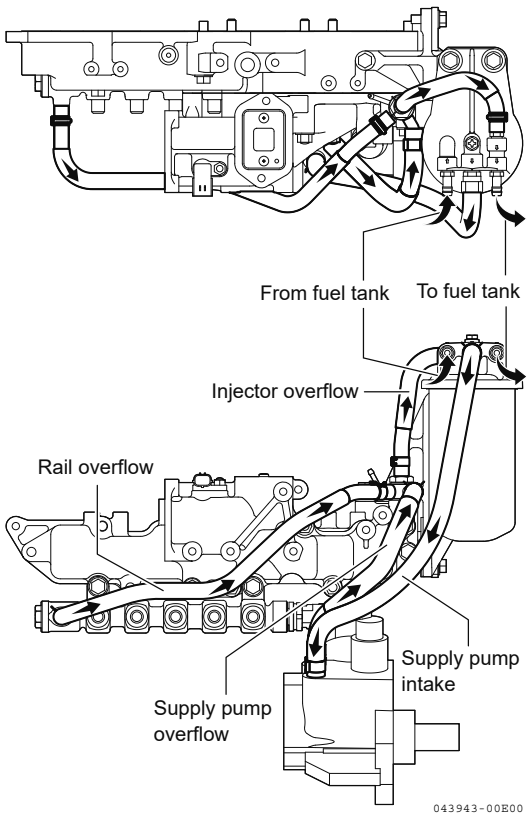


Figure 4-3-12

NOTICE

The fuel in the pipe may possibly spill at this time. Prepare a fuel container before its removal.

4. Remove the fuel return pipe (supply pump outlet) to the fuel filter (supply pump overflow).
5. Remove the return pipes from the common rail and injector (rail overflow and injector overflow).

NOTICE

Do not reuse either gasket.

6. Remove the fuel filter together with the mounting base from the engine as required.
7. Removal of high-pressure pipe (Supply pump - common rail)
   1- Clean around the cap nuts on both the pump and rail sides, using a brush or aspirator.
   2- Press the pipe against the bearing surface by hand and loosen the cap nut while holding the pipe using a tool.
   3- While pressing and holding the pipe against the bearing surface by hand, loosen and remove the cap nut by hand.
   4- Remove the high-pressure pipe.
   5- Clean the removed seat portions of the rail inlet with an aspirator or the like and cover them with a vinyl bag.
8. Remove the supply pump cover (drive gear) of the gear case.
9. Remove the supply pump drive gear nut (M18).

NOTICE

Be sure to put an alignment mark between the supply pump drive gear and the idle gear. Do not rotate the crankshaft of the engine after putting the mark.

10. Extract the supply pump drive gear by using the gear extraction tool.

NOTICE

Be sure to use the gear extraction tool.

11. Remove the supply pump nut (M8 - 3 pieces), and remove the supply pump.

NOTICE

- Never disassemble the supply pump.
- If you change the supply pump to the new one must be changed with whole pump.

Reassembly of Supply Pump

1. Reassembly of supply pump body
   Align the position of the supply pump drive shaft key (pin) to the drive gear position, and reinstall the supply pump to the gear case.
   Reinstall the supply pump with the 3 pieces of M8 nuts.

NOTICE

Be sure to apply oil to the O-ring at the time of installation so that is does not roll up.

Tightening torque for M8 nuts	16.7 - 20.9 ft·lb (22.6 - 28.4 N·m ; 2.3 - 2.9 kgf·m)

2. With the special M18 nuts, reinstall the supply pump drive gear to the supply pump drive shaft.

Tightening torque for M18 nut	55.3 - 62.7 ft·lb (75 - 85 N·m ; 7.7 - 8.7 kgf·m)

NOTICE

Make sure that the alignment mark with the idle gear is not misaligned.

NOTICE

Make sure that painting does not get into the coupler while reinstalling the coupler.

3. Reinstall the supply pump cover

Tightening torque for M8 bolts	16.7 - 20.9 ft·lb (22.6 - 28.4 N·m ; 2.3 - 2.9 kgf·m)

4. Reassembly of high-pressure pipe (Supply pump - common rail)

⚠ CAUTION

For high-pressure pipe, use a new one. If you reuse it, the displacement of the working face may occur, causing the fuel leaks.

1- Before reinstalling the high-pressure pipe, apply fuel to the cap nut thread portion.

2- Temporarily tighten the cap nuts (both the pump and rail sides) while pressing and fixing the seat portions.

3- Tighten the cap nuts to specification.

Tightening torque for cap nuts (rail side)	21.7 - 25.3 ft·lb (29.4 - 34.3 N·m ; 3.0 - 3.5 kgf·m)
Tightening torque for cap nuts (pump side)	

5. Reinstall the fuel filter (M10 - 2 pieces).

Tightening torque for M10 bolts	25.8 - 31.7 ft·lb (35 - 43 N·m ; 3.6 - 4.4 kgf·m)

6. Reinstall the common rail and the return pipe from the injector.
7. Reinstall the return pipe from the supply pump.
8. Reinstall the fuel supply pipe (supply pump inlet) from the fuel filter.
9. Reinstall the wiring coupler of the fuel temperature sensor.
10. Reinstall the wiring coupler of the SCV.

NOTICE

Be sure to perform priming the engine before starting. If air is mixed to the fuel, seizure to the supply pump and the injector may result.

11. Replace attached parts of the supply pump Spare parts for the fuel temperature sensor **(Figure 4-3-13, (1))** and the fuel metering valve (suction control valve) **(Figure 4-3-13, (2))** are available for replacement. See the below table for the part number and the tightening torque.

Part name	Part No.	Tightening torque
Fuel temperature sensor (with gasket)	129A00-51200	19.2 - 22.1 ft·lb (26 - 30 N·m ; 2.7 - 3.1 kgf·m)
Fuel metering valve (suction control valve) (with seal ring and O-ring)	129A00-51100	2.2 - 3.0 ft·lb (3.0 - 4.0 N·m ; 0.31 - 0.41 kgf·m)
Fuel metering valve seal ring	129A00-51110	-
Fuel metering valve O-ring	129A00-51120	-
Fuel metering valve fixing bolt	129A00-51130	-

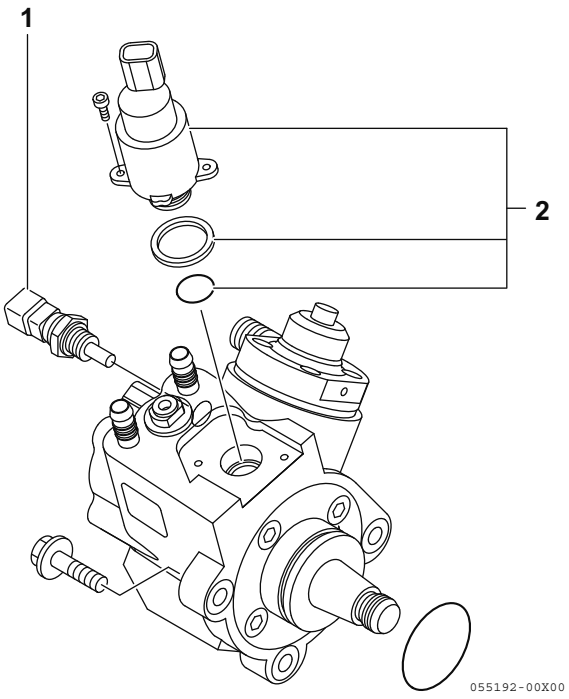


Figure 4-3-13

4-4 Cooling System

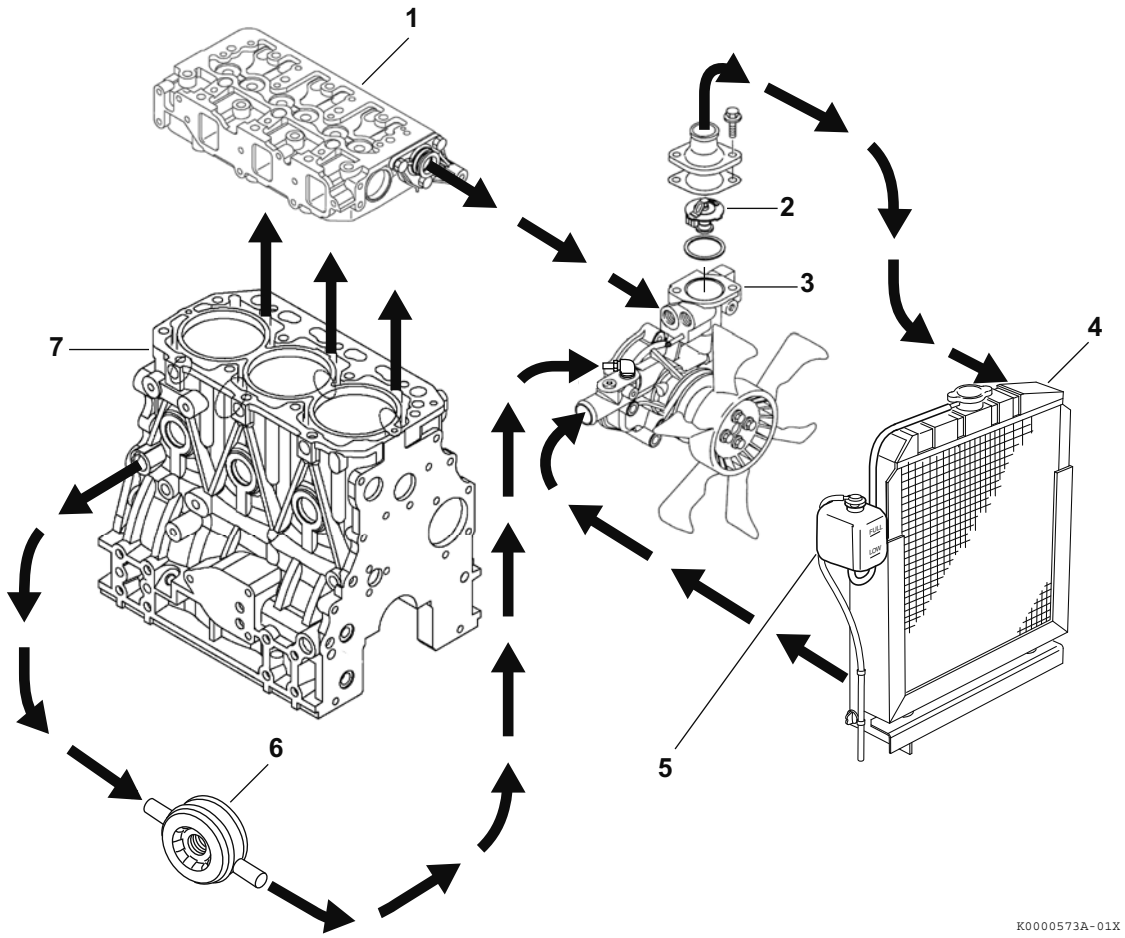
4-4-1 Before You Begin Servicing

Before performing any service procedures within this section, read the following safety information and review the *Safety Statements* section on page *4-1-1*.

4-4-2 Introduction

This section of the Service Manual describes the procedures necessary to service the TNV engine coolant pump. This engine coolant pump is representative of the coolant pumps used on other TNV model engines. For specific part detail, see the parts catalog for the engine you are working on.

4-4-3 Cooling System Diagram

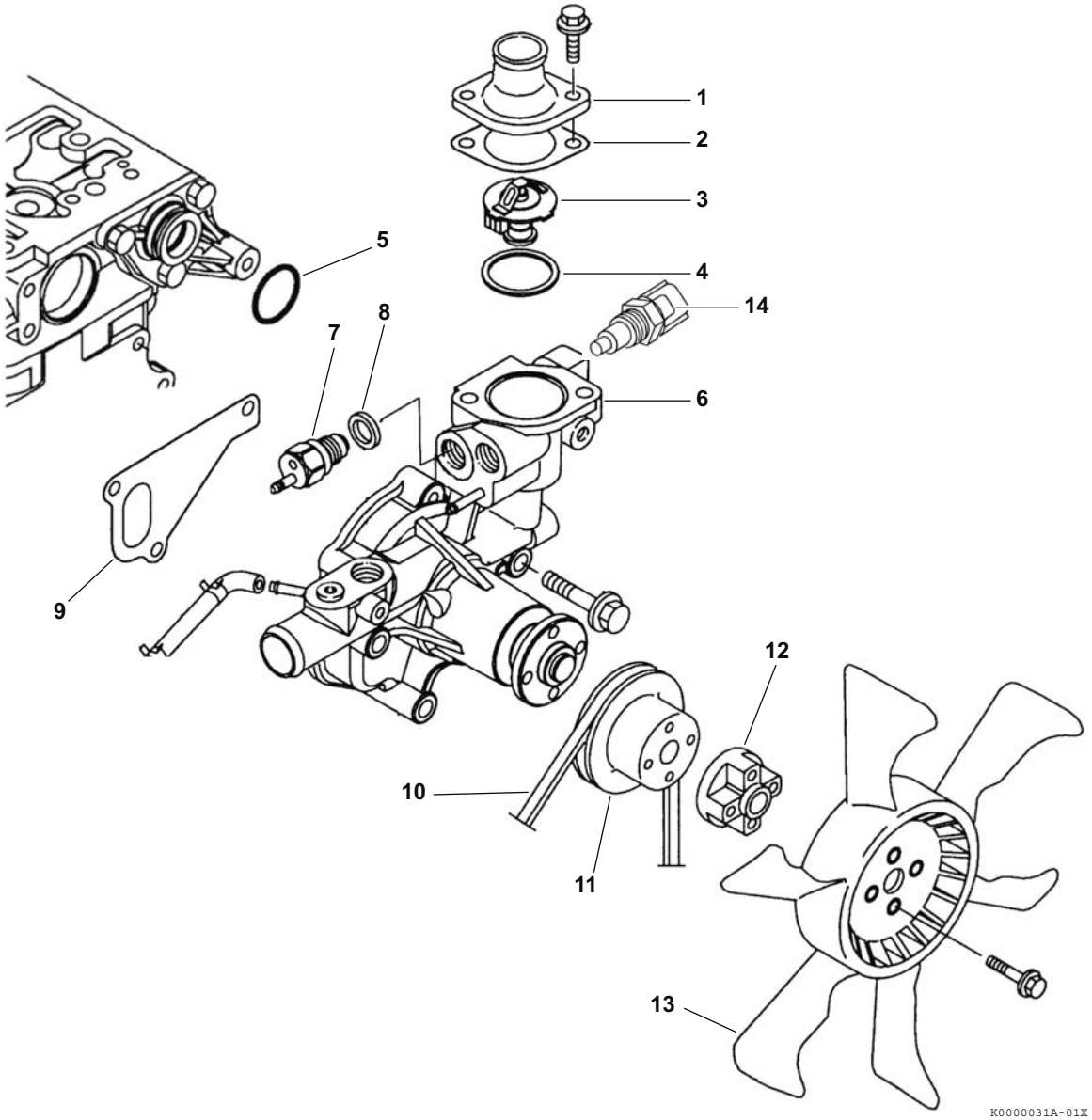


1 – Cylinder head
2 – Thermostat
3 – Engine coolant pump
4 – Radiator
5 – Coolant recovery tank
6 – Engine oil cooler*1
7 – Cylinder block

Figure 4-4-1

**1 Not standard on all models.*

4-4-4 Engine Coolant Pump Components



1 – Thermostat cover
2 – Thermostat cover gasket
3 – Thermostat
4 – Thermostat O-ring
5 – Special O-ring
6 – Engine coolant pump
7 – Temperature switch
8 – Gasket
9 – Engine coolant pump gasket
10 – V-belt
11 – Engine coolant pump V-pulley
12 – Spacer
13 – Engine coolant fan
14 – Water temperature sensor (Electronically controlled engine)

Figure 4-4-2

4-4-5 Engine Coolant System Check

Check the engine coolant system for leakage.

1. With the radiator properly filled, install a cooling system tester **(Figure 4-4-3, (1))**.

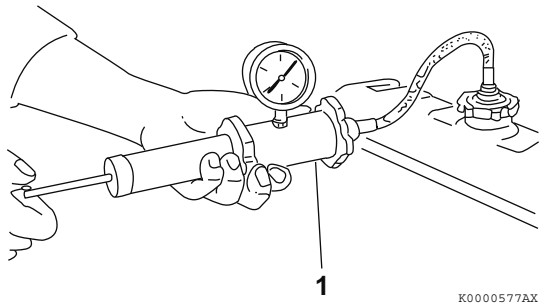


Figure 4-4-3

2. Apply 10.8 - 14.8 psi (75 - 105 kPa; 0.75 - 1.05 kgf/cm²) to the cooling system. If the pressure reading drops, the engine coolant system is leaking. Identify the source of the leak and repair it.

4-4-6 Engine Coolant Pump

Removal of Engine Coolant Pump

Verify the condition of the engine coolant pump before disassembling it from the engine. Check the engine coolant pump shaft bearing for abnormal noise, sticking, excessive play and water leakage. Replace the coolant pump if any of these conditions are present.

⚠ CAUTION

Pinch Hazard!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

NOTICE

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.

NOTICE

Make sure the engine and engine coolant are not hot.

---

1. Before removing the engine coolant pump or thermostat, it will be necessary to drain the engine coolant. Drain the coolant into a clean container if the coolant is to be reused. Otherwise, properly dispose of the coolant.
2. Remove the radiator cap **(Figure 4-4-4, (1))**.
3. Remove the drain plug or open the drain cock **(Figure 4-4-4, (2))** at the lower portion of the radiator and drain the coolant.

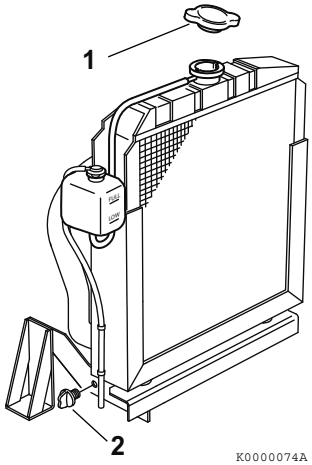


Figure 4-4-4

4. Drain the coolant from the engine block.
   - On models equipped with an oil cooler, remove the coolant hose **(Figure 4-4-5, (1))** at the oil cooler.

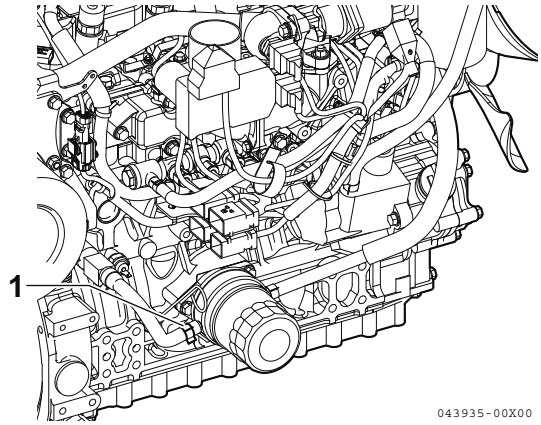


Figure 4-4-5

   - On models not equipped with an oil cooler, remove the coolant drain plug **(Figure 4-4-6, (1))** from the engine block.

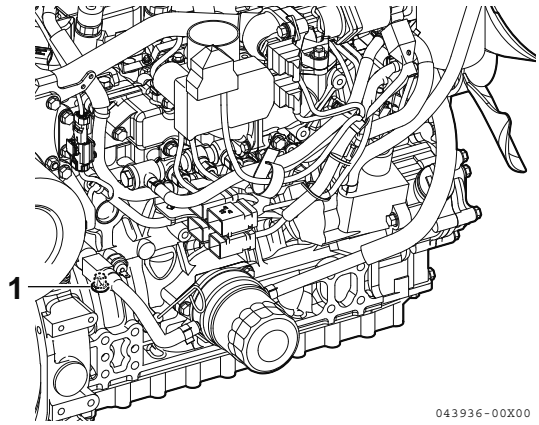


Figure 4-4-6

5. Loosen the alternator mounting bolts. Loosen and remove the V-belt and rotate the alternator away from the engine and out of the way.
6. Remove the engine coolant fan guard (if equipped), engine coolant fan **(Figure 4-4-7, (1))**, spacer **(Figure 4-4-7, (2))** and engine coolant pump V-pulley **(Figure 4-4-7, (3))**.

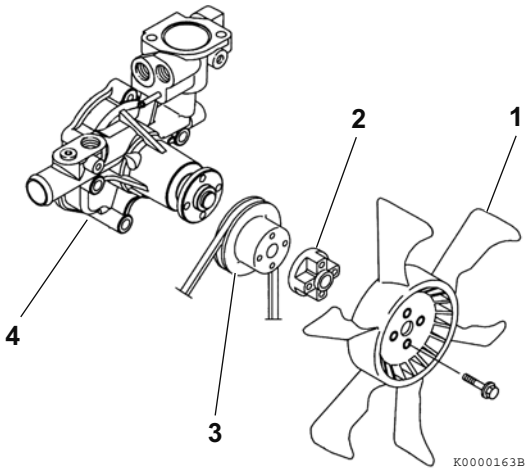


Figure 4-4-7

7. Disconnect the coolant hoses and the temperature switch lead wire from the engine coolant pump.
8. Remove the engine coolant pump **(Figure 4-4-7, (4))**. Discard the gasket.

Disassembly of Engine Coolant Pump

1. Remove the thermostat cover **(Figure 4-4-8, (1))**. Discard the gasket.

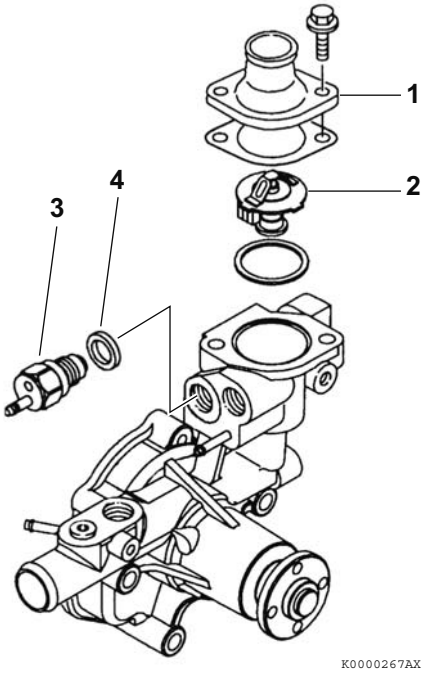


Figure 4-4-8

2. Remove the thermostat **(Figure 4-4-8, (2))**. Discard the O-ring. Remove the temperature switch **(Figure 4-4-8, (3))** and gasket **(Figure 4-4-8, (4))**. Discard the gasket.

Cleaning and Inspection

■ Temperature switch

1. Check for proper operation of the temperature switch. Connect a continuity light or ohmmeter to the temperature switch. Connect one lead to the terminal of the switch **(Figure 4-4-9, (1))** and the other lead to the metal portion of the switch **(Figure 4-4-9, (2))**.

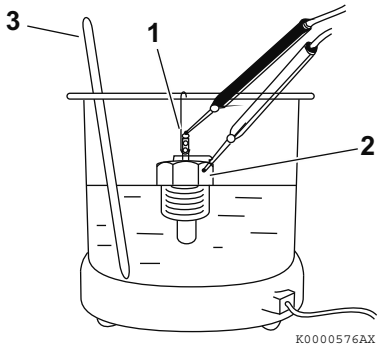


Figure 4-4-9

2. Place the temperature switch and an accurate thermometer **(Figure 4-4-9, (3))** in engine coolant.
3. Slowly increase temperature of the fluid using an external heat source.
4. The temperature switch is operating properly if the continuity light or ohmmeter indicates continuity when the fluid temperature reaches 225 °F - 235 °F (107 °C - 113 °C).

■ Water temperature sensor

1. Inspect the water temperature sensor to make sure that it is properly operating. As shown in the following figure, connect an electric resistor to the coupler of the water temperature sensor **(Figure 4-4-10, (1))**.

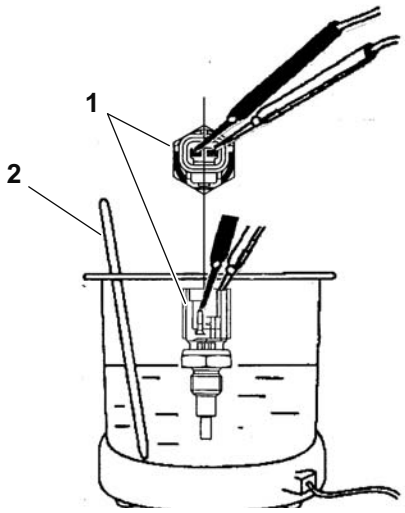


Figure 4-4-10

2. Dip the water temperature sensor and an accurate thermometer **(Figure 4-4-10, (2))** into the cooling water.
3. Measure the electric resistance value while slowly raising the cooling water temperature using an external heat source.
4. The resistance value at each of the following temperatures is within the permissible range specified, the water temperature sensor is correctly operating.

Cooling water temperature (°C)	Resistance (kΩ)
20	$2.45^{+0.14}_{-0.13}$
80	0.318 ± 0.008
100	(0.1836)

■ Thermostat

1. Check for proper operation of the thermostat. Place the thermostat **(Figure 4-4-11, (1))** and an accurate thermometer **(Figure 4-4-11, (2))** in warm water.

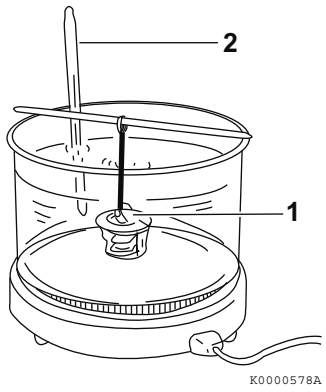


Figure 4-4-11

2. Slowly increase the temperature of the water using an external heat source.
3. The thermostat is operating properly if it starts to open at the temperature value stamped on the flange of the thermostat, and fully opens as the temperature of the water is increased.

■ Radiator cap

1. Check for proper operation of the radiator cap. Install the radiator cap **(Figure 4-4-12, (1))** on a cooling system tester.

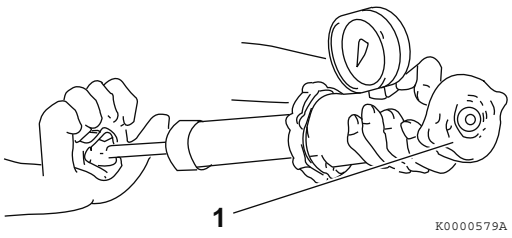


Figure 4-4-12

2. Apply 10.8 - 14.8 psi (75 - 105 kPa; 0.75 - 1.05 kgf/cm²) to the radiator cap. The radiator cap relief valve must open within the specified range.

Reassembly of Engine Coolant Pump

1. Reinstall the thermostat **(Figure 4-4-13, (1))** and a new O-ring.

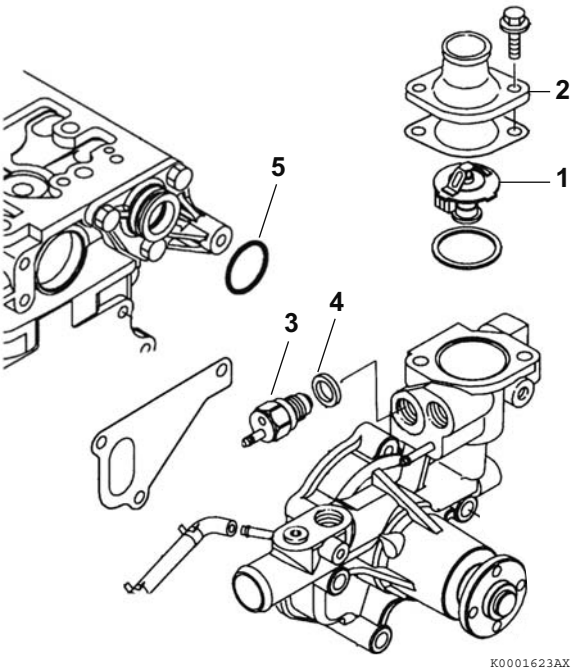


Figure 4-4-13

2. Reinstall the thermostat cover **(Figure 4-4-13, (2))** and a new gasket. Tighten the thermostat cover bolts.
3. Reinstall the temperature switch **(Figure 4-4-13, (3))** and a new gasket **(Figure 4-4-13, (4))**.

Installation of Engine Coolant Pump

1. Position the engine coolant pump on the engine and install a new gasket. Install a new special O-ring **(Figure 4-4-13, (5))** on assembly between the engine coolant pump and the joint.

NOTICE

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.

2. Reinstall the engine coolant pump bolts. Tighten the bolts.
3. Inspect and reinstall the coolant hoses and the temperature switch lead wire.
4. Reinstall the engine coolant pump V-pulley **(Figure 4-4-14, (1))**, spacer **(Figure 4-4-14, (2))** engine coolant fan **(Figure 4-4-14, (3))** and engine coolant fan guard (if equipped).

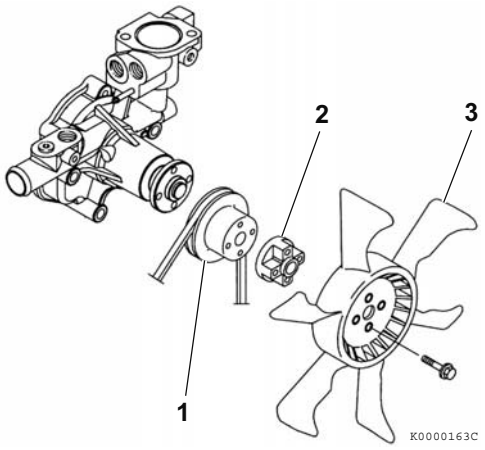


Figure 4-4-14

5. Inspect the condition of the V-belt. There must be clearance **(Figure 4-4-15, (1))** between the V-belt and the bottom of the pulley groove. If there is no clearance **(Figure 4-4-15, (2))** between the V-belt and the bottom of the pulley groove, replace the V-belt.

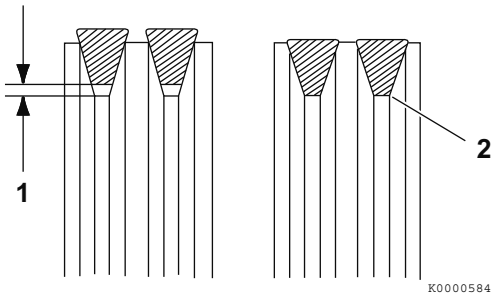


Figure 4-4-15

6. Reinstall the V-belt. Tighten the V-belt to the proper tension.
7. Reinstall and tighten the drain plug or close the drain cock in the radiator. Reinstall and tighten the engine block drain plug or reconnect the coolant hose at the oil cooler.
8. Fill the radiator and engine with engine coolant.

NOTICE

- Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and/or shorten engine life.
- Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.
- Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

4-5 Lubrication System

4-5-1 Before You Begin Servicing

Before performing any service procedures within this section, read the following safety information and review the *Safety Statements* section on page *4-1-1*.

4-5-2 Introduction

This section of the Service Manual describes the procedures necessary to service the 4TNV98C Trochoid oil pumps.

4-5-3 Lubrication System Diagram

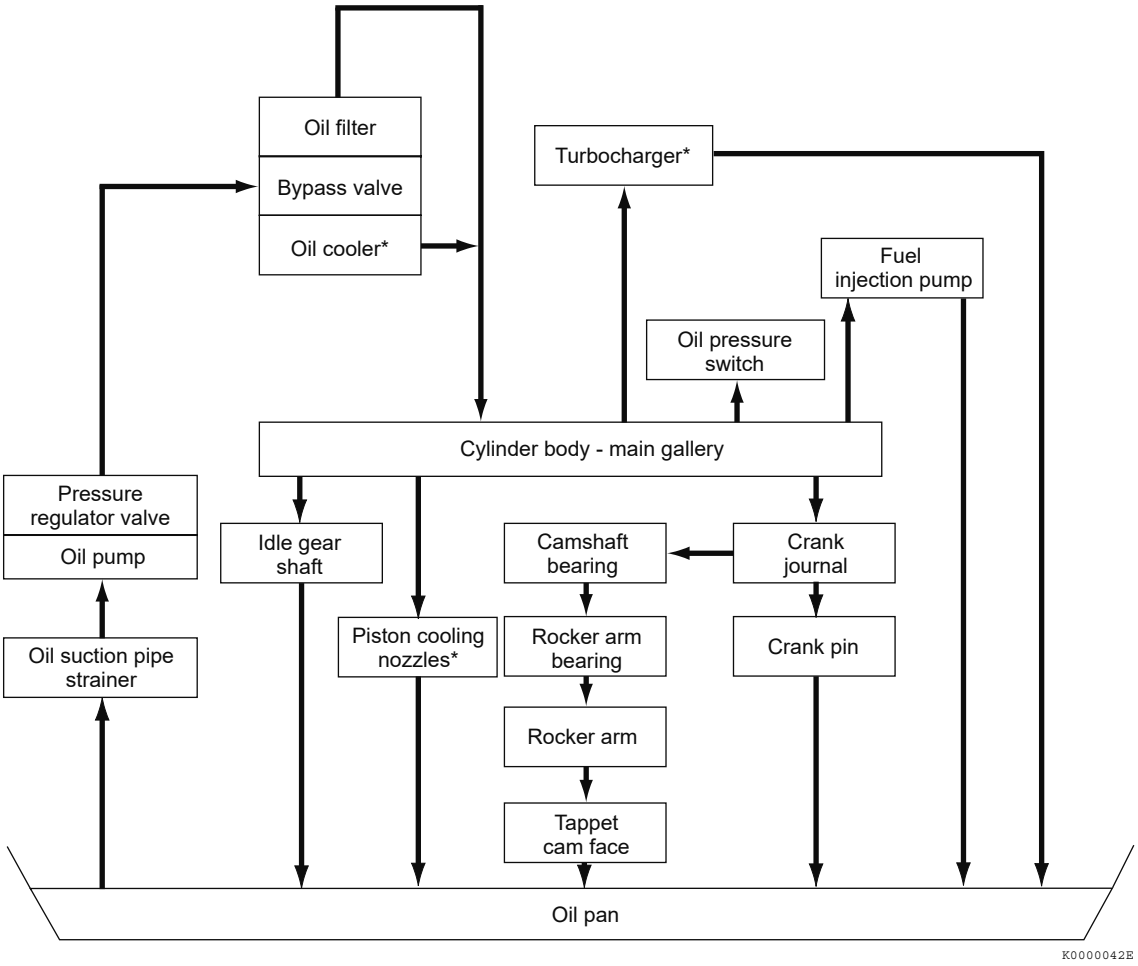


Figure 4-5-1

Note: Items marked are not standard equipment on all models.*

4-5-4 Checking Engine Oil Pressure

Perform an engine oil pressure check if there is any indication of low oil pressure such as the oil pressure indicator is on or the oil pressure gauge indicates low oil pressure.

1. Disconnect the wire lead from the oil pressure switch or sending unit **(Figure 4-5-2, (1))**.

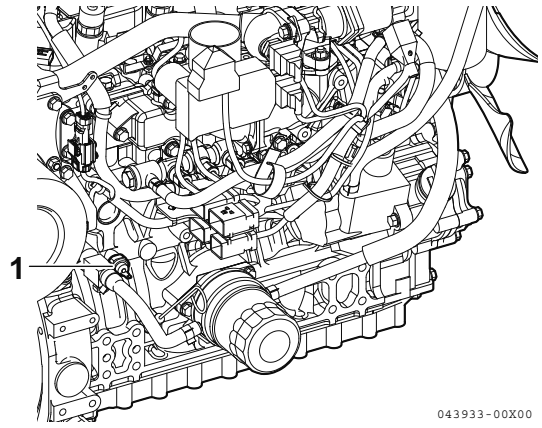


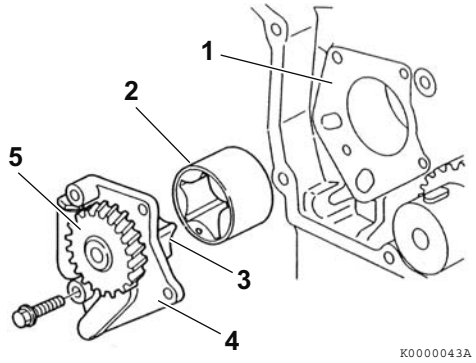
Figure 4-5-2

2. Remove the oil pressure switch.
3. Install a mechanical oil pressure gauge in the oil pressure switch port.
4. Start the engine:
   - If the mechanical oil pressure test gauge indicates good oil pressure, replace the faulty oil pressure switch or sending unit, or faulty machine oil pressure gauge in instrument panel.
   - If the mechanical oil pressure test gauge indicates low oil pressure, troubleshoot the lubrication system to locate the cause of the low oil pressure. *See Failure Diagnostic List on page 4-10-5.* Repair as necessary.

4-5-5 Oil Pump Components

4TNV98C (Trochoid Oil Pump)

The oil pump on these model engines is located in the front gear case and is driven by the same gear train that drives the camshaft and fuel injection pump. You must remove the front gear case cover to gain access to the oil pump.



1 – Gear case housing
2 – Outer rotor
3 – Inner rotor
4 – Cover plate
5 – Drive gear

Figure 4-5-3

Disassembly of Oil Pump

NOTICE

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

Remove the engine cooling fan guard (if equipped), engine cooling fan **(Figure 4-5-4, (3))**, spacer **(Figure 4-5-4, (2))**, engine coolant pump V-pulley **(Figure 4-5-4, (1))** and V-belt.

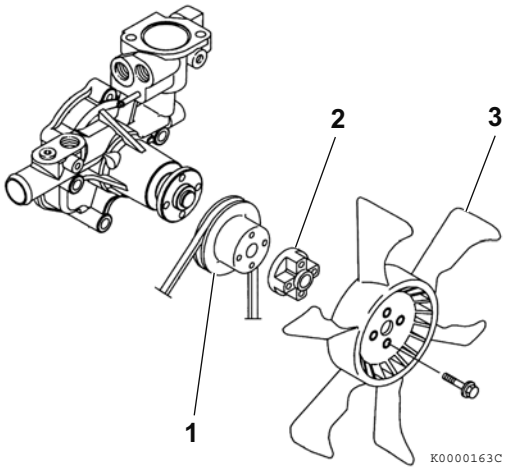


Figure 4-5-4

1. Remove the crankshaft pulley and the gear case cover. *See Removal of timing gear case cover on page 4-2-26.*
2. Remove the oil pump assembly bolts. Remove the oil pump assembly **(Figure 4-5-5, (1))** from the gear case housing **(Figure 4-5-5, (2))**.

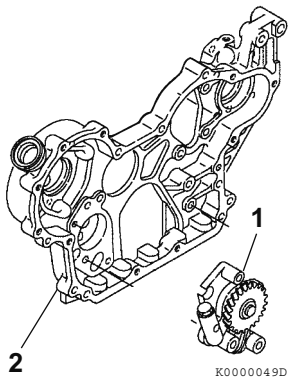


Figure 4-5-5

Cleaning and Inspection

Wash the oil pump, oil pressure regulator and oil pump cavity. Inspect for wear or damage. Replace as necessary.

NOTICE

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.

■ Check outer rotor outside clearance

Determine the outside clearance of the outer rotor. Insert a feeler gauge between the outer rotor **(Figure 4-5-6, (1))** and gear case oil pump cavity **(Figure 4-5-6, (2))**.

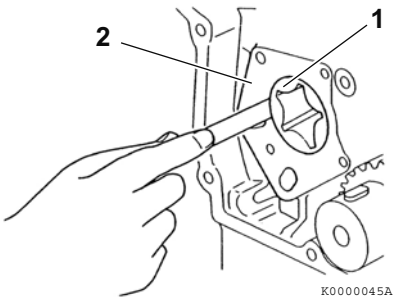


Figure 4-5-6

Record the measurement(s) and see "3-2 Engine Service Standard" section for the service limit.

■ Outer rotor to inner rotor tip clearance

Determine the outer rotor to inner rotor tip clearance. Insert a feeler gauge between the top of an inner rotor tooth **(Figure 4-5-7, (1))** and the top of an outer rotor tooth **(Figure 4-5-7, (2))** and measure the clearance.

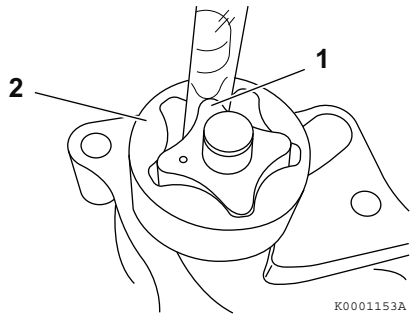


Figure 4-5-7

Record the measurement(s) and see "3-2 Engine Service Standard" section for the service limit.

■ Check outer rotor side clearance

Determine the side clearance of the outer rotor across the pump cavity. Measure the depression using a depth micrometer **(Figure 4-5-8, (1))**.

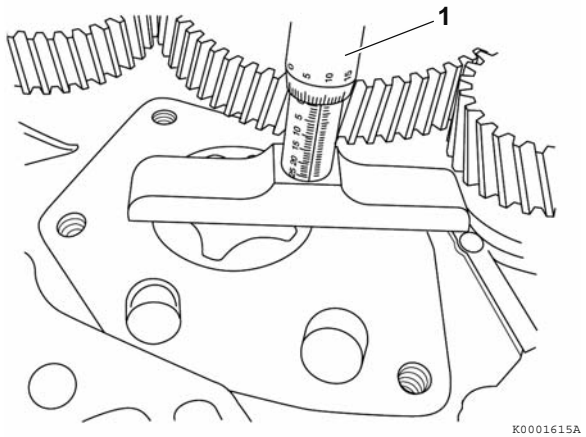


Figure 4-5-8

Record the measurement(s) and see "3-2 Engine Service Standard" section for the service limit.

■ Check rotor shaft clearance

Determine the rotor shaft clearance. Measure the outside diameter of the rotor shaft **(Figure 4-5-9, (1))** and the bore diameter in the gear case housing **(Figure 4-5-9, (2))**.

Calculate the difference between the two measurements to determine the clearance.

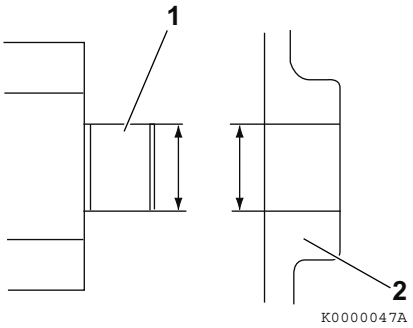


Figure 4-5-9

Record the measurement(s) and see "3-2 Engine Service Standard" section for the service limit.

Reassembly of Oil Pump

1. Lubricate the outer rotor and pump bore in the gear case with clean engine oil.
2. Reinstall the outer rotor in the gear case housing. The punch mark **(Figure 4-5-10, (1))** on the end of the outer rotor must face away from the gear case housing **(Figure 4-5-10, (2))**.

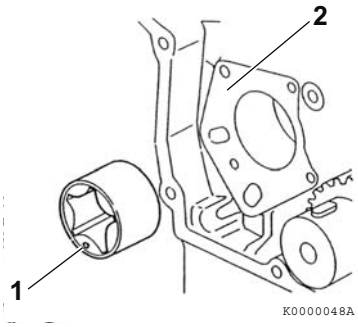


Figure 4-5-10

3. Reinstall the oil pump assembly **(Figure 4-5-11, (1))** into the gear case housing **(Figure 4-5-11, (2)**. Tighten the bolts to specified torque.

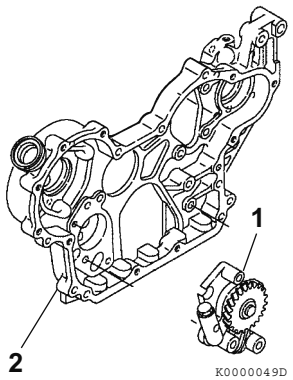


Figure 4-5-11

4. Reinstall the gear case cover and crankshaft pulley. *See Installation of gear case cover on page 4-2-47.*
5. Reinstall the engine coolant pump V-pulley **(Figure 4-5-12, (1))**, spacer **(Figure 4-5-12, (2))**, engine cooling fan **(Figure 4-5-12, (3))** and engine cooling fan guard (if equipped).

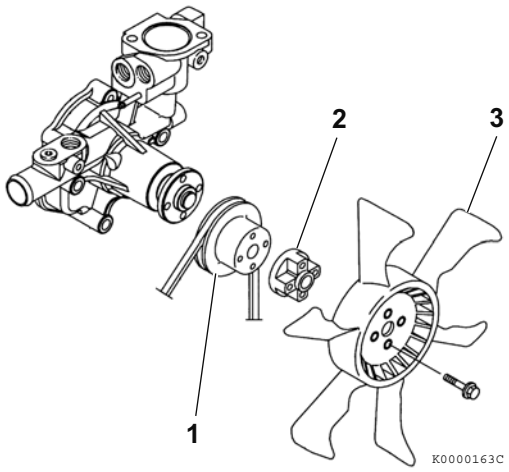


Figure 4-5-12

6. Reinstall the V-belt. Tighten the V-belt to the proper tension.

4-6 Starter Motor

4-6-1 Before You Begin Servicing

Before performing any service procedures within this section, read the following safety information and review the *Safety Statements* section on page *4-1-1*.

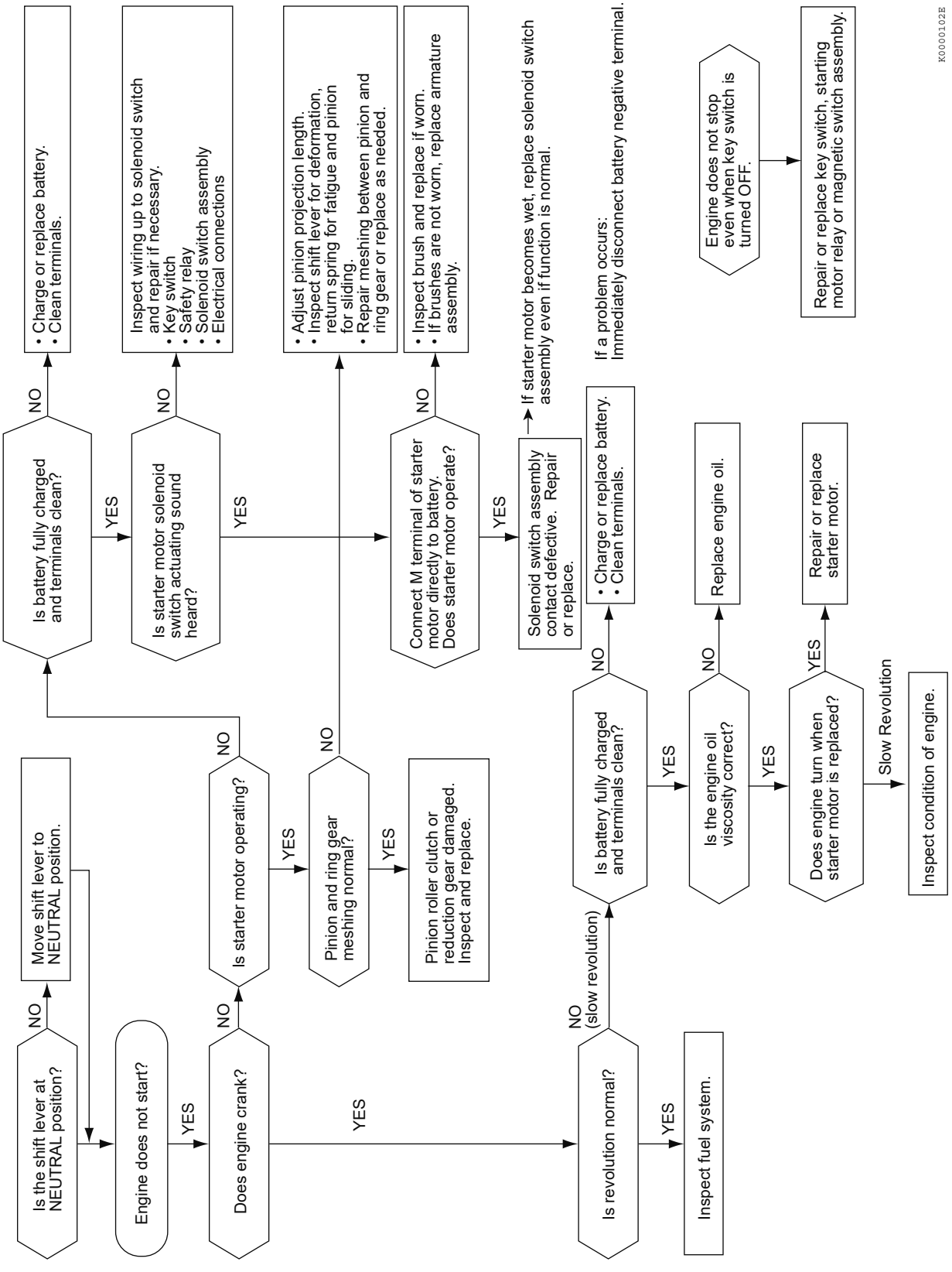
4-6-2 Introduction

This section of the Service Manual covers the servicing of the starter motor. YANMAR Part No. 129900-77010 is typical equipment on 4TNV98C model engines and is used in this section to show the service procedures for a representative starter motor. For specific part detail, see the *YANMAR Parts Catalog* for the engine you are working on.

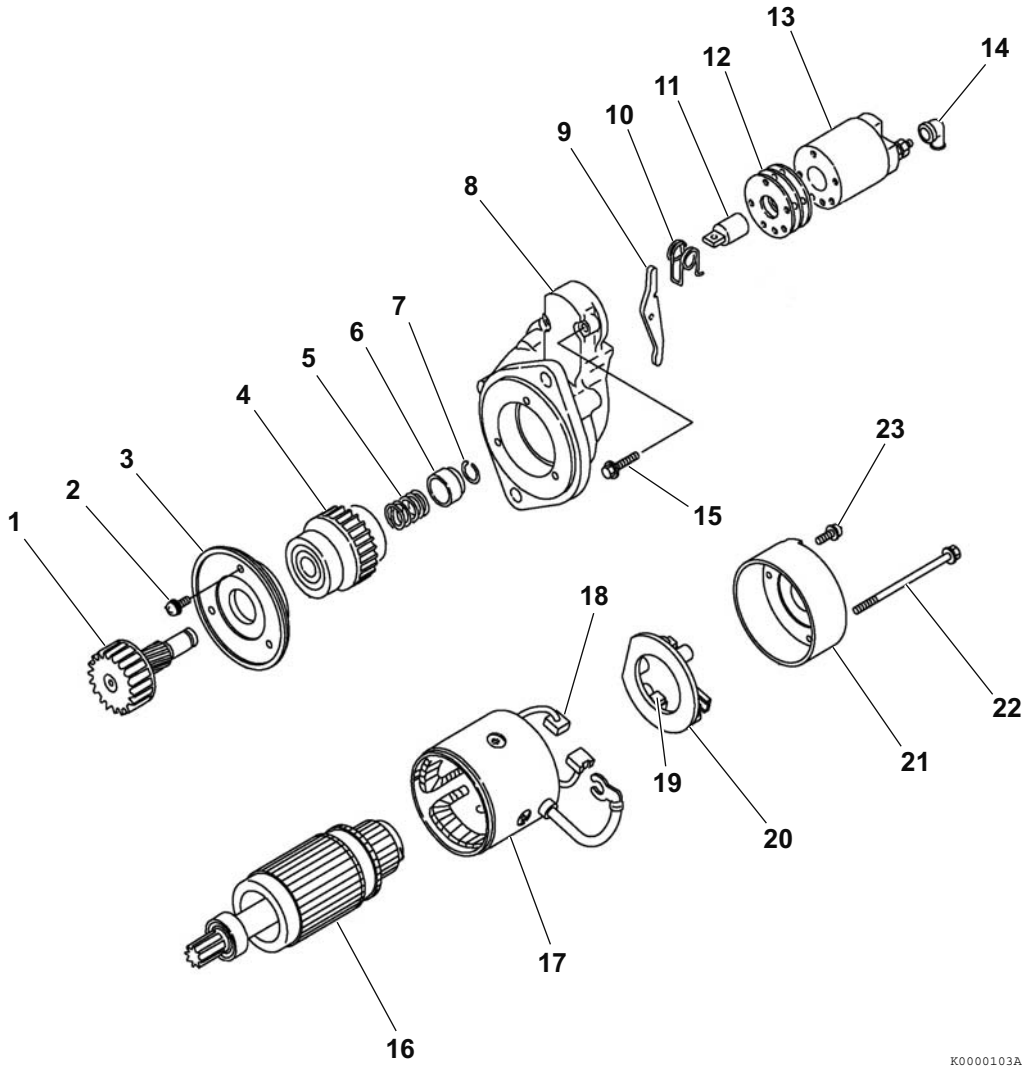
4-6-3 Starter Motor Specifications

Yanmar Part Number			129940-77011
Mfg. Part Number			S14-102 (HITACHI)
Nominal Output			4.0 HP (3.0 kW)
Weight			14.3 lbs (6.5 kg)
Revolution Direction (As Viewed From Pinion)			Clockwise
Engagement System			Magnetic Shift
No-load	Terminal Voltage / Current		12 V / 160 A or less
	Revolution		3600 rpm (min^{-1}) and over
Loaded	Terminal Voltage / Current		3.0 V / 1300 A or less
	Torque		19.5 ft·lbf (26.5 N·m) and over
Clutch System			Overrunning
Pinion Projection Voltage at 212°F (100°C)			8 V or less
Pinion DP or Module / Number of Teeth			DP 3 / 9
Brush	Spring Force		7.9 lbf (35 N)
	Height	Standard	0.75 in. (19 mm)
		Limit	0.35 in. (9 mm)
Magnetic Switch	Series Coil Resistance		0.37 Ω at 68°F (20°C)
	Shunt Coil Resistance		0.62 Ω at 68°F (20°C)
Commutator	Outside Diameter	Standard	1.44 in. (36.5 mm)
		Limit	1.40 in. (35.5 mm)
	Run-Out	Standard	0.001 in. (0.03 mm)
		Limit	0.008 in. (0.2 mm)
	Insulation Depth	Standard	0.020 to 0.031 in. (0.5 to 0.8 mm)
		Limit	0.008 in. (0.2 mm)
Armature	Run-Out	Standard	0.001 in. (0.03 mm)
		Limit	0.008 in. (0.2 mm)
Bearing Type	Armature Front	Nominal Number	6004DD
	Armature Rear		608ZZ
	Pinion Front		–
	Pinion Rear		–
Pinion Projection Length (L)			0.012 to 0.059 in. (0.3 to 1.5 mm)

4-6-4 Starter Motor Troubleshooting



4-6-5 Starter Motor Components



1 – Pinion shaft
2 – M4 bolts (3 used)
3 – Bearing retainer
4 – Pinion clutch assembly
5 – Return spring
6 – Pinion stop
7 – Retaining ring
8 – Gear housing
9 – Shift lever
10 – Torsion spring
11 – Plunger
12 – Dust covers (shims)
13 – Magnetic switch assembly (solenoid)
14 – Cover
15 – M6 bolts (2 used)
16 – Armature assembly
17 – Field coil assembly
18 – Positive (+) brushes
19 – Negative (-) brushes
20 – Brush holder assembly
21 – Rear cover
22 – M5 through bolts (2 used)
23 – M4 bolts (2 used)

Figure 4-6-1

4-6-6 Starter Motor

⚠ WARNING

Shock Hazard!

- **Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.**
- **Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. Always keep the connectors and terminals clean.**
- **Failure to comply could result in death or serious injury.**

Note: While starter motor design varies between models, the basic repair procedures are the same. The following procedures are typical and may differ from the stater being serviced.

Removal of Starter Motor

1. Disconnect the battery cables at the battery, negative (-) cable first.
2. Remove the electrical wires from the magnetic switch assembly.
3. Remove the starter mounting bolts **(Figure 4-6-2, (1))**. Remove the starter motor from the flywheel housing.

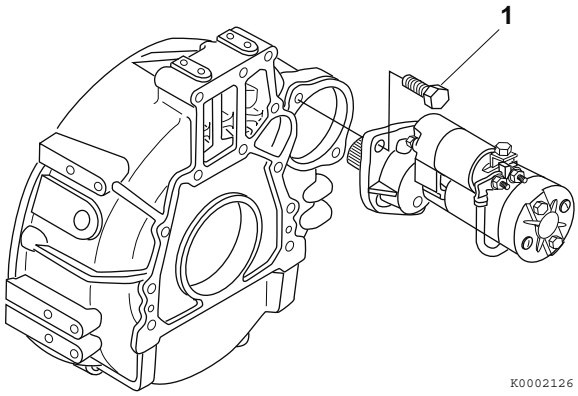


Figure 4-6-2

Disassembly of Starter Motor

1. Loosen the M8 nut from the magnetic switch (solenoid) assembly **(Figure 4-6-3)**. Disconnect the wire from the magnetic switch.

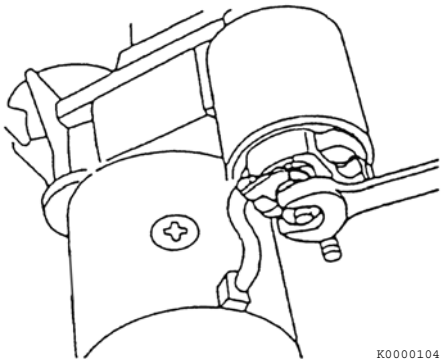


Figure 4-6-3

2. Remove the two M4 bolts **(Figure 4-6-4, (1))** securing the rear cover **(Figure 4-6-4, (2))** to the brush holder assembly **(Figure 4-6-4, (3))**.

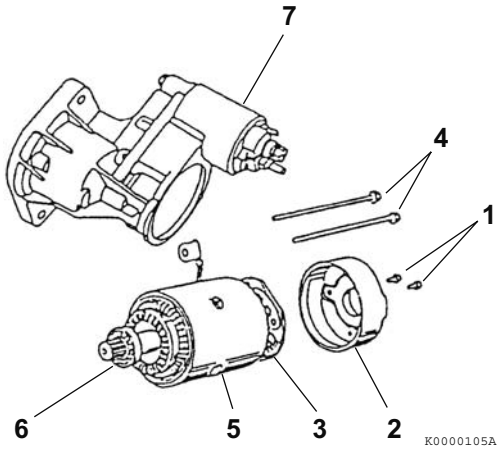


Figure 4-6-4

3. Remove the two M5 through bolts **(Figure 4-6-4, (4))**. Separate the rear cover **(Figure 4-6-4, (2))**, field coil assembly **(Figure 4-6-4, (5))** with the armature assembly **(Figure 4-6-4, (6))** from the gear housing **(Figure 4-6-4, (7))**.

4. Pull the brush springs up using a brush spring puller. On the negative (-) side, bring the brush spring into contact with the side of the brush for lifting from the commutator surface. On the positive (+) side, remove the brush from the brush holder assembly **(Figure 4-6-5, (1))**.

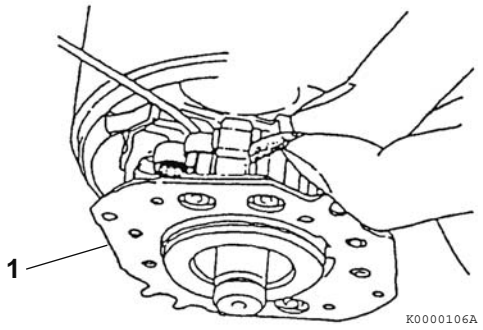


Figure 4-6-5

5. Remove the brush holder assembly **(Figure 4-6-6, (1))** from the armature assembly **(Figure 4-6-6, (3))**.

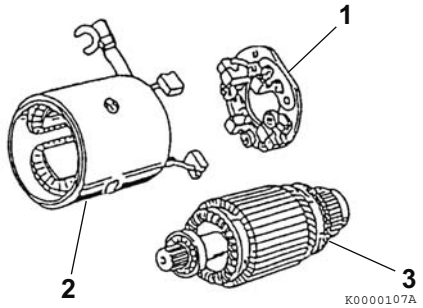


Figure 4-6-6

6. Pull the armature assembly **(Figure 4-6-6, (3))** out from the field coil assembly **(Figure 4-6-6, (2))**.
7. Remove the two M6 bolts **(Figure 4-6-7, (1))** retaining the magnetic switch assembly **(Figure 4-6-7, (2))** to the gear housing. Remove the magnetic switch assembly, dust cover(s) **(Figure 4-6-7, (3))** and torsion spring **(Figure 4-6-7, (4))** from the gear housing.

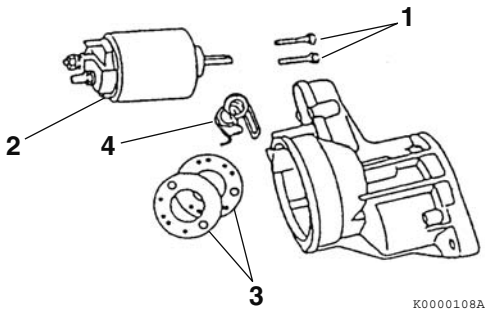


Figure 4-6-7

8. Disassemble the dust cover **(Figure 4-6-8, (1))** and shift the lever **(Figure 4-6-8, (2))** from the gear housing.

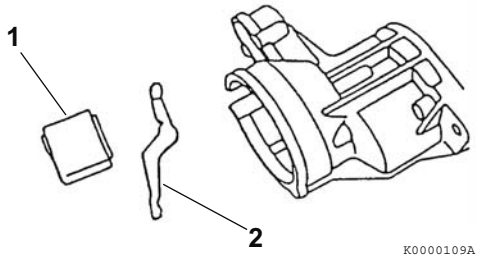


Figure 4-6-8

9. Remove the three M4 bolts **(Figure 4-6-9, (1))** securing the bearing retainer assembly **(Figure 4-6-9, (2))** to the gear housing. Remove the bearing retainer assembly from the gear housing.

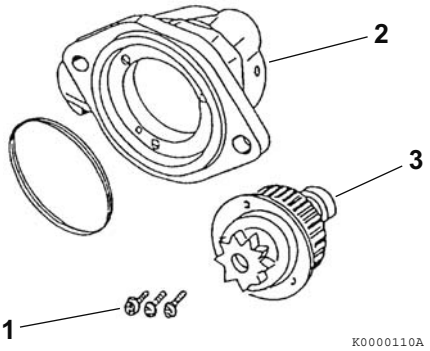


Figure 4-6-9

10. Remove the pinion clutch assembly **(Figure 4-6-9, (3))** from the bearing retainer assembly.
11. Using a flat-blade screwdriver, remove the retaining ring **(Figure 4-6-10, (1))** from the shaft of the pinion.

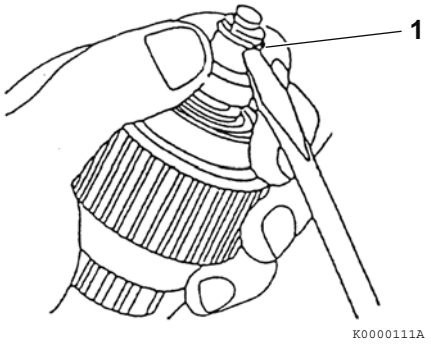


Figure 4-6-10

12. Disassemble the pinion stop **(Figure 4-6-11, (3))**, return spring **(Figure 4-6-11, (4))**, pinion clutch assembly **(Figure 4-6-11, (1))**, and pinion shaft **(Figure 4-6-11, (5))**.

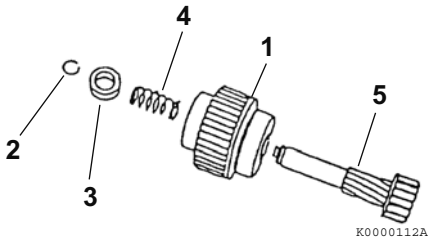


Figure 4-6-11

Cleaning and Inspection

■ Armature

Commutator surface inspection

If the commutator surface is rough, polish the surface with a #500 to #600 emery cloth **(Figure 4-6-12)**.

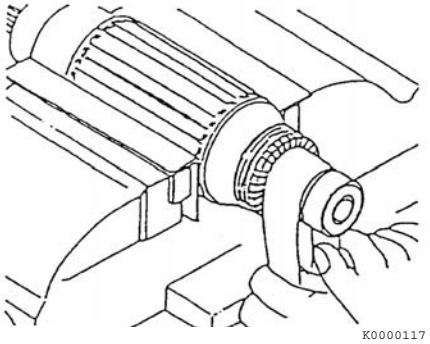


Figure 4-6-12

Measure commutator outside diameter

Measure the commutator outside diameter **(Figure 4-6-13)**. Replace the armature if the measurement is less than the limit.

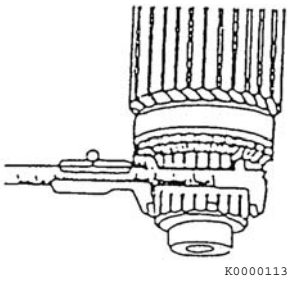


Figure 4-6-13

See 4-6-3 Starter Motor Specifications on page 4-6-2 for the service limit.

Measure commutator insulation depth

Measure the depth of the insulating material **(Figure 4-6-14, (1))** between commutator segments **(Figure 4-6-14, (2))**. If the depth measures less than the limit, use a hacksaw blade **(Figure 4-6-14, (3))** to remove the insulating material until the depth is within the limit.

A normal commutator condition is indicated in **(Figure 4-6-14, (4))**. An abnormal commutator condition is indicated in **(Figure 4-6-14, (5))**.

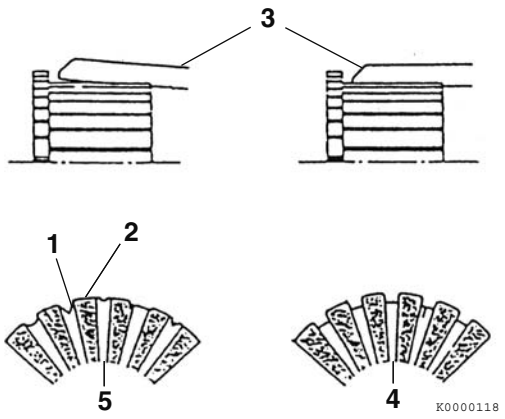


Figure 4-6-14

See 4-6-3 Starter Motor Specifications on page 4-6-2 for the service limit.

Armature coil continuity test

Check for continuity between the commutator segments using a multimeter **(Figure 4-6-15)**. The multimeter should indicate continuity.

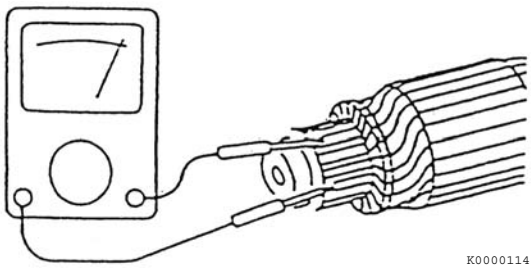


Figure 4-6-15

If the multimeter does not indicate continuity, replace the armature.

Armature coil insulation test

Check for continuity between a commutator segment and the shaft or armature using a multimeter **(Figure 4-6-16)**. The multimeter should not indicate continuity.

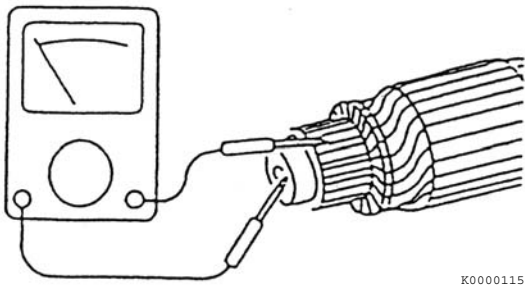


Figure 4-6-16

If the multimeter indicates continuity, replace the armature.

Measure armature and commutator run-outs

Measure the armature core run-out and the commutator run-out using a dial indicator **(Figure 4-6-17)**. Replace the armature if either of the measurements is less than the limit.

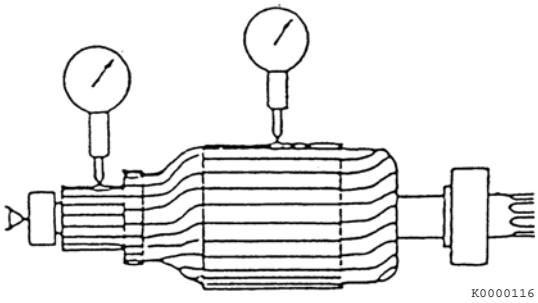


Figure 4-6-17

See 4-6-3 Starter Motor Specifications on page 4-6-2 for the service limit.

■ Field coil

Field coil continuity test

Check for continuity between the field coil terminals using a multimeter **(Figure 4-6-18)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the field coil assembly.

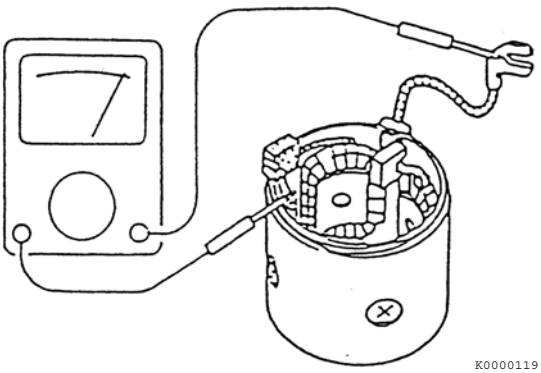


Figure 4-6-18

Field coil insulation test

Check for continuity between the field coil terminal and the yoke using a multimeter **(Figure 4-6-19)**. The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the field coil assembly.

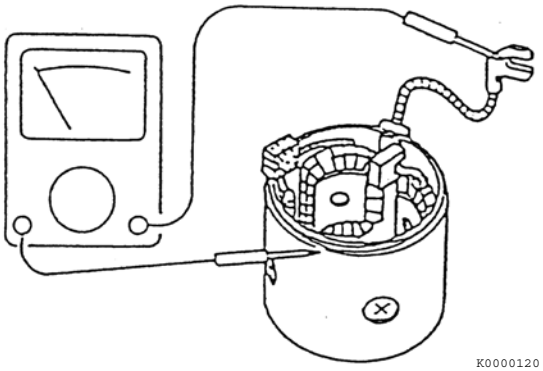


Figure 4-6-19

Measure brush length

Measure the length of the brush **(Figure 4-6-20)**. Replace the brush if the length is less than the limit.

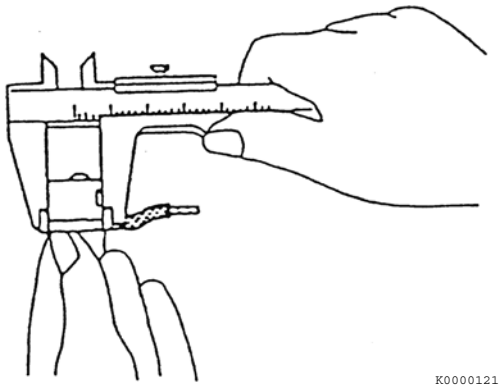


Figure 4-6-20

See 4-6-3 Starter Motor Specifications on page 4-6-2 for the service limit.

■ Magnetic switch

If the starter motor becomes wet, replace the magnetic switch even if the magnetic switch assembly function is normal.

Shunt coil continuity test

Check for continuity between the “S” terminal and the switch body using a multimeter **(Figure 4-6-21)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

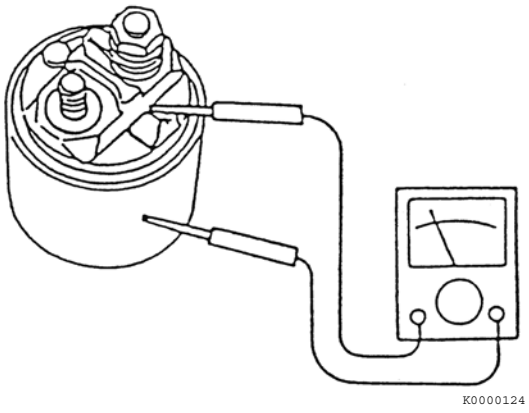


Figure 4-6-21

Series coil continuity test

Check for continuity between the “S” and “M” terminals using a multimeter **(Figure 4-6-22)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

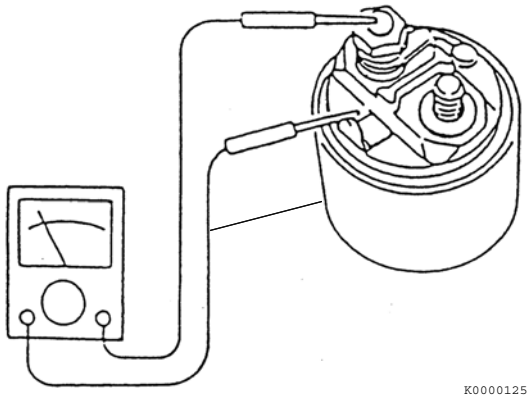


Figure 4-6-22

Coil resistance test

See 4-6-3 Starter Motor Specifications on page 4-6-2 for the service limit.

Contact continuity test

Depress the plunger at the bottom of the magnetic switch. Check for continuity between the “B” and “M” terminals using a multimeter **(Figure 4-6-23)**. The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the magnetic switch.

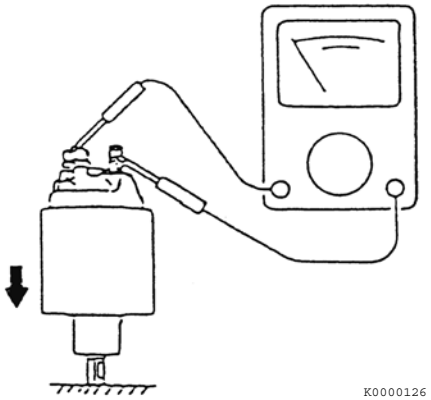


Figure 4-6-23

■ Pinion clutch assembly

Pinion clutch assembly inspection

Manually rotate the pinion clutch assembly in the drive direction **(Figure 4-6-24)**. It should rotate freely in the drive direction and is locked by turning it in the opposite direction. Replace the pinion clutch assembly if the results are different.

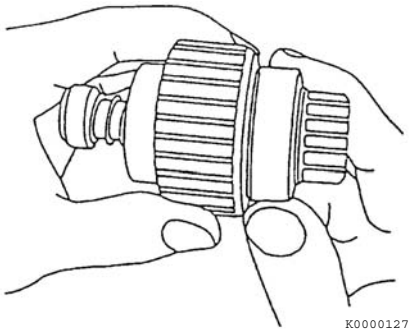


Figure 4-6-24

Slide the pinion clutch assembly on the shaft. It should slide smoothly on the shaft **(Figure 4-6-25)**. Rust, too much grease or damage could prevent the pinion clutch from sliding smoothly. If the pinion clutch assembly does not slide smoothly, clean the shaft and pinion clutch assembly or replace the damaged component.

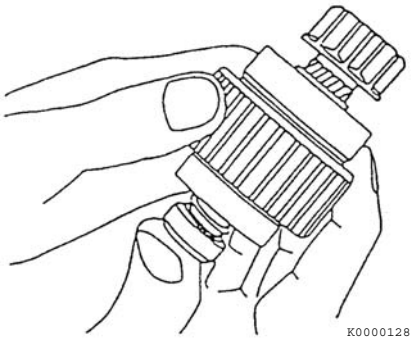


Figure 4-6-25

Ball bearing inspection

Rotate each ball bearing while holding the pinion clutch assembly **(Figure 4-6-26)**. Replace the ball bearing if it does not rotate smoothly or has excessive play.

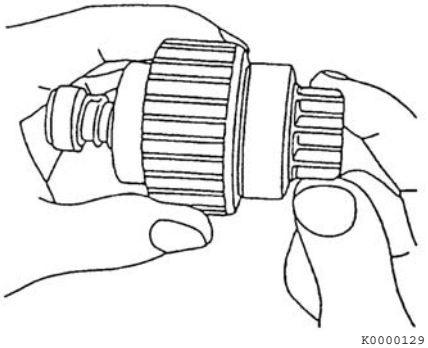


Figure 4-6-26

Reassembly of Starter Motor

1. Apply the appropriate starter bendix grease (obtain locally) to the pinion shaft. Reassemble the pinion shaft **(Figure 4-6-27, (5))**, pinion clutch assembly **(Figure 4-6-27, (1))**, return spring **(Figure 4-6-27, (4))** and pinion stop **(Figure 4-6-27, (3))**. Reinstall the retaining ring **(Figure 4-6-27, (2))** in the groove in the pinion shaft. Slide the piston stop over the retaining ring.

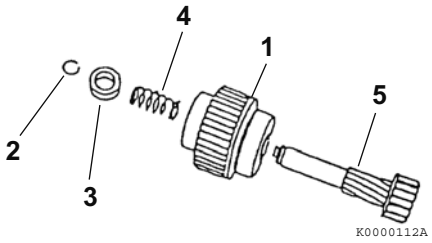


Figure 4-6-27

2. Reinstall the pinion clutch assembly into the bearing retainer assembly.
3. Reinstall the bearing retainer assembly and pinion assembly to the gear housing. Reinstall and tighten the three M4 bolts.
4. Apply a small amount of high temperature lithium grease (obtain locally) to the sliding portions of the shift lever **(Figure 4-6-28, (1))**. Reassemble the torsion spring **(Figure 4-6-28, (2))**, shift lever and dust cover(s) **(Figure 4-6-28, (3))**, plunger **(Figure 4-6-28, 4)** and magnetic switch assembly **(Figure 4-6-28, (5))**.

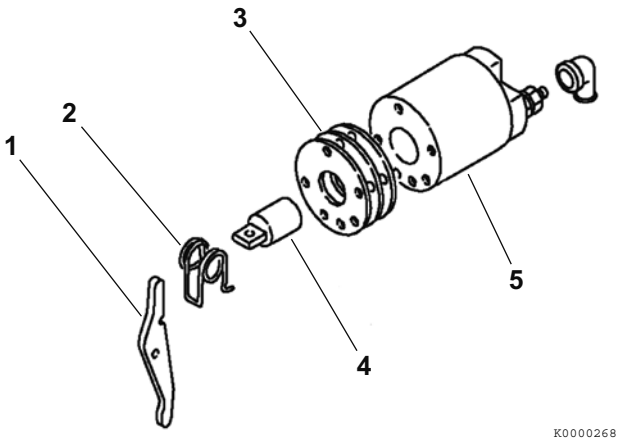


Figure 4-6-28

5. Reassemble the magnetic switch assembly to the gear housing. Pry the pinion away from the gear housing to allow installation of the magnetic switch assembly **(Figure 4-6-29)**.

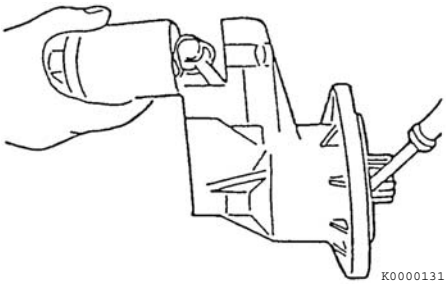


Figure 4-6-29

6. Secure the magnetic switch assembly to the gear housing using the two M6 bolts.

7. Carefully install the armature assembly **(Figure 4-6-30, (1))** into the field coil assembly **(Figure 4-6-30, (2))**.

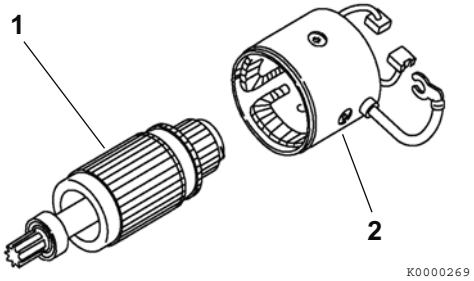


Figure 4-6-30

8. Position the brush springs in brush holders **(Figure 4-6-31)**. Reinstall the brushes in the brush holders. Reversing the brushes will cause the starter motor to turn backwards.

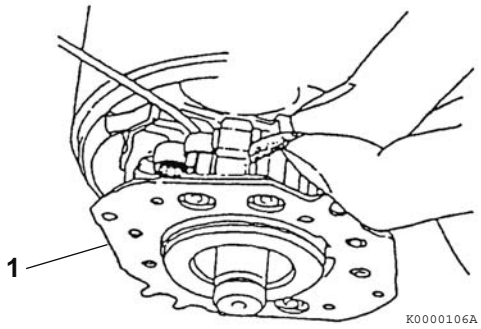


Figure 4-6-31

9. Carefully install the brush holder assembly to the armature assembly.
10. Reinstall the field coil assembly with the armature assembly to the gear housing.
11. Reinstall the rear cover to the brush holder assembly. Securely tighten the two bolts.
12. Reinstall the two M4 through bolts **(Figure 4-6-32)**. Securely tighten the through bolts. Reconnect the wire to the magnetic switch assembly. Tighten the M8 nut. Reinstall the cover over the connection.

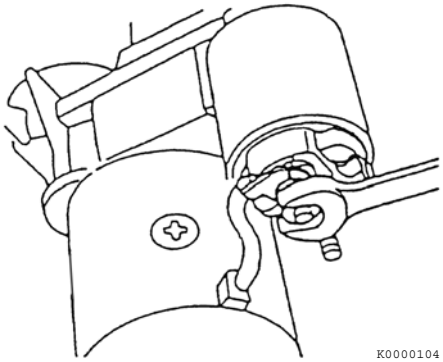


Figure 4-6-32

Check Pinion Projection Length

1. Connect the positive (+) lead from a battery to the “S” terminal.
2. Connect the negative (-) lead to the “M” terminal.
3. Lightly pull the pinion away from the gear housing.
4. Turn the switch ON and measure the pinion moving distance L in the thrust direction **(Figure 4-6-33)**. Perform this test within 10 seconds. *See 4-6-3 Starter Motor Specifications on page 4-6-2 for the service limit.*

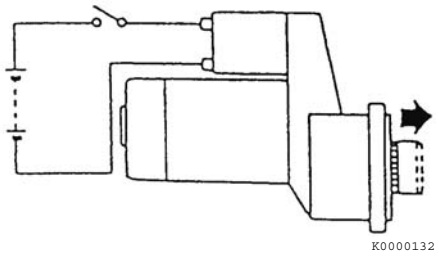


Figure 4-6-33

5. If the measured L dimension is outside the standard range, adjust the dust covers to obtain the standard range. Dust covers **(Figure 4-6-34, (1))** are available in 0.020 in. (0.5 mm) and 0.031 in. (0.8 mm) thicknesses.

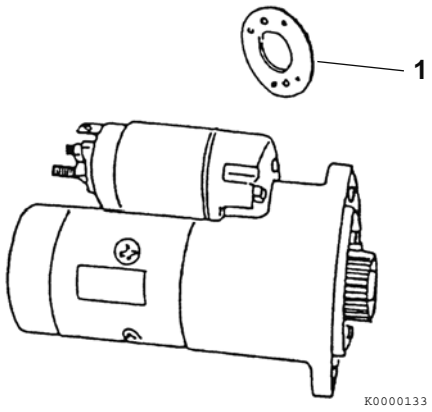


Figure 4-6-34

No-Load Test

Test the characteristics of the starter motor by performing a no-load test.

NOTICE

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test.

1. Secure the starting motor in a vise or other suitable fixture.
2. Connect an ammeter **(Figure 4-6-35, (1))** in series between the battery positive (+) terminal **(Figure 4-6-35, (2))** and the main positive (+) terminal **(Figure 4-6-35, (3))** on the starter motor.

   Note: The ammeter and all wire leads used in this test must have a capacity equal to or greater than the amperage draw specification for the starter motor being tested.

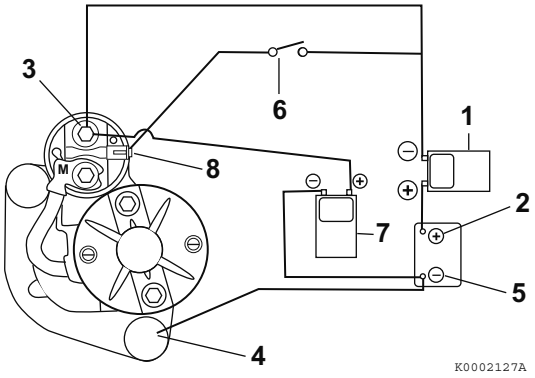


Figure 4-6-35

3. Connect a wire lead between the mounting base of the starter motor **(Figure 4-6-35, (4))** and the battery negative terminal **(Figure 4-6-35, (5))**.
4. Connect a voltmeter **(Figure 4-6-35, (7))** to the battery negative (-) terminal **(Figure 4-6-35, (5))** and the main positive (+) battery terminal **(Figure 4-6-35, (3))** on the starter motor.
5. Install a switch **(Figure 4-6-35, (6))** in a circuit between the battery positive (+) terminal **(Figure 4-6-35, (2))** and the starter magnetic switch (solenoid) terminal **(Figure 4-6-35, (8))** on the starter motor.
6. Use a suitable tachometer to monitor the rpm of the starter.
7. Turn the switch to the ON position. Monitor the rpm, amperage draw and voltage. For test specifications. For test specifications, *see 4-6-3 Starter Motor Specifications on page 4-6-2*.

Installation of Starter Motor

1. Reinstall the starter motor to the flywheel housing.
2. Reinstall the starter mounting bolts **(Figure 4-6-36, (1))**. Tighten the bolts to specification.

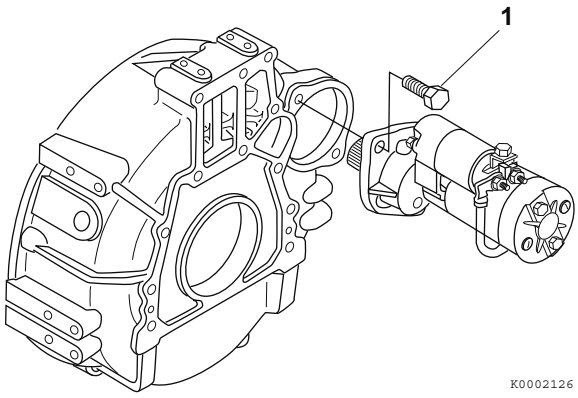


Figure 4-6-36

3. Reconnect the electrical wires to the magnetic switch assembly (solenoid). Be sure to place the cover over the battery positive (+) cable connection.
4. Reconnect the battery cables at the battery.

4-7 Alternator

4-7-1 Before You Begin Servicing

Before performing any service procedures within this section, read the following safety information and review the *Safety Statements* section on page *4-1-1*.

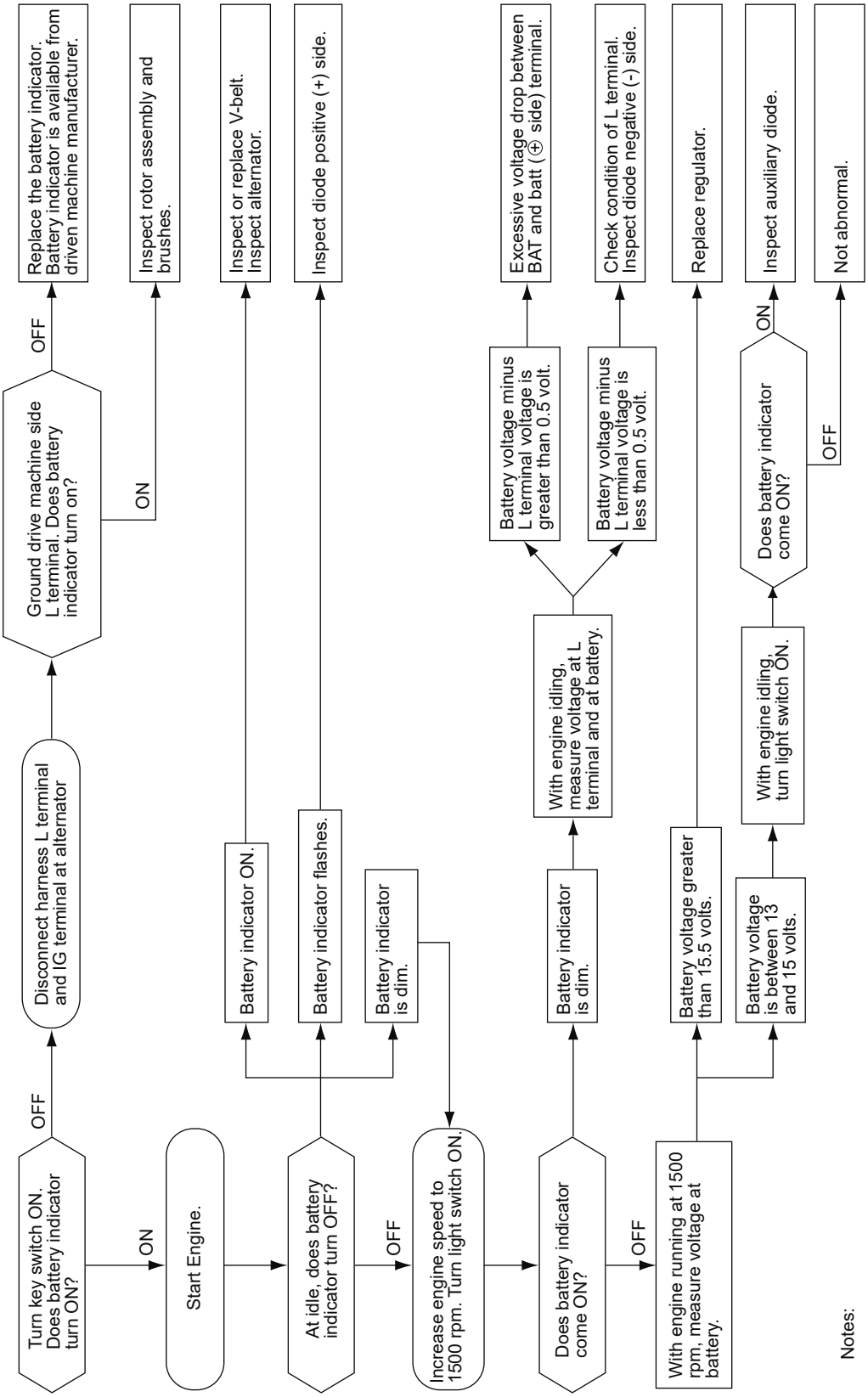
4-7-2 Introduction

This section of the Service Manual describes the servicing of the alternators. YANMAR Part No. 129423-77200 alternator is used in this section to show the service procedures for the representative alternator. For specific part detail, see the *Parts Catalog* for the engine you are working on.

4-7-3 Alternator Specifications

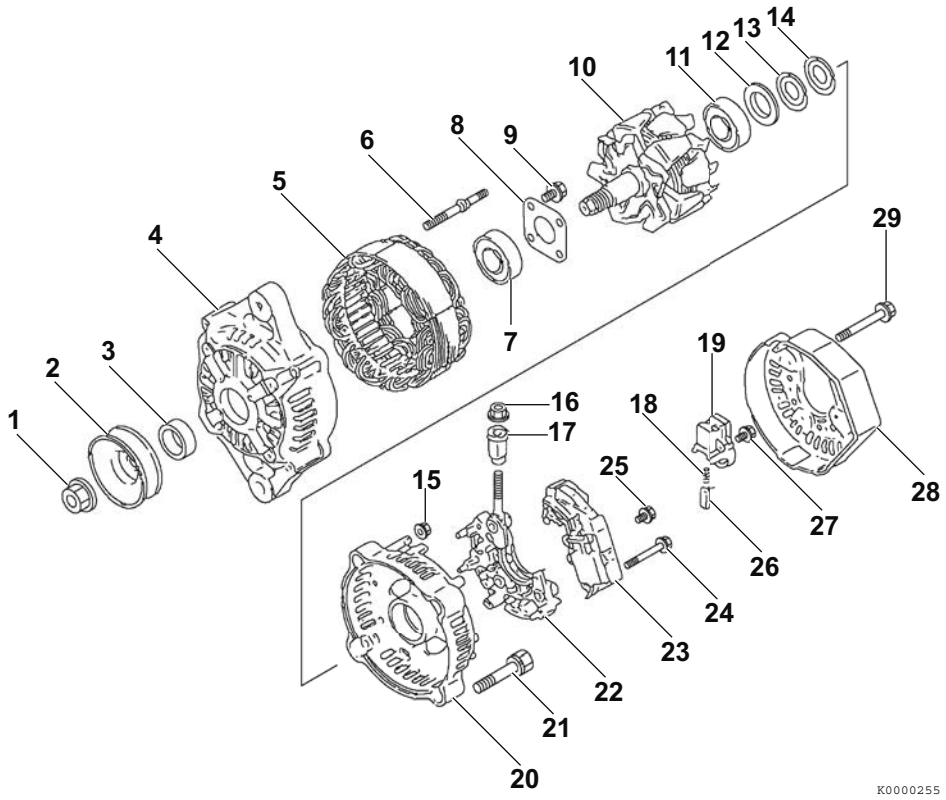
YANMAR Part No.	129908-77200
Nominal output (13.5 volts heat)	80 A
Weight	9.92 lb (4.5 kg)
Revolution direction (as viewed from pulley)	Clockwise
Rating	Continuous
Battery voltage	12 V
Rated revolution	6000 min^{-1} (rpm)
Operating range	1000 - 18000 min^{-1} (rpm)
Grounding characteristics	Negative (-) side of circuit
Integrated regulator	IC regulator
Outside diameter of pulley	2.724 in. (69.2 mm)
Belt shape	Type A

4-7-4 Alternator Troubleshooting



4-7-5 Alternator Components

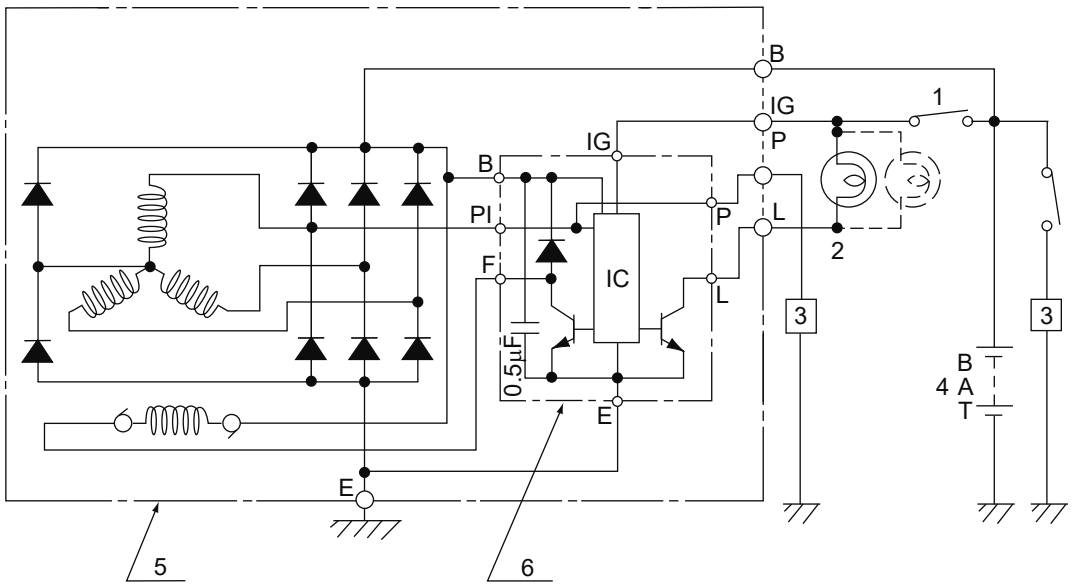
YANMAR Part No. 129423-77200 alternator is used in this section to show the service procedures for the representative alternator. For specific part detail, see the *Parts Catalog* for the engine you are working on.



1 – Nut
2 – Pulley
3 – Collar
4 – Front frame housing
5 – Stator assembly
6 – Stud (2 used)
7 – Front frame housing bearing
8 – Bearing cover
9 – Bearing cover bolt (4 used)
10 – Rotor assembly
11 – Rear frame housing bearing
12 – Bearing cover
13 – Thrust washer
14 – Thrust washer
15 – Nut (2 used)
16 – Nut
17 – Insulation bushing
18 – Spring (2 used)
19 – Brush holder
20 – Rear frame housing
21 – Bolt (2 used)
22 – Holder
23 – IC regulator assembly
24 – Bolt (2 used)
25 – Bolt
26 – Brush (2 used)
27 – Bolt
28 – Rear cover
29 – Bolt (3 used)

Figure 4-7-1

4-7-6 Alternator Wiring Diagram



1 – Key switch
2 – Charge lamp (3.4 watts maximum)
3 – Load
4 – Battery
5 – Alternator assembly
6 – IC regulator assembly

Figure 4-7-2

NOTICE

Do not short-circuit the charging system between alternator terminals IG and L. Damage to the alternator will result.

NOTICE

Do not connect a load between alternator terminals L and E. Damage to the alternator will result.

NOTICE

Do not remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.

4-7-7 Alternator Standard Output

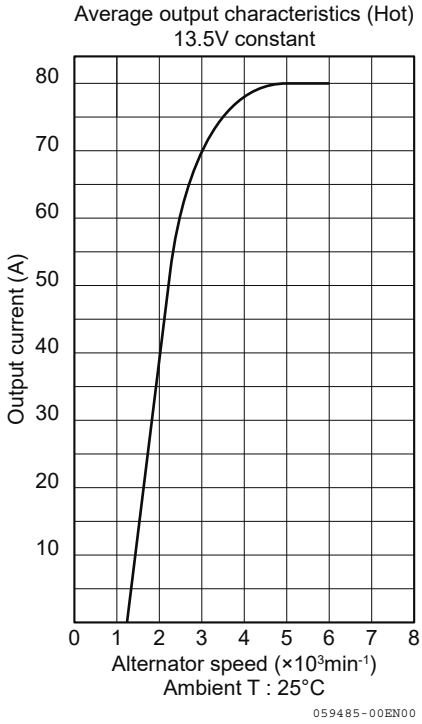


Figure 4-7-3

4-7-8 Alternator

⚠ WARNING

Shock Hazard!

- **Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.**
- **Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. Always keep the connectors and terminals clean.**
- **Failure to comply could result in death or serious injury.**

Removal of Alternator

⚠ CAUTION

Pinch Hazard!

Carefully rotate the alternator toward the cylinder block while loosening the V-belt. Failure to comply may result in minor or moderate injury.

1. Disconnect the electrical wires from the alternator.
2. Loosen the V-belt.
3. Remove the V-belt adjuster from the alternator bolt **(Figure 4-7-4, (1))**.
4. Remove the nut **(Figure 4-7-4, (2))** from the gear case stud. Remove the alternator.

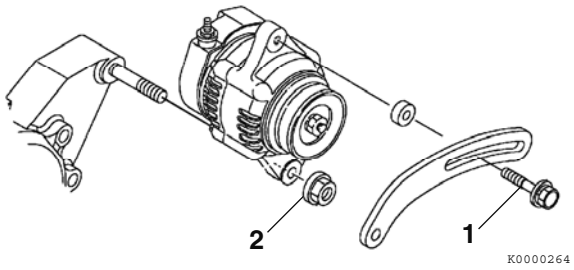


Figure 4-7-4

Disassembly of Alternator

1. Remove the nut **(Figure 4-7-5, (1))** from the shaft of the rotor assembly. Remove the pulley **(Figure 4-7-5, (2))**.

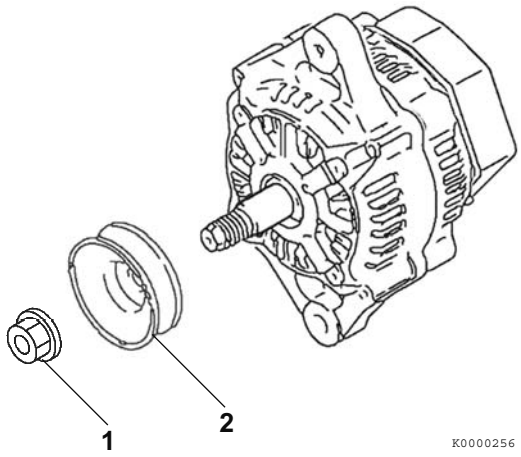


Figure 4-7-5

2. Remove the three bolts **(Figure 4-7-6, (1))** retaining the rear cover **(Figure 4-7-6, (2))** to the rear frame assembly.

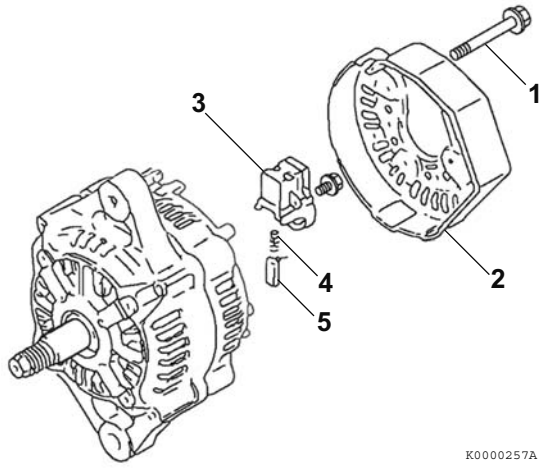


Figure 4-7-6

3. Remove the brush holder **(Figure 4-7-6, (3))**. Remove the brush springs **(Figure 4-7-6, (4))** and brushes **(Figure 4-7-6, (5))**.
4. Remove the bolt retaining the regulator assembly **(Figure 4-7-7, (1))** to the holder **(Figure 4-7-7, (2))**.

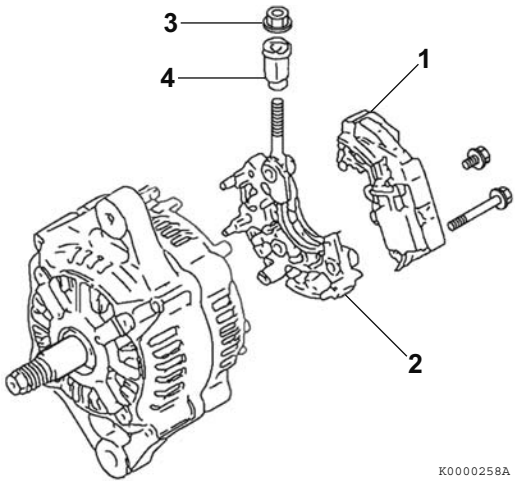


Figure 4-7-7

5. Remove the bolts retaining the holder **(Figure 4-7-7, (2))** to the rear frame housing. Remove the holder.
6. Remove the nut **(Figure 4-7-7, (3))** retaining the insulation bushing **(Figure 4-7-7, (4))**. Remove the insulation bushing.
7. Remove the two bolts **(Figure 4-7-8, (1))** and two nuts **(Figure 4-7-8, (2))** securing the rear frame housing to the front frame housing.

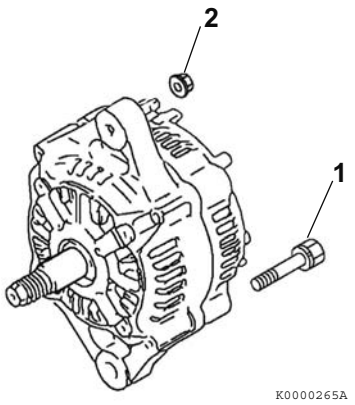


Figure 4-7-8

8. Using a press, remove the rotor assembly **(Figure 4-7-9, (1))** from the front frame housing **(Figure 4-7-9, (2))** and rear frame housing **(Figure 4-7-9, (1))**.

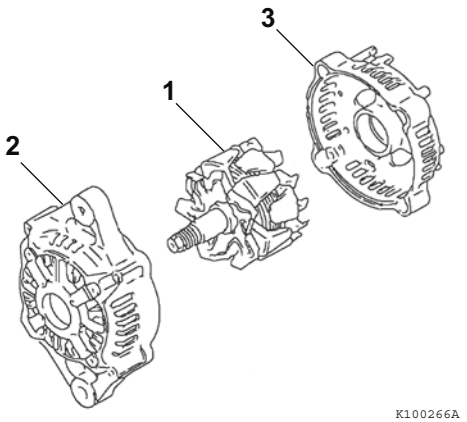


Figure 4-7-9

9. Remove the stator assembly **(Figure 4-7-10, (1))** from the front frame housing.

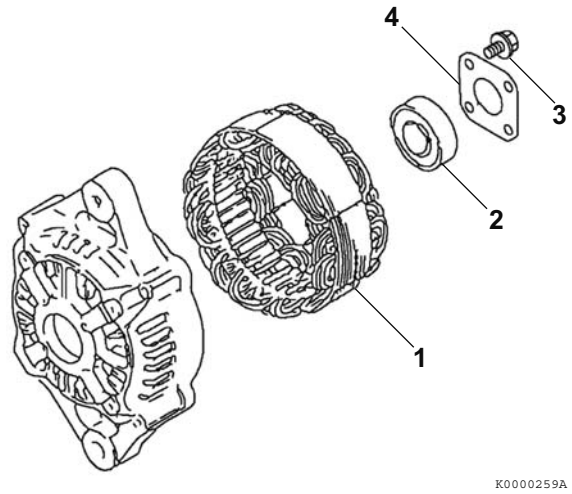


Figure 4-7-10

10. If it is necessary to replace the bearing **(Figure 4-7-10, (2))** in the front frame housing, remove the four bolts **(Figure 4-7-10, (3))** securing the plate **(Figure 4-7-10, (4))** to the front frame housing. Remove the plate. Use a puller to remove the bearing. Discard the bearing.
11. If it is necessary to replace the bearing **(Figure 4-7-11, (1))** in the rear frame housing, use a puller to remove. Discard the bearing. Remove the bearing cover **(Figure 4-7-11, (2))** and two thrust washers **(Figure 4-7-11, (3))**.

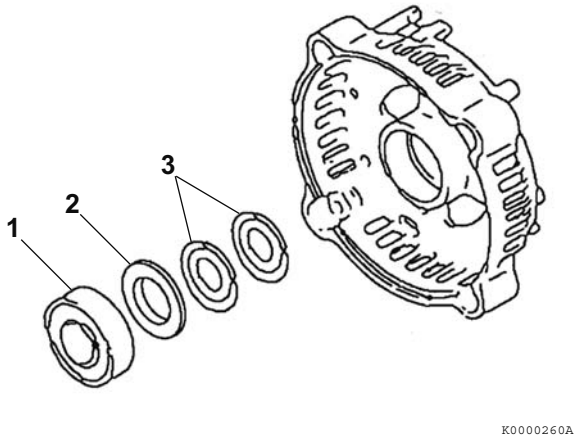


Figure 4-7-11

Reassembly of Alternator

1. If removed, reinstall the two trust washers **(Figure 4-7-12, (3))** and bearing cover **(Figure 4-7-12, (2))** in the rear frame housing. Lubricate the outside diameter of a new bearing **(Figure 4-7-12, (1))**. Press the bearing into the rear frame housing.

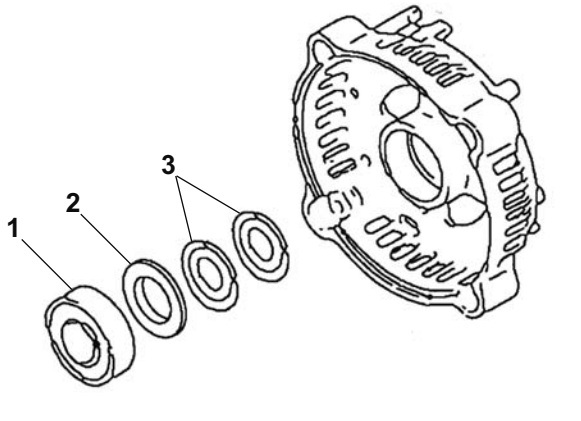


Figure 4-7-12

2. If removed, lubricate the outside diameter of a new front frame housing bearing. Press the bearing **(Figure 4-7-13, (2))** into the front frame housing. Reinstall the plate **(Figure 4-7-13, (4))** to the front housing. Tighten the four bolts **(Figure 4-7-13, (3))**.

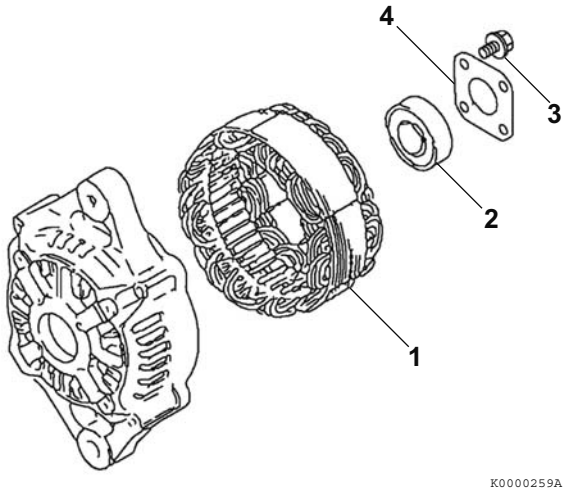


Figure 4-7-13

3. Position the stator assembly **(Figure 4-7-13, (1))** on the front frame housing studs.
4. Lubricate the shaft of the rotor assembly **(Figure 4-7-14, (1))**. Press the rotor assembly into the front frame housing **(Figure 4-7-14, (2))** and rear frame housing **(Figure 4-7-14, (3))**.

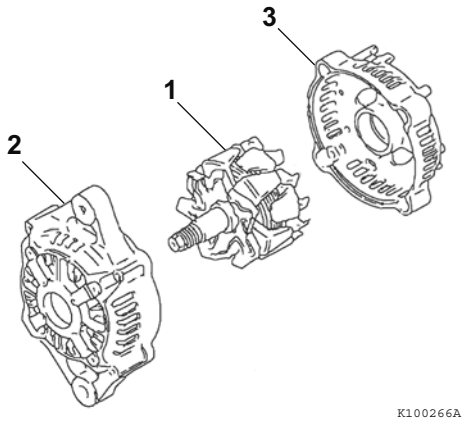


Figure 4-7-14

5. Align the front frame housing with the rear frame housing. Reinstall the two bolts **(Figure 4-7-15, (1))** and two nuts **(Figure 4-7-15, (2))**.

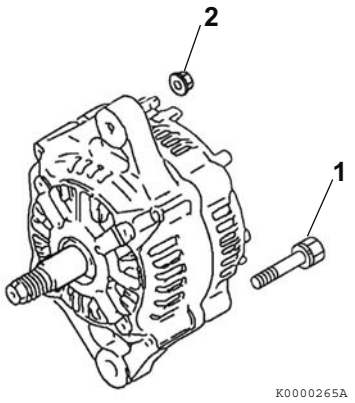


Figure 4-7-15

6. Reinstall the insulation bushing **(Figure 4-7-16, (4))** and nut **(Figure 4-7-16, (3))**.

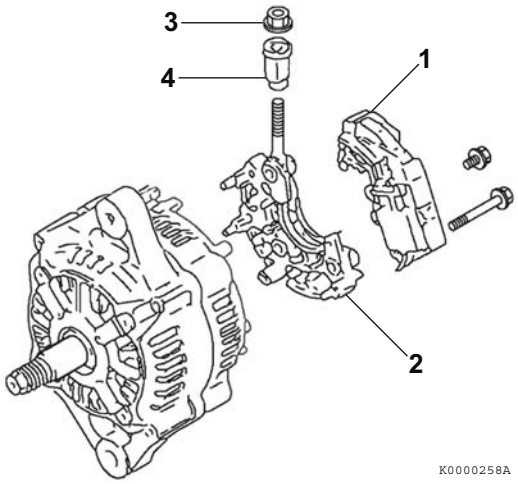


Figure 4-7-16

7. Reassemble the regulator assembly **(Figure 4-7-16, (1))** to the holder **(Figure 4-7-16, (2))**.

8. Reinstall the brush holder **(Figure 4-7-17, (3))**, springs **(Figure 4-7-17, (4))** and brushes **(Figure 4-7-17, (5))**.
9. Reattach the regulator assembly and holder to the rear frame housing.

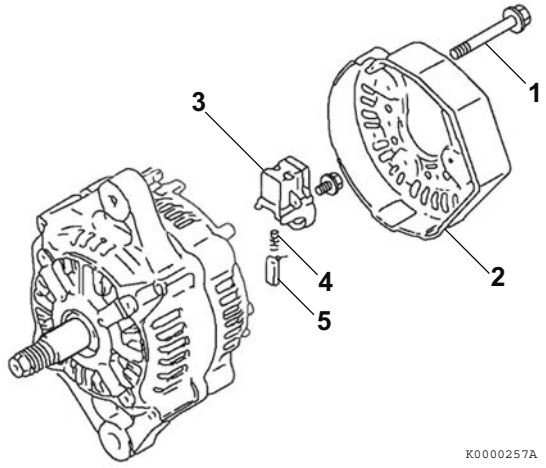


Figure 4-7-17

10. Reinstall the rear cover **(Figure 4-7-17, (2))** to the rear frame housing with three bolts **(Figure 4-7-17, (1))**.
11. Reassemble the pulley **(Figure 4-7-18, (2))** and nut **(Figure 4-7-18, (1))** to the shaft of the rotor assembly. Tighten the nut.

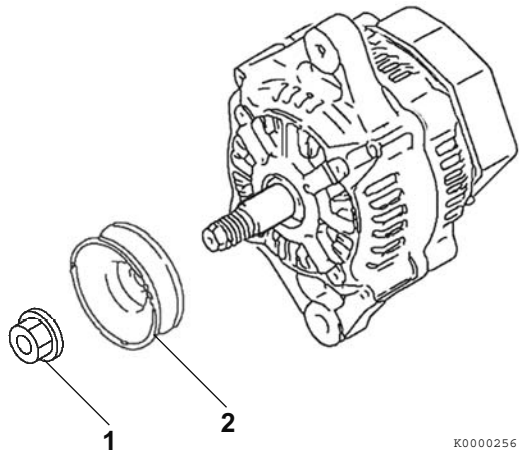


Figure 4-7-18

Installation of Alternator

1. Position the alternator on the gear case. Loosely reinstall the nut **(Figure 4-7-19, (2))** on the gear case stud and the V-belt adjuster bolt **(Figure 4-7-19, (1))**.

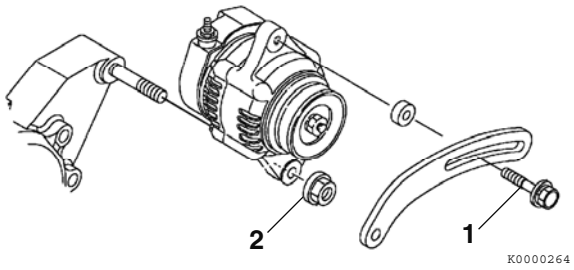


Figure 4-7-19

2. Reconnect the electrical wires to the alternator. Tighten the nuts to 15 - 20 in.-lb (1.7 - 2.3 N·m; 17 - 23 kgf·m).
3. Reinstall the V-belt. Tighten the V-belt to the proper tension.
4. Start the engine. Listen for any unusual sounds from the alternator.

NOTICE

Do not operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

5. Verify that the charge indicator is ON while the engine is operating. If the charge indicator is not ON, repair the problem before operating the engine.

4-8 Electronic Control System

4-8-1 Before You Begin Servicing

Before performing any service procedures within this section, read the following safety information and review the *Safety section on page 4-1-1*.

4-8-2 System Structure

YANMAR TNV engines come with the following systems

- Common rail system as shown in the **(Figure 4-3-1)** *on page 4-3-2*.
- Exhaust Gas Recirculation (EGR) system that controls the exhaust gas recirculation flow rate depending on the engine load and speed.
- System that controls the Diesel Particulate Filter (DPF) condition (for clogging), and controls the DPF regeneration by controlling the intake throttle.

(Figure 4-8-1) illustrates the outline of the electronic control system.

Features of the electronic engine control system include:

- Engine speed control schemes
  Droop control/Isochronous control/Low-idling speed up/High-idling speed down/Auto deceleration
- Starting aid
  Auto preheating/After heating
- Engine failure detection
- CAN communication with the control system of the driven machine
- Diesel Particulate Filter (DPF) regeneration control

However components and features vary depending on the driven machine. For details, refer to the operation manual provided by the driven machine manufacturer for these functions.

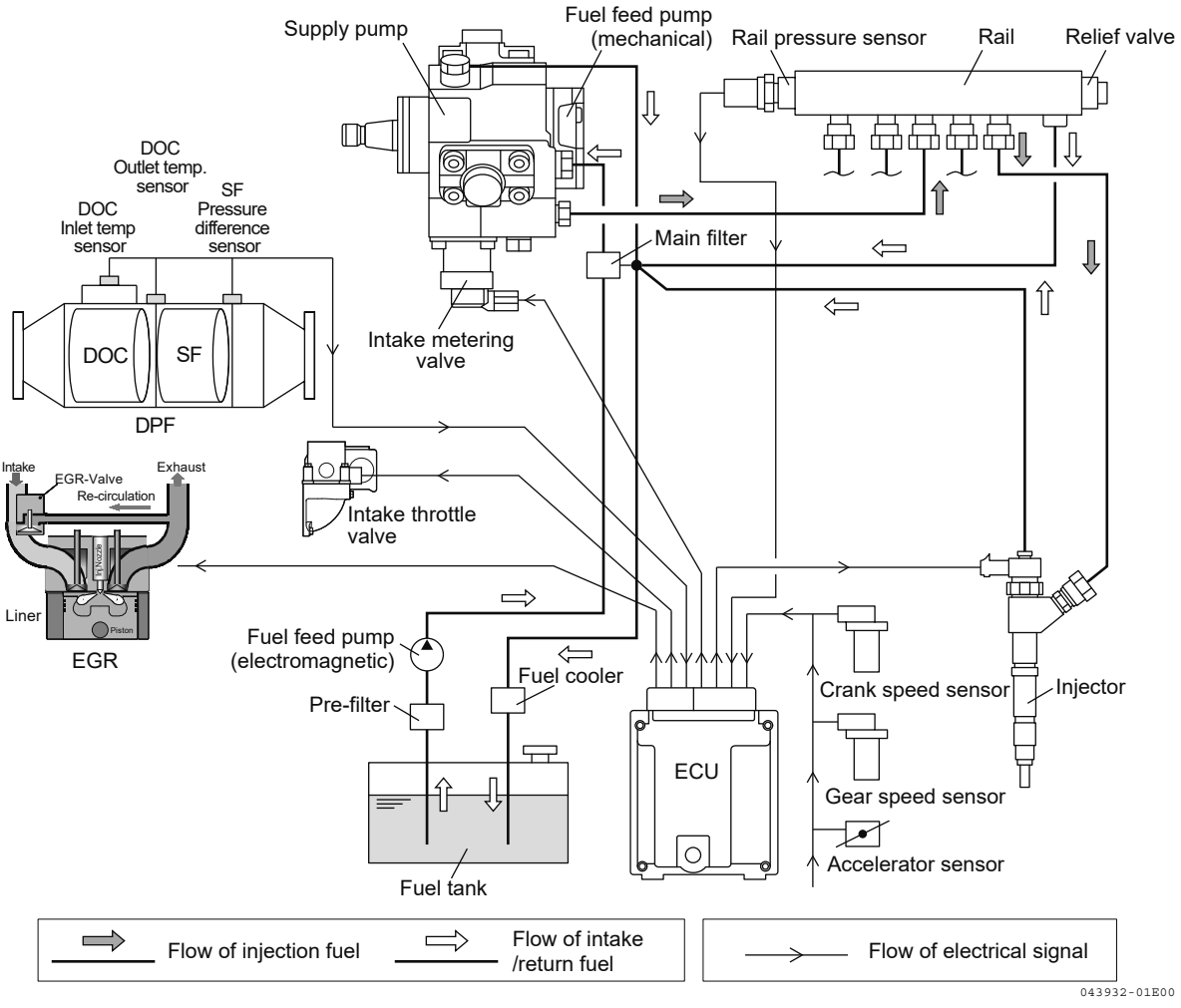


Figure 4-8-1

4-8-3 Electronic Engine Speed Control

■ Speed control

The electronically controlled engines have no governor lever. For these engines, the position signal of the throttle lever or accelerator pedal of the driven machine is converted into an electric signal by the accelerator sensor **(Figure 4-8-2)**, which is then delivered to the fuel injector through the ECU **(Figure 4-8-3)**, allowing the engine speed to be controlled.

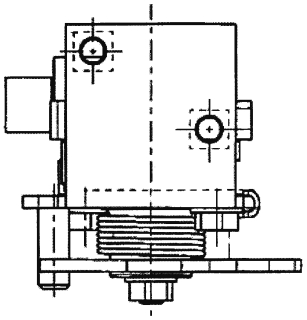


Figure 4-8-2

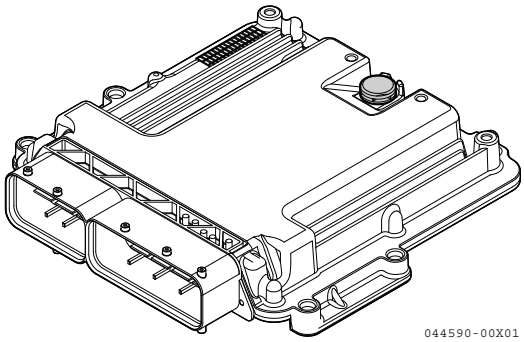


Figure 4-8-3

■ Engine speed curves

(Figure 4-8-4) shows typical engine speed curves that outline the relationship between engine speed and load.

Droop control

The VM series engines for general use are designed so that the engine speed is reduced by a certain percentage from 30 % load to full rated load. See curves (1) in **(Figure 4-8-4)** below. The same percentage droop is maintained at any no load speed.

Isochronous control

The CL series consists of isochronous design engines, the speed of which is kept constant from no load to full rated load. See curves (2) in **(Figure 4-8-4)** below.

Some VM series engines for general use may be custom-engineered and have the isochronous capability. Consult the operation manual for the driven machine for application details of such engines.

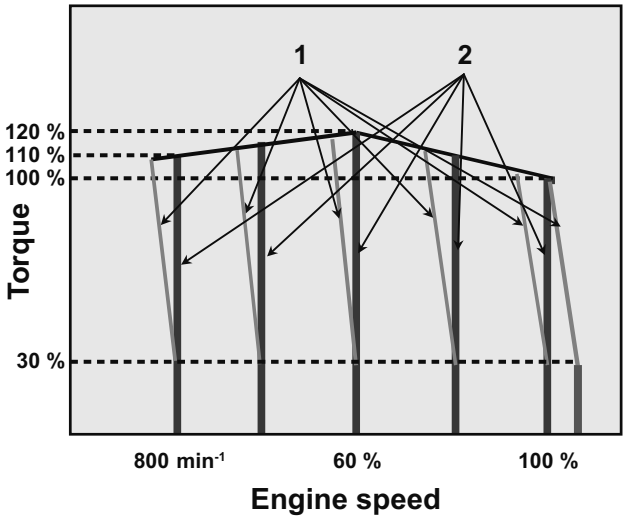


Figure 4-8-4

■ Other engine speed control

Low-idling speed up

This feature increases the low-idling speed to some extent depending on the engine coolant temperature. When the coolant temperature reaches a predetermined value, this feature returns the engine speed to the normal low idle setting, thus reducing the warm-up time.

High-idling speed down

The high-idling speed is controlled to 1500 min^{-1} when starting the engine in cold weather conditions (-15 °C or below). At least 10 seconds after the engine starts, the engine speed returns to the normal high idle setting by operating the accelerator lever. The engine speed is maintained at 1500 min^{-1} if the accelerator lever is not operated, thus preventing the seizures of the turbocharger. This is a standard feature. However it depends on the engine model. Refer to the operation manual provided for your engine model.

Auto deceleration (optional)

This feature brings the running engine in low idle mode automatically when the accelerator pedal is not operated for a predetermined period of time. When the pedal is operated, i.e., the accelerator sensor is activated, the low idle mode is cancelled.

A certain ON/OFF combination of switches (1) - (4) on the operator's console **(Figure 4-8-5)** will implement this optional feature. For details, see the operation manual for the driven machine.

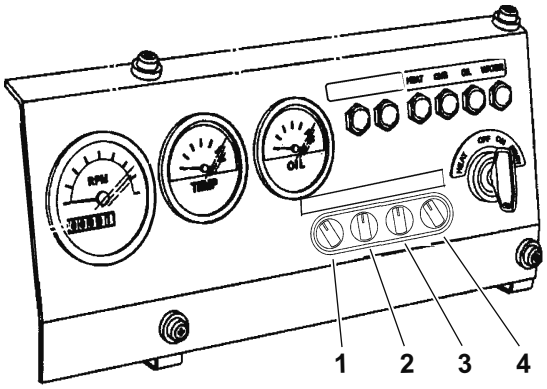


Figure 4-8-5

Others

Other optional features can be provided by selecting certain ON/OFF combinations of switches (1) - (4) on the operator's console **(Figure 4-8-5)** will implement this optional feature. For details, see the operation manual for the driven machine.

4-8-4 Diesel Particulate Filter (DPF)

The DPF consists of the diesel oxidation catalyst (DOC) and the Soot Filter SF, held by a case that sends the exhaust gas to the DOC and the SF. **(Figure 4-8-6)**
The role of the DPF is to prevent the discharge of PM by breaking down the hazardous constituents with the DOC and collecting the PM with the SF. The PM clogs the SF if left there and the engine performance decreases, so a means of regeneration is required. YANMAR engines use a continuous regeneration method. While continuing the operation, the DPF collects the PM and is regenerated at the same time. To perform the regeneration, the PM collected in the SF is combusted with NO_2 generated in the DOC and O_2 in the exhaust gas. At the same time, the DOC purifies the exhaust gas elements such as HC and CO into H_2O and CO_2.

Apart from the PM, ash also collects in the SF. This comes mostly from metallic components in the additives to the lubricating oil. Part of the lubricating oil is burnt in the high temperature combustion chamber and exhausted along with the combustion gas. In that case, metallic components are collected together with the PM in the SF. However, because the amount of ash is very little compared to the PM, it does not clog the SF immediately.

Because ash is a metallic component, it cannot be combusted in the DPF for treatment like the PM. Therefore, ash is over-accumulated in the SF over a long period of time. This increases the pressure loss and has adverse effects on the engine. In this case, maintenance must be performed to remove the SF with the accumulated ash from the DPF. Yanmar recommends to do this maintenance once every 3,000 operating hours.

Be sure to use the specified fuel and lubricating oil so that the DPF can fulfill its function. For fuel, use diesel fuel (ultra-low sulfur) with a sulfur mass of 15 ppm or lower. If you use a fuel other than the specified, performance of the catalyst contained in the DOC deteriorates rapidly due to sulfur. Because of this, the DPF cannot develop its regeneration capabilities and PM accumulates easier. This leads to increased fuel consumption and a deterioration of general engine receptiveness caused by decreased engine performance and frequent switching to the regeneration mode.

For lubricating oil, use low ash oil. If you use any other than the specified lubricating oil, a large amount of ash is vented through the exhaust and the DPF will clog within a short period of time. This will not only cause the engine output to decrease and the fuel costs to increase, but also makes earlier maintenance of the SF necessary.

Outline of Diesel Particulate Filter (DPF)

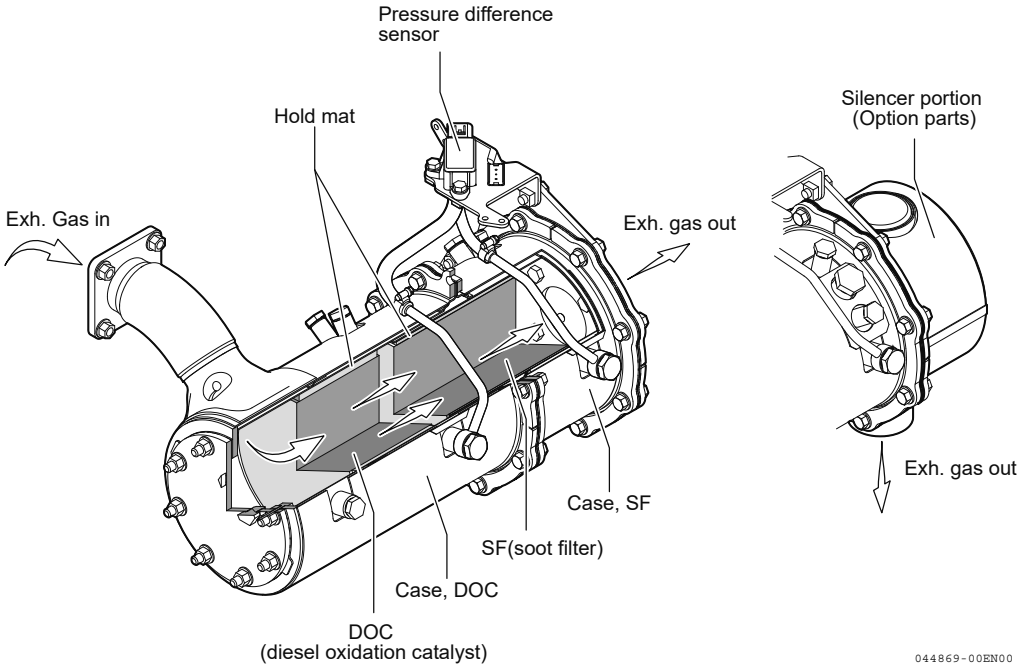


Figure 4-8-6

■ Overview of Diesel Particulate Filter (DPF) regeneration control

Electrical components such as the DPF differential pressure sensor, temperature sensor, and intake throttle are installed in the DPF. If the DPF cannot perform continuous regeneration due to low load operation, the ECU uses these electrical components to control assisted DPF regeneration (DPF regeneration control) automatically to prevent PM from over-accumulating.

■ Self-regeneration

Regeneration without the use of regeneration assistance devices (normal)

During the operation at high speed or high load, the exhaust temperature rises and PM is continuously combusted and eliminated.

■ Assisted regeneration

Regeneration with the use of assistance devices (e.g. the intake throttle)

When the differential pressure in the SF inlet/outlet in the DPF rises, the differential pressure sensor installed to the DPF detects the increase. The ECU commands the intake throttle to open the throttle according to the detected differential pressure to adjust the amount of engine intake air. The ECU also controls the regeneration by performing after-injection to increase the exhaust temperature. At this time, the EGR valve is closed.

■ Reset regeneration

Regeneration with the combined use of assisted regeneration and post-injection

Approximately every 100 hours of operation, the assisted regeneration and post-injection are automatically used together to control regeneration by increasing the exhaust temperature to burn off and remove PM.

These automatic regenerations can be performed during operation. No special operation is required for the operator. The following conditions may occur due to the characteristics of the DPF system, but they are not malfunctions.

- The engine sound may change due to the adjustment of intake throttle valve and degree of opening of the EGR valve when starting and completing the DPF regeneration.
- White smoke may be discharged from the exhaust pipe right after starting a cold engine or during acceleration.
  This is due to discharge of water vapor. When the exhaust temperature increases, the white smoke disappears. Always perform the DPF regeneration in a well-ventilated and safe location.
- The exhaust gas is purified through the catalyst installed in the DPF, so the smell of the exhaust gas is different from the exhaust gas of a conventional diesel engine.

⚠ CAUTION

- **During reset regeneration, post-injection is used and fuel is burned directly inside the DPF (burned by chemical reaction inside the DOC). Through this heat, regeneration occurs inside the SF, but the combustion increases the temperature of the exhaust gas to close to 600 °C (1112 °F). Stay away from the exhaust gas. Extremely hot exhaust gas may burn you. Be careful that neither people nor flammable materials are near the exhaust gas outlet.**
- **Post-injection can cause the fuel consumption to increase by a small amount.**
- **Through this genuine YANMAR regeneration method, the dilution of the lubricating oil with fuel caused by the post-injection is kept to a minimum, but some dilution is possible for low-load operation (low temperature exhaust gas) of fork lifters or similar machines. Make sure that you do a daily check of the oil level.**

■ Stationary regeneration

Although the DPF performs the regeneration control, if the operation conditions with idling at no load and low speed/low load operation are frequently repeated, the PM may not be regenerated.
If the ECU determines that performing the stationary regeneration is required at this time, the DPF regeneration request lamp comes on.
If the DPF regeneration request lamp comes on, immediately perform the stationary regeneration by performing the following operation. If the operation is continued with the DPF regeneration request lamp being come on, an excessive amount of PM will accumulate. Abnormal combustion of PM may cause fire and damage to the DPF.

If the DPF regeneration request lamp is lit, immediately conduct the stationary regeneration by performing the following operation.

If the operation is continued with the DPF regeneration request lamp lit up, an excessive amount of PM will accumulate. Abnormal combustion of PM may cause fire and damage to the DPF.

Operation procedures of stationary regeneration

1. Move to a well-ventilated and safe location.
2. Move the accelerator lever to the lowest position and operate the engine in idling.

   Note: If the DPF regeneration prohibition switch is installed, turn the DPF regeneration prohibition switch to "Regeneration Permitted".

3. Operate the interlock mechanism including the parking brake and activate the interlock function.

   Note: When the ECU verifies that the interlock mechanism is enabled with the regeneration interlock switch, the DPF regeneration approval lamp starts blinking.

4. Press the DPF regeneration request switch for 3 seconds (standard) or longer to start the stationary regeneration. (The time required to start the stationary regeneration can be changed. Refer to the operation manual for the detailed operation.)
   - When the stationary regeneration starts, the engine speed increases gradually to high idle speed. Then the reset regeneration is performed at that operation condition.
   - When the stationary regeneration starts, the DPF regeneration request lamp turns off, the DPF regeneration approval lamp switches from blinking to continuously lit, and the exhaust temperature warning lamp lights up.
   - The stationary regeneration is complete after approximately 25 to 30 minutes.
   - If you want to interrupt the stationary regeneration, perform one of the following operations.
     - Turn the interlock switch to "Regeneration Disabled".
     - Turn the DPF regeneration prohibition switch to "Regeneration Prohibited".
     - Raise the accelerator lever above the lowest position.
     - Turn off the power switch.
5. When the above-mentioned time has elapsed, the engine speed decreases to low idling, the regeneration approval lamp and the exhaust temperature warning lamp turn off, and the stationary regeneration is complete.

■ Precautions for stationary regeneration

- Do not disconnect SMARTASSIST DIRECT (SAD) or the computer while performing the stationary regeneration. (Check the remaining battery level. Stationary regeneration takes approximately 1 hour to complete.)
- Be sure to check the remaining fuel level to avoid the engine from running out of fuel. (Stationary regeneration requires sufficient fuel that can run the engine for at least 1 hour.)
- Make sure that no other failure other than excessive deposits is observed.

■ Recovery regeneration (optional)

The DPF can not be regenerated by the reset regeneration or the stationary regeneration when the excessive PM is accumulated. Therefore, optional recovery regeneration function is available.

The recovery regeneration requires longer regeneration time and lower temperature than that of the reset regeneration and the stationary regeneration. However, the function varies depending on the driven machine. For details, refer to the operation manual provided by the driven machine manufacturer for these functions.

■ Precautions for recovery regeneration

- Do not disconnect SMARTASSIST DIRECT (SAD) or the computer while performing the recovery regeneration. (Check the remaining battery level.
  Recovery regeneration takes approximately 4 hour to complete.)
- Be sure to check the remaining fuel level to avoid the engine from running out of fuel. (Recovery regeneration requires sufficient fuel that can run the engine for at least 4 hour.)
- Make sure that no other failure other than excessive deposits is observed.

■ DPF service

DOC: Maintenance-free parts
Replacement only, every 9000 hrs of operation

SF: Parts that require maintenance If your engine is equipped with DPF cleaning alarm, clean the DPF when the alarm lamp comes on. If your engine is not equipped with DPF cleaning alarm, clean the DPF every 3000 hrs of operation. Contact your authorized YANMAR industrial engine dealer or distributor for the detailed information about cleaning the DPF.

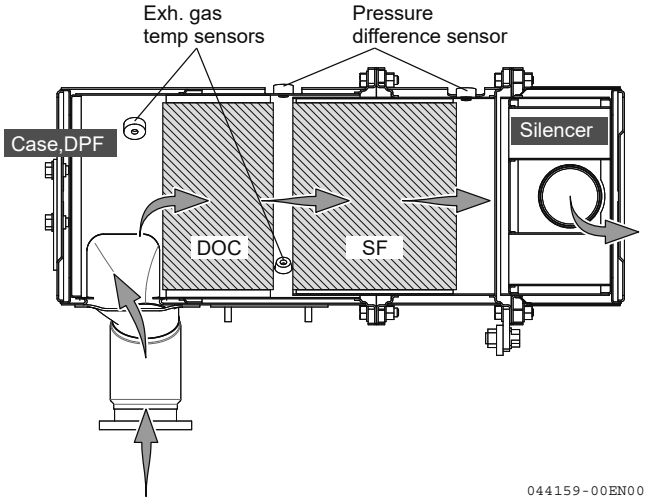


Figure 4-8-7

Item	Engine type	Emission warranty (Useful life)	Periodic maintenance interval	
			Replacement	Clean
DOC	19 - 37 kW	5000 hrs or 7 years, whichever comes first.	Every 9000 hrs of operation	N/A
	≥ 37 kW	8000 hrs or 10 years, whichever comes first		
SF	19 - 37 kW	5000 hrs or 7 years, whichever comes first	Every 9000 hrs of operation	With DPF cleaning alarm: when the alarm comes on Without DPF cleaning alarm: every 3000 hrs of operation
	≥ 37 kW	8000 hrs or 10 years, whichever comes first		

4-8-5 Troubleshooting of electronic control system

How to detect faults on the electronic control engine equipped with a fault indicator lamp (optional).

⚠ WARNING

- **Never use the ECU for other purposes than intended or in other ways than specified by YANMAR. Doing so could result in the violation of emission control regulations and will void the product warranty.**
- **When replacing the ECU, the correction value of the old ECU need to be written to the new ECU. Be sure to contact your local YANMAR dealer. If the correction value is not correctly written to the new ECU, the engine may fail to provide the expected performance.**
- **Improper use or misuse of the ECU may result in death or serious injury due to an abrupt and unexpected increase in engine speed.**

Fault Detection Capability

ECU has a fault detection capability that diagnoses various faults based on the information detected by the electronic control sensors and other engine fault detection sensors. Depending on the fault detected by the sensors, the operation that is performed when the fault occurs can be set individually as option. ECU turns on the fault indicator lamp (optional), and the indicator indicates that the fault is detected.

The fault indicator lamp comes on for approximately 2 seconds when the power is supplied to ECU, then goes off. The flashing pattern tells you that the power is supplied to ECU. The fault indicator lamp is located on a panel as shown in **(Figure 4-8-8, (1))**.

NOTICE

Shut down the engine if the fault indicator comes on. Continuing running the engine with the fault indicator being on may result in a serious malfunction of or damage to the engine, and will void the engine warranty.

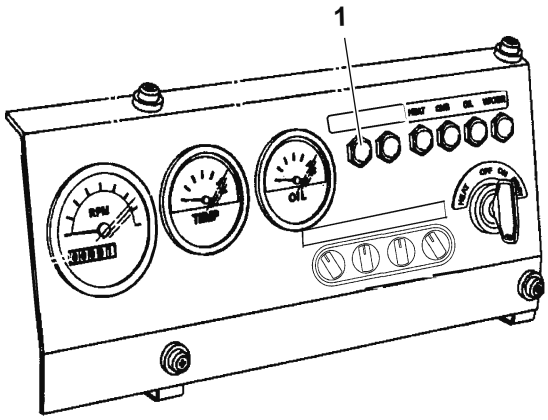


Figure 4-8-8

Figure 4-8-8 Typical operator's console

Figure 4-8-9 exemplifies flashing patterns of the fault indicator lamp.
The fault indicator lamp comes on for approximately 2 seconds when the switch is turned on, and goes off while the engine is running. If a fault occurs in ECU, this indicator lamp will come on 3 seconds after the indicator lamp goes off, and the lamp continuously stays on. If a fault occurs while the engine is running, the fault indicator lamp comes on at the time of fault occurrence.

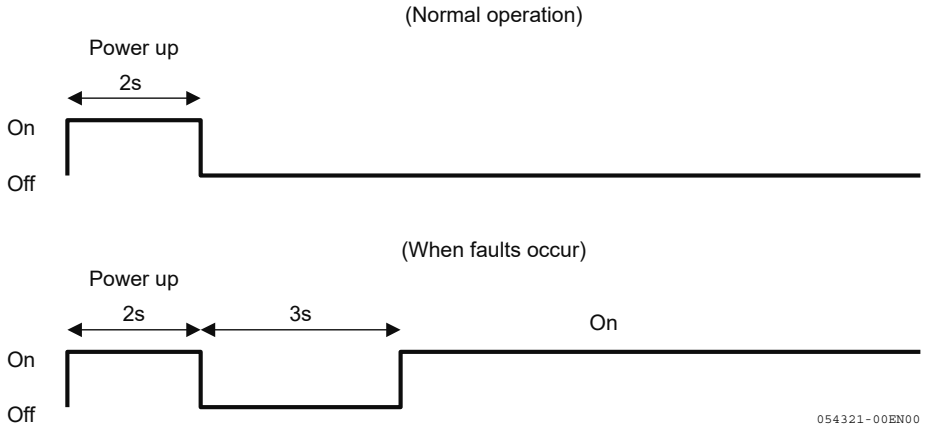


Figure 4-8-9

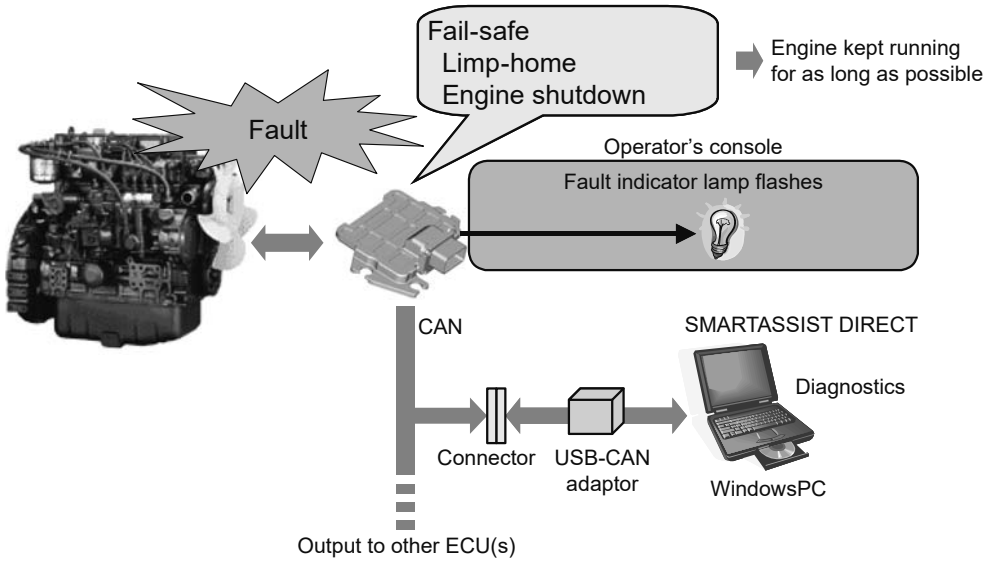


Figure 4-8-10

NOTICE

If the fault indicator lamp comes on, stop the engine immediately and contact your local YANMAR dealer.

As shown in **Figure 4-8-10**, SMARTASSIST DIRECT (SA-D), Yanmar genuine diagnosis tool, is required to connect to your engine for fault diagnosis.
SA-D allows reviewing detailed fault information, historical fault/alarm logs and freeze frame data. In addition, you can monitor the engine status and perform the fault diagnosis by using SMARTASSIST DIRECT. Events in the fault/alarm logs can be time stamped.

4-8-6 SMARTASSIST DIRECT (SA-D)

When the ECU or injectors are replaced, you need to rewrite the individual data inside the ECU.

A special treatment is also necessary when replacing DPF or sensors that affects the electronic control system.

A connector is provided at an end of the harness of the driven machine so that the YANMAR genuine SMMARTASSIST DIRECT (SA-D) can be loaded with data from the ECU. See **Figure 4-8-11** and **Figure 4-8-12**.

Contact your authorized YANMAR industrial engine dealer or distributor that can handle SA-D to repair or replace the electronic control parts. Also, refer to the SMARTASSIST DIRECT operation manual for the detailed operation.

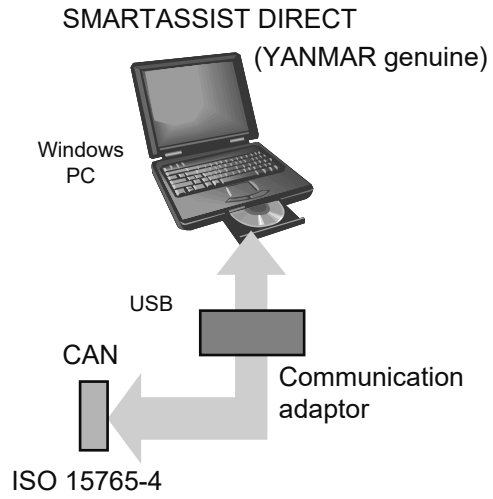
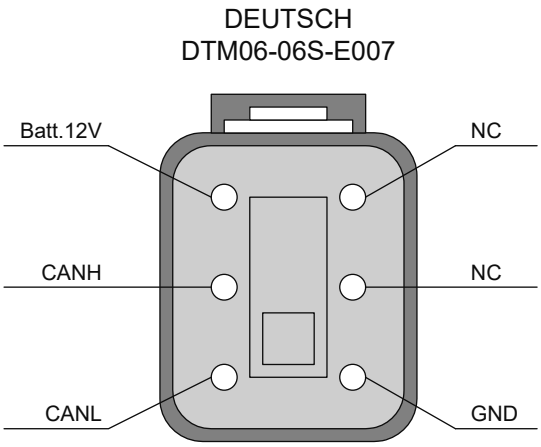


Figure 4-8-11



Mating connector (SMARTASSIST DIRECT side)
DEUTSCH
DTM04-06P-E003

Figure 4-8-12

■ About SA-D use

SA-D is a diagnosis tool that automatically transmits the following information to the YANMAR data server (SMARTASSIST CORE (SA-C)) from the ECU equipped in your driven machine via the Internet.

- Injector, exhaust gas post-treatment equipment, parts replacement information for controllers that are necessary for exhaust gas warranty claims.
- Accumulated operation information required for the reuse of exhaust gas post-treatment equipment.
- Operation history of an engine including fault history, operation time, engine speed, and load ratio.

All the obtained data will be used for the following purposes.

- To prevent improper service in the market
- To provide more accurate and prompt service
- To improve product quality through YANMAR Research and Development

4-8-7 Replacement of Components

If any part for the electronic control system must be repaired or replaced as a result of periodic maintenance or the failure diagnosis conducted using the SMARTASSIST DIRECT, do not attempt to repair the individual device of the electronic control system. Refer to the separate TROUBLESHOOTING manual, and replace the parts or entire assembly.

In addition, the following parts are used for the calculation of the accumulated PM amount. Therefore, when there is a fault in these parts, the accumulated PM amount may be miscalculated. Be sure to perform the DPF regeneration in order to eliminate the calculation error of the accumulated PM amount when you replace the parts.

- Injector
- Supply pump
- EGR valve
- ECU
- EGR pressure sensor
- DPF differential pressure sensor
- DPF inside temperature sensor
- Exhaust manifold temperature sensor
- Cooling water temperature sensor
- Rail CMP or rail pressure sensor
- DOC
- Intake throttle
- EGR gas temperature sensor
- DPF inlet temperature sensor
- Intake manifold temperature sensor
- Fuel temperature sensor
- Crankshaft rotation sensor

■ Processing the DPF regeneration after the parts replacement

Start and warm-up the engine until the cooling water temperature is 60 °C or higher.

- With optional recovery regeneration function equipped, when the ECU determines that the PM sediment amount is 12g/l or more, the recovery regeneration request is displayed. Perform the recovery regeneration.
- Without optional recovery regeneration function equipped, when the ECU determines that the PM sediment amount is 10g/l or more, the stationary regeneration request is displayed. Perform the stationary regeneration.
- When none of the above regeneration requests is displayed by the ECU, perform the stationary regeneration using SMARTASSIST DIRECT.

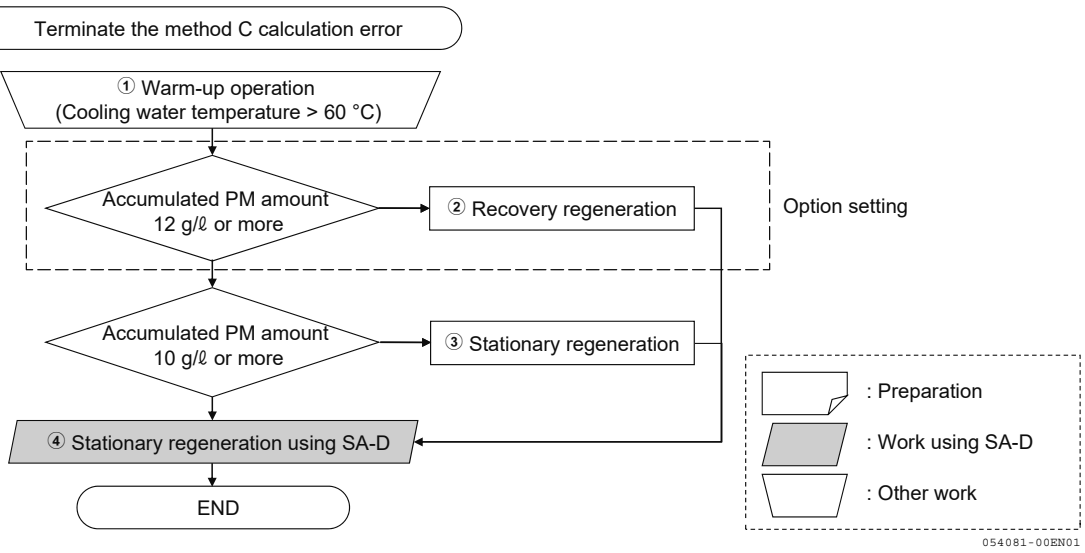


Figure 4-8-13

Calculation of PM sediment amount in DPF

ECU calculate the PM sediment amount that is accumulated in soot filter (SF) by following 2 methods:

- Method C calculates the difference between the estimated PM sediment amount that is discharged from the engine and the estimated PM sediment amount that is burned inside the SF.
- Method P calculates the PM sediment amount accumulated in the SF from the pressure difference between the inlet and outlet of the SF.

ECU uses the PM sediment amount whichever is greater for regeneration control.

■ Processing after the ECU replacement (when it is impossible to inherit from the old ECU)

When the history data could not be inherited from the old ECU at the time of replacing the ECU, process the DPF regeneration and check the accumulated ash amount in accordance with the following procedures.

1. Start and warm-up the engine until the cooling water temperature is 60 °C or higher.
   - With optional recovery regeneration function equipped, when the ECU determines that the PM sediment amount is 12g/l or more, the recovery regeneration request is displayed. Perform the recovery regeneration.
   - Without optional recovery regeneration function equipped, when the ECU determines that the PM sediment amount is 10g/l or more, the stationary regeneration request is displayed. Perform the stationary regeneration.
   - When none of the above regeneration requests is displayed by the ECU, perform the stationary regeneration using SMARTASSIST DIRECT.
2. After the completion of the regeneration, operate the engine at high idling for 10 minutes or more until the method P is stabilized.
   - Check the sediment amount of the method P using SMARTASSIST DIRECT (SA-D).
   - When the sediment amount exceeds 5g/l, clean the soot filter (SF).

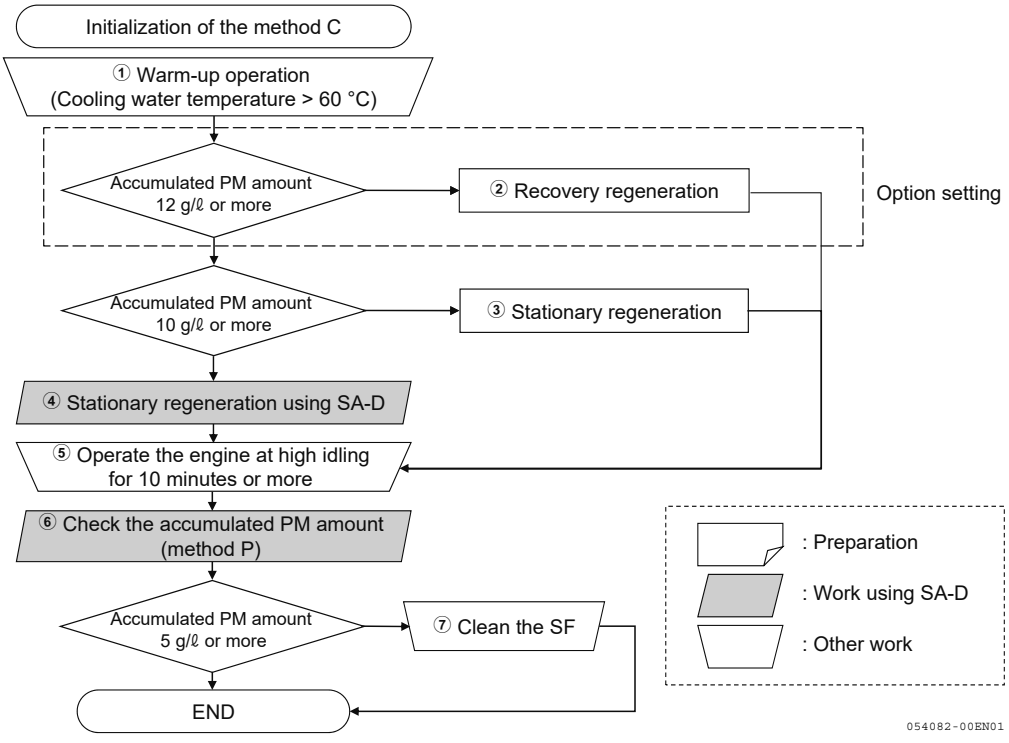


Figure 4-8-14

■ Required processing at the CR-related parts replacement

Replacement parts	SA-D operation	
	Bosch	
	ECU rewrite	Processing DPF regeneration
ECU	O	O*2
Injector	O	O
DPF	O	O
SF	O	O
DOC	O	O
Rail	O	O
Supply pump	–	O
Other*1	–	O

**1: EGR valve, intake throttle, DPF differential pressure sensor, DPF inlet temperature sensor, DPF inside temperature sensor, EGR pressure sensor, intake manifold temperature sensor, EGR gas temperature sensor, exhaust manifold temperature sensor, crankshaft speed sensor, fuel temperature sensor, cooling water temperature sensor.*

**2: When the history data could not be inherited from the old ECU, processing the DPF regeneration is required. Furthermore, it is required to clean the SF when the accumulated amount by method P after the DPF regeneration exceeds 5 g/ℓ.*

4-8-8 Installation Position of Sensors

Do not unnecessarily touch the sensor coupler portion with your bare hands.
The sensor may be damaged due to static electricity.

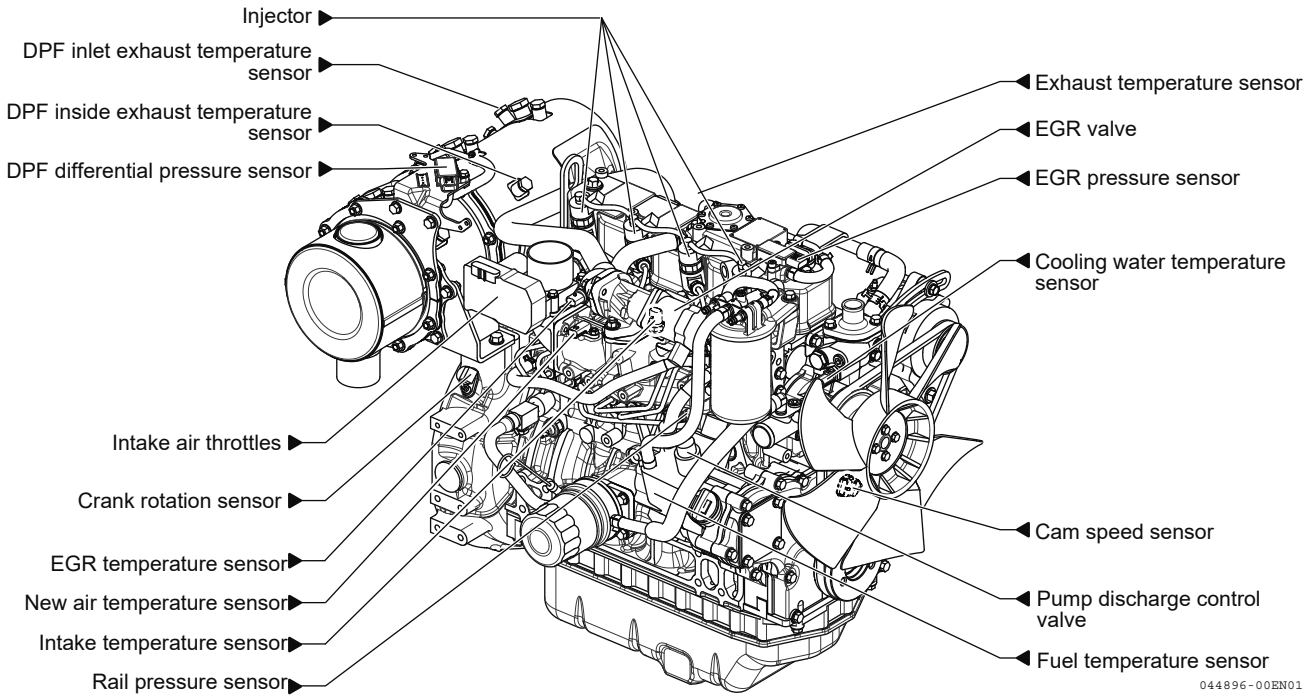


Figure 4-8-15

Crank Rotation Sensor

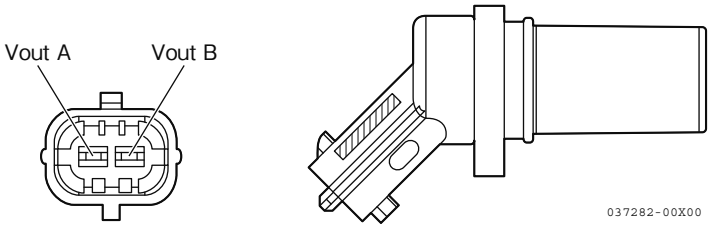


Figure 4-8-16

Part No.	129A00-21710
Sensor installation tightening torque	8 ± 2 N·m

Cam Speed Sensor

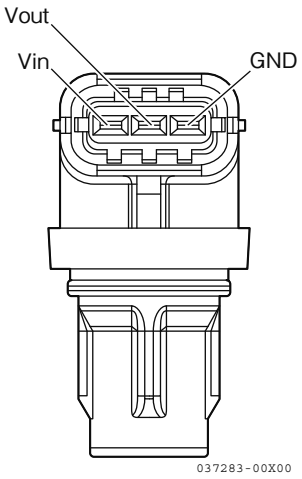


Figure 4-8-17

Part No.	129A00-14710
Sensor installation tightening torque	8 ± 0.5 N·m

New Air Temperature Sensor

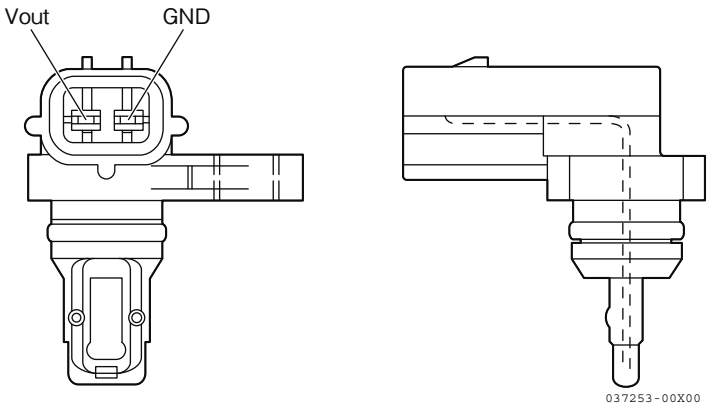


Figure 4-8-18

Part No.		129927-44900
Sensor installation tightening torque	With turbocharger	7.0 ± 1.4 N·m
	Without turbocharger	3.5 ± 0.5 N·m

EGR Temperature Sensor

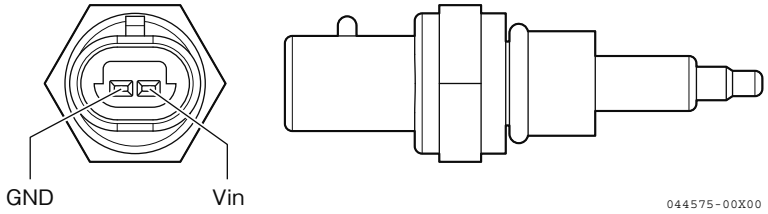


Figure 4-8-19

Part No.	129A00-13750
Sensor installation tightening torque	14 ± 3 N·m

Intake Temperature Sensor

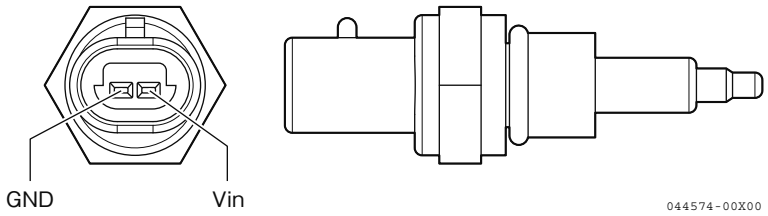


Figure 4-8-20

Part No.	129A00-12720
Sensor installation tightening torque	14 ± 3 N·m

Fuel Temperature Sensor (equipped on supply pump)

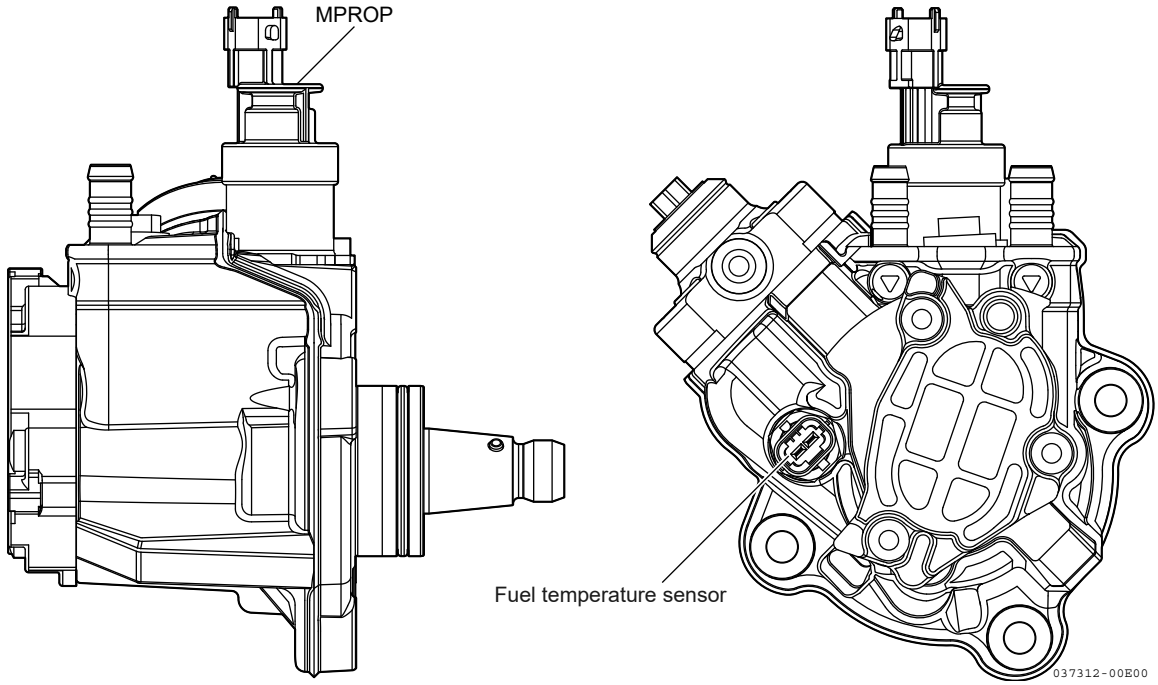


Figure 4-8-21

Part No.	129A00-51200
Sensor installation tightening torque	28 ± 2 N·m

Cooling Water Temperature Sensor

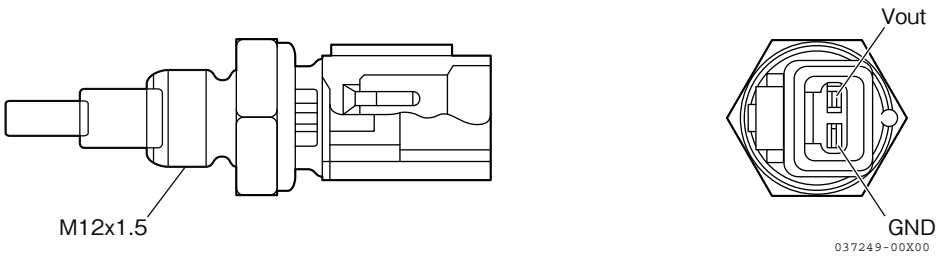


Figure 4-8-22

Part No.	129927-44900
Sensor installation tightening torque	22 ± 2 N·m

Diesel Particulate Filter (DPF) Inside/Inlet, Exhaust Temperature Sensor

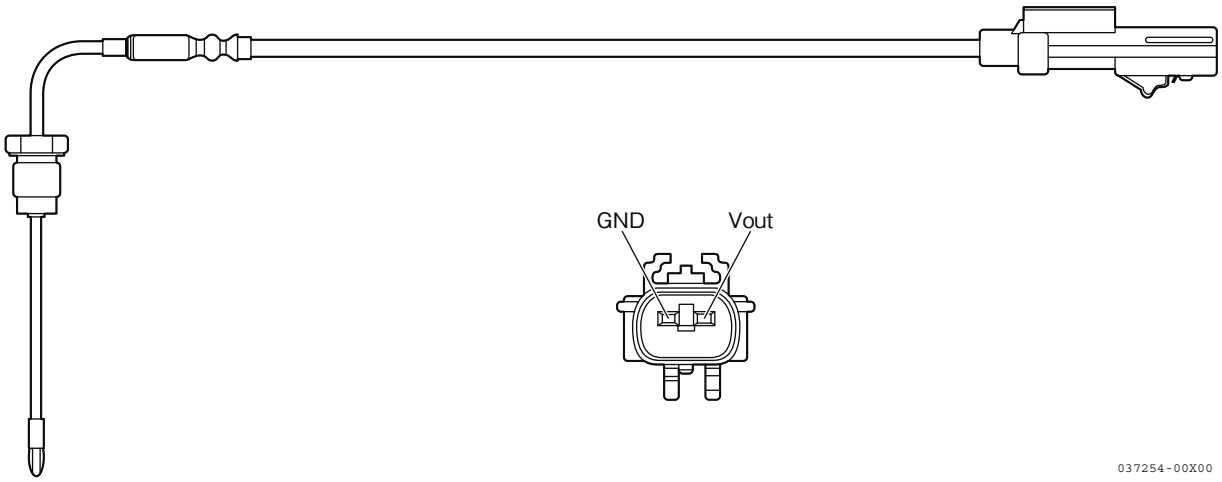


Figure 4-8-23

	Exhaust temperature sensor	DPF inside exhaust temperature sensor	DPF inlet exhaust temperature sensor
Part No.	129A00-13760 (Main)	129A00-13980	129A00-13990
Sensor installation tightening torque	25 - 40 N·m	25 - 40 N·m	25 - 40 N·m
Safety precaution	Do not lift the DPF by holding the sensor part.		

Rail Pressure Sensor

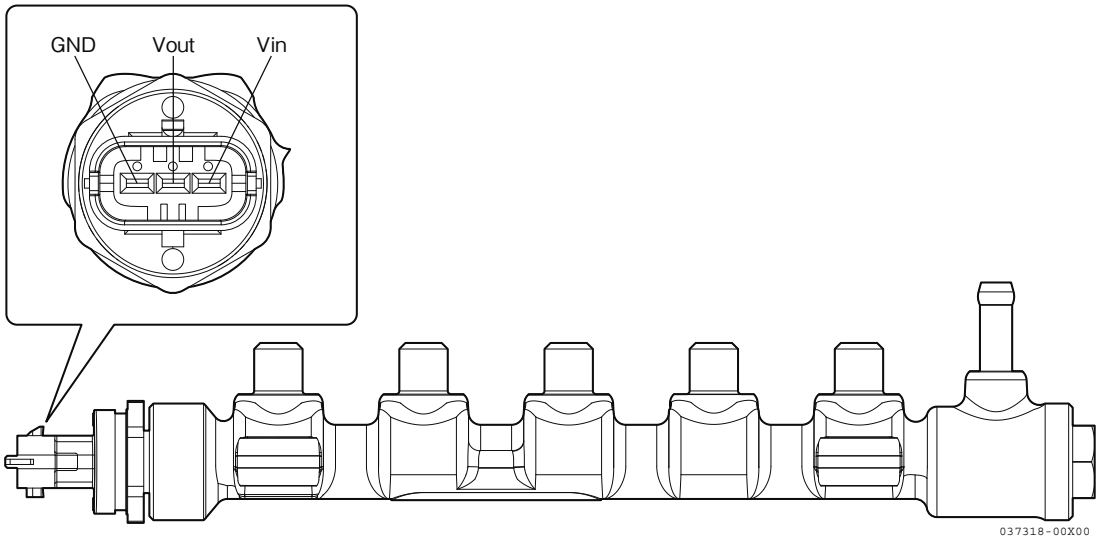


Figure 4-8-24

Part No.	129A00-57100
Sensor installation tightening torque	95 ± 5 N·m

EGR Pressure Sensor

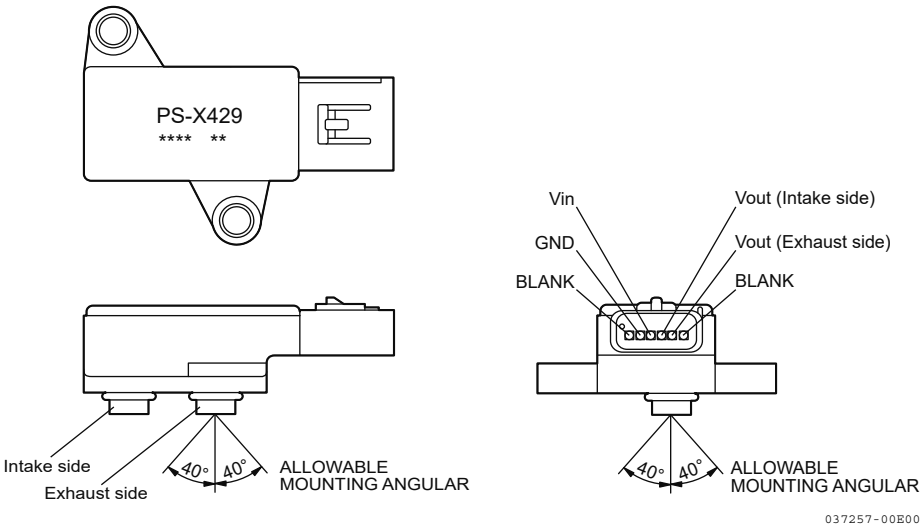


Figure 4-8-25

Part No.	129A00-12700
Sensor installation tightening torque	7 ± 1.4 N·m

Diesel Particulate Filter (DPF) Differential Pressure Sensor

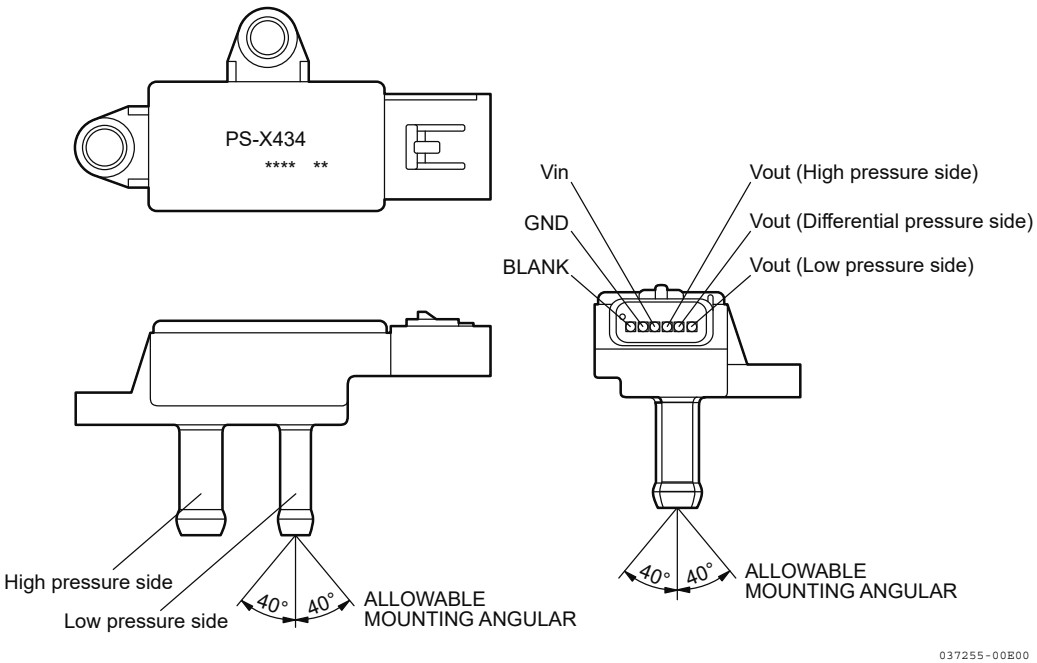
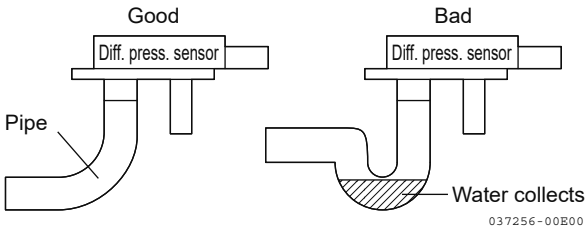


Figure 4-8-26

Part No.	129A00-17700
Sensor installation tightening torque	7 ± 1.4 N·m
Safety precaution	If you install a pipe to the DPF differential pressure sensor, do not install it as shown in the below figure. If water collects, the pressure cannot be detected.  Differential pressure sensor pipe installation (example)

EGR Valve

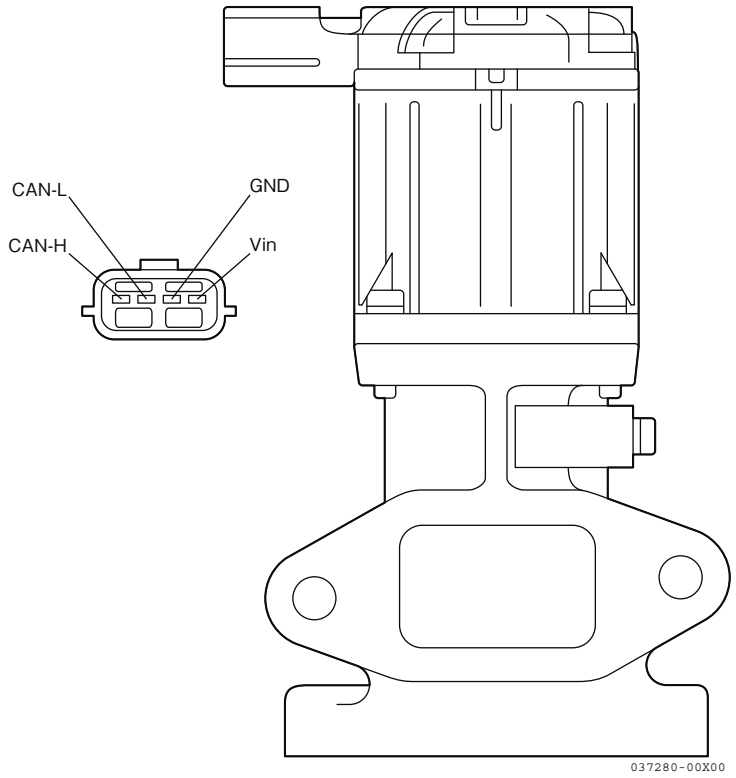


Figure 4-8-27

	4TNV98C, 4TNV98CT
Part No.	129E00-13901

Intake Air Throttles

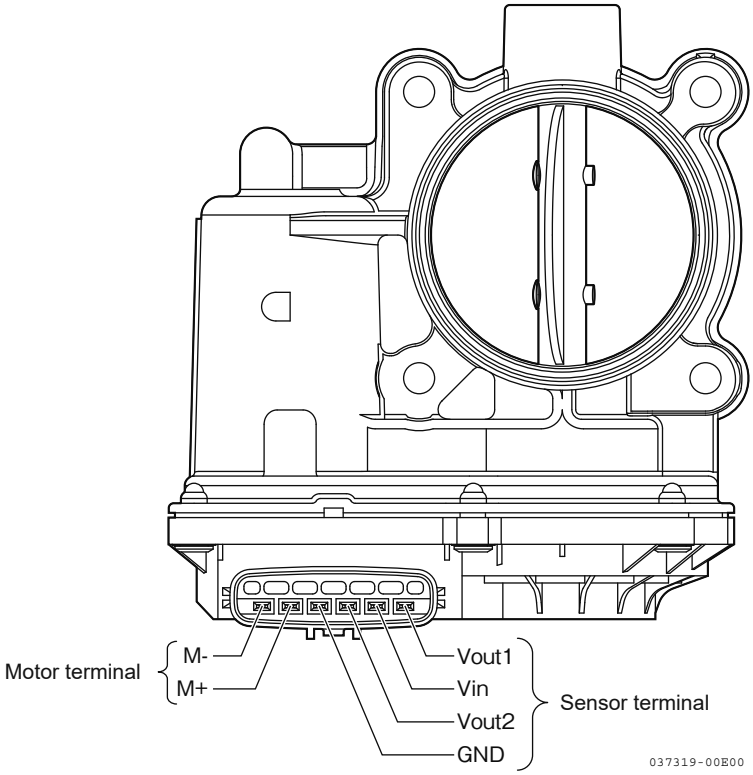


Figure 4-8-28

Part No.	129A00-12900
Sensor installation tightening torque	9.0 ± 1.8 N·m
Safety precaution	Be sure to read the precautions before handling the intake throttle.

4-9 Electric Wiring

4-9-1 Electric Wiring Precautions

Failure to follow these precautions may result in the failure of an electrical component and the loss of warranty coverage on that item as well as related items. Make sure that all users read and understand these precautions.

NOTICE

Do not reverse the positive (+) and negative (-) ends of the battery cable. The alternator diode and stator coil will be damaged.

NOTICE

When the battery indicator goes out, it should not come on again. The battery indicator only comes on during operation if the alternator fails. However, if an LED is used in the battery indicator, the LED will shine faintly during normal operation.

NOTICE

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated in the *Battery Cable Resistance chart* in the *Electric Wiring Section* of this manual. The starter motor will malfunction and fail if the resistance is higher than the specified value.

NOTICE

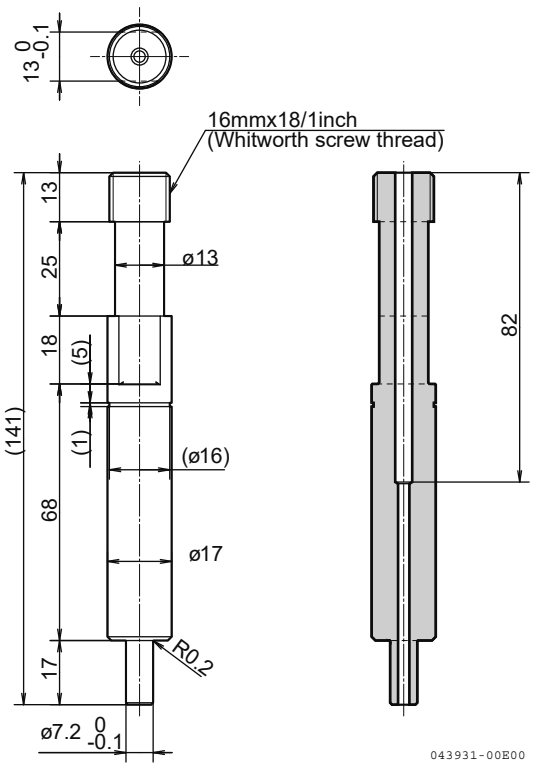
Removing the battery cables or the battery while the engine is operating may cause damage to the current limiter depending on the electrical equipment being used. This situation could cause loss of control of output voltage. The continuous high voltage of 23 - 24 V (for 5000 min^{-1} (rpm) dynamo) will damage the current limiter and other electrical equipment.

NOTICE

Reversing the battery cable connections at the battery or on the engine will destroy the SCR diode in the current limiter. This will cause the charging system to malfunction and may cause damage to the electrical harnesses.

4-10 Failure Diagnosis

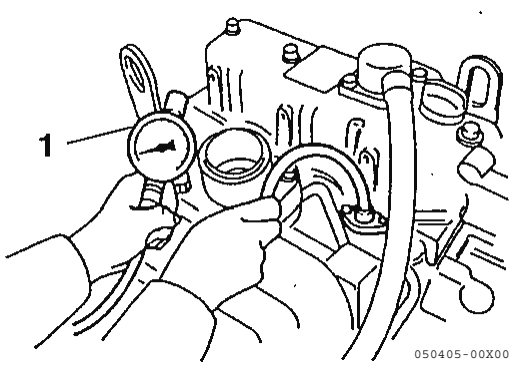
4-10-1 Special Service Tools

Compression gauge	For measuring compression pressure YANMAR Part No.129978-92950 For detailed dimensions, *refer to Compression gauge adapter (129A00-92950) on page 4-2-4.*	

4-10-2 Tier 4 (BOSCH) Compression Inspection Procedures

1. Warm up the engine.
2. Stop the engine.
3. Remove the high-pressure fuel line assembly.
4. Remove the injector harnesses (couplers) of all cylinders.
5. Remove the injector fuel return hose assembly of all cylinders.
6. Remove the injectors of all cylinders. Fill in the cylinder No. on the injector before removal.
7. Install the injectors and the high-pressure lines of all cylinders in the direction where there is no influence of the inspection operation.
   Install the harnesses (couplers) in the injectors.
8. Connect the service tool (SMARTASSIST-Direct) while the engine key is turned ON. Cut the injector fuel injection of all cylinder with the active control mode.
9. Install the special-purpose adapter and the compression gauge to the cylinder you want to measure.
10. Crank and inspect the engine until the display of the compression gauge becomes stable.
11. When the compression inspection is complete, turn OFF the active control, turn OFF the SA-D communication, turn OFF the engine key.
12. Remove the special-purpose adapter and the compression gauge to the cylinder you want to measure.
13. Insert the injectors to the correct cylinders.
    Tighten the injectors.

    Note: Be sure to install the injector packings to all cylinders.



14. Install the injector fuel return hose assembly of all cylinders.
15. Install the injector harnesses (couplers) of all cylinders.
16. Install the new high-pressure fuel line assembly.
17. Open the cock of the fuel system.
18. Test the engine. Check for the fuel leaks.

    Note: Take care not to adhere or mix the foreign matter when you install the injector, rail, and high-pressure fuel line.

■ Standard compression pressure (reference value)

Engine model	Compression pressure at 250 min^{-1}		Deviation between cylinders
	Standard	Limit	
4TNV98C 4TNV98CT	3.14 - 3.34 MPa (32 - 34 kgf/cm^2)	2.45 - 2.65 MPa (25 - 27 kgf/cm^2)	0.2 - 0.3 MPa (2 - 3 kgf/cm^2)

■ Engine speed and compression pressure (use for reference)

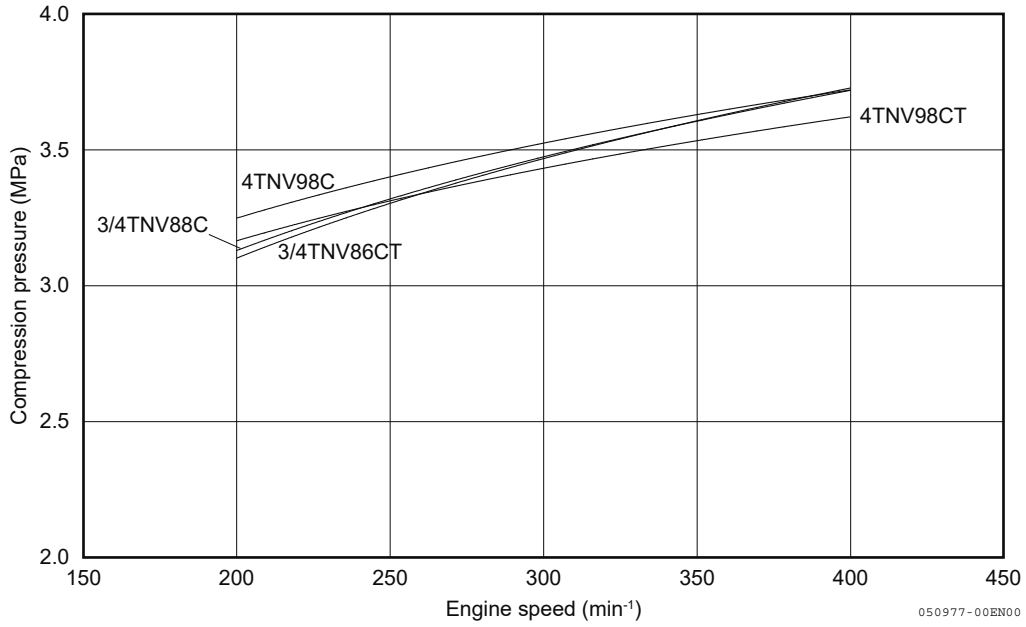


Figure 4-10-1

4-10-3 Measured Value and Troubleshooting

When the measured compression pressure is below the limit value, inspect each part by referring to the table below.

No.	Item	Cause	Corrective action
1	Air cleaner element	Clogged element	Clean the element.
		Broken element	Replace the element.
		Defect at element seal portion	
2	Valve clearance	Excessive or no clearance	Adjust the valve clearance.
3	Valve timing	Incorrect valve clearance	Adjust the valve clearance.
4	Cylinder head gasket	Gas leak from gasket	Replace the gasket.
			Retighten the cylinder head bolts to the specified torque.
5	Intake/exhaust valve	Sticking valve	Replace the intake/exhaust valve.
	Valve seat	Gas leak due to worn valve seat or foreign matter trapped in valve	Lap the valve seat.
6	Piston	Gas leak due to scratching or wear	Perform honing and use an oversized part.
	Piston ring		
	Cylinder		

4-10-4 Quick Reference Table for Troubleshooting

The following table summarizes the general trouble symptoms and their causes. If any trouble symptom occurs, take corrective action before it becomes a serious problem so as not to shorten the engine service life.

For details of troubleshooting on electronic control (ECU), refer to the SA-D section in Tier 4 Troubleshooting Manual.

Failure Diagnostic List

Cause \ Symptoms and conditions of failures		Defective start					Engine stall after start			Defective rotation control						Insufficient engine output			Noise/vibration				Lubricant				Cooling water		Intake		Exhaust			Fuel			Electrics/electronics					Action	Referenced page number
		Starter not rotate		Starter rotates			Exhaust fume				Without load				At work	Exhaust color														At work													
		ECU indicator lamp not on just after key-on	ECU indicator lamp on just after key-on (2 seconds)	Engine not start (not even initial combustion)	Engine not start (stall after serial combustion)	Engine starts later then ever	None	Little	Much	Speed change by accelerator not available (constant speed)	Specified speed setting not available	Poor acceleration	Return to low speed not smooth	Hunting	Hunting	Normal	White	Black	Knocking noise at combustion too high	Combustion noise uneven	Noise other than combustion from engine	Engine vibration too big	Lubricant consumption too much	Lubricant diluted with fuel	Lubricant mixed with water	Oil pressure too low (oil pressure lamp on)	Overheated (water temperature lamp on)	Water temperature too low	Pressure down (air cleaner lamp on)	Pressure up	White exhaust color	Black exhaust color	Blow-by too much	Exhaust temperature up	Fuel consumption too much	Fuel mixed with water (oil-water separator lamp on)	Fuel filter contaminated too early	Battery charge defect (charge lamp on)	ECU indicator lamp flashing	ECU indicator lamp not on just after key-on (2 seconds)	Prescribed ECU control function not operate	Fuse meltdown, disconnection (repeated)		
Engine system	Intake/exhaust valve clearance incorrect			O			O									O					O								O				O								Valve clearance adjustment	*See Measuring and Adjusting Valve Clearance on page 4-2-22*
	Compression failure at valve seat			O												O		O			O								O		O	O	O	O								Valve seat facing	*See Valve face and valve seat on page 4-2-16.*
	Intake/exhaust valve seizure			O					O						O	O		O			O	O		O					O		O	O										Correction or replacement of intake/exhaust valve	See Removal of intake/exhaust valves on page 4-2-12.
	Cylinder head gasket blow-out															O								O		O																	Gasket replacement	See Removal of cylinder head on page 4-2-11.
	Piston ring sticking or breakage			O					O					O			O				O	O	O			O				O		O	O										Piston ring replacement	See Removal of pistons on page 4-2-30.
	Wear of piston ring, piston or cylinder			O					O								O						O	O						O		O										Horning work and usage of over-sized parts	See Honing and Boring on page 4-2-39.
	Seizure of crank pin metal or bearing parts			O			O							O	O						O	O									O											Repair or replacement	See Inspection of crankshaft on page 4-2-37.
	Closed gap position fault of piston ring						O										O						O									O											Correction of closed gap position	See Reassembly of pistons on page 4-2-40.
	Reverse assembling of piston ring																O						O							O		O											Correction of assembling	See Reassembly of pistons on page 4-2-40.
	Wear of crank pin metal and journal metal													O	O	O					O	O			O																		Measurement and replacement	See Inspection of crankshaft on page 4-2-37.
	Connecting rod bolt loose																				O	O			O																		Tightening at specified torque	
	Foreign material entered into combustion chamber			O																	O		O									O											Disassembling and repair	See Disassembly of Engine on page 4-2-25.
	Gear backlash too big																				O																						Gear mesh adjustment	See Checking timing gear backlash on page 4-2-26.
	Wear of intake/exhaust valve guide																O						O									O											Measurement and replacement	See Inspection of valve guides on page 4-2-15.
	Open/close timing failure of intake/exhaust valve			O													O	O			O									O	O											Valve clearance adjustment	*See Measuring and Adjusting Valve Clearance on page 4-2-22.*
	Engine vibration isolating support loose, damage													O	O						O	O																					Repair or replacement of faulty parts	
Turbocharger	Blower contamination																	O													O		O										Floor cleaning	
	Operation defect of waste gate																	O													O		O										Disassembling and inspection	
	Wear of radial metal																O						O								O												Disassembling and inspection	

Symptoms and conditions of failures / Cause		Defective start					Engine stall after start			Defective rotation control						Insufficient engine output			Noise/vibration				Lubricant				Cooling water		Intake		Exhaust			Fuel			Electrics/electronics						Action	Referenced page number
		Starter not rotate		Starter rotates			Exhaust fume				Without load				At work	Exhaust color														At work													
		ECU indicator lamp not on just after key-on	ECU indicator lamp on just after key-on (2 seconds)	Engine not start (not even initial combustion)	Engine not start (stall after serial combustion)	Engine starts later then ever	None	Little	Much	Speed change by accelerator not available (constant speed)	Specified speed setting not available	Poor acceleration	Return to low speed not smooth	Hunting	Hunting	Normal	White	Black	Knocking noise at combustion too high	Combustion noise uneven	Noise other than combustion from engine	Engine vibration too big	Lubricant consumption too much	Lubricant diluted with fuel	Lubricant mixed with water	Oil pressure too low (oil pressure lamp on)	Overheated (water temperature lamp on)	Water temperature too low	Pressure down (air cleaner lamp on)	Pressure up	White exhaust color	Black exhaust color	Blow-by too much	Exhaust temperature up	Fuel consumption too much	Fuel mixed with water (oil-water separator lamp on)	Fuel filter contaminated too early	Battery charge defect (charge lamp on)	ECU indicator lamp flashing	ECU indicator lamp not on just after key-on (2 seconds)	Prescribed ECU control function not operate	Fuse meltdown, disconnection (repeated)		
Cooling water system	Radiator super cooled																																									Thermostat replacement	*See Disassembly of Engine Coolant Pump on page 4-4-6.*
	Insufficient radiator cooling																	○								○						○											Thermostat replacement or check for fan belt loose	*See Disassembly of Engine Coolant Pump on page 4-4-6.*
	Insufficient cooling water quantity																	○								○						○											Water leak inspection of cooling water system	*See Engine Coolant System Check on page 4-4-4.*
	Water jacket cracks																								○	○																	Repair or replacement	*See Disassembly of Engine Coolant Pump on page 4-4-6.*
	Fan belt elongation																	○								○						○											Adjustment of belt tension	
	Thermostat fault																	○								○	○			○													Inspection or replacement	*See Disassembly of Engine Coolant Pump on page 4-4-6.*
Lubricant system	Incorrect lubricant			○			○									○							○			○							○										Usage of correct lubricant	
	Lubricant system leakage																						○			○																	Repair	
	Insufficient discharge rate of trochoid pump																									○																	Inspection and repair	
	Lubricant filter clogged																									○							○										Cleaning or replacement	
	Regulator valve fault																									○																	Cleaning, adjustment or replacement	
	Insufficient lubricant quantity						○																			○																	Replenishment of correct lubricant	
	Excess filling into crankcase																						○			○				○													Engine oil check	
Fuel system	Incorrect fuel															○	○	○		○										○	○				○	○								Usage of correct fuel	
	Water entered into fuel system			○	○				○					○	○		○			○										○					○									Drainage of fuel filter	
	Fuel filter clogged			○		○	○					○				○																										Cleaning or replacement	
	Air entered into fuel system			○	○		○							○	○	○																										Bleeding	
	Fuel pipe clogged, cracked			○			○									○																										Cleaning or replacement	
	Insufficient fuel feeding to fuel supply pump			○	○		○					○				○																										Check of fuel tank cock, fuel filter, fuel pipe, fuel feed pump	
	Priming not available			○																																						Valve in priming pump pinched dust (disassembled cleaning)	*See Fuel System Components on page 4-3-5.*
	Strainer at feed pump inlet clogged					○						○				○																										Cleaning of strainer	
	Sealing defect of fuel tank																																			○	○						Check of fuel tank and cap, as well as installation of genuine parts	
Intake	Air filter clogged								○			○						○		○			○						○		○		○										Cleaning of air filter	
	Engine operation at high temperature or high land																	○									○		○			○											Consideration of matching output reduction with load	
	Exhaust pipe clogged							○				○						○		○											○		○											Cleaning of exhaust pipe	

Symptoms and conditions of failures / Cause		Defective start					Engine stall after start			Defective rotation control						Insufficient engine output			Noise/vibration				Lubricant				Cooling water		Intake		Exhaust				Fuel				Electrics/electronics					Action	Referenced page number
		Starter not rotate		Starter rotates			Exhaust fume				Without load			At work		Exhaust color													At work															
		ECU indicator lamp not on just after key-on	ECU indicator lamp on just after key-on (2 seconds)	Engine not start (not even initial combustion)	Engine not start (stall after serial combustion)	Engine starts later then ever	None	Little	Much	Speed change by accelerator not available (constant speed)	Specified speed setting not available	Poor acceleration	Return to low speed not smooth	Hunting	Hunting	Normal	White	Black	Knocking noise at combustion too high	Combustion noise uneven	Noise other than combustion from engine	Engine vibration too big	Lubricant consumption too much	Lubricant diluted with fuel	Lubricant mixed with water	Oil pressure too low (oil pressure lamp on)	Overheated (water temperature lamp on)	Water temperature too low	Pressure down (air cleaner lamp on)	Pressure up	White exhaust color	Black exhaust color	Blow-by too much	Exhaust temperature up	Fuel consumption too much	Fuel mixed with water (oil-water separator lamp on)	Fuel filter contaminated too early	Battery charge defect (charge lamp on)	ECU indicator lamp flashing	ECU indicator lamp not on just after key-on (2 seconds)	Prescribed ECU control function not operate	Fuse meltdown, disconnection (repeated)		
Electric system	Fuse meltdown, disconnection	O	O				O																															O		O	Inspection and replacement of fuse Repair or replacement of harness	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Starter fault		O	O																																					Repair or replacement of starter	*See Starter Motor on page 4-6-1.*
	Alternator fault			O																																O					Repair or replacement of alternator	*See Removal of Alternator on page 4-7-7.*
	Wiring disconnection	O	O	O			O																													O	O	O	O		Repair or replacement of harness disconnection	
	Wiring short-circuit (insulator broken), electric power load of added device too big	O																																						O	Inspection, repair or replacement of harnesses Review of added devices	
	Battery voltage descent		O	O																																-					Inspection and charging of battery	
	Key switch fault, disconnection	O					O																															O			Repair or replacement of harness Key switch replacement	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Instantaneous interruption of key switch				O		O																																		Key switch replacement	
	Failure, disconnection, short-circuit of starter relay		O																																						Repair or replacement of harness Replacement of starter relay	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Main relay fault (Error other than contact sticking that ECU can't detect)	O																																				O			Repair or replacement of harness Replacement of main relay	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Actuator relay fault (Error of contact that ECU can't detect)		O	O			O																																		Replacement of actuator relay	
	The start assist relay may be faulty. (Error of contact that ECU can't detect)			O		O													O											O												Replacement of start assist relay	
	Accelerator sensor signal error (Error at which level ECU can't detect)										O			O	O					O																						Repair or replacement of accelerator sensor	Monitor the accelerator sensor by the diagnosis tool.
	Water temperature sensor signal error (Error at which level ECU can't detect)			O		O								O	O				O																							Replacement of water temperature sensor	Monitor the cooling water temperature by the diagnosis tool.
	Speed sensor signal error (Cause of noise etc. that ECU can't detect)				O	O	O							O	O					O																						Cleaning or replacement of speed sensor Repair or replacement of fuel supply pump	Monitor the engine rotational speed by the diagnosis tool.
	Rack position sensor signal error (Level that ECU can't detect)					O	O						O	O	O					O																						Repair or replacement of fuel supply pump	Monitor the rack position sensor signal by the diagnosis tool.
	Operation defect of rack actuator (Level that ECU can't detect)					O	O						O	O	O					O																						Repair or replacement of fuel supply pump	Check the movement of rack actuator by the diagnosis tool.
	ECU failure lamp disconnected																																						O			Replace the lamp. Repair or replace the harness.	
	ECU faulty (ECU self diagnosis failure)	O	O								O																												O	O		Replace the ECU.	

Symptoms and conditions of failures / Cause		Defective start					Engine stall after start			Defective rotation control					Insufficient engine output			Noise/vibration				Lubricant				Cooling water		Intake		Exhaust				Fuel			Electrics/electronics					Action	Referenced page number
		Starter not rotate		Starter rotates			Exhaust fume				Without load			At work	Exhaust color														At work													
		ECU indicator lamp not on just after key-on	ECU indicator lamp on just after key-on (2 seconds)	Engine not start (not even initial combustion)	Engine not start (stall after serial combustion)	Engine starts later then ever	None	Little	Much	Speed change by accelerator not available (constant speed)	Specified speed setting not available	Poor acceleration	Return to low speed not smooth	Hunting	Hunting	Normal	White	Black	Knocking noise at combustion too high	Combustion noise uneven	Noise other than combustion from engine	Engine vibration too big	Lubricant consumption too much	Lubricant diluted with fuel	Lubricant mixed with water	Oil pressure too low (oil pressure lamp on)	Overheated (water temperature lamp on)	Water temperature too low	Pressure down (air cleaner lamp on)	Pressure up	White exhaust color	Black exhaust color	Blow-by too much	Exhaust temperature up	Fuel consumption too much	Fuel mixed with water (oil-water separator lamp on)	Fuel filter contaminated too early	Battery charge defect (charge lamp on)	ECU indicator lamp flashing	ECU indicator lamp not on just after key-on (2 seconds)	Prescribed ECU control function not operate	Fuse meltdown, disconnection (repeated)		
Engine stop or operation limits by ECU failure diagnosis function	ECU control function operating		○							○	○				○																									Not failure Implement regular usage	Check the causes of engine stop or starter restraint by a diagnosis tool.
	Disconnection/short-circuit of water temperature sensor										○				○																						○				Repair or replacement of harness Replacement of water temperature sensor	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Disconnection/short-circuit of accelerator sensor									○																											○				Repair or replacement of harness Replacement of accelerator sensor	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Speed sensor signal error				○		○																														○				Repair or replacement of harness Repair or replacement of fuel supply pump	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Engine over speed						○																														○				Check operating machine's driving. Check speed sensor signal.	
	CAN communication error									○																											○		○		Repair or replacement of harness ECU Replacement	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Disconnection/short-circuit of EGR valve motor										○				○																						○				Repair or replacement of harness Replacement of EGR valve	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Disconnection/short-circuit of start assist relay			○		○																							○								○				Repair or replacement of harness Relay replacement	For harness inspection method, *see Failure Diagnosis on page 4-10-1.*
	Main relay "OFF" not available																																			○	○				Relay replacement	
	Malfunction by ECU self-diagnosis		○																																		○				ECU Replacement	

CHAPTER 5

ELECTRIC SYSTEM

5-1 Electric Equipment of Machine 5-1-1
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5-2-1 Parts Layout of Electrical Equipment 5-2-1
5-2-2 LCD Monitor and Alarm Systems 5-2-1
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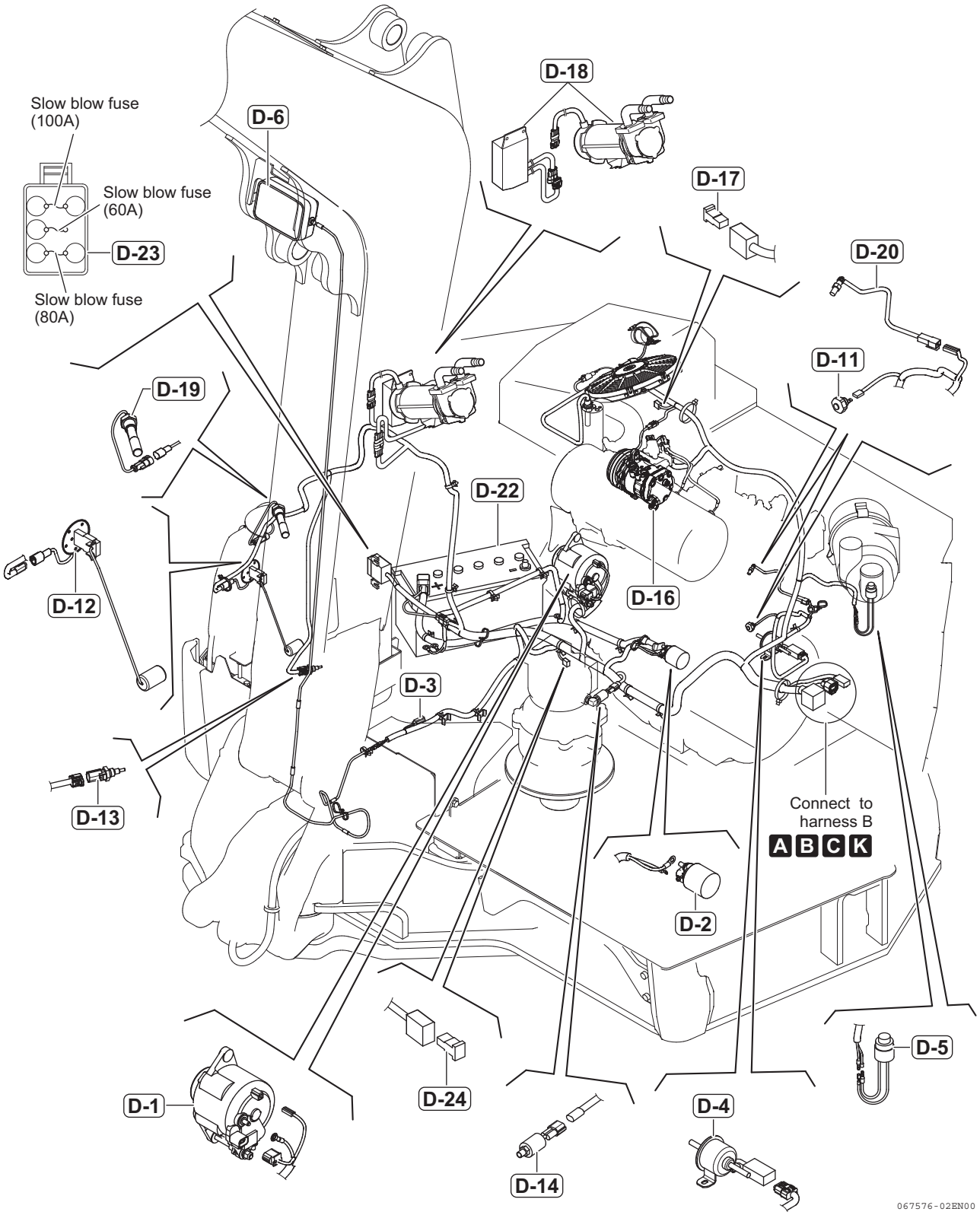
5. Electric System

5-1 Electric Equipment of Machine

5-1-1 Parts Layout of Electrical Equipment

1) Equipment and Electric Wiring: Harness A



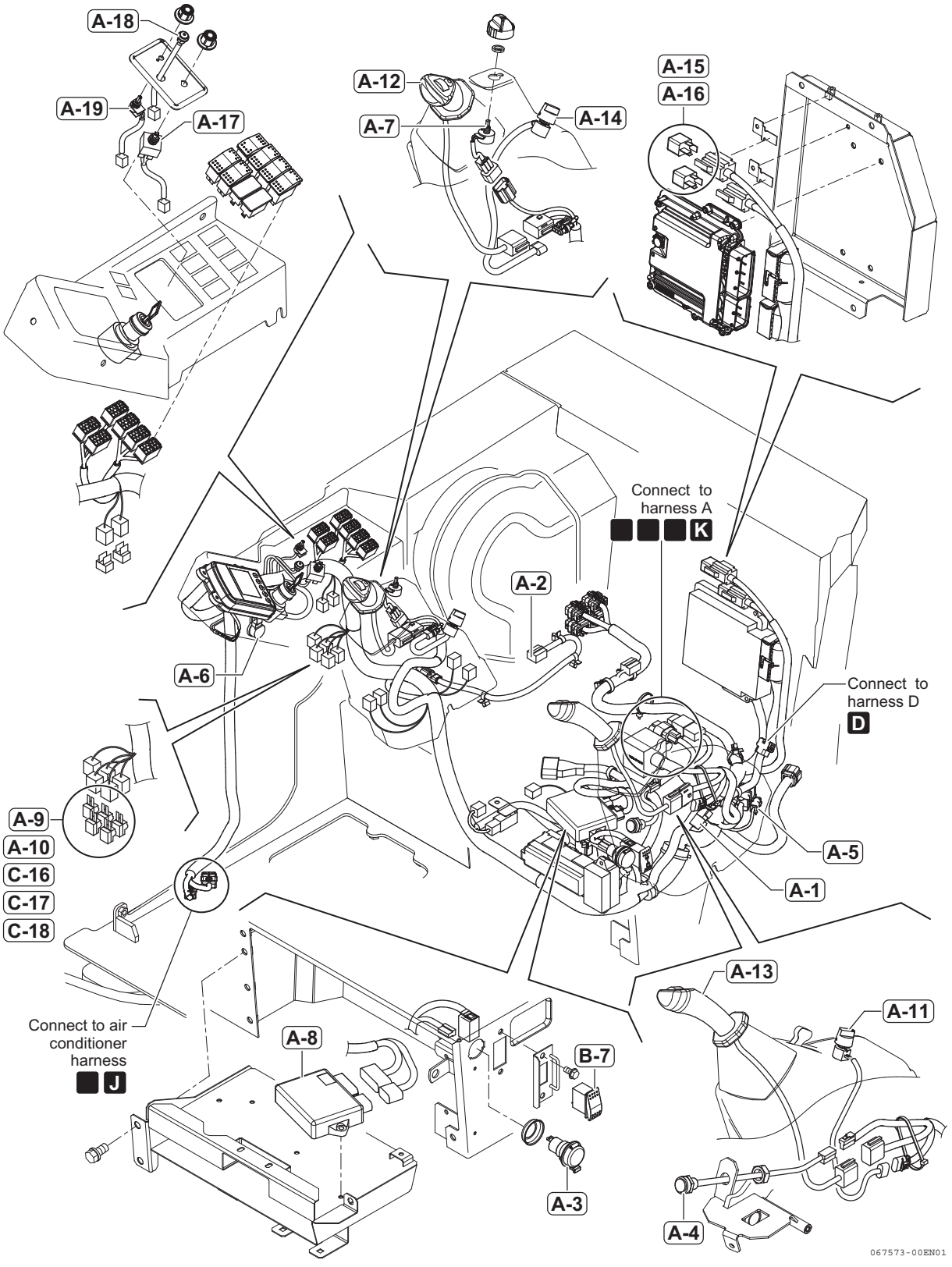
5. ELECTRIC SYSTEM

Ref. No.	Part	Ref. No.	Part
D-1	Generator	D-13	Hydraulic oil temperature sensor
D-2	Starter motor	D-14	Control oil pressure detection switch
D-3	Pressure switch (YCEE option)	D-15	(Refer to 5-1-10.)
D-4	Fuel pump	D-16	Compressor
D-5	Air cleaner switch	D-17	Diode 3A
D-6	Work lamp (boom)	D-18	Refueling pump*
D-7	(Refer to 5-1-10.)	D-19	Fuel level sensor*
D-8	(Refer to 5-1-11 and 5-1-12.)	D-20	Glow plug
D-9	(Refer to 5-1-11 and 5-1-12.)	D-21	(Refer to 5-1-10.)
D-10	(Refer to 5-1-11 and 5-1-12.)	D-22	Battery 130E41R
D-11	Engine oil pressure switch	D-23	Slow blow fuse box
D-12	Fuel gauge	D-24	Slow blow fuse, charge

* S/N 1A001 to 1B387: optional, S/N 1B388 and above: standard.

