SERVICE MANUAL

MITSUBISHI DIESEL ENGINE

S4E

(for BD2F · BS3F)

MITSUBISHI
HEAVY INDUSTRIES, LTD.

FOREWORD

This service manual has instructions and procedures for the subject on the front cover. The information, specifications, and illustrations used in this manual are based on information that was current at the time this issue was written.

Correct servicing will give this engine a long productive life. Before attempting to start a test, repair or rebuild job, be sure that you have studied the respective sections of this manual, and know all the components you will work on.

Safety is not only your concern but everybody's concern. Safe working habits cannot be bought or manufactured; they must be learned through the job you do. By learning what CAUTION or WARNING symbol emphasizes, know what is safe – what is not safe. Consult your foreman, if necessary, for specific instructions on a job, and the safety equipment required.

NOTES, CAUTIONS and WARNINGS

NOTES, CAUTIONS and WARNINGS are used in this manual to emphasize important and critical instructions. They are used for the following conditions:

NOTE .... An operating procedure, condition, etc., which it is essential to highlight.

⚠ CAUTION .... Operating procedures, practices, etc., which if not strictly observed, will result in damage to or destruction of engine.

⚠ WARNING ...... Operating procedures, practices, etc., which if not correctly followed, will result in personal injury or loss of life.

January 1978

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SERVICE GUIDE

RECOMMENDED PERIODICAL SERVICING SCHEDULE

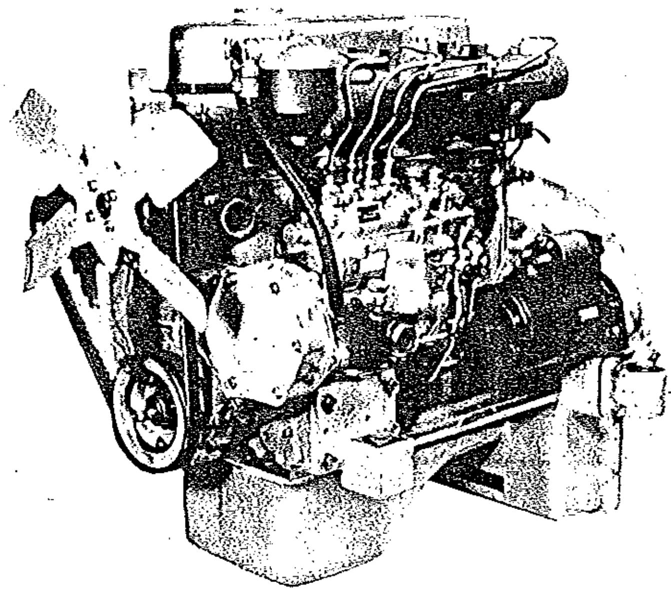
○ refers to engines in regular service.
◎ refers to new engines being broken in.

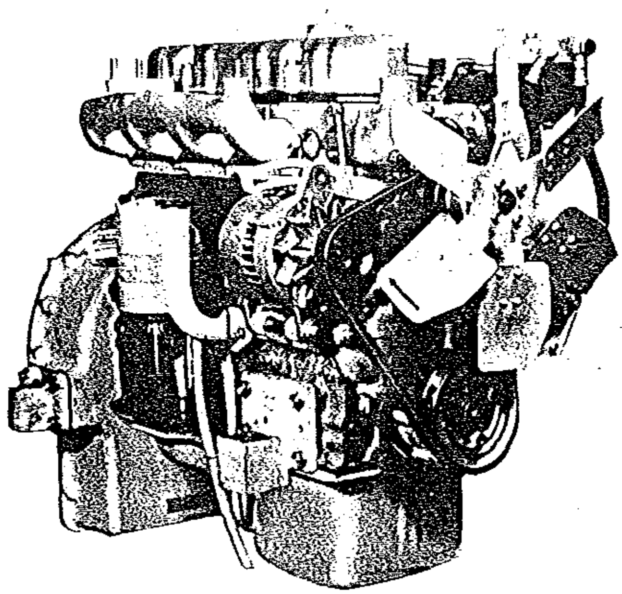
What to service		What to do	Criteria	Servicing intervals (hrs) Daily (10)	75	150	300	600	1200	Remarks
Lubrication system	Oil pan	Check oil level and replenish.		○						
		Change oil.	7.0 liters (1.8 gallons)		◎			○		
	Oil filter	Replace filter element.						○		
	Oil circuit	Clean by flushing.							○	
Fuel system	Fuel filter	Drain out sludge and condensate.						○		
		Replace filter element.							○	
	Feed pump	Clean inlet connection.						○		
	Injection nozzles	Check injection pressure.	120 ± 5 kg/cm^2 (1706 ± 71 psi)						○	
		De-carbon and clean nozzles and seats.							○	
	Fuel tank	Drain out condensate and sludge.	60 liters (16 gallons)			○				
		Clean by flushing.						○		
Cooling system	Radiator	Check water level and replenish.	16 liters (4.2 gallons)	○						
		Change coolant.						○		
		Clean radiator fins.			○					
	Fan belt	Check and adjust tension.	12 mm (1/2 in.) of deflection					○		
	Thermostat	Check for performance.						○		
	Coolant circuit	Clean by flushing.							○	
Intake system	Air cleaner	Clean element.					○			Standard duty conditions
		Replace element.						○		
	Bolts and nuts on muffler and air cleaner	Check for tightness and retighten.			◎			○		
Electrical equipment	Starter	Inspect brushes and commutator for wear; recondition as necessary.						○		
	Battery	Check acid level and replenish.			○					
		Check electrolyte S.G.			○					
	Glow plugs	Inspect for condition.						○		
Engine proper	Valve clearance	Check and adjust.	0.25 mm (0.0098 in.) for both intake and exhaust valves						○	
	Major bolts	Retighten.							○	
	Packings and seals	Inspect for leakage and repair.		○						