Each reference number (e.g., A-1) corresponds to the numbers described in Section "2-9 Wiring Diagram" and APPENDIX Wiring Diagram.

2) Equipment and Electric Wiring: Harness B

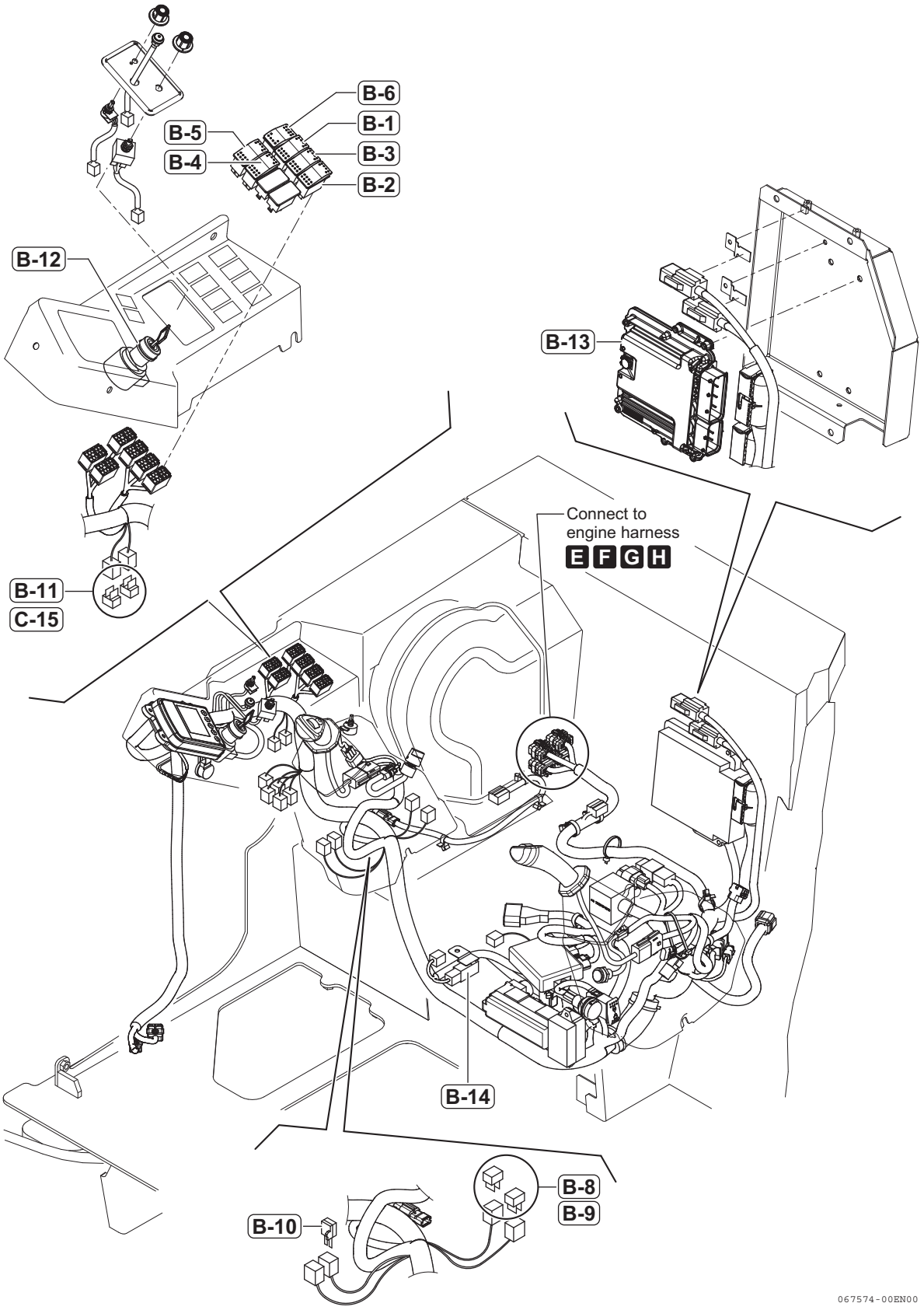


5. ELECTRIC SYSTEM

Ref. No.	Part	Ref. No.	Part
A-1	Indicator lamp (YCEE)	A-13	Remote control lever L (P.T.O.2)
A-2	Seat switch (YCEE)	A-14	P.T.O. flow control dial (P.T.O.2)
A-3	Power output (12v)	A-15	Glow relay (Wiring color: R, R/W, L/W, B)
A-4	Cut-off switch	A-16	Starter relay (Wiring color: W, R/B, G, P)
A-5	Quick coupler controller (For US machines only)	A-17	Blower switch
A-6	Buzzer	A-18	AC switch
A-7	Engine control dial	A-19	Thermo switch
A-8	Hydraulic ECU	B-7	Engine stop switch
A-9	Diode (3A) (Wiring color: Br/Y, Br/W)	C-16	Diode (3A) (Wiring color: O, O/L)
A-10	Diode (3A) (Wiring color: G/Y, G)	C-17	Diode (Wiring color: B, O)*
A-11	P.T.O. flow control dial (P.T.O.1)	C-18	Diode (Wiring color: P, Y/B)*
A-12	Remote control lever R (P.T.O.1)		

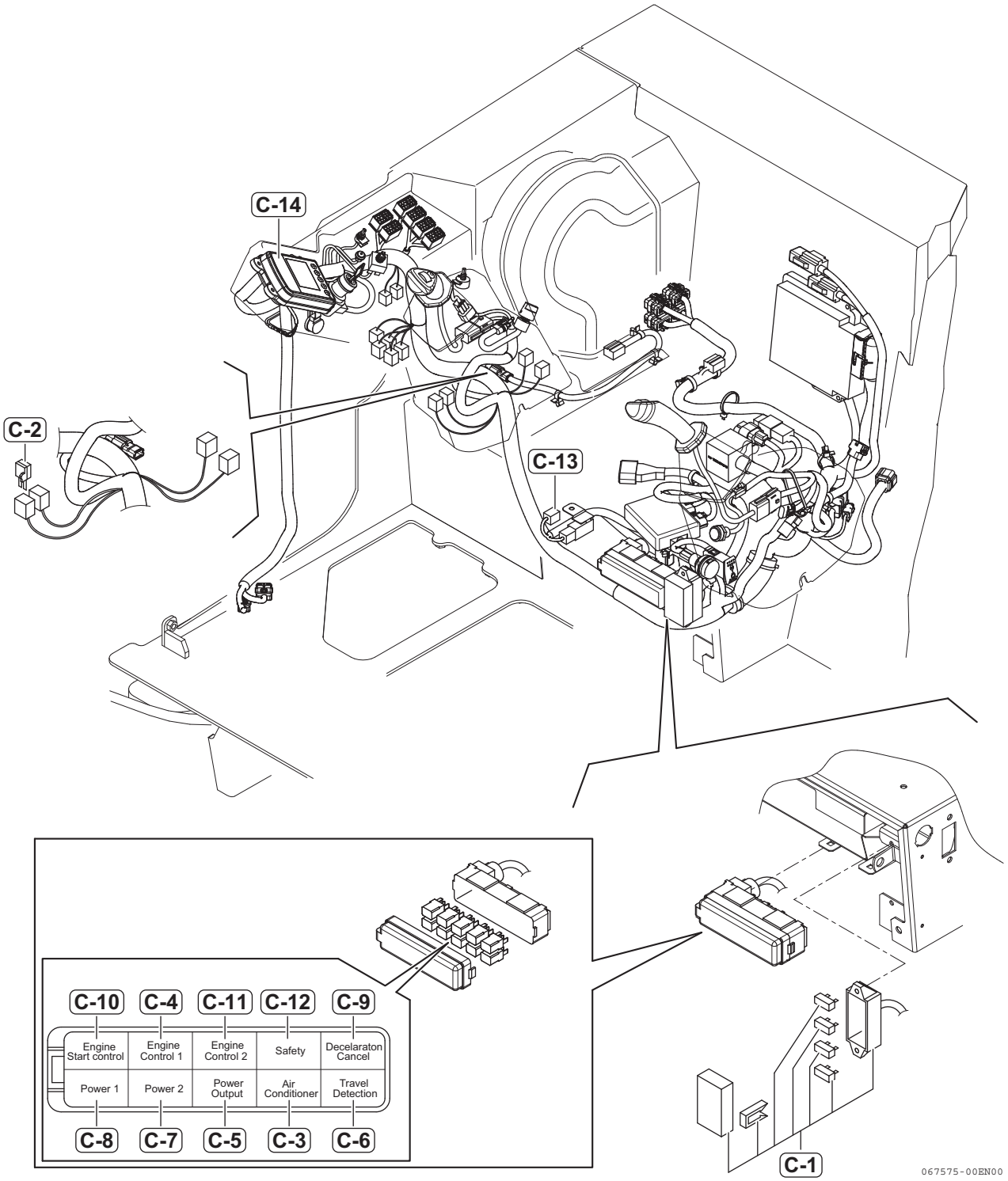
*Applicable S/N:1B259 and above)

Each reference number (e.g., A-1) corresponds to the numbers described in Section "2-9 Wiring Diagram" and APPENDIX Wiring Diagram.


B-6
B-1
B-5
B-3
B-4
B-2
B-12
B-13
Connect to
engine harness
E F G H
B-11
C-15
B-14
B-8
B-9
B-10
067574-00EN00

Ref. No.	Part	Ref. No.	Part
B-1	Wiper switch	B-9	Diode (Wiring color: P, B/W, W)
B-2	Travel automatic dual speed switch	B-10	Diode
B-3	Light switch	B-11	Resistor (Wiring color: B/W, B)
B-4	Auto deceleration switch	B-12	Starter switch
B-5	Eco mode switch	B-13	Engine ECU
B-6	DPF regeneration switch	B-14	Coupler for SMARTASSIST-Direct
B-7	(Refer to 5-1-1 and 5-1-2.)	C-15	Resistor (Wiring color: O, O/B)
B-8	Diode (Wiring color: Br, Br)		

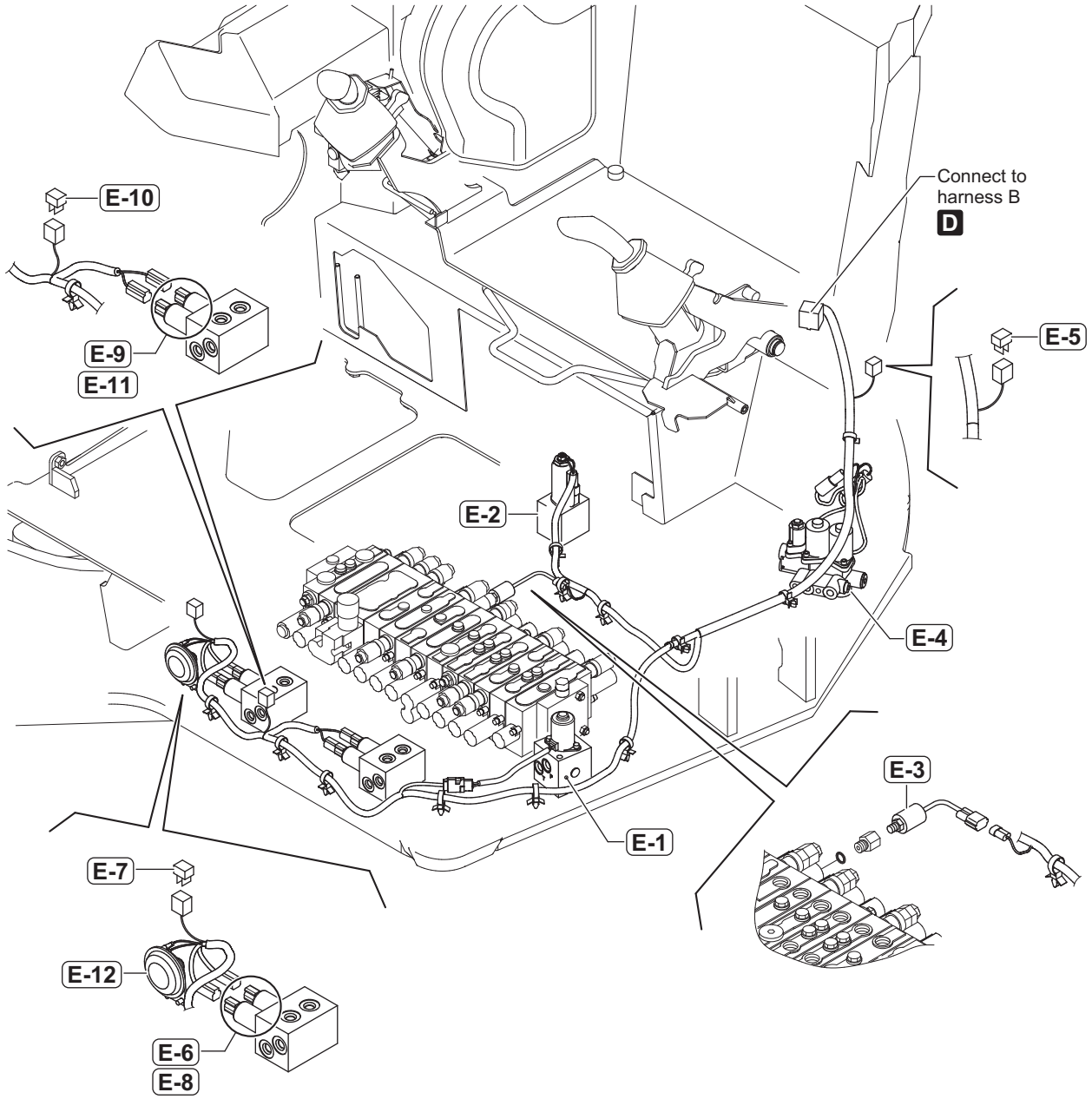
Each reference number (e.g., A-1) corresponds to the numbers described in Section "2-9 Wiring Diagram" and APPENDIX Wiring Diagram.


C-14
C-2
C-13
C-10
C-4
C-11
C-12
C-9
Engine Start control
Engine Control 1
Engine Control 2
Safety
Decelaraton Cancel
Power 1
Power 2
Power Output
Air Conditioner
Travel Detection
C-8
C-7
C-5
C-3
C-6
C-1
067575-00EN00

Ref. No.	Part	Ref. No.	Part
C-1	Fuse box	C-9	Deceleration cancel relay
C-2	Diode	C-10	Starter control relay
C-3	Air conditioner relay	C-11	Interlock relay
C-4	EGR valve relay	C-12	Safety relay
C-5	Power output relay	C-13	Connector (LCD monitor data)
C-6	Travel detection relay	C-14	LCD monitor
C-7	Power relay 2	C-15	(Refer to 5-1-3 and 5-1-4.)
C-8	Power relay 1	C-16	(Refer to 5-1-1 and 5-1-2.)

Each reference number (e.g., A-1) corresponds to the numbers described in Section "2-9 Wiring Diagram" and APPENDIX Wiring Diagram.

3) Harness D

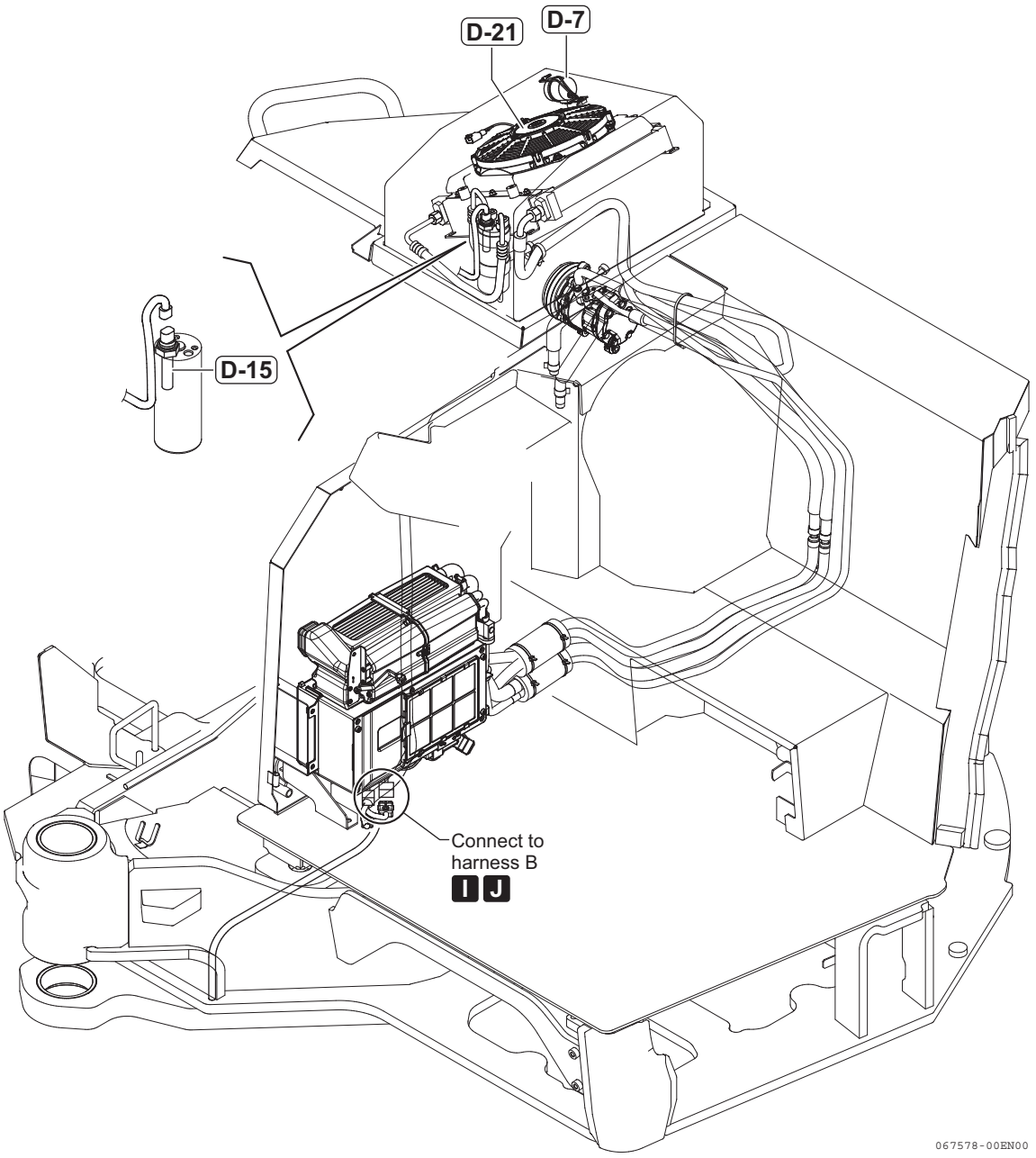


Ref. No.	Part	Ref. No.	Part
E-1	Quick coupler solenoid valve (for US machines only)	E-7	Diode (P.T.O.2 valve)*
E-2	ESS proportional solenoid valve	E-8	Proportional solenoid valve (P.T.O.2 A) (Wiring color: W/R, G/R)
E-3	Travel oil pressure detection switch	E-9	Proportional solenoid valve (P.T.O.1 B) (Wiring color: W, G)
E-4	Cut-off solenoid valve	E-10	Diode (P.T.O.valve)*
E-5	Diode (solenoid valve)	E-11	Proportional solenoid valve (P.T.O.1 A) (Wiring color: W, Y/W)
E-6	Proportional solenoid valve (P.T.O.2 B) (Wiring color: W/R, Y/R)	E-12	Horn

*Applicable S/N:1A001 to AH287

Each reference number (e.g., A-1) corresponds to the numbers described in Section "2-9 Wiring Diagram" and APPENDIX Wiring Diagram.

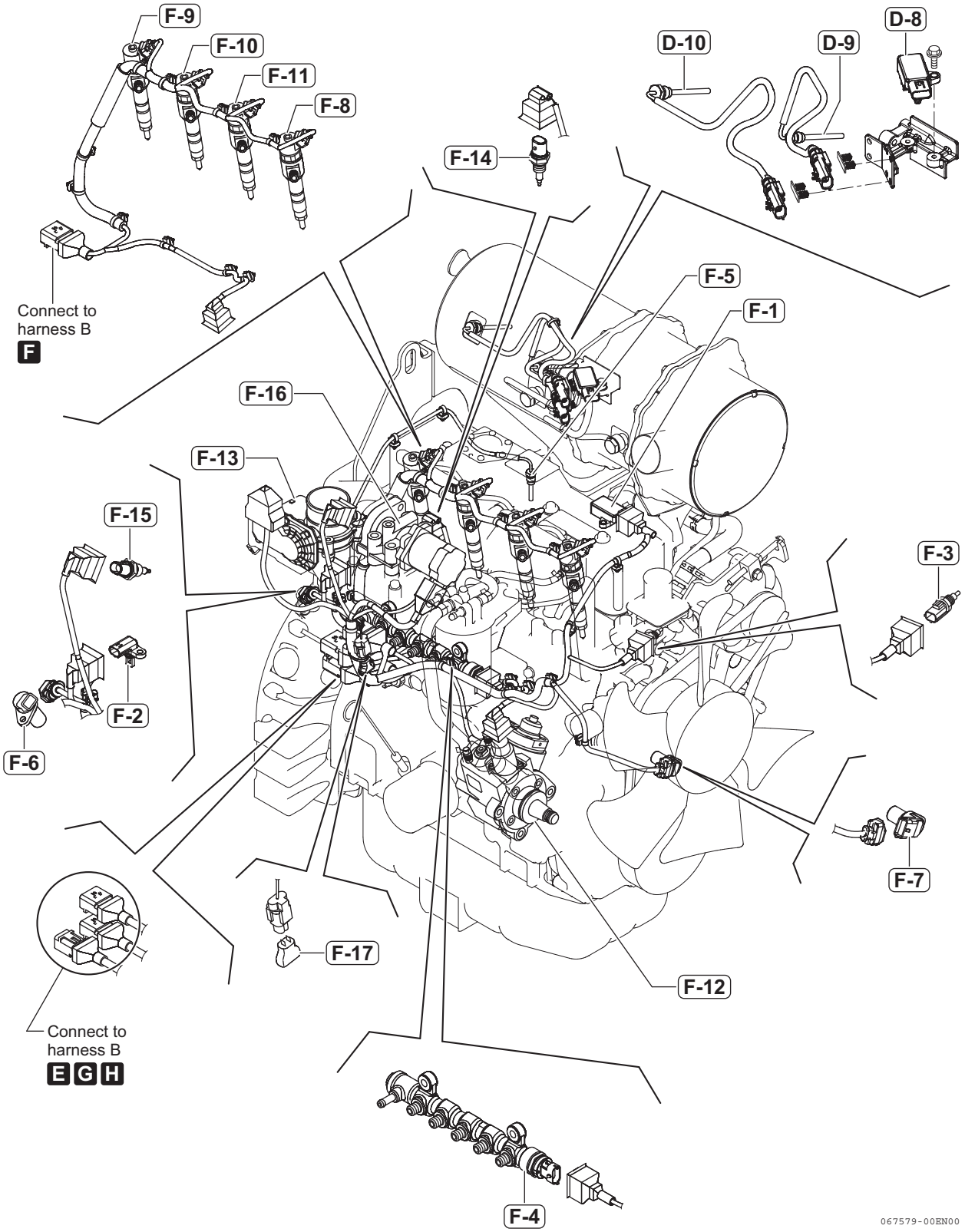
4) Air Conditioner



Ref. No.	Part	Ref. No.	Part
D-7	Travel alarm	D-21	Condenser fan motor
D-15	Refrigerant pressure switch		

Each reference number (e.g., A-1) corresponds to the numbers described in Section "2-9 Wiring Diagram" and APPENDIX Wiring Diagram.

5) Engine harness



Ref. No.	Part	Ref. No.	Part
F-1	EGR pressure sensor	F-11	Injector
F-2	New air temperature sensor	F-12	Supply pump
F-3	Coolant temperature sensor	F-13	Intake throttle
F-4	Rail pressure sensor	F-14	Intake temperature sensor
F-5	Exhaust temperature sensor	F-15	EGR temperature sensor
F-6	Crank rotation sensor	F-16	EGR valve
F-7	Cam speed sensor	F-17	Resistor
F-8	Injector	D-8	DPF differential pressure sensor
F-9	Injector	D-9	DPF intermediate temperature sensor
F-10	Injector	D-10	DPF inlet temperature sensor

Each reference number (e.g., A-1) corresponds to the numbers described in Section "2-9 Wiring Diagram" and APPENDIX Wiring Diagram.

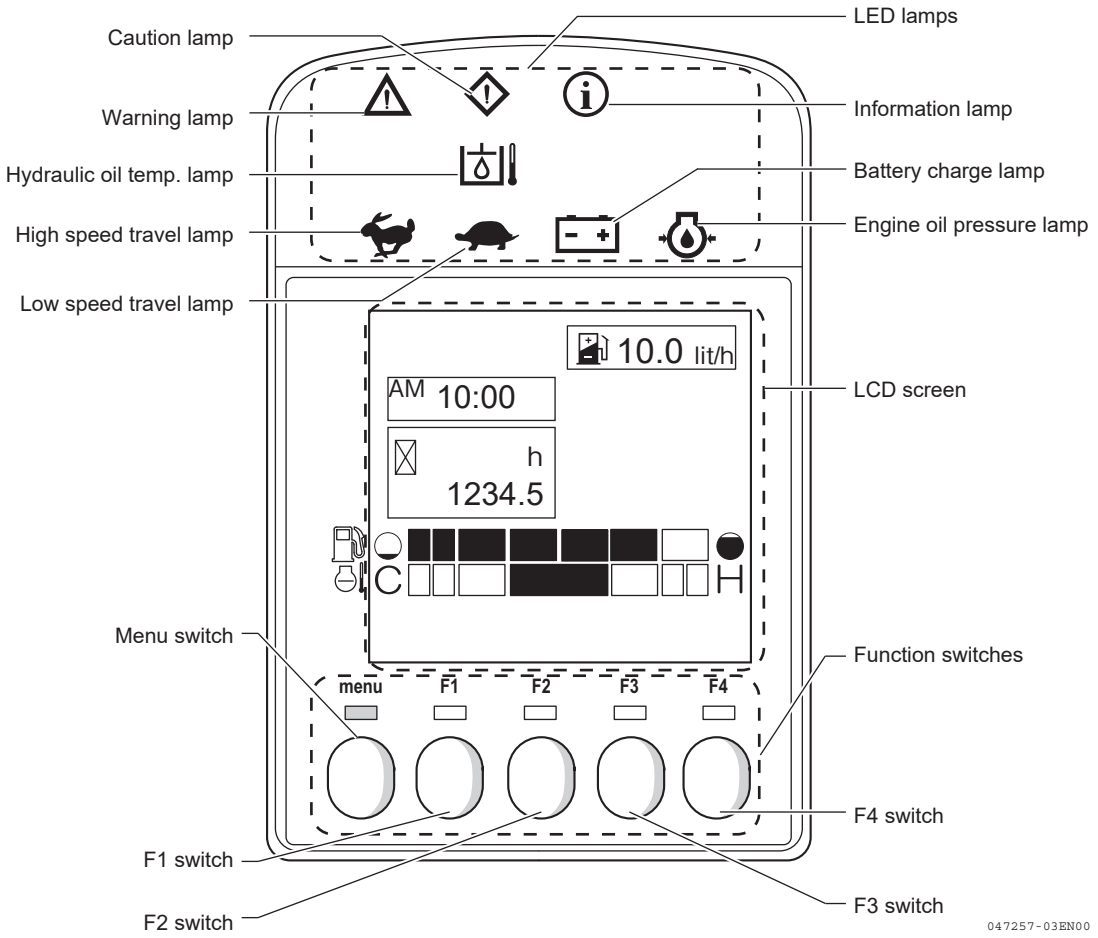
5-1-2 LCD Monitor and Alarm Systems

For safer machine operation, the operator needs to have a clear understanding of the machine's condition. However, it is difficult for the operator to keep an eye on every aspect of the machine he/she is operating.
Therefore, gauges and alarms are installed to warn the operator of any trouble of the machine at the early stage.

Note:

The monitors do not give a full assurance of the machine's condition. The indications shown on them should be used as a guide for daily check and periodic maintenance according to the operation and maintenance manual.

1) Part Name



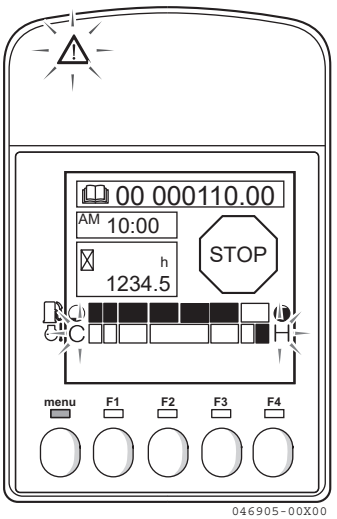
2) Alarm Sensor Function

- When the starter switch is turned to the ON position, relevant LED lamps should come on and the buzzer should sound for a few seconds, then the lamps should go out and the buzzer should stop.
- The battery charge and engine oil pressure lamps should stay on until the engine is started.
- All the LED lamps should remain off while the engine is running.

3) In the event of Machine Failure

In the event of machine failure, icon(s) and error code(s) corresponding to the failure(s) are displayed on the LCD screen and the warning and/or caution lamps flash, where applicable.

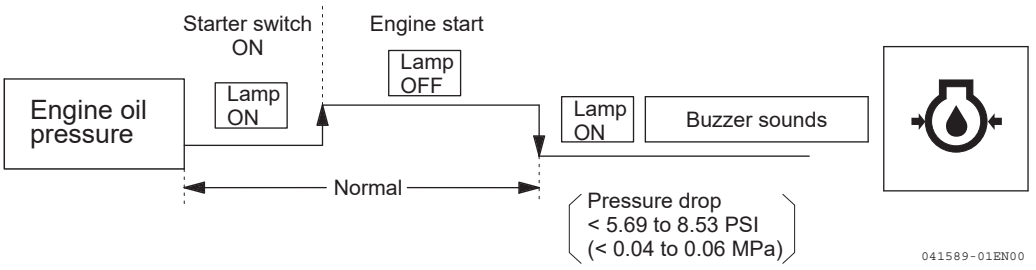
For details of error codes, refer to Section 5-5.



4) Sensor Operation

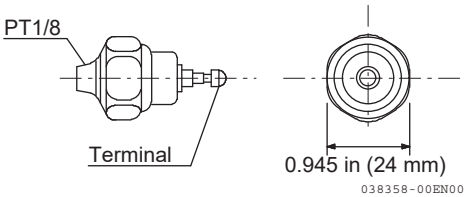
(1) Oil pressure switch (for detecting low engine oil pressure)

When the engine oil pressure falls, the lamp comes on and the buzzer sounds.



When this switch detects low engine oil pressure, it causes the engine oil pressure warning lamp on the LCD monitor to come on and the buzzer to sound.

- Working pressure: 5.69 to 8.53 PSI (0.04 to 0.06 MPa)
- Installation position: Engine block

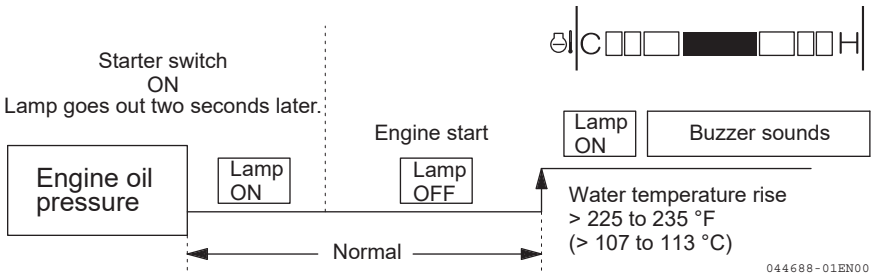


If the buzzer sounds, the following items must be checked.
- Engine oil degradation
- Oil filter element clogging
- Oil pressure switch malfunction
  For details of the inspection procedure, refer to Section 4-4-4 of Chapter 4 “Engine.”
- Pressure regulator malfunction
- Lube oil pump wear or breakage

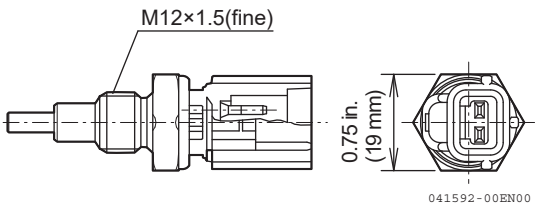
(2) Water temperature sensor

This sensor displays the temperature of the engine cooling water.

If the temperature of the engine cooling water rises abnormally during operation of the machine, the water temperature meter and the warning lamp flash and the error code and icon that indicate an abnormal cooling water temperature are displayed and at the same time the buzzer sounds.



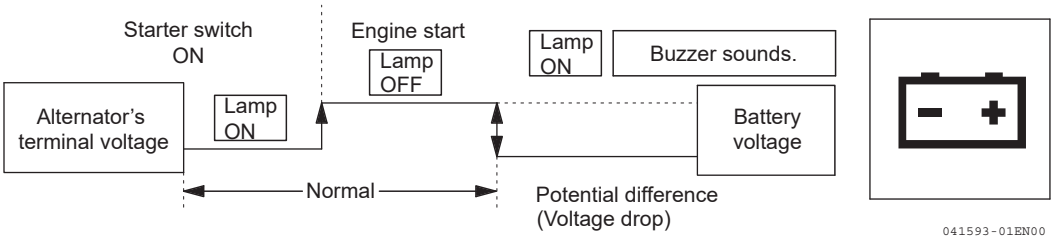
Turned on: Cooling water temp.: 225 to 235 °F (107 to 113°C)
Turned off: Cooling water temp.: 212 °F (100°C) or less
Installation position: Cooling water pump on engine



If the buzzer sounds, checks must be carried out in accordance with Section 4-3-5 of Chapter 4 “Engine” and Chapter 8 “Troubleshooting.”

(3) Battery charge

When a potential difference occurs between the output voltage of the alternator and the voltage of the battery, the battery charge lamp comes on and the buzzer sounds, and at the same time, the caution lamp flashes.



If the buzzer sounds, the following items must be checked.
- Battery degradation or malfunction
- Refer to Section 5-2 “Circuit Description of Engine Start and Stop.”

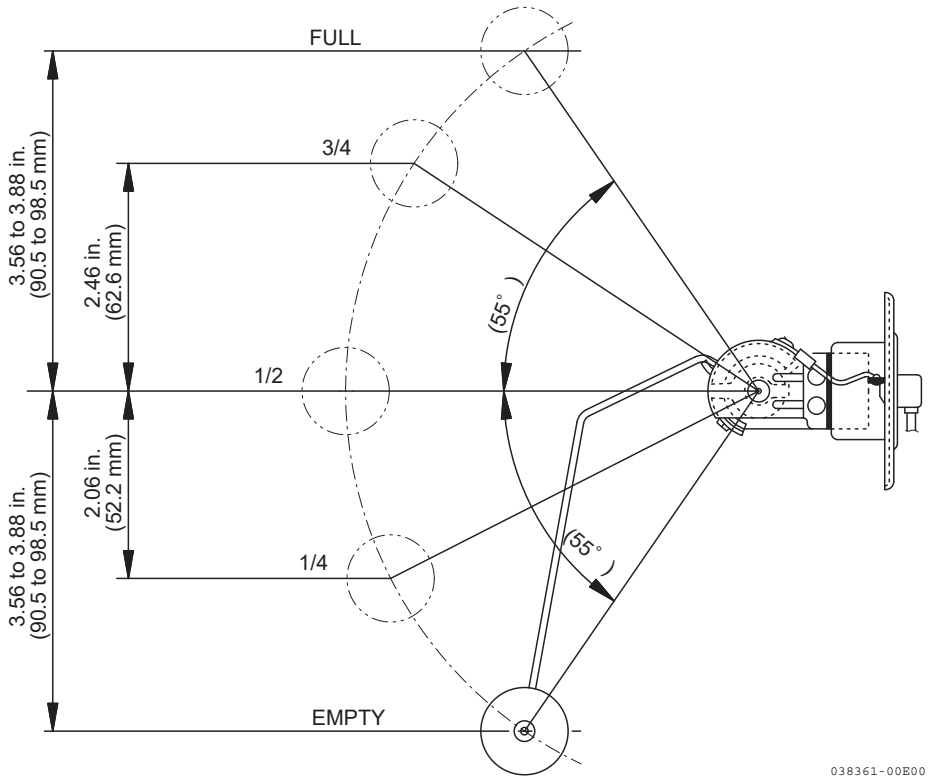
(4) Fuel meter

When the starter switch is turned to the ON position, the fuel meter is activated and indicates the fuel level in the fuel tank.

When the fuel level in the tank becomes low, the fuel meter and the caution lamp flash.

The remaining fuel level indication can change depending on the inclination of the machine body, which does not constitute a malfunction.

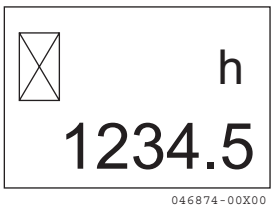
Fuel gauge unit



Float position	Resistance (Ω)
FULL	9.5 to 11.0
1/2	29 to 35
EMPTY	82 to 92

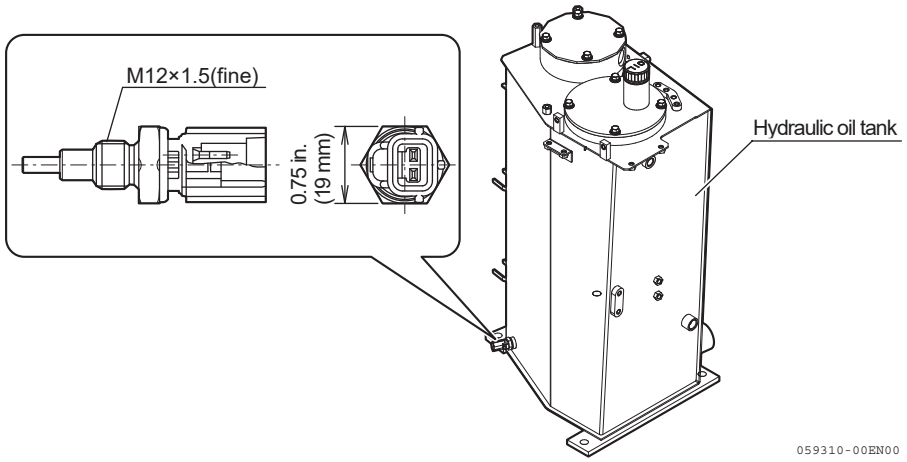
(5) Hour meter

When the starter switch is turned to the ON position, the hour meter is activated.



(6) Hydraulic oil temperature sensor

This sensor measures the hydraulic oil temperature in the hydraulic oil tank.



5) Accelerator dial

For details of accelerator dial, refer to "5-4 Hydraulic ECU (Controller)".

5. ELECTRIC SYSTEM

5-2 Circuit Description of Engine Start and Stop

1. Engine Start

Starter switch is in "OFF" position.

Starter switch **30** is always supplied with electric current from battery. (Battery - Slow blow fuse 100A - Fuse 5A - Starter switch **30**)

↓

Engine ECU is supplied with electric current.

Engine ECU **K1**, **K3** and **K5** are also always supplied with electric current from battery. (Battery - Slow blow fuse 100A - Fuse 20A - Engine ECU **K1**, **K3**, **K5**)

↓

Turn starter switch to "ON" position.

Terminals **30** and **AC** are connected.

↓

Power relay 1 is actuated and terminals **D** and **E** are connected.

Starter switch (**30** - **AC**) - Power relay 1 **C**

↓

Electric current flows to Engine ECU **K88**, and Engine ECU perform the initial operation of common rail system before engine startup.

Battery - Slow blow fuse 100A - Power relay 1 (**E** - **D**) - Fuse 5A - Engine ECU **K88**

↓

Glow relay is actuated by engine ECU and it activates glow plug to heat the engine. Heating time varies depending on coolant temperature.

Engine ECU **K70** - Glow relay **C**

Battery - Slow blow fuse 80A - Glow relay (**A** - **D**) - Glow plug

↓

Turn Starter switch to "START" position.

Terminals **30**, **AC** and **50** are connected.

↓

Electric current flows to Engine ECU **K35**.

Starter switch (**30** - **50**) - Engine ECU **K35**

↓

Electric current flows to Starter control relay through Safety relay, and Starter control relay is actuated. Terminals **E** and **D** of Starter control relay are connected.

Starter switch (**30** - **50**) - Fuse 5A - Safety relay (**E** - **B**) - Starter control relay **C**
Note: If lock lever is in unlock position, electric current flows to Safety relay **C** through Cut-off switch. Terminals **E** and **B** of Safety relay are not connected, and electric current does not flows to starter control relay.

↓

Electric current flows from Engine ECU **K29** to Engine ECU **K14** through Starter control relay.

Engine ECU **K29** - Starter control relay (**E** - **D**) - Engine ECU **K14**

↓

Electric current flows from Engine ECU **K73** to Engine ECU **K28** through Starter relay, and Starter relay is actuated. Terminals **A** and **D** of Starter relay are connected.

Engine ECU **K73** - Starter relay (**C** - **B**) - Engine ECU **K28**

↓

Electric current is supplied from battery to Starter motor **S** through Starter relay, to rotate the starter motor.

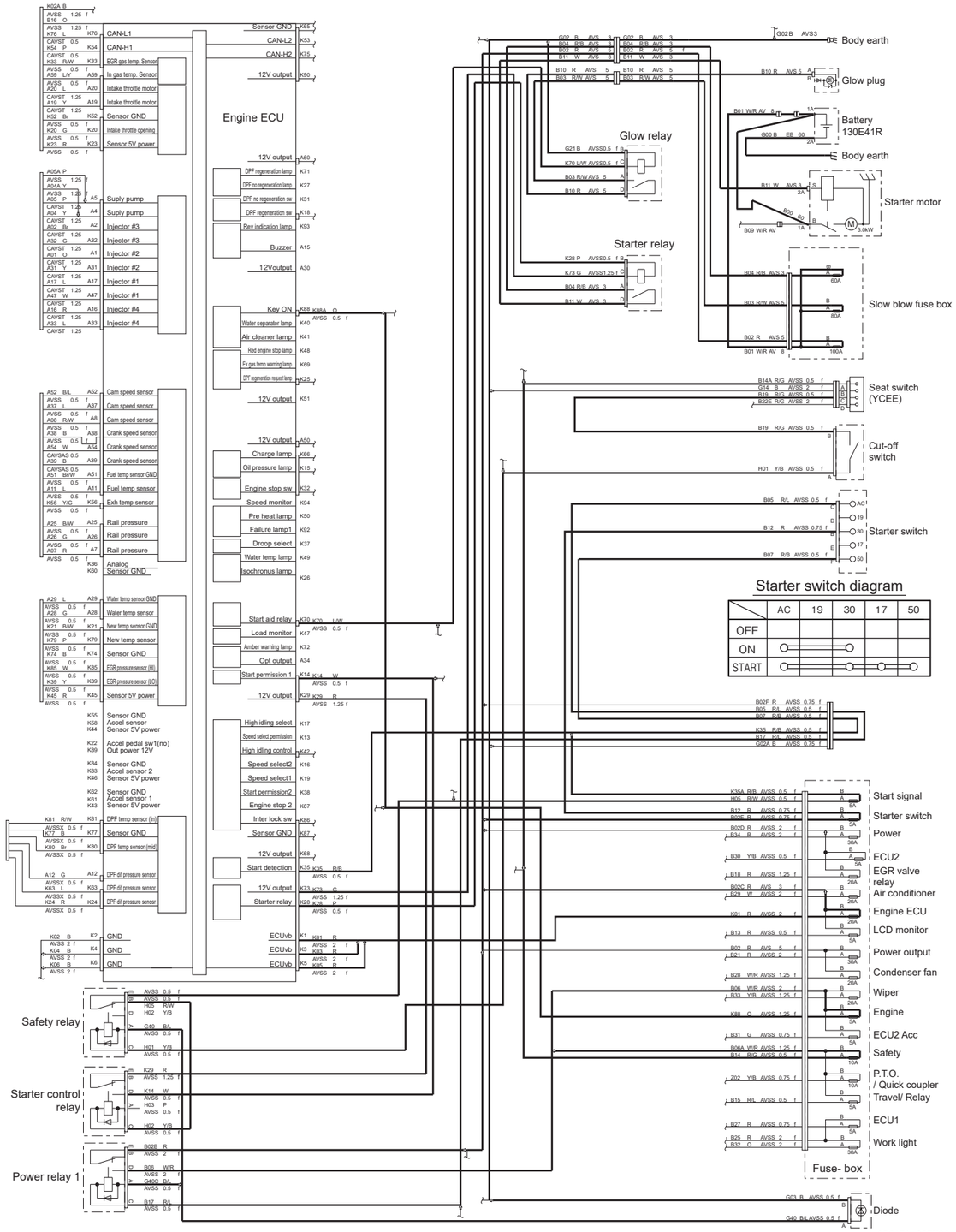
Battery - Slow blow fuse 60A - Starter relay (**A** - **D**) - Starter motor **S**

2. Engine Stop

Turn starter switch to "OFF" position.

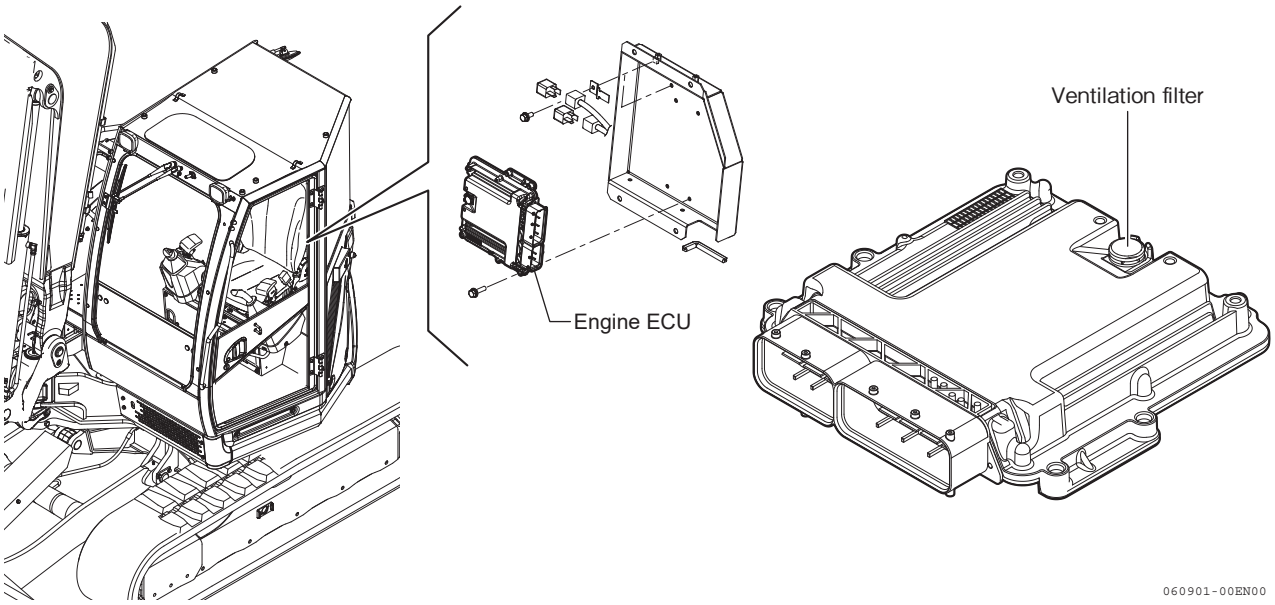
↓

Engine ECU performs the engine stop control to stop the engine.



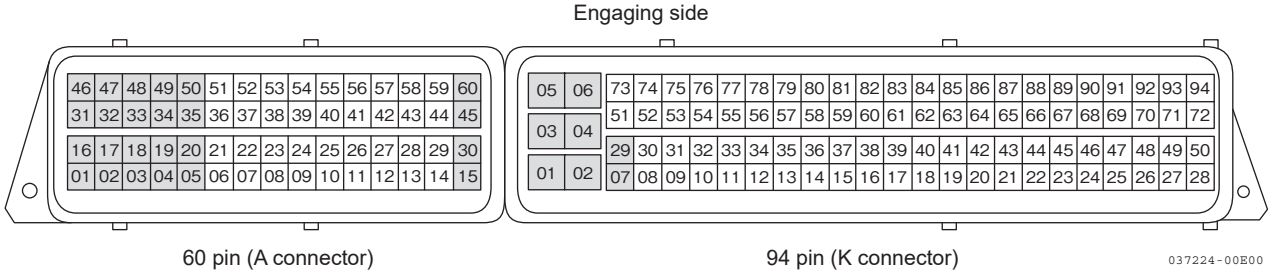
5-3 Engine ECU (engine controller)

5-3-1 Outline



● **Circuit symbols**

The figure below shows the pin numbers of the engine ECU. In the electrical wiring diagram, a circuit symbol is indicated as by those pin numbers with an additional letter “A” or “K”.



Circuit symbols are indicated as by those pin numbers with an additional letter “A” or “K”.

Pin numbers of the engine ECU connector

■ Operating requirements

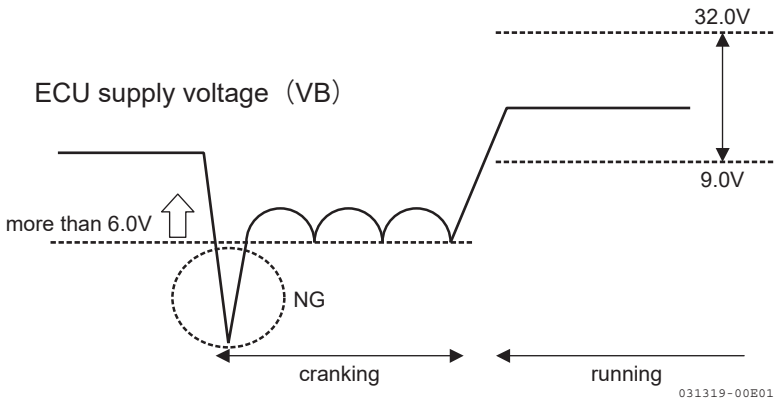
The table below shows the operating requirements of the engine ECU.

Item		Operating requirements
Rating	Rated voltage	12 V DC
	Operating ambient temperature range	-40 °C - 79 °C
	Storage ambient temperature range	-40 °C - 105 °C
Basic performance	Available voltage range	9.0 V - 32.0 V DC
	Minimum operating voltage	6.0 V DC or greater

■ Minimum operating voltage

The minimum operating voltage of the engine ECU is 6.0 V DC. If the engine ECU power supply voltage reaches below 6.0 V, the engine ECU stops its operation. Once the power supply voltage is regained, the engine ECU is restarted from the initial condition.

For example, in case of humping and injector energization in the compression process in cranking during low temperature starting, engine start is disabled if the power voltage of engine ECU becomes 6.0 V or below even for a moment. Be sure to check the battery voltage and engine ECU power voltage.



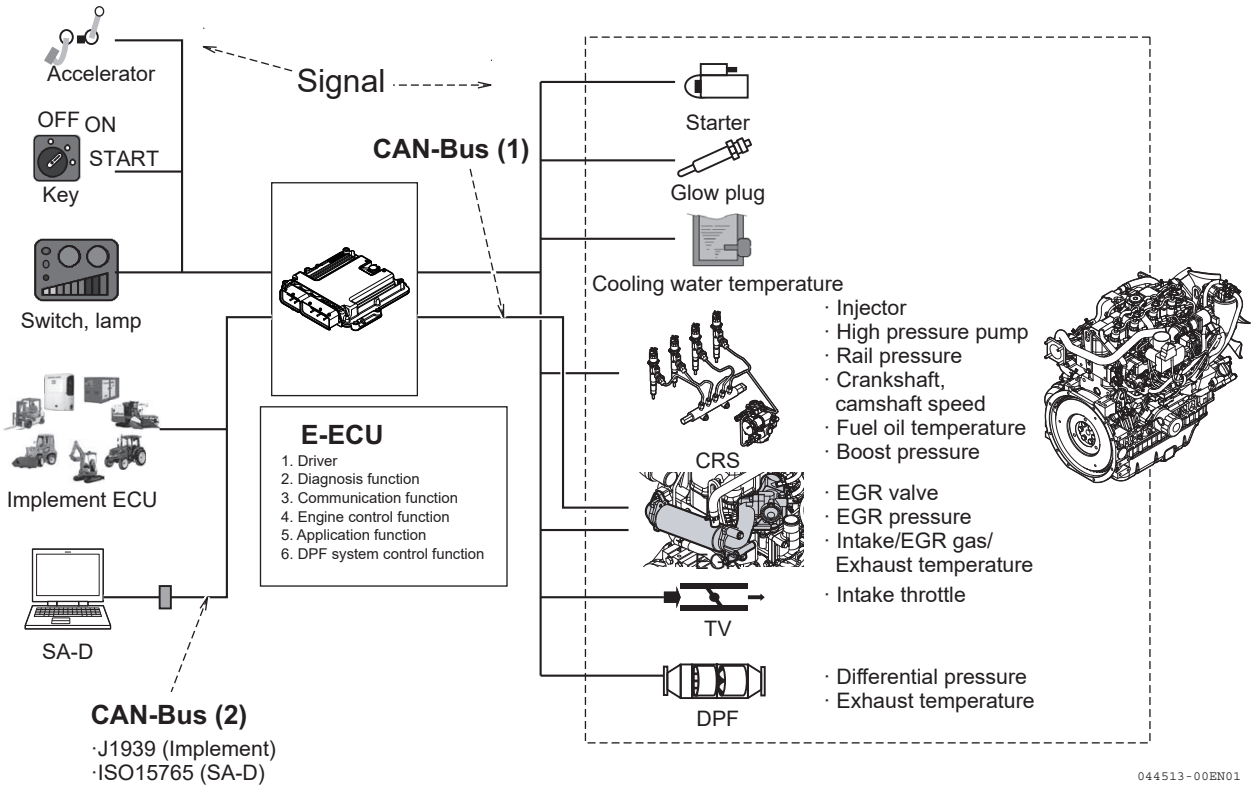
Engine ECU power supply voltage conditions at engine start

5-3-2 Control Functions

■ Structure of the Control Functions

The system overview of the electronic control system for Tier 4 is shown in the figure below.
The engine controller (engine ECU) software can be roughly divided into functions as shown below.

1. Driver : The portion that connects the hardware with the software
2. Diagnosis function : The failure diagnosis portion for the engine or other control devices
3. Communication function : The communication portion with a checker or other ECUs
4. Engine control function : The fuel injection control and EGR control by the common rail system (CRS)
5. Application function : The driven machine application functions such as the engine speed instruction (acceleration), starter control, starting aid function (glow plug), and interface portion with the device (CAN communication, switches, and lamps)
6. DPF system control function : The PM detection and DPF regeneration control (intake air throttle control, multi-stage injection) portions



System overview of electronic control system for Tier 4

■ Engine Control Overview

● Self-hold function of the engine ECU power supply

• Recording the history data

The engine ECU records the history of engine operations such as the failure history or operating hours on the internal EEPROM. In order to avoid losing these history data, the engine ECU holds the power supply by itself until the recording to the EEPROM is complete even when the key switch is turned OFF accidentally.

• EGR valve closing operation

The engine ECU moves the EGR valve to the fully closed condition when the engine is stopped so that the starting sequence begins with the valve fully closed. Therefore, the engine ECU holds the power supply by itself until the stop action of the EGR valve is complete when the key switch is turned OFF.

● Starting control

The basic startup sequence of an engine is shown in the figure on the right.

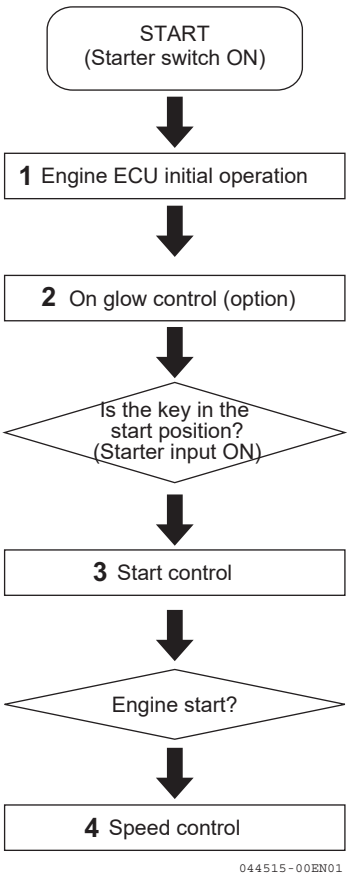
1. Engine ECU initial operation

   The engine ECU conducts the initial operation just after the starter switch input is turned to ON. The engine ECU initial operation includes the learning process of the EGR pressure sensor and DPF differential pressure sensor and the readout of the history data recorded in the EEPROM inside the engine ECU without startup of the engine. It is necessary to restrain the starter operation by the starter motor relay and inhibit startup of the engine during the engine ECU initial operation.
2. On-glow control

   If the on-glow control is configured, the energizing time to the glow plug relay is controlled according to the coolant temperature. This will illuminate the preheat lamp. When the on-glow control is finished, the engine will wait until the starter switch is turned to the START position.
3. Starting control

   If the starter switch is turned to the START position (the starter input terminal is ON), cranking starts and the engine speed is detected, the starting rack position control is initiated.
4. Speed control

   If the engine speed reaches equal to or greater than 600 min^{-1} (which varies depending on the engine model), the controller transitions from the start control to the speed control. The injection volume is controlled through the speed control so that the engine speed is kept at the speed instructed by the accelerator. The engine stops when the engine speed reaches 0 min-1, or the starter switch is turned to OFF.



● **Regulation**

There is a short delay before the engine speed is stabilized by the specified regulation in a certain situation, such as when the engine load or speed has changed instantly.

The following engine regulation settings are available:

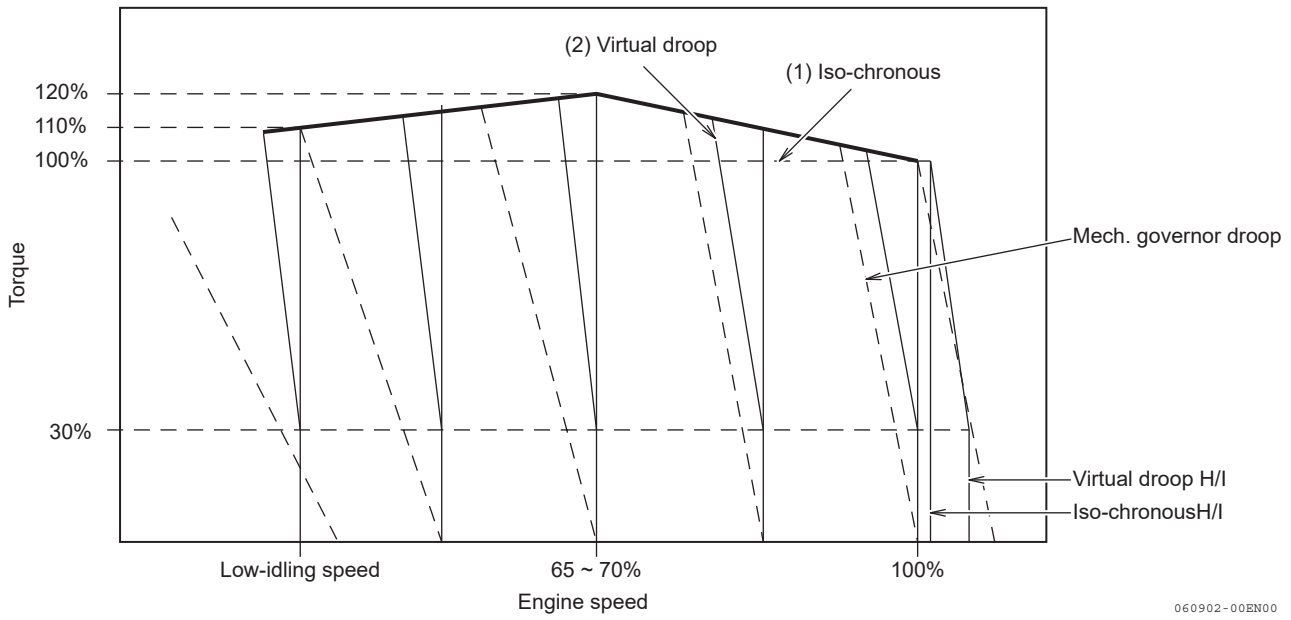
1. Iso-chronous

   The speed is constant (regulation = 0 %) regardless of the load.

2. Virtual droop (the torque curve of the base engine)

   Regulation with approximately 120 min^{-1} (which varies depending on the engine model) is performed regardless of the speed.

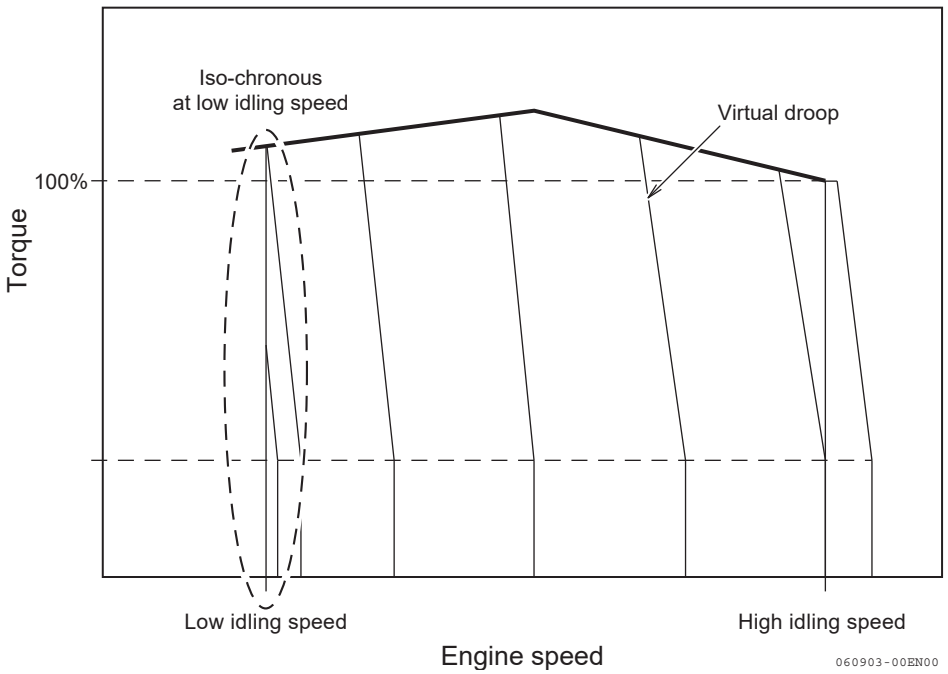
   The speed is maintained to reach a load factor of around 30 % so that the idle (no-load) speed does not change even if the horsepower loss is somewhat changed after installation to a driven machine.



(Example) Conceptual figure of the standard torque curve

Iso-chronous Control at Low Idle Speed

The engine can be configured so that the engine speed will not decrease lower than the low-idling speed even while the virtual droop is active.



Iso-chronous control at low idle speed

● **EGR control**

The common rail engine provides NOx reduction by installing an electronic control EGR valve.

The engine ECU calculates the EGR valve opening based on the engine speed, engine load factor, intake air temperature/EGR temperature/exhaust gas temperature, and EGR downstream/upstream pressures (intake air pressure/exhaust air pressure) and adjusts the exhaust gas recirculation volume by controlling the EGR valve.

The EGR valve is active under normal warm conditions, however, it is designed not to open when the coolant temperature is 60 °C or lower in order to prevent sulfuric acid corrosion of the engine under cold conditions due to concentration of exhaust gas components.

■ Electric Acceleration

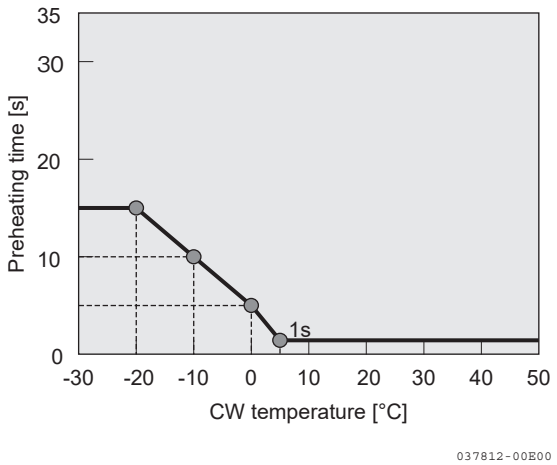
● Acceleration input

Engine ECU calculates the target engine speed based on the input voltage from the acceleration sensor or the input value from the CAN communication. (Because the actual engine speed is determined by the relationship between the engine maximum torque and the load torque, it does not necessarily match the target engine speed.)

■ Starting Aid Control

● On-glow control (preheat)

When the starter switch is set to the ON position, the system automatically energizes the glow plug relay and keeps it energized for a particular amount of time depending on the coolant temperature. The engine can configured the system to turn ON the preheat lamp while the relay is being energized.
The preheat control status (preheat underway/stopping) is output via CAN communication.
The preheat time for on-glow control is configured as shown in the figure below.



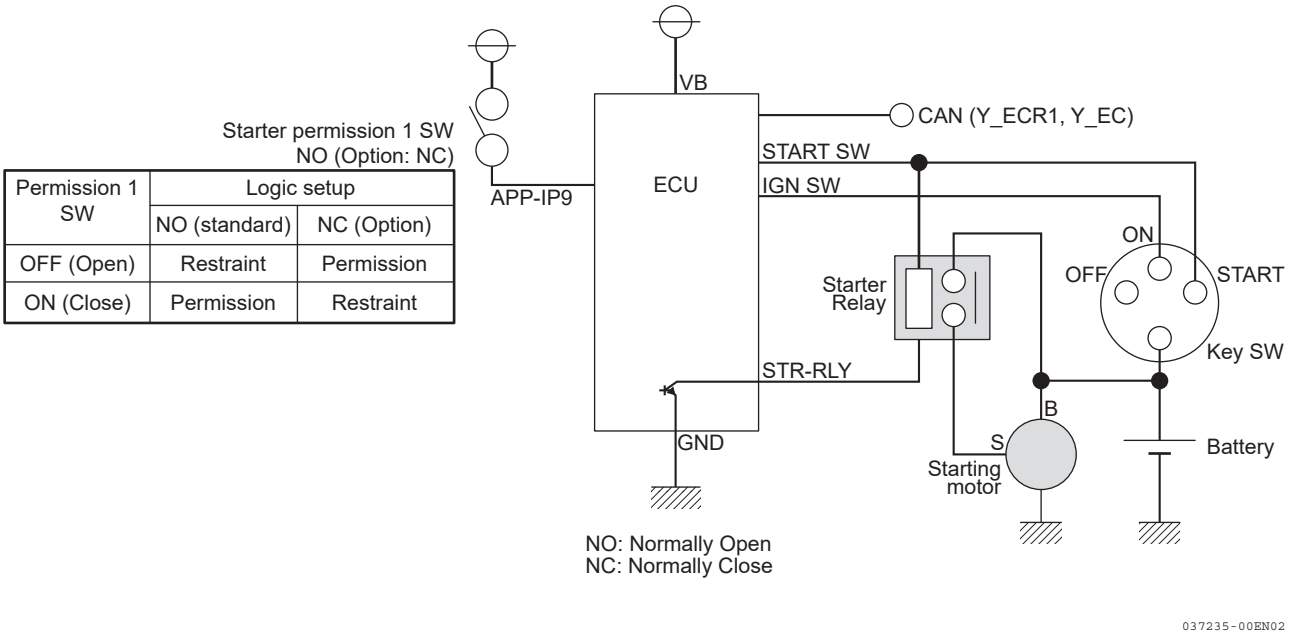
On-glow control preheat time

● Glow plug protection function

To protect the glow plug and glow plug relay, the relay is kept not to energize for a specified time after it is deenergized until it is reenergized. However, the state of the lamp depends on the state of ON/OFF control regardless of the relay. The control status of glow plug is output via the CAN communication.

■ Starter Motor Restraint Control

On the YANMAR electronic control system for Tier 4, the learning process for the EGR pressure sensor and the DPF differential pressure sensor and readout of the history data recorded in the EEPROM inside the engine ECU are performed as the engine ECU initial operation after the starter switch is turned to ON. Therefore, the starter motor restraint control is performed by connecting the starter relay to the engine ECU as shown in the figure below in order to prevent the engine from being started during the engine ECU initial operation. (“Starter motor restraint” means restraining the starter motor from rotating.)



Permission 1 SW	Logic setup	
	NO (standard)	NC (Option)
OFF (Open)	Restraint	Permission
ON (Close)	Permission	Restraint

■ Engine Stop Function

Beside an overload and lack of fuel, the causal factors of engine stop (hereinafter referred to as “engine stop factor”) include the following.

(1) Method by starter switch
(2) Method by external switch
(3) Control fault detection

(1) Method by starter switch

When the starter switch is turned to OFF, engine ECU performs engine stop control to stop the engine.

(2) Method by external switch (SHUDNSW terminal)

Connect an engine stop switch to the SHUDNSW terminal and turn ON the engine stop switch.

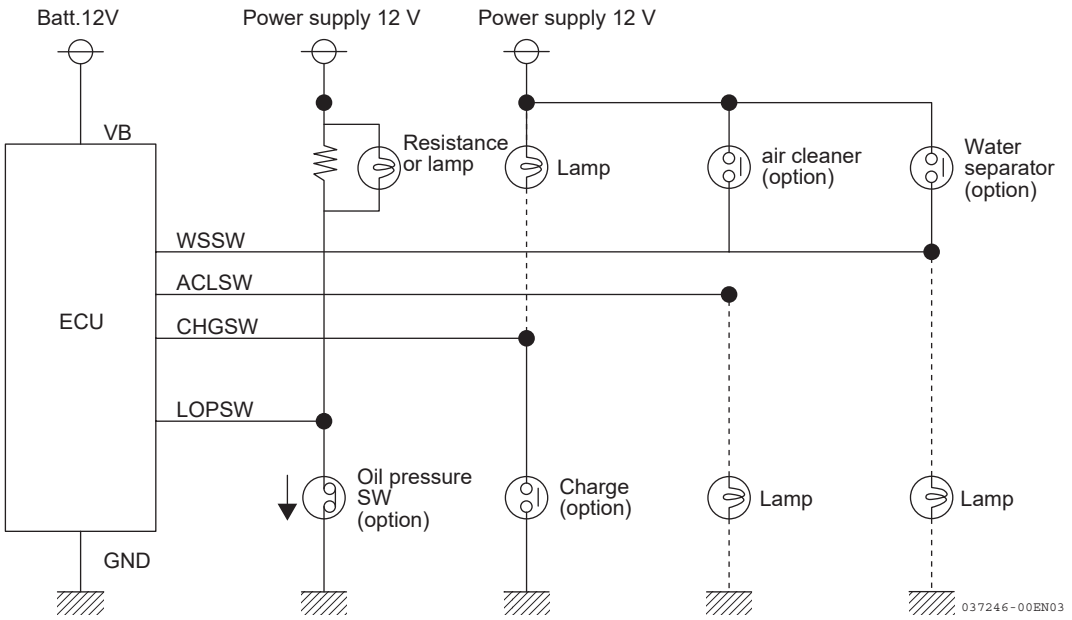
(3) Fault detected by the engine ECU

The engine may stop due to a fault detected by the engine ECU.

■ Engine Fault Detection

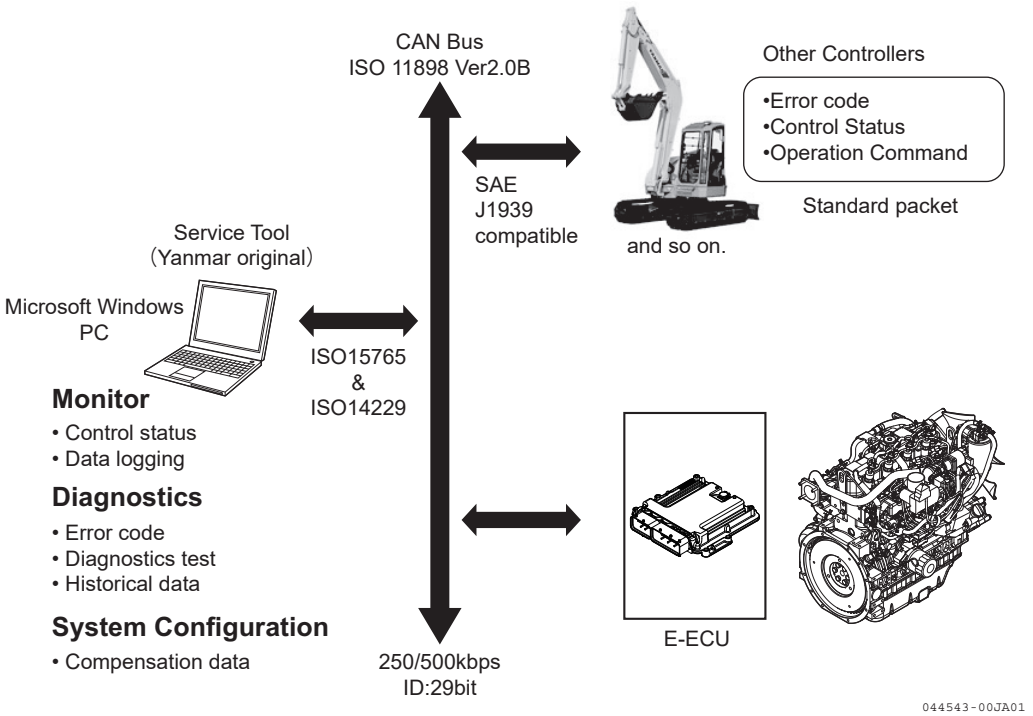
The engine ECU can be connected with various engine fault detection sensors as shown in the figure below, in addition to electronic control sensors. Fault handling actions performed depending on the status of each sensor are configured, and the engine ECU outputs the status of each sensor through the CAN communication.

The figure below shows standard circuit as an example. For details of circuit connections on each model, refer to wiring diagram.



■ CAN Communication Function

The engine ECU is complete with a single CAN communication port that can be used for either communications with SMARTASSIST-Direct (SA-D) or communications with another controller (inter-ECU communications).
Through inter-ECU communications, the engine ECU can receive various control commands such as target speed instructions from the ECU of the driven machine. In addition, the engine ECU sends control state information such as the actual engine speed as well as information commands such as error codes to the ECU of the driven machine.



CAN communication overview

■ Diesel Particulate Filter (DPF) System Control

● Overview

YANMAR's DPF system continuously burns particulate matter that accumulates on the SF (soot filter). This is called DPF regeneration.

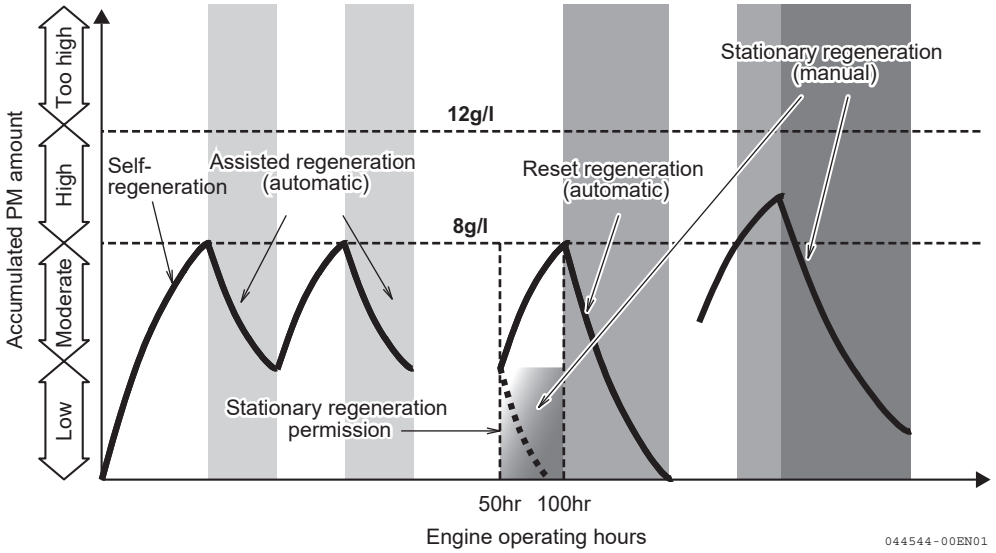
Electrical equipment such as the DPF differential pressure sensor, temperature sensors and intake throttle are installed to the DPF system. If the DPF can not continue to regenerate while operating at low load, the engine ECU automatically assist the DPF regeneration (DPF regeneration assistance) using the electrical equipment and avoiding accumulation of particulate matter.

The table below shows the outline of DPF regeneration assistance. YANMAR uses an original DPF regeneration method that combines regeneration by the regeneration assistance devices (intake air amount control by the intake throttle and extension of the injection timing by the common rail) and regeneration by the common rail multi-step injection (post-injection by the common rail).

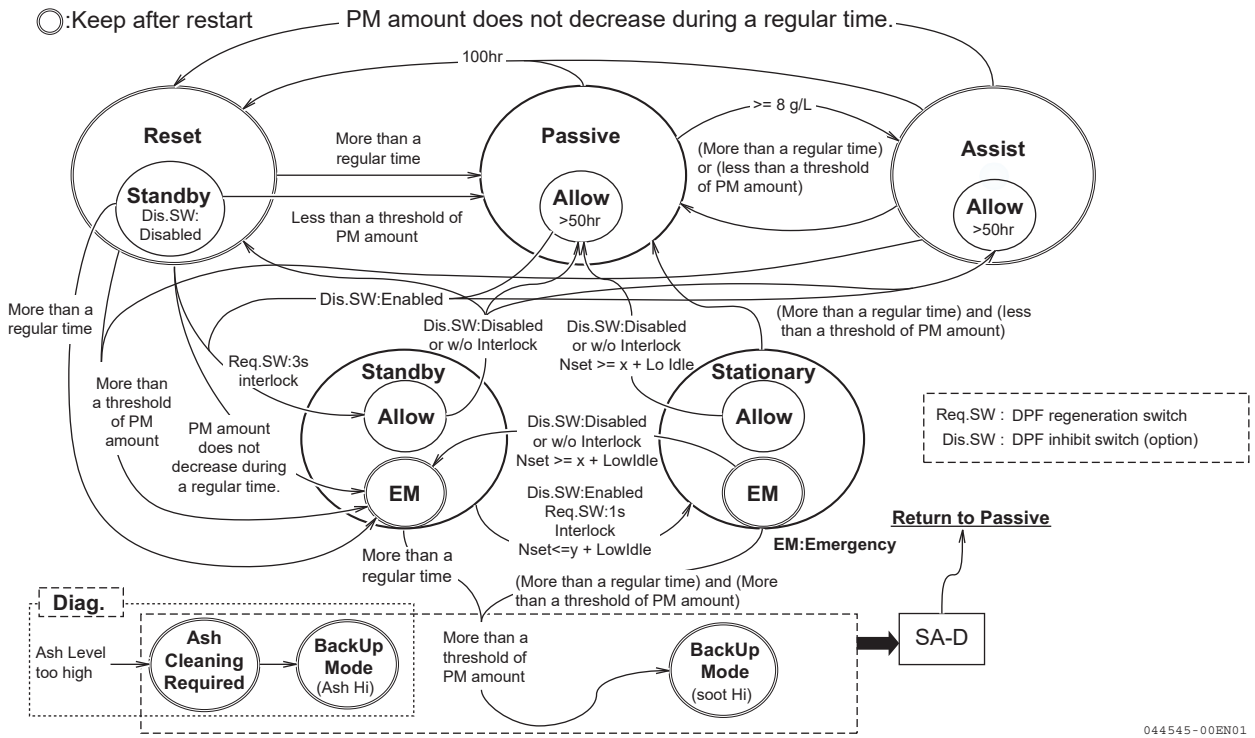
Outline of DPF regeneration control

Terminology	Control content	Explanation	Remarks
Self regeneration	Regeneration without regeneration assist unit (normal)	In a high speed and high load operation, the exhaust temperature rises and PM are burnt and removed continuously.	These regenerations can be performed during operation. No operator intervention is needed.
Assisted regeneration	Regeneration with regeneration assist unit.	In a low speed and low load operation, the exhaust temperature is too low for continuous regeneration. Therefore engine ECU automatically performs the regeneration controls shown on the left to increase the exhaust temperature and burn/remove PM.	
Reset regeneration	Regeneration with assist regeneration and post injection		
Stationary regeneration	Regeneration with more effective reset regeneration and automatic control to engine speed suitable for DPF regeneration	In a low speed/low load operation continuing long time, the assisted regeneration/reset regeneration may not be enabled because the exhaust temperature does not rise sufficiently. If the PM deposit amount reaches a certain level in this situation, the DPF regeneration request icon is displayed and the caution lamp flashes. At that time, the operator can start the stationary regeneration to burn/remove PM by operating the DPF regeneration switch.	When the DPF regeneration icon is displayed, the operator should move the driven machine to a safe place without any flammable matters nearby to perform the stationary regeneration. For details of operation, refer to Operation manual. Do not perform any working operation because a special control dedicated for DPF regeneration takes place.

The figures below show a conceptual figure and the state transitions of DPF regeneration control in YANMAR DPF system.



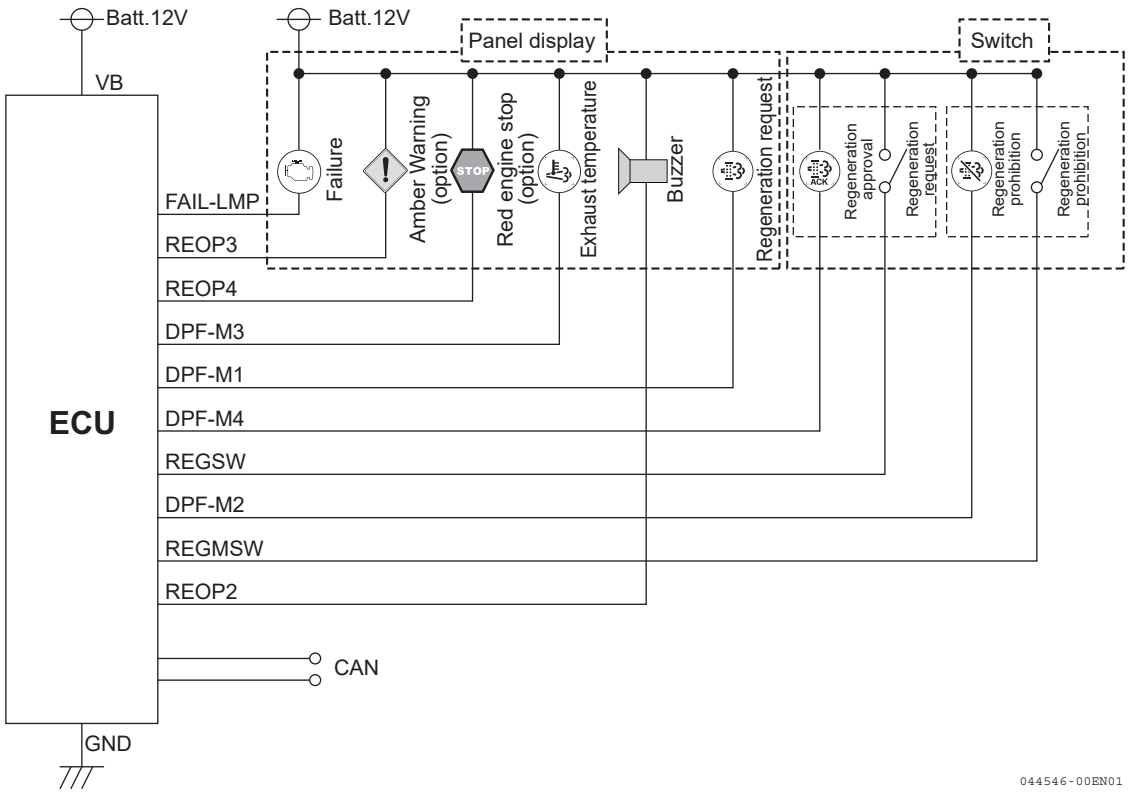
Conceptual figure of DPF regeneration control in YANMAR DPF system



Transition of DPF regeneration control in standard DPF system

● **DPF regeneration and operator interface**

The YANMAR DPF system offers DPF regeneration and operator interfaces including lamps for DPF alarm display and switches for DPF regeneration control operation as shown in the figure below. Beside these contact input/output terminals, it also offers CAN communication interfaces.



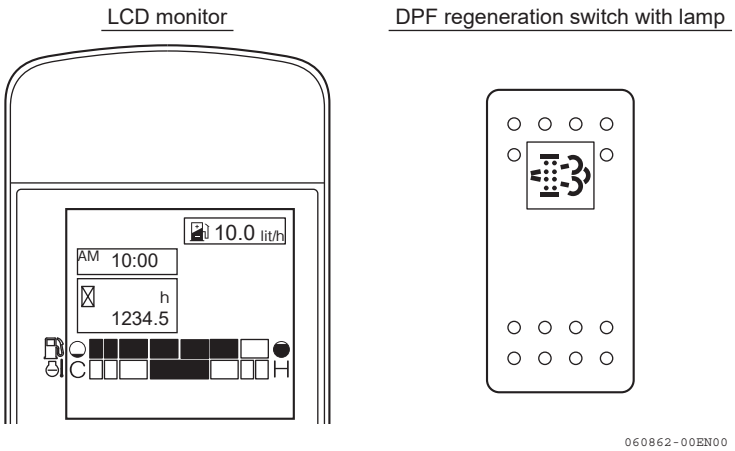
Example of wiring diagram used for DPF regeneration & operator interface

Specifications of switches

Name	Specification
DPF regeneration request switch	Used for starting manual stationary regeneration.
DPF regeneration inhibit switch (option)	• Used for inhibiting manual reset generation. • Used for interrupting reset/stationary regeneration.
Interlock switch	Because engine-ECU changes the target engine speed automatically in stationary regeneration, it is necessary to inform engine-ECU that the interlock mechanism such as the parking brake, neutral is enabled (drive force interrupted). This switch is used.

The table below shows operator interface displays and operations.

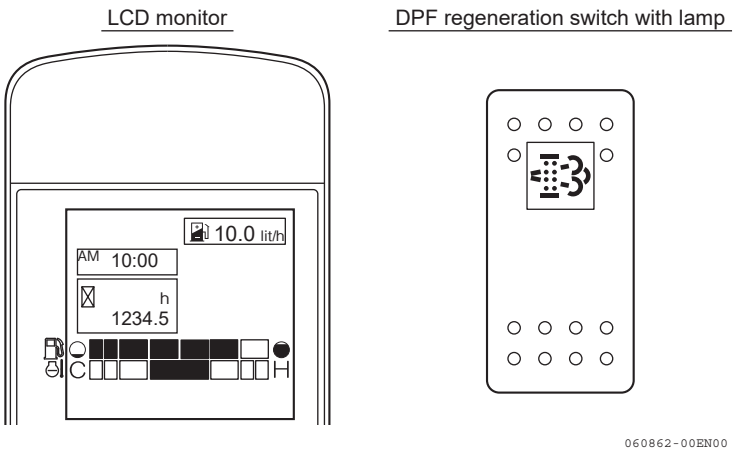
[1] Self regeneration (normal operation) and assist regeneration operating



Description

- When 50 hours have passed since the last reset/stationary regeneration, DPF transfers to the state [2] described below.

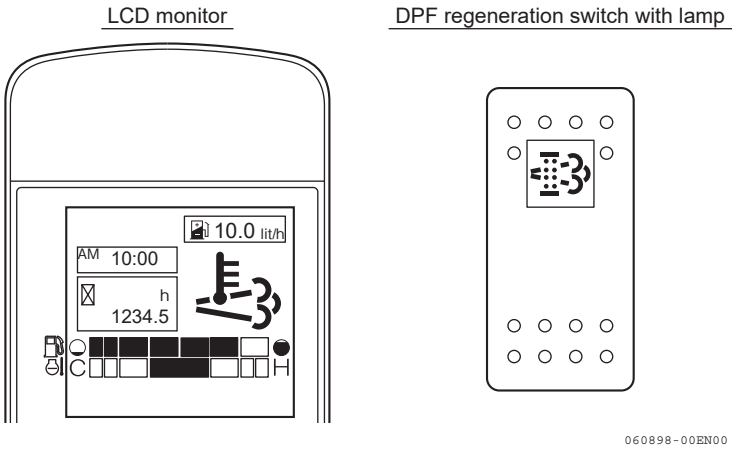
[2] Self regeneration (normal operation) and assist regeneration operating (Elapsed time since last reset: 50 hours or more)



Description

- When 100 hours have passed since the last reset regeneration, reset regeneration is started automatically (transfer to [3] described below).
- When 50 hours have passed since the last reset regeneration, stationary regeneration execution is permitted.
- At that time, setting the interlock switch to lock position and holding the DPF regeneration switch to “ON” state for 10 seconds or more causes DPF to transfer to the stationary regeneration standby state ([4] described later). For the operation method after the stationary regeneration standby state, refer to [4] described later.

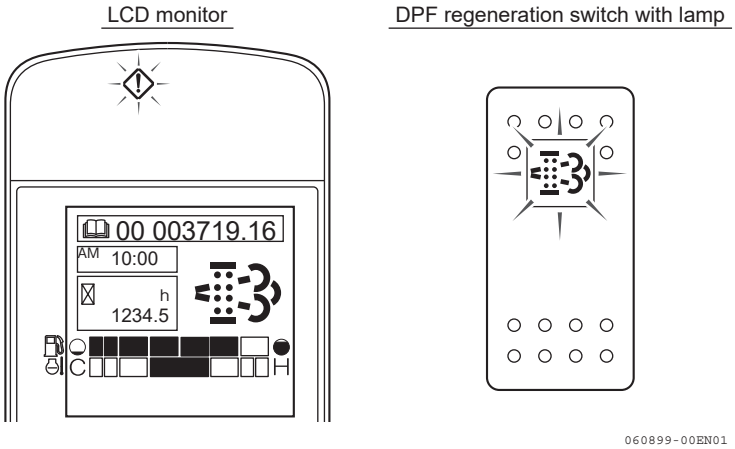
[3] Reset regeneration operating (Elapsed time since last reset: 100 hours)



Description

- The reset regeneration is completed in approximately 25 to 30 minutes. (After the reset regeneration completion, DPF transfers to [1] described before.)
- As in [2] described before, setting the interlock switch to lock position and holding the DPF regeneration switch to “ON” state for 10 seconds or more causes DPF to transfer to the stationary regeneration standby state ([4] de-scribed later).

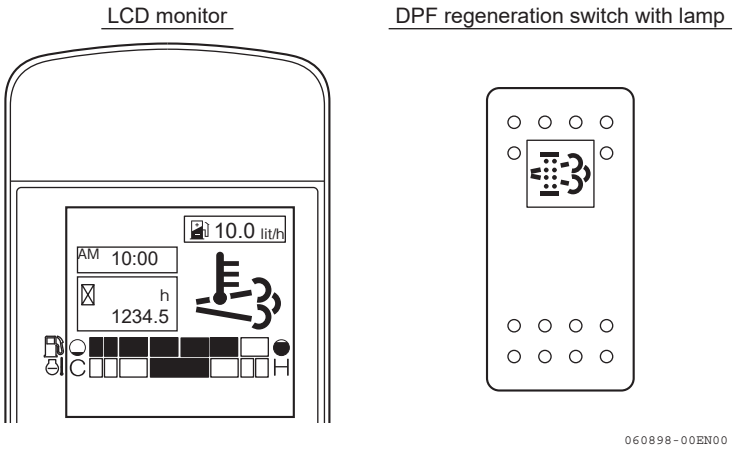
[4] Stationary regeneration standby



Description

- An operator intervention ([2], [3] above) (hereinafter referred to as “Allow state”) or detection of certain PM deposit amount or more (hereinafter referred to as “Emergency state”) causes DPF to transfer to the stationary regeneration standby.
- When the transition is made from the above “Allow” condition to the stationary regeneration standby, only the DPF regeneration request icon is displayed on LCD monitor. When the transition is made from the above “Emergency” condition, the regeneration request icon is displayed and the caution lamp blinks, and error code "00 003719.16" is displayed.
- Make sure to refer to operation manual and confirm the operation procedures and precautions for the DPF stationary (manual) regeneration before starting stationary regeneration (transfer to [5] de-scribed later).
- If a certain length of time elapses and/or the PM deposit amount reaches to or above a certain level, DPF automatically transfers to the backup mode ([6] described later).

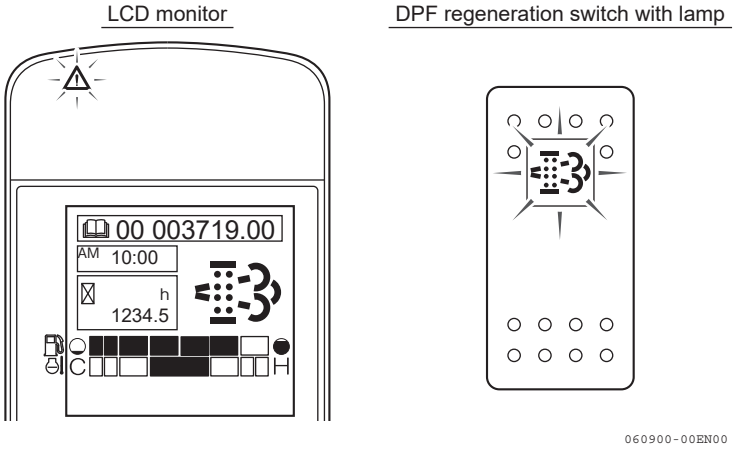
[5] Stationary regeneration operating



Description

- The stationary regeneration is completed in approximately 25 to 30 minutes. (After the stationary regeneration completion, DPF transfers to [1] described before.)
- If the stationary regeneration has started in the Allow state, setting the interlock switch to unlock position interrupts the stationary regeneration and DPF transfers to the state [3] described before.
- If the stationary regeneration has started in the Emergency state, any of the following operations interrupts the stationary re-generation and DPF transfers to the stationary regeneration standby state ([4] described before).
  - When the interlock switch is set to unlock position
  - Command an accelerator position equal to or more than the minimum position
  - Turn starter switch to OFF

[6] Backup mode



Description

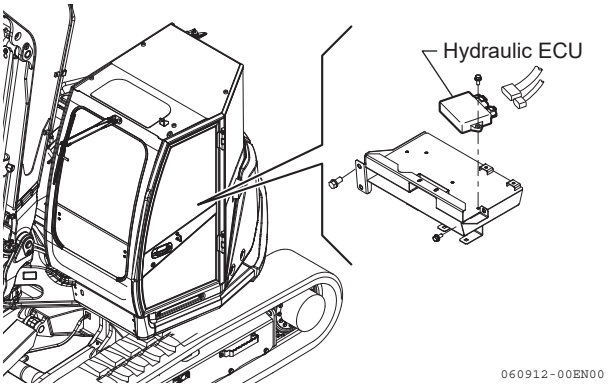
- In the backup mode, the engine is operated with speed limit and/or max. injection amount limit.
- In the backup mode, error code for the relevant factor as listed below is displayed along with the specified error code: "00 003719.00".

1. If PM deposit amount (C method) is equal to or larger than a certain amount, error code: "00 522573.00"
2. If PM deposit amount (P method) is equal to or larger than a certain amount, error code: "00 522574.00"
3. If PM deposit amount is equal to or larger than a certain amount even after stationary regeneration has been executed for a specified time, error code: "00 522575.07"
4. If a certain length of time elapses in stationary regeneration standby state, error code: "00 522577.11"

- To cancel the backup mode, it's necessary to use SMARTASSIST-Direct (SA-D).

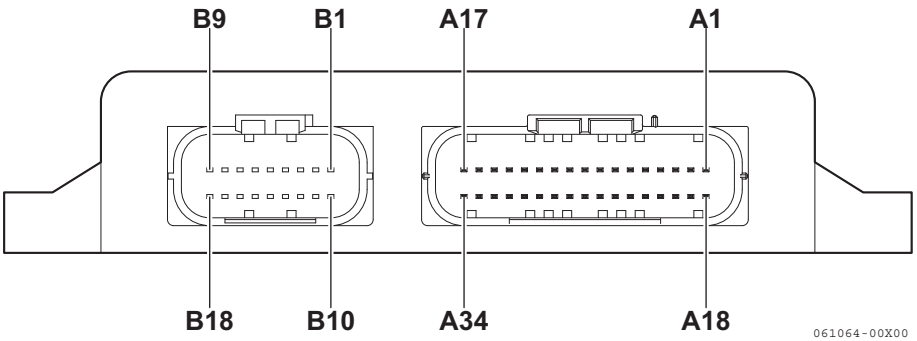
5-4 Hydraulic ECU (Controller)

5-4-1 Outline



The figure below shows the pin numbers of the hydraulic ECU.

View from engaging side



Pin numbers of the hydraulic ECU connector

5-4-2 Engine Control

On this machine, the hydraulic ECU is connected to the accelerator sensor and engine control switches and transmits instructions such as target engine speeds to the engine ECU via CAN, thereby controlling the engine.

1) Accelerator sensor input

(1) Accelerator sensor input

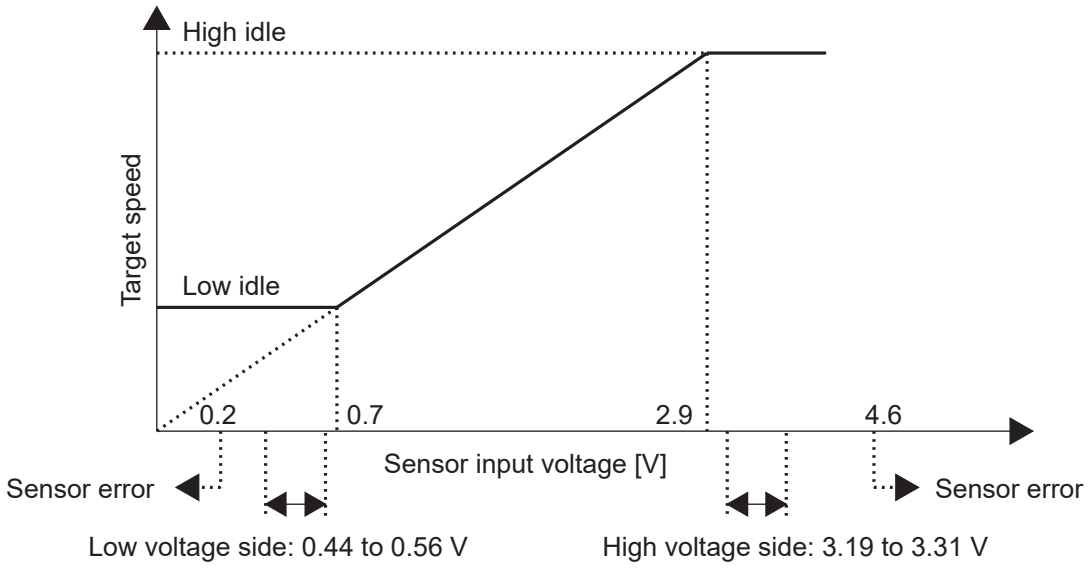
The hydraulic ECU calculates a target engine speed as a control standard based on the input voltage from the accelerator sensor. The hydraulic ECU sends the target engine speed instructions to the engine ECU via CAN communication to control the engine speed. (Note that the actual engine speed is not always identical to the target engine speed because it is determined based on the relationship between the maximum engine torque and load torque.)

The accelerator sensor input voltage is converted into rotational speed and as shown in the figure below, it is preset so that the input voltage is converted into low idle speed at a voltage of 0.7V and into high idle speed at a voltage of 2.9V.

If the input voltage from the accelerator sensor becomes 0.2V or less or 4.6V or more, the hydraulic ECU detects an accelerator sensor failure.

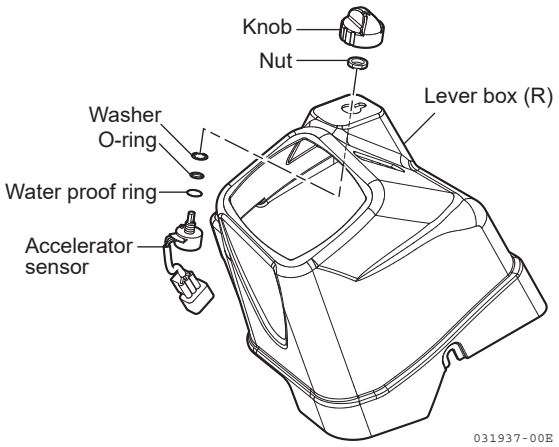
The hydraulic ECU has a detection error in the electrical circuit in regard to the input voltage from the accelerator sensor, and the sum of these values is ±0.125V.

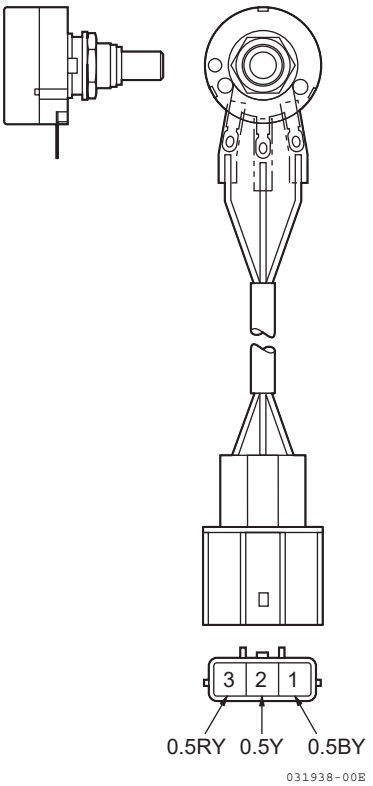
Therefore, the accelerator sensor input voltage must be within the range shown in the figure below.



Accelerator Sensor Input

(2) Engine control dial (accelerator sensor)

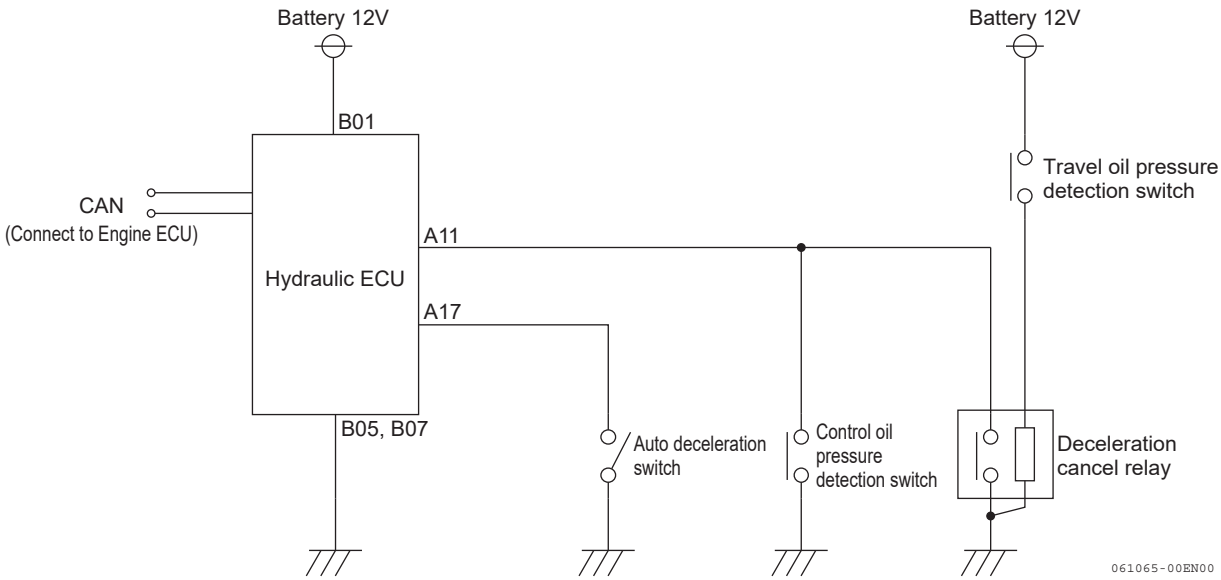




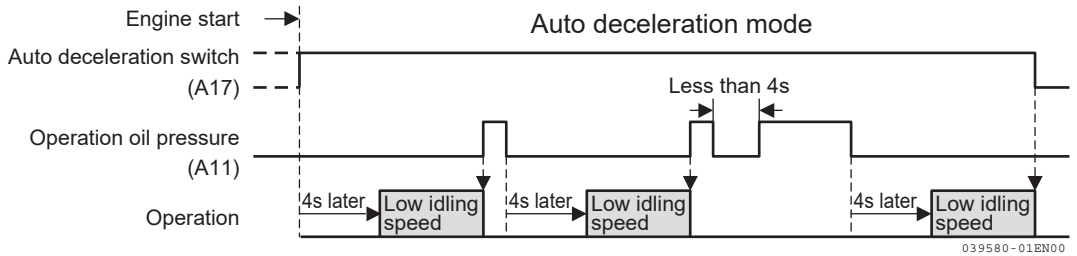
2) Auto deceleration mode

When the auto deceleration switch is in ON position and all the control levers are in neutral position, the engine speed is reduced to low idle to reduce fuel consumption.

The figure below shows the connection diagram for auto deceleration mode.



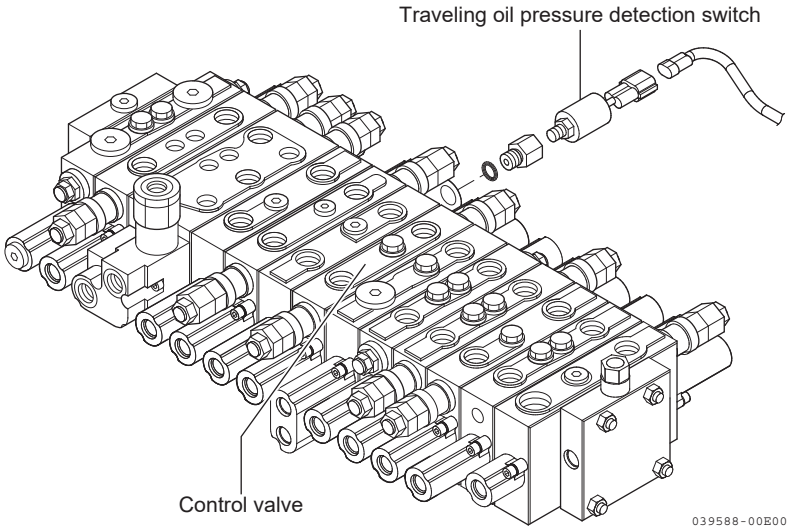
The figure below shows the operation timing for auto deceleration mode.

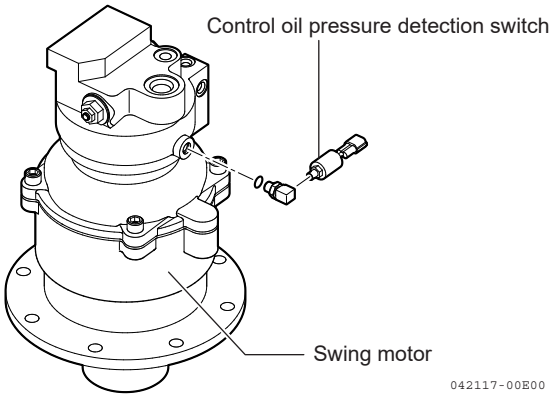


Pin numbers of the hydraulic ECU connector

When the auto deceleration switch is ON and operation oil pressure is OFF (in non-operational condition) for more than 4 seconds, the auto deceleration changes the engine target speed to the low idling speed regardless of the accelerator input.

Operation oil pressure switches

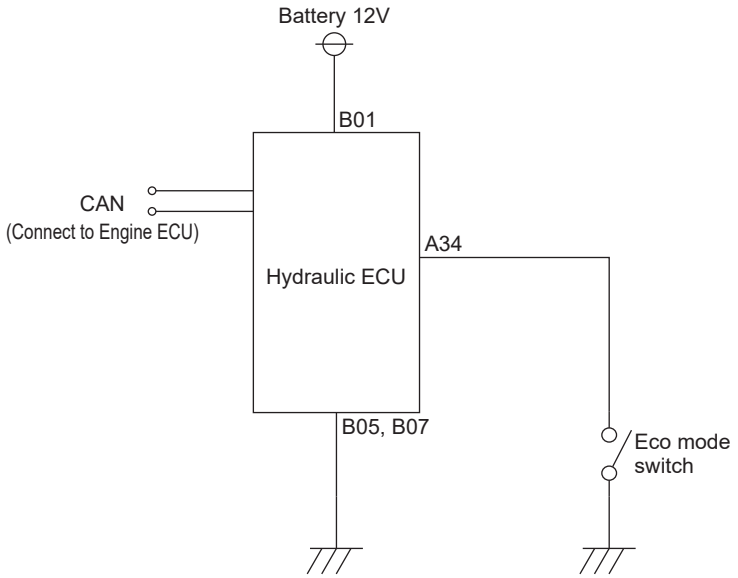




3) Eco mode

When the eco mode switch is in ON position, the maximum target speed determined by accelerator sensor input is limited to the specified speed.

The figure below shows the connection diagram for auto deceleration mode.

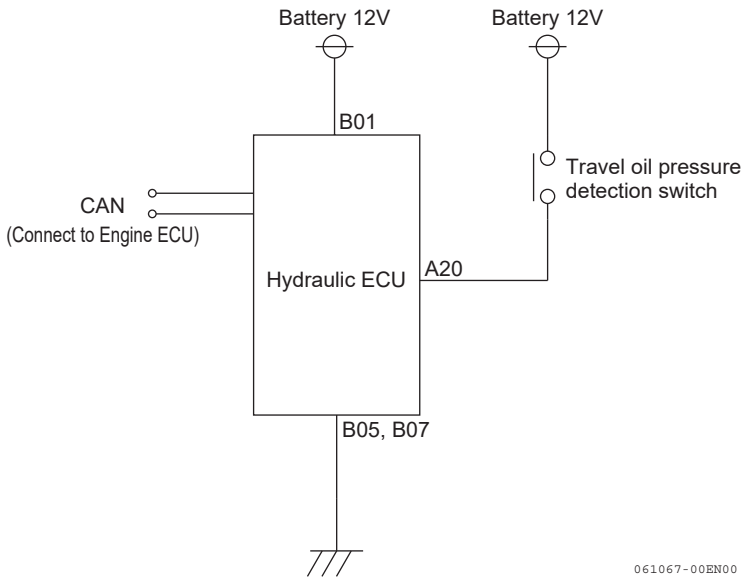


Eco mode switch	Limit speed (min^{-1})
OFF	1900
ON	1700

4) Switching between isochronous control and droop control

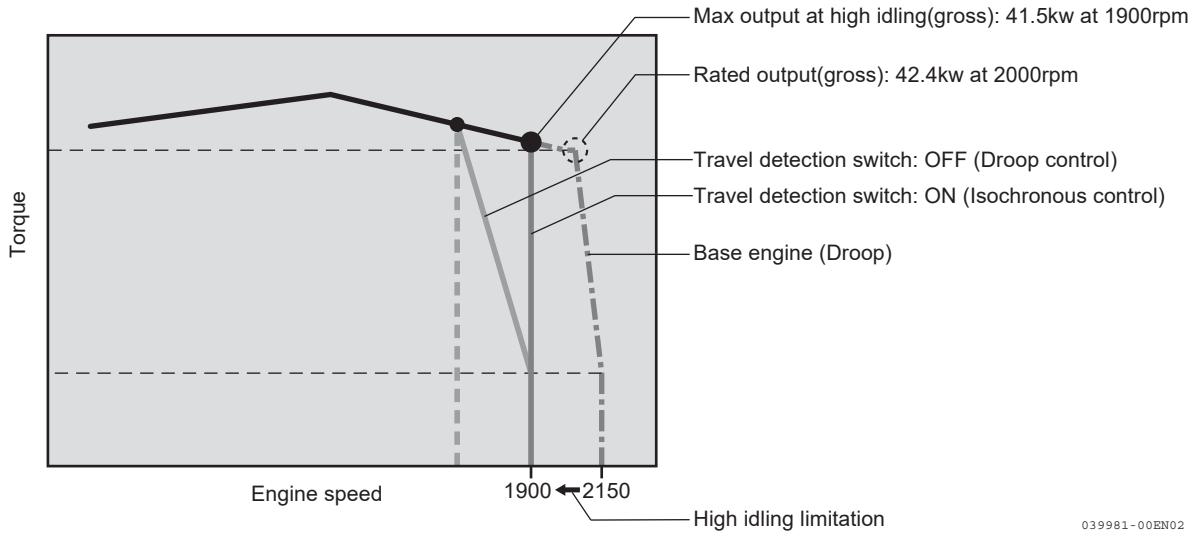
When the travel oil pressure detection switch is on, the hydraulic ECU transmits instructions to the engine ECU via CAN and switches the engine speed control mode from virtual droop control to isochronous control.
Refer to Section 5-3 "Engine ECU (engine controler)" for details of engine speed control.

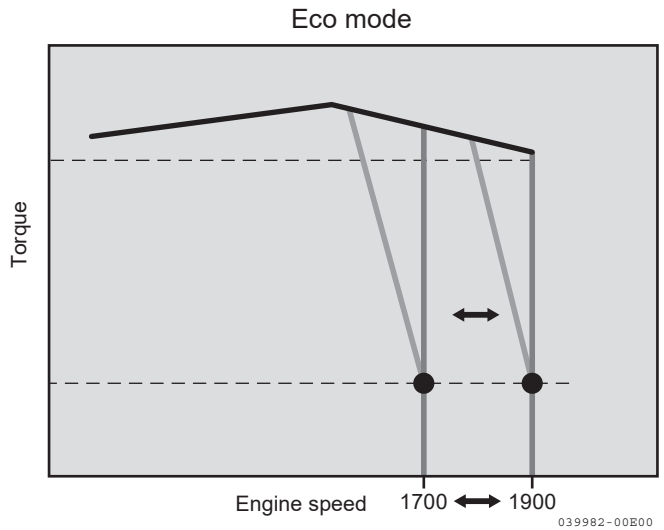
The figure below shows the connection diagram for switching isochronous and droop control.



5) Engine speed and output control

This unit utilizes the electronic control functions to improve the performance including specific diesel fuel consumption, heat balance, and noise. The image outline of the engine torque curve controlled by the electronic control function is as shown in the figure below.

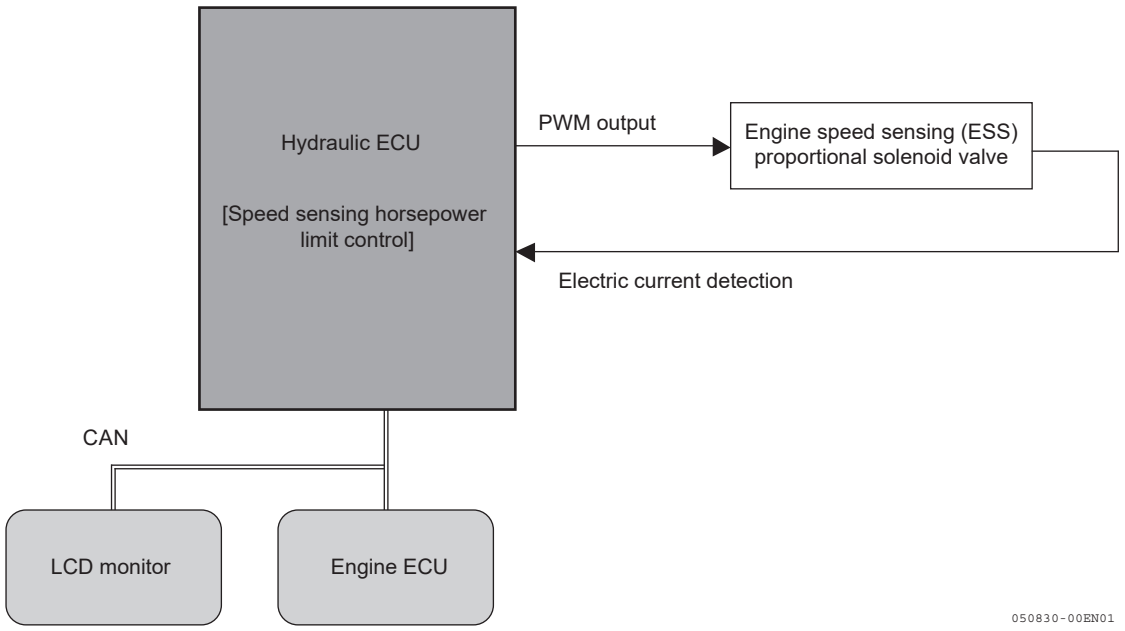




5-4-3 Speed Sensing Horsepower Limit Control

In cases where the hydraulic horsepower exceeds the engine horsepower, for example, when the machine is operating with the air conditioner switched on at high attitude, the ECU reduces the hydraulic horsepower based on the control amount calculated to avoid significant drops in engine speed.

Function	Outline
Acquisition of engine information	Information including engine speed is received via CAN communication.
Control of pump swash plate	Control amount for the pump swash plate is calculated based on the difference between the target engine speed and actual engine speed and, based on the calculated control amount, the inclination angle of the swash plate is controlled by the proportional solenoid valve.



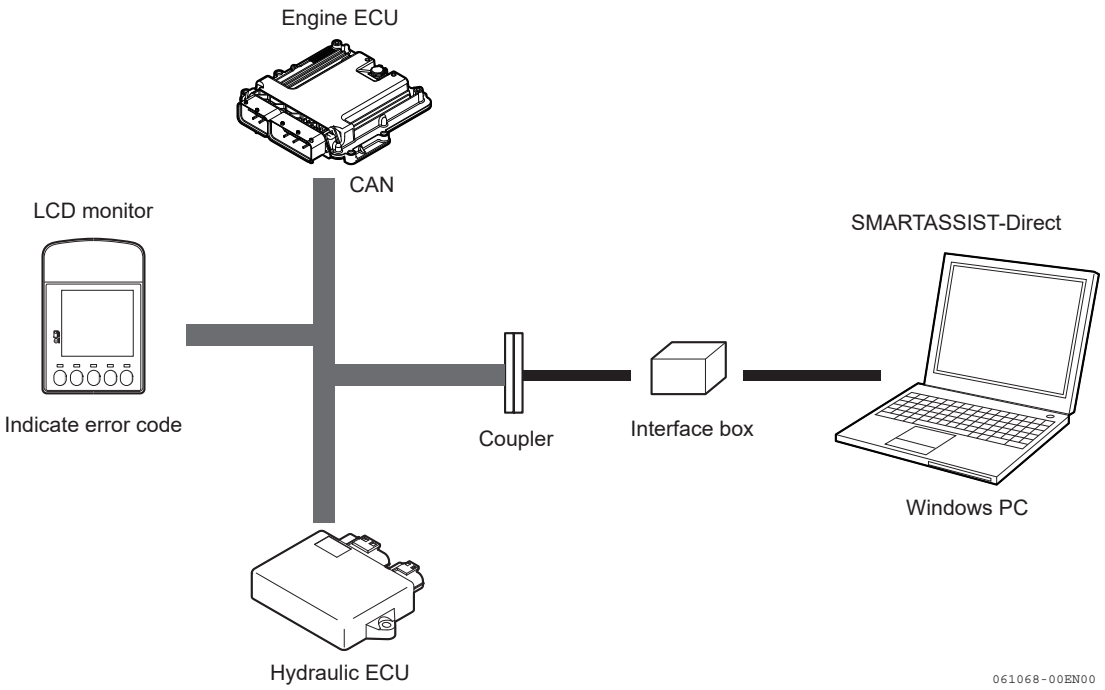
5-5 Error Code

The LCD monitor and the controllers including the engine ECU and hydraulic ECU are connected via CAN.
If the LCD monitor or any of the controllers detects an abnormality, an error code corresponding to the abnormality is displayed on the LCD monitor. For detailed description of error codes, refer to the error code list.

Connecting SMARTASSIST-Direct (SA-D), a controller failure diagnosis tool, to the controllers allows checking of detailed failure information and history for the engine ECU and hydraulic ECU as well as implementation of status monitoring and diagnostic tests.
For detailed information and operation of SA-D, refer to the SMARTASSIST-Direct operation manual and the engine troubleshooting manual.

Note:

Information on the LCD monitor cannot be checked by SA-D.

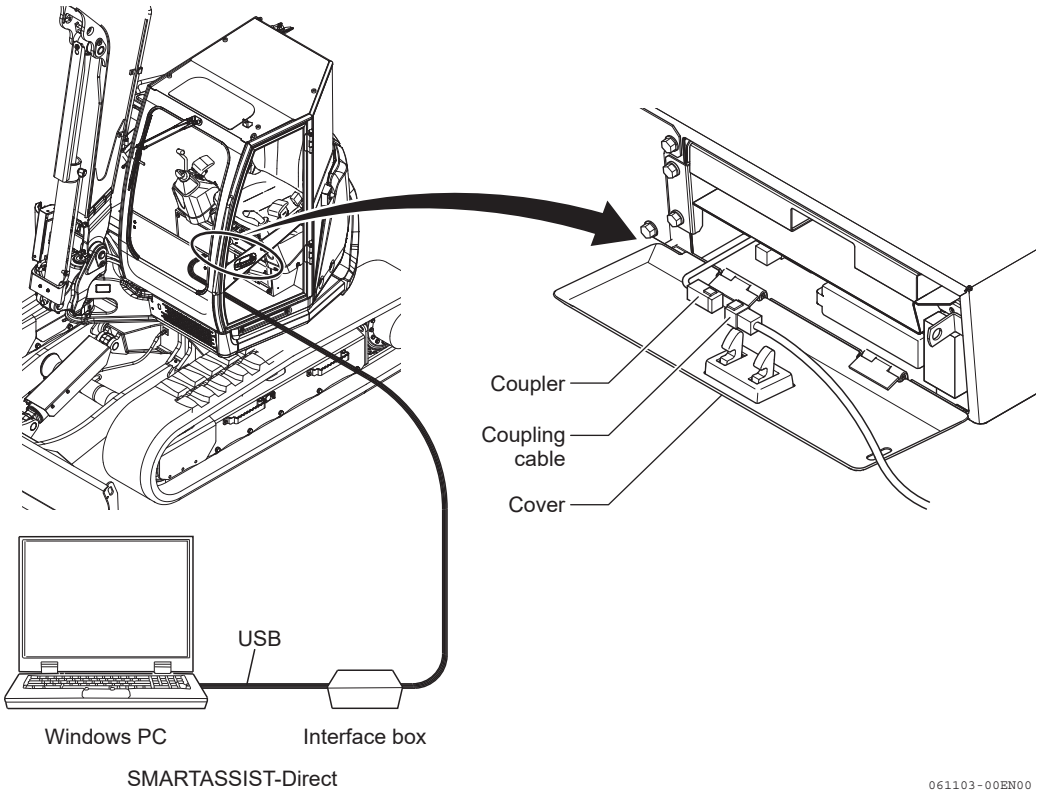


■ SA-D Connection Procedure

(1) Open the seat mount cover and disconnect the coupler for connecting SA-D and connect the SA-D coupling cable to the coupler.

(2) Turn the starter switch to the ON position and start the SA-D software.
- For details of the SA-D software operation method, refer to the SMARTASSIST-Direct operation manual.
- When the starter switch is in the OFF position, SA-D cannot communicate with the controllers.

(3) To remove SA-D, first turn the starter switch to the OFF position, then disconnect the SA-D coupling cable from the coupler and connect the coupler to the original coupler under the seat. Then, close the seat mount cover.



Error Code List

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 000051.03	Caution	Intake throttle position sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Intake throttle position sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle position sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000051.04	Caution	Intake throttle position sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Intake throttle position sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle position sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000091.03	Caution	Accelerator sensor malfunction: High voltage	The sensor voltage is higher than 4.6 V.	1. Improper connector engagement, 2. Faulty wire harness, 3. Accelerator sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, accelerator sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000091.04	Caution	Accelerator sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V.	1. Improper connector engagement, 2. Faulty wire harness (Sensor 5V disconnection or short to ground), 3. Accelerator sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, accelerator sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000100.01	Warning	Low engine oil pressure alarm	After the engine starts, the engine oil pressure switch stays on for a specific period of time at an engine speed of 600 min^{-1} or more and at a battery voltage of 9V or more.	1. Low engine oil pressure, 2. Engine lubrication system failure, 3. Faulty wire harness (Engine oil pressure switch wire short to ground), 4. Engine oil pressure switch failure (Short to ground on a wire inside the engine oil pressure switch), 5. Engine ECU internal circuit failure	Check the amount of engine oil, engine lubrication system, wire harness, engine oil pressure switch and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000100.04	Warning	Engine oil pressure switch disconnection	Before the engine starts with the starter switch in the "ON" position, the engine oil pressure switch stays off for one second at a battery voltage of 9 V or more.	1. Improper connector engagement, 2. Faulty wire harness (Engine oil pressure switch wire disconnection or short to power), 3. Engine oil pressure switch failure (Wire disconnection or short to power on a wire inside the engine oil pressure switch), 4. Engine ECU internal circuit failure	Check the connector, wire harness, engine oil pressure switch and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000102.03	Warning	EGR low pressure-side sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor signal wire short to ground), 3. EGR pressure sensor failure (Improper sensor output due to short to ground on a wire inside the EGR pressure sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000102.04	Warning	EGR low pressure-side sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000102.13	Warning	EGR low pressure-side sensor malfunction: Abnormal learning value	The final offset value for the intake manifold pressure is lower than the threshold value or higher than the threshold value.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000105.03	Warning	Intake manifold temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Intake manifold temperature sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake manifold temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000105.04	Warning	Intake manifold temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Intake manifold temperature sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake manifold temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000108.03	Caution	Atmospheric pressure sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Failure of atmospheric pressure sensor inside engine ECU, 2. Engine ECU internal circuit failure	Check the atmospheric pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000108.04	Caution	Atmospheric pressure sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Failure of atmospheric pressure sensor inside engine ECU, 2. Engine ECU internal circuit failure	Check the atmospheric pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000108.10	Caution	Abnormal atmospheric pressure sensor characteristics	The final offset values for both the intake manifold pressure and the exhaust manifold pressure remain at 5 kPa or higher for 600 ms.	1. Failure of atmospheric pressure sensor inside engine ECU, 2. Engine ECU internal circuit failure, 3. Abnormal characteristics of both EGR high pressure-side and low pressure-side sensors, 4. Obstruction due to foreign matter in the sensor area or frozen sensor	Check the atmospheric pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000110.00	Warning	Abnormally-high coolant temperature (Overheating)	60 seconds after the engine starts, the coolant temperature remains at 110°C or higher for 20 seconds.	1. Engine overheating, 2. Insufficient engine coolant, 3. Engine cooling system failure, 4. Coolant temperature sensor system failure	Check the amount of engine coolant, engine cooling system and coolant temperature sensor system. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 000110.03	Warning	Coolant temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor ground wire disconnection or short to power, sensor signal wire disconnection or short to power), 3. Coolant temperature sensor failure (Improper sensor output due to wire disconnection inside the coolant temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, coolant temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000110.04	Warning	Coolant temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor signal wire short to ground), 3. Coolant temperature sensor failure (Improper sensor output due to short to ground on a wire inside the coolant temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, coolant temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000157.00	Warning	Abnormally high rail pressure	The rail pressure remains at 170 MPa or higher for a specified period of time (5 seconds).	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump and rail pressure sensor. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000157.03	Warning	Rail pressure sensor malfunction: High voltage	The sensor voltage is higher than 4.75 V when the engine not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Rail pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, rail pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000157.04	Warning	Rail pressure sensor malfunction: Low voltage	The sensor voltage is lower than 0.24 V when the engine not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Rail pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, rail pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000157.15	Warning	Abnormal rail pressure deviation: Excessively high rail pressure	The actual rail pressure is higher than the target value and the pressure difference remains at 20 MPa or higher for a specific period of time (5 seconds).	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump and rail pressure sensor. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000157.16	Warning	Common rail pressure limiting valve (PLV) open	The common rail pressure limiting valve (PLV) is open.	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system and supply pump. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000157.18	Warning	Abnormal rail pressure deviation: Too low rail pressure	The actual rail pressure is lower than the target value and the pressure difference remains at 20 MPa or higher for a specific period of time (3 seconds).	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV stuck closed, 5. SCV intermittent fault, 6. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump and rail pressure sensor. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000167.01	Caution	Battery charge alarm	After the engine start, the engine speed is higher than 600 min^{-1} and the battery charge switch stays on for 10 seconds or more.	1. Abnormal battery charging, 2. Alternator failure, 3. Faulty wire harness (Battery charge switch wire short to ground), 4. Battery charge switch failure (Short to ground on a wire inside the battery charge switch), 5. Engine ECU internal circuit failure	Check the alternator, connector, wire harness, battery charge switch and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000167.05	Caution	Battery charge switch disconnection	Before the engine starts with the starter switch in the "ON" position, the battery charge switch stays off for one second.	1. Improper connector engagement, 2. Faulty wire harness (Battery charge switch wire disconnection or short to power), 3. Battery charge switch failure (Wire disconnection or short to power on a wire inside the battery charge switch), 4. Engine ECU internal circuit failure	Check the connector, wire harness, battery charge switch and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000172.03	Caution	Intake (new air) temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.85 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor ground wire disconnection or short to power, sensor signal wire disconnection or short to power), 3. Temperature sensor failure (Improper sensor output due to wire disconnection inside the temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake (new air) sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000172.04	Caution	Intake (new air) temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.15 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor signal wire short to ground), 3. Temperature sensor failure (Improper sensor output due to short to ground on a wire inside the temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake (new air) sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000173.03	Caution	Exhaust manifold temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Exhaust manifold temperature sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, exhaust manifold temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000173.04	Caution	Exhaust manifold temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. Exhaust manifold temperature sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, exhaust manifold temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000174.00	Caution	Abnormally high fuel temperature	After the engine starts, the fuel temperature remains at 90ºC or higher for a specific period of time.	1. Low level of fuel in the fuel tank, 2. Inability to cool due to clogged fuel cooler, 3. Fuel temperature sensor system failure	Check the fuel temperature sensor system, fuel tank and fuel cooler. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 000174.03	Caution	Fuel temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor ground wire disconnection or short to power, sensor signal wire disconnection or short to power), 3. Fuel temperature sensor failure (Improper sensor output due to wire disconnection inside the fuel temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, fuel temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000174.04	Caution	Fuel temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor signal wire short to ground), 3. Fuel temperature sensor failure (Improper sensor output due to short to ground on a wire inside the fuel temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, fuel temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000190.00	Warning	Overspeed	The engine speed exceeds the threshold value.	1. Crank speed sensor malfunction (Temporary failure caused by external factors such as radio waves), 2. Cam speed sensor malfunction (Temporary failure caused by external factors such as radio waves), 3. Engine ECU internal circuit failure, 4. Injector failure	Check the crank speed sensor, cam speed sensor, injector and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000237.13	Caution	CAN communication failure: Abnormal received VI data	When the engine is not cranking, with the starter switch in the "ON" position and at a battery voltage of 10 V or higher, the received VI data does not match the existing VI data on the engine ECU.	1. CAN communication error of the machine controller, 2. Engine ECU internal circuit failure	Check the connector, wire harness, machine controller and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000237.31	Caution	CAN communication failure: VI data reception timeout	When the engine is not cranking, with the starter switch in the "ON" position and at a battery voltage of 10 V or higher, no response is received to three VIN requests.	1. CAN communication error of the machine controller, 2. Improper connector engagement, 3. Wire harness disconnection or short circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, machine controller and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000412.03	Caution	EGR gas temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR gas temperature sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR gas temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000412.04	Caution	EGR gas temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR gas temperature sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR gas temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000630.12	Caution	Engine ECU malfunction: EEPROM memory clearance error	When switching between the EEPROM pages (sectors), the page is not cleared.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000633.03	Warning	High-pressure pump drive circuit malfunction: High-side short to VB	A short to VB condition continues for a specific period of time (300 ms).	1. Improper connector engagement, 2. Faulty wire harness (SCV positive output short to power, SCV negative output short to power), 3. SCV failure due to coil short circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, SCV (MPROP) and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000633.05	Warning	High-pressure pump drive circuit malfunction: Open circuit	An open condition is detected in the high-pressure pump drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (SCV (MPROP) disconnection), 3. SCV (MPROP) failure due to wire disconnection, 4. Engine ECU internal circuit failure	Check the connector, wire harness, SCV (MPROP) and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000633.06	Warning	High-pressure pump drive circuit malfunction: High-side short to ground	A shot to ground condition is detected in the high-pressure pump drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (SCV (MPROP) high-side short to power), 3. SCV(MPROP) failure due to short to power, 4. Engine ECU internal circuit failure	Check the connector, wire harness, SCV (MPROP) and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000651.03	Caution	Cylinder No. 4 injector malfunction: Short circuit	A low-side short to +B is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000651.05	Caution	Cylinder No. 4 injector malfunction: Open circuit (Inherent to injector)	High-side or low-side open is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Injector drive circuit open), 3. Engine ECU internal circuit failure, 4. Injector internal circuit open	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000651.06	Caution	Cylinder No. 4 injector malfunction: Coil short circuit	High-side and low-side short circuits are detected on the Injector coil.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000652.03	Caution	Cylinder No. 3 injector malfunction: Short circuit	A low-side short to +B is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000652.05	Caution	Cylinder No. 3 injector malfunction: Open circuit (Inherent to injector)	High-side or low-side open is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Injector drive circuit open), 3. Engine ECU internal circuit failure, 4. Injector internal circuit open	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000652.06	Caution	Cylinder No. 3 injector malfunction: Coil short circuit	High-side and low-side short circuits are detected on the Injector coil.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 000653.03	Caution	Cylinder No. 2 injector malfunction: Short circuit	A low-side short to +B is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000653.05	Caution	Cylinder No. 2 injector malfunction: Open circuit (Inherent to injector)	High-side or low-side open is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Injector drive circuit open), 3. Engine ECU internal circuit failure, 4. Injector internal circuit open	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000653.06	Caution	Cylinder No.2 injector malfunction: Coil short circuit	High-side and low-side short circuits are detected on the Injector coil.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000654.03	Caution	Cylinder No. 1 injector malfunction: Short circuit	A low-side short to +B is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000654.05	Caution	Cylinder No.1 injector malfunction: Open circuit (Inherent to injector)	High-side or low-side open is detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Injector drive circuit open), 3. Engine ECU internal circuit failure, 4. Injector internal circuit open	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 000654.06	Caution	Cylinder No. 1 injector malfunction: Coil short circuit	High-side and low-side short circuits are detected on the Injector coil.	1. Improper connector engagement, 2. Faulty wire harness (Short in the injector drive circuit), 3. Engine ECU internal circuit failure, 4. Short in the injector internal circuit	Check the connector, wire harness, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 001209.03	Warning	EGR high pressure-side sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 001209.04	Warning	EGR high pressure-side sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 001209.13	Warning	EGR high pressure-side sensor malfunction: Abnormal learning value	The final offset value for the exhaust manifold pressure is lower than the threshold value or higher than the threshold value.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, EGR pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 001485.02	Caution	Main relay malfunction: Early opening	After the starter switch is turned to the "OFF" position, engine ECU power is shut down before EEPROM writing process.	1. Improper connector engagement, 2. Faulty wire harness (Short to ground on the main relay coil side downstream wire), 3. Main relay contact failure (Main relay contact stuck), 4. Engine ECU internal circuit failure	Check the connector, wire harness, main relay and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 001485.07	Caution	Main relay malfunction: Contact stuck	The main relay does not open even when 150 ms have passed since engine ECU was shut off.	1. Improper connector engagement, 2. Faulty wire harness (Short to ground on the main relay coil side downstream wire), 3. Main relay contact failure (Main relay contact stuck), 4. Engine ECU internal circuit failure	Check the connector, wire harness, main relay and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002791.00	Caution	EGR overvoltage	The voltage supplied to the EGR valve remains higher than 18V for 5 seconds.	1. Overcharged battery, 2. EGR valve internal circuit failure	Check the battery and EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002791.01	Caution	EGR undervoltage	The voltage supplied to the EGR valve remains lower than 8V for 13 seconds.	1. Deteriorated battery, 2. EGR valve short to power, 3. EGR valve internal circuit failure	Check the wire harness, battery and EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002791.07	Caution	Abnormal EGR feedback	The motor drive overload condition continues for a specific period of time.	1. EGR valve internal circuit failure	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002791.09	Caution	Abnormal engine ECU data on EGR	Disruption of the signal transmitted from the engine ECU to EGR is detected.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR valve internal circuit failure	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002791.12	Caution	Open circuit between EGR motor and coil	Open circuit to the motor is detected.	1. DC motor failure of the EGR valve	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002797.06	Caution	Injector drive circuit malfunction: Bank 1 short circuit	High-side and low-side shorts to ground or high-side short to +B are detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Injector bank 1 high-side short to power, injector bank 1 high-side short to ground, injector bank 1 low-side short to power, injector bank 1 low-side short to ground), 3. Injector failure due to short to power, 4. Engine ECU internal circuit failure	Check the connector, wire harness, injector and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 002798.06	Caution	Injector drive circuit malfunction: Bank 2 short circuit	High-side and low-side shorts to ground or high-side short to +B are detected in the injector drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (Injector bank 2 high-side short to power, injector bank 2 high-side short to ground, injector bank 2 low-side short to power, injector bank 2 low-side short to ground), 3. Injector failure due to short to power, 4. Engine ECU internal circuit failure	Check the connector, wire harness, injector and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002950.03	Caution	Intake throttle drive circuit malfunction: H bridge output 1 short to power	Output terminal 1 of the drive circuit is shorted to VB.	1. Improper connector engagement, 2. Faulty wire harness (High-side short to power in the intake throttle drive circuit), 3. Intake throttle failure due to short to power, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002950.04	Caution	Intake throttle drive circuit malfunction: H bridge output 1 short to ground	Output terminal 1 of the drive circuit is shorted to ground.	1. Improper connector engagement, 2. Faulty wire harness (High-side short to ground in the intake throttle drive circuit), 3. Intake throttle failure due to short to ground, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002950.05	Caution	Intake throttle drive circuit malfunction: No load in H bridge circuit	No load (open) is detected in the drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (High-side open in the intake throttle drive circuit, low-side open in the intake throttle drive circuit), 3. Intake throttle failure due to open circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002950.06	Caution	Intake throttle drive circuit malfunction: H bridge circuit overloaded	The temperature of a component of the drive circuit exceeds the threshold value.	1. Improper connector engagement, 2. Faulty wire harness (High-side short in the intake throttle drive circuit, low-side short in the intake throttle drive circuit), 3. Intake throttle failure due to short circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002951.03	Caution	Intake throttle drive circuit malfunction: H bridge output 2 short to VB power	Output terminal 2 of the drive circuit is shorted to VB.	1. Improper connector engagement, 2. Faulty wire harness (Low-side short to power in the intake throttle drive circuit), 3. Intake throttle failure due to short to power, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 002951.04	Caution	Intake throttle drive circuit malfunction: H bridge output 2 short to ground	Output terminal 2 of the drive circuit is shorted to ground.	1. Improper connector engagement, 2. Faulty wire harness (Low-side short to ground in the intake throttle drive circuit), 3. Intake throttle failure due to short to ground, 4. Engine ECU internal circuit failure	Check the connector, wire harness, intake throttle and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003242.00	Caution	DPF inlet temperature sensor: Abnormally high temperature	The DPF inlet temperature remains at 700 ºC or higher for a specific period of time (15 seconds).	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF inlet temperature sensor system failure, 4. Engine ECU internal circuit failure, 5. Combustion gas blow-by (Piping damage in the passage to DOC), 6. Defective injector (Decrease in injection quantity, incorrect injection timing)	Check the connector, wire harness, DPF inlet temperature sensor, engine ECU, injector and exhaust piping. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003242.03	Warning	DPF inlet temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor ground wire disconnection or short to power, sensor signal wire disconnection or short to power), 3. DPF inlet temperature sensor failure (Improper sensor output due to wire disconnection inside the DPF inlet temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF inlet temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003242.04	Warning	DPF inlet temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor signal wire short to ground), 3. DPF inlet temperature sensor failure (Improper sensor output due to short to ground on a wire inside the DPF inlet temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF inlet temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003250.00	Warning	DPF intermediate temperature sensor: Abnormally high temperature (Post injection failure)	During regeneration, the DPF intermediate temperature remains at 700 ºC or higher for a specific period of time (30 seconds).	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF intermediate temperature sensor system failure, 4. Engine ECU internal circuit failure, 5. Defective injector (Increase in injection quantity, incorrect injection timing)	Check the connector, wire harness, DPF intermediate temperature sensor, engine ECU and injector. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003250.01	Caution	DPF intermediate temperature sensor: Abnormally low temperature	The DPF regeneration failure timer reaches a specific value (1200 seconds).	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF intermediate temperature sensor system failure, 4. Engine ECU internal circuit failure, 5. DOC deterioration due to external factors such as sulfur poisoning (Increase in activation temperature), 6. Combustion gas blow-by (Catalytic damage, piping damage in the passage to DOC), 7. Defective injector (Decrease in injection quantity, incorrect injection timing)	Check the connector, wire harness, DPF intermediate temperature sensor system, engine ECU, injector, DOC and piping. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003250.03	Warning	DPF intermediate temperature sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor ground wire disconnection or short to power, sensor signal wire disconnection or short to power), 3. DPF intermediate temperature sensor failure (Improper sensor output due to wire disconnection inside the DPF intermediate temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF intermediate temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 003250.04	Warning	DPF intermediate temperature sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness (Sensor signal wire short to ground), 3. DPF intermediate temperature sensor failure (Improper sensor output due to short to ground on a wire inside the DPF intermediate temperature sensor), 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF intermediate temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003251.00	Warning	DPF differential pressure sensor: Abnormally high differential pressure	After the engine starts, the DPF differential pressure remains at 50 kPa or higher for a specific period of time (15 seconds).	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF differential pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF differential pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003251.03	Warning	DPF differential pressure sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF differential pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF differential pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003251.04	Warning	DPF differential pressure sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF differential pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF differential pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003251.13	Warning	DPF differential pressure sensor malfunction: Abnormal learning value	The final offset value for the DPF differential pressure is lower than the threshold value or higher than the threshold value.	1. Improper connector engagement, 2. Faulty wire harness, 3. EGR pressure sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF differential pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003609.03	Warning	DPF high pressure-side sensor malfunction: High voltage	The sensor voltage is higher than 4.8 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF high pressure-side sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF high pressure-side sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003609.04	Warning	DPF high pressure-side sensor malfunction: Low voltage	The sensor voltage is lower than 0.2 V when the engine is not cranking.	1. Improper connector engagement, 2. Faulty wire harness, 3. DPF high pressure-side sensor failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, DPF high pressure side sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003719.00	Warning	DPF backup mode	The engine ECU has been switched into the backup mode and the DPF is not under recovery regeneration.	1. Engine ECU left in the stationary regeneration standby emergency mode for a specific period of time, 2. Engine ECU internal circuit failure, 3. DOC deterioration due to external factors such as sulfur poisoning (Increase in activation temperature), 4. Combustion gas blow-by (Catalytic damage, piping damage in the passage to DOC), 5. Defective injector (Decrease in injection quantity, incorrect injection timing)	Connect the SMARTASSIST-Direct (SA-D) and perform a DPF recovery regeneration. Check the injector, engine ECU, DOC and piping. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003719.07	Warning	DPF recovery regeneration prohibition	When the recovery regeneration is started, the amount of PM accumulated in the DPF (according to Method C) remains larger than the threshold value for a specific period of time or the total amount of time the amount of PM accumulated in the DPF (according to Method P) is larger than the threshold value exceeds a specified value.	PM is overaccumulated and the recovery regeneration cannot be performed.	Check the soot filter. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003719.09	Warning	DPF recovery regeneration failure	The engine ECU determines that the recovery regeneration has failed.	1. DPF intermediate temperature sensor system failure, 2. DOC deterioration or DOC breakage due to external factors such as sulfur poisoning, 3. Defective injector (Decrease in injection quantity, incorrect injection timing)	Check the DPF intermediate temperature sensor system, injector and DOC. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003719.16	Caution	Stationary DPF regeneration standby (Stationary regeneration request)	The engine ECU is switched into the stationary regeneration mode due to factors other than external switch and CAN commands when the DPF is not under stationary regeneration.	1. Inadequate regeneration capability due to low operating load, 2. Reset regeneration with regeneration prohibition switch on continued for a specific period of time, 3. Engine ECU internal circuit failure, 4. DOC deterioration due to external factors such as sulfur poisoning (Increase in activation temperature), 5. Combustion gas blow-by (Catalytic damage, piping damage in the passage to DOC), 6. Defective injector (Decrease in injection quantity, incorrect injection timing)	Perform a stationary (manual) DPF regeneration. Check the injector, engine ECU, DOC and piping. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003720.00	Warning	DPF ash cleaning request 2	The ash deposit density is 60 g/L or more.	1. Engine ECU internal circuit failure, 2. Increase in actual differential pressure of the soot filter (Ash accumulation)	Replace or clean the soot filter. Check the DPF and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 003720.16	Caution	DPF ash cleaning request 1	The ash deposit density is greater than or equal to 50 g/L and less than 60 g/L.	1. Engine ECU internal circuit failure, 2. Increase in actual differential pressure of the soot filter (Ash accumulation)	Replace or clean the soot filter. Check the DPF and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 004257.12	Caution	Injector drive IC failure	An injector drive IC failure is detected by the engine ECU.	-	-

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 522243.05	Caution	Starting aid relay malfunction: Open circuit	When no current is supplied to the starting aid relay, open circuit is detected by the IC inside the engine ECU.	1. Improper connector engagement, 2. Faulty wire harness (Starting aid relay output circuit open, starting aid relay output short to power), 3. starting aid relay failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, starting aid relay and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522243.06	Caution	Starting aid relay malfunction: Short circuit to GND	When current is supplied to the starting aid relay, a short to ground is detected by the IC inside the engine ECU.	1. Improper connector engagement, 2. Faulty wire harness (Starting aid relay output short to ground), 3. Starting aid relay failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, starting aid relay and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522400.02	Caution	Crank speed sensor malfunction: Abnormal signal	A specific number of abnormal pulses (15 pulses) are detected.	1. Improper connector engagement, 2. Faulty wire harness, 3. Crank speed sensor failure, 4. Engine ECU internal circuit failure, 5. Pulser malfunction or incorrect sensor installation	Check the connector, wire harness, crank speed sensor, engine ECU and pulser. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522400.05	Caution	Crank speed sensor malfunction: No signal	No crank signal is input during a specific number of rotations of the cam (2 rotations).	1. Improper connector engagement, 2. Faulty wire harness, 3. Crank speed sensor failure, 4. Engine ECU internal circuit failure, 5. Pulser malfunction or incorrect sensor installation	Check the connector, wire harness, crank speed sensor, engine ECU and pulser. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522401.02	Caution	Cam speed sensor malfunction: Abnormal signal	An incorrect number of cam pulses or an incorrect cam position is detected during a specific number of rotations of the crank (2 rotations).	1. Improper connector engagement, 2. Faulty wire harness, 3. Cam speed sensor failure, 4. Engine ECU internal circuit failure, 5. Pulser malfunction or incorrect sensor installation	Check the connector, wire harness, cam speed sensor, engine ECU and pulser. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522401.05	Caution	Cam speed sensor malfunction: No signal	No cam pulse signal is input during a specific number of rotations of the crank (2.2 rotations).	1. Improper connector engagement, 2. Faulty wire harness, 3. Cam speed sensor failure, 4. Engine ECU internal circuit failure, 5. Pulser malfunction or incorrect sensor installation	Check the connector, wire harness, cam speed sensor, engine ECU and pulser. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522401.07	Caution	Abnormal angle offset	A state where the phase difference between the cam and crank is larger than 30 degrees or smaller than -20 degrees is detected twice.	1. Improper connector engagement, 2. Faulty wire harness, 3. Cam speed sensor failure, 4. Engine ECU internal circuit failure, 5. Pulser malfunction or incorrect sensor installation	Check the connector, wire harness, cam speed sensor, engine ECU and pulser. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522571.03	Warning	High-pressure pump drive circuit malfunction: Low-side short to VB	The high-pressure pump drive circuit remains low-side shorted to VB for a specific period of time (300 seconds).	1. Improper connector engagement, 2. Faulty wire harness (SCV (MPROP) low-side short to power), 3. SCV (MPROP) failure due to short to power, 4. Engine ECU internal circuit failure	Check the connector, wire harness, injector and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522571.06	Warning	High-pressure pump drive circuit malfunction: Low-side short to ground	A short to ground is detected in the high-pressure pump drive circuit.	1. Improper connector engagement, 2. Faulty wire harness (SCV (MPROP) low-side wire short to ground), 3. SCV (MPROP) low-side short to ground, 4. Engine ECU internal circuit failure	Check the connector, wire harness, SCV (MPROP) and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522572.06	Warning	High-pressure pump drive circuit malfunction: Overcurrent	The drive current is higher than the threshold value.	1. Improper connector engagement, 2. Faulty wire harness, 3. SCV (MPROP) failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, SCV (MPROP) and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522572.11	Warning	High-pressure pump drive circuit malfunction: Pump overload	An overheat state of the drive circuit is detected.	1. Improper connector engagement, 2. Faulty wire harness, 3. SCV (MPROP) failure, 4. Engine ECU internal circuit failure	Check the connector, wire harness, SCV (MPROP) and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522573.00	Caution	DPF PM overaccumulation (Method C)	The engine ECU is switched into the recovery regeneration mode due to PM overaccumulation evaluated using Method C.	1. Inadequate regeneration capability due to low operating load, 2. Regeneration not performed in response to the stationary regeneration request, 3. DPF intermediate temperature sensor system failure	Check the DPF intermediate temperature sensor system. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522574.00	Caution	DPF PM overaccumulation (Method P)	The engine ECU is switched into the recovery regeneration mode due to PM overaccumulation evaluated using Method P.	1. Inadequate regeneration capability due to low operating load, 2. Regeneration not performed in response to the stationary regeneration request, 3. DPF differential pressure sensor system failure	Check the DPF differential pressure sensor system. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522575.07	Caution	DPF regeneration failure: Stationary regeneration failure	The engine ECU is switched into the recovery regeneration mode due to failure to complete a stationary regeneration within a specified period of time.	1. DPF intermediate temperature sensor system failure, 2. DOC deterioration or DOC breakage due to external factors such as sulfur poisoning, 3. Defective injector (Decrease in injection quantity, incorrect injection timing)	Check the DPF intermediate temperature sensor system, injector and DOC. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522576.12	Caution	Engine ECU malfunction: EEPROM memory read error	An EEPROM read failure is determined based on the checksum.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522577.11	Caution	DPF regeneration failure: Stationary regeneration not performed	When a stationary regeneration request is sent, a stationary regeneration is not performed within a specified period of time and the engine ECU is switched into the backup mode.	1. Improper connector engagement, 2. Faulty wire harness (Regeneration not performed in response to the stationary regeneration request, regeneration request not displayed, defective regeneration request switch), 3. Engine speed remains decreased to low idling during regeneration, 4. Engine ECU internal circuit failure	Check the connector, wire harness, LCD monitor, regeneration request switch and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522578.12	Caution	Engine ECU malfunction: EEPROM memory writing error	When writing to EEPROM, the engine ECU fails to write the same data three times.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 522579.12	Caution	Short circuit between EGR motor and coil	Overcurrent due to a short circuit between the EGR motor and coil is detected.	1. DC motor failure of the EGR valve	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522580.12	Caution	EGR position sensor malfunction	An excessive high or low EGR position sensor signal voltage is detected.	1. EGR valve internal circuit failure	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522581.07	Warning	EGR valve stuck open	An excessively large number of steps between the fully open position and the fully closed position during initialization is required (45 steps or more).	1. EGR valve stuck	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522582.07	Warning	EGR initialization failure	The time taken to complete initialization exceeds the specified range.	1. EGR valve internal circuit failure, 2. EGR valve malfunction, 3. EGR valve stuck	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522583.01	Caution	EGR high-temperature thermistor malfunction	The thermistor voltage on the high-temperature side in the control unit is 0.2 V or less.	1. EGR valve internal circuit failure	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522584.01	Caution	EGR low-temperature thermistor malfunction	The thermistor voltage on the low-temperature side in the control unit is 0.2 V or less.	1. EGR valve internal circuit failure	Check the EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522585.12	Warning	Engine ECU internal abnormality: CY146 SPI communication error	The communication between the CPU and the H bridge control IC is not normally performed.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522588.12	Warning	Engine ECU internal abnormality: Supply 1 overvoltage error	The 5V supply voltage to the actuator drive is excessively high.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522589.12	Warning	Engine ECU internal abnormality: Supply 1 undervoltage error	The 5V supply voltage to the actuator drive is excessively low.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522590.12	Caution	Engine ECU internal abnormality: Sensor supply voltage error 1	The 5 V supply voltage to the sensor exceeds the threshold value.	1. Improper engagement of the sensor connector that uses sensor power supply 1 (K43 or K44 terminal), 2. Faulty wire harness, 3. Engine ECU internal circuit failure	Check the connector, wire harness and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522591.12	Caution	Engine ECU internal abnormality: Sensor supply voltage error 2	The 5 V supply voltage to the sensor exceeds the threshold value.	1. Improper engagement of the sensor connector that uses sensor power supply 2 (K43 or A08 terminal), 2. Faulty wire harness, 3. Engine ECU internal circuit failure	Check the connector, wire harness and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522592.12	Caution	Engine ECU internal abnormality: Sensor supply voltage error 3	The 5 V supply voltage to the sensor exceeds the threshold value.	1. Improper engagement of the sensor connector that uses sensor power supply 3 (A07 terminal), 2. Faulty wire harness, 3. Engine ECU internal circuit failure	Check the connector, wire harness and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522596.09	Caution	CAN communication failure: TSC1 reception timeout (SA1)	When the engine is not cranking, at a battery voltage of 10V or higher, a reception timeout is detected 2 seconds after the starter switch is turned to the "ON" position, and the reception timeout continues for a specific period of time.	1. CAN communication error of the machine controller, 2. Improper connector engagement, 3. Wire harness disconnection or short circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, machine controller and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522600.09	Caution	CAN communication failure: Y_EC reception timeout	When the engine is not cranking, at a battery voltage of 10V or higher, a reception timeout is detected 2 seconds after the starter switch is turned to the "ON" position, and the reception timeout continues for a specific period of time.	1. CAN communication error of the machine controller, 2. Improper connector engagement, 3. Wire harness disconnection or short circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, machine controller and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522610.09	Caution	EGR CAN communication failure: Reception timeout	When the engine is not cranking, at a battery voltage of 10V or higher, a reception timeout is detected 2 seconds after the starter switch is turned to the "ON" position, and the reception timeout continues for a specific period of time.	1. Improper connector engagement, 2. Wire harness disconnection or short circuit, 3. Engine ECU internal circuit failure, 4. EGR valve internal circuit failure	Check the engine ECU, connector, wire harness and EGR valve. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522617.12	Caution	Out of range for EGR target values	The EGR valve position instructed by the engine ECU stays out of range for a specific period of time.	1. Engine ECU software malfunction	Check the EGR valve and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 522618.09	Caution	CAN communication failure: EBC1 reception timeout	When the engine is not cranking, at a battery voltage of 10V or higher, a reception timeout is detected 2 seconds after the starter switch is turned to the "ON" position, and the reception timeout continues for a specific period of time.	1. CAN communication error of the machine controller, 2. Improper connector engagement, 3. Wire harness disconnection or short circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, machine controller and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522619.09	Caution	CAN communication failure: Y_DPFIF reception timeout	When the engine is not cranking, at a battery voltage of 10V or higher, a reception timeout is detected 2 seconds after the starter switch is turned to the "ON" position, and the reception timeout continues for a specific period of time.	1. CAN communication error of the machine controller, 2. Improper connector engagement, 3. Wire harness disconnection or short circuit, 4. Engine ECU internal circuit failure	Check the connector, wire harness, machine controller and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522744.04	Caution	Engine ECU internal abnormality: Actuator drive circuit 1 short to ground	Overcurrent at the UB2 terminal is detected by the IC inside the engine ECU.	1. Improper engagement of the actuator connector that uses 12V power supply 1 (UB2: K68 terminal), 2. Faulty wire harness (12V power supply 1 (UB2: K68 terminal) wire short to ground), 3. Engine ECU internal circuit failure	Check the connector, wire harness and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 522994.04	Caution	Engine ECU internal abnormality: Actuator drive circuit 2 short to ground	Overcurrent at the UB3 terminal is detected by the IC inside the engine ECU.	1. Improper engagement of the actuator connector that uses 12V power supply 2 (UB3: K90 or A50 terminal), 2. Faulty wire harness (12V power supply 2 (UB3: K90 or A50 terminal) wire short to ground), 3. Engine ECU internal circuit failure	Check the connector, wire harness and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523249.05	Warning	Crank and cam speed sensor malfunction: No signal	No signal from the crank and cam speed sensors is detected.	1. Simultaneous malfunction of crank speed sensor and cam speed sensor, 2. Starter system failure	Check the connector, wire harness, crank speed sensor, cam speed sensor, engine ECU and pulser. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523460.07	Warning	Rail pressure control abnormality: Pump and fuel temperature sensor malfunctions during rail pressure sensor malfunction	The rail pressure sensor and high pressure pump drive circuit (MPROM) are defective or the rail pressure sensor and fuel temperature sensor are defective.	1. Rail pressure sensor or wiring fault, 2. SCV or wiring fault, 3. Fuel temperature sensor or wiring fault	Check the connector, wire harness, SCV (MPROP), fuel temperature sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523462.13	Warning	Cylinder No. 1 injector malfunction: Improper correction value	The injector correction value is not input or consistent and unable to read from EEPROM.	1. Input failure of the injector correction value, 2. Engine ECU internal circuit failure	Connect the SMARTASSIST-Direct (SA-D) and re-enter the injector correction value. Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523463.13	Warning	Cylinder No. 2 injector malfunction: Improper correction value	The injector correction value is not input or consistent and unable to read from EEPROM.	1. Input failure of the injector correction value, 2. Engine ECU internal circuit failure	Connect the SMARTASSIST-Direct (SA-D) and re-enter the injector correction value. Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523464.13	Warning	Cylinder No. 3 injector malfunction: Improper correction value	The injector correction value is not input or consistent and unable to read from EEPROM.	1. Input failure of the injector correction value, 2. Engine ECU internal circuit failure	Connect the SMARTASSIST-Direct (SA-D) and re-enter the injector correction value. Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523465.13	Warning	Cylinder No. 4 injector malfunction: Improper correction value	The injector correction value is not input or consistent and unable to read from EEPROM.	1. Input failure of the injector correction value, 2. Engine ECU internal circuit failure	Connect the SAMRTASSIST-Direct (SA-D) and re-enter the injector correction value. Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523468.09	Warning	Common rail pressure limiting valve (PLV): Malfunction	After the common rail pressure limiting valve opens, the rail pressure falls outside the range of 50 to 120 MPa.	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump and rail pressure sensor. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523469.00	Warning	Common rail pressure limiting valve (PLV): Excessive number of times valve open	The number of times the common rail pressure limiting valve opens exceeds 50.	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump, rail pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523470.00	Warning	Common rail pressure control value (PLV): Excessively-long valve opening time	While the rail pressure sensor is in normal operation, the total amount of time the common rail pressure limiting valve is open exceeds 5 hours.	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump, rail pressure sensor and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523471.06	Caution	Engine ECU internal abnormality: Actuator drive circuit 3 short to ground	Overcurrent at the UB5 terminal is detected by the IC inside the engine ECU.	1. Improper engagement of the actuator connector that uses 12V power supply 3 (UB5: K73 terminal), 2. Faulty wire harness (12V power supply 3 (UB5: K73 terminal) wire short to ground), 3. Engine ECU internal circuit failure	Check the connector, wire harness and engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 523473.12	Warning	Engine ECU internal abnormality: AD converter malfunction 1	A pulse error is detected through AD converter diagnosis.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523474.12	Warning	Engine ECU internal abnormality: AD converter malfunction 2	A voltage error is detected through AD converter diagnosis.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523475.12	Warning	Engine ECU internal abnormality: External monitor IC and CPU malfunctions 1	An error is detected through mutual diagnosis between the external monitor IC and CPU.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523476.12	Warning	Engine ECU internal abnormality: External monitor IC and CPU malfunctions 2	A communication error between the external monitor IC and CPU is detected.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523477.12	Warning	Engine ECU internal abnormality: ROM malfunction	During self maintenance of the engine ECU power after the starter switch is turned to the "OFF" position, the checksum fails in the entire ROM area.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523478.12	Warning	Engine ECU internal abnormality: Shutoff path 1 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects an error in the response from the CPU to the external monitor IC.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523479.12	Warning	Engine ECU internal abnormality: Shutoff path 2 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects an operational error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523480.12	Warning	Engine ECU internal abnormality: Shutoff path 3 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects a response time error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523481.12	Warning	Engine ECU internal abnormality: Shutoff path 4 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects a communication error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523482.12	Warning	Engine ECU internal abnormality: Shutoff path 5 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects an undervoltage value in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523483.12	Warning	Engine ECU internal abnormality: Shutoff path 6 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects an external monitor IC error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523484.12	Warning	Engine ECU internal abnormality: Shutoff path 7 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects an OS call time out error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523485.12	Warning	Engine ECU internal abnormality: Shutoff path 8 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects a positive test error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523486.12	Warning	Engine ECU internal abnormality: Shutoff path 9 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects an operating time error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523487.12	Warning	Engine ECU internal abnormality: Shutoff path 10 failure	During the shutoff path test performed by the external monitor IC after the engine ECU power is turned on, the external monitor IC detects an overvoltage error in the shutoff path test.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
00 523488.00	Warning	Engine speed recognition error	An error is detected through mural diagnoses of the engine speed.	1. Engine ECU internal circuit failure	Check the engine ECU. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523489.00	Warning	Common rail pressure limiting valve (PLV): Non-operating	When abnormally-high common rail pressure has occurred (the rail pressure remains at 160 MPa or higher for 10 seconds or more), the common rail pressure limiting valve does not open.	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump and rail pressure sensor. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
00 523491.00	Warning	Rail pressure control abnormality: High fuel temperature when common rail pressure limiting valve is open	After the common rail pressure limiting valve opens, the fuel temperature exceeds 80℃.	1. Rail pressure sensor system failure, 2. SCV drive circuit system failure, 3. SCV stuck open, 4. SCV intermittent fault, 5. Fuel system failure (Air intrusion, fuel shortage)	Check the fuel system, supply pump and rail pressure sensor. Turn the starter switch to the "OFF" position and then to the "ON" position to check if the error code is displayed again.
28 000096.02	Caution	Short circuit of fuel sensor	Sensor resistance is 1 Ω or less.	• Connection failure of connectors • Harness wiring failure (sensor signal line short circuited to GND or sensor GND line short circuited to power supply) • Defective fuel sensor • Engine ECU internal circuit failure	Check the connectors, harnesses and fuel sensor. Turn the starter switch to the “OFF” position and then the “ON” position. Then check that the error code is displayed again.
28 000096.04	Caution	Disconnection of fuel sensor	Sensor resistance is 100 Ω or more.	• Connection failure of connectors • Harness wiring failure (nearly broken wiring of sensor signal line, sensor 5 V line or sensor GND line) • Defective fuel sensor • Engine ECU internal circuit failure	Check the connectors, harnesses and fuel sensor. Turn the starter switch to the “OFF” position and then the “ON” position. Then check that the error code is displayed again.
28 000100.00	Warning	Abnormal engine oil pressure	Engine oil pressure decrease during engine operation	• Insufficient amount of engine oil • Clogging of engine oil filter • Defective engine oil pressure switch or engine oil pressure decrease	Check the engine oil filter element, engine oil pressure switch and lube oil pump.
28 000167.01	Caution	Low battery charge	Low battery charge signal detected during engine operation	• Connection failure of connectors • Disconnection or short circuit of harness • Defective engine ECU	Check the battery, alternator and harnesses.
28 000639.12	Warning	CAN communication error (Engine ECU)	LCD monitor cannot receive data from engine ECU.	Engine data cannot be obtained due to disconnection of CAN communication line or defective engine ECU.	Check that the connectors, terminals and harnesses for CAN communication are correctly connected. Also, check the engine ECU for blown fuse.
28 520777.02	Caution	Short circuit of hydraulic oil temperature sensor	Sensor resistance is 80 Ω or less.	• Connection failure of connectors • Harness wiring failure (sensor signal line short circuited to GND or sensor GND line short circuited to power supply) • Defective hydraulic oil temperature sensor	Check the connectors, harnesses and hydraulic oil temperature sensor. Turn the starter switch to the “OFF” position and then the “ON” position. Then check that the error code is displayed again.
28 520777.04	Caution	Disconnection of hydraulic oil temperature sensor	Sensor resistance is 30 KΩ or more.	• Connection failure of connectors • Harness wiring failure (nearly broken wiring of sensor signal line, sensor 5 V line or sensor GND line) • Defective hydraulic oil temperature sensor	Check the connectors, harnesses and hydraulic oil temperature sensor. Turn the starter switch to the “OFF” position and then the “ON” position. Then check that the error code is displayed again.
28 520780.00	Caution	Air cleaner clogging	Air cleaner clogging signal is detected.	• Air cleaner clogged • Short circuit of air cleaner switch connector	Clean the air cleaner. If the error code is still displayed, check if the connectors, terminals and harnesses of the dust indicator are correctly connected. Also, check the installation condition.
28 520805.12	Warning	CAN communication error (Hydraulic ECU)	LCD monitor cannot receive data from hydraulic ECU.	Data cannot be obtained due to disconnection of CAN communication line or defective hydraulic ECU.	Check that the connectors, terminals and harnesses for CAN communication are correctly connected. Also, check the hydraulic ECU for blown fuse.
E1 000091.02	Caution	Accelerator sensor malfunction: Intermittent fault	Accelerator sensor voltage of lower than 0.1 V is intermittently detected.	• Accelerator sensor failure • Layer short circuit of harness • Contact failure due to faulty connector	Check if the connectors, terminals and harnesses of the accelerator sensor are correctly connected. Also, check the installation condition.
E1 000091.03	Caution	Accelerator sensor malfunction: High voltage	Accelerator sensor voltage is higher than 4.6 V.	Inability to detect accelerator setting due to continuous short circuit to power supply (5V, 12V)	Check if the connectors, terminals and harnesses of the accelerator sensor are correctly connected. Also, check the installation condition.
E1 000091.04	Caution	Accelerator sensor malfunction: Low voltage	Accelerator sensor voltage is lower than 0.2 V.	Inability to detect accelerator setting due to accelerator sensor failure, disconnection or continuous short circuit to GND	Check if the connectors, terminals and harnesses of the accelerator sensor are correctly connected. Also, check the installation condition.
E1 012544.02	Warning	Boom angle sensor malfunction: Intermittent fault	Sensor voltage of lower than 0.1 V (instantaneous value) is intermittently detected.	• Boom angle sensor failure • Layer short circuit of harness • Contact failure due to faulty connector	Check if the connectors, terminals and harnesses of the boom angle sensor are correctly connected. Also, check the installation condition.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
E1 012544.03	Warning	Boom angle sensor malfunction: High voltage	Sensor voltage (after filtering) is higher than 4.9 V.	Inability to detect boom angle due to continuous short circuit to power supply (5V, 12V)	Check if the connectors, terminals and harnesses of the boom angle sensor are correctly connected. Also, check the installation condition.
E1 012544.04	Warning	Boom angle sensor malfunction: Low voltage	Sensor voltage (after filtering) is lower than 0.1 V.	Inability to detect boom angle due to boom angle sensor failure, disconnection or continuous short circuit to GND	Check if the connectors, terminals and harnesses of the boom angle sensor are correctly connected. Also, check the installation condition.
E1 013312.02	Warning	Arm angle sensor malfunction: Intermittent fault	Sensor voltage of lower than 0.1 V (instantaneous value) is intermittently detected.	• Arm angle sensor failure • Layer short circuit of harness • Contact failure due to faulty connector	Check if the connectors, terminals and harnesses of the arm angle sensor are correctly connected. Also, check the installation condition.
E1 013312.03	Warning	Arm angle sensor malfunction: High voltage	Sensor voltage (after filtering) is higher than 4.9 V.	Inability to detect arm angle due to continuous short circuit to power supply (5V, 12V)	Check if the connectors, terminals and harnesses of the arm angle sensor are correctly connected. Also, check the installation condition.
E1 013312.04	Warning	Arm angle sensor malfunction: Low voltage	Sensor voltage (after filtering) is lower than 0.1 V.	Inability to detect arm angle due to arm angle sensor failure, disconnection or continuous short circuit to GND	Check if the connectors, terminals and harnesses of the arm angle sensor are correctly connected. Also, check the installation condition.
E1 016640.08	Caution	Alternator failure	No alternator pulse is detected during boom raising operation in boom height limit mode.	Disconnection of alternator pulse signal wire Defective alternator	Check if the connectors, terminals and harnesses of the alternator are correctly connected.
E1 016896.00	Warning	Abnormal engine speed	Engine speed does not decrease to crane-mode speed when crane mode is activated.	Inability to activate engine high idle speed control due to relay contact failure or disconnection	Check if the connectors, terminals and harnesses between the high idle speed control relay and E-ECU are correctly connected. Also, check the high idle speed control relay operation.
E1 020736.03	Warning	Boom bottom pressure sensor malfunction: High voltage	Boom bottom sensor voltage (after filtering) is higher than 4.8 V.	Inability to detect boom bottom pressure due to continuous short circuit to power supply (5V, 12V)	Check if the connectors, terminals and harnesses of the boom bottom pressure sensor are correctly connected. Also, check the installation condition.
E1 020736.04	Warning	Boom bottom pressure sensor malfunction: Low voltage	Boom bottom sensor voltage (after filtering) is lower than 0.2 V.	Inability to detect boom bottom pressure due to boom bottom pressure sensor failure, disconnection or continuous short circuit to GND	Check if the connectors, terminals and harnesses of the boom bottom pressure sensor are correctly connected. Also, check the installation condition.
E1 021248.03	Warning	Boom rod pressure sensor malfunction: High voltage	Boom rod sensor voltage (after filtering) is higher than 4.8 V.	Inability to detect boom rod pressure due to continuous short circuit to power supply (5V, 12V)	Check if the connectors, terminals and harnesses of the boom rod pressure sensor are correctly connected. Also, check the installation condition.
E1 021248.04	Warning	Boom rod pressure sensor malfunction: Low voltage	Boom rod sensor voltage (after filtering) is lower than 0.2 V.	Inability to detect boom rod pressure due to boom rod pressure sensor failure, disconnection or continuous short circuit to GND	Check if the connectors, terminals and harnesses of the boom rod pressure sensor are correctly connected. Also, check the installation condition.
E1 024832.03	Warning	Abnormal sensor 5V power supply	Sensor power-supply voltage is lower than 4.5 V.	Abnormal sensor operation due to power supply voltage drop	Check the installation condition of each sensor and the harnesses connecting condition (short circuit).
E1 025088.02	Caution	EEPROM error in hydraulic ECU	EEPROM error in hydraulic ECU	Provisional values are used because data is broken or faulty.	Restart the hydraulic ECU (by turning the starter switch to the “OFF” position and then the “ON” position.) If the error is still not resolved, replace the hydraulic ECU.
E1 025088.12	Caution	EEPROM error in hydraulic ECU	EEPROM error in hydraulic ECU	Provisional values are used because data is broken or faulty.	Restart the hydraulic ECU (by turning the starter switch to the “OFF” position and then the “ON” position.) If the error is still not resolved, replace the hydraulic ECU.
E1 025600.09	Caution	CAN communication error (Engine ECU)	Hydraulic ECU cannot receive data from engine ECU.	Engine data cannot be obtained due to disconnection of CAN communication line or defective ECU.	Check that the connectors, terminals and harnesses for CAN communication are correctly connected. Also, check the hydraulic ECU for blown fuse.
E1 025856.09	Caution	CAN communication error (LCD monitor)	Hydraulic ECU cannot receive data from LCD monitor (Hydraulic ECU is operating normally.)	• Disconnection or short circuit of CAN communication line between LCD monitor and hydraulic ECU • Blown fuse of LCD monitor • Hydraulic ECU failure or LCD monitor failure (Inability to send and receive data)	Check if the connectors, terminals and harnesses for CAN communication are correctly connected. Also, check the hydraulic ECU for blown fuse.
E1 026112.12	Caution	Hydraulic ECU malfunction	Malfunction of hydraulic ECU arbitration port or defective internal memory	• Arbitration port failure • Defective ROM • Broken RAM • Initialization failure	Check that hydraulic ECU is correctly mounted and that the connectors, terminals and harnesses for arbitration port are correctly connected. Also, rewrite the hydraulic ECU software. If the error is still not resolved, replace the hydraulic ECU.
E1 026368.12	Caution	Engine ECU malfunction	Hydraulic ECU receives error signal from engine ECU.	Due to defective rotation sensor, engine rotation cannot be detected or any other engine trouble occurs.	Check the engine ECU condition.

Error code	Classification	Error description	Detection condition	Causes	Corrective measures
E1 028928.07	Warning	Boom proportional solenoid valve malfunction	After boom proportional solenoid valve drive command is issued, boom angle is still increased (boom is raised) by a specific number of degrees or larger.	Boom proportional solenoid valve malfunction or boom angle sensor failure	Check if the connectors, terminals and harnesses of the boom proportional solenoid valve and boom angle sensor are correctly connected. Also, check the boom proportional solenoid valve operation.
E1 029184.00	Warning	Boom height limit exceeded	When boom height limit mode is activated, boom angle is still increased (boom is raised) by a specific number of degrees or larger, exceeding preset boom height limit angle.	Boom proportional solenoid valve malfunction	Check if the connectors, terminals and harnesses of the boom proportional solenoid valve are correctly connected. Also, check the boom proportional solenoid valve operation.
E1 029440.05	Warning	Abnormal output of boom proportional solenoid valve (Low current)	Driving current for boom proportional solenoid valve is lower than command value from hydraulic ECU.	Proportional solenoid valve cannot be activated due to disconnection or other faults.	Check if the connectors, terminals and harnesses of the boom proportional solenoid valve are correctly connected.
E1 029440.06	Warning	Abnormal output of boom proportional solenoid valve (High current)	Driving current for boom proportional solenoid valve is higher than command value from hydraulic ECU.	Proportional solenoid valve opens wider than the target angle due to short circuit to power supply or other faults.	Check if the connectors, terminals and harnesses of the boom proportional solenoid valve are correctly connected.
E1 029952.07	Warning	Arm solenoid valve malfunction	After arm solenoid valve drive command is issued, arm is moved toward the arm-in side by a specific number of degrees or larger.	Arm solenoid valve failure	Check if the connectors, terminals and harnesses of the arm solenoid valve are correctly connected. Also, check the arm solenoid valve operation.
E1 030208.00	Warning	Arm-in limit exceeded	When arm-in limit mode is activated, arm is moved toward the arm-in side by a specific number of degrees or larger, exceeding preset arm-in limit angle.	Arm solenoid valve failure	Check if the connectors, terminals and harnesses of the arm solenoid valve are correctly connected. Also, check the arm solenoid valve operation.
E1 030464.05	Caution	Abnormal output of speed sensing proportional solenoid valve (Too small feedback current)	Driving current for speed sensing proportional solenoid valve is smaller than command value of hydraulic ECU.	Proportional solenoid valve cannot be activated due to disconnection or other fault or defect.	Check that the connectors, terminals and harnesses of the speed sensing proportional solenoid valve are correctly connected.
E1 030464.06	Caution	Abnormal output of speed sensing proportional solenoid valve (Too large feedback current)	Driving current for speed sensing proportional solenoid valve is larger than command value of hydraulic ECU.	Proportional solenoid valve is moved exceeding the target due to short circuit to power supply or other fault or defect.	Check that the connectors, terminals and harnesses of the speed sensing proportional solenoid valve are correctly connected.
E1 030976.03	Warning	Cut-off relay malfunction (OFF)	After cut-off relay is activated once or more times with the starter switch in the "ON" position, activation monitoring contact input is OFF.	Cut-off relay is not activated even though hydraulic ECU instructs activation of cut-off relay.	Check the cut-off relay operation. Also, check if the connectors, terminals and harnesses of the cut-off relay are correctly connected.
E1 030976.04	Warning	Cut-off relay malfunction (ON)	Although cut-off relay has never been activated since the starter switch was turned to the "ON" position, activation monitoring contact input is ON.	Cut-off relay is activated even though hydraulic ECU does not instruct activation of cut-off relay.	Check the cut-off relay operation. Also, check if the connectors, terminals and harnesses of the cut-off relay are correctly connected.
E1 031488.07	Warning	Cut-off valve malfunction	After cut-off valve closing command is issued, boom angle or arm angle is still changed by a specific number of degrees or larger.	Cut-off valve failure	Check the cut-off valve operation. Also, check the cut-off relay operation and installation condition.
E1 031744.03	Warning	Low-speed travel relay malfunction	In crane mode, relay monitoring port stays on. (Travel speed is not switched to low speed.)	Even when crane mode is activated, low-speed travel relay does not operate.	Check if the hydraulic ECU connector is correctly connected. Also, check the low-speed travel relay operation.
E1 033024.00	Caution	Abnormal power supply voltage of hydraulic ECU (Above the upper limit)	Hydraulic ECU power supply voltage is higher than 16.0 V.	Abnormal voltage causes breakage of hydraulic ECU.	Check the connecting conditions of the alternator and battery.
E1 033024.01	Caution	Abnormal power supply voltage of hydraulic ECU (Voltage reduction)	Hydraulic ECU power supply voltage is lower than 10.0 V.	Warning against power supply voltage reduction (Operable)	Check the connecting conditions of the alternator and battery. Also, check the battery charging condition.
E1 033024.11	Caution	Abnormal power supply voltage of hydraulic ECU (Below the lower limit)	Hydraulic ECU power supply voltage is lower than 8.0 V.	Hydraulic ECU does not operate normally due to power supply voltage reduction	Check the connecting conditions of the alternator and battery. Also, check the battery charging condition.
E1 033792.02	Caution	Incorrect initial value of implement angle sensor	Initial settings of boom angle sensor and/or arm angle sensor are not correct or they are not input.	• Initial settings not performed • Set value outside the angle range	Perform the initial settings of the hydraulic ECU following the specified procedure. Restart the hydraulic ECU (turn the starter switch to the “OFF” position and then to the “ON” position) to reflect the initial settings.
E1 034048.02	Caution	Hydraulic ECU malfunction (Option mismatch)	Option data mismatch between LCD monitor and hydraulic ECU	Option data stored on LCD monitor and hydraulic ECU are not matched.	Check if correct hydraulic ECU and/or LCD monitor are installed. If so, perform the initial settings of the hydraulic ECU following the specified procedure. Restart the hydraulic ECU (turn the starter switch to the “OFF” position and then to the “ON” position) to reflect the initial settings.

CHAPTER 6

HYDRAULIC SYSTEM

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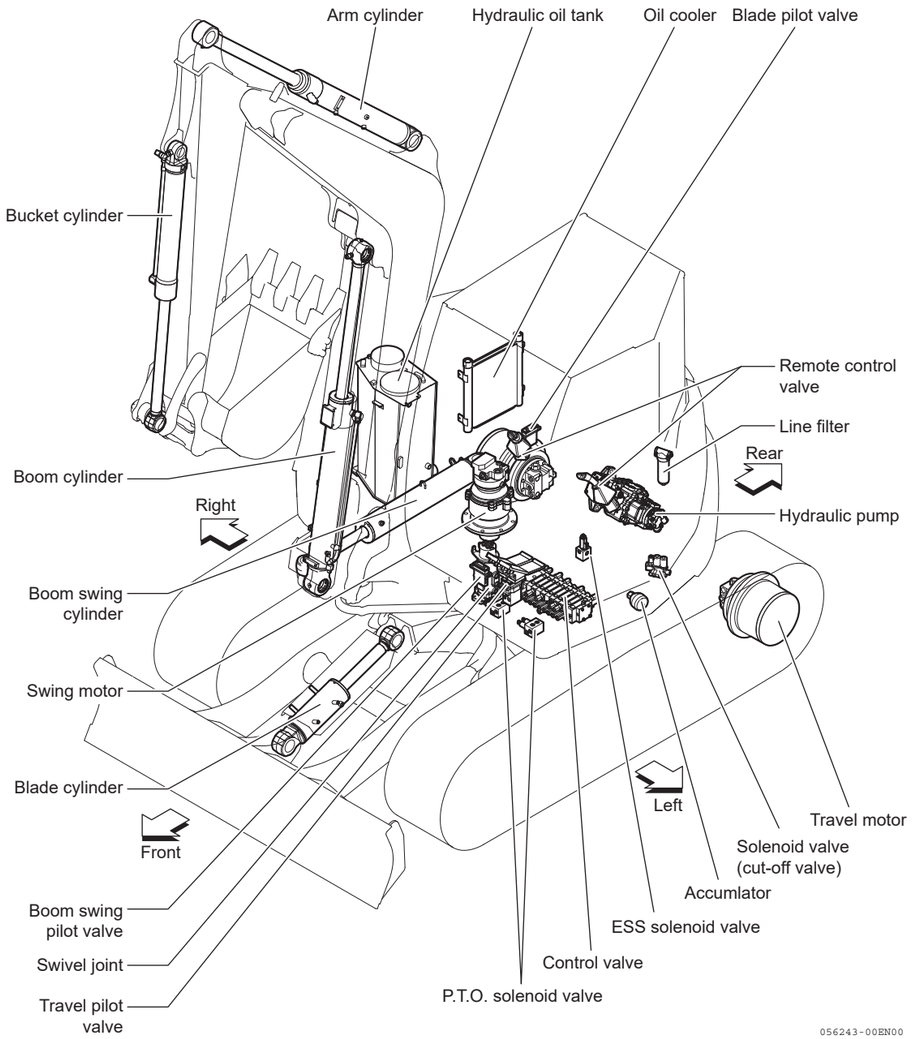
6. HYDRAULIC SYSTEM

6. Hydraulic System

6-1 Outline

The hydraulic system consists of an engine, variable displacement piston pumps, a control valve, a boom cylinder, an arm cylinder, a bucket cylinder, a boom swing cylinder, a blade cylinder, a swing motor, a swivel joint, two travel motors and a hydraulic oil tank. The oil discharged from the piston pumps flow to the actuators through the control valve.

The hydraulic pilot control system comprises a pilot pump, a line filter, a cut-off valve, left and right remote control valves, a blade pilot valve, a boom swing pilot vale and P.T.O. solenoid valves. The oil discharged from the pilot pump flows into the pilot ports of the control valve through the line filter, the cut-off valve and the pilot valves to control the valve spool movement in proportion to the pressure at the port.



6. HYDRAULIC SYSTEM

1) Hydraulic Pump

The variable displacement piston pumps and the pilot pump are linked to the flywheel of the engine through the coupling. The number of revolutions of each hydraulic pump is identical to the engine speed.

[cu. in. (cu. cm) / rev]

No.	Pump		Discharge volume
1	Piston pump	P1	2.26 (37)
2	Piston pump	P2	2.26 (37)
3	Piston pump	P3	1.71 (28)
4	Pilot pump	P4	0.61 (10)

2) Oil Flow

When the lock lever is set to the "Unlock" position, the safety switch becomes magnetized and electricity flows to the solenoid B of the cut-off valve to switch it. Then the circuit of the pilot pump P4 is opened.

(1) Piston pumps P1, P2 and P3

The pumps take in oil through the suction filter from the hydraulic oil tank and discharge it. The discharged oil flows to the ports P1, P2 and P3 of the control valve and returns from the ports T1 and T2 to the hydraulic oil tank through the oil cooler and the return filter. This circulation is repeated.

The bypass valve in the return filter opens at a differential pressure of 21 PSI (0.147MPa).

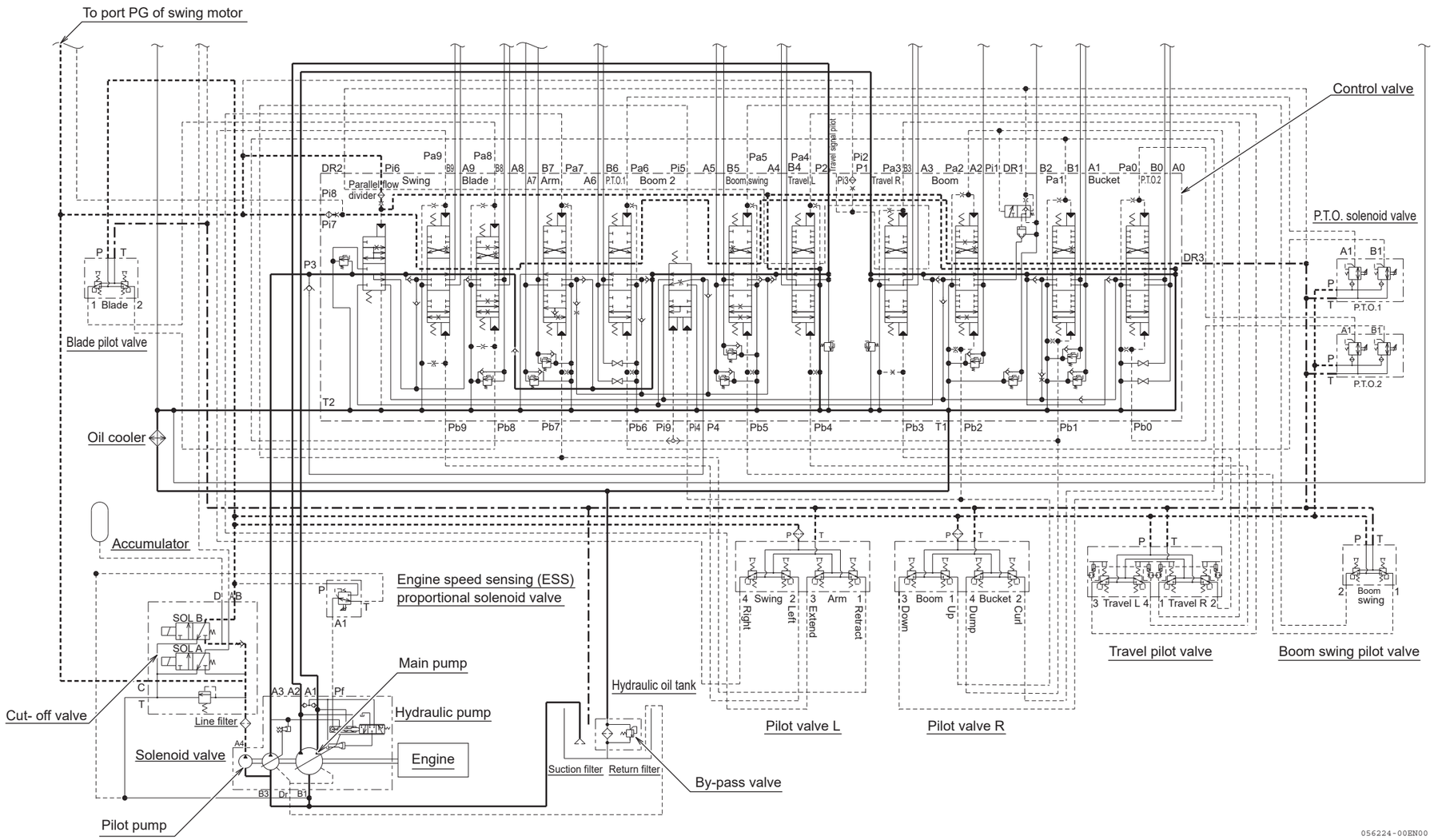
(2) Pilot pump P4

The oil from the pilot pump P4 flows back to the hydraulic oil tank through the line filter, the port B of the solenoid valve, the pilot valves (right, left, travel, blade, boom swing and P.T.O.).

Also, the oil from the pilot pump P4 is fed to the port PG of the swing motor through the port C of the solenoid valve.

3) System Relief Valve

The system relief valves R1, R2 and R3 of the control valve control the discharge pressure of the pumps.



6-1-1 Control Valve Operation

1) Oil Flow from Hydraulic Pump

(1) Piston pump P1

The oil from the piston pump P1 is fed to the right travel motor, the boom cylinder, the bucket cylinder through the port P1 of the inlet section, the travel (R), boom, bucket and P.T.O.2 sections.

(2) Piston pump P2

The oil from the piston pump P2 is fed to the left travel motor, the boom swing cylinder, the arm cylinder and the P.T.O. through the port P2 of the inlet section, the travel (L), boom swing, P.T.O. and arm sections.

(3) Piston pump P3

The oil from the piston pump P3 flows through the port P3 of the parallel-flow divider to the swing and blade sections, and also to the arm and P.T.O. sections to be combined with the oil from the piston pump P2.

2) Simultaneous Operation of Boom and Bucket

A parallel passage is provided for the boom and bucket sections. The parallel passage has a throttle in the bucket section, so that the oil can flow to the boom section more smoothly than to the bucket section when the boom is given a heavier load. Therefore, the boom and the bucket can be operated simultaneously.

3) Anti-drift Valve (Reduction of Boom Drifting)

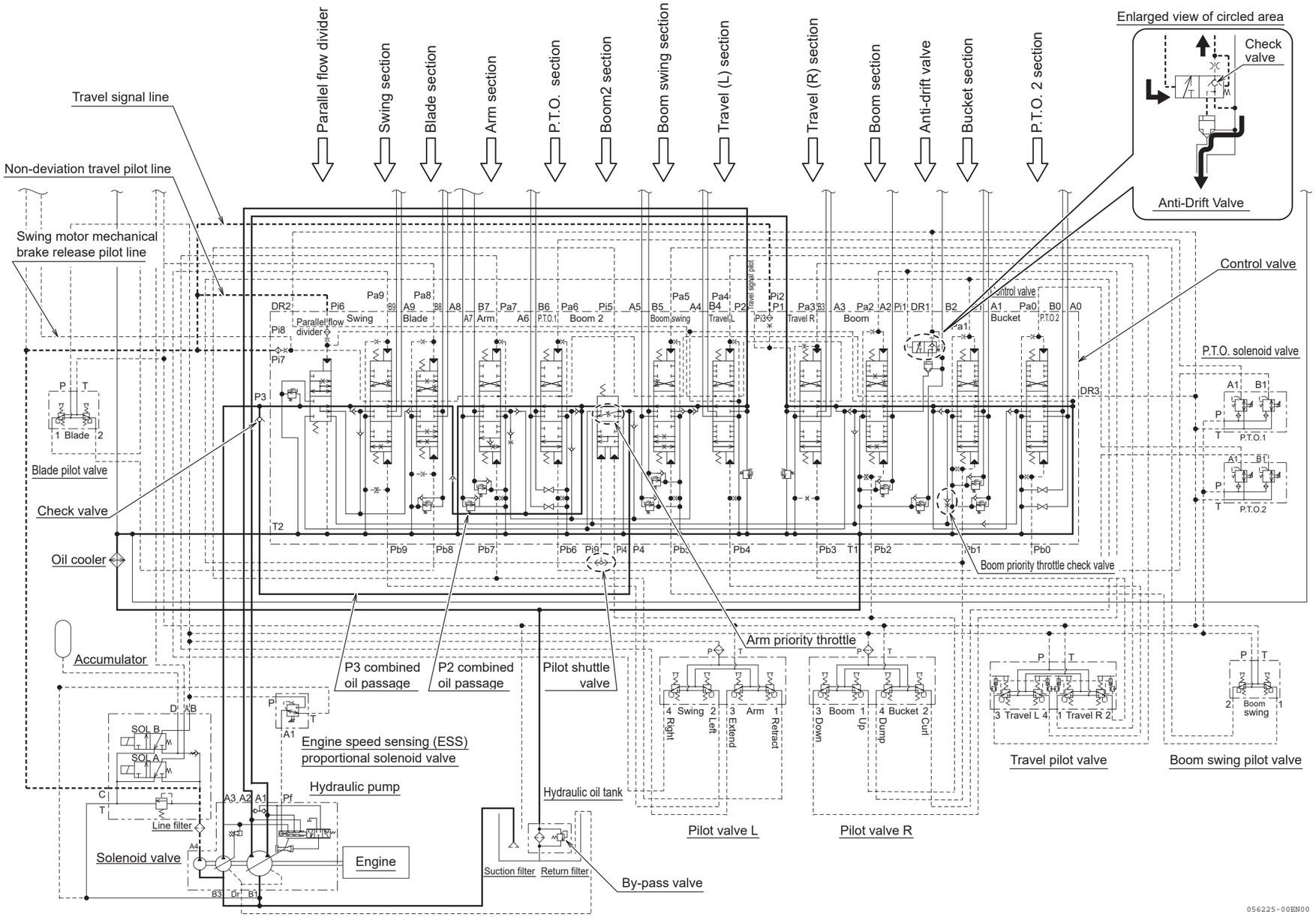
The anti-drift valve is installed in the boom section to reduce the boom drifting.

4) Track Drive Lock

When the lock lever is set to the "Lock" position, the oil from the pilot pump P4 is not fed to the pilot valve because the solenoid valve B is not moved. Therefore, the machine does not operate even when the control levers, travel levers (pedals), the blade lever, the boom swing pedal and P.T.O. switches.

5) Non-deviation travel pilot line

The oil from the pilot pump P4 flows to the port Pi6, then flows in parallel through the travel (L), boom and bucket sections, and returns to the hydraulic oil tank. When the travel (L) section is operated and simultaneously the boom or bucket section is also operated, the pressure develops in the circuit from the port Pi6 and the spool of the parallel-flow divider is moved. At that time, the oil from the piston pump P3 is divided at the parallel-flow divider and supplied to the swing, arm, boom and bucket sections.



6-1-2 Additional Operation of Control Valve

Control in swing motor mechanical brake release pilot line

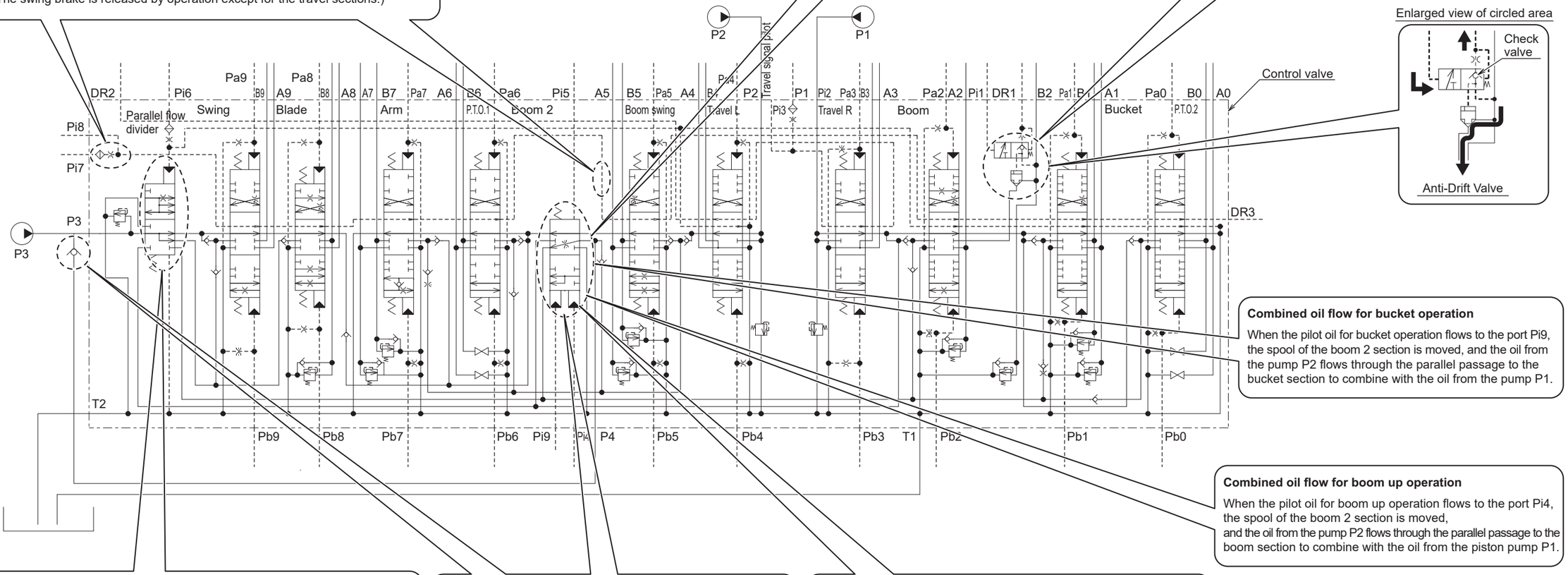
The oil discharged from the cut-off valve is supplied to each of the swing, blade, arm, P.T.O.1, boom swing, boom, bucket and P.T.O.2 sections through the port Pi7 and flows back to the hydraulic oil tank. When one of these sections is actuated, the spool blocks the oil and the pilot pressure is caused.
The pilot pressure flows through the port Pi8 to the port SH of the swing motor mechanical brake to open the swing brake release valve.
Therefore, the swing motor mechanical brake is not released before any of the swing, blade, arm, P.T.O.1, boom swing, boom, bucket or P.T.O.2 is operated.
(The swing brake is released by operation except for the travel sections.)

Combined oil flow for arm operation

As long as all the sections upstream the arm section for the pump P2 and the pump P3 are in neutral, all the oil from the pump P2 and that from the pump P3 are combined in the arm section, and the combined oil flows to the arm cylinder.
However, when the boom or bucket section of the piston pump P1 circuit is operated, some of the oil from the piston pump P2 flows to that section; therefore, not all the amount of oil from the pump P2 is combined.

Anti-drift valve (Reduction of boom drifting)

The anti-drift valve is installed in the bottom end circuit of the boom cylinder. The valve keeps blocking the oil in the circuit while the boom is not operated, in order to prevent the boom from drifting due to internal leakage from the clearance between the control valve body and the spool.
When the boom control lever is pushed forward, the pilot oil pressure for the boom down operation is led to the port Pi1 and opens the check valve to keep the circuit function as the low pressure return passage.



Combined oil flow for bucket operation

When the pilot oil for bucket operation flows to the port Pi9, the spool of the boom 2 section is moved, and the oil from the pump P2 flows through the parallel passage to the bucket section to combine with the oil from the pump P1.

Combined oil flow for boom up operation

When the pilot oil for boom up operation flows to the port Pi4, the spool of the boom 2 section is moved,
and the oil from the pump P2 flows through the parallel passage to the boom section to combine with the oil from the piston pump P1.

Non-deviation travel

The oil from the pilot pump P4 flows to the port Pi6, then flows in parallel through the travel (L) section and the boom and bucket sections, and returns to the hydraulic oil tank.
When the travel (L) section is operated and simultaneously the boom or bucket section is also operated, the pressure develops in the circuit from the port Pi6 and the spool of the parallel-flow divider section is moved.
At that time, the oil from the gear pump P3 is divided at the parallel-flow divider and supplied to the swing section, the arm section and the boom and bucket sections.
Consequently, even when the oil from the piston pumps P1 and P2 flows only to the travel (R) and travel (L) sections, respectively, in the most upstream for the pumps P1 and P2, the swing, the arm, the boom, or the bucket can be operated.
In other words, the machine can travel with no deviation even when any of the control levers are moved during the traveling of the machine.