CONSTRUCTION AND FUNCTION

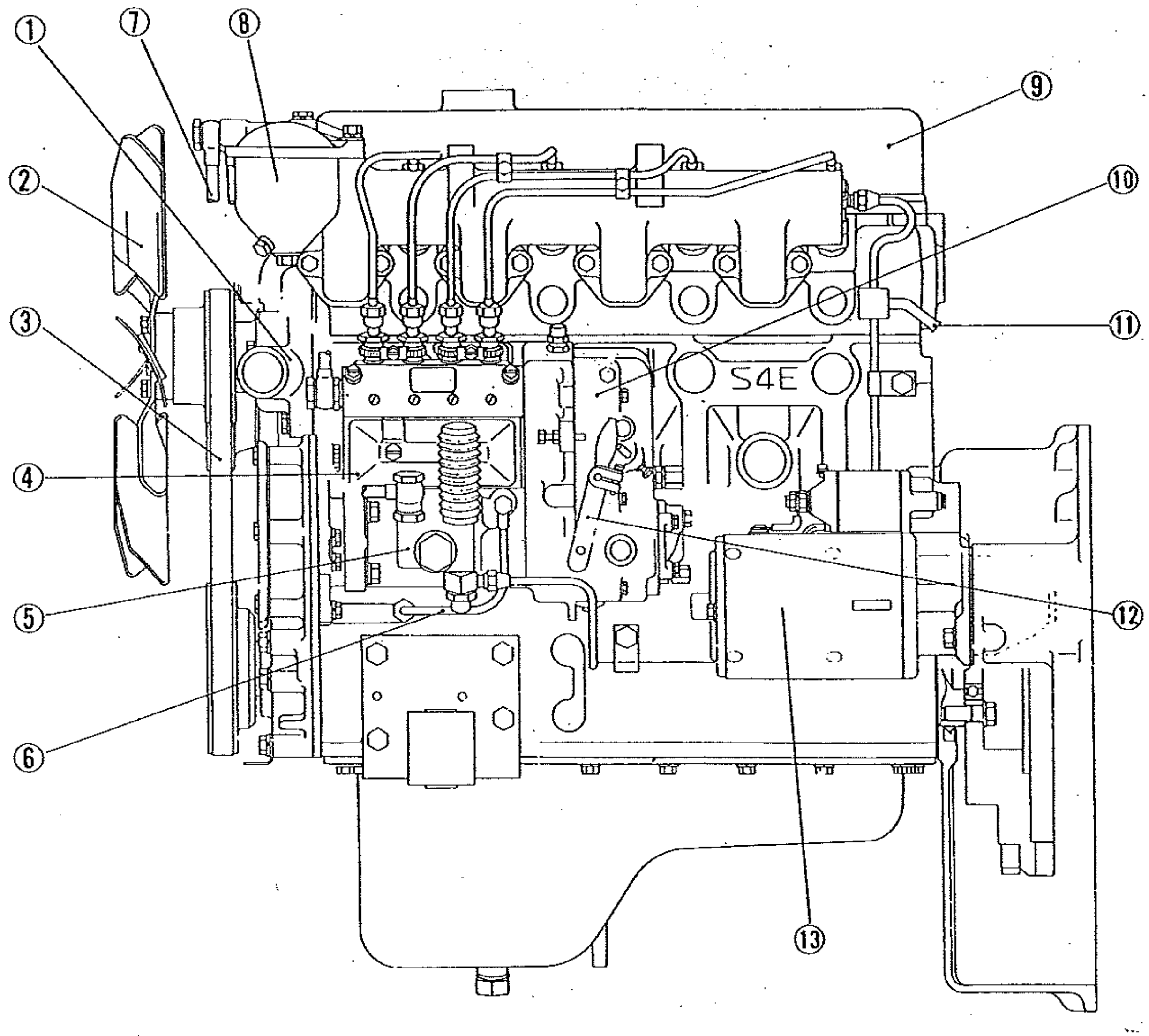
Description