Control in simultaneous operation of boom up and swing

When the boom up and swing are operated simultaneously, the oil from the pump P3 flows through the check valve and the boom 2 section to the boom section to combine with the oil from pumps P1 and P2.

Control in simultaneous operation of boom up and arm retract

As mentioned in Section "6. Combined Oil Flow for Boom Up Operation", the oil from the pumps P1 and P2 is combined in the boom up operation. However, when boom up and arm retract are operated simultaneously, the pilot oil pressure for the arm retract operation is led to the port Pi5 and moves the spool of the boom 2 section back to give priority to the arm retract operation.

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6-2 Circuit Operation

6-2-1 Boom

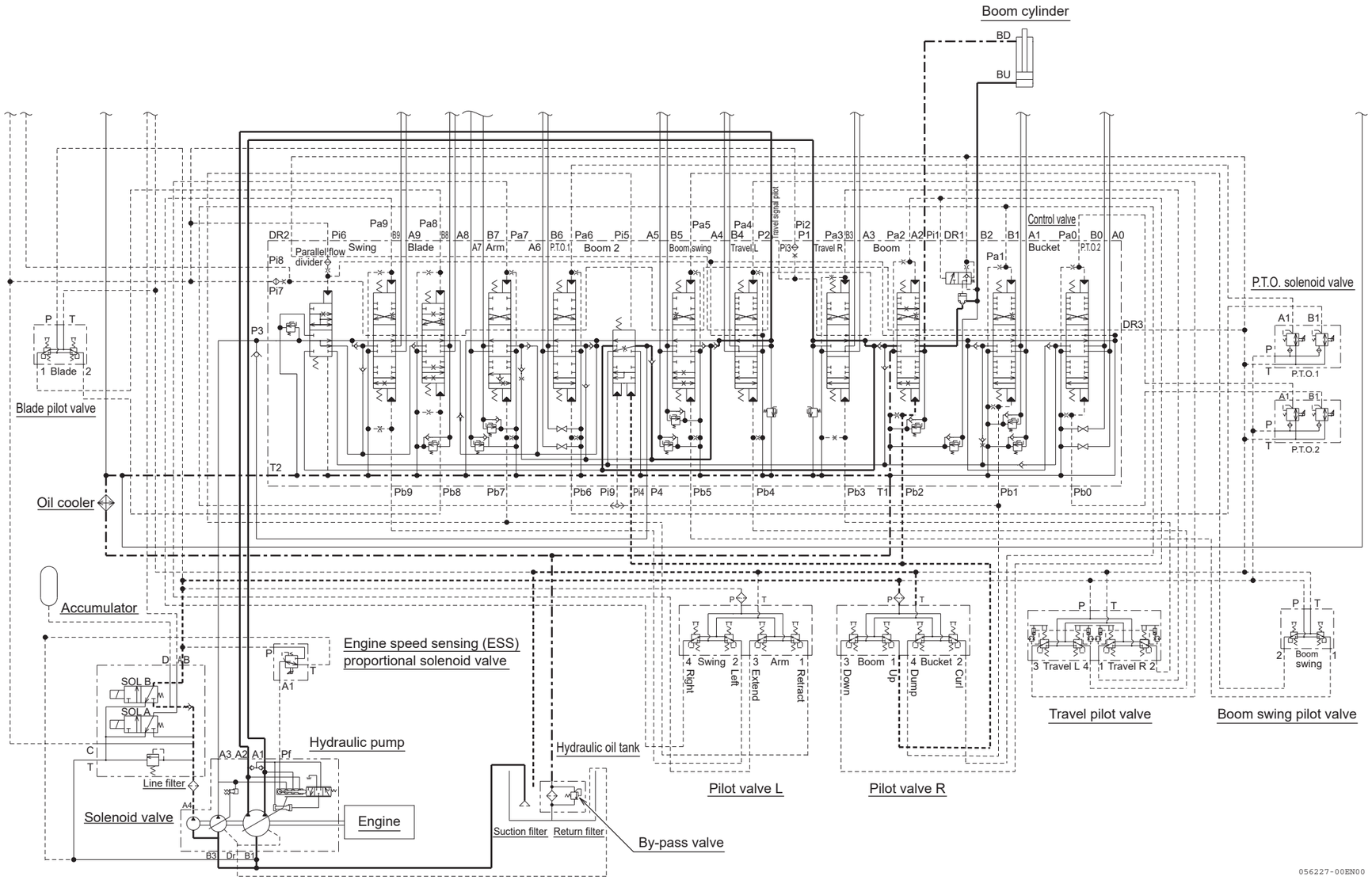
1) Boom “Up”

(1) Pilot pressure flow

When the boom control lever is pulled back to raise the boom, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 1 of the pilot valve (RH) to the port Pb2 of the boom section and the port Pi4 of the boom 2 section to move their spools.

(2) Oil flow from hydraulic pump

The oil discharged from the piston pump P1 flows to the boom section through the port P1 of the inlet section, while the oil discharged from the piston pump P2 flows to the boom section through the port P2 of the inlet section and the parallel passage, and combines with the oil from the piston pump P1. Then the combined oil opens the check valve of the anti-drift valve in the boom section and flows through the port B2 to BU of the boom cylinder to extend its cylinder rod, raising the boom. The return oil from BD of the boom cylinder flows back to the hydraulic oil tank through the port A2 of the boom section, the ports T1 and T2 of the control valve and the oil cooler.



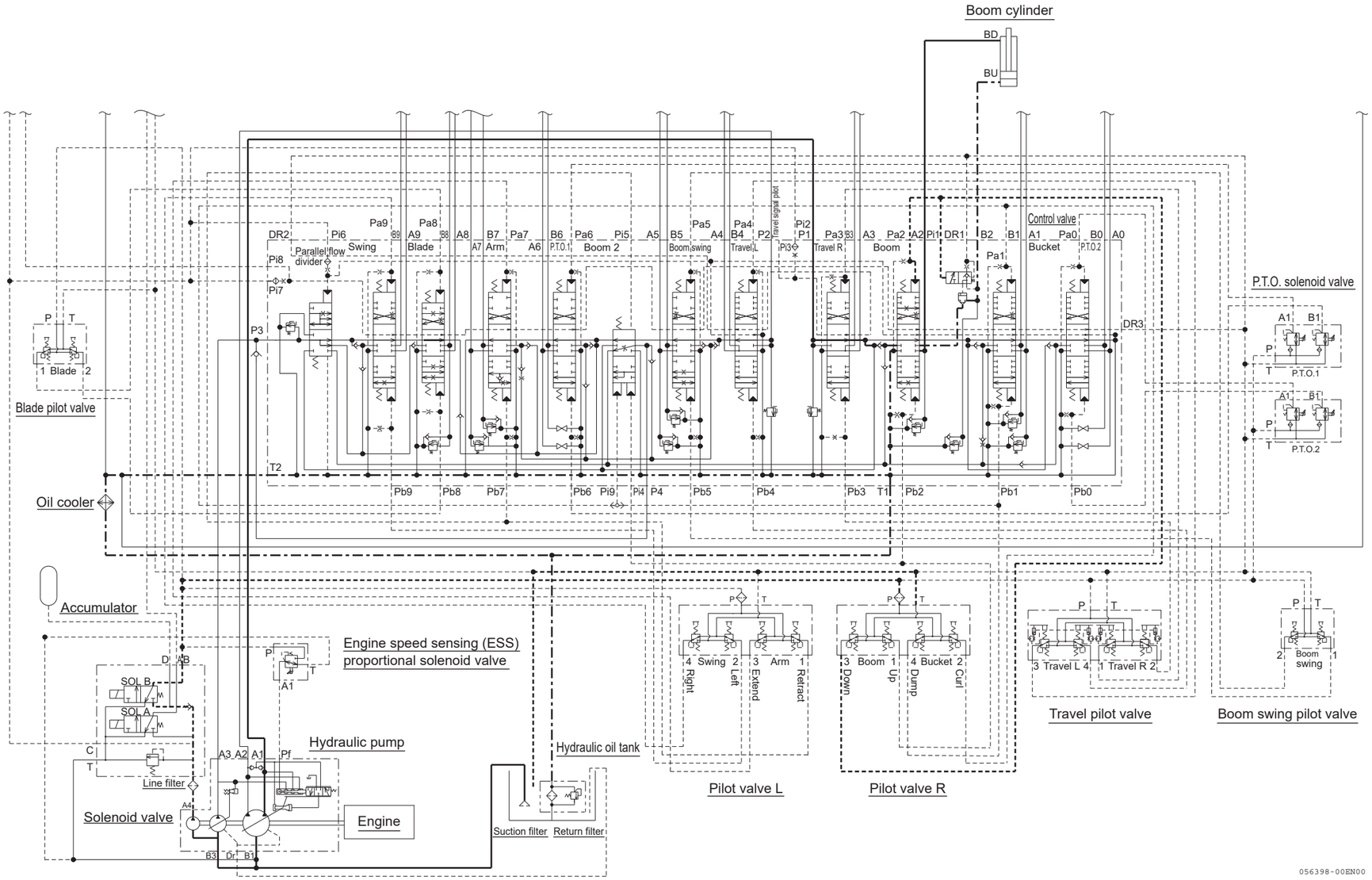
2) Boom "Down"

(1) Pilot pressure flow

When the boom control lever is pushed forward to lower the boom, the oil from the pilot pump P4 flows to the port Pi1 of the anti-drift valve through the port B of the cut-off valve and the port 3 of the pilot valve (RH) and presses the poppet d of the anti-drift valve to open the puppet b. The pilot oil also flows to the port Pa2 of the boom section to move its spool.

(2) Oil flow from hydraulic pump

The oil discharged from the piston pump P1 flows to the boom section through the port P1 of the inlet section and flows through the port A2 to BD of the boom cylinder to retract the cylinder rod, down the boom. The return oil from BU of the boom cylinder flows through the port B2 of the boom section, opens the check valve of the anti-drift vale and flows back to the hydraulic oil tank through the ports T1 and T2 of the control valve and the oil cooler.



6-2-2 Arm

1) Arm "Retract"

(1) Pilot pressure flow

When the arm control lever is pulled back to retract the arm, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 1 of the pilot valve (LH) to the port Pi5 of the boom 2 section to hold its spool in normal position, and also to the port Pb7 of the arm section to move its spool.

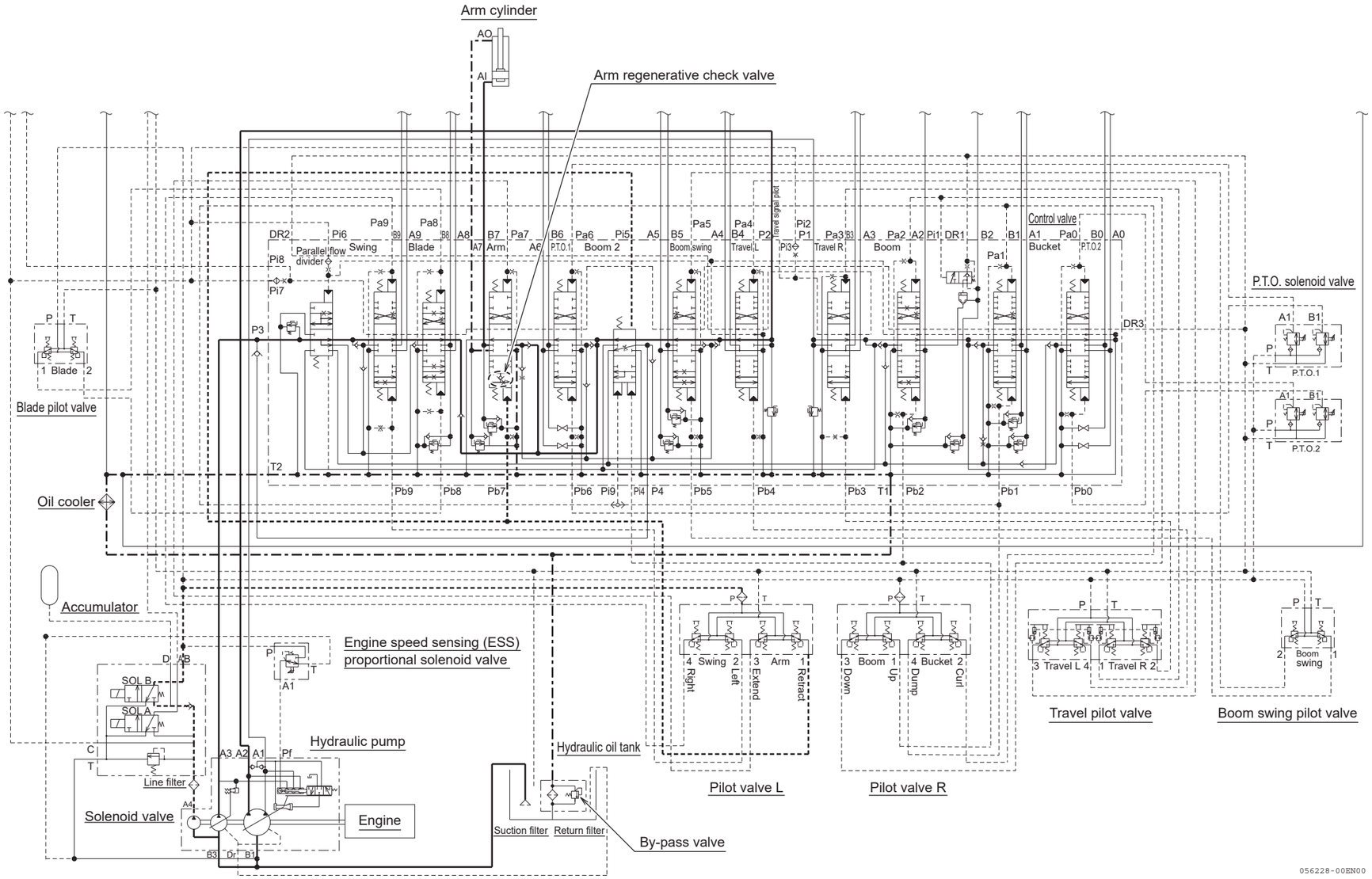
(2) Oil flow from hydraulic pump

The oil from the piston pump P2 flows through the port P2 of the inlet section and the parallel passage to the arm section. All the oil from the pump P3 flows through the port P3 of the parallel-flow divider and the parallel passage to the arm section and combines with the oil from the piston pump P2. The combined oil flows through the port B7 of the arm section to AI of the arm cylinder to extend its cylinder rod.

The return oil from AO of the arm cylinder flows back to the hydraulic oil tank through the port A7 of the arm section, the ports T1 and T2 of the control valve and the oil cooler.

(3) Arm regenerative circuit

During light load operations, if the pressure of the return oil from the port AO of the arm cylinder is higher than the pressure of the oil flowing to the port AI of the arm cylinder, some of the return oil flows through the check valve and is combined with the oil flowing to the port AI of the arm cylinder, thereby increasing the arm operation speed.



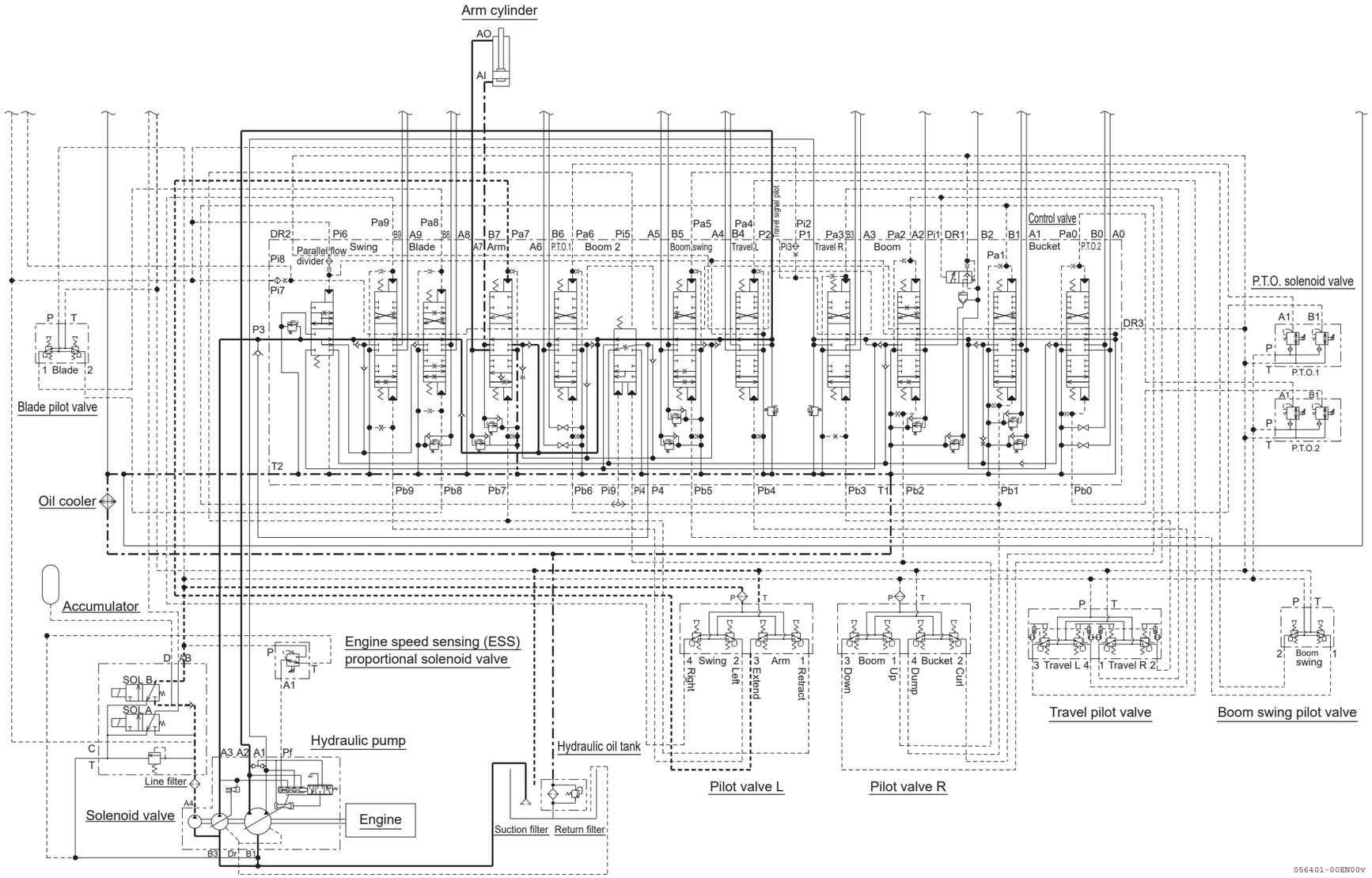
2) Arm "Extend"

(1) Pilot pressure flow

When the arm control lever is pushed forward to extend the arm, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 3 of the pilot valve (LH) to the port Pa7 of the arm section to move its spool.

(2) Oil flow from hydraulic pump

The combined oil flows in the opposite direction to the oil flow in the Arm Retract operation with regard to the arm cylinder.



6-2-3 Bucket

1) Bucket “Curl”

(1) Pilot pressure flow

When the bucket control lever is moved to the left to curl the bucket, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 2 of the pilot valve (RH) to the port Pa1 of the bucket section and the port Pi9 of the boom 2 section to move their spools.

(2) Oil flow from hydraulic pump

The oil from the piston pump P1 flows through the port P1 of the inlet section to the bucket section, while the oil discharged from the piston pump P2 flows to the bucket section through the port P2 of the inlet section and parallel passage, and combined oil flows through the port A1 of the bucket section to BKI of the bucket cylinder to extend its cylinder rod.

The return oil from BKO of the bucket cylinder flows back to the hydraulic oil tank through the port B1 of the bucket section, the ports T1 and T2 of the control valve and the oil cooler.

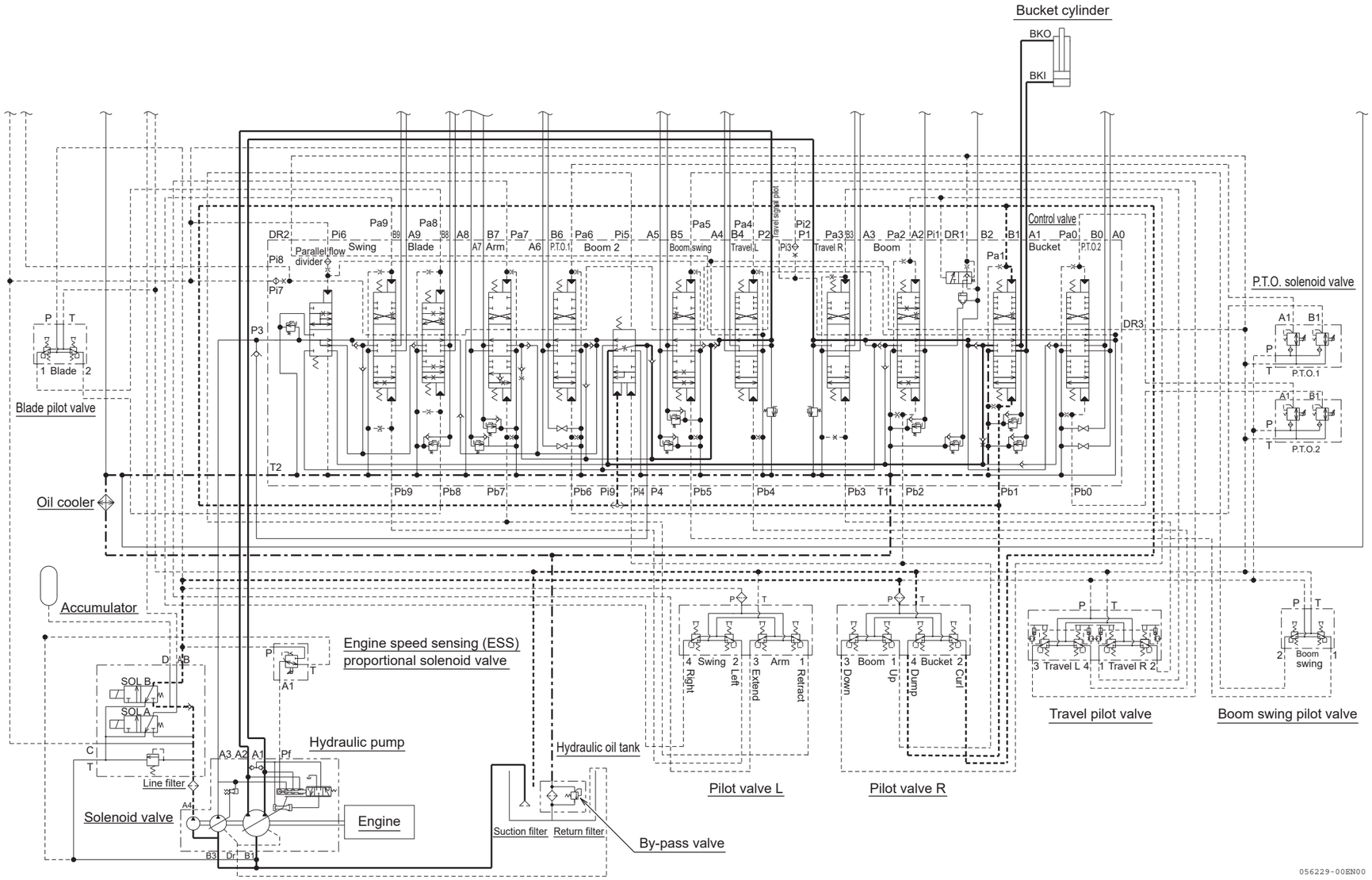
2) Bucket “Dump”

(1) Pilot pressure flow

When the bucket control lever is moved to the right to dump the bucket, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 4 of the pilot valve (RH) to the port Pb1 of the bucket section and the port Pi9 of the boom 2 section to move their spools.

(2) Oil flow from hydraulic pump

The oil flows in the opposite direction to the oil flow in the Bucket Curl operation with regard to the bucket cylinder.



6-2-4 Swing

1) Right Swing

(1) Pilot pressure flow

When the swing control lever is moved to the right, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 4 of the pilot valve (LH) to the port Pa9 of the swing section to move its spool.

(2) Oil flow from hydraulic pump

The oil from the pump P3 flows through the port P3 of the parallel-flow divider and the port A9 of the swing section to the port A of the brake valve, so that the swing motor is rotated.
The return oil from the port B of the brake valve flows back to the hydraulic oil tank through the port B9 of the swing section, the ports T1 and T2 of the control valve and the oil cooler.

2) Left Swing

(1) Pilot pressure flow

When the swing control lever is moved to the left, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 2 of the pilot valve (LH) to the port Pb9 of the swing section to move its spool.

(2) Oil flow from hydraulic pump

The oil flows in the opposite direction to the oil flow in the Right Swing operation with regard to the swing motor.

3) Release and Operation of Swing Motor Mechanical Brake

(1) Release of swing motor mechanical brake

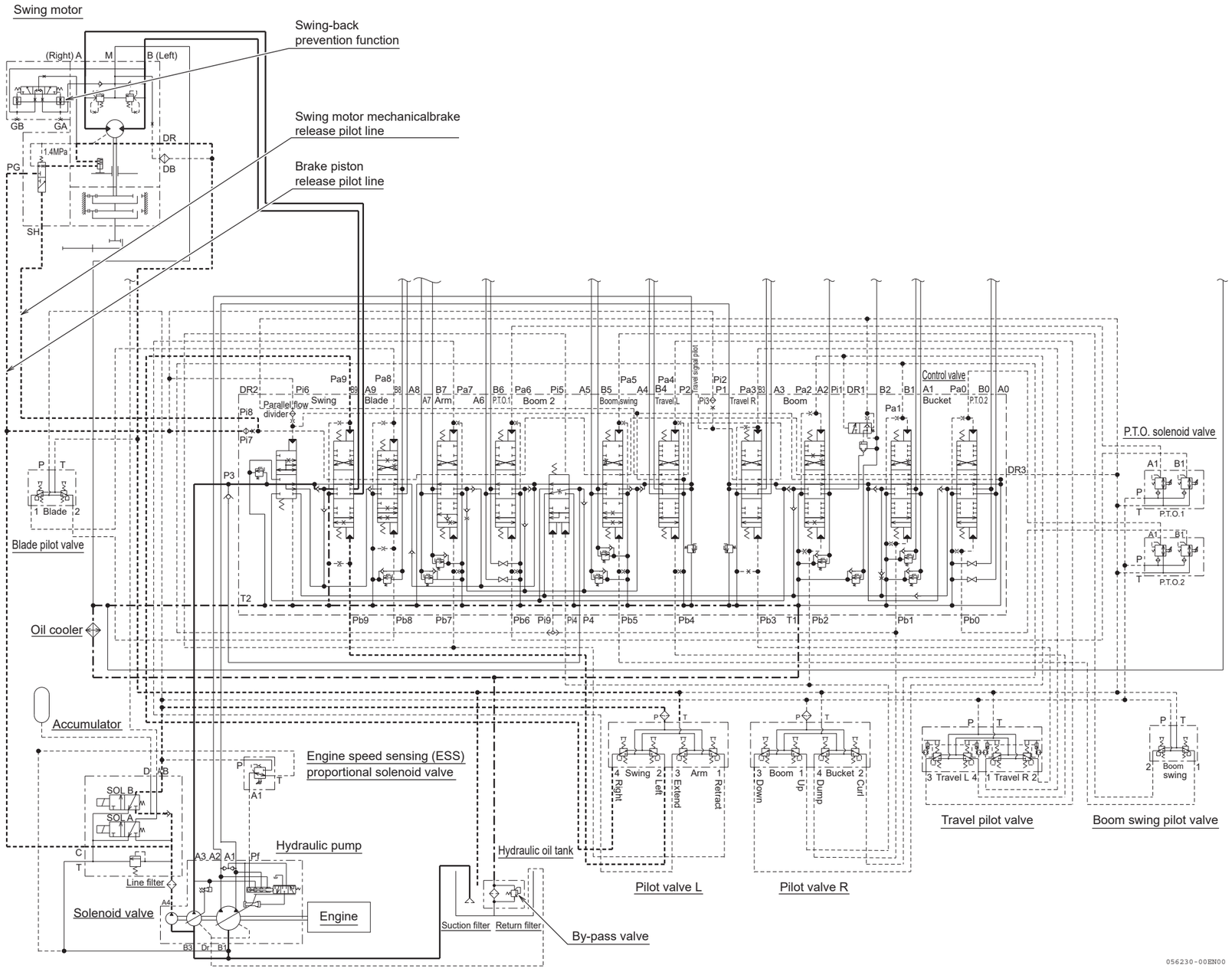
The pilot pressure for releasing the swing motor hydraulic timer is supplied to each of the swing, blade, arm, P.T.O., boom swing, boom, bucket and P.T.O.2 sections through the port C of the cut-off valve and the port Pi7 of the parallel-flow divider, and flows back to the hydraulic oil tank. When the spool of the swing section is moved, the spool blocks the swing motor mechanical brake release pilot line from the port C of the cut-off valve, and pilot pressure is caused. The pilot pressure flows through the port Pi8 to the port SH of the swing motor to move the spool of the hydraulic timer, while the pilot pressure from the port C of the cut-off valve flows to the port PG of the swing motor and presses the piston (with a spring) of the mechanical brake to release the brake.
The swing motor hydraulic timer release pilot pressure is caused to release the brake when the spool of the swing, blade, arm, P.T.O., boom swing, boom, bucket or P.T.O.2 sections is moved.

(2) Operation of swing motor mechanical brake

When the swing control lever is returned to the "Neutral" position, the swing motor mechanical brake release pilot line opens to release the pilot pressure. Therefore, the piston (with a spring) of the swing motor mechanical brake is released to operate the brake.

4) Swing Motor Hydraulic Brake Operation

When the swing control lever is returned to the "Neutral" position, the oil flow to the swing motor is blocked and the pressures at the ports A and B of the brake valve become equal and consequently the brake is applied. However, the swing motor continues to rotate in a short time due to its inertia. This causes the motor to act like a pump and increases the circuit pressure on the port B2 side. The increased pressure opens the relief valve SR1 to let the oil on the lower pressure side escape to the port A2, so that the circuit pressure is absorbed and cavitation is prevented on the port A2 side.
The port MU of the swing motor has the drain function and a circuit which directly takes in the return oil flowing from the port T2 to the hydraulic oil tank to prevent negative pressure in the swing motor.
The brake valve has a swingback prevention function, which decreases the inverting action caused when starting and stopping operating the brake valve.



6-2-5 Boom Swing

1) Right Boom Swing

(1) Pilot pressure flow

When the boom swing pedal is moved on the right, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 1 of the boom swing pilot valve to the port Pb5 of the swing section to move its spool.

(2) Oil Flow from Hydraulic Pump

The oil from the piston pump P2 flows through the port P2 of the inlet section and the port B5 of the boom swing section to BSR of the boom swing cylinder to retract its cylinder rod.

The return oil from BSL of the boom swing cylinder flows back to the hydraulic oil tank through the port A5 of the boom swing section, the ports T1 and T2 of the control valve and the oil cooler.

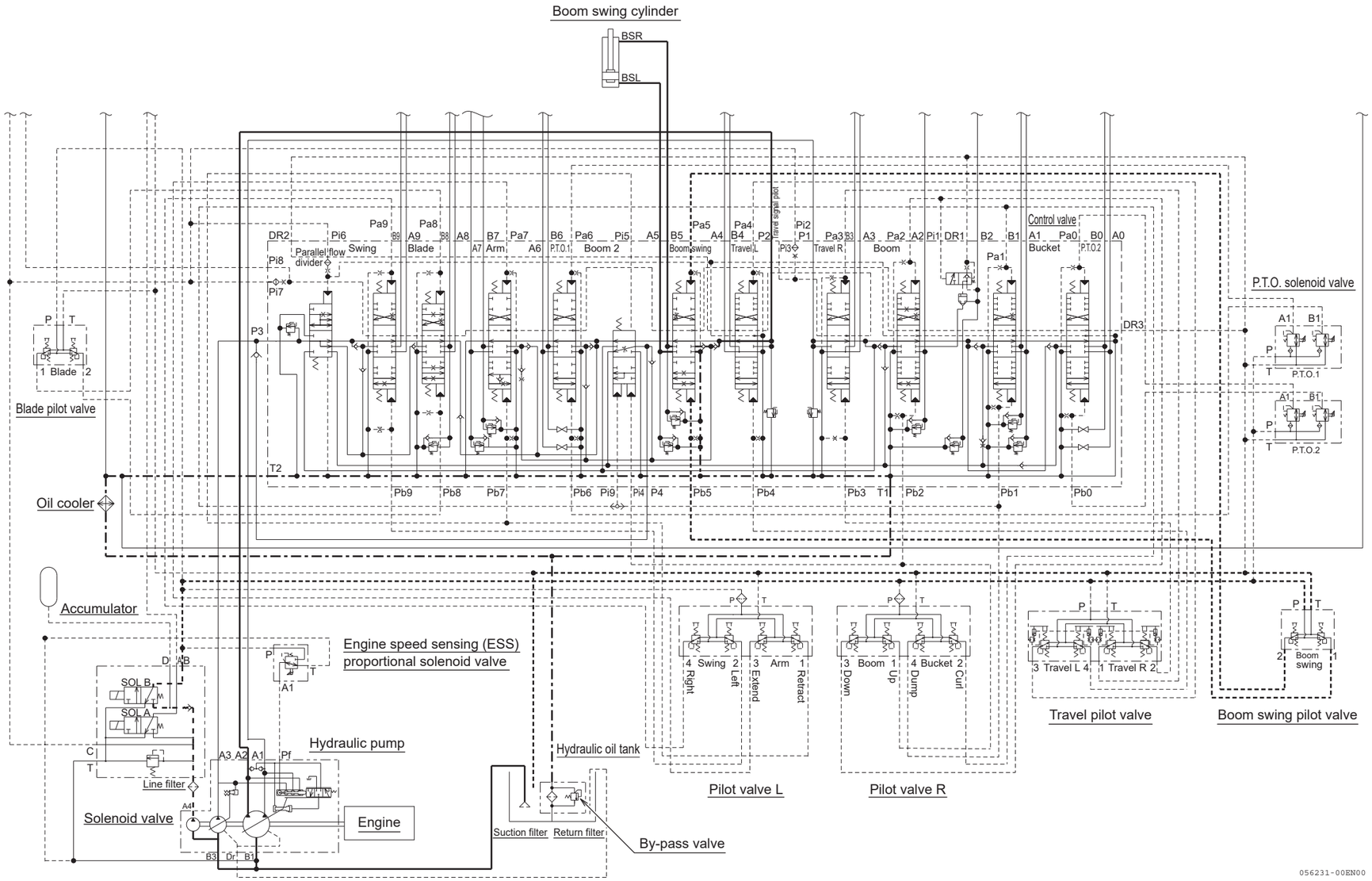
2) Left Boom Swing

(1) Pilot pressure flow

When the boom swing pedal is moved on the left, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 2 of the boom swing pilot valve to the port Pa5 of the swing section to move its spool.

(2) Oil Flow from Hydraulic Pump

The oil flows in the opposite direction to the oil flow in the right boom swing operation with regard to the boom swing cylinder.



6-2-6 Blade

1) Blade "Down"

(1) Pilot pressure flow

When the blade lever is pushed forward to lower the blade, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 1 of the blade pilot valve to the port Pa8 of the blade section to move its spool.

(2) Oil Flow from Hydraulic Pump

The oil from the pump P3 flows through the port P3 of the parallel-flow divider, the parallel passage, the port A8 of the blade section and the port B of the swivel joint to BLD of the blade cylinder to extend its cylinder rod, lowering the blade.

The return oil from BLU of the blade cylinder flows back to the hydraulic oil tank through the port A of the swivel joint, the port B8 of the blade section, the ports T1 and T2 of the control valve and the oil cooler.

2) Blade "UP"

(1) Pilot pressure flow

When the blade lever is pulled backward to lift up the blade, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 2 of the blade pilot valve to the port Pa8 of the blade section to move its spool.

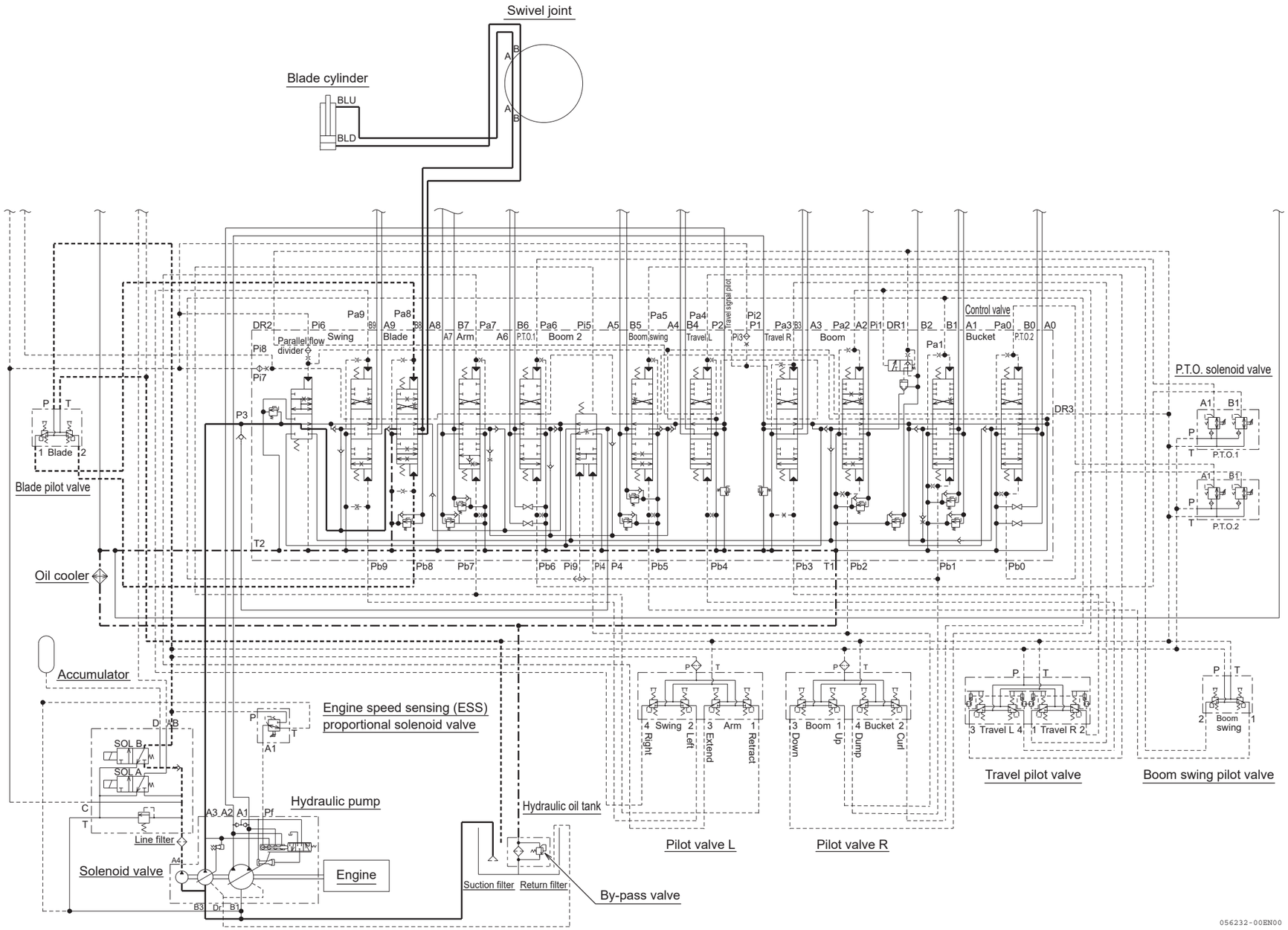
(2) Oil Flow from Hydraulic Pump

When the blade lever is pulled back to raise the blade, the spool is pulled back.

The oil flows in the opposite direction to the oil flow in the blade down operation with regard to the blade cylinder.

3) Circuit Relief Valve Installed in Blade "Up" Circuit

When the blade is raised while the machine is traveling, the oil quantity control function of the hydraulic pump operates to reduce its discharge volume, and the travel speed is slowed down. To minimize such speed reduction, a circuit relief valve with the set pressure lower than that of the system relief valve is installed in the blade cylinder circuit for raising the blade.



6-2-7 Travel

1) Forward Travel (Right)

(1) Pilot pressure flow

When the right travel lever is pushed forward, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 1 of the travel pilot valve to the port Pa3 of the travel section to move its spool.

(2) Oil Flow from Hydraulic Pump

The oil from the piston pump P1 flows through the port P1 of the inlet section, the port A3 of the right travel section and the port F of the swivel joint to the port P1 of the right travel motor to rotate it.

The return oil from the port P2 of the right travel motor flows back to the hydraulic oil tank through the port F of the swivel joint, the port B3 of the right travel section, the ports T1 and T2 of the control valve and the oil cooler.

2) Forward Travel (Left)

(1) Pilot pressure flow

When the left travel lever is pushed forward, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 3 of the travel pilot valve to the port Pa4 of the travel section to move its spool.

(2) Oil Flow from Hydraulic Pump

The oil from the piston pump P2 flows through the port P2 of the inlet section, the port A4 of the left travel section and the port C of the swivel joint to the port P2 of the left travel motor to rotate it.

The return oil from the port P1 of the left travel motor flows back to the hydraulic oil tank through the port E of the swivel joint, the port B4 of the left travel section, the ports T1 and T2 of the control valve and the oil cooler.

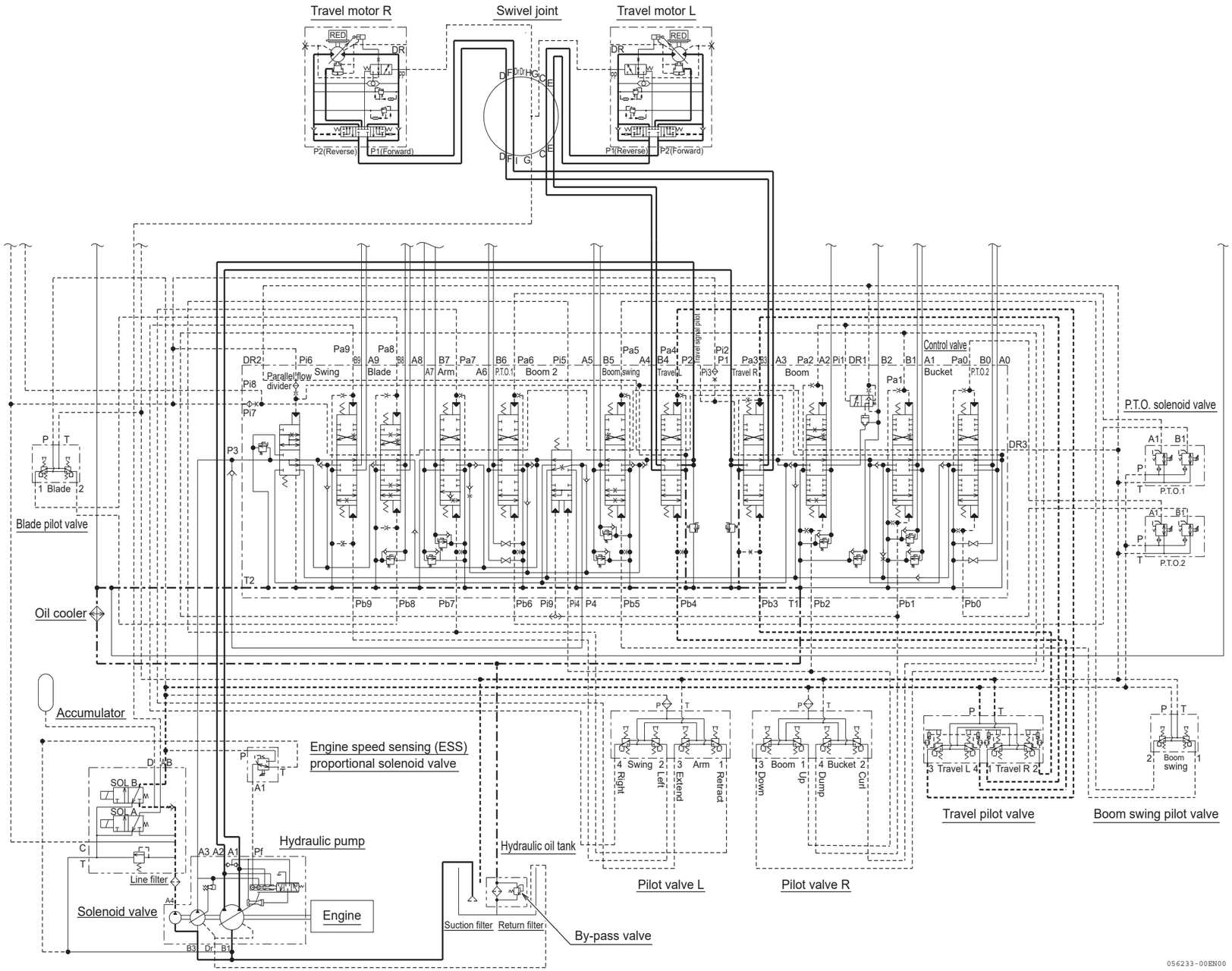
3) Reverse Travel (Right and Left)

(1) Pilot pressure flow

When the right (left) travel lever is pulled backwards, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the port 2 (4) of the travel pilot valve to the port Pb3 (Pb4) of the travel section to move its spool.

(2) Oil Flow from Hydraulic Pump

The oil flows in the opposite direction to the oil flow in the Forward Travel operation with regard to the right or left travel motor.



4) Travel Automatic Dual Speed Function

When the travel automatic dual speed switch is turned on, the signal is transmitted from the switch to the solenoid valve A to increase the travel speed.

(1) Pilot oil flow

When the travel automatic dual speed switch is turned on, the signal is transmitted from the switch to the cut-off valve and the solenoid valve A is opened. The oil from the pilot pump P4 flows through the port A of the solenoid valve A to the port G of the swivel joint and is divided into two flows to the ports G and H there to flow to the port Pp of each travel motor.

(2) Increase in output speed of travel motor

The pilot oil from the pilot pump P4 moves the swash plate control piston to reduce the inclination angle of the swash plate, which shortens the piston stroke of the travel motor and decreases the travel motor capacity to increase its output speed. This increases the travel speed.

Meanwhile, the travel driving force weakens as the output torque of the travel motor becomes smaller due to the shortened piston stroke.

(3) Automatic shifting to low speed during high speed operation

When the load is increased during high speed operation, the operating pressure of the spool exceeds the pilot pressure of port PP, and the spool is returned. At that time, the swash plate control piston is returned by the spring force and the inclination angle of swash plate is increased. Then, it lengthens the piston stroke of the travel motor and increases the travel motor capacity to decrease its output speed.

Meanwhile, the travel driving force strengthens as the output torque of the travel motor becomes bigger due to the longer piston stroke.

5) Operation of Travel Motor Brake

(1) Hydraulic brake valve

In the brake operation, a sudden shock is caused because the oil flow is cut off by the double counter balance valve. The brake valve, which is a shockless type, absorbs that shock while applying the brake.

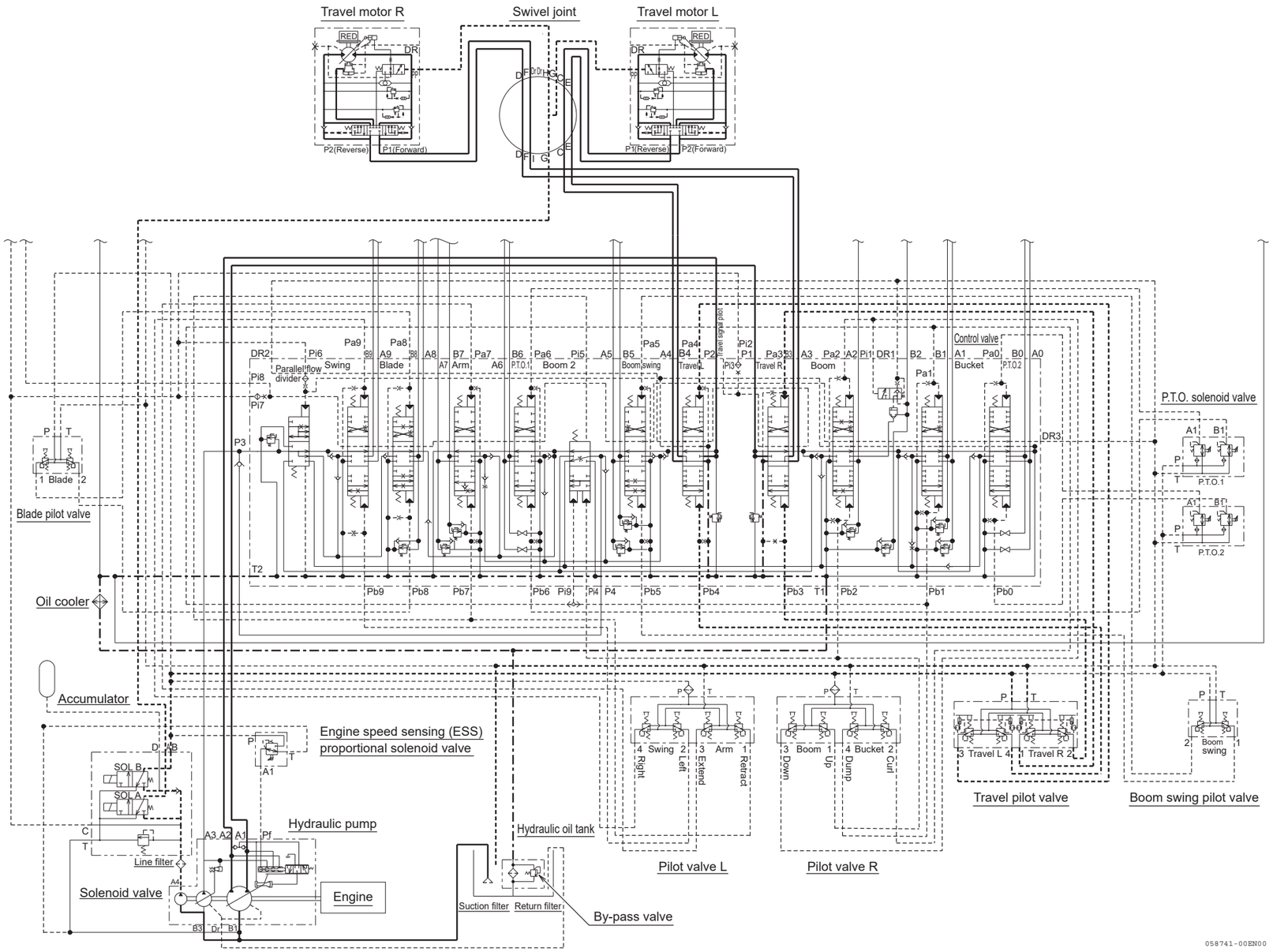
(2) Mechanical brake

Operation of mechanical brake

When the travel levers are in the neutral position, no pressure develops in the circuit and the spool of the double counter balance valve returns to the neutral position. Then no pressure oil flows to the piston of the mechanical brake so that the brake is applied due to the spring force to work as the parking brake.

Release of mechanical brake

When the travel lever is operated, the spool of the double counter balance valve is moved by the circuit pressure, and at the same time, the piston of the mechanical brake is moved by the pilot pressure to release the brake.



6-2-8 Non-deviation Travel (with Boom, Arm, Bucket or Boom Swing Operation)

Oil Flow from Hydraulic Pump

1) Travel Sections

The oil from the piston pump P1 and that from the piston pump P2 flow through the ports P1 and P2 of the inlet section to the right and left travel sections, respectively. The right and left travel sections are each connected in series in their respective section groups and located the most upstream in the circuits of the piston pumps P1 and P2, respectively. Therefore, all of the oil from each piston pump flows to the travel motor when the travel lever is operated.

The pilot oil for the non-deviation travel pilot line from the port C of the cut-off valve flows to the port Pi6, then flows back to the hydraulic oil tank through the travel (L) section, and the boom, bucket and P.T.O.2 sections. When the travel (L) section is operated and simultaneously the boom or bucket section is also operated, the pressure develops in the circuit from the port Pi6 and the spool of the parallel-flow divider is moved.

2) Travel with Boom Operation

The oil from the pump P3 flows to the parallel-flow divider, where the oil is divided. The divided oil flows through the parallel passage to the boom section. Therefore, the machine can travel with no deviation even when the boom control lever is moved while the machine is traveling.

3) Travel with Arm Operation

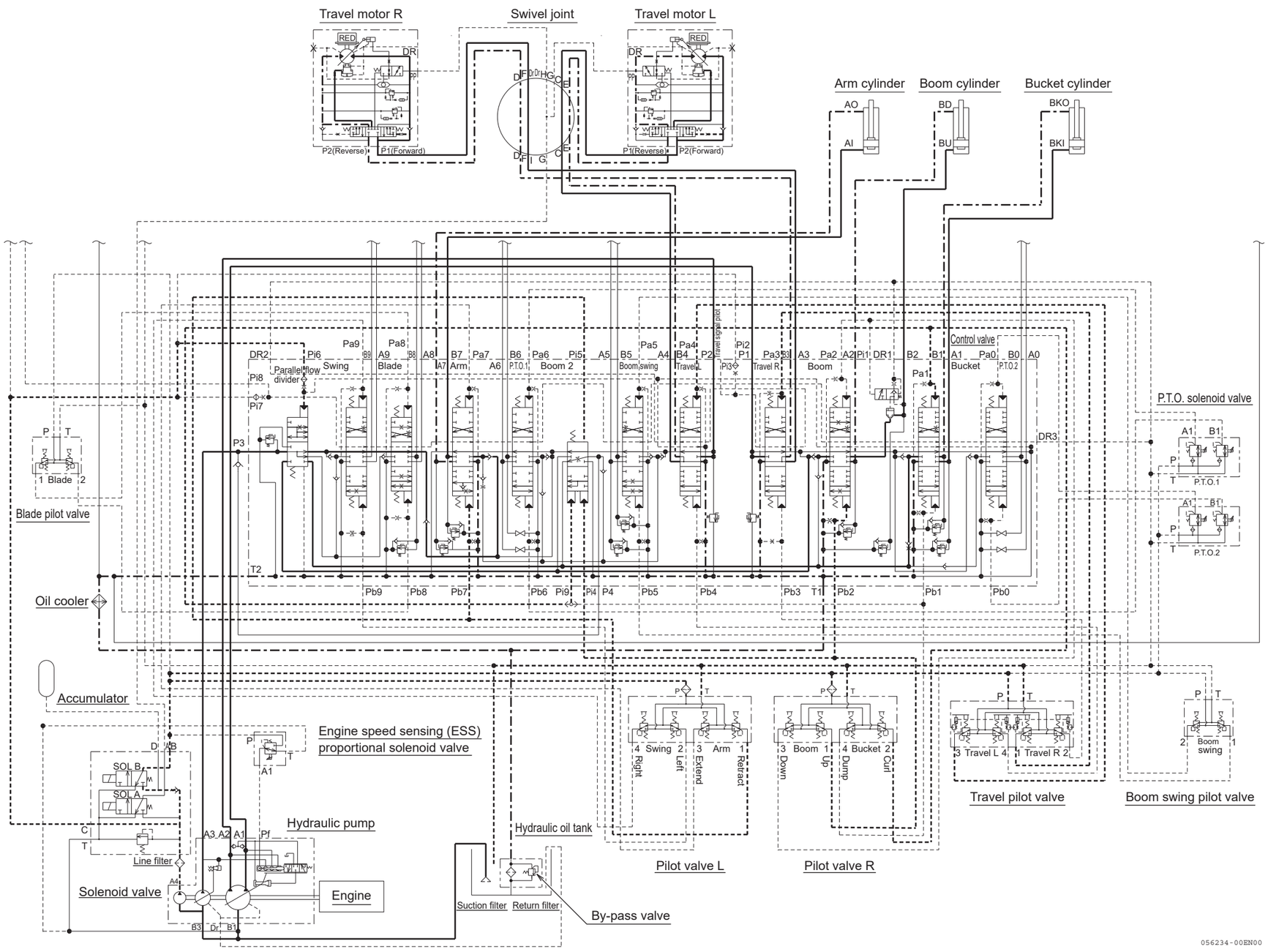
The oil from the pump P3 flows through the parallel-flow divider, swing and blade sections and the parallel passage to the arm section. Therefore, the machine can travel with no deviation even when the arm control lever is moved while the machine is traveling.

4) Travel with Bucket Operation

The oil from the pump P3 flows to the parallel-flow divider, where the oil is divided. The divided oil flows through the parallel passage to the bucket section. Therefore, the machine can travel with no deviation even when the bucket control lever is moved while the machine is traveling.

5) Travel with Boom Swing Operation

All the oil in the circuit of the piston pump P2 is supplied to the travel section in the most upstream for the pump P2, and the boom swing section in the downstream is supplied with no oil. None of the oil from the gear pump P3 is supplied to the boom swing section, either, so that the boom does not swing while the machine is traveling.



6-2-9 Simultaneous Operation of Boom Up and Arm Retract

1) Pilot Pressure Flow

When the arm control lever is pulled back to retract the arm while the boom is being raised, the boom 2 section receives the pilot pressure from the ports Pi4 and Pi5 at the same time to keep the spool in the neutral position.

2) Oil Flow from Hydraulic Pump

(1) Oil flow to boom section

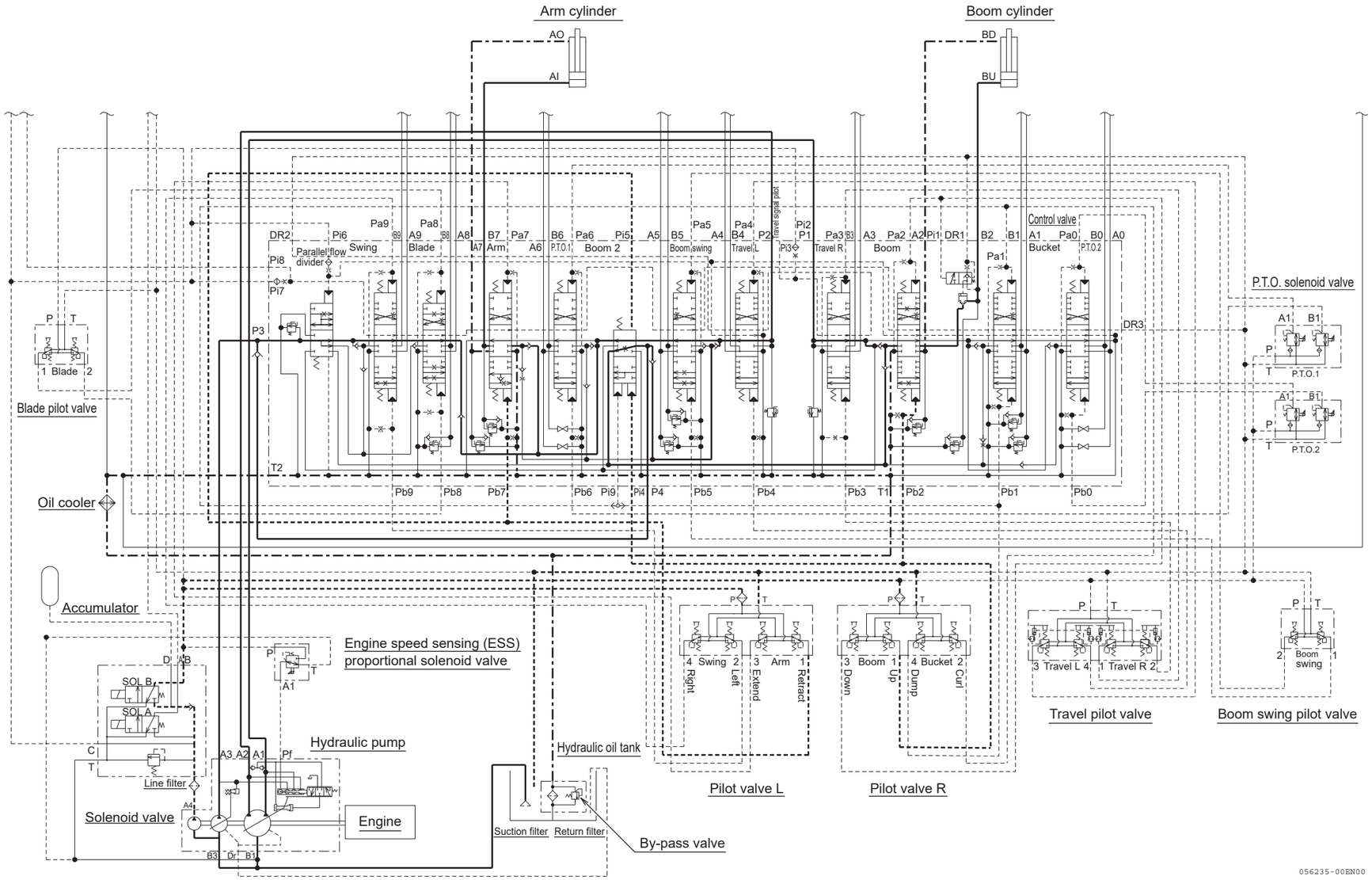
The oil from the piston pump P2 flows through the port P2 of the inlet section to the boom 2 section. Then the boom 2 section controls the oil from the piston pump P2 and allows some of the oil to flow through the parallel passage to the boom section to combine with the oil from the piston pump P1.

(2) Oil flow to arm section

The boom 2 section controls the oil from the piston pump P2 to the boom section. Therefore, the oil from the piston pump P2 can flow more smoothly to the arm section to combine with the oil from the pump P3.

When a load is applied to the arm, the oil flow is decreased due to the hose power control shift of the pump P3 and the boom speed is slowed down. To make up for the slowed speed, the oil from the pump P3 flows through the check valve, the boom 2 section, the parallel passage to the boom section to combine with the oil from the piston pump P1. This circuit increases the speed of the boom "up" operation.

Refer to Section "5-3-1 Boom" and Section "5-3-2 Arm" for the oil flow with regard to the boom and arm cylinders.



6-2-10 Simultaneous Operation of Boom Up and Bucket

1) Pilot Pressure Flow

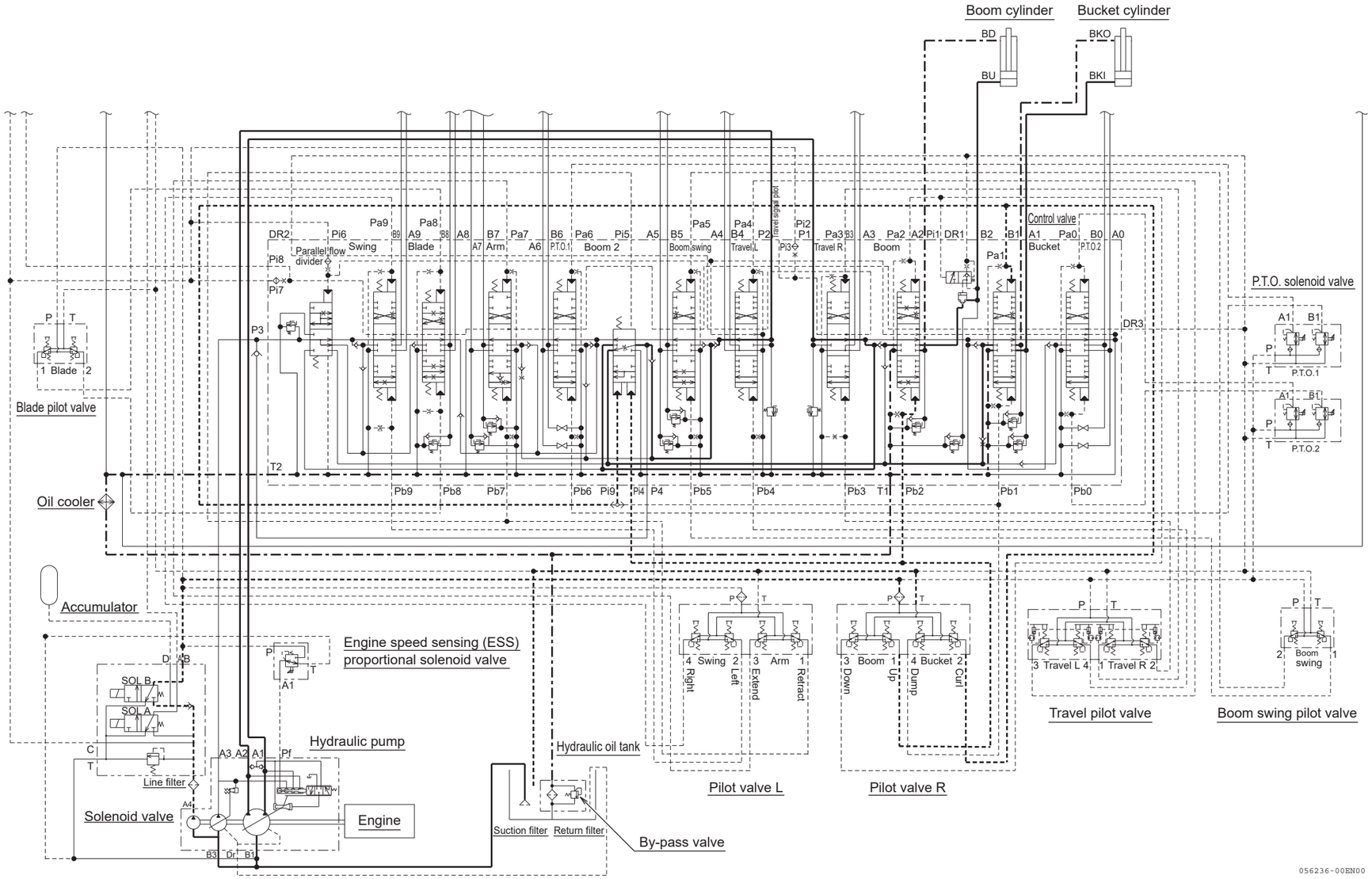
When the bucket control lever is moved while the boom is being raised, the pilot pressure flows to the port Pi4 of the boom 2 section to move its spool.

2) Oil Flow from Hydraulic Pump

The oil from the piston pump P2 flows through the port P2 of the inlet section to the boom 2 section, where the oil is divided. The divided oil flows through the parallel passage to the boom and bucket sections.

The check valve with a boom priority orifice (Ø0.13 in. [3.4 mm]) is installed in the parallel passage in the bucket section so that the oil can flow more smoothly to the boom section when the bucket control lever is moved while the boom with a heavy load is being raised. Therefore, the boom and the bucket can operate simultaneously.

Refer to Section "5-3-1 Boom" and Section "5-3-3 Bucket" for the oil flow with regard to the boom and bucket cylinders.



6-2-11 Simultaneous Operation of Boom Up and Swing

1) Pilot Pressure Flow

When the swing control lever is moved while the boom is being raised, the pilot pressure flows to the port Pi4 of the boom 2 section to move its spool.

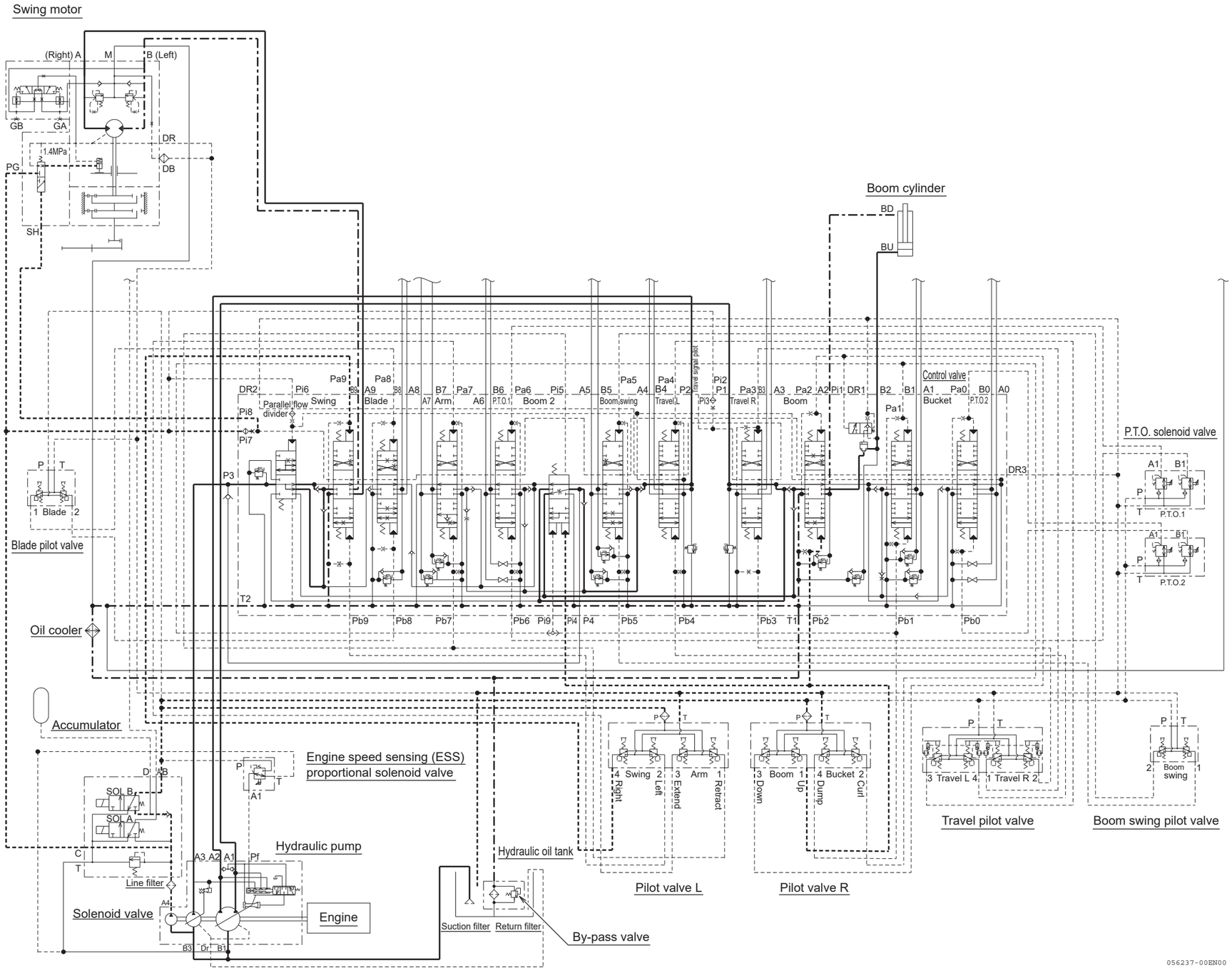
2) Oil Flow from Hydraulic Pump

The oil from the piston pump P2 flows through the port P2 of the inlet section to the boom 2 section, where the oil is divided. The divided oil flows to the boom section through the parallel passage.

The oil from the pump P3 flows through the parallel-flow divider to the swing section, while the oil discharged from the pump P3 flows to the boom section through the check valve, the port P4 of the boom 2 section and parallel passage, and combines with the oil from the piston pump P1.

The oil flow quantity from the pump P3 is controlled to match the swing speed to the boom-up speed.

Refer to Section "5-3-1 Boom" and Section "5-3-4 Swing" for the oil flow with regard to the boom cylinder and the swing motor.



6-2-12 Simultaneous Operation of Arm and Bucket

1) Pilot Pressure Flow

When the bucket control lever is moved while the arm is being retracted, the boom 2 section receives the pilot pressure from the ports Pi5 and Pi9 at the same time to keep its spool in the neutral position.

2) Oil Flow from Hydraulic Pump

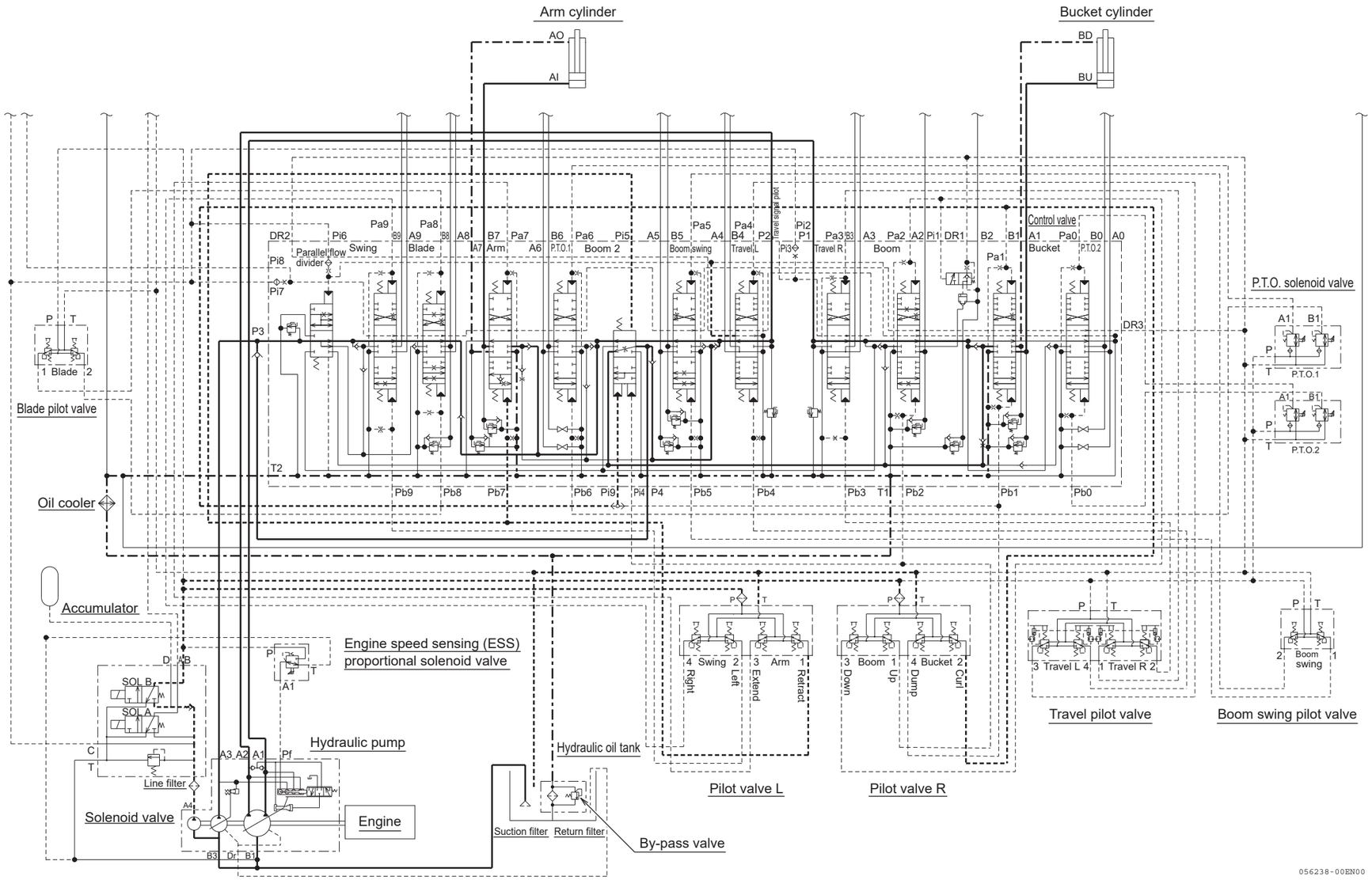
(1) Oil flow to arm section

The oil from the pump P3 flows through the parallel-flow divider and blade sections and the parallel-passage to the arm section and combines with the oil from the piston pump P2.

(2) Oil flow to bucket section

When the arm is given a heavy load, the horsepower control shift of the pump P3 works to decrease the discharge volume of the piston pump P1, so the bucket speed slows down. To make up for the bucket speed reduction, the oil from the pump P3 flows through the check valve, the port P4 of the boom 2 section and the parallel passage to the bucket section and combines with the oil from the piston pump P1.

Refer to Section "5-3-2 Arm" and Section "5-3-3 Bucket" for the oil flow with regard to the arm and bucket cylinders.



6-2-13 Hydraulic P.T.O.

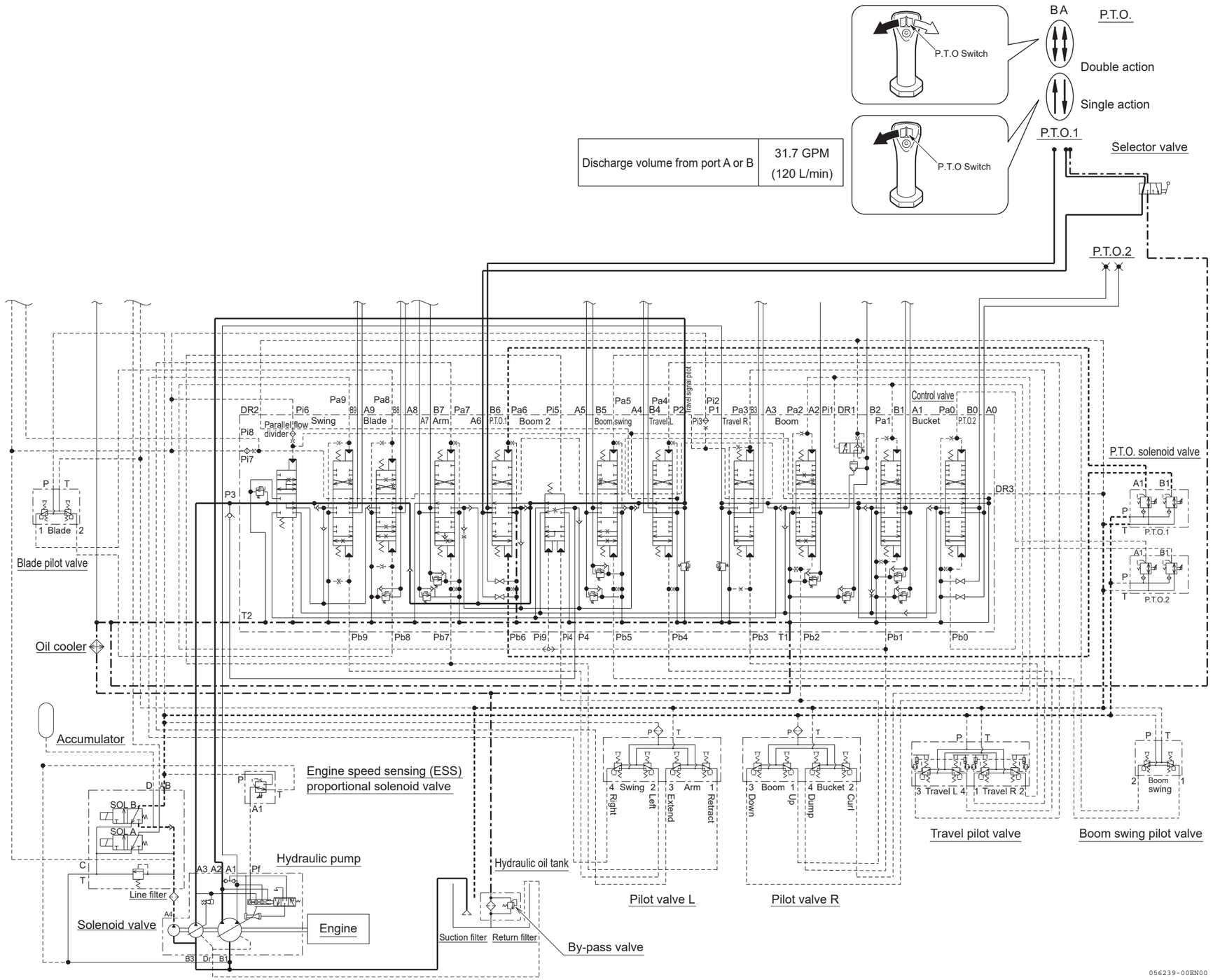
P.T.O. slide switch controls the solenoid valve through the output current of the solenoid driver in the control lever.

1) Single Acting Actuators (Example: Breaker, etc,)
(Selector valve is in "Single acting" position)
(1) Pilot pressure flow
When the P.T.O. slide switch is moved to left side, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the P.T.O. solenoid valve to the port Pb6 of the P.T.O. section to move its spool.

(2) Oil flow from hydraulic pump
The oil from the piston pump P2 flows through the port P2 of the inlet section to the P.T.O. section. Meanwhile, the oil from the pump P3 flows through the port P3 of the parallel flow divider and the parallel passage to the P.T.O. section and all of the oil from the pump P3 combines with the oil from the pump P2. The combined oil flows through the port B6 of the P.T.O. section to the port "B" of the P.T.O. circuit.
The return oil from the port "A" of the P.T.O. circuit flows to the hydraulic tank through the oil cooler directly.

2) Double Acting Actuators (Example: Tilt bucket, etc.)
(Selector valve is in "Double acting" position)
(1) Pilot pressure flow
When the P.T.O. slide switch is moved to left side, the oil flow is same as the flow in "Single acting actuator.
When the P.T.O. slide switch is move to right side, the oil from the pilot pump P4 flows through the P.T.O. solenoid valve to the port Pa6 of the P.T.O. section to move its spool.

(2) Oil flow from hydraulic pump
When the P.T.O. slide switch is moved to left side, the oil flows to P.T.O. circuit in same direction to the oil flow in the "Single Acting Actuators". The return oil from the port "A" of the P.T.O. circuit flows to the hydraulic tank through the port A6 of the P.T.O. section, the port T1 and T2 and the oil cooler.
When the P.T.O slide switch is moved to right side, the oil flows in opposite direction to the oil flow when the P.T.O. slide switch is moved to left side.



6-2-14 P.T.O.2

P.T.O.2 slide switch on the left control lever controls the solenoid valve through the output current of the solenoid driver in the control lever.

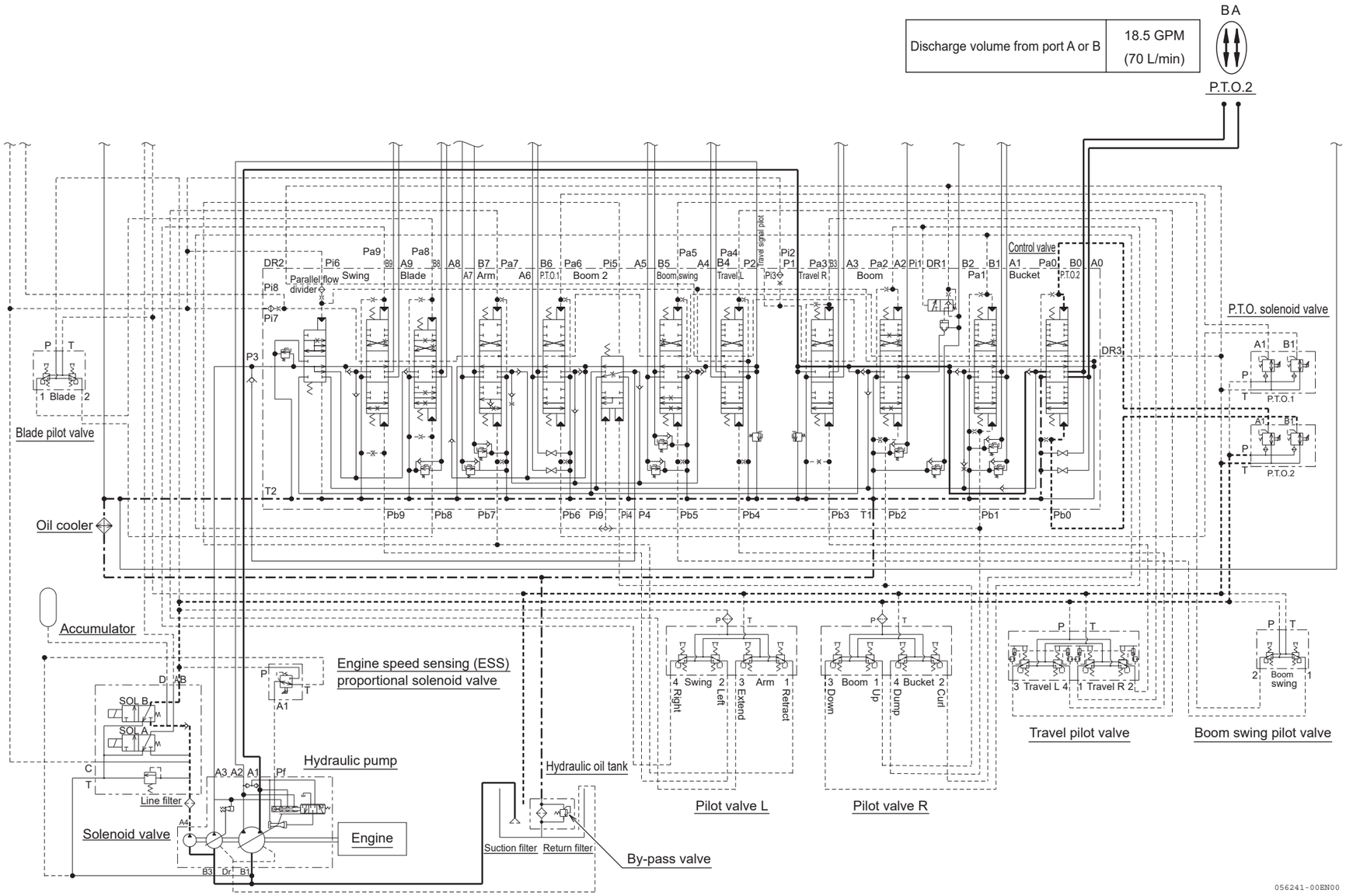
1) Pilot pressure flow

When the P.T.O.2 slide switch is moved to left side, the oil from the pilot pump P4 flows through the port B of the cut-off valve and the P.T.O.2 solenoid valve to the port Pb0 of the P.T.O.2 section to move its spool.

2) Oil flow from hydraulic pump

The oil from the piston pump P2 flows through the port P1 of the inlet section and the port B0 of the P.T.O.2 section to the port B of the P.T.O.2 circuit.

The return oil from the port A of the P.T.O.2 circuit flows to the hydraulic oil tank through the port A0 of P.T.O.2 section, the port T1 and T2 and the oil cooler.



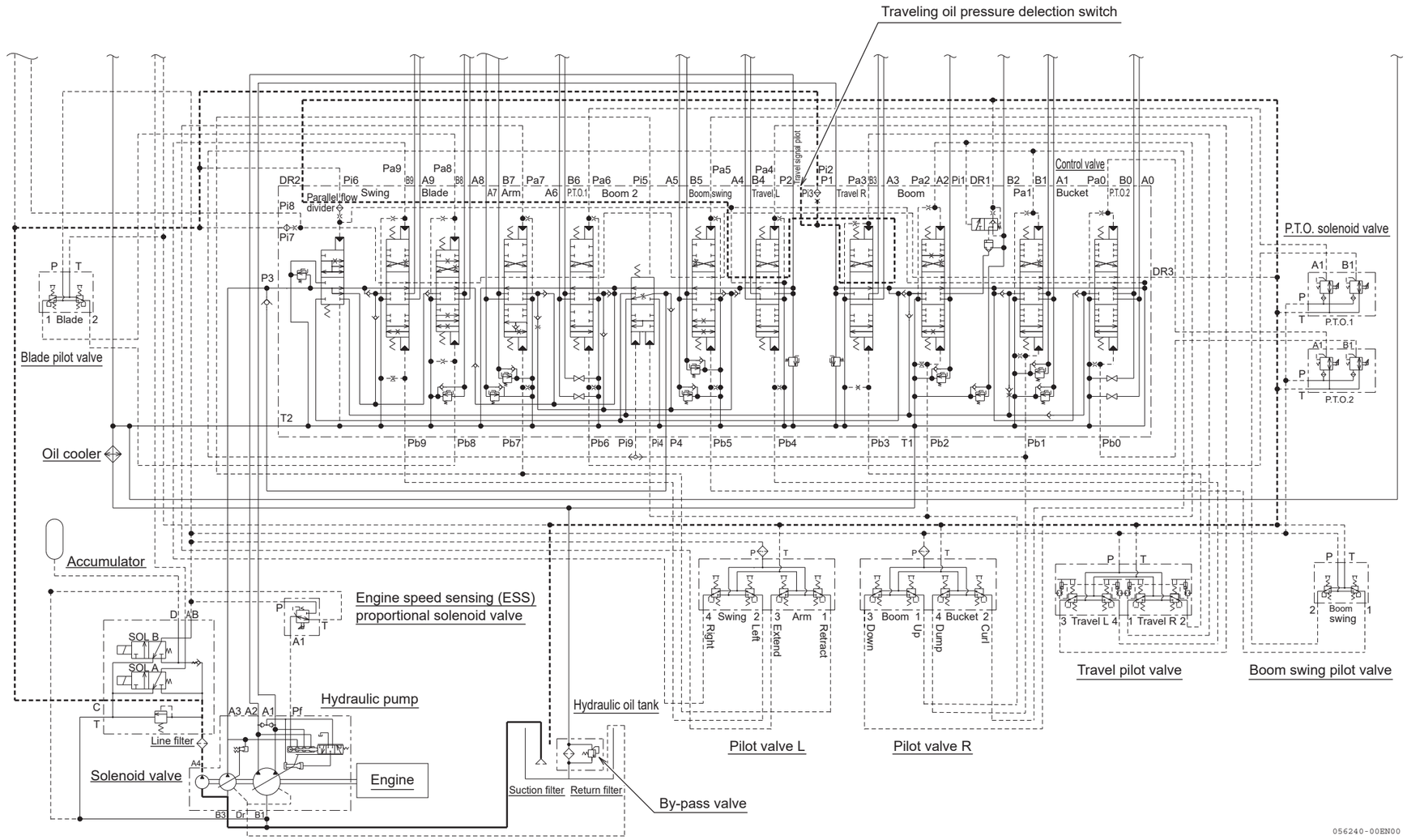
6-2-15 Travel Alarm

1) Travel Levers in Neutral (No Buzzer Sounds)

The pilot pressure from the port C of the cut-off valve flows back to the hydraulic oil tank through the port Pi2 of the inlet section and the right and left travel sections.
Therefore, no pilot pressure flows to the port Pi3 of the inlet section so that the pilot oil pressure switch does not operate.

2) Travel Lever in Operation (A Buzzer Sounds)

When the travel lever is operated, the spool of the travel section is moved to block the pilot line. Therefore, the pilot pressure flows to the port Pi3 of the inlet section so that the pilot oil pressure switch operates and a buzzer sounds.



6-2-16 Auto Deceleration

1) When the implement and travel control levers are in the neutral position

Pilot oil from port C of the cut-off valve flows as follows:

(1) The pilot oil flows into port Pi2 of the inlet section, then passes through the right and left travel sections and returns to the hydraulic oil tank.

Therefore, since no pilot pressure is applied to port Pi3, the oil pressure switch is not activated.

(2) The pilot oil flows into port Pi7 of the parallel flow divider section, then passes through the swing, blade, arm, P.T.O., boom swing, boom, bucket and P.T.O. 2 sections and returns to the hydraulic oil tank.

Therefore, since no pilot pressure is applied to port Pi8, the pilot oil at port PG of the swing motor does not flow into the brake chamber of the motor.

Thus, no pressure is applied to the brake chamber and the oil pressure switch is not activated.

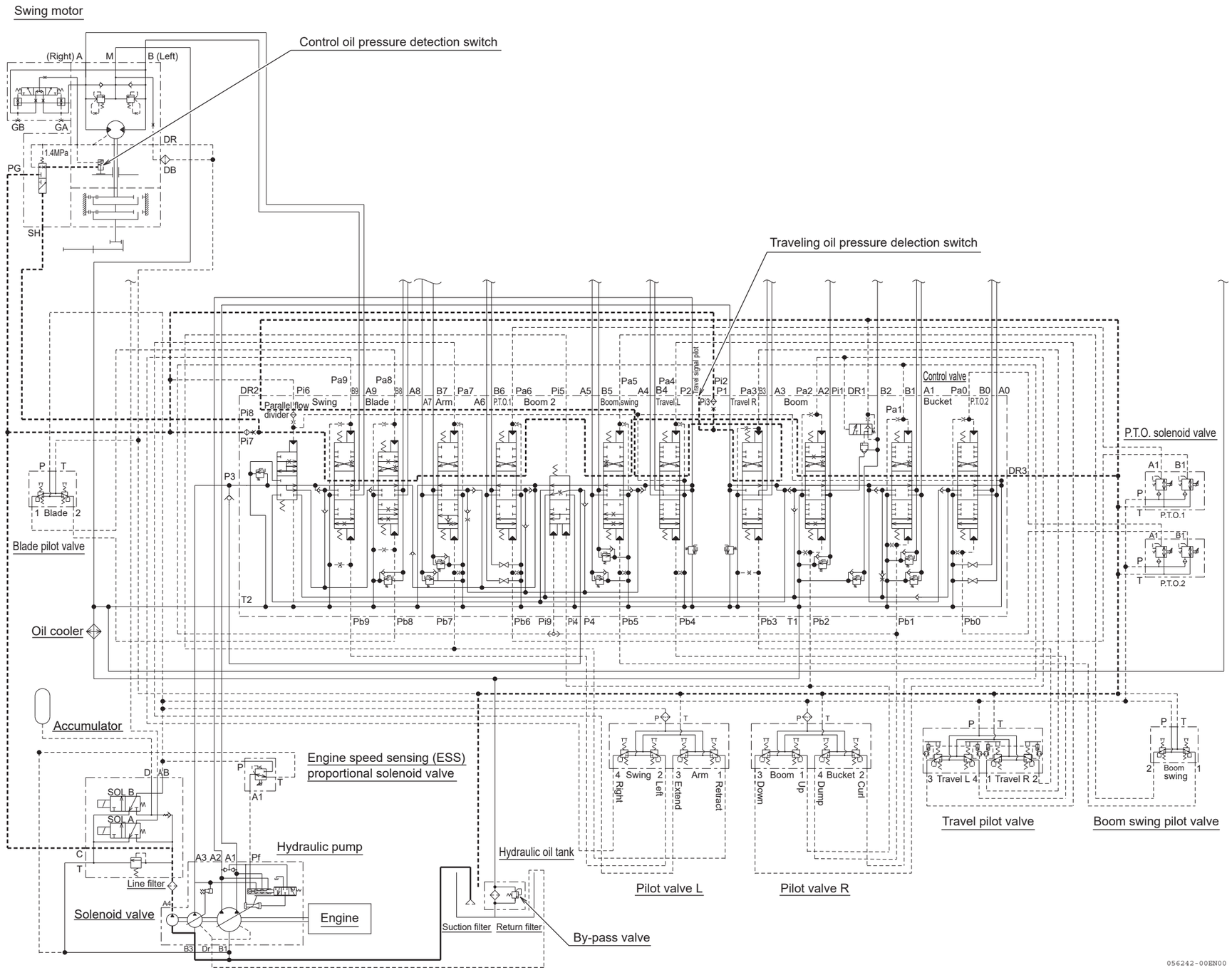
As described above, since the oil pressure switches are not activated, the auto deceleration function of the engine ECU is not deactivated.

2) During operation

(1) When the right or left control lever, blade lever, boom swing pedal or P.T.O. 1 or 2 switch is moved, the spool of the corresponding section is shifted and the pilot oil passage is blocked, thereby applying pilot pressure to port Pi8.

Since the pilot oil at port Pi8 flows into port SH of the swing motor and the pilot oil from port C of the cut-off valve flows into port PG of the swing motor, pilot pressure is applied to the mechanical brake chamber. This causes the oil pressure switch installed at the mechanical brake chamber to be activated, resulting in deactivation of the auto deceleration function.

(2) When the right or left travel lever is moved, the spool of the travel section is shifted and the pilot oil passage is blocked, thereby applying pilot pressure to port Pi3. This causes the oil pressure switch installed at port Pi3 to be activated and the deceleration release relay to operate, resulting in deactivation of the auto deceleration function



6-3 Hydraulic Pump

6-3-1 Structure and Theory of Operation

This pump assembly consists of two axial piston pumps K7SP36 and K7V28 and a gear pump. The structures and theory of operation of K7SP36 and K7V28 are described below.

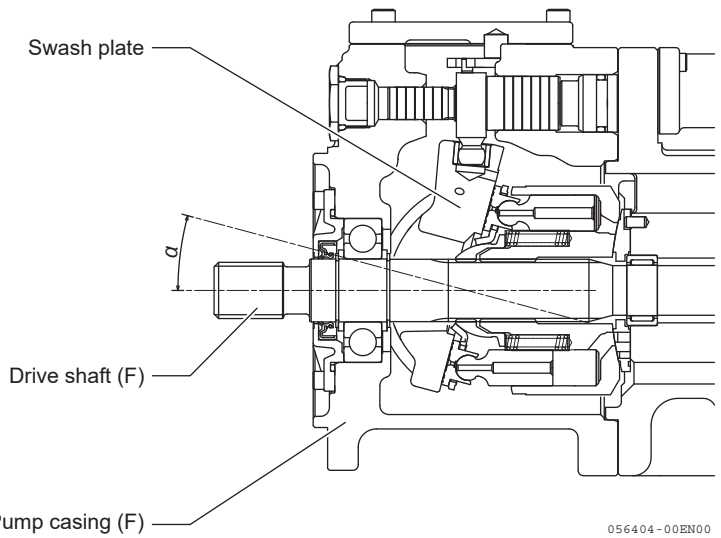
1. K7SP36

(1) Structure

This pump is a split-flow type double pump that uses the valve plate to split a flow of oil discharged from the single cylinder block into two flows to the two discharge ports, enabling feeding of oil in two independent discharge lines. This pump is mainly comprised of four parts: the rotary group that is a major part performing a rotary motion, the swash plate group that varies the flow rate, the valve block group that switches between oil suction and discharge and the regulator group that controls the tilting angle of the swash plate.

The rotary group consists of a drive shaft (F), a cylinder block, piston-shoe assemblies, a set plate, a spherical bush and cylinder springs. The drive shaft (F) is supported by bearings at both ends. The shoe is swaged over the end of the piston forming a spherical coupling to mitigate the thrust load generated by the load pressure. In addition, the shoe has a pocket to maintain a hydraulic balance so that it can lightly slide against the swash plate. The piston-shoe assemblies are pressed against the swash plate by the cylinder springs via the set plate and spherical bush. Similarly, the cylinder block is pressed against the valve plate by the cylinder springs.

The swash plate group consists of a swash plate, a tilting bush, a tilting pin, a servo piston and other components. The swash plate is supported against the arc-shaped surface of the pump casing (F) by the cylindrical portion formed on the side opposite the shoe sliding surface. The regulator controls the supply and discharge of hydraulic oil to and from the larger-diameter chamber of the servo piston to move the servo piston to the right or left and the spherical portion of the tilting pin coupled to the servo piston causes the swash plate to swing along the arc-shaped surface of the pump casing (F), thereby varying the tilting angle (α) of the swash plate, i.e. the flow rate of the pump.



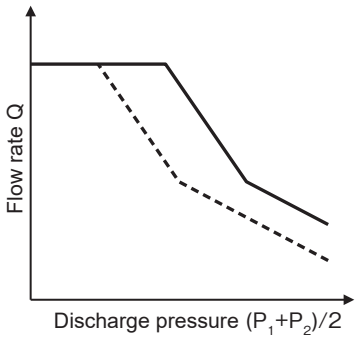
The valve block group consists of a valve block, a valve plate and a spring pin. The valve plate is installed on the valve block and serves to feed and collect hydraulic oil to and from the cylinder block. The valve plate is provided with one intake port and two discharge ports. The oil that has been sucked into the cylinder block through the intake port is divided into two flows by the two discharge ports of the valve plate and the two flows of oil flow through the valve block into the discharge hoses.

The regulator group comprises a hydraulic servomechanism that consists of a feedback lever, a compensator piston, springs, a sleeve, a spool and other components and is provided with position feedback linked to the servo piston.

(2) Theory of Operation

When the drive shaft is driven by a prime mover (electric motor, engine, etc), the cylinder block spline-coupled to the shaft is also rotated. With the swash plate tilted, the pistons arranged in the cylinder block reciprocate relative to the cylinders while rotating with the cylinder block. Looking at a single piston, the piston moves away from the valve plate during the first half (intake stroke) of a revolution of the cylinder block and moves towards the valve plate during the second half (discharge stroke) of the revolution.

The discharge pressures P1 and P2 of the pump are added together in the regulator group and the flow rate of the pump varies depending on the total pressure. Therefore, the input torque is maintained almost constant to achieve total horsepower control, thereby realizing prevention of overloading of the prime mover. The third pump K7V28 is connected to the rear end of this pump via the valve block. The load pressure P3 of the third pump and the power shift pressure Pf exerted on the pump from the outside allow power shift control to switch between the two different horsepower settings as shown in the figure below.



The discharge pressures P1 and P2 of the pump act on the stepped portion of the compensator piston. When the discharge pressures P1 and P2 rise, the spool is pushed and moved to the right to a point where the total force of the inner and outer springs and the hydraulic pressure balance each other. When the spool moves to the right, the oil passage to the larger-diameter chamber of the servo piston formed by the sleeve and the spool opens and oil flows into the chamber, causing the servo piston to be pushed to the left by the discharge pressure. The higher of the two pressures (P1 and P2) is selected and supplied as the discharge pressure by the check valve. The higher of the two pressures (P1 and P2) also always acts on the smaller-diameter chamber of the servo piston by the check valve. The swash plate and the servo piston are connected via the tilting pin, and when the servo piston is pushed to the left, the tilting angle of the swash plate becomes smaller, reducing the pump flow rate.

The movement of the servo piston is transmitted to the feedback lever via the feedback pin. The feedback lever rotates around the pin mounted on the pump casing (F) as the pivot and moves the sleeve to the right. The sleeve is moved to the right until the oil passage to the larger-diameter chamber of the servo piston is closed and stopped at the position when the oil passage is closed.

When the discharge pressures P1 and P2 decrease, the spool is pushed back by the springs and the oil passage to the larger-diameter chamber of the servo piston is connected to the low pressure side. Thus, the servo piston is moved to the right by the force from the smaller-diameter chamber and the tilting angle of the swash plate becomes larger, increasing the pump flow rate. This causes the feedback lever to rotate around the pin as the pivot to move the sleeve to the left until the oil passage formed by the spool and the sleeve is closed.

A brief description of power shift control is given below.
The load pressure P3 of the third pump K7V28 and the power shift pressure Pf act on the stepped portion and left end of the Pf piston respectively. When the load pressure P3 of the third pump K7V28 or the power shift pressure Pf increases, the spool is moved to the right by the compensator piston. As stated above, this causes the tilting angle of the swash plate to decrease, resulting in a decrease in the set horsepower. Conversely, when P3 or Pf decreases, the set horsepower increases.

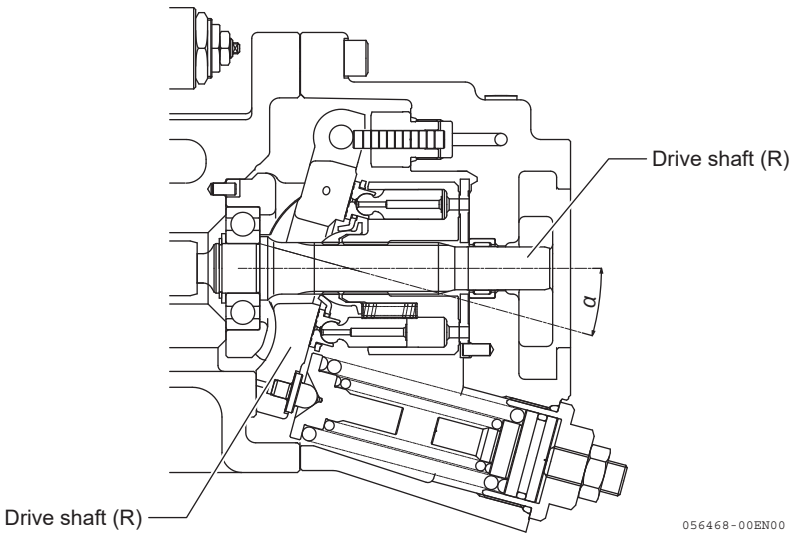
2. K7V28

(1) Structure

This pump is mainly comprised of four parts: the rotary group that is a major part performing a rotary motion, the swash plate group that varies the flow rate, the valve cover group that switches between oil suction and discharge and the regulator group that controls the tilting angle of the swash plate.

The rotary group consists of a drive shaft (R), a cylinder block, piston-shoe assemblies, a set plate, a spherical bush and cylinder springs. The drive shaft (R) is supported by bearings at both ends. The shoe is swaged over the end of the piston forming a spherical coupling to mitigate the thrust load generated by the load pressure. In addition, the shoe has a pocket to maintain a hydraulic balance so that it can lightly slide against the swash plate. The piston-shoe assemblies are pressed against the swash plate by the cylinder springs via the set plate and spherical bush so that they can smoothly slide on the swash plate. Similarly, the cylinder block is pressed against the valve plate by the cylinder springs.

The swash plate group consists of a swash plate, a swash plate support, a tilting rod, a stop ring, a fulcrum pin and other components. The swash plate is supported against the swash plate support by the cylindrical portion formed on the side opposite the shoe sliding surface. Since the discharge pressure of the pump acts on the pin, the swash plate is constantly subjected to a force generated by the pin in a direction of decreasing the tilting angle (α) of the swash plate. At the same time, the swash plate is constantly subjected to a force generated by the outer and inner springs located symmetrically in relation to the pin with respect to the drive shaft (R) in a direction of increasing the tilting angle (α) of the swash plate.



The valve cover group consists of a pump casing (R), a valve plate and spring pins. The valve plate with arc-shaped ports is installed on the pump casing (R) and serves to feed and collect hydraulic oil to and from the cylinder block. The hydraulic oil flows through the oil passage opened by the valve plate and the pump casing (R) into the discharge hoses.

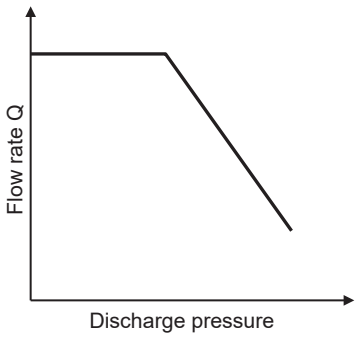
The regulator group consists of an outer spring, an inner spring, a spring seat, an adjusting ring, a hexagon socket set screw, a pin, a piston case and other components and controls the pump flow rate by applying a moment that acts to vary the tilting angle directly to the swash plate.

In addition, the K7V28 pump uses a common suction port shared with the gear pump installed on the rear end of the pump assembly.

(2) Theory of Operation

When the drive shaft (R) is driven by the drive shaft (F), the cylinder block spline-coupled to the shaft is also rotated. With the swash plate tilted, the pistons arranged in the cylinder block reciprocate relative to the cylinders while rotating with the cylinder block. Looking at a single piston, the piston moves away from the valve plate during the first half (intake stroke) of a revolution of the cylinder block and moves towards the valve plate during the second half (discharge stroke) of the revolution.

The discharge pressure P3 of the pump acts on the pin via the piston case and constantly pushes the pin via the tilting rod in a direction of decreasing the tilting angle of the swash plate. At the same time, the outer and inner springs located symmetrically in relation to the pin with respect to the drive shaft (R) always push the pin via the spring seat and the fulcrum pin in a direction of increasing the tilting angle of the swash plate.

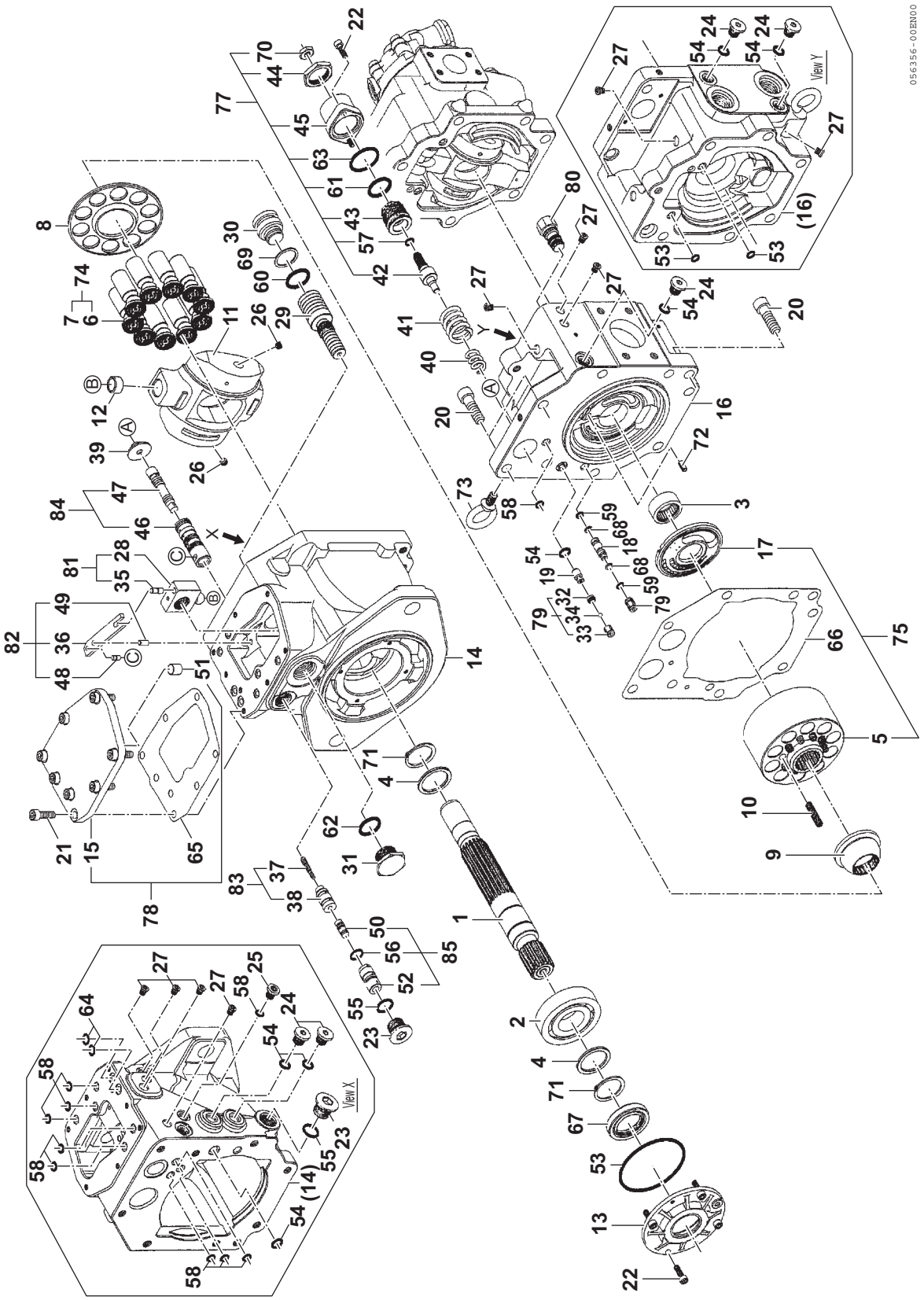


When the pump discharge pressure increases and the moment that acts on the swash plate generated by the pin pushed against the swash plate by the increased pressure becomes larger than the moment generated by the springs, the pin rotates the swash plate counterclockwise to decrease the tilting angle of the swash plate, resulting in a decrease in the pump flow rate. The swash plate stops at a position where the moment generated by the pin and the moment generated by the springs balance each other.

When the pump discharge pressure decreases and the moment generated by the springs to operate the swash plate becomes larger than the moment generated by the pin, the springs rotate the swash plate clockwise, resulting in an increase in the pump flow rate. The swash plate stops at a position where the moment generated by the pin and the moment generated by the springs balance each other.

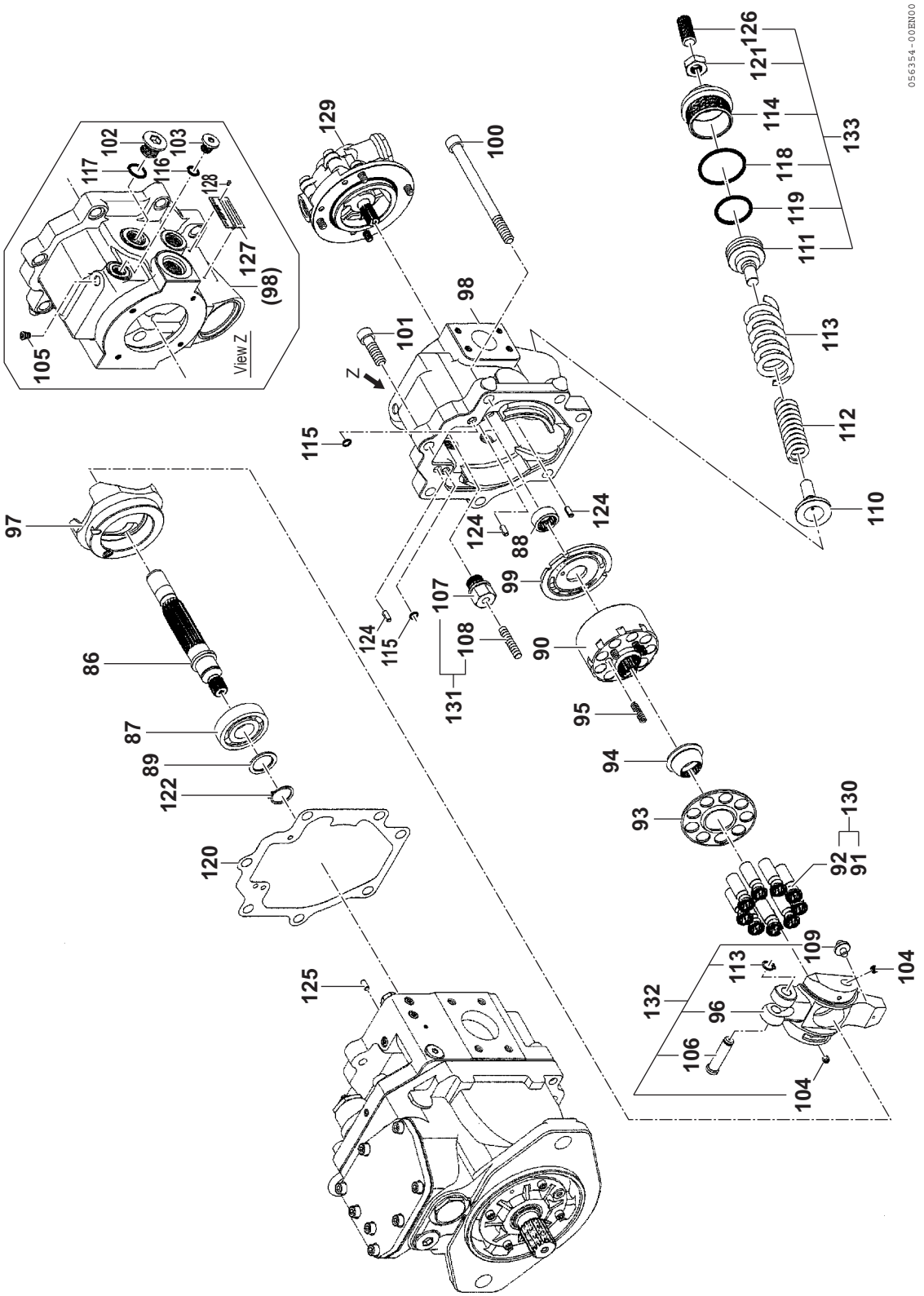
In this way, the pump performs horsepower control to maintain the input torque almost constant, thereby preventing the prime mover from overloading.

Exploded view and parts comprised



6. HYDRAULIC EQUIPMENT

No.	Part	Q'ty	No.	Part	Q'ty
1	Drive shaft (F)	1	44	Lock nut (C)	1
2	Ball bearing	1	45	Spring cover	1
3	Needle bearing	1	46	Sleeve	1
4	Bearing spacer	2	47	Spool	1
5	Cylinder block	1	48	Pin	1
6	Piston	10	49	Pin	1
7	Shoe	10	50	Pf piston	1
8	Set plate	1	51	Pin	1
9	Spherical bush	1	52	Pf piston case	1
10	Cylinder spring	10	53	O-ring	1
11	Swash plate	1	54	O-ring	8
12	Tilting bush	1	55	O-ring	2
13	Seal cover (F)	1	56	O-ring	1
14	Pump casing (F)	1	57	O-ring	1
15	Top cover	1	58	O-ring	10
16	Valve block	1	59	O-ring	2
17	Valve plate	1	60	O-ring	1
18	Seal pipe	1	61	O-ring	1
19	Spacer	1	62	O-ring	1
20	Hexagon socket head bolt	3	63	O-ring	1
21	Hexagon socket head bolt	8	64	O-ring	2
22	Hexagon socket head bolt	6	65	Sheet packing T	1
23	Plug	2	66	Sheet packing F	1
24	Plug	6	67	Oil seal	1
25	Plug	1	68	Back-up ring	2
26	Plug	2	69	Back-up ring	1
27	Plug	9	70	Hexagon nut	1
28	Tilting pin	1	71	Snap ring	2
29	Servo piston	1	72	Spring pin	1
30	Stopper (L)	1	73	Eye bolt	2
31	Plug	1	74	Piston ASSY	1
32	Seat	2	75	Cylinder ASSY	1
33	Stopper	2	76	Swash plate ASSY	1
34	Steel ball	2	77	Spring cover ASSY	1
35	Feedback pin	1	78	Top cover ASSY	1
36	Feedback lever	1	79	Check valve 1 ASSY	2
37	Compensator piston	1	80	Plug ASSY	1
38	Piston case	1	81	Tilling pin ASSY	1
39	Spring seat (C)	1	82	Feedback lever ASSY	1
40	Inner spring	1	83	Compensator piston ASSY	1
41	Outer spring	1	84	Spool ASSY	1
42	Adjust stem (C)	1	85	Pf piston ASSY	1
43	Adjust screw (C)	1			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6. HYDRAULIC EQUIPMENT

No.	Part	Q'ty	No.	Part	Q'ty
86	Drive shaft (R)	1	110	Spring seat	1
87	Ball bearing	1	111	Adjusting ring	1
88	Needle bearing	1	112	Inner spring	1
89	Bearing spacer	1	113	Outer spring	1
90	Cylinder block	1	114	Plug	1
91	Piston	9	115	O-ring	4
92	Shoe	9	116	O-ring	1
93	Set plate	1	117	O-ring	1
94	Spherical bush	1	118	O-ring	1
95	Cylinder spring	6	119	O-ring	1
96	Swash plate	1	120	Sheet packing R	1
97	Swash plate support	1	121	Hexagon nut	1
98	Pump casing (R)	1	122	Snap ring	1
99	Valve plate	1	123	Snap ring	1
100	Hexagon socket head bolt	6	124	Spring pin	3
101	Hexagon socket head bolt	1	125	Pin	1
102	Plug	1	126	Set screw	1
103	Plug	1	127	Name plate	1
104	Plug	2	128	Pin	2
105	Plug	1	129	Gear pump	1
106	Tilling rod	1	130	Piston ASSY	1
107	Piston case	1	131	Cylinder ASSY	1
108	Pin	1	132	Swash plate ASSY	1
109	Fulcrum pin	1	133	Plug ASSY	1

6-3-2 Troubleshooting

General Precautions

Countermeasures to be taken against abnormalities detected during the operation of the axial piston pumps are described below.

The following general precautions should be followed.

- Check the conditions that caused the abnormality before starting work.
  Before starting work, check hydraulic components such as the pumps, motors and valves, the hydraulic circuit, the electrical system or other relevant components based on the abnormal state and the nature of the abnormality and find out possible causes of the abnormality.
- Read the service manual carefully before proceeding with disassembly and then follow the correct disassembling procedures.
- Be careful not to allow foreign substances such as dust to enter the pump even during partial disassembly.
- Handle all components carefully to prevent damage because they are high-precision finished components.

Checking for Pump Abnormalities

Since the pump assembly consists of many components such as built-in regulators as well as a gear pump attached, it is difficult to identify causes of failures. Investigation of the following items will allow identification of defective components.

- Inspection of filter elements and drained oil
  Inspect filter elements for excessive amounts of impurities. Although small amounts of metal particles produced due to wear of the shoes and cylinders are acceptable, large amounts of metal particles in the filters present the possibility of components such as shoes or cylinders being damaged.
  Also, check the oil drained in the pump casing for metal particles.
- Inspection of the pump for abnormal vibration and noise.
  Inspect the pump for abnormal vibration and noise. Abnormal vibration or noise presents the possibility of cavitation or the internal parts of the pump being damaged.
- Interchanging the discharge hoses
  Interchange the discharge hoses for pumps P1 and P2 to check whether pump P1 or pimp P2 is defective or whether the circuit or any of the components downstream of the pump is defective.
- Measurement of pressure at relevant points
  If a control-related problem occurs, measure the pressure at relevant points before disassembling the pump for inspection.

Overloading of prime mover

Cause	Corrective Measures	Remarks
Tilt control failure due to seizure or breakage of pump internal parts	Replace damaged parts.	Check filters and drained oil for excessive amounts of metal wear particles.
Incorrect connection of the hose to regulator port Pf	Connect the correct hose to the port.	-
Malfunction of the attached pump (gear pump)	If the gear pump is defective, replace it.	-

Abnormal decrease in pump flow rate/Failure of discharge pressure to rise

Cause	Corrective Measures	Remarks
Malfunction of the regulator group	Inspect and repair the regulator group (by disassembling it and clean the parts).	-
Seizure or breakage of pump internal parts	Replace damaged parts.	Check filters and drained oil.
Incorrect hose connections	Connect hoses correctly.	-

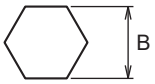
Abnormal noise and vibration

Cause	Corrective Measures	Remarks
Cavitation	Take measures to prevent cavitation. Measure the intake pressure and check whether the hydraulic oil has become cloudy.	• The intake pressure is low. • Air is sucked from the suction hose. • The resistance of the suction hose is high.
Damage to shoe swaged portions	Replace the damaged piston-shoe assemblies, swash plate and related parts.	-
Cracks in cylinders	Replace the cracked cylinders.	-
Incorrect pump installation	Install the pump correctly.	-
Hunting of the regulator	Repair the regulator.	-
Malfunction of the attached pump (gear pump)	Replace the gear pump.	-

6-3-3 Disassembly and Reassembly

1. Required tools

The tools necessary to disassemble/reassemble K7SP36/K7V28 pump are shown in the following list.



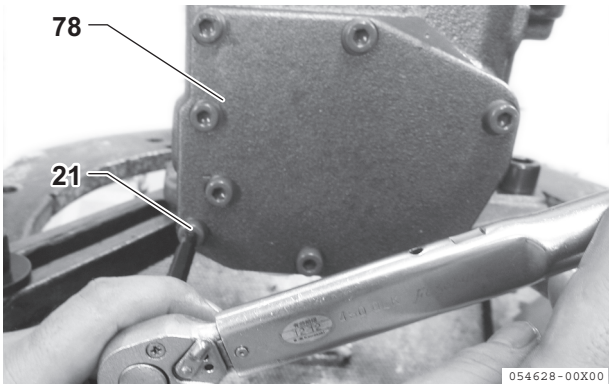
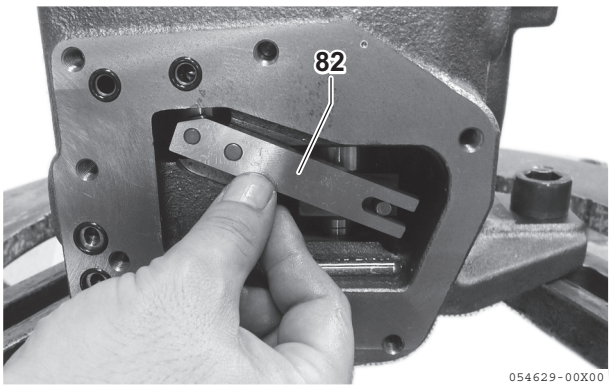
Tool name and size		○: Necessary tool	Part name			
		Pump model				
Names	B	K7SP36/K7V28	Hexagon socket head cap screw	Pressure plug (Taper thread)	ROH plug VP plug (Parallel thread)	Hexagon socket head set screw
Allen wrench	4	○	M5	Rc 1/16	-	M8
	5	○	M6	Rc 1/8	G 1/8	M10
	6	○	M8	Rc 1/4	G 1/4	M12, M14
	8	○	M10	Rc 3/8	G 3/8	M16, M18
	10	○	M12	Rc 1/2	G 1/2	M20
	12	○	M14	-	G 3/4	-
	14	○	M16, M18	Rc 3/4	-	-
Double ring spanner	17	○	-	-	-	M10
	19	○	M12	-	G 1/4	Plug ass'y
	24	○	M16	-	-	Piston case
	36	○	-	-	G 3/4	Plug, Lock nut (C)
Adjustable angle wrench	-	○	Medium size 1 set, Smallsize 1 set			
Screwdriver	-	○	Flat-blade screwdriver (medium size) 2 pieces			
Hammer	-	○	Plastic hammer 1 piece			
Plier	-	○	TSR-160 for stop ring TSR-160 for snap ring			
Steel bar	-	○	Steel bar for Key 10 × 8 × 200 or similar dimensions			
Torque wrench	-	○	Capable of tightening with the specified torques			
Torx Plus	30IP	○	Exclusive tool of MH plug M7 × O.75			

2. Disassembly

Procedure	
(1) Decide where to perform disassembly of the hydraulic pump. ***Notes:*** *Choose a clean place.* *Put a rubber plate, cloth or any cover on the workbench to prevent parts from being damaged by hitting them on the workbench.*	

(2) Remove dust, rust or other foreign matter from the pump surface with wash oil or the like.	

(3) Remove the drain port plugs **23** and **102** and drain oil from the pump casing (F) **14** and pump casing (R) **98**. ***Note:*** *Drain oil through the respective drain ports of the main pump and third pump.*	

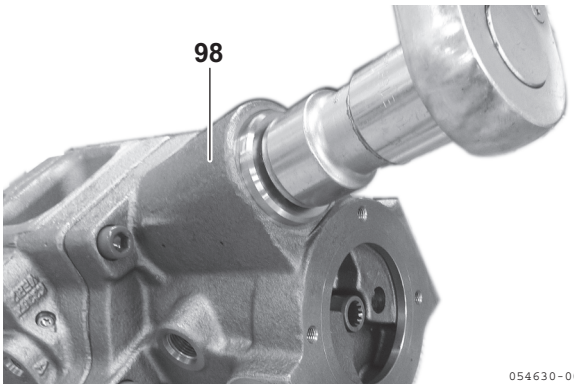
Procedure	
(4) Remove the hexagon socket head bolts **21**, the top cover assembly **78** and the sheet packing T **65**. Then take the feedback lever assembly **82** out of the pump casing (F) **14**. ***Note:*** *Since the pump can be held in a stable position and disassembled easily by placing it with its top cover side down, the top cover assembly and the feedback lever assembly should be removed in advance.*	 

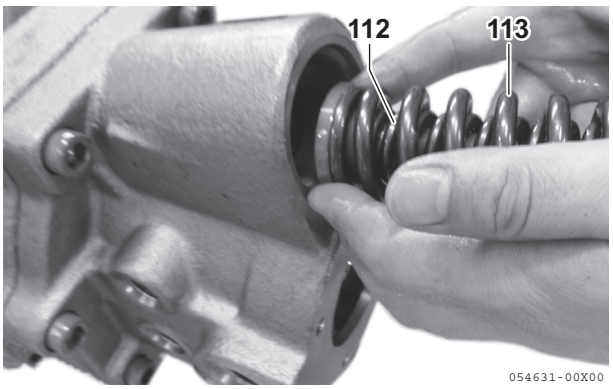
(5) <Disassembly of K7V28> Place the pump with its top cover side down horizontally on the workbench, remove the hexagon socket head bolts with flange and the gear pump **129**. ***Note:*** *When placing the pump with its top cover side down, be sure to put a rubber plate or any cover on the workbench and take care not to damage the mounting surface.*	

Procedure

(6) Remove the plug assembly **133** with the adjusting ring **111** installed, and then take the outer spring **113**, the inner spring **112** and the spring seat **110** out of the third pump.

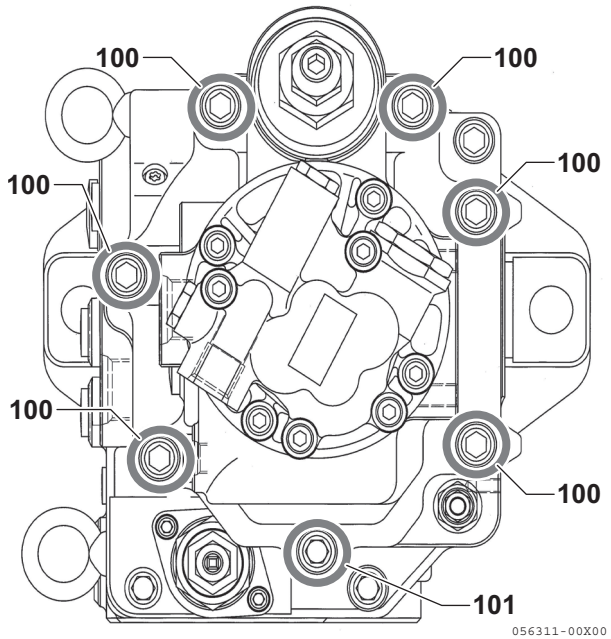
Note:
*Do not loosen the hexagon nut **121** installed on the plug **114**, or the set horsepower of the regulator (for K7V28) will be changed.*

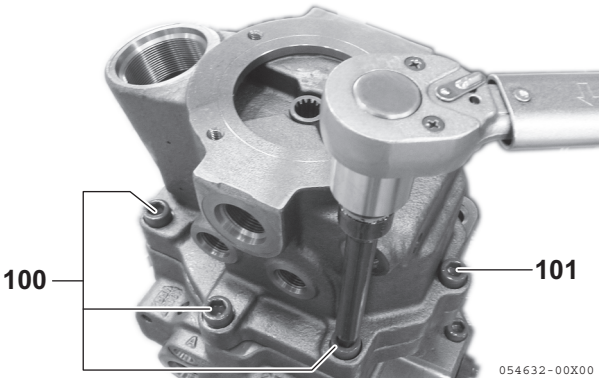


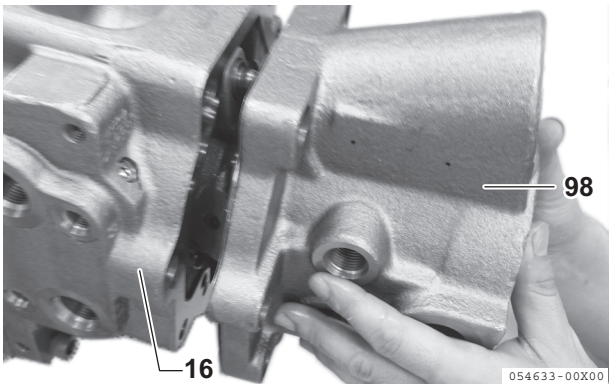
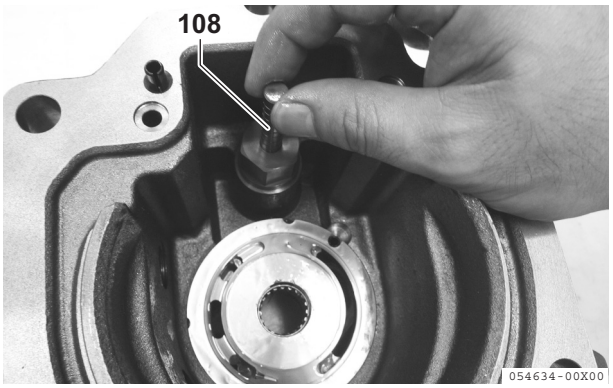
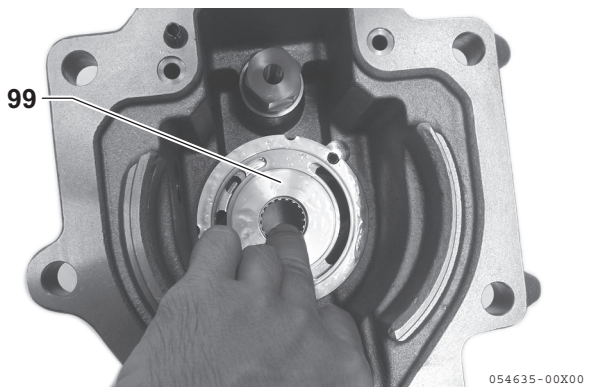
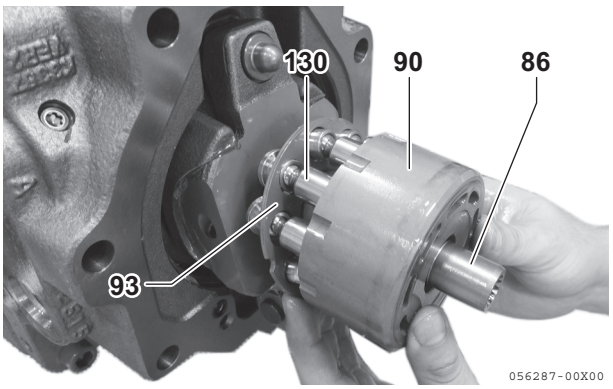


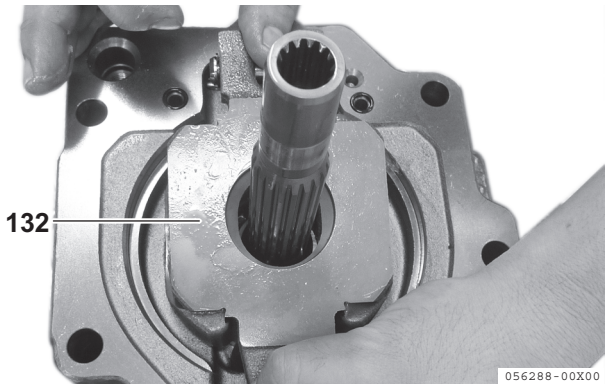
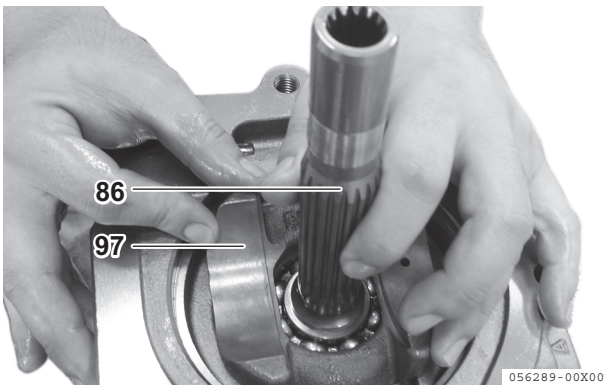
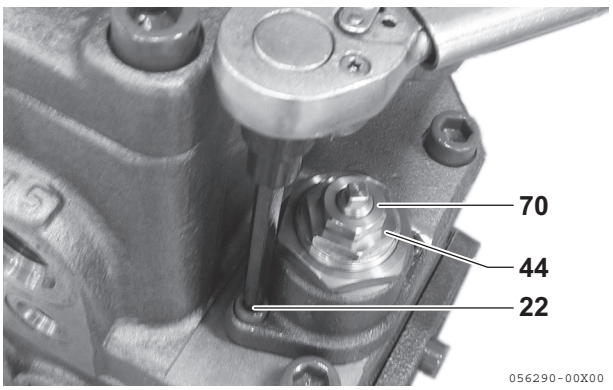
(7) Remove the hexagon socket head bolts **100** and **101** coupling the pump casing (R) **98**, the valve block **16** and the pump casing (F) **14**.

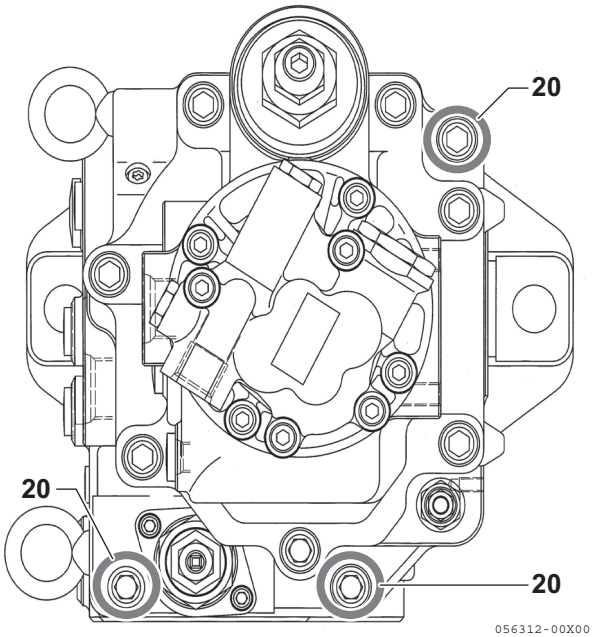
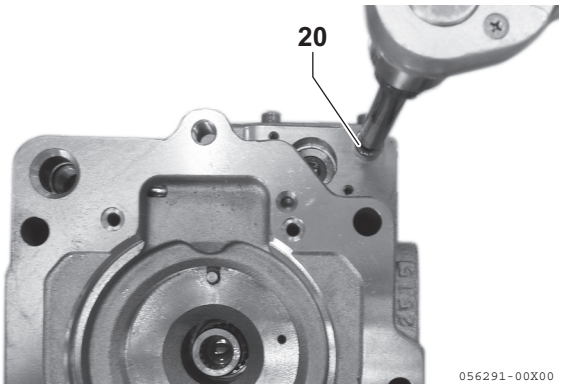
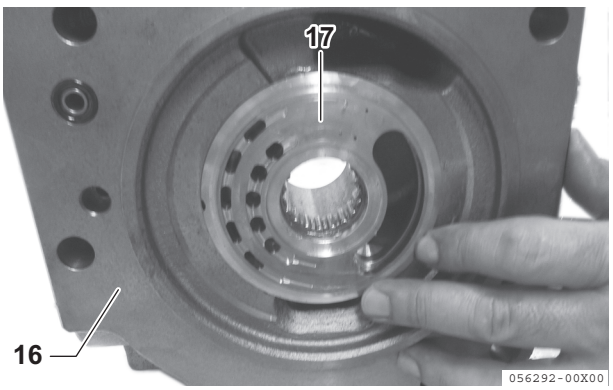
Note:
*To remove them from the third pump, remove the seven hexagon socket head bolts **100** and **101** indicated by circles in the figure below.*

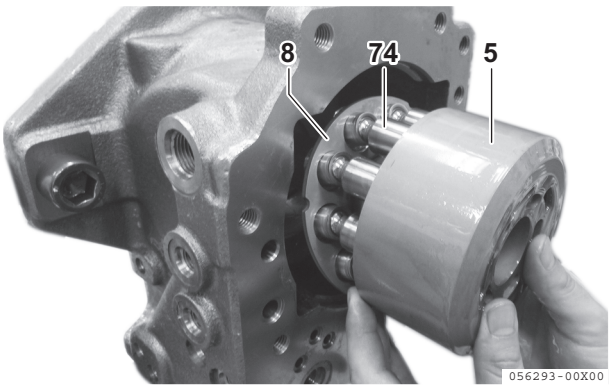
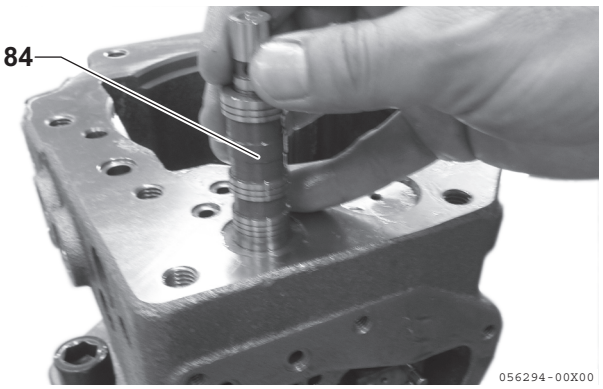
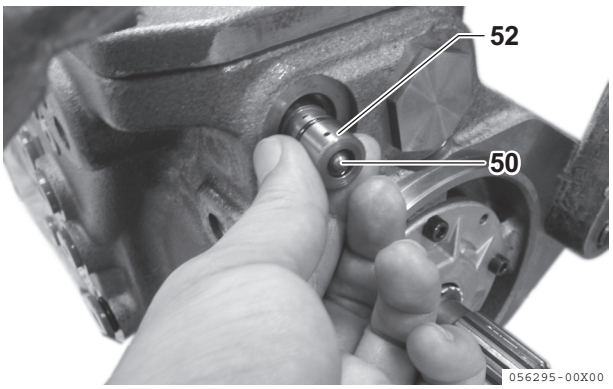
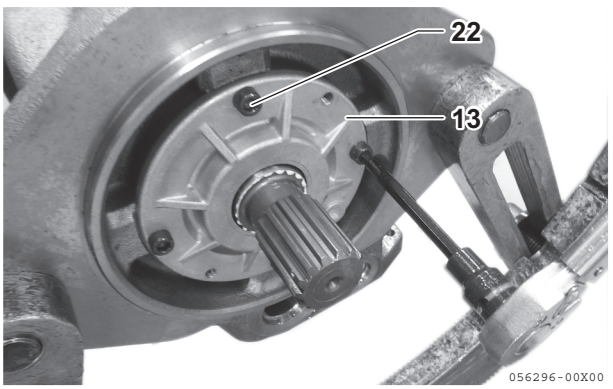


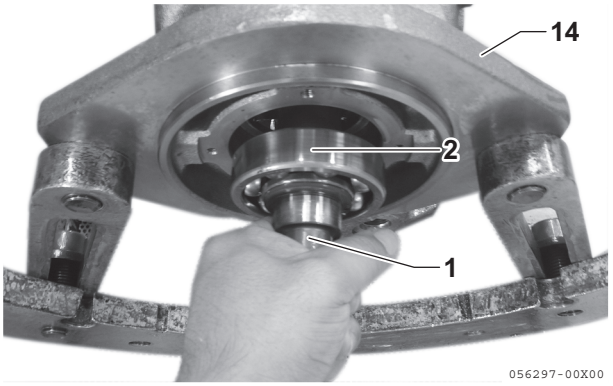
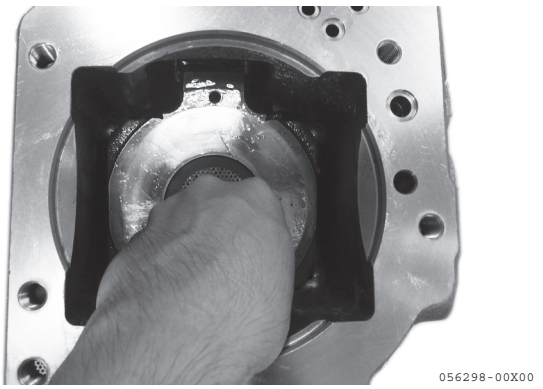


Procedure	
(8) Remove the pump casing (R) **98** from the valve block **16** pulling straight along the center of the drive shaft. ***Notes:*** • *When removing the pump casing (R) **98**, note that the valve plate **99**, the sheet packing R **120** or the pin **108** might fall off.* • *Take care not to damage the needle bearing **88**.*	
(9) Take the pin **108** and the valve plate **99** of the third pump out of the pump casing (R) **98**. Then remove the sheet packing (R) **120**. ***Notes:*** • *During the procedure of the step (8), the pin, the valve plate and the sheet packing (R) **120** might come off.* • *Be careful not to damage the sliding surface and mounting surface of the valve plate.*	 
(10) Remove the cylinder block **90** together with the piston assemblies **130**, the set plate **93**, the spherical bush **94** and the cylinder springs **95** pulling the cylinder block straight along the drive shaft (R) **86**. ***Note:*** *Be careful not to damage the sliding surfaces of the cylinder block, spherical bush, shoes, swash plate, etc.*	

Procedure	
(11) Remove the swash plate assembly **132** from the swash plate support **97**. ***Note:*** *When removing the swash plate assembly, be careful not to damage the needle bearing rolling contact surface of the drive shaft (R) and the sliding surface of the swash plate.*	
(12) Remove the swash plate support **97** together with the drive shaft (R) **86** and the ball bearing **87** from the valve block **16**.	
(13) Remove the plug assembly **80** from the valve block **16**.	
(14) <Disassembly of K7SP36> Remove the hexagon socket head bolts **22** and the spring cover assembly **77** from the valve block **16**, and then take out the outer spring **41**, the inner spring **40** and the spring seat (C) **39**. ***Notes:*** • *Do not loosen the lock nut (C) **44** and hexagon nut **70** of the spring cover assembly, or the set horsepower of the main pump will be changed.* • *Sufficient care must be exercised during disassembly and reassembly as the regulator group consists of high precision parts.*	

Procedure	
(15) Loosen the three hexagon socket head bolts **20** (indicated by circles in the figure below) and remove the valve block **16** from the pump casing (F) **14**. Then remove the sheet packing F **66**. ***Note:*** *When removing the valve block, be careful not to damage the needle bearing rolling contact surface of the drive shaft (F) **1**.*  056312-00X00	 056291-00X00
(16) Remove the valve plate **17** of the main pump from the valve block **16**. ***Note:*** *During the procedure of the step (15), the valve plate might come off.*	 056292-00X00

Procedure	
(17) Remove the cylinder block **5** together with the piston assemblies **74**, the set plate **8**, the spherical bush **9** and the cylinder springs **10** pulling the cylinder block straight along the drive shaft (F) **1**. Also remove the spool assembly **84**. ***Note:*** *Be careful not to damage the sliding surfaces of the cylinder block, spherical bush, shoes, swash plate, etc.*	 
(18) Remove the ROH plug **23** and take out the Pf piston case **52**, the Pf piston **50**, the piston case **38** and the compensator piston **37**.	
(19) Loosen the hexagon socket head bolts **22** and remove the seal cover (F) **13**. ***Notes:*** • *Be careful not to damage the oil seal installed on the seal cover (F) when removing the seal cover (F).* • *The seal cover (F) can be removed easily by screwing the bolts into the two threaded holes in the seal cover (F) evenly.*	

Procedure	
(20) Tapping the end face of the drive shaft (F) **1** with a plastic hammer or any similar tool, take the drive shaft (F) **1** and the ball bearing **2** out of the pump casing (F) **14**.	
(21) Pull out the swash plate **11** from the tilting pin **28** and take it out of the pump casing (F) **14**. ***Note:*** *Be careful not to damage the shoe sliding surface of the swash plate and the arc-shaped supporting portions of the swash plate and pump casing (F).*	
(22) As necessary, remove the stopper (L) **30**, the servo piston **29**, the tilting pin **28** and the plug **31** from the pump casing (F) **14**. ***Notes:*** • *When removing the tilting pin, be sure to use a jig to prevent damage to the tilting pin head.* • *Since an adhesive is applied to the threaded portions of the tilting pin and servo piston, take care not to damage the servo piston when removing the tilting pin.* • *Be careful not to damage the both end faces of the stopper (L).*	
(23) As necessary, remove the needle bearing **3***1 from the valve block **16**. ***Note:*** **1. Do not remove the needle bearing unless it needs to be replaced when it has reached the end of its life.*	

Procedure	
(24) As necessary, remove the piston case **107** and the needle bearing **88**[2] from the pump casing (R) **98**. ***Note:*** **2. Do not remove the needle bearing unless it needs to be replaced when it has reached the end of its life.*	

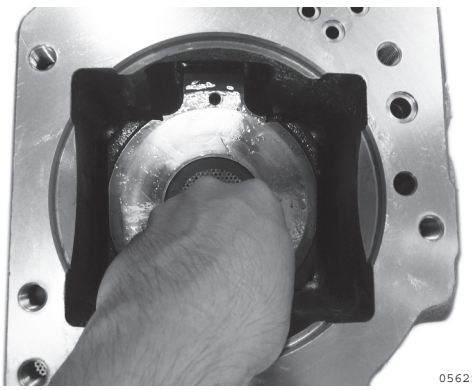
(25) Remove the check valve 1 assembly **79**, the seal pipe **18** and the spacer **19** from the pump casing (F) **14**. This is the end of disassembly procedures.	

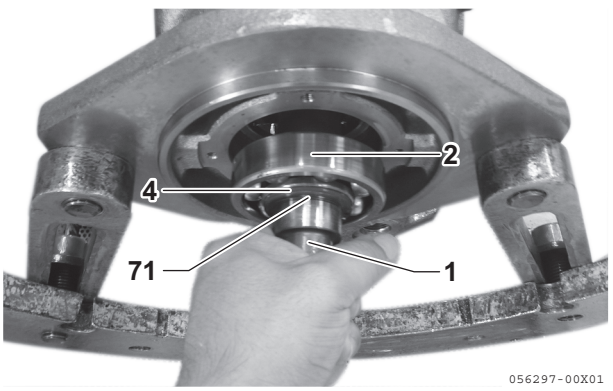
3. Reassembly

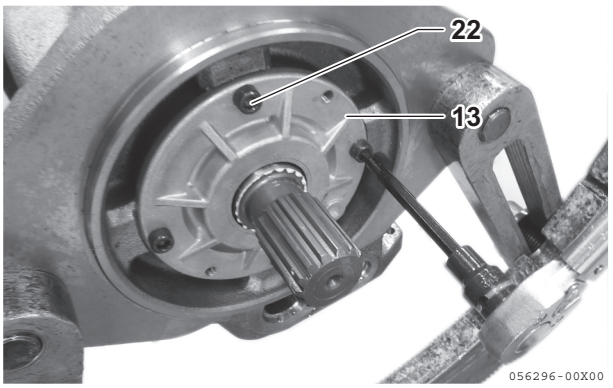
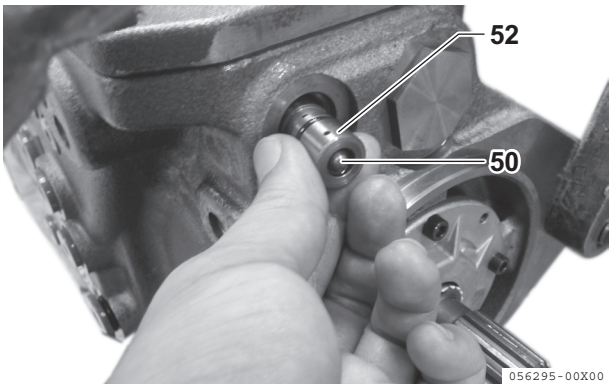
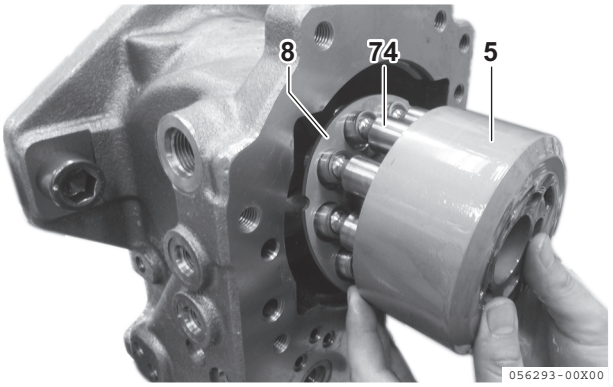
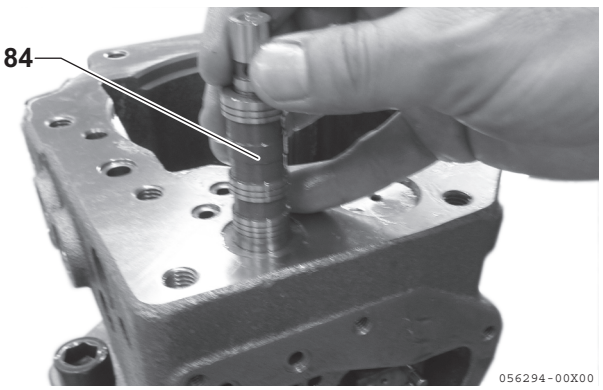
Basically, reassemble the hydraulic pump in the reverse order of the disassembly procedure. Pay attention to the following items when performing reassembly.

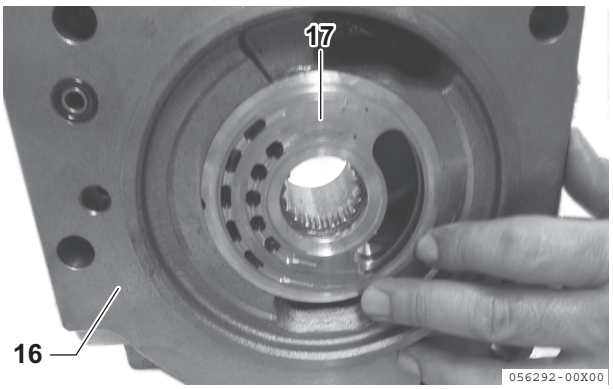
Notes:

- *Be sure to repair parts if damaged in disassembly and prepare replacement parts in advance.*
- *Before assembly, clean all parts well with wash oil, and then dry them by air blow.*
- *Be sure to apply clean hydraulic oil to sliding portions and bearings.*
- *In principle, replace all seal parts such as O-rings, oil seals and sheet packings with new ones.*
- *Tighten mounting bolts and plugs for each part to the specified torques shown in "Service Standard" with a torque wrench.*

Procedure	
(1) <Reassembly of K7SP36> Install the swash plate **11** into the pump casing (F) **14** properly with its tilting bush **12** fitted onto the tilting pin **28**. ***Notes:*** • *Install the check valve 1 assembly, the seal pipe and the spacer into the pump casing (F) in advance taking care of installation direction and fall of parts.* • *If the stopper (L), the servo piston, the tilting pin and the plug have been removed, install them into the pump casing (F) in advance.* • *When engaging the tilting pin with the servo piston, use a jig to prevent the tilting pin from rotating by couple of force. Apply Three Bond #1305N to its threaded portion and tighten it to the specified torque of 177 ft•lbf (240 N•m). After tightening the tilting pin, check that the servo piston can be smoothly moved.* • *When installing the swash plate, apply grease to the sliding surfaces of the swash plate and pump casing (F), so that the drive shaft (F) can be installed easily.*	 056298-00X00

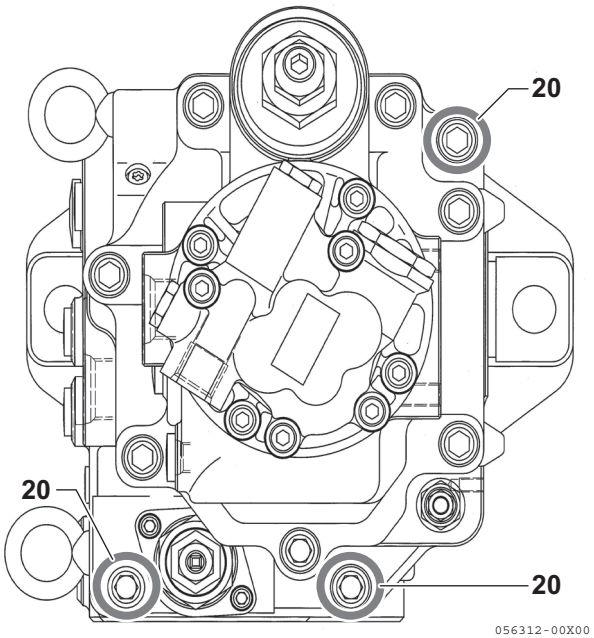
(2) Install the drive shaft (F) **1** with the ball bearing **2**, the bearing spacer **4** and the snap ring **71** assembled into the pump casing (F). ***Notes:*** • *Do not tap the drive shaft (F) **1** with a hammer or a similar tool.* • *Use a plastic hammer to put the ball bearing in the pump casing (F) by tapping the outer race of the ball bearing, and then use a steel bar or a similar tool to install it securely in the pump casing.*	 056297-00X01

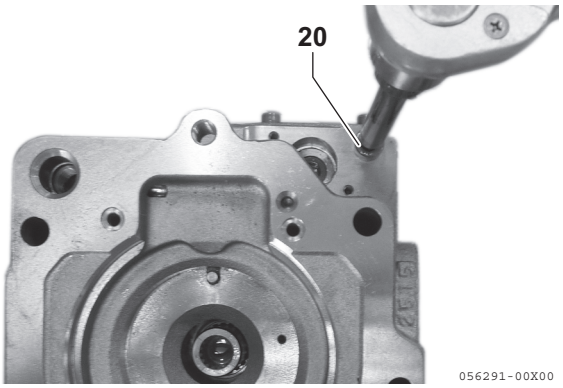
Procedure	
(3) Install the seal cover (F) **13** onto the pump casing (F) **14** and tighten the hexagon socket head bolts **22**. ***Notes:*** • *Be sure to properly install the oil seal **67** onto the seal cover (F) in advance.* • *When installing the seal cover (F) onto the pump casing (F), be careful not to damage the oil seal, or oil leaks may be caused after reassembly.*	
(4) Install the compensator piston **37**, the piston case **38**, the Pf piston case **52** and the Pf piston **50** into the pump casing (F) and then install the ROH plug **24**. ***Note:*** *When installing the Pf piston case, apply grease thinly to the O-ring on the outside of the Pf piston case or take any other measures to prevent the O-ring from breakage.*	
(5) Assemble the cylinder block **5**, the piston assemblies **74**, the set plate **8**, the spherical bush **9** and the cylinder springs **10**. Install them to the drive shaft (F) **1** aligning the phases of the spline teeth of the spherical bush and cylinder block. Also install the spool assembly **84**. ***Notes:*** *Be careful not to damage the sliding surfaces of the cylinder block, spherical bush, shoes, swash plate, etc.* *Be sure to install the spool assembly **84** with its hole for the pin **48** facing up.*	 

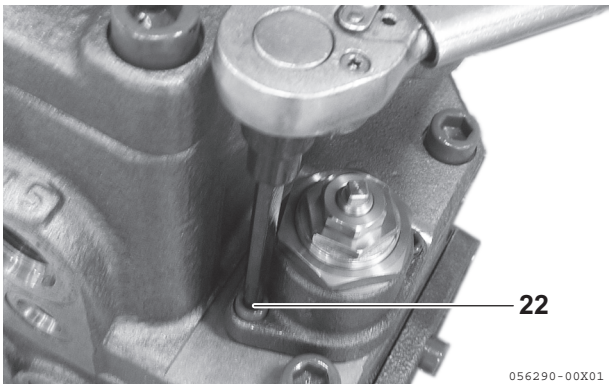
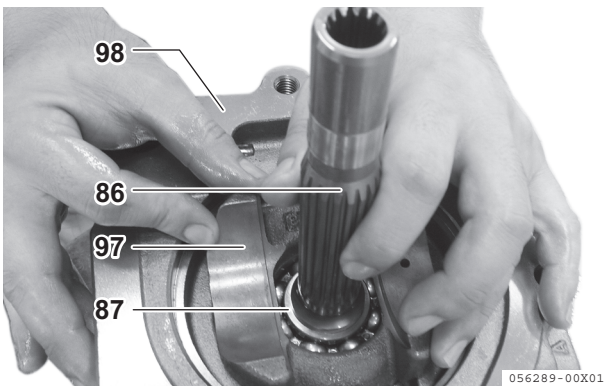
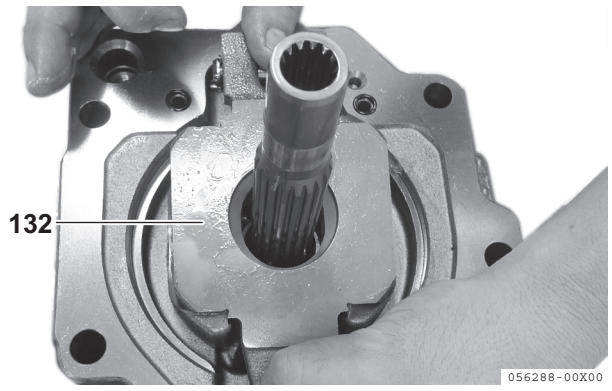
Procedure	
(6) Install the valve plate **17** on the pump casing (F) side of the valve block **16** fitting the spring pin **72** with the groove in the valve plate. ***Notes:*** • *Apply grease to the mating surfaces of the valve block and valve plate to prevent the valve plate from falling off.* • *Take care not to mistake the intake and discharge port sides of the valve plate.*	

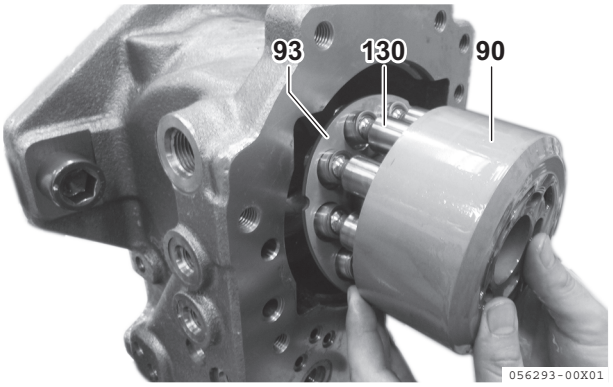
(7) Install the sheet packing F **66** on the mating surface properly and tighten the hexagon socket head bolts **20** (indicated by circles in the figure below) to couple the pump casing (F) with the valve block.

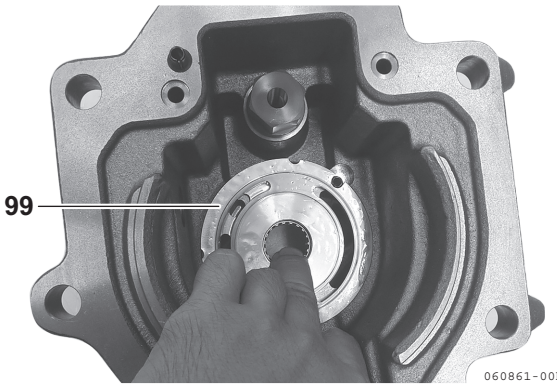
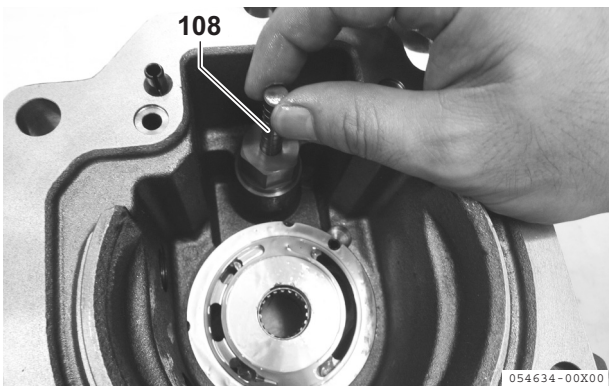
Note:
When installing the valve block, be careful not to damage the needle bearing rolling contact surface of the drive shaft (F) and the sheet packing (F).

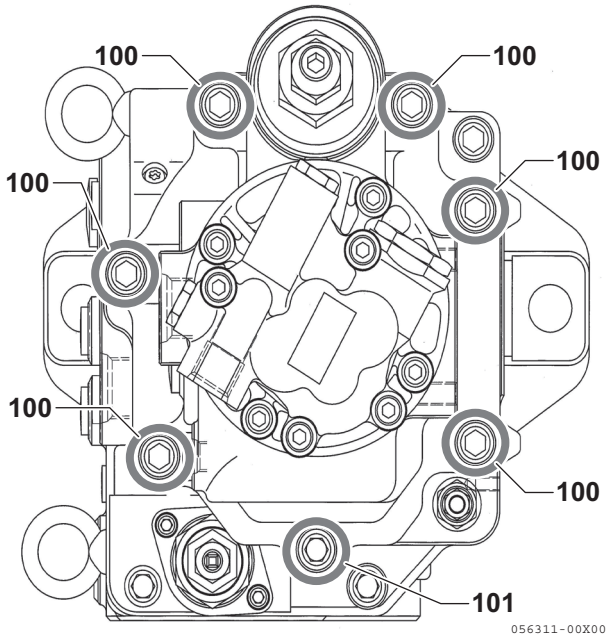
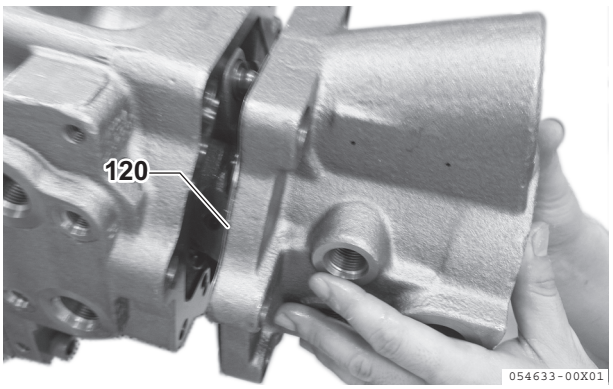
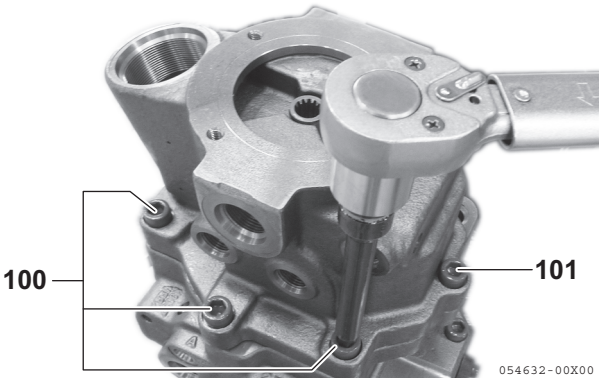
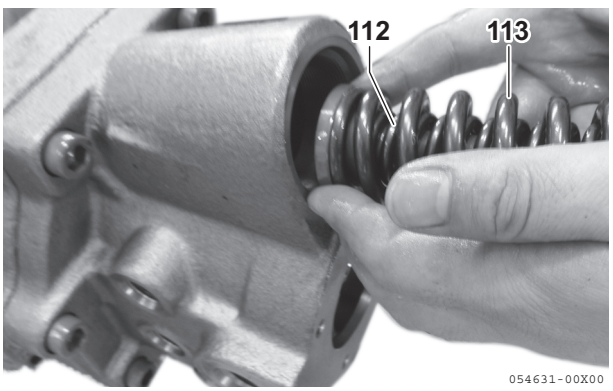
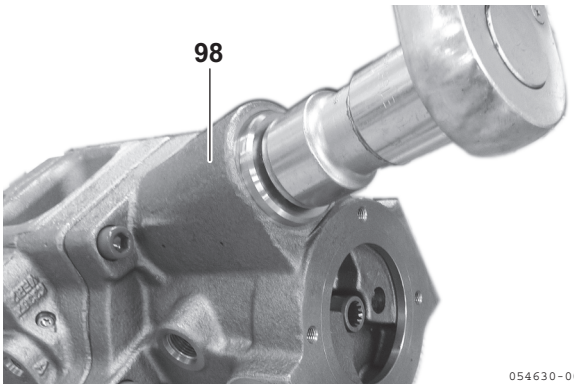




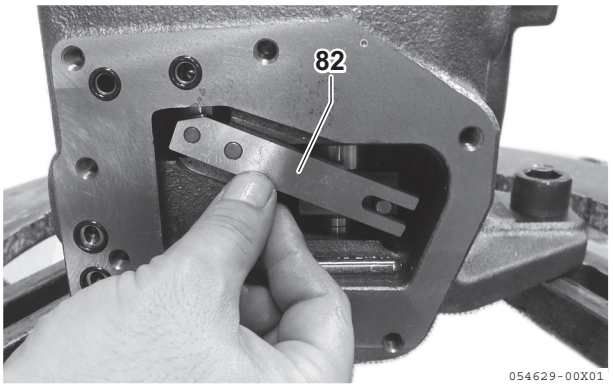
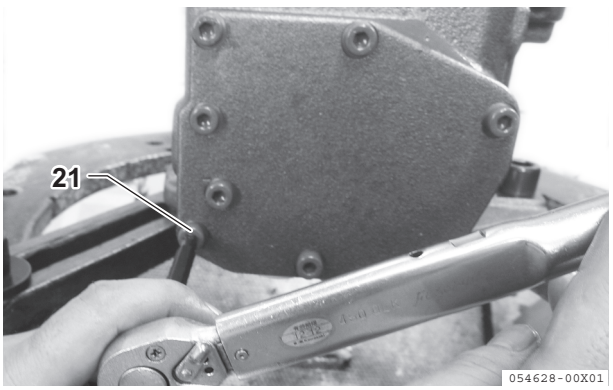
Procedure	
(8) Install the outer spring **41**, the inner spring **40** and the spring seat (C) **39** into the pump casing (F). Then install the spring cover assembly **77** onto the valve block and tighten the hexagon socket head bolts **22**.	
(9) Install the plug assembly **80** to the valve block **16**.	
(10) <Reassembly of K7V28> Install the drive shaft (R) **86** with the ball bearing **87**, the bearing spacer **89** and the snap ring **122** assembled and the swash plate support **97** into the valve block from the pump casing (R) **98** side by tapping the swash plate support evenly with a plastic hammer. ***Note:*** *When installing the swash plate support, be careful not to damage the arc-shaped surface of the swash plate support and the drive shaft (R).*	
(11) Install the swash plate assembly **132** onto the swash plate support. ***Notes:*** • *Apply grease to the arc-shaped surfaces of the swash plate support and swash plate to prevent the swash plate from falling off.* • *Take care of the installation direction of the swash plate. (Refer to the assembly cross section drawing.)*	

Procedure	
(12) Assemble the cylinder block **90**, the piston assemblies **130**, the set plate **93**, the spherical bush **94** and the cylinder springs **95**. Then install them to the drive shaft (R) aligning the phases of the spline teeth of the spherical bush and cylinder block with each other. ***Note:*** *Be careful not to damage the sliding surfaces of the cylinder block, spherical bush, shoes, swash plate, etc.*	

(13) Install the valve plate **99** into the pump casing (R) **98** fitting the spring pins **124** with the groove in the valve plate. Then install the pin **108** into the piston case. ***Notes:*** • *Apply grease to the mating surfaces of the pump casing (R) and valve plate to prevent the valve plate from falling off.* • *Take care not to mistake the intake and discharge port sides of the valve plate.* • *If the piston case **107** has been removed, install the piston case to the pump casing (R) in advance.*	 

Procedure	
(14) Install the sheet packing R **120** on the mating surface property and fasten the pump casing (R) on the valve block with the hexagon socket head bolts **100** and **101**. ***Notes:*** • *Tighten the hexagon socket head bolts **100** and **101** indicated by circles in the figure below.* • *When installing the pump casing (R), be careful not to damage the needle bearing rolling contact surface of the drive shaft (R) and the sheet packing R.*  056311-00X00	 054633-00X01  054632-00X00
(15) Install the spring seat **110**, the inner spring **112** and the outer spring **113** into the pump casing (R) **98**, and then tighten the plug assembly **133**.	 054631-00X00  054630-00X00

Procedure	
(16) Install the gear pump **129** to the pump casing (R) **98** and tighten the hexagon socket head bolts with flange.	

(17) Install the feedback lever assembly **82** into the pump casing (F) **14**. After installing the sheet packing T **65** properly on the mating surface, install the top cover assembly **78** on it and tighten the hexagon socket head bolts **21**. ***Note:*** *Make sure that the pin **48** of the feedback lever is properly installed to the sleeve **46**.* *Also, make sure that the feedback pin **35** of the tilting pin **28** is securely put in the groove of the feedback lever.*	 

(18) Install the drain port plugs **23** and **102**. This is the end of reassembly procedures.	

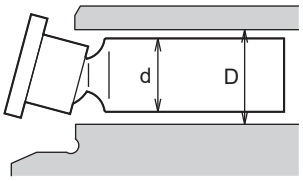
6-3-4 Service Standards

● Replacement criteria for parts subject to wear

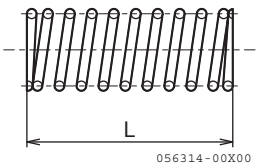
Repair or readjust parts if wear exceeds the standard values shown in the table below.

Be sure to replace parts if they are severely damaged externally.

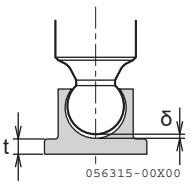
Part and inspection item	Standard value / Recommended value for replacement (mm)		Remedy
	Pump model		
	K7SP36	K7V28	
Clearance between piston and cylinder bore (D-d)	0.032 / 0.056	0.024 / 0.044	Replace piston assembly or cylinder
Play of swaged portion of piston and shoe (δ)	0 - 0.1 / 0.3	0 - 0.1 / 0.22	Replace piston assembly
Thickness of shoe (t)	3.9 / 3.7	2.9 / 2.75	Replace piston assembly
Free length of cylinder spring (L)	41.1 / 40.3	31.3 / 30.6	Replace cylinder spring
Combined height of set plate and spherical bush (H-h)	17.2 / 15.6	12.6 / 11.3	Replace set plate or spherical bush



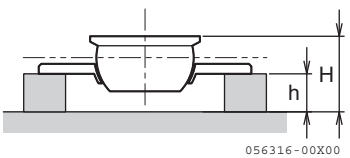
Clearance between piston and cylinder bore (D-d)



Free length of cylinder spring (L)



Play of swaged portion of piston and shoe (δ)
Thickness of shoe (t)

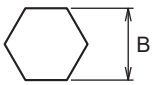


Combined height of set plate and spherical bush (H-h)

● Correction criteria for cylinder, valve plate and swash plate (shoe sliding portion)

Surface roughness for valve plate (sliding portion), swash plate (shoe sliding portion) and cylinder (sliding portion)	Surface roughness needing to be corrected	3-Z
	Standard surface roughness (correction value)	0.4 Z or less (Lapping)

● **Tightening torque**



Part	Size	Tightening torque ft·lbf (N·m)	Tool (mm)	
Hexagon socket head bolt	M5	5.1 (6.9)	0.16 (4)	
	M6	8.9 (12)	0.2 (5)	
	M8	21.4 (29)	0.24 (6)	
	M10	42 (57)	0.31 (8)	
	M12	72.2 (98)	0.39 (10)	Hexagon bar wrench
	M14	118 (160)	0.47 (12)	
	M16	177 (240)	0.55 (14)	
	M18	243.3 (330)	0.55 (14)	
	M20	317.2 (430)	0.67 (17)	
Hexagon socket head bolt with flange (for gear pump)	M8	12.5 (17)	0.24 (6)	Same as above
ROH plug	G1/8	12.5 (17)	0.2 (5)	Same as above
	G1/4	26.6 (36)	0.24 (6)	
	G3/8	54.6 (74)	0.31 (8)	
	G1/2	81.1 (110)	0.39 (10)	
	G3/4	125.4 (170)	0.47 (12)	
MH plug	M7×0.75	13.3 (18)	1.18 (30)	Torx plus

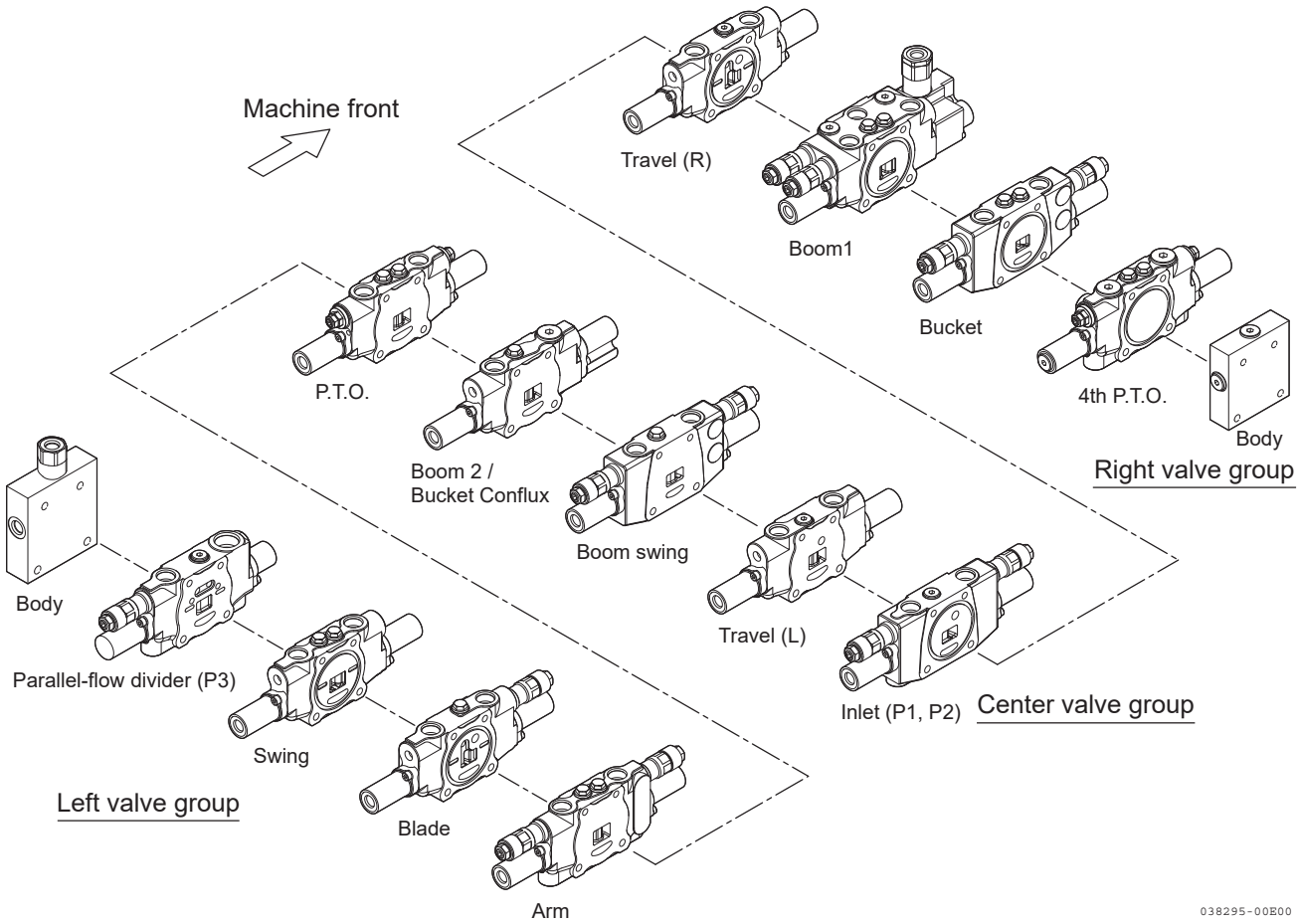
The recommended tightening torques for hose fittings are shown in the dimensional outline drawing and the tightening torques for the parts in the assembly cross section drawing.
Refer to these drawings together with this document when connecting hoses or performing disassembly and reassembly.

6-4 Control Valve

6-4-1 Main Control Valve

The main control valve (Fig. 2-1) is located between the pump and the actuators on the hydraulic circuit. The oil that flows from the main pump is controlled by each component inside the main control valve. Thereby, the direction of operation and the speed of the cylinder and the motor change.

1. The main control valve consists of the following:



(1)	Body assembly	Fig. 2-2
(2)	4th P.T.O. section assembly	Fig. 2-3
(3)	Bucket section assembly	Fig. 2-4
(4)	Boom 1 section assembly	Fig. 2-5
(5)	Travel (right) section assembly	Fig. 2-6
(6)	Inlet (P1, P2) section assembly	Fig. 2-7
(7)	Travel (left) section assembly	Fig. 2-8
(8)	Boom swing section assembly	Fig. 2-9
(9)	Boom 2/bucket conflux section assembly	Fig. 2-10
(10)	P.T.O. section assembly	Fig. 2-11
(11)	Arm section assembly	Fig. 2-12
(12)	Blade section assembly	Fig. 2-13
(13)	Swing section assembly	Fig. 2-14
(14)	Parallel-flow divider (P3) section assembly	Fig. 2-15
(15)	Body section	Fig. 2-16

2. Control valve function

(1) Control in neutral position

The oil passes through the center bypass passage in the main control valve and is discharged from the return port.

(2) Control valve operation

The control valve switches the direction of oil flow in order to operate, stop, or change the direction of operation for the cylinder or motor. The pump oil is supplied to each section through the center bypass passage and parallel passage. The return oil from each control valve is discharged from the return port through the return passage.

(3) The load check valve prevents the descent of the cylinder and motor during operation.

(4) The relief valve limits circuit pressure.

(5) Straight travel function

Traveling remains straight, even when each of the implements (boom, bucket, and 4th P.T.O. section) is operated while traveling.

(6) Arm conflux function (both retract and extend operations)

When the arm cylinder is operated, the operation speed is maintained by combining the oil from the P1 and P2 sides.

(7) Boom 2-speed function

When the boom is raised, the passage in the control valve is used to combine the oil in the P1 and P2 pumps.

(8) Bucket curl conflux function

When the bucket curl is operated, the oil is combined from the P1 and P2 sides.

(9) Anti-drift valve

The anti-drift valve is installed on the bottom side of the boom to reduce the natural descent of the boom cylinder.

(10) Boom preference circuit

To ensure the boom operation when both the boom raising and bucket curl are operated simultaneously, a poppet with a throttle is installed in the parallel passage.

(11) Swing parking brake release signal

When the swing, blade, arm, P.T.O., boom swing, boom, bucket, and 4th P.T.O. section are operated, the swing parking brake release signal is generated.

(12) When the left and right travel section are operated, the signal pressure is generated.

3. Controlling the hydraulic pilot section

1) 4th P.T.O., bucket, travel, swing, P.T.O., arm, blade, and boom swing

(1) In neutral

The hydraulic oil discharged from the pump passes through the neutral passage and is discharged from the return port. The cylinder ports (A and B) of the hydraulic oil are closed.

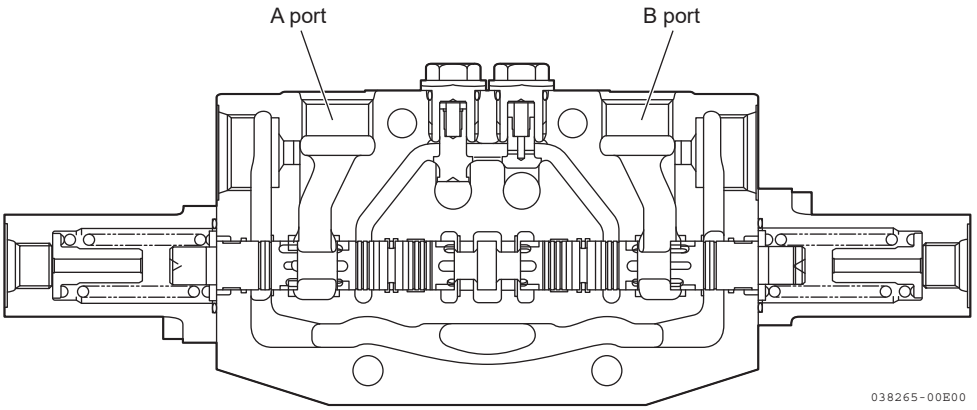


Fig. 1-1

(2) When the Pa port is pressurized

As shown in Fig. 1-2, when the Pa port is pressurized to switch the spool, the hydraulic oil flow in the neutral passage is closed and the load check valve is pushed up to let the hydraulic oil flow in the cylinder port “A”.

The return hydraulic oil in the cylinder port “B” flows to the tank passage through the throttle part of the spool and is discharged from the return port. The same is true when the Pb port is pressurized (there is no load check in the travel section).

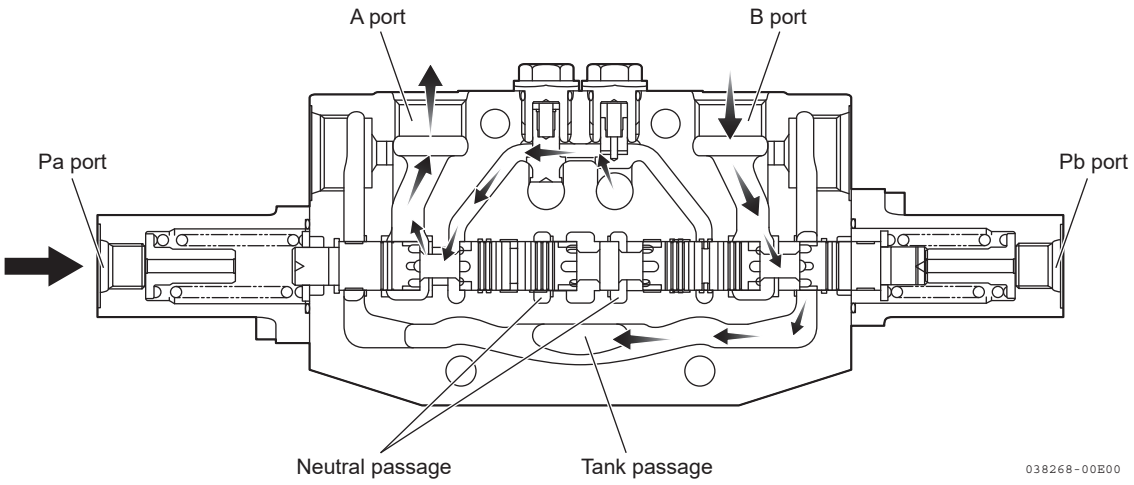


Fig. 1-2

2) Boom 1

(1) In neutral

The hydraulic oil discharged from the pump passes through the neutral passage and is discharged from the return port. The cylinder ports (A and B) of the hydraulic oil are closed.

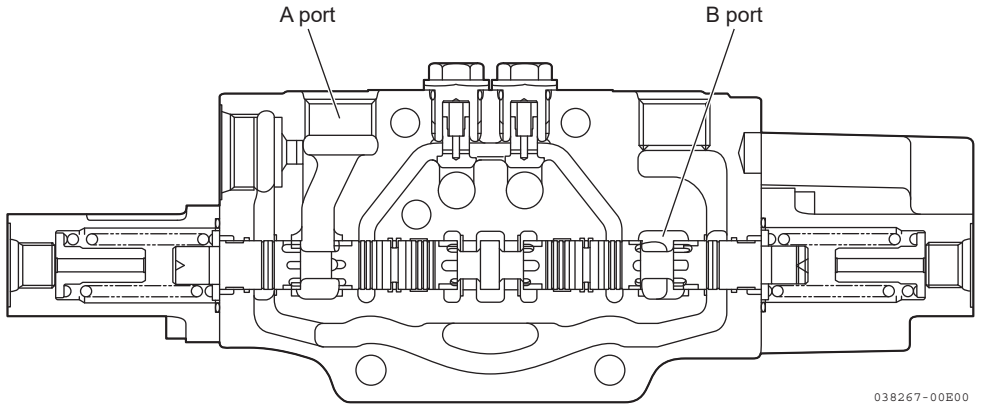


Fig. 1-3

(2) When the Pa port is pressurized (boom lowering operation)

When the Pa port is pressurized, Pi1 port is pressurized at the same time and the boom is lowered. The Pa pressurization enables the main spool to operate; the Pi1 pressurization enables the main poppet to operate.

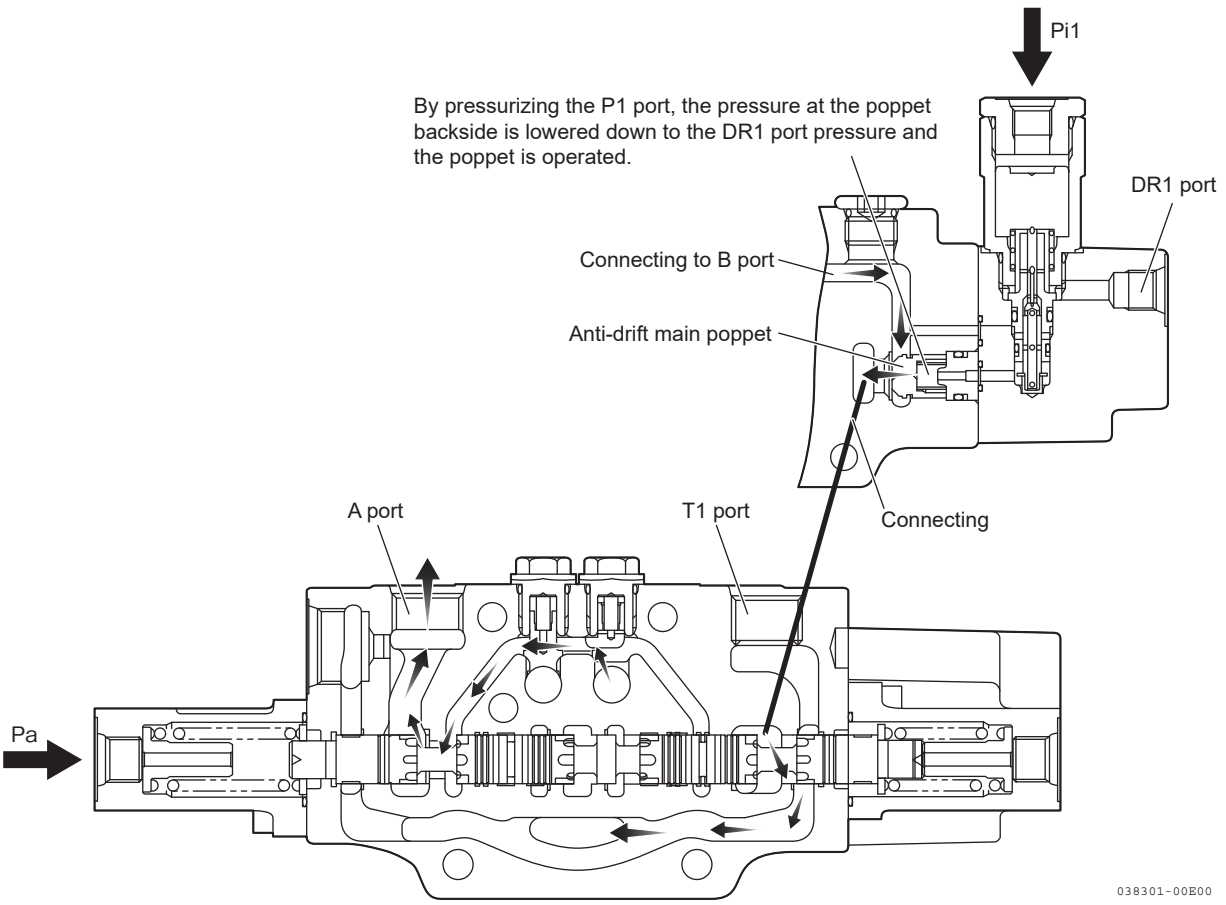


Fig. 1-4

(3) When the Pb port is pressurized (boom raising operation)

When the Pb port is pressurized, the boom is raised. The Pb pressurization enables the main spool to operate; the main poppet of the anti-draft operates by pushing up the hydraulic oil from the main spool.

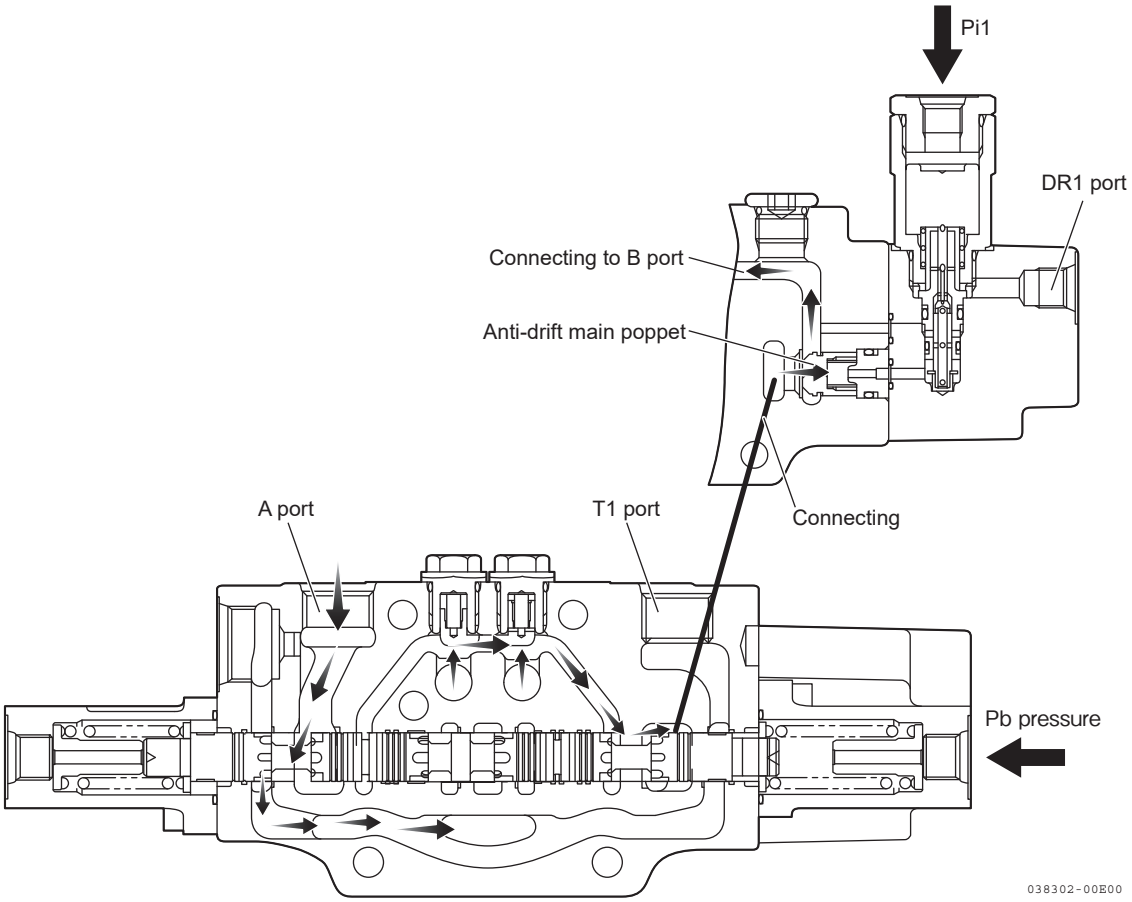


Fig. 1-5

3) Boom 2/bucket conflux

(1) In neutral

The hydraulic oil discharged from the pump passes through the neutral passage and is discharged from the return port.

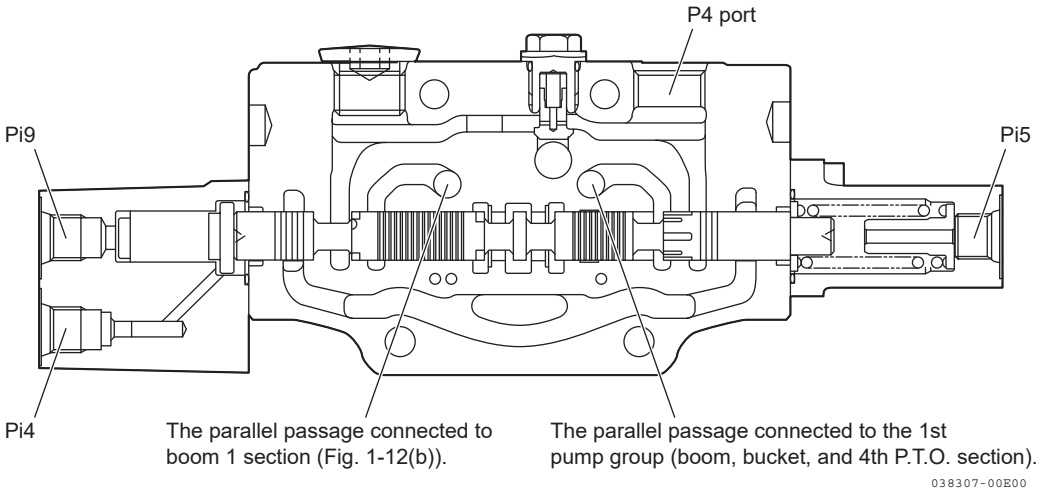


Fig. 1-6

(2) Pressurizing the Pi9 port (bucket curl conflux)

By pressurizing the Pi9 port, the spool moves 5mm to the right. The Pi9 port is connected to the bucket section through the parallel passage (Fig. 1-12(a)) via the spool throttle.

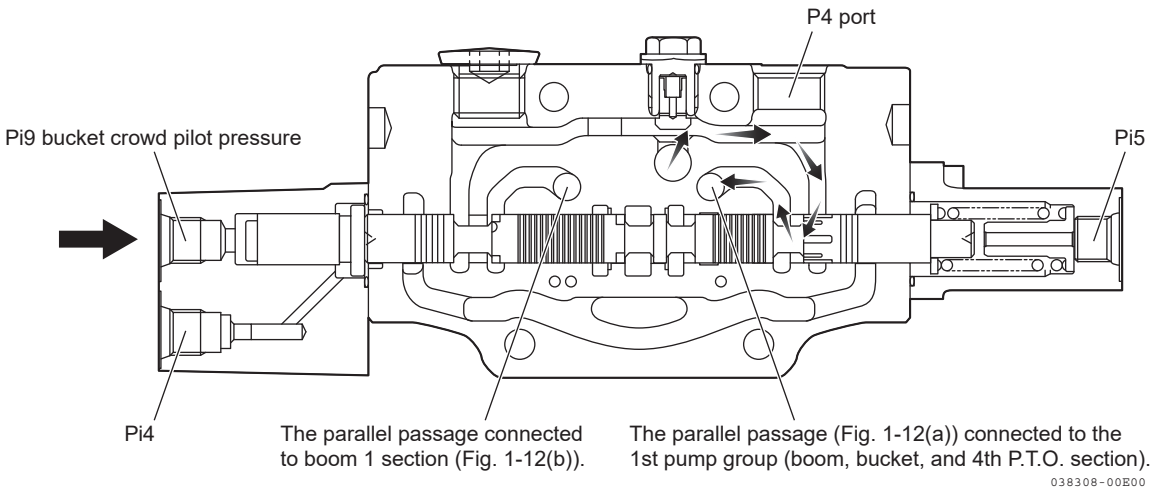


Fig. 1-7

(3) Pressurizing the Pi4 port (boom raising conflux)

The Pi4 port is pressurized and the spool is at full stroke at the time of the boom raising operation. To boom 1, the hydraulic oil flows to the parallel passages as shown in Fig. 1-12(a) and Fig. 1-12(b).

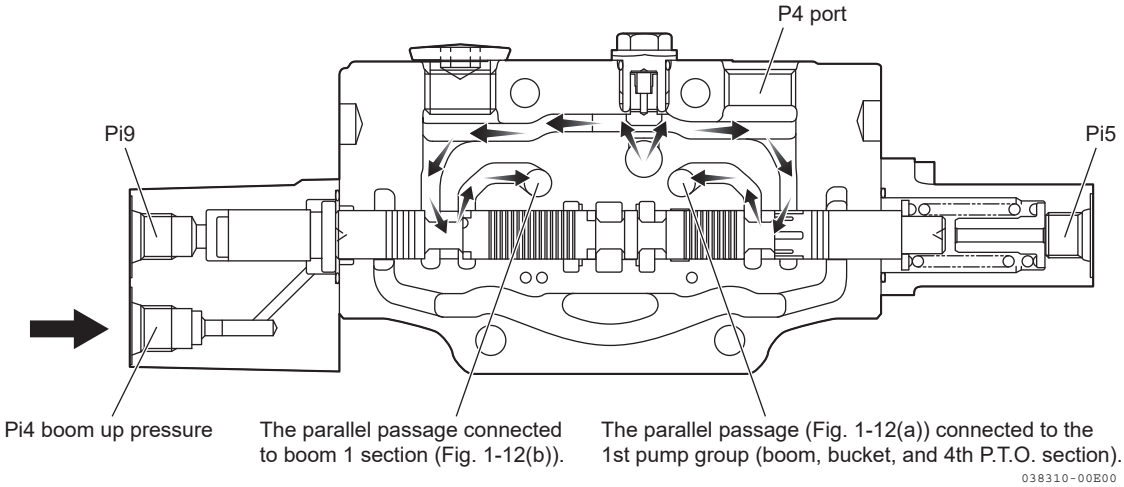


Fig. 1-8

(4) Pressurizing the Pi5 port (arm retract and boom raising operation)

When the arm crowd operation begins, the Pi5 port is pressurized and the force of Pi5 and spring set load pushes the main spool. Therefore, the spool returns to the neutral position.

The hydraulic oil from the P2 port is not supplied to the boom but to the prioritized arm.

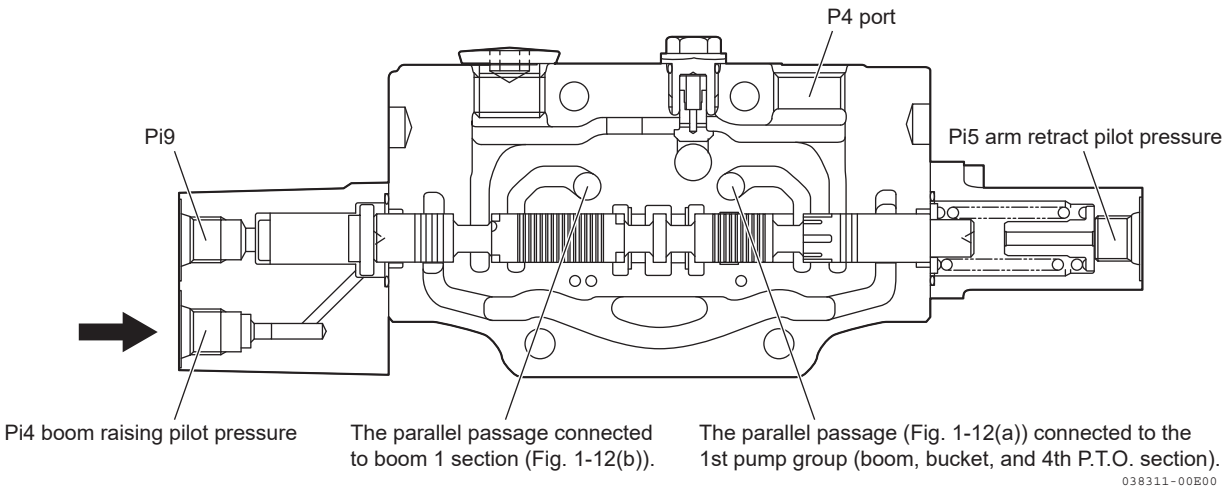


Fig. 1-9

4) Parallel-flow divider (P3)

(1) In neutral

The hydraulic oil from the P3 port is supplied to the P3 pump group through the neutral passage when the parallel-flow divider is not operated (during an independent operation).

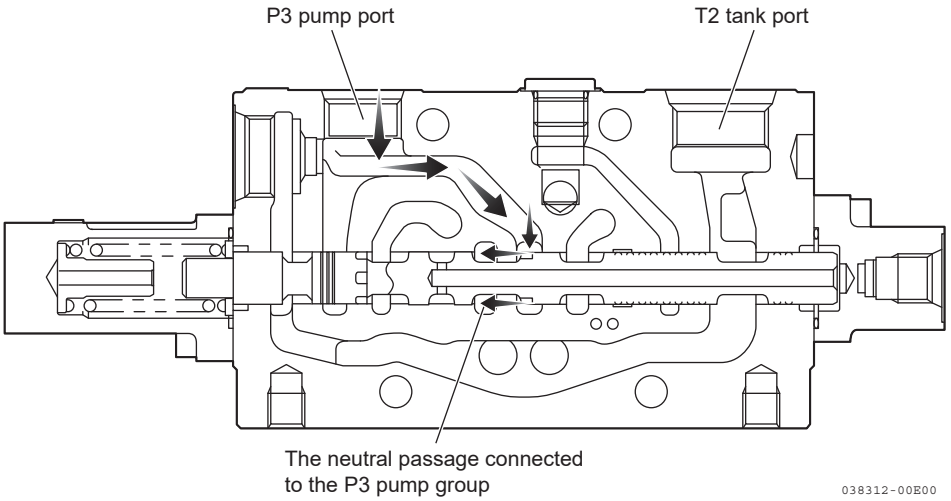


Fig. 1-10

(2) When traveling by the parallel-flow divider

When one of the main spools (travel left, boom 1, bucket, or 4th P.T.O. section) is operated, the parallel-flow divider operates. When the parallel-flow divider operates, the hydraulic oil is supplied to boom 1, bucket, and 4th P.T.O. section.

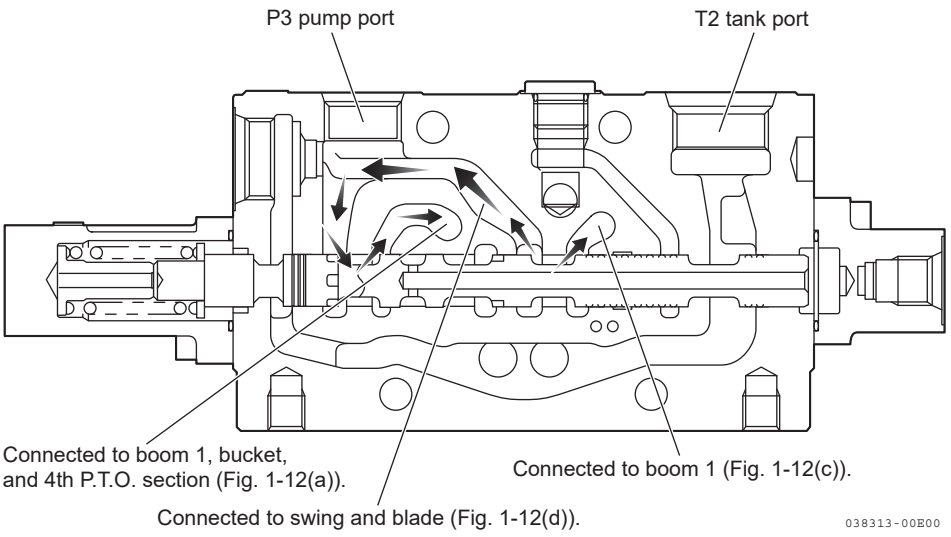


Fig. 1-11

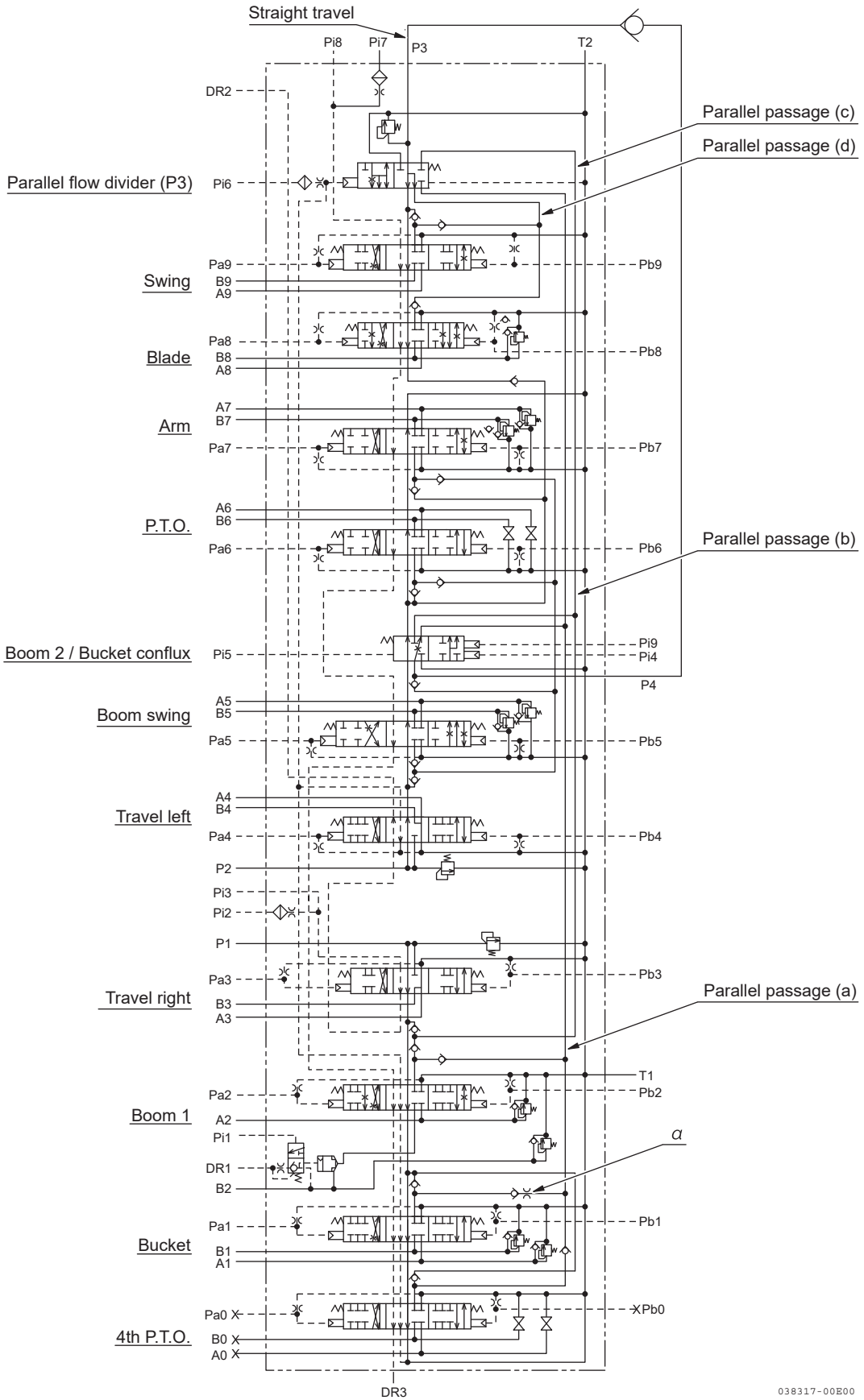


Fig. 1-12 (Hydraulics circuit)

6-4-2 Disassembly

CAUTION: The following precautions must be taken at the time of disassembly.

Be sure to stop the engine after ensuring that the actuator is not muffled with pressure. When you disassemble the engine with the muffled pressure in the actuator, the high-pressure oil may spout out or the parts may come out.

1. Release the air pressure in the tank. If there is pressure in the tank, the oil may spout out at the time of disassembly.
2. Clean around the parts to be disassembled and prevent foreign material from entering the valve at the time of disassembly.
3. When you store the disassembled parts, attach tags that make clear how the parts need to be reassembled.
4. Replace the seals (O-rings, backup rings, and wipers) with new ones.

CAUTION:

The relief valve and shutoff valve are, in principle, replaced as part of the assembly. Do not disassemble them unless there is an abnormality. Refer to "Servicing Procedure for Relief Valve" at the time of disassembly. Mark the assembly position of each part for reassembly.

1. Disassembly of accessories

Remove the relief valve assembly **18**, **19**, **20**, **21** and the shutoff valve assembly **22** in Fig. 2-1.

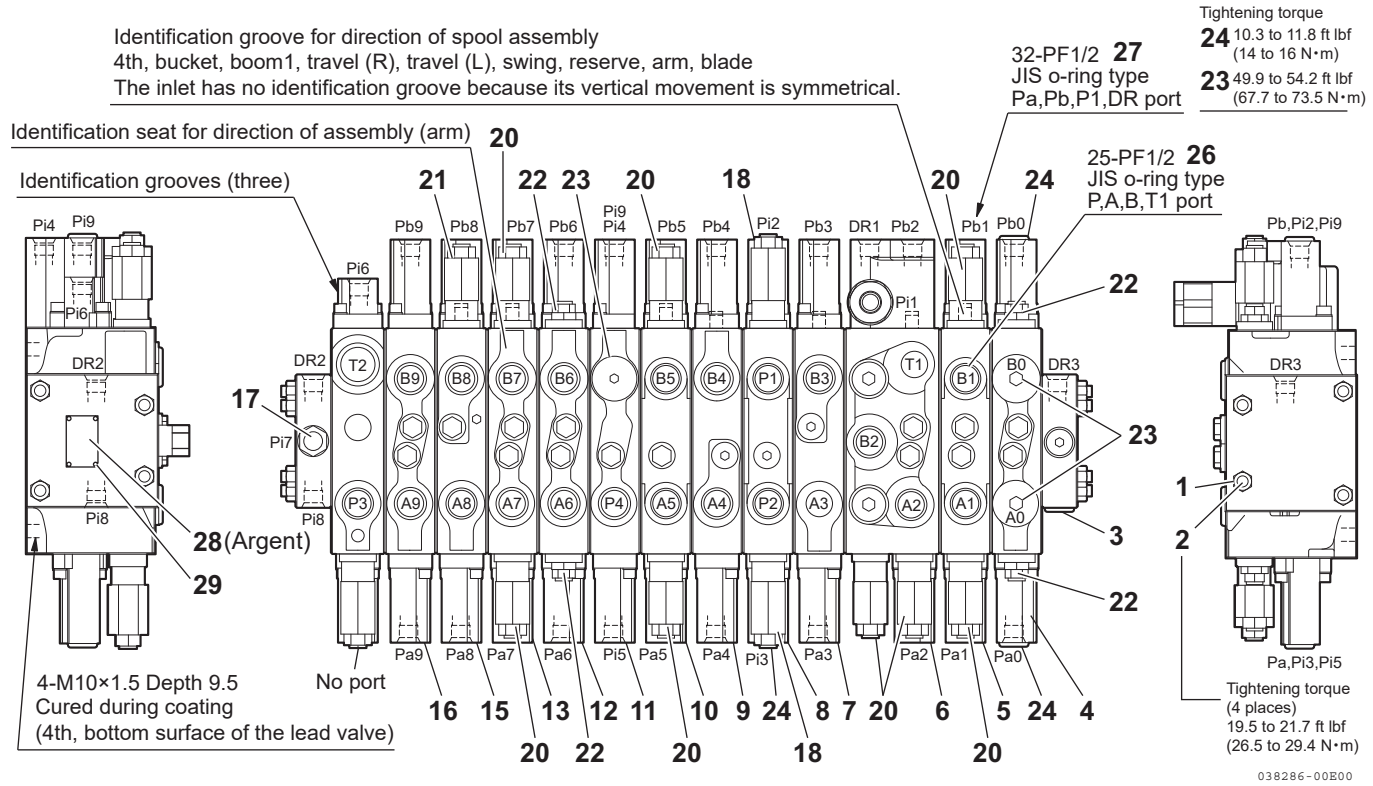


Fig. 2-1

No.	Description	Q'ty	Remark	No.	Description	Q'ty	Remark
1	Nut	8		16	Spool S/assy	1	Parallel flow divider (P3)
2	Tie rod	4		17	Body assembly	1	
3	Body assembly	1		18	Relief valve assy	2	P1, P2
4	Spool S/assy	1	4th P.T.O.	19	Relief valve assy	1	P3
5	Spool S/assy	1	Bucket	20	Relief valve assy	8	A1, B1, A2, B2, A5, B5, A7, B7
6	Spool S/assy	1	Boom 1	21	Relief valve assy	1	B8
7	Spool S/assy	1	Travel right	22	Shut off valve assy	4	A0, B0, A6, B6
8	Spacer S/assy	1	Inlet (P1, P2)	23	Plug assy	3	A0, B0, boom 2
9	Spool S/assy	1	Travel left	24	Plug assy	3	Pa0, Pb0, Pi3
10	Spool S/assy	1	Boom swing	25	Shipping plug	1	PF3/4
11	Spool S/assy	1	Boom 2	26	Shipping plug	23	PF1/2
12	Spool S/assy	1	P.T.O.	27	Shipping plug	29	PF1/4
13	Spool S/assy	1	Arm	28	Nameplate	1	
14	Spool S/assy	1	Blade	29	Drive screw	2	1.85×4.81
15	Spool S/assy	1	Swing				

2. Disassembly of body assembly

Loosen the plug assembly (hexagon diameter 0.2 in (6 mm)) **2** in Fig. 2-2 for removal.

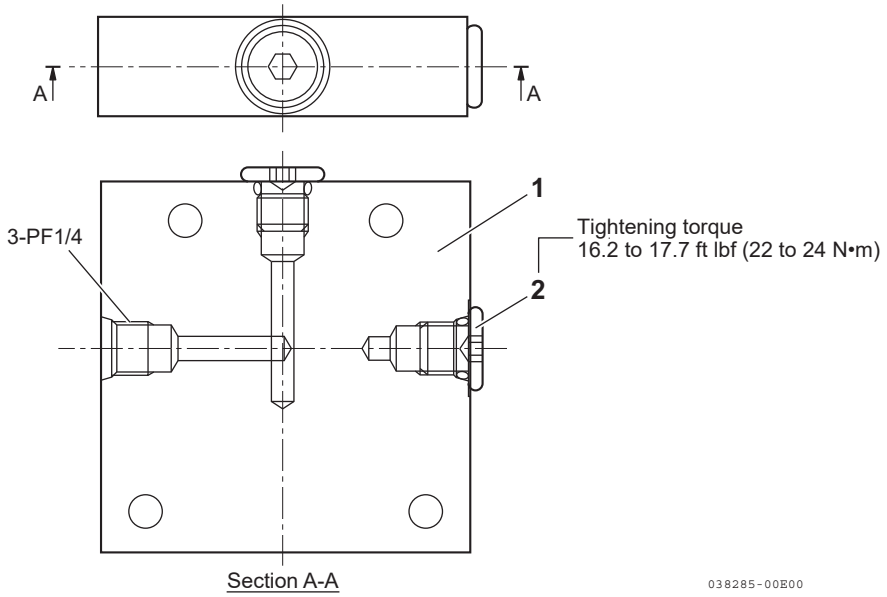


Fig. 2-2

3. Disassembly of each section

1) Disassembly of 4th P.T.O. section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **14** to remove the cap **3** in Fig. 2-3. Then, remove the spring seat **4**, spring **6**, spring seat **5**, and O-ring **12**. After that, pull out the spool **2** from the valve housing **1**.

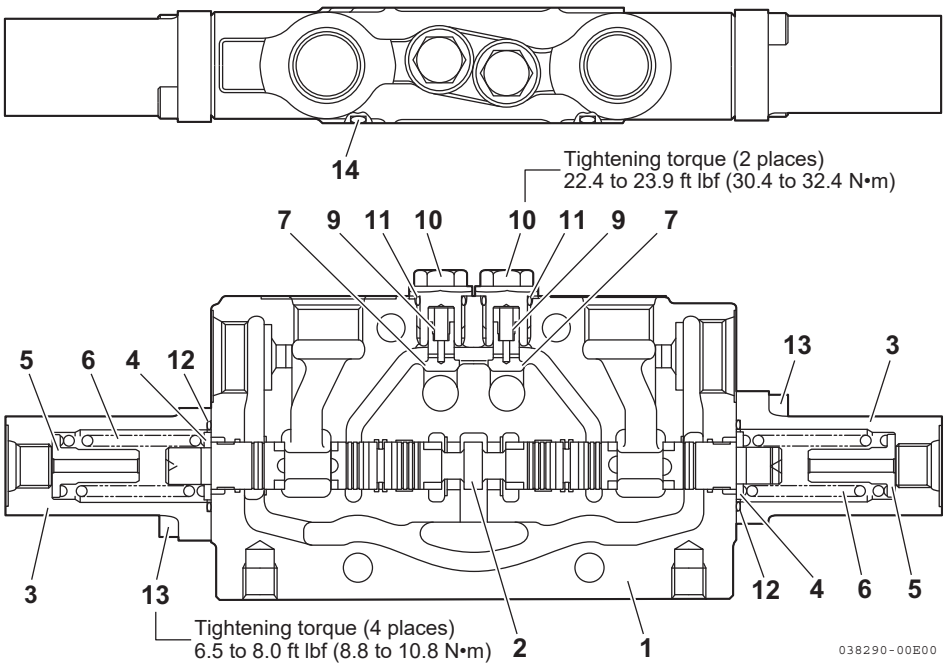


Fig. 2-3

CAUTION:

Be sure to pull out the spool directly to avoid damage and scratches. If damaged or scratched, the spool may damage the body hole when you pull it out or it may be difficult to insert it during reassembly; even inserted, it may cause malfunction. Mark the assembly position for each spool. If mis-assembled, the actuator may malfunction which is very dangerous (the same applies to the other sections).

2) Disassembly of bucket section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-4. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **12**. After that, pull out the spool **2** from the valve housing **1**.

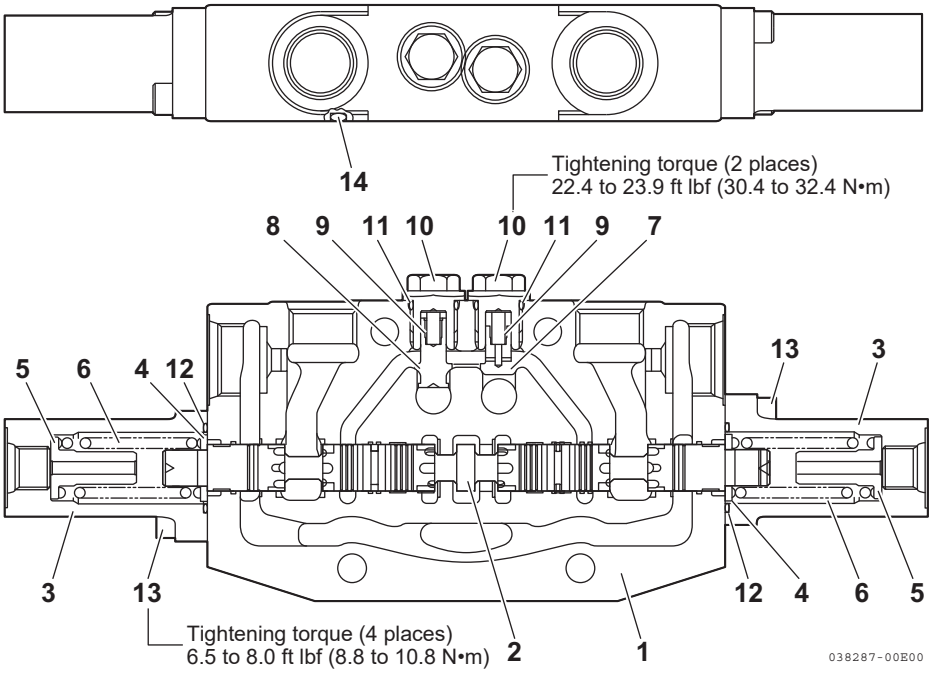


Fig. 2-4

3) Disassembly of boom 1 section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **20** to remove the anti-draft assembly **7** in Fig. 2-5. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **13**. Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **14** to remove the cap **3** on the opposite side. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **13**. After that, pull out the spool **2** from the valve housing **1**. After removing the cap **7**, pull out the spacer **17** by using a M4 (pitch: 0.7) thread in the spacer **17** (due to the large friction of the O-ring **18** and the backup ring **19**, it cannot be pulled out by hand). After that, remove the spring **16** and poppet **17**.

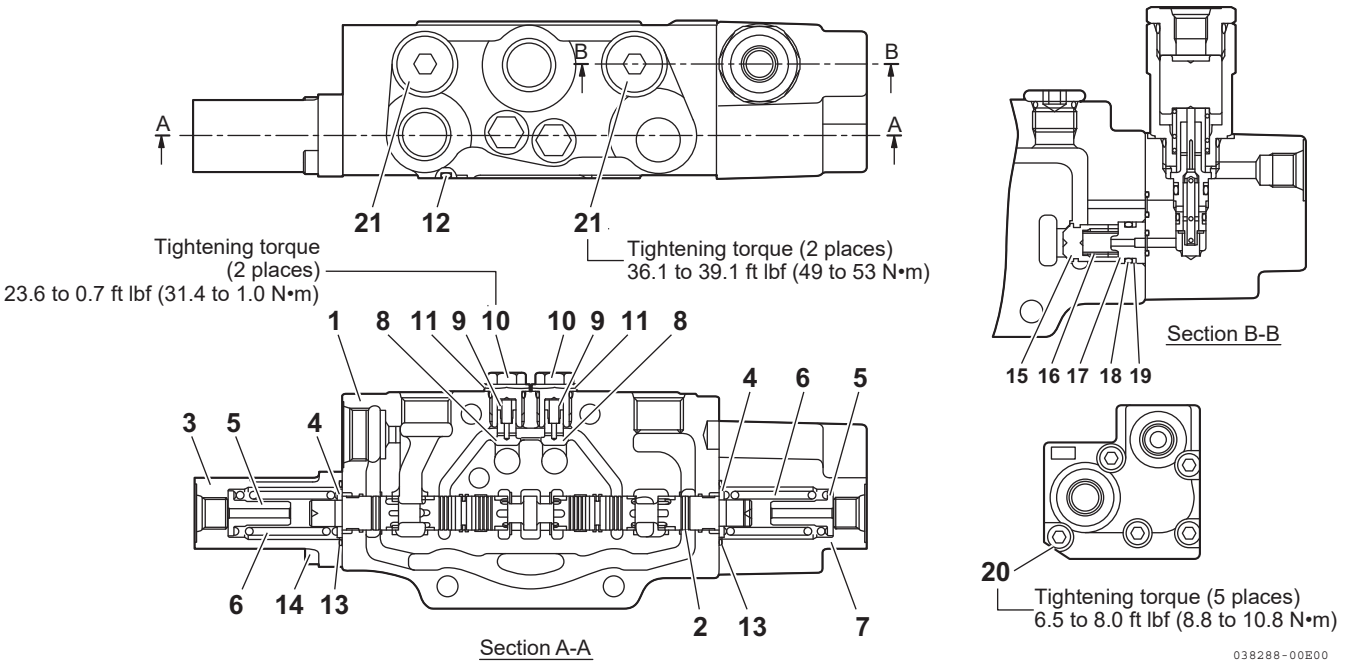


Fig. 2-5

4) Disassembly of travel right section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **10** to remove the cap **3** in Fig. 2-6. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **9**. After that, pull out the spool **2** from the valve housing **1**.

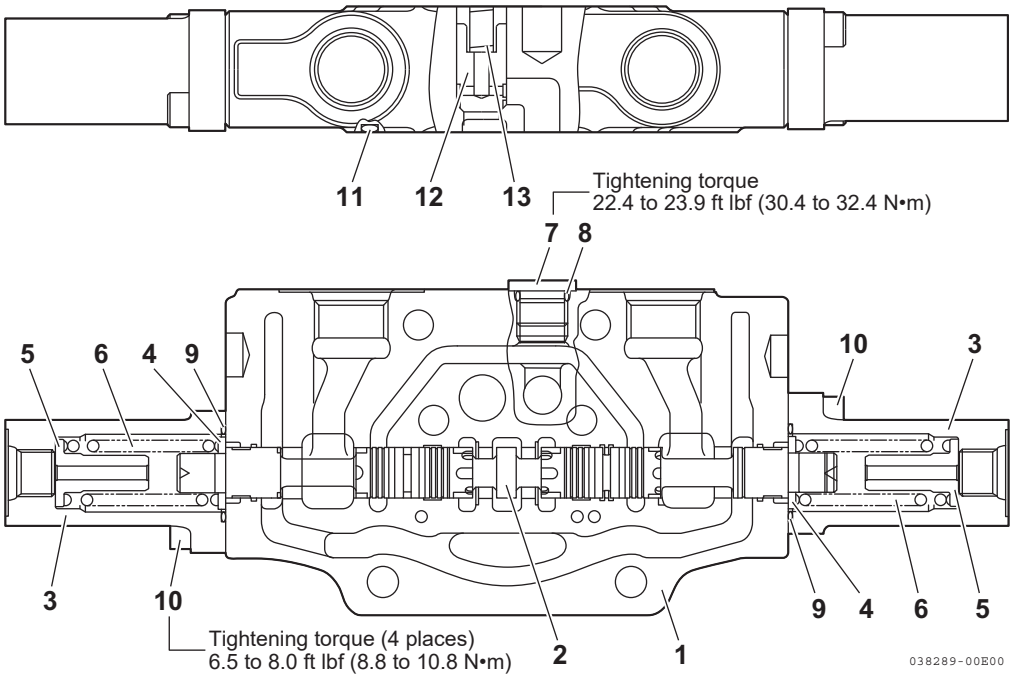


Fig. 2-6

5) Disassembly of inlet (P1, P2) section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **6** to remove the cap **3** in Fig. 2-7. Then, remove the O-ring **4**. Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **6** to remove the cap **5** on the opposite side. After that, pull out the spool **2** from the valve housing **1**.

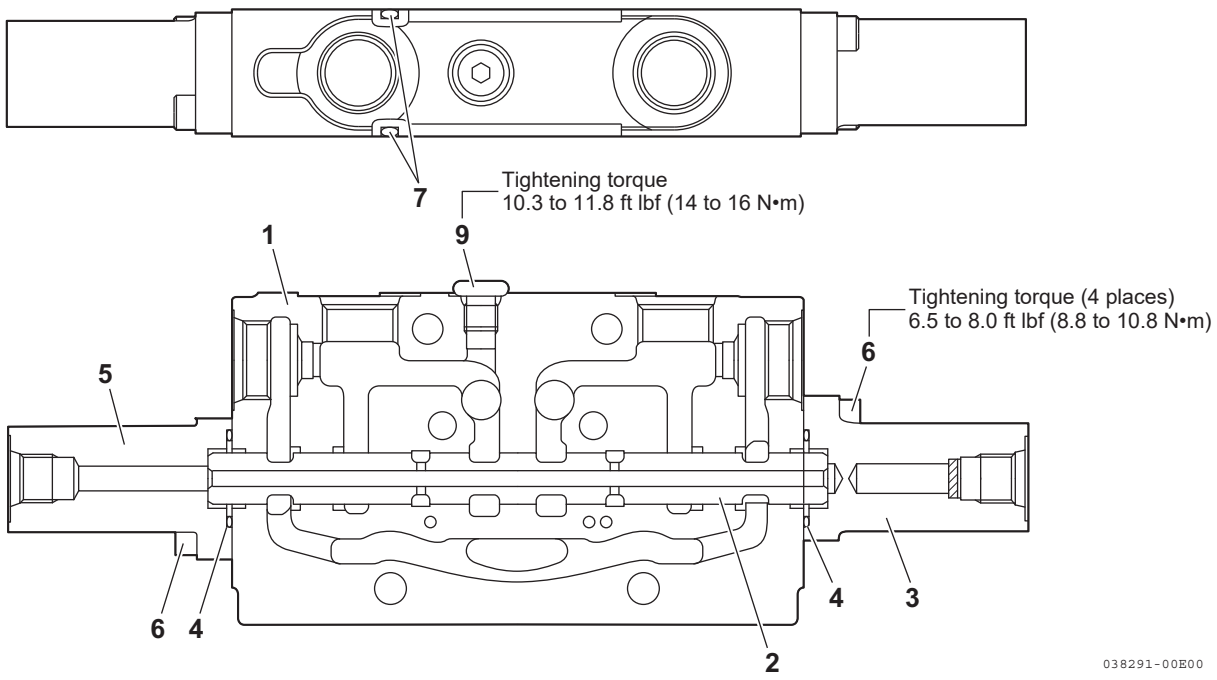


Fig. 2-7

CAUTION:

Do not disassemble the cap filter as it is fixed with caulk. If disassembled and reassembled, the filter may fall and break, causing all moving parts to malfunction.

6) Disassembly of travel left section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **10** to remove the cap **3** in Fig. 2-8. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **9**. After that, pull out the spool **2** from the valve housing **1**.

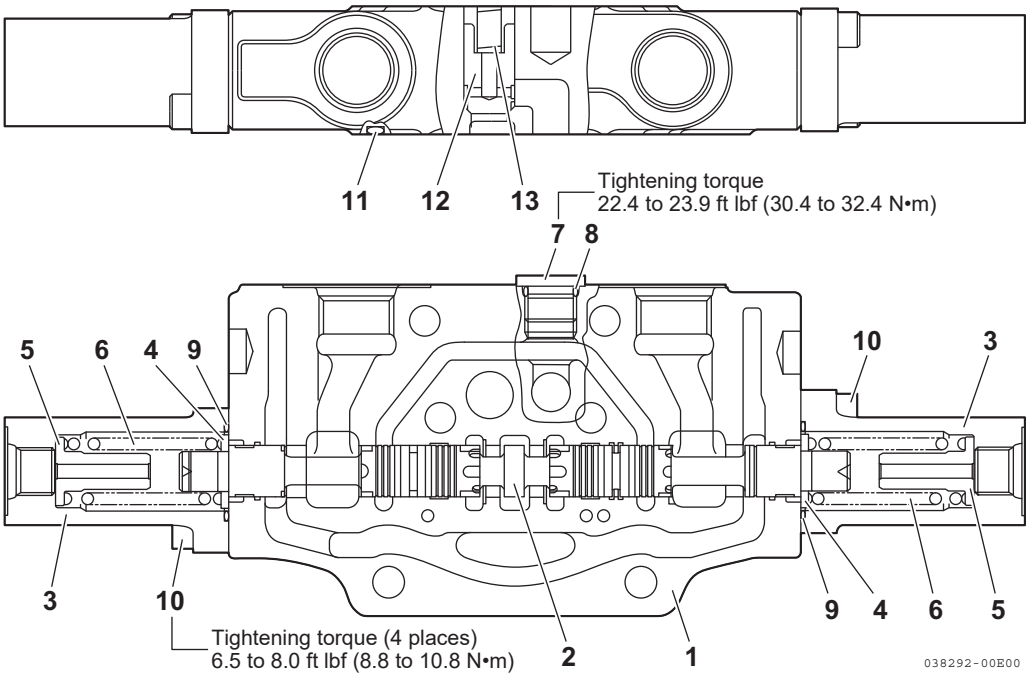


Fig. 2-8

7) Disassembly of boom swing section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-9. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **12**. After that, pull out the spool **2** from the valve housing **1**.

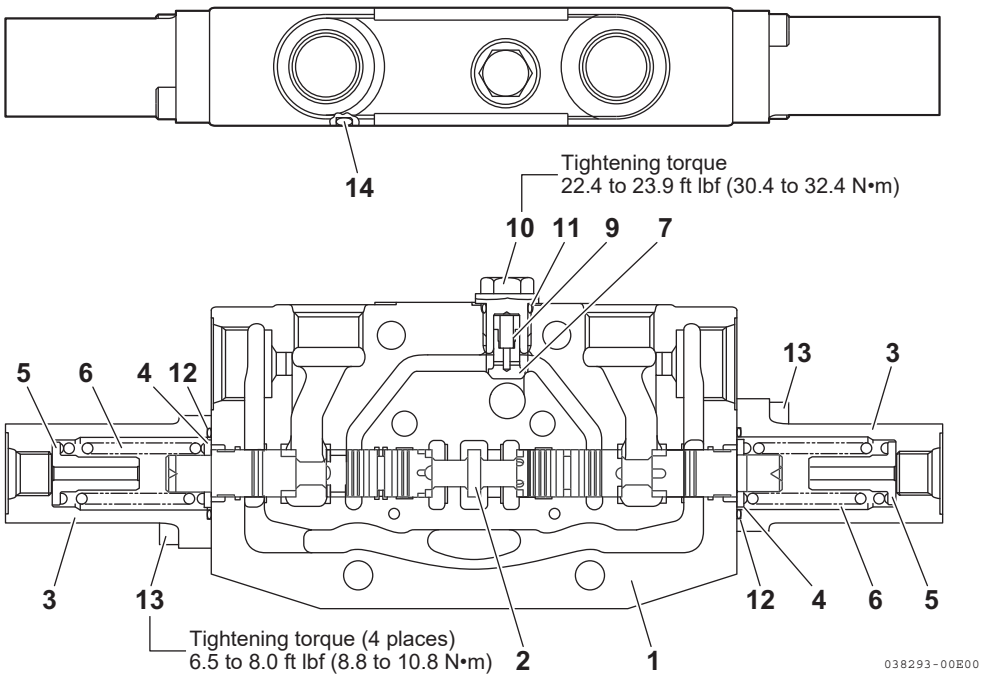


Fig. 2-9

8) Disassembly of boom 2/bucket conflux section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-10. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **12**. Loosen the socket head bolt (hexagon diameter 5mm) **13** to remove the cap **15** on the opposite side and remove the piston **16**. After that, pull out the spool **2** from the valve housing **1**.

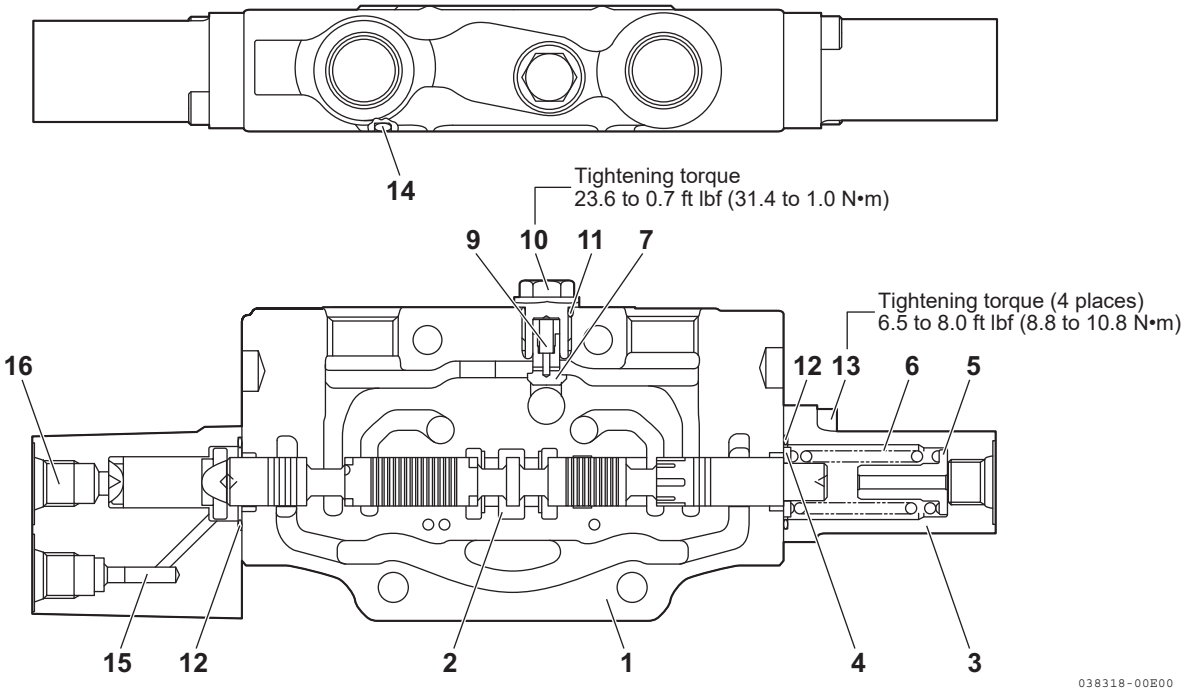


Fig. 2-10

9) Disassembly of P.T.O. section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-11. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **12**. After that, pull out the spool **2** from the valve housing **1**.

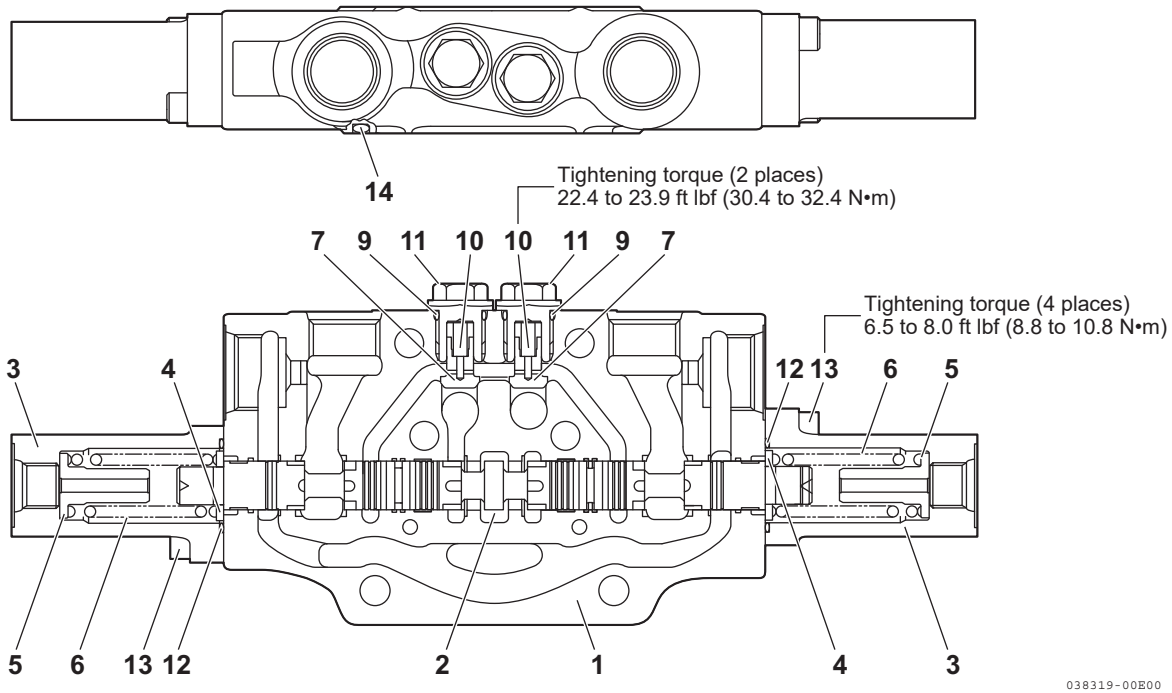


Fig. 2-11

10) Disassembly of arm section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-12. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **12**. After that, pull out the spool **2** from the valve housing **1**.

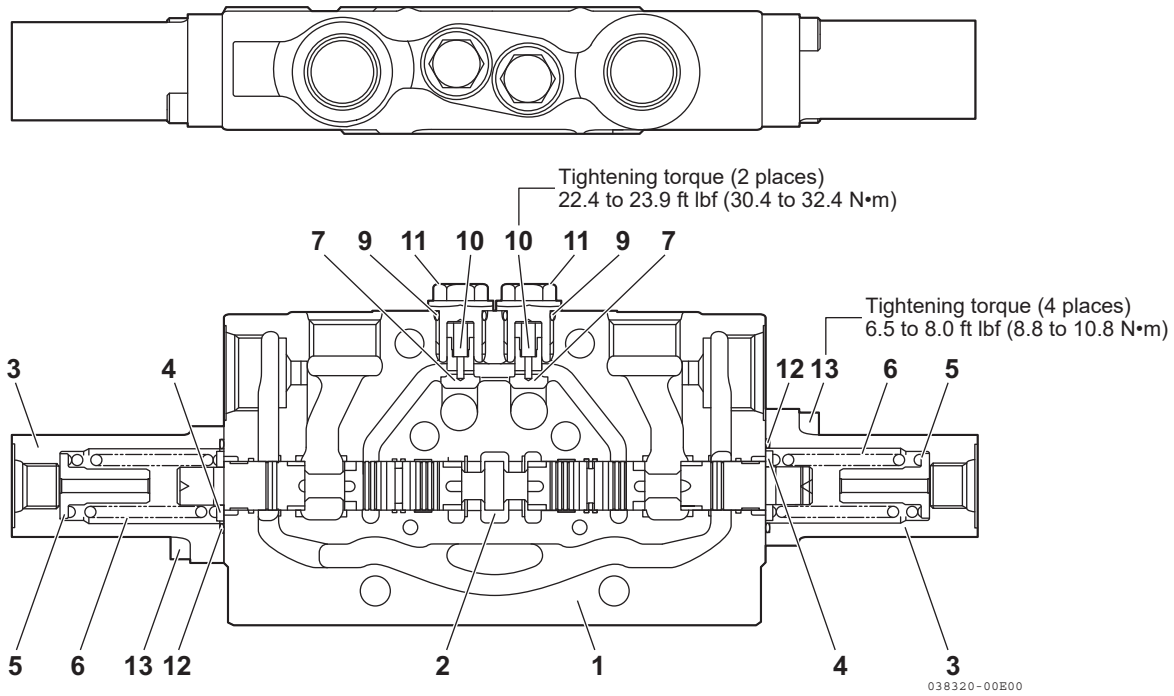


Fig. 2-12

11) Disassembly of blade section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-13. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **12**. After that, pull out the spool **2** from the valve housing **1**.

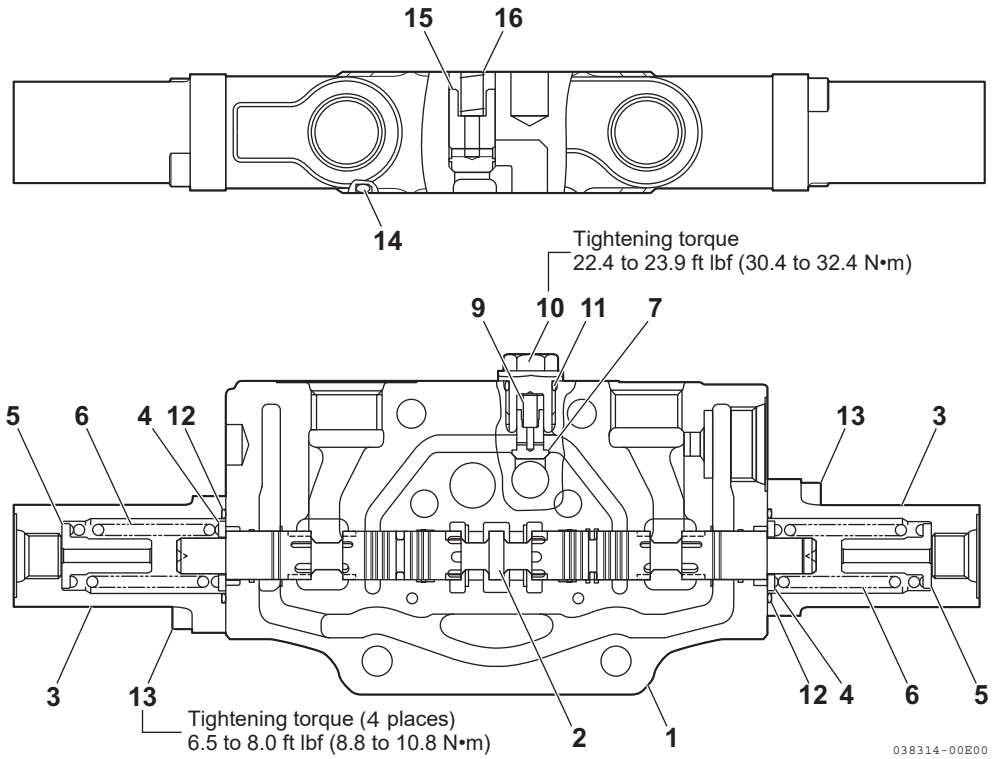


Fig. 2-13

12) Disassembly of swing section

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-14. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **12**. After that, pull out the spool **2** from the valve housing **1**.

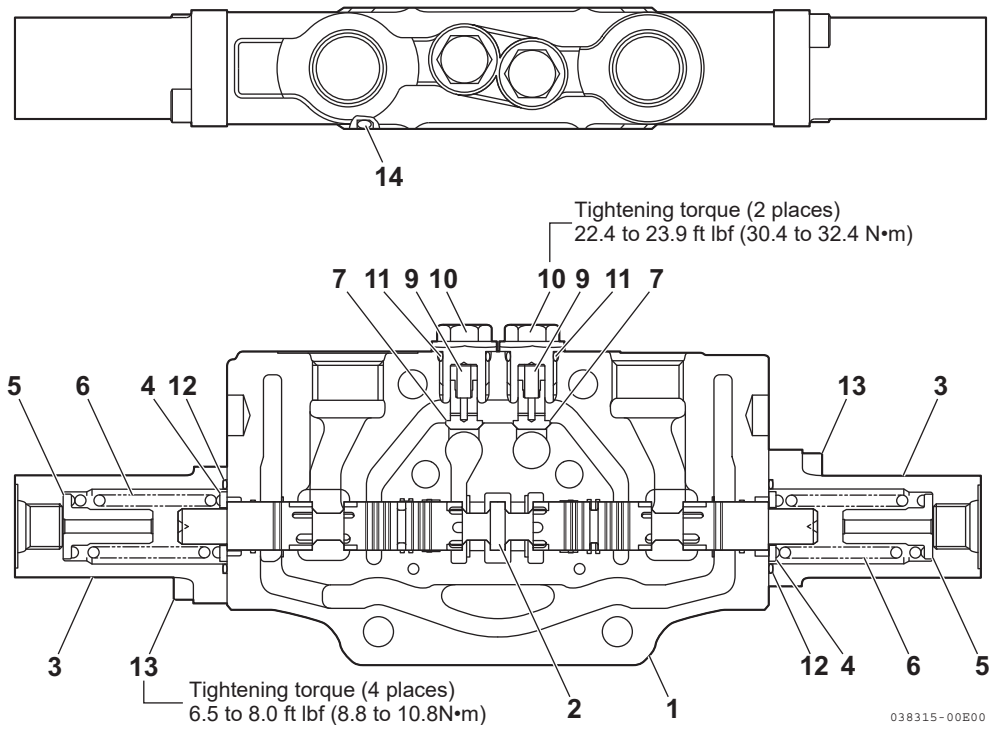


Fig. 2-14

13) Disassembly of parallel flow divider (P3)

Loosen the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** to remove the cap **3** in Fig. 2-15. Then, remove the spring seat **4**, spring **6**, spring seat **5** and O-ring **7**. Remove the cap **8** and O-ring **7** on the opposite side. After that, pull out the spool **2** from the valve housing **1**.

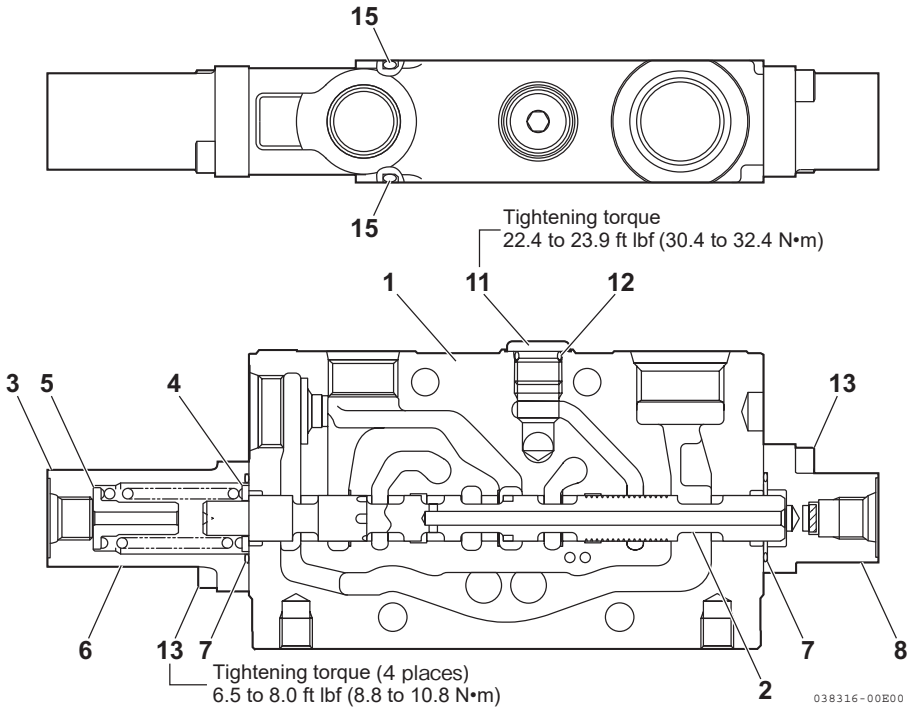


Fig. 2-15

CAUTION:

Do not disassemble the cap filter as it is caulking fix. If disassembled and reassembled, the filter may fall and damage, causing each moving part to malfunction.

14) Disassembly of body assembly

Loosen and remove the plug assembly (hexagon diameter 0.7 in (19 mm)).

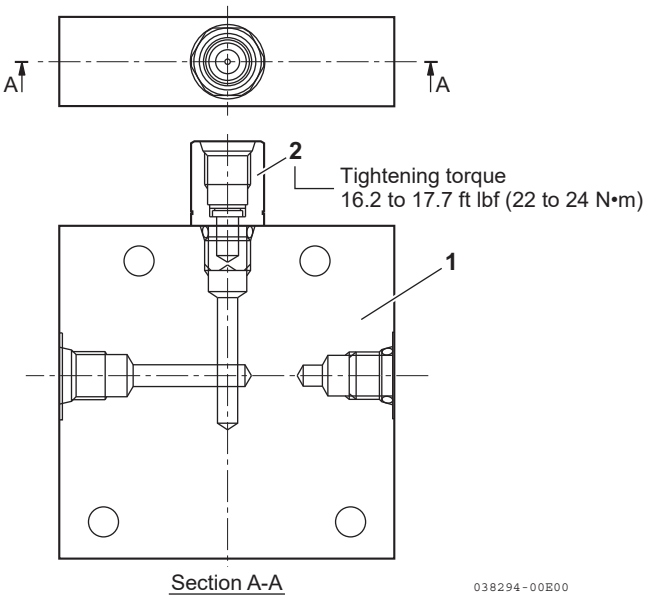


Fig. 2-

Sort the above listed, disassembled parts by sections and attach tags that make the assembly position clear.

4. Removal of load check poppet and plugs

Before removing the tie rod and disassembling the valve housing, remove the load check poppet and plugs. The poppet and plugs to be removed are as follows:

4th P.T.O.	(Fig. 2-3)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2
Bucket	(Fig. 2-4)	: (10) Plug×2, (9) Spring×2, (7) Poppet, (8) Poppet
Boom1	(Fig. 2-5)	: (10) Plug×2, (9) Spring×2, (8) Poppet×2
Travel right	(Fig. 2-6)	: (7) Plug
Inlet (P1, P2)	(Fig. 2-7)	: (9) Plug assembly
Travel left	(Fig. 2-8)	: (7) Plug
Boom swing	(Fig. 2-9)	: (10) Plug, (9) Spring, (7) Poppet
Boom 2/bucket conflux	(Fig. 2-10)	: (10) Plug, (9) Spring, (7) Poppet
P.T.O.	(Fig. 2-11)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2
Arm	(Fig. 2-12)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2
Blade	(Fig. 2-13)	: (10) Plug, (9) Spring, (7) Poppet
Swing	(Fig. 2-14)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2
Parallel flow divider (P3)	(Fig. 2-15)	: (11) Plug, (12) O-ring

5. Disassembly of valve housing

Loosen the nut (hexagon diameter 0.3 in (8 mm)) **2**, remove the tie rod **1**, and disassemble the valve housing of each section in order.

Disassemble the parts in the matching surface of the below sections.

Body Assy	(Fig. 2-2)	: Nothing
4th P.T.O.	(Fig. 2-3)	: (14) O-ring
Bucket	(Fig. 2-4)	: (14) O-ring
Boom1	(Fig. 2-5)	: (12) O-ring
Travel right	(Fig. 2-6)	: (11) O-ring, (12) Poppet, (13) Spring
Inlet (P1, P2)	(Fig. 2-7)	: (7) O-ring×2
Travel left	(Fig. 2-8)	: (11) O-ring, (12) Poppet, (13) Spring
Boom swing	(Fig. 2-9)	: (14) O-ring
Boom2/bucket conflux	(Fig. 2-10)	: (14) O-ring
P.T.O.	(Fig. 2-11)	: (14) O-ring
Arm	(Fig. 2-12)	: Nothing
Blade	(Fig. 2-13)	: (14) O-ring, (16) Spring, (15) Poppet
Swing	(Fig. 2-14)	: (14) O-ring
Parallel flow divider (P3)	(Fig. 2-15)	: (15) O-ring×2
Body Assy	(Fig. 2-16)	: Nothing

Sort the above listed, disassembled parts by sections and attach tags that make the assembly position clear.

6-4-3 Cleaning

Clean all disassembled parts completely with mineral oil. Blow compressed air to dry them and place each part on clean paper or cloth for checking.

6-4-4 Checking

Perform checks to ensure that there are no burrs, scratches, notches and other defects on all surfaces of each part.

(1) Check that the seal groove surface of the valve housing is smooth and free from dust, dent, and rust.
(2) If there is a dent or crack on the check seat surface of the valve housing, remove it by lapping. It must be performed carefully to avoid any lapping agent from remaining in the valve.
(3) All sliding parts and engagement parts must move lightly. All grooves and passages must be free of foreign material.
(4) If the springs are damaged or deformed, replace them with new ones.
(5) If the relief valve doesn't function well, perform checks according to the separate operation manual.
(6) Replace all O-rings.

6-4-5 Reassembly

At the time of reassembly, the following care must be taken for the handling of O-rings (or seals):

(1) The O-rings must be free from formational defects and damages caused at the time of handling.
(2) The O-rings and their applied parts must be sufficiently lubricated with grease or hydraulic oil.
(3) The O-rings must not be stretched to the extent that they are permanently deformed.
(4) The O-rings must not be rolled over at the time of installation. Twisted O-rings are difficult to untwist naturally and may cause oil leaks.

1. Reassembly of valve housing

Install the poppet and springs in each section as shown below:

Travel right	(Fig. 2-6)	: (12) Poppet, (13) Spring
Travel left	(Fig. 2-8)	: (12) Poppet, (13) Spring
Blade	(Fig. 2-13)	: (16) Spring, (15) Poppet

Install the O-rings in each section as shown below:

Body assy	(Fig. 2-2)	: Nothing
4th P.T.O.	(Fig. 2-3)	: (14) O-ring
Bucket	(Fig. 2-4)	: (14) O-ring
Boom1	(Fig. 2-5)	: (12) O-ring
Travel right	(Fig. 2-6)	: (11) O-ring
Inlet	(Fig. 2-7)	: (7) O-ring×2
Travel left	(Fig. 2-8)	: (11) O-ring
Boom swing	(Fig. 2-9)	: (14) O-ring
Boom 2/bucket conflux	(Fig. 2-10)	: (14) O-ring
P.T.O.	(Fig. 2-11)	: (14) O-ring
Arm	(Fig. 2-12)	: Nothing
Blade	(Fig. 2-13)	: (14) O-ring
Swing	(Fig. 2-14)	: (14) O-ring
Parallel flow divider (P3)	(Fig. 2-15)	: (15) O-ring×2
Body assy	(Fig. 2-16)	: Nothing

Install the valve housing of each section in Fig. 2-1 to the tie rod **1** in the correct order. Then, tighten the nut (hexagon diameter 0.3 in (8 mm)) **2** to the tie rod **1**.

Tightening torque: 19.5 to 21.7 ft lbf (26.5 to 29.4 N•m)

2. Reassembly of section

1) Installing the spool to 4th P.T.O., bucket, travel right, travel left, boom swing, P.T.O., arm, blade, and swing section

Pinch the spring **6** between the spring seats **4** and **5**, install the spool **2** to the valve housing **1** in the same direction prior to disassembly, install the cap **3** with the O-ring **12** with the socket head bolt (hexagon hole diameter 0.2 in (5 mm)) **13** in Fig. 2-3, 4, 6, 8, 9, 11, 12, 13, and 14. Install the cap on the opposite side in the same way (Note: O-ring **9** and socket head bolt **10** for travel section).

Tightening torque: 6.5 to 8.0 ft lbf (8.8 to 10.8 N•m)

2) Installing the spool to the boom 1 section

Pinch the spring **6** between the spring seats **4** and **5**, install the spool **2** to the valve housing **1** in the same direction prior to disassembly, install the cap **3** in Fig. 2-5 with the O-ring **13** with the socket head bolt (hexagon hole diameter 0.2 in (5 mm)) **14**.

Tightening torque: 6.5 to 8.0 ft lbf (8.8 to 10.8 N•m)

Prior to installing the anti-drift valve assembly **7**, insert the poppet **15** and spring **16** first to the valve housing **1** and insert the spacer **17** with the O-ring **18** and the backup ring **19** to the same hole.

On the anti-drift valve side, pinch the spring **6** between the spring seats **4** and **5**, install the anti-drift valve assembly with the socket head bolt (hexagon hole diameter 0.2 in (5 mm)) **20**.

Tightening torque: 6.5 to 8.0 ft lbf (8.8 to 10.8 N•m)

3) Installing the inlet section

Install the spool **2** to the valve housing **1** in the same direction prior to disassembly and install the cap **36** in Fig. 2-7 with the O-ring **4** and filter **3** with the socket head bolt (hexagon diameter 0.2 in (5 mm)).

Tightening torque: 6.5 to 8.0 ft lbf (8.8 to 10.8 N•m)

Install the cap **5** with the O-ring **4** with the socket head bolt (hexagon diameter 0.2 in (5 mm)) **6** on the opposite side in the same way.

4) Installing the spool to the boom 2/bucket conflux section

Pinch the spring **6** between the spring seats **4** and **5**, install the spool **2** to the valve housing **1** in the same direction prior to disassembly, install the cap **3** in Fig. 2-10 with the O-ring **12** with the socket head bolt (hexagon hole diameter 0.2 in (5 mm)) **13**.

Tightening torque: 6.5 to 8.0 ft lbf (8.8 to 10.8 N•m)

Install the cap **15** with the O-ring **12** and piston **16** with the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13** on the opposite side.

Tightening torque: 6.5 to 8.0 ft lbf (8.8 to 10.8 N•m)

5) Installing the spool to the parallel flow divider (P3) section

Install the O-ring **7** to the cap with filter **8** and install with the socket head bolt (hexagon hole diameter 0.2 in (5 mm)) **13** in Fig. 2-15.

Tightening torque: 6.5 to 8.0 ft lbf (8.8 to 10.8 N•m)

Pinch the spring **6** between the spring seats **4** and **5**, install the spool **2** to the valve housing **1** in the same direction prior to disassembly, install the cap **3** with the O-ring **7** with the socket head bolt (hexagon diameter 0.2 in (5 mm)) **13**.

Tightening torque: 21.7 ft lbf (29.4 N•m)

3. Installing the load check and other parts

Install the load check, spring, and plug (be sure to install the O-ring) as shown below:

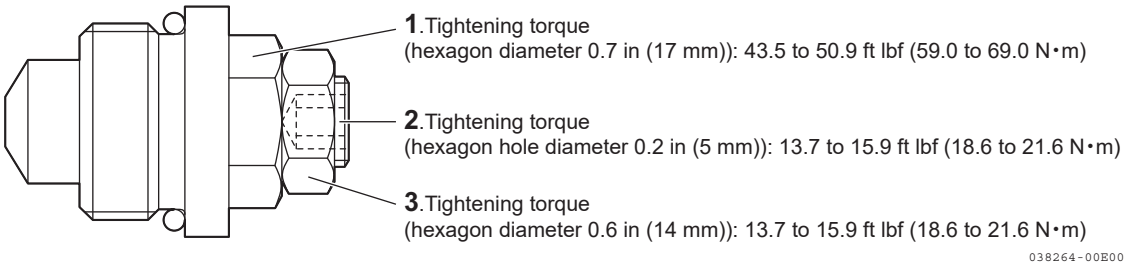
Body assy	(Fig. 2-2)	: (2) Plug assembly Plug tightening torque: 16.2 to 17.7 ft lbf (22 to 24 N•m) (hexagon diameter 0.2in (5mm))
4th P.T.O.	(Fig. 2-3)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2 Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Bucket	(Fig. 2-4)	: (10) Plug×2, (9) Spring×2, (7) Poppet, (8) Poppet Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Boom1	(Fig. 2-5)	: (10) Plug×2, (9) Spring×2, (8) Poppet×2 Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Travel right	(Fig. 2-6)	: (7) Plug Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.2in (6mm))
Inlet (P1, P2)	(Fig. 2-7)	: (9) Plug assembly Plug tightening torque: 10.3 to 11.8 ft lbf (14 to 16 N•m) (hexagon diameter 0.2in (5mm))
Travel left	(Fig. 2-8)	: (7) Plug Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.2in (6mm))
Boom swing	(Fig. 2-9)	: (10) Plug, (9) Spring, (7) Poppet Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Boom 2/bucket conflux	(Fig. 2-10)	: (10) Plug, (9) Spring, (7) Poppet Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
P.T.O.	(Fig. 2-11)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2 Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Arm	(Fig. 2-12)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2 Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Blade	(Fig. 2-13)	: (10) Plug, (9) Spring, (7) Poppet Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Swing	(Fig. 2-14)	: (10) Plug×2, (9) Spring×2, (7) Poppet×2 Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.6in (14mm))
Parallel flow divider (P3)	(Fig. 2-15)	: (11) Plug assembly Plug tightening torque: 21.7 to 23.9 ft lbf (29.4 to 32.4 N•m) (hexagon diameter 0.2in (6mm))
Body assembly	(Fig. 2-16)	: (2) Plug assembly Plug tightening torque: 16.2 to 17.7 ft lbf (22 to 24 N•m) (hexagon diameter 0.7 in (19mm))

4. Installing the accessories

Install the relief valves **18**, **19**, **20**, **21** in Fig. 2-1.

Tightening torque: 50.9 to 57.5 ft lbf (69 to 78 N•m)

Install the shutoff valve assembly **24** (Fig. 2-15) in the same way. Install in this order (from 1 to 3):



CAUTION:

Insert the spool slowly and directly into the hole. After inserting the spool, slide the spool by hand. If there is reluctance or rugged movement, a spool operation failure may occur.

CAUTION:

After the assembly is finished, recheck the forgotten parts for assembly. If you forget tightening, oil leaks may result from the loosened parts. The instructions for tightening torque in this document are wet values (the conditions in which hydraulic oil is adhered).

6-4-6 Servicing Procedure for Relief Valve

1. Main relief valve

(1) Disassembly: Refer to Fig. 6-1.

Remove the plug **2**, sleeve **3**, main poppet **4**, and spring **9**.

Loosen the adjuster kit **7**. Remove the pilot poppet **6** and spring **8**.

Do not disassemble the pilot seat **5**, because it has caulking at the plug tip.

[1] Hold the body **2** with a vice to remove the plug **2**. (Remove the whole plug unit including the inner parts.)

[2] Remove the body **2** from the vice. Then, remove the sleeve **3**, spring **9**, and main poppet **4**.

[3] Remove the O-ring **13** from the body.

[4] Hold the plug **2** with a vice to loosen the lock nut of the adjuster kit **7**.

[5] Remove the adjuster kit. Then, remove the spring **8**, pilot poppet **6**, and O-ring **15**.

[6] Remove the O-rings **10** and **12**, and backup ring **11** from the plug **2**.

The relief valve is, in principle, replaced with the assembly. Do not disassemble it unless there is abnormality.

(2) Cleaning and checking

Clean all parts completely with mineral oil. Blow compressed air to dry them and then check each part.

[1] The seat surface of each poppet and plug must be free from any defects and have an even contact surface.

[2] The main poppet **4** and sleeve **3** must slide lightly and smoothly. The outer circumference of main poppet and the inner circumference of sleeve must be free of scratches.

[3] The spring **8** must be free from breakage, deformation, and wear.

[4] The cut holes in the main poppet **4** and pilot seat **5** must not be filled with foreign material.

[5] The O-rings and backup rings must be replaced with new ones.

If you find a minor damage during the above checks, remove it by lapping. If an abnormal part is found, replace with the whole relief valve assembly.

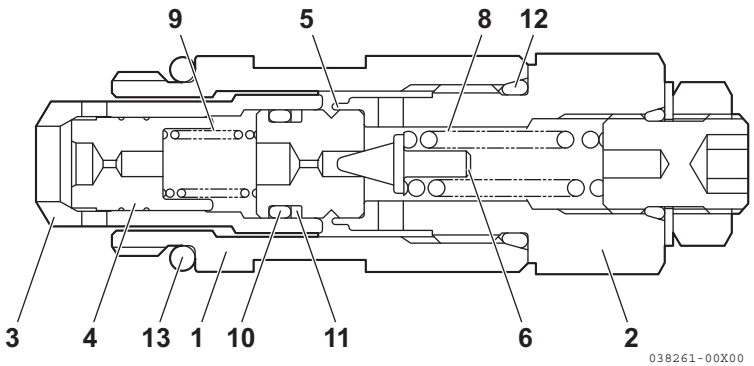


Fig. 6-1

(3) Reassembly

[1] Install the pilot poppet **6** and spring **8** to the plug **2**.

[2] Install the O-ring **15** to the adjuster kit and temporarily tighten the adjuster kit on the plug **2**.

[3] Install the O-rings **10** and **12**, and backup ring **11** to the plug **2**.

Note:

Check the location of the O-rings and the backup ring.

[4] Install the O-ring **13** to the body **1**.

[5] Install the main poppet **4** and spring **9** to the sleeve **2**, and insert them into the body **1**.

[6] Install the plug **2** with the pilot poppet and other parts installed into the body **1**.

[7] Hold the body **1** with a vice to tighten the plug **2**.

Tightening torque: 57.9 to 65.1 ft lbf (78.5 to 88.3 N•m)

[8] Install the body to the valve housing.

Tightening torque: 57.9 to 65.1 ft lbf (78.5 to 88.3 N•m)

(4) Set pressure adjustment procedure

Install a correctly adjusted pressure gauge in the inlet circuit (on the pump port side) and adjust the pressure as follows:

[1] Loosen the lock nut and turn the adjuster screw counterclockwise to set the pressure at a low level.

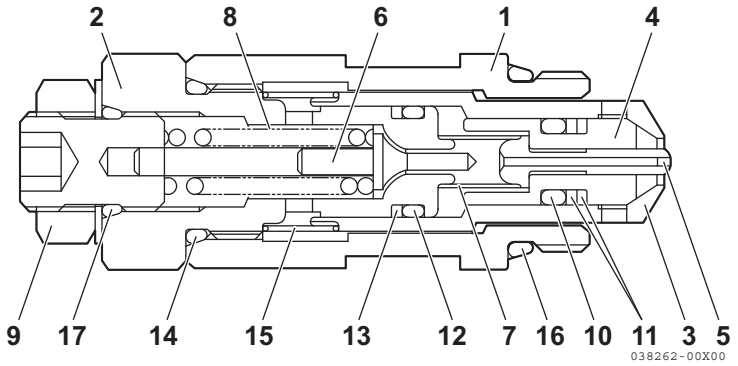
[2] Run the engine at medium speed. (To ensure the speed is sufficient when the set pressure load is applied to the pump.)

[3] Move one of spools, which corresponds to the relief valve in the control valve to be adjusted, to its stroke end, and read the pressure gauge.

[4] Turn the adjuster screw clockwise until the specified set pressure is obtained. Reference data: pressure increment per turn of adjuster screw (2567.2 PSI (17.7 MPa)/turn)

2. Port relief valve

1) Instruction



Item	Description	Q'ty	Torque ft lbf (N•m)	Tool in (mm)	Remark
1	Cap	1	50.9 to 58.3 ft lbf (69 to 79 N•m)	0.9 in (24 mm)	
2	Plug	1	50.9 to 58.3 ft lbf (69 to 79 N•m)	0.9 in (24 mm)	
3	Poppet	1			
4	Main poppet	1			
5	Piston	1			
6	Pilot poppet	1			
7	Spring, main	1			
8	Pilot spring	1			
9	Adjuster kit	1	19.9 to 22.9 ft lbf (27 to 31 N•m)	0.7 in (17 mm) 0.2 in (6 mm)	Nut Screw
10	O-ring	1			
11	Back-up ring	1			
12	O-ring	1			
13	Back-up ring	1			
14	O-ring	1			
15	O-ring	1			
16	Spring	1			
17	O-ring	1			

(1) Disassembly

Remove plug **2** from cap **1**. Remove poppet **3**, main poppet **4**, piston **5** and spring **7**, **15**. Loosen adjuster kit **9** then remove pilot poppet **6** and pilot spring **8**.

(2) Assembly

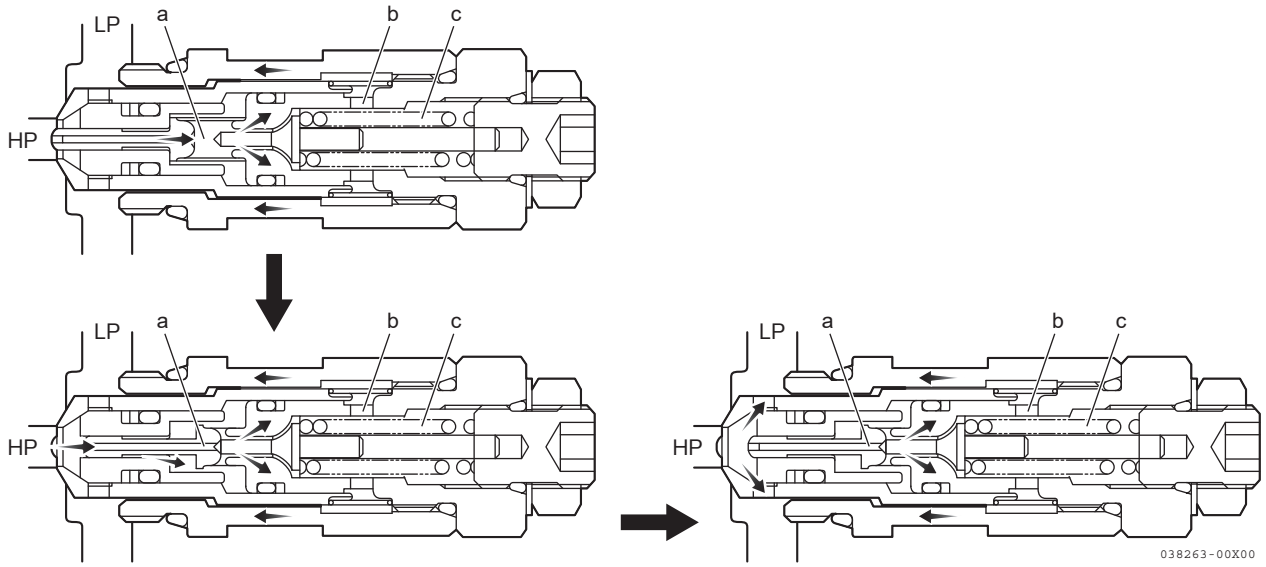
Before assembly, wash all parts with clean oil, then dry by air blow.
Inspect the parts to make sure there is no contamination, damage such as dent or score or wear.
Replace relief valve if there is any defect on the parts.
Do not reuse seals and back-up rings and exchanging all seals and back-up rings are necessary.
Before installation of main poppet **4**, install O-ring **10** and back-up rings **11**.
Put piston **5** into main poppet **4** and then put them into poppet **3**.
Install poppet **3** and spring **7**, **15** on plug **2**.
Put pilot poppet **6** and pilot spring **8** into plug **1**, and then tighten adjuster kit **9** temporarily.
Tighten cap **1** and plug **2**.
After adjust the pressure, tighten the nut and lock adjuster kit **9**.
Reference data: pressure increment per turn of adjuster screw

For low pressure port (Blade section) : 2582 PSI (17.8 MPa) /turn
For high pressure port (Other sections) : 4119 PSI (28.4 MPa) /turn

2) Function

(1) Relieving

The pressurized oil in work port (HP) flows through the orifice of piston **5**. The pressurized oil opens pilot poppet **6** against force of the spring **8** in spring chamber (a). This allows the oil flow to go through spring chamber (a) to passage (b). The oil then returns to tank passage (LP). When the pilot poppet **6** is opened, it causes a decrease in the pressure in spring chamber (c) that allows piston **5** and main poppet **4** move up until the oil pressure is released.



6-4-7 Installation

When you attention to install the control valve following;

- Note that extra bending doesn't join the valve.
- Tighten all the installation bolts thoroughly.
- The valve must note that seals might be damaged by the excessive heat and the spatter when the welding work is done soon in the vicinity.
- Do not remove the care of each port until the time of piping for the going into it prevention of garbage.
- Obtain the linkage axially to operate the spool within 3°.

6-4-8 Running

- It is confirmed that pressure is gradually raised after it is confirmed that the valve array is normal, and the hydraulic fluid is clean (a low idol operates the working machine the inching), and there is no external leakage.
- The oil pressure hydraulic fluid must be used, and the aniline point must use from 179.6 to 235.4 °F (82 to 113 °C) for oil.
- Do not raise the relief valve more than the regulated set pressure.
- Work really after doing the warmth driving enough.
- Especially, note the following respect to prevent the stick by the heat shock of the spool when the temperature of the hydraulic fluid and the temperature of the valve start for low.
- Neither the main relief valve nor the overload relief valve are continuously suddenly operated, and operate so that the hydraulic fluid in each actuator may circulate, and raise each part uniformly when you drive warmth.
- Do not do suddenly at the low temperature so that a minute operation and the compound operation may cause partial generation of heat caused by each part orifices.

6-4-9 Troubleshooting

Before performing any test, visually inspect the complete hydraulic system for oil leakage and for parts damage.

WARNING:

To prevent personal injury, when testing and adjusting the hydraulic system, move the machine to a smooth horizontal location and lower the mast and carriage to the ground. If the mast and carriage can not be on the ground, make sure they are blocked correctly to keep them from falling unexpectedly. Move away from machines and personnel that are at work. There must be only one operator. Keep other personnel away from the machine, or in a location where the operator can see them.

Before any hydraulic plug, line or component is removed, make sure all hydraulic pressure in the system is released.

Symptom: Spool cannot be stroked or attachment speed is not correct.

Check point	Correction
Hydraulic fluid temperature is too high.	Remove resistance in the circuit.
Contamination.	Flush the circuit and exchange hydraulic fluid.
Too much torque to tighten connector.	Check tightening torque.
Deformative valve housing by improper mounting.	Loosen the mounting bolts and check the flatness.
Pressure is too high.	Check pump pressure and work port pressure.
Spool is bent.	Exchange spool section assembly.
Return spring damage.	Exchange parts.
Out of alignment for spring and cap.	Loosen socket head bolt for pilot cap and tighten again.
Pilot pressure is not high enough.	Check pilot valve and pilot relief pressure.
Compensator spool is stuck.	Clean up or exchange spool section assembly.

Symptom: Load cannot be held.

Check point	Correction
Leakage in cylinder.	Check the cylinder.
Leakage from spool.	Check for scratches on spool.
Leakage from overload relief valve.	Clean up valve housing and relief valve.
Leakage from anti-drift valve.	Disassemble anti-drift valve unit and clean up. Check for damage or scratches.
Contamination in load check valve.	Clean up load check valve. Exchange check valve or spool section depending on damage.

6-5 Pilot Valve

6-5-1 Remote Control Valve

Pilot valve unit for arm rest installation
Type 4TH5

Maintenance Instructions

1. Introduction

1) Foreword

This manual deals with the instructions relative to servicing and maintenance operations for the hydraulic pilot control unit 4TH5 for the inspections and servicing operations associated with the hydraulic system of the machine to which they are connected. Please consult the maintenance manual supplied by the equipment manufacture.
It is recommended that only qualified personnel perform the installation, connection and maintenance of this device, and that all operations shall be carried out in compliance with the technical standards in force and the cleanliness regulations specific to this type of installation.

To ensure maximum performance and safety during maintenance operations we advise you to **Read this manual thoroughly**

All information, illustrations, instructions and characteristics contained in this document are based on the latest product information available at the time of publication. In its attempts to maintain a high-quality product, MANNESMANN REXROTH reserves the right to make design or technical modifications at any time and without prior notification.

2) Safety Instructions

Please pay a special attention to the signals of safety alerts and special instructions in this manual. They are indicated in the following manner:

Indicates information or instructions which must be followed to guarantee your safety during operations.

CAUTION :
Warning against possible equipment damage.

Note :
Useful information.

2. Troubleshooting

CAUTION :

Before starting any procedures of troubleshooting or removing the hydraulic pilot control unit, inspect the global machine's hydraulic system to eliminate all possible malfunctions not related to the pilot control unit.

Abnormal operation of equipment connected to the hydraulic pilot unit

Malfunction	Probable case	Additional checks	Remedy
No machine movement (for hydraulic signal receivers only)	(1) Leak	See <Visual defects>	
	(2) Control valve seized or blocked		Replace pilot unit
Lack of speed of one or several machine movement(s) (for hydraulic signal receivers only)	(1) Poor pressure signal		Replace pilot unit
	(2) Leak	See <Visual defects>	
No machine movement (for electric signal receivers only)	(1) Electric function failure		Replace handle
	(2) Handle poorly connect	Check the connection	

Abnormal Hydraulic Pilot Unit Operation

Malfunction	Probable case	Additional checks	Remedy
Handle does not automatically return to neutral position: (1) Manual return with friction	(1) Faulty cardan		Replace cardan
Handle does not automatically return to neutral position: (2) Manual return without friction	(1) Lip seal too hard inside guide		Replace guides + plungers
	(2) Regulation unit setting spring broken	Remove the regulation unit for visual inspection	Replace pilot control unit
	(3) Regulation unit plater broken		
Handle turns	(1) Handle parts loose		Tighten all handle parts

Visual Defects

Malfunction	Probable case	Additional checks	Remedy
Rubber boot damaged			Replace boot
Leak on arm rest originating from under the boot	Leak between guide and push buttons	Lift the boot to perform a visual inspection	Replace guides + plungers
Seepage on body	Porous body		Replace the pilot unit

3. Fundamental Rules

1) General Information Concerning Pilot Control Unit Connection

When removing the pilot control unit, all openings must be plugged immediately to prevent any contamination of the hydraulic system.

When replacing the pilot control unit, remove the plastic plugs from the openings and lines just before making the connections.

Do not tighten connectors to a torque greater than that specified in the assembly instructions.

Check the hydraulic installation's oil quality and filtration capacity during all servicing/maintenance operations.

The use of teflon tape, hemp and joint filler is prohibited.

Hydraulic lines and connections must not be under any strain whatsoever.

4. Removal / Installation of the Pilot Control Unit Connection

1) General Recommendations

CAUTION :

Before removing the pilot control unit from the machine, the block and its surroundings must be thoroughly cleaned with a high-pressure cleaner.

No impurities must enter the hydraulic system. Plastic plugs are to be fitted on lines and orifices immediately following their removal.

Wear protective clothing and use suitable equipment to prevent accidents, particularly concerning the hydraulic fluid.

Set all actuators connected to the machine in neutral position (on the ground, at lower limit...) to avoid accidents which could result from uncontrolled movements of the equipment when the hydraulic system is disconnected.

With the machine off, release the pressure remaining in the system by manipulating all of the distribution spools. This is performed by moving the handle in all directions.

2) Pilot Control Unit Removal

Immediately after disconnecting the lines from the control device, fit the sealing plugs. Make sure to collect any possible oil leakage in a suitable receptacle.

Unscrew the mounting screws and remove the control device.

3) Installation of the Hydraulic Pilot Control Unit

Contact faces must be perfectly clean.

Check the evenness of the support area on the machine (tolerance : 0.5 mm).

Check the condition of the line connector seals.

Clean the pilot control unit if it has been in storage for a long period of time.

Correctly place and secure the pilot control unit onto the machine with the mounting screw (maxi torque : 10 N·m).

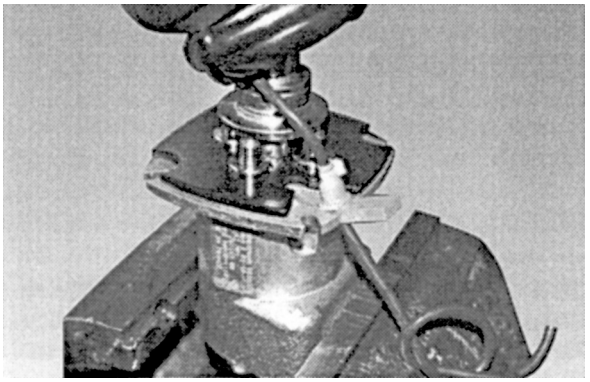
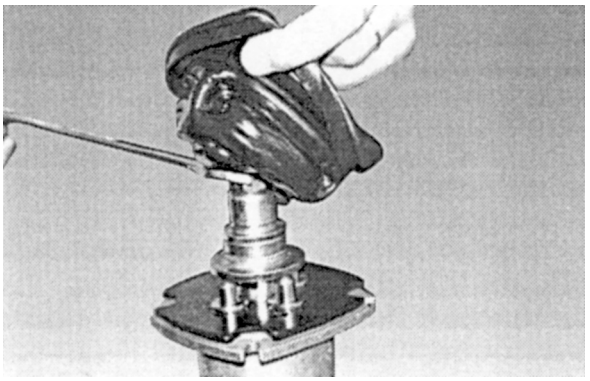
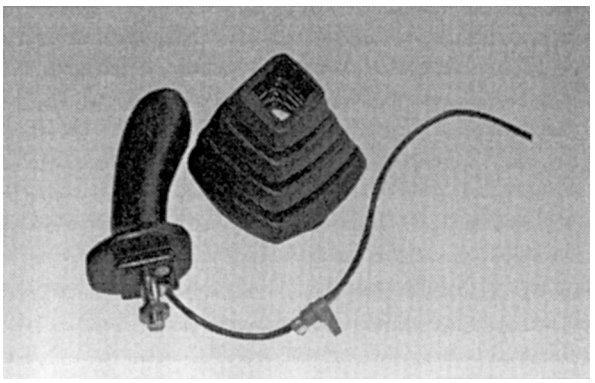
Connect the lines to the control unit as per the connecting diagram and tighten to the torque specification (maxi torque : 30 N·m).

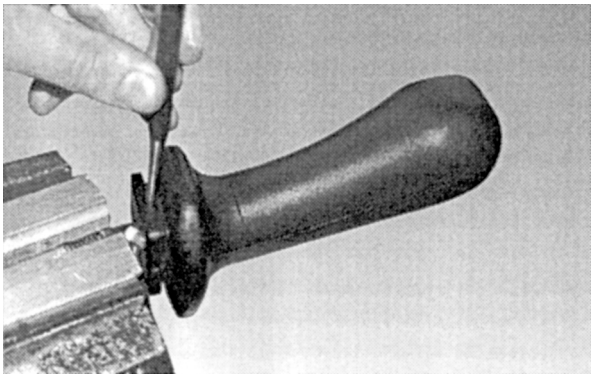
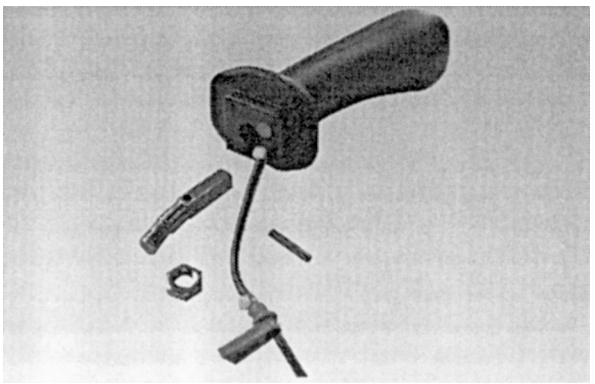
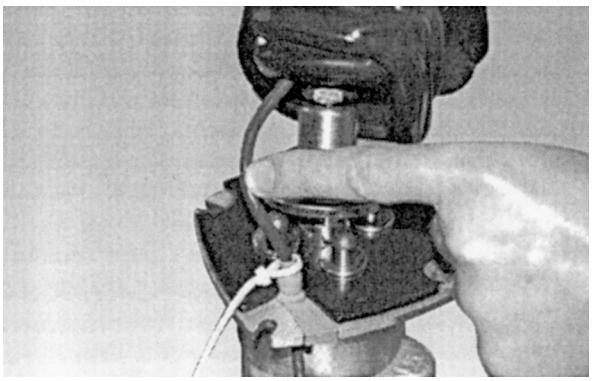
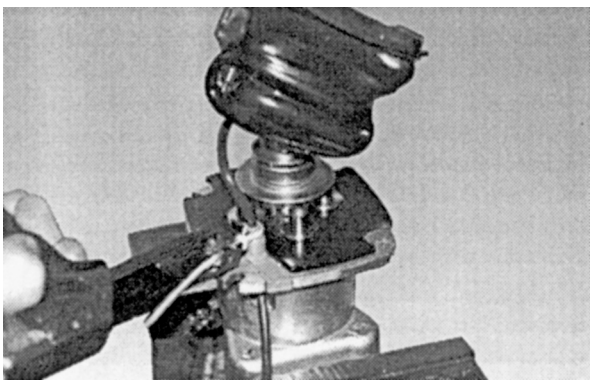
Ensure that the hoses are not twisted or rubbed.

Once correctly installed, the unit can be placed into operation.

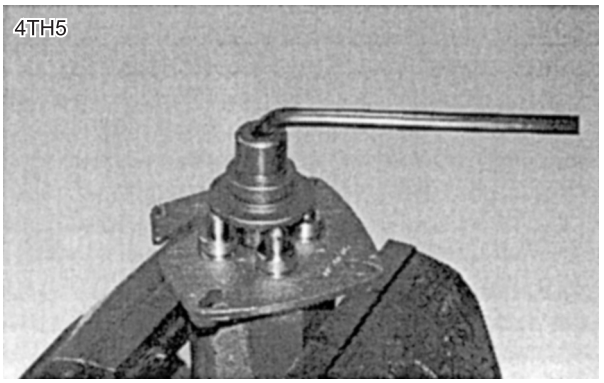
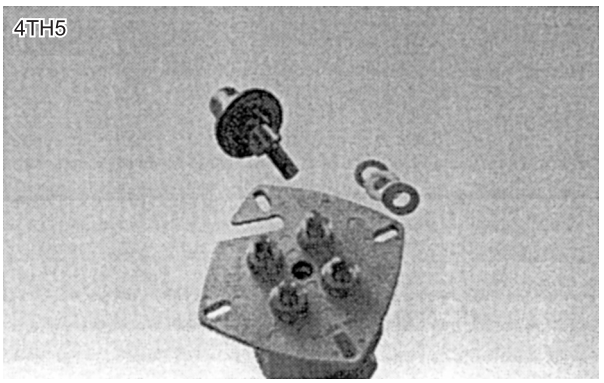
5. Pilot Control Unit Repair Procedures

1) Boot or Handle Replacement

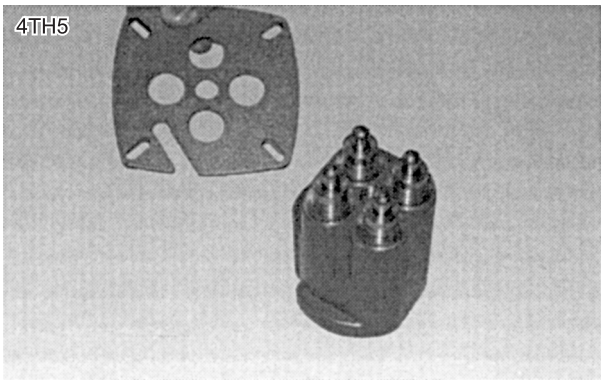
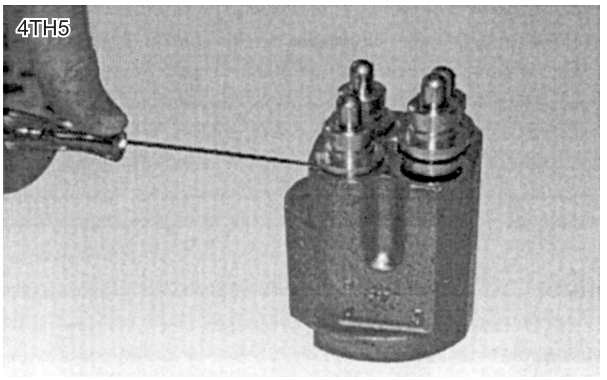
Procedure	
Preliminary operations Remove the pilot control unit from the machine's arm rest of free the unit by unscrewing the 4 screws fixing the plate in order to release the electrical cable. Hold the pilot control unit using a vice or a vice-grip wrench (clamp onto the body above the arm rest, 65 opening). ***Note :*** *The pilot control unit does not need to be removed from the machine to release the cable. However, it is recommended to lift the control unit by undoing the 4 fixing screws on the arm rest.* *It is unnecessary to remove the units without electrical functions.* **Machine off :** **- place all of the machine's equipment connected to the pilot control unit in neutral position,** **- release stored pressure by operating all of the pilot unit's control valves by moving the handle in all directions.** **Handle removal** Lift and turn the boot inside out. Remove the grommet from its emplacement to free the cable. Loosen the handle mounting nut (19 mm open-end wrench). Reassembly : torque : 30±3 N·m Unscrew and remove the handle.	 
Boot replacement Remove the faulty boot and replace it with a new boot. Replace the handle following the disassembly instructions in reverse order.	

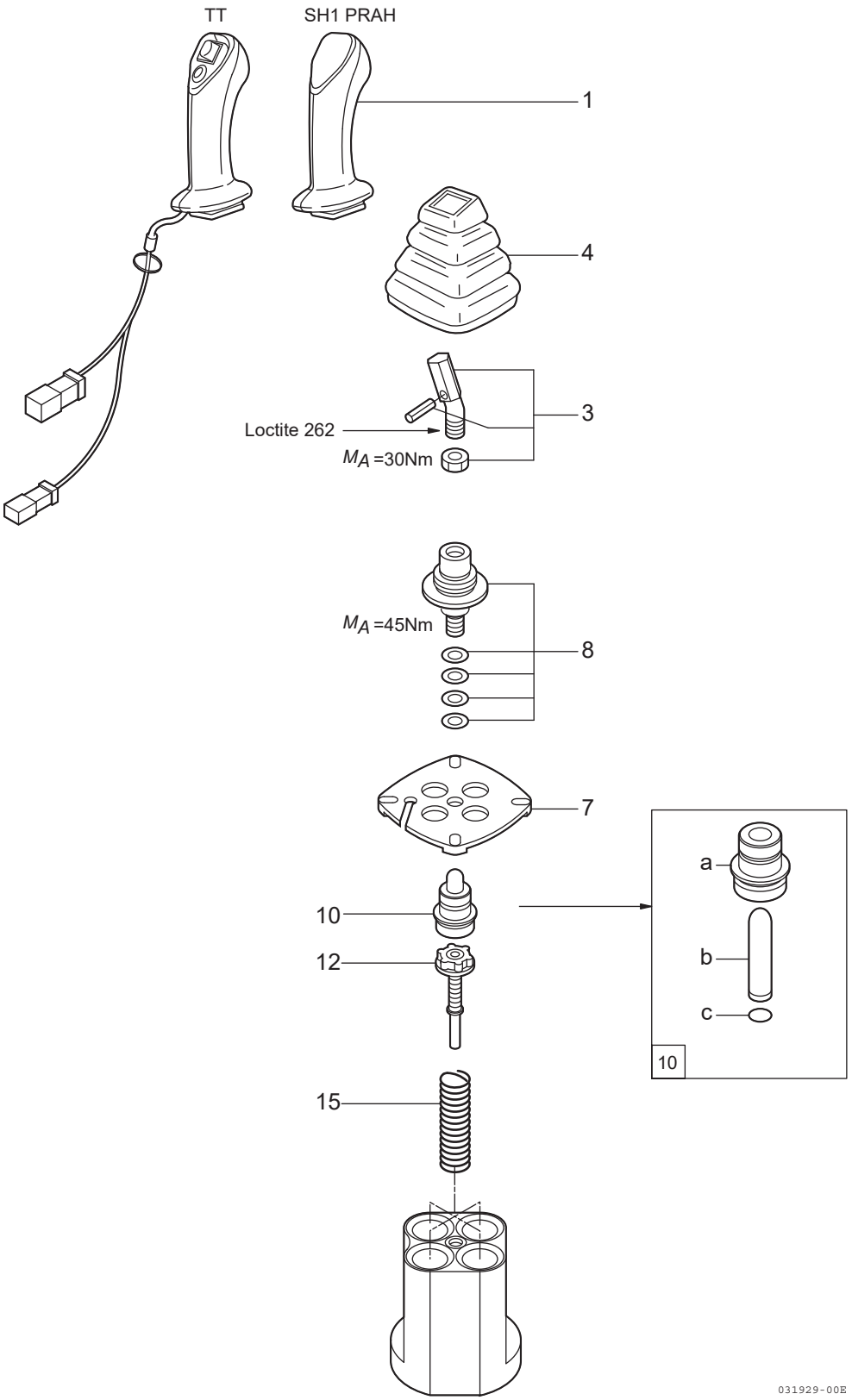
Procedure	
Handle replacement Clamp the threaded section of the bent lever in a vice fitting with V-shaped vice clamps. Remove the pin (5 mm pin driver)	
Remove : - pin, - bent lever, - handle. Replace the bent lever onto the new handle and secure it with the pin (5 mm pin driver) ***Note :*** *Respect the position of the bent lever to ensure that the handle is correctly oriented as indicated by the machine's technical specifications.* Replace the nut on the threaded section and replace the boot.	
Screw the handle onto the pilot control unit and tighten the nut (19 mm open-end wrench). Connect the new handle's electrical wiring to the machine's electric system. Fit the grommet into its emplacement while leaving enough cable length so as to enable the correct handle operation.	
Secure the cable to the grommet with a cable clamp. Fold down the boot.	

2) Cardan Replacement

Procedure	
Preliminary operations Remove the pilot control unit from the machine's arm rest. Secure the pilot control unit in a vice (clamp onto the body). Remove the handle. ***Note :*** *It is recommended to remove the pilot control unit from the machine. Nevertheless, the servicing on machine is possible by securing the unit into a vice-grip wrench (65 opening). This is performed by extracting the body from the arm rest so as to clamp the vice-grip wrench onto the body in order to hold it above the arm rest.* **Removal of the cardan** Fit an Allen wrench into the assembly screw and unscrew it (8 mm Allen wrench). Reassembly : torque : 45±4 N·m Remove : - the cardan, - the shim (s) Reassembly : Adjust the pre-depression of the cardan by selecting the shims necessary to obtain play-free contact between the switch-plate and the plungers. In neutral position, the depression of the plungers must not exceed 0.2 mm. In order to check this value, observe the displacement of the plunger located opposite to the one being pressed. ***Note :*** *The pre-depression may be difficult to achieve on site. Could be necessary to readjust it after reassembly and system working control.*	 

3) Guide / Plunger and Regulation Unit Replacement

Procedure	
Preliminary operations Remove the pilot control unit from the machine's arm rest. Remove the handle. Remove the cardan. ***Note :*** *It is recommended to remove the pilot control unit from the machine. Nevertheless, the servicing on machine is possible by securing the unit into a vice-grip wrench (65 opening). This is performed by extracting the body from the arm rest so as to clamp the vice-grip wrench onto the body in order to hold it above the arm rest.*	
Removal Secure the pilot control unit to a vice. Remove the retaining plate. Reassembly : Line up the notches for the grommet in both the plate and the body.	
Insert the end of a thin screwdriver between the guide and the body, carefully lift the guide to remove it from the body. ***Note :*** *Hold the guide with the other hand during the extraction operation to limit the effect of the return spring.* Remove the guide / plunger assembly. Repeat the operation for the other 3 sub-assemblies. Reassembly : Use the retaining plate to insert the 4 guides into the body simultaneously and perpendicularly. Reassemble in reverse order.	
Regulation unit verification Extract the regulation units from the body (using flat nose pliers). Visually check that the guides / plungers are in good condition. If defects are present, replace the 4 sub-assemblies. Inspect the regulation units and particularly their spring. If defects are detected, replace the 4 units.	


TT
SH1 PRAH
1
4
3
Loctite 262
M_A =30Nm
M_A =45Nm
8
7
10
12
15
a
b
c
10
031929-00E

Item	Description
1	Handle TT
3	Lever kit
4	Rubber boot
7	Retaining plate
8	Cardan kit composed of : 1 cardan + shims
10	Plunger kit composed of : 4 plunger guides a 4 plain plungers b 4 spring rings c
12	Regulating kit
15	Set of 4 return springs

Item	Description
1	Handle SH1 PRAH + Deutsch connectors 2 & 6 pins
3	Lever kit
4	Rubber boot
7	Retaining plate
8	Cardan kit composed of : 1 cardan + shims
10	Plunger kit composed of : 4 plunger guides a 4 plain plungers b 4 spring rings c

6-5-2 Travel Pilot Valve

1. Outline

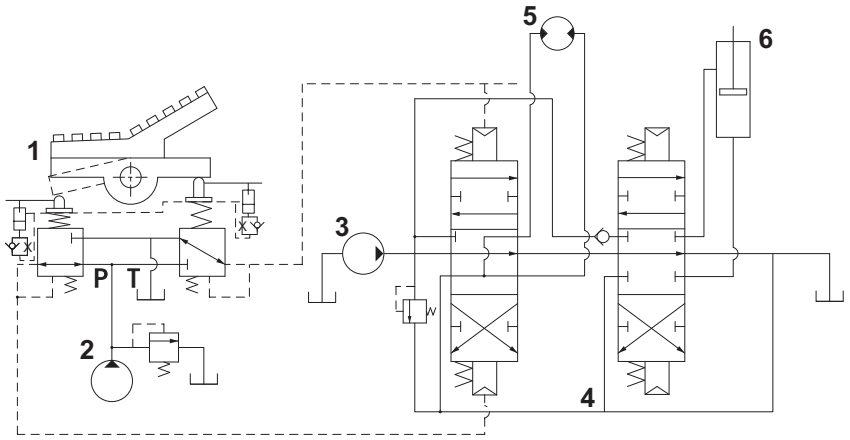
The damper-embedded pilot valve, PVD6P, is a reducing-type valve using 4 secondary-pressure-controlling reducing valves contained in a single valve casing. The outlet pressure varies according to the angle of the operating section. The PVD6P also includes a damping mechanism coupled to the valve casing, a mechanism which prevents hunting (lever-hunting) in the man-machine system.

Maximum primary pressure	1000 PSI (6.9 MPa)
Secondary pressure	0 to 420 PSI <maximum control pressure> (0 to 2.9 MPa)
Allowable back pressure	At maximum 42 PSI (0.29 MPa)
Rated flow volume	2.64 GPM (10 L/min)

2. Operation Theory

The dumper-embedded pilot valve includes in its main body a damping function to prevent hunting (lever-hunting) in the man-machine system.

The following explains the operation of the damper-embedded pilot valve, separating it into **2** sections: "a. reducing valve" and "b. operation section damping mechanism" based on the hydraulic circuit diagram below, the assembly cross-section drawing in **16**, and the damping operation explanation drawing in **7**. The following figure shows a typical usage of the pilot valve.



Hydraulic circuit diagram

1) Reducing Valve Section

(1) When the pilot valve operating section is at the neutral position

The spool **17**, pushed upward by the return spring **27** through the spring seat **12**, is at its neutral position as shown in the assembly cross-section drawing.

Since the outlet port is joined only with the tank port T as a result of the spool switching function, the pressure at the outlet ports **1** and **2** is the same as the pressure at the tank port T.

(2) When the pilot valve operating section is tilted from the neutral position

As shown in the assembly cross-section drawing, when the cam **21** is rotated clockwise, the push rod **3** at the port **1** is pressed downward, which pushed the spool downward with the help of the spring seat, the secondary-pressure-setting spring **26**, the shim **13**, and the washer **14**. As a result, the port P and the port 1 are joined each other and the oil supplied from the pilot pump starts to flow into the port **1**, generating a flow pressure.

When the pressure at the port **1** increases to a pressure equivalent to the force of the secondary-pressure-setting spring, having been set by the tilted operating section, the oil pressure applied to the spool and the spring force are kept in balance, which keeps the port **1** outlet pressure constant.
Since the spool at the port **2** remains neutral, the return oil from the control valve flows out through the tank port T.
Depending on the specifications, the push rod touches the top of the spool directly when the operating section is tilted fully, which forcefully pushes down the spool, joining the port P and the outlet port, resulting in an equal pressure at both ports.

2) Operation Section Damping Mechanism

(1) When the operating section is at the neutral position

As shown in the assemble cross-section drawing & the push rod is pushed upward by the damping spring **10** through the piston **9**.

(2) When the operating section is tilted from the neutral position (Refer to the damping operation explanation drawing **1**)

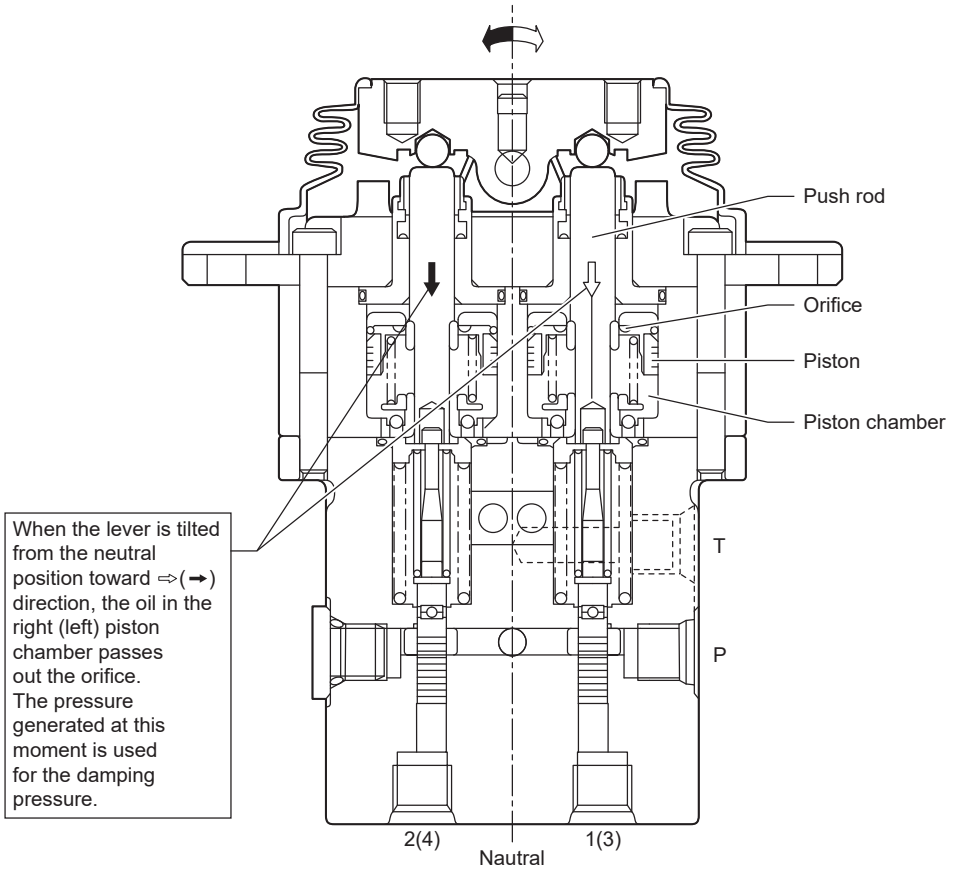
As you see in the drawing, when the cam is rotated clockwise, the push rod at the port **1** is pressed downward and the piston moves downward.
At this moment, the oil in the damping piston chamber passes out through the orifice in the piston, producing a pressure used for damping.
On the other hand, the push rod at the port **2** is moved upward by the damping spring through the piston.
At this moment, the oil in the tank room is absorbed into the damping piston chamber through the **3** ball check valve portions (using the ball **24**). The oil outside the piston chamber flows through the path that joins with the port T at the top of the casing.

(3) When fully tilted operating section is tilted in reverse direction (Refer to the damping operation explanation drawing **2**)

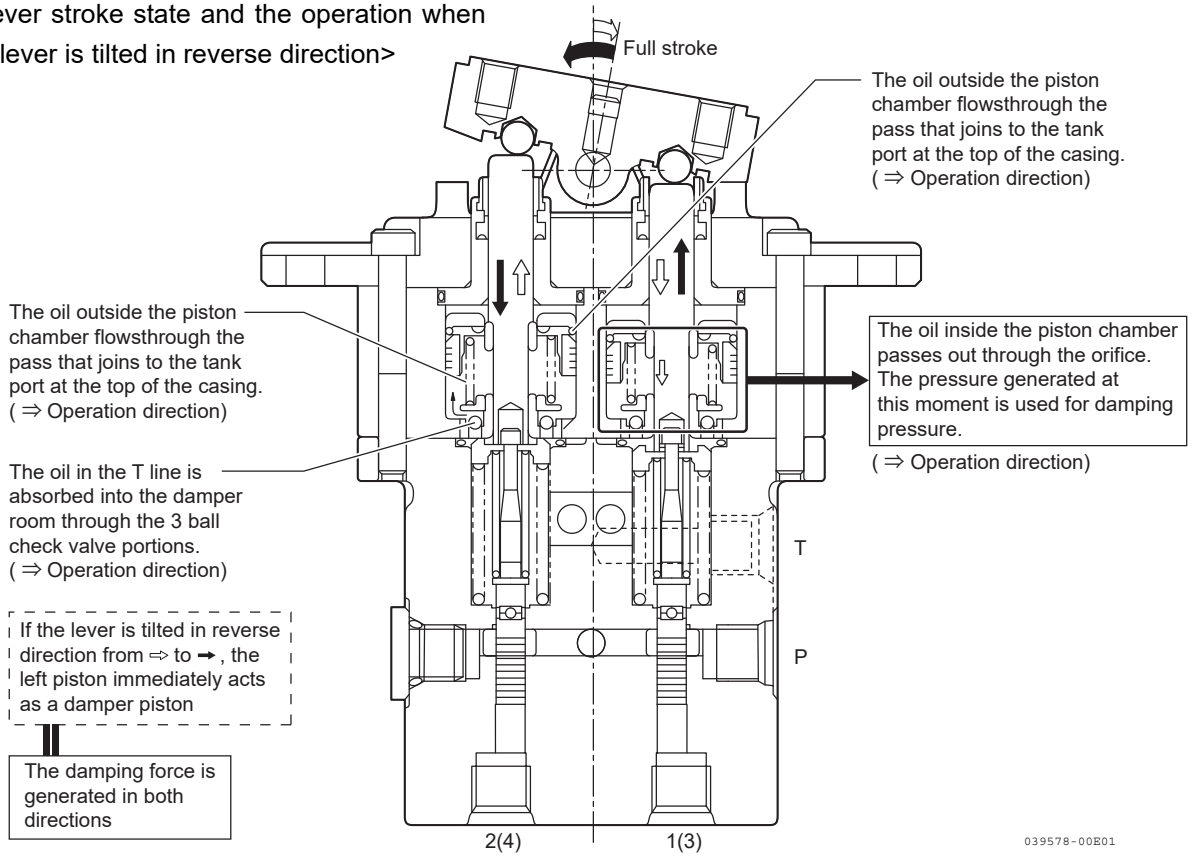
In the operation explanation drawing, if the cam, having been fully tilted clockwise, is tilted anticlockwise, the push rod at the port **2** is pushed downward and the piston moves downward. At this moment, as in the case above, the 0il inside the damping piston passes out through the orifice in the piston, producing a pressure used for damping.
On the other hand, the push rod at the port **1** is moved upward by the return spring **27** and the damping spring.
As in the case above, the oil in the tank room is absorbed into the damping piston chamber through the **3** ball check valve portions. The oil outside the piston chamber flows through the path that joins to the tank port from the casing top.
In other words, the damping force is generated in both cases when the operating section is tilted from the neutral position to the fully tilted position and from the fully tilted position to the neutral position.

Damping operation explanation drawing

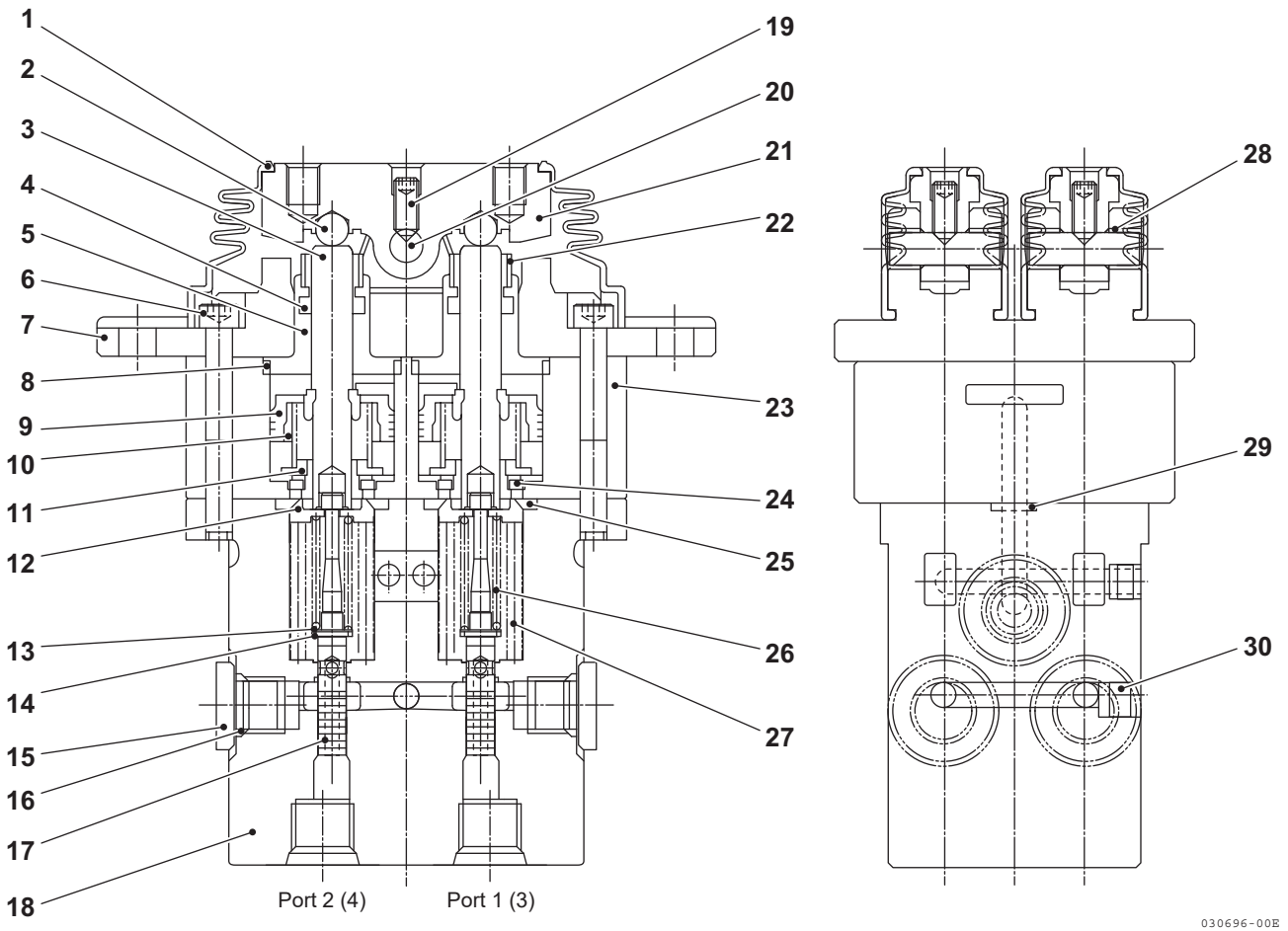
(1) <Operation when the lever is tilted from the neutral position>



(2) <Lever stroke state and the operation when the lever is tilted in reverse direction>



3. Cross Section Drawing and Component Parts



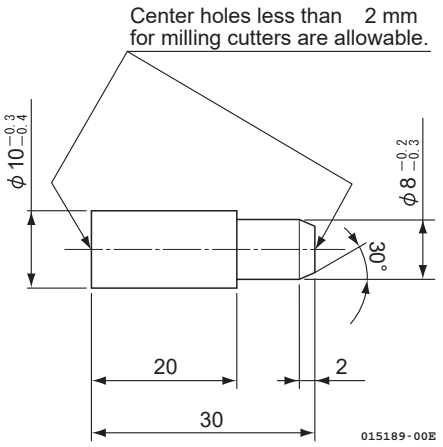
No.	Description	Q'ty	No.	Description	Q'ty
1	Bellows	2	16	O-ring	3
2	Steel ball	4	17	Spool	4
3	Push rod	4	18	Casing	1
4	Packing	4	19	Set screw	2
5	Plug	4	20	Cam shaft	2
6	Allen screw	4	21	Cam	2
7	Cover	2	22	Grease cap	4
8	O-ring	4	23	Casing damper	1
9	Piston	4	24	Steel ball	12
10	Spring	4	25	O-ring	4
11	Spring seat	4	26	Spring	4
12	Spring seat	4	27	Spring	4
13	Shim	4	28	Bush	4
14	Washer	4	29	O-ring	2
15	RO plug	3	30	Plug	2

4. Special Tool

1) Special Jig for Disassembling/Reassembling

Special jig 1 (for removing the bush)

(Unit: mm)



5. Disassembly and Reassembly

1) Disassembling Instructions

(1) Operational precautions in general

[1] Prepare a solid and rattle-free working bench that is wide enough to place parts on and that does not allow the parts to drop or move.

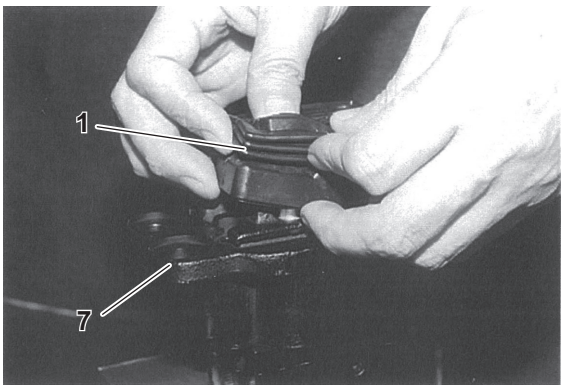
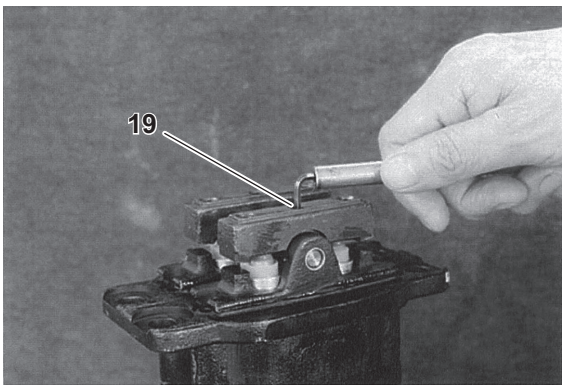
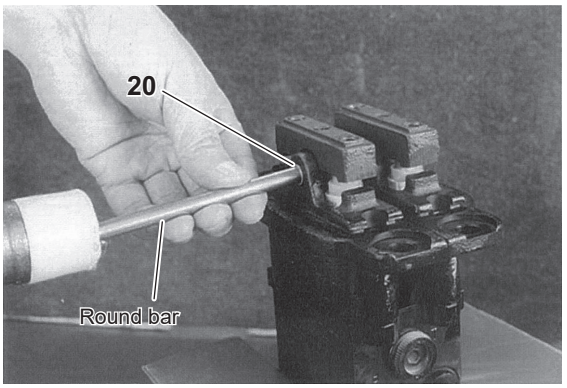
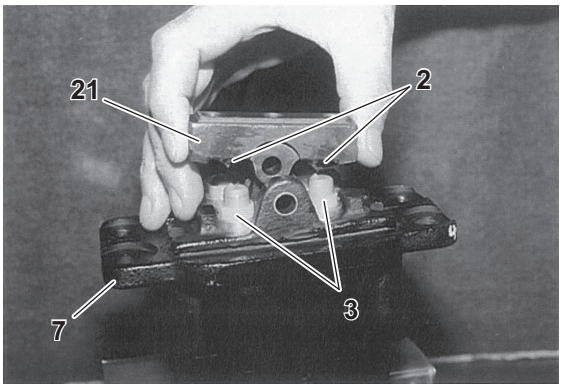
[2] Prepare tools and materials.

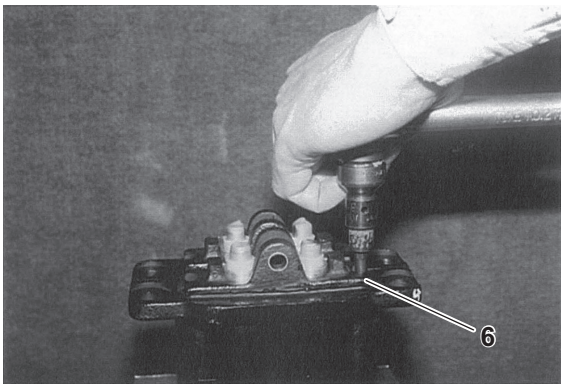
[3] Since the parts are very precise, handle them with much care not to bump them each other or drop them.

[4] Do not hit or wrench the parts even when they are hardly moved. Other wise, burrs may be generated or the parts may be damaged, causing an oil leakage or degradation in performance. Always work with patience with much care.

[5] Leaving the parts disassembled may cause them to rust as a result of humidity or contamination. If it is absolutely necessary to stop working before reassembling, pay attention to prevent rust and dust.

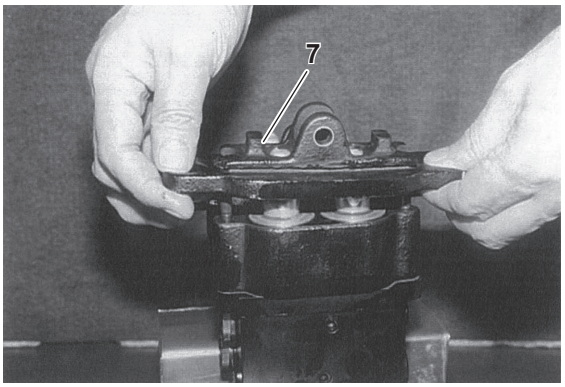
(2) Disassembling procedures

Procedure	
(1) Clean the pilot valve with kerosene. ***Note:*** *Close each port with a blind plug.* (2) Fix the pilot valve on a vice using cushion sheets. Remove the bellows **1** from the cover **7** by pulling the bellows upward.	
(3) Loosen the setscrew **19** with an Allen wrench. ***Note:*** *Be careful because Loctite #241 is applied to the setscrew and the tightening torque is large.*	
(4) Putting a round bar (Ø0.28 in. [7 mm] or less) on one end of the cam axis **20**, tap the bar gently with a hammer to pullout the axis.	
(5) Remove the cam **21**. ***Caution:*** **- Treat the cam and the steel ball 2 as a single assembly. (Disassembling impossible)** **- Note down the positional relationship between the cam and the cover 7.** **- Be careful because the push rod 3 may push out while the cam is removed.**	

Procedure	
(6) Unscrew the Allen screw **6** with an Allen wrench.	

(7) Remove the cover **7**.

Caution:
- Note down the positional relationship between the cover and the casing (damper) 23.
- Be careful because the push rod 3 and the plug 5 may be pushed out by the damping spring 10 while the cover is removed. (The plug remains inside the casing as a result of the sliding resistance of the O-ring 8 only.)

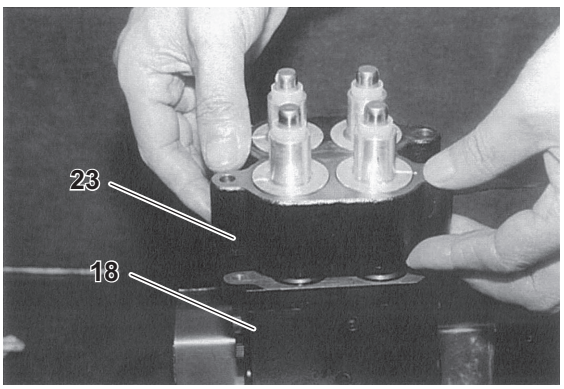


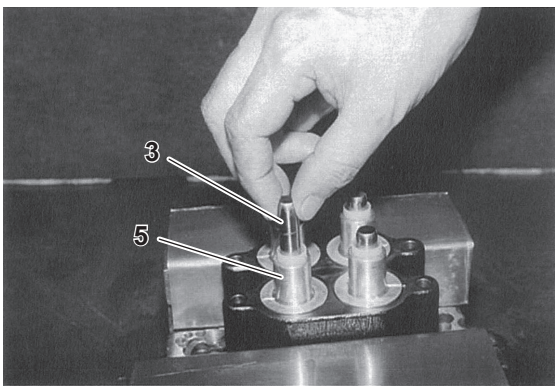
(8) Remove the upper casing assembly and fix it in a vice.

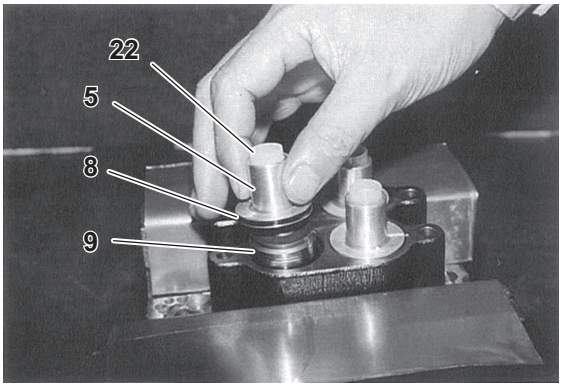
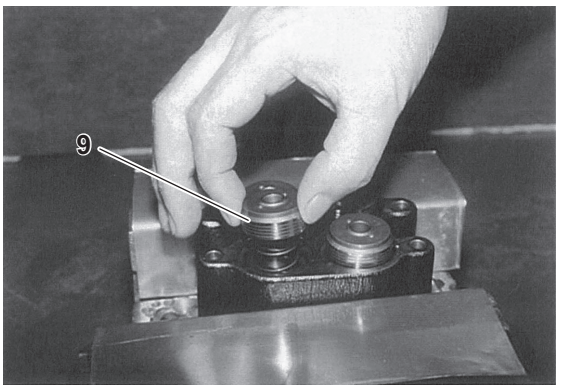
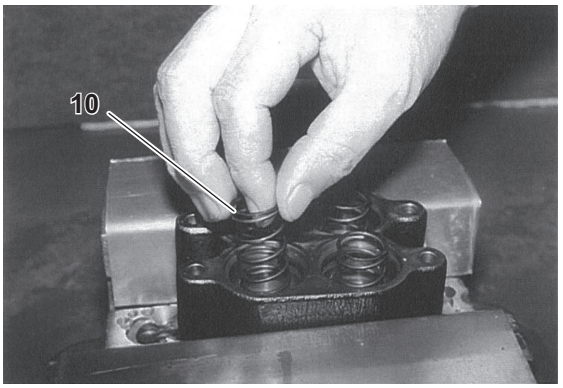
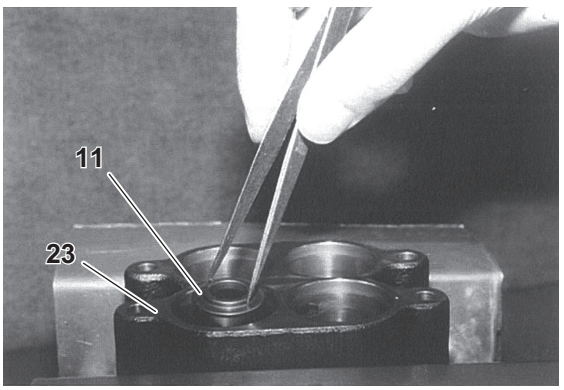
Note:
*Note down the positional relationship between the casing (damper) **23** and the casing **18**.*

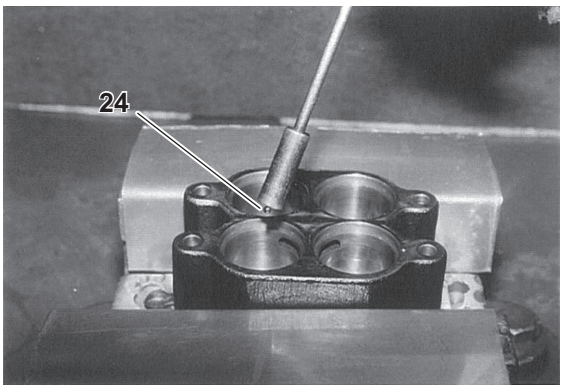
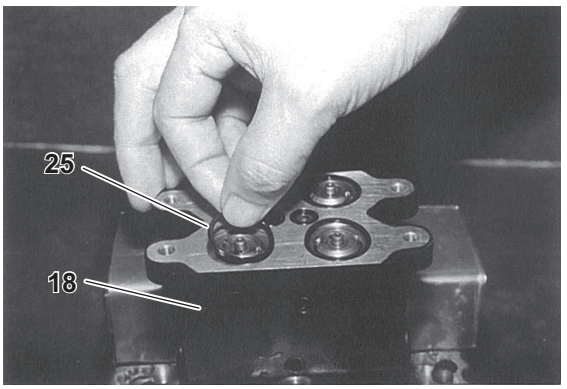
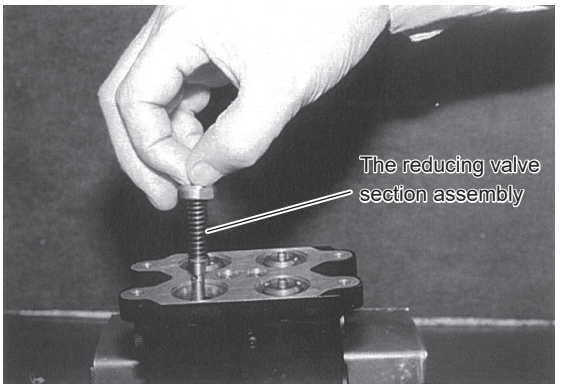
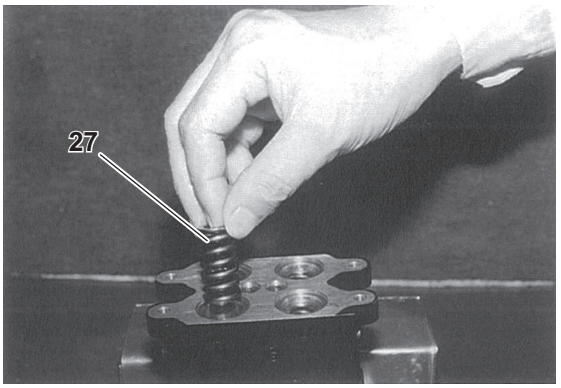
(9) Pull out the push rod **3** from the plug **5**.

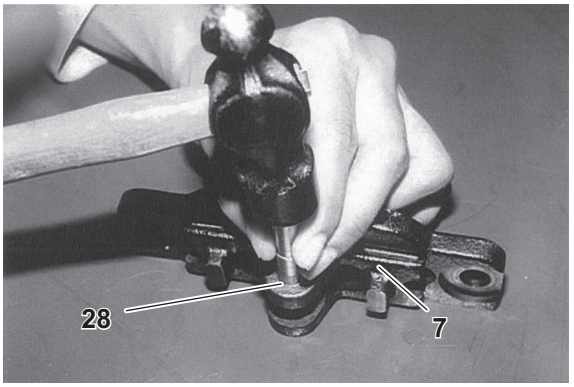
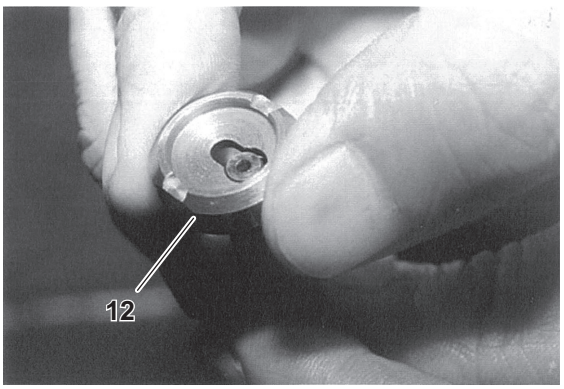
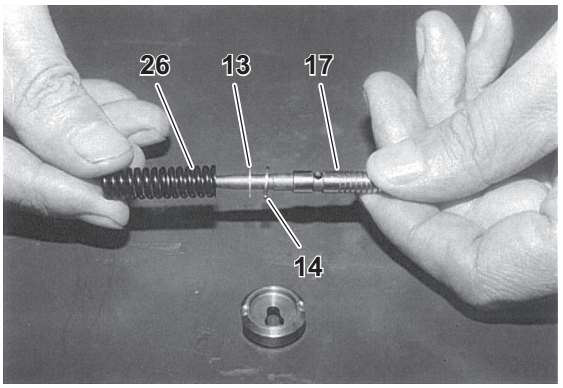
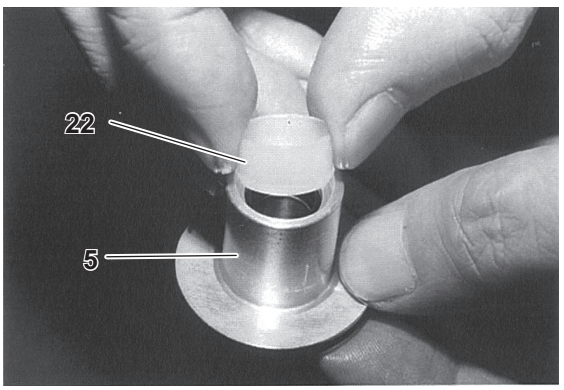
Notes:
- *Note down the positional relationship between the plug and the push rod.*
- *Be careful because the plug may be pushed out while the push rod is removed.*
- *Take care not to scratch the push rod surface.*

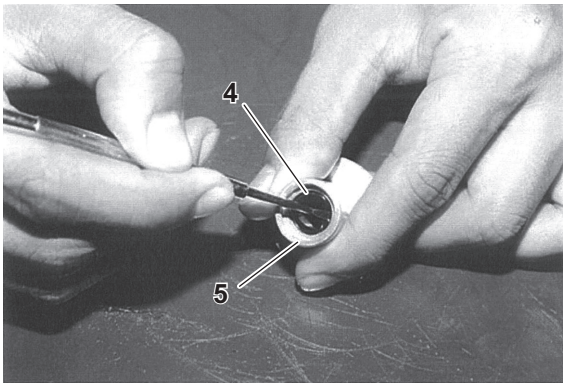


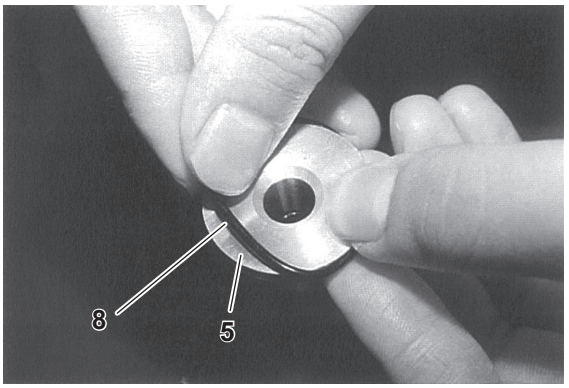


Procedure	
(10) Pull out the plug **5** with the grease cup **22**, the packing **4**, and the O-ring **8** attached. ***Notes:*** • *Note down the positional relationship between the plug and the casing **23**.* • *Be careful because the piston **9** is pushed out by the damping spring **10** while the plug is removed.*	
(11) Remove the piston **9**. ***Note:*** *Note down the positional relationship between the piston and the hole in the casing.*	
(12) Remove the damping spring **10** from the casing. ***Note:*** *Note down the relationship between the damping spring and the hole in the casing.*	
(13) Remove the spring seat **11** from the casing **23** using a tool, such as a pair of tweezers. ***Note:*** *Note down the positional relationship between the spring seat and the hole in the casing.*	

Procedure	
(14) Remove the steel ball **24** using a device, such as a magnet. ***Note:*** *Take care not to lose the steel ball.*	
(15) Fixing the lower casing assembly in a vice, remove the O-rings (**25** and **29** from the casing **18**).	
(16) Remove the reducing valve section assembly and the return spring **27** from the casing **18**. ***Note:*** *Note down the positional relationship with the casing hole.*	 

Procedure	
(17) Place the cover **7** with its side downward on a flat table. Putting the special jig 1 on the bush **28**, tap the tool with a hammer to pull out the bush.	
(18) Disassemble the reducing valve as follows: Push down the spring seat **12**. Pressing the secondary pressure spring **26**, slide the spring seat sideway and remove the spool **17** through the larger hole. ***Notes:*** • *Take care not to scratch the spool surface.* • *Do not lower the spring seat by more than 0.16 in.(4mm).* • *Treat the parts as a single assembly until they are installed.*	
(19) Remove the secondary-pressure-setting spring **26**, Shim **13**, and the washer **14** from the spool **17**. ***Notes:*** • *Treat the parts as a single assembly until they are installed.* • *The washer, whose thickness varies depending on the spool assembly, is for adjustment to preset the secondary-pressure-setting spring.* • *However, in some cases, the washer is not used.*	
(20) Remove the grease cup **22** from the plug **5**.	

Procedure	
(21) Remove the packing **4** from the plug **5**. ***Notes:*** • *Remove the packing using a tool such as a small flat-head screw driver.* • *Take care not to scratch the internal surface of the plug.*	

(22) Remove the O-ring **8** from the plug **5**.	

(23) Cleaning the parts [1] Put the parts into the kerosene contained in a rough-cleaning container, and clean them. (Rough-cleaning) [2] Put the parts into the kerosene contained in a finish-cleaning container, and rotate them slowly until their internal surfaces can be cleaned well (Finish-cleaning). Wipe out the kerosene from the parts with a clean waste cloth. ***Notes:*** • *If the parts are washed immediately after put into the kerosene, they are easily scratched. Wait until contaminations and oily substances are detached and floated on the surface of the kerosene.* • *Contaminated kerosene tends to cause the parts to be damaged, and the performance of the parts becomes degraded after they are assembled.* • *Pay much attention to the degree of contamination of the kerosene.* • *Do not dry the parts with compressed air. Otherwise, they may be scratched or rusted with the dust or moisture in the air.*	

Procedure	
(24) Preventing the parts from rusting Apply a rust inhibitor to the parts. ***Note:*** *Leaving the parts without wiping the kerosene causes them to rust, resulting in degraded performance after assembled.*	

2) Assembling instructions

(1) Operational precautions in general

[1] As done for disassembling, prepare a working bench and tools.

[2] Pay attention as done for disassembling.

[3] Before assembling, remove bits of metal or foreign material from all the parts, and also check that there is no burrs or dents on the parts. If you find burrs or dents, remove them with an oilstone.

[4] As a rule, replace all O-rings and NHU packing with new one.

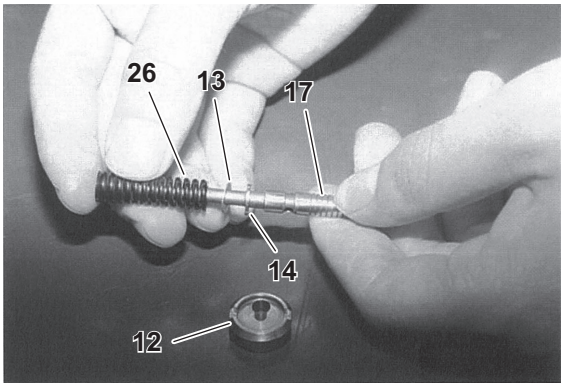
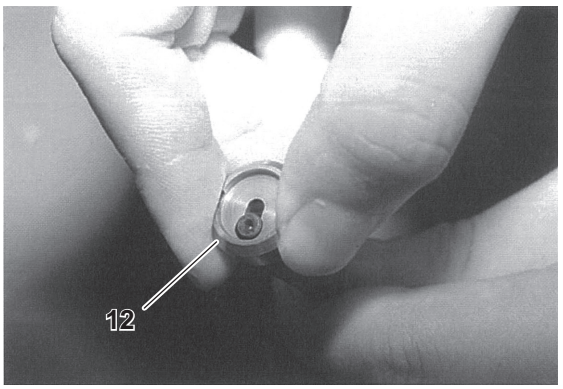
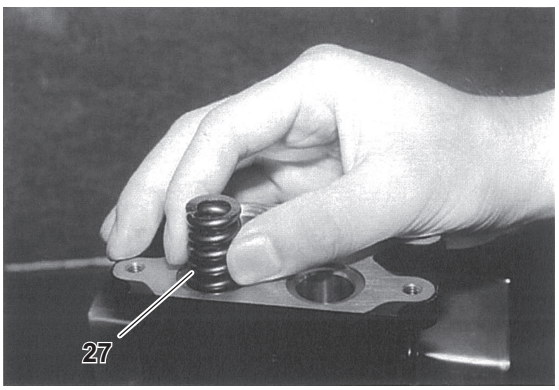
[5] Install the O-rings and NHU packing, taking care not to damage them. (Apply a little amount of grease for smooth installation.)

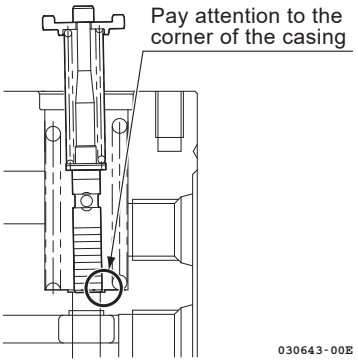
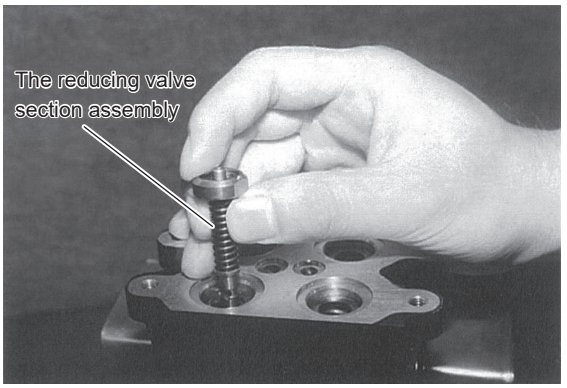
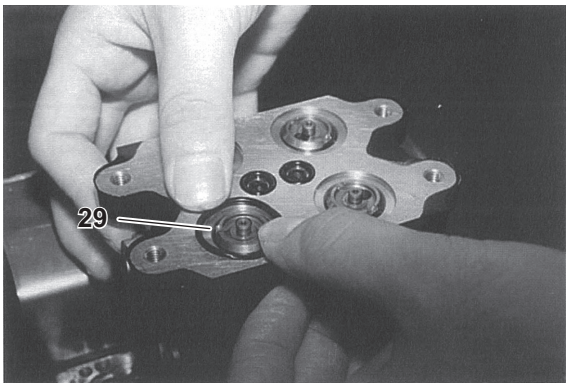
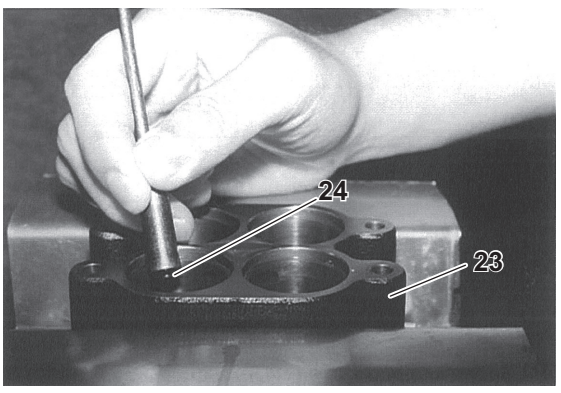
[6] To prevent the parts from dropping, use grease.

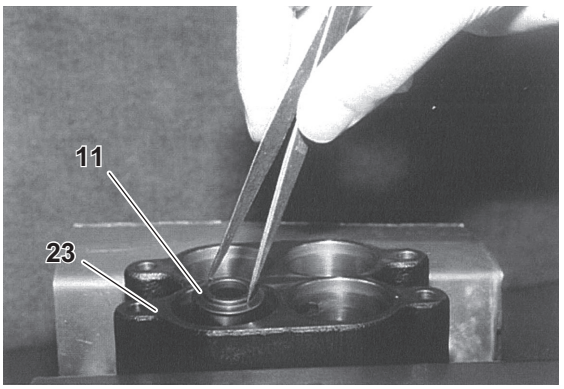
[7] Tighten the bolts with the torque shown in the assembly cross-section drawing.

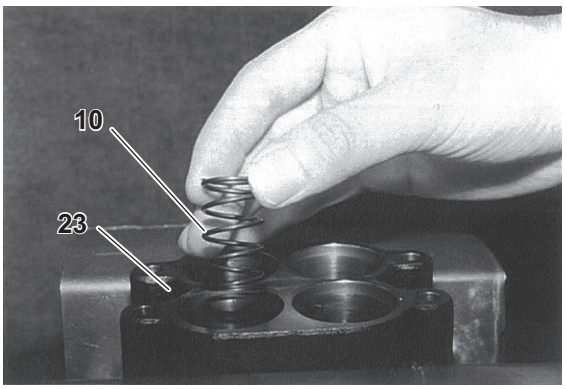
[8] After the assembling is completed, close all the ports with plugs to prevent dust from entering.

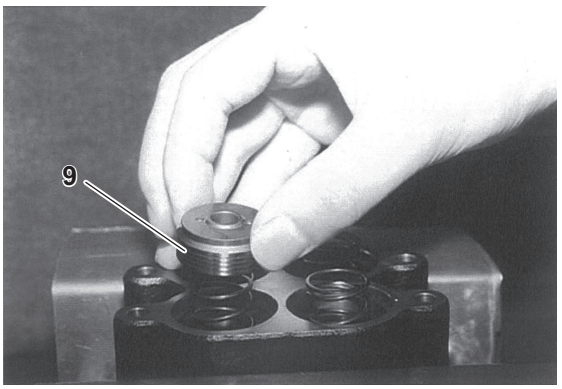
(2) Assembling procedures

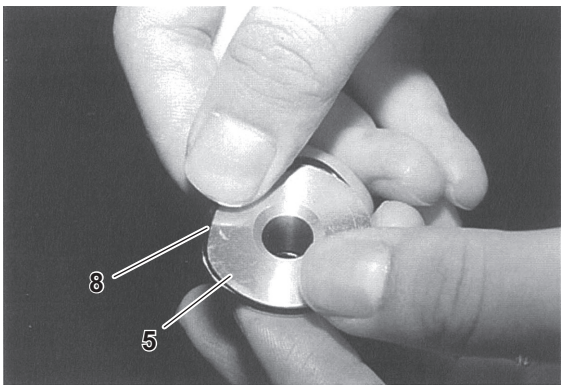
Procedure	
(1) Attach the washer **14**, the shim **13**, the secondary-pressure-setting spring **26**, and the spring seat **12** to the spool **17** in this order. ***Note:*** *The washer, whose thickness varies depending on the spool assembly, is for adjustment to preset the secondary-pressure-setting spring.* *However, in some cases, the washer is not used.*	
(2) Insert the spool **17** into the spring seat **12** through the larger hole. Pushing the spring seat and pressing the secondary pressure spring, slide the spring sideway to install the spool. ***Notes:*** • *Take care not to scratch the spool surface.* • *Do not lower the spring seat by more than 0.16 in.(4mm).*	
(3) Fix the casing **18** on the vice. Install the return spring **27** into the casing **18**. ***Note:*** *Install it at the previous position before it was disassembled.*	

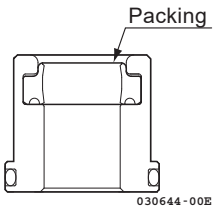
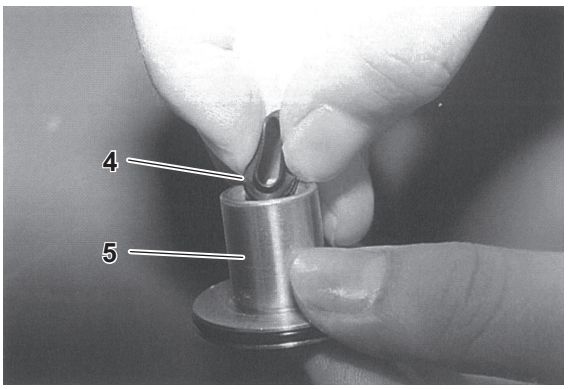
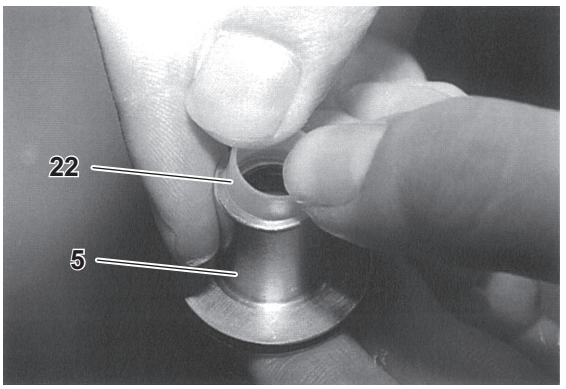
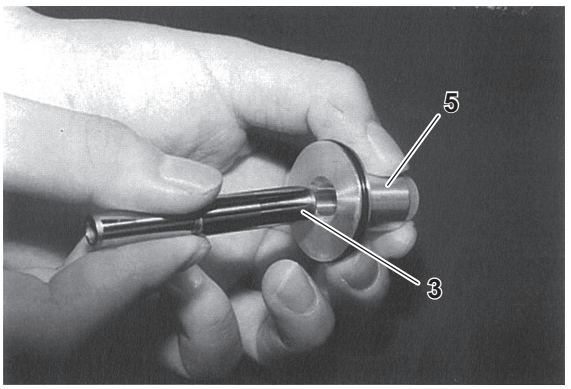
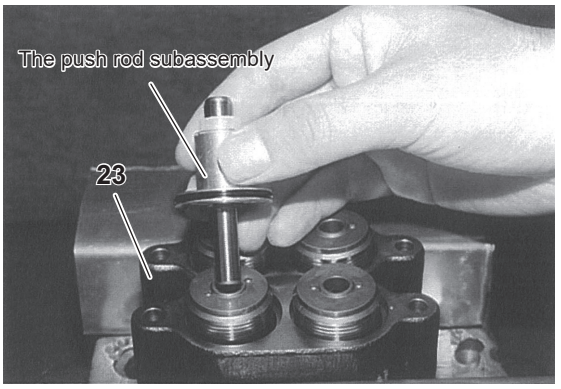
Procedure	
(4) Install the reducing valve section subassembly, assembled in **1** and **2** above, into the casing **18**. ***Notes:*** • *Install it at the previous position before it was disassembled.* • *Take care not to hit the bottom of the spool strongly onto the corner of the casing while installing the reducing valve section subassembly. Pay attention to the corner of the casing.* 	
(5) Install the O-rings **25** and **29** in the casing **18**.	
(6) Fixing the upper casing **23** in a vice, install the steel ball **24**.	

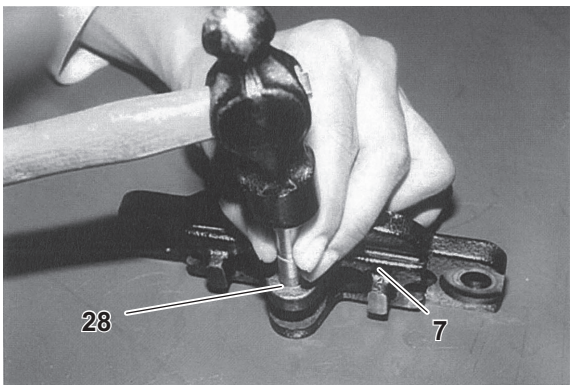
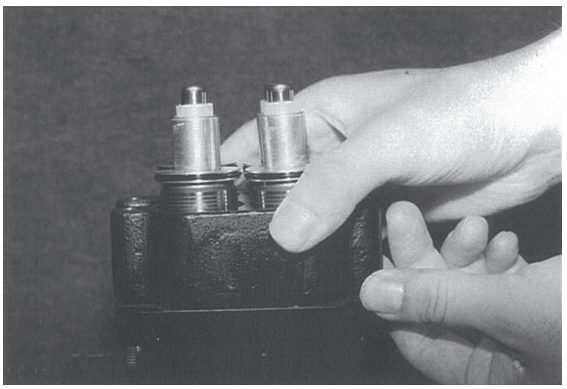
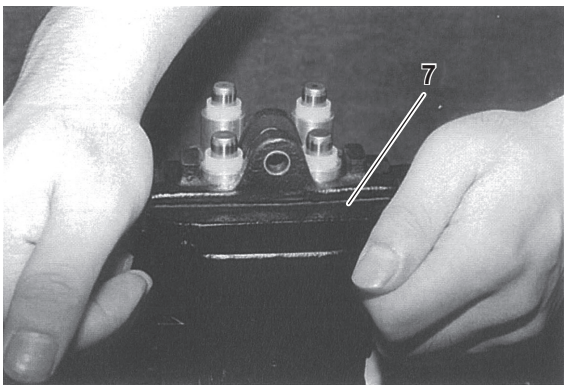
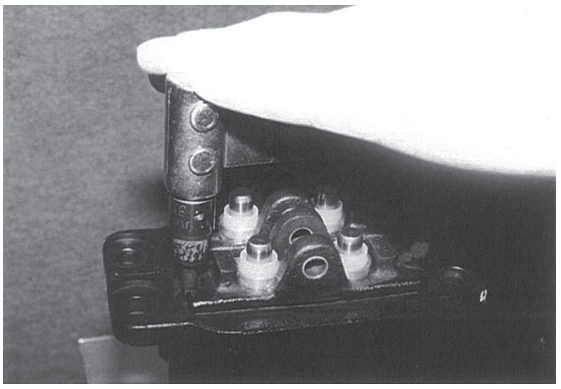
Procedure	
(7) Install the spring seat **11** in the casing **23** using a tool, such as a pair of tweezers. ***Note:*** *Install it at the previous position before it was disassembled.*	

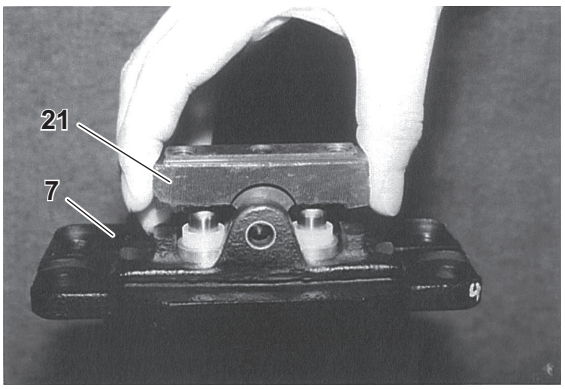
(8) Install the damping spring **10** in the casing **23**. ***Notes:*** • *Install it at the previous position before it was disassembled.* • *Take care not to place the spring on top of the seat.*	

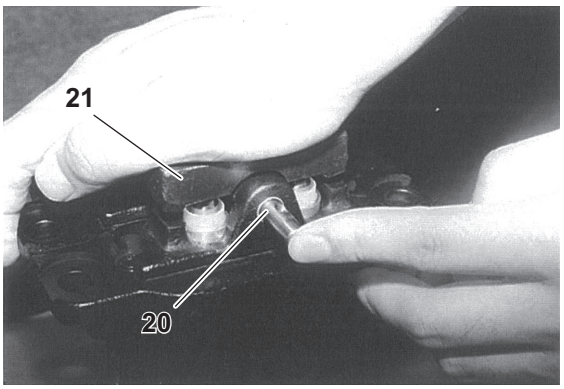
(9) Install the piston **9**. ***Note:*** *Install it at the previous position before it was disassembled.*	

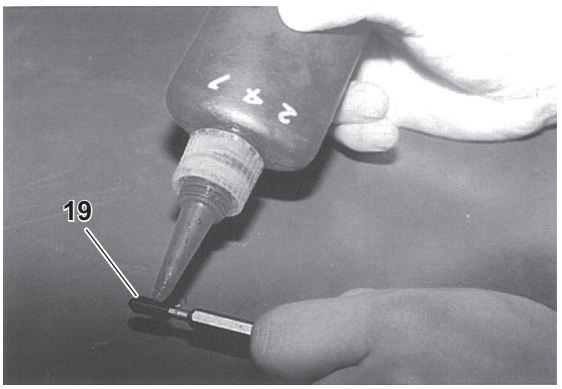
(10) Install the O-ring **8** on the plug **5**.	

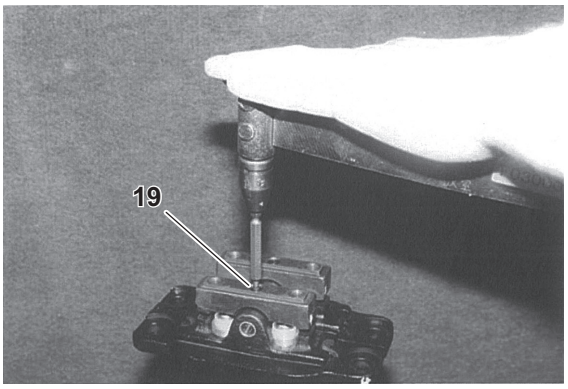
Procedure	
(11) Install the packing **4** into the plug **5**. ***Notes:*** • *When you install the packing, pay attention to its direction. (Refer to the following figure.)* • *Apply a thin film of grease to the packing before installing it.*  	
(12) Install the grease cup **22** into the plug **5**.	
(13) Install the push rod **3** into the plug **5**. • *Apply the hydraulic oil to the surface of the push rod before installing it.* • *Do not insert the push rod with a strong force so as not to damage the lip of the packing **4**.*	
(14) Install the push rod subassembly, assembled in 10-13 above, in the casing **23**.	

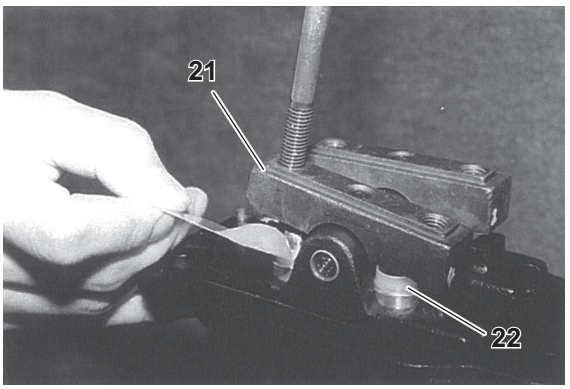
Procedure	
(15) Place the cover **7** with its side downward on a flat table. Putting the special jig 1 on the bush **28**, tap the tool with a hammer to press it into the cover. ***Note:*** *Be careful because the end of the bush come out of the cover.*	
(16) Fix the lower cover assembly, assembled in 1-5 above, in a vice and install in it the upper cover assembly, assembled in 6-14 above. ***Note:*** *Install it at the previous position before it was disassembled.*	
(17) Install the cover **7** into the casing **23**. ***Notes:*** • *Install it at the previous position before it was disassembled.* • *Be careful because the cover moves upward by the force of the damping spring **10**.*	
(18) Tighten two allen head cap screws with the torque specified. **Tightening torque: 5.9 to 7.1 ft•lbf (8.0 to 9.6 N•m)** ***Note:*** *Pay attention to place the cover at horizontal position.*	

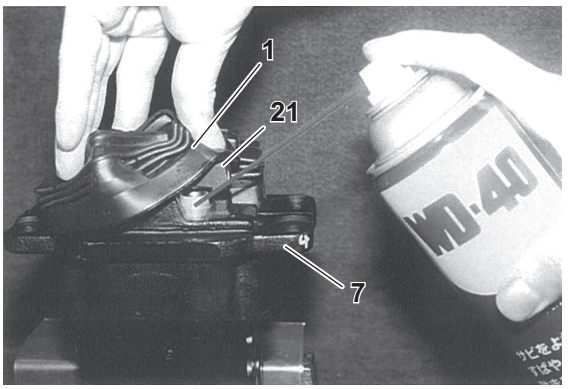
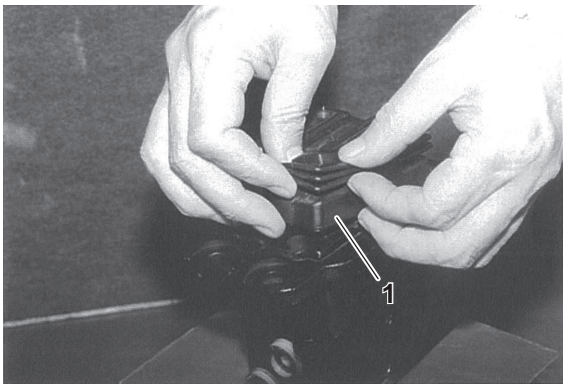
Procedure	
(19) Install the cam **21** into the cover **7**. ***Note:*** *Install it at the previous position before it was disassembled.*	

(20) Holding down the cam **21**, insert the cam shaft **20** from outside. ***Note:*** *Apply grease to the cam shaft bearing.*	

(21) Apply Loctite#241 or equivalent to the surface of the set-screw **19**.	

(22) Tighten the setscrew **19** with the torque specified. **Tightening torque: 4.4 to 5.8 ft•lbf (5.9 to 7.9 N•m)**	

Procedure	
(23) Tilting the cam **21**, apply grease to the top of the push rod **3** and also inject grease into the grease cup **22** in the plug **5**. ***Notes:*** • *When you apply or inject grease, use a soft spatula so as not to scratch the surfaces of the push rod and the plug.* • *Apply grease according to the above method within every shorter term either 6 months or 500 service hours.*	

(24) Engaging the upper edge of the bellows **1** with the cam **21**, fit the lower edge of the bellows into the groove of the cover **7**. ***Notes:*** • *Before fitting the lower end of the bellows into the groove of the cover, spray anti-rust oil over the parts inside the bellows.* • *Be careful because anti-rust and water-proof capabilities are degraded if the bellows is not fixed completely or fixed bellows is twisted.*	 

3) Troubleshooting and corrective measures

Troubleshooting is not easy. Some assumed causes are listed in the table below. Since repair is difficult, refer to the assumed causes and corrective measures in the table.

Symptoms, assumed causes, and corrective measures in general are listed in the table below.

In most cases, a trouble is not caused by a failure only with a single part, but caused by a failure involving more than one part. For this reason, be aware of the fact that corrections may also be necessary other than listed.

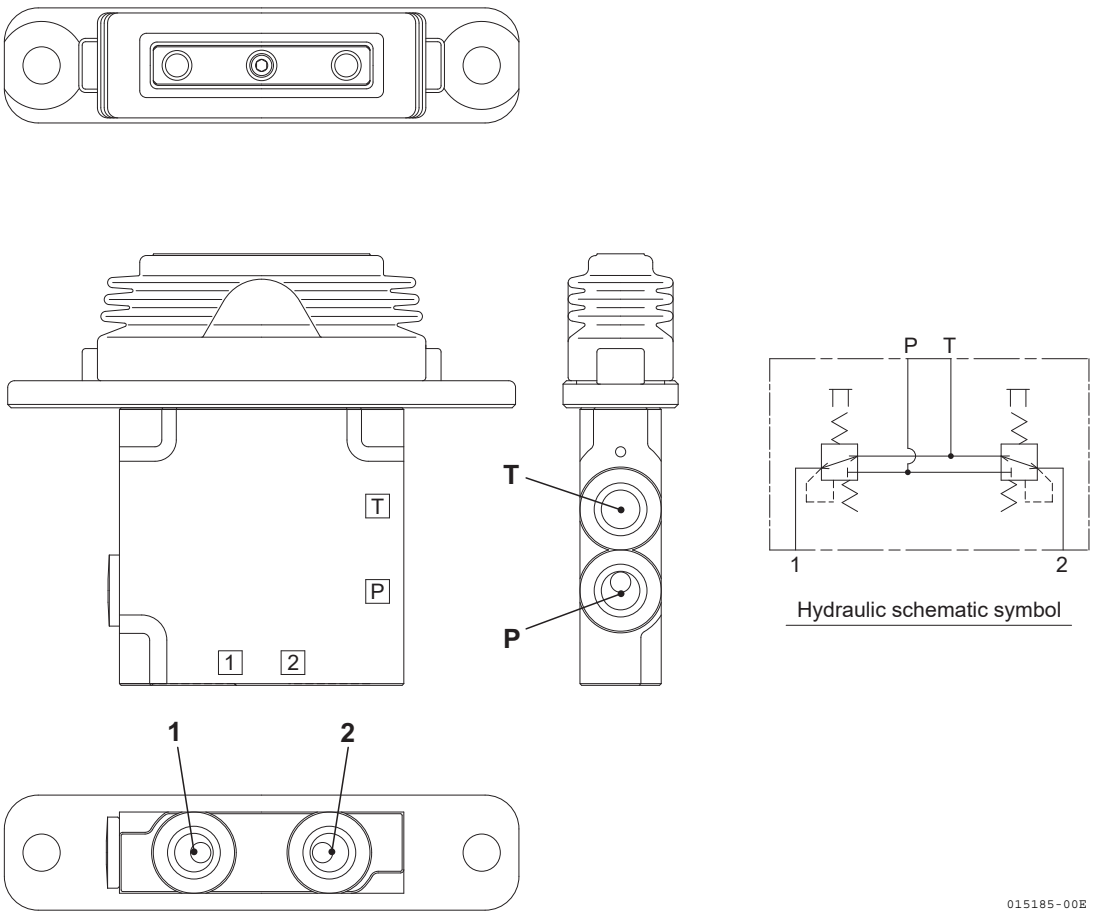
Also, the table below does not cover all the assumed causes and corrective measures. The persons in charge of repair must further investigate problems and causes as necessary.

Symptom	Cause	Correction
Secondary pressure does not rise.	(1) Insufficient primary pressure (2) The secondary-pressure-setting spring **26** no longer has enough elasticity. (3) The gap between the spool and the casing is too wide. (4) The operating section is not fixed firmly.	(1) Secure primary pressure. (2) Replace with a new one. (3) Replace with a new pilot valve Complete unit. (4) Disassembling/reassembling, and replacement of the operating section.
Secondary pressure is unstable.	(1) Sticking portion in sliding part. (2) Fluctuations in tank line pressure. (3) Air trapped in the pipe.	(1) Correct the sticking portion. (2) Return the oil into the oil tank directly. (3) Bleed the pipe several times.
Secondary pressure is too high.	(1) Tank line pressure is high. (2) Sticking portion in sliding part.	(1) Return the oil into the oil tank directly. (2) Correct the sticking portion.
Damping function does not work.	(1) Air is trapped inside the piston chamber. (2) Sticking portion in sliding part. (3) The damping spring **10** no longer has enough elasticity. (4) The gap between the damping piston **9** and the casing (damper) **23** is too wide. (5) Malfunction of the check valve. (6) The orifice of the damping piston **9** is too large.	(1) Bleed the air several times. (2) Correct the sticking portion. (3) Replace with a new one. (4) Replace with a new pilot valve complete unit. (5) Disassemble and investigate the check valve portion. (6) Replace the damping piston.
Damping torque is large.	(1) Sticking portion in sliding part. (2) Clogging of the orifice in the damping piston **9**.	(1) Correct the sticking portion. (2) Correct or replace the damping piston.
Excess play of lever.	(1) Wear-out of push rod and/or steel ball due to lack of grease.	(1) Exchange push rod and/or steel ball for new one. (2) Apply grease within every shorter term either 6 months or 500 service hours. (Refer to P.18)

6-5-3 Blade and Boom Swing Pilot Valve

1. Outline

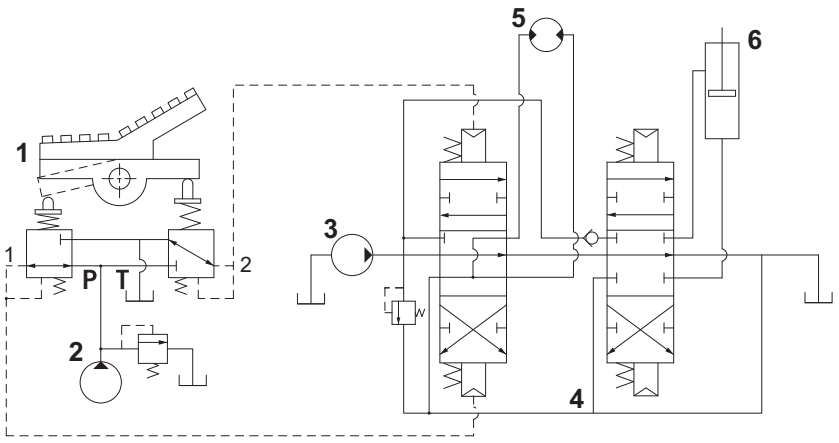
This valve is a remote control valve with a pressure reducing system. It consists of two pressure-reducing valves to regulate the secondary side pressure and control system for the valves. The secondary side pressure is controlled by the blade lever movement and it is proportional to the lever stroke.



Primary side pressure	Maximum 1000 PSI (6.9 MPa)
Secondary side pressure	0 to 420 PSI <Maximum control pressure> (0 to 2.9 MPa)
Back pressure limit	42 PSI (0.29 MPa)
Rated oil flow	2.64 GPM (10 L/m)

2. Operation Theory

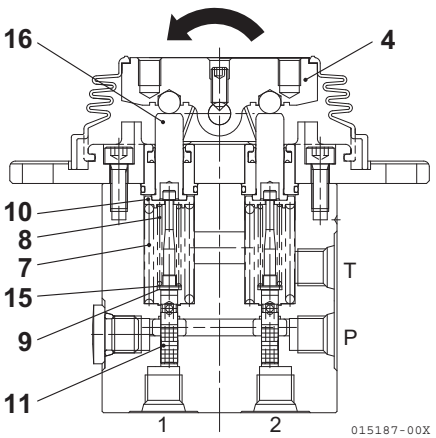
Hydraulic schematic example of a typical use of the valve is shown below to explain the operation theory.



Hydraulic circuit schematic

1) Control Lever in Neutral

Spool **11** is pushed up by spring **7** via spring seat **10** and kept in the neutral position shown to the right. Accordingly, spool **11** connects the secondary side ports 1 and 2 to the return circuit port T only so that the secondary side pressure is the same as that of the return circuit port T.



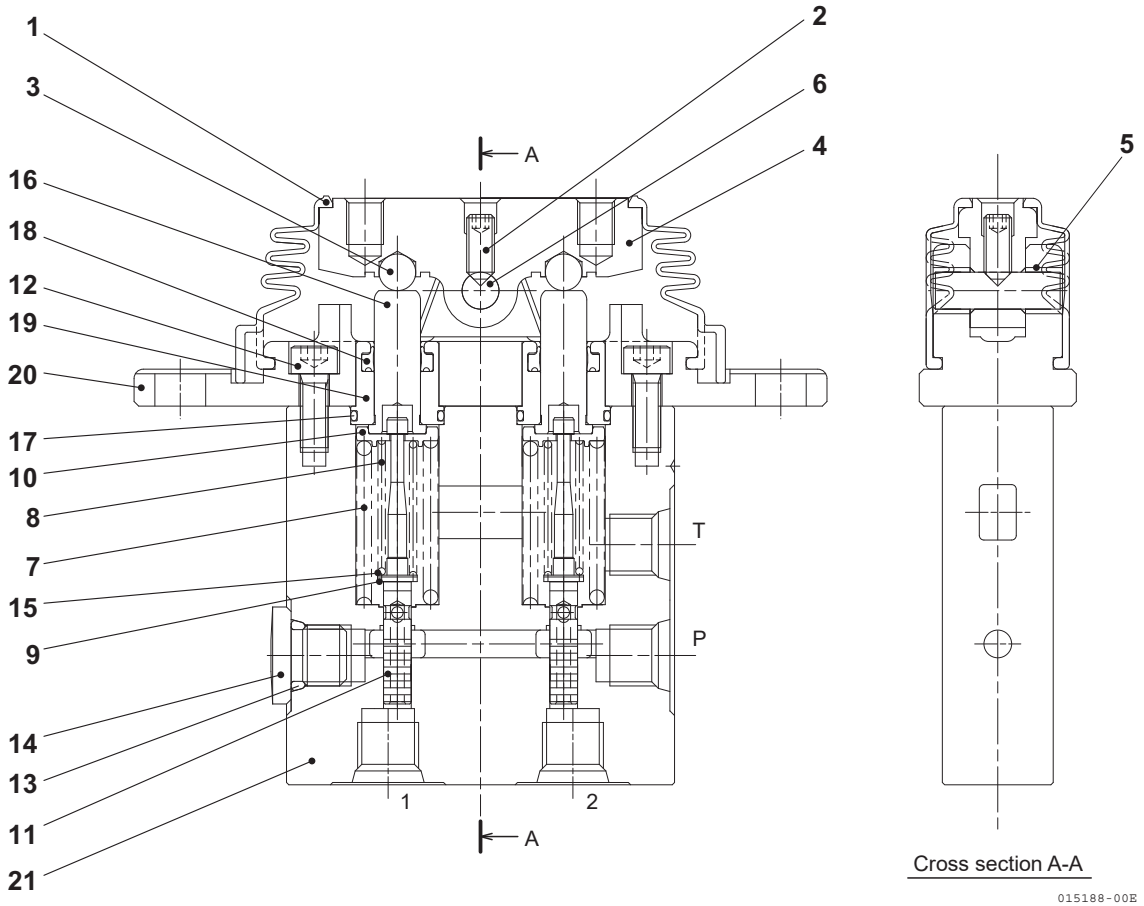
2) Control Lever Operated

When the control lever is operated to move cam **4** in the direction of an arrow, push rod **16** of the port 1 side is pushed down and spool **11** is moved downward via spring seat **10**, spring **8**, shim **15** and washer **9**. The port P connects to the port 1 and oil discharged by the pilot oil pump flows to the port 1 to develop pressure in the circuit.

When the lever is moved to raise the oil pressure in the port 1 circuit till the designed force of spring **8**, the pressure spool **11** receives and the spring force balance, consequently keep the pressure in the port 1 circuit constant.

Spool of the port 2 side holds its neutral condition and pilot oil from main control valve returns to reservoir through the return circuit port T.

3. Cross Section Drawing and Component Parts

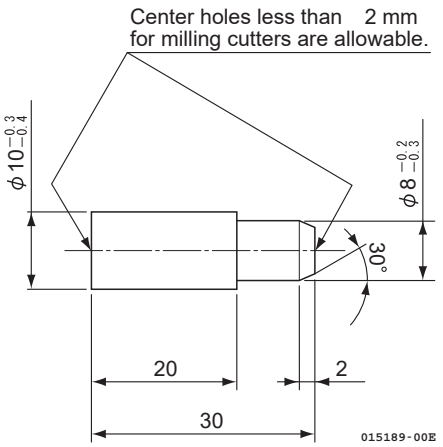


No	Description	Q'ty	No	Description	Q'ty
1	Rubber boot	1	12	Allen head cap screw	2
2	Allen head screw	1	13	O-ring	1
3	Steel ball	2	14	Plug	1
4	Cam	1	15	Shim	2
5	Bushing	2	16	Push rod	2
6	Cam shaft	1	17	O-ring	2
7	Spring (Return)	2	18	Gasket	2
8	Spring (Secondary side pressure regulating)	2	19	Plug	2
9	Washer	2	20	Cover	1
10	Spring seat	2	21	Casing	1
11	Spool	2			

4. Special Tool

Jig to remove bushing

(Unit: mm)



5. Disassembly and Reassembly

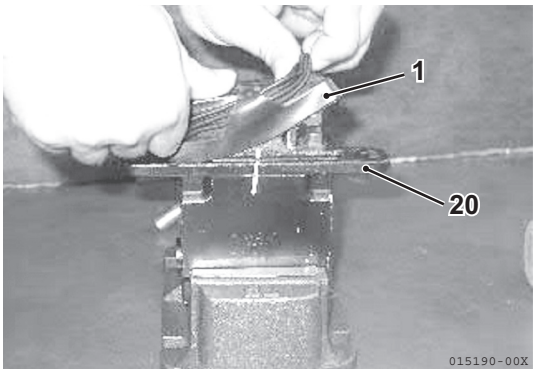
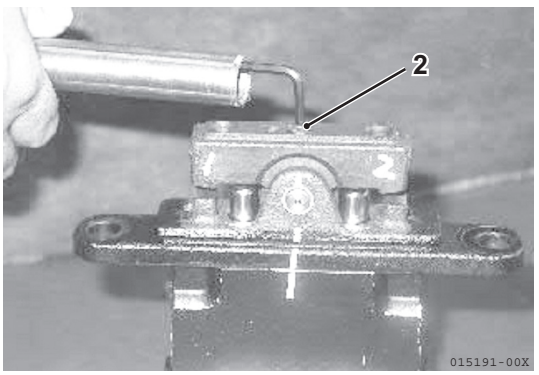
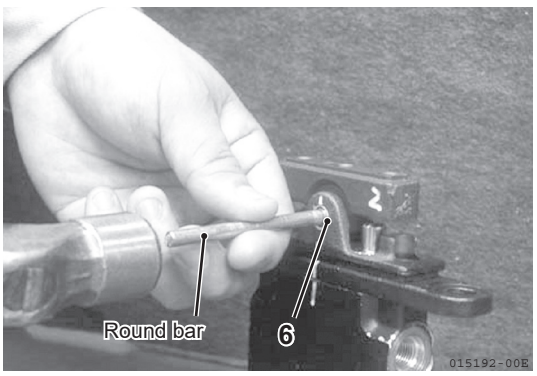
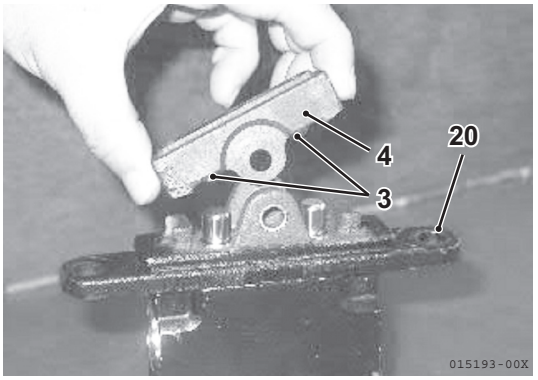
1) Precautions

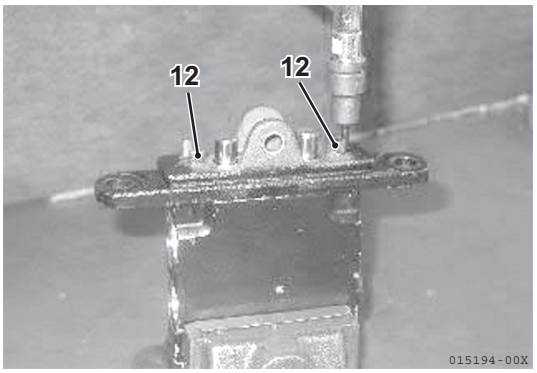
(1) Since the parts of this equipment are generally precision-made for tight clearances, be sure to perform disassembly and reassembly in a clean place that is free from dust.
(2) Prepare clean tools and treated oil.
(3) First, clean the external surface of the removed valve body.
(4) Before beginning disassembly, review the drawings of the internal structure and prepare the required parts according to the purpose and extent of the disassembly.
(5) In principle, replace the removed O-rings with new ones.
(6) Handling of O-rings
[1] Lubricate the O-rings and the O-ring fitting seats with clean grease or hydraulic oil.
[2] The O-rings may not be damaged in handing or distorted by heat
[3] Do not extend any O-rings with such great force as to permanently deform them.
[4] O-ring should be installed to the plug with a jig.

2) Tools

Tool	Q'ty	Size	Remarks
Allen key	1	6	
Hammer	1	-	
Bushing removing jig	1	-	Refer to 4. Special Tool
Screwdriver	1	-	
Others	• Kerosene • Grease • Vapor phase corrosion inhibitor • Loctite 241 • Round bar (O.D.:0.28 in.(7 mm) or less)		

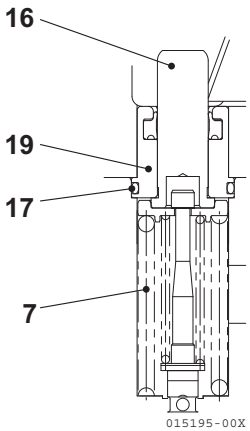
3) Disassembly

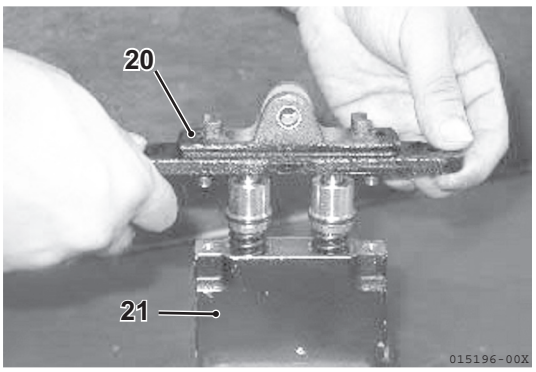
Procedure	
(1) Plug each port and clean the valve by kerosene. (2) Fix the valve on a vise with using buffing plates. (3) Pull up rubber boot **1** to remove it from cover **20**.	
(4) Loosen allen head screw **2**. ***Note :*** *Much torque is required to loosen it because screw lock agent is applied on its thread.*	
(5) Punch out cam shaft **6** by using a round bar and hammer.	
(6) Remove cam **4**. ***Notes :*** • *Cam **4** and steel ball **3** are inseparable.* • *Put marks on cam **4** and cover **20** to reassemble them as they were.*	

Procedure	
(7) Remove two allen head cap screws **12**.	

(8) Remove cover **20**.

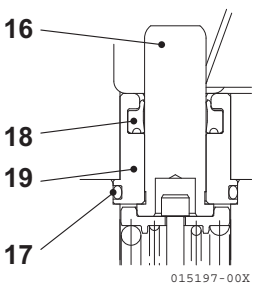
Notes :
- *Put marks on casing **21** and cover **20** to reassemble them as they were.*
- *When removing, take care of push rod **16** and plug **19** for popping out by spring **7** (plug **19** may remain in casing **21** but it must be temporary due to friction of O-ring **17**).*

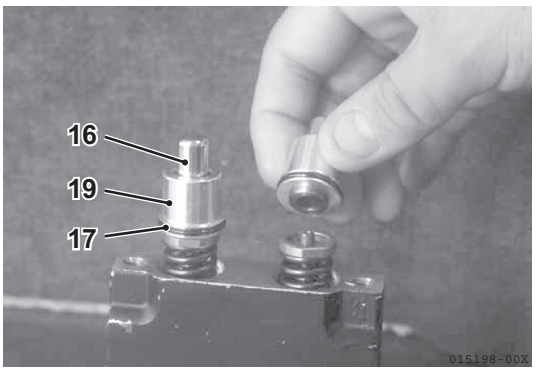


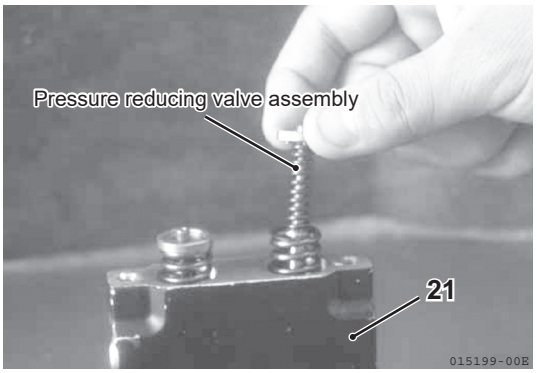
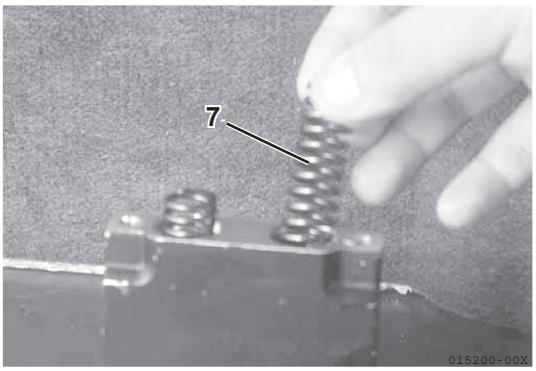
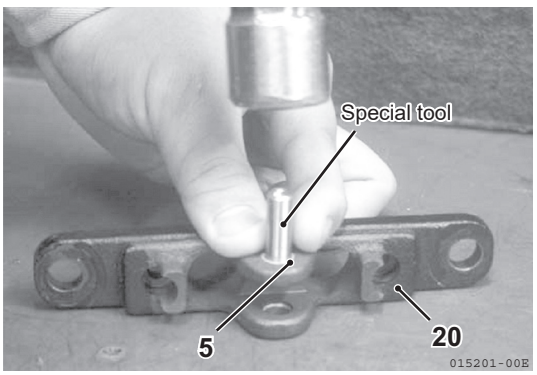
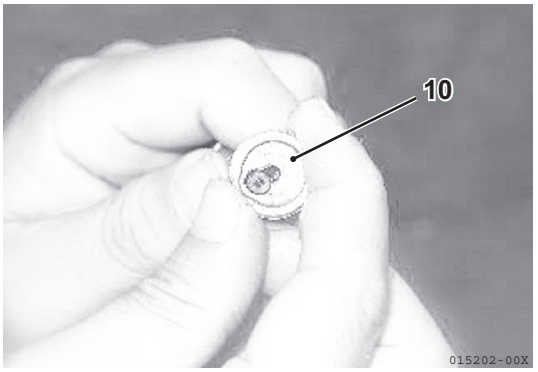


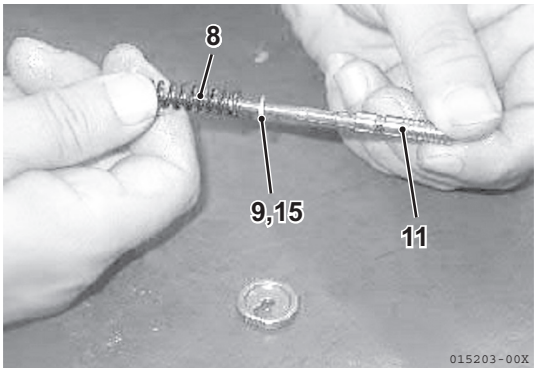
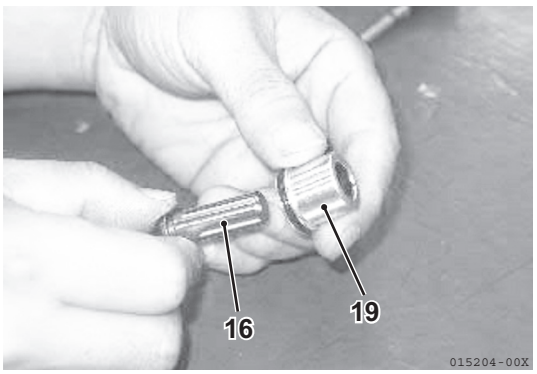
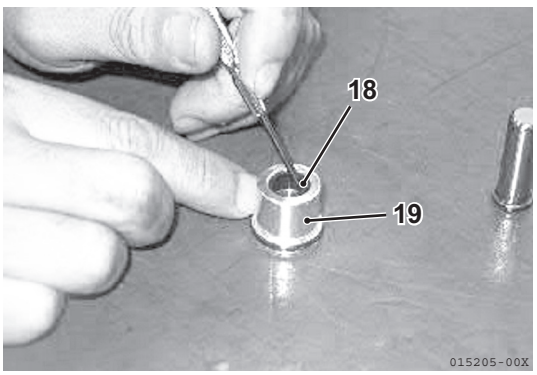
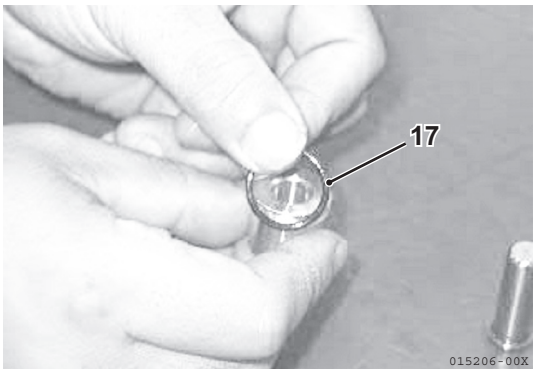
(9) Remove plug **19** with push rod **16**, gasket **18** and O-ring **17**.

Note :
*Put marks on plug **19** and casing **21** to reassemble them as they were.*

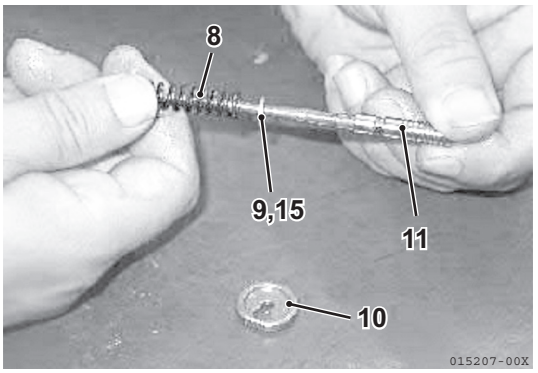
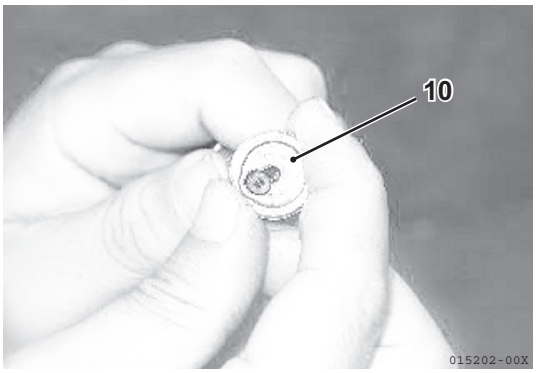
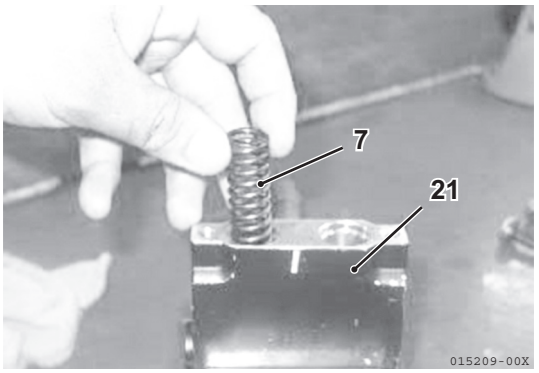


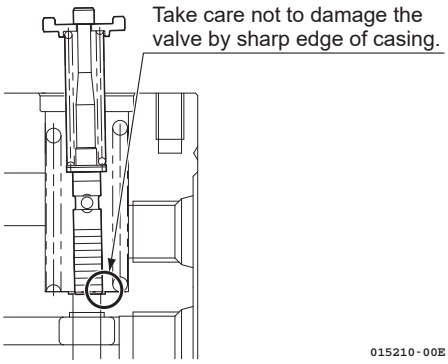
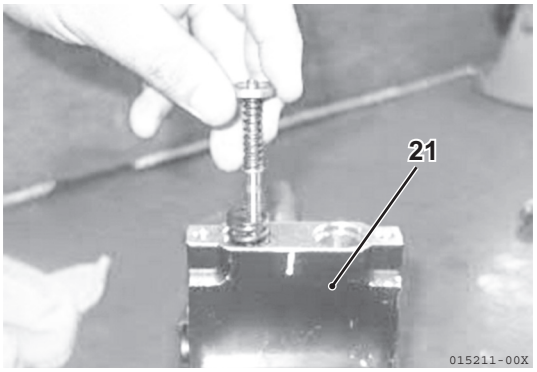
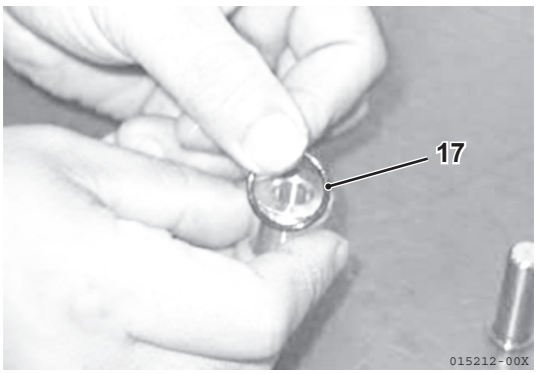
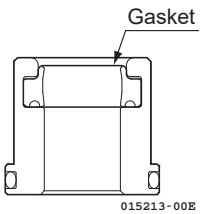
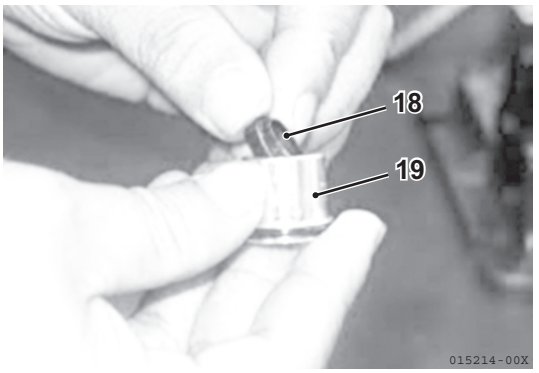


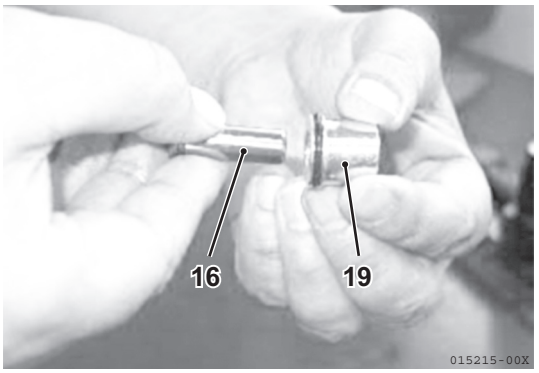
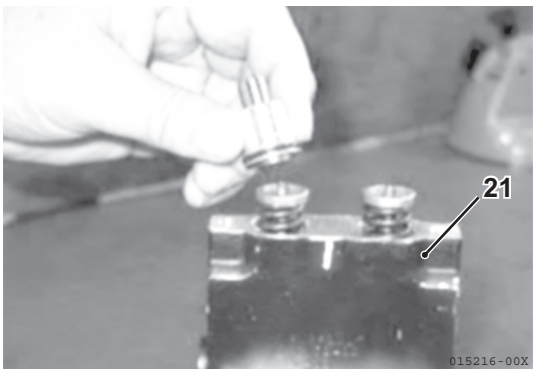
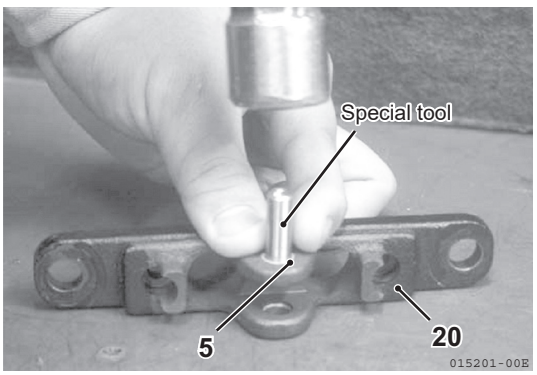
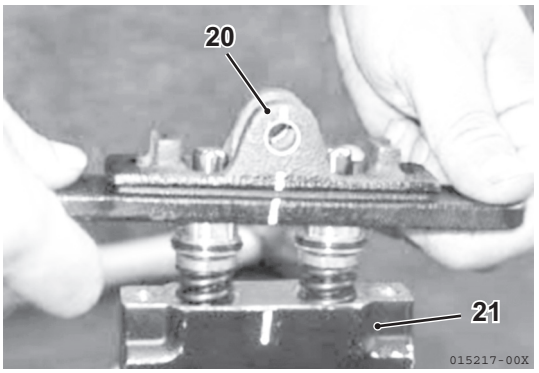
Procedure	
(10) Remove pressure reducing valve assembly and spring **7** from casing **21**. ***Note :*** *Do not mix up two assemblies to reinstall them as they were.*	 
(11) Put cover **20** on a flat surface and lightly strike bushing **5** by using a special tool and hammer to remove it.	
(12) If disassembling of pressure reducing valve assembly is required, press spring seat **10** to bow spring **8**, laterally displace spring seat **10** and remove it from spool **11** through larger opening of it. ***Notes :*** • *Be careful not to damage spool surface.* • *Do not press down spring seat **10** more than 0.16 in.(4 mm).* • *Always keep pressure reducing valve as assembly.*	

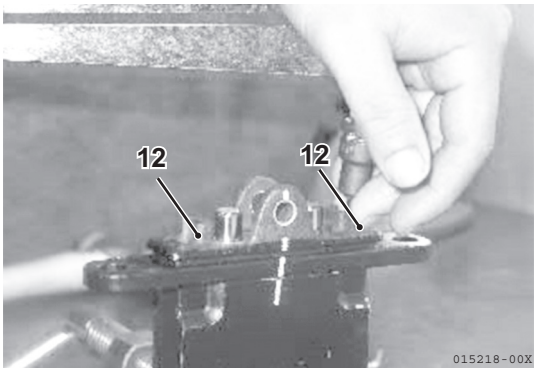
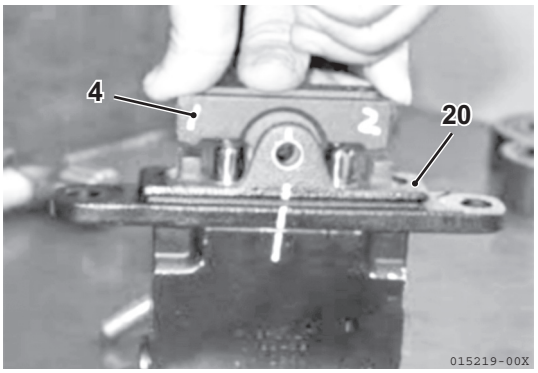
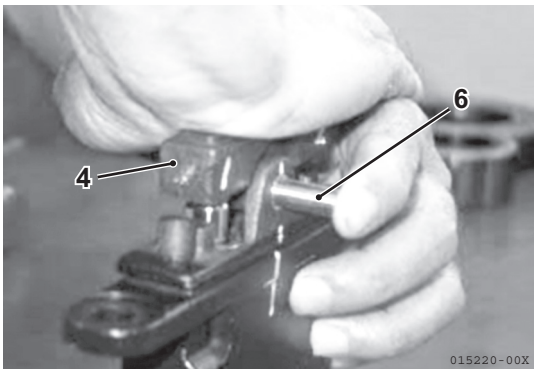
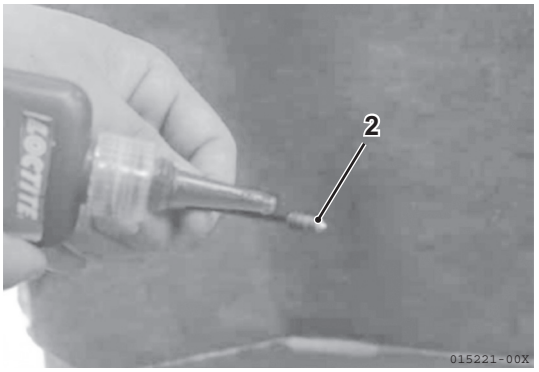
Procedure	
(13) Separate spool **11**, spring **8**, shim **15** and washer **9**. ***Notes :*** • *Always keep pressure reducing valve as assembly.* • *Washer **9** is used for presetting of spring **8**. Its thickness differs assembly by assembly and some may have no washer **9**.*	
(14) Remove push rod **16** from plug **19**.	
(15) Remove gasket **18** from plug **19**. ***Notes :*** • *Use appropriate tool to remove gasket **18**.* • *Take care not to damage inner surface of plug **19**.*	
(16) Remove O-ring **17** from plug **19**.	

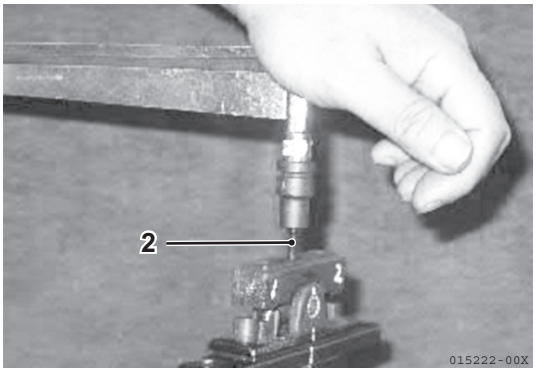
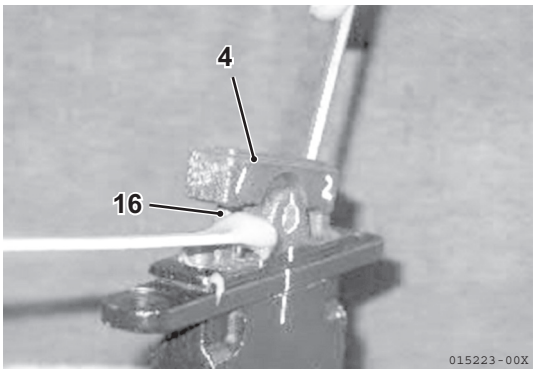
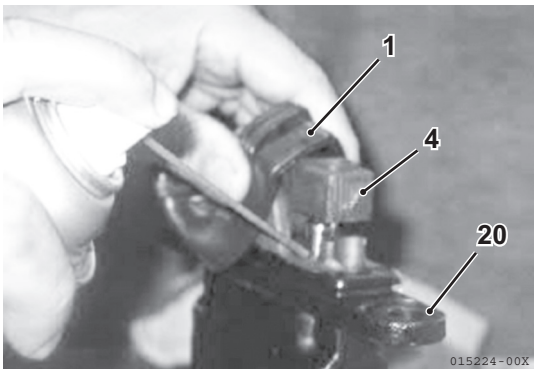
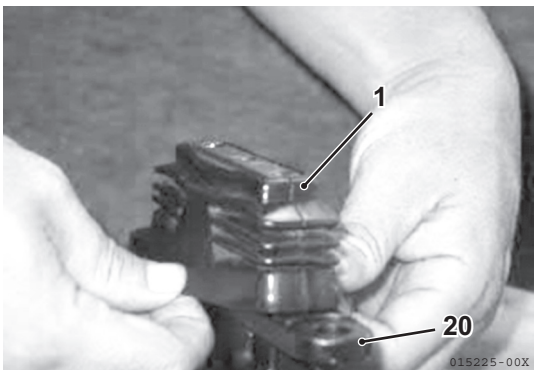
4) Reassembly

Procedure	
(1) Install washer **9**, shim **15** and spring **8** on spool **11** in order. ***Note :*** *Washer **9** is used for presetting of spring **8**. Its thickness differs assembly by assembly and some may have no washer **9**.*	
(2) Install spring seat on spool **11** through larger opening of it, press spring seat to bow spring and laterally displace spring seat to fix it on spool **11**. ***Notes :*** • *Be careful not to damage spool surface.* • *Do not press down spring seat **10** more than 0.16 in.(4 mm).*	
(3) Fix casing **21** on a vise with using buffing plates and install spring **7** on casing **21**. ***Note :*** *Reinstall the part to the original position before disassembling.*	

Procedure	
(4) Install pressure reducing valve sub-assembled at the steps (1) and (2) in casing **21**. ***Notes :*** • *Reinstall the part to the original position before disassembling.* • *When installing pressure reducing valve, be careful not to excessively press the bottom of spool **11** to sharp edge of casing **21**.*  	
(5) Install O-ring **17** on plug **19**.	
(6) Install gasket **18** on plug **19**. ***Notes :*** • *Take care of installation direction of gasket **18**.* • *Coat grease on gasket **18** before installing.*  	

Procedure	
(7) Install push rod **16** on plug **19**. ***Notes :*** • *Coat hydraulic oil on push rod **16** before installing.* • *Do not strongly press push rod **16** or lip of gasket **18** may be damaged.*	
(8) Install push rod sub-assembled at the steps (5), (6) and (7) in casing **21**.	
(9) Put cover **20** on a flat surface and lightly strike bushing **5** by using a special tool and hammer to fit it. ***Note :*** *Be careful for the end of bushing **5** not to project from the inside of cover **20**.*	
(10) Put cover **20** on casing **21**. ***Note :*** *Reinstall the part to the original position before disassembling.*	

Procedure	
(11) Tighten two allen head cap screws **12** to 6.42 to 6.56 ft•lb (8.7 to 8.9 N•m).	
(12) Install cam **4** on cover **20**. ***Note :*** *Reinstall the part to the original position before disassembling.*	
(13) Install cam shaft **6** with pressing cam **4** down. ***Note :*** *Coat grease on cam shaft **6** before installing it.*	
(14) Apply Loctite **241** or equivalent of it on allen head screw **2**.	

Procedure	
(15) Tighten allen head screw **2** to 4.4 to 5.8 ft•lb (5.9 to 7.9 N•m).	
(16) Move cam **4** to coat grease on the top of push rod **16**. ***Note :*** *Use soft spatula or something so as for surfaces of push rod **16** and plug **14** not to damage.*	
(17) Put rubber boot **1** over cam **4** and then fit its bottom end into a groove of cover **20**. ***Notes :*** • *Spray anti-rusting oil on all parts in rubber boot **1** before installing it.* • *Securely fit rubber boot **1** into a groove of cover **20**, or its dust and waterproof performances go down.*	 

5) Servicing Instruction

All parts disassembled should be rinsed by cleaning oil. According to the criteria below, repair or replace with a new one as required.

Notes :

- *It is preferable that seals like a gasket and O-ring are to be replaced with new ones every time once removed but can be reused unless it has damage.*
- *Single service parts supply of spool **11** or casing **21** is disapproved because both parts fitting is controlled at the factory.*

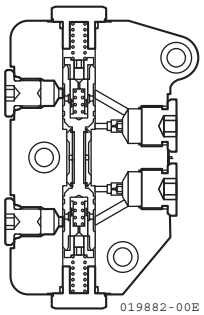
No.	Symptoms	Criteria	Corrections
1	Low secondary side pressure	• Low primary side pressure • Spring **8** broken or weakened • Excessive clearance between spool **11** and casing **21** • Too much play in control lever movement	• Obtain proper primary side pressure • Replace spring **8** • Replace complete assembly • Replace lever
2	Unstable secondary side pressure	• Sticky friction part • Return line pressure fluctuation • Air in the circuit	• Repair • Direct return to reservoir • Purge air
3	High secondary side pressure	• High return line pressure • Sticky friction part	• Direct return to reservoir • Repair

6-6 Swing Motor

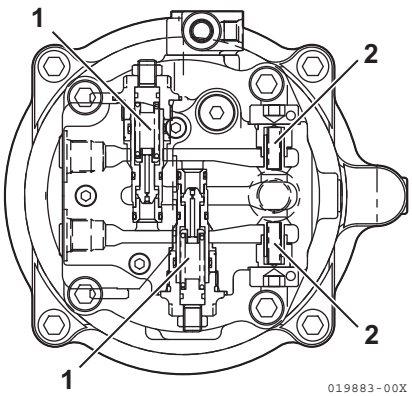
6-6-1 Overview

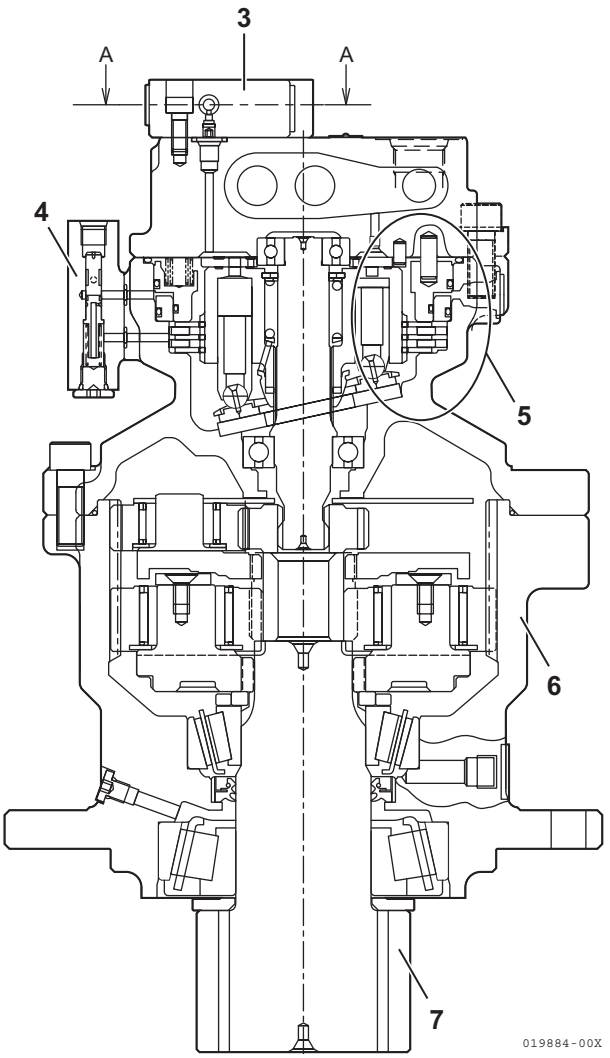
1. Features

(1) This motor unit consists of a compact planetary reduction gear and a hydraulic motor.
(2) The well-balanced hydraulic design ensures the stable functioning over a long period of time and provides a good mechanical efficiency and volumetric efficiency.
(3) The construction is designed simple with high pressure relief valves, make-up valves and other functional components incorporated in the motor.
(4) This motor ensures the sufficient durability under severe operating conditions.



Section A-A

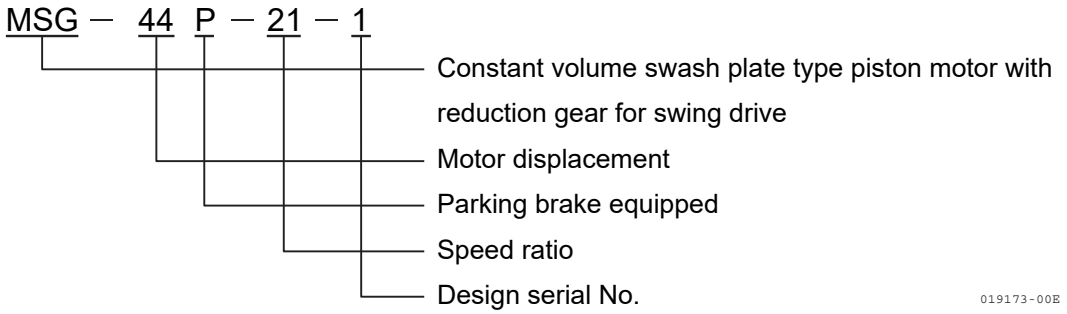




No.	Parts
1	Relief valve
2	Make-up valve
3	Anti swing back valve
4	Hydraulic timer valve
5	Mechanical brake
6	Planetary double action gears
7	Pinion shaft

2. Type Indication

Example:



3. Specifications

Type		MSG-50
Total displacement	cu.in. (cu.cm)	49.9 (818) or less
Motor displacement	cu.in. (cu.cm)	2.42 (39.7) or less
Reduction ratio		1/20.6 (Planetary two-stage)
Mass	lbs. (kg)	176 (80)

6-6-2 Description of Functions and Operation

1. Motor

Refer to Fig. 1 Motor Construction.

The cylinder block incorporates nine pistons. The end face of the cylinder block is in contact with the valve plate having two ports A and B (distributing valve to change over between high and low pressures).

<Principle of generating torque>

When high pressure oil (Pressure P) is introduced to the B port, the inclined surface is pushed by a force of “F = P x A, A: piston sectional area” per piston and the piston receives a reaction force from the inclined surface. The piston that is restricted in the moving direction by the cylinder block due to the reaction force generates a rotating force. The total of rotating force by the reaction force of the high pressure side pistons works on the cylinder block. The generated rotating force is transmitted as a torque to the shaft via the spline to turn the shaft.

On the other hand, if the high pressure oil is introduced to the A port, the opposite rotation is caused.

The output torque and the revolution are calculated as follows:

Output torque (T)

$$T = \frac{P \times D \times i \times \eta m \times \eta G}{2 \times \pi \times 100}$$

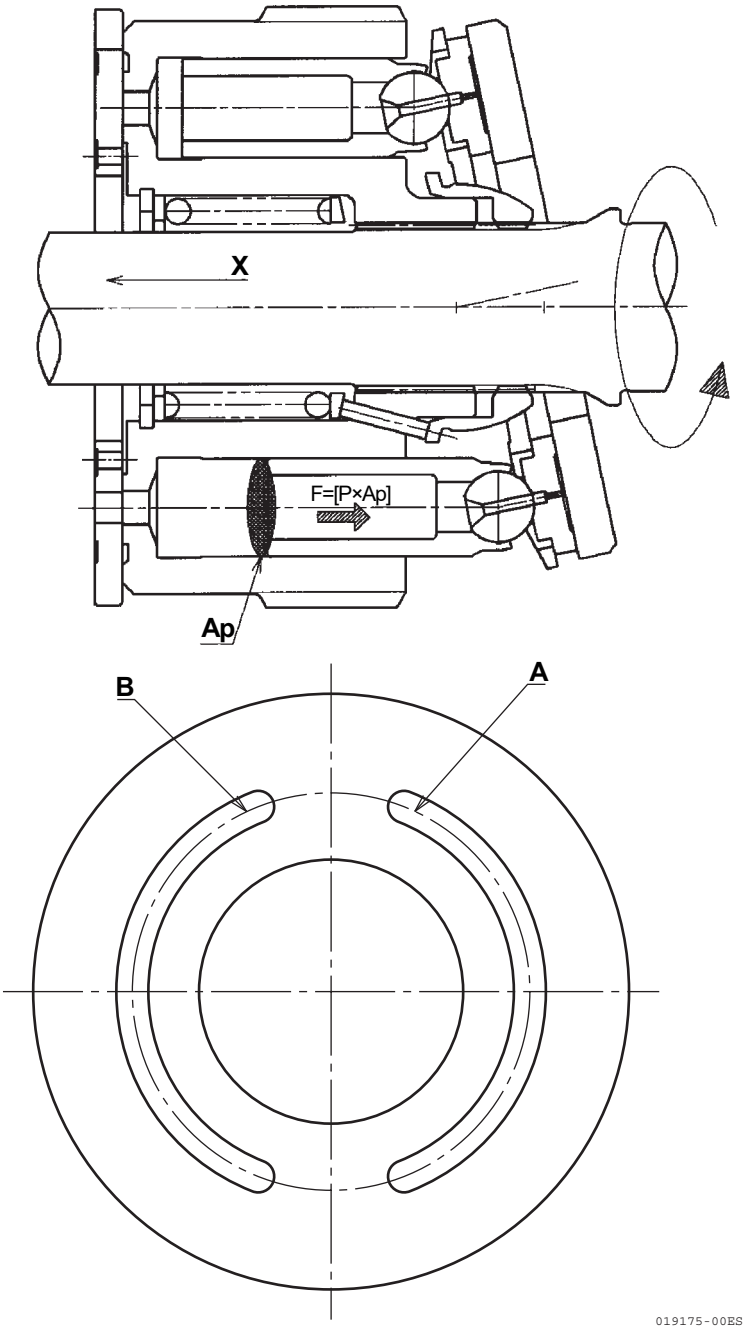
Output speed (N)

$$N = \frac{Q \times 1000 \times \eta v}{D \times i}$$

D : Displacement (cm^3/rev)
P : Effective drive pressure (MPa)
Q : Inflow (L/min)
ηm : Mechanical efficiency (motor) (%×10^{-2})
ηv : Volumetric efficiency (motor) (%×10^{-2})
i : Speed ratio of reduction gear
ηG : Efficiency of reduction gear (%×10^{-2})

019174-00E

Fig. 1 Motor Construction



View X-X of Valve Plate (Outline)

2. Parking Brake (for the Parking Brake Spec. Only)

The parking brake is of wet type multi-plate construction of hydraulic release type and has a shaft lock mechanism that changes between ON and OFF of the brake by external signal pressures.

1) Parking brake ON

Refer to Fig. 2.1 Construction.

When the hydraulic pressure for brake release is shut, the disc coupled to the periphery of the cylinder block via the spline is pushed by the spring force against the brake piston (pinned to the case so that it will not rotate) and the cylinder block and the case are secured by the frictional force. Thus the shaft is locked.

2) Parking brake OFF

Refer to Fig. 2.2 Construction.

When the brake release pressure is introduced to the brake cylinder chamber (C) via the “PB” port (“PG” port for the parking brake spec.), the brake piston is operated by the release pressure in opposition to the spring force to eliminate the force of friction with the disc, thus allowing the shaft to rotate freely.

3) Hydraulic timer (for the hydraulic timer spec. only)

Refer to Fig. 2.3 Construction.

The hydraulic timer is provided to prevent dragging of the parking brake during braking. It has a role to secure a delay time to keep the parking brake unapplied while the hydraulic dynamic brake is absorbing the swing inertia energy.

The delay time is set by controlling the flow rate by throttling the oil discharged from the cylinder chamber using an orifice.

When the control valve is returned to neutral from the motor rotating state, the valve changeover pressure “SH”, interlock with the control valve changeover signal, becomes a low pressure and the valve is moved by the spring to the position shown in the figure and the brake cylinder chamber is connected to the drain via the valve.

(In this state, the rotating energy of the upper body is converted to thermal energy and absorbed by the hydraulic dynamic braking action via the cross relief overload relief valve.) While the oil in the brake cylinder chamber C tries to move in the direction to push the disc by the spring force being exerted on the brake piston, since the oil discharged from the brake cylinder chamber is controlled in the flow rate by the orifice in the valve unit, the brake piston will not come in contact with the disc and no braking force will be produced until the preset time passes.

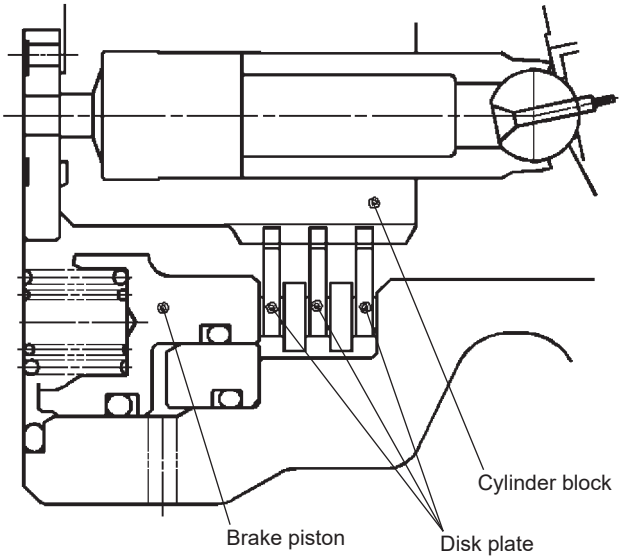


Fig.2.1 Parking Brake is ON. (Brake releasing pressure is not supplied from "PB"("PG") port.)

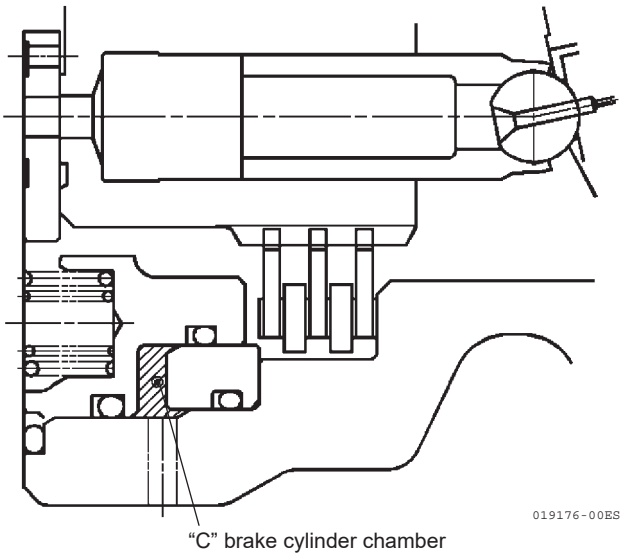
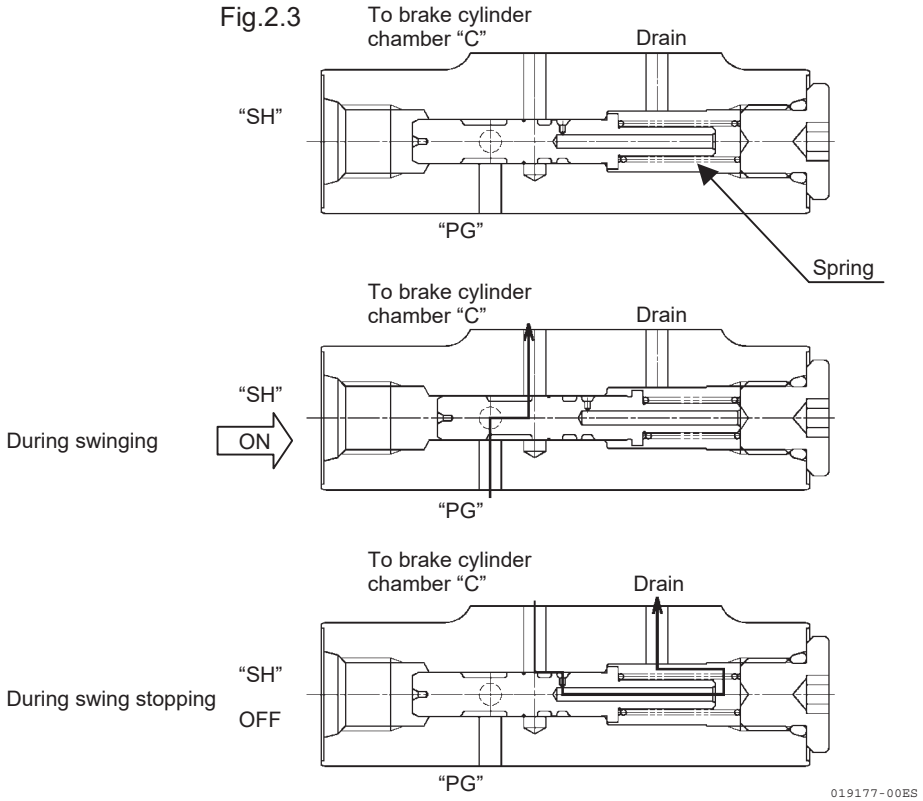


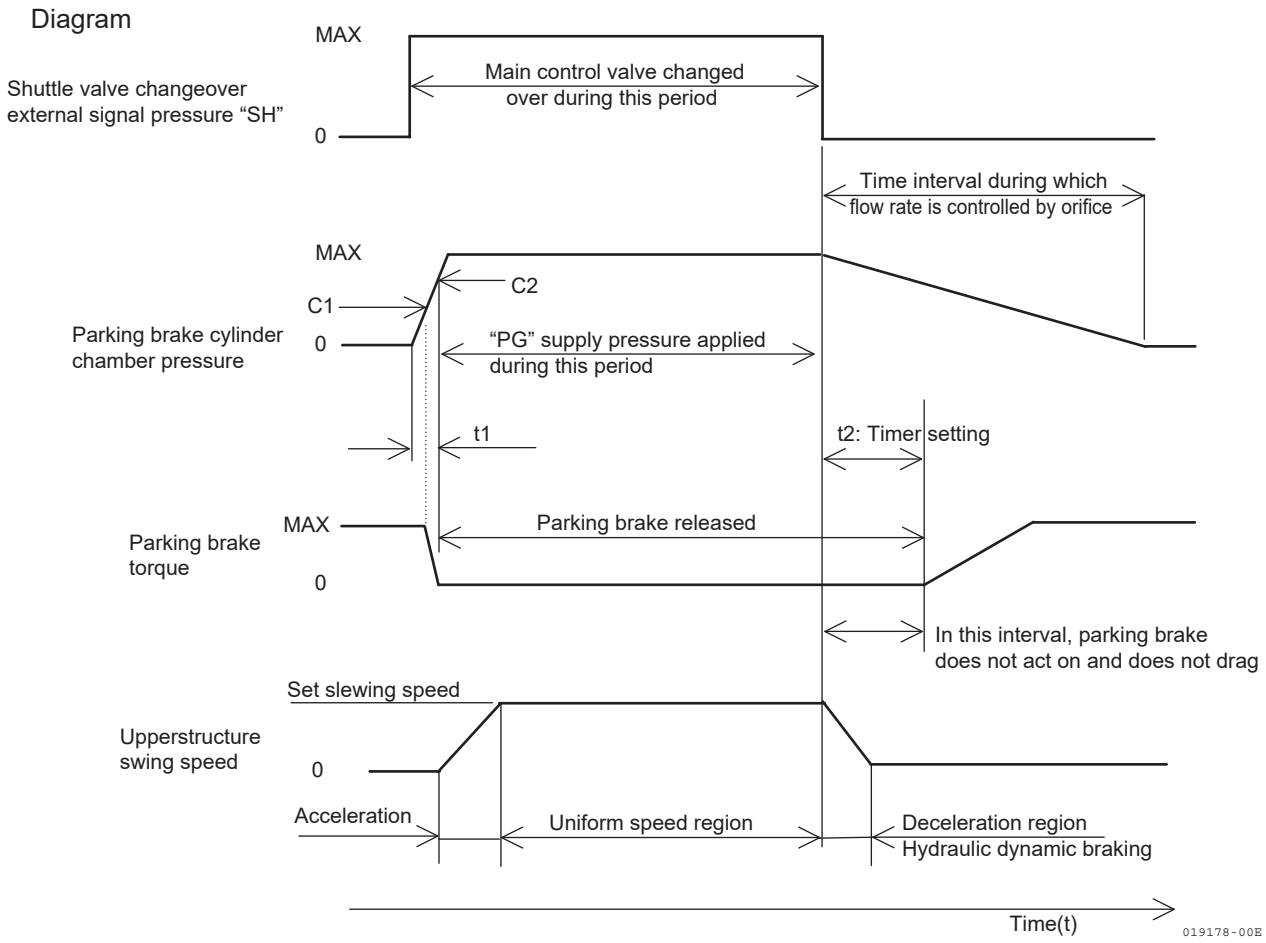
Fig.2.2 Parking Brake is OFF. (Brake releasing pressure not supplied from "PB"("PG") port.)

Fig.2.3



The above function is explained using the diagram below.

Diagram



3. Principle of Operation of the Relief Valve

The relief valves determine the drive force and the brake force for hydraulic excavator swing and are installed in the main port A and B lines. The circuit is configured to return the oil flowing past the relief valve to the counterpart main low pressure line through the make-up valve.
A shockless function is also incorporated to reduce shock produced at the start of both acceleration and deceleration.

The construction of the relief valve, as shown in Fig. 3.1, consists of;
a) A direct-acting differential area type relief valve
b) A shockless piston

The installation of a shockless type relief valve helps reduce shock and stress produced in the strength members.

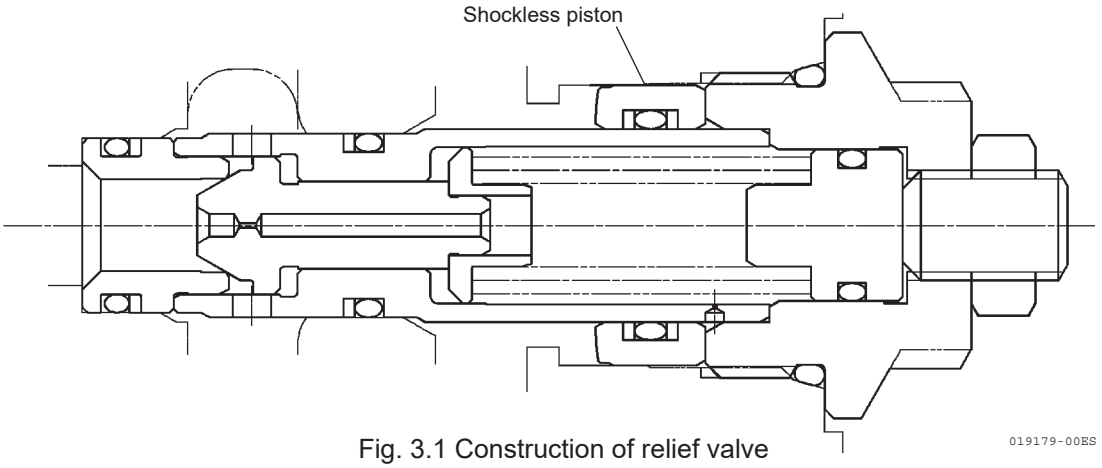


Fig. 3.1 Construction of relief valve

The relief valve operates in two stages as follows.
• First stage : Refer to Fig. 3.2.
At the start of operation, the shockless piston moves to maintain the spring chamber at a low pressure. Thus, the pressure receiving area of the poppet becomes the poppet seat area (S1), a considerably larger area than the pressure receiving area (S1 – S2) at the specified relief setting. For this reason, the relief operating pressure is kept at a low pressure until the shockless piston completes its movement.

The low pressure holding time depends on the poppet orifice diameter, the free piston pressure receiving area and the free piston stroke.

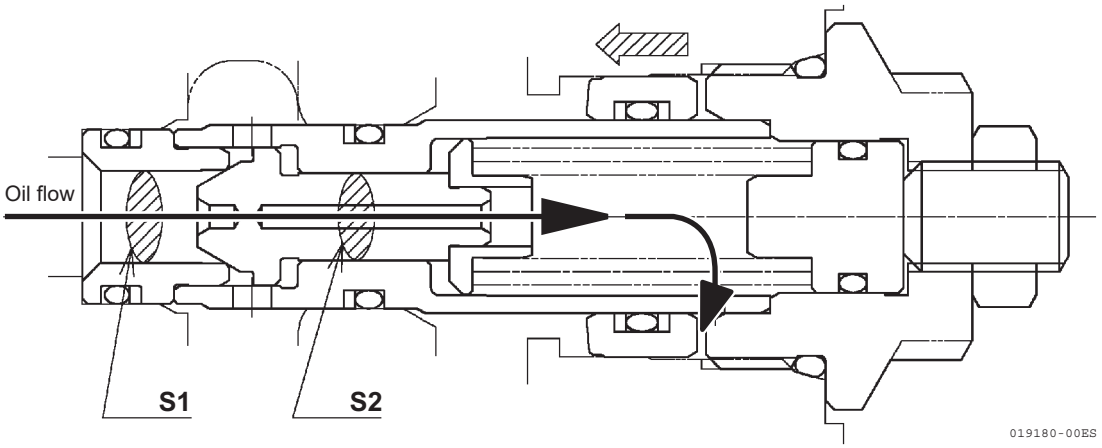


Fig. 3.2 Operation of relief valve in first stage

• Second stage : Refer to Fig. 3.3

When the shockless piston completes its movement, the pressure inside the spring chamber increases and pressures on both sides of the poppet become equal. Then the relief valve operates at the specified set pressure.

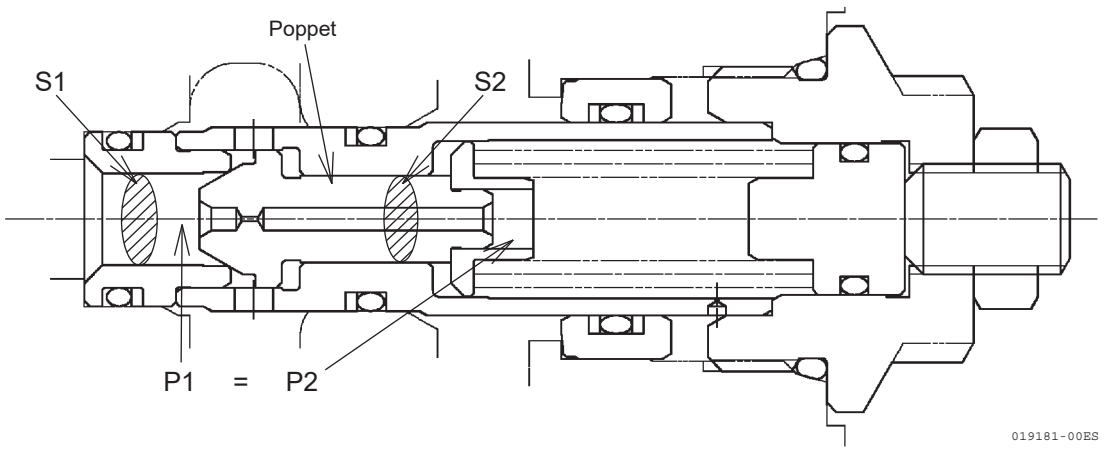


Fig. 3.3 Operation of relief valve in second stage

Fig. 4 shows the pressure waveforms of the conventional type and the shockless type.

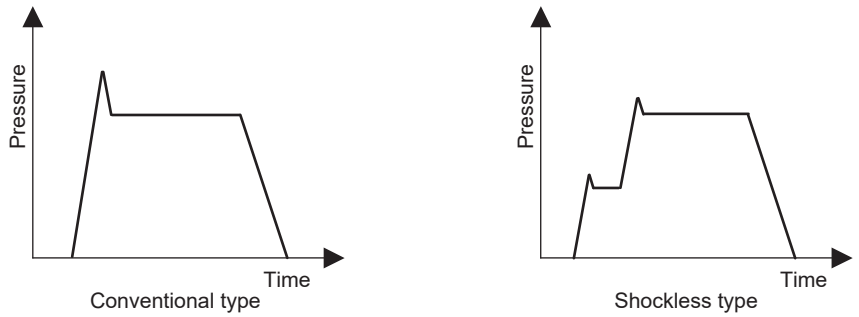


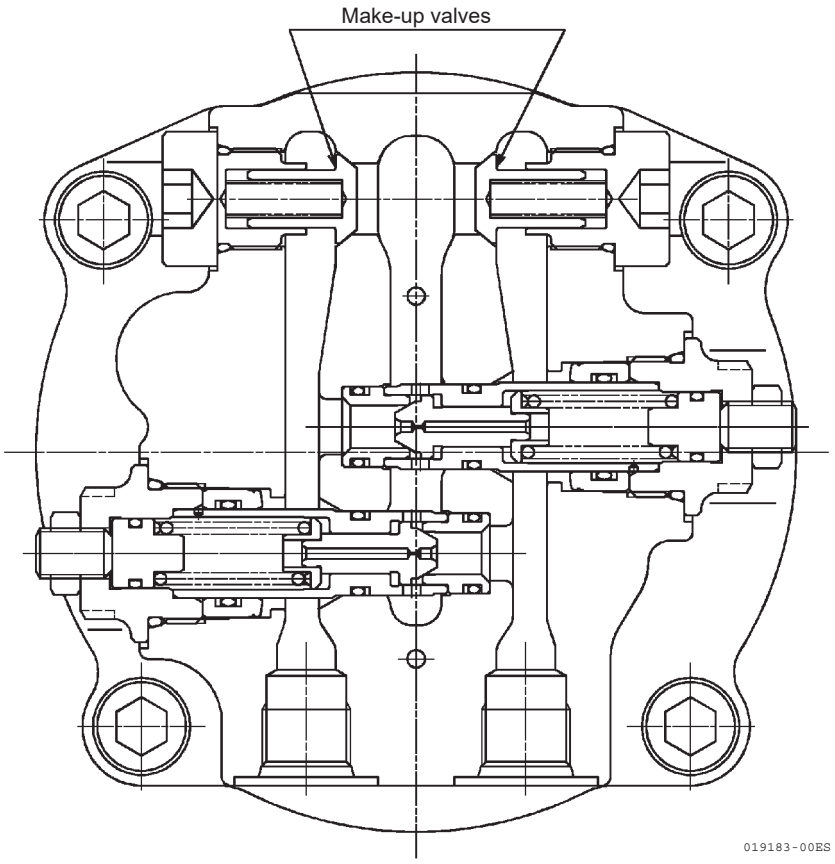
Fig. 4 Comparison of pressure waveforms 019182-00E

4. Make-up Valve

The make-up valve has the following two functions.

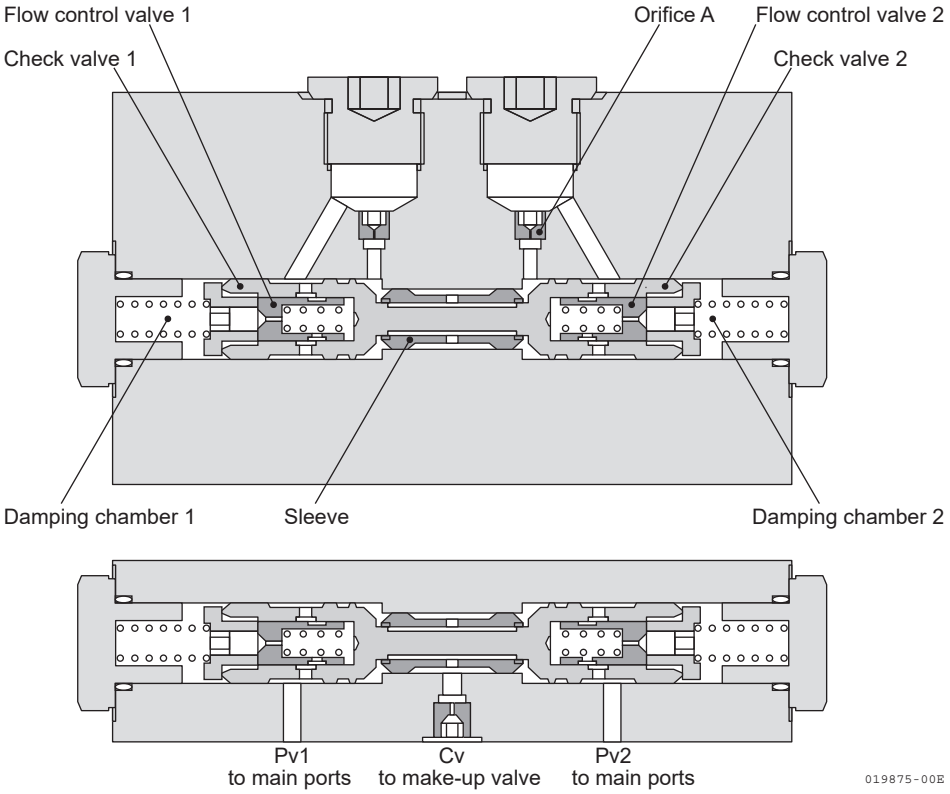
One is to prevent cavitation produced by overrun of the piston motor in order to prevent the overrun of the upperstructure. When the motor is turned due to the inertia of the upperstructure, the motor acts like a pump. In cases where the quantity of oil discharged from the motor is larger than the quantity of oil supplied to the motor, additional oil is supplied to the motor main circuit via the make-up valve from outside to prevent the occurrence of negative pressure inside the circuit.

The other is to prevent the occurrence of negative pressure in the circuit during braking. When the circuit between the control valve and the motor is closed, some oil flows into the motor drain line and some oil leaks from the control valve. Therefore, to prevent negative pressure in the closed circuit and ensure proper braking performance, additional oil is supplied via the make-up valve.



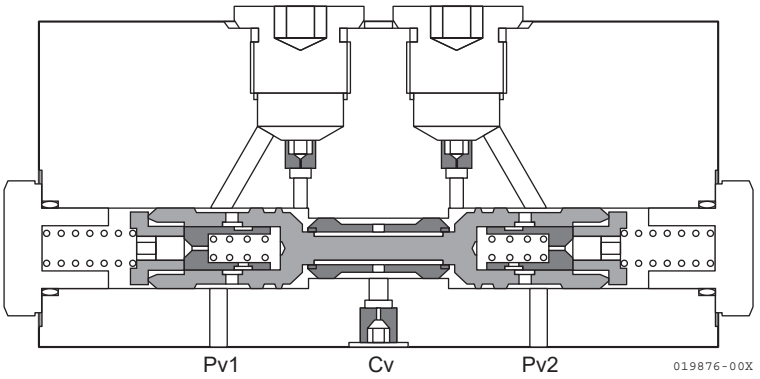
5. Anti Swing Back Valve

Anti swing back valve makes the Main port connect to Drain line in a second in order to prevent Swing back of upper carriage at swing stop motion.



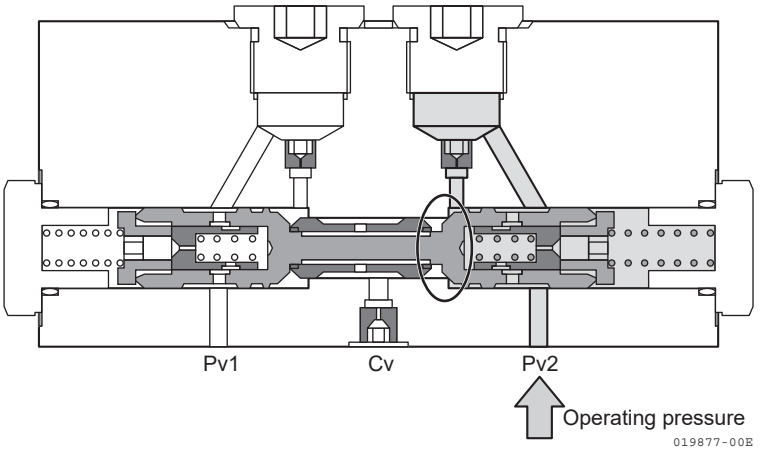
• **Neutral condition**

Check valve stands in center position by spring force when control valve is not operated. (P1 and P2 have same pressure.)



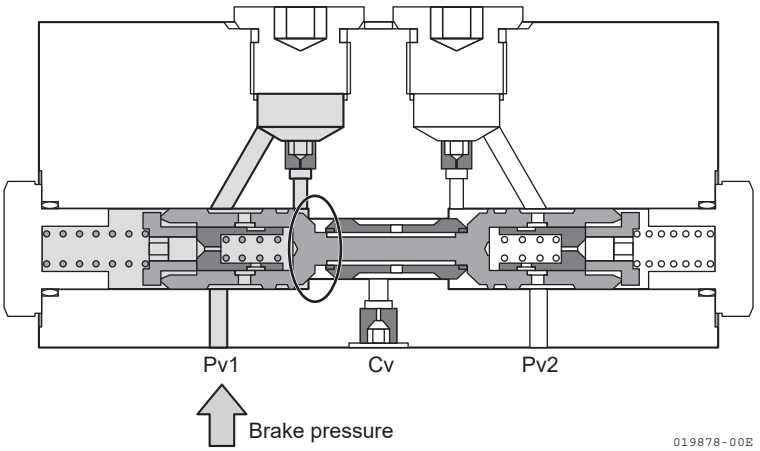
• **Acceleration and operating condition**

Check valve is pushed and block the passage when slew motor is operated.



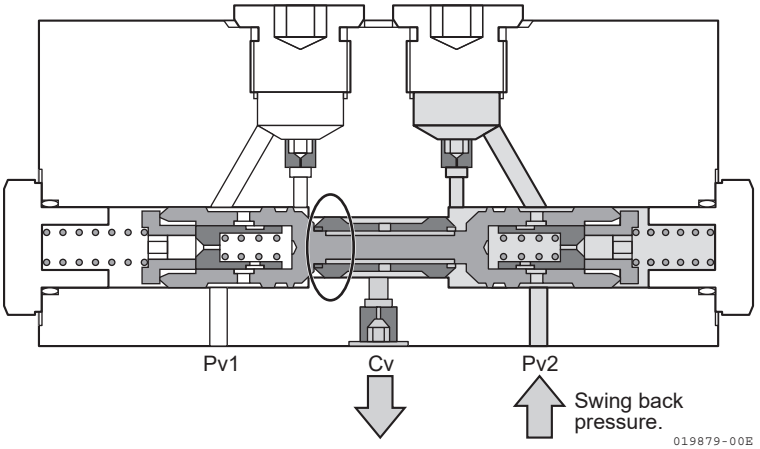
• **Braking condition**

Check valve is pushed and block the passage by brake pressure.



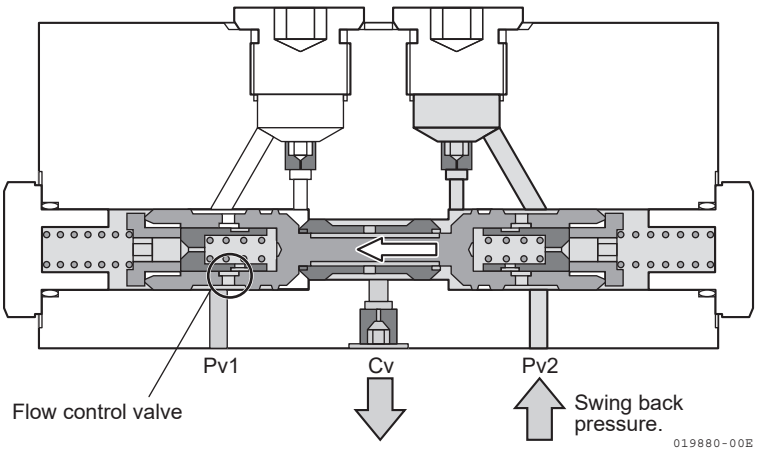
• **Swing back condition 1**

After swing stop, the slew motor start to swing back due to the swing back pressure.
This pressure pushes the sleeve in the direction of the check valve (Low pressure side) and makes sleeve contact with check valve.
At the same time, the passage from Pv2 to Cv is opened.
The pressure is led to Cv trough this passage.



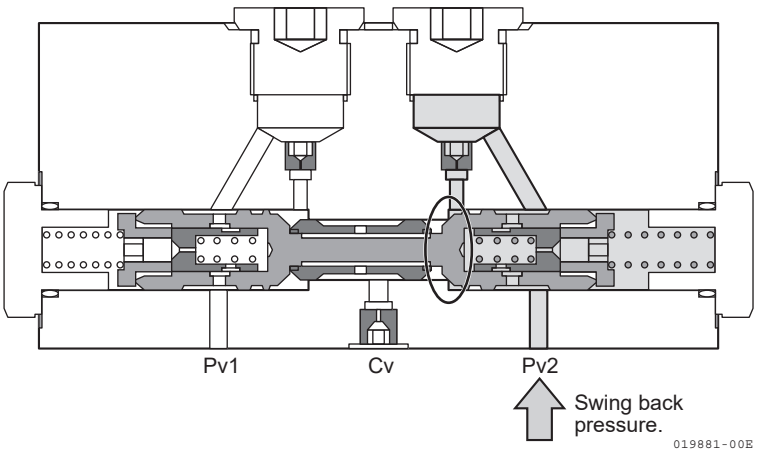
• **Swing back condition 2**

Swing back pressure pushes also the check valve in the direction of the arrow.
Check valve moves constant speed because Flow control valve restricts the flow from damping chamber 1.



• **Swing back condition 3**

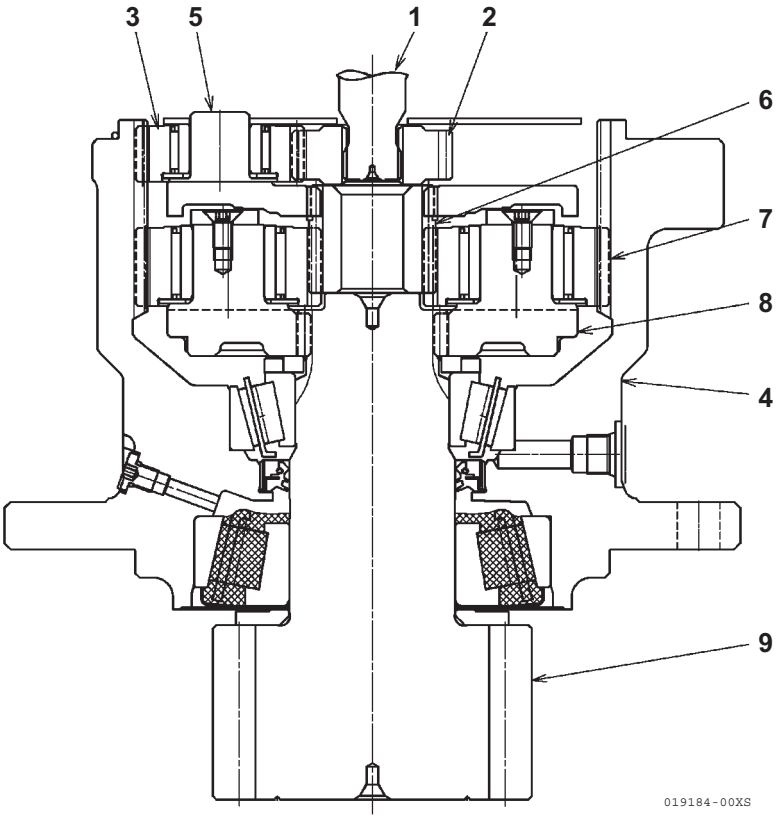
Finally, Check valve shut the passage between Pv2 and Cv2.



6. Reduction Gear (Planetary Two-stage)

Refer to the cross section.

The motor shaft **1** is coupled to the drive gear **2** via a spline. The drive force of the hydraulic motor is transmitted from the drive gear **2** to the engaged planetary gear **3**. The planetary gear **3** is meshed with the ring gear of the reduction gear housing **4**. Thus, while rotating, it revolves around the ring gear. The planetary gear **3** is held by the holder **5** via the bearing and the holder transmits the revolving motion of the planetary gear **3** to the sun gear **6** coupled via the spline. The sun gear **6** meshes with the planetary gear **7** and as with the first stage, transmits the rotary motion to the planetary gear **7**. Since the planetary gear **7** is meshed with the ring gear of the housing **4**, it revolves while rotating. Since the planetary gear **7** is held by the holder **8** via the bearing, the holder **8** transmits the revolving motion of the planetary gear **7** to the pinion shaft **9** coupled via the spline.



6-6-3 Precautions for Handling

1. Inspection

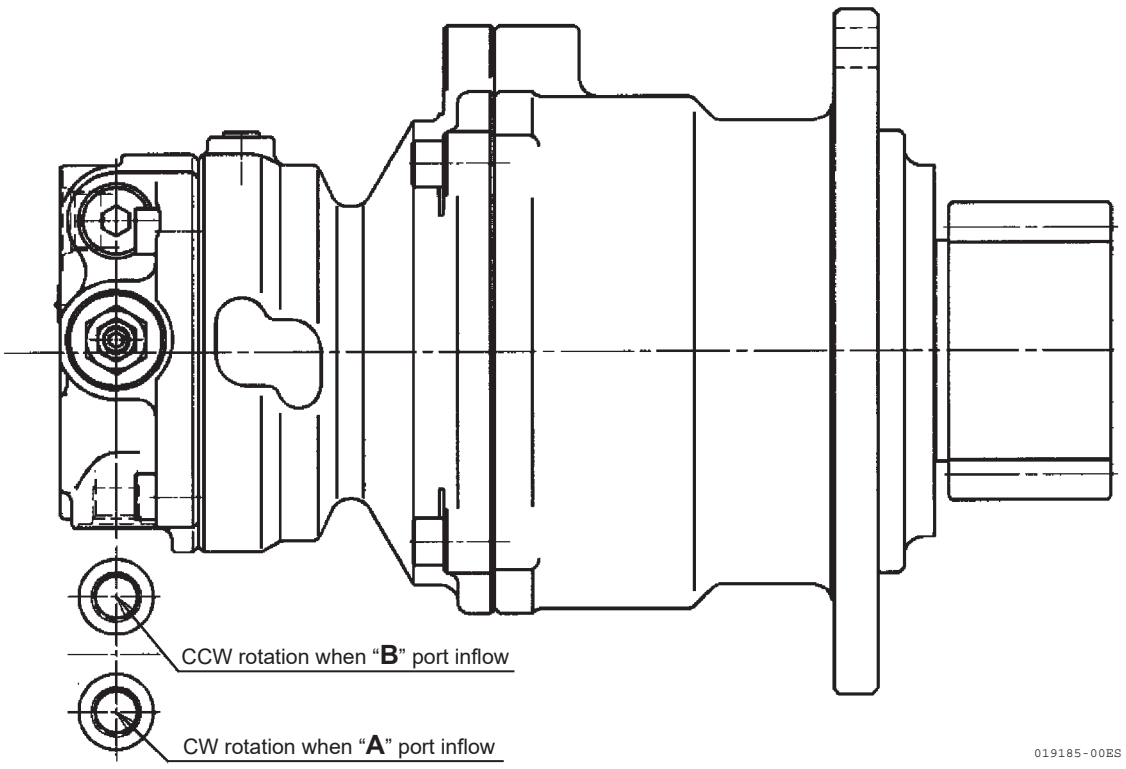
Prior to installing the piston motor, make sure that;

a) No part has been damaged during transportation. No part is missing.
b) All the tightened parts are not loose.
c) All the ports are completely sealed and no foreign matter has entered the piston motor.
d) There are some necessity to change seals in case of the motor is in stock for a long time.

2. Rotating Direction

The relation between the oil flow direction and the rotating direction is as described in the following table.

Oil inflow port	Oil outflow port	Rotating direction (when viewed from motor output shaft end)
A	B	Clockwise
B	A	Counterclockwise



6-6-4 Troubleshooting

If a problem occurs when the motor runs in the reverse direction, refer to the following troubleshooting table to investigate the cause and take corrective action.

1. Motor Function

Troubleshooting table

Problem	Probable Cause	Corrective Action
1. The motor will not run	(1) Equipment other than the piston motor, valves (incorporated in the motor) and reduction gear has failed.	Check to see if oil at the specified pressure is present at the inlet of the motor, then check each piece of equipment and repair any defective one.
	(2) The pressurized oil leaks due to abnormal wear of the motor sliding area.	Replace the abnormally worn part. Completely wash all parts, remove any scratches and burrs from the surface, then reassemble them while taking care to prevent foreign matter.
	(3) Operational failure due to damage to a major part of the motor. If this is the case, the motor produces abnormal noise.	Disassemble the motor and replace the damaged part. Completely wash all parts, then reassemble them while taking care to prevent foreign matter.
	(4) Operational failure due to damage to a major part of the reduction gear. If this is the case, the reduction gear produces abnormal noise.	Disassemble the reduction gear and replace the damaged part. Completely wash all parts, then reassemble them while taking care to prevent foreign matter.
	(5) An overload is applied to the motor to actuate the relief valve.	Check the load and run the motor under a load suitable for the relief set pressure.
2. The motor revolution is too low.	(1) The oil in the rated amount is not supplied to the motor due to a troubled hydraulic pump, pressure control valve, etc. to cause a drop in revolution.	Check to see if the oil is supplied to the inlet of the motor in the rated amount, then check and repair if necessary each piece of equipment.
	(2) The motor's volumetric efficiency has dropped to cause a drop in revolution.	Disassemble the motor and check the sliding area for abnormal wear. Repair the worn area or replace the worn part.
3. The motor revolution fluctuates excessively.	(1) Because of wear of the motor sliding area, a large amount of high pressure oil is leaking through the drain port, causing the revolution to drop considerably with consequent large revolution fluctuation. The revolution will also fluctuate due to wear of the bearing.	Disassemble the motor and replace the abnormally worn part. Completely wash all parts, then reassemble them while taking care to prevent foreign matter.
4. Oil leak.	(1) Oil is leaking due to a broken oil seal or O-ring.	Replace the broken oil seal or O-ring with a new one. When inserting a new oil seal, exercise sufficient care to prevent damage to the lip. Note that the maximum safe working temperature of the oil seal and the O-ring is 176 °F (80 °C). If the temperature of the hydraulic fluid will rise above 176 °F (80 °C), take such measures as placing a cooler in the hydraulic circuit.

Problem	Probable Cause	Corrective Action
4. Oil leak.	(2) Due to a cause of 1. (2) or 3. (1), the motor case is exposed to a pressure to cause the oil seal to be broken, causing oil leak. • Oil seal Pressure resistance : 44 PSI (0.3 MPa). (Momentary max.) Normal pressure : 15 PSI (0.1 MPa) max.	Repair the motor as explained in 1. (2) and 3. (1) and replace the oil seal with a new one. When inserting a new oil seal, exercise sufficient care to prevent damage to the lip.
	(3) The back pressure has risen due to a cause of clogging of the drain piping by foreign matter or a too small, too long piping to cause the oil seal to be broken, causing oil leak. • Oil seal Pressure resistance : 44 PSI (0.3 MPa). (Momentary max.) Normal pressure : 0.1 MPa max.	Remove the clogging of the drain piping. Check the piping system and reduce the piping resistance. By the above corrective action, ensure that a pressure over 44 PSI (0.3 MPa) will not be applied to the oil seal, then replace the oil seal with a new one. When inserting a new oil seal, exercise sufficient care to prevent damage to the lip.
5. Excessive abnormal noise, rotation fluctuation and pressure fluctuation due to cavitation.	(1) The amount of drain has increased due to a drop in the motor efficiency.	Take corrective action as explained in 2. (2) and 3. (1).
	(2) The make-up valve failed to operate properly.	Take corrective action referring to 1. (3) in valve troubleshooting.
	(3) The make-up valve supply pressure or supply oil amount is not sufficient.	Check the oil pressure and amount to the make-up valve and if not correct, set them to the specified levels.

2. Motor-Incorporated Valve Function

Troubleshooting table

Problem	Probable Cause	Corrective Action
1. The motor will not run or its rotating speed is too slow.	(1) Equipment other than the piston motor, valves (incorporated in the motor) and reduction gear has failed.	Check to see if oil at the specified pressure is present at the inlet of the valve, then check each piece of equipment and repair any defective one.
	(2) The amount of internal leak increased because the O-ring in the relief valve was cut.	Replace the O-ring or the back-up ring with a new one.
	(3) The amount of leak increased because of poor sealing of the valve or the piston area.	Either repair the damaged area or replace the piston and the rear cover with new ones.
	(4) The seat of the make-up valve is faulty or the valve itself failed. 1) Foreign matter is present. 2) The sliding surface of the check valve is rough or damaged. 3) The spring is broken.	 1) Remove foreign matter completely, repair any damaged part, completely wash all parts, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve. 2) Correct the sliding surface or replace the valve with a new one. 3) Replace the broken spring. When replacing the spring, remove foreign matter completely, repair any damaged part, wash all parts completely, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve.
	(5) The seat of the relief valve is faulty. 1) Foreign matter is present. 2) The spring is broken.	 1) Remove foreign matter completely, repair any damaged part, completely wash all parts, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve. 2) Replace the relief valve assembly.
	(6) The cracking pressure of the relief valve has dropped. 1) The spring has settled. 2) The poppet orifice is clogged.	 1) Replace the relief valve assembly. 2) Wash the orifice with treated oil and reassemble it.
2. The motor will not stop or it is too slow to come to a stop.	(1) The seat of the make-up valve is faulty or the valve itself failed. 1) Foreign matter is present. 2) The sliding surface of the check valve is rough or damaged. 3) The spring is broken.	 1) Remove foreign matter completely, repair any damaged part, completely wash all parts, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve. 2) Correct the sliding surface or replace the valve with a new one. 3) Replace the broken spring. When replacing the spring, remove foreign matter completely, repair any damaged part, wash all parts completely, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve.

Problem	Probable Cause	Corrective Action
2. The motor will not stop or it is too slow to come to a stop.	(2) The seat of the relief valve is faulty. 1) Foreign matter is present. 2) The spring is broken.	 1) Remove foreign matter completely, repair any damaged part, completely wash all parts, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve. 2) Replace the relief valve assembly.
	(3) The cracking pressure of the relief valve has dropped. 1) The spring has settled. 2) The poppet orifice is clogged.	 1) Replace the relief valve assembly. 2) Wash the orifice with treated oil and reassemble it.
	(4) The amount of leak has increased. 1) The amount of internal leak increased because the O-ring in the valve was cut. 2) The amount of leak increased due to poor sealing of the valve and the piston area.	 1) Take corrective action referring to 1. (2) and (3). 2) Replace the relief valve assembly.
3. Abnormal noise is heard.	(1) The make-up valve failed. 1) Foreign matter is present. 2) The spring is broken.	 2) Replace the broken spring. When replacing the spring, remove foreign matter completely, repair any damaged part, wash all parts completely, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve.
	(2) The oil supply pressure or amount to the make-up valve is not sufficient.	Check the oil pressure and amount to the make-up valve and if not correct, set them to the correct levels.
	(3) The relief set pressure has changed and the valve is resonating with other relief valves.	Readjust the set pressure of the relief valve.
4. Shock is too large when the swing motion comes to a stop.	(1) The shockless function does not work. 1) Foreign matter is present. 2) No pressurized oil is supplied to the piston chamber. 3) The piston's sliding surface is worn excessively, increasing the amount of leak.	 1) Remove foreign matter completely, repair any damaged part, completely wash all parts, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve. 2) Wash the relief valve sub-assembly and remove foreign matter clogging the orifice. 3) Correct the damaged part or replace the piston with a new one.
	(2) The relief set pressure has risen.	Readjust the set pressure of the relief valve.
	(3) The relief valve does not operate. 1) Foreign matter is present.	Remove foreign matter completely, repair any damaged part, completely wash all parts, then reassemble them. If the damage is too deep causing a large amount of leak, replace the valve.

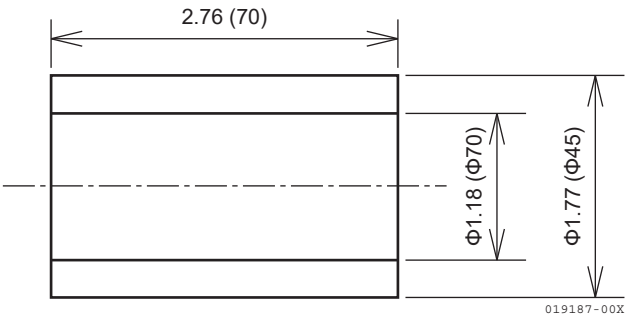
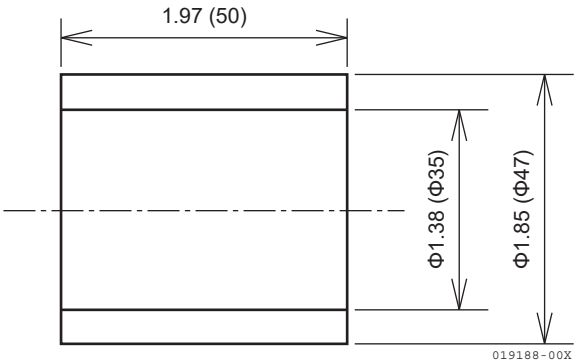
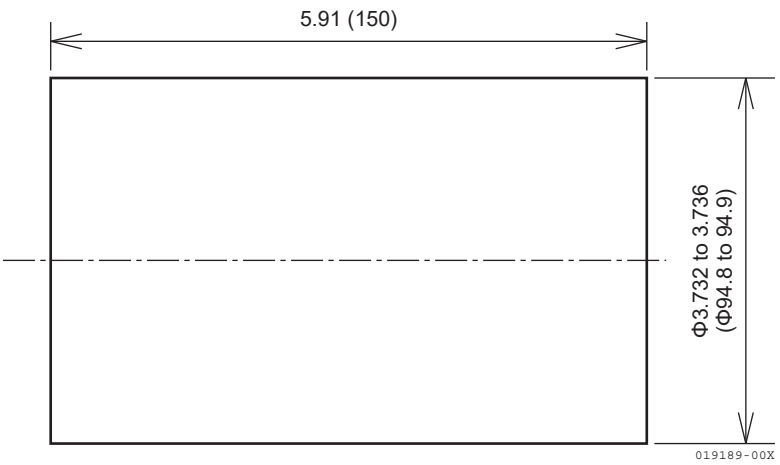
3. Parking Brake and Hydraulic Timer Function (*Parking Brake and Hydraulic Timer Spec. Only)

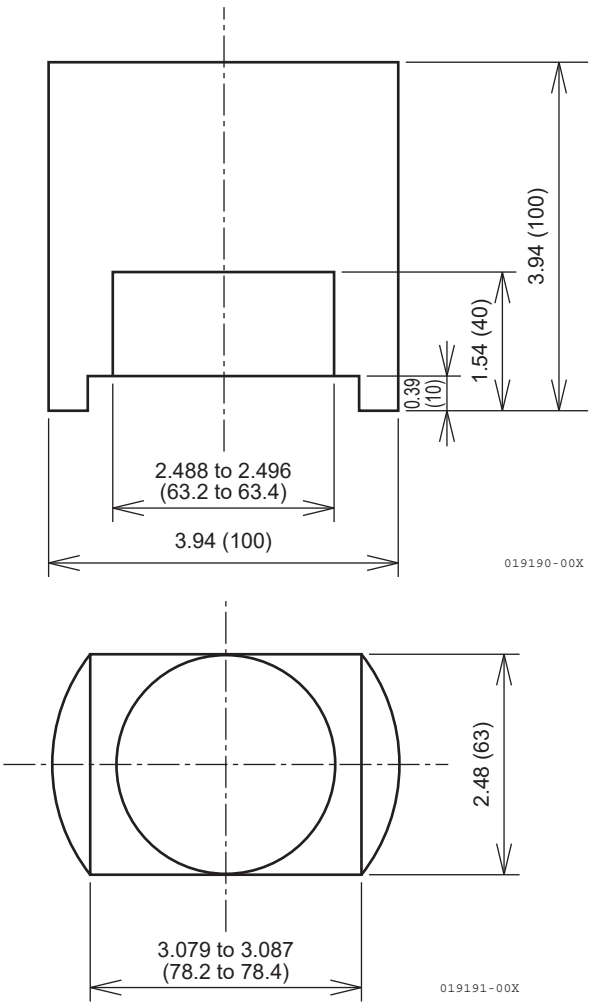
Problem	Probable Cause	Corrective Action
1. The motor will not run. → The parking brake will not be released.	(1) The release pressure “PB” (“PG”) or the valve changeover signal pressure “SH” (*hydraulic timer spec. only) is not present. Or the supply pressure is too low (not at the specified level). Accordingly, the brake piston will not operate or the timer valve will not change over.	Adjust the “PB” (“PG”) or “SH” pressure to the specified level.
	(2) The motor drain pressure is too high for the valve to operate.	Measure the motor drain pressure and check and repair if necessary the drain circuit for clogging. If the amount of motor drain is too much, check and repair the motor.
	(3) The timer valve will not change over. (*Hydraulic timer spec. only) 1) The sliding part of the valve body or the valve is worn or damaged to cause an operational failure. 2) Foreign matter is present on the sliding part of the valve body or the valve to cause an operational failure. 3) The spring is broken.	Check the parts and correct damage. 1) If the sliding part is damaged excessively, replace it with a new one. 2) Wash the sliding part and remove foreign matter. 3) Replace the spring.
	(4) The brake piston will not operate. 1) The O-ring in the brake piston is worn excessively or cut to cause the pressurized oil to leak. 2) The sliding part of the brake piston is worn or damaged to cause a piston operational failure. 3) Foreign matter is present on the piston sliding part to cause an operational failure.	1) Replace the O-ring with a new one. 2) Check the parts and correct damage. If the sliding part is damaged excessively, replace it with a new one. 3) Wash the sliding part and remove foreign matter.
2. The parking brake force is weak. No brake force is produced. (*Parking brake spec. only)	(1) The disc friction material is worn.	Replace the disc with a new one.
	(2) The spring in the piston has settled.	Replace the spring with a new one.
	(3) The sliding part of the brake piston is faulty or stuck or the disc friction surface has deteriorated.	Correct the sliding part. If damaged excessively, replace it with a new one. Note that the disc friction material surface cannot be corrected.
	(4) The timer valve does not change over and the cylinder chamber is not depressurized. (*Hydraulic timer spec. only) 1) The spring of the valve has settled. 2) (*Hydraulic timer spec. only) The signal pressure “SH” is present or the back pressure of the signal system is too high. 3) Others same as 1) to 3) in 1. (3).	1) Replace the spring with a new one. 2) Check the pressure of the “SH” signal system. If the back pressure is too high, take necessary action to reduce it to the specified level. 3) Others same as 1) to 3) in 1. (3).
	(5) The orifice or the filter is clogged and the cylinder chamber is not depressurized.	Wash or replace the filter or the orifice.

Problem	Probable Cause	Corrective Action
3. The parking brake drags or produces abnormal noise, vibration, shock, other problems or abnormal heat. (*Parking brake spec. only)	(1) The release pressure “PB” (“PG”) is too low and the brake piston is rubbing against the disc.	Adjust the “PB” (“PG”) supply pressure to the specified level.
	(2) The O-ring in the brake piston is worn excessively or cut to cause the pressure in the cylinder chamber to drop.	Replace the O-ring with a new one.
	(3) The causes of timer valve operational failure are the same as those of 1) to 3) in 2. (4).	
	(4) The hydraulic timer is faulty. (*Hydraulic timer spec. only) The timer set time is too short and the parking brake acts as a dynamic brake. 1) The orifice is not set properly. 2) The valve seat is faulty. 3) Foreign matter is present on the seat. 4) The spring has settled or is damaged.	 1) Disassemble and check the timer. Then assemble the orifice properly. 2) If the seat surface is damaged excessively, correct or replace it. 3) Wash the parts to remove foreign matter. 4) Replace the spring with a new one.

6-6-5 Employment Tool

No.	Tool name	Remarks
1	Plastic hammer	
2	Driver (-)	
3	Snap-ring pliers (for hole)	
4	Snap-ring pliers (for shaft)	
5	Hand press	
6	Vice	
7	Hexagon socket screw keys	Hexagon width across flats • 0.10 in. (2.5 mm) • 0.12 in. (3 mm) • 0.20 in. (5 mm) • 0.24 in. (6 mm) • 0.31 in. (8 mm) • 0.47 in. (12 mm)
8	Torque wrench	Setting torque • 1.81 ft•lbf (2.45 N•m) • 7.2 ft•lbf (9.8 N•m) • 11.6 ft•lbf (15.7 N•m) • 18.1 ft•lbf (24.5 N•m) • 23.9 ft•lbf (32.4 N•m) • 28.9 ft•lbf (39.2 N•m) • 51.7 ft•lbf (70 N•m) • 115.9 ft•lbf (157 N•m) • 130.7 ft•lbf (177 N•m) • 275.3 ft•lbf (373 N•m)
9	Bit for torque wrench	Hexagon width across flats • 0.10 in. (2.5 mm) • 0.20 in. (5 mm) • 0.24 in. (6 mm) • 0.47 in. (12 mm)
10	Socket	Hexagon width across flats 27
11	Pin set	
12	Radio pliers	

No.	Tool name	Configuration for reference
21	(2-3) Ball bearing press fitting jig	
22	(2-28) Ball bearing press fitting jig	
23	(1-7) Oil seal press fitting jig	

No.	Tool name	Configuration for reference
24	(1-10) Color assembly jig	

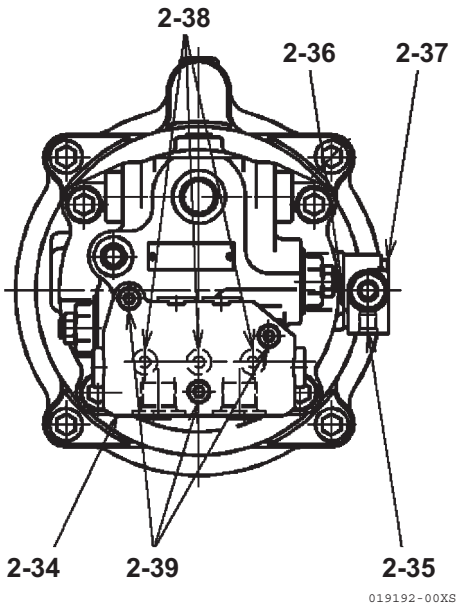
6-6-6 Disassembly Procedure

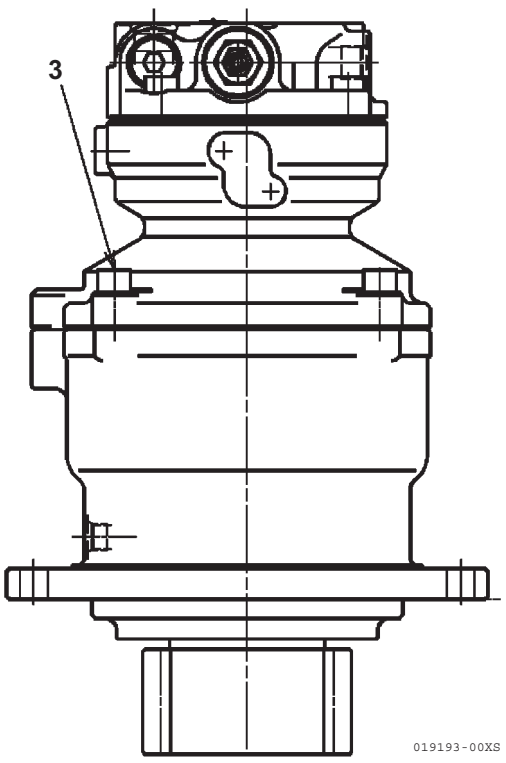
1. Precautions Before Disassembly

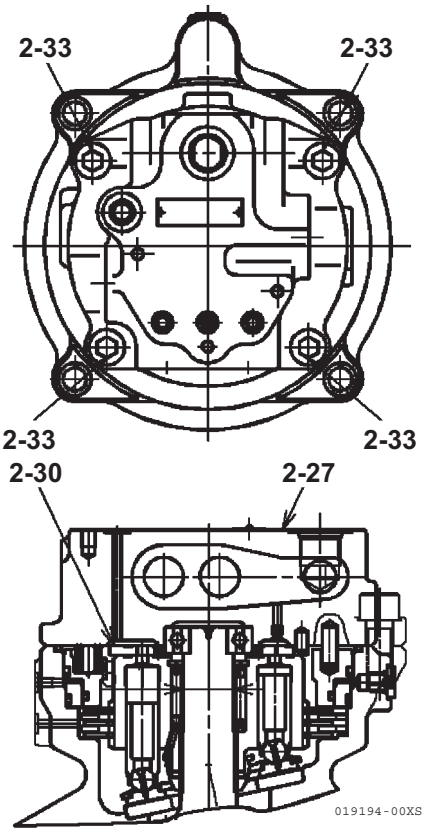
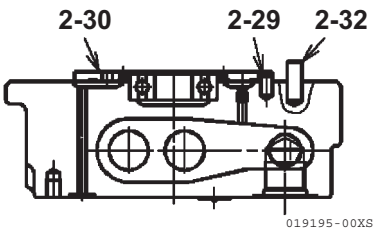
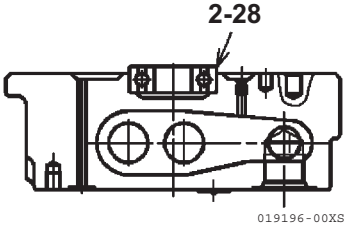
a) Completely remove dirt and dust adhering to the outside.
b) Discharge all hydraulic fluid in the piston motor case and the port oil passage.
c) Use a clean, dust-free work area. Handle parts with care to prevent dirt and dust from adhering.
d) Do not over-disassemble.

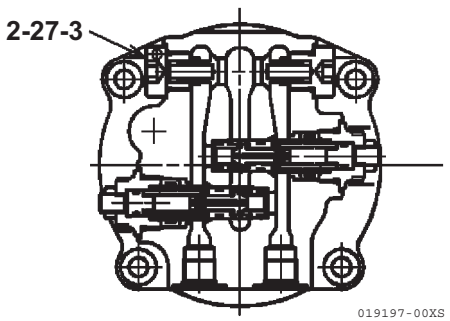
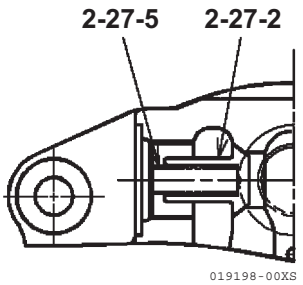
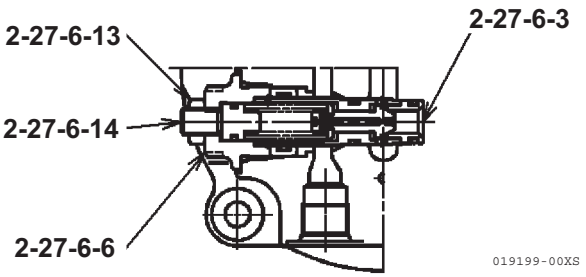
2. Disassembly

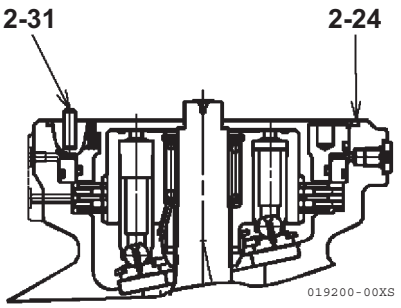
Disassemble the parts by the following procedure.

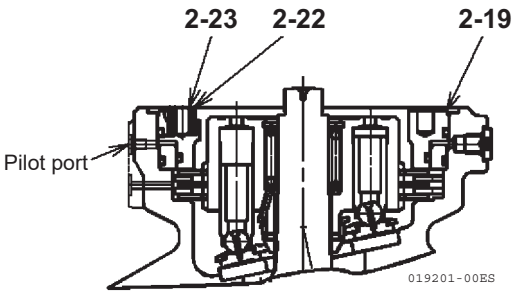
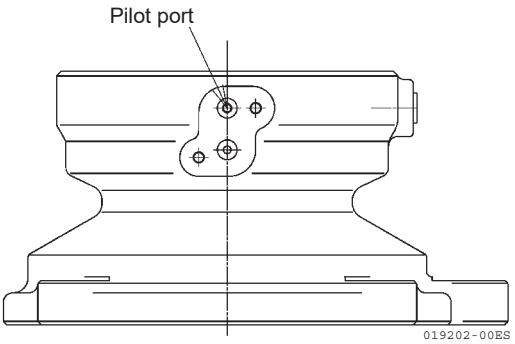
Procedure	
1. Removing the anti swing back valve (*1 Anti swing back valve spec. only) Remove the socket head bolts **2-39**. Remove the anti swing back **2-34**, O-ring **2-38**. For the disassembly and re-assembly of the anti swing back valve, refer to the separate Instruction and Service Manual. 2. Remove the timer valve. (*3 hydraulic timer spec. only) Remove the socket head bolt **2-37**. Remove the timer valve assembly **2-35**, O-ring **2-36**.	

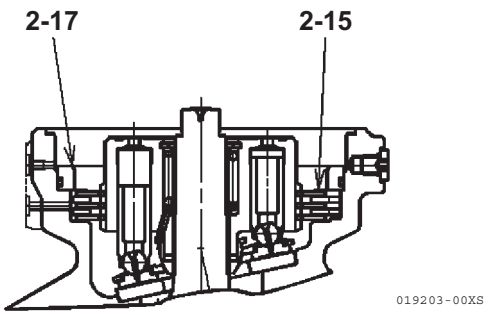
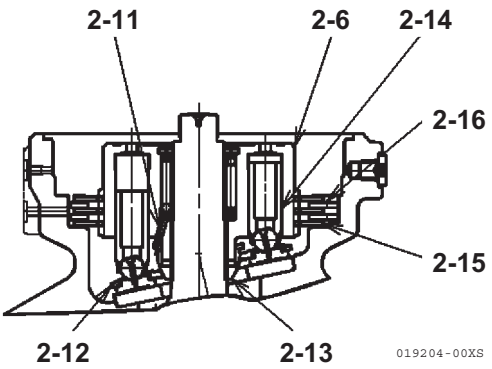
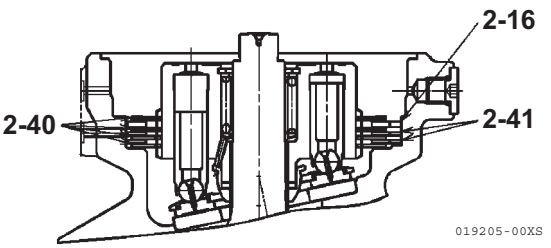
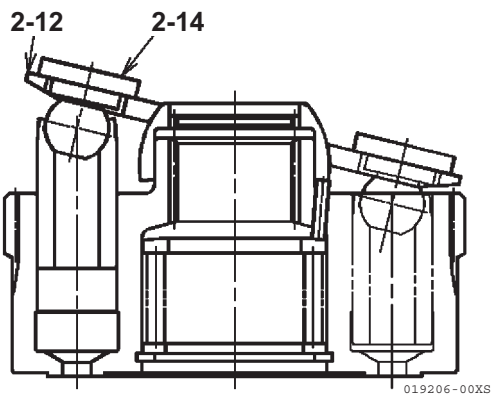
3. Separating the motor and the reduction gear secure the motor assembly in a vice and remove the socket head bolt **3**.	

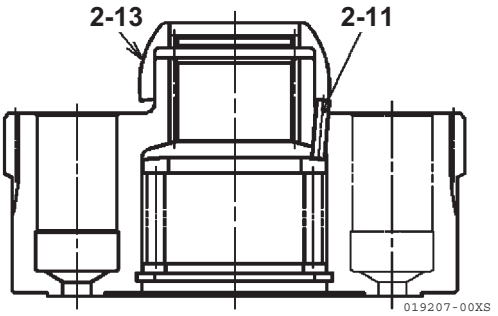
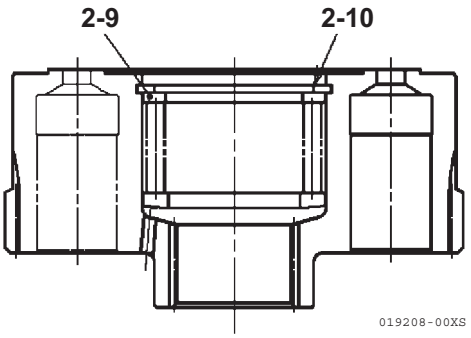
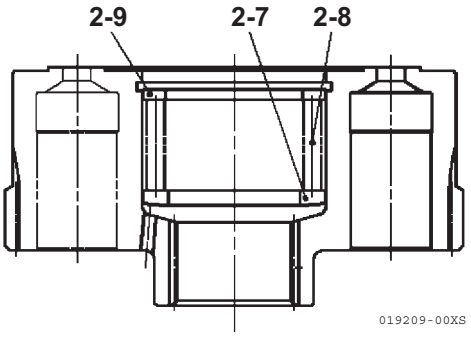
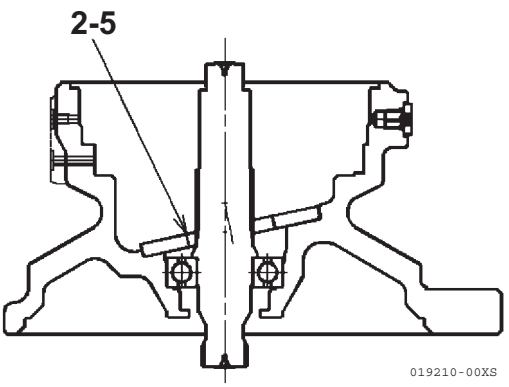
Procedure	
4. Disassembling the motor (1) Secure the motor assembly in a vice. Remove the socket head bolts **2-33** and separate the cover assembly **2-27**. ***Note:*** *When separating the cover assembly **2-27**, be careful not to drop the valve plate **2-30**.*	
(2) Remove the valve plate **2-30** and the pin **2-29**, **2-32**. ***Note:*** *The valve plate **2-30** may remain on the motor side.*	
(3) Remove the bearing **2-28**. ***Note:*** *Do not disassemble the bearing when it is not needed to change.* *The disassembled bearing must be not used.*	

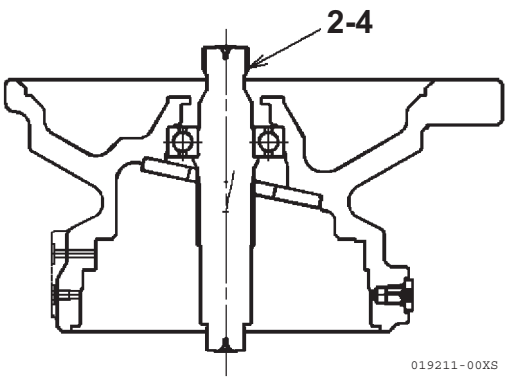
Procedure	
(4) Disassemble the check valve. 1) Loosen to remove the plug **2-27-3**.	
2) Remove the spring **2-27-5** and the check valve **2-27-2**.	
(5) Remove the relief valve. 1) Loosen the plug **2-27-6-6** to remove the relief valve assembly **2-27-6**. ***Notes:*** • *Do not move the set screw, nut.* ***2-27-6-13, 14****.* *Otherwise, the set pressure will change.* • *Do not disassemble the relief valve assembly* ***2-27-6*** *because it is a functional component.* ***Note:*** • *When remove the relief valve assembly, the poppet seat* ***2-27-6-3*** *may remain on the motor side.*	

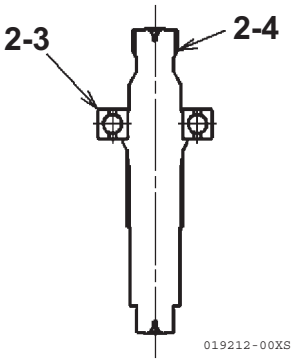
Procedure	
(6) Remove the valve pin **2-31**, the O-ring **2-24**. ***Note:*** *The pin **2-31** may remain on the cover assembly side.*	

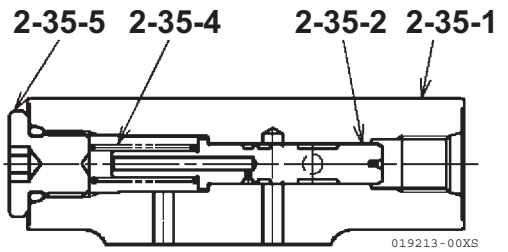
(7) (*2 Parking brake spec. only) Remove the spring **2-22**, **2-23**, and utilizing the pilot port of the case **2-1**, remove the pilot brake piston **2-19**. ***Note:*** *The piston may be ejected by the air pressure. Exercise sufficient care during removal. At the beginning of the work, set a lower air pressure and adjust it while checking the piston for ejection.*	 

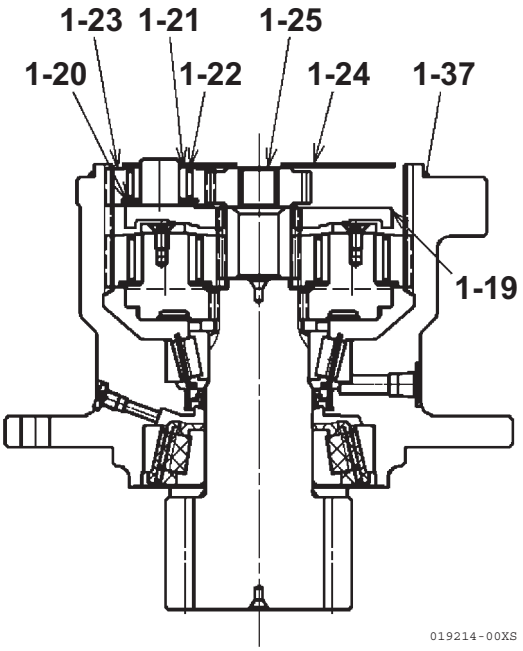
Procedure	
(8) Remove the collar **2-17**. (*Parking brake spec. only) ***Notes:*** • *It is better for work ability to remove the disk before above procedure.* • *Take care not to deform the friction plate when collar is disassembled.*	
(9) Remove the cylinder block and other associated parts. **2-6** Cylinder block and other **2-11** Pin **2-13** Retainer holder **2-12** Retainer plate **2-14** Piston assembly ***2-15** disk, **2-16** Friction plate (*2 Parking brake spec. only)	
*Regarding high parking brake torque spec. **2-16** Friction plate t=3.0 **2-41** Friction plate t=1.6 **2-40** Disk	
(10) Remove the retainer plate **2-12** and the piston assembly **2-14**.	

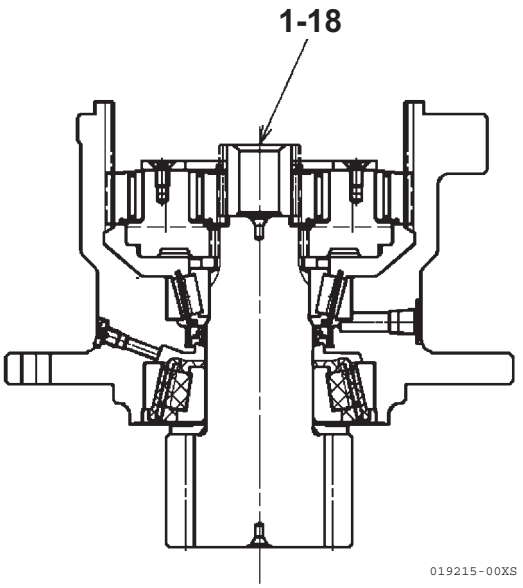
Procedure	
(11) Remove the pin **2-11** and the retainer holder **2-13**.	
(12) While pushing the washer **2-9**, remove the snap ring **2-10**. ***Note :*** *Do not disassemble when it is not needed.* *Rotary parts should be changed as cylinder block assembly.*	
(13) Remove the collar **2-7**, the spring **2-8** and the washer **2-9**. ***Note :*** *Do not disassemble when it is not needed.* *Rotary parts should be changed as cylinder block assembly.*	
(14) Remove the thrust plate **2-5**.	

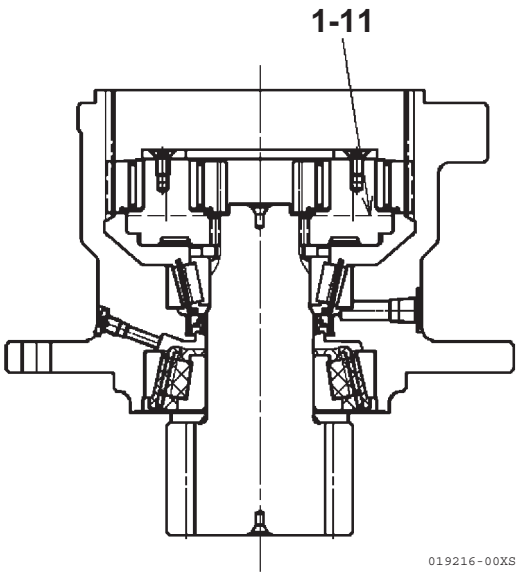
Procedure	
(15) Lightly strike the end of the shaft **2-4** with a plastic hammer to remove the shaft.	

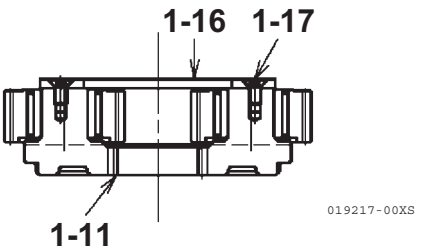
(16) Disassemble the shaft **2-4** and the ball bearing **2-3**. ***Note :*** *Do not disassemble the bearing when it is not needed to change.* *The disassembled bearings must not be used.*	

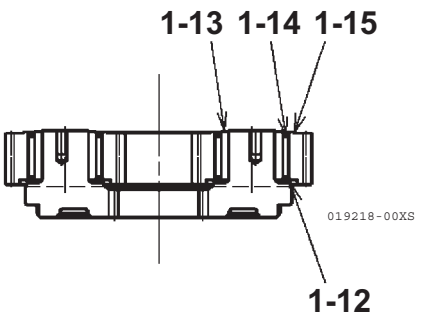
Procedure	
5. Disassemble the timer valve. (*3 Hydraulic timer spec. only) (1) Remove the plug **2-35-5** and remove the spool **2-35-2**, the spring **2-35-4**. ***Note :*** *Timer valve should be changed as valve assembly.* ***Note :*** *Take care not any deformation and scratch on fitting face of motor case while disassemble.*	

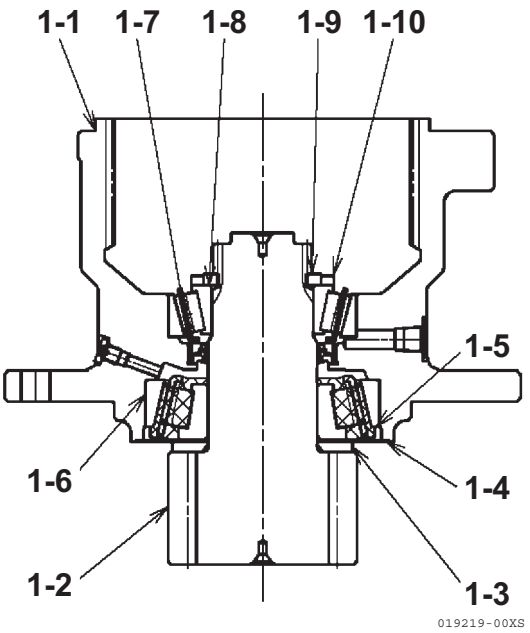
Procedure	
6. Disassembling the reduction gear (1) Remove the following parts. **1-37** O-ring **1-24** Thrust plate **1-25** Drive gear **1-23** Planetary gear **1-22** Needle bearing **1-21** Inner race **1-20** Thrust washer **1-19** Holder	

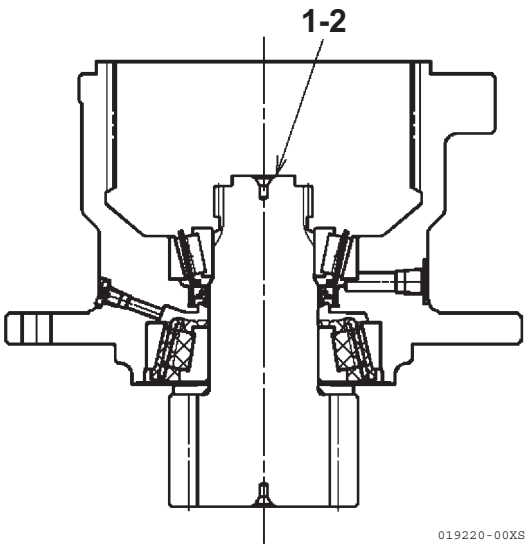
(2) Remove the sun gear **1-18**.	

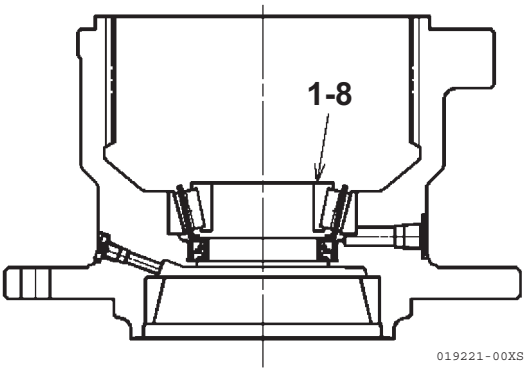
Procedure	
(3) Remove the holder **1-11** and other associated parts.	

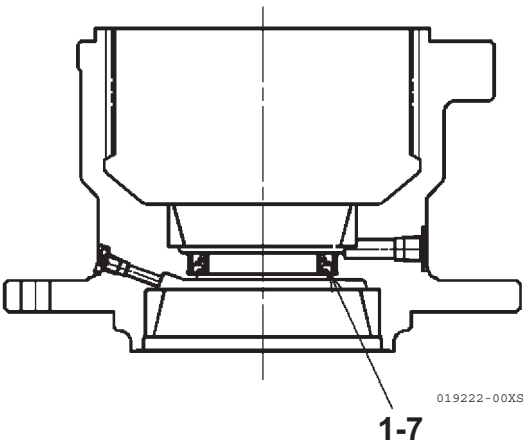
(4) Loosen the screw **1-17** to remove the thrust plate **1-16**. ***Note :*** *The screw is hard to remove because loctite was used during assembly. To facilitate the removal of the screw, warm the screw with a drier.*	

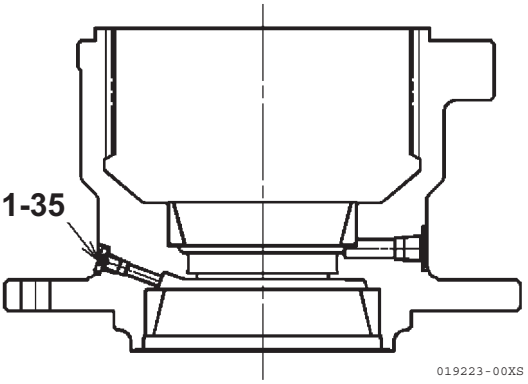
(5) Remove the following parts. **1-15** Planetary gear **1-14** Needle bearing **1-13** Inner race **1-12** Thrust washer	

Procedure	
Note : *About disassemble around the pinion shaft.* *Housing **1-1**, taper roller bearing **1-6** **1-8** plate **1-9**, pinion shaft **1-2**, collar **1-3** plate **1-4** **1-5** should be changed as housing assembly.* *Accordingly do not disassemble when it is not needed.* (6) Remove the following parts. **1-10** Collar **1-9** Plate	

(7) Remove the pinion shaft **1-2**. ***Note :*** *When removing the shaft, be careful not to drop it. If it is hard to remove, lightly strike it with a plastic hammer.*	

Procedure	
(8) Remove the inner race of the taper roller bearing **1-8**.	

(9) Break the oil seal **1-7** to remove it. ***Note :*** *The removed oil seal must not be used again.* *When removing it, exercise care to prevent damage to the outer races of the taper roller bearings **1-8** and **1-6**.*	

(10) Remove the plug **1-35**.	

6-6-7 Assembly Procedure

Precautions for assembly

a) Wash all parts with treated oil and blow oil completely.

b) Be sure that the washed parts are free of dust and other foreign matter. Handle them with care so that they will not be dented or damaged.

c) Always replace seals, bearings and pins with new ones.

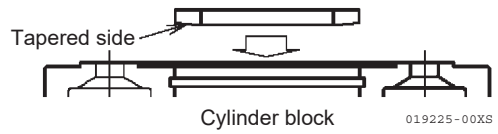
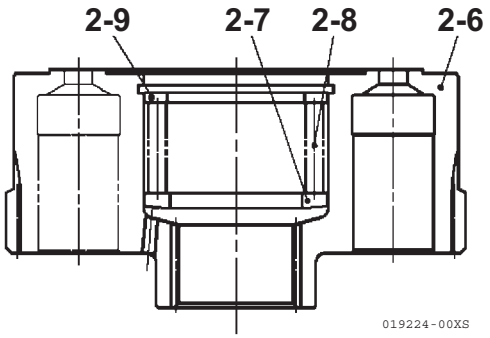
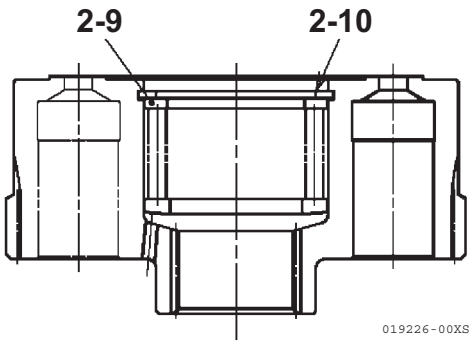
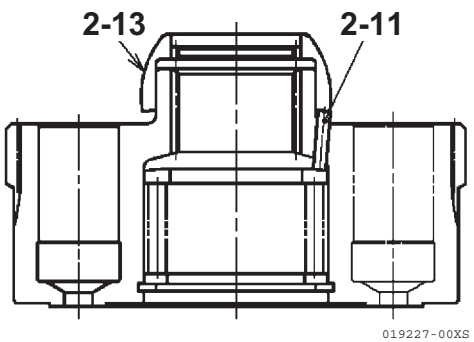
d) Tighten all the tightening areas to the specified torque.

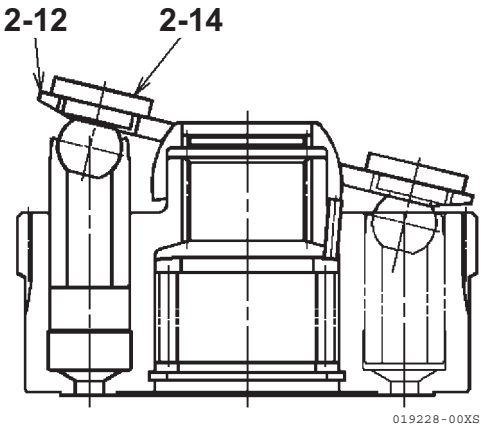
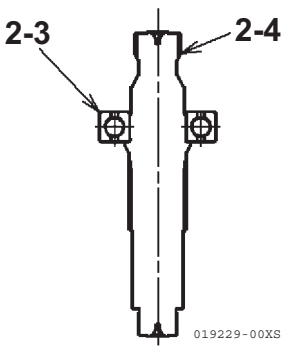
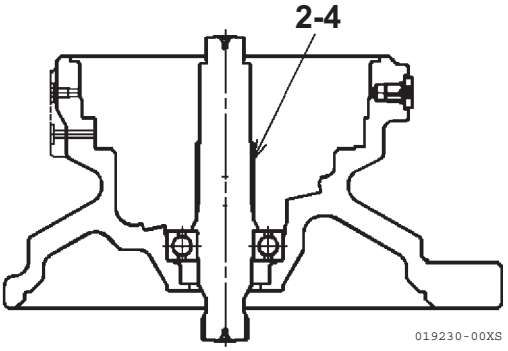
e) Apply grease to the oil seals and the O-rings in advance. (In particular, the oil seal lips must be oiled.)

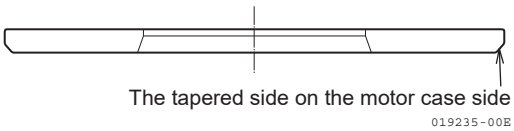
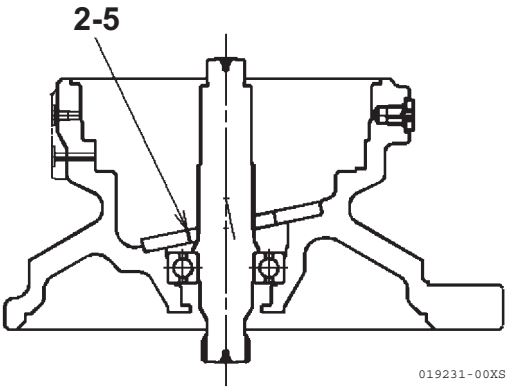
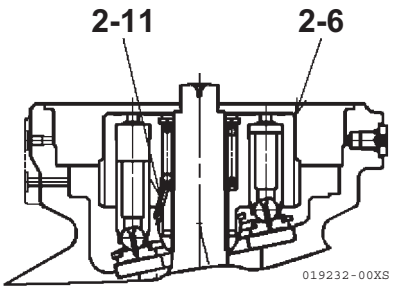
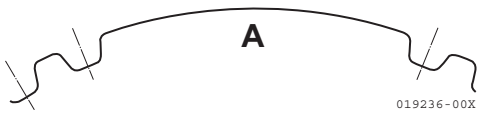
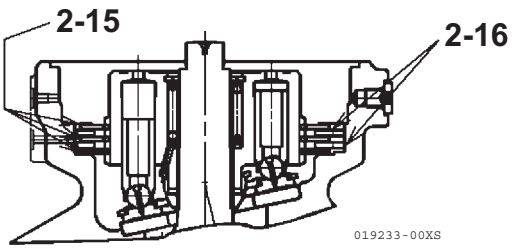
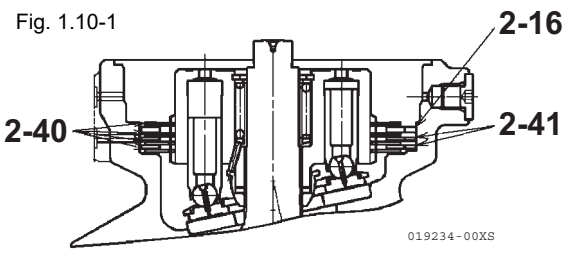
f) Many small parts are used. Exercise care so as not to lose them (such as dropping them in holes).

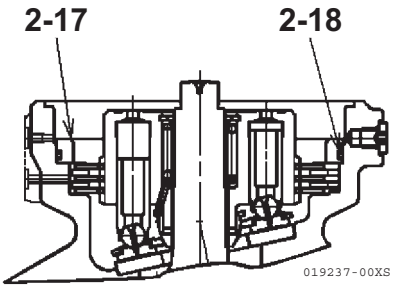
Assembly

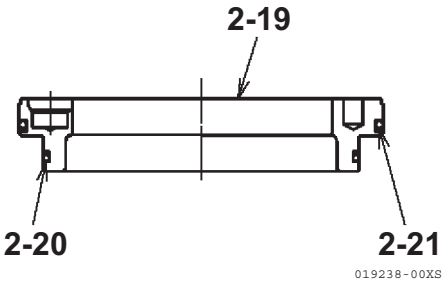
Assemble the parts by the following procedure.

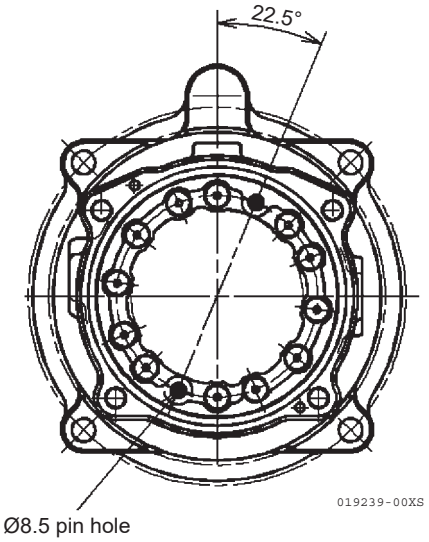
Procedure	
1. Assembling the motor (1) Assemble the collar **2-7**, the spring **2-8** and the washer **2-9** in the cylinder block **2-6**. ***Note :*** *Be sure to assemble the collar **2-7** in the correct direction.*  	
(2) While pushing the washer **2-9**, assemble the snap ring **2-10**. ***Note :*** *Make sure that the snap-ring was installed correctly.*	
(3) Apply grease to the pin **2-11** and assemble it in the cylinder block **2-6**. (4) Assemble the retainer holder **2-13**.	

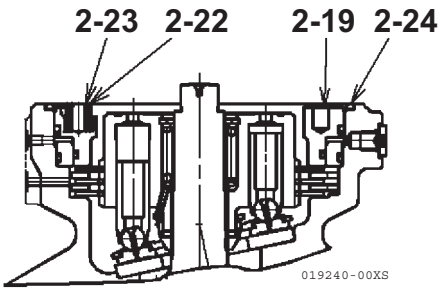
Procedure	
(5) Set the piston assembly **2-14** on the retainer plate **2-12** and assemble it in the cylinder block **2-6**. ***Note :*** *Apply an ample amount of hydraulic fluid to the sliding part before assembly.* ***Note :*** *Pay attention to the direction of the retainer plate.*	
(6) Press-fit the ball bearing **2-3** on the shaft **2-4**. (jig No.21)	
(7) Press-fit the shaft **2-4** and the ball bearing **2-2** in the case **2-1**.	

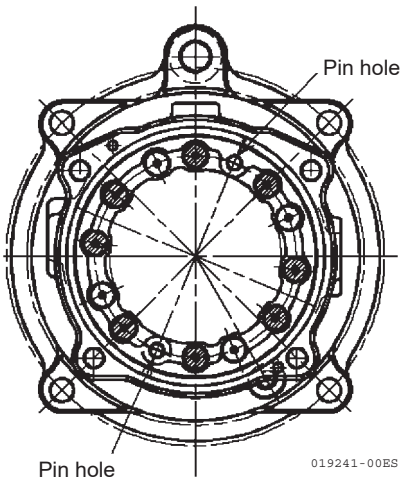
Procedure	
(8) Apply grease to the back side of the thrust plate **2-5** and assemble it. ***Note :*** *The thrust plate must be assembled in the correct direction.*  	
(9) Assemble the cylinder block **2-6** and other associated parts. ***Note :*** *During assembly, be sure that the pin **2-11** will not come out.*	
(10) (*Parking brake spec. only) Assemble the disk **2-15**, the friction plate **2-16**. ***Note :*** *Pay attention to the position of the friction plate and disk.* ***Note :*** *"**A**" of each disk are placed some position.*  	
* Regarding high parking brake torque spec. Assemble the disk **2-40**, the friction plate **2-16**, **2-41**. (Refer to Fig. 1.10-1)	Fig. 1.10-1 

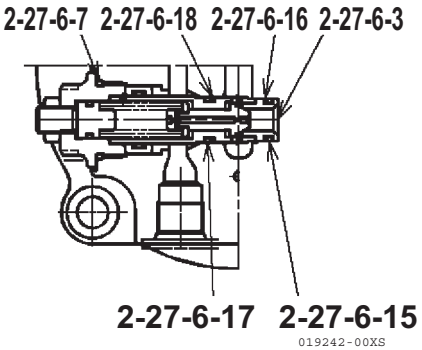
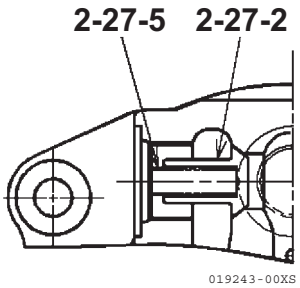
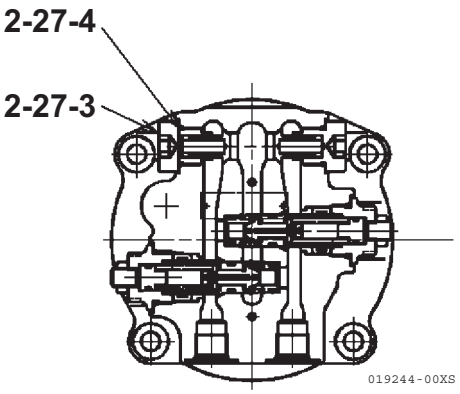
Procedure	
(11) (* Parking brake spec. only) Apply grease on the O-ring **2-18** and assemble it in the collar **2-17**. ***Note :*** *To prevent from disks coming out, be sure to install the brake piston in the motor case by hand press.*	

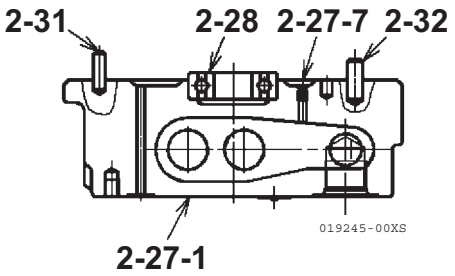
(12) (*2 Parking brake spec. only) Apply grease to the O-ring **2-20 2-21** and assemble that in the brake piston **2-19**. (13) (*2 Parking brake spec. only) Assemble the brake piston **2-19** in the case.	

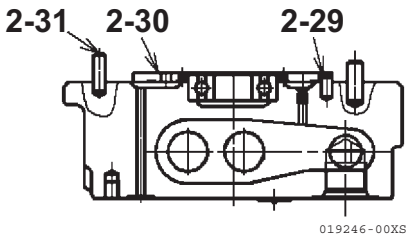
Note : *Place the brake piston on right position shown in the drawing. Pin are not able to be assembled if the position is wrong.*	

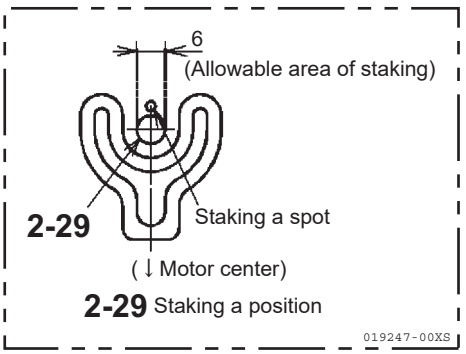
Procedure	
(14) Apply grease to the spring (**2-22**, large size 12 peace), the spring (**2-23** small size 8 peace), the O-ring **2-24** and assemble them.	

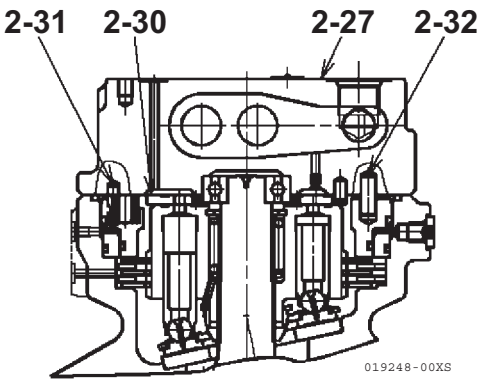
Note : *Install the spring (**2-23**, small size) on right position shown in the drawing*	 Position of install the spring (**2-23** small size).

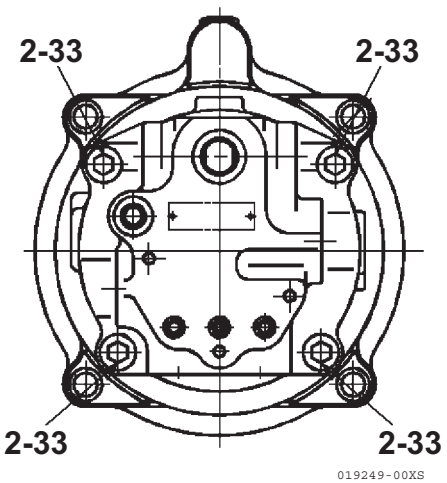
Procedure	
(15) Apply grease to the O-ring **2-27-6-7**, **2-27-6-15**, **2-27-6-17** and the backup ring **2-27-6-16**, **2-27-6-18**, then assemble them in the relief valve **2-27-6** and install them in the cover **2-27-1**. Tightening torque : 260 to 290.1 ft•lbf (353 to 393 N•m) (hex.27) ***Note :*** *The poppet-seat **2-27-6-3** may remain in the cover.*	
(16) Assemble the check valve **2-27-2**, the spring **2-27-5** in the cover.	
(17) Apply grease to the O-ring **2-27-4** and assemble it in plug **2-27-3** and install in the cover. Tightening torque : 108.5 to 123.3 ft•lbf (147 to 167 N•m)	

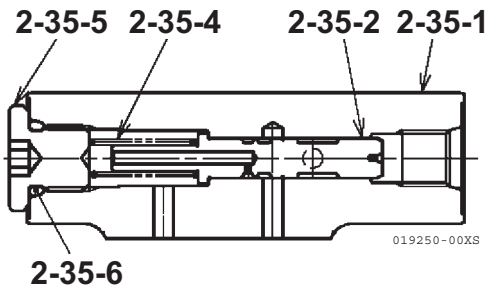
Procedure	
(18) Press fit the ball bearing **2-28**. (jig No.22) Install the pin **2-31**, **2-32** and screw the orifice **2-27-7** in to the cover **2-27-1**. ***Note :*** *Screw the orifice, then stake it circularly.*	

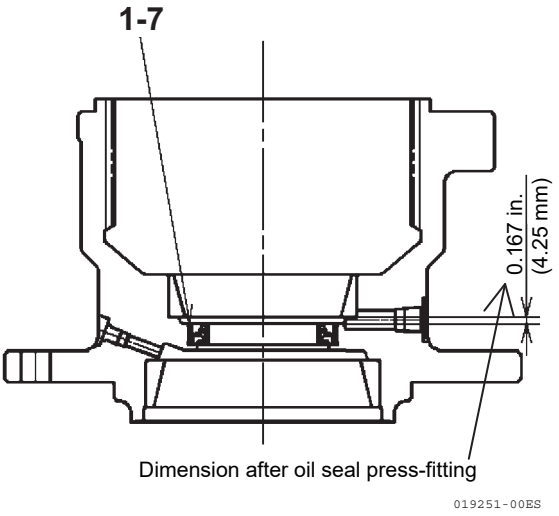
(19) Install the pin **2-29**, then install the valve plate **2-30**. To prevent it from falling, apply grease to the back side.	

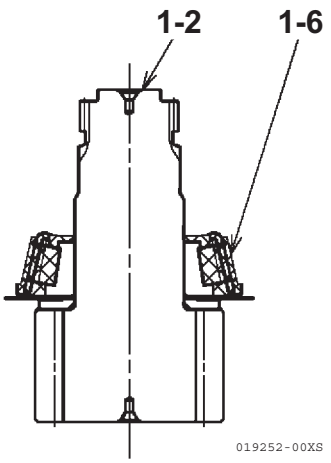
Note : *Stake at right position shown as below after.*	

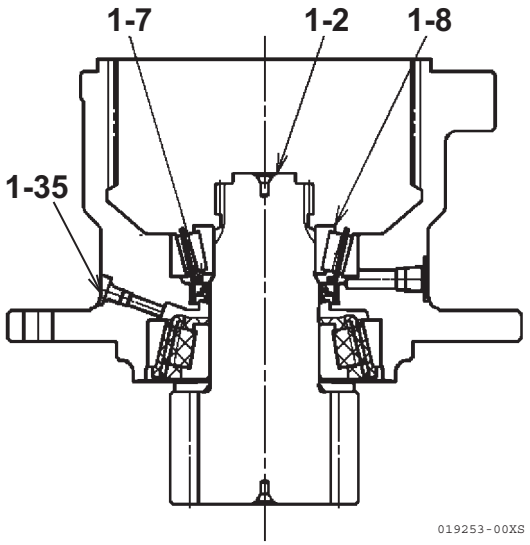
Procedure	
(20) While paying attention to the location of the pin **2-31 2-32**, install the cover **2-27** and other associated parts to the case **2-1**. ***Note :*** *Exercise care so that the pin **2-25** and the valve plate **2-24** will not fall.* ***Note :*** *Regarding position of pin **2-32** refer to note of **1-13** brake piston installation.*	

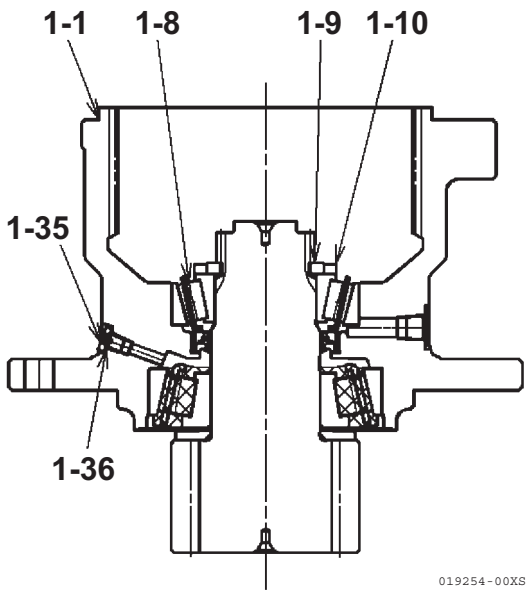
(21) Loosely tighten the socket head bolts **2-33**, then using a torque wrench, tighten them to the specified torque. Tightening torque : 123.3 to 138.0 ft•lbf (167 to 187 N•m)	

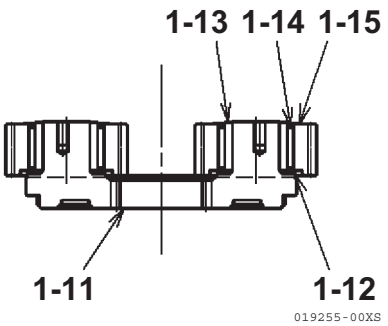
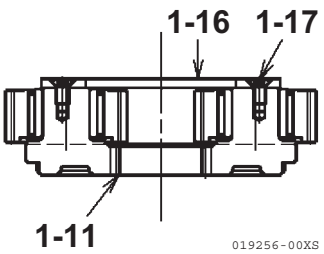
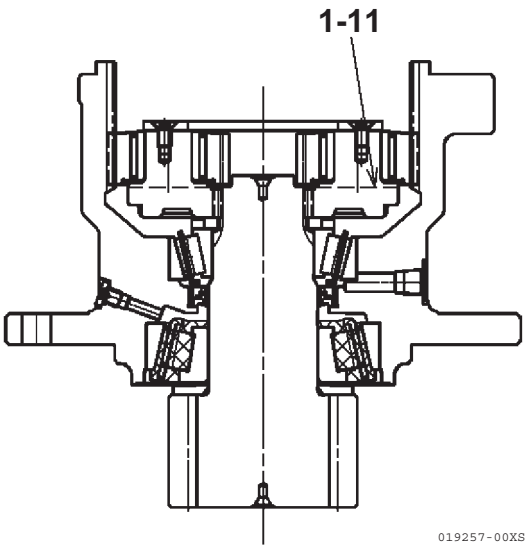
Procedure	
2. Assembling timer valve (1) (*Hydraulic timer spec. only) Assemble the spool **2-35-2**, the spring **2-35-4** in the body **2-35-1**. (2) Apply gear to the O-ring **2-35-6** assemble it in the plug **2-35-5** and install it. Tightening torque : 28.9 to 30.4 ft•lbf (37.2 to 41.2 N•m)	

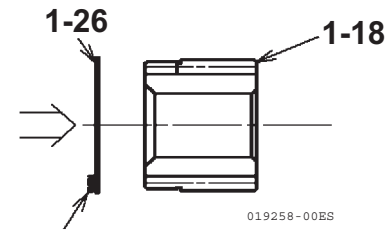
Procedure	
3. Assembling the reduction gear (1) Press-fit the oil seal **1-7**. ***Note :*** *Prior to press-fit, apply grease to the oil seal mounting area of the housing and the periphery of the oil seal.*	

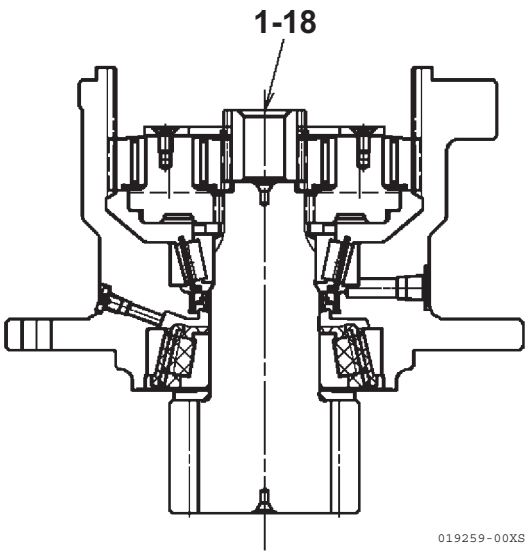
(2) Apply grease to the inner race of the taper roller bearing **1-6** assembled on the pinion shaft **1-2**. Grease bland : Shell Alvania Grease 2 Grease amount of enclose quantities : 4.88 to 5.49 cu.in. (80 to 90 cu.cm) [about 0.146 to 0.165 lbs. (66 to 75 g)	

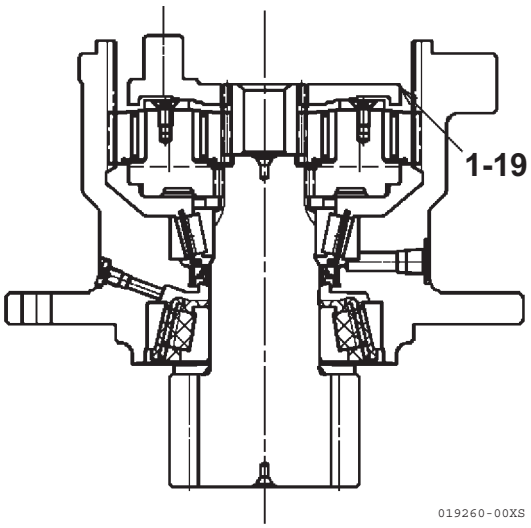
Procedure	
(3) Install the pinion shaft **1-2** and other associated parts. Install the taper roller bearing inner race **1-8**. ***Note :*** *Prior to assembling the pinion shaft **1-2**, etc. apply grease to the lip of the oil seal **1-7**.* ***Note :*** *Prior to installing pinion shaft, make sure that there is no plug **1-35**.* *There is possibility to brake oil seal because of internal air pressure if plug is installed.*	

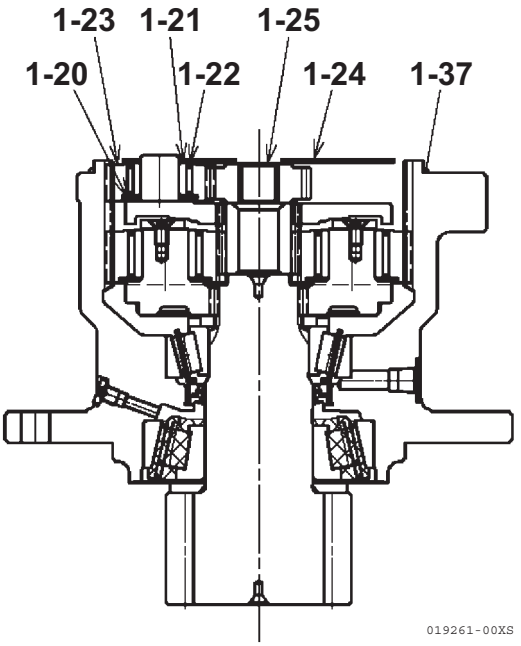
(4) Assemble the collar **1-10** while applying 11770N on inner race of the taper roller bearing **1-8**. (jig No. 24) Apply grease to the O-ring **1-36** assemble it to the plug **1-35** and install it in the housing. Tightening torque : 11.0 to 12.2 ft•lbf (14.9 to 16.5 N•m)	

Procedure	
(5) Install the following parts on the holder **1-11**: **1-12** Thrust washer **1-13** Inner race **1-14** Needle bearing **1-15** Planetary gear	
(6) Install the following parts on the holder **1-11**: **1-16** Thrust plate **1-17** Screw ***Note :*** Apply loctite 242 to the screw prior to tightening it. Tightening torque : 14.5 to 21.7 ft•lbf (19.6 to 29.4 N•m) (hex.5)	
(7) Install the holder **1-11** and other associated parts.	

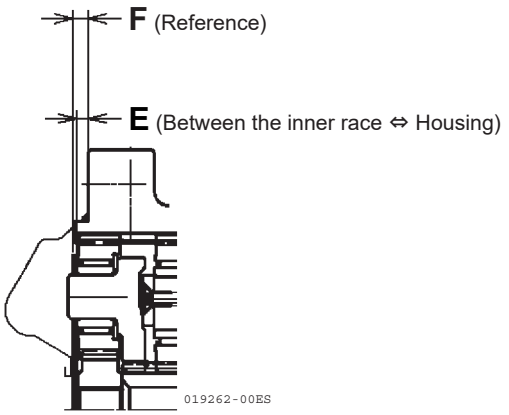
Procedure	
(8) Assemble the snap ring **1-26** in the sun gear **1-18** right direction shown as drawing. (Rounded face is left)	 Assembling direction of the snap ring

(9) Install the sun gear **1-18**.	

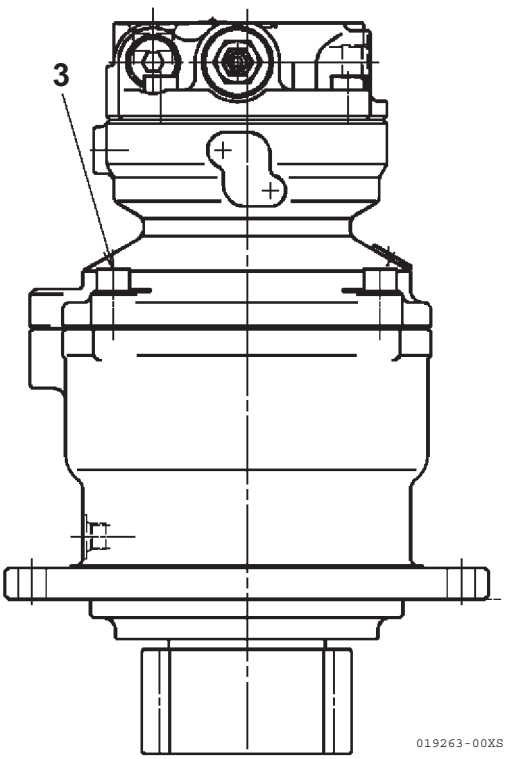
(10) Install the holder **1-19**.	

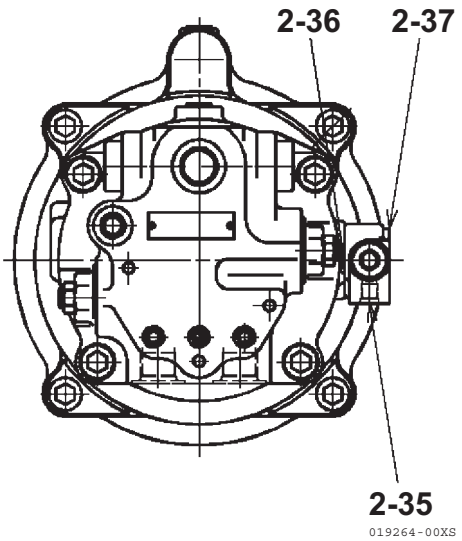
Procedure	
(11) Install the following parts. **1-20** Thrust washer **1-21** Inner race **1-22** Needle bearing **1-23** Planetary gear **1-25** Drive gear **1-24** Thrust plate **1-37** O-ring	

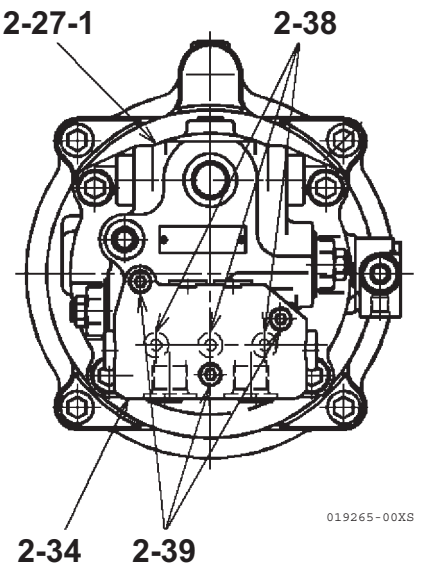
Note :
*Selection for thrust plate **15**.*
*When any consisting parts of reduction unit were changed, select and install thrust plate corresponding to the measured value "**E**" referring to the below table.*



E dimension (mesuared value)	Less than 0.209 to 0.228 (5.3 to 5.8)	Less than 0.228 to 0.256 (5.8 to 6.5)	0.256 to 0.276 (6.5 to 7.0)
Part No. of thrust plate **1-23** (Plate thickness)	B0841-23031 0.105 to 0.116 (2.66 to 2.94)	B0841-23030 0.086 to 0.095 (2.18 to 2.42)	B0841-23029 0.067 to 0.075 (1.7 to 1.9)
F dimension (mesuared value)	0.313 to 0.344 (7.96 to 8.74)	0.314 to 0.343 (7.98 to 8.72)	0.323 to 0.350 (8.2 to 8.9)

Procedure	
4. Assembling the whole motor assembly (1) Checking direction of reduction gear assembly, then place it on the motor assembly and loosely tighten the socket head bolt **3**, then tighten it to the specified torque. Tightening torque : 123.3 to 138.0 ft•lbf (167 to 187 N•m) (hex.12)	

Procedure	
5. Installing the timer valve assembly. (*Hydraulic timer spec. only) Tight the socket head bolt **2-37** to fix valve assembly **2-35** after placing O-ring **2-36** on motor case **1-1**. Tightening torque : 6.5 to 8.0 ft•lbf (8.8 to 10.8 N•m) (hex.5)	

Procedure	
6. Install in anti swing back valve. (*1 Anti swing back valve spec. only) (1) Install the O-ring **2-38** in the cover **2-27-1**. (2) Place the valve assembly **2-34** on the cover **2-27-1** and tighten the socket head bolts **2-39**. Tightening torque : 22.4 to 25.4 ft•lbf (30.4 to 34.4 N•m) (hex.6) (For the disassemble and re-assembly of the anti swing back valve, refer to the separate instruction and service manual of anti swing back valve.)	

6-6-8 Quality Check After Reassembly.

Checking points before and after operation.

(1) Air leak test of motor.
Seal all piping ports on the motor except one point with plugs and apply compressed air 44 PSI (0.3 MPa) through open port in water for two minutes, observe that there are no bubbles.

(2) Checking before and after operation.

a) Fill the motor case with hydraulic fluid before starting up.

b) Bleed air from every ports.

c) Start the gear motor at a low speed and gradually increase it after having verified that it is functioning correctly without any noises or vibrations.

d) During the running in stage follow the steps given bellow.
1] Check a oil leak.
2] Check the correct revolution and direction of rotation.
3] Make sure that the oil temperature does not exceed 194 °F (90 °C).
4] Make sure that the motor case temperature does not exceed 194 °F (90 °C).
5] Make sure that the functioning is regular and without any excessive noises and vibrations.
6] Make sure there are no other problems in general.

6-7 Travel Motor

6-7-1 Product Overview

1. Product Users

This product is a hydraulic driven rotary actuator.
The product contains a reduction gear, hydraulic motor, brake valve and parking brake in one compact unit. It has been developed for use as an actuator for application requiring low-rpm, high torque operation such as construction and marine machine.

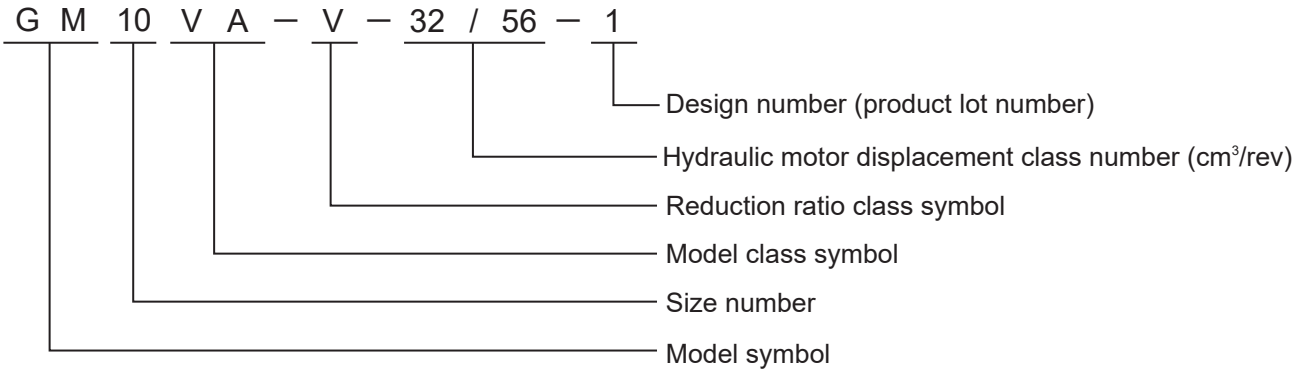
2. Specifications

The specifications shown are general specifications for each item listed.
Combinations of specifications in the following table will differ depending on the model used. Specifications for the individual product used are shown on the external dimensions drawings, which are provided separately.

Item \ Model			GM10VA
Rated output torque		ft•lbf (N•m)	7235 (9810)
Max. speed		min^{-1}	60
Reduction ratio			1/50.111
Hydraulic motor	Max. displacement	cu.in./rev. (cm^3/rev.)	3.4 (55.8)
	Max. speed	min^{-1}	3310
	Max. pressure	PSI (MPa)	4554 (31.4)
	2-speed switch	PSI (MPa)	284 to 995 (1.96 to 6.86)
Parking brake	Brake torque	ft•lbf (N•m)	89.2 (121)
	Brake free pressure	PSI (MPa)	91.4 (0.63)
Weight		lbs (kg)	183 (83)

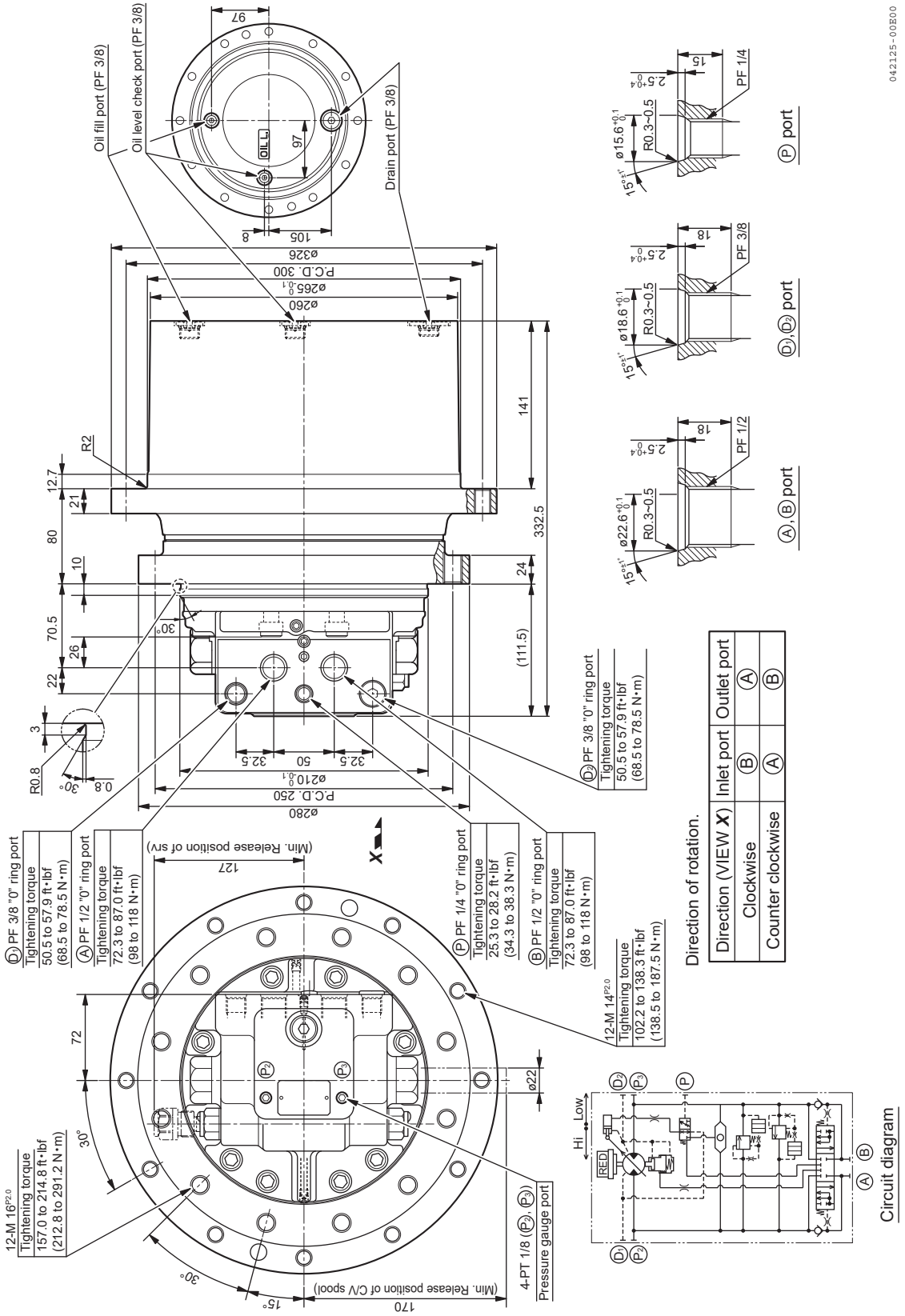
3. Model Labeling

Model numbers are indicated on the product name plate.



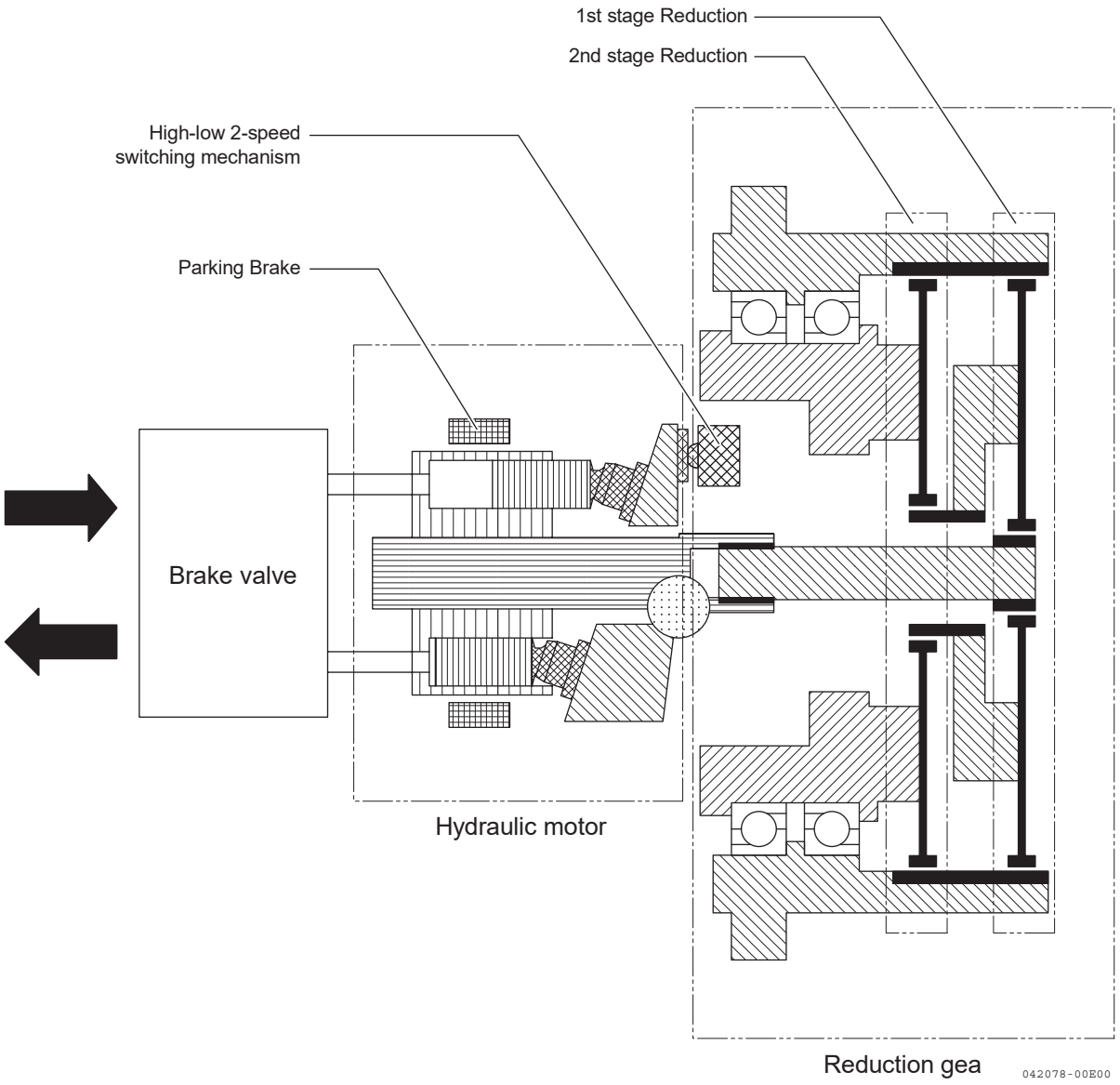
6-7-2 External Dimensions

Unit: mm

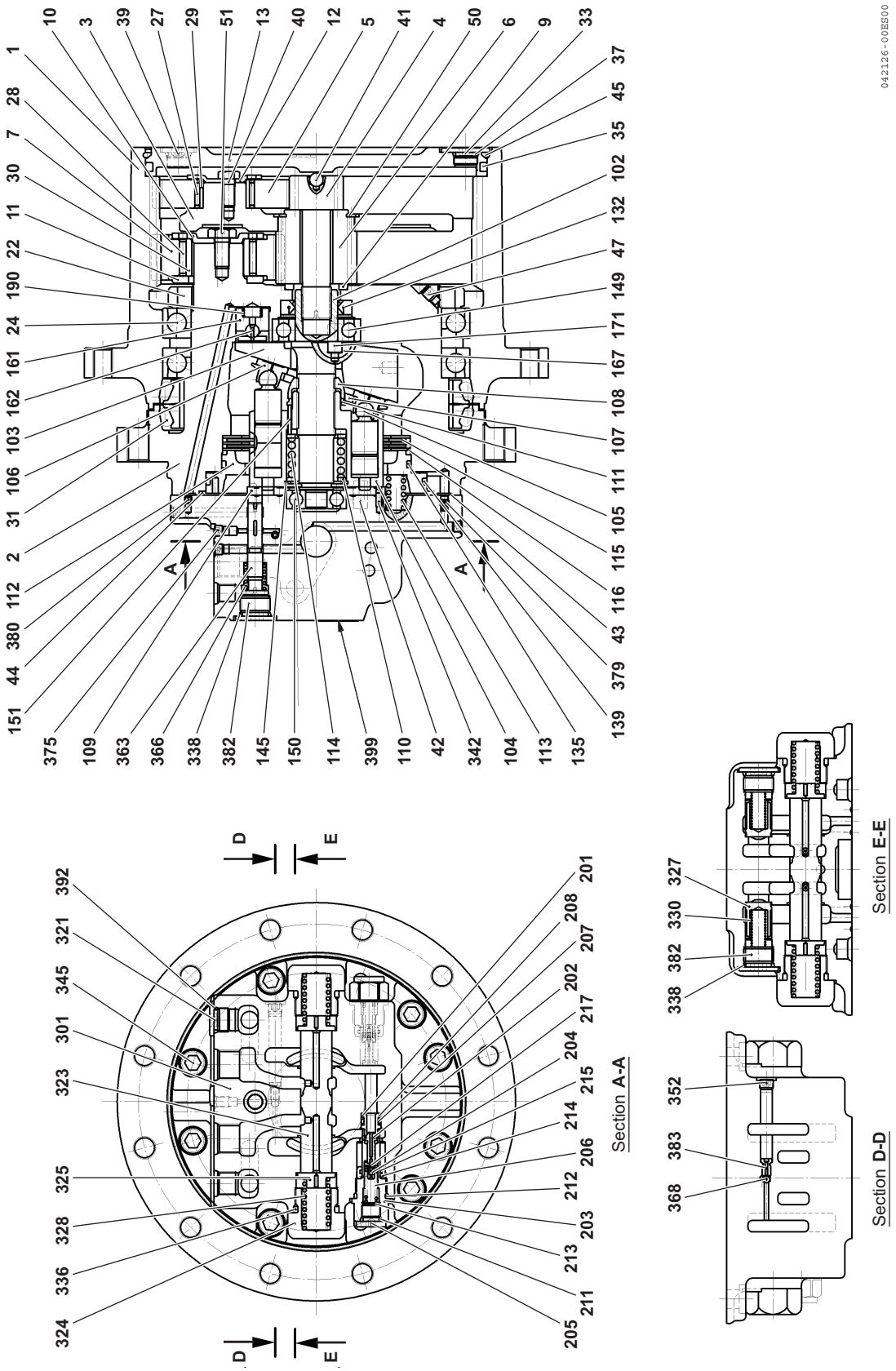


6-7-3 Basic Configuration and Drawing

1. Motor Basic Configuration



2. Assembly Cross Section



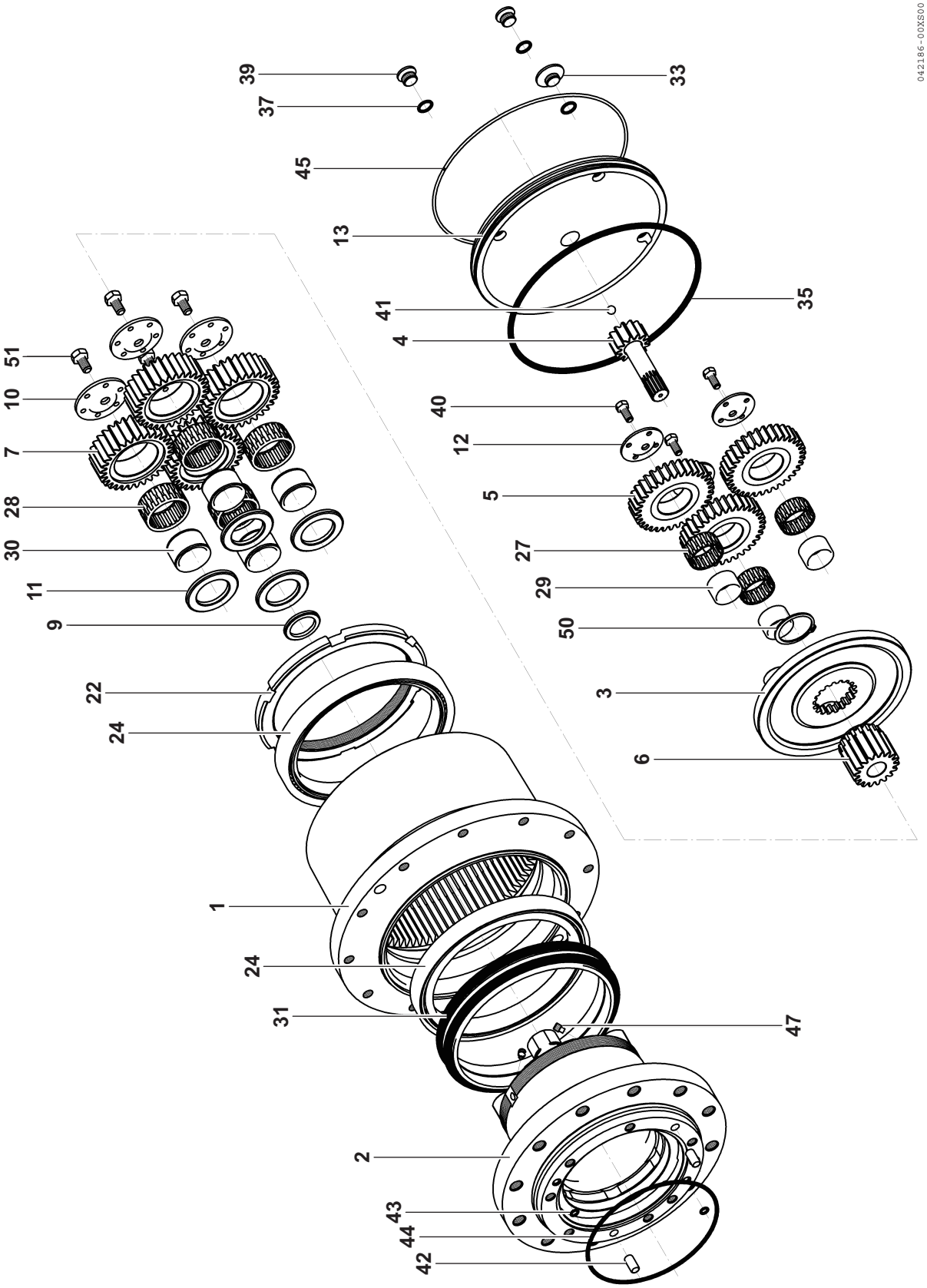
3. Parts List (GM10VA)

No.	Parts name	Q'ty	No.	Parts name	Q'ty
1	Hub	1	111	Washer	1
2	Spindle	1	112	Piston	1
3	Carrier	1	113	Spring	10
4	Sun gear (1)	1	114	Spring	1
5	Planetary gear (1)	3	115	Friction plate	2
6	Sun gear (2)	1	116	Mating plate	3
7	Planetary gear (2)	4	132	Oil seal	1
9	Thrust collar (1)	1	135	O-ring	1
10	Thrust washer (1)	4	139	O-ring	1
11	Thrust washer (2)	4	145	Snap ring	1
12	Thrust washer (3)	3	149	Ball bearing	1
13	Cover	1	150	Ball bearing	1
22	Ring nut	1	151	Roller	3
24	Ball bearing	2	167	Pivot	2
27	Needle roller bearing	3	171	Parallel pin	2
28	Needle roller bearing	4	190	Spring	1
29	Inner race	3			
30	Inner race	4		Valve kit	2
			201	• Valve seat	1
	Floating seal kit	1	202	• Valve	1
31	• Floating seal	2	203	• Sleeve	1
			204	• Collar	1
33	Plug	1	205	• Plug	1
35	O-ring	1	206	• Spring	1
37	O-ring	3	207	• O-ring	1
39	Plug	2	208	• Backup ring	2
40	Hexagon head bolt	3	211	• O-ring	1
41	Steel ball	1	212	• O-ring	1
42	Parallel pin	2	213	• Shim	1
43	O-ring	2	214	• Piston	1
44	O-ring	1	215	• O-ring	1
45	Ring	1	217	• Orifice	1
47	Hexagon socket set screw	2			
50	Retaining ring	1		Rear flange Ass'y	1
51	Hexagon head bolt	4		• Rear flange kit	1
			301	• • Rear flange	1
	Cylinder & Piston kit	1	323	• • Spool	1
	• Piston kit	1	352	• • Hexagon socket plug	3
	• • Piston Ass'y	9	368	• • Steel ball	1
105	• • • Piston	1	375	• • Hexagon socket plug	4
106	• • • Shoe	1	379	• • Filter	1
104	• Cylinder block	1	380	• • Orifice	1
			383	• • Plug	1
	Piston kit	1	399	• • Name plate	1
161	• Piston	1			
162	• Shoe	1	321	• Plug	1
			324	• Plug	2
102	Shaft	1	325	• Spring retainer	2
103	Swash plate	1	327	• Valve	2
107	Retainer plate	1	328	• Spring	2
108	Thrust ball	1	330	• Spring	2
109	Timing plate	1	336	• O-ring	2
110	Washer	2	338	• O-ring	3

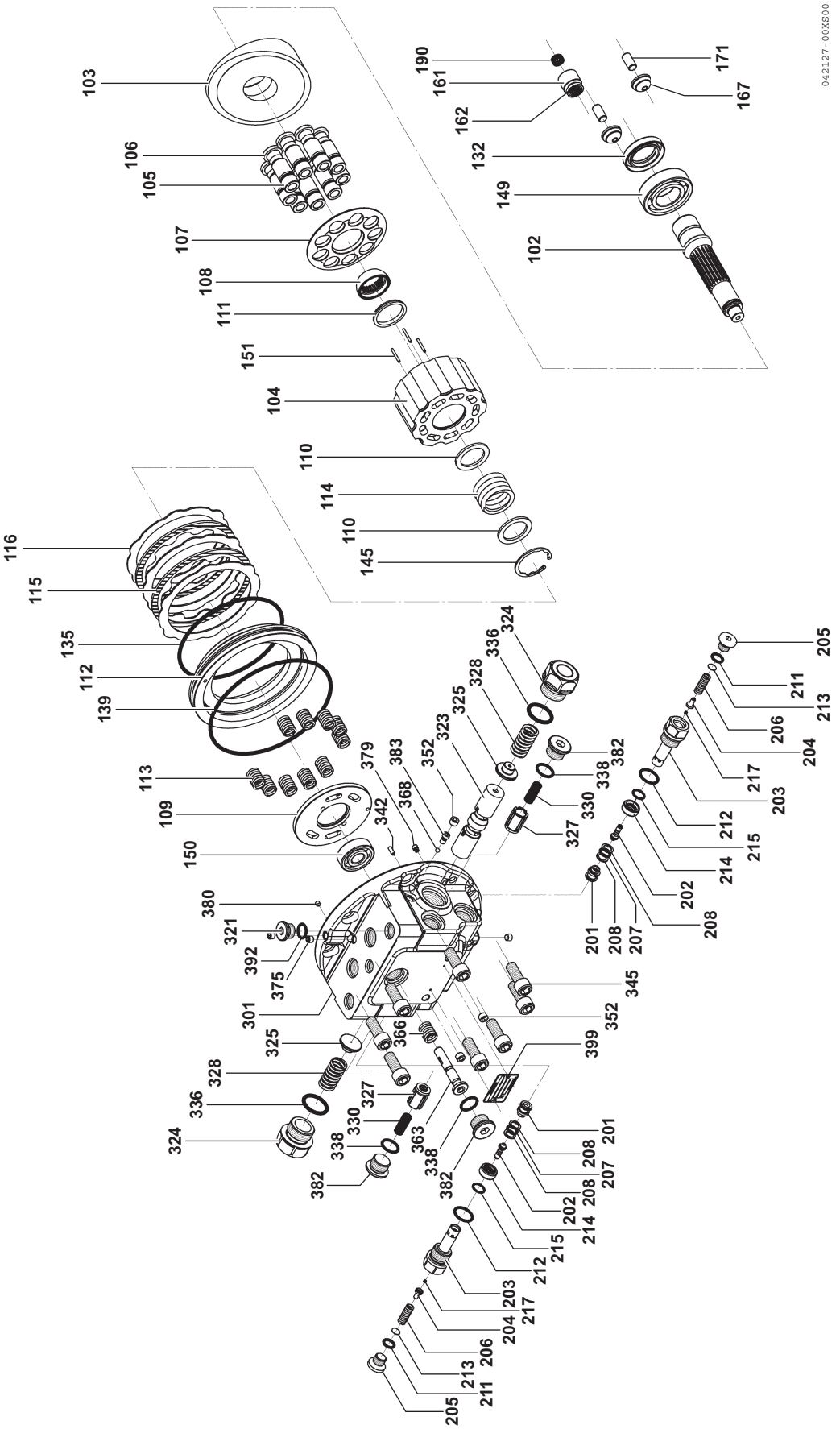
No.	Parts name	Q'ty	No.	Parts name	Q'ty
363	• Spool	1	392	• O-ring	1
366	• Spring	1	342	Parallel pin	1
382	• Plug	3	345	Hexagon socket bolt	8

4. Exploded View

1) Reduction Gear



2) Hydraulic Motor



6-7-4 Operating Description

1. Reduction Gear

1) Function

This reduction gear unit is composed of the two stage planetary gear mechanism.

The reduction gear reduces the high speed of the hydraulic motor and converts it to low-speed, high-torque rotation.

2) Operating Description

The rotation of the hydraulic motor shaft is transmitted to the sun gear **4** of the first stage which is linked with the shaft **102** in spline.

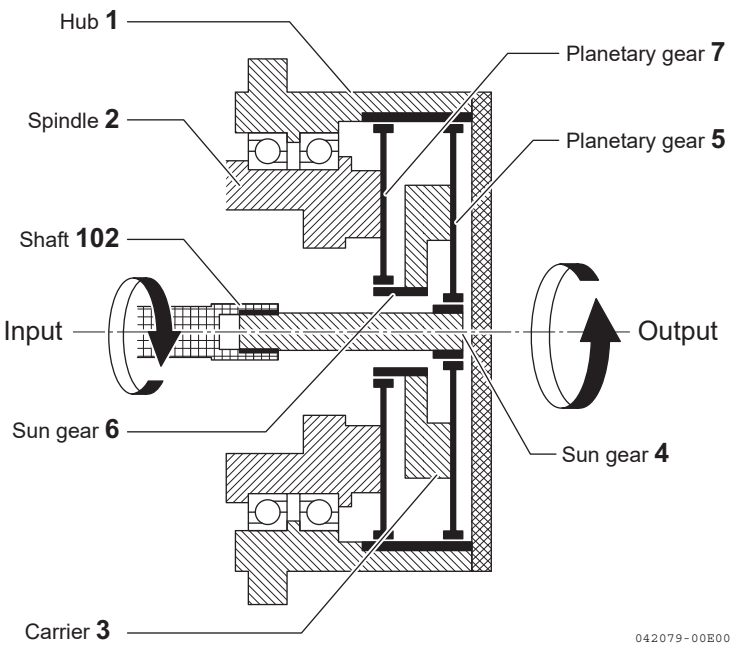
The sun gear **4** is meshed with three planetary gears **5**, and three planetary gears **5** mesh with the hub **1** while rotating on their axis.

At that time, the hub is rotated by the planetary gears **5**.

The hub rotation is transmitted to the carrier **3** which is connected to the planetary gears **5**, and that causes the sun gear **6** rotation of the second stage.

The rotation of the sun gear **6** is transmitted to the hub via four planetary gears **7** of the second stage.

The generated rotation of reduction gear is the output rotation.



2. Hydraulic Drive

This section describes the hydraulic motor, brake valve, parking brake, and the high-low 2-speed switching mechanism of the hydraulic motor.

1) Function

(1) Hydraulic Motor

This hydraulic motor is a swash plate type axial piston motor, converting the hydraulic force from the pump to rotary motion.

(2) Brake Valve

[1] The travel motor controls the force of rotational inertia of the body to brake and stop the rotation smoothly.

[2] Checks the valve function to prevent cavitation on the hydraulic motor.

[3] Opens the port to release the parking brake force when the travel motor operates, and closes the port when the motor is stopped.

(3) High-Low 2-Speed Switching Mechanism

Switches the hydraulic motor between high speed rotation with low torque, and low speed rotation with high torque.

(4) Parking Brake

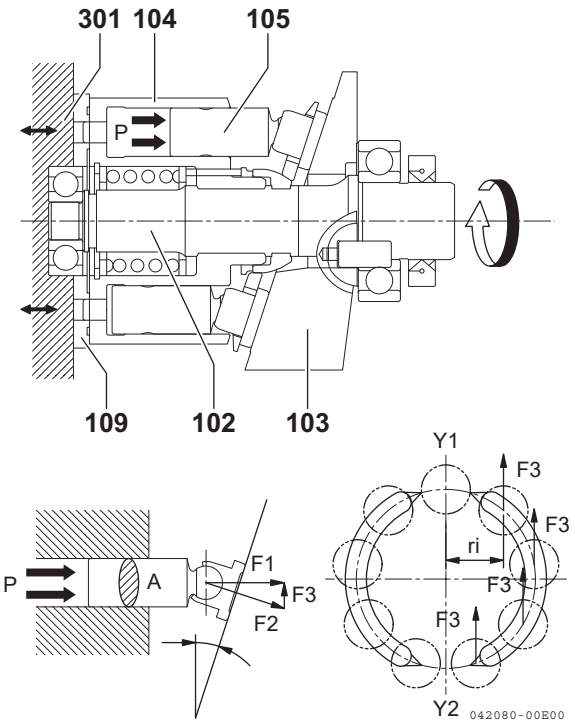
The parking brake is used to prevent the machine from moving spontaneously or slipping while parking on a slope. It uses a friction plate brake mechanism, and is installed on the hydraulic motor.

2) Operating Principles and Description

(1) Hydraulic Motor

Hydraulic fluid fed by pump enters the rear flange **301** of the travel motor, and is led from the timing plate **109** to the cylinder block **104** through the brake valve mechanism. This pressure oil is led only to one side of (Y_1 - Y_2) tied between the top dead point and the bottom dead point of the piston **105** stroke. The pressure led to one side of the cylinder block pushes 4 or 5 pistons **105**, generating the power (F1 kgf = P kgf/cm^2 × A cm^2). This power enters on the swash plate **103**, but the swash plate is fixed having an angle (α) against the axis of the drive shaft **102**, and divided into the component of force (F2, F3). The radial component of force (F3) generates torque (= F_3 × ri) against the line. The total torque T [= $\sum(F_3 \times ri)$] is the connected turning force, and rotates the cylinder block **104** through the piston **105**.

The cylinder block **104** is connected to the drive shaft **102** with the spline, and rotates the drive shaft **102** to transmit torque.



(2) Brake Valve

Port **A** and Port **B** are the input and output ports for the working fluid. The following description assumes that the working fluid (hydraulic) is fed through port **A**.

If the fluid is fed through port **B**, the flow and motion are reversed. The direction of rotation of the motor is also reversed.

[1] Normal Operation

Hydraulic fluid is fed from the pump to port **A**, causing the hydraulic motor to rotate. The details are as follows.

First, the hydraulic fluid fed from the pump enters at port **A** and opens the valve **327**.

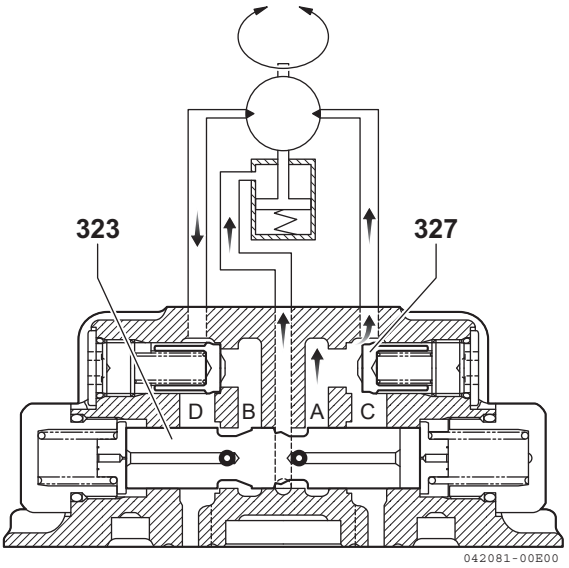
The fluid passes through the valve **327**, enters the hydraulic motor through port **C** and applies rotary force to the hydraulic motor.

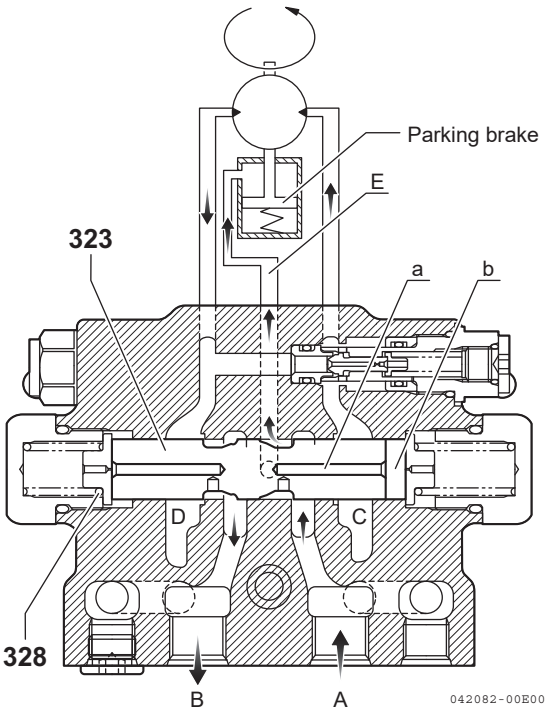
At the same time, hydraulic fluid enters at port **A** and passes through small holes in the spool **323** and through channel **a** to chamber **b**.

The hydraulic pressure in chamber **b** causes the spool **323** to move from the central position to the left. At this time a groove in the spool **323** forms a channel for hydraulic fluid to pass between port **D** and port **B**.

Hydraulic fluid ejected from the hydraulic motor flows from port **D** to port **B**, and the hydraulic motor rotates. The hydraulic fluid returns to the oil tank.

Also, as the spool **323** oscillates to the left, hydraulic fluid enters port **E**. The hydraulic fluid at port **E** flows to the parking brake and 2-speed switching valve.





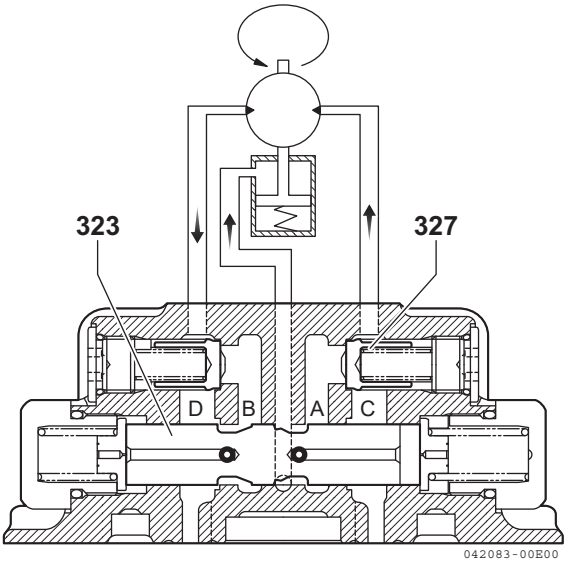
[2] Stop / Stall (Braking Operation)

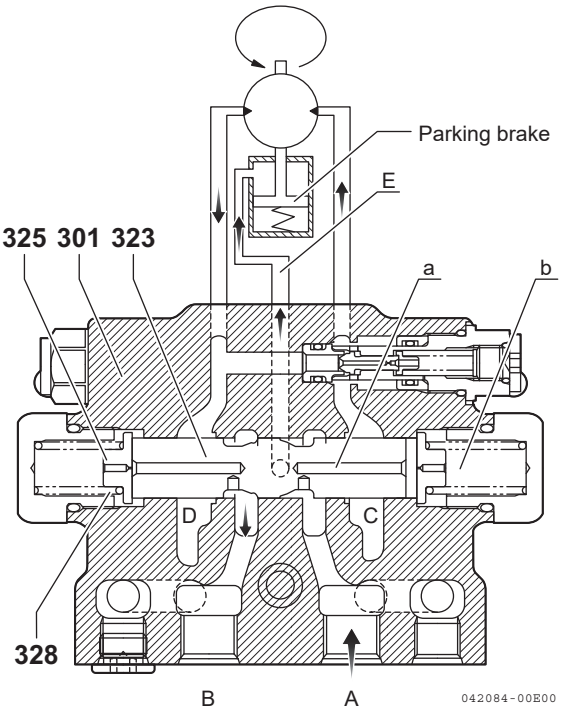
If pressurized oil supply through the port **A** is suspended while traveling, the hydraulic force to push up the spool is lost, and the spool **323** which is slid to left side, tries to return to the neutral position through the spring retainer **325** due to the spring **328** force. At that time, the oil in the chamber **b** tries to flow out to the port **A** side through the passage **a** in the spool **323**, its flow is restricted and some back pressure is generated by the throttle effect in the passage **a** controlling the return speed of the spool **323**. At the same time, the hydraulic motor tries to rotate with its inertia force even though the pressurized oil is suspended, and the return oil from the hydraulic motor tries to return to the port **B** side from the port **D** through the passages on the spool groove and rear flange.

When the spool **323** entirely returns to neutral position, the passage on the hydraulic motor of the oil return side is completely closed by the spool **323**, and the hydraulic motor ceases its rotation. While the machine operates, the brake valve smoothly stops rotation of the hydraulic motor which tries to rotate with its inertia force, by means of throttling the return side passage of the hydraulic motor, generating back pressure due to the shape of the spool groove and controlling the return speed of the spool **323**.

On the other hand, when the brake is operated, the hydraulic motor tries to rotate with its inertia force and to take in oil with its pumping function.

However, because the passage on the intake side is closed its with the spool **323**, the oil supply is suspended. This causes cavitation in the hydraulic motor. To prevent the cavitation, the valve **327** is operated by very slight negative pressure to open the passages of the port **A** side and intake port **C** of the hydraulic motor. And when pressurized oil is supplied through the port **B**, each motion of the mentioned parts above becomes symmetrical on the right and left to stop the hydraulic motor.





[3] Anti-Racing Function

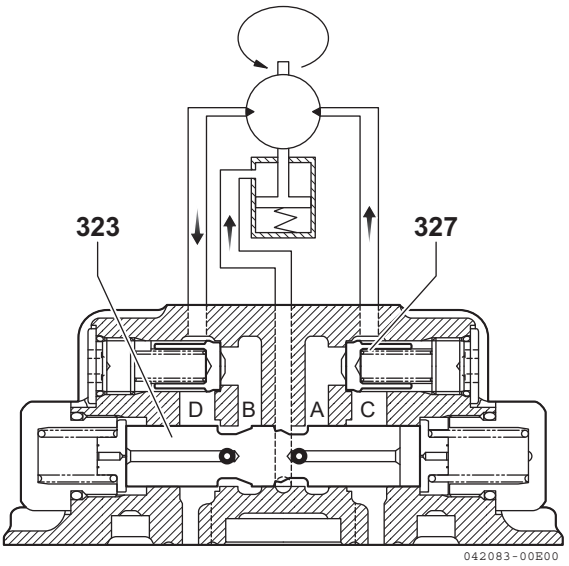
During normal operation, when a hydraulic motor is rotated by an outside force, a condition called racing runaway can occur. For example when used as the drive motor for an excavator, racing can occur when the vehicle moves down a steep slope.

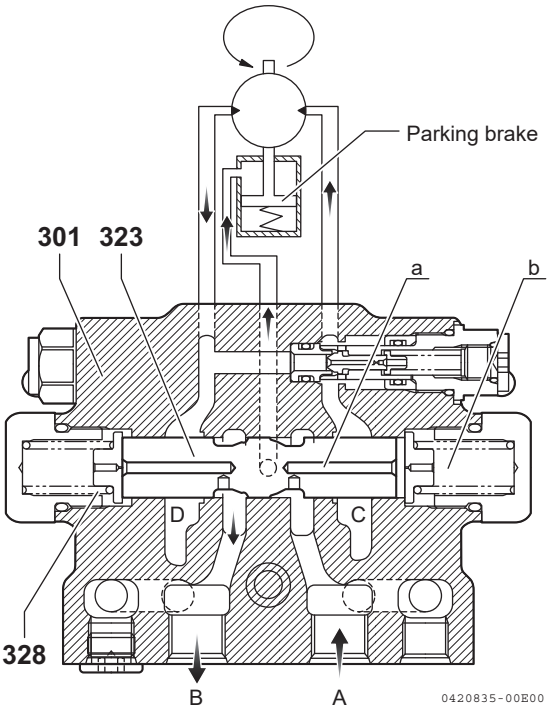
This section describes the mechanism used to prevent this condition.

During normal operation, the hydraulic motor is rotated by an outside force. The pressure of the hydraulic fluid feed (at port **A** or port **B**) falls.

As the pressure approaches the level at which racing begins, the spool **323** begins moving to the center towards the central position. The movement of the spool **323** reduces the size of the flow channel from port **D** to port **B** on the output side of the hydraulic motor. This restricts the amount of hydraulic fluid ejected from port **D** to port **B**. At the same time the pressure at port **D** (back pressure) increases.

Thus racing is prevented by controlling the flow rate and pressure at the escape port from the hydraulic motor.



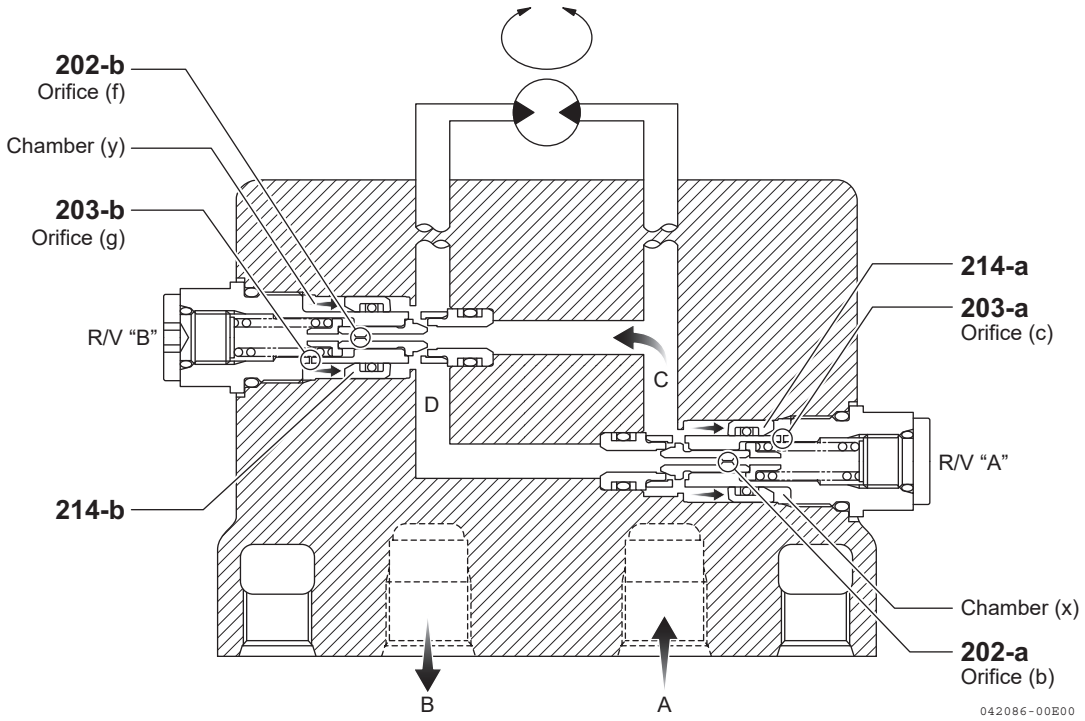


(3) Operation Description of Relief Valve

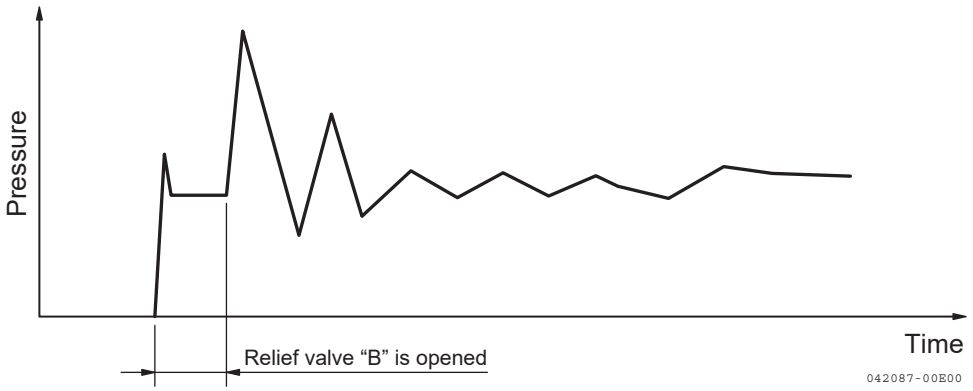
[1] Starting

The pressurized oil supplied from the pump is led to port **C** from port **A**. Port **C** is connected with the hydraulic pressure motor. Therefore, the hydraulic motor can give torque with the pressurized oil led to port **C**. At this time, the valve **202-a** of the relief valve (R/V) "A" is not opened for the pressurized oil of port **C**. The piston **214-a** moves to the stroke end of the direction of the arrow with the pressurized oil. The oil of the chamber **x** is led to port **D** through the orifice **c** of the sleeve **203-a**, the orifice **b** of the valve **202-a**.

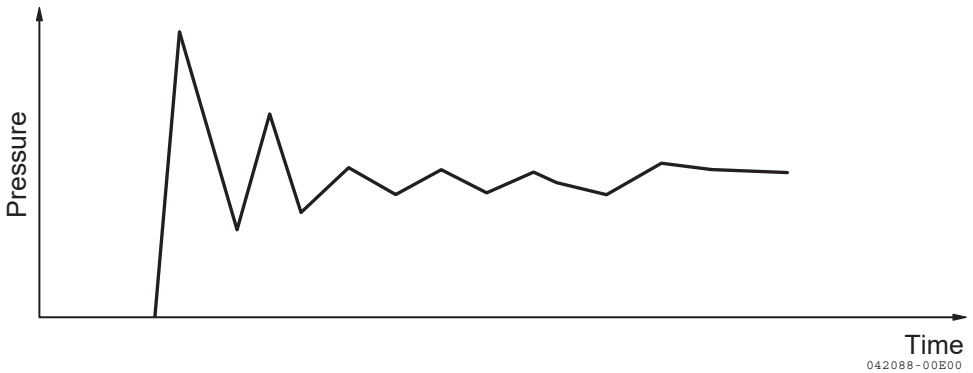
The pressurized oil of port **C** opens the valve **202-b** (**b**) of the relief valve "B" with the set pressure, and pressurized oil is led to port **D**. The pressurized oil from port **C** is led to the chamber **y** through the orifice **f** of the valve **202-b**, the orifice **g** of the sleeve **203-b**. If the piston **214-b** reaches the stroke end, the pressure between the orifice **f** of the valve **202-b** and the orifice **g** of the sleeve **203-b** rises. The cracking pressure of the valve **202-b** turns into more than the system pressure of the excavator with the pressure between the two orifices, and the valve **202-b** is closed. The pressure of port **C** rises by the operation of the relief valve (R/V) "A" and "B", and the hydraulic motor can obtain torque.



The pressure of the port **C** at starting is as follows.



However, when the piston **214-b** position has reached the stroke end at the last stop, the valve **202-b** of the relief valve (R/V) “B” is not opened.
The pressure of the port **C** in this case is as follows.



The pressure of the port **C** at starting changes with the position of piston **214-b**.

*When the pressurized oil supplied from the pump is led to port **D** from port **B**, replace relief valve (R/V) "A" and relief valve (R/V) "B" in the operation explanation.

[2] Stopping

If supply of pressurized oil in port **A** is lost, the counter balance valve will return to neutrality.

Port **D** will be intercepted if the counter balance valve returns to neutrality.

However, since the hydraulic motor rotates according to inertia, the pressure is generated in port **D**.

The pressurized oil of port **D** is led to the chamber **x** through the orifice **b** of the valve **202-a**, the orifice **c** of the sleeve **203-a**.

The piston **214-a** moves to the stroke end of the direction of the arrow with the pressurized oil led to the chamber **x**.

While the piston **214-a** is moving, the pressure in the chamber **x** does not rise.

The pressurized oil of port **D** opens the valve **202-a** of the relief valve (R/V) "A" with the set pressure, and pressurized oil flows into port **C**. (Pressure under piston movement: Primary relief pressure)

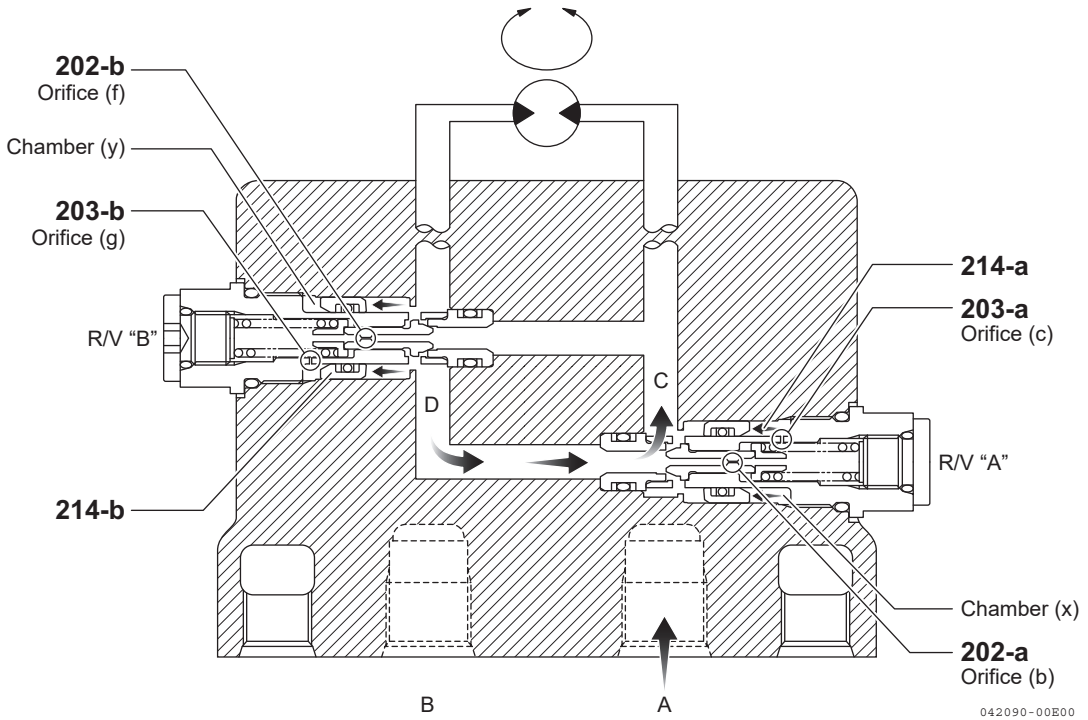
The pressure of port **D** is controlled by the operation of the relief valve (R/V) "A", and cavitation is prevented by supplying oil to port **C**.

If the piston **214-a** reaches the stroke end, the pressure of chamber **x** and the pressure between the orifice **b** of the valve **202-a** and the orifice **c** of the sleeve **203-a** will rise, and the valve **202-a** is closed.

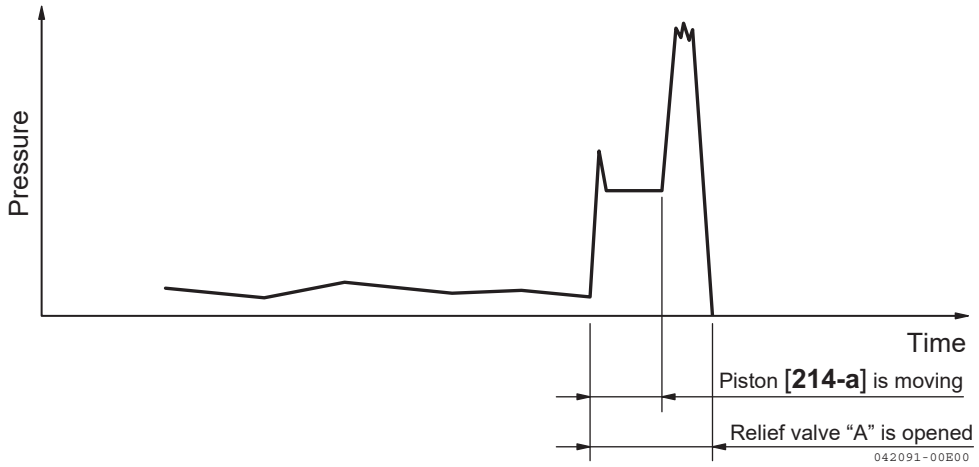
At this time, the relief valve (R/V) “A” is relieved above the system pressure of the excavator, and stops the hydraulic motor. (Pressure at the time of the completion of a piston move: Secondary relief pressure)

The piston **214-b** of the relief valve (R/V) “B” moves to the direction of the arrow with the pressurized oil of port **D**.

The oil of chamber **y** is led to port **C** through the orifice **g** of the sleeve **203-b**, the orifice **f** of the valve **202-b**.



The pressure of the port **D** at stopping is as follows.



Pressure under piston movement : Primary relief pressure
Pressure at the time of the completion of a piston move : Secondary relief pressure

(4) High-Low 2-Speed Switching Mechanism

[1] Low Speed

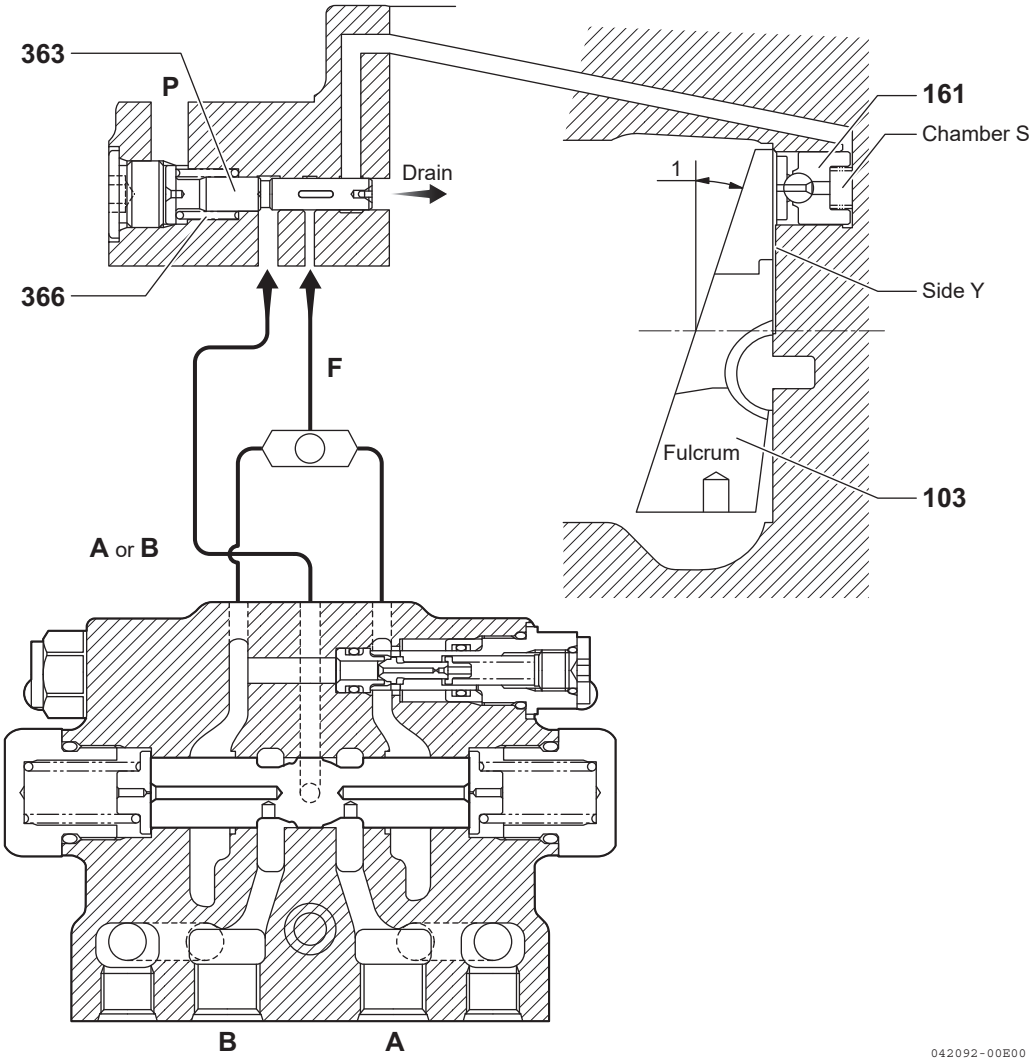
When the pilot pressure is shut off from port **P**, the motor operates at low speed level.

At this time the spool **363** is pressed to the left side by the force of the spring **366**, and the pressurized oil supply at port **F** is shut off.

The oil in chamber **S** is released into the motor case through the spool **363**.

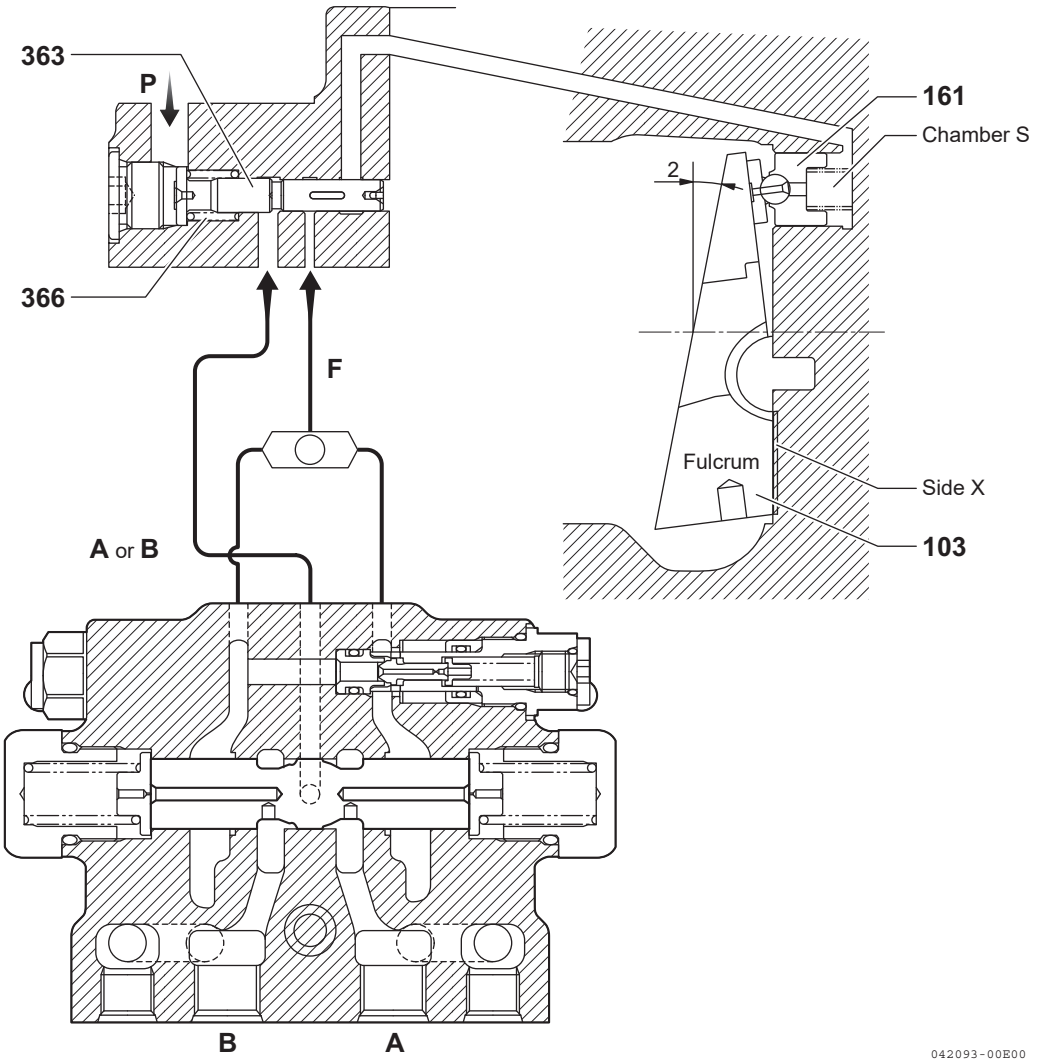
The force of the piston **161** is small. The swash plate **103** is parallel to side **Y**.

At this time the swash plate **103** is tilted at a maximum θ**1**, thus leading to low speed operation.



[2] High Speed

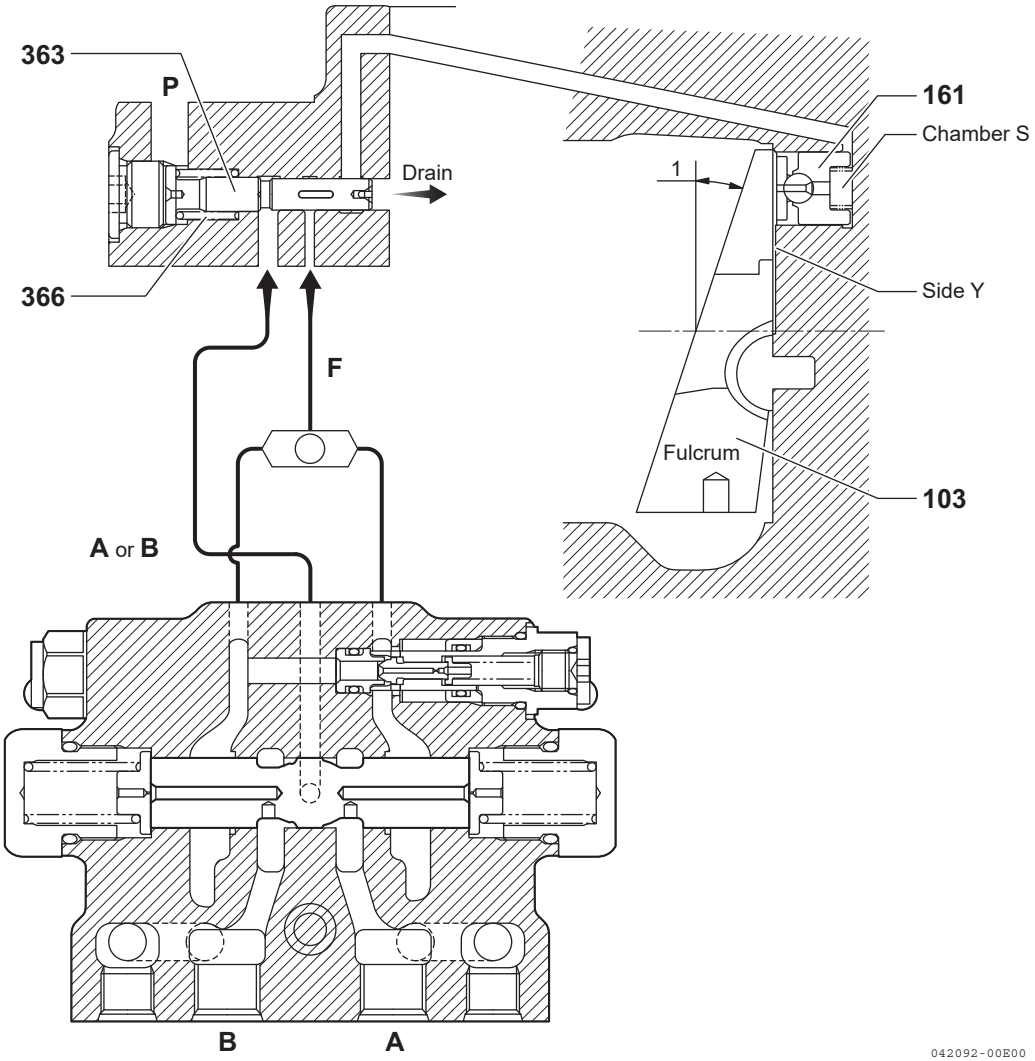
When the pilot pressure is supplied to port **P**, the motor operates at high speed level. At this time the pressure overcomes the force of the spring **366** and the spool **363** is pressed to the right side. The pressurized oil supply from port **F** then enters into chamber **S** through the spool **363**. The force of the piston **161** is increased by the pressurized oil of chamber **S**. The piston **161** pushes the swash plate **103** up until it touches side **X** and holds it. At this time the swash plate **103** is tilted at a minimum θ**2**, thus leading to high-speed operation.



[3] Automatic Switching from High Speed to Low Speed

As the load on the hydraulic motor increases, the pressure at port **A** or **B** increases. While operating at the high speed level, when the pressure at port **A** or **B** reaches setting pressure, the spool **363** is pressed leftwards. From this point, the operation is as described for 'Low Speed Level'. The force of piston **161** is reduced, and the hydraulic fluid of chamber **S** is opened to drain (motor case) through the spool **363**. The swash plate **103** is positioned along side **Y**.

At this time the swash plate **103** has its maximum angle θ**1**. Thus in this state the hydraulic motor has maximum displacement with low rotary speed.



(5) Parking brake

[1] Traveling

Hydraulic fluid is fed from the pump to port **A** or port **B**, causing the brake valve spool **323** to move to the left or right. The movement of the spool **323** opens port **E**. The hydraulic oil is fed from port **E** to cylinder chamber **c**. When the hydraulic pressure reaches 91.4 PSI (0.63 MPa), the force of the piston **112** exceeds the force of the spring **113**. The piston **112** moves in the direction of the rear flange **301**. The pressure from the piston **112** on the mating plate **116** and the friction plate **115** disappears, and the friction plate **115** is able to rotate freely.

The friction plate **115** is locked to the cylinder block **104** of the hydraulic motor. Thus the braking force of the cylinder block **104** is released, and the hydraulic motor is able to rotate freely.

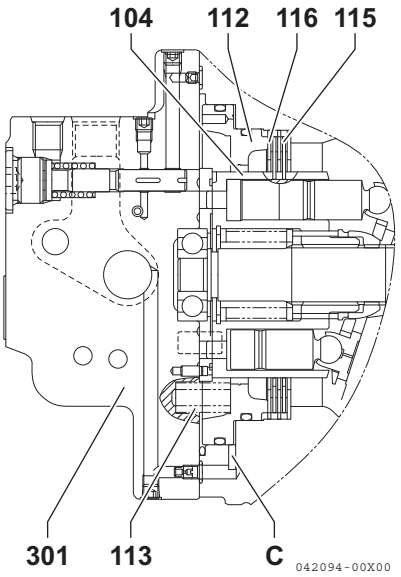
[2] Stopping

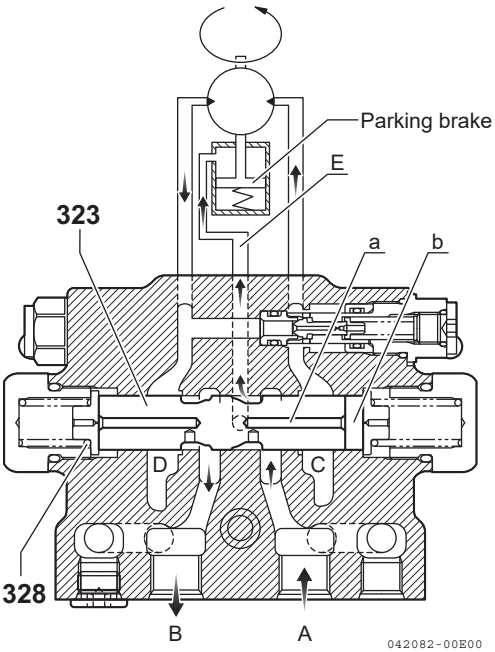
The supply of hydraulic fluid to port **A** or **B** is stopped. The brake valve spool **323** moves to the center position, shutting off port **E**. The pressure in cylinder chamber **c** falls. When this pressure falls below 91.4 PSI (0.63 MPa), the hydraulic force of the piston **112** becomes less than the force of the spring **113**. The spring **113** causes the piston **112** to press against the mating plate **116** and friction plate **115**.

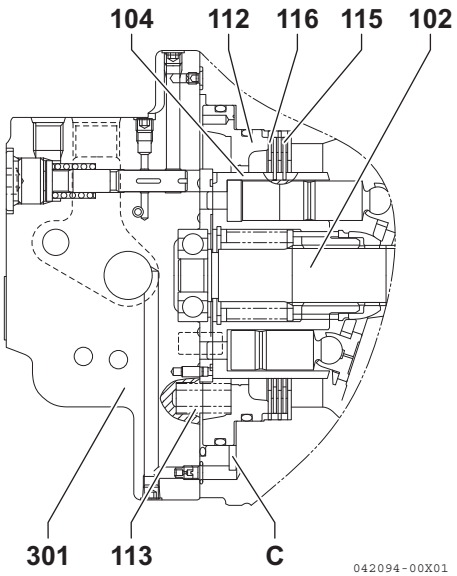
This pressure creates the friction that serves as the braking force. The friction plate **115** is locked to the cylinder block **104** of the hydraulic motor.

The cylinder block **104** is locked with the shaft **102** of the hydraulic motor.

Thus brake torque is applied to the hydraulic motor while stopped.







6-7-5 Troubleshooting

Problem 1	Problem 2	Possible cause	Action
Motor does not turn	Pressure will not increase	Relief set pressure is too low	Check the main relief valve
		Pump failure	Repair
		Direction switching valve is damaged	Repair
	Pressure does increase	Brake valve failure	Replace or repair brake valve
		Hydraulic motor failure	Repair
		Gear (reduction) damage	Replace motor assy
		Excessive load applied	Remove excessive load
Oil leakage	Leaking from mating surface	Flaws in surface	Repair flaws with grinder, sand-paper, etc.
		Bolts loose	Retighten
	Leaking from case	Plug loose	Retighten
		Cracked by stone etc.	Replace motor assy
	Leaking from floating seal	Worn-out sliding surface	Replace motor assy
		O-ring leaks	Replace motor assy
	Leaking from hydraulic motor	Bolts loose	Retighten
		O-ring damaged	Replace O-ring
		Seal surface flawed	Repair flaws with grinder, sand-paper, etc.
During use, rotates under load	Increased leakage of working fluid	Reduced hydraulic motor capacity	Replace motor assy
		Increased internal brake valve leakage	Replace or repair brake valve
	Parking brake does not function	Spring damage	Replace spring
		Friction plate worn down	Replace friction plate, mating plate
Reduction gear case surface temperature too high		Shortage gear oil	Fit to recommended level
		Pitching in bearings	Replace motor assy
		Working oil in gear case	Replace oil seal

Troubleshooting (Continued)

Problem 1	Problem 2	Possible cause	Action
Meanders when used as drive motor	Occurs at low pressure	Left-right ejection volume imbalance	Repair pump
		Left-right hydraulic motor drain volume imbalance	Replace motor assy
	Occurs at high pressure	Left-right ejection volume imbalance	Repair pump
		Left-right hydraulic motor drain volume imbalance	Replace motor assy
		Left-right brake valve operation imbalance	Replace brake valve
		Left or right control valve has low relief pressure	Set pressure correctly, or replace relief valve
Speed too slow	Pump ejection volume too low	Pump not operating property	Repair or replace pump
		High oil leakage outside pump	Repair or replace pump
		High oil leakage outside hydraulic motor	Replace motor assy
Abnormal sounds	From motor	Hydraulic motor or reduction gear damage	Replace motor assy
	From tubing	Tubing vibration occurring	Clamp tubing
2-speed switching does not function	Does not switch low to high speed	High pressure selection check valve malfunction	Inspect, repair or replace
		Switching valve malfunction	Repair or replace
		Pilot pressure too low	Set to required pressure
		2-speed switching piston malfunction	Repair or replace
	Does not switch from high to low speed	Switching valve malfunction	Repair or replace
		2-speed switching piston malfunction	Repair or replace

6-7-6 Service outline

1) Tools

(1) Standard tools

No.	Name	Description	Remarks	Q'ty
1	Hexagon wrench	Nominal 0.12 in. (3 mm) Nominal 0.24 in. (6 mm) Nominal 0.31 in. (8 mm) Nominal 0.39 in. (10 mm)	3 (For M6) 6 (For M8 and PF 1/4) 8 (For PF 3/8) 10 (For PF 1/2)	1 1 1 1
2	Socket wrench (Ratchet handle) (JIS B 4641)		Barrel type	1
3	Torque wrench (JIS B 4650)	Dial type: approx. 20 N Dial type: approx. 90 N Dial type: approx. 150 N Dial type: approx. 600 N		1 1 1 1
4	Torque wrench adapter	Nominal socket 13, 30 Nominal rod size 3, 6, 8		One each
5	Hexagon socket		Opposite side: 0.5 in., 0.7 in., 0.9 in., 1.4 in. (13 mm, 17 mm, 24 mm, 36 mm)	1
6	Extension bar (JIS B 4637)	5.9 in. (150 mm)		1
7	Hand hammer	Nominal 0.47 in. (12 mm)		1
8	Plastic hammer	ABT. 11.8 in. (300 mm)		1
9	Flat-blade screwdriver (JIS B 4609)	1.97 in. (50 mm) 5.9 in. (150 mm)		1 1
10	Snap ring pliers	For shafts For holes		1 1
11	Cutting plier (JIS B 4623)	7.9 in. (200 mm)		2
12	Lifting tool (Crane)		Lifting load 661 lbs (300 kg) or more Eyebolt (For PF3/8) Wire with hook	1 (2) (1)
13	Receptacles	Volume (W x D x H): 17.7 in. x 11.8 in. x 4.7 in. (450 mm x 300 mm x 120 mm)		2
14	Leather gloves			1 pair

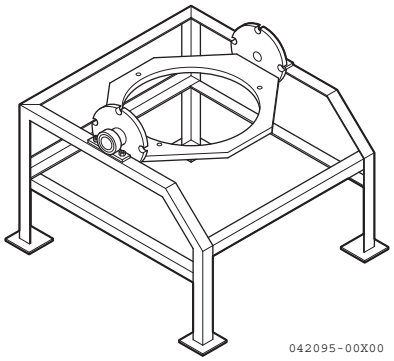
(2) Bolts

No.	Name	Description	Q'ty
1	Hexagon socket head cap screw (JIS B 1176)	Approx. M6 (P1.0) × 50 Approx. M16 (P2.0) × 40 Approx. M16 (P2.0) × 150	1 2 3

(3) Equipment and facilities

Applicable parts (Usage method or part No.)	Name	Description	Remarks	Q'ty
For disassembling and reassembling works	General work bench			1
For washing motor and parts	Washing tank			1
104, 149	Press machine	Press capacity: 441 lbf (1960 kg) or more		1
149	Heating tank	Heating capacity: over 100 °C Volume: 19.7 × 19.7 × 19.7 in. (500 × 500 × 500 mm)		1
For drying washed parts	Compressed air supply	Pressure: 42 to 71 PSI (0.29 to 0.49 MPa)		

(4) Special tools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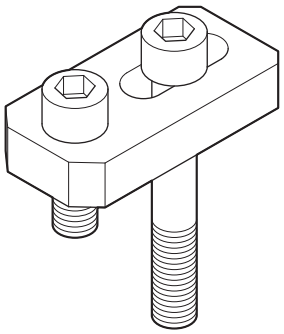
Name: Travel motor workbench

- Workbench for easy and safe disassembly and assembly of the travel motor.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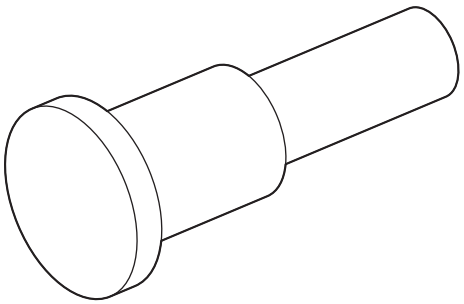
Name: Fixture

- For connecting the spindle **2** and hub **1**.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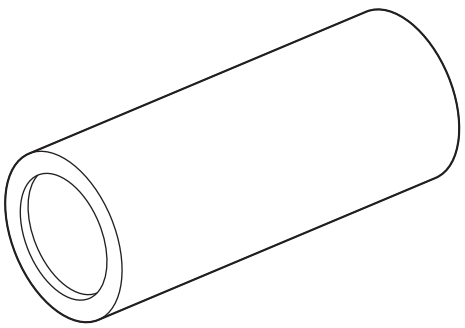
Name: Holder (Ⅰ)

- For inserting the spring **114**, washer **110** and snap ring **145** into the cylinder block **104**.
- For removing the spring **114** from the cylinder block **104**.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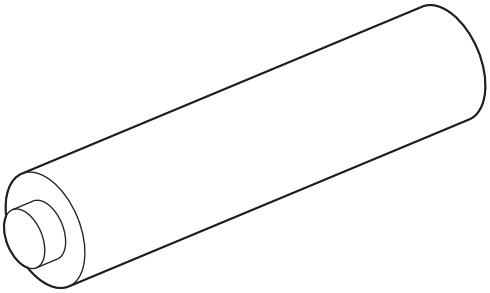
Name: Holder (Ⅱ)

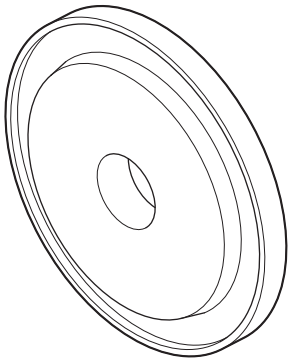
- For removing the ball bearing **149** from or inserting it onto the shaft **102**.



030578-00X

Name: Holder (Ⅲ)

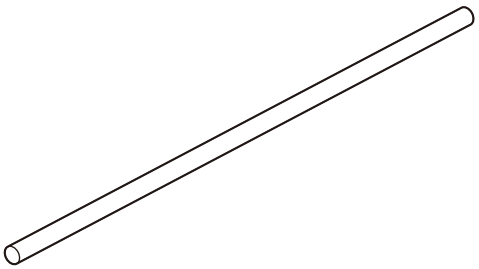
- For press fitting the oil seal **132** into the oil seal hole of the spindle **2**.



042097-00X00

Name: Press tool

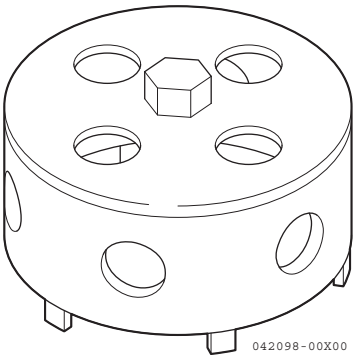
- For press fitting the ball bearing **24** into the hub **1**.



030581-00X

Name: Steel rod (Ⅰ)

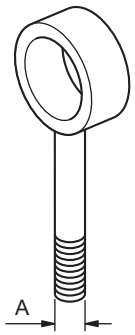
- For removing the ring **45** from the hub **1**.



042098-00X00

Name: Bearing preload adjuster

- For fitting ring nut **22** to spindle **2**.

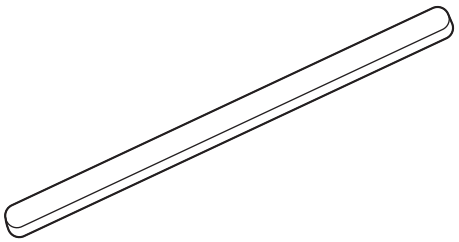


	"A"
Hub	M 14
Spindle	M 16
Motor	M 16

042221-00E00

Name: Eye bolt

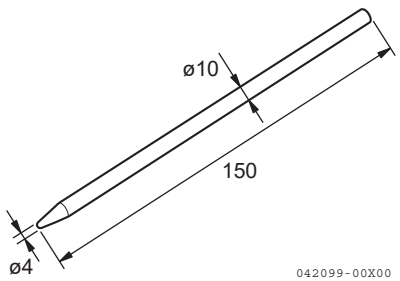
- For lifting the motor, spindle **2** and hub **1**.



030583-00X

Name: Slice

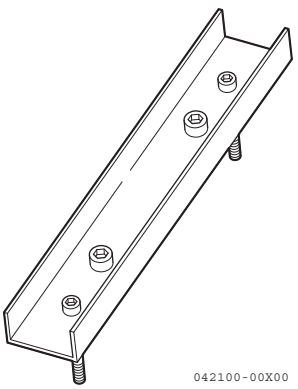
- For removing the timing plate **109** from the rear flange **301**.



042099-00X00

Name: Aluminum rod

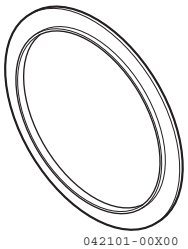
- For removing the outer race of the ball bearing **24**.



042100-00X00

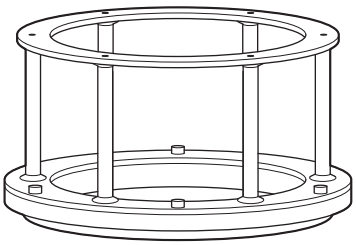
Name: Cover removable jig

- For removing the cover **13** from hub **1**.


042101-00X00

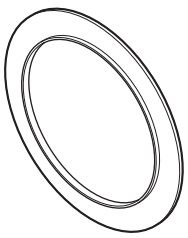
Name: F/S installation tool (Ⅰ)

- For installing the floating seal **31** to the hub **1**.


042104-00X00

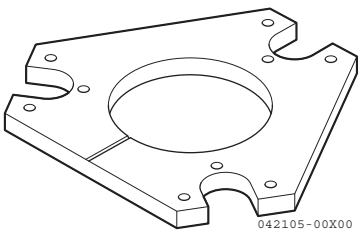
Name: F/S installation tool (Ⅱ)

- For installing the floating seal **31** to the hub **1** and spindle **2**.


042103-00X00

Name: F/S installation tool (Ⅲ)

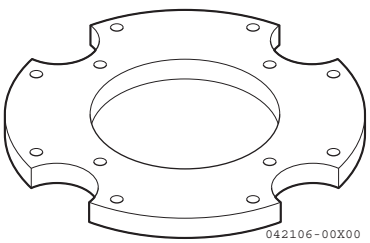
- For installing the floating seal **31** to the spindle **2**.


042105-00X00

Name: Thrust washer installation tool (carrier **3**)

- For installing three thrust washers (3) **12** to the carrier **3** with the hexagon head bolt.

Note:
Assembling work is possible without this jig.


042106-00X00

Name: Thrust washer installation tool (spindle **2**)

- For installing four thrust washers (1) **10** to the spindle **2** with the hexagon head bolt.

Note:
Assembling work is possible without this jig.

2) Tightening torque

Part No. (Structure drawing)	Bolt / Nut Used		Width across flats [in. (mm)]	Q'ty	Tightening torque [ft•lbf (N•m)]
	Name	Nominal designation			
33	Plug	PF 3/8	0.31 (8)	1	36.13 to 50.60 (48.99 to 68.61)
39	Plug	PF 3/8	0.31 (8)	2	36.13 to 50.60 (48.99 to 68.61)
40	Hexagon head bolt	M8 (P1.25)	0.51 (13)	3	21.0 to 28.2 (28.4 to 38.2)
47	Hexagon socket set screw	M8 (P1.25)	0.11 (3)	2	6.06 to 8.42 (8.21 to 11.41)
51	Hexagon head bolt	M10 (P1.5)	0.67 (17)	4	35.47 to 49.94 (48.09 to 67.71)
203	Sleeve	M22 (P1.5)	0.94 (24)	2	90.2 to 111.9 (122.3 to 151.7)
321	Plug	PF 3/8	0.31 (8)	1	36.13 to 50.60 (48.99 to 68.61)
324	Plug	M30 (P1.5)	1.42 (36)	2	231.4 to 289.3 (313.8 to 392.2)
345	Hexagon socket bolt	M12 (P1.75)	0.39 (10)	8	63.7 to 86.8 (86.3 to 117.7)
382	Plug	PF 1/2	0.39 (10)	3	57.9 to 86.8 (78.5 to 117.7)

3) Weight table

Applicable parts (Structure drawing)	Name	Weight [lbs (kg)]
	Travel motor assembly	Approx. 183 (83)
1	Hub	Approx. 50.7 (23)
2	Spindle	Approx. 50.7 (23)
201	Rear flange assembly	Approx. 24 (11)

6-7-7 Disassembly

1) Preparations

Perform the following preparations before disassembling.

(1) Workbench preparations
- Prepare a travel motor workbench.
- Prepare a sturdy workbench with which the internal parts of the travel motor can be disassembled or assembled, and that is wide enough to place parts so they do not move or fall off the bench while working.
- Spread a rubber or vinyl sheet on the workbench.

(2) Preparation of tools and materials
- Prepare the tools and materials listed in this manual.

2) General Suggestion When Working

⚠ CAUTION

Internal parts are coated with hydraulic fluid and gear oil and are slippery. If a part slips out of your hand and falls, it could result in bodily injury or could damage the part. Be very careful when handling.

⚠ CAUTION

Combustibles such as white kerosene are used to wash parts.
These combustibles are easily ignited, and could result in fire or injury.
Be careful when handling.

(1) Before disassembling, perform inspections and clearly determine the nature of any abnormalities which might be occurring, and work according to the disassembly procedure.

(2) Each part is manufactured to extreme precision. Handle with care and be sure not to hit the parts together or drop them.

(3) When working, do not attempt to forcefully hit or wrench tightly fitting parts.
Doing so can damage the parts so that they can not be mounted or their performance is reduced. Be patient when working.

(4) If you leave parts disassembled or partially disassembled, rust could develop on the parts due to moisture or dirt. If you have to interrupt work before completion, be careful to take measures to protect against rust or dust.

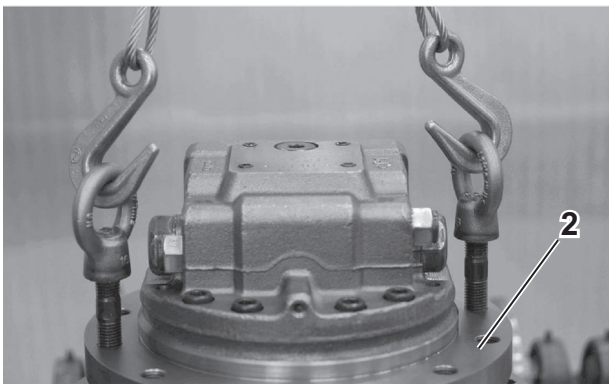
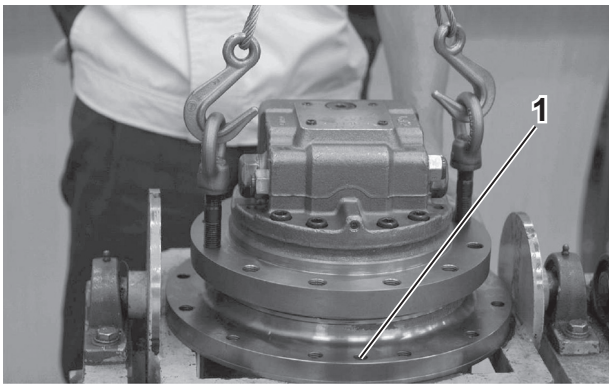
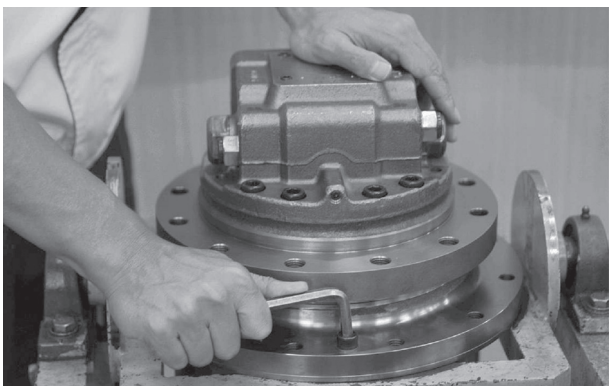
(5) Place a counter mark on mating faces of parts when disassembling.

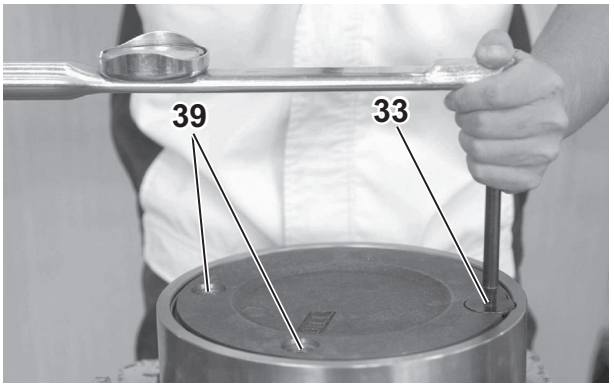
(6) Arrange removed parts neatly when disassembling so as not to damage or lose the parts while working.

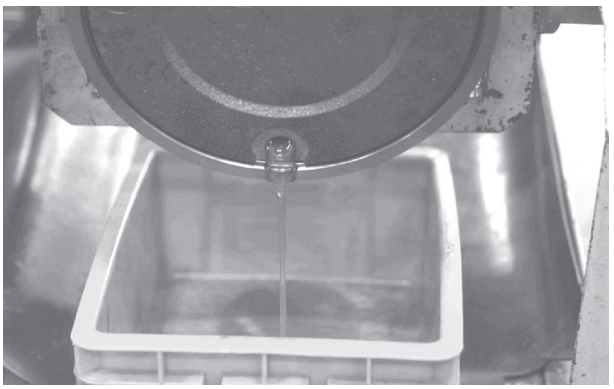
(7) As a rule, once any type of seal is disassembled, it should be replaced with a new one even if it shows no signs of damage. You should have a new ready when disassembling.

(8) The photographs and drawings contained in the manual are of representative models.
Disassembly procedure is however not affected even if the product you are using partially differs.

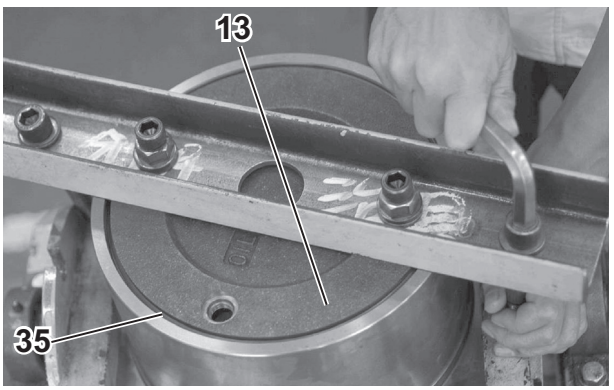
3) Disassembly procedure

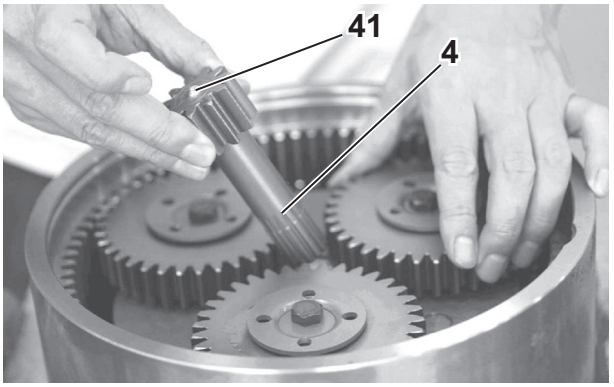
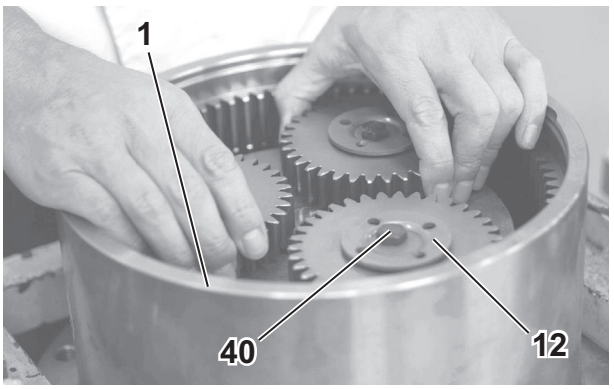
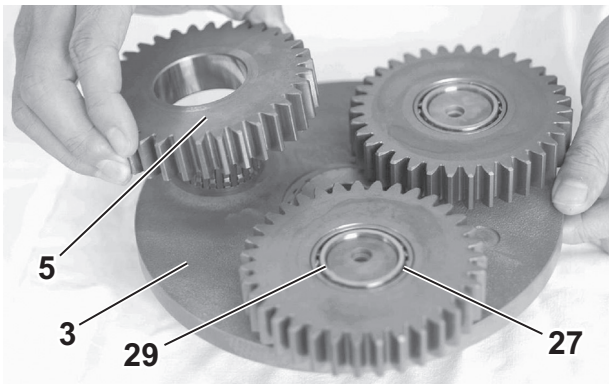
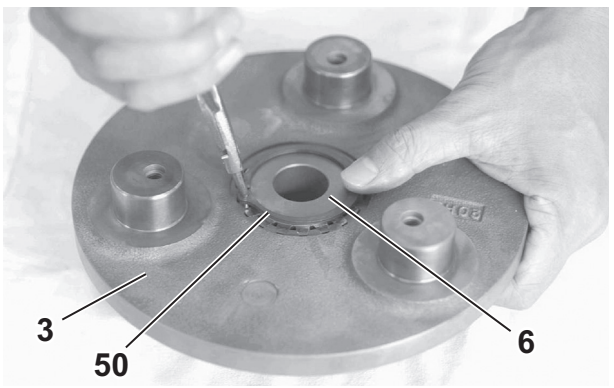
Procedure	
1. Washing the motor (1) Fasten the eye bolts to the spindle **2**. ***Note:*** *Fasten the two eyebolts in the screw holes for mounting the spindle so that they are positioned symmetrically.*	
(2) Hook the wire in the eyebolts, hoist the motor with a crane and carry to the washing tank. (3) Wash each part of the motor with a brush. ***Note:*** *Earth and sand get in the clearance between the hub **1** and spindle **2** (floating seal mounting section). Be sure to wash this part with special care.*	
2. Motor installation (1) Put the motor on a workbench. ***Note:*** *While matching the screw holes of the hub **1** and screw holes of the workbench, carefully place the travel motor in the mounting holes of the workbench.*	
(2) Mount the motor on the workbench so that the two hexagon socket head cap screws are positioned symmetrically. ***CAUTION:*** *Tighten the hexagon socket head cap screws securely. Failure to do so could result in injury caused by the motor falling when it is turned upside down.*	

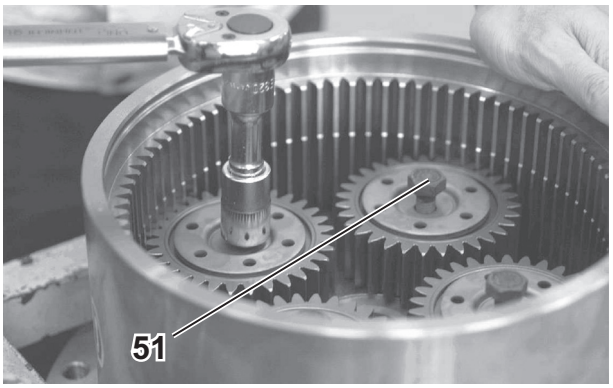
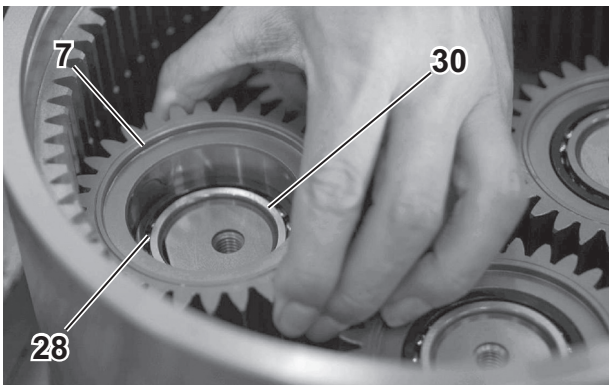
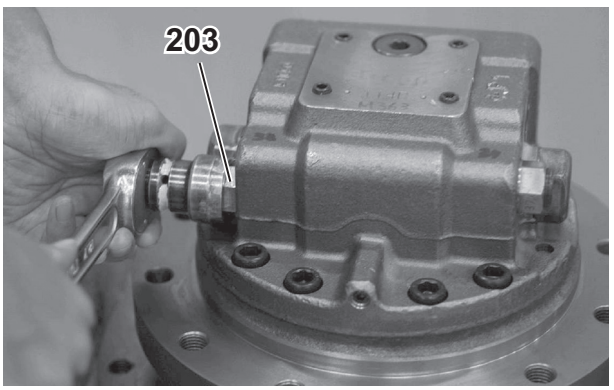
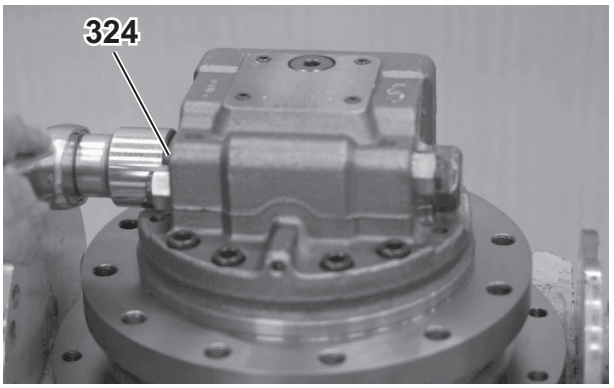
Procedure	
3. Lubricating oil extraction (1) Turn the motor upside down. (Turn up the side of reduction gear) (2) Loosen and remove plug **33** and plug **39**. ***Note:*** *When extracting the lubricating oil, place a container under the workbench.*	

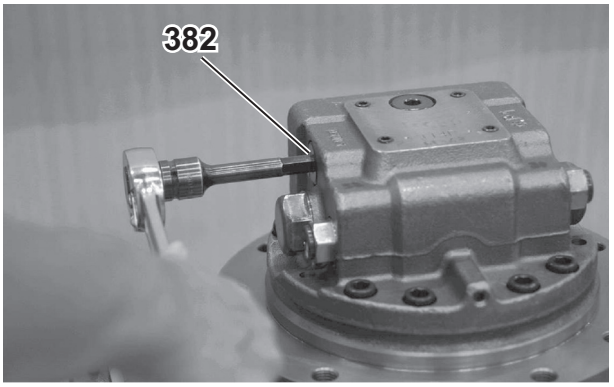
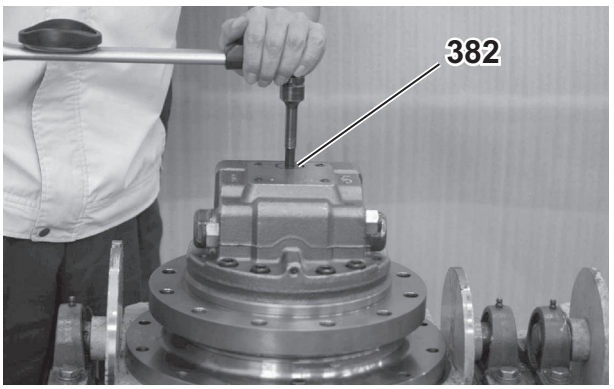
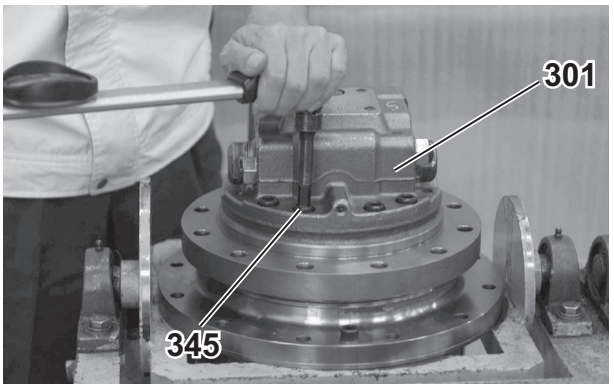
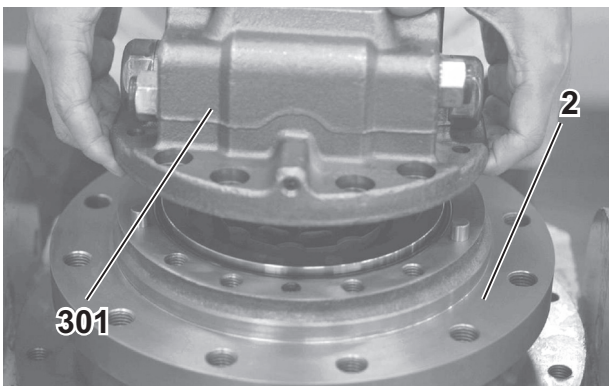
(3) Slowly turn the motor upside down and extract the lubricating oil. (Turn up the side of motor) (4) Remove the O-ring **37** from the plug **33** and the plug **39**. ***Note:*** *Do not reuse removed O-rings **37**.*	

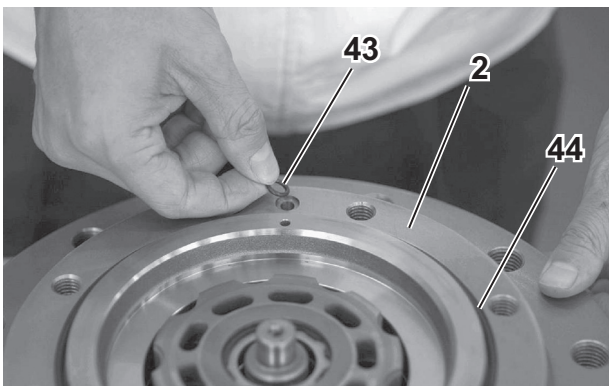
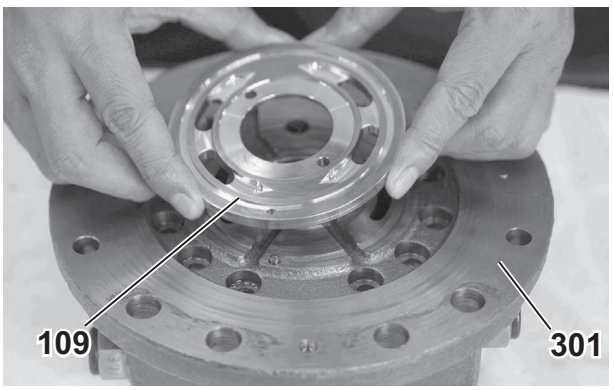
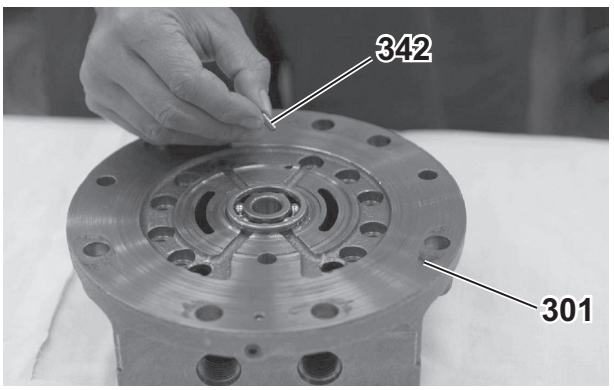
4. Cover removal (1) Turn the workbench. The side of the reduction gear is turned up. (2) Remove the ring **45** using a steel rod. (3) Fix two inside bolts of the cover removal jig to in the threaded holes of the plug **33** and the plug **39** of the cover **13**. (The plug **33** and plug **39** are fixed usually.)	

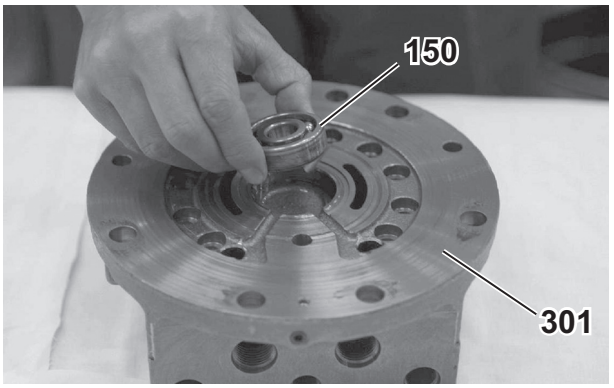
(4) Place a block against the two bolts outside of the cover removal jig and tighten the bolts to allow the cover **13** to come off little by little. ***Note:*** *If the cover **13** is hard to remove because of resistance of the O-ring **35**, lift it up while lightly tapping the outer rim of the cover with a plastic hammer.* (5) Remove the O-ring **35** from the cover **13**. ***Note:*** *Do not reuse a removed O-ring **35**.*	

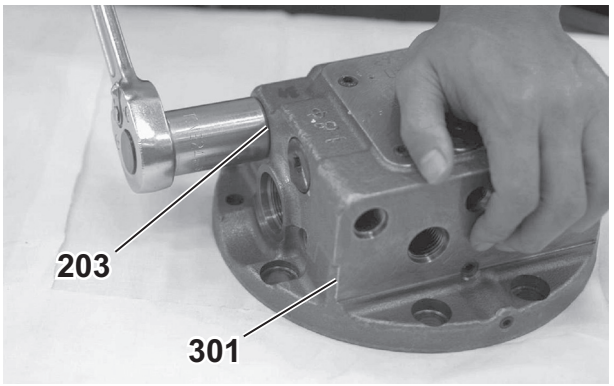
Procedure	
5. Sun gear (1) removal (1) Remove the sun gear (1) **4**. (2) Remove the steel ball **41** from the sun gear (1) **4**.	
6. Carrier assy removal (1) Remove the carrier assy from the hub **1**. ***CAUTION:*** *The carrier assy may come out together with the thrust collar (1) **9**.*	
(2) Disassemble carrier assy [1] Loosen the three hexagon head bolts **40** and remove them from the carrier **3**. [2] Remove the three thrust washers (3) **12**, planetary gears (1) **5**, needle roller bearings **27**, and inner rings **29** from the carrier **3**. ***Note:*** *Do not reuse removed hexagon head bolts **40**.*	
(3) Remove the retaining ring **50** from the sun gear (2) **6**. (4) Remove the sun gear (2) **6** from the carrier **3.**	

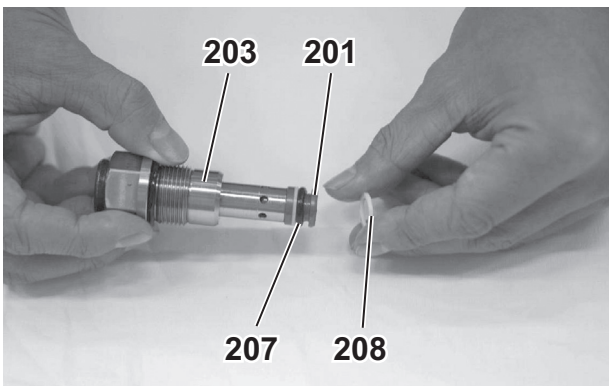
Procedure	
7. Planetary gear (2) removal (1) Loosen the four hexagon head bolts **51** and remove them from the spindle **2**. ***Note:*** *Do not reuse removed hexagon head bolts **51**.*	
(2) Remove the four planetary gears (2) **7**, needle roller bearings **28** and inner rings **30**. (3) Remove the four thrust washers (2) **11** from the spindle **2**. (4) Remove thrust collar (1) **9** from the spindle **2**.	
8. Rear flange removal (1) Turn the workbench so that the rear flange **301** is on top. ***Note:*** *This position makes it easier to remove the plugs at the next step.* *Do not loosen the bolts if the rear flange inside is not disassembled.* (2) Temporarily loosen the two sleeves **203**.	
(3) Temporarily loosen the two plugs **324**.	

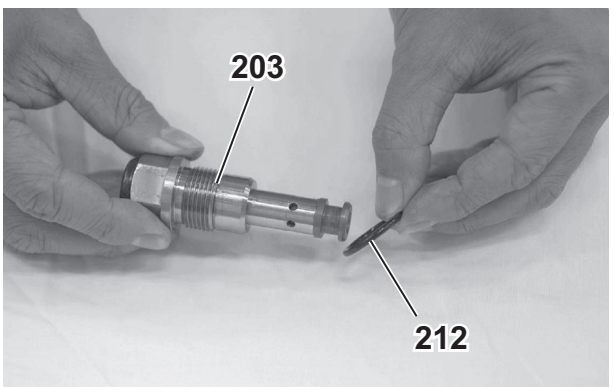
Procedure	
(4) Temporarily loosen the two plugs **382**.	
(5) Temporarily loosen the plug **382**.	
(6) Loosen and remove the eight hexagon socket bolts **345** from the rear flange **301**.	
(7) Remove the rear flange **301** from the spindle **2**. ***Note:*** *Hold the rear flange with both hands. Lift it up carefully to remove it. Perform the work with care and do not pry or strike the flange with force.* *Otherwise the timing plate **109** can drop and be damaged.*	

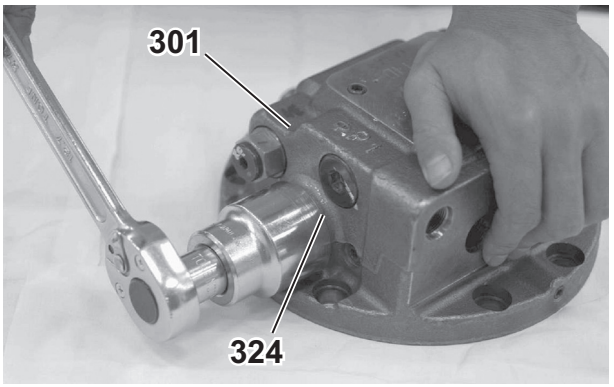
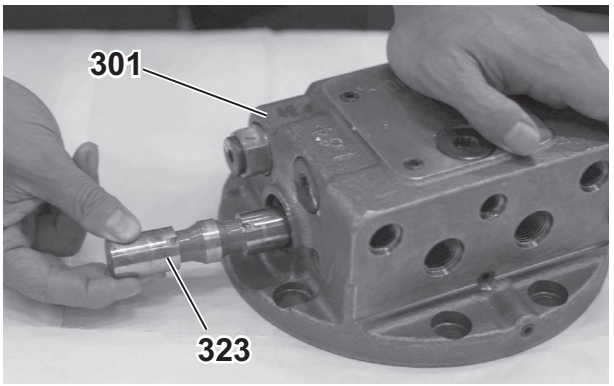
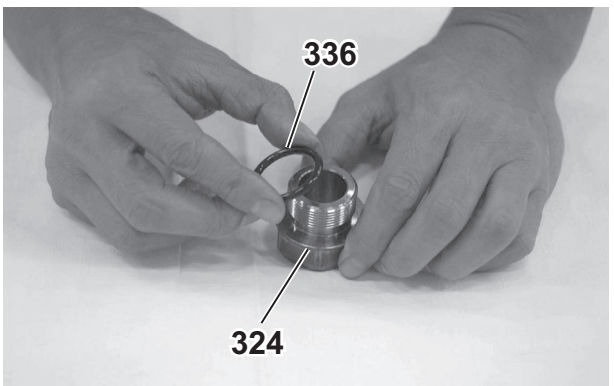
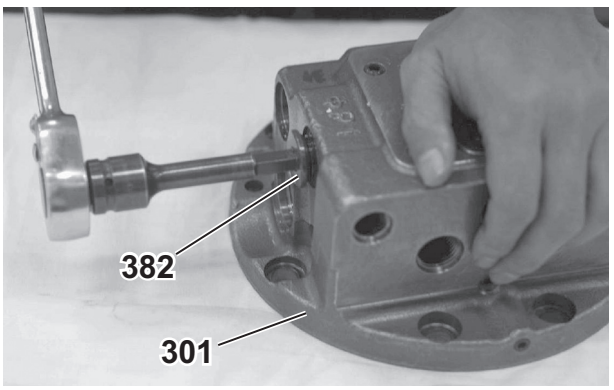
Procedure	
(8) Pull out the two parallel pins **42** from the spindle **2**.	
(9) Remove the two O-rings **43**, **44** from the spindle **2**. ***Note:*** *Do not reuse the removed O-rings **43**, **44**.*	
9. Disassembly of the rear flange mounting the parts (1) Put the removed rear flange **301** on the workbench. (The mating face with spindle **2** should point up.) (2) Remove the ten springs **113** from the rear flange **301**. (3) Remove the timing plate **109** from the rear flange **301**. ***Note:*** *The timing plate might be found stuck to the mating face of the rear flange. To separate the timing plate, insert a flat bar into the groove of the rear flange and raise the timing plate slowly. Never try to ply the timing plate off with a sharp or pointed tool or the precision finished mating faces will suffer costly damage.* (4) Pull out the parallel pin **342** from the rear flange **301**.	 

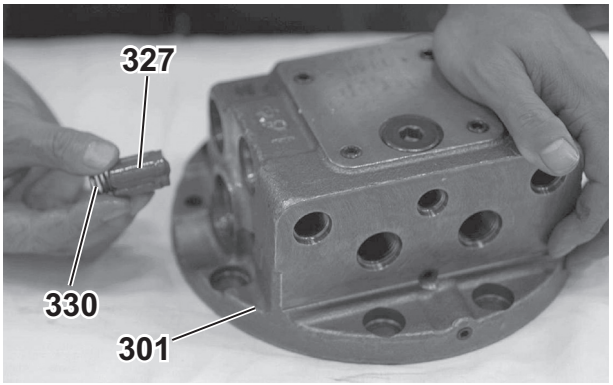
Procedure	
(5) Pull out the ball bearing **150** from the rear flange **301**.	

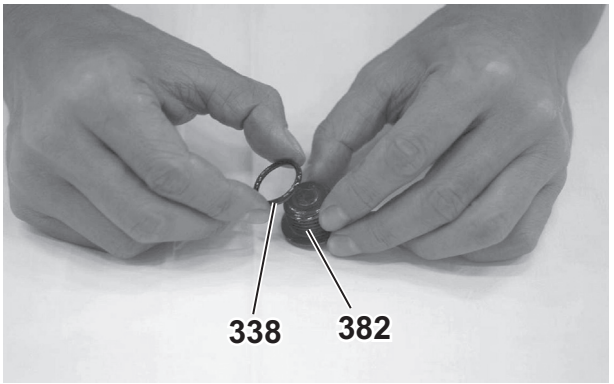
10. Disassemble the SRV in the rear flange (1) Remove the two sleeves **203** from the rear flange **301**.	

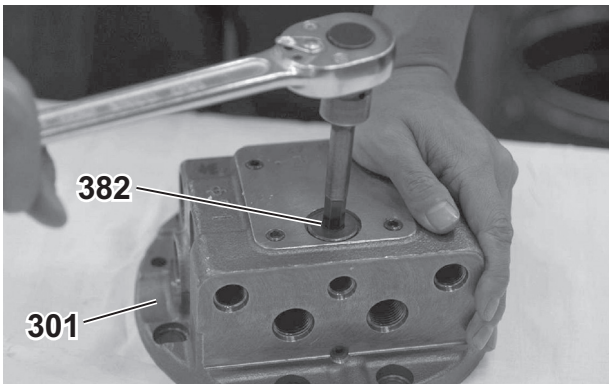
(2) Remove the O-ring **207** and backup ring **208** from the valve seat **201** one by one. ***Note:*** *Do not reuse the removed O-ring **207** and backup ring **208**.*	

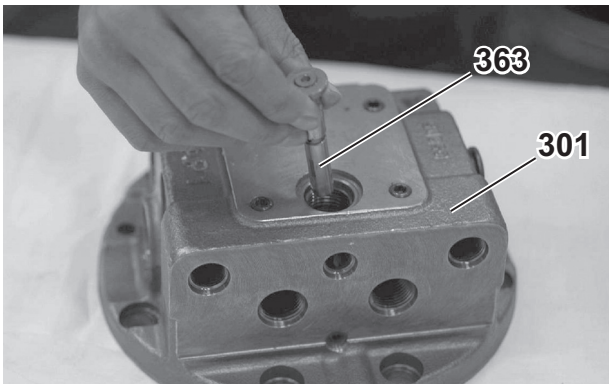
(3) Remove the O-ring **212** from the sleeve **203**. ***Note:*** *Do not reuse the removed O-ring **212**.*	

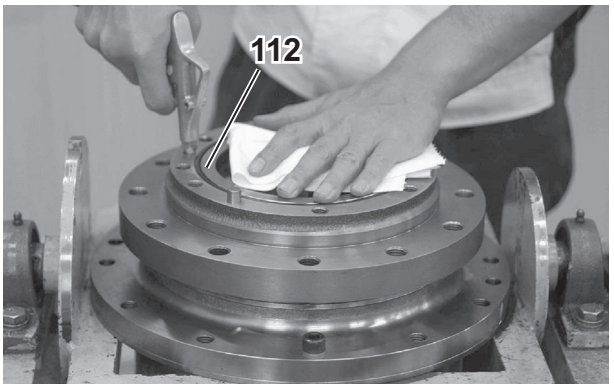
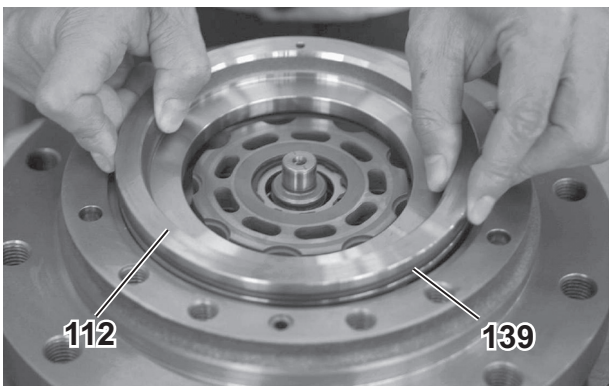
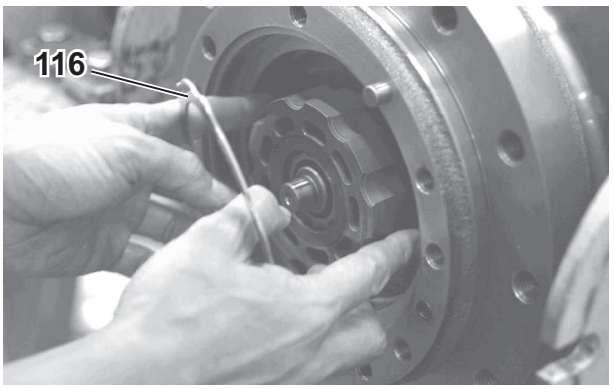
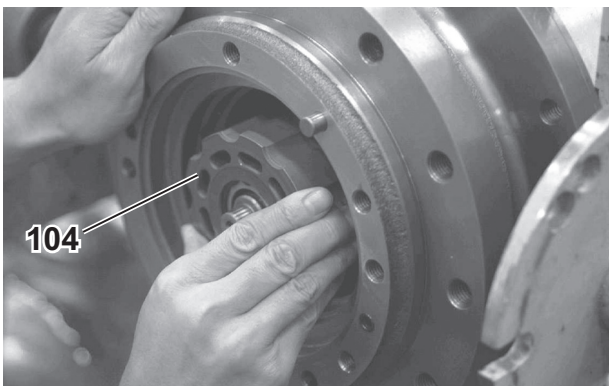
Procedure	
11. Disassemble the brake valve part in the rear flange (1) Remove the two plugs **324** from the rear flange **301**.	
(2) Remove the two spring retainers **325** and springs **328** from the rear flange **301**. (3) Remove the spool **323** from the rear flange **301**. ***Note:*** *To remove the spool **323**, place your hand on one part of the plug port of the rear flange **301** and tilt it down. Then the spool **323** falls down. Hold the tip and remove it.*	
(4) Remove the O-ring **336** from the plug **324**. ***Note:*** *Do not reuse the removed O-ring **336**.*	
(5) Remove the two plugs **382** from the rear flange **301**.	

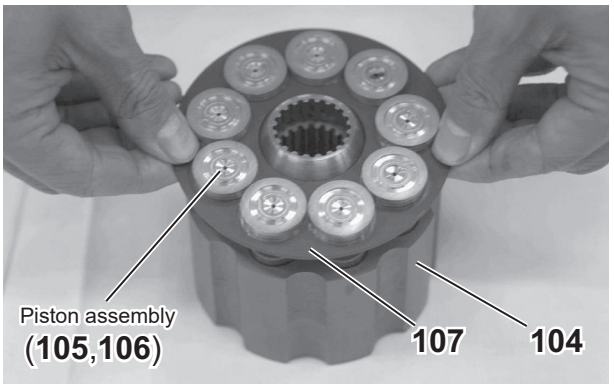
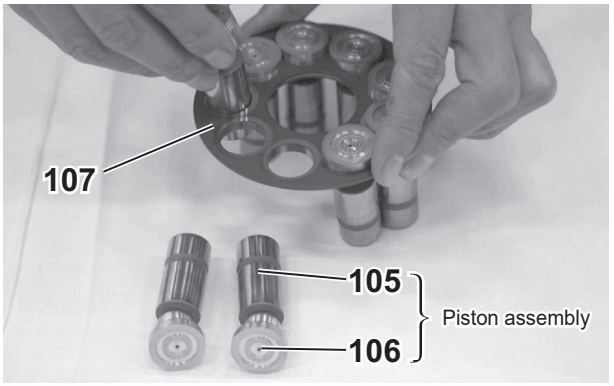
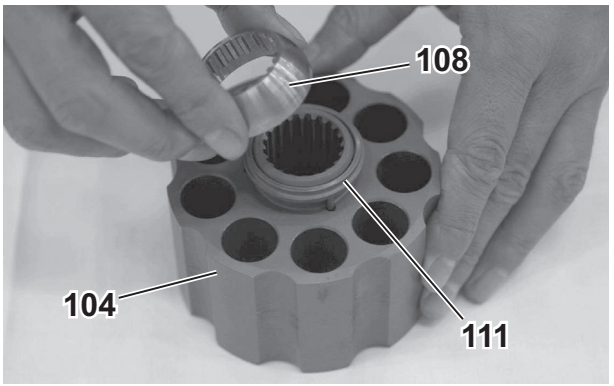
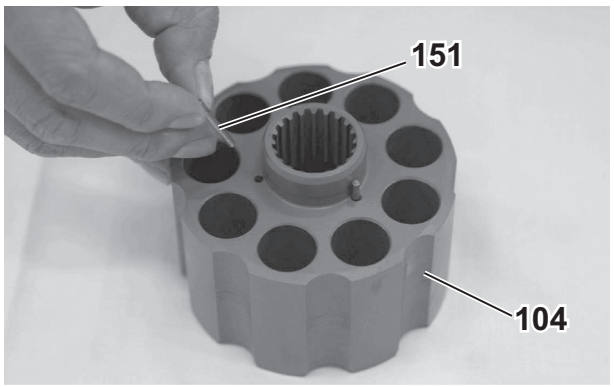
Procedure	
(6) Remove the two springs **330** and valves **327** from the rear flange **301**.	

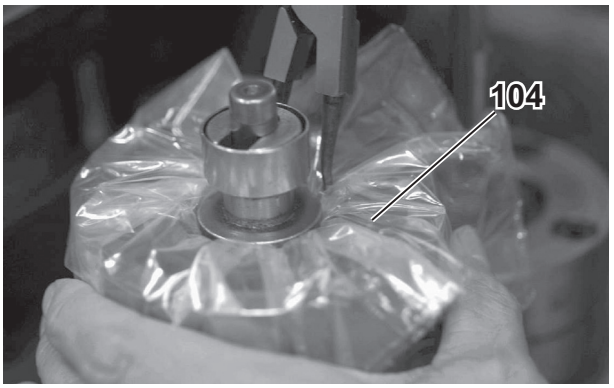
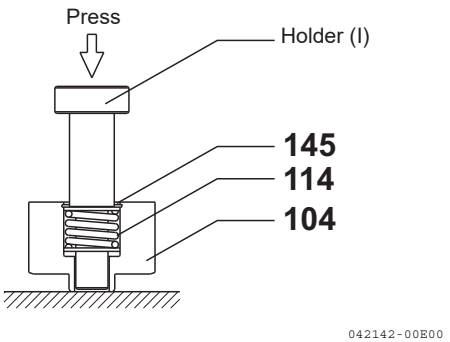
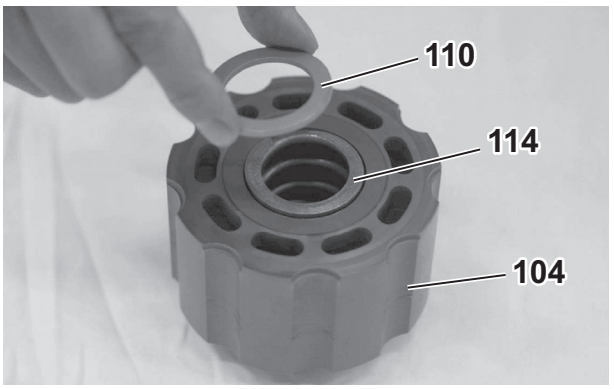
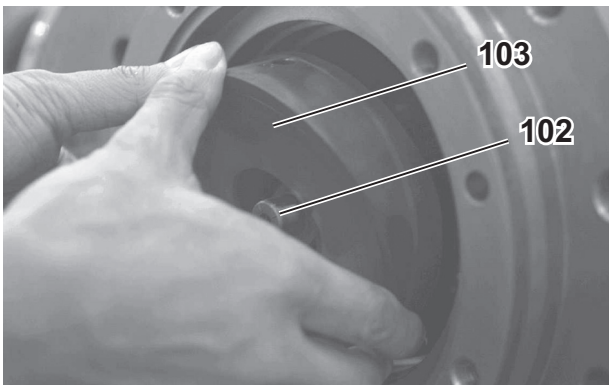
(7) Remove the O-ring **338** from the plug **382**. ***Note:*** *Do not reuse the removed O-ring **338**.*	

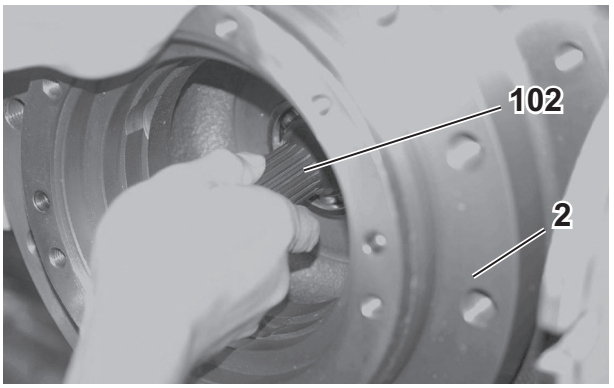
12. Removing the pilot valve in the rear flange. (1) Remove the plug **382** from the rear flange **301**. (2) Remove the O-ring **338** from the plug **382**. ***Note:*** *Do not reuse the removed O-ring **338**.*	

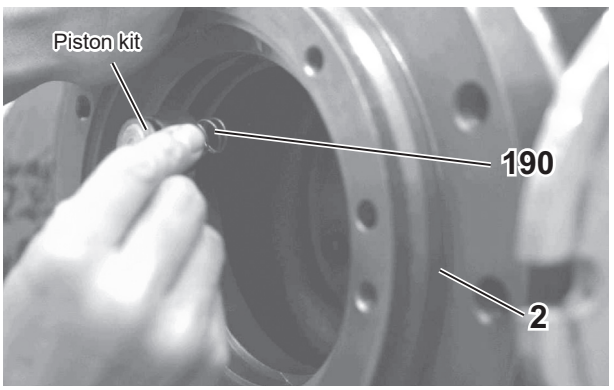
(3) Remove the spool **363** and the spring **366** from the rear flange **301**.	

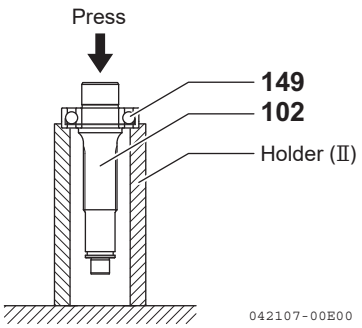
Procedure	
13. Disassembly of the parking brake ***CAUTION:*** *The abrupt injection of compressed air could cause the piston **112** to pop out.* *To ensure your safety, hold a protective cover over the piston **112**.* (1) Remove the piston **112** from the spindle **2** by injecting compressed air into the access hole in the spindle **2**.	
(2) Remove the O-rings **135**, **139** from the piston **112**. ***Note:*** *Do not reuse the removed O-rings **135**, **139**.*	
14. Disassembly of the Hydraulic motor ***Note:*** *Place an oil receptacle just below the motor to catch the oil.* (1) Turn the motor 90 degrees. (2) Drain the hydraulic oil from the motor. (3) Take out the three mating plates **116** and the two friction plates **115**.	
(4) Hold the cylinder block **104** by hand, turn alternately 2-3 times, and remove the **106** adhered on the swash plate **103**. ***Note:*** *If you remove the cylinder block **104** as it is, the shoe **106** remains adhered on the swash plate **103**, and the parts (piston, shoe and etc.) mounted on the cylinder block will come off the cylinder block **104** and fall into the spindle **2**.*	

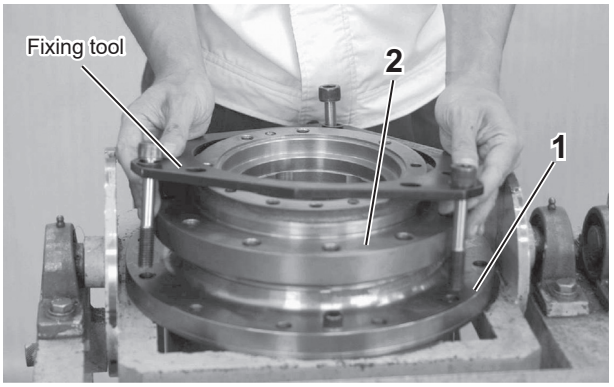
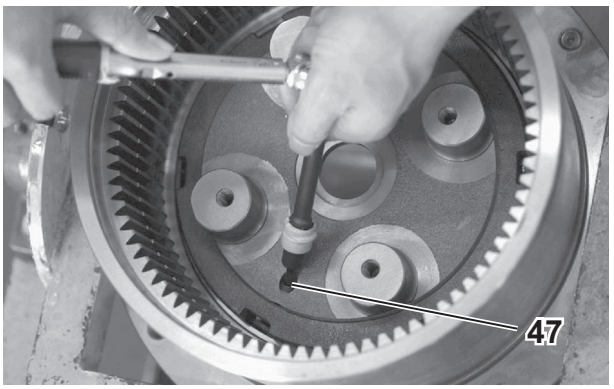
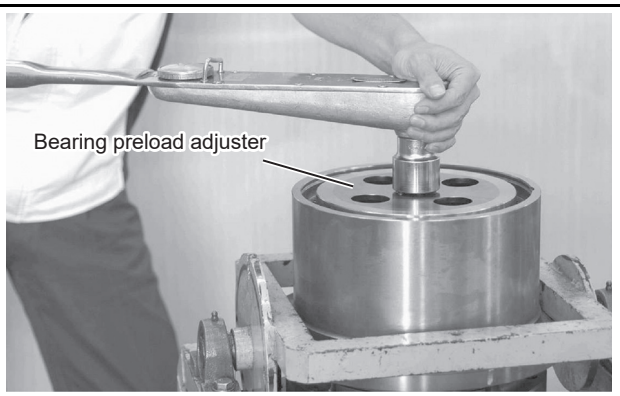
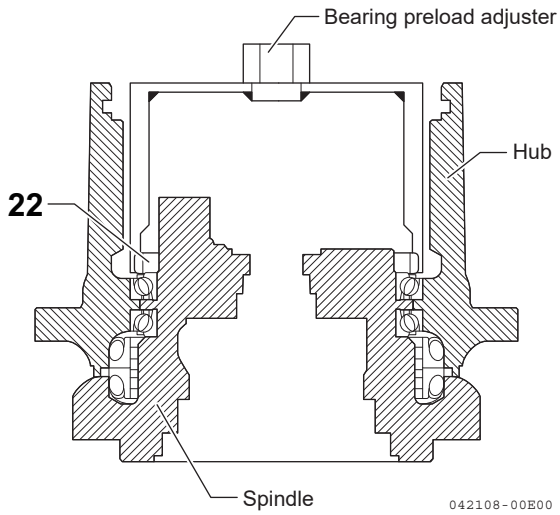
Procedure	
(5) Draw out the cylinder block **104** from the shaft **102**. (6) Remove the piston assembly (piston **105**, shoe **106**) and retainer plate **107** from the cylinder block **104**. ***Note:*** *When removing the piston assembly, grip the retainer plate **107** with both hands and remove it together with the retainer plate.* *The piston assembly is a minimum unit.* *If replacement is necessary, replace the piston assembly as one unit.*	
(7) Remove the nine piston assemblies (piston **105**, shoe **106**) from the retainer plate **107**.	
(8) Remove the thrust ball **108** from the cylinder block **104**.	
(9) Remove the washer **111** and the three rollers **151** from the cylinder block **104**.	

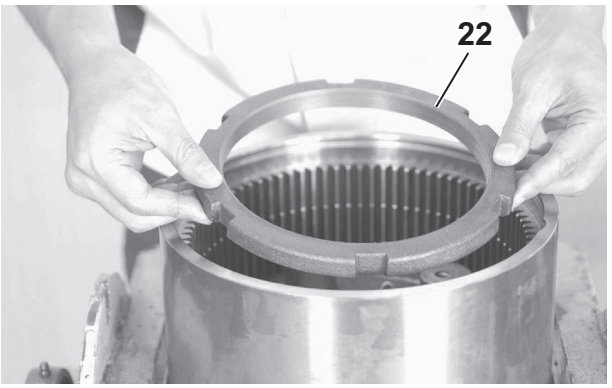
Procedure	
15. Removal of the spring inside the cylinder block (1) Place the cylinder block **104** on the press bench. ***Note:*** *The spring is removed only when replacing.* *The spring is removed by lining up the shaft centers of the holder (Ⅰ) and washer in order to prevent damage to the cylinder block through contact.* *Cover the cylinder block with a vinyl sheet to prevent the sliding surfaces of the cylinder block from being damaged.*	
(2) Place the holder (Ⅰ) on the washer **110**, and while clamping the holder with the press, remove the snap ring **145** with snap ring pliers. ***CAUTION:*** *Release the press slowly. Releasing it suddenly may cause the spring to fly out and causing the danger of injury.*	
(3) Remove the snap ring **145**, washer **110**, spring **114** and washer **110** from inside the cylinder block **104**.	
16. Removal of the swash plate (1) Take out the swash plate **103** from the shaft **102**. ***Note:*** *When removing the swash plate **103**, ensure that the pivot **167** is not adhered on the swash plate.*	

Procedure	
(2) Pull the shaft **102** out of the spindle **2**. Remove the ball bearing **149** at the same time. ***Note:*** *Lightly tap the tip of the shaft on the reduction side with a plastic hammer to allow the shaft to come off easily. Otherwise the shaft may pop out.*	

(3) Take out the two pivots **167** and the two parallel pins **171** from the spindle **2**. (4) Blow compressed air through the passage of the spindle **2**. Take out the 1st/2nd speed piston kit and spring **190** from the spindle **2**. • Piston assembly { Piston **161**; Shoe **162** }	

17. Removal of the ball bearing ***Note:*** *The ball bearing is removed only when replacing.* (1) Place the holder (Ⅱ) on the press bench and put the shaft **102** into the holder. (2) Remove the ball bearing **149** from the shaft **102** by pressing on the shaft end with a press. ***Note:*** *Do not reuse the removed ball bearing.*	

Procedure	
18. Removal of the ring nut (1) Fix the hub **1** and spindle **2** with the fixture. The fixture should be tightened gradually in opposite locations. (2) Invert the motor. (The reduction gear is turned up.)	
(3) Remove the two hexagon socket set screws **47**.	
(4) Loosen the ring nut **22** with the bearing preload adjuster. ***Note:*** *Do not reuse the removed ring nut **22**.*	 

Procedure	
(5) Take out the ring nut **22** from the spindle **2**.	

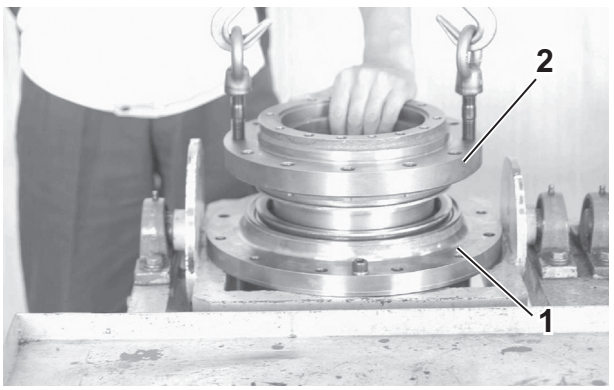
19. Removal of the ring nut

(1) Invert the motor. (Turn up the motor.)

(2) Remove the fixture.

(3) Fasten the eye bolt (2 bolts, for M16) in the mounting holes of the spindle **2** so that they are symmetrically positioned.

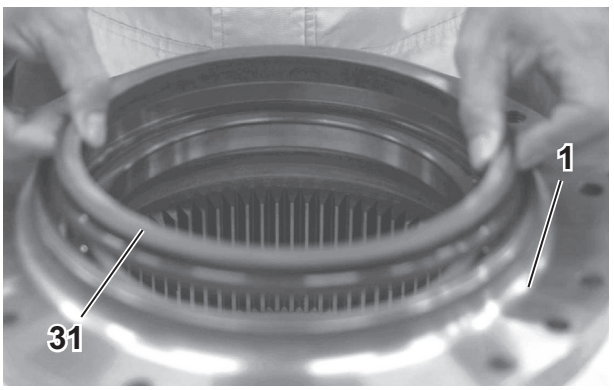
(4) Attach the hook on the eye bolts. Carefully and slowly hoist with a crane and remove the spindle **2** from the hub **1**.
At this time, the floating seal **31** and oil seal **132** come off together.



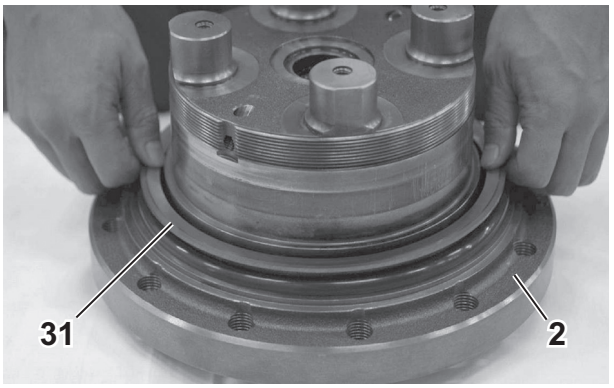
20. Ball bearing removal

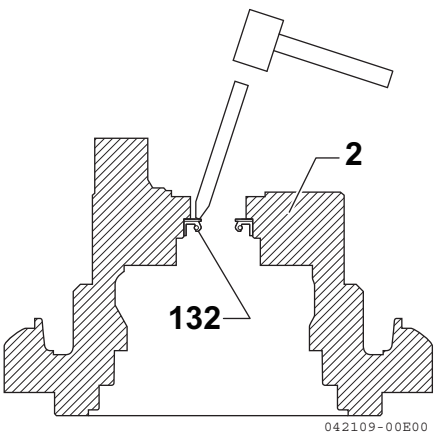
(1) Remove the floating seal **31** from the hub **1**.

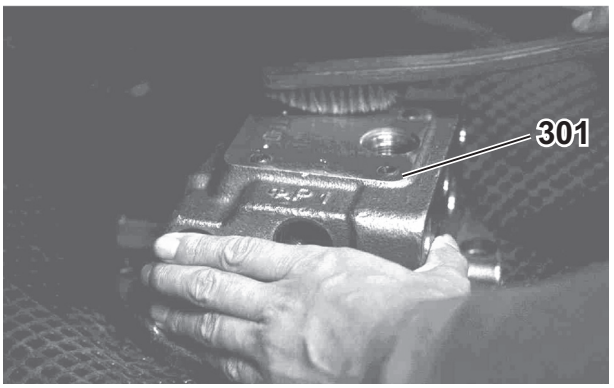
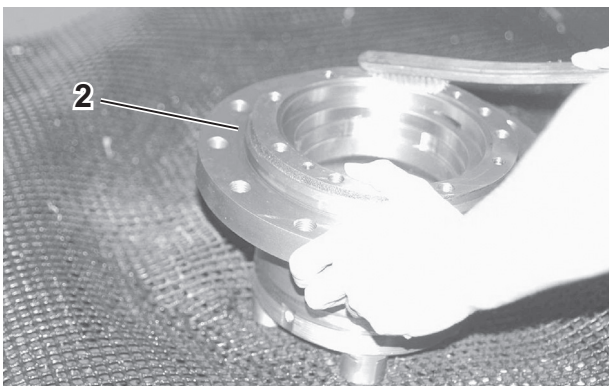
Note:
*Do not reuse the removed floating seal **31**.*

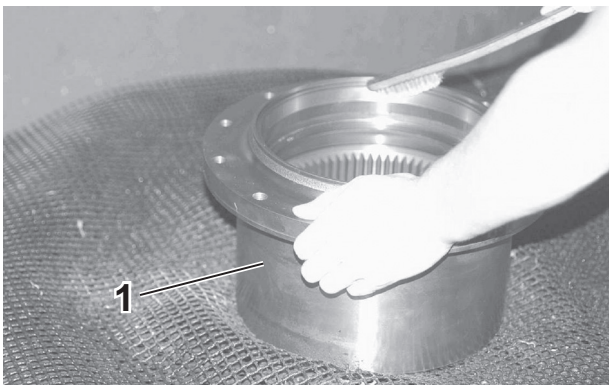


Procedure	
(2) Tap the end face of the ball bearing **24** with an aluminum rod (pin punch) and hammer to remove the ball bearing from the hub **1**. ***Note:*** *When the fit section of the outer race of the ball bearing **24** comes out of the hub **1**, the ball bearing **24** drops from the hub **1**.* *Therefore, place a receptacle under the workbench and spread a rubber mat on the receptacle so as not to damage the parts.* (3) Turn over the travel motor. (4) Tap the end face of the outer race of the ball bearing **24** with an aluminum rod (pin punch) and hammer to remove the ball bearing from the hub **1**. ***Note:*** *Remove ball bearing **24** little by little, tapping evenly the end face of outer race of the ball bearing at 3 or 4 points so that the ball bearing is not suck.*	

21. Removal of the spindle fittings (1) Remove the floating seal **31** from the spindle **2**.	

(2) Remove the oil seal **132** from the spindle **2**. ***Note:*** *Do not reuse the removed floating seal **31** and oil seal **132**.*	

Procedure	
22. Washing (1) Separate the hub **1**, spindle **2**, cover **13** and rear flange **301** (hereafter called the built-in parts) from other parts. (2) Wash the built-in parts in a wash tank. ***Note:*** *Carefully wash to remove any darts from the external surfaces.* ***CAUTION:*** • *Wash all parts carefully with kerosene. Be careful as there is a possibility that they ignite.* • *To prevent the built-in parts from being marred by dirt during washing, immerse the parts in kerosene long enough for any dirt or oil to become loose and float to the top before washing them.* (3) Fill a primary washing vessel with kerosene. Put the built-in parts in it and wash them.	 

23. Finish washing (1) Rinse the washed parts in the rinsing sink filled with clean kerosene by gently shaking each parts in the kerosene. (2) Using clean, lint-free cloth, wipe each rinsed part to remove dripping kerosene. ***Note:*** *Dry the inside of the hub **1** and the spindle **2** by spraying with compressed air until they are dry and clean.* *Let other parts dry naturally until they are dry and clean.* *After drying, coat every part with oil.*	

6-7-8 Service Standard

Follow these standards when disassembling and inspecting the motor. Handle the various parts carefully.
Be especially careful not to damage the moving and sliding parts.

1) Seals

Once disassembled, all seals (O-rings, oil seals, floating seals) should be replaced with new ones even if no damage is observed.

2) Service standards for parts subject to wear

(1) Replace all parts that have severe damage on appearance.

(2) Replace all parts that have the following problems.

Item No.	Parts	Trouble	Reference value	Allowance value
[1]	Hub	• Severe damage on appearance. • Pitting on ring gear teeth. • Abnormal wear such as scuffing.	–	–
[2]	Spindle	• Serious damage in appearance. • Abnormal wear such as scuffing.	–	–
[3]	Carrier assy	• Abnormal wear such as scuffing.	–	–
[4] [5] [6] [7]	Sun gear (1) Sun gear (2) Planetary gear (1) Planetary gear (2)	• Pitting on tooth surface. • Flaking phenomenon on rolling surface of bearing.	–	–
[10] [11] [12]	Thrust washer 1 Thrust washer 2 Thrust washer 3	• Sliding surface is tarnished. • Sliding surface is abnormally worn.		
[24]	Ball bearing	• Dents, flaking or uneven wear on the contact surface.	–	–
[27] [28]	Needle roller bearing	• Pitting on the roller. • Cage end face has abnormal wear.	–	–
[29] [30]	Inner race	• Flaking phenomenon on the rolling face of the bearing.	–	–
[301]	Rear flange	• Flaw on the sliding part with spools **323**, **363**.	–	–
[102]	Shaft	• Abnormal wear on contact surface with the oil seal **132**. • Abnormal wear on the spline.	–	–
[103]	Swash plate	• Seizure	–	–
[104]	Cylinder block	• Spline section is worn. • Inner surface of bore is worn too much. • Flaw and wear on the sliding surface with the timing plate **109**.	–	–
[105] [106]	Piston assembly Piston Shoe	• Clearance is found in the axial direction between the piston **105** and shoe **106**. • Shoe is abnormally worn and unequally worn.	Clearance 0.002 in. (0.05 mm)	Clearance 0.006 in. (0.15 mm)
[107]	Retainer plate	• Sliding part with the shoe **106** is worn unequally. • Flaw and unequal wear on the sliding surface with the thrust ball **108**.	–	–
[108]	Thrust ball	• Uneven wear on the sliding surface with the retainer plate 107.	–	–

Item No.	Parts	Trouble	Reference value	Allowance value
[109]	Timing plate	• Seizure or uneven wear on the sliding surface.	–	–
[115] [116]	Friction plate Mating plate	• Both end faces are unequally worn. • Torque is not the specified torque. • Seizure	Braking torque 88.5 ft•lbf (120 N•m) or more	Braking torque 88.5 ft•lbf (120 N•m) or more
[112]	Piston	• Flaw on circumference.	–	–
[149] [150]	Ball bearing	• Dents, flaking or uneven wear on the contact surface.	–	–
[161] [162]	Piston kit Piston Shoe	• Circumference is abnormally worn. • Shoe is abnormally worn and unequally worn.	–	–
[323] [363]	Spool	• Circumference worn unequally. • Flaw on circumference.	–	–

6-7-9 Assembly

Basically, the assembly procedure is reverse to the disassembly.

1) Preparations

Prepare a workbench, tools and materials in the same way as for disassembly.

2) General Suggestions When Working

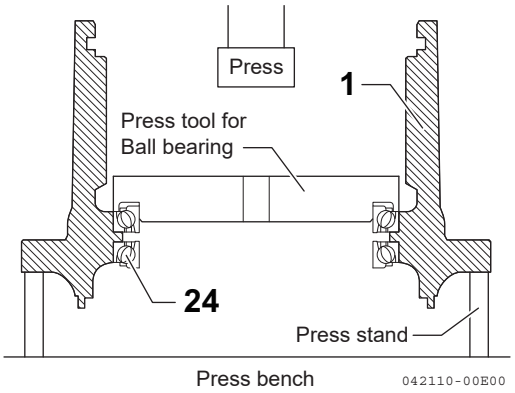
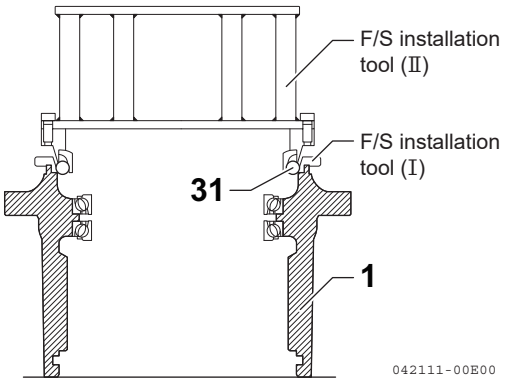
(1) Pay the same attention as for general suggestions for disassembly.
(2) When assembling, remove all foreign objects or metal fragments from parts, and make sure there are no burrs or dents, etc., on parts. If there are burrs or dents, remove them with an oilstone.
(3) Replace the O-rings, oil seals and floating seals with new ones.
(4) Grease is applied to the threaded portions and tapped holes of the spindle **2** as adhesive agent when assembling.
Remove the grease by using the tap (M10 P1.5), and wash with solvent. After that, remove the solvent of the holes by spraying with compressed air.
Replace the hexagon head bolts **51** with new ones.
(5) Grease is applied to the threaded portions and tapped holes of the carrier **3** as adhesive agent when assembling.
Remove the grease by using the tap (M8 P1.25), and wash with solvent. After that, remove the solvent of the holes by spraying with compressed air.
Replace the hexagon head bolts **40** with new ones.
(6) Be careful not to damage O-rings, oil seals and floating seals when mounting. (Apply a small amount of grease to make them slippery.)
(7) Be sure to coat the moving and sliding parts of the hydraulic motor section and valve section with clean hydraulic fluid (NAS standard class 9 or less) and assemble.
(8) Do not use cloth gloves for assembly. (To prevent fiber pieces from causing faulty operation.)
(9) Bolts and plugs should be tightened by the torque value given in 1-2. Tightening Torque Table.
(10) When the assembly is complete, plug all ports to prevent dirt from entering.
(11) The photographs and drawing contained in the manual are of representative models.
Disassembly procedure is however not affected even if the product you are using partially differs.

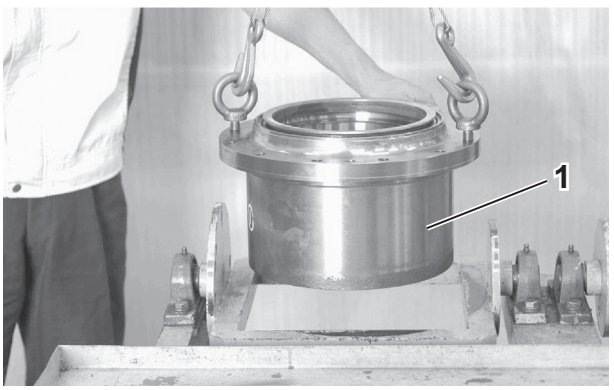
3) Assembling procedure

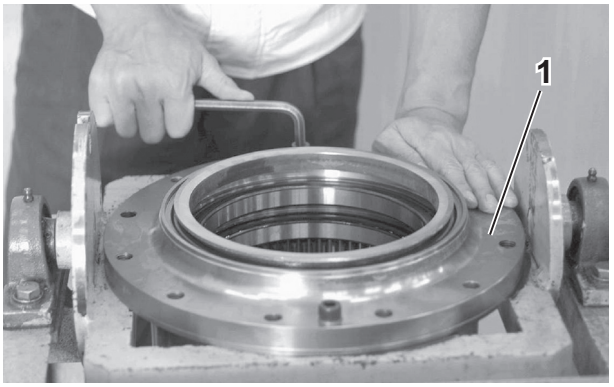
Note:
If reassembling after replacing parts, preload adjustment of the main bearing is necessary.
Before assembling, therefore, make sure the following parts have been replaced.

Renewal parts required for preload adjustment of the main bearing: Hub **1**, spindle **2**, ball bearing **24**.

Note:
If reassembling after replacing the parts listed above, be sure to reassemble using parts that have been adjusted. If you reassembly with parts that have not been adjusted, it will cause the travel motor to operate poorly or break down prematurely.

Procedure	
1. Hub section reassembly (1) Place the hub **1** on the press bench. (2) Insert the ball bearing **24** into the hub **1**. Place a press tool on the peripheral rim of the ball bearing **24** and press it and fit the ball bearing into the hub little by little. (3) Turn the hub **1** upside down (4) Insert the ball bearing **24** into the hub **1** in the same way ***Note:*** *Make sure that the installing direction of the angular ball bearing **24** is correct.* (5) Apply thinly grease on the outside circumference of the O-ring of the floating seal **31**, and fit the floating seal in the floating seal groove of the hub **1**. ***Note:*** • *When applying grease to the O-ring of the floating seal, remove the O-ring from the floating seal and apply lightly grease to the entire surface of it.* • *To mount the floating seal, place the F/S installation tool (Ⅱ), floating seal and F/S installation tool (Ⅲ) in that order, and press in until the F/S installation tool (Ⅱ) reaches the F/S installation tool (Ⅲ).* *Remove the installation tools, and make certain that the end face of the hub and the face of the floating seal are parallel with each other within a tolerance of 1mm.*	 

(6) Fasten two eye bolts in the screw holes of the hub **1** so that they are opposite of each other. (7) Attach the hook and wire to the eye bolts. Hoist the hub **1** with a crane, and put the hub **1** on the workbench.	

Note: *While matching the screw holes of the hub **1** and the mounting holes of the workbench, place the hub carefully in the mounting holes of the workbench.* (8) Fasten the hub **1** to the workbench so that the hexagon socket bolts are opposite of each other. ***CAUTION:*** *Tighten the hexagon socket bolts securely.* *Failure to do so could result in injury if the travel motor is turned upside down and falls.*	

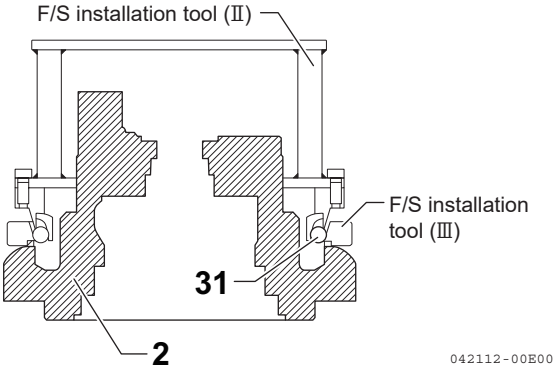
Procedure

2. Spindle assembly

(1) Apply grease thinly on the outside circumference of the O-ring of the floating seal **31** and mount the floating seal in the floating seal groove of the spindle **2**.

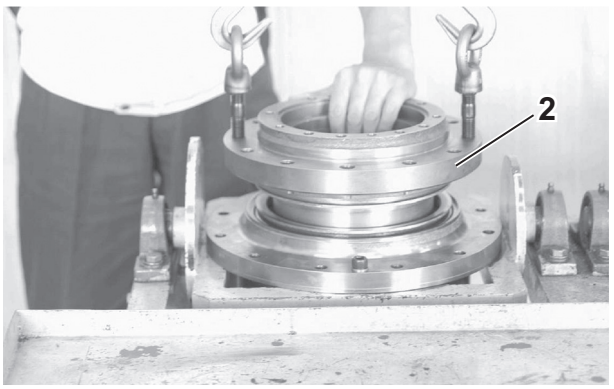
Note:

To mount the floating seal, place the F/S installation tool (Ⅲ), floating seal and F/S installation tool (Ⅱ) in that order, and press in until the F/S installation tool (Ⅱ) reaches the F/S installation tool (Ⅲ).
Remove the installation tools, and check the inclination of the surface of the floating seal to make sure it is within 1mm.

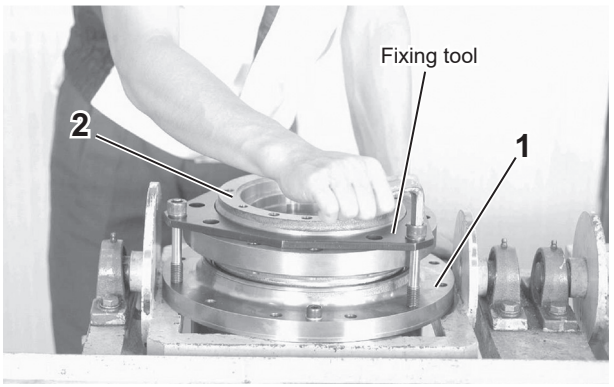


(2) Install the eyebolts to the spindle **2** that they are opposite of each other.

(3) Attach a wire with a hook to the eyebolts. Lift the spindle **2** by crane, and then slowly insert the spindle in the hub **1**.



(4) Fix the hub **1** and spindle **2** with the fixture in diagonal position.

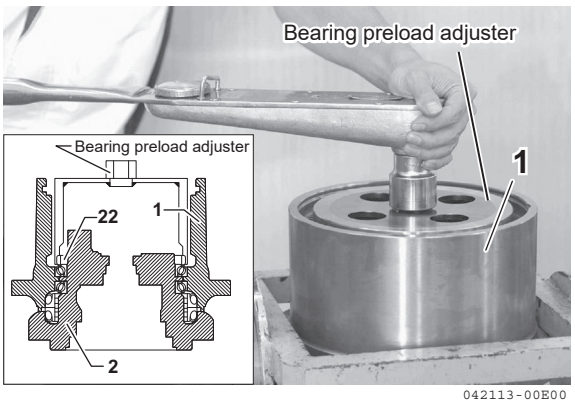


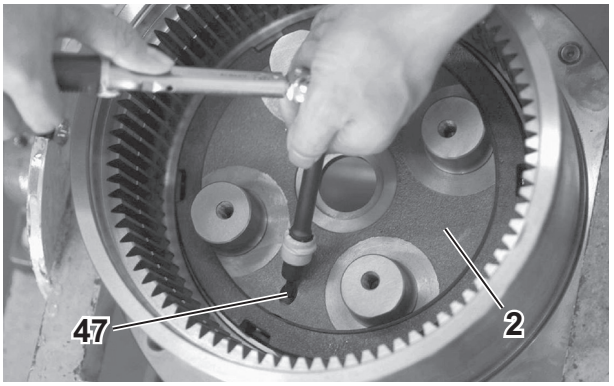
(5) Turn the motor upside down. (Turn up the reduction gear.)

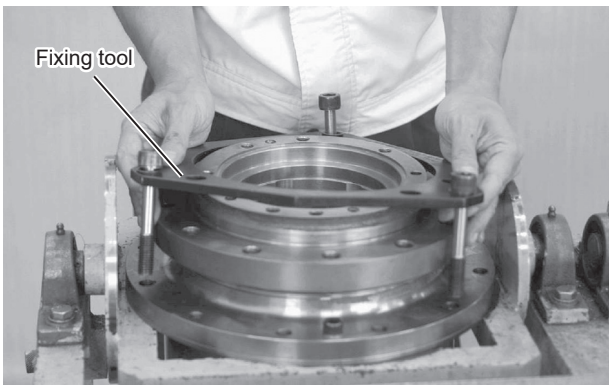
(6) Apply Loctite #638 to the thread part of the ring nut **22**.

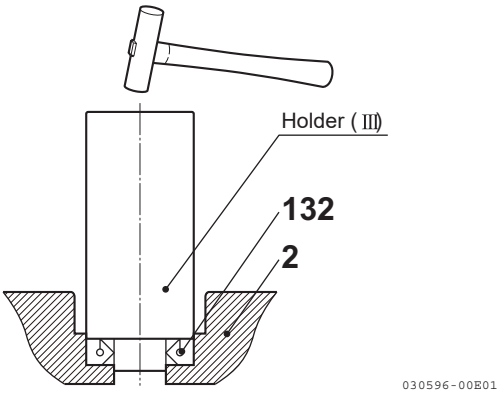
(7) Attach the ring nut **22** to the spindle **2** with the bearing preload adjuster.
Then, fit the ring nut **22** to the spindle **2** so that the side with the large chamfering is on the side of the ball bearing **24**.

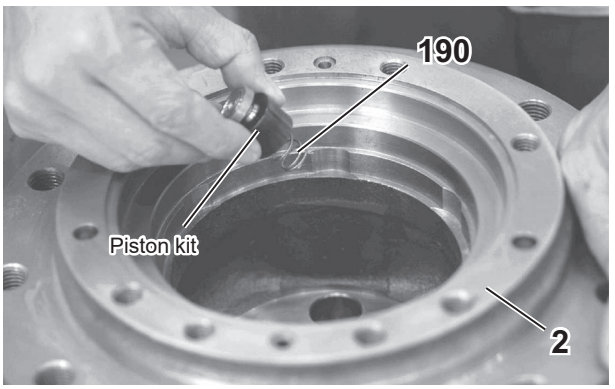
Tightening torque: 392.5 to 474.8 ft•lbf
(532.2 to 643.8 N•m)

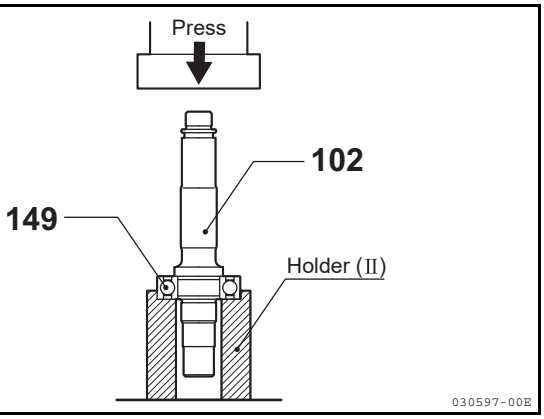


Procedure	
(8) Tighten the two hexagon socket set screws **47** with specified torque. **Tightening torque: 6.06 to 8.42 ft•lbf (8.21 to 11.41 N•m)** (9) After tightening up the screws, deform the entrance of the threaded holes to avoid loosening screws.	

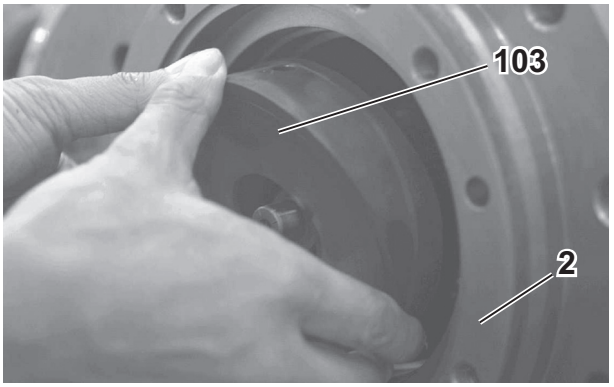
(10) Turn the motor upside down. (Turn up the motor.) (11) Remove the fixture.	

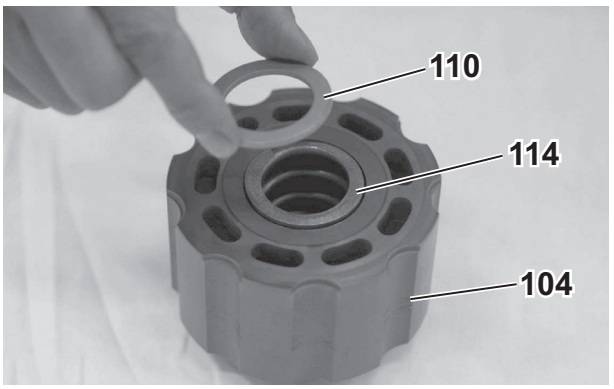
Procedure	
3. Assembling spindle fittings (1) Press fit the oil seal **132** into the spindle **2** with the holder (Ⅲ) and a hammer. ***Note:*** *Apply lithium grease to the lip section of the oil seal when mounting the oil seal.* *Press fit the oil seal **132** bore to the spindle **2** using the holder (Ⅲ) and a hammer.*	

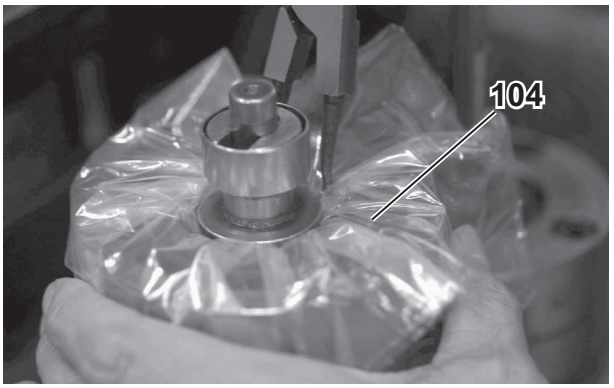
(2) Install the two parallel pins **177** into the pin holes of the spindle **2**. (3) Apply lithium grease to the hemispherical surface of the two pivots **167**, and fit it into the parallel pin **177** of the spindle **2**. (4) Apply lithium grease to the spring **190**, and install the spring into the piston kit (piston **161**, shoe **162**). (5) Apply hydraulic fluid to the sliding surface of the piston assy, install it into the piston hole of the spindle **2**.	

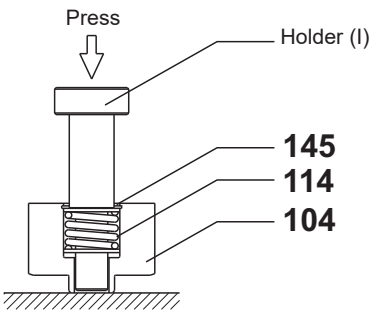
4. Installing shaft ***CAUTION*** *Wear thick leather gloves when handling the heated ball bearing.* (1) Put the ball bearing **149** in a heating tank and heat it at 100±10°C for ten minutes and then insert it into the motor shaft **102**.	

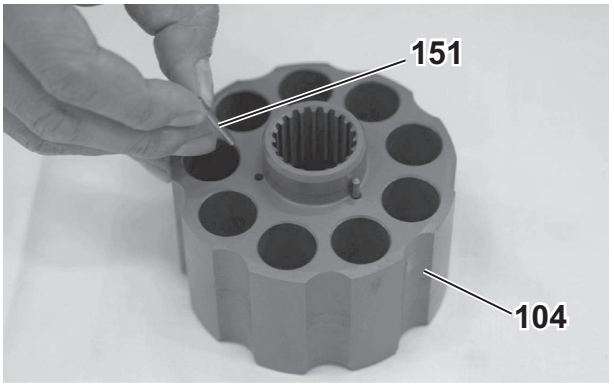
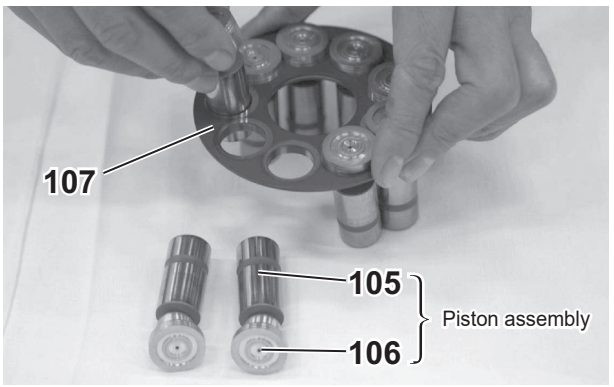
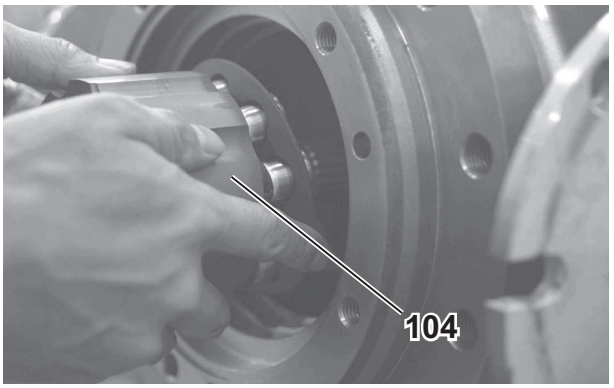
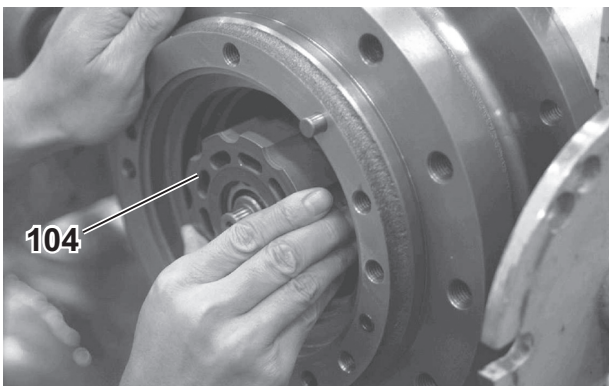
(2) Fit the motor shaft **102** slowly into the spindle **2**. (3) Turn the workbench 90 degrees. ***Note:*** *Take care not to scratch or cut the lip portion of the oil seal **132** in place with the splined foremost end of the shaft **102**.*	

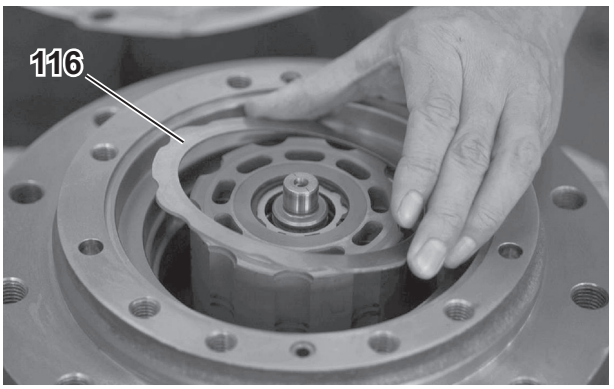
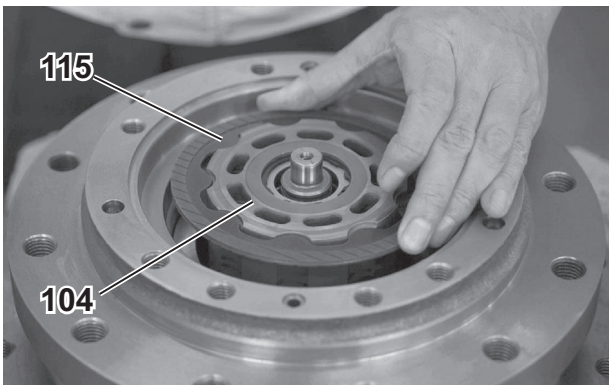
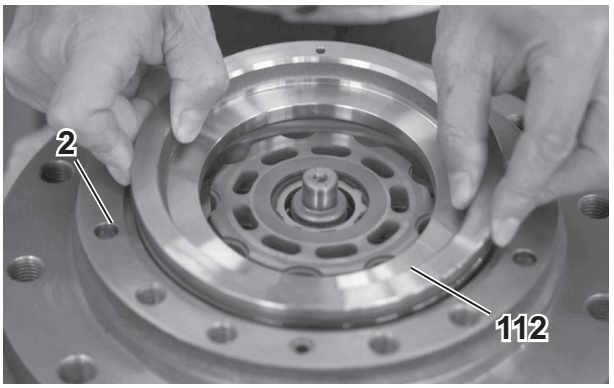
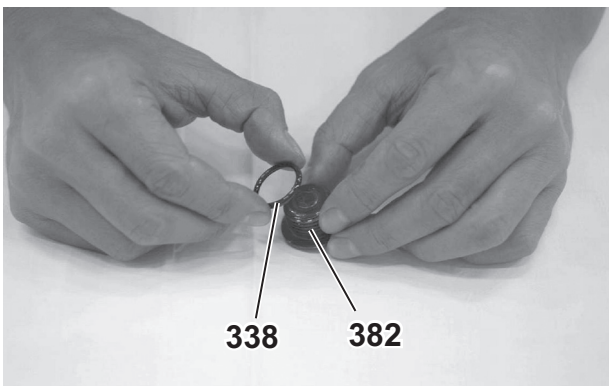
Procedure	
(4) Insert the swash plate **103** into the spindle **2**. ***Note:*** *Apply lithium grease to the mating surface of the swash plate **103** and the spindle **2**.* *Make sure that the pivots **167** mounted on the spindle **2** enter the pivot holes of the swash plate **103**.*	

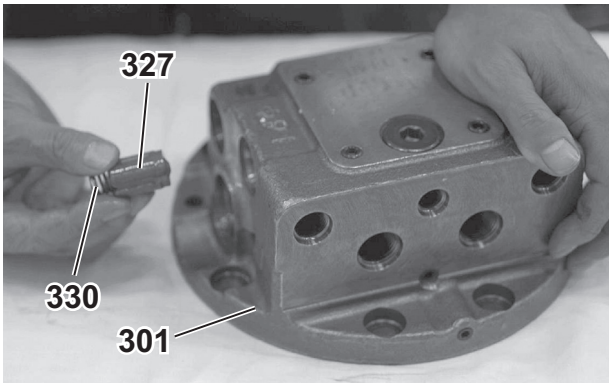
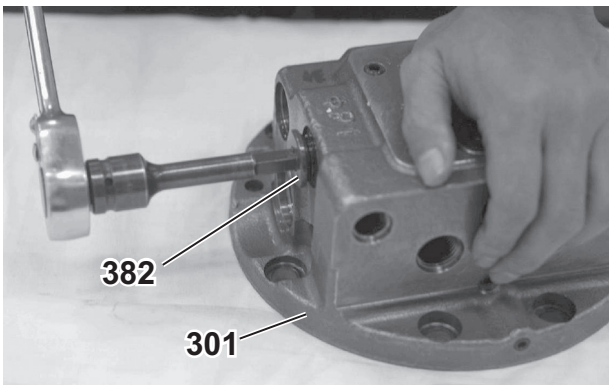
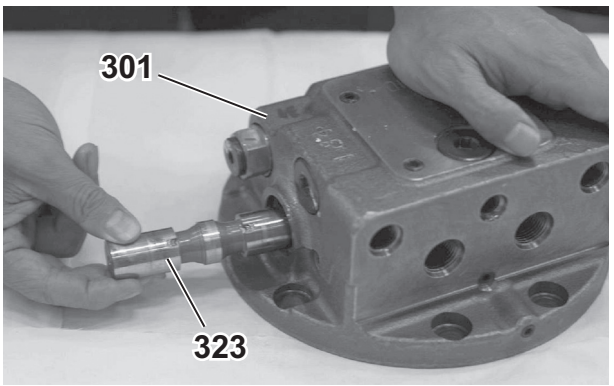
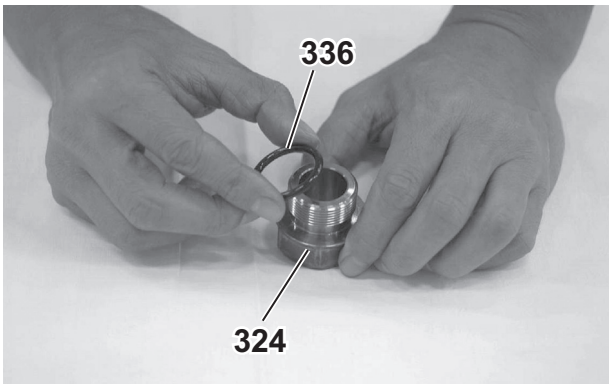
5. Assembling cylinder block interior ***Note:*** *Insert the THS snap rings **145** so that the snap edge faces to the entrance of the spring hole.* *Insert the washer **110** so that the sharp edge faces to the THS snap ring **145**.* (1) Insert the washer **110**, spring **114**, washer **110** and snap ring **145** in that order into the cylinder block **104**. (2) Place the cylinder block **104** on the press bench.	

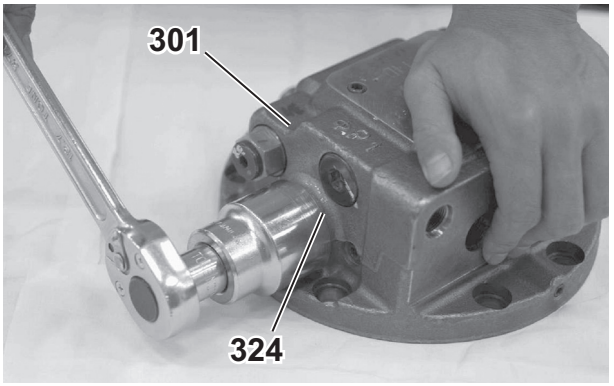
CAUTION *When inserting the snap ring **145**, if the tip of the pliers slips out of the hole of snap ring **145**, the snap ring **145** could jump out.* ***Note:*** *The press force of the spring **114** is 265.3 lbf (1180 N) or more.* *Cover the cylinder block **104** with a vinyl sheet so that the contact surface with the timing plate **109** does not get damaged.*	

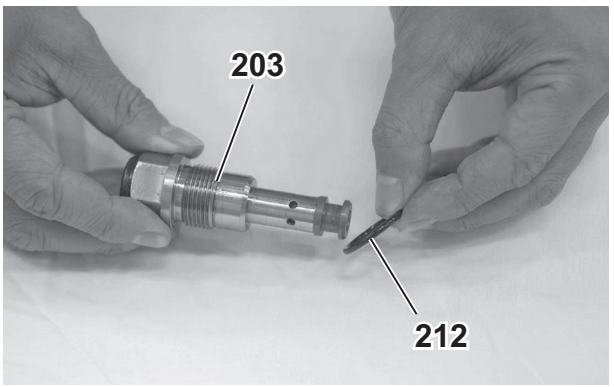
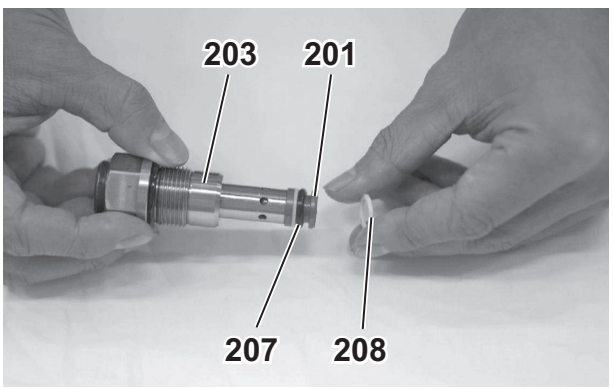
(3) Place the holder (Ⅰ) on the washer **110**, and while clamping with the press, fit the snap ring **145** in the snap ring groove of the cylinder block **104** with the snap ring pliers.	

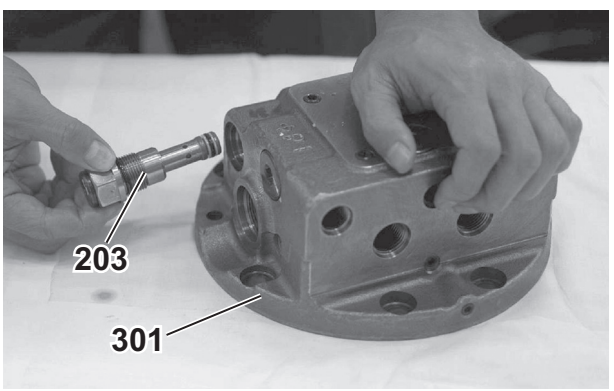
Procedure	
6. Assembly of the hydraulic motor parts (1) Place the three rollers **151** into the cylinder block **104**. Then place the washer **111** and the thrust ball **108** on the top.	
(2) Install the nine piston assemblies into the retainer plate **107**. ***Note:*** *After assembling, dip the assembly in hydraulic fluid.* (3) Fit the retainer plate **107** and the nine piston assemblies into the cylinder block **104**. ***Note:*** *Match the round surface sections of the retainer plate **107** and the thrust ball **108**.*	
(4) Install the cylinder block **104** to the shaft **102**. ***Note:*** *Install the cylinder block **104** into the spline of the shaft **102** by aligning the spline hole with the spline of the shaft.*	
(5) After installing the cylinder block **102**, turn it by hand and make sure that it fits properly. If not, inspect it. ***Note:*** *After installing the cylinder block **104**, do not raise it.* *If it raises, the thrust ball **108** separates and the cylinder block does not rotate.*	

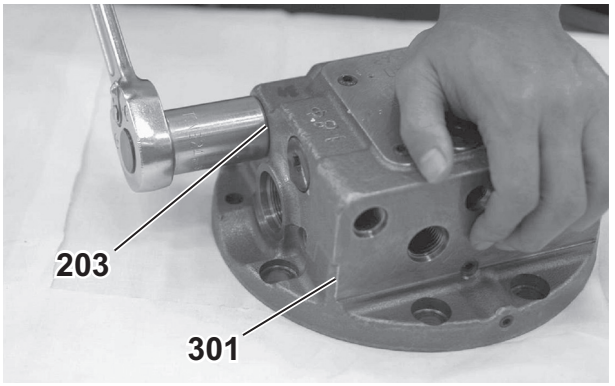
Procedure	
7. Assembly of parking brake section ***Note:*** *Install the friction plate to the cylinder block after immersing the friction plate **115** in hydraulic fluid.* (1) Turn the workbench 90 degrees. (2) Install the mating plate **116**.	
(3) Install the friction plate **115** into the groove outside of cylinder block **104** alternately. Then install mating plate **116**, friction plate **115** and mating plate **116**. (4) Fit the O-rings **135**, **139** to the O-ring groove of the piston **112**. At this time, apply a thin coat of grease to the O-rings.	
(5) Install the piston **112** into the spindle **2**. ***Note:*** *If the piston **112** does not fit into the spindle **2** because of the resistance of the O-rings, tap the edge of the piston **112** lightly and equally with a plastic hammer.* *Be careful not to damage the O-rings at this time.*	
8. Assembly of the brake valve parts in the rear flange (1) Fit the two O-rings **338** to the two plugs **382**. ***Note:*** *Apply grease to the two O-rings **338**.* (2) Install the two valves **327**, and the two springs **330** on the rear flange **301**. At this time, apply grease to it so that the valve **327**, spring **330** and plug **382** stick together.	

Procedure	
(3) Insert the two plugs **382** assembled in one piece in the rear flange **301** and temporarily tighten them. ***Note:*** *To insert the plug **382**, turn the tapped plug hole of the rear flange **301** to the top and align the center of the tapped hole with the center of the plug. This prevents the O-ring from being damaged and the spring **330** from coming out of the valve **327** due to contact between the bore of the rear flange and the valve.*	
Note: *If the spring **330** separates from the valve **327**, the valve **327** does not touch the sheet side of the rear flange **301** correctly. This causes an oil leak.* (4) After inserting the two plugs **382**, temporarily tighten them into the rear flange **301** with a hexagon wrench.	
(5) Insert the spool **323** into the rear flange **301**. ***Note:*** *Apply hydraulic fluid to the spool and insert the spool into the rear flange.* *To install the spool, align the hole of the rear flange with the spool shaft center so as to prevent the inner surface of the rear flange and the outer surface of the spool from being damaged due to interference.* *Otherwise internal leaks will occur after reassembly, resulting in performance deterioration of the travel motor.*	
(6) Insert the O-ring **336** into the plug **324**. ***Note:*** *Apply grease to the O-ring **336**.*	

Procedure	
(7) Install the spring retainer **325** and the spring **328** to the two plugs **324**. (8) Tighten the two plugs **324** to the rear flange **301**. ***Note:*** *When tightening the plugs to the rear flange, insert them carefully so that the spring is not deformed.* (9) Temporarily tighten the two plugs **324** to the rear flange **301** with a spanner.	

9. Reassembling the SRV part to the rear flange (1) Attach the O-ring **207** and backup ring **208** to the valve sheet **201**. (2) Attach the O-ring **212** to the sleeve **203**. ***Note:*** *Apply grease to the O-rings **207**, **212**.*	 

(3) Insert the sleeve **203** to the rear flange **301**. ***Note:*** *Internal parts of the sleeve kit shall be handled as a set. So do not use separately supplied parts.*	

Procedure	
(4) Temporarily tighten the two sleeves **203** with a wrench. ***Note:*** *When inserting the plug into the rear flange **301**, insert it carefully so that the spring is not deformed.*	

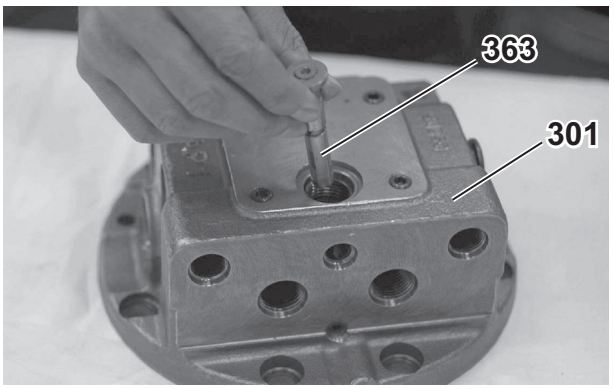
10. Assembly of the rear flange mounted parts

(1) Put the rear flange **301** on the workbench, with its inner face up.

[1] Insert the spindle **2**, then turn the rear flange **301** around.

[2] Insert the spring **366** and spool **363** into the rear flange **301**.

Note:
When inserting the plug into the rear flange, insert it carefully so that the spring stays in its position.



[3] Fit the O-ring **338** onto the plug **382**.

Note:
*Apply grease to the O-ring **338**.*

[4] Tighten the plug **382** to the rear flange **301**.

[5] Temporarily tighten the plug **382** to the rear flange **301**.

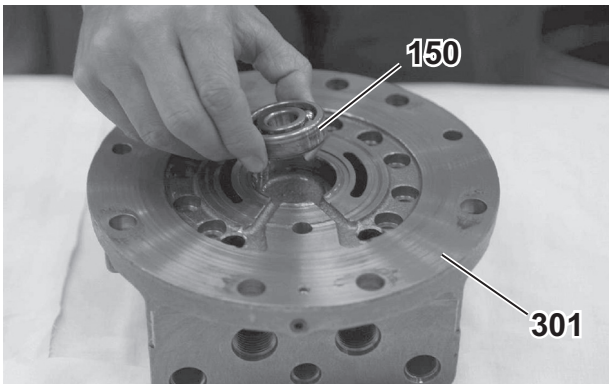
(2) Apply hydraulic fluid to the ball bearing **150**, and fit the deep groove ball bearing into the rear flange **301**.

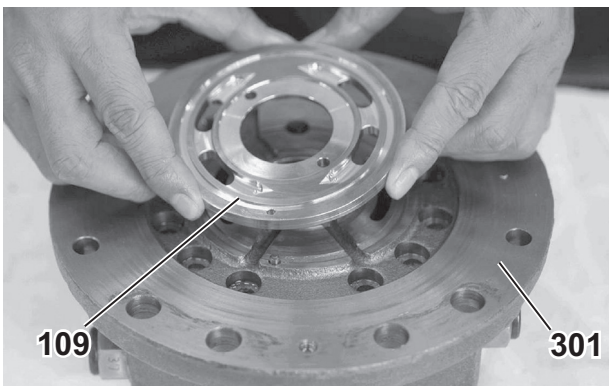
(3) Insert the two parallel pins **342** into the pin holes of the rear flange **301**.

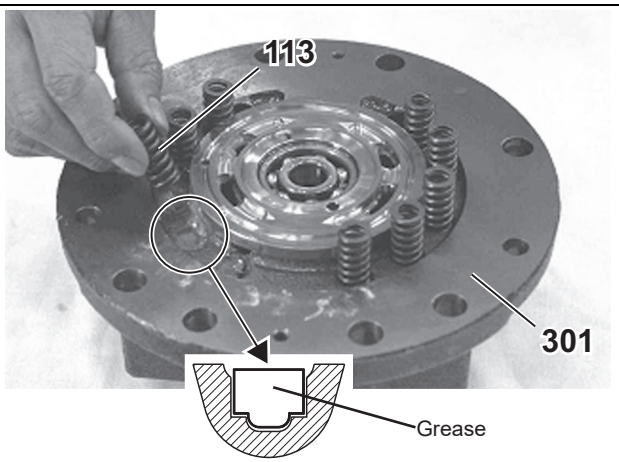
(4) Apply grease to the mating face of the timing plate **109** in contact with the rear flange **301**.

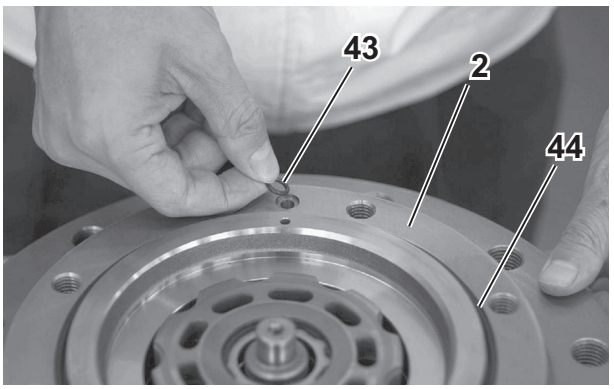
(5) Fit the timing plate **109** on the rear flange **301** using the parallel pin **342** and ball bearing **150** as a guide.

Note:
*Fit the timing plate **109** until the timing plate adheres to the rear flange **301**.*
*Adhesion prevents the timing plate **109** from falling from the rear flange **301** when mounting the rear flange **301** on the spindle **2**.*

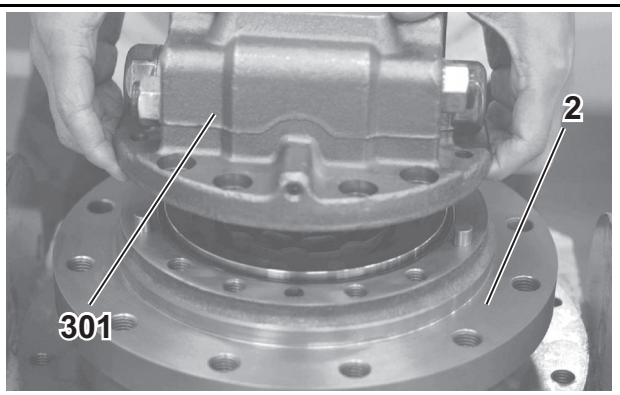


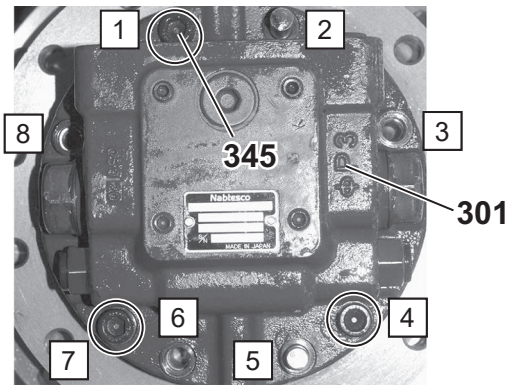
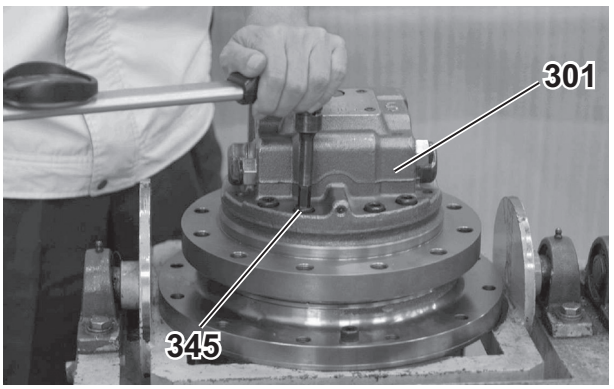
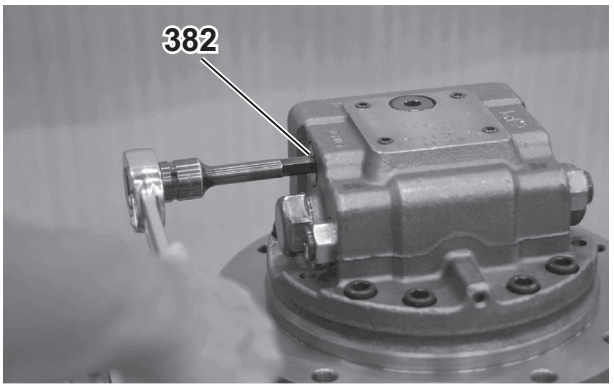
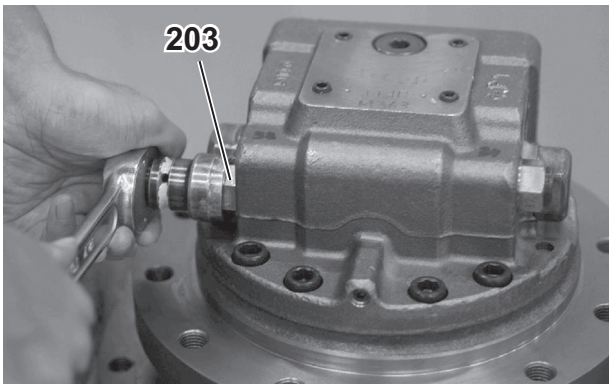


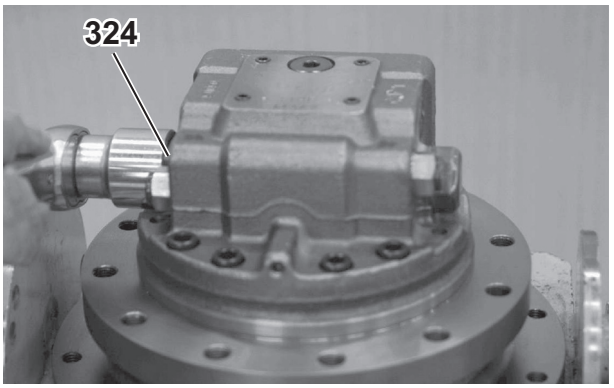
Procedure	
(6) Install the ten springs **113** into the rear flange **301**. ***Note:*** *Sufficiently apply grease to the spring to prevent the ten springs **113** from falling from the rear flange **301**.*	

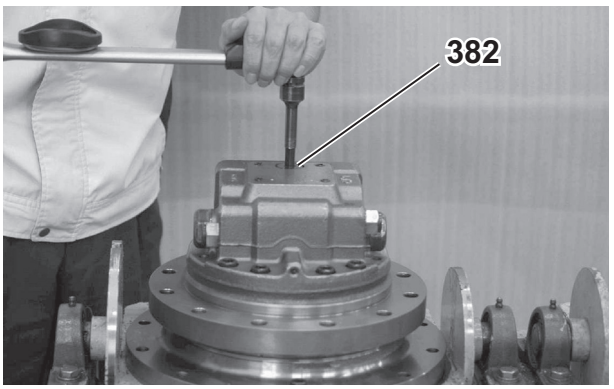
11. Connection of the rear flange with the spindle (1) Fit the O-rings **43**, **44** in the O-ring groove of the spindle **2**. ***Note:*** *Fit the O-ring **43** without applying grease.* *If reassembled with grease applied, the grease may bleed from the mating face of the rear flange **301** and spindle **2** when the travel motor is running.* *This may be mistaken as an oil leak, so do not apply grease.*	

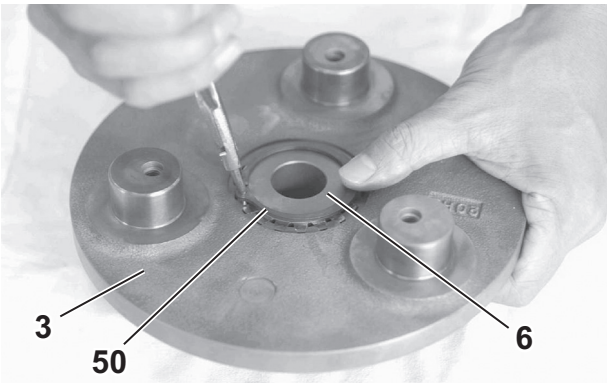
(2) Insert the two parallel pins **42** into the spindle **2**. (3) Put 1.2 liters of hydraulic fluid into the spindle **2**. (4) Apply hydraulic fluid to the timing plate **109** of the cylinder block **104**.	

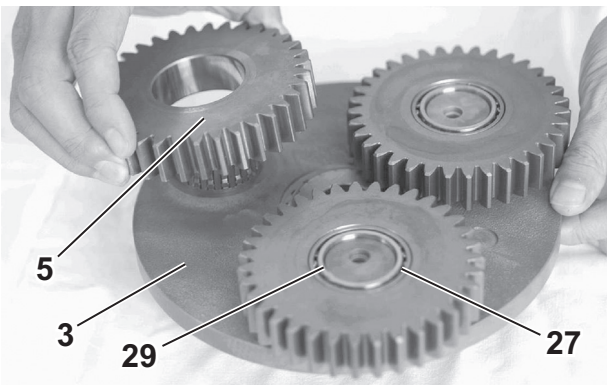
(5) Install the rear flange **301** onto the spindle **2** so that the two parallel pins **42** on the spindle enter the pinholes in the rear flange **301**.	

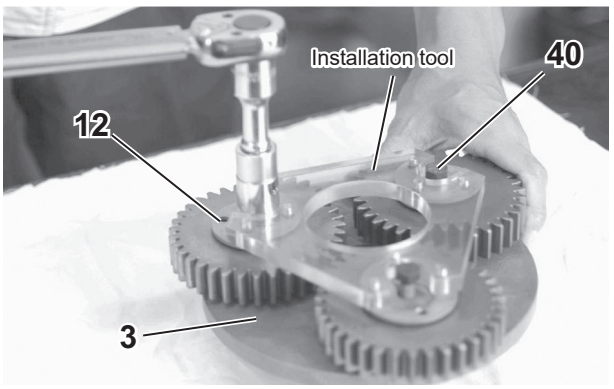
Procedure	
(6) Insert three hexagon socket head cap screws **345** (No.1, 4, 7). Temporarily tighten them **345** slowly and evenly with a hexagon wrench so as to keep the gap between the rear flange **301** and spindle **2** even. ***Note:*** *If you feel that something is wrong even a little while temporarily tightening, disassemble again and check that no part has any abnormality. After that, continue the assembling.*	
(7) Insert the remaining five hexagon socket head cap screws **345** and tighten them. (8) Tighten the eight hexagon socket bolts **345** equally and evenly with the specified torque. **Tightening torque: 63.7 to 86.8 ft•lbf (86.3 to 117.7 N•m)**	
(9) Tighten the plug **382** with the specified torque. **Tightening torque: 57.9 to 86.8 ft•lbf (78.5 to 117.7 N•m)**	
(10) Tighten the sleeve **203** with the specified torque. **Tightening torque: 90.2 to 111.9 ft•lbf (122.3 to 151.7 N•m)**	

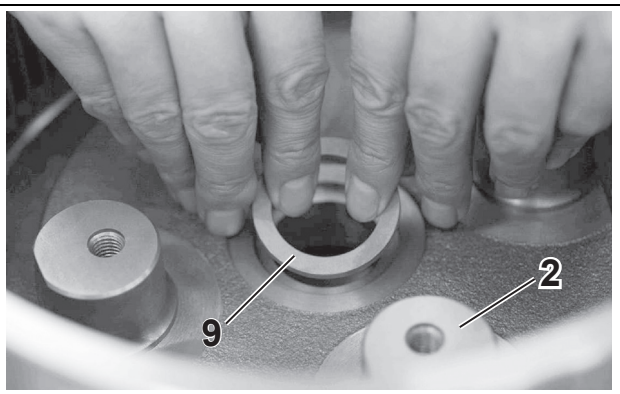
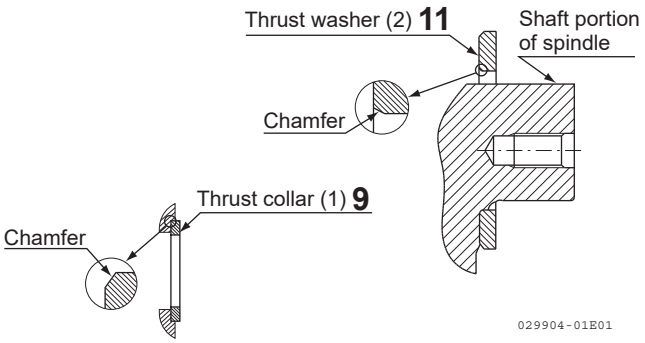
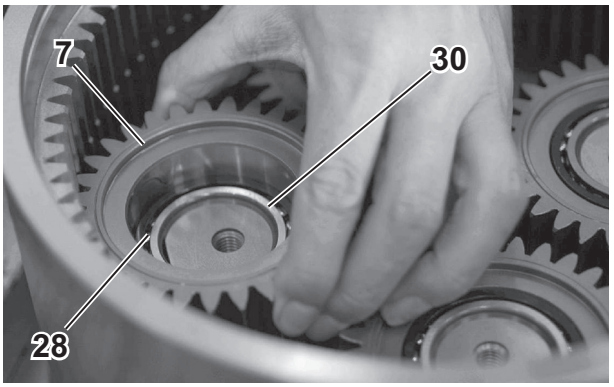
Procedure	
(11) Tighten the plug **324** with the specified torque. **Tightening torque: 231.4 to 289.3 ft•lbf (313.8 to 392.2 N•m)**	

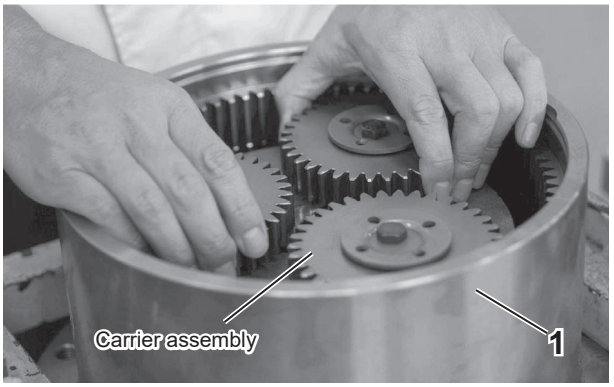
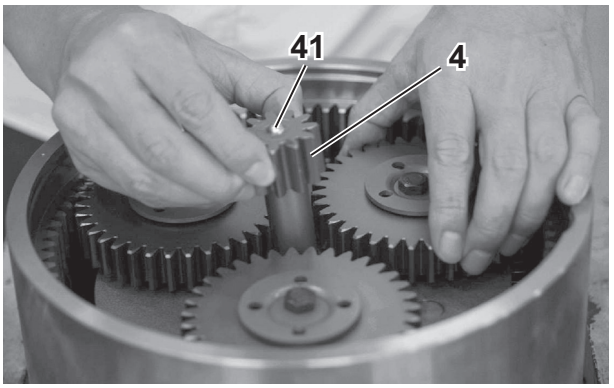
(12) Tighten the plug **382** with the specified torque. **Tightening torque: 57.9 to 86.8 ft•lbf (78.5 to 117.7 N•m)**	

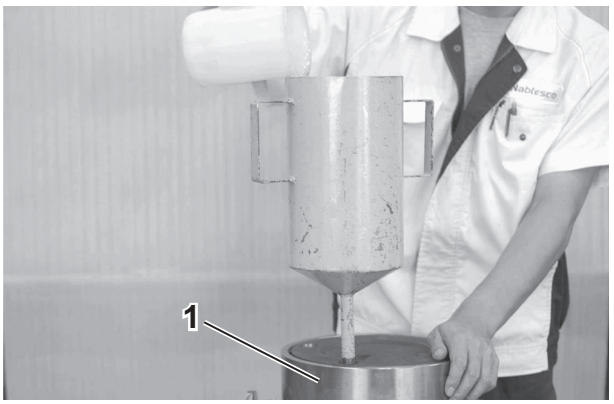
Procedure	
12. Carrier assy assembly (1) Insert the sun gear (2) **6** in the carrier **3**, and insert the retaining ring **50** into the retaining ring groove of the sun gear (2) **6**.	

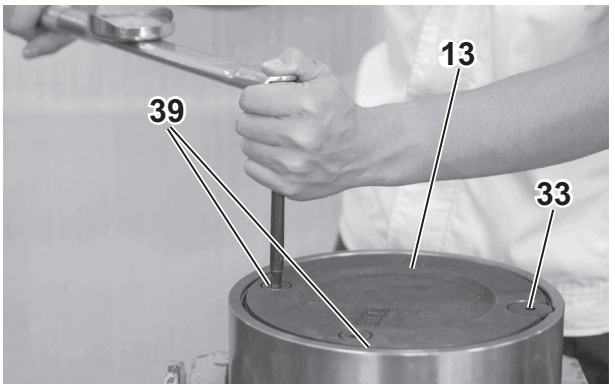
(2) Install the three inner races **29**, three needle roller bearings **27**, planetary gears (1) **5** and three thrust washers (3) **12** in that order to carrier **3**. ***Note:*** *If the tapped hole of the carrier **3** is smeared with oil or grease, degrease it by using the tap (M8 P1.25). After that, clean it with solvent, and remove the solvent of the holes by spraying with compressed air.* *Otherwise axial-force is not sufficiently applied, which may cause a bolt to loosen.*	

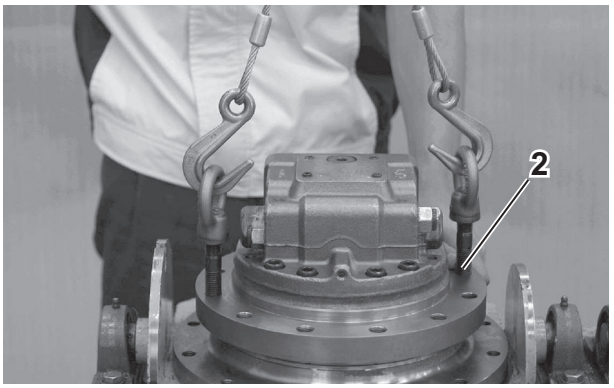
(3) Install the three thrust washers (3) **12** in that order to the carrier **3** with the installation tool (carrier **3**). (4) Install the three thrust washers (3) **12** to the carrier **3** with the three hexagon head bolts **40**. **Tightening torque: 20.9 to 28.2 ft•lbf (28.4 to 38.2 N•m)** ***Note:*** *If you do not use a jig, be careful when tightening the thrust washer (3) **12** on the circumference of the companion. After tightening, check if the planetary gears rotate smoothly.* [Carrier assy is complete]	

Procedure	
13. Planetary gear (2) assembly (1) Turn the workbench upside down. (Turn up the reduction gear). (2) Install the thrust collar (1) **9** to the spindle **2**.	
(3) Install the four thrust washers (2) **11**, to the shaft of the spindle **2**. ***Note:*** *Make sure that the inserting direction of the thrust collar (1) **9** and the four thrust washers (2) **11** is correct.*	
(4) Install the four inner races **30** onto the pole of the spindle **2**. (5) Install the four needle roller bearings **28** onto the pole of the spindle **2**. (6) Fit the four planetary gears (2) **7** to each pole of the spindle **2**, meshing with the internal teeth of the hub **1**. ***Note:*** *Remove adhesive material from the threaded hole of the spindle by applying M10 P1.5 tap.* *After that, clean and degrease the hole with solvent, and dry the solvent by spraying with compressed air.* *If this procedure is neglected, axial-force is not applied sufficiently, and a bolt may loosen.*	
(7) Install the four thrust washers (1) **10** to the spindle **2** with a jig to fix their position. (8) Install the four thrust washers (1) **10** onto the spindle **2** and tighten with the four hexagon head bolts **51**. **Tightening torque: 35.5 to 49.9 ft•lbf (48.09 to 67.71 N•m)** ***Note:*** *When the jig is not provided, make sure that the outer diameter of the washer (1) **107** does not interfere with the extruded rim of the planetary gear (1) **107**. After tightening, check that planetary gear **107** rotates smoothly.*	

Procedure	
14. Carrier assy assembly (1) Install the carrier assy, meshing with the internal teeth of the hub **1** and planetary gear (2) **7**.	
15. Sun gear(1) assembly (1) Insert the sun gear (1) **4** into the shaft **102**. At this time, install the steel ball **41** to the sun gear (1) **4**. ***Note:*** *When installing the steel ball, apply grease to the steel ball **41** for prevent it from falling from the sun gear (1) **4**.* (2) Fit the sun gear (1) **4**, meshing with the three planetary gears (1) **5**.	
16. Cover assembly (1) Fit the O-ring **35** in the O-ring groove of the hub **1**. ***Note:*** *Apply grease to the O-ring **35**.* (2) Place the cover **13** on the hub **1**. ***Note:*** *Install the cover **13** onto the hub **1**, tapping the outer circumference of the cover **13** with a plastic hammer. Be careful not to install the cover **13** forcibly by striking.* *Otherwise the O-ring **35** is damaged resulting in oil leakage, and it may cause lubricating oil to flow from the tapped holes.*	
(3) Install the ring **45** in the ring groove of the hub **1**. ***Note:*** *The free gap of the ring **45** does not install onto the notch of the hub **1**.*	

Procedure	
(4) Fill **1.1 liters** of lubricating oil into the hub **1**.	

(5) Fit the O-ring **37** to the plug **33** and plugs **39**. ***Note:*** *Apply grease thinly to the O-ring **37**.* (6) Tighten the plug **33** and plug **39** with the specified torque to the cover **13**. **Tightening torque: 36.1 to 50.6 ft•lbf (49 to 68.6 N•m)**	

17. Remove the reassembled motor from the workbench (1) Turn the workbench upside down. (2) Remove the bolts securing the motor to the workbench. (3) Fasten two eyebolts to the spindle **2**. ***Note:*** *Be sure that the two eyebolts are opposite to each other.* (4) Attach the hook and wire on the eyebolts and remove the motor from the workbench with a crane.	

6-7-10 Performance Confirmation Test

• After servicing the motor, perform the following tests by the following procedure.

1) Required Measuring Devices

Pressure gauge {for 497.5 PSI (3.43 MPa)}	2 pieces
Graduated cylinder {for 5.3 Qts. (5 L)}	1 piece
Stopwatch	1 piece

2) Test Procedure

1 Motor mounting / piping

Mount the motor to the body (frame section) and connect the piping.
The track shoe must not be attached here at this time.
[This is to conduct the performance test
(no-load operation) of motor.]

Note :
1. When connecting the piping, connect so that the pressure gauge (main circuit) can be mounted and the drain volume of the hydraulic motor can be measured.
2. When mounting the motor, do not strike it with a hammer, etc., but rather mount carefully using the bolt holes.

2 Brake-in operation of the motor

Speed ranges	Motor rpm	Pressure	Rotation direction	Running time
Low speed	10 min^{-1}	No-load	Left/right	Min. 1 minute each
High speed	20 min^{-1}			

3 Motor performance confirmation test

1 Pre-test preparatory operation
Perform preparatory operation approximately up to the following temperatures.
・Hydraulic fluid temperature : 113 to 131 °F (45 to 55 ˚C)
・Hub external temperature : 104 to 176 °F (40 to 80 ˚C)

2 Confirmation test
Measure the following items to decide whether the motor passes or fails the test.
Passing criteria
Motor drive pressure : Max. 227.5 PSI (1.57 MPa) / when 10 min^{-1}
Hydraulic motor drain volume : Max. 0.159 Gals/min. (0.6 L/min.) / when 10 min^{-1}

Good → Attach the track shoe

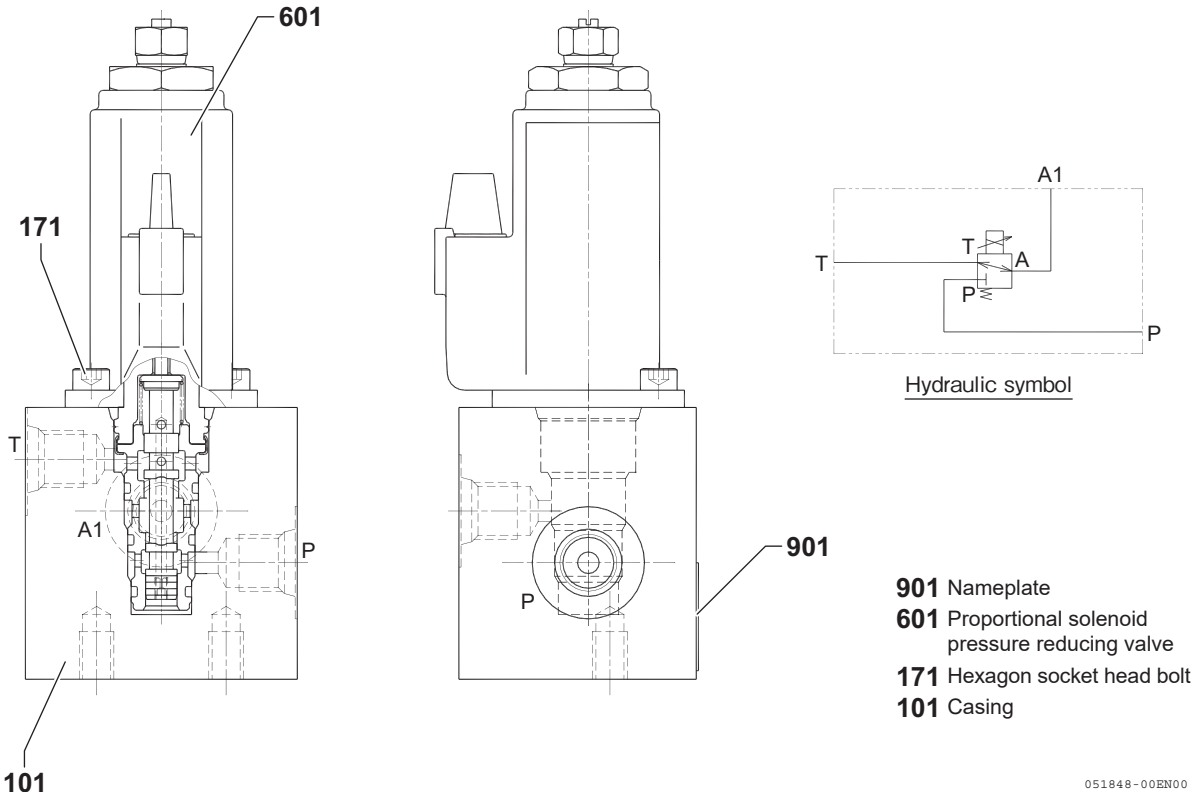
Not good → Disassemble and adjust again

6-8 ESS Proportional Solenoid Valve

1. Overview

- A cartridge-type proportional solenoid pressure reducing valve is incorporated in this solenoid valve block, which has pump port P, tank port T and secondary pressure port A1.
- The proportional solenoid pressure reducing valve generates secondary pressure proportional to the input current to the solenoid.

2. Main Components



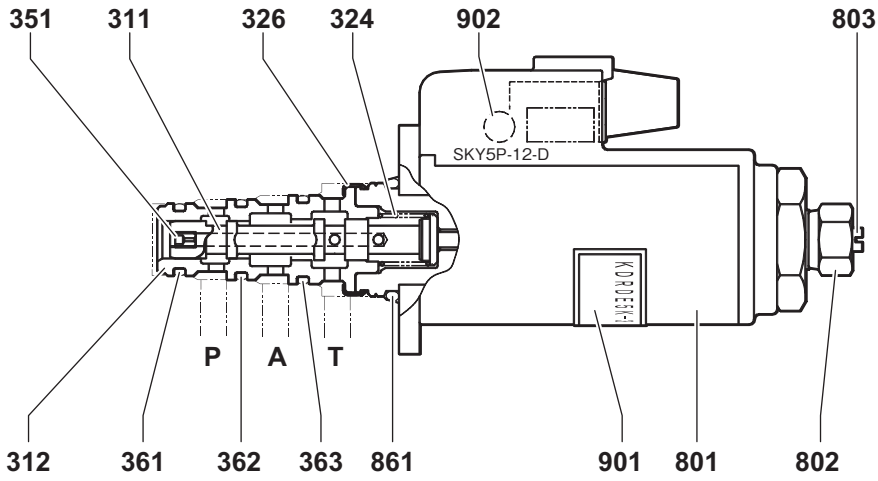
3. Specifications

Maximum allowable working pressure		1276 PSI (8.8 MPa)
Allowable back pressure		145 PSI (1.0 MPa) or less
Maximum flow (per spool)		2.6 GPM (10 L/min)
Amount of leakage (per spool)		12.2 cu.in./min (200 cm^3/min) or less
Waterproof property		JIS D 0203 S2 or equivalent
Earthquake resistance		JIS D 1601-1995 Type-3 Class-B Stage-70
Hydraulic oil		ISO VG32-68 or equivalent
Oil operating temperature range		-4 to 194°F (-20 to 90°C)
Maximum allowable contamination		NAS Class 10 or lower
Port size		JIS B 2351 G1/4
Electrical specifications		
	Solenoid type	Oil immersion type
	Coil insulation class	JIS C 3214 Class-H [356°F (180°C)]
	Connector type	DEUTSCH JAPAN LIMITED, 2P connector
Proportional solenoid pressure reducing valve		KDRDE5K-31/30E30-110
	Power-supply voltage	12V
	Rated current	0.7 A
	Recommended dither	80Hz/600mAp-p
	Coil resistance value	11.5Ω [at 68 °F (20 °C)]

4. Theory of Operation

Proportional solenoid pressure reducing valve

1) Structure



902	Code plate
901	Name plate
861	O-ring
803	Adjusting screw
802	Seal nut
801	Solenoid
363	O-ring
362	O-ring
361	O-ring
351	Throttle
326	Retaining ring
324	Spring
312	Sleeve
311	Spool

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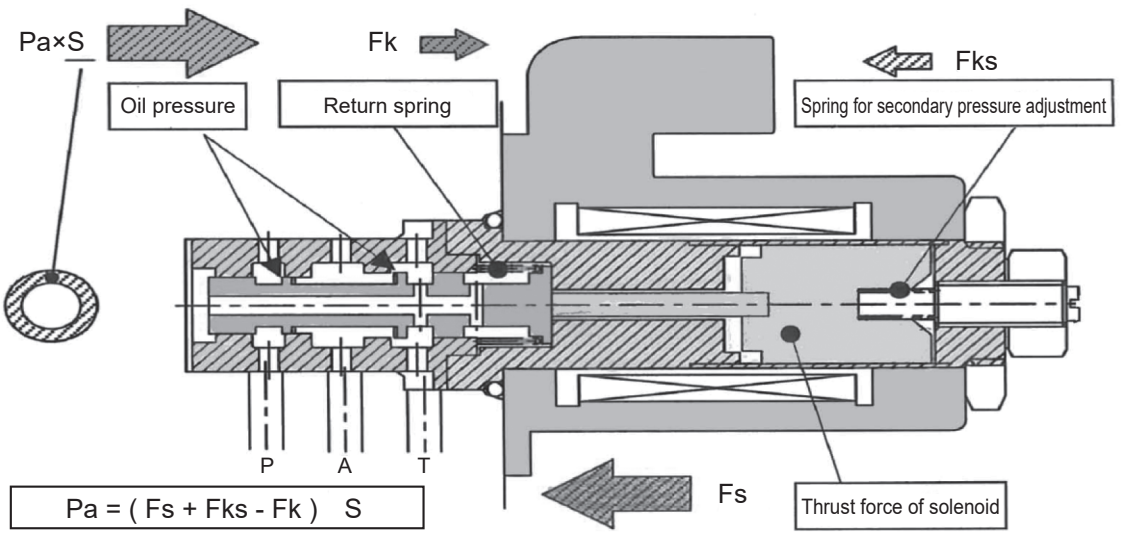
2) Theory of operation

Proportional solenoid **801** generates a thrust force proportional to the input current and pushes spool **311** with the thrust force. Accordingly, oil is led from the supply side (port P) via the notch of the spool into the secondary side (port A), resulting in a rise in pressure at port A.

The pressure (Pa) at port A acts on the pressure receiving area (S) of the spool and pushes the spool toward the solenoid.

The spool is moved to the point where the sum of the oil pressure (Pa x S) and the force (Fk) of spring **324** is balanced by the thrust force (Fs) of the solenoid. In this state, secondary pressure corresponding to the thrust force of the solenoid is generated due to the relationship between the opening areas on the supply and discharge sides of the spool.

In addition, the load (Fks) of the spring for secondary pressure adjustment (the spring of the solenoid) acts in the direction (leftward in the figure below) in which the thrust force of the solenoid is supported.



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5. Tools

Part No.	Tool used	Size	Part Name	Remarks
171	Hexagon key wrench	JIS B4648 (Nominal size: 4)	Hexagon socket head bolt	
802	Adjustable wrench	JIS B4604	Seal nut	Width across flats: 12

6. Tightening Torque

Part No.	Part		Tightening torque ft·lbf (N·m)
	Part Name	Nominal size	
171	Hexagon socket head bolt	M5×0.8	4.4 to 5.9 (6.0 to 8.0)
802	Seal nut	M6	5.1 to 5.8 (6.9 to 7.9)

7. Disassembly and Reassembly

1) Disassembly

(1) General precautions

- Since the parts of the proportional solenoid pressure reducing valve are precision-made, be careful not to drop them or hit them against each other when handing them.
- Never attempt to forcibly pry off any parts or hit them with force. Doing so may cause burrs or damage to the parts, resulting in decreased function.
- Do not leave the parts disassembled to prevent rust.

(2) Disassembly procedure

Remove the solenoid valve block from the machine and put it on a workbench.

Loosen and remove hexagon socket head bolts **171** and then remove proportional solenoid pressure reducing valve **601** from casing **101**.

Do not remove sleeve **312** from solenoid **801** unless there is some particular reason because sleeve **312** is swaged to solenoid **801** with retaining ring **326**.

2) Reassembly

(1) General precautions

- The same general precautions as for disassembly apply.
- Before beginning reassembly, make sure that there is no dust on all the parts and that there are no burrs on them. If any, remove them with an oilstone.
- As a general rule, replace the O-rings removed during disassembly with new ones.
- Be careful not to damage O-rings during installation. (Apply a small amount of grease to them before installation.)
- Be sure to tighten threaded fasteners to their respective tightening torque values shown in the tightening torque table above. Use a torque wrench to tighten them to the specified tightening torque values.
- After completion of reassembly, put a plug in each port to prevent dust from entering the valve block.

(2) Reassembly procedure

- Preparation of proportional solenoid pressure reducing valve **601**.
  If retaining ring **326** was cut and sleeve **312** was removed from solenoid **801**, a new proportional solenoid pressure reducing valve assembly must be used. If sleeve **312** was not removed from solenoid **801** during disassembly, the proportional solenoid pressure reducing valve can be used again.
- Installation of proportional solenoid pressure reducing valve **601**.
  Install proportional solenoid pressure reducing valve **601** into casing **101** and secure it with hexagon socket head bolts **171**. Be careful about the valve installation direction.

8. Special Notes

- Solenoid
  Do not hit the solenoid or apply excessively large force to it. Doing so may cause solenoid malfunctions.
- Input current
  Do not apply a current of more than 0.7 A to the solenoid coil.
- Dither adjustment
  If the pipes and related parts are slightly vibrating, in general, the dither frequency should be increased and the dither amplitude reduced.
  To improve operational performance including smoothness and reproducibility, the dither frequency should be reduced and the dither amplitude increased.
- Adjusting screws
  Do not change the settings of the adjusting screws unless necessary because they were adjusted correctly before shipping. Turning the adjusting screw clockwise will increase secondary pressure.

9. Servicing Standards

Inspection Item	Criteria
Quantity of oil leakage	The valve assembly must be replaced if the quantity of oil leakage has increased and affects the related system.
Solenoid	The valve assembly must be replaced if the solenoid has been deformed or damaged by external forces or any other forces.

10.Troubleshooting

Trouble		Causes	Measures
1	Pressure of proportional solenoid pressure reducing valve does not rise.	• Improper wire connection • Damaged solenoid • Sticking spool • Driver amplifier failure	• Inspect and repair the connection. • Replace. • Disassemble, inspect and clean. • Repair or replace the amplifier.

	Non-smooth operation	• Incorrect dither adjustment
		  • Too high dither frequency
		  • Too low dither amplitude
		• Spool slightly sticking
			• Readjust.
			
			• Disassemble, inspect and clean.

	Unstable output	• Incorrect dither adjustment
		  • Too low dither frequency
		  • Too high dither amplitude
			• Readjust.

	Slow response	• Low supply pressure	• Adjust the pressure within the specified working pressure range.
2	Oil leaks from solenoid	• Damaged O-ring • Damaged seal nut	• Replace the O-ring. • Replace the seal nut.

6-9 Cutoff Valve

1. Outline

This product is a manifold with a built-in check valve and two solenoid operated directional control valves.
The following is the description of how each function operate.

2. Operation Theory

1) Function of Solenoid

Described for port A only, as port A and port B are the same function.

(1) When solenoid is OFF [See Fig-2] item No.5
The pressurized oil circuit from port P to port A is blocked by **2** spool and **3** plunger.
As port A leads through port T, the port A pressure becomes the pressure of the tank.
Since Port C leads through Port P, the pressure of port C becomes always the same as the pressure of port P.

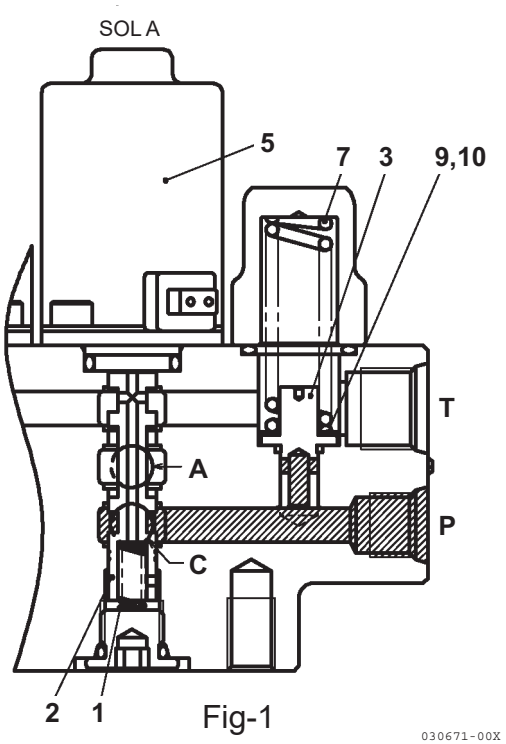


Fig-1

When the pressure of port P rises up to the setting pressure of relief valve, **3** plunger is pushed upward and **7** spring is compressed at the same time.
Then oil flows through P to T and escapes to port T at X.

When the pressure of port P declines below the setting pressure of the relief valve, **3** plunger goes lower than **7** spring and returns to [Fig-2] position.
This repetitive movement allows to stabilize the pressure in the circuit and keep it lower than the relief setting pressure.

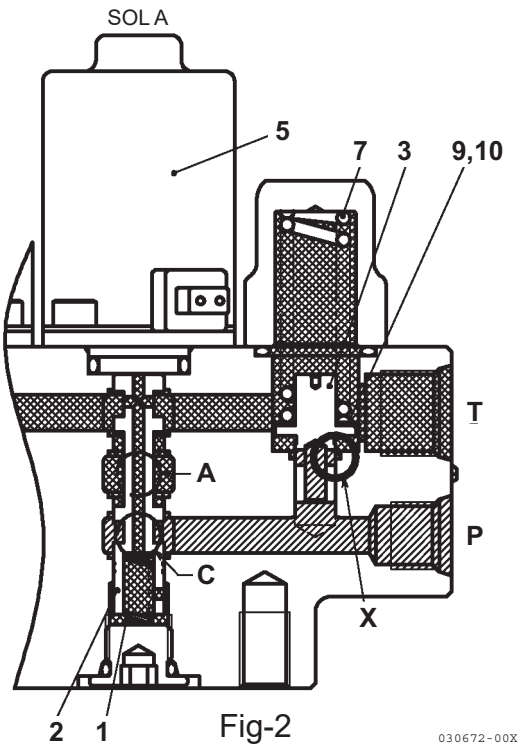


Fig-2

(2) When Solenoid is ON [See Fig-4] item No.5
When **5** solenoid is ON, **2** spool moves downward by the pushrod of **5** solenoid and open the circuit from port P to A, then close the circuit from port A to T, which leads to generate the same pressure in port A and port P.

When **5** solenoid is off, **1** spring pushes **2** spool upward and the spool goes back to [Fig-2] position.

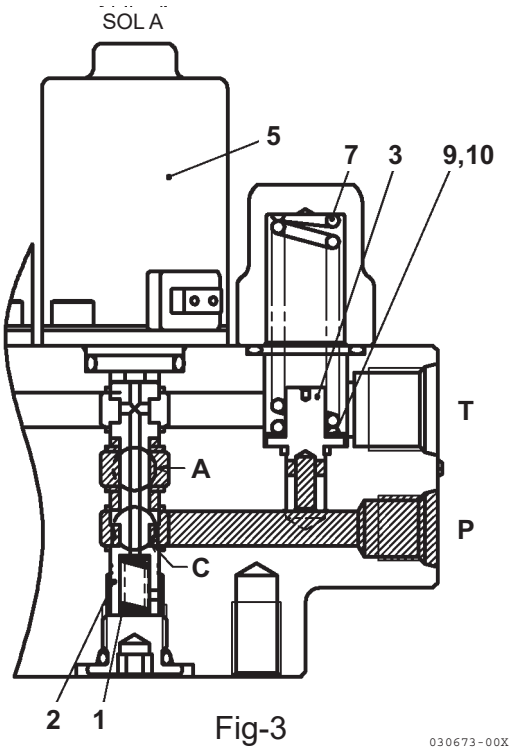


Fig-3
030673-00X

2) Function of Check Valve

(1) Port P→port PAC and port B
When the pressure of port P exceed the power of **14** spring **15** plunger moves to the right side and the pressurized oil flows from Port P to Port PAC.

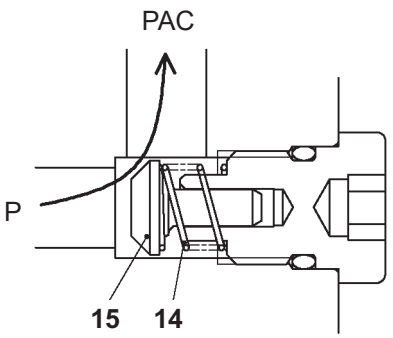


Fig-4
030674-00X

(2) Port PAC→port P
14 spring pushes **15** plunger back to the left side, which closes the circuit from Port PAC to Port P and prevent the adverse current.

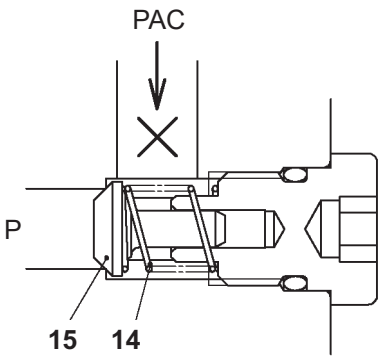


Fig-5
030675-00X

3. Component Parts

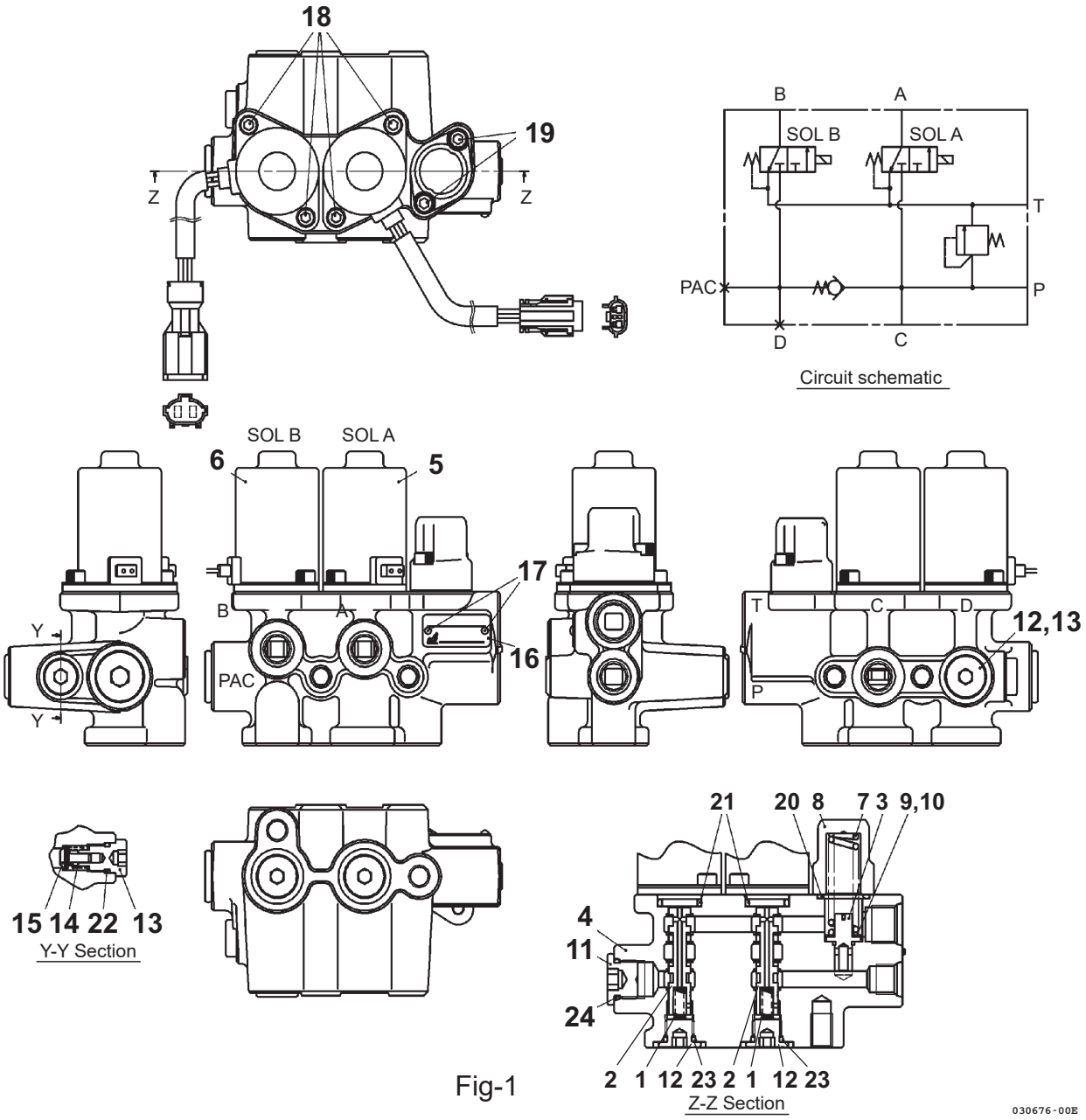
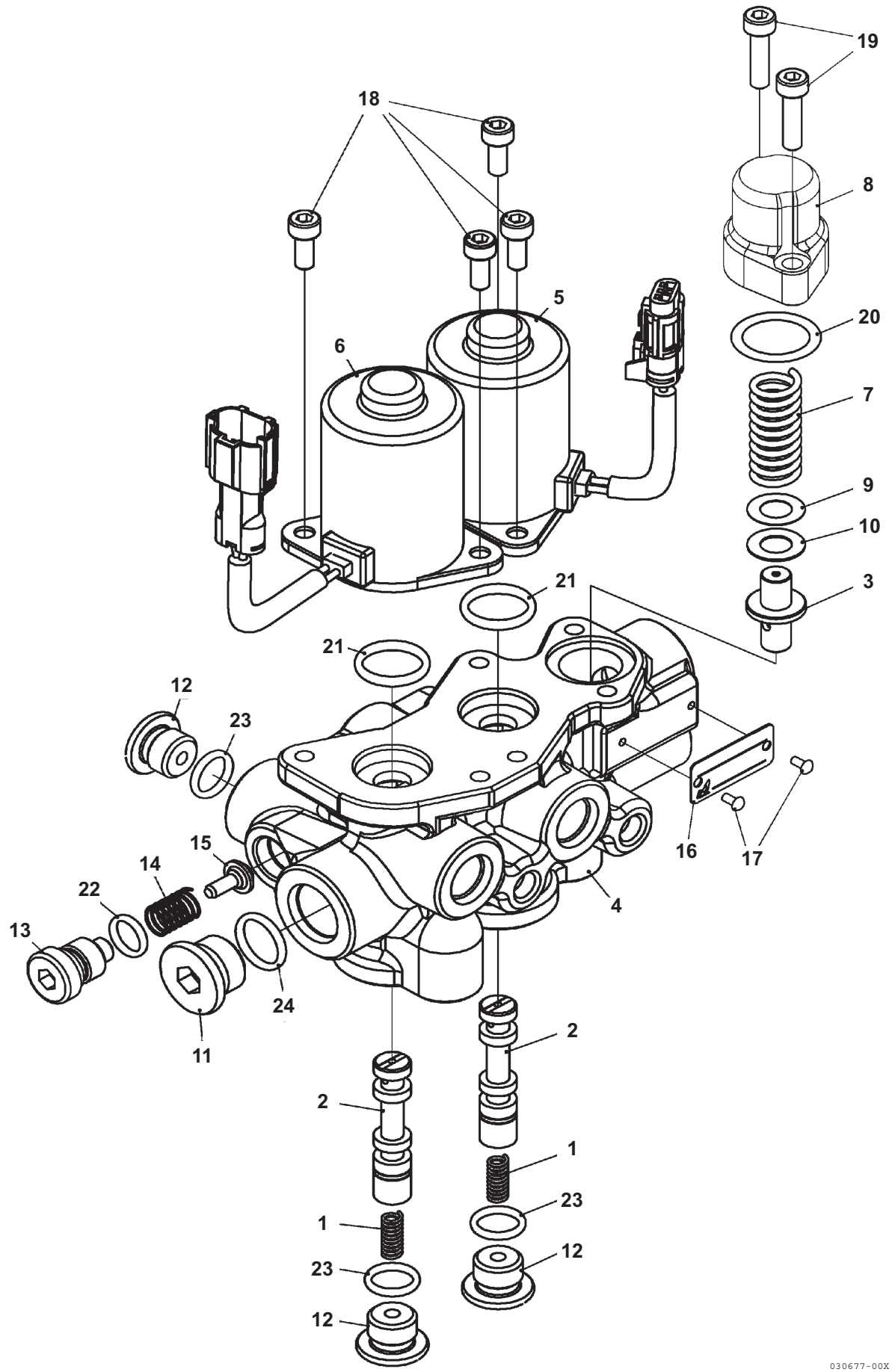


Fig-1

No.	Description	No.	Description
1	Spring compression	13	Plug
2	Spool	14	Spring
3	Plunger	15	Plunger
4	Body	16	Nameplate
5	Solenoid	17	Rivet screw
6	Solenoid	18	Hex socket bolt
7	Spring compression	19	Hex socket bolt
8	Cover	20	O-ring
9	Shim	21	O-ring
10	Shim	22	O-ring
11	Plug	23	O-ring
12	Plug	24	O-ring


19
18
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6
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13
24
11
16
17
4
2
2
1
23
12
1
23
12
030677-00X

4. Disassembly and Reassembly

1) Precautions

[1] Since all the parts of the hydraulic valves are processed with precision, disassemble or assemble at dustless clean area. Also use the clean tools and the clean oil for washing.

[2] Clean the disassembled parts and apply anti-rust oil.

[3] It is advisable to number all the parts when disassembling so that each parts can be reassembled in the initial places.

[4] When assembling, the parts should be washed and dirt & dust should be removed and then make sure it is free from burr or dents. If there are any burr or dents, use an oilstone to fix them.

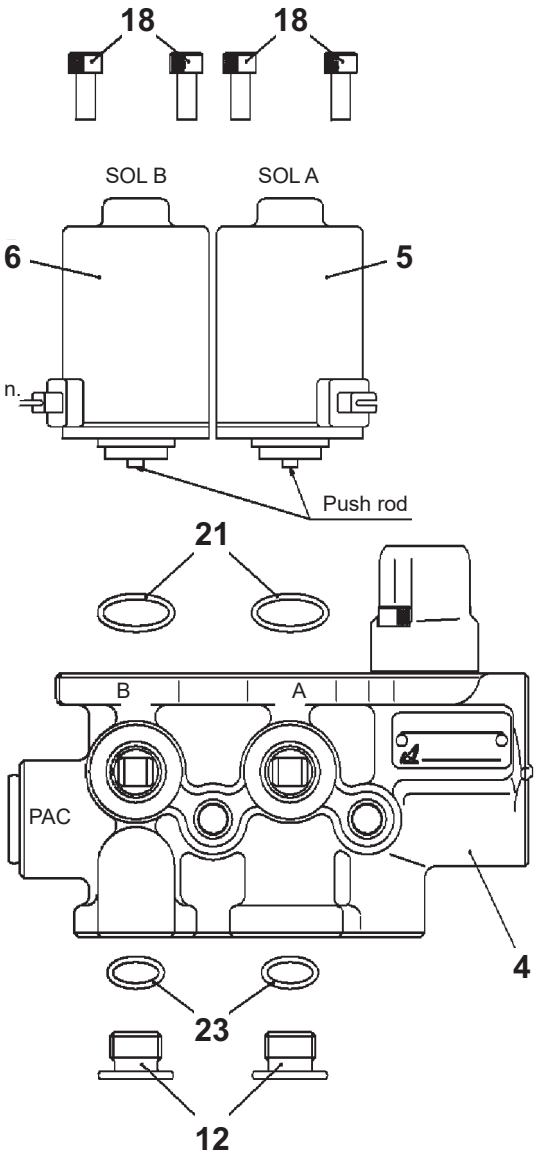
[5] Replace the seal with new one each time you disassemble.

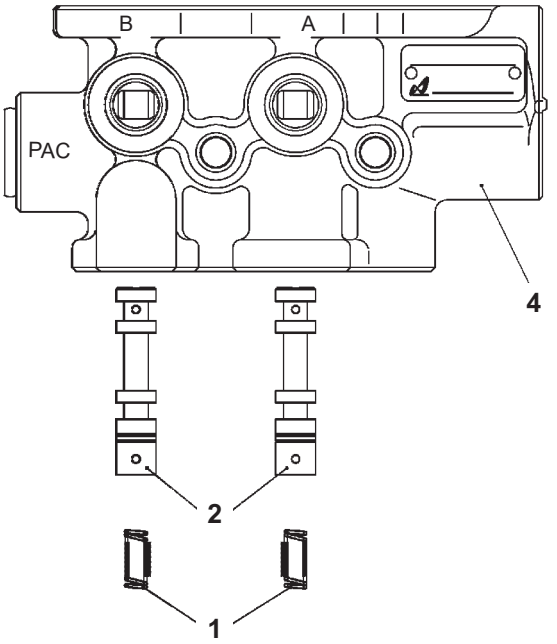
[6] When assembling, apply hydraulic oil to the friction surface and proper amount of grease to the seal.

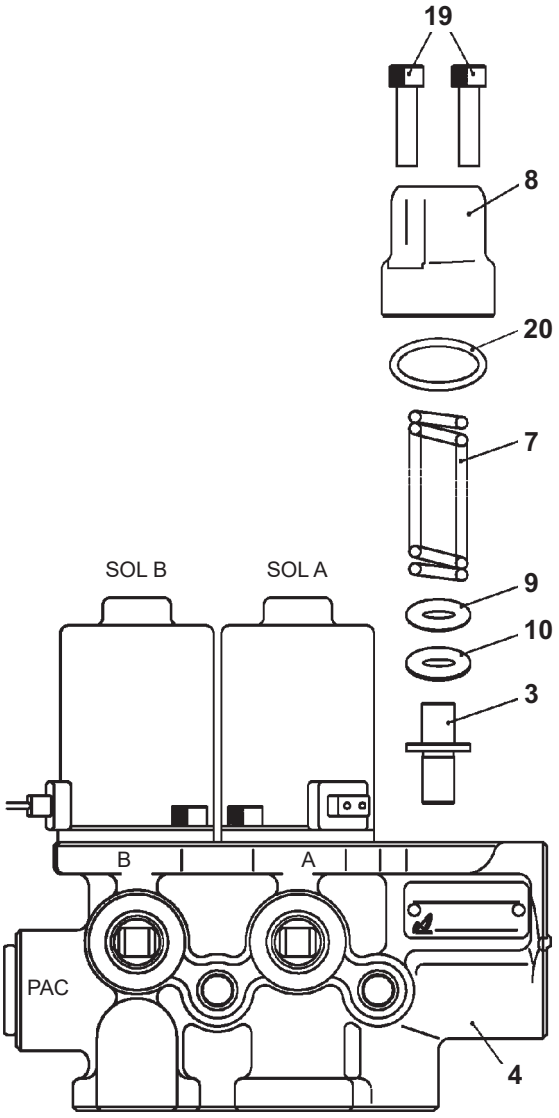
[7] Do not tap or force open even it's tight.

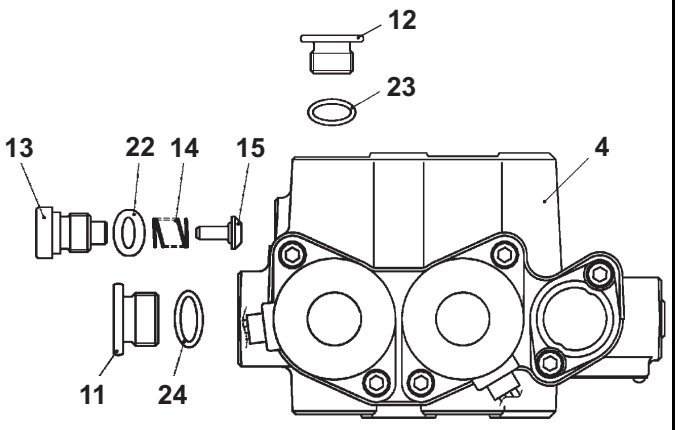
2) Disassembly Procedure

For assembly, reverse the order of disassembly.

Procedure	
1. Disassembly of the valve solenoid *As **4** body and **2** spool are controlled for the clearance fit, remember the position of the parts which you disassembled and place the parts exactly in the same position when reassembling. Also **5** **6** solenoid must be assemble the same position and direction. (1) Take off the **18** hex socket bolt (two per solenoid). (Use the hex socket screw keys 4mm, tightening torque: 3.92N•m) Detach **5** or **6** solenoid. ***Note:*** *Be careful not to lose the pushrods which are likely to drop off from the solenoids.* *When assemble, be sure to fit **21** O-ring into **5** **6** solenoid before attaching the solenoids to the **4** body.* *Fitting **21** O-ring into **4** body beforehand is likely damage **21** O-ring, which might affect the valve function and the amount of the leakage.* (2) Take off **21** O-ring. (3) Take off **12** plug (Use the hex socket screw keys 6mm, tightening torque: 26.5N•m) and then take off **23** O-ring.	 Fig-7 030678-00E

Procedure	
(4) Pull out **1** spring and **2** spool from **4** body.	

Procedure	
2. Disassembly of the relief valve (1) Take off **19** hex socket bolt (2pieces). (Use the hex socket screw keys 4mm, tightening torque: 3.92N•m) (2) Take off **8** cover **20** O-ring **7** spring and **9•10** shims and then pull out **3** plunger using needle nose pliers.	 Fig-9 030680-00X

3. Disassembly of the check valve (1) Take off **13** plug from **4** body. (Use the hex socket screw keys 6mm, tightening torque: 21.0N•m) Pull out **14** spring **15** plunger. Take off **22** O-ring. (2) Take off **11** plug and **24** o-ring. (Use hex socket screw keys 6mm, tightening torque: 48.5N•m) (3) Take off **12** plug and pull out **23** O-ring. (Use hex socket screw keys 6mm, tightening torque: 26.5N•m)	 030681-00X

5. Troubleshooting

Trouble	Cause	Corrective measure
Unstable pressure in the circuit.	• Malfunction of **3** plunger. • Have got contaminant.	• Disassemble and wash them. • Repair flaws. • If unrepairable, replace the valve assy.
	• Worn-out or breakage of the **7** spring.	• Renew **7** spring with new one.
The pressure of the port A and B do not increase, when the SOL is on. (Relief valve works normally)	• Shortage of the voltage.	• Check the voltage.
	• Malfunction of the coil of **5** or **6** solenoid.	• Replace **5** or **6** solenoid coil.
	• Malfunction of **2** spool.	• Disassemble and wash them.
	• Have got contaminant.	• Repair the flaws. If unrepairable, renew the assy.
The pressure of the port A and B do not drop, when the SOL is off. (Relief valve works normally)	• The breakage of **1** spring.	• Replace **1** spring with new one.
	• Malfunction of **2** spool.	• Disassemble and wash them.
	• Have got contaminant.	• Repair the flaws. If unrepairable, replace the valve assy.
External leakage of oil.	• The breakage of the O-ring.	• Replace O-rings with new ones.

CHAPTER 7

ADJUSTMENT AND REPAIR

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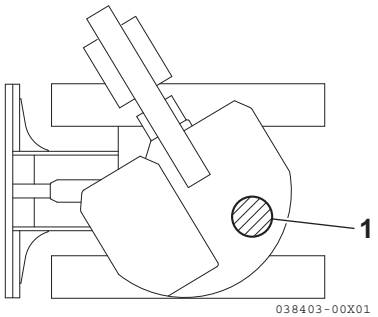
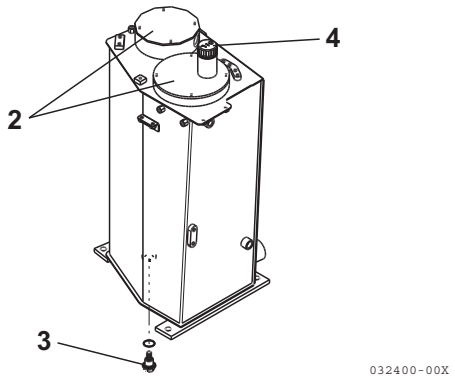
7. Adjustment and Repair

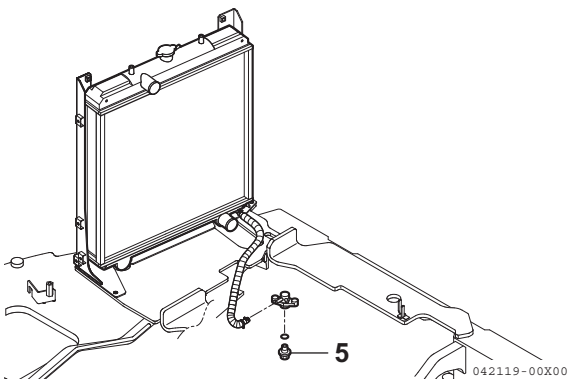
7-1 Engine and Electric Equipment

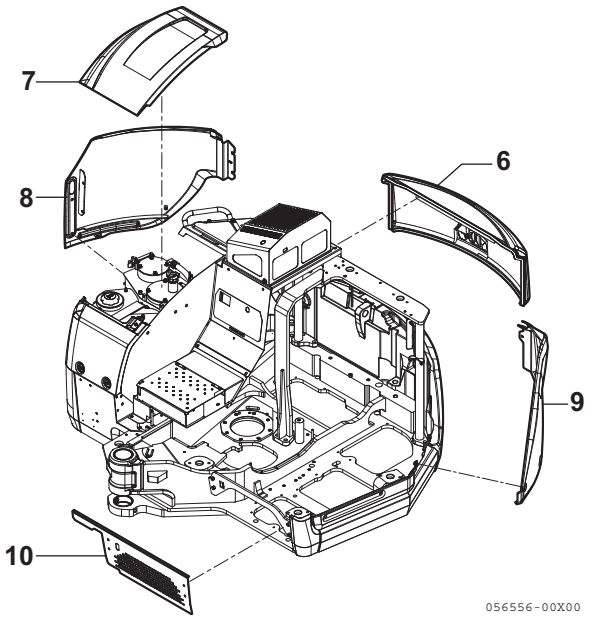
7-1-1 Removal and Reinstallation of Engine

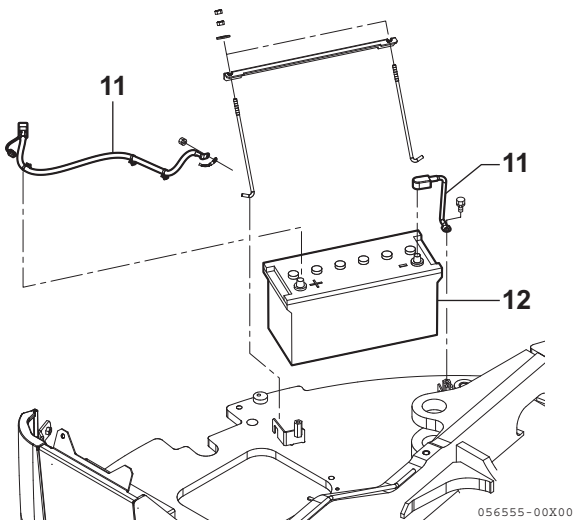
1) Removal

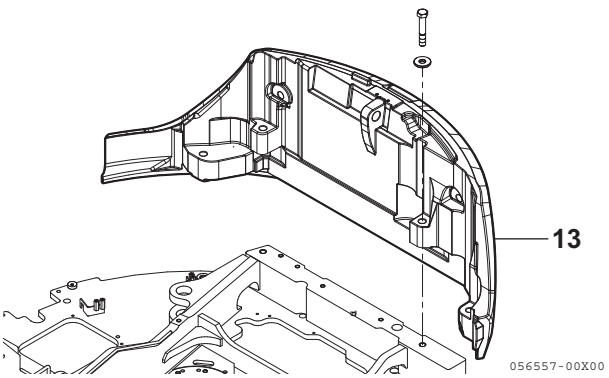
Procedure	
(1) Remove the cabin. Refer to Section "7-7-1 Removal and Reinstallation of Cabin" for the removal procedure of the cabin. (2) Swing the upperstructure so that drain plug **1** of hydraulic oil tank is positioned halfway between the right and left crawlers. Then, lower the bucket to the ground and stop the engine.	

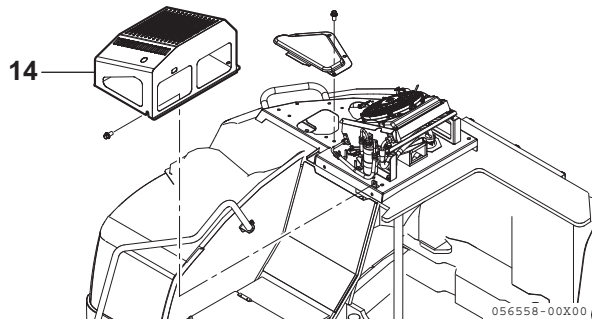
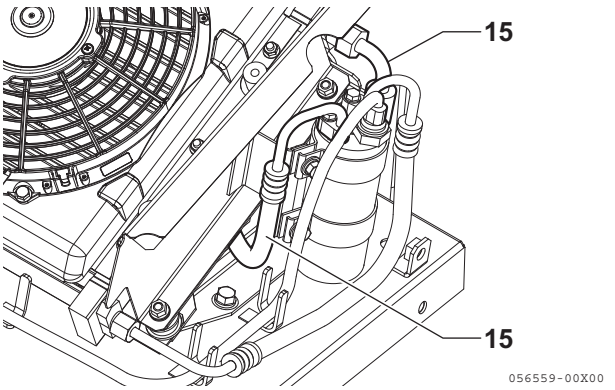
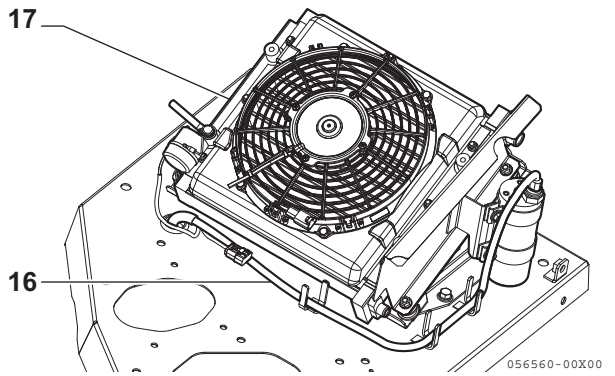
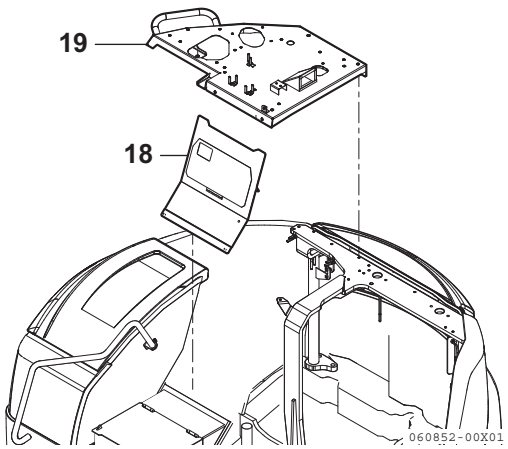
(3) Remove reservoir covers **2** and drain plug **3** from hydraulic oil tank to drain the hydraulic oil. Alternatively, replace oil supply port cap **4** with vacuuming cap and connect compression vacuum to hydraulic vacuum. Type: Hydraulic oil ISO VG46 Q'ty: 15.8 Gals (60 L)	

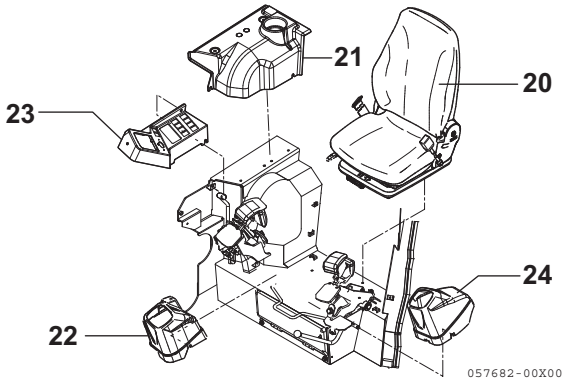
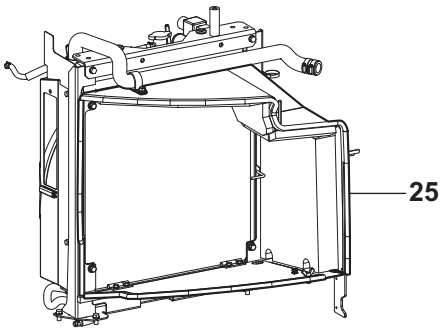
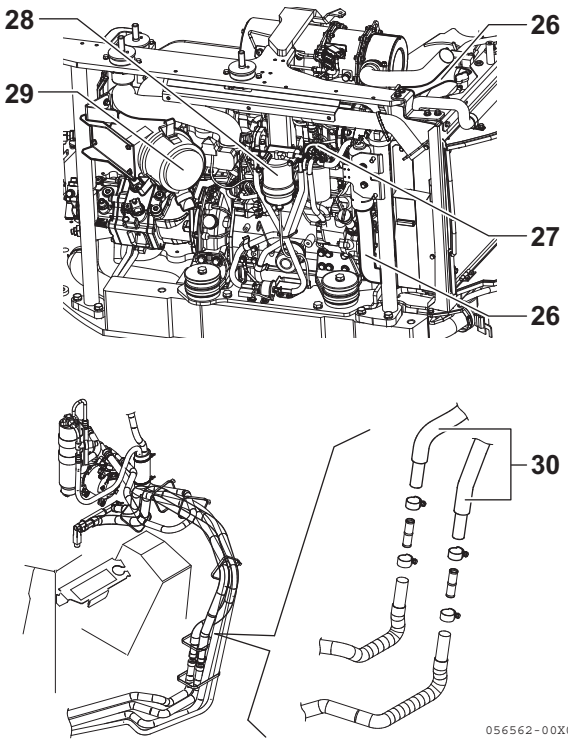
(4) Remove drain plug **5** from the two-way cock for cooling water to drain the cooling water. Q'ty: 9.8 Qts. (9.3 L)	

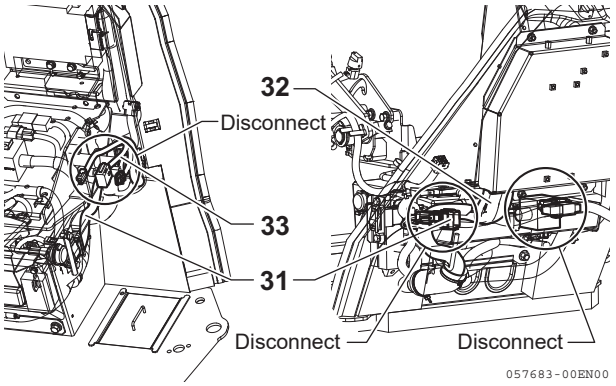
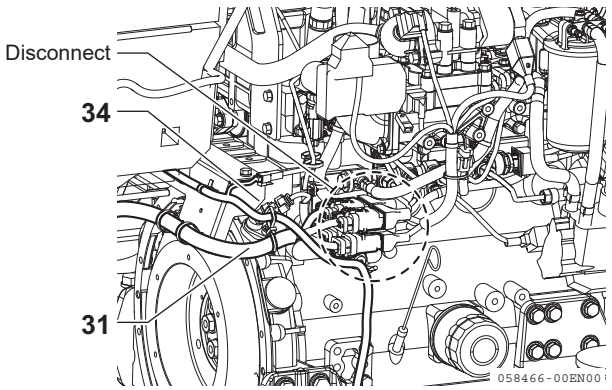
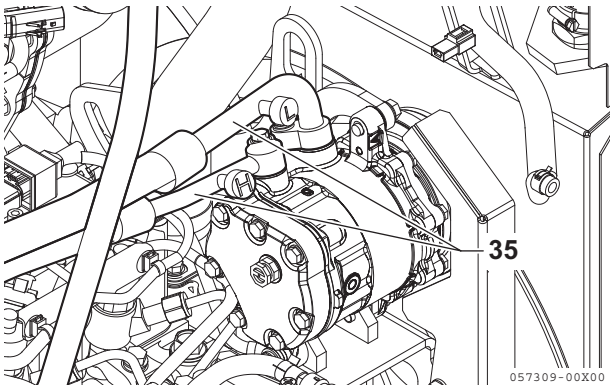
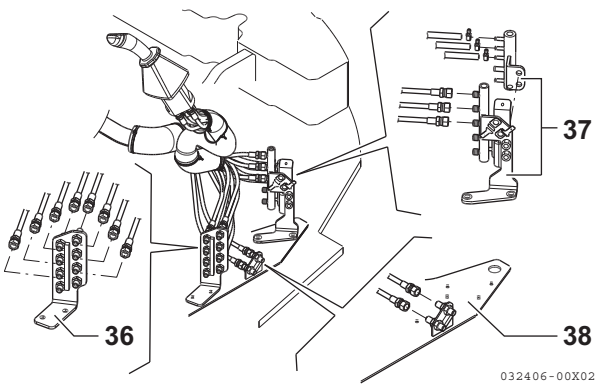
Procedure	
(5) Remove engine hood **6**, bonnet B (upper and cover) **7**, bonnet R **8**, cover L **9** and frame FL **10**. (6) Disconnect hoses from condenser and receiver dryer. (Before disconnect hoses, collect refrigerant.)	

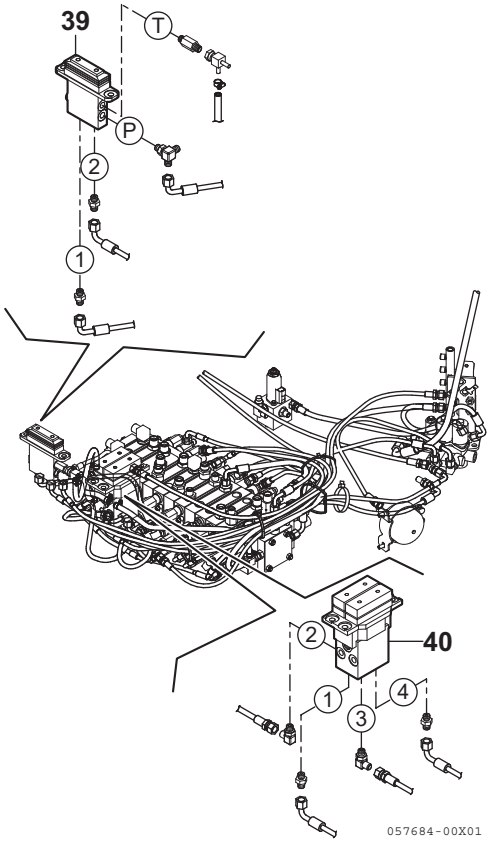
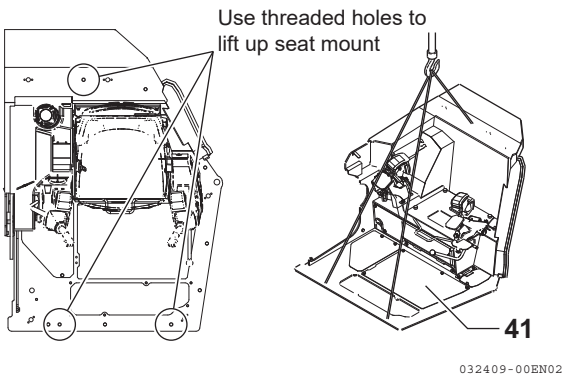
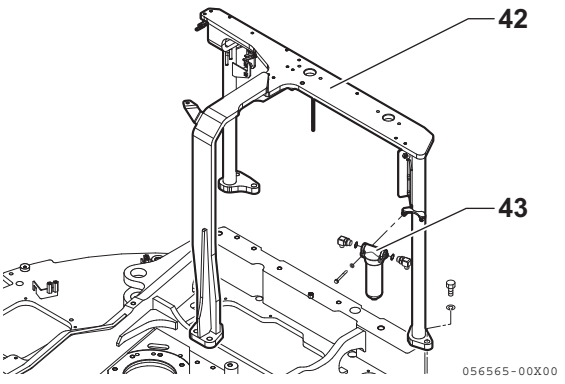
(7) Disconnect battery cables **11**, and remove the battery **12**.	

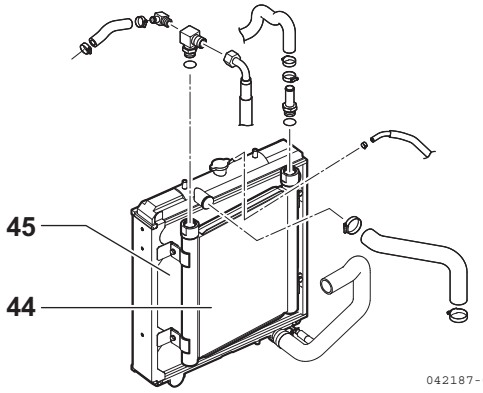
(8) Remove counterweight **13**.	

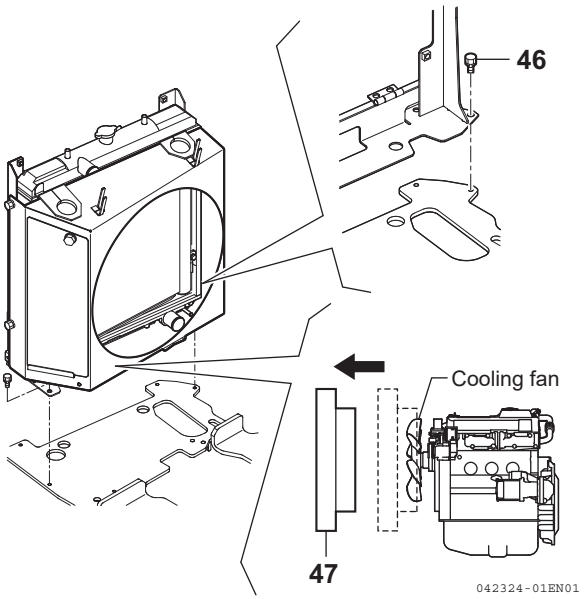
Procedure	
(9) Remove condenser cover **14**.	
(10) Disconnect air conditioner hoses **15**.	
(11) Disconnect harness **16** and remove condenser **17** (with receiver dryer).	
(12) Remove center cover **18** and cover **19** under the condenser.	

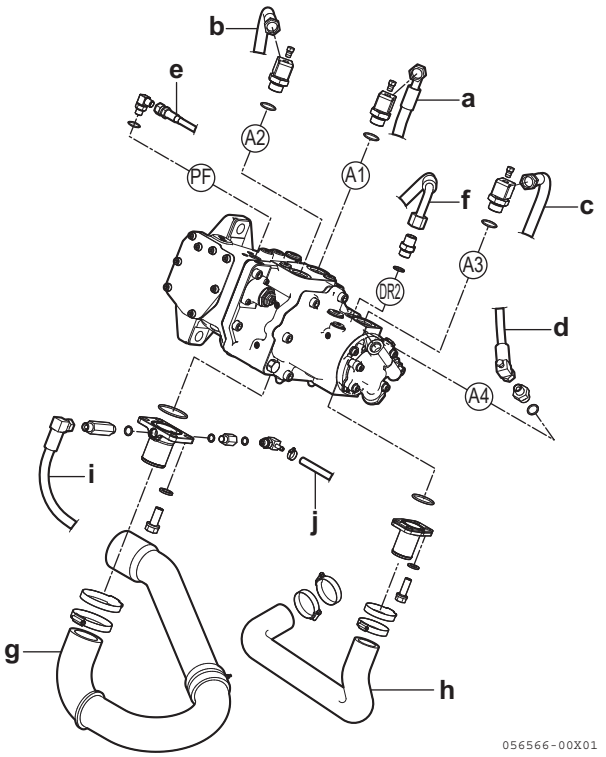
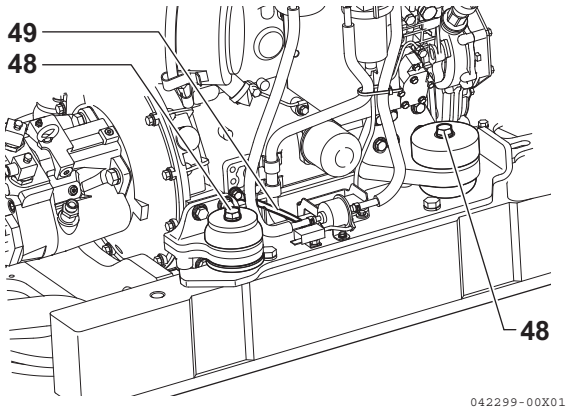
Procedure	
(13) Remove operator's seat **20**, side cover **21**, lever box R **22**, instrument panel **23** and lever box L **24**.	
(14) Remove the radiator cover **25**.	
(15) Disconnect cooling water hoses (A, B) **26** and fuel hose **27**. Remove water separator **28**. Disconnect couplers of harnesses. (16) Remove air cleaner **29** with bracket. (17) Disconnect refrigerant hose (AC unit to condenser) **30** in the back of seat mount.	

Procedure	
(18) Disconnect couplers of harness B **31**, harness C **32** and harness D **33** in the back of the seat mount.	
(19) Disconnect couplers of harness A **34** and harness B **31** from the engine.	
(20) Remove the compressor hoses **35**.	
(21) Disconnect pilot hoses from the joint of bracket STD **36**, bracket mount DR **37** and valve plate **38**. ***Note:*** *Make a mark on the installation position of each hose in advance.*	

Procedure	
(22) Disconnect pilot hoses from boom swing pilot valve **39** and travel pilot valve **40**. ***Note:*** *Make a mark on the installation position of each hose in advance.*	
(23) Lift seat mount **41** up to remove it. ***Note :*** *When lifting up seat mount, lift it up slowly and make sure that no harness and hose get caught.*	
(24) Remove line filter **43** from cabin mount bracket **42**. Remove cabin mount bracket **42**.	

Procedure	
(25) Disconnect hoses from oil cooler **44** and radiator **45**.	

(26) Remove the installation bolts **46** for radiator bracket, and move the radiator to separate the shroud **47** from the engine cooling fan completely.	

Procedure	
(27) Disconnect the hydraulic hoses from the hydraulic pump. a. Hose A1 f. Hose DR2 b. Hose A2 g. Hose S1 c. Hose A3 h. Hose S3 d. Hose A4 i. Hose Cut-off: T e. Hose PF j. Hose ESS:T ***Notes:*** • *Make a mark on the installation position of each hose in advance.* • *Remove the flange from the hydraulic pump.* • *Be careful not to lose the O-ring for the flange.*	
(28) Remove engine mount bolts **48** and remove the engine. ***Note:*** *Before remove the engine, remove engine ground cable **49**.*	

2) Reinstallation

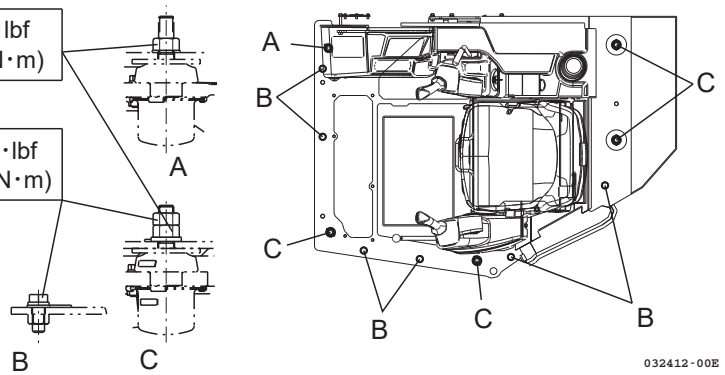
Reinstall the engine in the reverse order of the removal procedure.

- Apply the adhesive to installation bolts for engine mount and cabin mount bracket. Tighten them by specified tightening torque.

Adhesive	Three bond 1324 or its equivalent
Tightening torque	195.3 to 224.2 ft•lbf (264.8 to 304 N•m)

- Tighten installation bolts and nuts for seat mount by specified tightening torque.

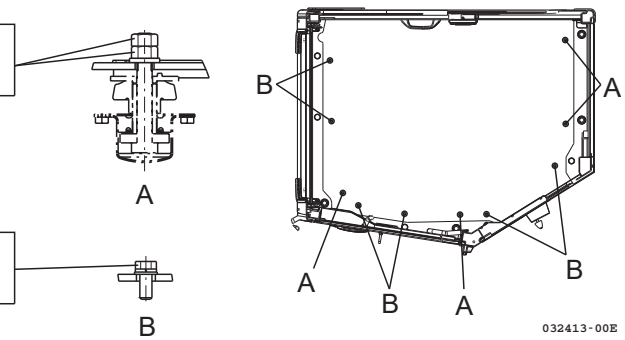
Tightening torque	195 to 217 ft·lbf (265 to 294 N·m)
Tightening torque	43.4 to 57.9 ft·lbf (58.9 to 78.5 N·m)



- When installing air conditioner hoses, apply oil to O-rings.
  (Specified oil: SP-10 or its equivalent)

- Tighten installation bolts and nuts for cabin by specified torque.

Tightening torque	195 to 217 ft·lbf (265 to 294 N·m)
Tightening torque	123 to 152 ft·lbf (167 to 206 N·m)

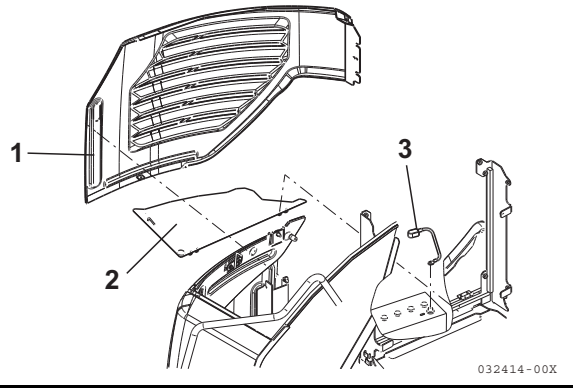
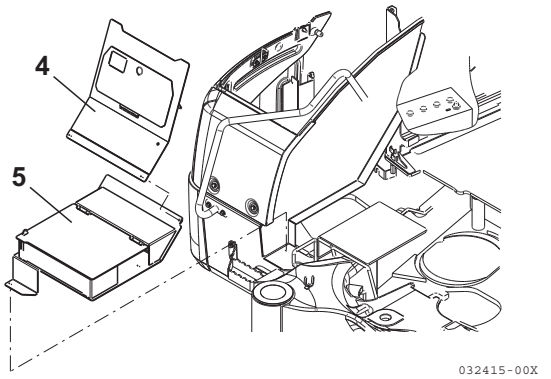
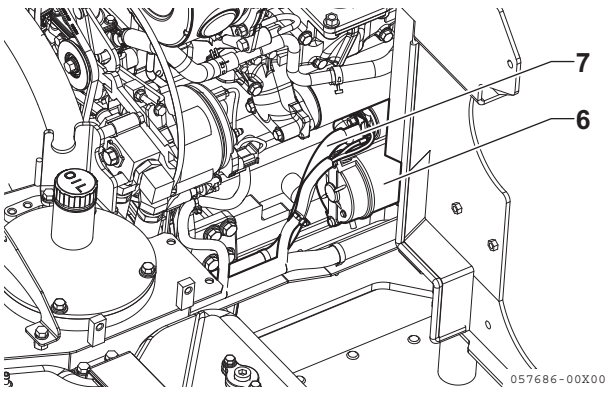


- Refrigerant for air conditioner

Refrigerant	R134a
Q'ty	1.54 to 1.76 lbs. (700 to 800 g)

7-1-2 Removal and Reinstallation of Starter Motor

1) Removal

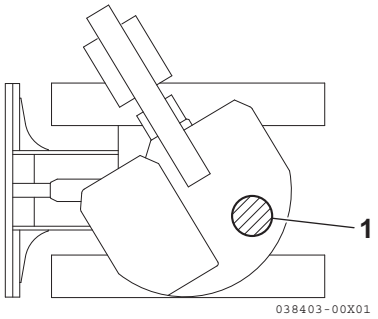
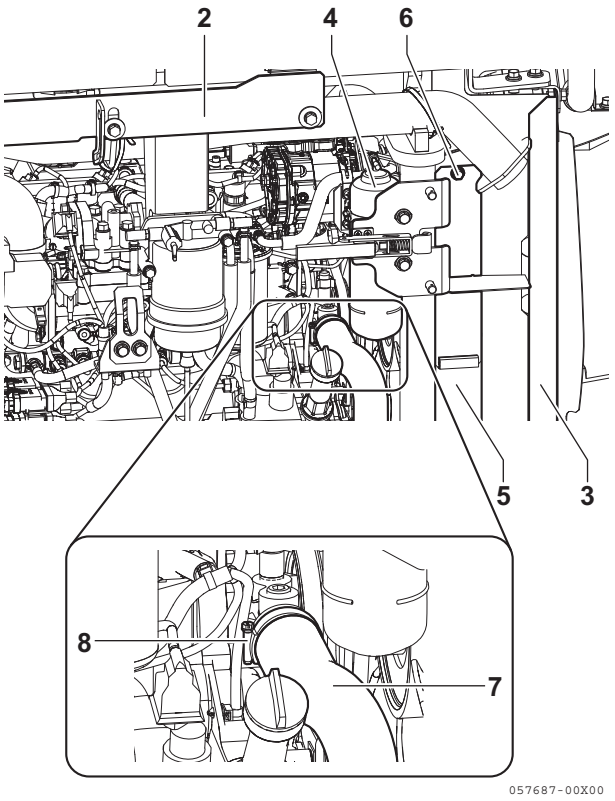
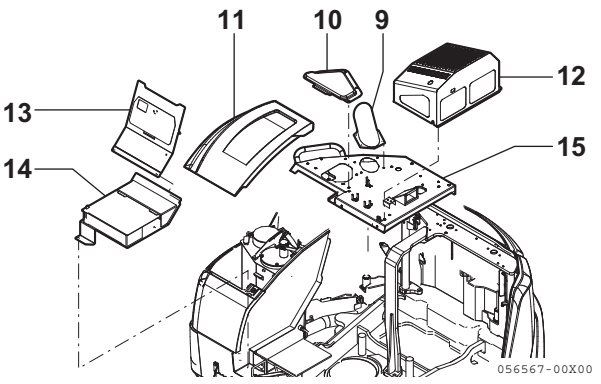
Procedure	
(1) Open bonnet R **1** and duct cover **2**, and then disconnect battery negative cable **3**.	
(2) Remove center cover **4** and base cover **5**.	
(3) Remove battery positive cable **7** from starter motor **6** and then remove starter motor **6** from the engine.	

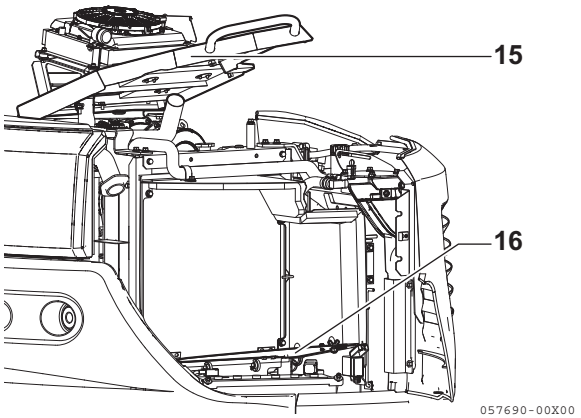
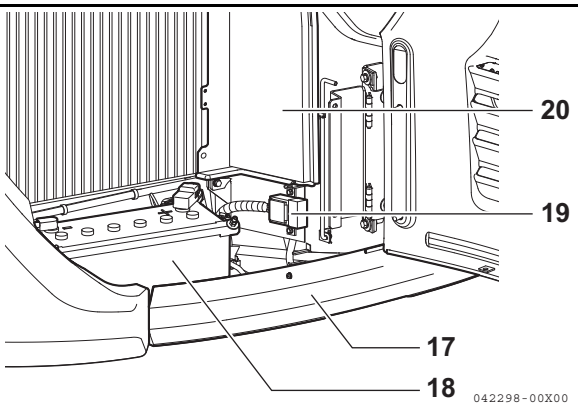
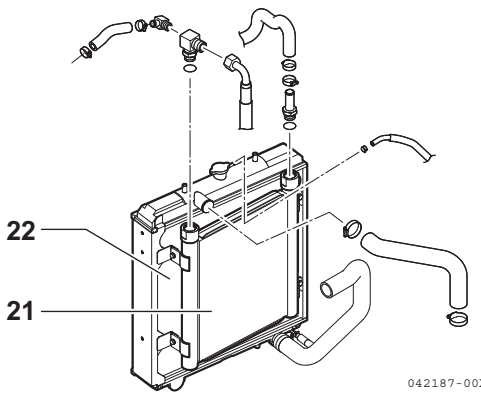
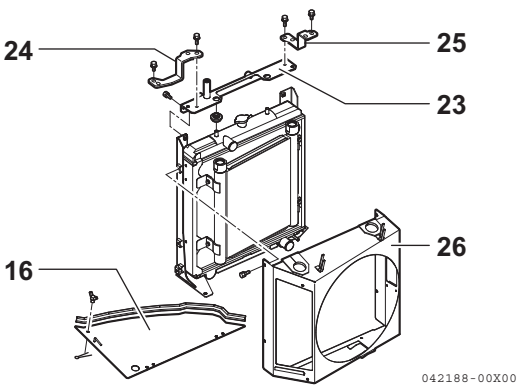
2) Reinstallation

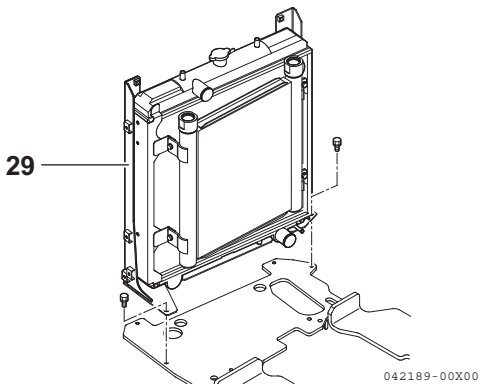
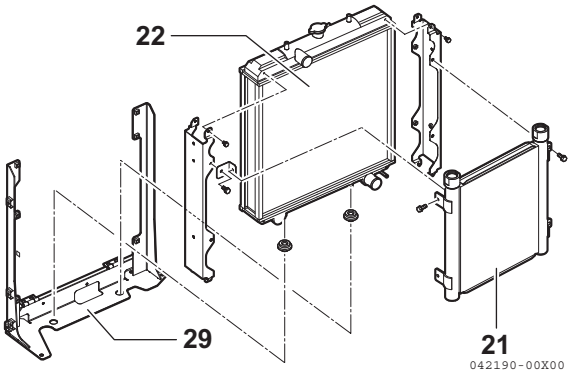
Reinstall the starter motor in the reverse order of the removal procedure.

7-1-3 Removal and Reinstallation of Radiator and Oil cooler

1) Removal

Procedure	
(1) Swing the upperstructure so that drain plug **1** for cooling water is positioned halfway between the right and left crawlers. Then, lower the bucket to the ground and stop the engine. (2) Replace oil supply port cap with vacuuming cap and connect compression vacuum to hydraulic vacuum. Alternatively, drain the hydraulic oil from hydraulic oil tank.	
(3) Open engine hood **2** and bonnet B **3**. Then remove sub tank **4**, shroud cover C **5** and shroud installation bolt **6**. (4) Drain the cooling water. Q'ty: 9.8 Qts. (9.3 L) (5) Loosen hose clip **8** of radiator hose **7** and pull out radiator hose **7**. ***Note:*** *When loosening hose clip **8**, it can be easily loosened by using universal joint socket.*	
(6) Remove exhaust cover **9**, upper cover **10**, bonnet B **11**, condenser cover B **12**, center cover **13** and tool box base **14**.	

Procedure	
(7) Remove condenser cover **15** installation bolt. lift up condenser cover A **15** and fix it by the rope. ***Note :*** *When lifting up the cover, take care not to contact condenser with cabin.*	
(8) Open duct cover **16**, and remove frame guard R **17** and battery **18**. (9) Remove slow blow fuse **19** and radiator duct **20**.	
(10) Disconnect hoses from oil cooler **21** and radiator **22**.	
(11) Remove radiator bracket **23**, radiator stay A **24**, radiator stay B **25**, shroud **26** and duct cover **16**.	

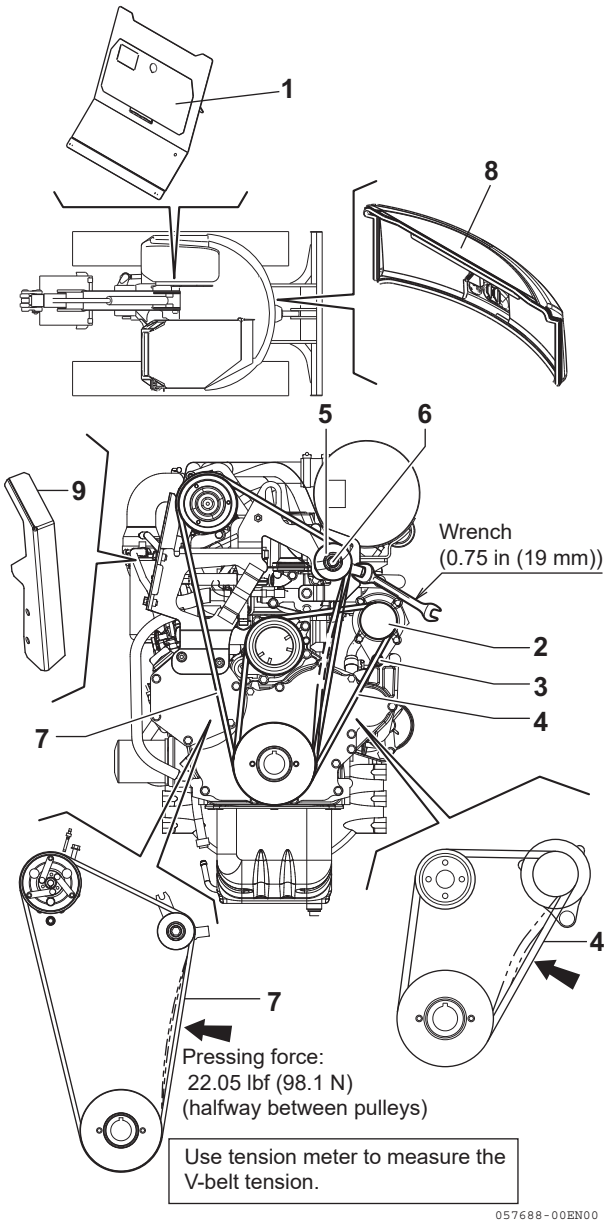
Procedure	
(12) Remove bracket (with radiator and oil cooler) **29**.	
(13) Remove radiator **22** and oil cooler **21** from bracket **29**.	

2) Reinstallation

Reinstall the radiator and the oil cooler in the reverse order of the removal procedure.

7-1-4 Removal and Reinstallation of Fan Belt and Compressor Driving Belt

1) Removal

Procedure	
(1) Remove center cover **1**. (2) Loosen adjuster bolt **3** of generator **2** to loosen tension of fan belt **4**. And loosen installation bolt **6** of tension pulley **5** to loosen tension of compressor driving belt **7**. (3) Open engine hood **8** and remove belt guard **9**. Then remove compressor driving belt **7**. After that, remove fan belt **4**.	

2) Reinstallation

Reinstall the fan belt and the compressor driving belt in the reverse order of the removal procedure.

Item		Fan belt	Compressor driving belt
Pressing force lbf. (N)		22.05 lbf. (98.1 N)	22.05 lbf. (98.1 N)
Slack in. (mm)	New belt	0.31 to 0.47 in. (8 to 12 mm)	0.59 to 0.63 in. (15 to 16 mm)
	Used belt	0.39 to 0.55 in. (10 to 14 mm)	0.75 to 0.79 in. (19 to 20 mm)

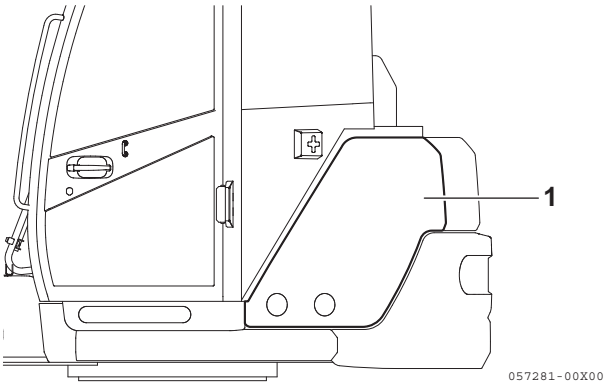
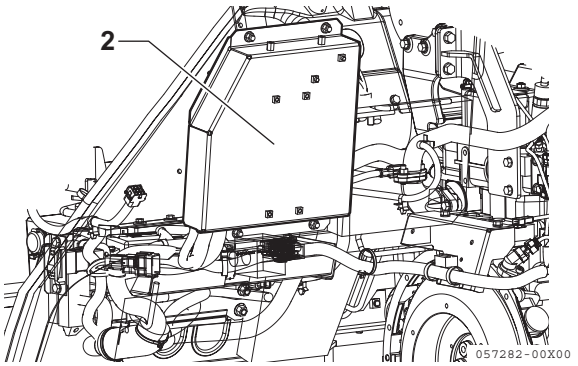
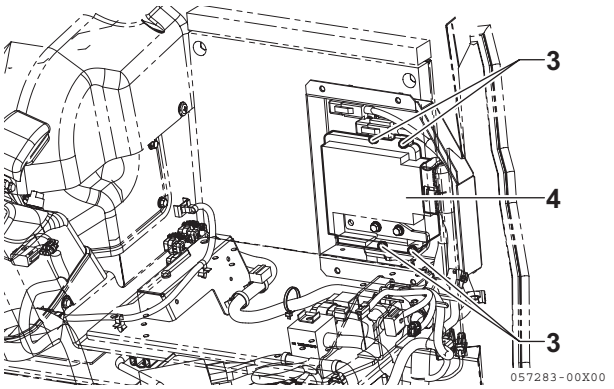
Note: Adjustment after replacing V-belt
When installing new belt, adjust the tension as "New belt" in the left figure. After adjusting, run the engine for 5 minutes or more. And then adjust the tension again using the specifications for "Used belt."

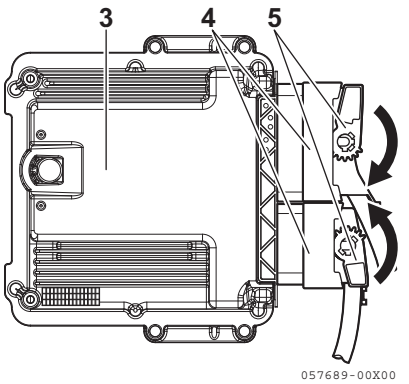
V-belt size

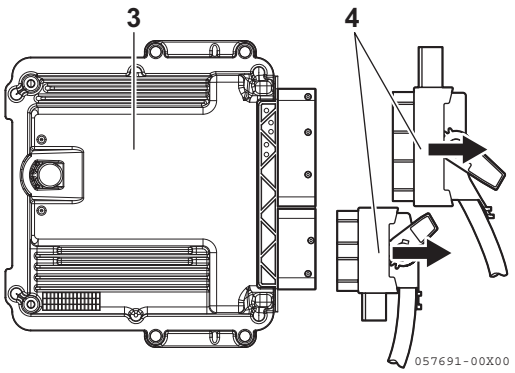
Fan belt	Raw edge A44
Compressor driving belt	Raw edge HM60

7-1-5 Removal and Reinstallation of Engine ECU

1) Removal

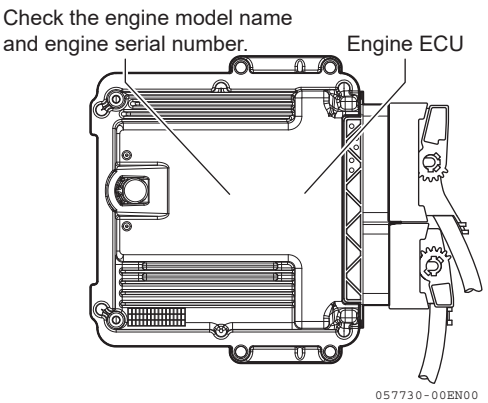
Procedure	
(1) Remove cover L **1**.	
(2) Remove E-ECU bracket **2**.	
(3) Loosen four bolts **3** and remove engine ECU **4** from the E-ECU bracket.	

Procedure	
(4) Turn lock levers **5** of couplers **4** in the direction of the arrow shown in the figure on the right.	

(5) Disconnect couplers **4** from engine ECU **3**.	

2) Reinstallation

Reinstall the engine ECU in the reverse order of the removal procedure.

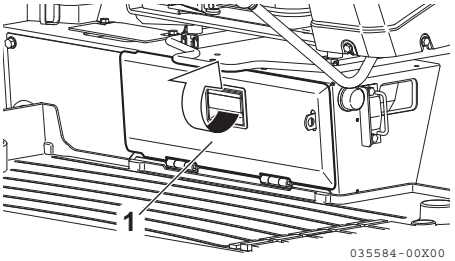
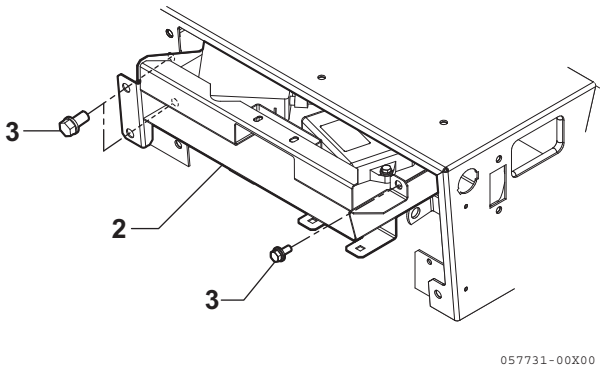
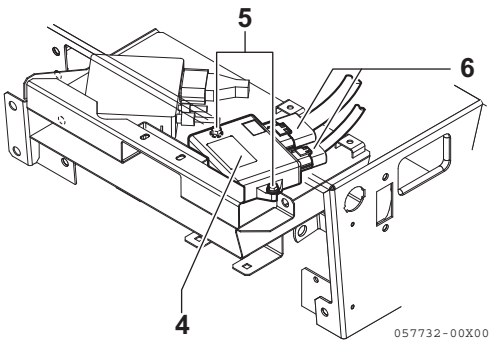


Notes:

1. *Install the engine ECU on the engine of the same engine model name and engine serial number as indicated on the engine ECU.*
2. *Do not connect or disconnect the connector to or from the engine ECU for at least 20 seconds after the power is turned on or off.*
3. *Do not touch any connector pins of the engine ECU with bare hands. Doing so might cause corrosion of the connector pins or static electricity, resulting in damage to the electronic circuit in the engine ECU.*
4. *Do not forcibly insert any devices such as the test probes of test equipment into female couplers (of the harness side). Doing so may cause contact failure of connector pins, resulting in malfunction.*
5. *Take care not to let water into the couplers when connecting or disconnecting connectors. Water can cause corrosion of connector pins, resulting in malfunction.*
6. *Do not connect or disconnect the connector to or from the engine ECU more than 10 times. Doing so may cause contact failure of connector pins, resulting in malfunction.*
7. *Take care not to drop the engine ECU. If it is dropped, do not use it.*

7-1-6 Removal and Reinstallation of Hydraulic ECU

1) Removal

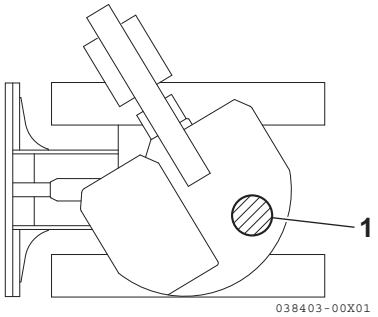
Procedure	
(1) Open cover **1** under the operator's seat.	
(2) Remove three bolts **3** from bracket **2** and pull out the bracket.	
(3) Remove two bolts **5** from hydraulic ECU **4** and disconnect couplers **6**.	

2) Reinstallation

Reinstall the hydraulic ECU in the reverse order of the removal procedure.

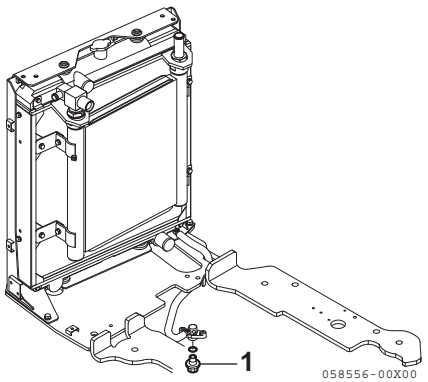
7-1-7 Removal and Reinstallation of Diesel Particulate Filter (DPF)

1) Removal

Procedure	
(1) Swing the upperstructure so that drain plug **1** for cooling water is positioned halfway between the right and left crawlers. Then, lower the bucket to the ground and stop the engine.	

(2) Remove drain plug **1** from the two-way cock for cooling water to drain the cooling water.

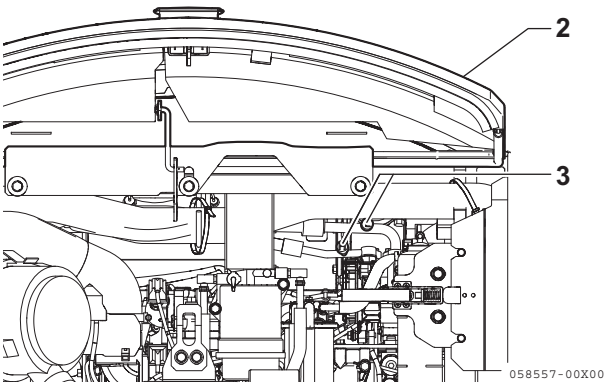
Q'ty	9.8 Gals (9.3 L)

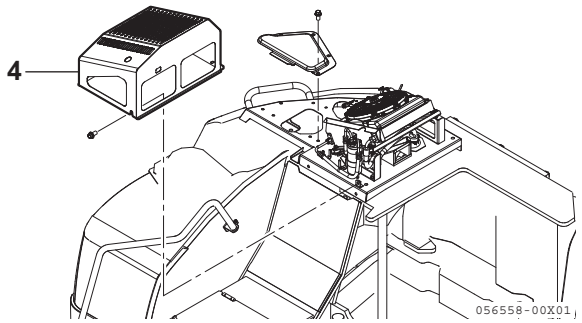
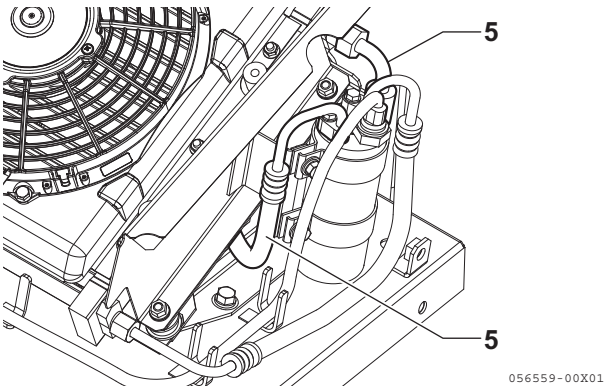
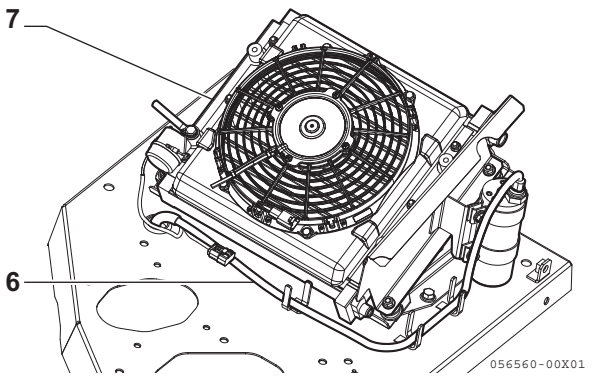
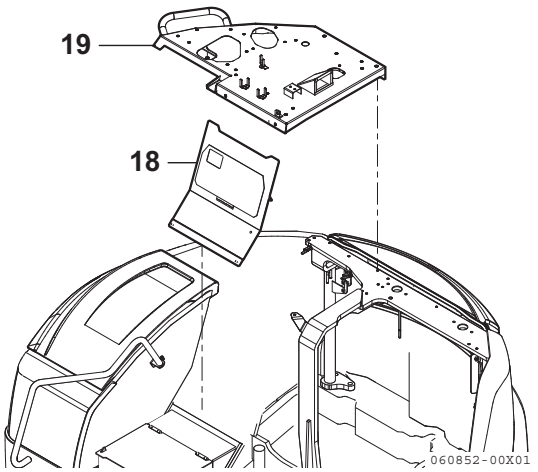


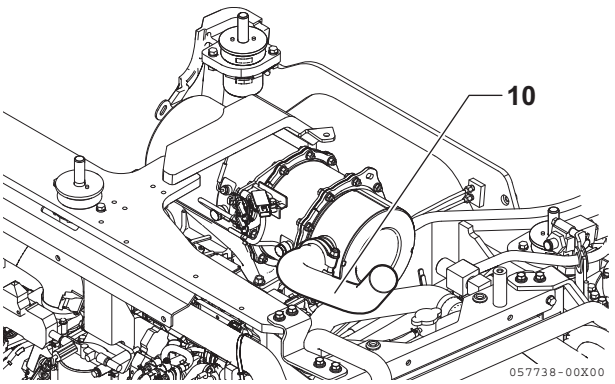
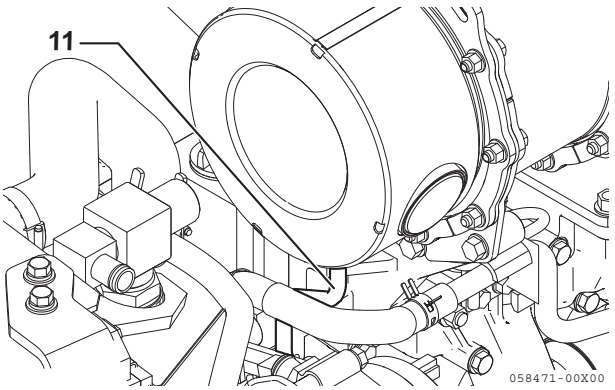
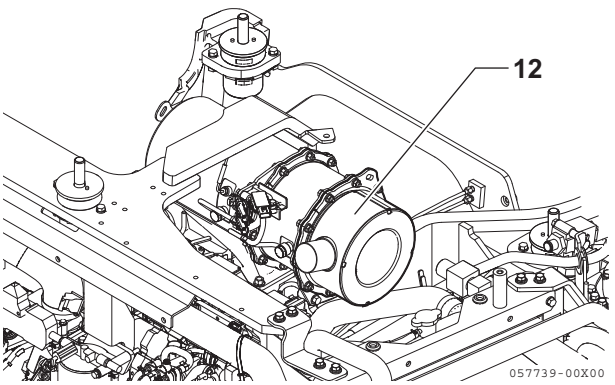
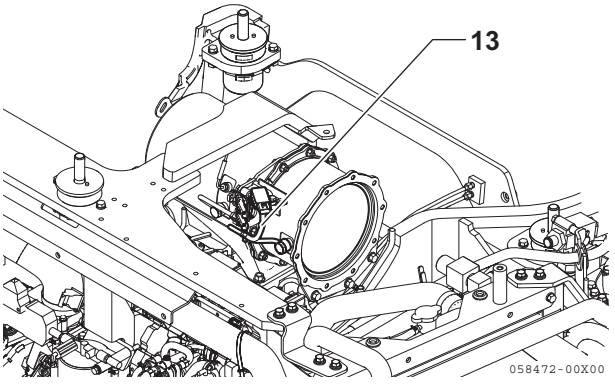
(3) Open engine hood **2** and collect refrigerant through charging valves **3** from air conditioner system by using a refrigerant collector.

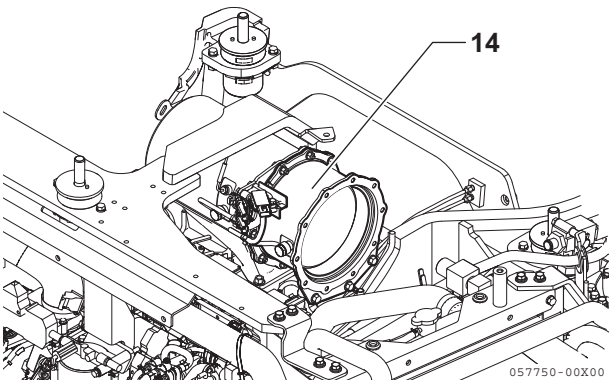
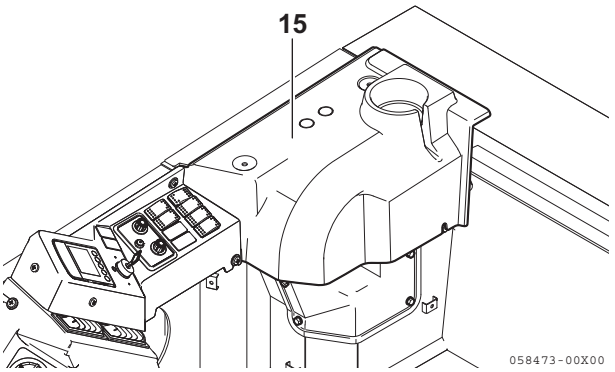
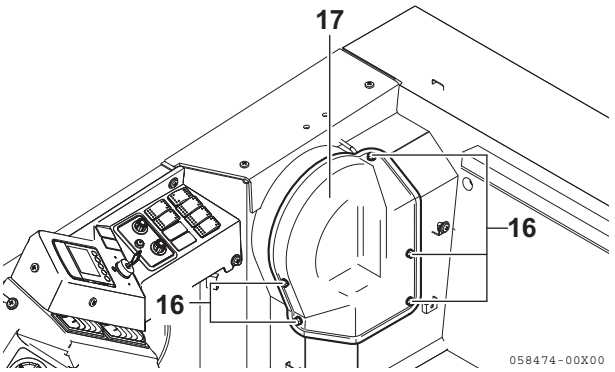
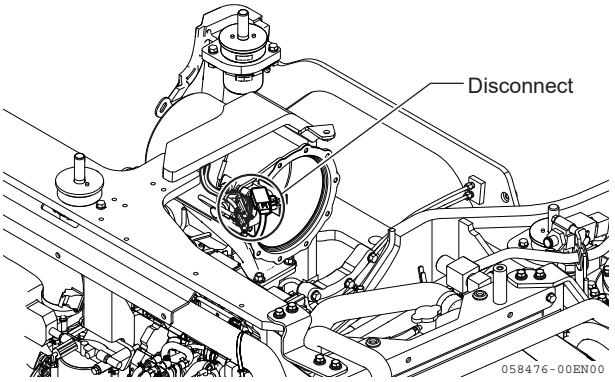
Refrigerant	R-134a
Q'ty	1.54 to 1.76 lbs. (700 to 800 g)

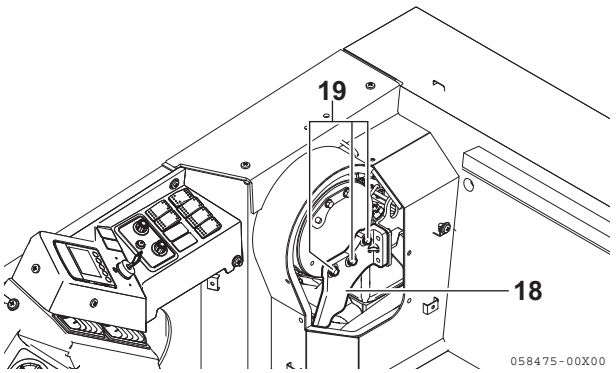
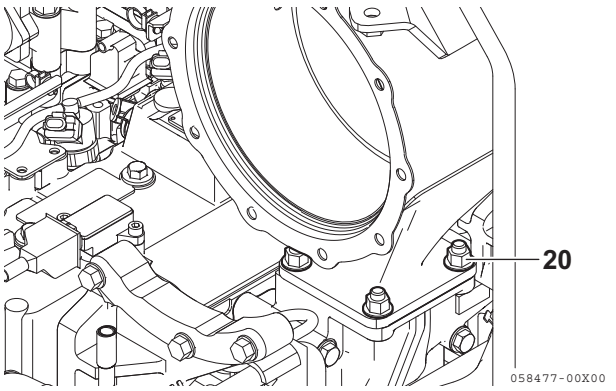
Note:
Do not release refrigerant to protect the environment.
Collect refrigerant and charge the air conditioner with refrigerant according to the instruction manual for the refrigerant collector and charger provided by the manufacturer.



Procedure	
(4) Remove condenser cover **4**.	
(5) Disconnect air conditioner hoses **5**.	
(6) Disconnect harness **6** and remove condenser **7** (with receiver dryer).	
(7) Remove center cover **8** and cover **9** under the condenser.	

Procedure	
(8) Remove exhaust pipe **10**.	
(9) Remove drain pipe **11**.	
(10) Remove the mounting bolts and nuts (10 pcs. each), and then remove DPF silencer **12**, the DPF stiffeners and gasket.	
(11) Remove pressure sensor hoses **13**.	

Procedure	
(12) Remove the mounting bolts and nuts (10 pcs. each), and then remove DPF soot filter **14**, the DPF stiffeners and gasket.	
[Removal of DOC (diesel oxidation catalyst)] (13) Remove side cover **15**.	
(14) Remove five bolts **16**, and then remove DPF cover **17**.	
(15) Disconnect harness A from the couplers of the temperature sensor and pressure sensor.	

Procedure	
(16) Remove three bolts **19** securing the DOC to DPF stay **18**.	
(17) Remove four nuts **20**, and then remove the DOC from the engine.	

2) Reinstallation

Reinstall the DPF in the reverse order of the removal procedure.

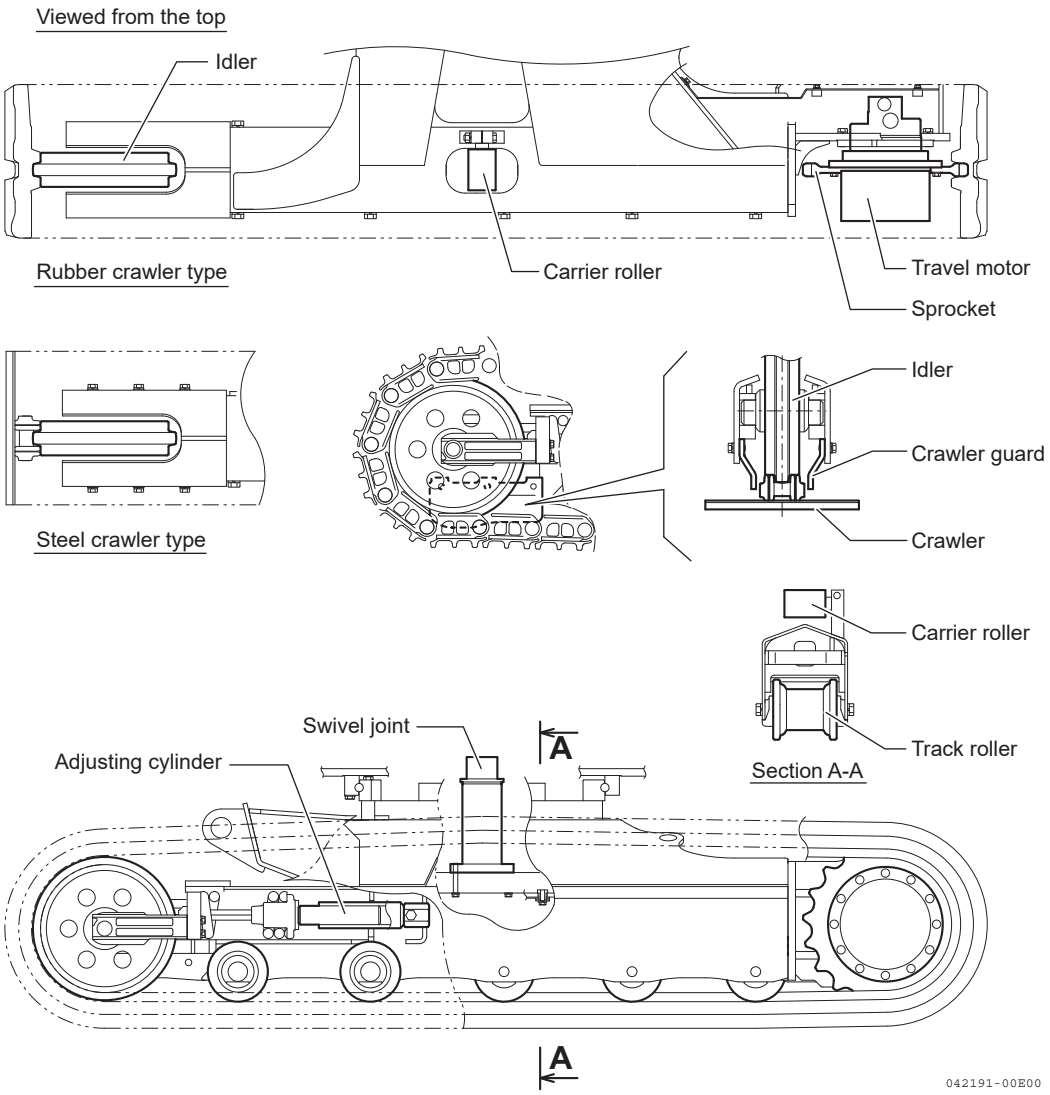
Note:

Each time the DPF assembly, soot filter or DOC has been replaced, the corresponding data stored on the engine ECU needs to be rewritten using SMARTASSIST-Direct.

7-2 Undercarriage

7-2-1 Outline

The undercarriage consists of travel motors, a track frame, carrier rollers, front idlers, crawlers (steel or rubber) and other parts.
The hydraulic oil fed through the control valve and the swivel joint from the hydraulic pump causes the travel motor to rotate, so that the power is transmitted to the crawler via the sprocket.
The machine travels forward or reverse by operating the travel levers.



7-2-2 Compatibility of Main Parts

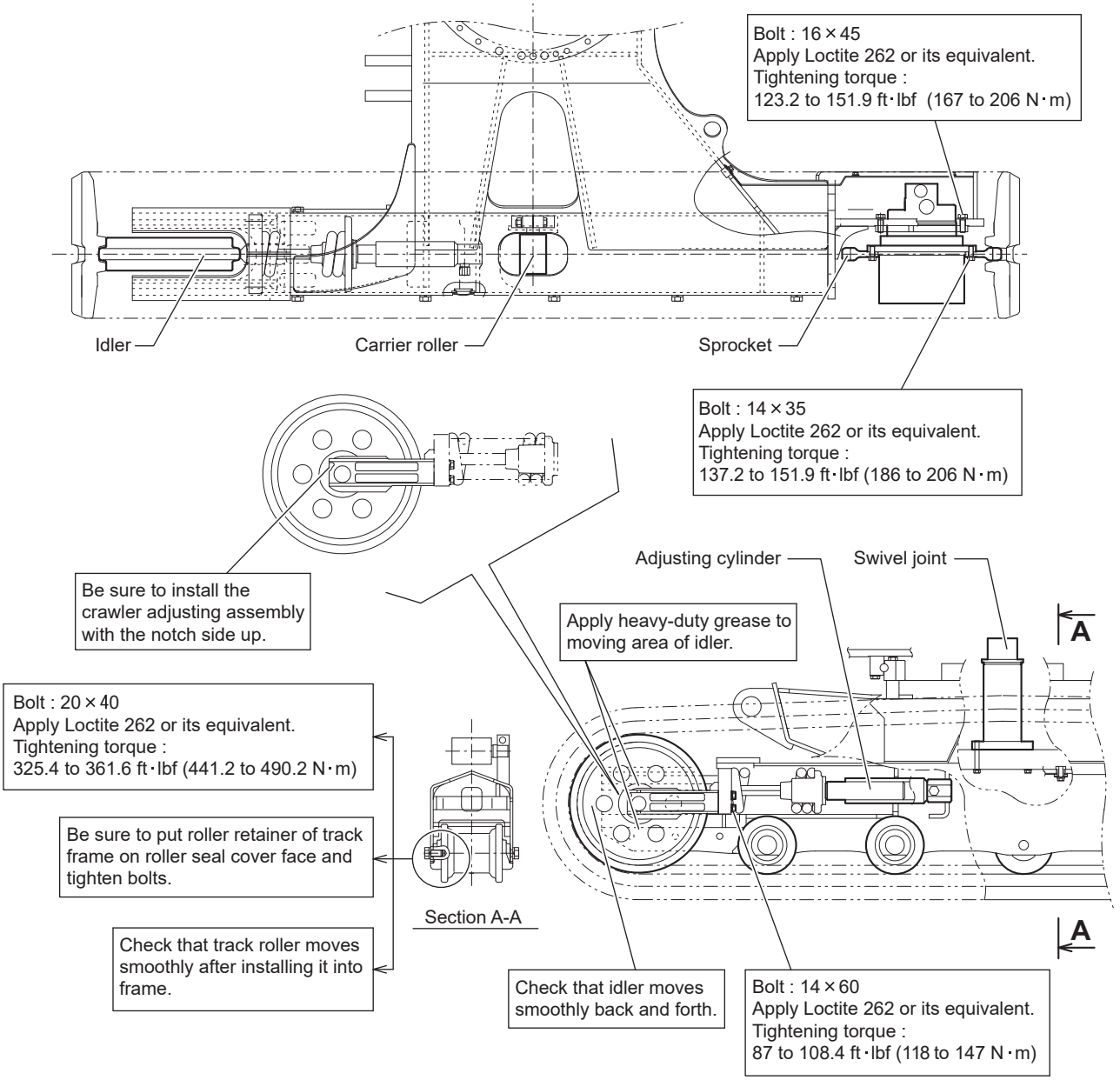
Compatibility of idler

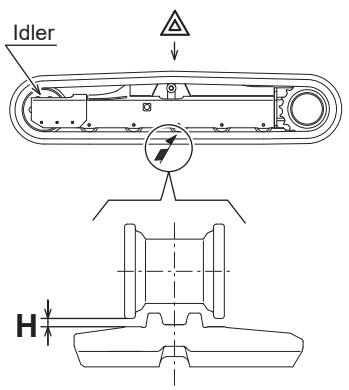
The idler has compatibility between steel and rubber crawlers by changing no part but the installation direction of the edge notch in the idler seal cover of the idler.

Compatibility of main part

Spec. / Parts	Steel crawler	Rubber crawler
Travel motor	○	○
Sprocket	○	○
Idler assembly	△ (with notch side down)	△ (with notch side up)
Track roller	○	○
Carrier roller	○	○
Crawler guard	× (Exclusive)	– (None)

7-2-3 Points of Reassembly (Rubber Crawler Type)





Crawler Tension Adjustment:

1. Raise the crawler on one side using the boom.
2. Bring the mark ⚠ on the inside surface of the rubber crawler to the upper center of the carrier roller.
3. Adjust the crawler tension so that the clearance **H** between the outside rolling surface of the third track roller from the idler and the crawler tread, as shown in the figure, is within the range from 0.8 to 1.0 in. (20 to 25 mm).
4. After rotating the crawler several times, check that the clearance H should be within the range from 0.8 to 1.0 in.(20 to 25 mm).
5. If not, readjust the crawler tension following the above steps 1 to 3. Then check the clearance **H** again, following the step 4.

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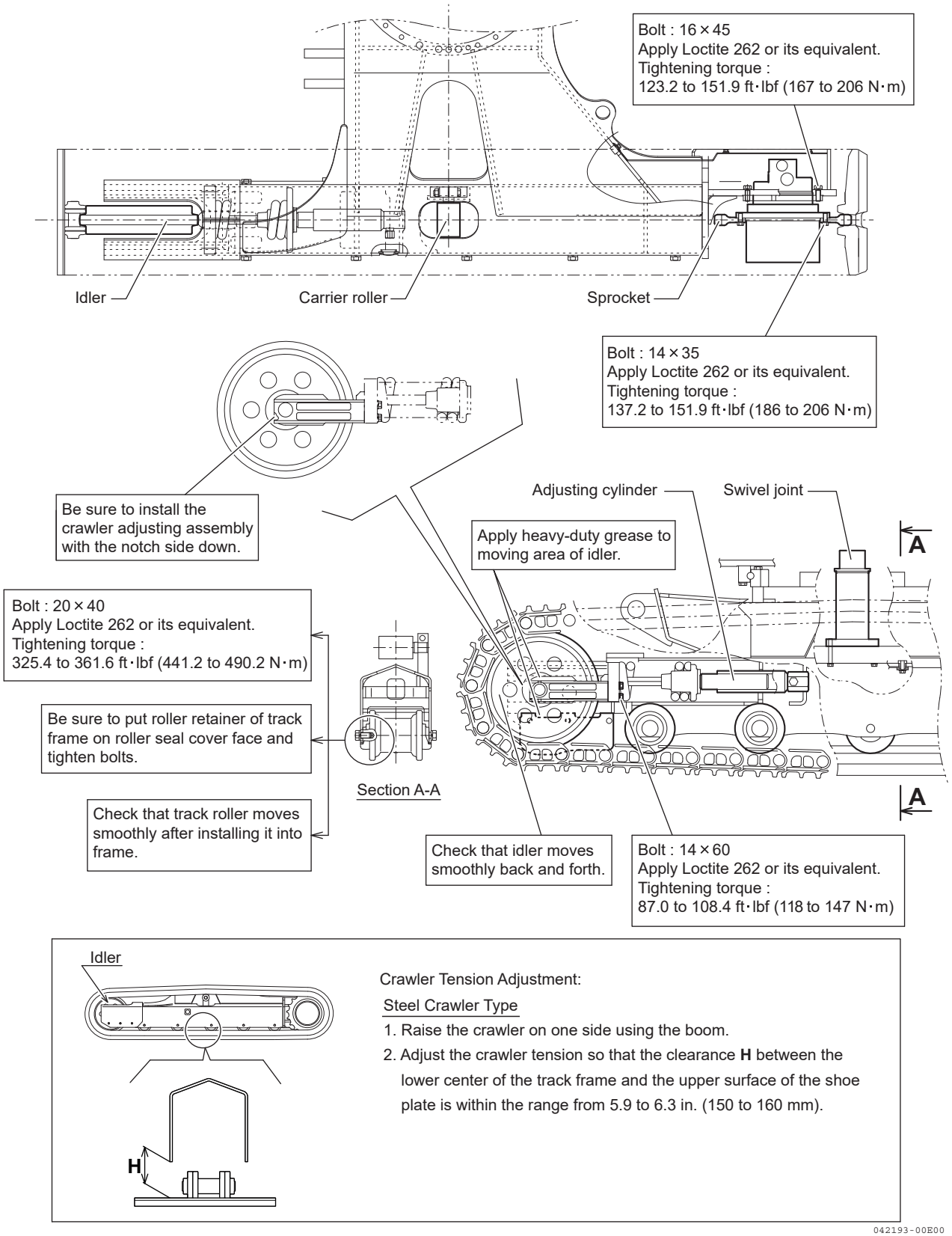
7-2-4 Points of Reassembly (Steel Crawler Type)

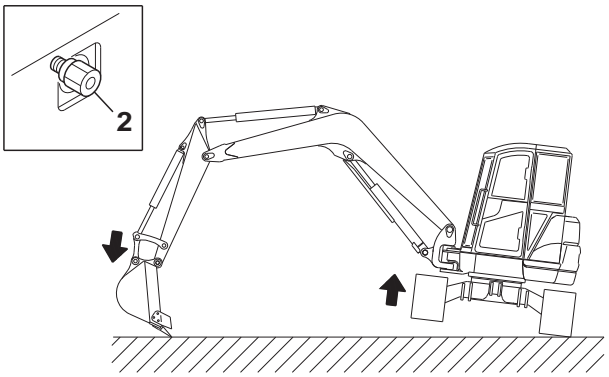


7-2-5 Removal and Reinstallation of Crawler

1) Removal of Rubber Crawler

⚠ Put safety blocks, which are strong enough to support the machine, under the machine while working with the machine body raised.

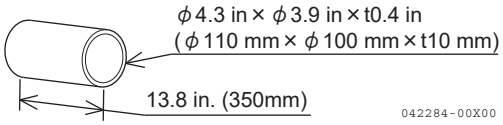
⚠ Do not loosen the nipple valve more than one turn since it might jump out due to the inside high-pressure grease.

Procedure	
(1) Turn the implement 90 degrees and lower it to the ground. Remove frame cover **1**. Then loosen nipple valve **2** (about 1 turn) and drain the grease.	

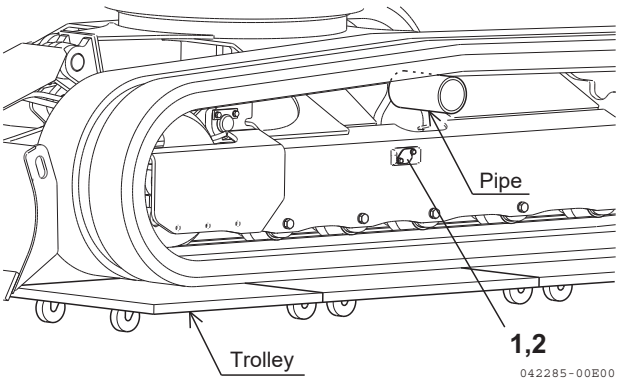
(2) Raise the crawler on one side using the boom, and then loosen the crawler tension.

Note:
If the grease does not come out smoothly from the nipple valve, put down the machine on the ground and move it forward and backward.

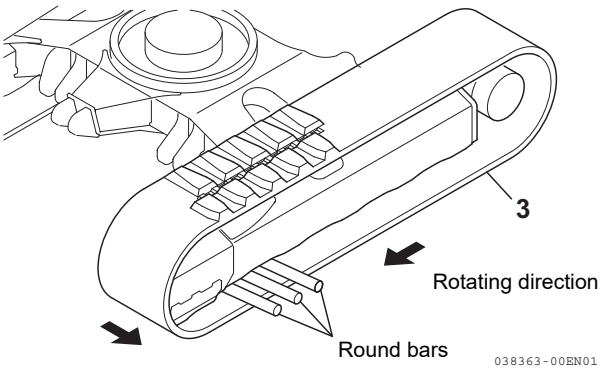
(3) Install the pipe shown in the following figure to carrier roller.



(4) Put trolleys under the crawler, and lower the machine to make space between the crawler and idler.



(5) Remove the crawler **3** from idler and sprocket by using a pinch bar (about 59 in. (1500 mm) in length). Alternatively, insert round bars between crawler **2** and the track frame, and turn the sprocket in the reverse direction. Side the crawler off when it is separated from the idler by the round bars.



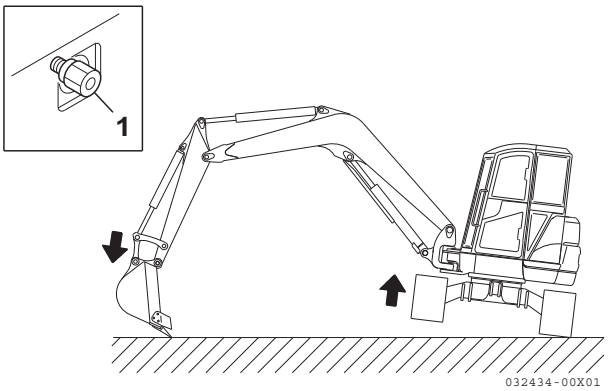
2) Reinstallation of Rubber Crawler

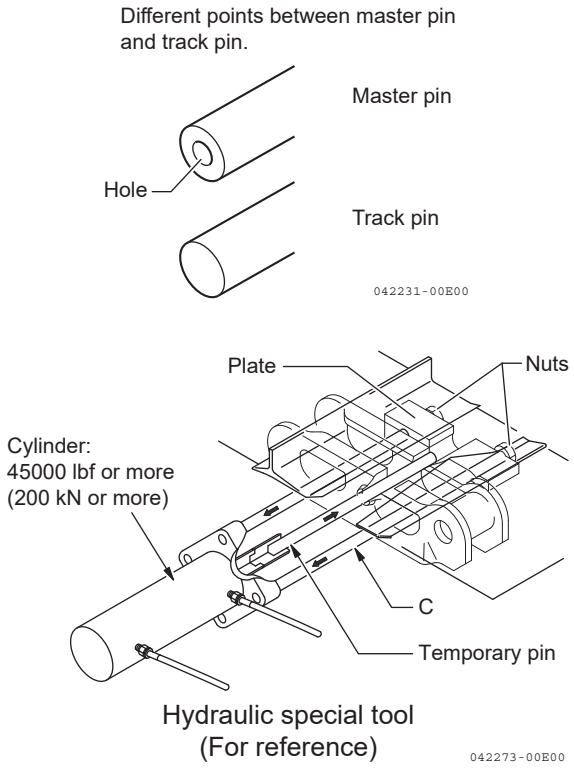
Reinstall the rubber crawler in the reverse order of the removal procedure.

3) Removal of Steel Crawler (with pulling out the master pin)

⚠ Put safety blocks, which are strong enough to support the machine, under the machine while working with the machine body raised.

⚠ Do not loosen the nipple valve more than one turn since it might jump out due to the inside high-pressure grease.

Procedure	
(1) Turn the implement 90 degrees to the right or the left and lower it to the ground to raise the crawler on one side. (2) Loosen nipple valve **1** to loosen the crawler tension. ***Note:*** *If the grease does not come out smoothly from the nipple valve, put down the machine on the ground and move it forward and backward.*	

(3) Lower the crawler to the ground. (4) Remove the master pin by using hydraulic special tool. ***Note:*** *Do not remove track pins other than master pin.*	

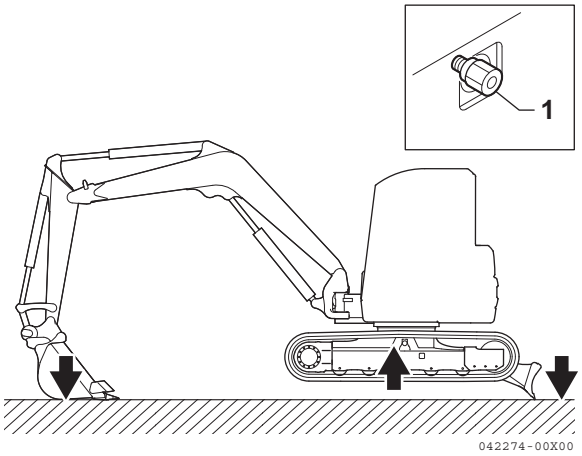
4) Reinstallation of Steel Crawler

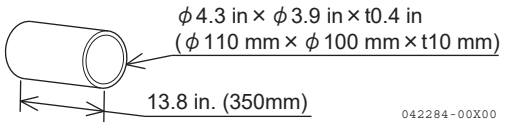
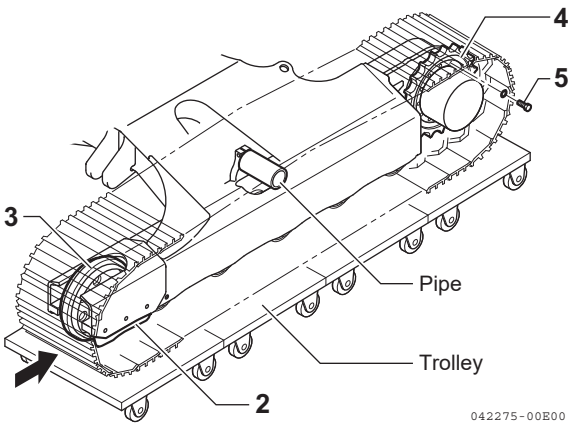
Reinstall the steel crawler in the reverse order of the removal procedure.

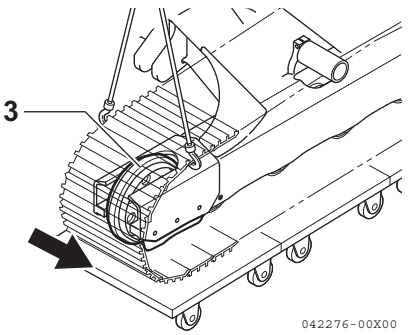
5) Removal of Steel Crawler (without pulling out the master pin)

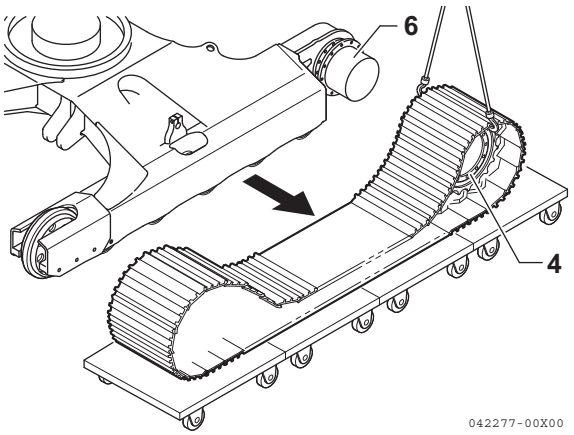
⚠ Put safety blocks, which are strong enough to support the machine, under the machine while working with the machine body raised.

⚠ Do not loosen the nipple valve more than one turn since it might jump out due to the inside high-pressure grease.

Procedure	
(1) Swing the upper structure, and raise the machine with the implement and the blade as the figure indicates. (2) Loosen nipple valve **1** to loosen the crawler tension. ***Note:*** *If the grease does not come out smoothly from the nipple valve, put down the machine on the ground and move it forward and backward.*	

(3) Put trolleys under the crawler, and install the pipe shown in the following to carrier roller.  (4) Remove the crawler guard **2**, and push the idler **3** to loosen the crawler tension. (5) Remove the installation bolts **5** for sprocket **4**	

(6) Lift up crawler on idler side slightly to disengage the track link from the idler **3**.	

Procedure	
(7) Lift up the crawler on sprocket side slightly, and pull out the sprocket **4** with the crawler from the travel motor **6**.	

6) Reinstallation of Steel Crawler

Reinstall the steel crawler in the reverse order of the removal procedure.

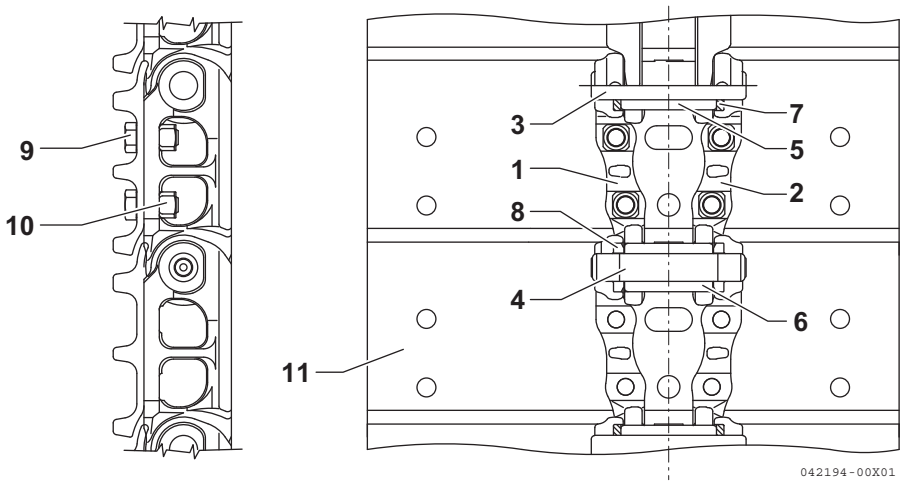
- When installing the sprocket, lift up the crawler and the sprocket and install the sprocket to the travel motor. If leaving the sprocket in the crawler is difficult to install, install them separately after removing the sprocket from the crawler.
- Apply the adhesive to installation bolts **5** for sprocket and tighten them by specified tightening torque.

Adhesive	Loctite 262 or its equivalent
Tightening torque	137.2 to 151.9 ft•lbf (186 to 206 N•m)

7-2-6 Disassembly and Reassembly of Steel Crawler

1) Structure and Component Parts

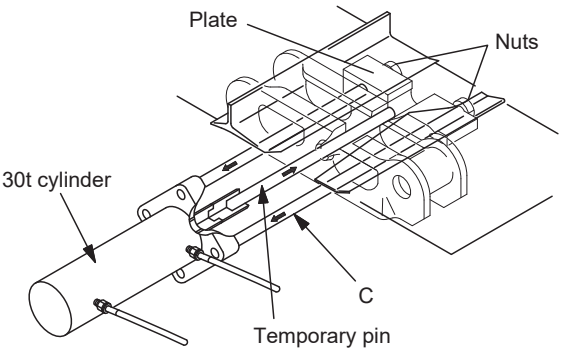
(1) Track shoe



No.	Part	Q'ty	No.	Part	Q'ty
1	Track link R	39	7	Dust seal	76
2	Track link L	39	8	Collar	2
3	Track pin	38	9	Track bolt	156
4	Master pin	1	10	Track nut	156
5	Track bush	38	11	Track shoe	39
6	Master bush	1			

2) Disassembly of Track Shoe Link

(1) Pull out track pins **3** using a hydraulic tool.
(2) Remove installation bolts **9** for track shoes **11**.
(3) Remove collars **8** and seals **7**.



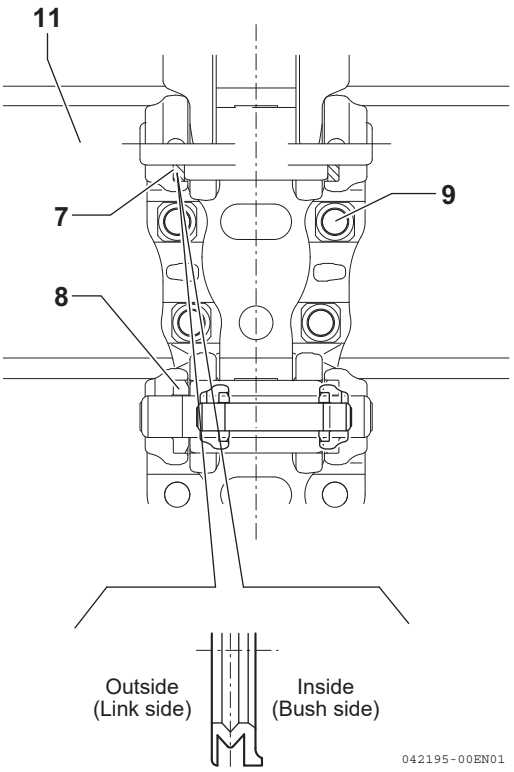
3) Reassembly

Reassemble the track shoe link in the reverse order of the disassembly procedure.

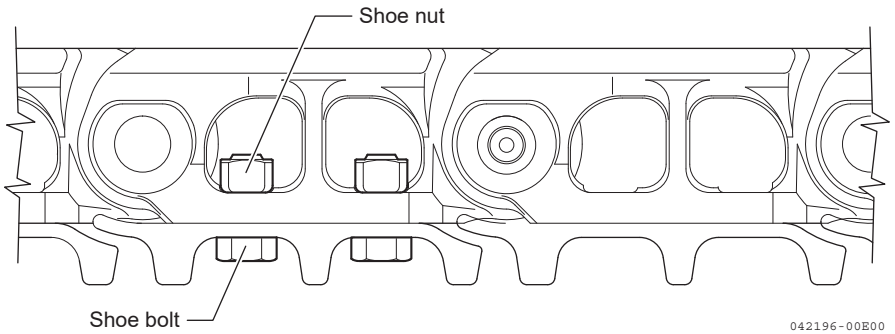
Notes:

- *Replace worn master pin and bush, track pins and bushes, collars and seals.*
- *Be sure to insert the seal in the correct direction.*
- *Apply grease to the pins and the bushes.*

Apply extreme pressure grease.



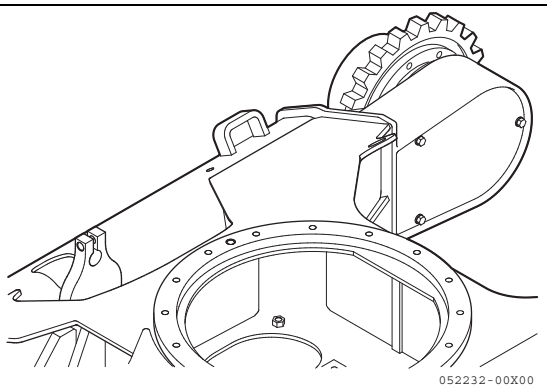
• Tightening torque of shoe bolt

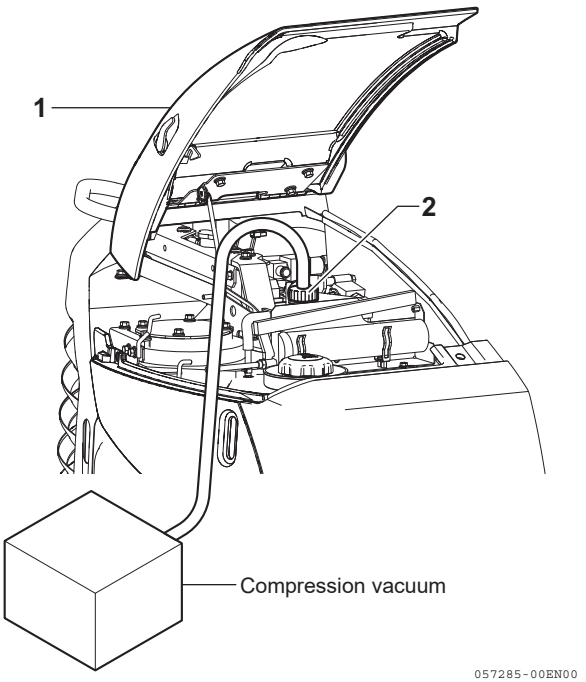


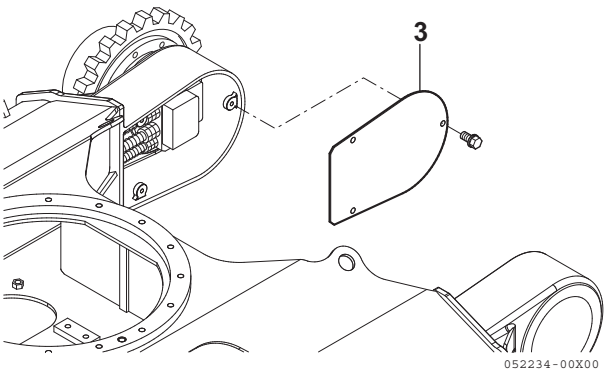
Shoe bolt (M14×1.5)	
Tightening torque	162.3 to 199.1 ft•lbf (220 to 270 N•m)

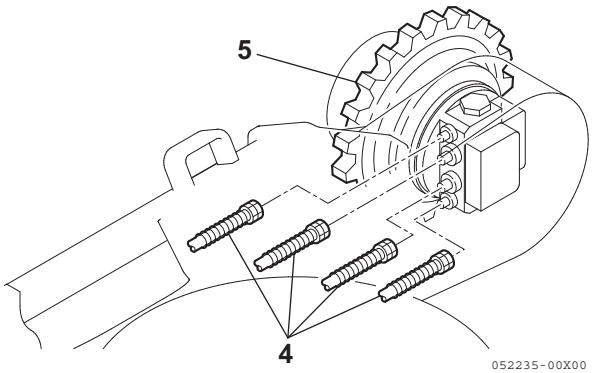
7-2-7 Removal and Reinstallation of Travel Motor

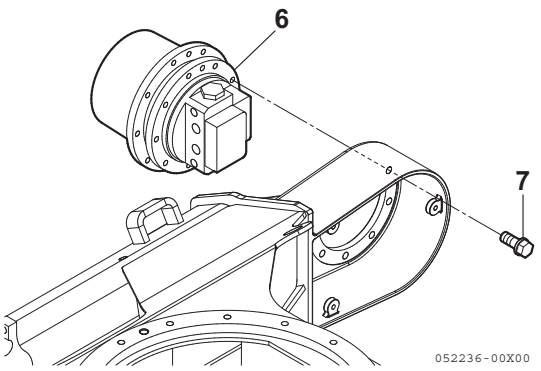
1) Removal

Procedure	
(1) Remove the rubber crawler or steel crawler on the side of the travel motor to be removed. (Refer to Section "7-2-5 Removal and Reinstallation of Crawler".)	

(2) Open bonnet B **1**. (3) Replace the oil filler cap of the hydraulic oil tank with vacuum master cap **2** to connect the compression vacuum. Then evacuate the hydraulic oil tank. (Refer to Section 1-10 for the vacuum master cap.)	

(4) Remove travel motor cover **3** on the side of the travel motor.	

Procedure	
(5) Disconnect four hoses **4** from the travel motor. ***Note:*** *Put a mark on the removed hoses to reinstall them to the correct positions.* (6) Remove sprocket **5**.	

(7) Remove nine mounting bolt (M16) **7** and remove travel motor **6**. Weight of travel motor: 191.8 lbs. (87 kg)	

2) Reinstallation

Reinstall the travel motor in the reverse order to the removal procedure.

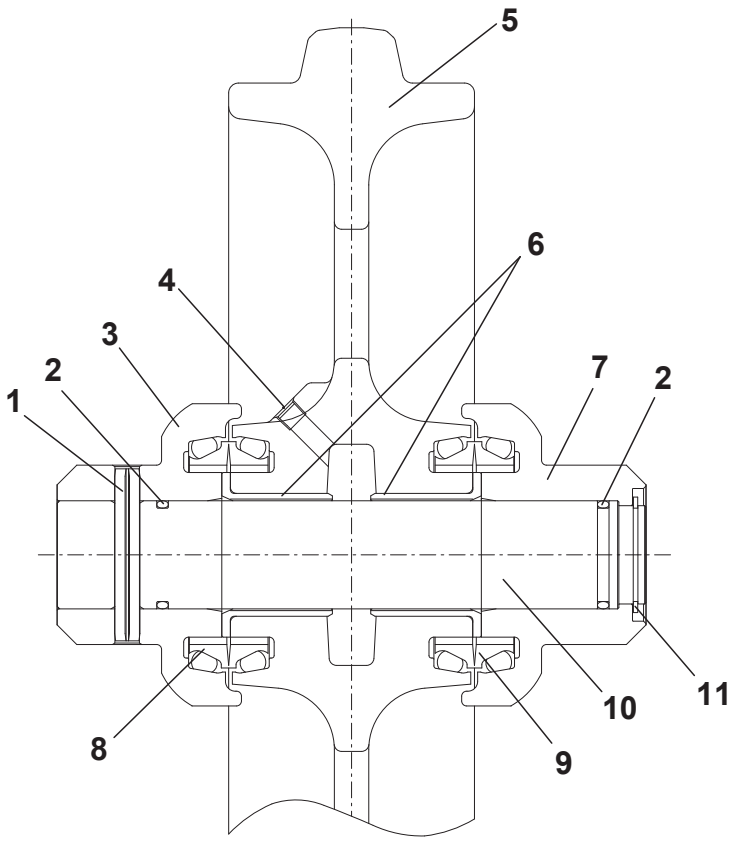
Note:

Apply Loctite 262 or its equivalent to the mounting bolts for the travel motor and sprocket.

Travel motor mounting bolt (M16)	
Tightening torque	123.2 to 151.9 ft•lbf (167 to 206 N•m)

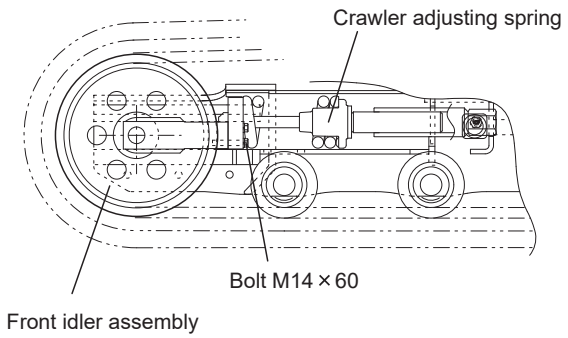
7-2-8 Disassembly and Reassembly of Idler

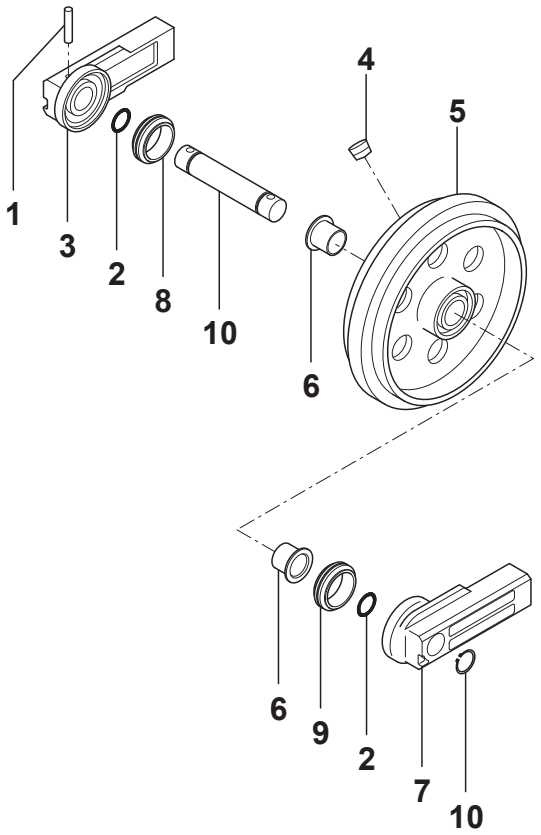
1) Structure and Component Parts



No.	Part	Q'ty	No.	Part	Q'ty
1	Spring pin 10×70	1	7	Idler seal cover B	1
2	O-ring 1A P38	2	8	Floating seal	1
3	Idler seal cover A	1	9	Floating seal	1
4	Screw plug (R) PT1/8	1	10	Shaft	1
5	Idler	1	11	External snap ring C 40	1
6	Bush	2			

2) Disassembly

Procedure	
(1) Remove the front idler assembly from the track frame. (2) Remove the crawler adjusting spring. Installation bolt (M14) for crawler adjusting spring: Adhesive — Apply Three Bond 1324 or its equivalent.; Tightening torque — 86.8 to 108.5 ft·lbf (118 to 147 N·m)	

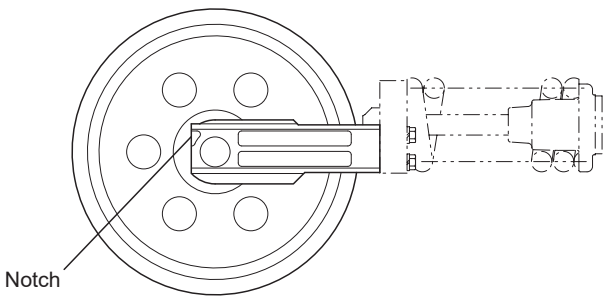
Procedure	
(3) Remove screw plug R (PT1/8) **4** from idler **5** and drain the engine oil. Type: Engine oil SAE 30 Q'ty: 0.095 Qts. (0.09 L) (4) Remove external snap ring C **11** from shaft **10** and remove idler seal cover B **7**. ***Note:*** *Remove snap ring C 11 while pressing the outer face of idler seal cover B 7 with a press or the like, and it can be removed easily.* (5) Pull shaft **10** (with idler seal cover A **3**) out of idler **5** and remove floating seals **8** and **9**. ***Notes:*** • *Since shaft **10** and idler seal cover A **3** are fixed by spring pin **1**, do not disassemble them unless necessary.* • *Measure the bore of bush **6**. If the measured value is within the allowable wear limit, do not remove the bush.*	

3) Reassembly

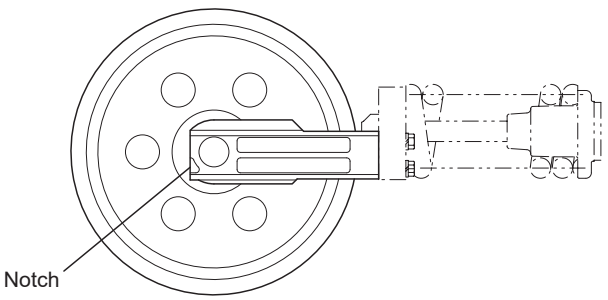
Reassemble the front idler in the reverse order of the disassembly procedure.

Notes:

- *Replace the O-rings and the floating seals with new ones.*
- *Refer to Section "7-2-11 Installation of Floating Seal" for the procedure for installing the floating seals.*
- *The floating seal cover has an edge notch, by which the installation direction of the idler to the rubber crawler type or the steel crawler type can be confirmed. Check that the notch is on the proper side before installing the idler.*



Rubber crawler type (with notch side up)

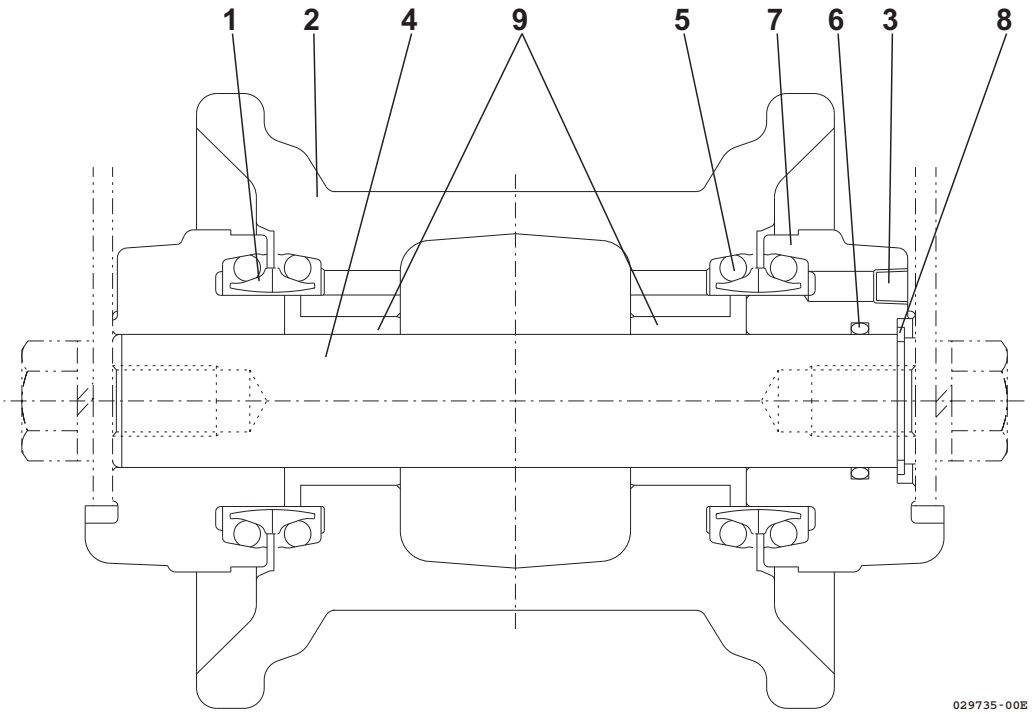


Steel crawler type (with notch side down)

Screw plug R (PT) 1/8	
Tightening torque	6.5 to 7.2 ft•lbf (8.8 to 9.8 N•m)

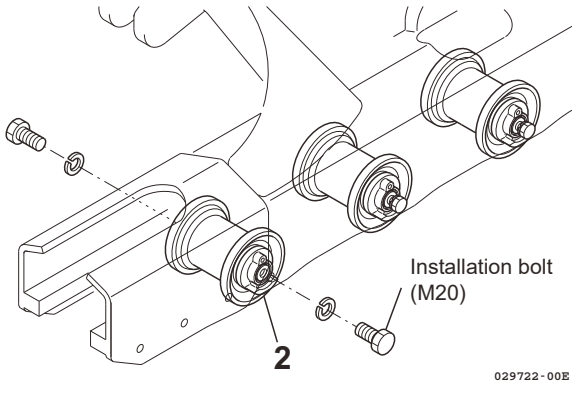
7-2-9 Disassembly and Reassembly of Track Roller

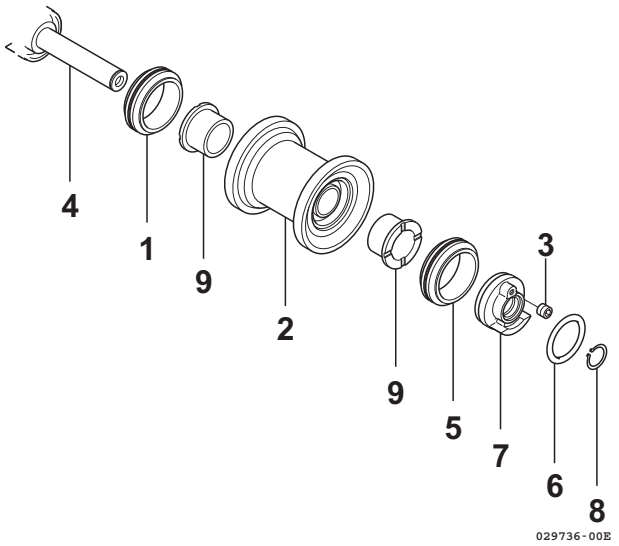
1) Structural and Component Part



No.	Part	Q'ty	No.	Part	Q'ty
1	Floating seal	1	6	O-ring 1A P38	1
2	Roller	1	7	Seal cover B	1
3	Plug R (PT) 1/8	1	8	External snap ring C 36	1
4	Shaft (with seal cover)	1	9	Bush	2
5	Floating seal	1			

2) Disassembly

Procedure	
(1) Remove track roller assembly **2** from the track frame. Installation bolt (M20) Adhesive: Apply Loctite 262 or its equivalent. Tightening torque: 274.9 to 296.6 ft·lbf (372.7 to 402.1 N·m)	

Procedure	
(2) Remove the plug R (PT) 1/8 **3** to drain engine oil. Type: Engine oil SAE 30 Q'ty: 0.21 Qts. (0.2 L) (3) Remove snap ring C **8** from track roller **2**. ***Note:*** *Remove the snap ring C while pressing the outer face of seal cover B **7** with a press or the like, and it can be removed easily.* (4) Remove seal cover B **7** and floating seal **5** from roller **2**. (5) Pull out shaft (with the seal cover) **4** and remove floating seal **1**. ***Notes:*** • *Since shaft **4** is press-fitted into the seal cover, they cannot be disassembled.* • *Measure the bore of bush **9**. If the measured value is within the allowable wear limit, do not remove the bush.*	

3) Reassembly

Reassemble the track roller in the reverse order of the disassembly procedure.

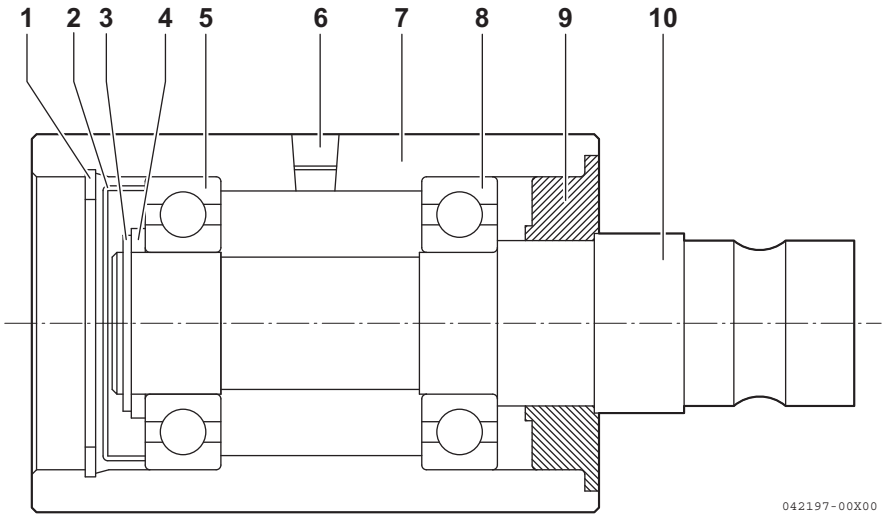
Notes:

- *Replace the O-ring and the floating seals with new ones.*
- *Refer to Section "7-2-11 Installation of Floating Seal" for the procedure for installing the floating seals.*

Plug R (PT) 1/8	
Adhesive	Apply Loctite 572 or its equivalent
Tightening torque	6.5 to 7.2 ft•lbf (8.8 to 9.8 N•m)

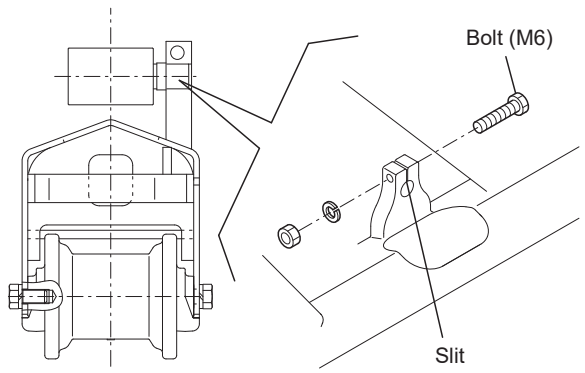
7-2-10 Disassembly and Reassembly of Carrier Roller

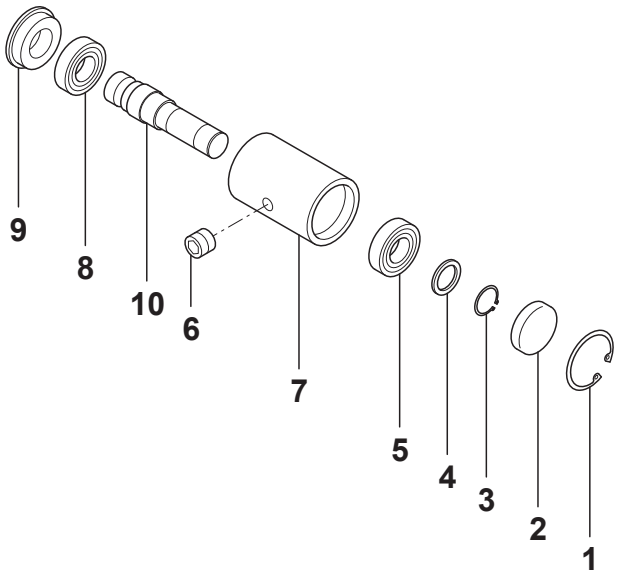
1) Structural Drawings and Component Part



No.	Part	Q'ty	No.	Part	Q'ty
1	External snap ring C (72)	1	6	Plug R (PT) 1/8	1
2	Cap	1	7	Roller	1
3	External snap ring C (35)	1	8	Bearing 6207	1
4	Washer	1	9	Seal	2
5	Bearing 6207	1	10	Shaft	1

2) Disassembly

Procedure	
(1) Remove the tightening bolt for the carrier roller assembly to remove the roller from the track frame. ***Note:*** *Put a wedge into the slit in the bracket to remove the roller smoothly.*	

Procedure	
(2) Remove snap ring C **1** and cap **2**. (3) Remove snap ring C **3** and washer **4**. Then, pull out shaft **10** with a press. (4) Remove seal **9** and bearings **5** and **8**. (5) Remove plug R (PT) 1/8 **6**.	

3) Reassembly

Reassemble the carrier roller in the reverse order of the disassembly procedure.

Notes:

- *Replace the cap and the seal with new ones.*
- *Supply inside of the roller with ALBANIA EP-2 or its equivalent.*

Plug R (PT) 1/8	
Adhesive	Apply Loctite 242 or its equivalent
Quantity of grease	0.11 Qts. (0.1 L)

7-2-11 Installation of Floating Seal

1) Inspection for Damage

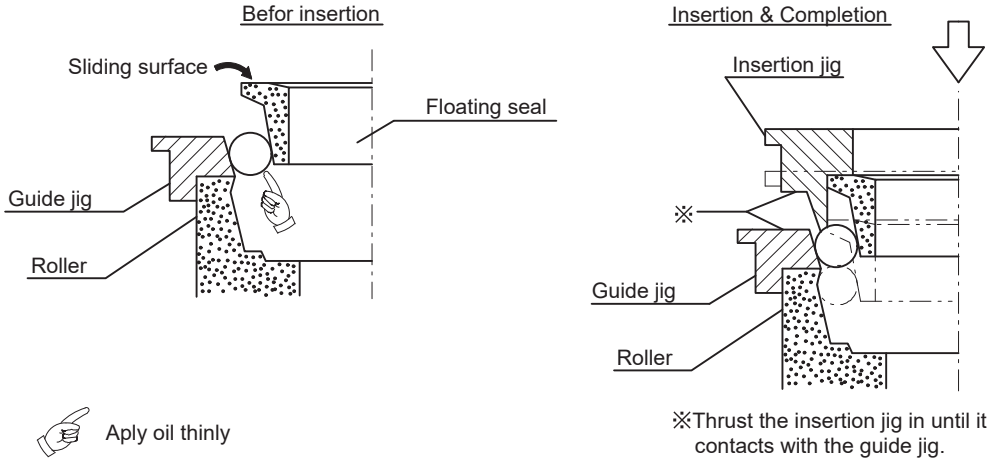
(1) Check for flaws or breakages on the sliding surface of the floating seal.
(2) Check for flaws, breakages or distortion on the O-ring.
(3) Check for fins or burrs on the collar and roller bush.

Note:

The fins or burrs will cause damage to the O-ring. Remove any fin or burr with sand paper or the like.

2) Use of Jigs

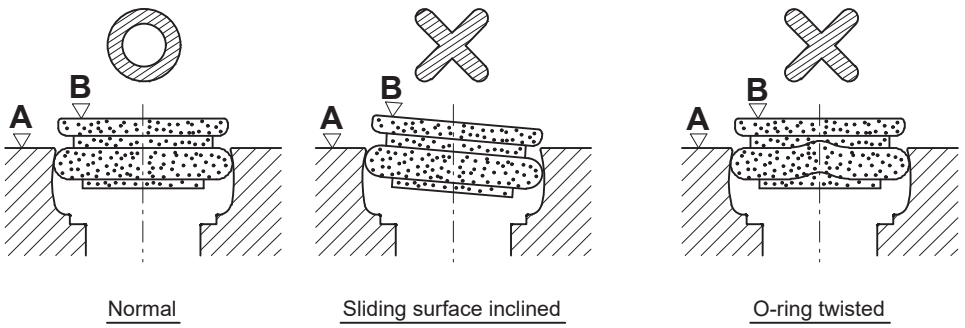
(1) Clean the collar, roller, roller bush, etc. with oil or compressed air.
(2) Do not use a waste cloth to wipe the sliding surface of the floating seal. Use a paper cleaner instead.
(3) Installation using jigs:



(4) Check that there is no inclination of the sliding surface and no distortion in the O-ring.

Note:

A & B should be parallel.



(5) Clean the sliding surface completely and apply oil thinly.
(6) Assemble the roller assembly. Avoid placing heavy stress on the sliding surface.

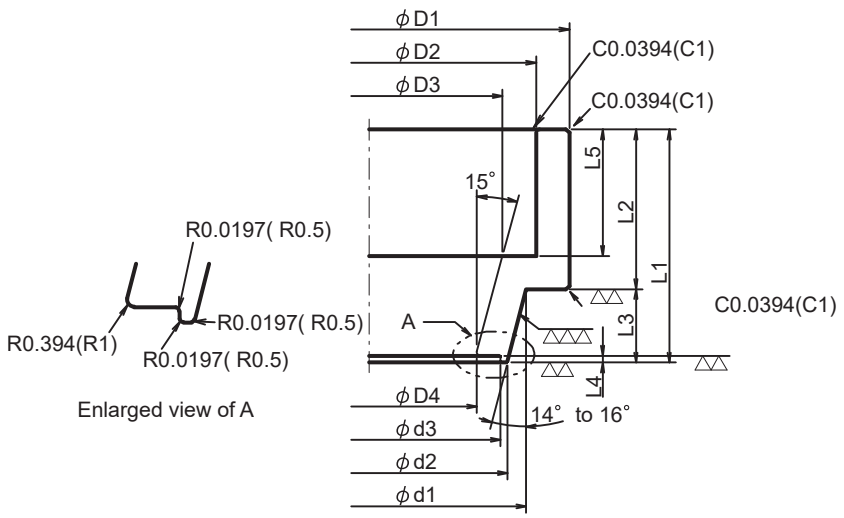
3) Inspection after Installation

(1) After putting oil into the roller, seal it. Then, turn the roller manually 2 to 3 times to from an oil film on the sliding surface.
(2) Turn the roller manually to check that the torque is not excessively high.
(3) Check that there is no oil leak.

7-2-12 Drawings of Jigs

• Floating seal

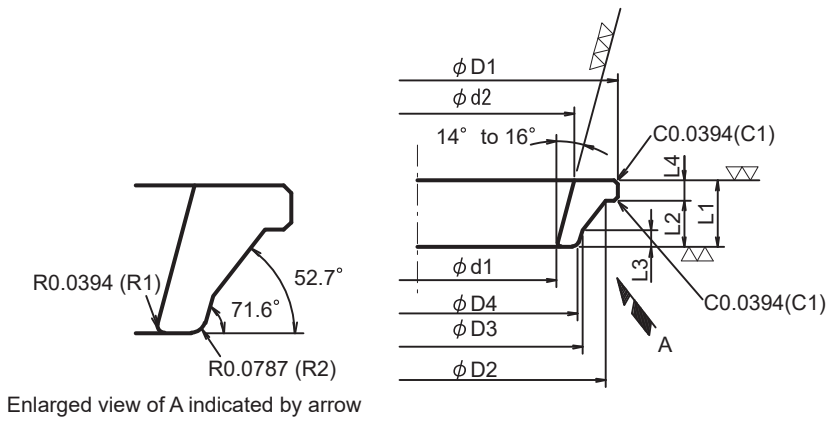
Floating seal installation jig



Unit: in. (mm)

Jig No.	A-030
ØD1	4.72 (120)
ØD2	3.94 (100)
ØD3	3.15 (80)
ØD4	2.76 (70)
Ød1	3.6968 to 3.7008 (93.9 to 94)
Ød2	3.2559 to 3.2598 (82.7 to 82.8)
Ød3	3.0984 to 3.1024 (78.7 to 78.8)
L1	2.76 (70)
L2	[1.89 (48)]
L3	0.87 (22)
L4	0.079 (2)
L5	1.38 (35)
Used for	Track roller

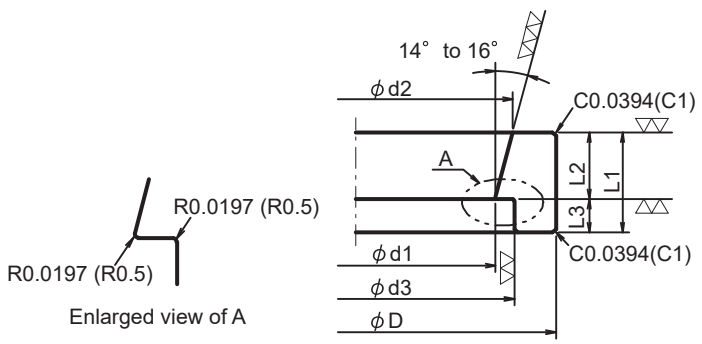
Floating seal installation jig (guide jig) for roller



Unit: in. (mm)

Jig No.	A-031
ØD1	4.72 (120)
ØD2	4.45 (113)
ØD3	3.90 (99)
ØD4	3.78 (96)
Ød1	3.2795 to 3.2854 (83.3 to 83.45)
Ød2	3.7008 to 3.7067 (94 to 94.15)
L1	0.787 (20)
L2	0.55 (14)
L3	0.20 (5)
L4	[0.24 (6)]
Used for	Track roller

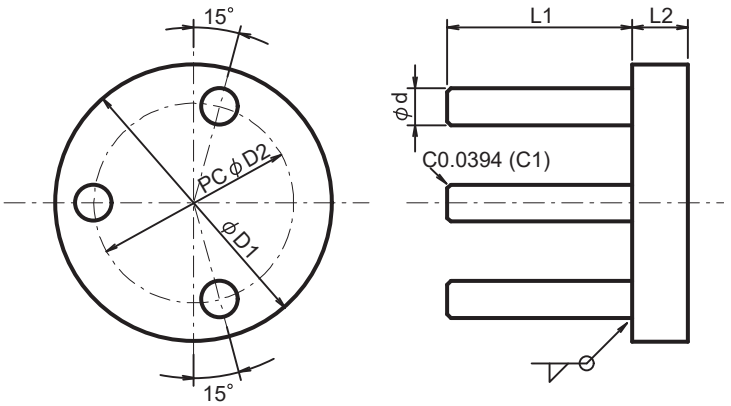
Floating seal installation jig (guide jig) for cover



Unit: in. (mm)

Jig No.	A-032
ØD	4.72 (120)
Ød1	3.2795 to 3.2854 (83.3 to 83.45)
Ød2	3.7008 to 3.7067 (94 to 94.15)
Ød3	3.7441 to 3.7480 (95.1 to 95.2)
L1	1.18 (30)
L2	0.79 (20)
L3	[0.39 (10)]
Used for	Track roller

• Seal cover holding jig



Unit: in. (mm)

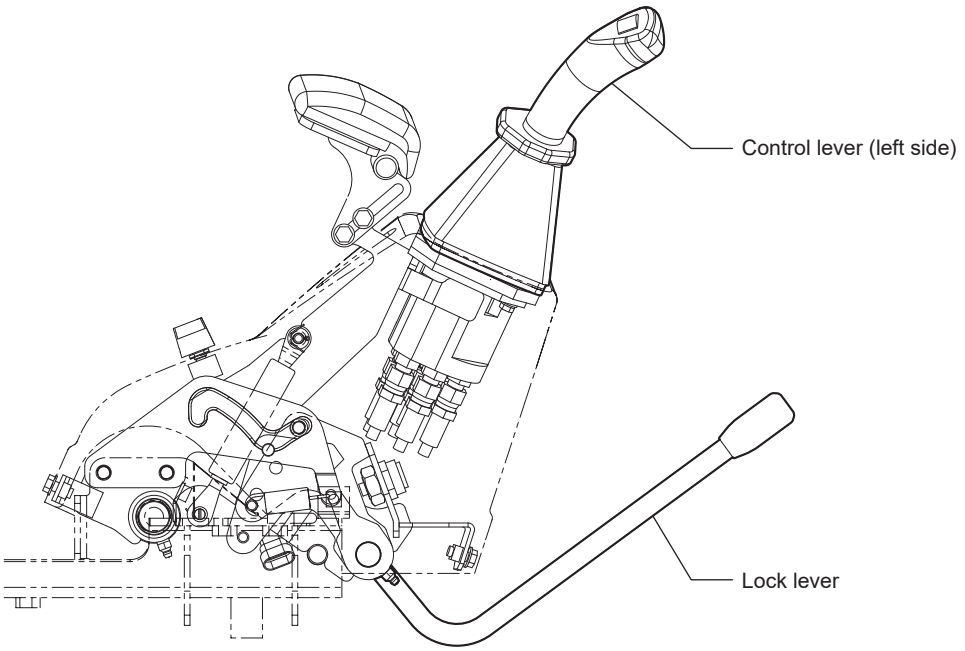
Jig No.	A-019A
ØD1	2.95 (75)
ØD2	2.13 (54)
Ød	0.39(10)
L1	1.97 (50)
L2	0.59 (15)
Used for	Track roller

7-3 Controls

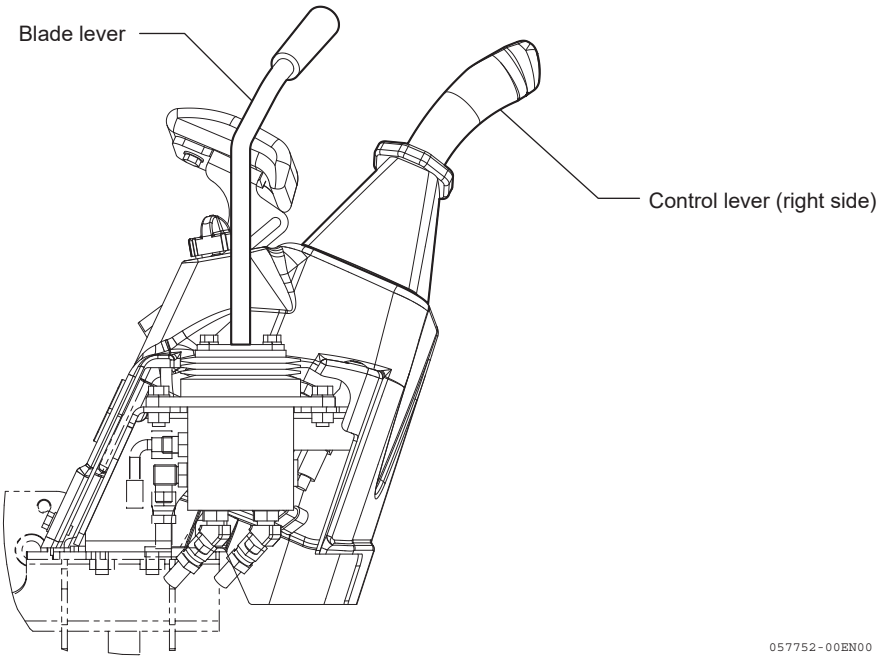
7-3-1 Control Lever

1) Structural Drawings

Lever Stand (left side)

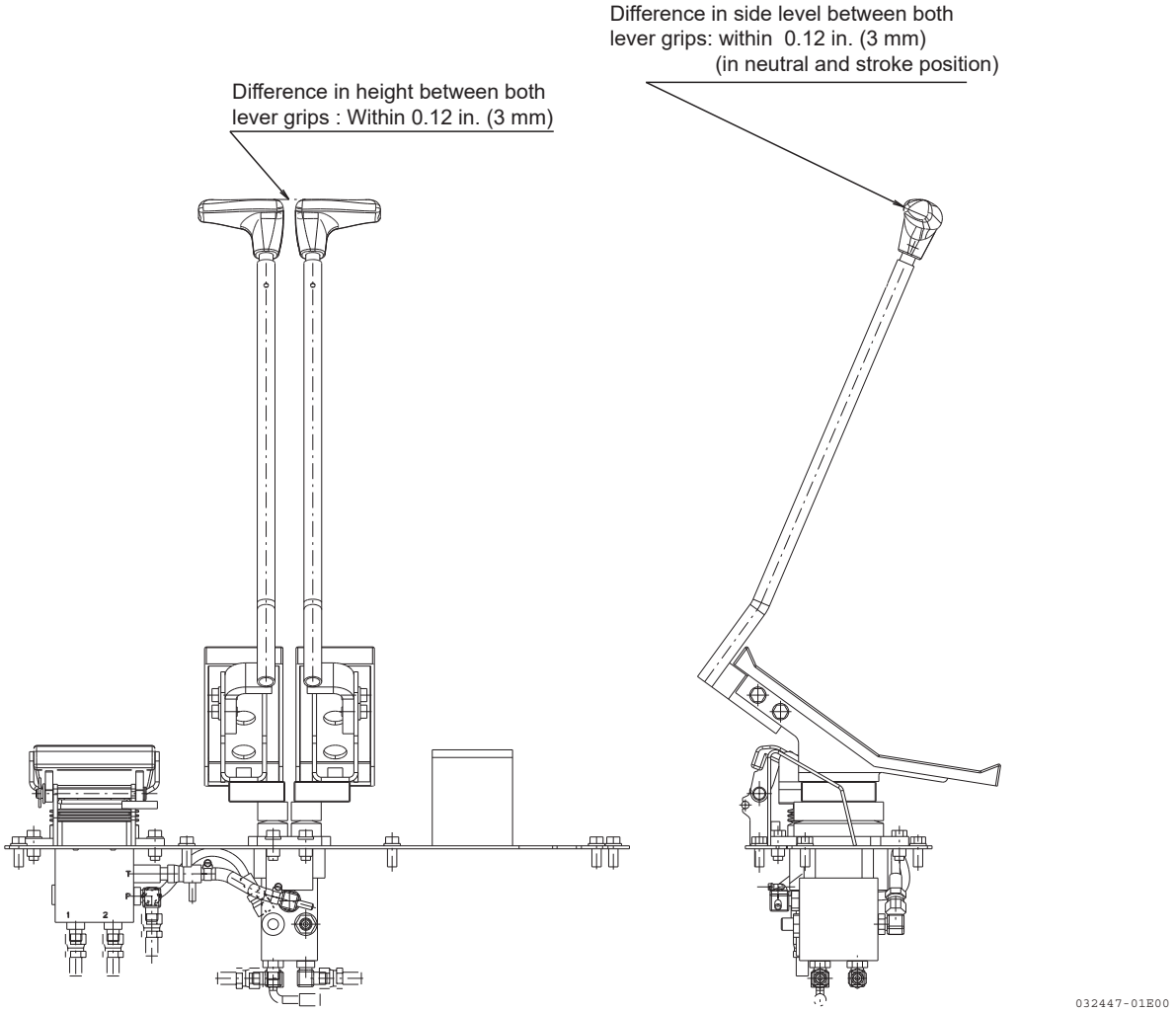


Lever Stand (right side)



7-3-2 Travel Lever

1) Structural Drawings

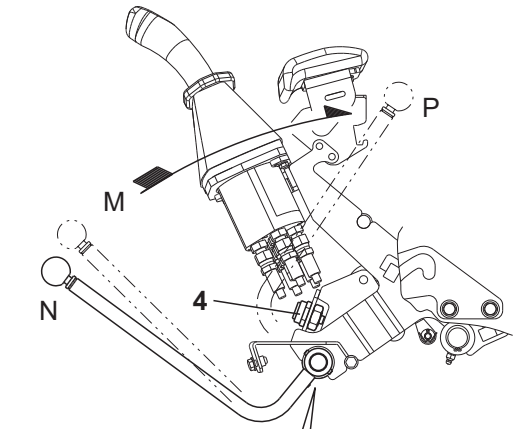


7-3-3 Adjustment of Lock Lever

1) Operation of Lock Lever

(1) The operating force for moving the lock lever from M to P should be less than 13.23 lbf (58.8 N).

(2) Lock lever switch **1** should not allow the implements to operate when the lock lever is between M and P.

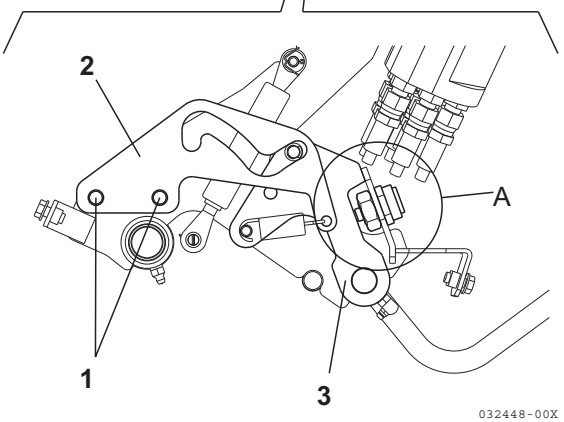


2) Adjustment of Lock Lever

(1) Loosen two bolts **1** to temporary fit the lock guide **2**.

(2) Adjust the lock guide **2** so that the rod **3** move smoothly when operating control lever. Then, tighten bolts **1**.

(3) After adjustment, measure the operating force for moving the lock lever again.

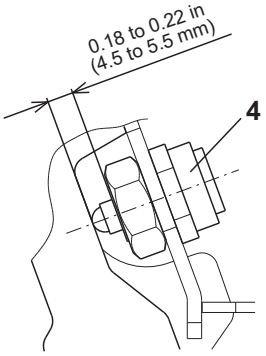


032448-00X

3) Adjustment of Lock Lever Switch

(1) Move the lock lever to the N position.

(2) Loosen the bolt of the bracket and adjust so that the dimension of switch **4** is 0.18 to 0.22 in. (4.5 to 5.5 mm) with the switch completely pressed in.



Details of A

Tightening torque

21.7 to 25.3 ft·lbf
(29.4 to 34.3 N·m)
※Note: Overtorque may cause the switch to be damaged.

Lock lever switch operation

Lever position	Switch condition	Switch circuit	Cut-off valve operation	Implement operation
N	Pushed	ON	Operate	Operate
P	Normal	OFF	Stop	Can not operate

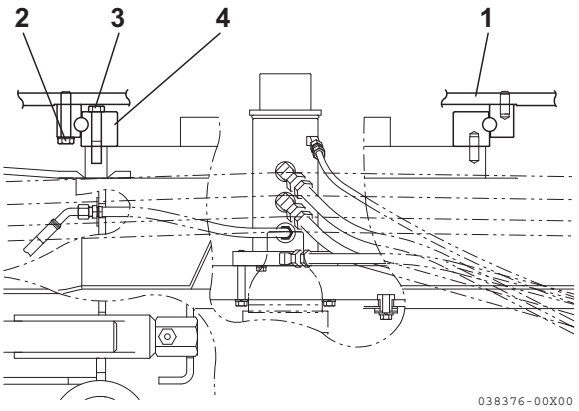
032449-00E

7-4 Swing Bearing

7-4-1 Removal and Reinstallation of Swing Bearing

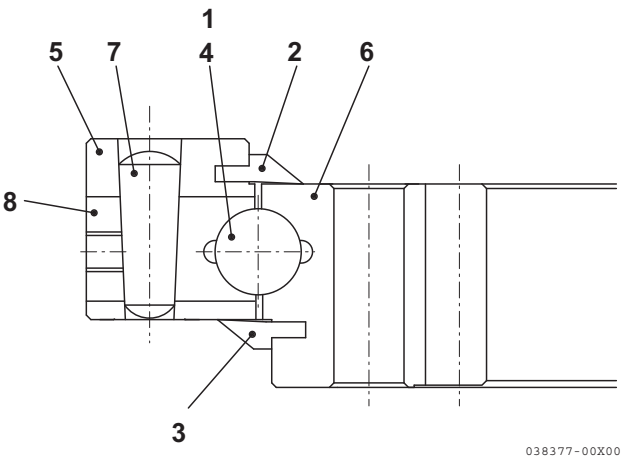
1) Removal

(1) Remove the implement. Refer to Section "7-6-1 Removal and Reinstallation of Implement".
(2) Remove the engine. Refer to Section "7-1-1 Removal and Reinstallation of Engine".
(3) Remove the swing motor. Refer to Section "7-5-13 Removal and Reinstallation of Swing Motor".
(4) Remove the hydraulic hoses of the swivel joint. Refer to Section "7-5-14 Removal and Reinstallation of Swivel Joint".
(5) Suspend turning frame **1** at three points temporarily.
(6) Remove bolts **2** (28 pcs.) for the outer race of the swing bearing.
(7) Lift up turning frame 1.
(8) Remove bolts **3** (30 pcs.) for the inner race of the swing bearing.
(9) Remove the swing bearing **4**.



2) Exploded View and Component Parts of Swing Bearing

No.	Part	Q'ty
1	Steel ball	72
2	Seal A	1
3	Seal B	1
4	Support	72
5	Outer race	1
6	Inner race	1
7	Taper pin	1
8	Plug	1



3) Inspection

(1) Check the gear tooth surfaces for the nicks, flaws, cracks, wear and breakage. Replace if the damage is excessive.
(2) Check for abnormal sound. Clean, grease or replace if necessary.
(3) Check for the play in the inner and outer races and rotation fluctuation. Refer to the service standards for repair or replacement.
(4) Check for the grease leak from the swing bearing seal. Replace if the leakage is excessive.

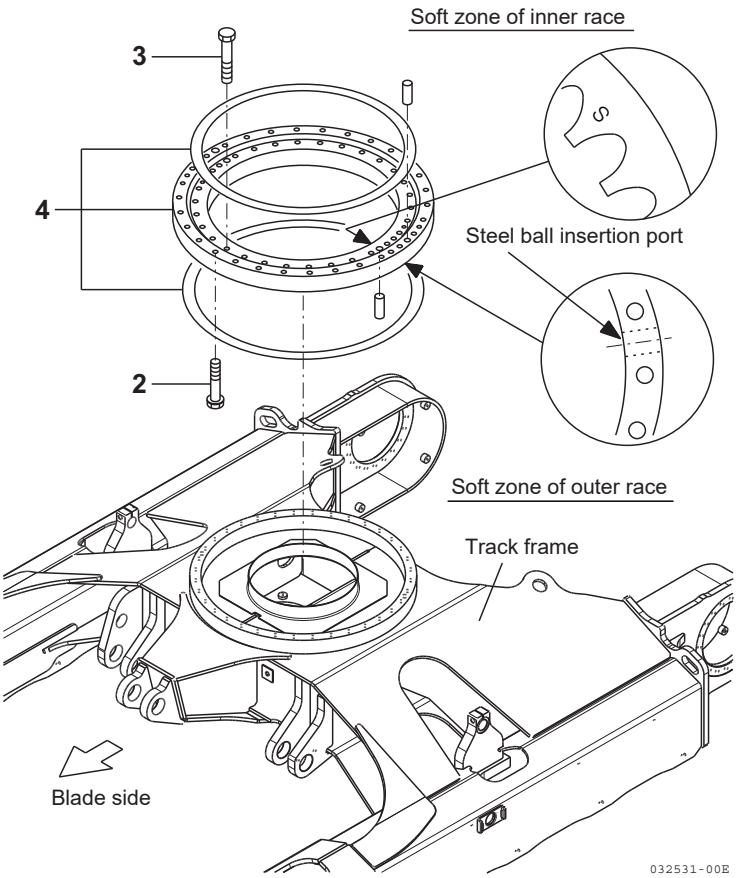
4) Reinstallation

Reinstall the swing bearing in the reverse order of the removal procedure.

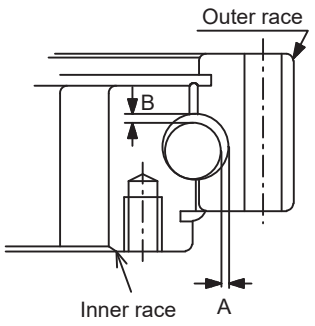
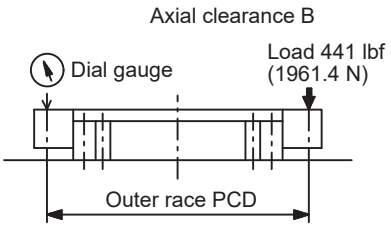
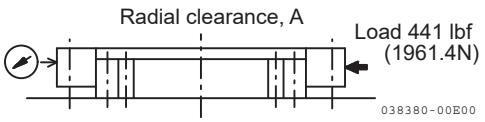
(1) Points of Reinstallation

A soft zone is made on the inner and outer races of the swing bearing, and the "S" mark is put on the upper surface of the inner race.

The outer race also has a soft zone at the steel ball insertion port. In order to decrease the load on the soft zone, install the inner and outer races with the "S" mark and the steel ball insertion port positioned on the left side of the track frame, respectively, as shown in the figure at the right.



5) Service Standard

			Standard	Remarks
			0.002 to 0.008 in. (0.04 to 0.20 mm)	–
			0.002 to 0.008 in. (0.04 to 0.20 mm)	–
Steel ball diameter			Ø1.125 in. (Ø28.575 mm)	–
Tightening torque	Turning frame×outer race Track frame×inner race	M16×85 M16×90	231.4 to 245.8 ft•lbf (313.7 to 333.3 N•m)	Apply Loctite 262 or its equivalent.

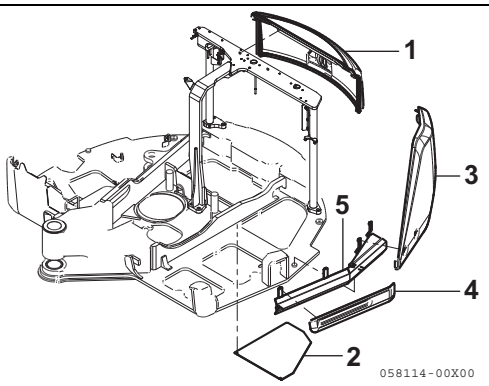
Note:

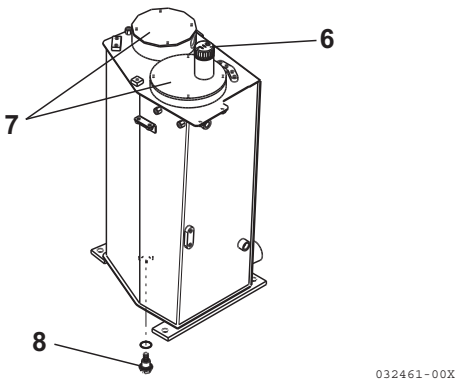
Supply multi-purpose grease to the swing bearing.

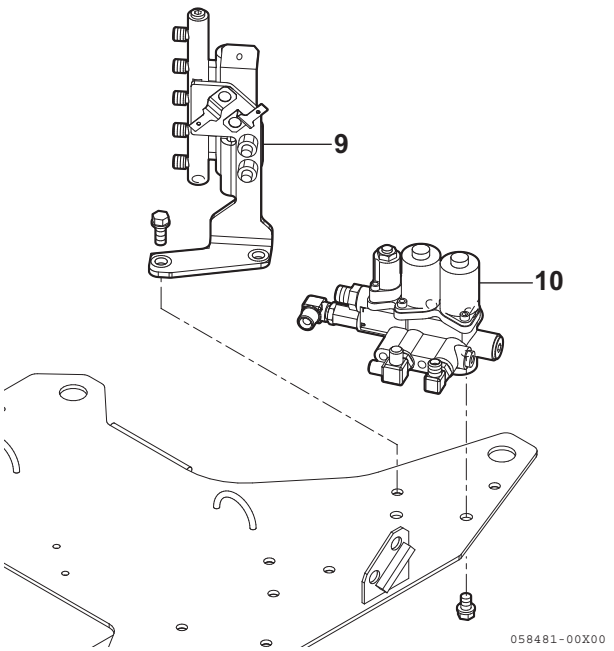
7-5 Hydraulic Equipment

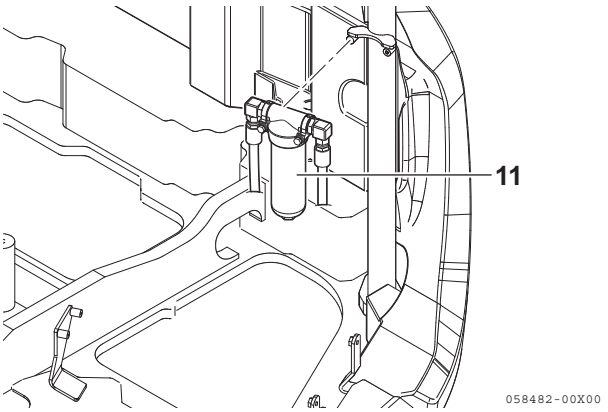
7-5-1 Removal and Reinstallation of Hydraulic Pump

1) Removal

Procedure	
(1) Remove engine hood **1**, pump cover **2**, cover L **3**, frame cover L **4** and frame guard L **5**.	

(2) When disconnecting the hydraulic hoses, prevent the oil from flowing out as follows: [1] Open bonnet B and replace hydraulic oil filler cap **6** with vacuuming cap. [2] Connect hose to vacuum compressor and vacuum the air in hydraulic tank. Alternatively, remove tank cover **7** and drain plug **8** to drain the hydraulic oil. Hydraulic oil: 15.8 Gals (60 L)	

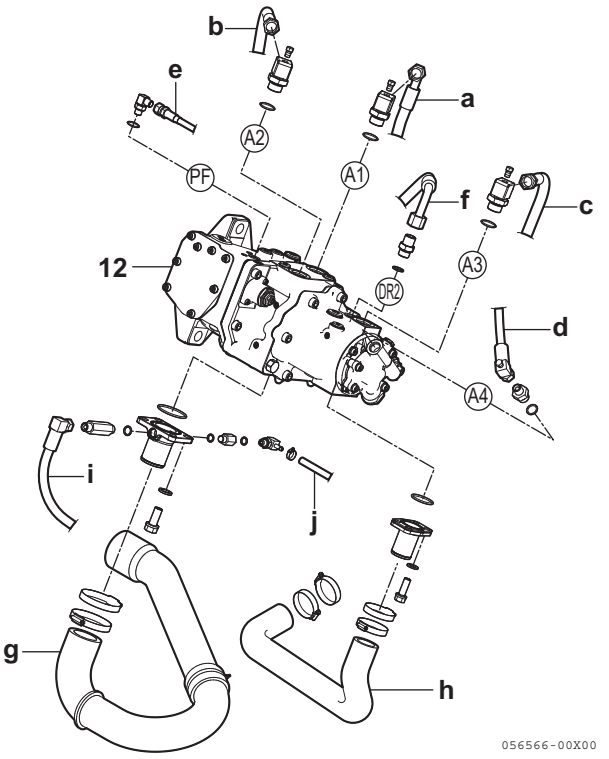
(3) Remove the mounting bolts for pilot block **9** and solenoid valve **10**, move them toward the seat mount and secure them with rope or any other appropriate means.	

Procedure	
(4) Remove the line filter mounting bolts and move line filter **11** toward the seat mount.	

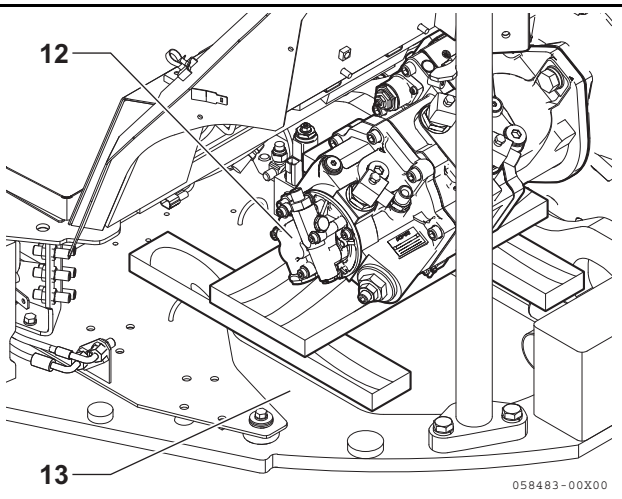
(5) Disconnect the hydraulic hoses from the hydraulic pump **12**.

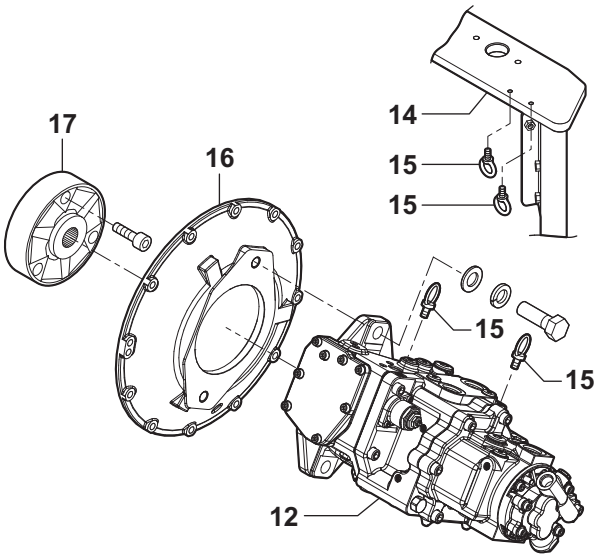
a. Hose A1
b. Hose A2
c. Hose A3
d. Hose A4
e. Hose PF
f. Hose DR2
g. Hose S1
h. Hose S3
i. Hose Cut-off: T
j. Hose ESS: T

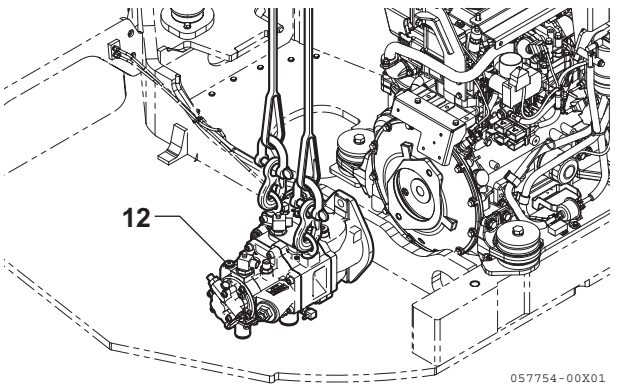
Notes:
- *Make a mark on the installation position of each hose in advance.*
- *Remove the flange from the hydraulic pump.*
- *Be careful not to lose the O-ring for the flange.*



(6) Put a wood block between hydraulic pump **12** and turning frame **13** to support the hydraulic pump.

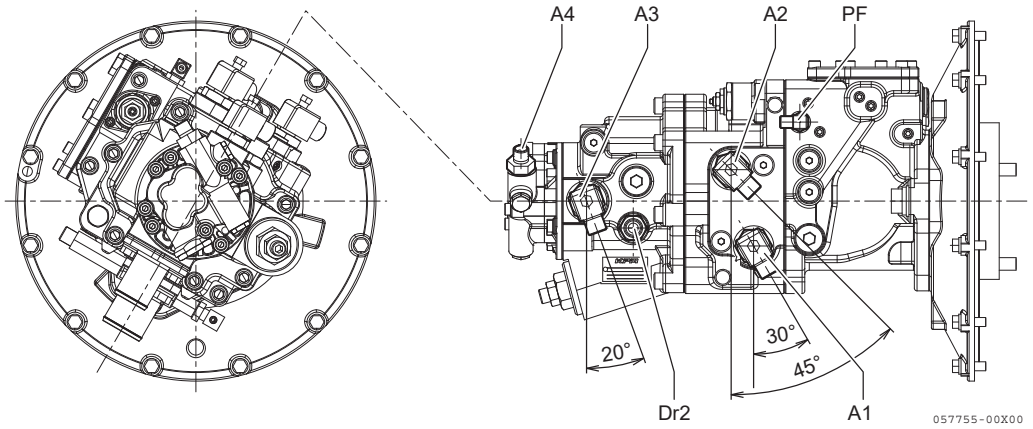


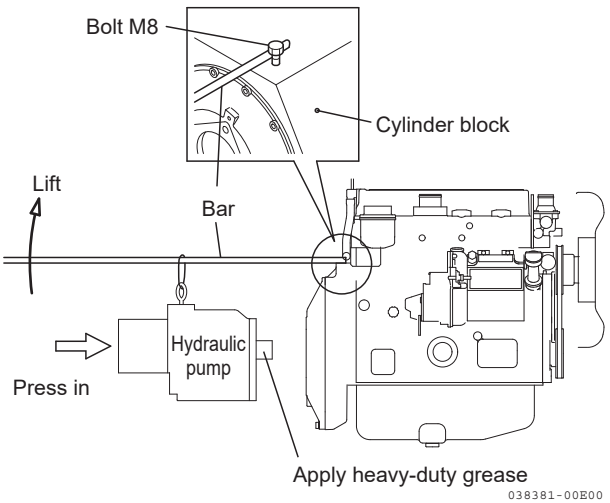
Procedure	
(7) Remove the eye bolts **15** from the cabin mount **14**. Install the eye bolts **15** to the hydraulic pump **12**. (8) Install the shackles and ropes to the eye bolts. Hang the hydraulic pump temporarily. (9) Insert a bar between flywheel cover **16** and the hydraulic pump to pull the spline shaft of the hydraulic pump out of coupling **17**.	

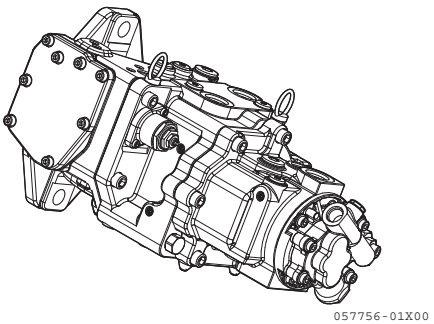
(10) Remove the hydraulic pump **12** with lifting it up.	

2) Reinstallation

Install flanges and connectors to the hydraulic pump.

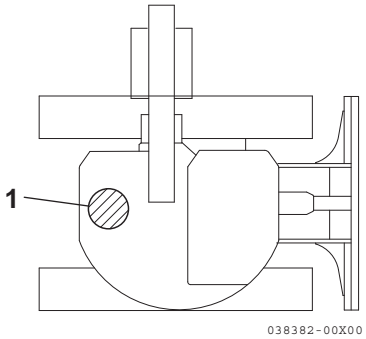


Procedure	
(1) Reinstallation procedure of hydraulic pump. [1] Prepare a long bar in advance. [2] Apply heavy-duty grease to the spline shaft of the hydraulic pump. [3] Put a wire through the eye bolt of the hydraulic pump and make an appropriate length of a loop with the wire. [4] Put the bar through the wire loop and put the top of the bar on the cylinder block of the engine to lift the hydraulic pump. [5] Align the top of the spline shaft of the hydraulic pump with the hole in the coupling, and securely insert the spline shaft into the engaged area. [6] Tighten the bolts for the hydraulic pump. Installation bolt (M18): Tightening torque — 216.8 to 239 ft•lbf (294 to 324 N•m) (2) Reinstall the other parts in the reverse order of their removal procedure.	 ***Note:*** *Install a bolt of M8 ×25 or so to the unused bolt hole in the engine cylinder block to prevent the top of the bar from slipping.*

(3) After completing the reassembly, release air from the hydraulic pump. Refer to Section "1-10 Air Release of Hydraulic Equipment." (4) Check if the hydraulic oil level in the hydraulic oil tank is proper. (5) Make trial runs enough to check for oil leak and abnormal operation.	

7-5-2 Removal and Reinstallation of Control Valve

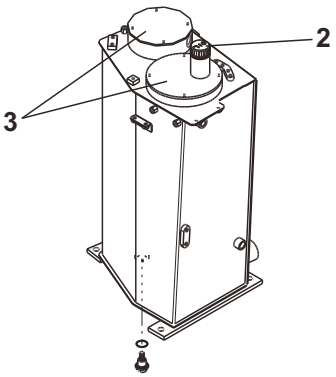
1) Removal

Procedure	
(1) Turn the upperstructure so that control valve **1** is positioned on the opposite side to blade, lower the bucket to the ground and stop the engine.	

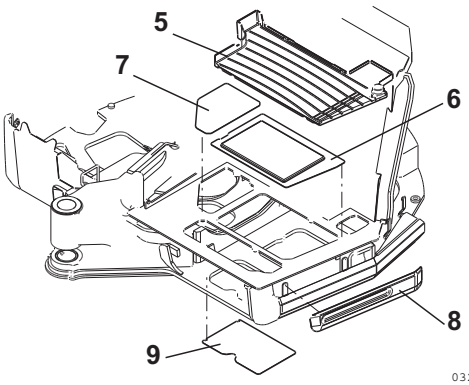
(2) When removing the hydraulic hoses, prevent the oil from flowing out as follows:

[1] Open bonnet B and replace hydraulic oil filler cap **2** with vacuuming cap.
[2] Connect hose to vacuum compressor and vacuum the air in hydraulic tank. Or remove tank cover **3** and drain the hydraulic oil from the tank.

Hydraulic oil	15.8 Gals (60 L)

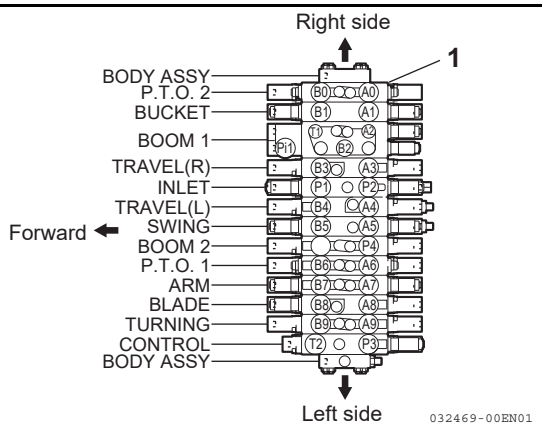


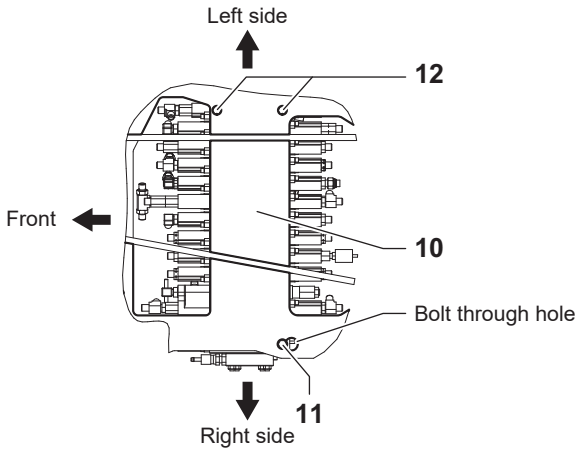
(3) Remove floor mat **5**, step **6**, plate A **7**, frame cover L **8** and cover A **9**.



(4) Disconnect all the hydraulic hoses and the pilot hoses from control valve **1**.

Notes:
- *Put the identification mark on the hoses so as not to reinstall to the wrong place.*
- *Put the cap or the like on each hose connection port to prevent dusts.*



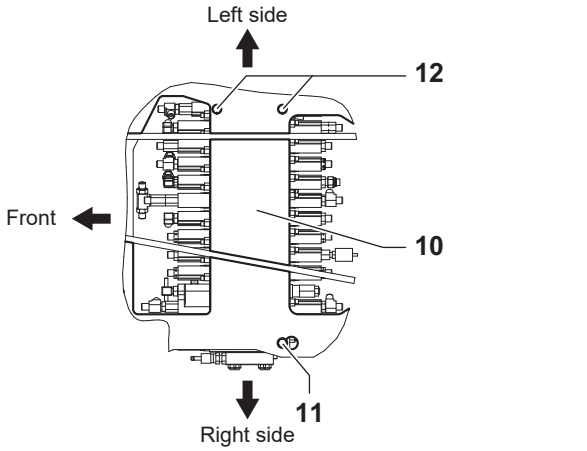
Procedure	
(5) Remove control valve **1** from valve plate **10**. [1] Loosen bolt **11** on the right side and remove **2** bolts **12** on the left side. [2] Move control valve slightly backward. Lift up control valve and pull out head of bolts **11** from bolt through hole. Then, pull out control valve to left side.	 View from under control valve 058484-00EN00

2) Reinstallation

Reinstall control valve in the reverse order of the removal procedure.

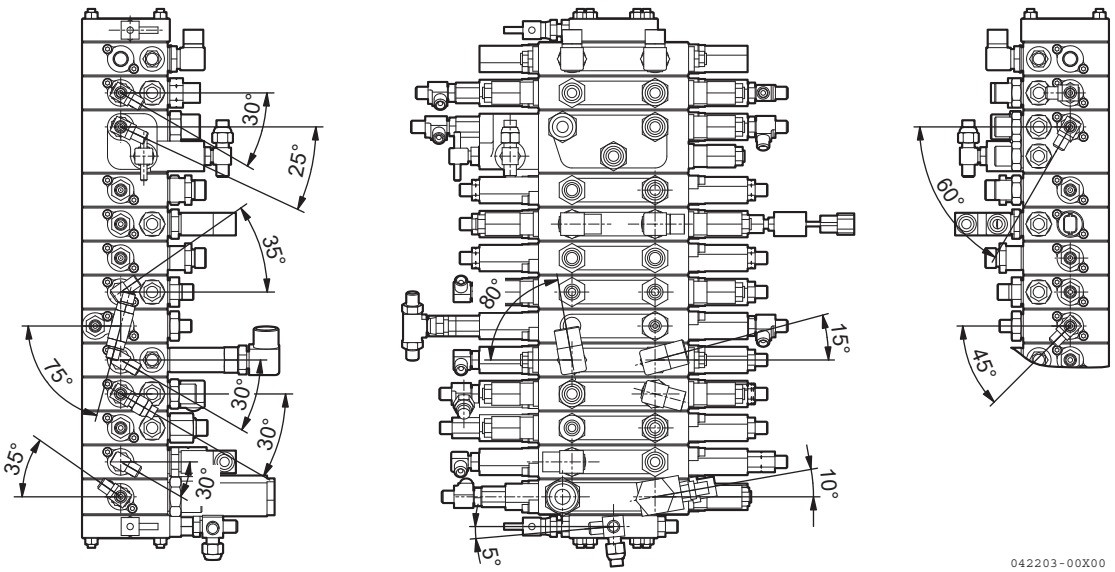
Notes:

- *When install control valve, firstly tighten bolts **11** about 2 or 2.5 turns. Secondly insert head of bolts **11** into bolt through holes with lifting up control valve. Thirdly, move control valve forward to place it in normal position. Finally, tighten all bolts **11**, **12** by specified tightening torque.*
- *Bolt **11** and **12** are different in length.*
  Bolt 11: M10X12
  Bolt 12: M10X16



View from under control valve 058484-00EN01

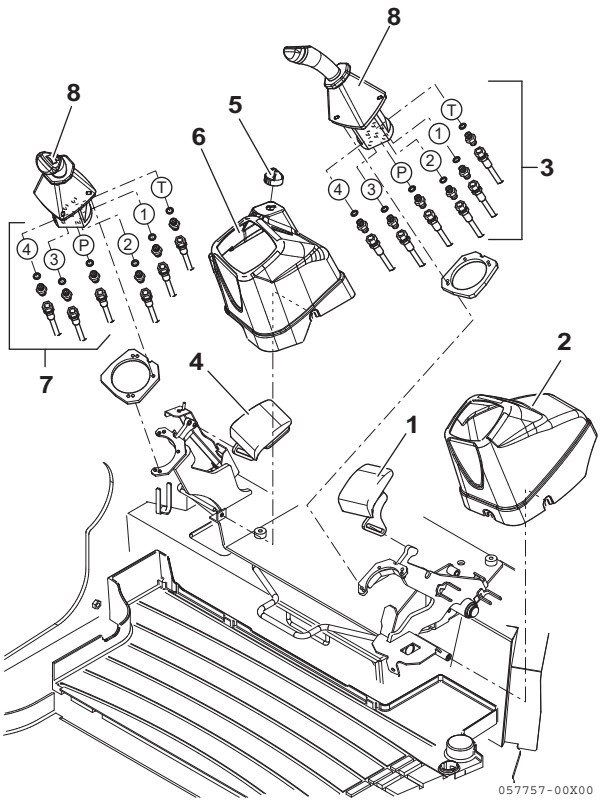
Connector and joint setting angles



042203-00X00

7-5-3 Removal and Reinstallation of Remote Control Valves

3) Removal

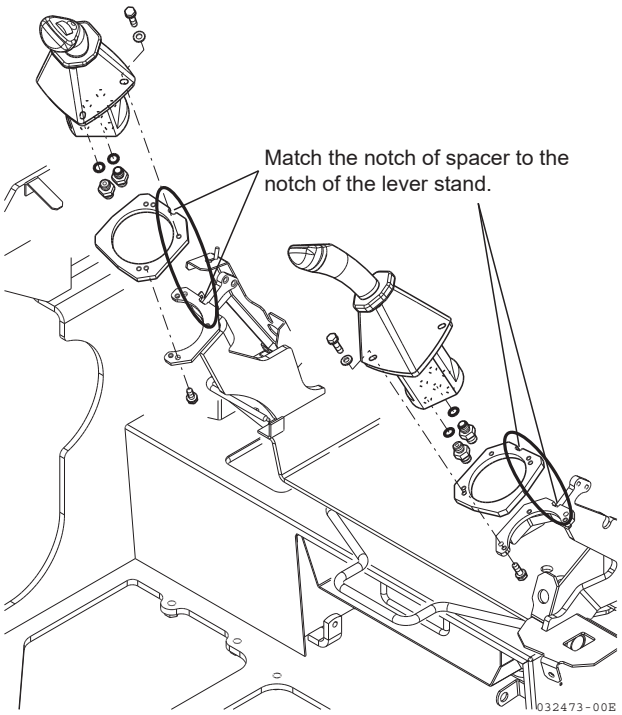
Procedure	
(1) Remove arm rest L **1** and lever box L **2**. Disconnect pilot hoses L **3**. (2) Remove arm rest R **4**, accelerator knob **5** and lever box R **6**. Disconnect pilot hoses R **7**. ***Note:*** *Make a mark on the installation position of each hoses in advance.* (3) Remove remote control valves L and R **8**.	

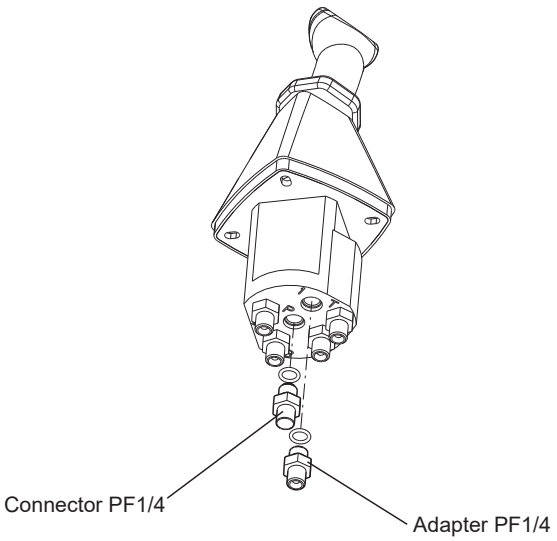
4) Reinstallation

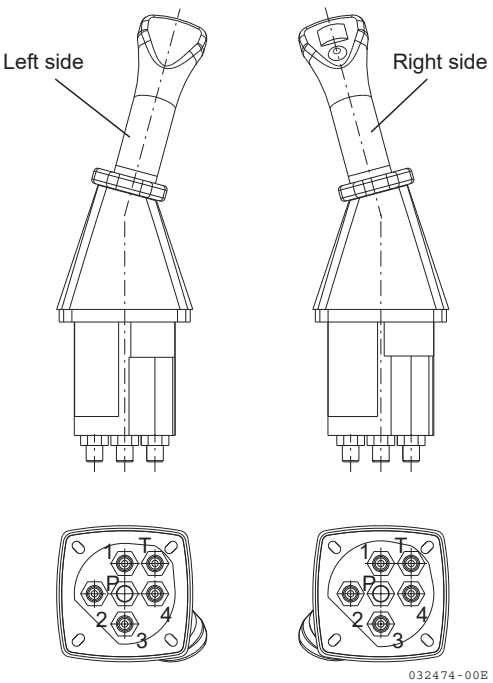
Reinstall the remote control valves in the reverse order of the removal procedure.

Note:

Install valve spacer so that the notch of the spacer is at the back.





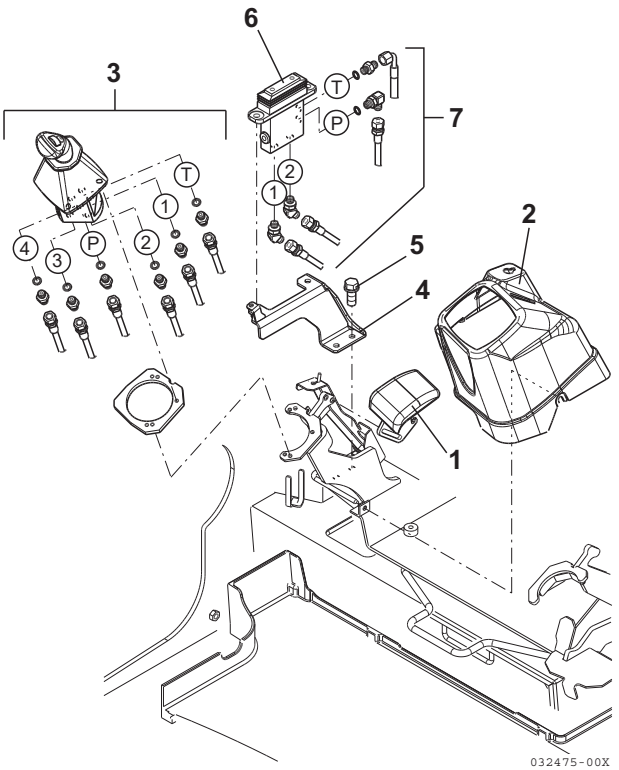


	Port
Left side	P
Right side	P

	Port
Left side	1.2.3.4.T
Right side	1.2.3.4.T

7-5-4 Removal and Reinstallation of Blade Pilot Valve

1) Removal

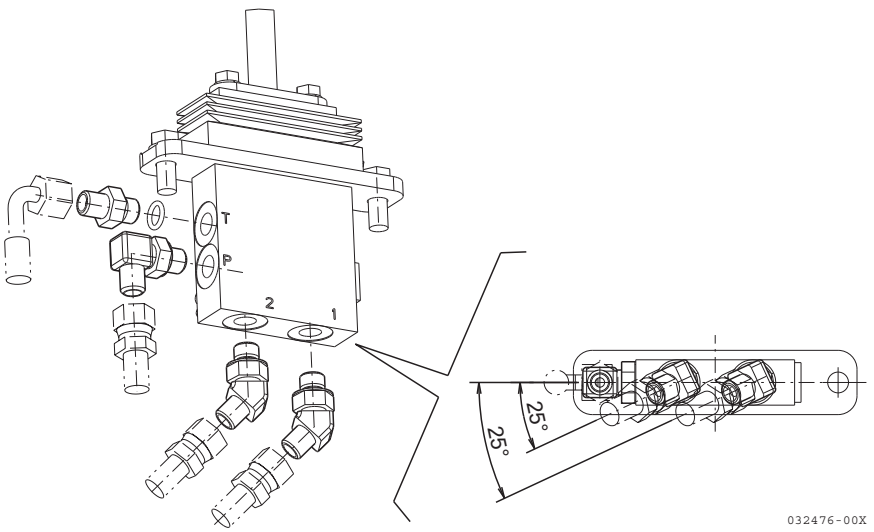
Procedure	
(1) Remove arm rest R **1**, lever box R **2** and remote control valve (with hoses) **3** from the seat mount. (2) Remove installation bolt **5** of blade valve stay **4** and remove blade valve stay (with blade pilot valve and pilot hoses) **4**. (3) Disconnect blade pilot hoses **7** form blade pilot valve **6**. Then remove blade pilot valve **6** from blade valve stay **4**. ***Note:*** *Make a mark on the installation position of each hoses in advance.*	

2) Reinstallation

Reinstall blade pilot valve in the reverse order of the removal procedure.

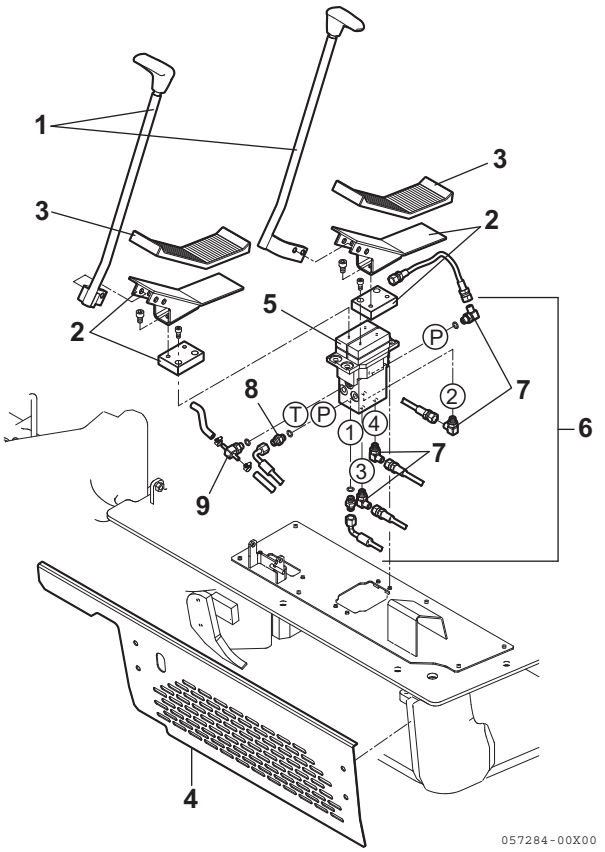
Installation of blade lever grip: Apply adhesive (Three bond 1324 or its equivalent) to about one third length of the thread portion from top of the lever.

Connector and joint setting angles



7-5-5 Removal and Reinstallation of Travel Pilot Valve

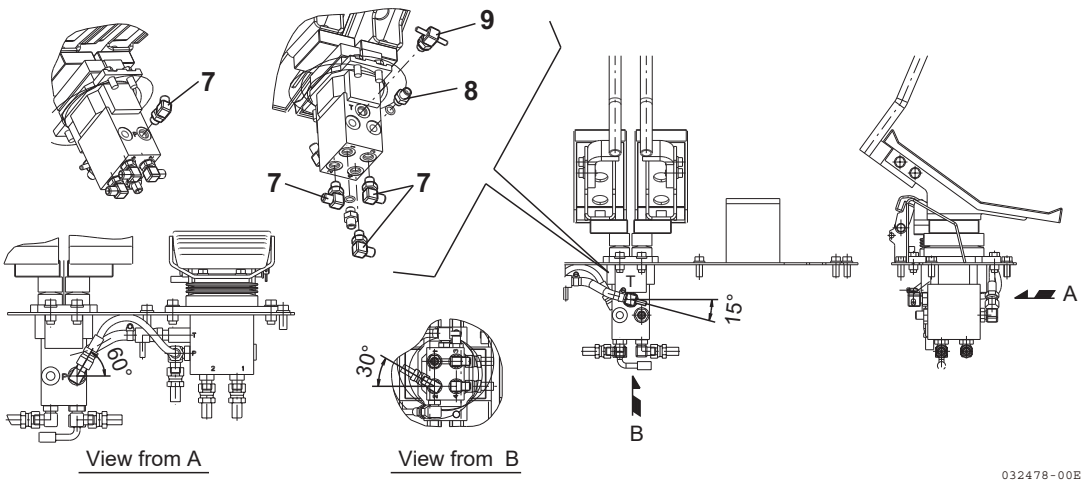
1) Removal

Procedure	
(1) Remove travel levers **1**, pedals and blocks **2**, covers **3** and frame FL **4**. (2) Disconnect travel pilot hoses **6** from travel pilot valve **5**. (3) Remove connectors 02FF **7**, adapter PF1/4 **8** and nipple G1/4 **9** from the side of travel pilot valve **5**. Then turn connectors 02FF **7** on the bottom of the valve **5** about 90 degrees to remove travel pilot valve **5**. ***Note:*** *Make a mark on the installation position of each hoses in advance.*	

2) Reinstallation

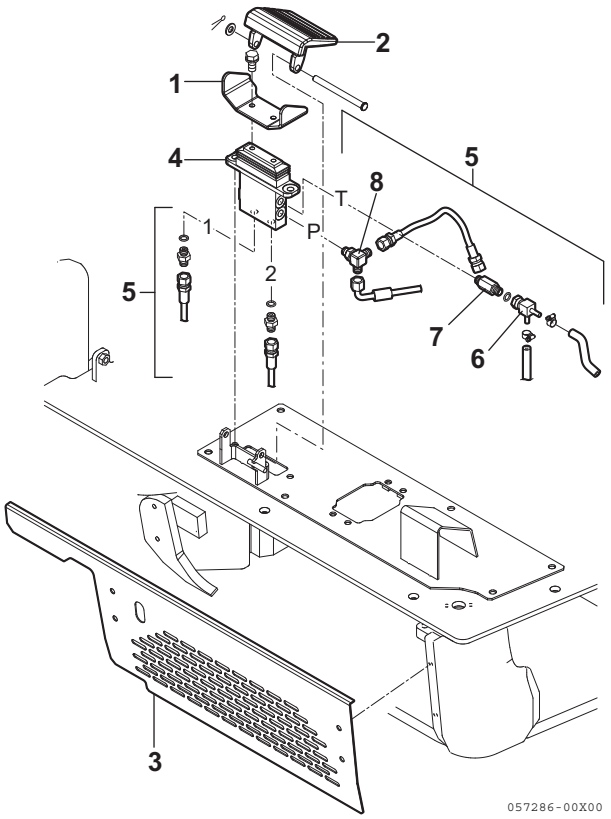
Reinstall travel pilot valve in the reverse order of the removal procedure.

Connector and joint setting angles



7-5-6 Removal and Reinstallation of Boom Swing Pilot Valve

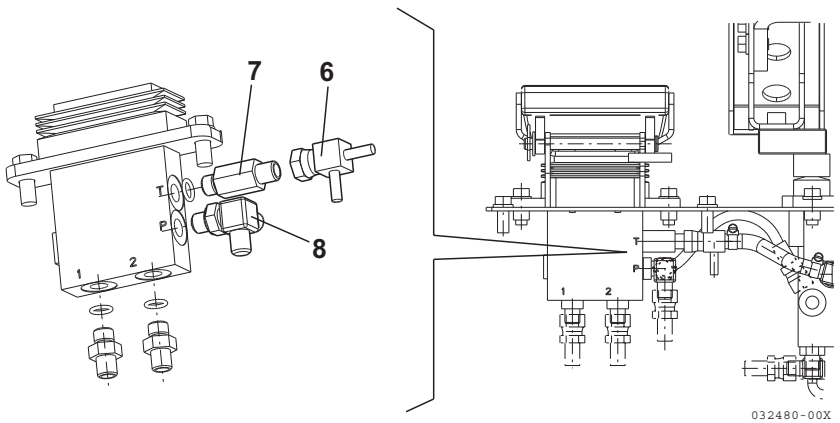
1) Removal

Procedure	
(1) Remove boom swing pedal **1**, cover **2** and frame FL **3**. Disconnect boom swing pilot hoses **5** from boom swing pilot valve **4**. (2) Remove nipple female G1/4 **6**, connector 1/4-1/4 **7** and adjustable elbow 1/4 **8**. And then remove boom swing pilot. ***Note:*** *Make a mark on the installation position of each hoses in advance.*	

2) Reinstallation

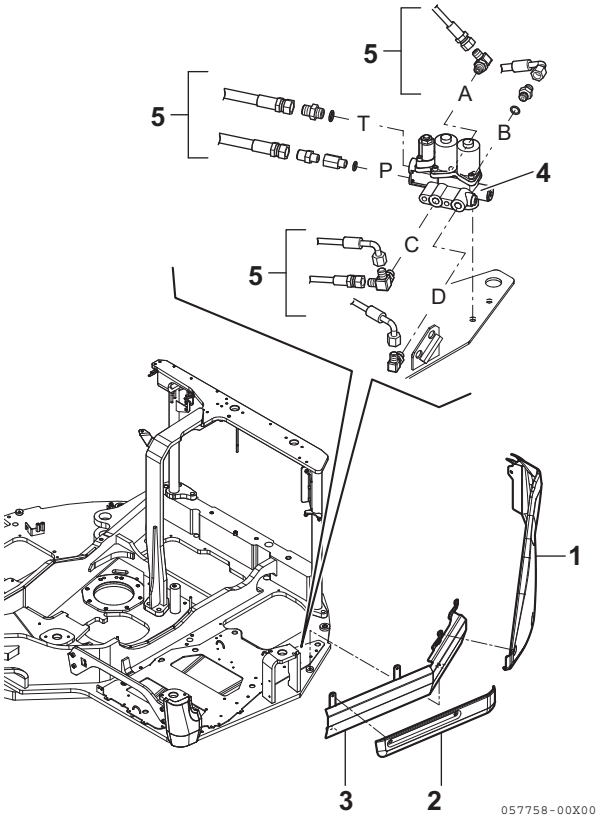
Reinstall boom swing pilot valve in the reverse order of the removal procedure.

Connector and joint setting angles



7-5-7 Removal and Reinstallation of Solenoid Valve

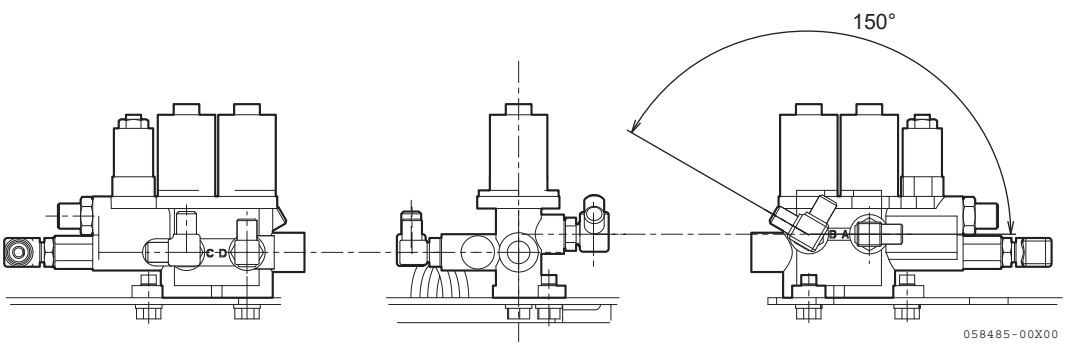
1) Removal

Procedure	
(1) Open engine hood and remove cover L **1**, frame cover L **2** and frame guard L **3**. (2) Disconnect hoses **5** from solenoid valve **4**. (3) Remove solenoid valve **4**. ***Note:*** *Make a mark on the installation position of each hoses in advance.*	

2) Reinstallation

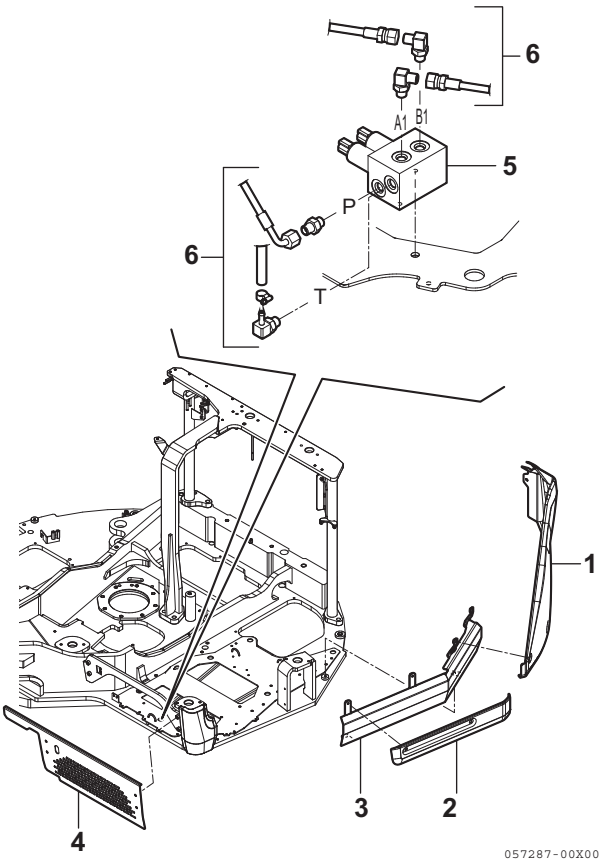
Reinstall solenoid valve in the reverse order of the removal procedure.

Connector and joint setting angle



7-5-8 Removal and Reinstallation of P.T.O.1 Solenoid Valve

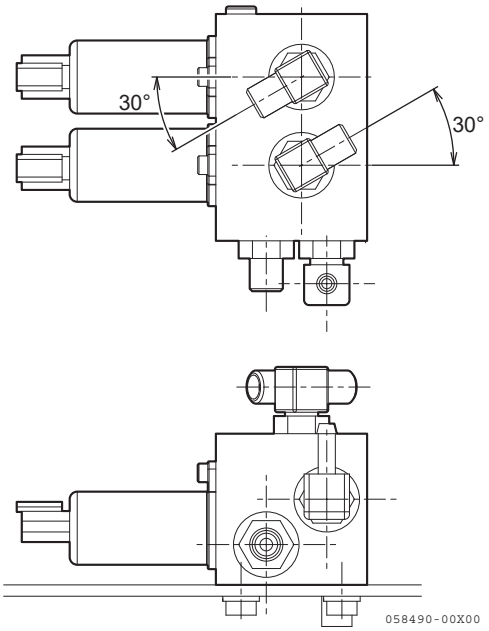
1) Removal

Procedure	
(1) Open engine hood and remove cover L **1**, frame cover L **2**, frame guard L **3** and frame cover FL **4**. (2) Disconnect P.T.O. pilot hoses **6** from P.T.O. solenoid valve **5**. ***Note:*** *Make a mark on the installation position of each hoses in advance.* (3) Remove P.T.O. solenoid valve **5**.	

2) Reinstallation

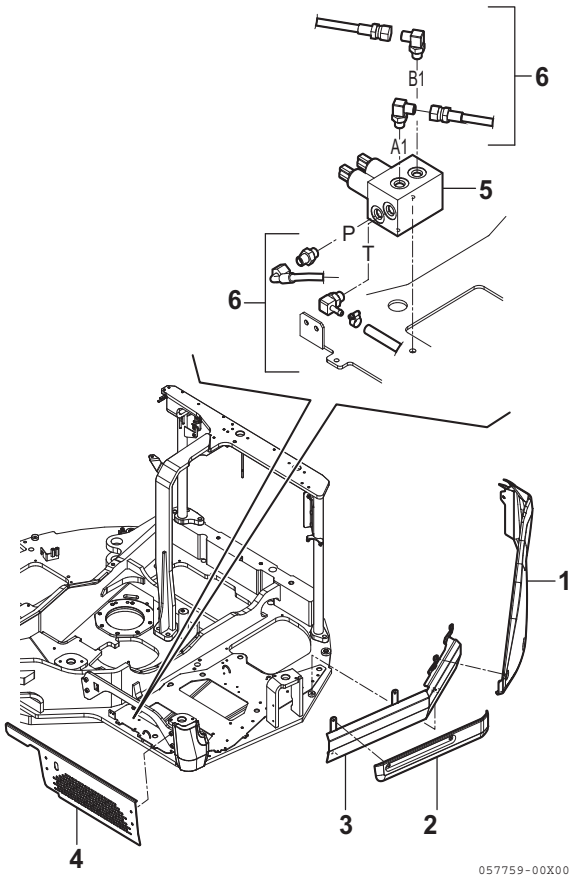
Reinstall P.T.O. solenoid valve in the reverse order of the removal procedure.

Connector and joint setting angle



7-5-9 Removal and Reinstallation of P.T.O.2 Solenoid Valve

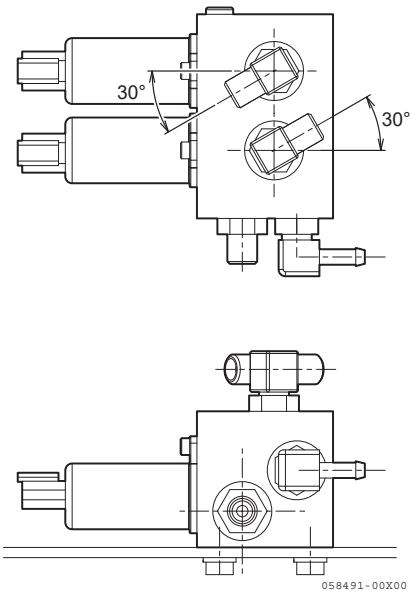
1) Removal

Procedure	
(1) Open engine hood and remove cover L **1**, frame cover L **2**, frame guard L **3** and frame cover FL **4**. (2) Disconnect P.T.O. pilot hoses **6** from P.T.O. solenoid valve **5**. ***Note:*** *Make a mark on the installation position of each hoses in advance.* (3) Remove P.T.O. solenoid valve **5**.	

2) Reinstallation

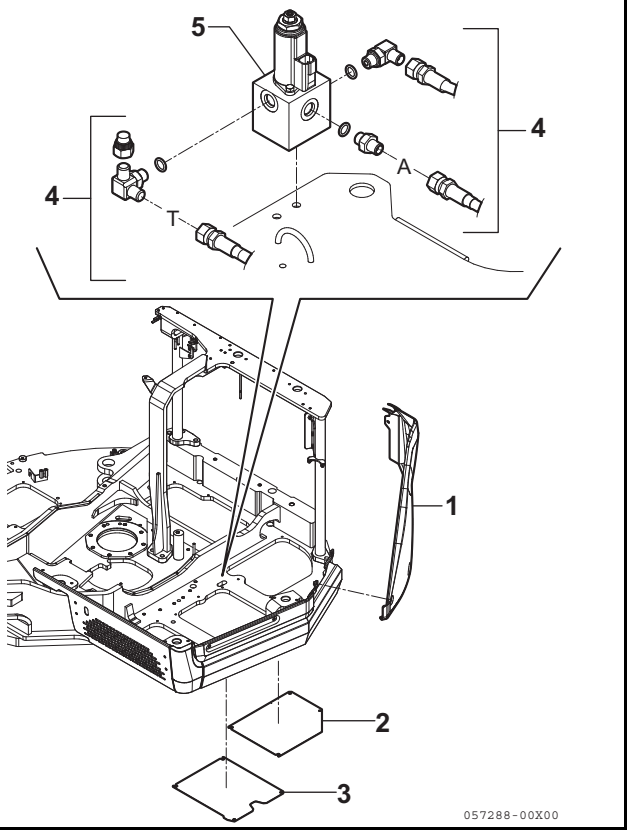
Reinstall P.T.O. solenoid valve in the reverse order of the removal procedure.

Connector and joint setting angle



7-5-10 Removal and Reinstallation of ESS Solenoid Valve

1) Removal

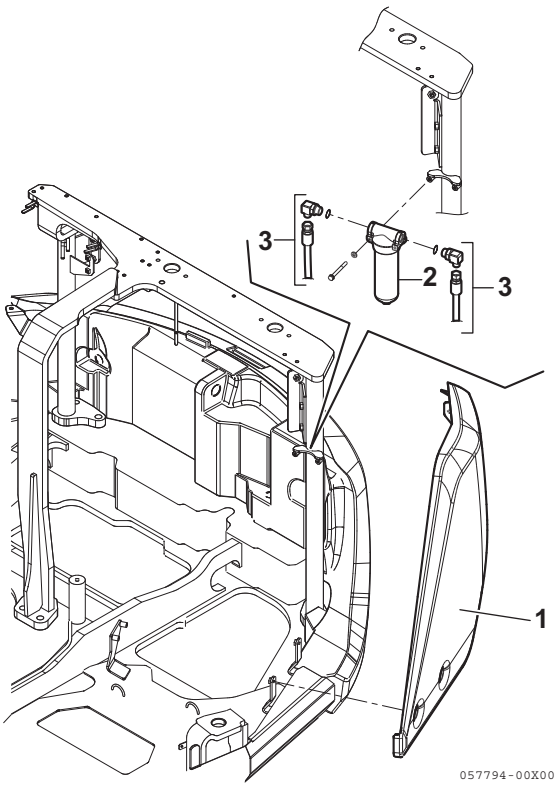
Procedure	
(1) Open engine hood and remove cover L **1**, pump cover **2** and under cover **3**. (2) Disconnect ESS pilot hoses **4** from ESS solenoid valve **5**. ***Note:*** *Make a mark on the installation position of each hoses in advance.* (3) Remove ESS solenoid valve **5**.	

2) Reinstallation

Reinstall ESS solenoid valve in the reverse order of the removal procedure.

7-5-11 Removal and Reinstallation of Line Filter

1) Removal

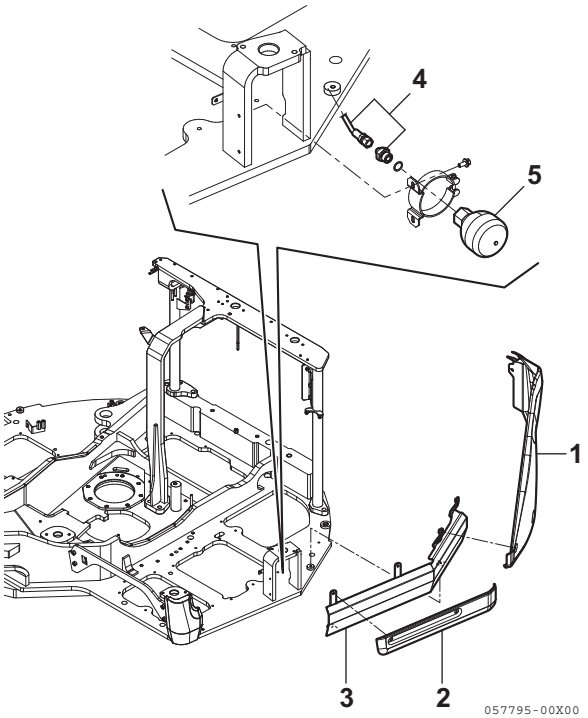
Procedure	
(1) Open engine hood and remove cover L **1**. (2) Disconnect hoses **3** from line filter **2**. (3) Remove line filter **2**.	

2) Reinstallation

Reinstall line filter in the reverse order of the removal procedure.

7-5-12 Removal and Reinstallation of Accumulator

1) Removal

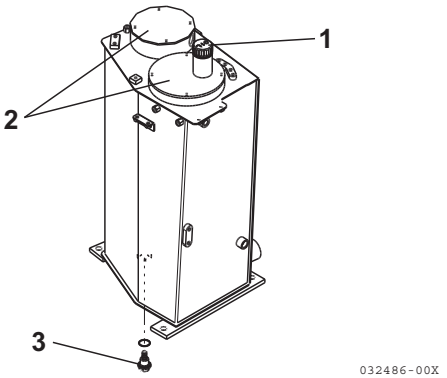
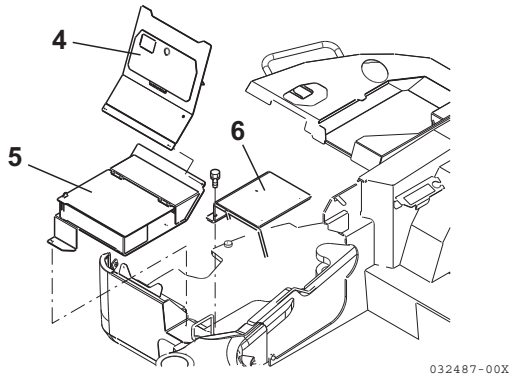
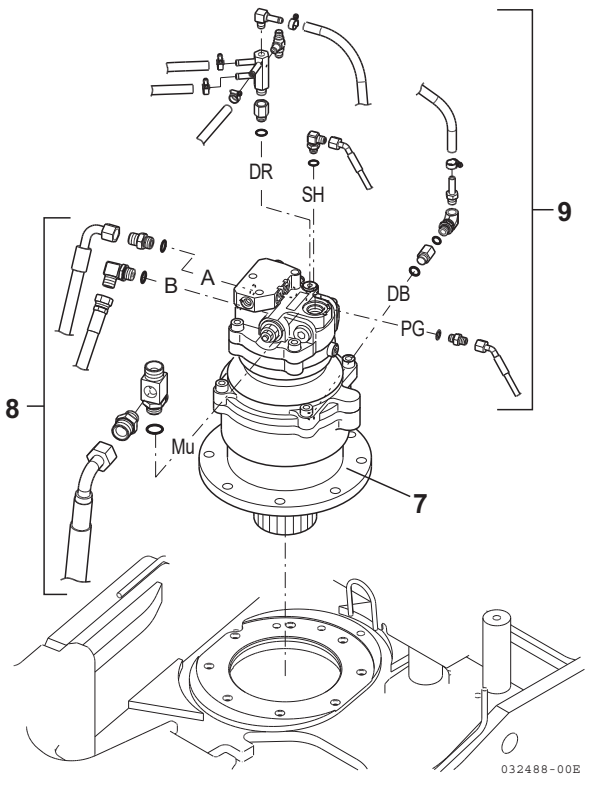
Procedure	
(1) Open engine hood and remove cover L **1**, frame cover L **2** and frame guard L **3**. (2) Disconnect hose **4** from accumulator **5**. (3) Remove accumulator **5**.	

2) Reinstallation

Reinstall the accumulator in the reverse order of the removal procedure.

7-5-13 Removal and Reinstallation of Swing Motor

1) Removal

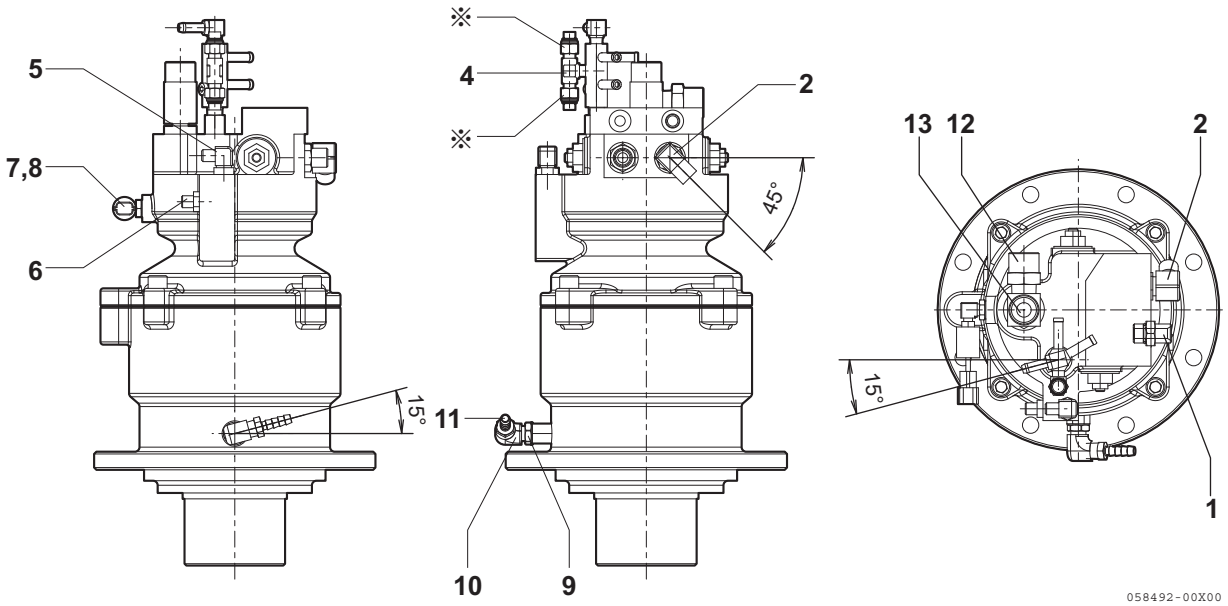
Procedure	
(1) When disconnecting the hydraulic hoses, prevent the oil from flowing out as follows: [1] Open bonnet B and replace hydraulic oil filler cap **1** with vacuuming cap. [2] Connect hose to vacuum compressor and vacuum the air in hydraulic tank. Alternatively, remove tank cover **2** and drain plug **3** to drain the hydraulic oil. Hydraulic oil: 15.8 Gals (60 L)	
(2) Remove center cover (with tool box cover) **4**, tool box base **5** and bracket cover **6**.	
(3) Disconnect the drain hoses **8** and the hydraulic hoses **9** from the swing motor **7**, and then remove the swing motor **7**. ***Notes:*** • *Make a mark on the installation position of each hoses in advance.* • *Use the universal joint socket to ease removing the bolt under ACU bracket.*	

2) Reinstallation

Reinstall the swing motor in the reverse order of the removal procedure.

Swing motor installation bolt	
Adhesive	Three bond 1324 or its equivalent
Tightening torque	195.3 to 224.2 ft•lbf (264.8 to 304 N•m)

Connector and joint setting angles



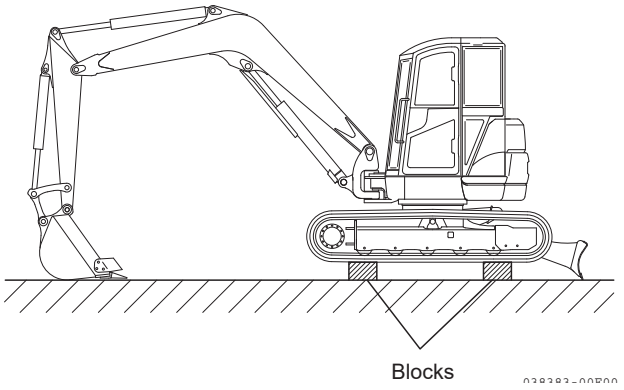
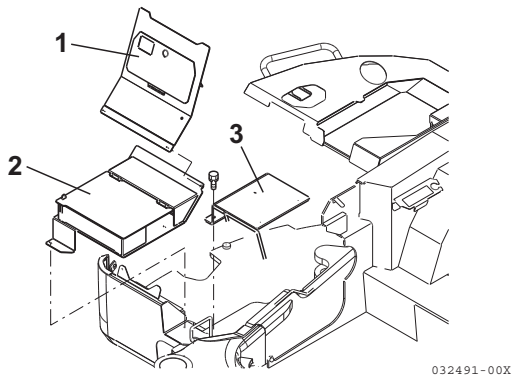
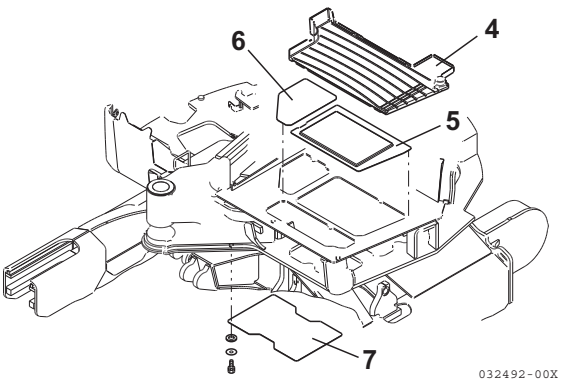
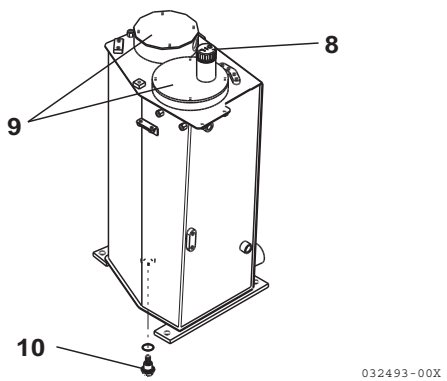
Note:

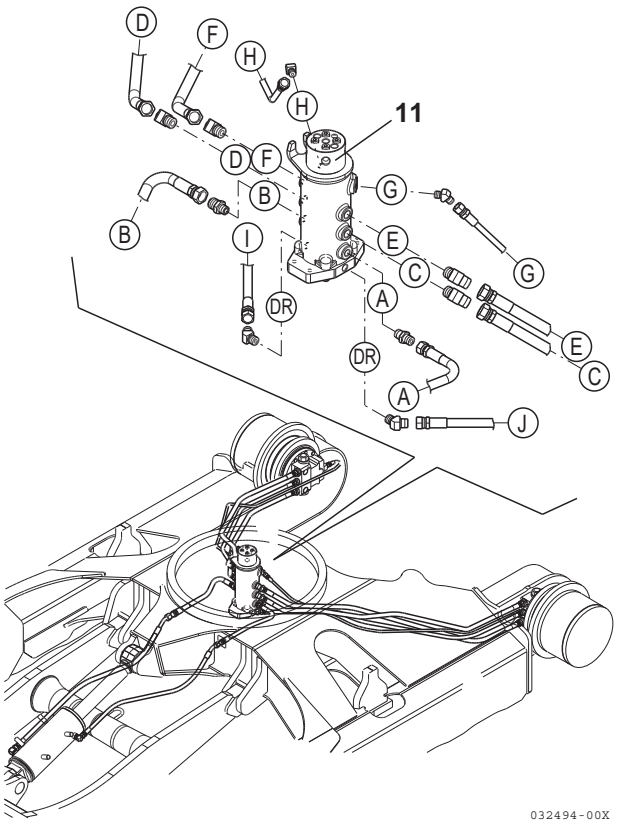
※ mark: Screw cap G1/4 is not used for holding valve spec (AS/NZ spec).

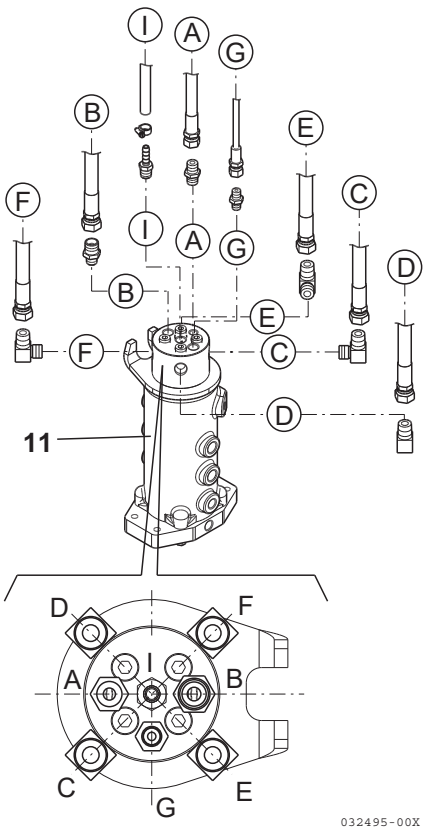
No.	Part	No.	Part
1	Connector PF1/2-1/2	8	Pressure switch
2	Connector 1/2L	9	Adapter male-female G3/8
3	Joint 3/8	10	Elbow 3/8
4	Connector 3-1/4	11	Nipple 3/8
5	Connector 3/8-1/4	12	Connector PF1-PT3/4
6	Adapter male-male PF1/4	13	Connector PF1-PT3/4
7	Connector PF1/4-PT1/8		

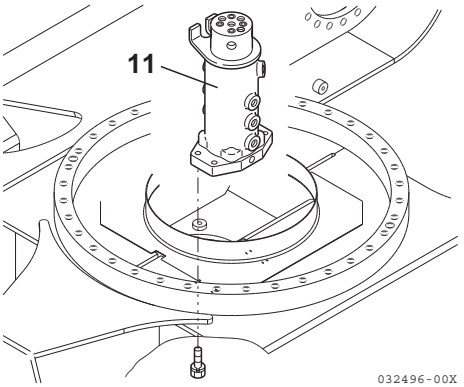
7-5-14 Removal and Reinstallation of Swivel Joint

1) Removal

Procedure	
(1) Operate the implement and the blade to raise the machine, and put blocks under it. (2) Turn the implement to the left, lower the bucket to the ground and stop the engine. ***Note:*** *To prevent the machine from dropping, be sure to put blocks.*	
(3) Remove center cover (with tool box cover) **1**, tool box base **2** and bracket **3**.	
(4) Remove floor mat **4**, step **5**, plate A **6** and under cover **7**.	
(5) When disconnecting the hydraulic hoses, prevent the oil from flowing out as follows: [1] Open bonnet B and replace hydraulic oil filler cap **8** with vacuuming cap. [2] Connect hose to vacuum compressor and vacuum the air in hydraulic tank. Alternatively, remove tank cover **9** and drain plug **10** to drain the hydraulic oil. Hydraulic oil: 15.8 Gals (60 L)	

Procedure	
(6) Disconnect hydraulic hoses from the track frame side of swivel joint **11**. G. High-speed (L) H. High-speed (R) E. Travel motor (L) F. Travel motor (R) C. Travel motor (L) D. Travel motor (R) A. Blade cylinder (Rod) B. Blade cylinder (Bottom) J. Drain (L) I. Drain (R) ***Note:*** *Make a mark on the installation position of each hoses in advance.*	

(7) Disconnect hydraulic hoses from the turning frame side of swivel joint **11**. A. Blade cylinder (Rod) B. Blade cylinder (Bottom) C. Travel motor (L) D. Travel motor (R) E. Travel motor (L) F. Travel motor (R) G. High-speed pilot I. Drain ***Note:*** *Make a mark on the installation position of each hoses in advance.*	

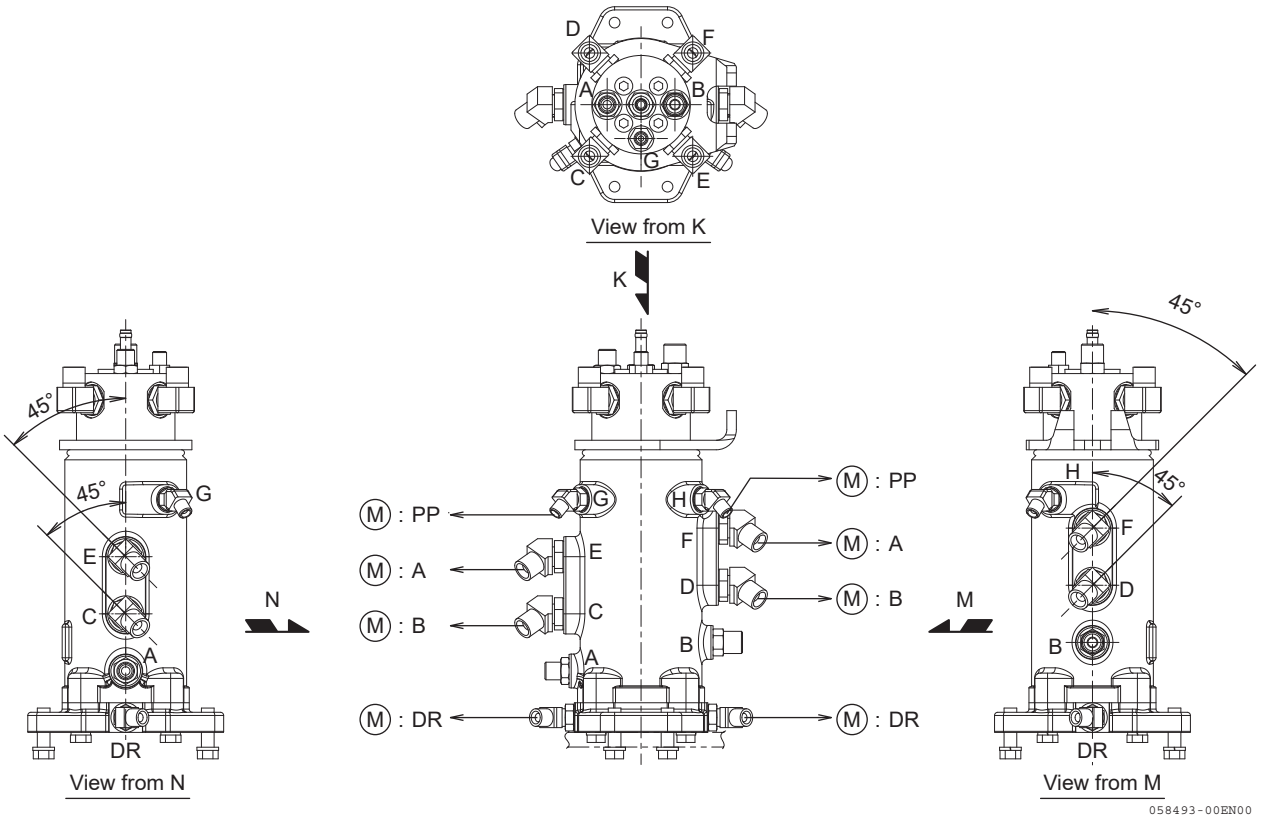
Procedure	
(8) Remove swivel joint **11**. Lift and take down the swivel joint **11** with rope. ***Note:*** *Mark the frame and the swivel joint to reinstall them in the correct direction.*	

2) Reinstallation

Reinstall the swivel joint in the reverse order of the removal procedure.

Swivel joint installation bolt	
Adhesive	Loctite 262 or its equivalent
Tightening torque	57.9 to 72.4 ft•lbf (78.5 to 98.1 N•m)

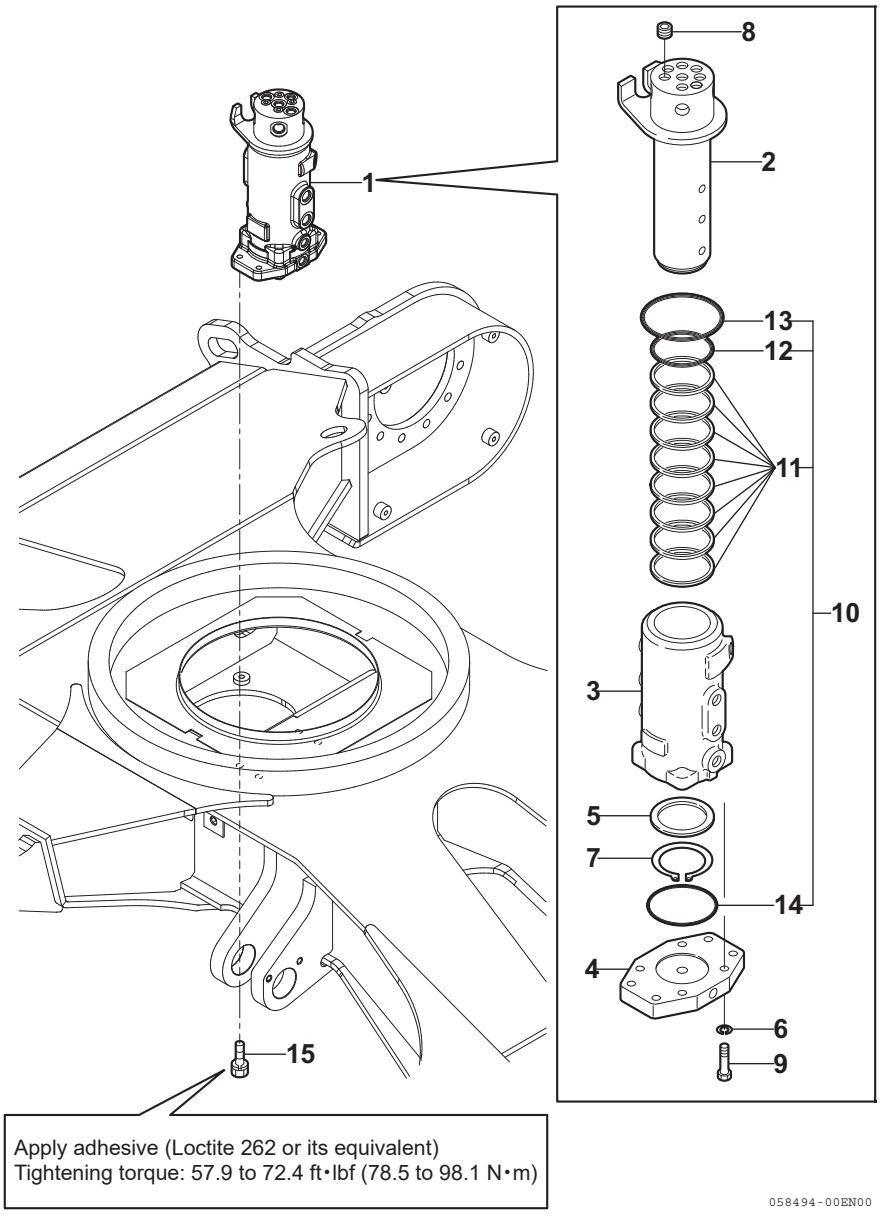
Connector and joint setting angle



7-5-15 Disassembly and Reassembly of Swivel Joint

1) Swivel Joint

The swivel joint is used to prevent the hydraulic piping from twisting when the upperstructure swings. The swivel joint consists of the shaft, hub and seal kit. The shaft and hub have holes and grooves, and the oil supplied from the port of the shaft, passing through the hub groove, is fed to the actuators of the undercarriage.



No.	Part	Q'ty	No.	Part	Q'ty	No.	Part	Q'ty
1	Swivel joint ASSY	1	6	Spring washer 10	4	11	Seal	8
2	Shaft ASSY	1	7	External snap ring 72	1	12	O-ring 1B P 80.0	1
3	Rotor	1	8	Screw plug R3/8	4	13	O-ring 1B P 100.0	1
4	Flange	1	9	Bolt M10×40	4	14	O-ring 1B G 95.0	1
5	Spacer	1	10	Seal kit	1	15	Bolt M12×40	4

2) Disassembly and Reassembly of Swivel Joint

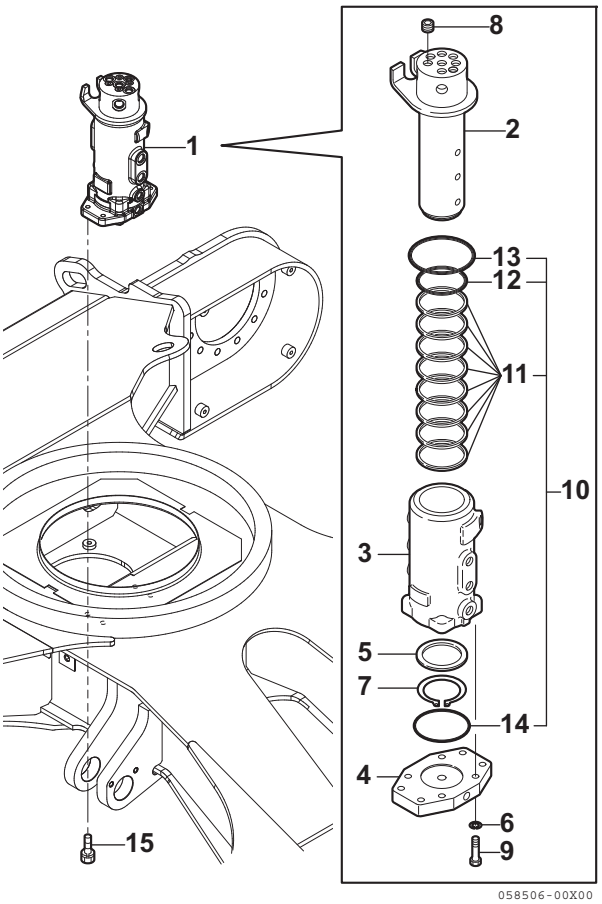
Disassembly

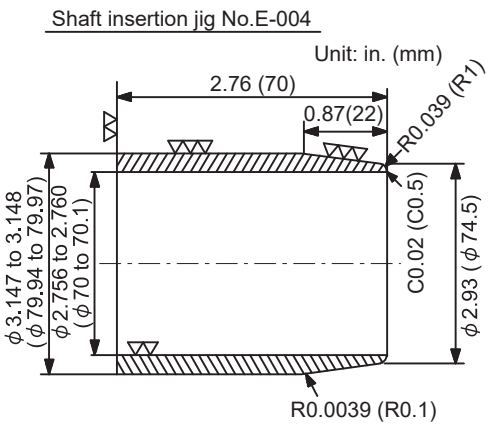
(1) Remove bolts **9**.
(2) Remove flange **4** and O-ring **14**.
(3) Remove external ring **7** and spacer **5** from shaft **2**.
(4) Pull shaft **2** out of rotor **3** and remove O-ring **13**.
(5) Remove seals **11** and O-ring **12** from rotor **3**.

Reassembly

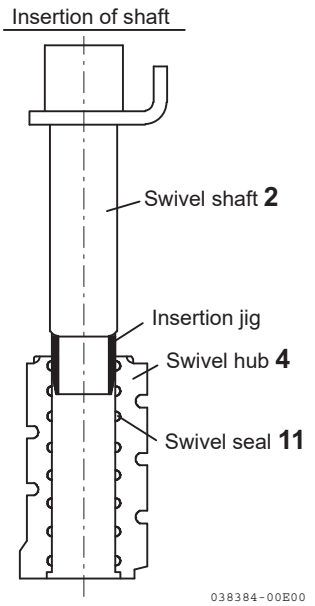
(1) Install seals **11** and O-ring **12** into rotor **3**.
(2) Apply multipurpose grease to the inner surface of rotor **3**.
(3) Install O-ring **13** on shaft **2** and insert the shaft into rotor **3** slowly.
  • Use a jig E-004
  • Apply multipurpose grease to the outer surface of the shaft.
(4) Install spacer **5** and external ring **7** to shaft **2**.
(5) Install O-ring **14** and flange **4** on rotor **3** in this order and tighten bolts **9**.

Tightening torque: 40.6 ft•lbf (55 N•m)





Note : *The □▽▽▽ areas must be hard chromium plated.*



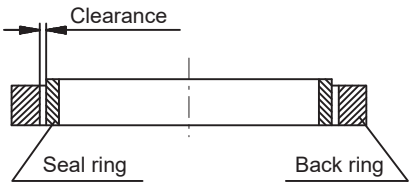
3) Cautions for Handling and Storing Seals

(1) O-rings are packed in the package that is suitable for storage.
(2) Do not leave the O-rings outside the package.
(3) For storing, put the O-rings in the packages and place them in a dark and cool place (in a parts box or cardboard box) under 104°F (40°C) to avoid direct sunlight.
(4) Do not put anything on the O-rings, or they may be distorted.

4) How to Fit O-rings (for inner side)

• Before fitting

(1) There may be a clearance (within 3% of the shaft dia.) between the seal ring and the back ring.
This is normal condition.
(2) Check that there is no distortion, flaw or other abnormality on the seal ring and the back ring.



• Fitting

(1) Dry the seal groove. Push an end of the seal ring into the groove and fit the whole part while pressing the seal ring with your fingers.
Take care not to twist the seal ring.
(2) Use lithium soap group multipurpose grease.
(3) For fitting a seal ring, make it heart-shaped as shown in the figures at the right and press one end of it into the groove. Then, fit the whole seal ring while pressing it with your finger (Figs. 1 and 2).
(4) When using jigs for fitting seal rings, use the jigs with round edges to avoid damaging the seal rings. (Fig. 3)
(5) If the seal ring is distorted after fitting, correct the distortion with the jig before assembly. (Fig. 4)

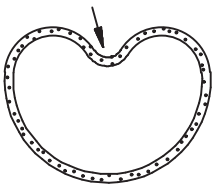


Fig. 1

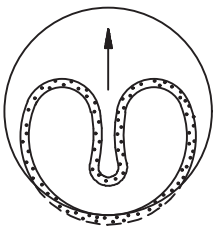


Fig. 2

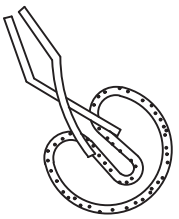


Fig. 3

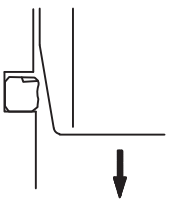


Fig. 4

038385-00E00

5) Repair and Replacement of Parts

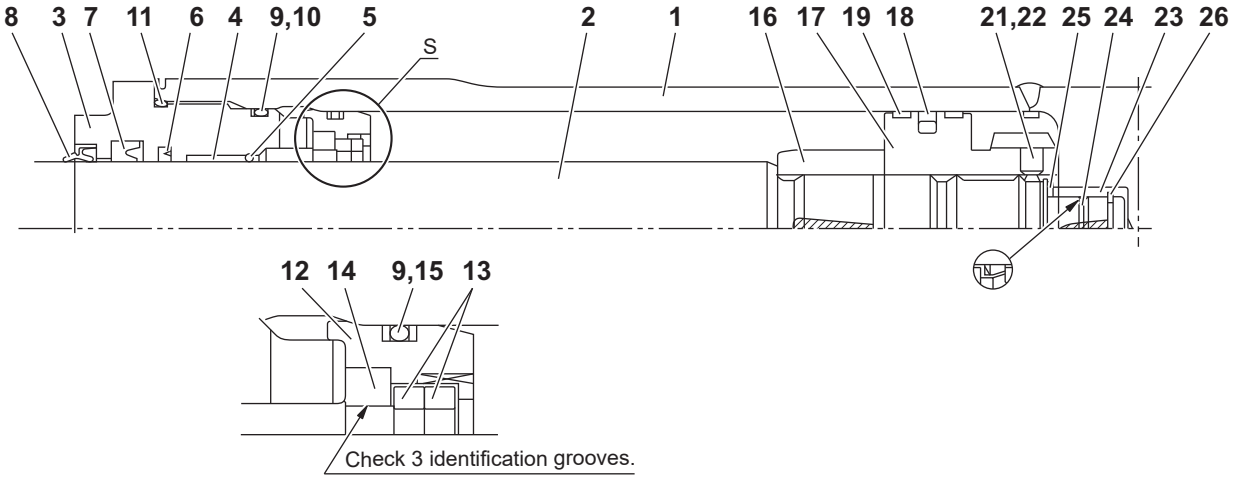
(1) Disassemble and reassemble at a place free from dust.
(2) Completely remove the contamination, foreign matter (sludge), etc. from the disassembled parts.
(3) Check for flaws or nicks on the seal surface of the shaft.
Repair or replace the part when necessary.
(4) Replace the shaft if it is worn.
(5) Replace all seals in reassembly.

7-5-16 Disassembly and Reassembly of Hydraulic Cylinders

1. Arm cylinder

1) Cross-sectional Views and Part Names

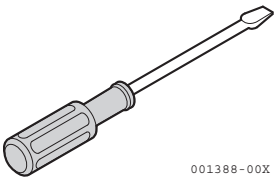
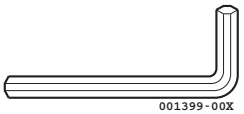
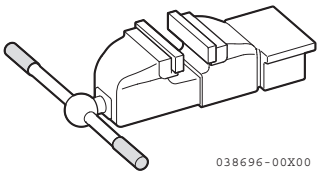
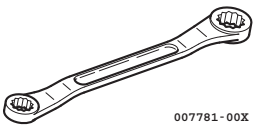
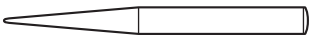
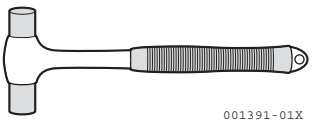
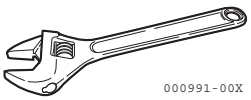
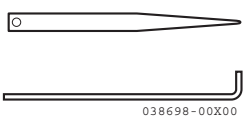
Arm Cylinder



No.	Part	No.	Part
1	Cylinder tube ASSY	14	Collar
2	Piston rod ASSY	15	Buck-up ring
3	Cylinder head	16	Cushion bearing
4	Bush	17	Piston
5	Snap ring	18	Seal ring ASSY
6	Buffer ring	19	Slide ring
7	U-ring	21	Setting screw
8	Wiper ring	22	Steel ball
9	O-ring	23	Cushion bearing
10	Buck-up ring	24	Cushion seal
11	O-ring	25	Snap ring
12	Holder	26	Stopper
13	Cushion seal		

2) Necessary Tools

(1) General tools

No.	Tool Name		Q'ty
1	Flathead screwdriver	 001388-00X	1
2	Hexagon key wrench	 001399-00X	1 set
3	Vice	 038696-00X00	1
4	Wrench (for piston nut)	 007781-00X	1 set
5	Punch	 038697-00X00	1
6	Torque wrench	009708-01X	1 set
7	Plastic hammer	 001391-01X	1
8	Adjustable wrench	 000991-00X	1
9	Spatula	 038698-00X00	1 set

(2) Special tools

For Seal ring inserting/correcting jig

Ref.	Name
[1]	Seal ring inserting jig (inner)
[2]	Seal ring inserting jig (Outer)
[3]	Seal ring correcting jig

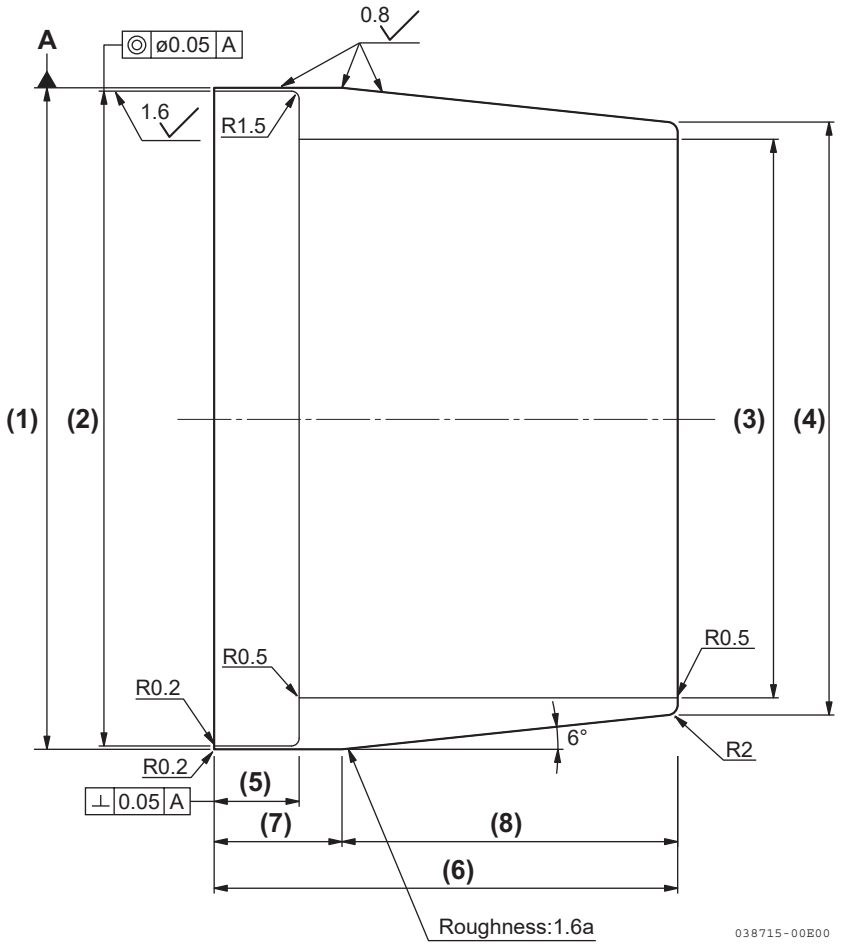
For Cylinder head disassembly and assembly jig

Ref.	Name
[4]	Cylinder head disassembly and assembly jig set
[4-1]	Chuck
[4-2]	Wedge assembly
[4-2-1]	Wedge
[4-2-2]	Hexagon socket head bolt
[4-2-3]	Nut
[4-2-4]	Spring pin
[4-3]	Block
[4-4]	Retainer assembly
[4-4-1]	Press fitting jig
[4-4-2]	Cover
[4-5]	Lever

[1] Seal ring inserting jig (inner)

Material: STKM13A or equivalent

Roughness: 6.3a

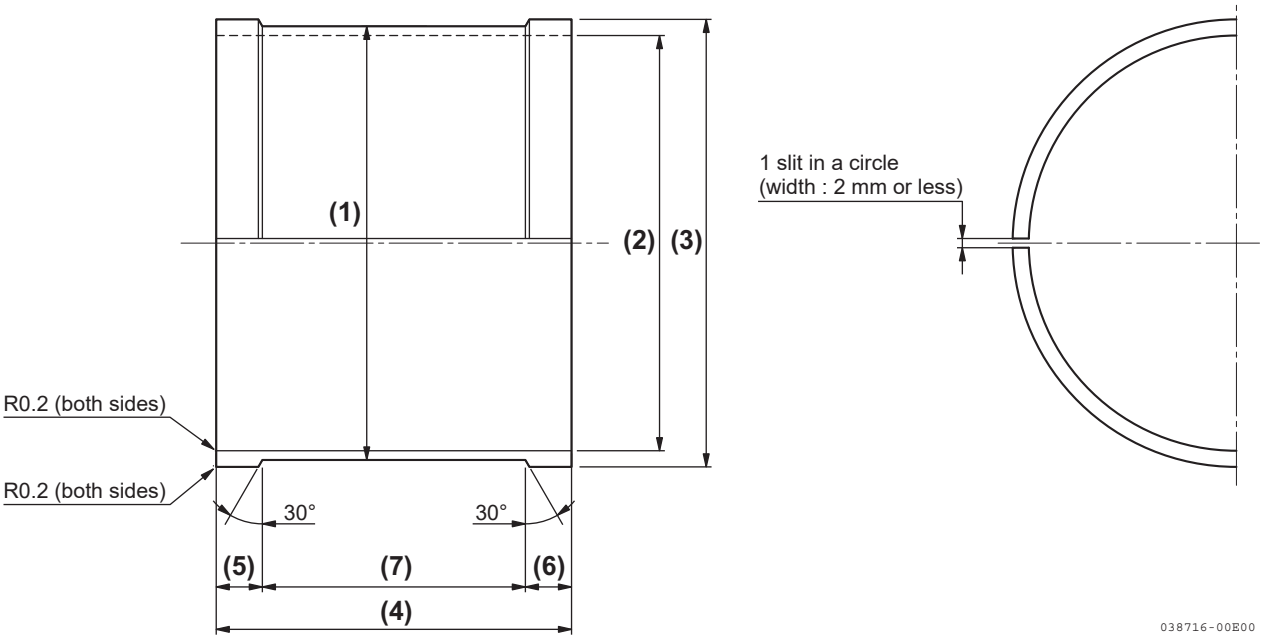


Unit: mm

Cylinder	Arm
Tube diameter	Ø100
(1)	Ø101 +0.25/0
(2)	Ø99.7 +0.300/0
(3)	Ø84
(4)	Ø90.7 +0.1/-0.1
(5)	22.5 +0.1/-0.1
(6)	77 +0.2/-0.2
(7)	28
(8)	49

[2] Seal ring inserting jig (outer)

Material: PTR-FLE
Roughness: 1.6a

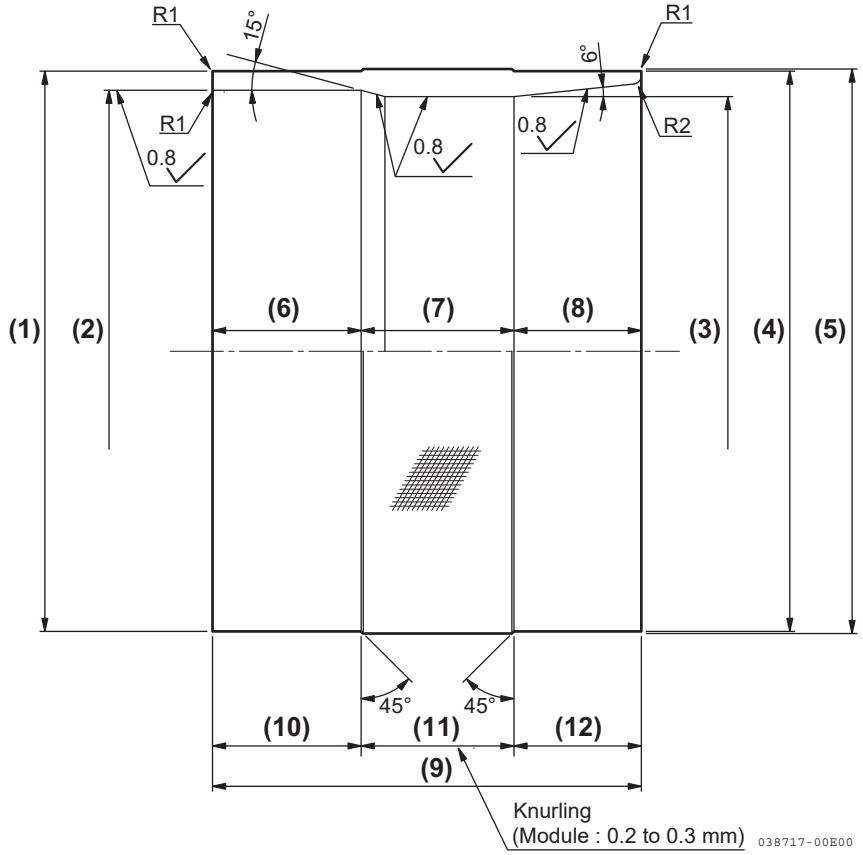


Unit: mm

Cylinder	Arm
Tube diameter	Ø100
(1)	Ø99 +0.2/-0.2
(2)	Ø95 +0.2/-0.2
(3)	Ø102 +0.2/-0.2
(4)	77 +0.2/-0.2
(5)	10
(6)	10
(7)	57

[3] Seal ring correcting jig

Material: STKM13C or equivalent
Roughness: 6.3a

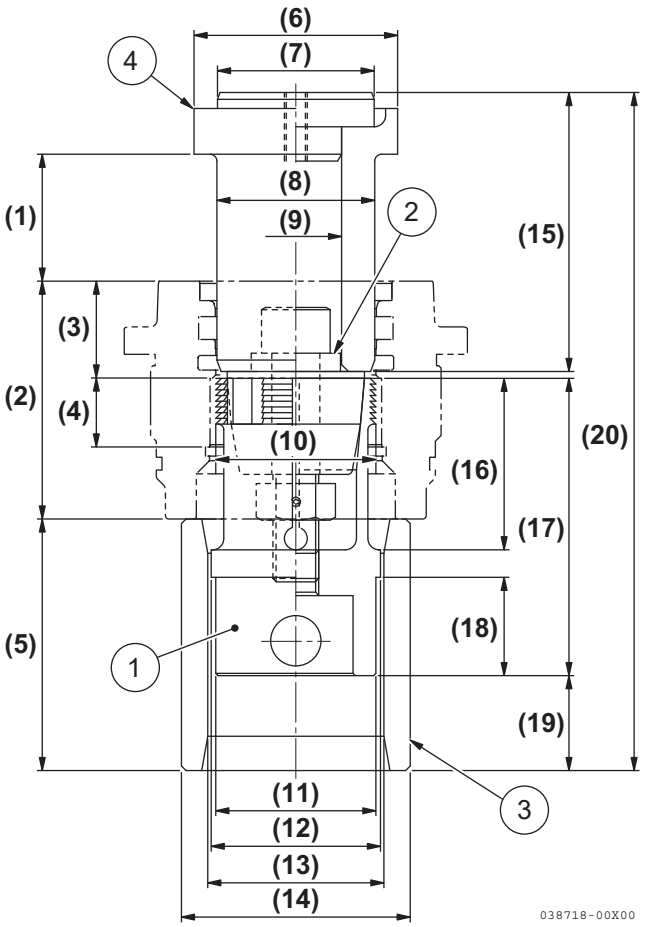


Unit: mm

Cylinder	Arm
Tube diameter	Ø100
(1)	Ø112
(2)	Ø103 +0.100/0
(3)	Ø100H8 +0.054/0
(4)	Ø112
(5)	Ø113
(6)	31
(7)	32
(8)	30
(9)	93
(10)	31
(11)	32
(12)	30

[4] Cylinder head disassembly and assembly jig set

Component parts:
4-1. Chuck
4-2. Wedge assembly
4-3. Block
4-4. Retainer assembly
4-5. Lever



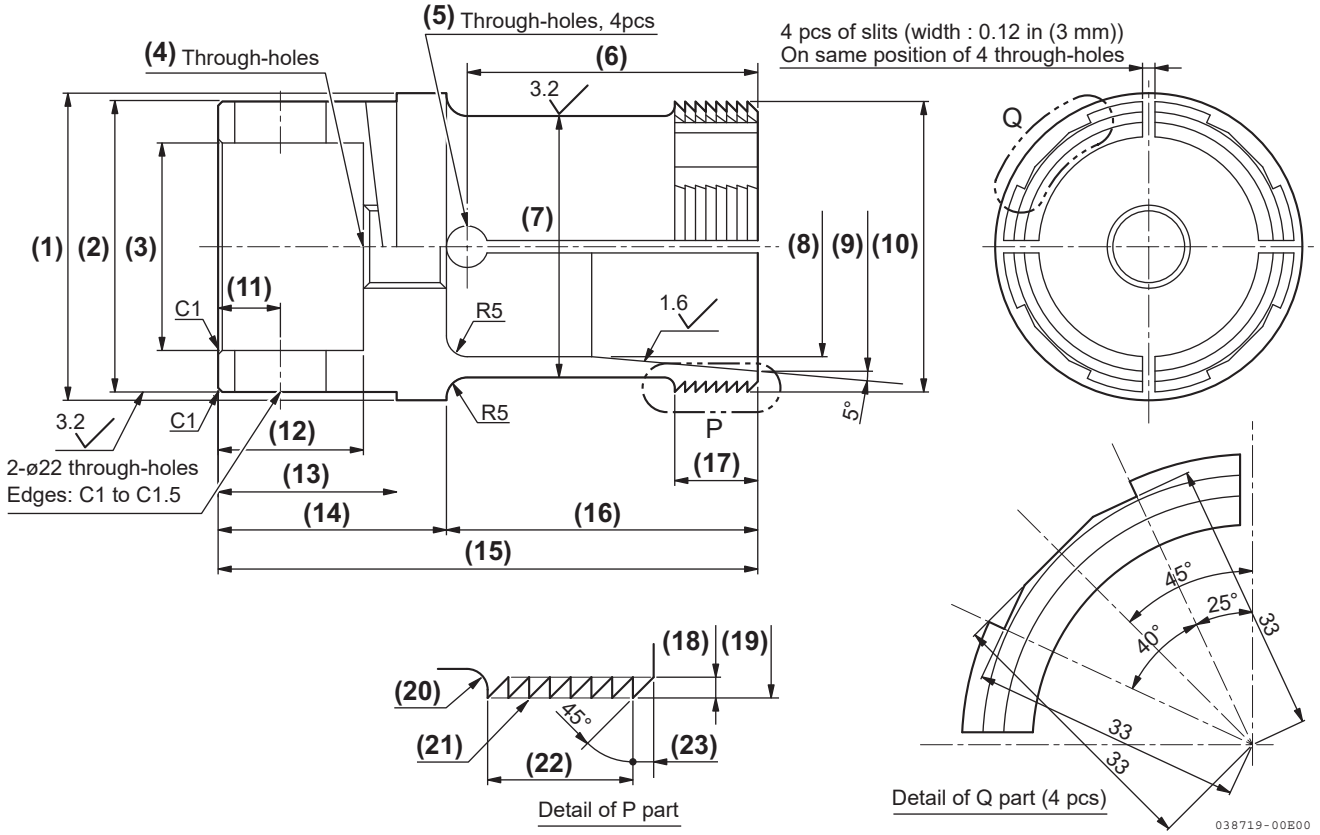
Unit: mm

Cylinder	Arm
Rod diameter	Ø65
(1)	55.5
(2)	100
(3)	42.5
(4)	30
(5)	100
(6)	Ø84
(7)	Ø64
(8)	Ø64
(9)	Ø40
(10)	Ø65
(11)	Ø65
(12)	Ø69
(13)	Ø72
(14)	Ø100
(15)	117
(16)	65
(17)	120
(18)	42
(19)	37.5
(20)	277.5

[4-1] Chuck

Material: SCM435 or SCM440

Roughness: 12.5a

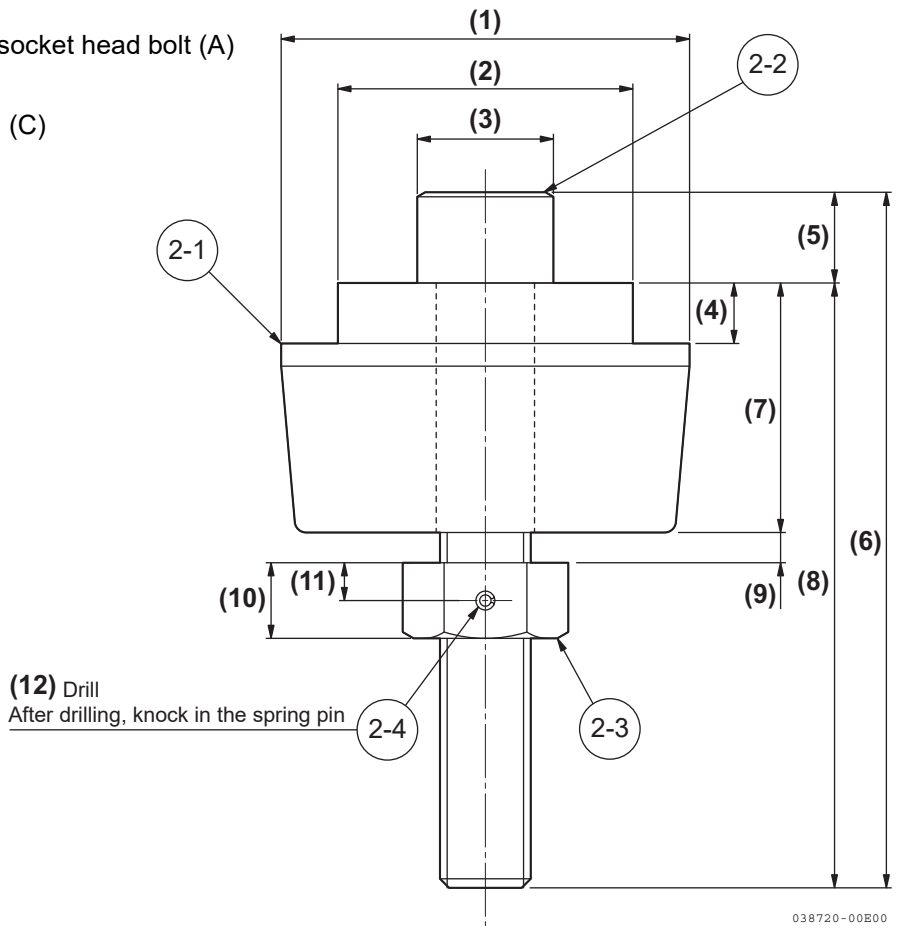


Unit: mm

Cylinder	Arm	Cylinder	Arm
Rod diameter	Ø65	Rod diameter	Ø65
(1)	Ø69	(13)	42
(2)	Ø65 0/-0.05	(14)	55
(3)	Ø45	(15)	120
(4)	M12 x 1.75	(16)	65
(5)	Ø6	(17)	15
(6)	60	(18)	1.5
(7)	Ø62	(19)	Ø65
(8)	Ø59	(20)	R1.5
(9)	Ø59 +0.05/-0.05	(21)	Pitch 1.5
(10)	Ø65 +0.05/-0.05	(22)	15
(11)	10	(23)	1.5
(12)	30		

[4-2] Wedge assembly

Component parts:
(4-)2-1. Wedge
(4-)2-2. Hexagon socket head bolt (A)
(4-)2-3. Nut (B)
(4-)2-4. Spring pin (C)

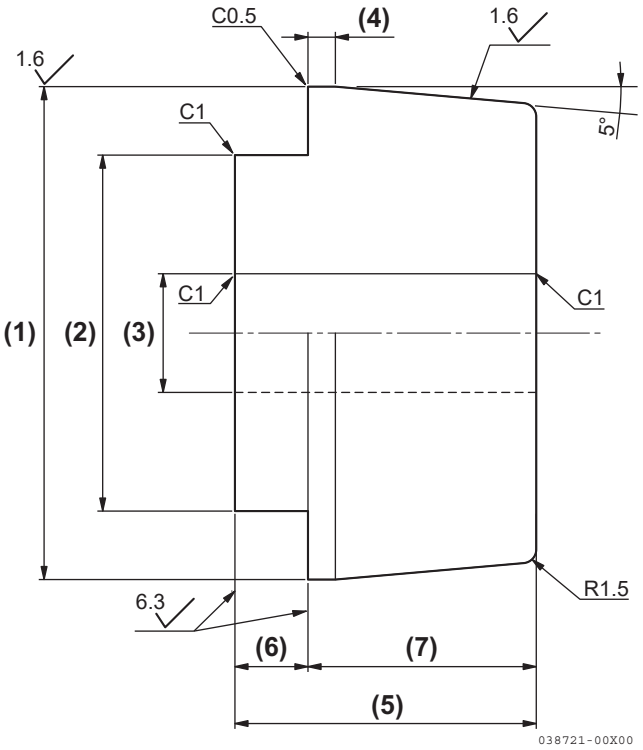


Unit: mm

Cylinder	Arm
Rod diameter	Ø65
A	M12x1.75x80-12.9
B	M12x1.75-4
C	2.5x18
(1)	Ø57
(2)	Ø39
(3)	Ø18
(4)	8
(5)	12
(6)	92
(7)	33
(8)	80
(9)	4 +0.5/-0.5
(10)	10
(11)	5
(12)	Ø2.5 +0.1/0

[4-2-1] Wedge

Material: SCM435 or SCM440
Heat treating: Quenching and tempering



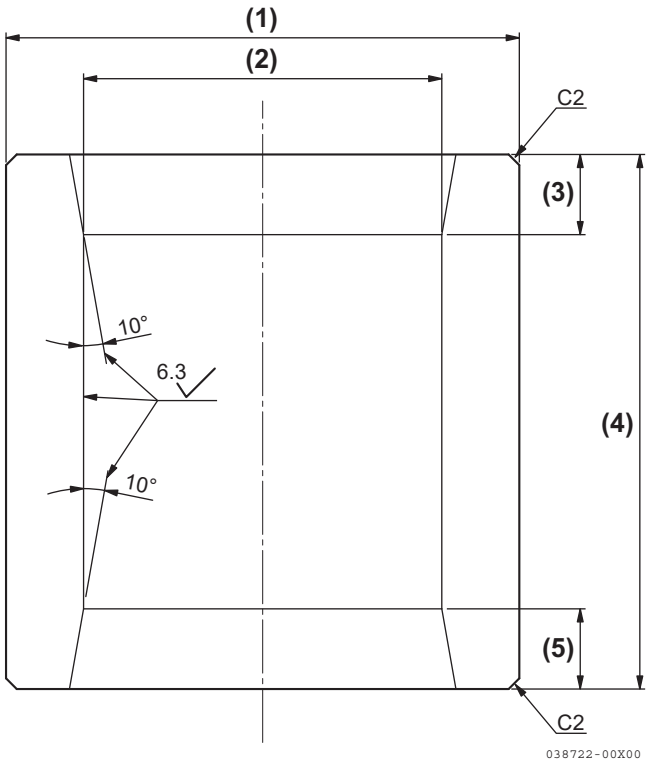
Unit: mm

Cylinder	Arm
Rod diameter	Ø65
(1)	Ø57 +0.05/-0.05
(2)	Ø39
(3)	Ø13
(4)	3
(5)	35
(6)	8
(7)	25

[4-3] Block

Material: SS400 or STKM13A

Roughness: 12.5a

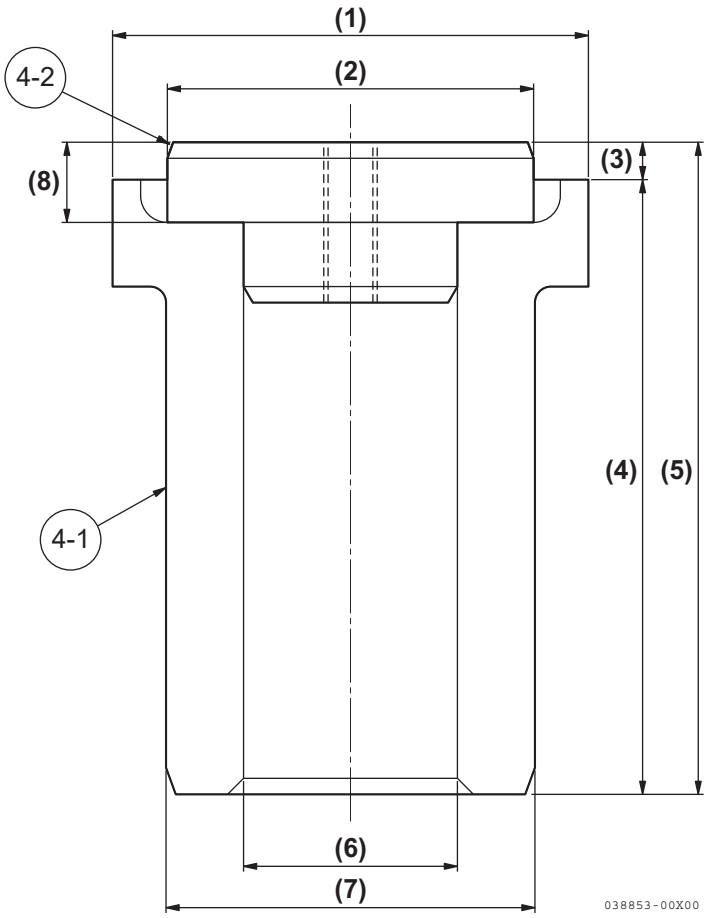


Unit: mm

Cylinder	Arm
Rod diameter	Ø65
(1)	Ø100
(2)	Ø72
(3)	15
(4)	100
(5)	15

[4-4] Retainer assembly

Component parts:
(4-)4-1. Press fitting jig
(4-)4-2. Cover

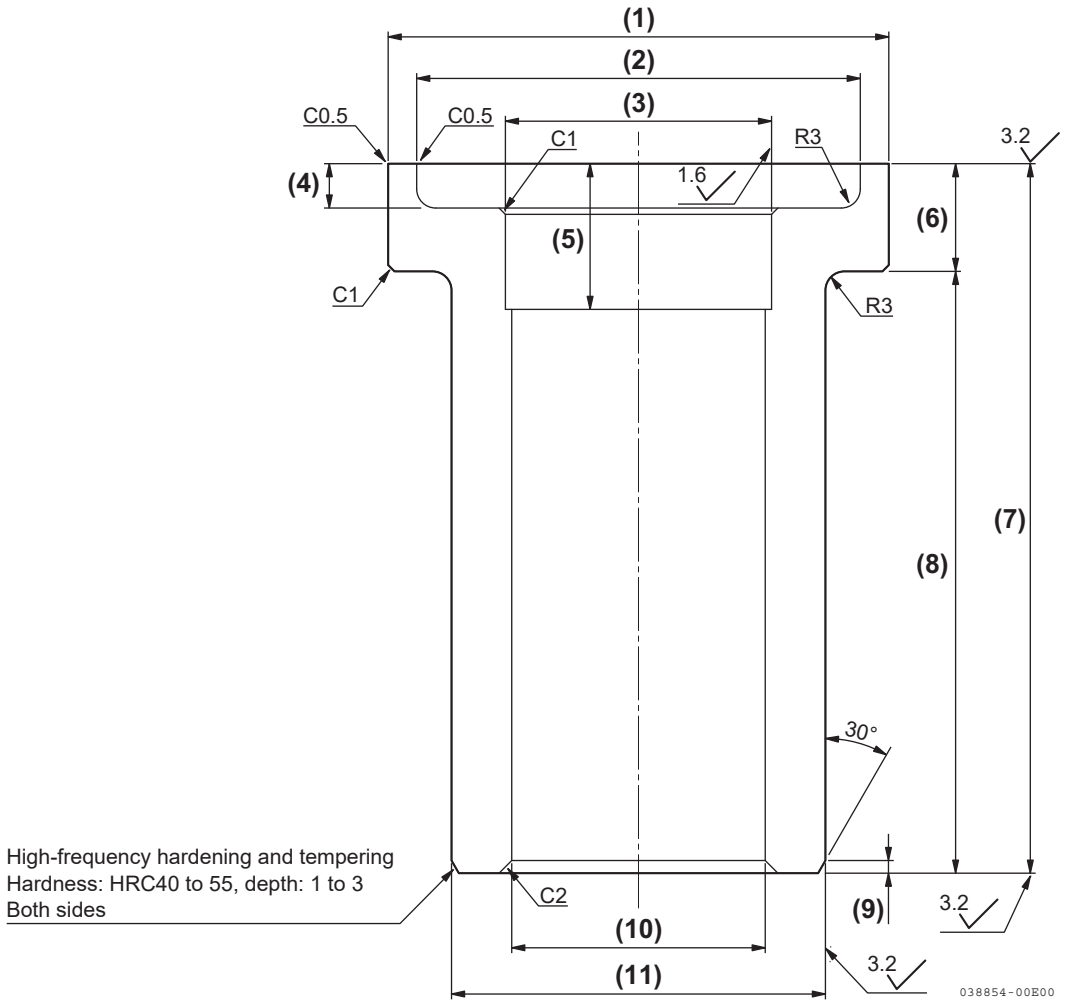


Unit: mm

Cylinder	Arm
Rod diameter	Ø65
(1)	Ø84
(2)	Ø58.5
(3)	5
(4)	112
(5)	117
(6)	Ø40
(7)	Ø64
(8)	13

[4-4-1] Press fitting jig

Material: S45C or equivalent

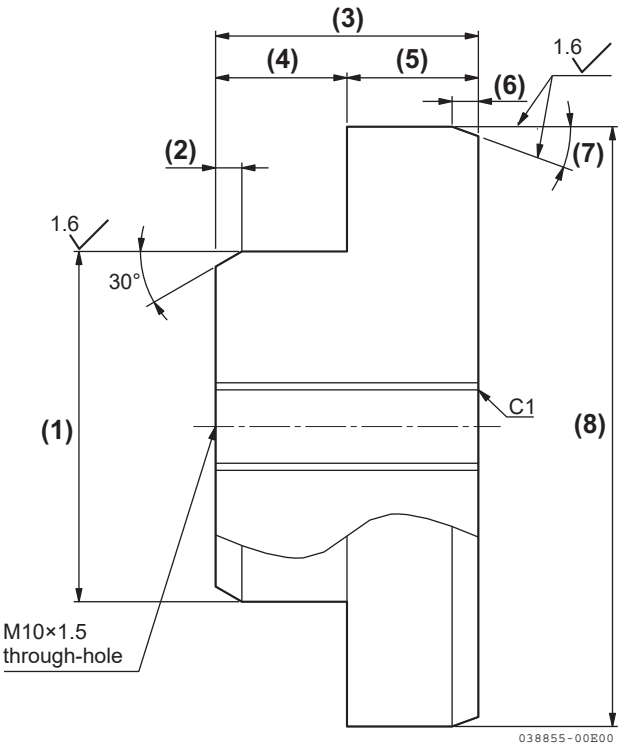


Unit: mm

Cylinder	Arm
Rod diameter	Ø65
(1)	Ø84
(2)	Ø74 +0.5/0
(3)	Ø42 +0.03/0
(4)	8
(5)	23
(6)	17
(7)	112
(8)	95
(9)	5
(10)	Ø40
(11)	Ø59

[4-4-2] Cover

Material: S25C or equivalent

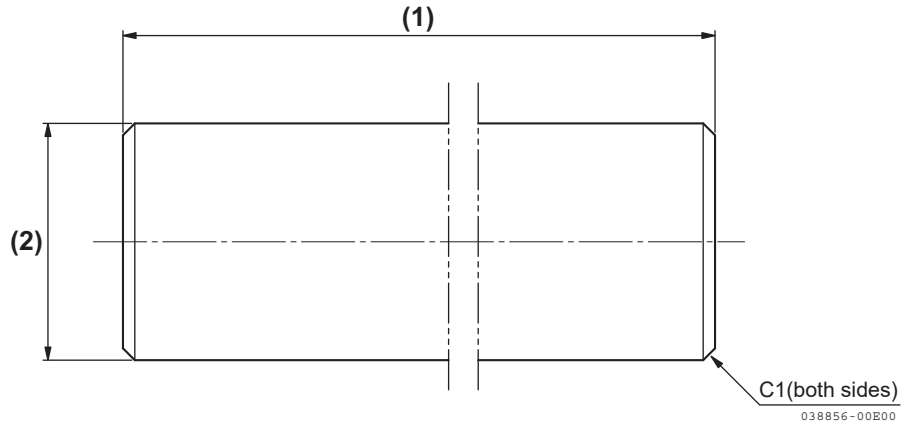


Unit: mm

Cylinder	Arm
Rod diameter	Ø65
(1)	Ø42 +0.09/+0.07
(2)	2
(3)	27
(4)	15
(5)	12
(6)	2
(7)	30 degree
(8)	Ø64 0/-0.1

[4-5] Lever

Material: S25C or equivalent



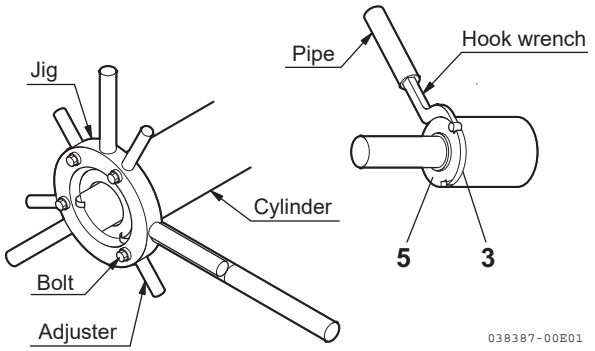
Unit: mm

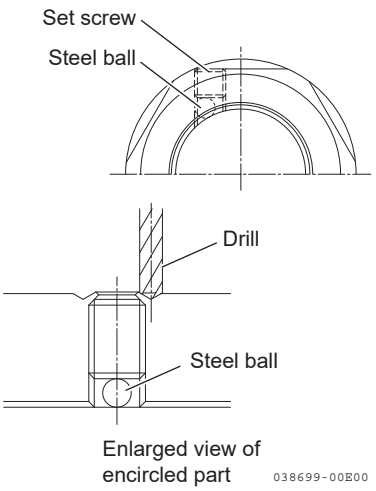
Cylinder	Arm
Rod diameter	Ø65
(1)	200
(2)	Ø13

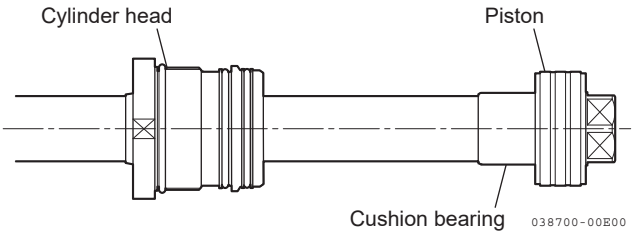
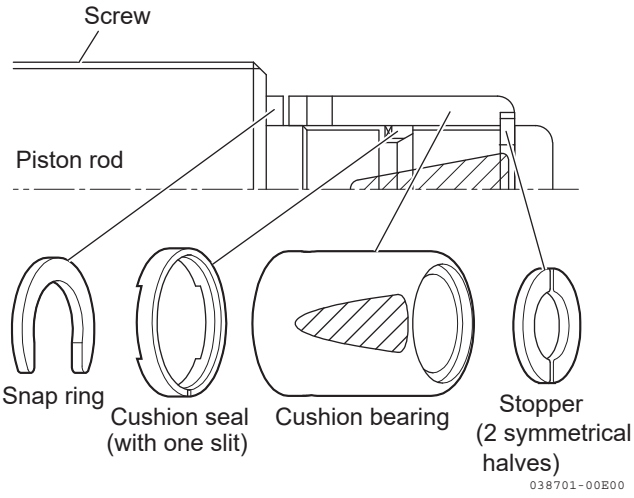
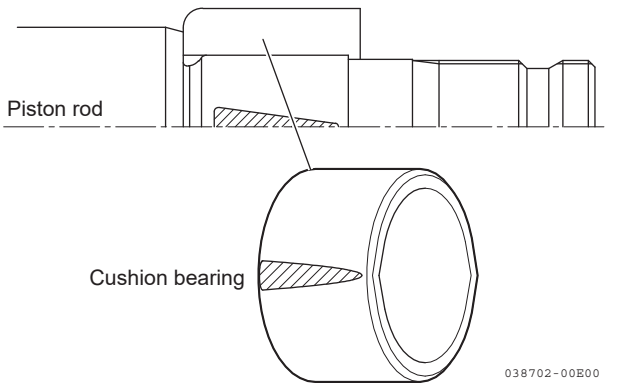
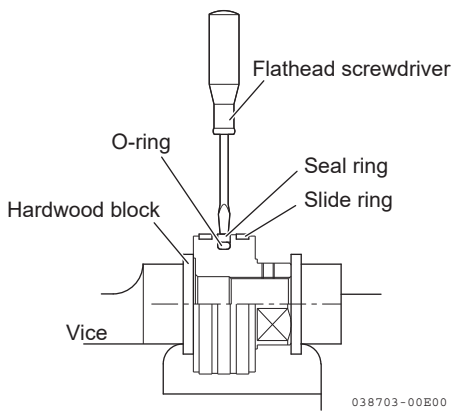
3) Precautions for Disassembly and Assembly

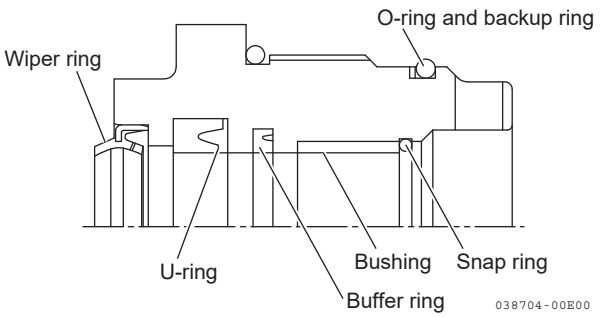
(1) All parts are manufactured to extreme precision. During disassembly or assembly, be sure to handle them carefully to avoid damage such as dents and scratches due to dropping or hitting.
(2) Remove any burrs or flash from seal fit portions or O-ring grooves.
(3) Do not reuse lock washers once they are removed.
(4) Once removed, replace the seals and O-rings with new ones.
(5) Clean each part and blow it dry with air, and then install it.

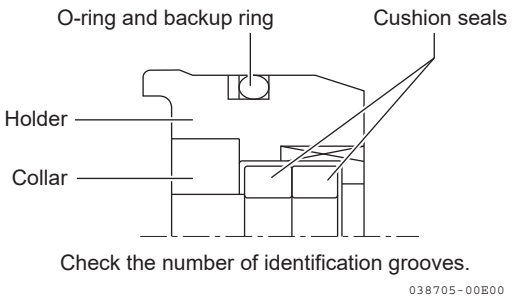
4) Disassembly

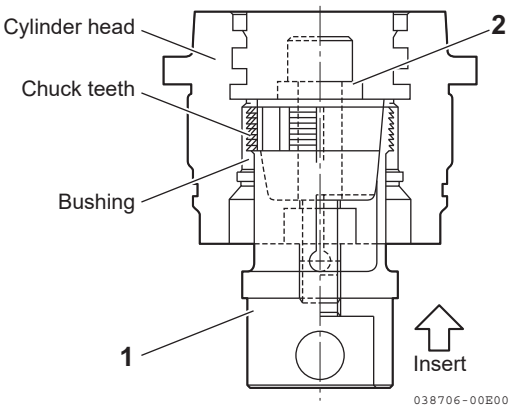
Procedure	
(1) Drain the hydraulic oil from the hydraulic cylinder. (2) Hold the cylinder in the bottom end using the pin hole or other means, and place the rod end of the cylinder on a wood block. (3) Raise the two folded portions of the lock washer (on the cylinder head side and tube side) and loosen the cylinder head. ***Note:*** *Use a hook wrench or jig to loosen the head.* (4) Slowly pull the cylinder rod out of the cylinder tube. Slowly pull out the cylinder rod after the piston comes into contact with the end face of the head.	

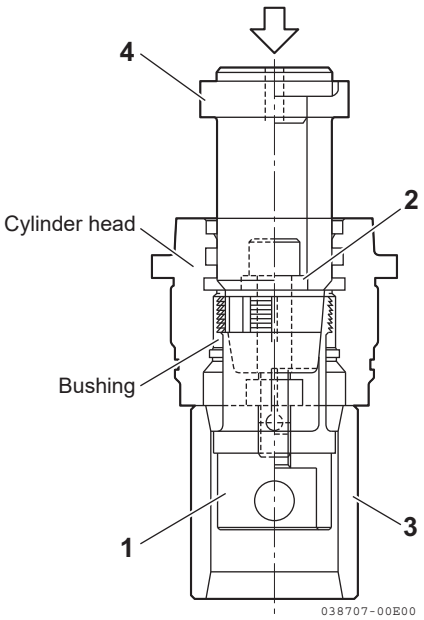
(5) Scrape off the two punch-caulked points around the piston nut set screw using a drill, and then, loosen the set screw. (6) Remove the steel ball from inside the set screw. *Width across flats of set screw Unit: in.(mm) Arm cylinder: Width across flats of set screw 0.20 (5) (7) Remove the piston nut. A torque of approximately 1.5 times the tightening torque is required to loosen the piston nut. To loosen the piston nut easily, use a tool, such as a hydraulic jack or a torque multiplier wrench. *Width across flats of piston nut Unit: in.(mm) Arm cylinder: Width across flats of nut 2.95 (75)	

Procedure	
(8) Remove the piston and cushion bearing. When the nut is separable from the piston, remove the piston.	
(9) To remove the cushion bearing on the retraction side, remove the snap ring and slide the cushion bearing to the piston rod screw side, and then, remove the stopper (two symmetrical halves). (10) After removing the cushion bearing, widen the slit in the cushion seal and remove it.	
(11) Remove the cushion bearing on the extension side.	
(12) Remove the slide ring, seal ring and O-ring from the piston. • Using your hand, remove the slide ring. • To remove the seal ring, put a flathead screwdriver perpendicular to the ring and hit the screwdriver with a hammer or similar tool to cut the ring. • For removal of the O-ring, use a tool, such as a spatula, to pull it out.	

Procedure	
(13) Remove the buffer ring, U-ring, backup ring and O-ring from the cylinder head using a flathead screwdriver or similar tool. (14) Put a flathead screwdriver or similar tool on the wiper ring and tap on the screwdriver with a hammer or similar tool to remove the press-fitted wiper ring.	

(15) Remove the collar, cushion seals, O-ring and backup ring from the holder. * Number of identification grooves: • Collar for the arm cylinder: **2**	

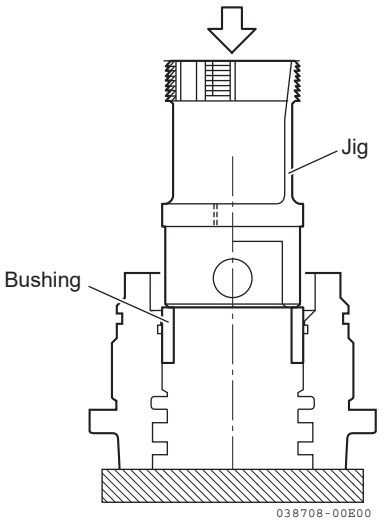
(16) Remove the snap ring using a flathead screwdriver, and then, push the bushing out using a jig and press by following the steps (17) to (19) below. * How to use the jig: • Make up a jig by installing wedge **2** on chuck **1**. • Insert the jig into the cylinder head from the snap ring side and push the chuck teeth into the bushing using a lever and wrench.	

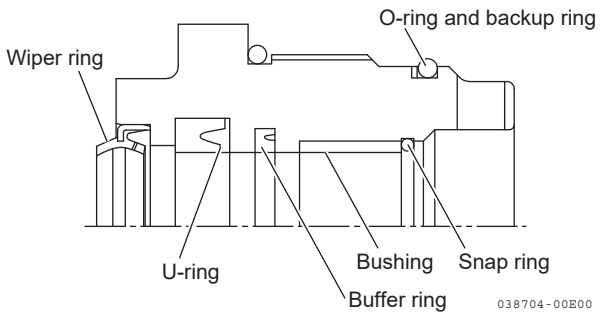
Procedure	
(17) Tighten the bolt until wedge **2** is fully inserted into chuck **1**. (18) Put the cylinder head on block **3** and set retainer assembly **4** into the cylinder head, and then, press retainer assembly **4** until the bushing is removed from the cylinder head. (19) Remove the bushing from chuck **1** using a lever and wrench.	

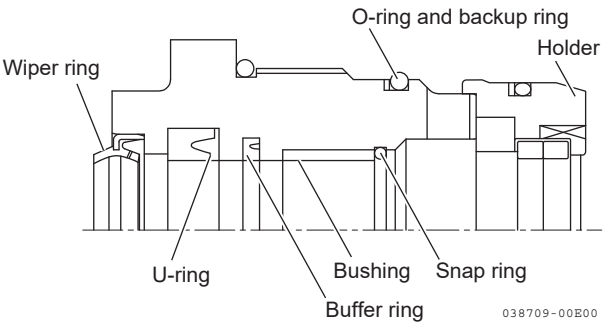
5) Assembly

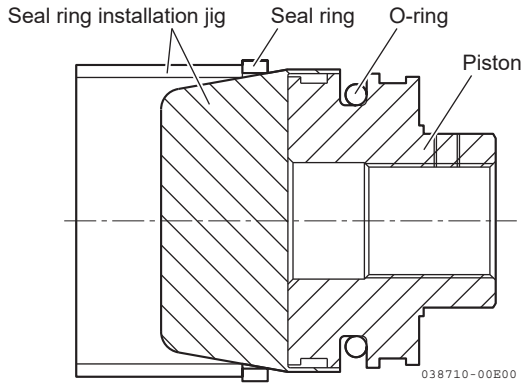
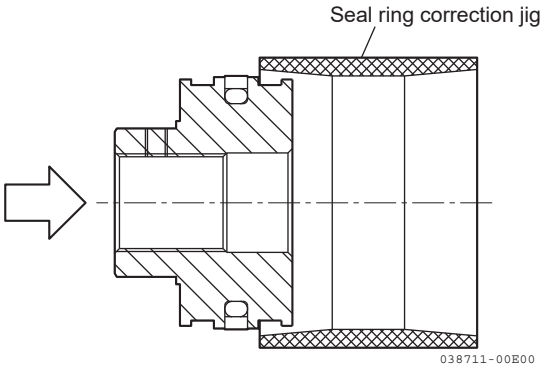
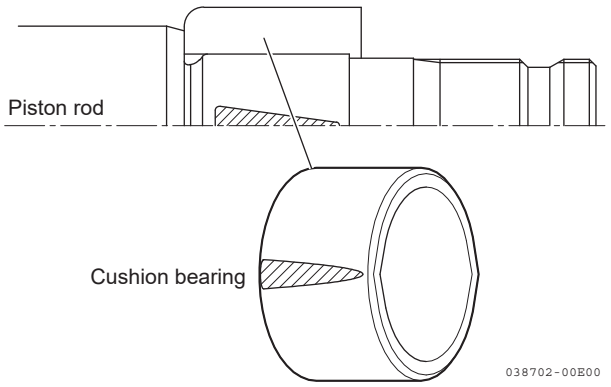
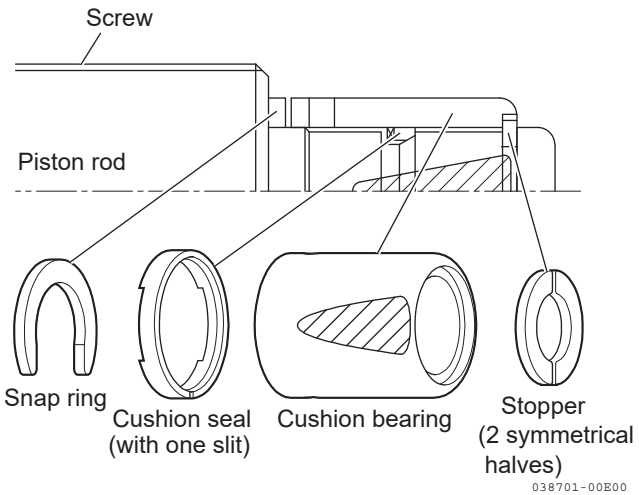
To assemble the cylinders, perform the disassembly procedures in reverse order.

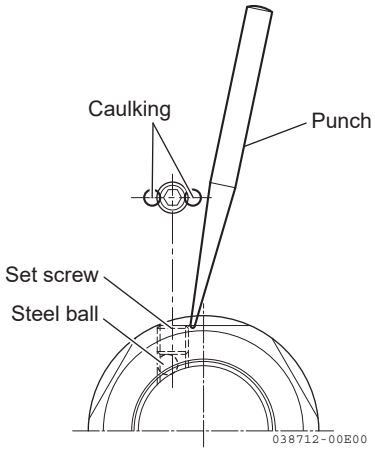
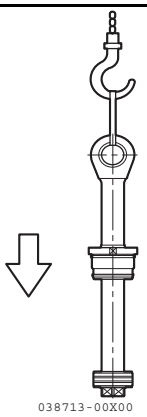
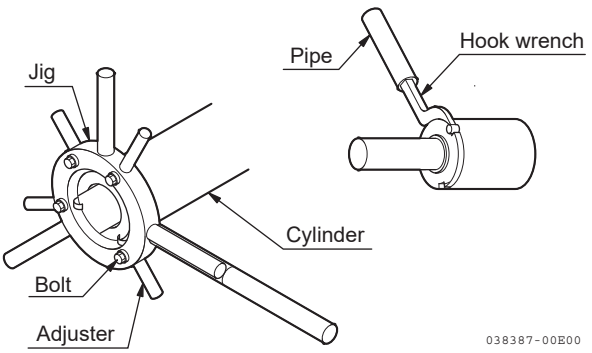
[Points to Assembly]

Procedure	
(1) Apply hydraulic oil to the inner face of the cylinder head before press-fitting the bushing into the cylinder head. (2) After press-fitting the bushing, be sure to confirm that the bushing is installed in the correct position. (3) Make sure to install the buffer ring and U-ring in the correct direction. (4) Do not damage the buffer ring and U-ring during installation. After installation, make sure that the rings are securely installed using a tool, such as a spatula.	

(5) When installing the cylinder rod into the cylinder head, be careful not to damage the lip surfaces of the wiper ring, U-ring and buffer ring.	

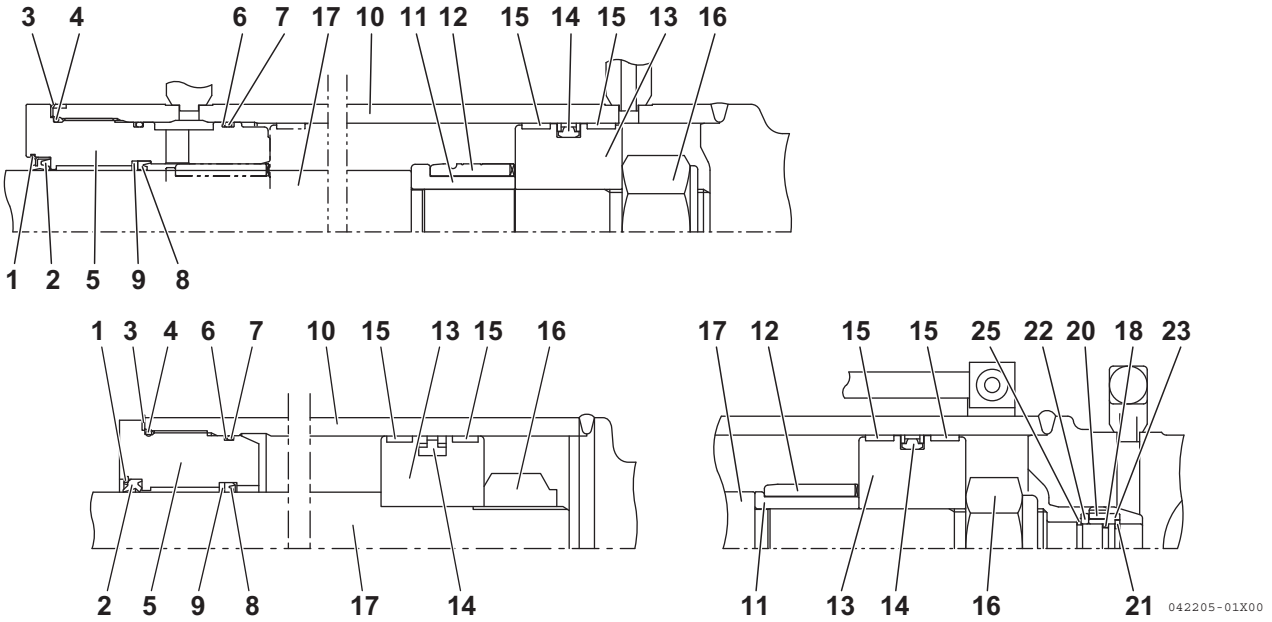
(6) For cylinders with a cushion mechanism on the extension side, be careful not to forget to install the holder.	

Procedure	
(7) Install the O-ring onto the piston taking care not to twist it and install the seal ring using a jig.	
(8) Because the seal ring is stretched when installed, correct the deformed seal ring using a correction jig. (9) Widen the gap cut in the slide ring with both hands and install it onto the piston. Take care not to widen the gap too much.	
Extension-side Cushion (10) Install the cushion bearing in the correct direction with its flattened face put in the position as shown in the figure on the right.	
Retraction-side Cushion (11) Install the cushion seal onto the piston rod with the slit facing the screw, and then, install the cushion bearing, stopper and snap ring.	

Procedure	
(12) Tighten the piston nut to the specified torque, and then, install the steel ball into the set screw and tighten the set screw to the specified torque. After that, caulk around the set screw head at two places using a punch. * For tightening torques, see the table below. Unit: ft•lbf (N•m) | | Arm cylinder | | Piston nut | 2124 (2880) | | Set screw | 25.6 to 37.4 (18.9 to 27.6) |	
(13) Hold the cylinder tube horizontally or vertically. (14) When installing the piston into the cylinder tube, be careful not to damage the slide ring, seal ring and other seals and rings. (15) When the cylinder tube is held vertically, let the piston rod slide down into the cylinder tube under its own weight.	
(16) Apply adhesive to the threaded portion on the cylinder head, and then, tighten the cylinder head to the specified torque. After that, fold the lock washer at two locking positions to prevent the cylinder head from loosening. * Adhesive: THREE BOND #1901 or equivalent * Tightening torques Unit: ft•lbf (N•m) | | Tightening torque | | Arm cylinder | 701 (951) |	
(17) Trial operation Install the cylinder in the machine and run the engine at low idle speed. Slowly extend and retract the cylinder 4 to 5 times up to 2 to 4 in. (50 to 100 mm) from the end of the stroke. Then, extend and retract the cylinder through its full stroke 3 or 4 times. ***Note:*** *Moving the cylinder rapidly may cause aeration of the hydraulic oil.*	

2. Boom, Bucket, Boom swing and Blade Cylinders (Applicable serial number: 1A001 to 1A156)

1) Sectional View and Parts



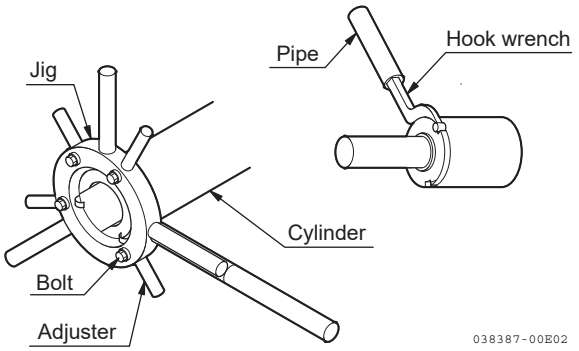
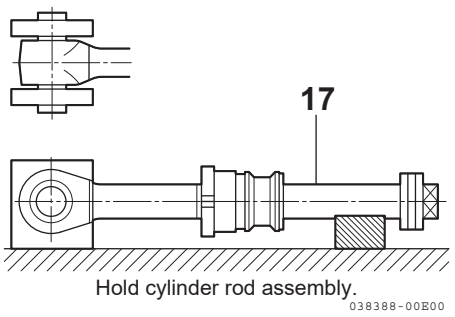
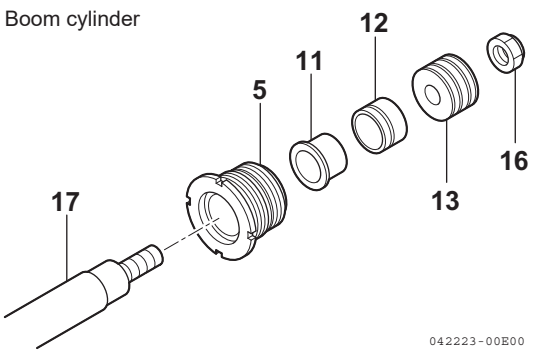
Unit: in. (mm)

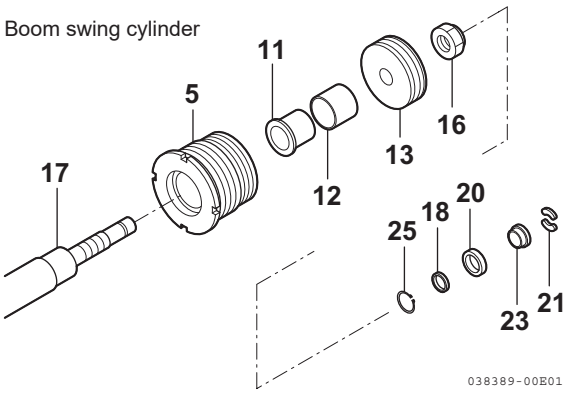
No.	Part	Boom	Bucket	Boom swing	Blade
1	Spring ring	○	○	○	○
2	Dust seal	○	○	○	○
3	Lock washer	○	○	○	○
4	O-ring	○	○	○	○
5	Head	○	○	○	○
6	Back-up ring	○	○	○	○
7	O-ring	○	○	○	○
8	ISI packing	○	○	○	○
9	Back-up ring	○	○	○	○
10	Cylinder tube (Inside diameter)	Ø4.5(Ø115)	Ø3.7(Ø95)	Ø4.7(Ø120)	Ø5.1(Ø130)
11	Cushion collar	○	—	○	—
12	Cushion plunger	○	—	○	—
13	Piston	○	○	○	○
14	Piston seal	○	○	○	○
15	Wearing ring	○	○	○	○
16	U-nut	M45×3.0	M42×3.0	M42×3.0	M48×3.0
17	Rod (Outside diameter)	Ø2.6 (Ø65)	Ø2.4 (Ø60)	Ø2.4 (Ø60)	Ø2.6 (Ø65)
18	O-ring	—	—	○	—
19	Cushion plunger	—	—	—	—
20	Cushion ring	—	—	○	—
21	Stopper	—	—	○	—
22	Spacer	—	—	○	—
23	Cushion collar	—	—	○	—
24	Cover (stopper)	—	—	—	—
25	External snap ring C	—	—	○	—

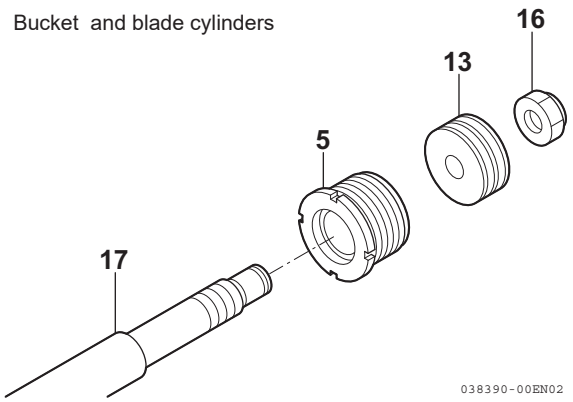
2) Cautions for Disassembly and Reassembly

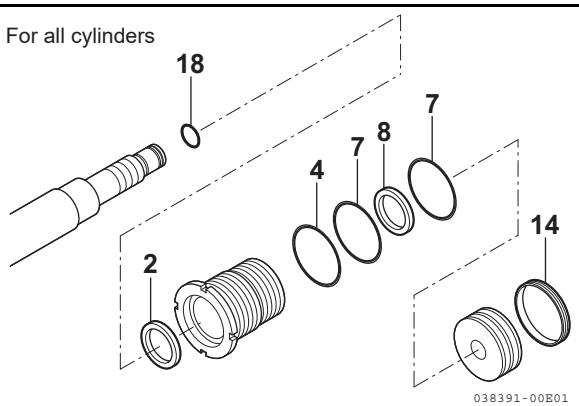
(1) Parts are produced so accurately. Be careful not to damage any parts by dropping them or knocking them together.
(2) If there are any burrs on the surface of the seal installation part or the O-ring groove, remove them.
(3) Never use the lock washer removed once.
(4) Replace once removed seals and O-rings with new ones.
(5) Clean all the parts and dry them by air blow.

3) Disassembly

Procedure	
(1) Drain the oil from the hydraulic cylinder. (2) Hold the cylinder in the bottom end or the pin hole on the bottom side, and put the rod side of the cylinder on a block. (3) Raise the pawl of lock washer **3** on head **5** to loosen head **5**. ***Note:*** *Use a hook wrench or a jig to loosen head **5**.*	
(4) Pull rod assembly **17** out of cylinder tube **10**, and then hold the cylinder rod assembly in the rod end or the pin hole on the rod side.	
(5) Disassembly of boom cylinder. Remove U-nut **16**, and then piston **13**, cushion collar **11**, cushion plunger **12** and head **5** from rod **17** in order.	

Procedure	
(6) Disassembly of boom swing cylinder. [1] Take external snap ring C **25** off the groove, and then slide cushion collar **23** to remove stopper **21**, cushion collar **23**, cushion ring **20**, and external snap ring C **25** in order. [2] Remove U-nut **16**, then piston **13** and head **5**.	Boom swing cylinder 

(7) Disassembly of bucket and blade cylinders. Remove U-nut **16**, and then piston **13** and head from rod **17** in order.	Bucket and blade cylinders 

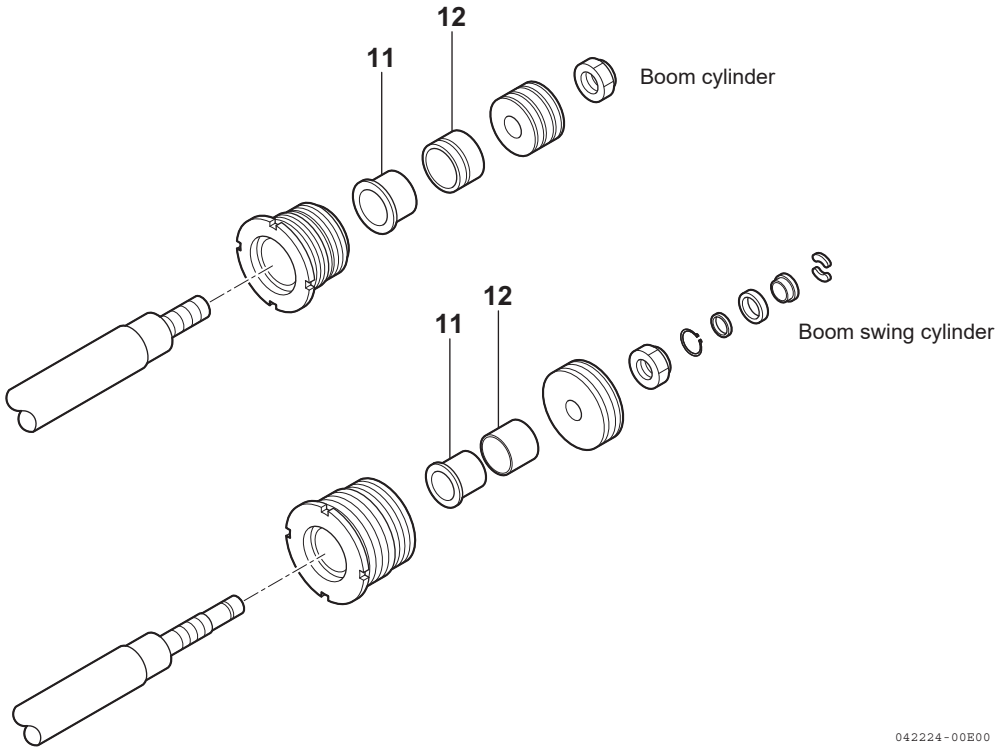
(8) Remove O-rings **4**, **7** and **18** and the dust seal **2**, ISI packing **8** and SPGW seal **14**. ***Note:*** *Use a sharp tool to raise each O-ring or SPGW seal **14**, and then insert a spatula to remove it.*	For all cylinders 

4) Reassembly

Reassemble the hydraulic cylinder in the reverse order of the disassembly procedure.

Notes:

- *Take care not to install cushion collar **11** and cushion plunger **12** in the wrong direction.*
- *Replace O-rings, packings and seals with new ones.*



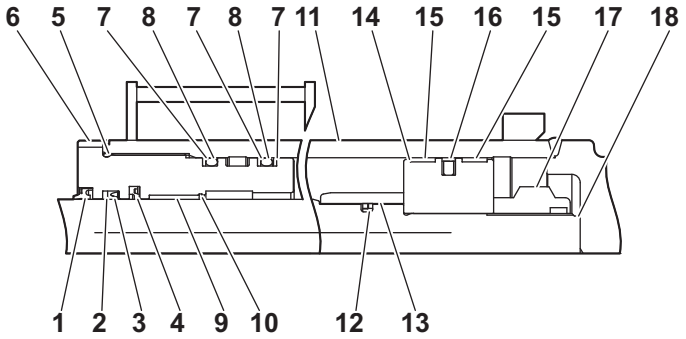
U-nut size and tightening torque

Cylinder	U-nut size (width across flats)	U-nut tightening torque ft•lbf (N•m)	Adhesive
Boom	M45 (2.76 in. (70 mm))	2098 to 2171 (2845 to 2943)	Three Bond 1324 or its equivalent
Bucket	M42 (2.56 in. (65 mm))	1773 to 1845 (2404 to 2502)	
Boom swing	M42 (2.56 in. (65 mm))	1773 to 1845 (2404 to 2502)	
Blade	M48 (2.95 in. (75 mm))	2605 to 2677 (3532 to 3630)	

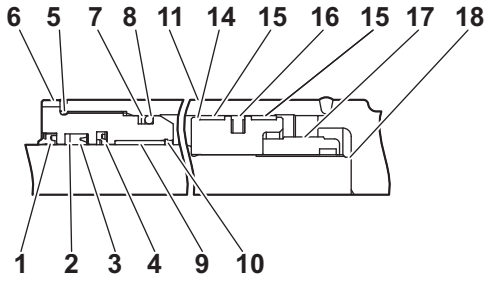
3. Boom, Bucket, Boom Swing and Blade Cylinders (Applicable Serial Number: 1A157 and above)

1) Sectional View and Parts

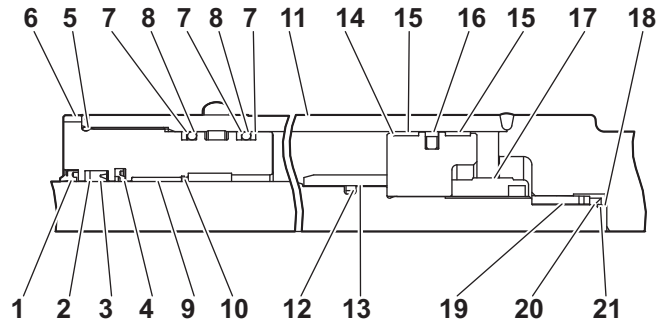
Boom



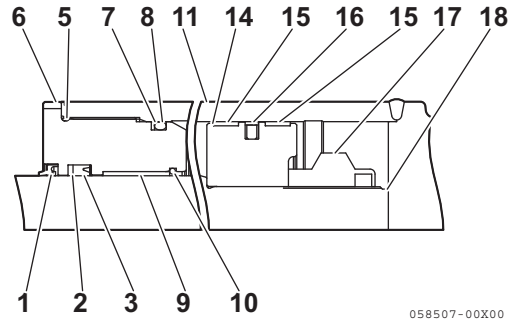
Bucket



Boom swing



Blade



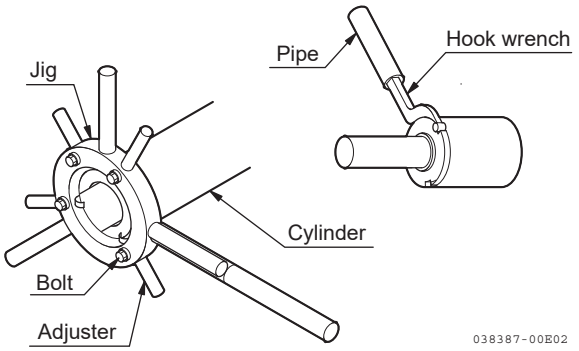
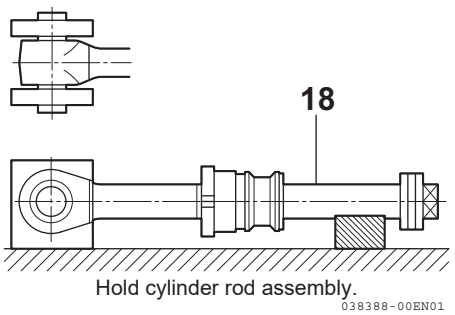
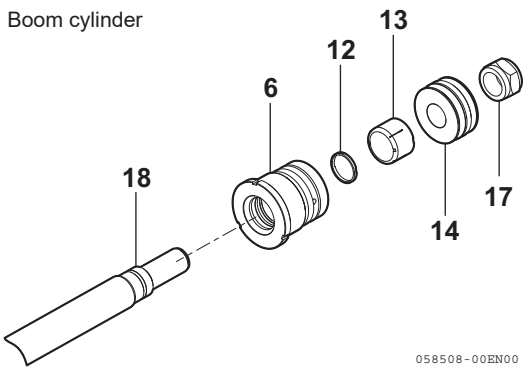
Unit: in. (mm)

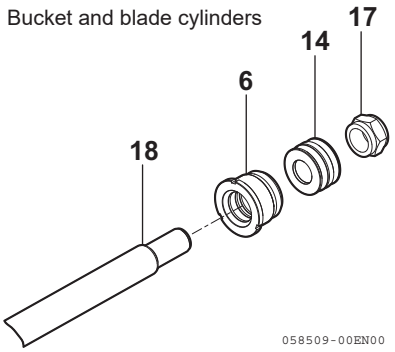
No.	Part	Boom	Bucket	Boom swing	Blade
1	Dust seal	○	○	○	○
2	Back-up ring	○	○	○	○
3	Rod packing	○	○	○	○
4	Buffer ring	○	○	○	—
5	O-ring	○	○	○	○
6	Head	○	○	○	○
7	Back-up ring	○	○	○	○
8	O-ring	○	○	○	○
9	Rod bush	○	○	○	○
10	Retaining ring	○	○	○	○
11	Cylinder-tube (Inside diameter)	Ø4.5 (Ø115)	Ø3.7 (Ø95)	Ø4.7 (Ø120)	Ø5.1 (Ø130)
12	Seal ring	○	—	○	—
13	Cushion plunger	○	—	○	—
14	Piston	○	○	○	○
15	Wear ring	○	○	○	○
16	Piston seal	○	○	○	○
17	Lock nut	M48×2	M48×2	M42×2	M52×2
18	Rod (Outside diameter)	Ø2.6 (Ø65)	Ø2.4 (Ø60)	Ø2.4 (Ø60)	Ø2.6 (Ø65)
19	Cushion plunger	—	—	○	—
20	Plate ring	—	—	○	—
21	Retaining ring	—	—	○	—

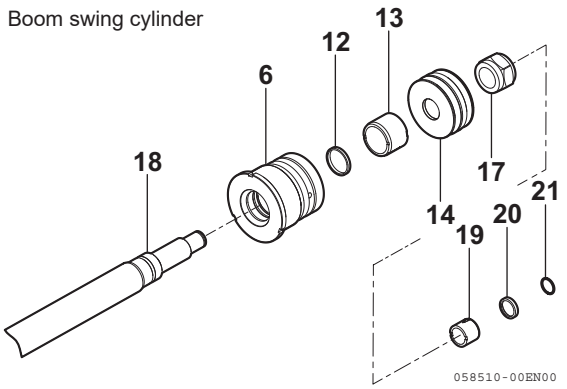
2) Cautions for Disassembly and Reassembly

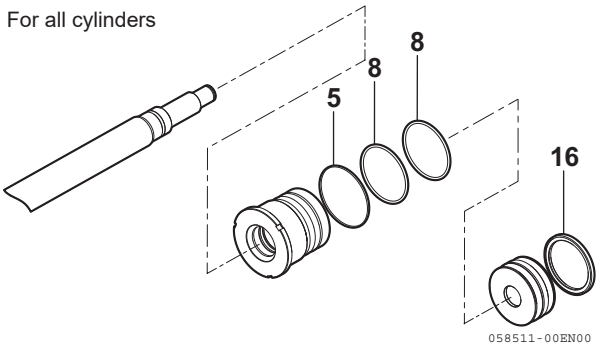
(1) Parts are produced so accurately. Be careful not to damage any parts by dropping them or knocking them together.
(2) If there are any burrs on the surface of the seal installation part or the O-ring groove, remove them.
(3) Never use the lock washer removed once.
(4) Replace once removed seals and O-rings with new ones.
(5) Clean all the parts and dry them by air blow.

3) Disassembly

Procedure	
(1) Drain the oil from the hydraulic cylinder. (2) Hold the cylinder in the bottom end or the pin hole on the bottom side, and put the rod side of the cylinder on a block. (3) Raise the pawl of lock washer **3** on head **6** to loosen head **6**. ***Note:*** *Use a hook wrench or a jig to loosen head **6**.*	
(4) Pull rod assembly **18** out of cylinder tube **10**, and then hold the cylinder rod assembly in the rod end or the pin hole on the rod side.	
(5) Disassembly of boom cylinder. Remove lock nut **17**, and then piston **14**, cushion plunger **13**, seal ring **12** and head **6** from rod **18** in order.	

Procedure	
(6) Disassembly of bucket and blade cylinder. Remove lock nut **17**, and then piston **14** and head **6** from rod 18 in order.	Bucket and blade cylinders 

(7) Disassembly of boom swing cylinder. [1] Remove retaining ring **21**, and then plate ring **20** and cushion plunger **19** in order. [2] Remove lock nut **17**, and then piston **14**, cushion plunger **13**, seal ring **12** and head **6** from rod **18** in order.	Boom swing cylinder 

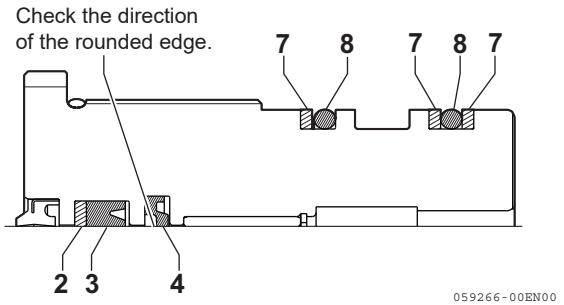
(8) Remove O-rings **5** and **8** and piston seal **16**.	For all cylinders 

4) Reassembly

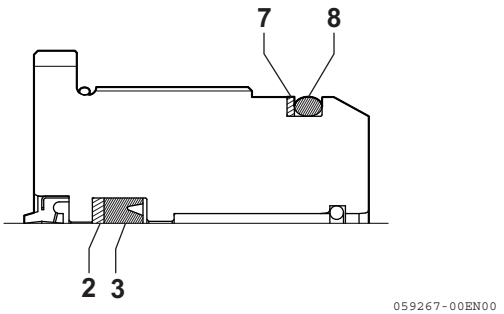
Reassemble the hydraulic cylinder in the reverse order of the disassembly procedure.

(1) Press-fit rod bush **9** into head **6** using a press or a similar tool.
(2) Install retaining ring **10** into head **6**.
(3) Install O-ring **5** onto head **6**.
(4) Install O-ring **8** and back-up ring **7** onto head **6**.
Notes:
*When installing O-ring **8** and back-up ring **7**, pay attention to their relative positions.*
(5) Install back-up ring **7**, O-ring **8** and back-up ring **7** in order onto head **6**. (For the boom and boom swing cylinders only.)
(6) Install buffer ring **4** into head **6**. (For the boom, swing and bucket cylinders only.)
Notes:
*Buffer ring **4** has a thin ring with one rounded edge. Make sure that the buffer ring is installed in the correct direction, paying attention to the rounded edge.*
(7) Install rod packing **3** and back-up ring **2** into head **6**. When installing rod packing **3**, pay attention to its correct installation direction.
(8) Drive dust seal **1** into head **6** with a hammer or similar tool.

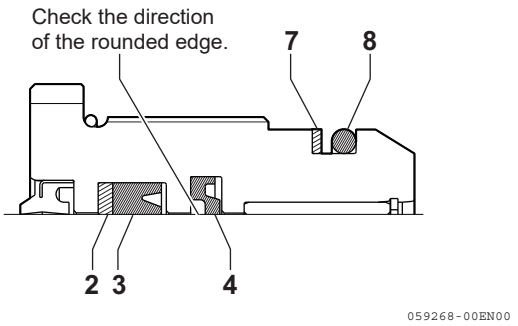
Boom cylinder
Boom swing cylinder



Blade cylinder



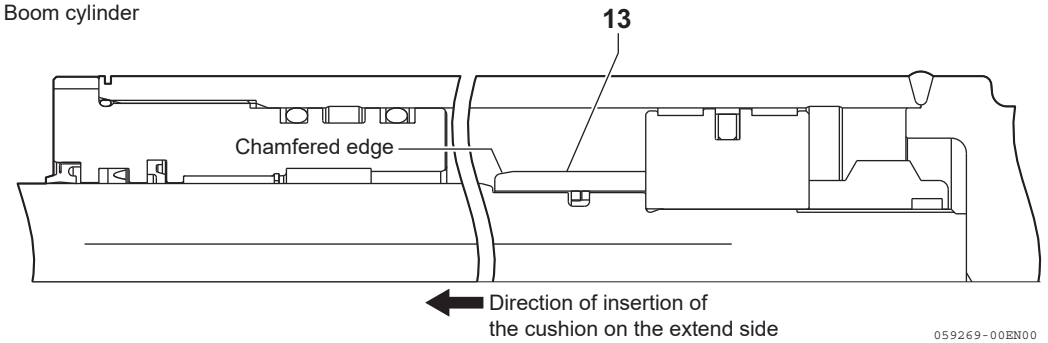
Bucket cylinder



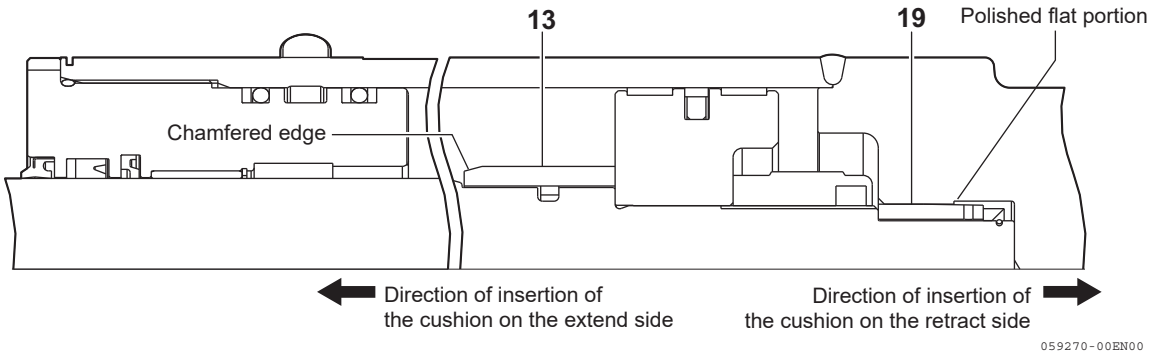
Notes:

- *Take care not to install cushion plunger **13** and **19** in the wrong direction.*
- *Replace O-rings, packings and seals with new ones.*

Boom cylinder



Boom swing cylinder



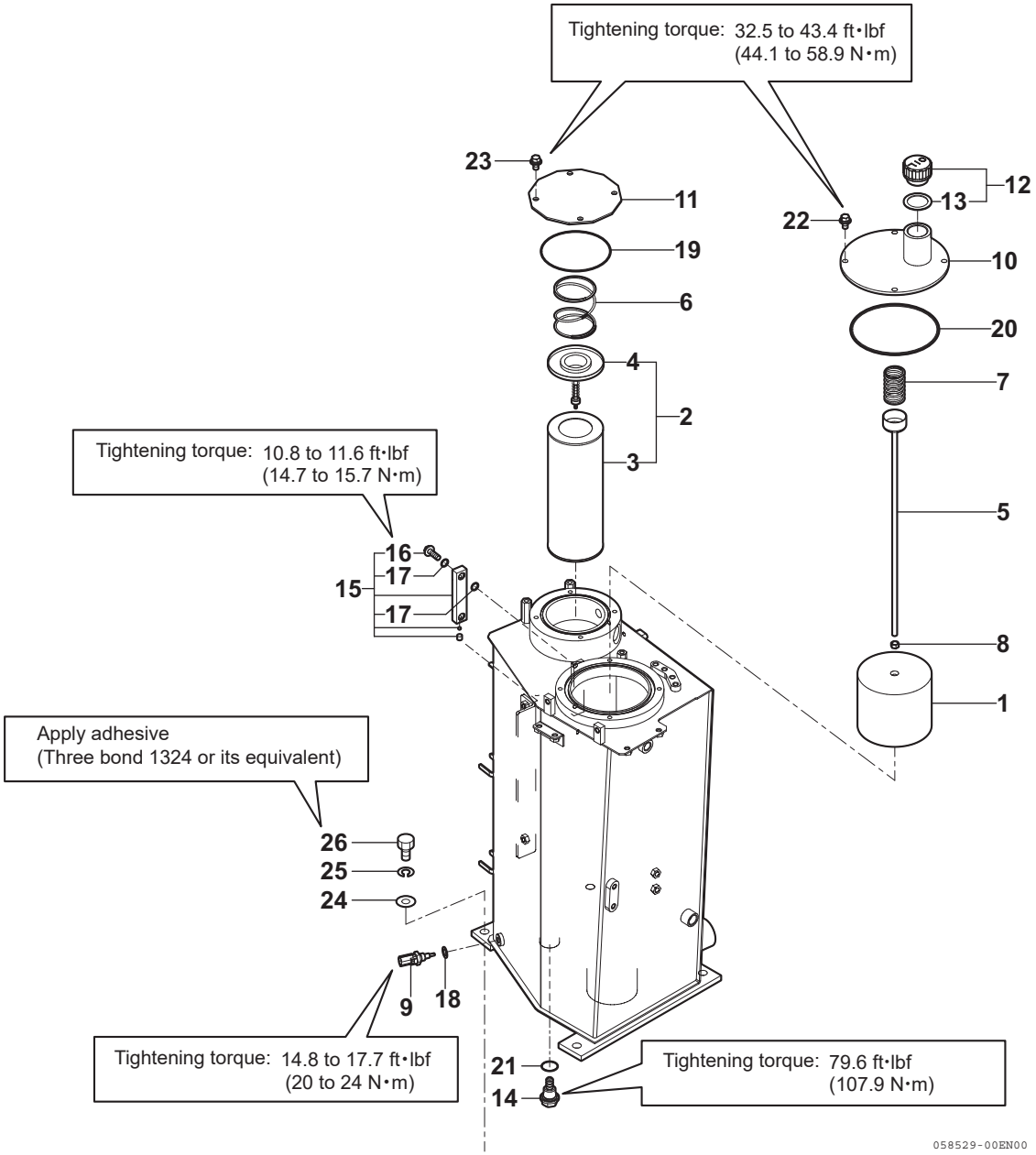
Tightening torque

Unit: ft•lbf (N•m)

Cylinder	Head tightening torque	Lock nut tightening torque
Boom	885 to 929 (1200 to 1260)	2036 to 2242 (2760 to 3040)
Bucket	738 to 774 (1000 to 1050)	2036 to 2242 (2760 to 3040)
Boom swing	1033 to 1048 (1400 to 1470)	1612 to 1781 (2185 to 2415)
Blade	1062 to 1106 (1440 to 1500)	2729 to 3024 (3700 to 4100)

7-5-17 Hydraulic Oil Tank

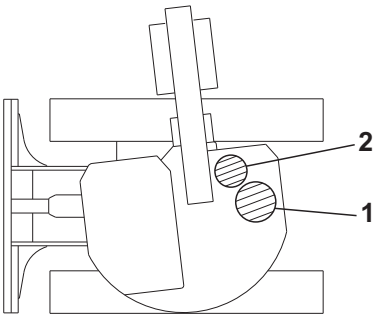
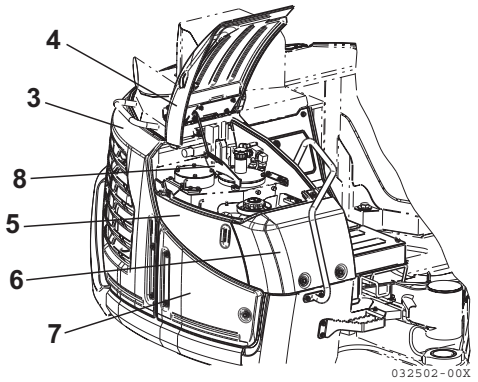
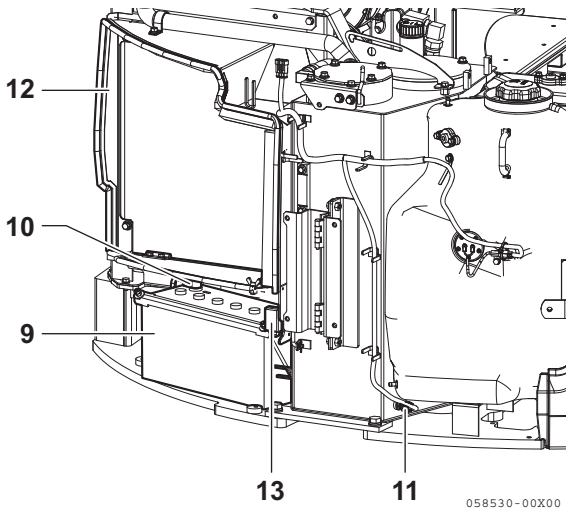
Component parts

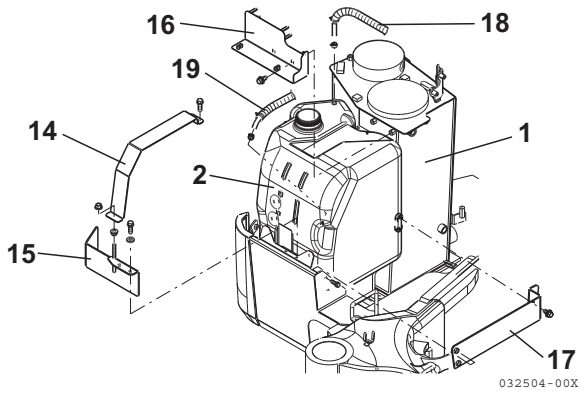


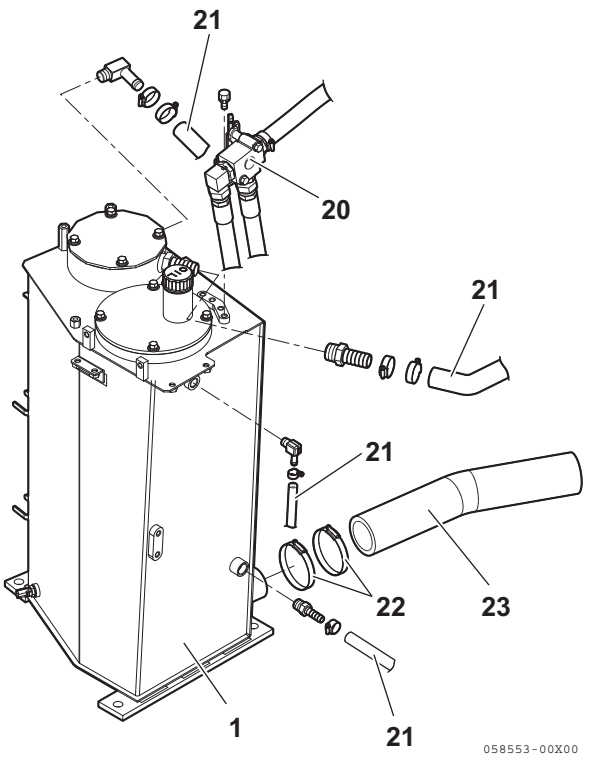
No.	Part	Q'ty	No.	Part	Q'ty	No.	Part	Q'ty
1	Suction filter	1	10	Cover	1	19	O-ring 1A G 135.0	1
2	Return filter	1	11	Tank cover	1	20	O-ring 1A G 170.0	1
3	Filter element	1	12	Oil supply port cap	1	21	O-ring 1A S 30.0	1
4	By-pass valve	1	13	Packing	1	22	Bolt M10×20	4
5	Filter rod	1	14	Drain plug	1	23	Bolt M10×20	4
6	Filter spring	1	15	Oil level gauge	1	24	Washer 16	4
7	Filter spring	1	16	Bolt M10	2	25	Spring washer 16	4
8	Nut M10	1	17	O-ring	4	26	Bolt M10×16	4
9	Temperature sensor	1	18	Seal washer	1			

Removal and Reinstallation of Hydraulic Oil Tank

1) Removal

Procedure	
(1) Swing the upperstructure so that drain plugs of the hydraulic oil tank **1** and the fuel tank **2** are positioned halfway between the right and left crawlers. Lower the bucket to the ground and stop the engine. (2) Drain the hydraulic oil from hydraulic oil tank and the fuel from fuel oil tank. Hydraulic oil tank Q'ty 15.8 Gals. (60 L) Fuel tank Q'ty 30.4 Gals. (115 L)	
(3) Open engine hood and remove bonnet R **3**, bonnet B upper **4**, bonnet B rear **5**, bonnet B front **6**, bonnet RF **7** and cover stay **8**.	
(4) Disconnect negative cable **10** and positive terminal from battery **9** and remove battery **9**. (5) Remove slow blow fuse **13** from radiator duct **12** and then remove radiator duct **12** from bracket. (6) Disconnect harness A from temperature sensor **11**.	

Procedure	
(7) Remove bracket UP **14**, bracket F **15**, grease gun bracket **16** and bracket L **17**, and disconnect fuel hoses **18** and **19** from fuel tank **2**. Then, remove the fuel tank **2**.	

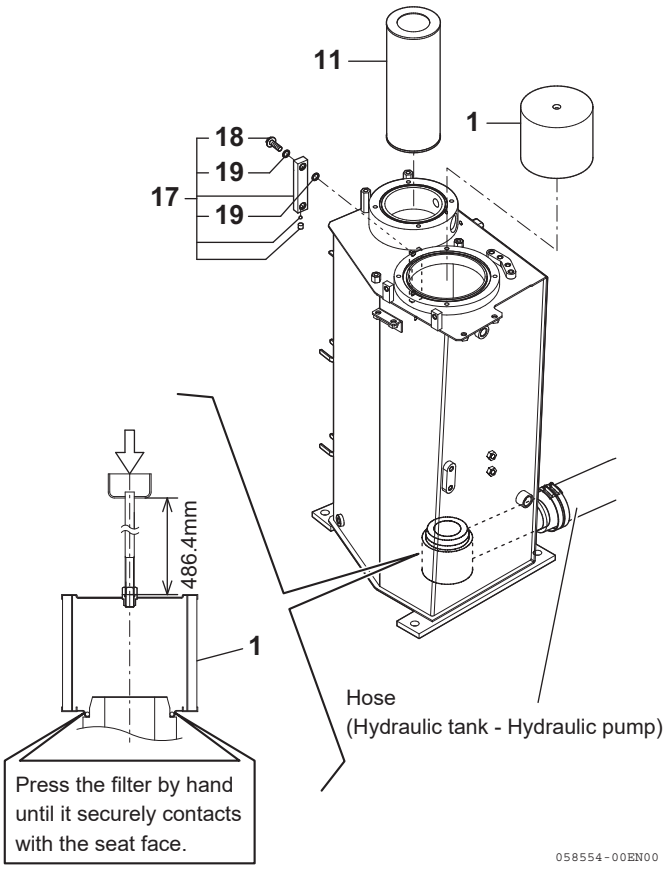
(8) Disconnect selector valve (with stay and hoses) **20** and hoses **21** from hydraulic oil tank **1**, and loosen suction hose bands **22**. Then remove hydraulic oil tank **1**. ***Note:*** *When disconnecting suction hose **23**, pull the suction hose to the fuel tank side while shaking the hydraulic oil tank.*	

2) Reinstallation

Reinstall the fuel tank and the hydraulic oil tank in the reverse order of the removal procedure.

Notes:

- *Completely drain the oil from the hydraulic oil tank and wipe the impurities off the bottom of the tank.*
- *Replace return filter **11** with a new one.*
- *Clean suction filter **1**. Replace it if the wire gauze is damaged.*
- *Replace the oil when it reaches the replacement time or it has been deteriorated. If reusing the oil, maintain the oil quality so that it has no impurities.*
- *Check packing **19** of oil level gauge **17** for oil leak, and replace any defective packing or other parts if necessary.*
- *Press in suction filter **1** until it securely contacts with the seat face of the suction port of the hydraulic oil tank.*

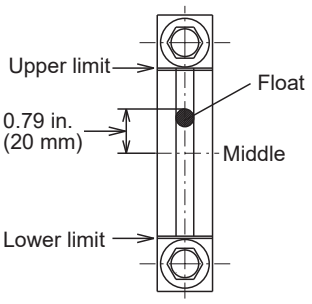


3) Oil Level Check

(1) Place the machine on a firm and flat ground when checking the hydraulic oil level.

(2) Check the hydraulic oil level with the oil level gauge when the oil temperature is 32 to 86 °F (0 to 30°C).

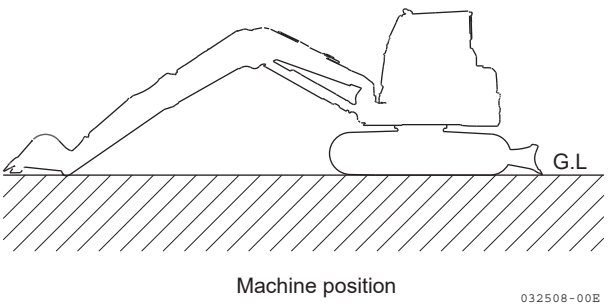
(3) The proper oil level is 0.79 in. (20 mm) above the middle of the oil level gauge. The hydraulic oil level increases or decreases depending on the hydraulic oil temperature due to its nature; therefore, check it when the oil is cooled.



4) Machine Position in Oil Level Check

(1) Retract the bucket and arm cylinder rods completely to lower the bucket to the ground.

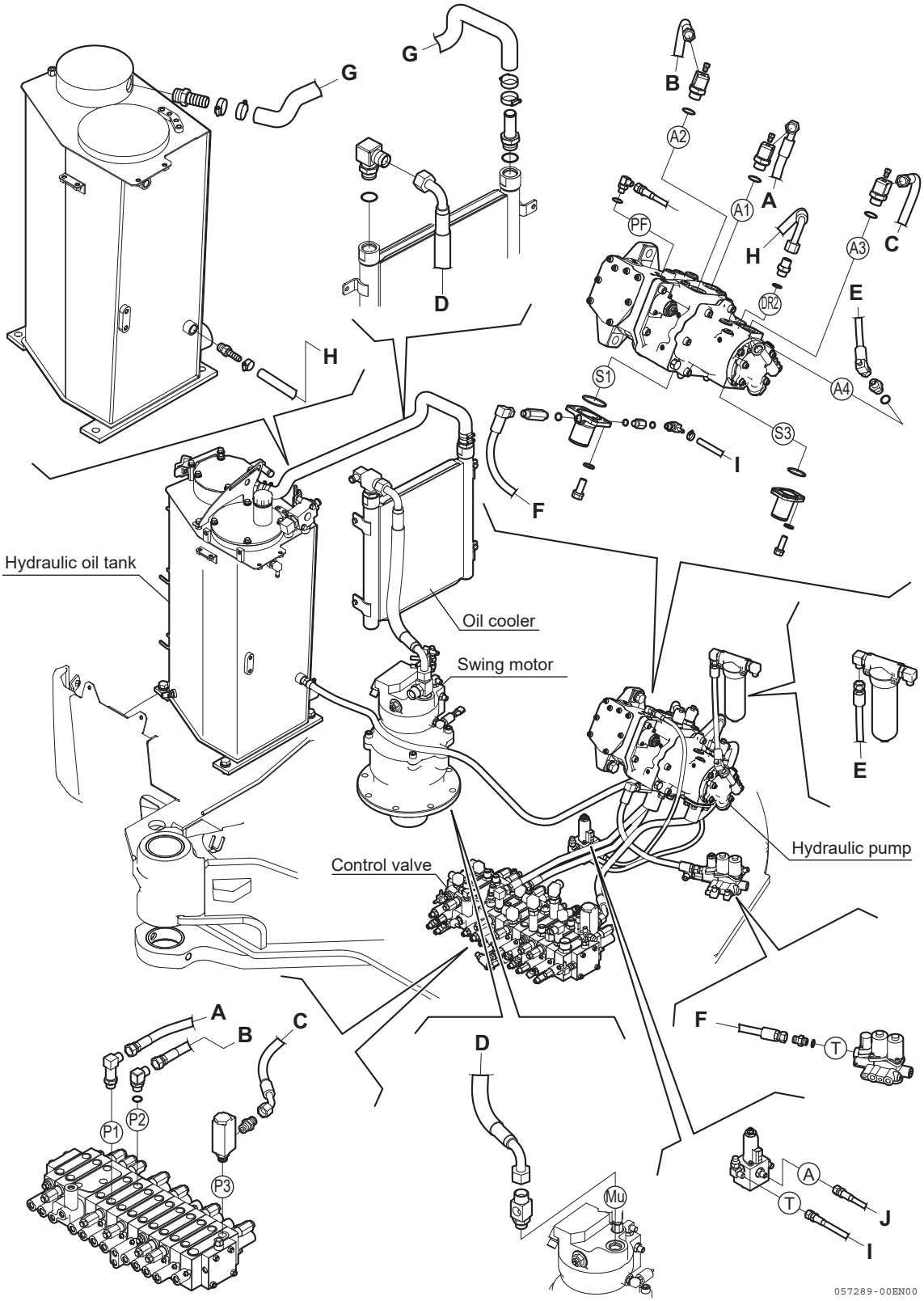
(2) Lower the blade to the ground.



7-5-18 Piping Layout

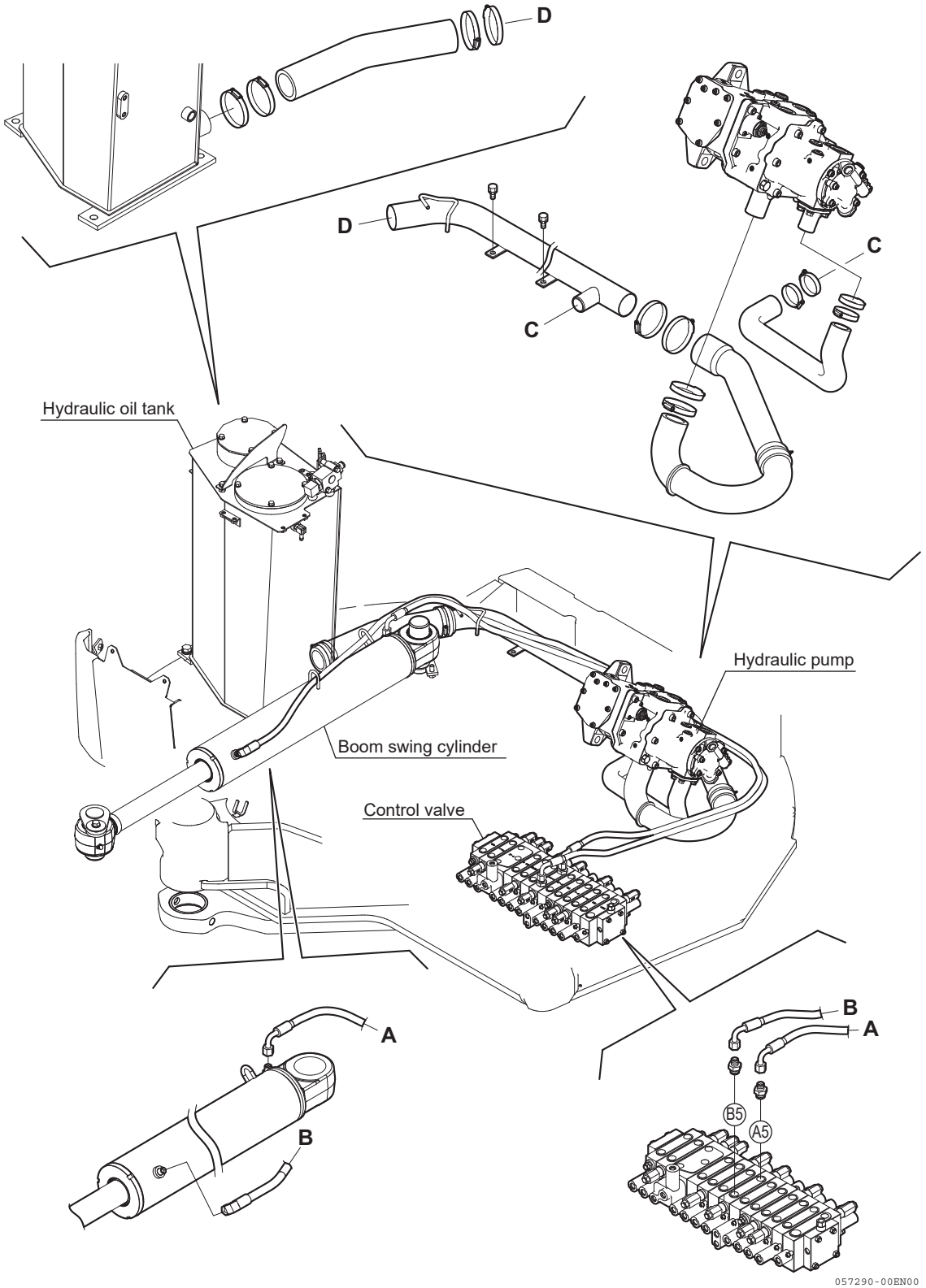
1) Upperstructure

- Hydraulic pump → control valve
- Swing motor → oil cooler → hydraulic oil tank



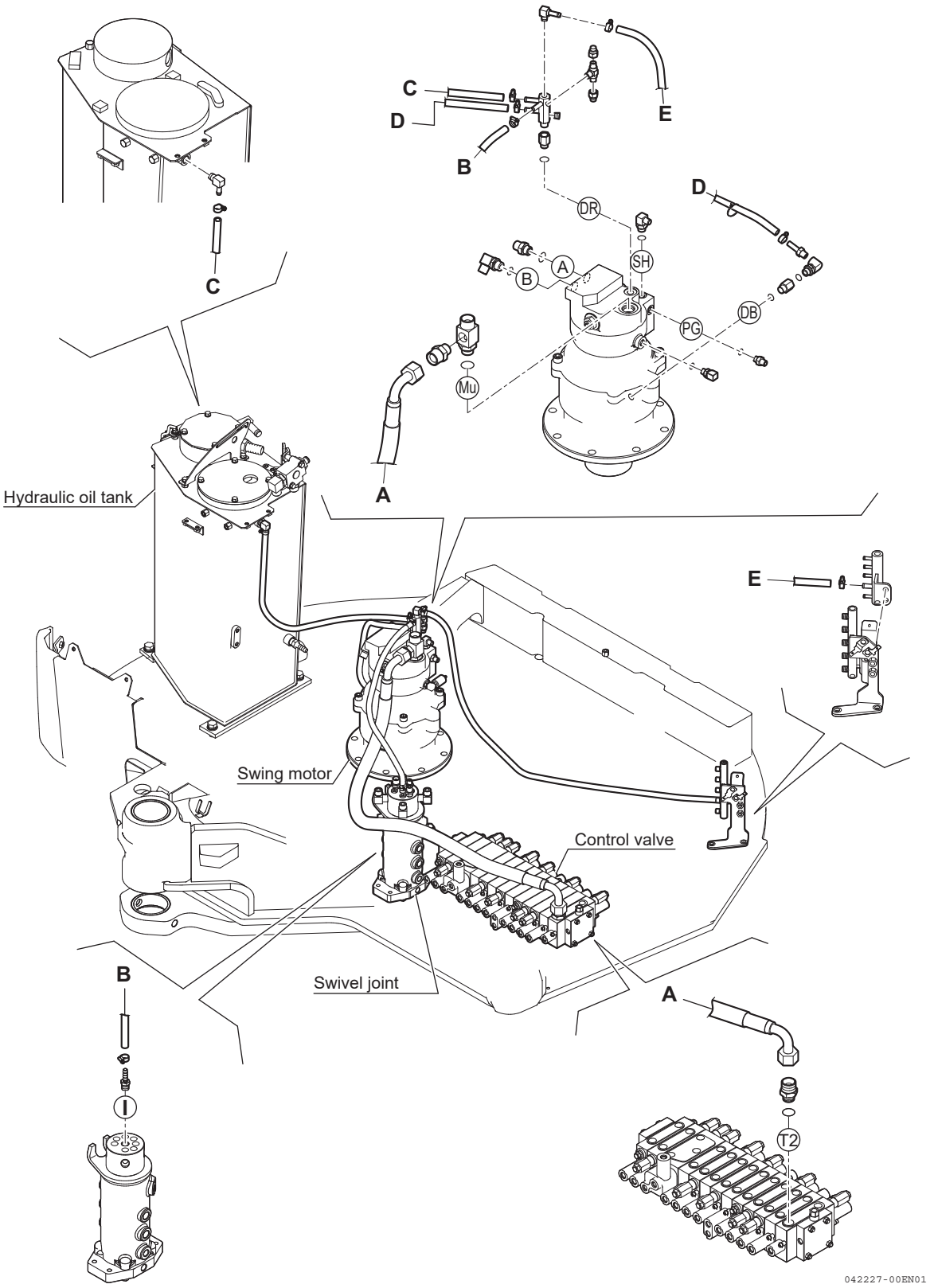
2) Upperstructure

- Hydraulic oil tank → hydraulic pump
- Control valve → boom swing cylinder



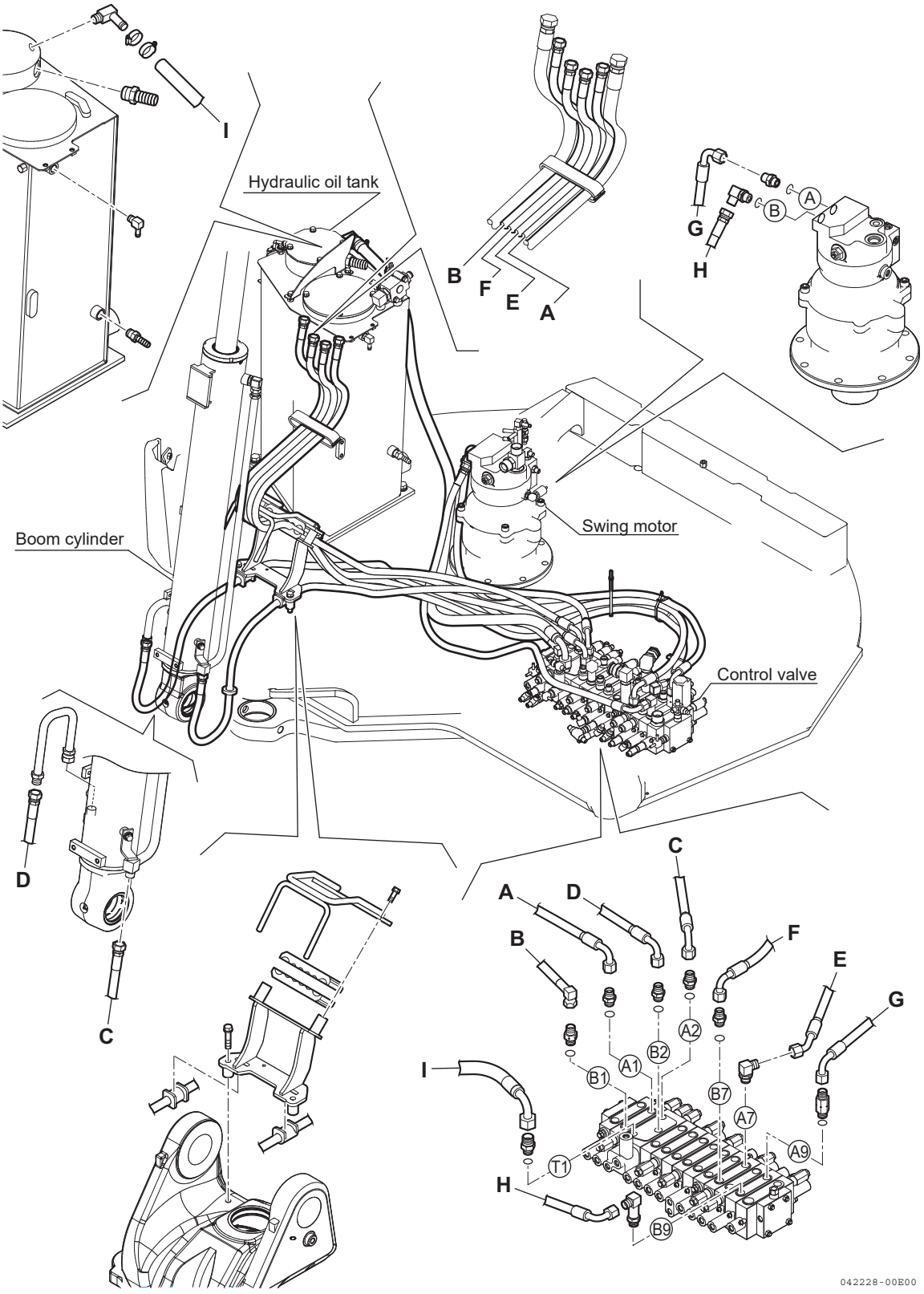
3) Upperstructure

• Control valve and swivel joint → swing motor → hydraulic oil tank



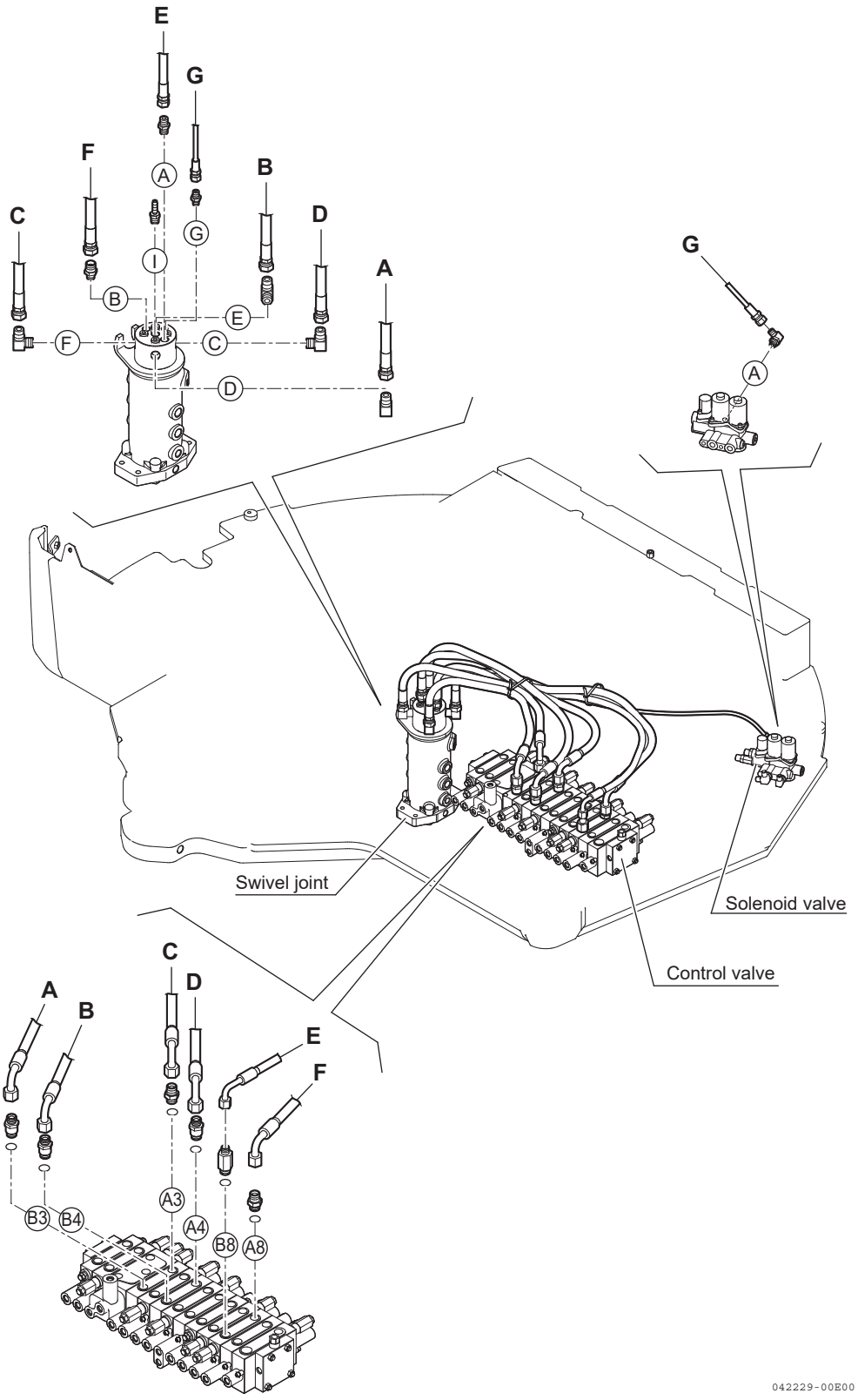
4) Upperstructure

- Control valve ←→ implement and swing motor
- Control valve → hydraulic oil tank



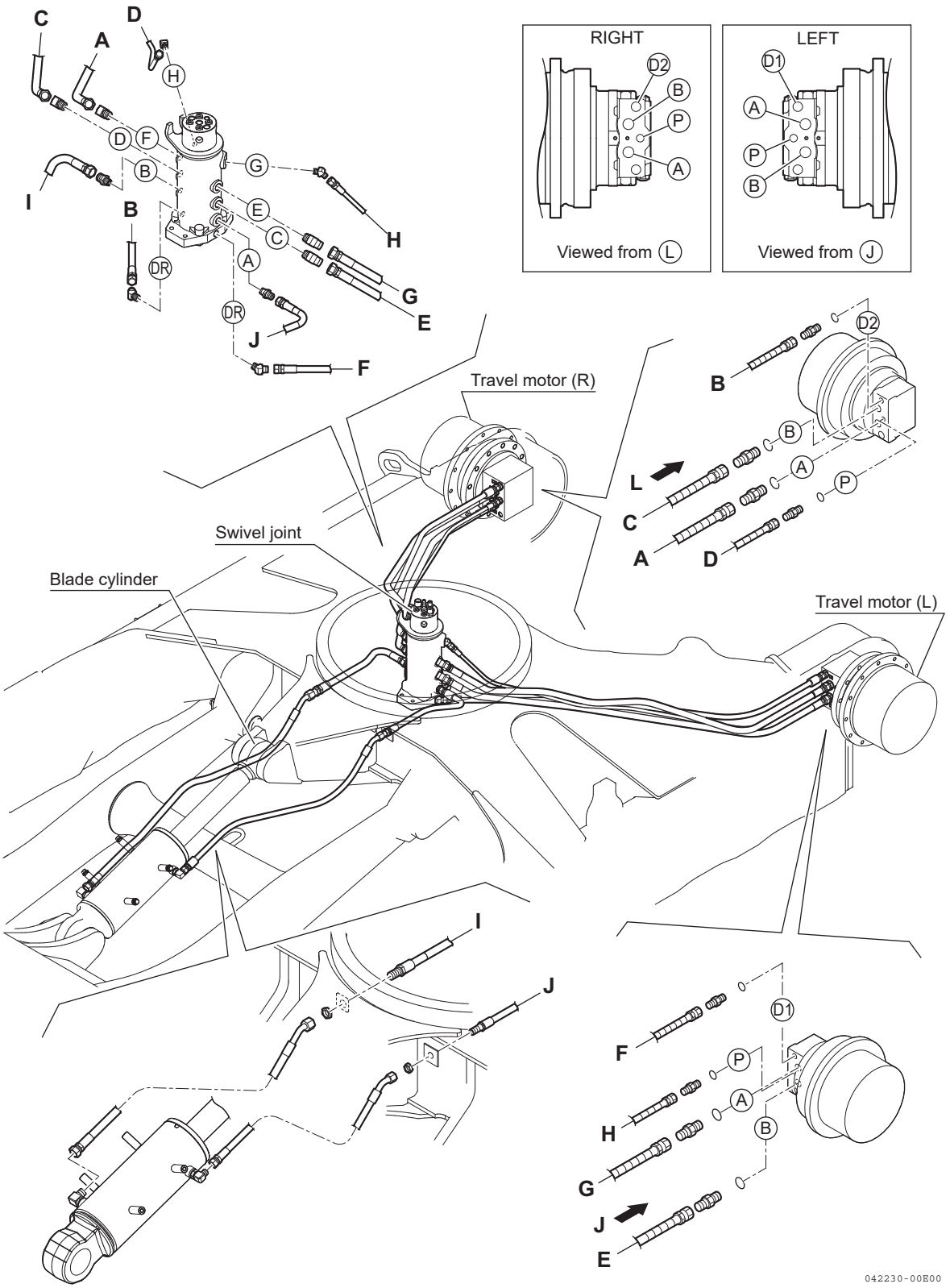
5) Upperstructure

- Control valve ←→ swivel joint
- Solenoid valve ←→ swivel joint



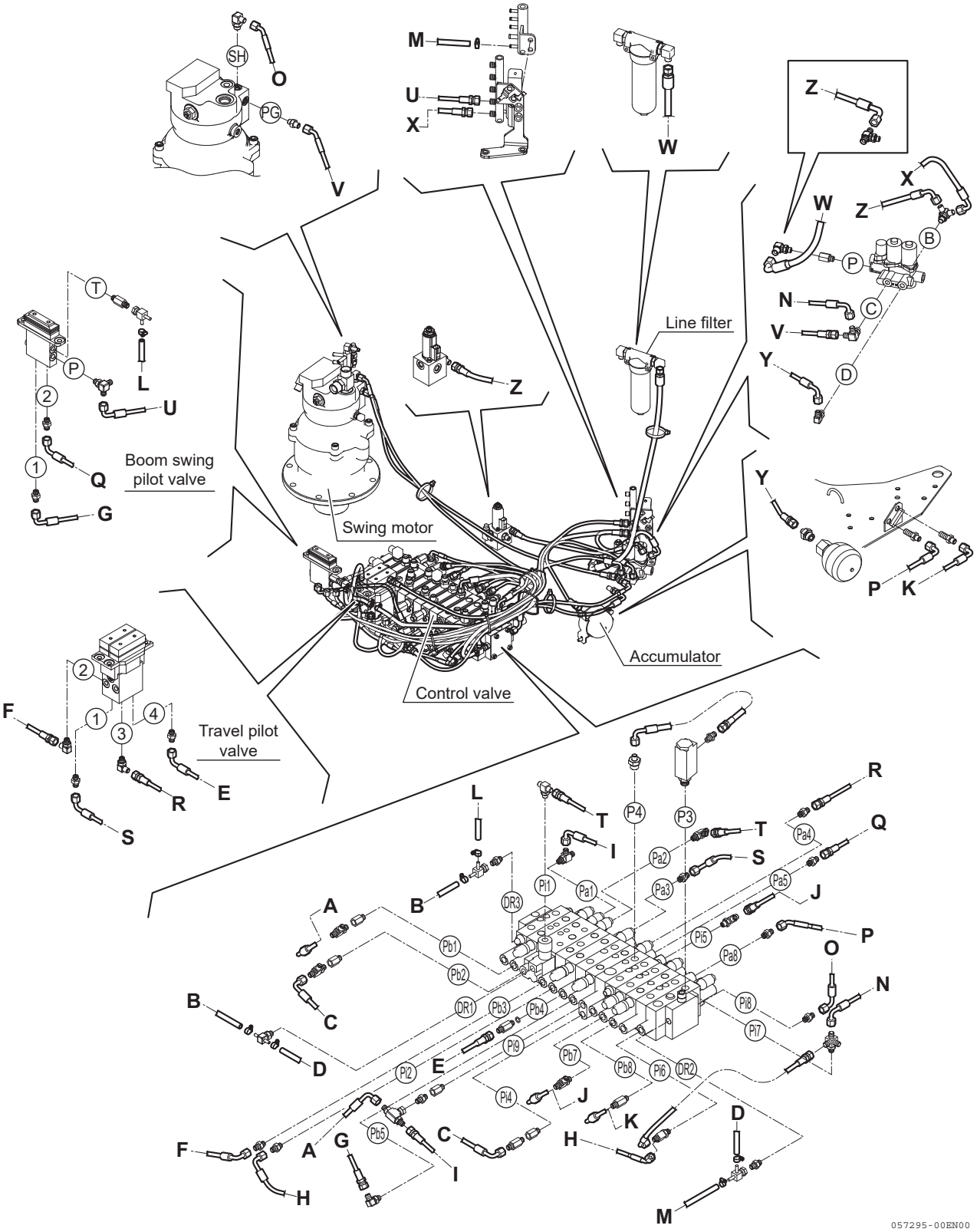
6) Undercarriage

• Swivel joint ←→ travel motor and blade cylinder



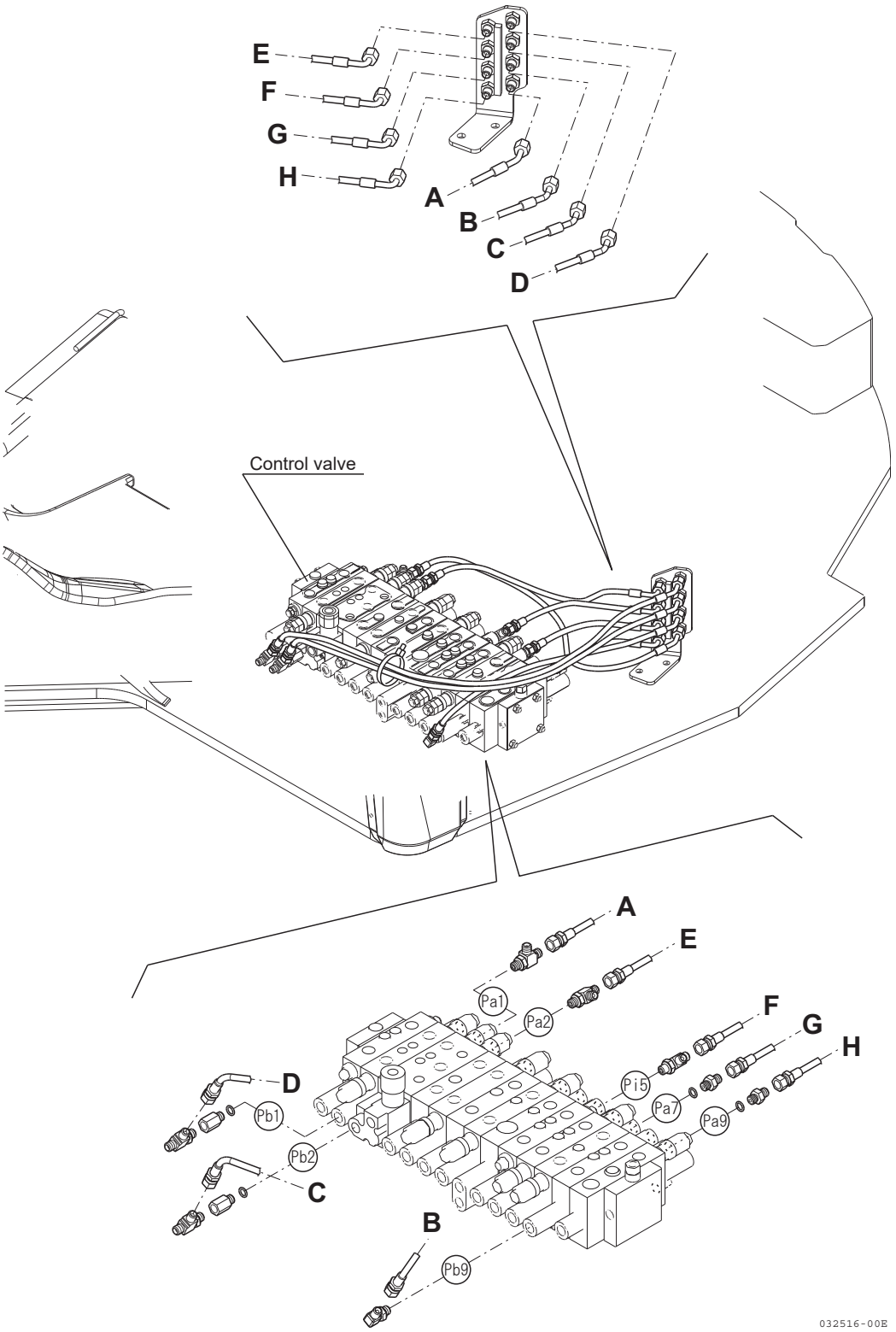
7) Pilot control

- Control valve ←→ solenoid valve, swing motor, boom swing pilot valve and travel pilot valve
- Control valve → accumulator and line filter



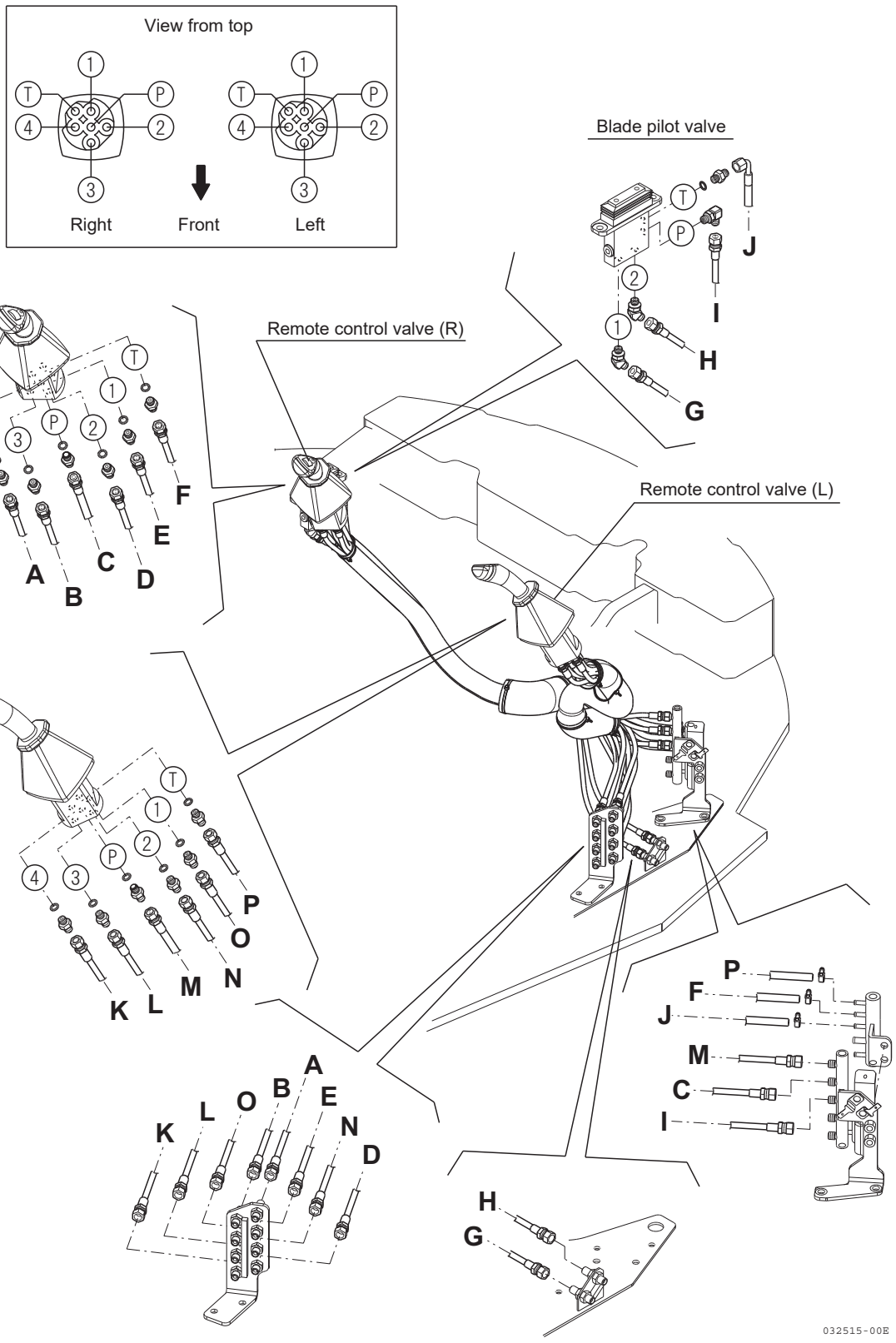
8) Pilot control

• Control valve ←→ pipe bracket



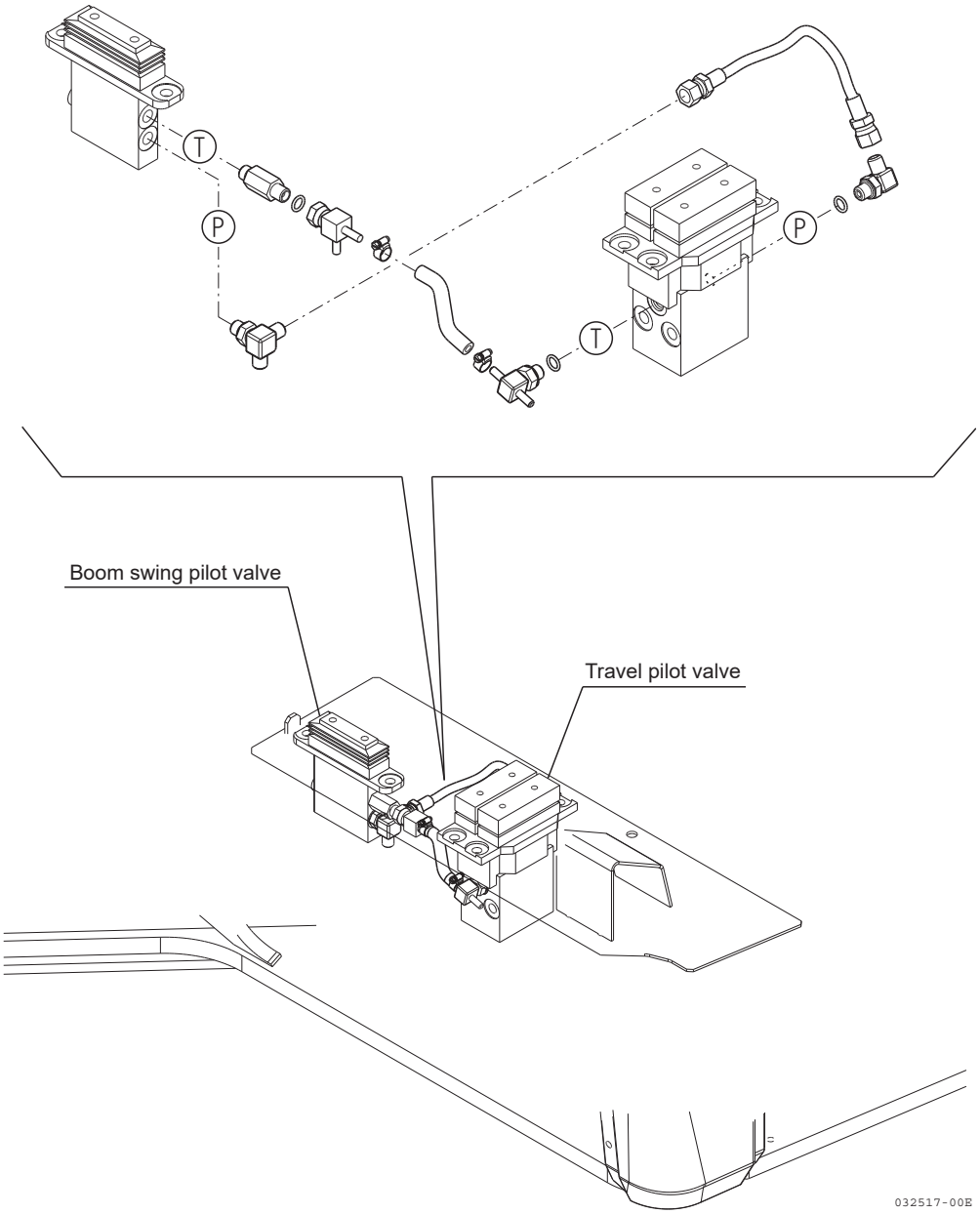
9) Pilot control

• Remote control valve and blade pilot valve ←→ pipe bracket



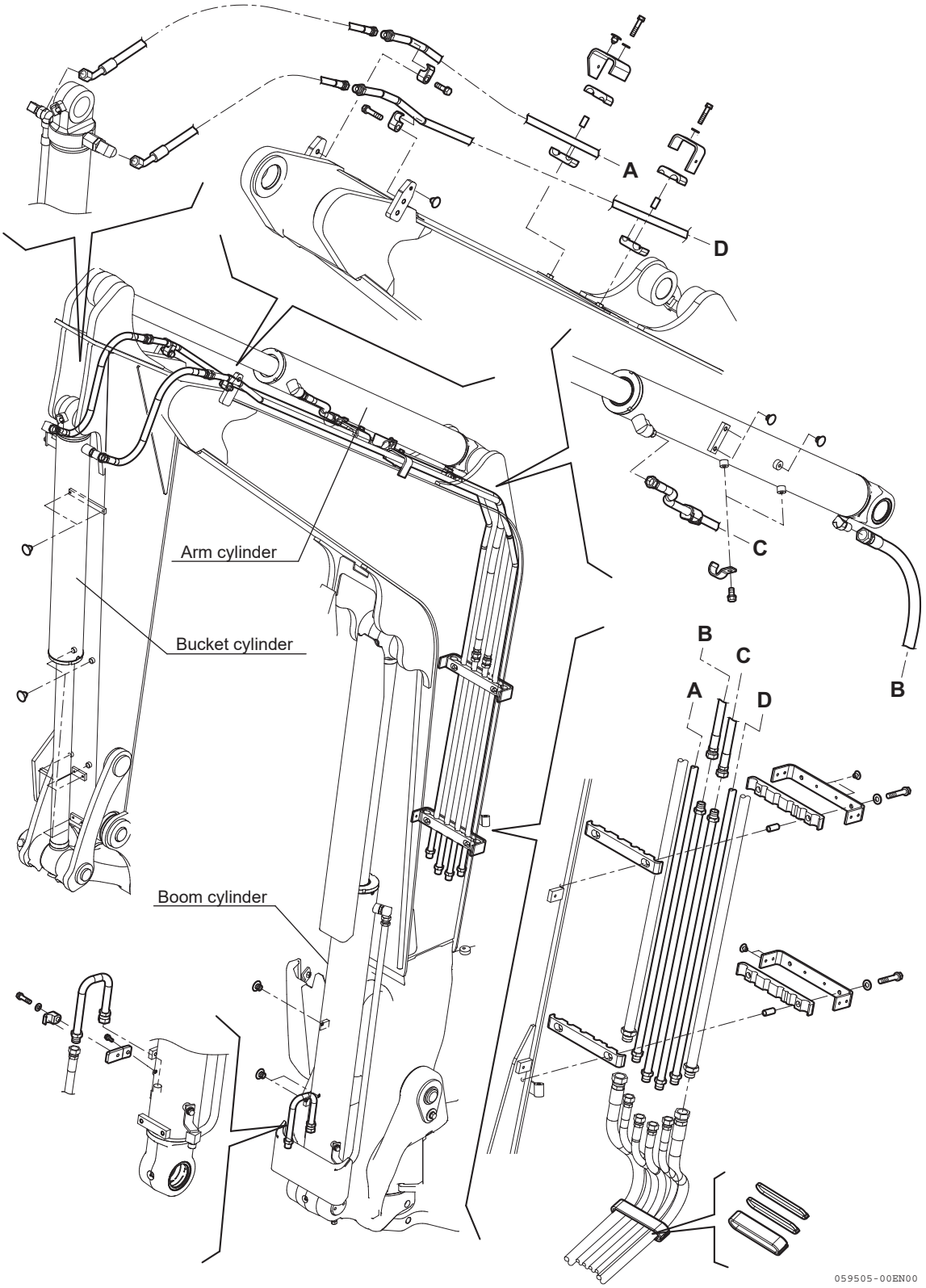
10) Pilot control

• Travel pilot valve ←→ boom swing pilot valve



11) Implement

• Hydraulic cylinders



7-6 Implement

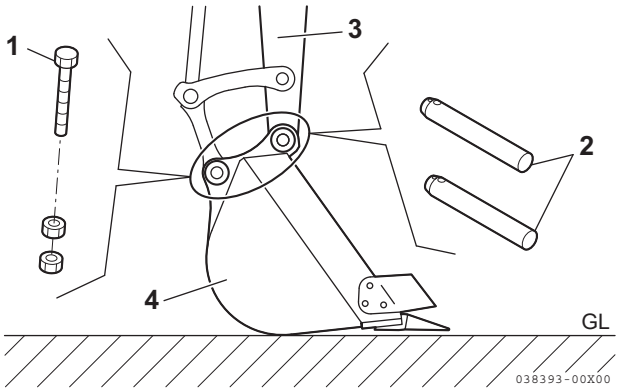
7-6-1 Removal and Reinstallation of Implement

1) Removal

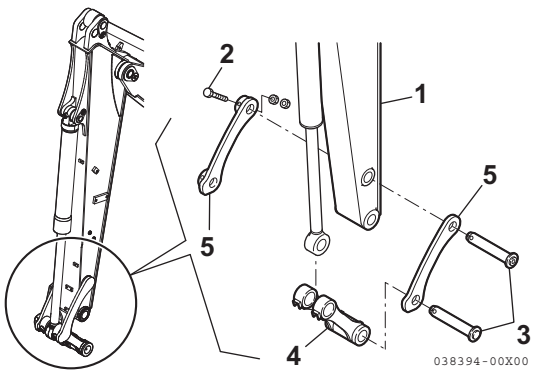
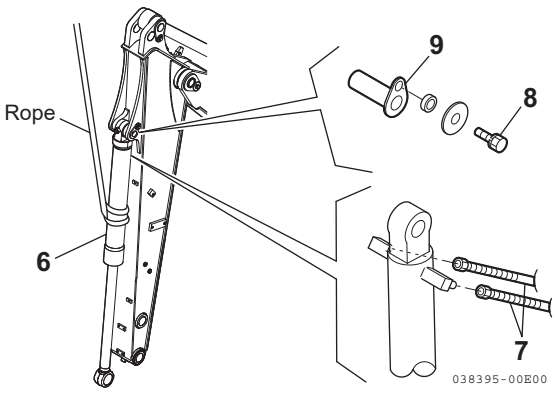
Notes:

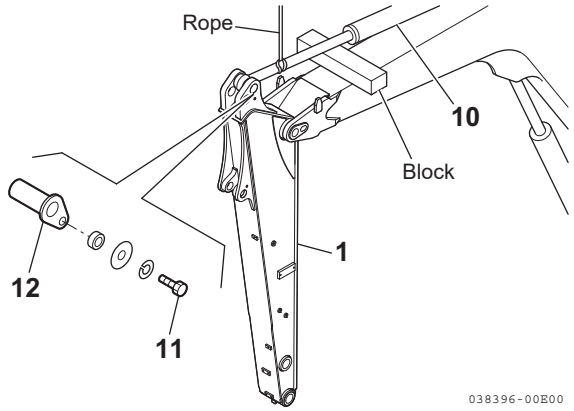
- *When removing the pin, check the number of shims installed and their positions.*
- *When removing the hose, put a plug into the hose connection port to keep the oil from flowing out.*

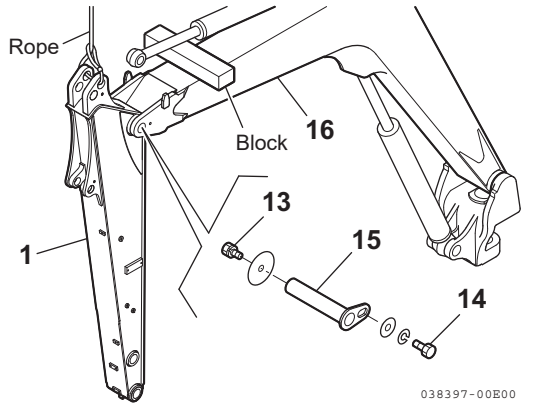
[Removal of bucket]

Procedure	
(1) Lower the bucket to the ground with its back side down and stop the engine. (2) Remove bolts **1** (M16) and pull out pins **2** to remove bucket **4** from arm **3**.	

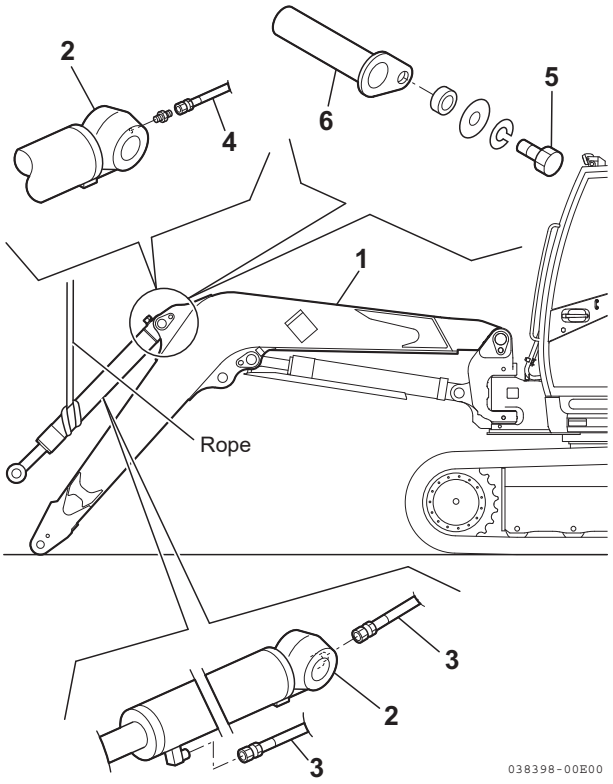
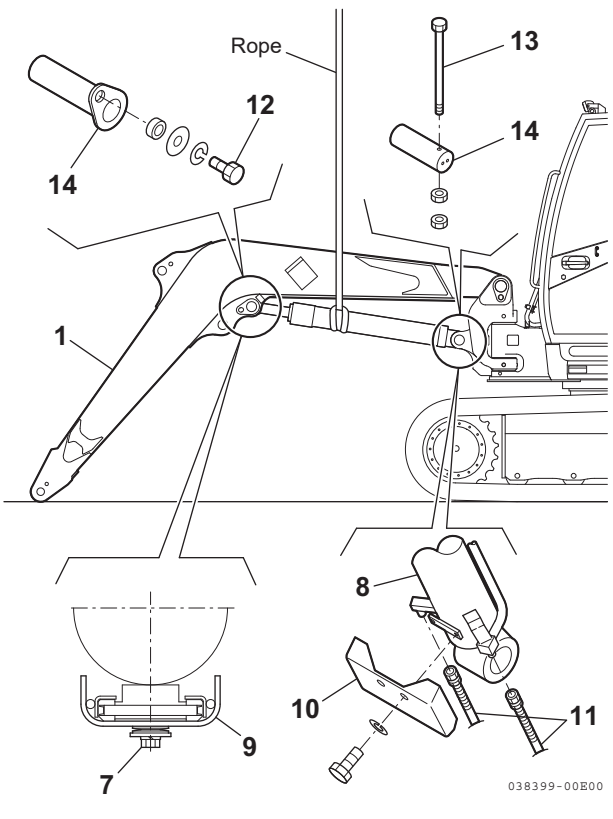
[Removal of arm]

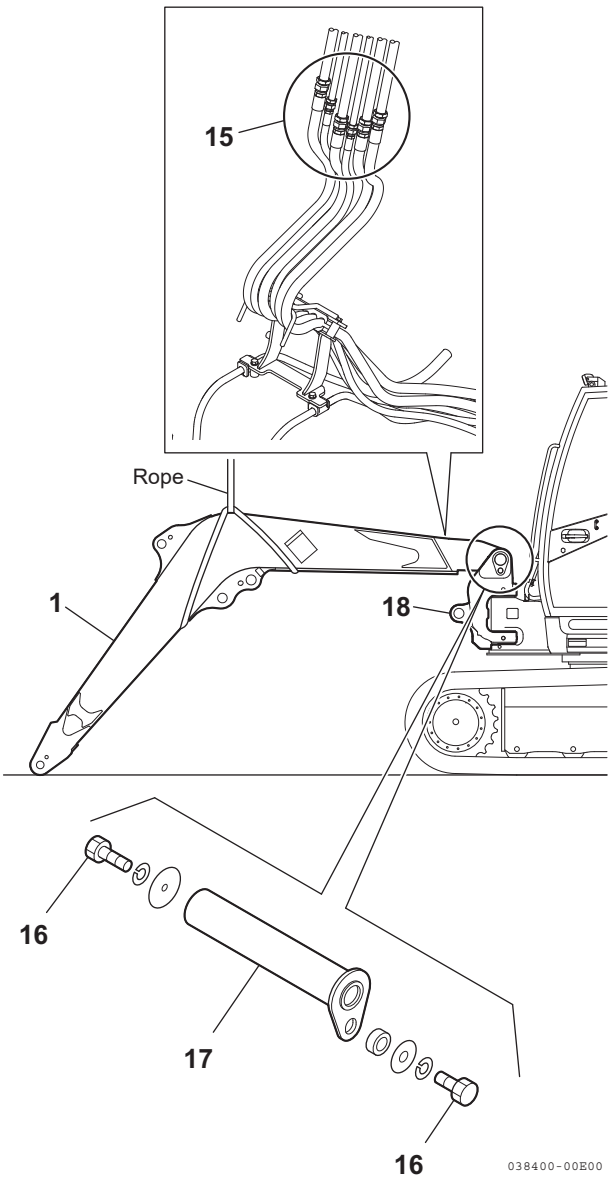
Procedure	
(1) Remove the bucket. (2) Adjust the angle of arm **1** so that it is perpendicular to the ground. Lightly place the top end of arm **1** on the ground and stop the engine. (3) Remove bolt **2** (M16) and pull out pins **3** to remove bucket link **4** and bucket arms **5**.	
(4) Remove hydraulic hoses **7** from bucket cylinder **6**. (5) Put rope round bucket cylinder **6**. Then remove bolt **8** (M12) and pull out pin **9**. (6) Lift up bucket cylinder **6** to remove it from arm **1**. ***Note:*** *Put a plug into the hose connection port of bucket cylinder **6** and the connection port of hydraulic hose **7**.*	

Procedure	
(7) Put rope onto arm cylinder **10**, and slightly lift it up. (8) Remove bolt **11** (M14) to pull out arm pin **12**. Start the engine and retract the arm cylinder rod to disconnect it from arm **1**. (9) Slacken the rope to put down arm cylinder **10** on the block.	

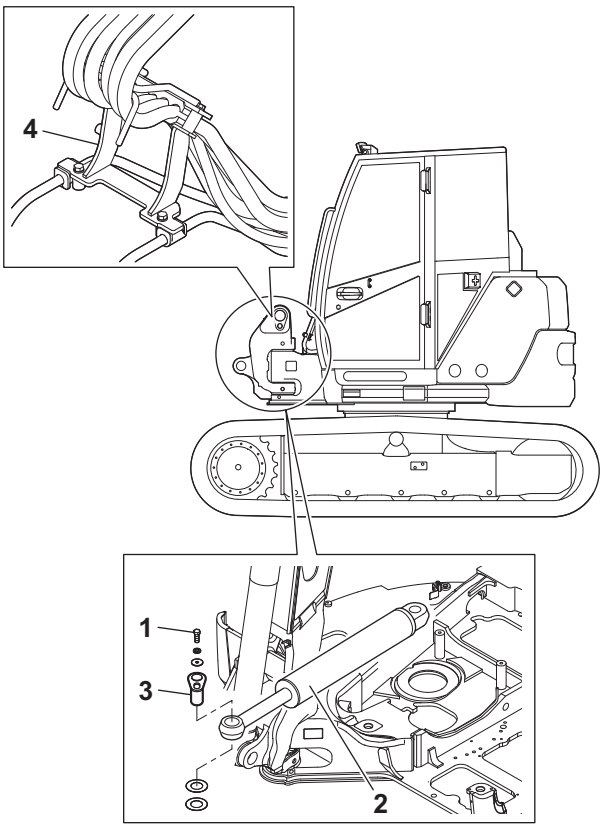
(10) After putting rope onto arm **1**, remove bolts (M14) **13** and (M14) **14** to pull out pin **15**. (11) Lift up arm **1** to remove it from boom **16**.	

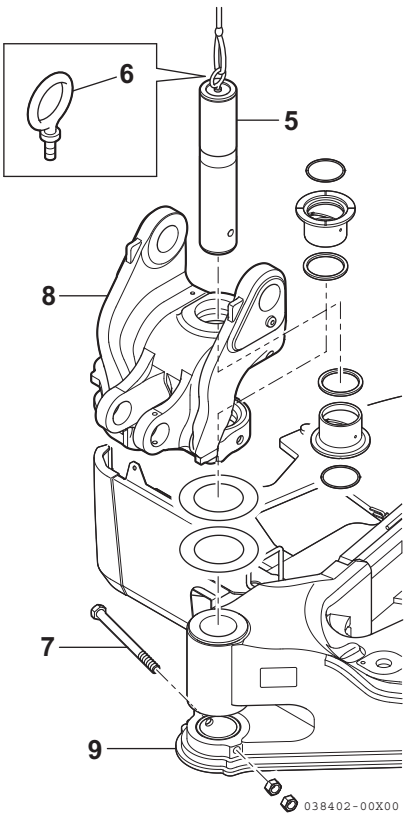
[Removal of boom]

Procedure	
(1) Lower boom **1** to place the top end of boom **1** on the ground. Then, put rope onto arm cylinder **2**. (2) Remove hydraulic hoses **3** from arm cylinder **2**. ***Note:*** *Put a plug into the hose connection port of arm cylinder **2** and the connection port of hydraulic hose **3**.* (3) Disconnect grease hose **4** from the fulcrum part of arm cylinder bottom **2**. (4) Remove bolt (M14) **5** to pull out pin **6**, and lift up arm cylinder **2** to remove it from boom **1**.	
(5) Remove bolt (M10) **7** to remove slide cover **9** from boom cylinder **8**. (6) After putting rope onto boom cylinder **8**, remove guard **10** to remove hydraulic hoses **11** from boom cylinder **8**. ***Note:*** *Put a plug into the hose connection port of boom cylinder **8** and the connection port of hydraulic hose **11**.* (7) Remove bolts (M14) **12** and (M12) **13** to pull out pins **14**, and lift up boom cylinder **8** to remove it from boom **1**.	

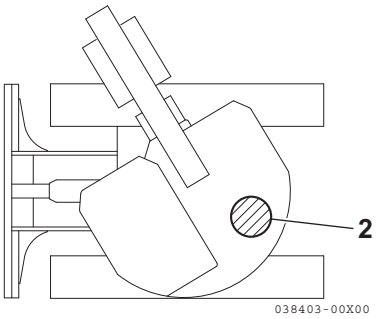
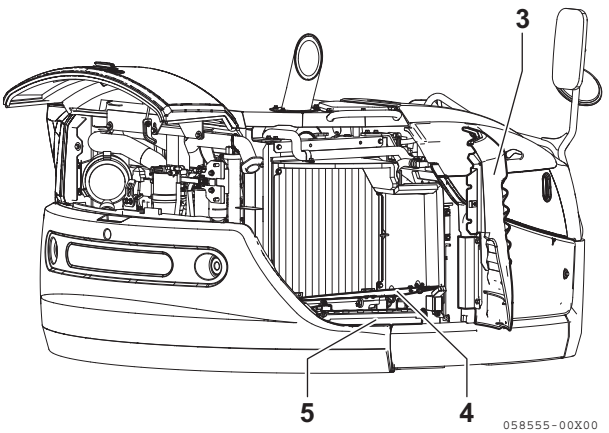
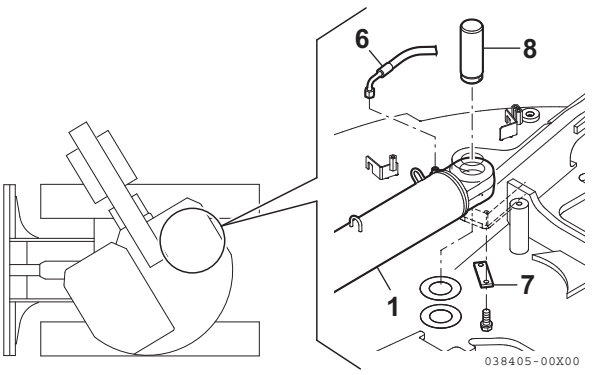
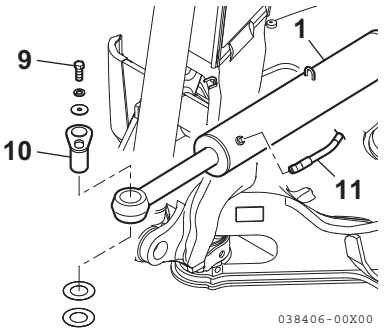
Procedure	
(8) After putting rope round boom **1**, disconnect hydraulic hoses (for arm and bucket cylinders) **15** from the piping tubes. ***Note:*** *Put a plug into the connection port of hydraulic hose **15** and the hose connection port of the piping tube.* (9) Remove bolts (M14) **16** to pull out pin **17**, and lift up boom **1** with the rope to remove it from boom bracket **18**.	

[Removal of boom bracket]

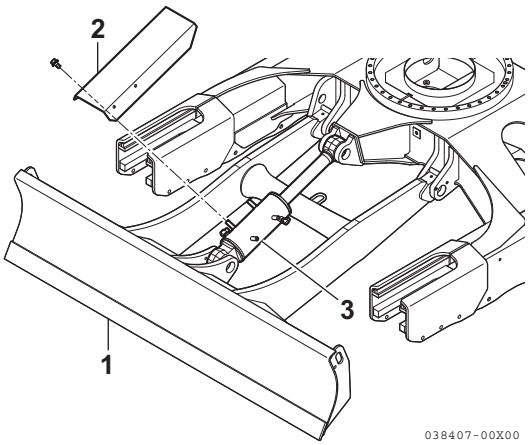
Procedure	
(1) Remove the bucket. Refer to "Removal of Bucket" in Section 7-6-1. (2) Remove the arm. Refer to "Removal of Arm" in Section 7-6-1. (3) Remove the boom. Refer to "Removal of Boom" in Section 7-6-1. (4) Remove bolt (M14) **1** to pull out pin **3** from the rod side of boom swing cylinder **2**. (5) Remove hose clamp **4**.	

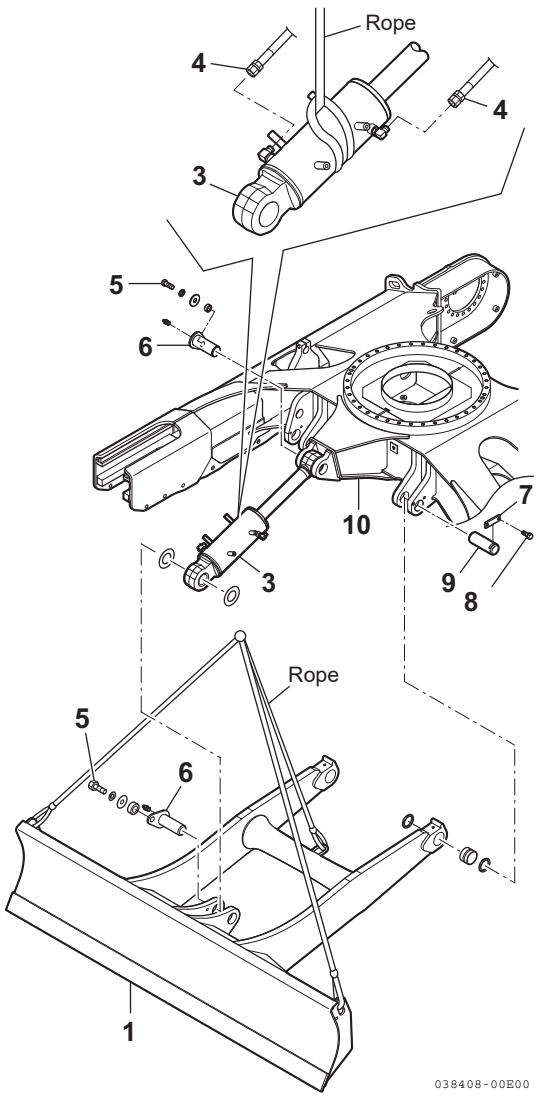
(6) Install eye bolt **6** into the tapped hole (M12) in pin **5** and put rope through eye bolt **6**. (7) Remove bolt (M18) **7** and lift up pin **5** to remove it from boom bracket **8**. (8) Lift up boom bracket **8** with rope to remove it from turning frame **9**.	

[Removal of boom swing cylinder]

Procedure	
(1) Swing the upperstructure so that bottom side **2** of boom swing cylinder **1** is positioned halfway between the right and left crawlers. Then, lower the bucket to the ground and stop the engine.	
(2) Open bonnet R **3** and duct cover **4**, and then remove battery **5**.	
(3) Disconnect hydraulic hose **6** from boom swing cylinder **1**. (4) Remove lock plate **7** from under the turning frame, and then pull out pin **8**.	
(5) Remove the bolt (M14) **9** to pull out pin **10**. (6) Slightly pull out boom swing cylinder **1**, and disconnect hydraulic hose **11**. (7) Remove boom swing cylinder **1**.	

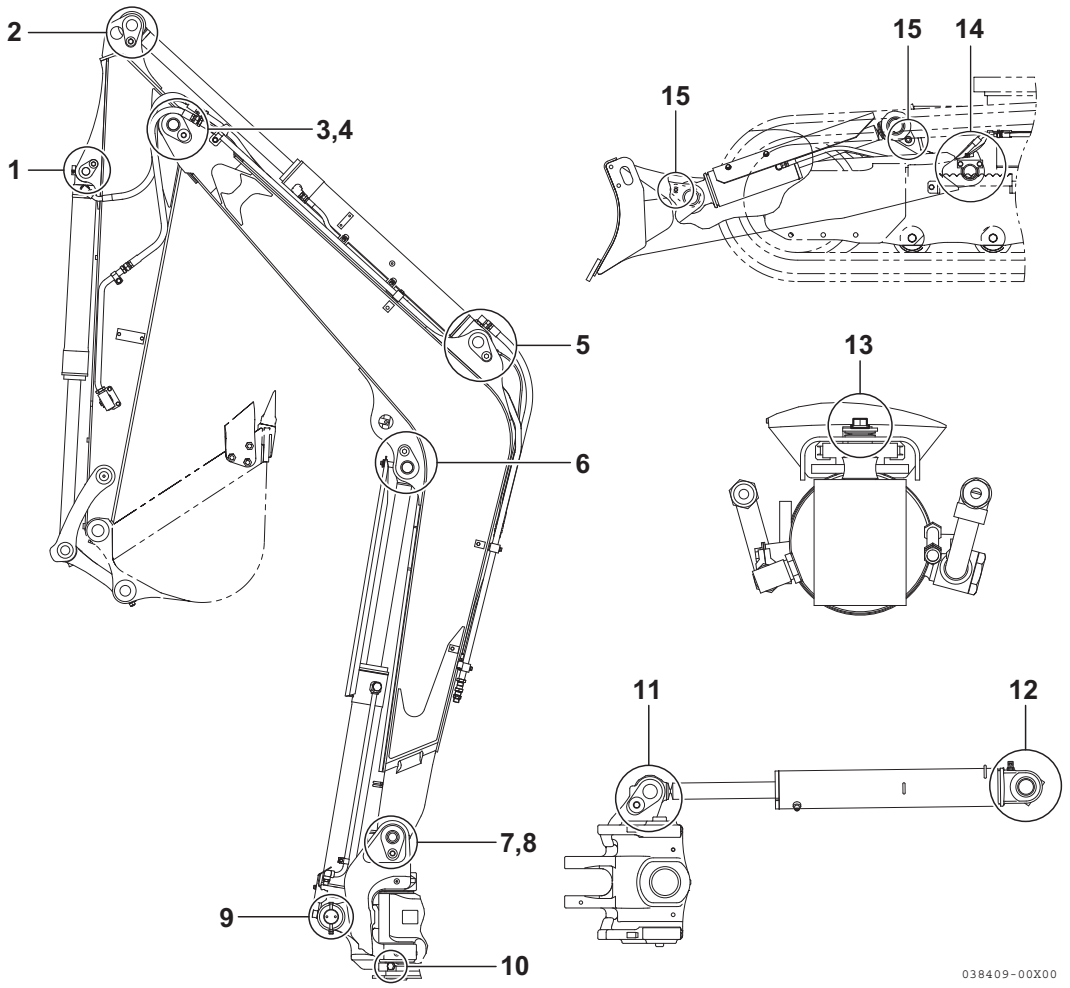
[Removal of blade]

Procedure	
(1) Turn the implement to the left, lower the bucket and blade **1** to the ground and stop the engine. (2) Remove cover **2** from blade cylinder **3**.	

(3) Disconnect hydraulic hoses **4** from blade cylinder **3**. ***Note:*** *Put a plug into the hose connection ports of blade cylinder **3** and the connection ports of hydraulic hoses **4**.* (4) After putting rope onto blade cylinder **3**, remove bolts (M14) **5** to pull out pins **6** and lift up blade cylinder to remove it. (5) After putting ropes onto blade **1**, remove bolts (M12) **8** from lock plates **7** to pull out pins **9** and lift up blade **1** to remove it from track frame **10**.	

2) Reinstallation

Reinstall the implement in the reverse order of the removal procedure.



Notes:

- *Adjust the clearance in the installation area of each fulcrum pin with shims so that it is 0.039 in. (1 mm) or less.*
- *To prevent damage to the pins and the bushes, apply heavy-duty grease to the holes and the pins before installation.*
- *Be sure to install the O-rings when installing the bucket.*
- *After installation, supply multipurpose grease No.2 or its equivalent.*

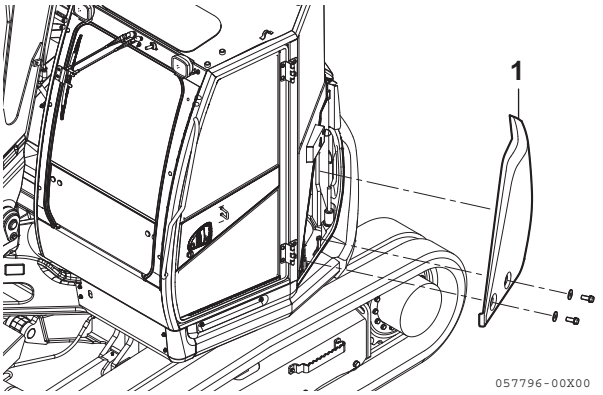
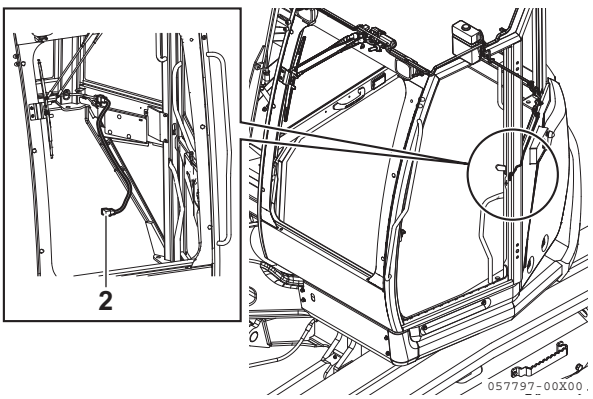
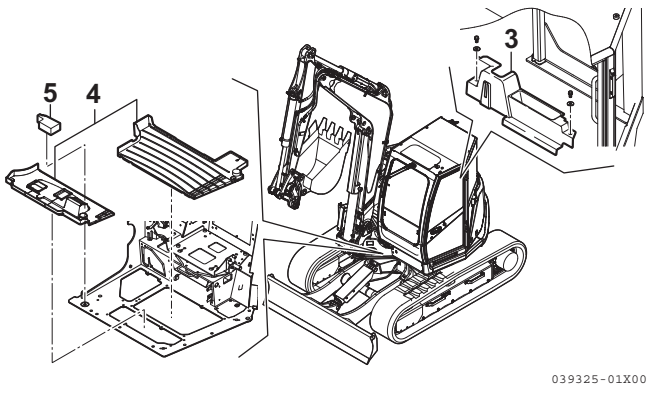
Tightening Torque and Adhesive

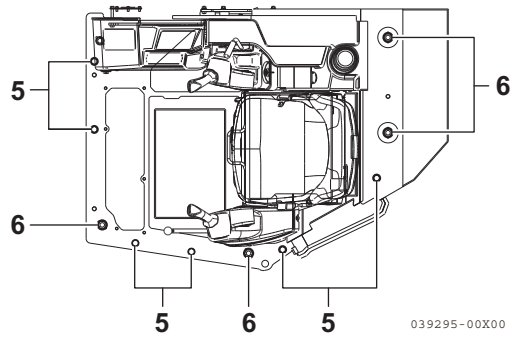
Size	Applicable Part	Tightening Torque	Adhesive
M10	13	32.6 to 43.4 ft•lbf (44.1 to 58.8 N•m)	—
M12	1, 12, 14	57.9 to 72.3 ft•lbf (78.5 to 98.1 N•m)	Apply Three Bond 1324 or its equivalent.
M14	2, 3, 4, 5, 6, 7, 8, 11, 15	86.8 to 108.5 ft•lbf (117.7 to 147.1 N•m)	
M12	9	—	—
M18	10	—	—

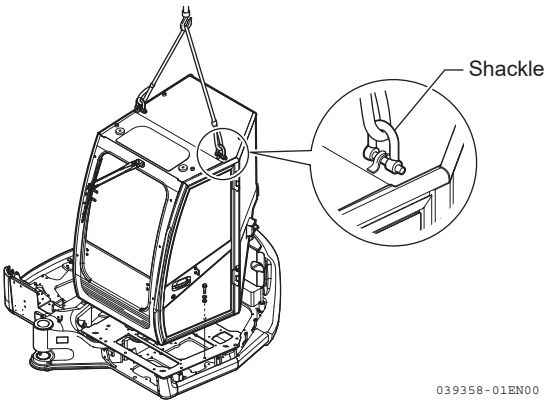
7-7 Cabin

7-7-1 Removal and Reinstallation of Cabin

1) Removal

Procedure	
(1) Remove cover L **1**.	
(2) Disconnect coupler **2** of cabin harness from the harness B.	
(3) Remove washer tank cover **3**, floor mats **4** and sponge **5**.	

Procedure	
(4) Remove mounting bolts (6 pcs.) **5** and nuts (8 pcs.) **6**.	

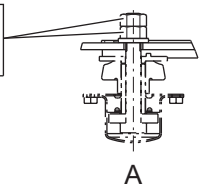
(5) Install shackles to the hooks on the cabin roof and lift the cabin up with rope. ***Notes:*** • *Be sure to close the cabin door before lifting the cabin up.* • *Take care that the cabin does not contact with other parts when lifting it up.*	

2) Reinstallation

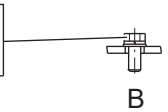
Reinstall the cabin in the reverse order to the removal procedure.

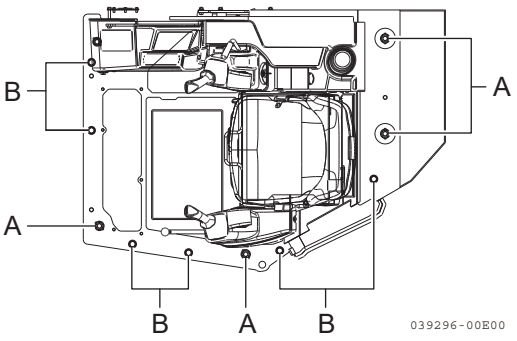
• Tighten mounting bolts and nuts for cabin by specified torque.

Tightening torque	195 to 217 ft•lbf (265 to 294 N•m)



Tightening torque	123 to 152 ft•lbf (167 to 206 N•m)

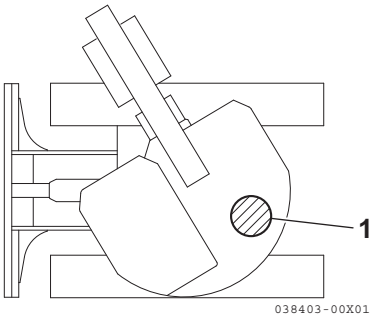


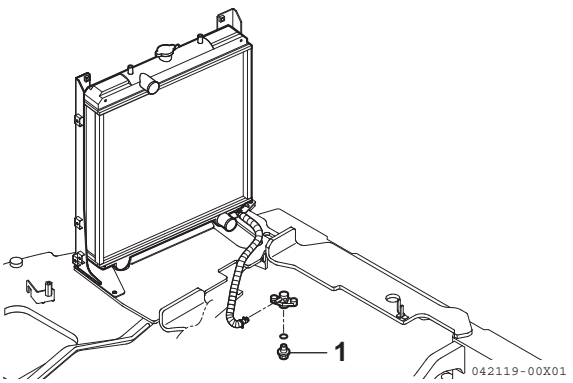


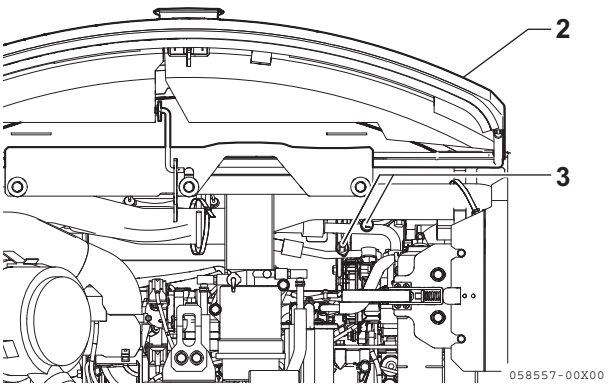
7-8 Air Conditioner

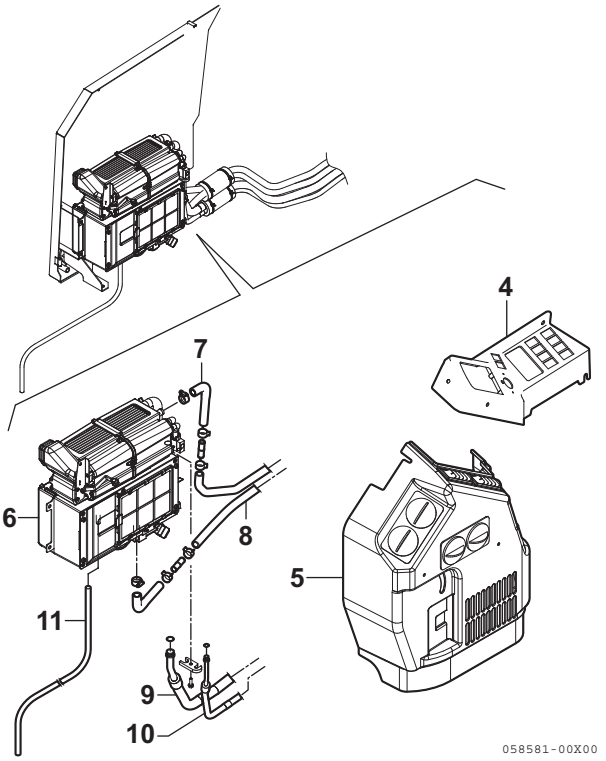
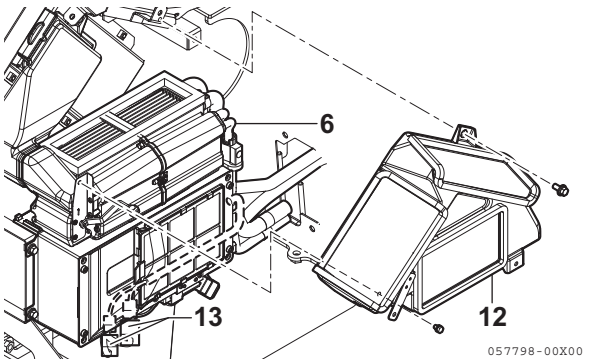
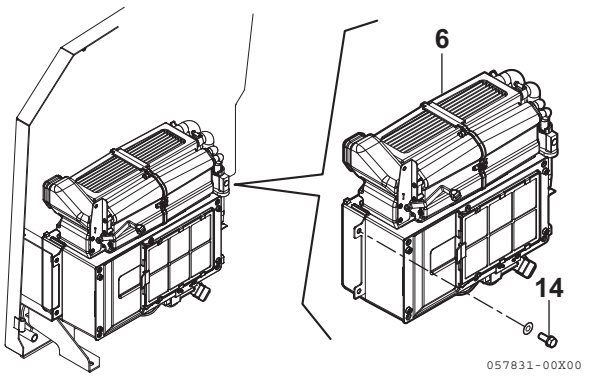
7-8-1 Removal and Reinstallation of Air Conditioner

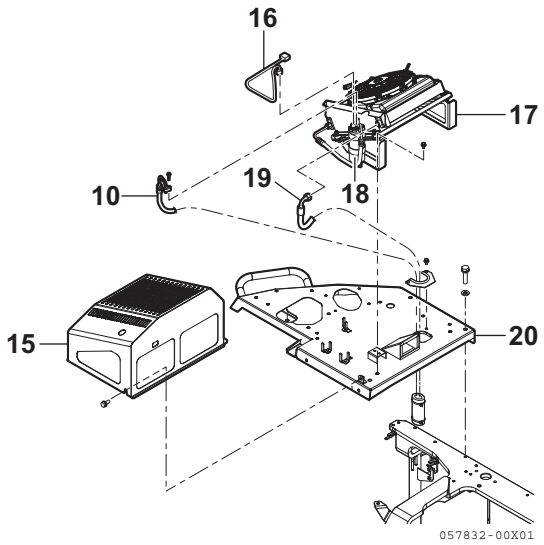
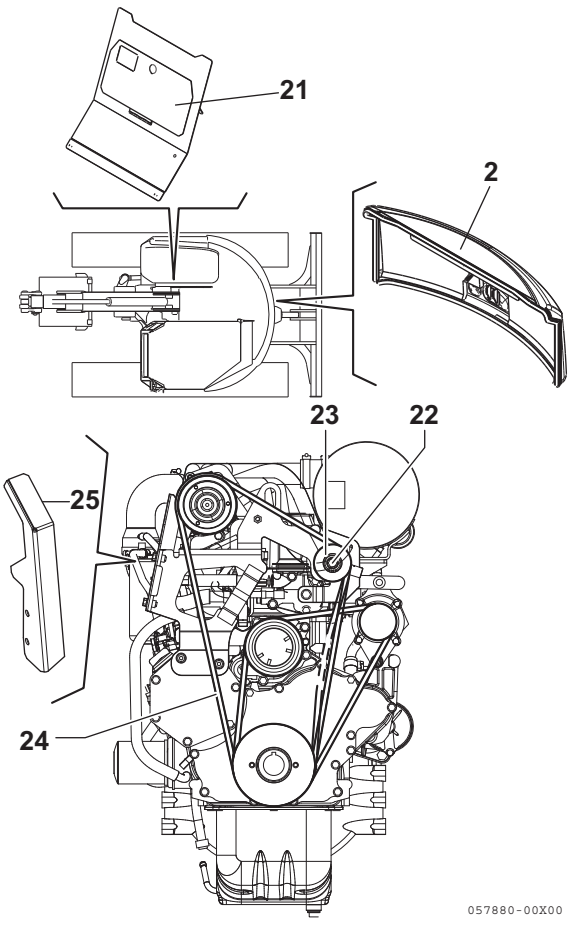
1) Removal

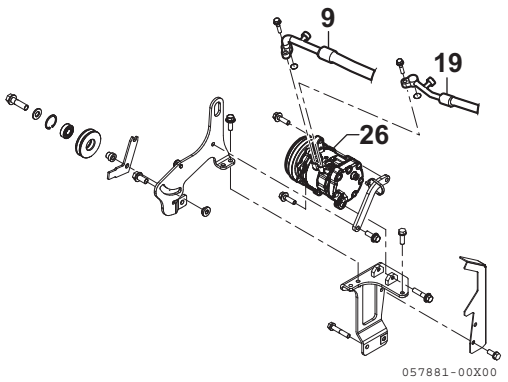
Procedure	
(1) Swing the upperstructure so that drain plug **1** for cooling water is positioned halfway between the right and left crawlers. Then, lower the bucket to the ground and stop the engine.	 038403-00X01

(2) Remove drain plug **1** from the two-way cock for cooling water to drain the cooling water. Q'ty: 9.8 Gals (9.3 L)	 042119-00X01

(3) Open engine hood **2** and collect refrigerant through charging valves **3** from air conditioner system by using a refrigerant collector. Refrigerant: R-134a Q'ty: 1.54 to 1.76 lbs. (700 to 800 g) ***Note:*** *Do not release refrigerant to protect the environment.* *Collect refrigerant and charge the air conditioner with refrigerant according to the instruction manual for the refrigerant collector and charger provided by the manufacturer.*	 058557-00X00

Procedure	
(Removal of Air Conditioner Unit) (4) Remove instrument panel **4** and A/C cover **5**. (5) Disconnect heater hose A **7**, heater hose ASSY **8**, suction hose **9**, exp. valve hose **10** and drain hose **11** from air conditioner unit **6**. ***Note:*** *To prevent degradation of air conditioner system, plug ports immediately after disconnecting hoses.*	
(6) Disconnect harness B from coupler **13** of air conditioner unit 6. (7) Remove the AC duct mounting bolts (3 pcs.) and then remove AC duct **12**.	
(8) Remove bolts (4 pcs.) **14** and remove air conditioner unit **6**.	

Procedure	
(Removal of Condenser) (9) Remove condenser cover **15**. (10) Disconnect harness A assy **16** from condenser ASSY **17**, receiver dryer **18** and travel alarm. (11) Disconnect exp. valve hose **10** from receiver dryer **18**. And disconnect discharge hose **19** from condenser ASSY **17**. ***Note:*** *To prevent degradation of receiver dryer, plug the port of receiver dryer immediately after disconnecting the hose.* (12) Remove condenser ASSY **17** with receiver dryer **18** from condenser base ASSY **20**.	
(Removal of Compressor) (13) Remove center cover **21**. (14) Loosen installation bolt **22** of tension pulley **23** to loosen tension of compressor driving belt **24**. (15) Open engine hood **2** and remove belt guard **25**. Then remove compressor driving belt **24**.	

Procedure	
(16) Disconnect hoses **9** and **19** from compressor **26**. ***Note:*** *To prevent degradation of air conditioner system, plug ports immediately after disconnecting hoses.* (17) Remove compressor **26** from brackets.	

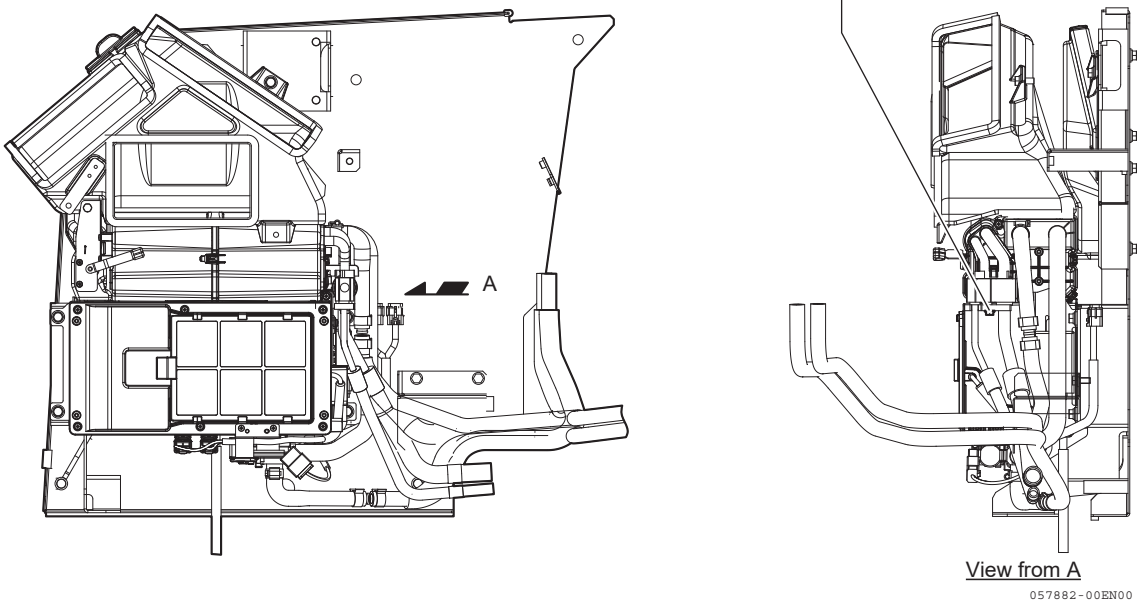
2) Reinstallation

Reinstall the air conditioner in the reverse order of the removal procedure.

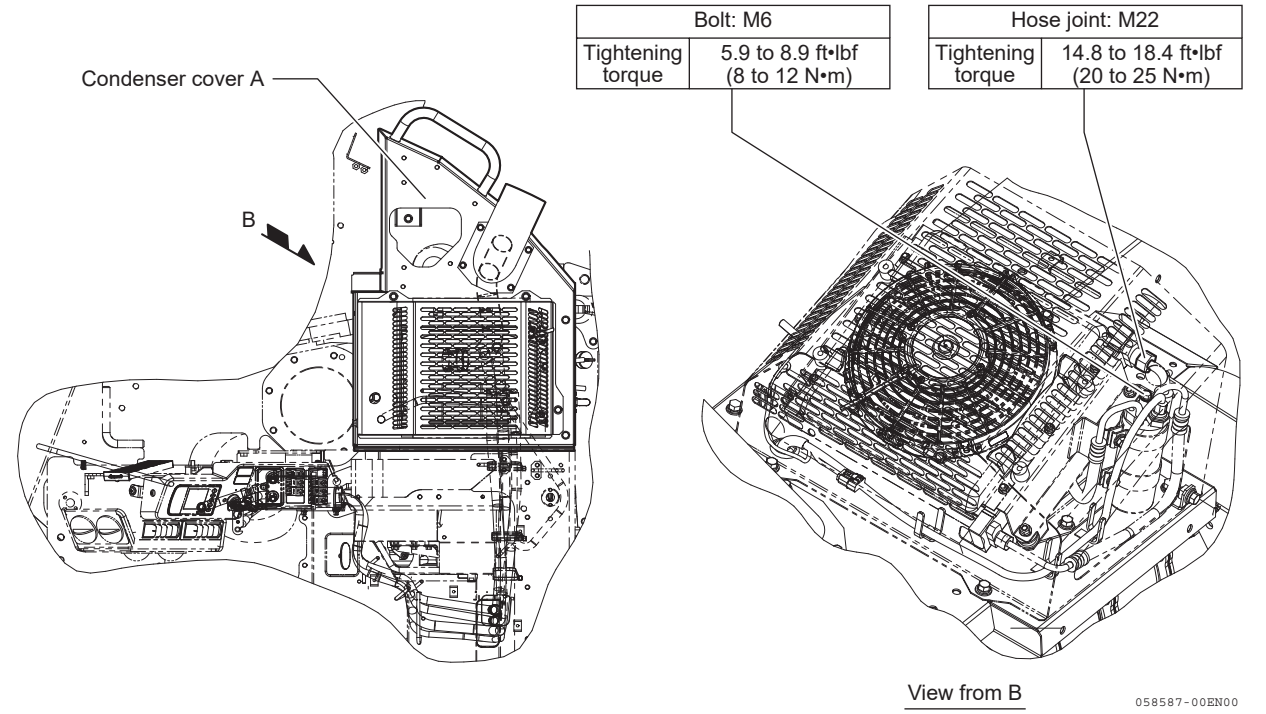
(1) Tightening torques

A. Air conditioner unit

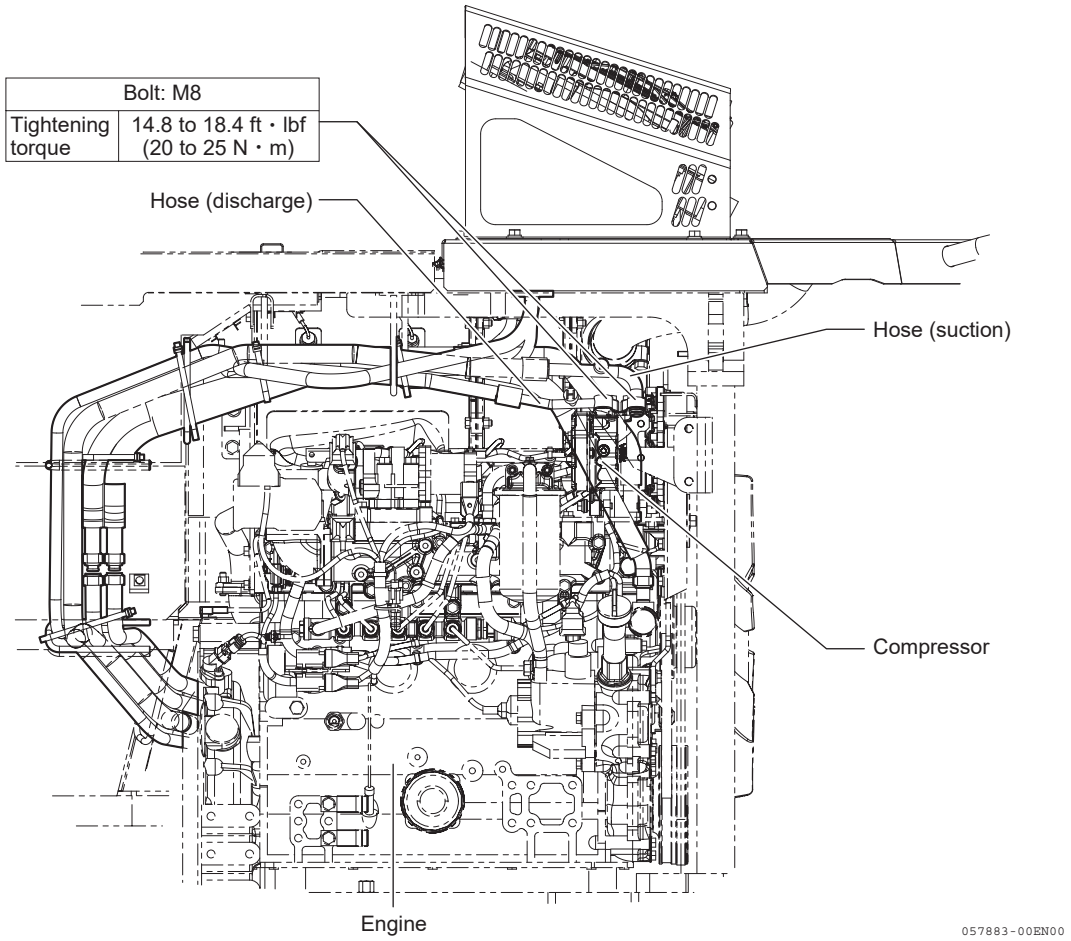
Bolt:M6	
Tightening torque	5.9 to 8.9 ft•lbf (8 to 12N•m)

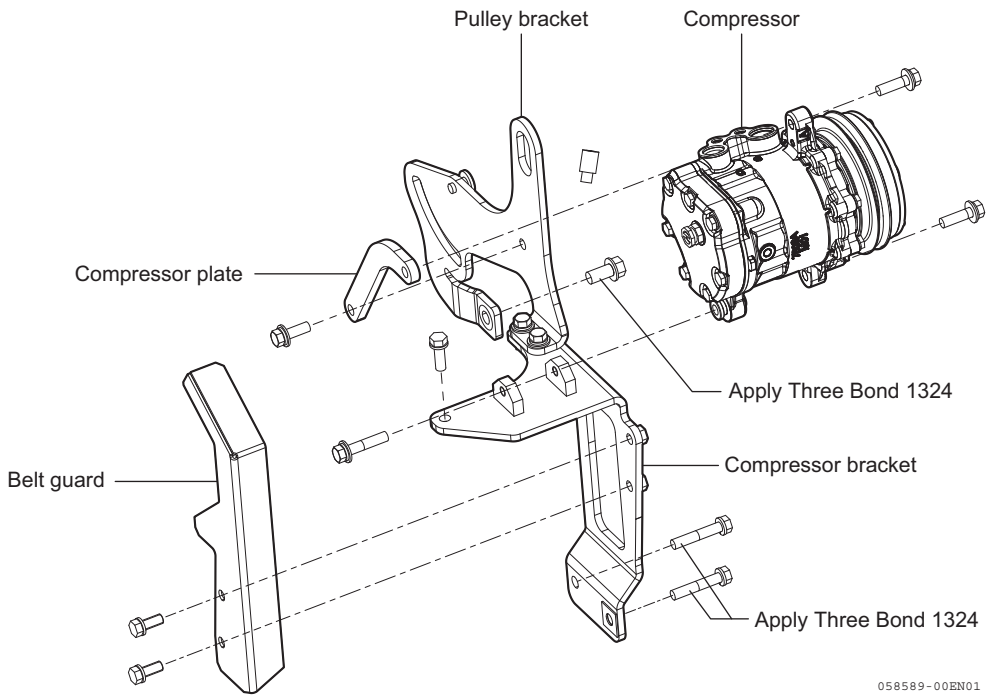


B. Condenser and receiver drier



C. Compressor





(Detail of compressor and brackets)

(2) Adjustment of lubricating oil level at the time of air conditioner components replacement

Note:

- *It is required to adjust lubricating oil level at the time of air conditioner components replacement, as too little lubricating oil will result in compressor seizure and too much lubricating oil may reduce cooling performance.*
- *Apply lubricating oil (compressor oil: SP-10) to the O-ring portion of piping joint and tighten it.*
- *If lubricating oil (compressor oil: SP-10) is adhered to the painting surface or resin portion, peeling of paint or breakage of the resin portion may result. If adhered, promptly wipe it off.*
- *Tighten the piping or the like with the specified tightening torque.*

A. At the time of replacing compressor

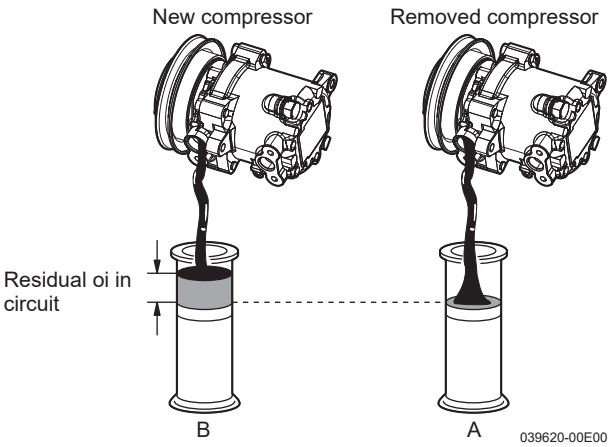
As the required amount of oil is enclosed in the compressor, the excess oil must be extracted from the new compressor at the time of compressor replacement in the following procedure:

[1] Prepare 2 pieces of measuring cylinder and extract the oil to the measuring cylinder A from the removed compressor.

[2] Extract the oil to the measuring cylinder B from the new compressor.

[3] Compare the amount of oil in the measuring cylinders A and B and remove the excess oil from B, so the amount is equal to A.

[4] Return the oil in the measuring cylinder B to the new compressor.



Note:

As compressor oil tends to contain water content, promptly adjust the oil level and seal the compressor right after adjustment.

(3) Compressor driving belt

Refer to Section "7-1-4 Removal and Reinstallation of Fan Belt and Compressor Driving Belt" for the reinstallation procedure of the compressor driving belt.

Item		Compressor driving belt
Pressing force		22.05 lbf (98.1 N)
Slack	New belt	0.59 to 0.63 in. (15 to 16 mm)
	Used belt	0.75 to 0.79 in. (19 to 20 mm)
V-belt size		Raw edge HM60

3) Air Conditioner Specifications

Item			Specifications
A/C system			Reheat
Cooler capacity (Airflow)		Unit	3.7± 10% kW (1) Airflow: 11300 ± 10% ft³/h (320 ± 10 % m³/h) (2) Mode: COLD (3) Duct: Not equipped
Heater capacity (Airflow)		Unit	4.0 ± 10 % kW (1) Airflow: 10947 ± 10% ft³/h (310 ± 10 % m³/h) (2) Mode: HOT (3) Duct: Not equipped
Nominal service voltage			DC12V
Compressor	Body	Model	SD7B08PE8313
		Discharge volume	4.81 in³/rev (78.9 cc/rev)
		Number of cylinders	7
		Maximum allowable speed	6500 rpm
		Lube oil	SP-10
		Lube oil quantity	4.27 in³ (70 cc)
	Magnetic clutch	Type	Dry-type single plate
		Driving belt	Type M
		Pulley effective outer dia.	φ4.57 in (φ116 mm)
		Power consumption	43 W
Condenser with electric fan	Condenser	Model	Serpentine
		Core dimensions (Height x Width x Depth)	12.5 × 13.2 × 1.7 in. (318 × 336 × 44 mm)
Receiver-drier		Capacity	14.6 in³ (240 cm³)
		Desiccant	Synthetic zeolite
		Desiccant quantity	0.22 lbs (100 g)
A/C unit	Evaporator	Model	Plate and fin
		Core dimensions (Height x Width x Depth)	9.3 × 9.8 × 2.0 in (235 × 250 × 50 mm)
	Heater core	Model	Aluminum brazing
		Core dimensions (Height x Width x Depth)	3.46 × 12.4 × 1.4 in. (88 × 315 × 36 mm)
	Blower motor	Model	Double shafts
		Consumption current	12 A or lower
	Auxiliary device	Electronic thermo stat (Thermoswitch)	OFF: 37.4 ± 1.8°F (3 ± 1°C) to 59 ± 1.8°F (15 ± 1°C) DIFF: 1 ±0.5 K

Item			Specifications
Control unit	A/C switch		Push type (ON / OFF)
	Temperature control switch		Dial type (40 level control)
	Airflow control switch	Fan switch (manual)	Dial type (3 level control)
Refrigerant high pressure piping	Auxiliary device	Dual pressure switch	OFF: 28.4 PSI (0.196 MPa) [G] or lower OFF: 455.4 PSI (3.14 MPa) [G] or higher
Refrigerant		Type	HFC-134a (R-134a)
		Quantity	1.54 ± 0.11 lbs (700 ± 50 g)

CHAPTER 8

TROUBLESHOOTING

8-1 Non-breakdowns 8-1-1
8-1-1 Natural Release of Bucket 8-1-1
8-1-2 Discontinuous Arm Movement 8-1-1
8-1-3 Thermal Shock of Travel Motor 8-1-2
8-1-4 Elongation of Boom Swing Cylinder on 60 degrees Swing 8-1-3
8-1-5 Time Lag on Travel Speed Switching 8-1-4
8-1-6 Fluctuation in Oil Level of Hydraulic Oil Tank due to Temperature Change 8-1-5
8-2 Quick Reference Table for Troubleshooting 8-2-1

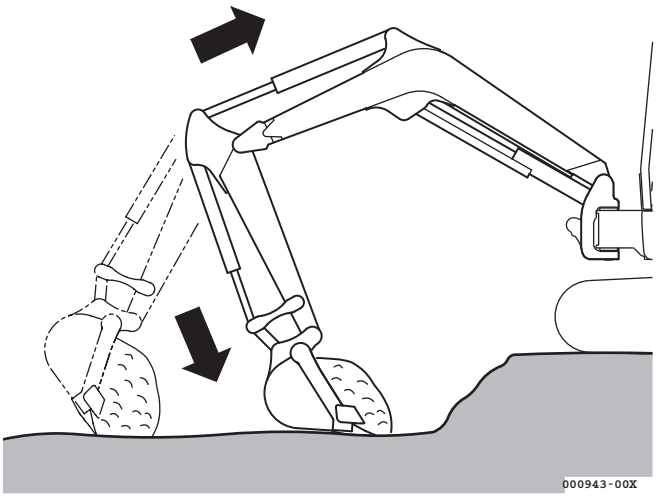
8. Troubleshooting

8-1 Non-breakdowns

8-1-1 Natural Release of Bucket

Phenomenon

When the arm is extended while scooping with the bucket, the scooping side of the bucket is restricted by the arm and causes back pressure because oil cannot be supplied to the bucket cylinder in time.
When the boom is raised immediately in this condition, the bucket is released naturally because of the back pressure in the piston side of the cylinder



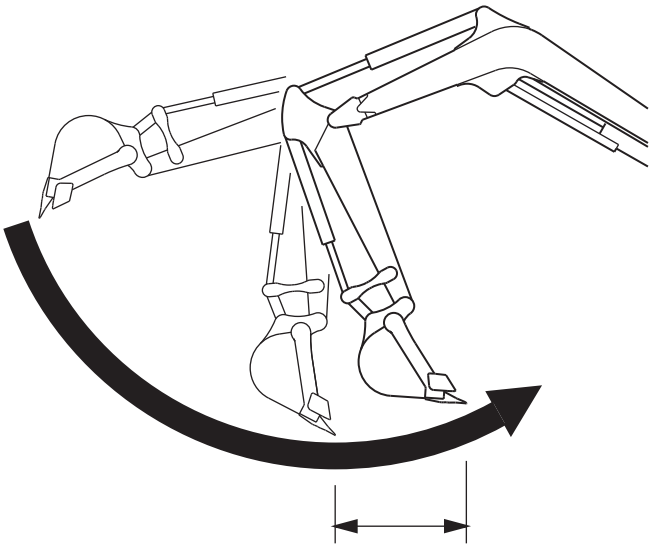
Operation

This problem can be solved by using a sequence of three actions of bucket scooping, arm extension and boom raising.
(For the models that cannot make the triple sequence actions, extend the arm after raising the boom.)

8-1-2 Discontinuous Arm Movement

When scooping with the arm, the arm tends to move slower as it draws near to the perpendicular and it may stop momentarily.
This may happen because the oil supply cannot catch up with the cylinder extension speed. This is a charac-teristic of hydraulic equipment.

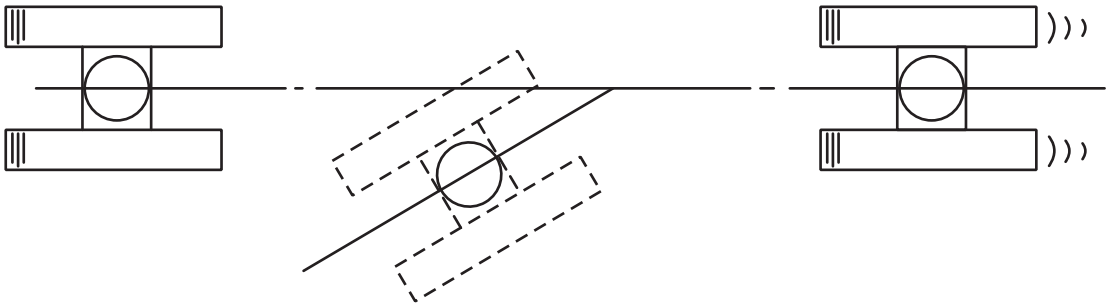
Specifically, this phenomenon appears when the engine speed is in the low to medium speed range. Advise your users fully that this will happen in hydraulic equipment and that this is not a breakdown.



8-1-3 Thermal Shock of Travel Motor

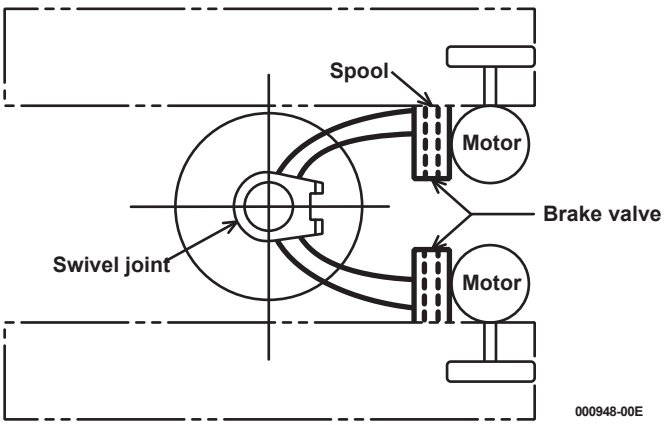
Phenomenon

When the travelling operation is made for pivot turning in cold temperatures after raising the hydraulic oil temp to more than 140°F (60°C) higher than the ambient temp. through relief valve operation, etc. without travelling after starting the engine, the machine may travel straight instead of making a pivot turn.



(Travel straight in spite of turning operation.) 000947-00E

Reason



When the hot hydraulic oil is suddenly fed to the cold brake valve and motor, the spool in the brake valve sticks momentarily due to thermal expansion canceling the braking force.

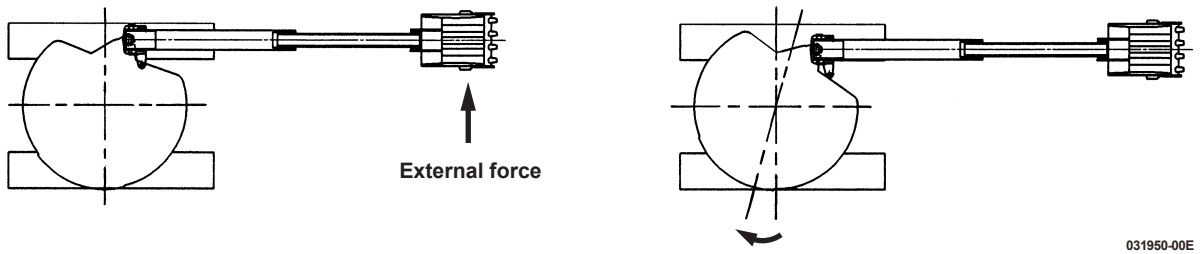
Evaluation

Since the phenomenon disappears in 20 to 30 seconds and the above situation is generally rare, this phenomenon presents no problem.

8-1-4 Elongation of Boom Swing Cylinder on 60 degrees Swing

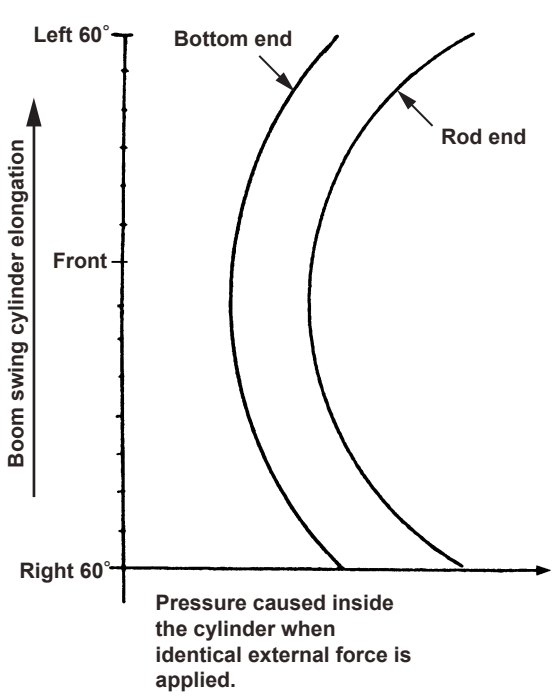
Phenomenon

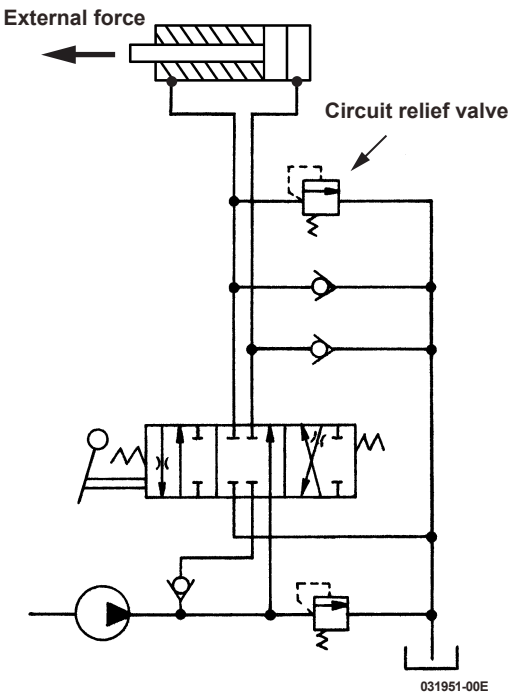
The boom swing cylinder elongates in digging operation at a 60 degrees swing.



Reason

When an outside sideways force is applied to the bucket, the force extends (retracts) the boom swing cylinder. At the 60 degrees swing position, however, the cylinder's internal pressure is higher than in other positions due to the link ratio. This activates the circuit relief valve and elongates the boom swing cylinder.





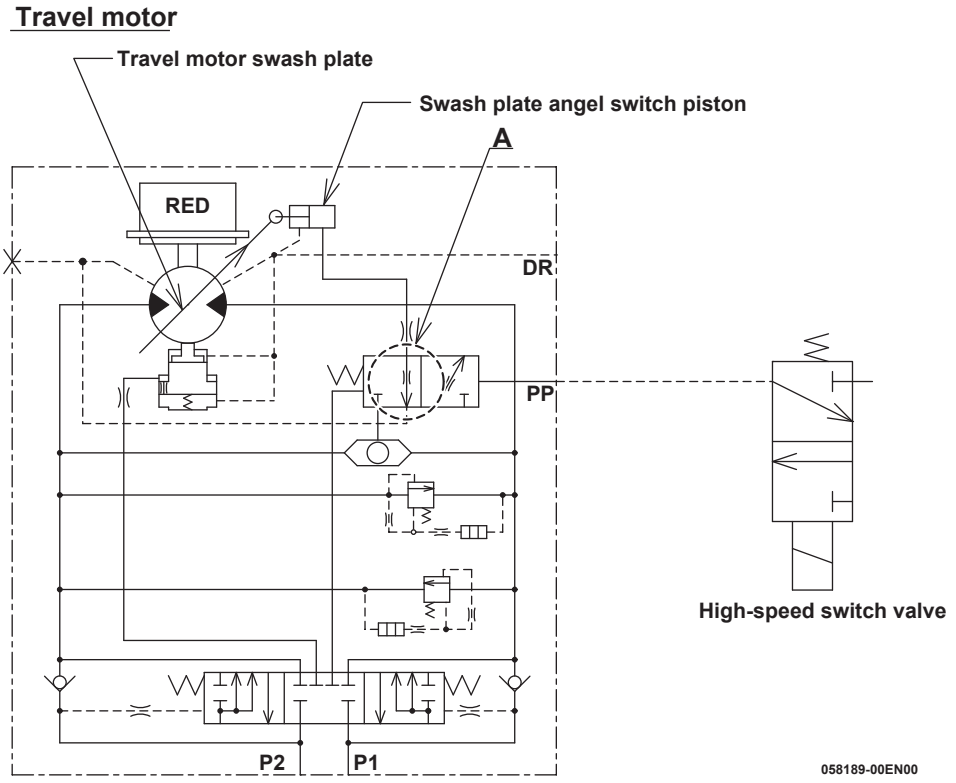
8-1-5 Time Lag on Travel Speed Switching

Phenomenon

In cold temperatures, there is a time lag in switching from the high-travel speed to low-travel speed (with the travel automatic dual speed switch turned OFF.).

Reason

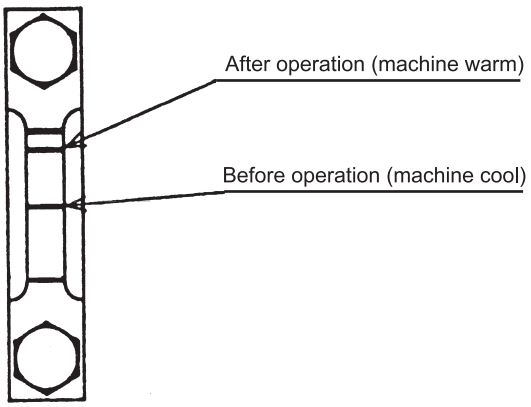
The shock caused during switching from the high-speed to low-speed is lightened by the throttles of A. In cold tem-peratures, however, the passage resistance of the throttles becomes larger and it takes more time for the swash plate of the travel motor to return to the low speed.



8-1-6 Fluctuation in Oil Level of Hydraulic Oil Tank due to Temperature Change

Phenomenon

The oil level of the hydraulic oil tank varies between before operation (the machine is cool) and after operation (the machine is warm).



031952-00E

Reason

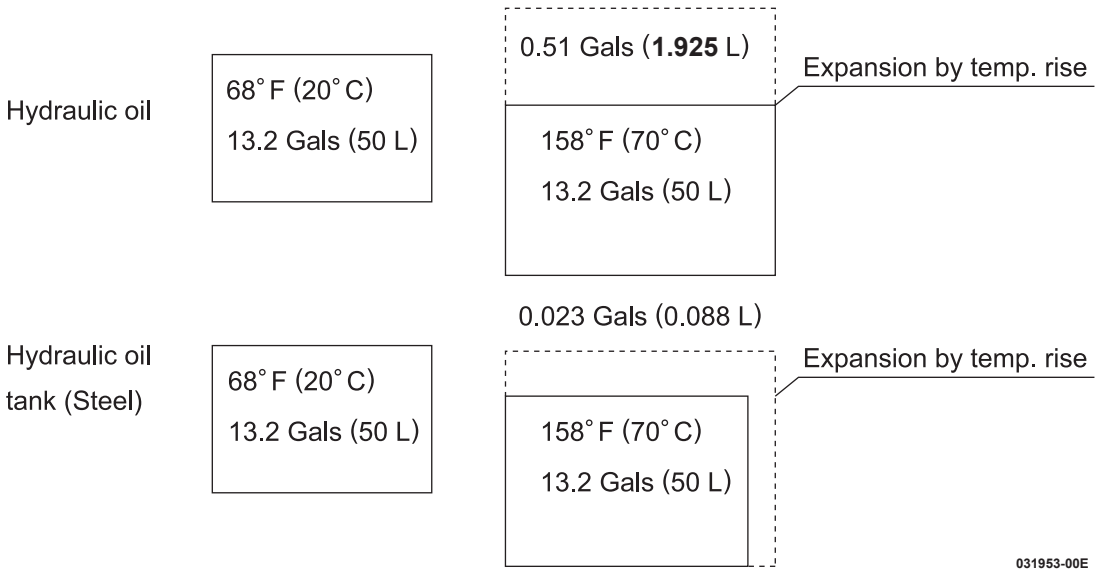
The oil level changes because the thermal expansion factor of oil is far larger (about 20 times) than that of steel.

1. Liner thermal expansion factor of steel : 11.7×10^{-6}

2. Cubical thermal expansion factor of steel : 3.51×10^{-5}

3. Cubical thermal expansion factor of hydraulic oil : 7.7×10^{-4}

(Example)



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8-2 Quick Reference Table for Troubleshooting

The following table summarizes the general trouble symptoms and their causes.
If any trouble symptom occurs, take corrective action before it becomes a serious problem.

Trouble symptoms are shown in columns and their causes are shown in rows.

Whether boxes where the column and rows intersect are marked with a circle should be checked.

Example: When the bucket does not move at all

Trouble symptom: Implement does not move at all. (Bucket)

Items relevant to causes whose corresponding boxes are marked with a circle must be inspected and repaired.

Cause \ Symptoms and conditions of failures		Implement does not move at all										Implement's force			
		All implements	Boom	Arm	Bucket	Boom swing	Swing	Blade	Travel R	Travel L	P.T.O.	Boom	Arm	Bucket	Boom swing
1. Hydraulic pump	Hydraulic pump ASSY	○													
	Piston pump P1			○		○				○	○		○		○
	Piston pump P2		○		○				○			○		○	
	Gear pump P3						○	○							
	Pilot pump P4		○	○	○	○	○		○	○	○	○	○	○	○
	Cut-off valve	○	○	○	○	○	○		○	○	○	○	○	○	○
	Travel speed switch valve														
2. Control valve	Sections related to P1 flow														
	Sections related to P2 flow														
	Sections related to P3 flow														
	Boom section		○									○			
	Arm section			○									○		
	Bucket section				○									○	
	Boom swing section					○									○
	Blade section							○							
	Swing section						○								
	Travel R section								○						

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8. TROUBLESHOOTING

Troubleshooting table

Cause \ Symptoms and conditions of failures		Implement																																						Travel				Engine and electrical equipment													
		Implement does not move at all										Implement's force is weak or its speed is slow										Implement does not move smoothly										Implement drifts									Unintended movement of implement	Cannot change the travel speed to high	Cannot return the travel speed to low	Crawler tension loosens	Jumping of crawler link	Engine does not start	Engine speed does not increase	Engine overheating	Battery dies or battery cannot be charged	Electrical equipment does not work	Fuel meter does not work	Engine water temp. meter does not work	Engine oil pressure lamp lights up	Battery charge lamp lights up	Hour meter does not work	LCD monitor does not work (starter switch is turned on)	Auto deceleration function does not work	Eco mode function does not work
		All implements	Boom	Arm	Bucket	Boom swing	Swing	Blade	Travel R	Travel L	P.T.O.	All implements	Boom	Arm	Bucket	Boom swing	Swing	Blade	Travel R	Travel L	P.T.O.	Boom	Arm	Bucket	Boom swing	Swing	Blade	Travel R	Travel L	P.T.O.	Boom	Arm	Bucket	Boom swing	Swing	Blade	Travel R	Travel L	P.T.O.																						
1. Hydraulic pump	Hydraulic pump ASSY	○										○																																														
	Piston pump P1		○		○				○				○		○				○			○		○				○																													
	Piston pump P2		○			○				○	○		○	○	○	○				○	○	○				○				○	○																									
	Piston pump P3		○	○		○				○	○			○			○			○		○				○				○	○																									
	Pilot pump P4	○	○	○	○	○	○	○	○	○		○		○			○	○	○	○	○	○				○	○			○	○										○																
2. Control valve	Sections related to P1 flow									○		○		○								○		○				○		○																											
	Sections related to P2 flow																					○			○				○	○																									
	Sections related to P3 flow																					○		○	○																													
	Boom section		○										○									○			○						○									○															
	Arm section			○	○																			○																														
	Bucket section				○										○									○				○																										
	Boom swing section					○	○																			○			○																								
	Blade section						○	○										○									○		○			○																				
	Swing section						○										○									○				○		○																			
	Travel R section								○	○																				○			○																		
	Travel L section									○											○									○			○		○															
	P.T.O. section									○	○																								○		○												
	Inlet section										○																										○											
	Boom2 section		○	○							○	○									○	○	○							○																			
	Parallel flow divider section										○	○		○			○		○						○					○																			
3. System relief valve	Relief valve P1		○		○				○				○		○		○		○			○		○	○			○																							
	Relief valve P2		○			○				○	○		○	○		○			○			○	○		○				○	○																						
	Relief valve P3		○	○		○					○			○			○		○						○					○																					
	Relief valve P4		○		○	○	○			○	○	○		○			○	○	○	○	○	○				○			○	○											○										
4. Circuit relief valve	Relief valve (Boom)		○		○		○					○	○	○								○		○		○				○																					
	Relief valve (Arm)			○	○																											○																	
	Relief valve (Bucket)				○										○									○										○															
	Relief valve (Boom swing)					○	○																												○													
	Relief valve (Blade)						○	○										○									○																				
	Relief valve (Swing motor)						○										○									○										○											
5. Pilot valve	Right		○		○								○		○							○		○																							
	Left			○			○							○			○						○			○																						
	Boom swing					○	○																																									
	Travel						○		○	○									○	○								○	○																			
	Blade							○	○								○																															

| Cause \ Symptoms and conditions of failures | | Implement | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Travel | | | | Engine and electrical equipment | | | | | | | | | | | | | | | | | | |

| Symptoms and conditions of failures / Cause | | Implement | | |

APPENDIX
ViO80-1A(YCEE) Wiring Diagram

HARNESS B

Connect to CABIN HARNESS

SMART'ASSIST - Remote controller

Indicator lamp (YCEE) | Seat switch (YCEE) | Power output (12v) | Cut-off switch | Quick coupler controller | Buzzer | Engine control dial

Wiper switch | Travel automatic dual speed switch | Light switch | Auto deceleration switch | Eco mode switch | DPF regeneration switch | Engine stop switch | Diode | Diode | Diode | Resistor | Starter switch

Starter switch diagram

	AC	19	30	17	50
OFF					
ON		○	○		
START		○	○	○	○

Start signal | Starter switch | Power | ECU2 | EGR valve relay | Air conditioner | Engine ECU | LCD monitor | Power output | Condenser fan | Wiper | Engine | ECU2 Acc | Safety | P.T.O. / Quick coupler | Travel Relay | ECU1 | Work light | Diode

Fuse box

Thermo switch | A/C switch | Blower switch

Hydraulic ECU | Engine ECU | LCD monitor | Connector (LCD monitor data)

Starter relay | Glow relay | P.T.O. flow control dial (P.T.O.2) | Remote control lever L (P.T.O.2) | Remote control lever R (P.T.O.1) | P.T.O. flow control dial (P.T.O.1) | Diode (3A) | Diode (3A) | Connector for SMARTASSIST-Direct | Diode (3A) | Resistor

Power relay | Power relay | Travel detection relay | Power output relay | EGR valve relay | Air conditioner relay | Starter control relay | Safety relay | Starter lockout relay | Acceleration cancel relay

AIR CONDITIONER HARNESS

Condenser relay | Compressor relay | Blower motor | Resistor | Valve CMP | Evaporator sensor | Air conditioner controller | A/C controller (TKS-C121A0)

HARNESS D

Horn | Proportional solenoid valve (P.T.O.1 A) | Diode (P.T.O.valve) | Proportional solenoid valve (P.T.O.1 B) | Proportional solenoid valve (P.T.O.2 A) | Diode (P.T.O.2 valve) | Proportional solenoid valve (P.T.O.2 B) | Diode | Cut-off solenoid valve | Travel oil pressure detection switch | EPR proportional solenoid valve | Quick coupler solenoid valve

HARNESS A

Starter motor | Generator | Pressure switch (YCEE option) | Fuel pump | Air cleaner switch | Work lamp (boom) | Travel alarm | Horn | Slow blow fuse box | Body earth | Battery 130E41R | Condenser fan motor | Glow plug | Fuel level sensor | Refueling pump | Diode 3A | Compressor | Refrigerant pressure switch | Control oil pressure detection switch | Hydraulic oil temperature sensor | Fuel gauge | Engine oil pressure switch | Body earth | Body earthearth | DPF differential pressure sensor | DPF inlet temperature sensor | DPF outlet temperature sensor

ENGINE HARNESS

Resistor | EGR valve | EGR gas temperature sensor | Intake manifold temperature sensor | Intake throttle | Supply pump | Injector | Injector | Injector | Injector | Cam speed sensor | Crank speed sensor | Exhaust manifold temperature sensor | Rail pressure sensor | Coolant temperature sensor | Intake temperature sensor | EGR pressure sensor

Wiring color

W	White	P	Pink
R	Red	Br	Brown
B	Black	Lg	Light green
Y	Yellow	Sb	Sky blue
G	Green	Or	Orange
L	Blue	Gr	Gray
		V	Violet

Example: W/B — Base color: White; Stripe: Black

Band marking (No relation with wiring color.)

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