Exterior views



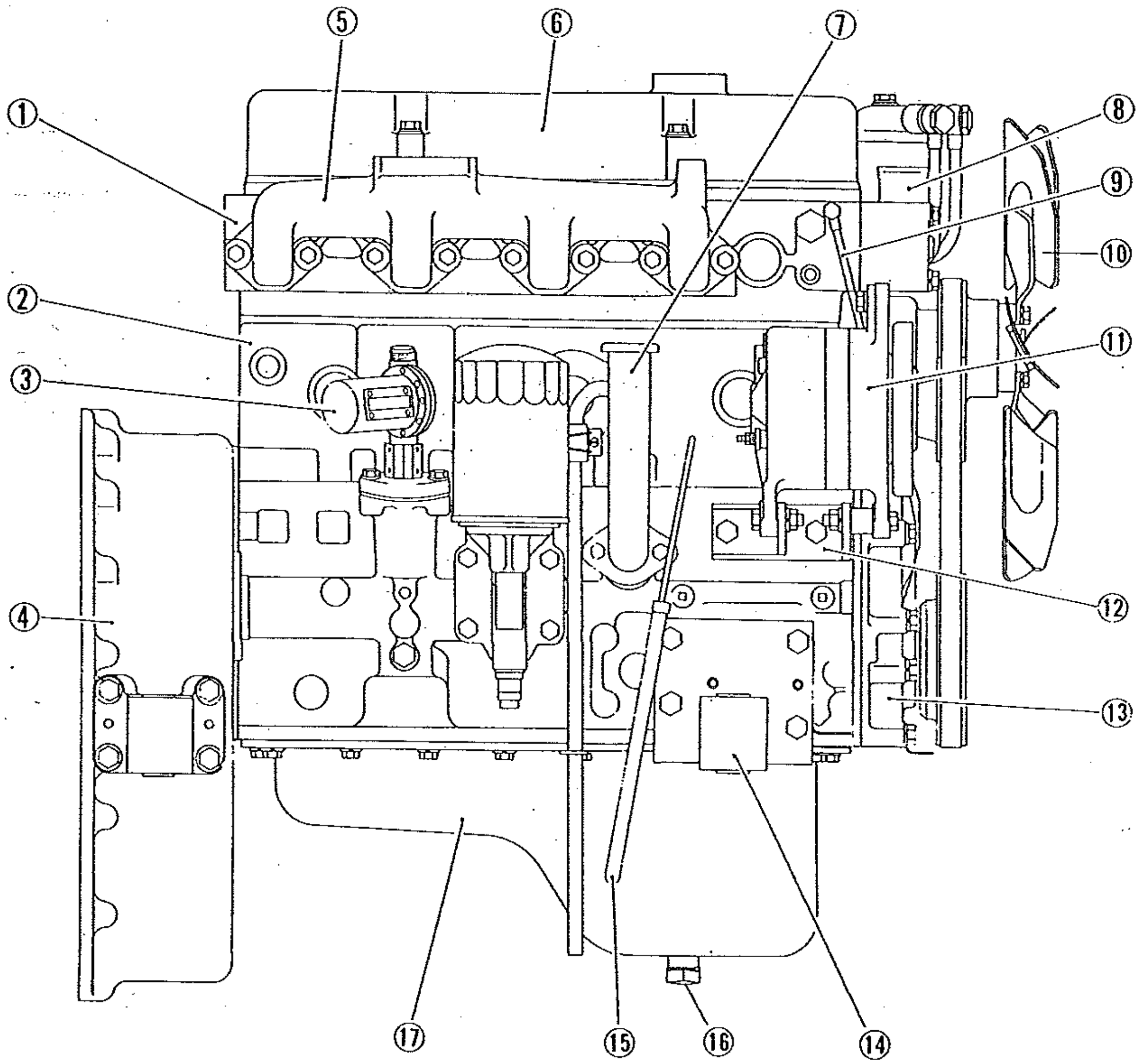


Left-side view



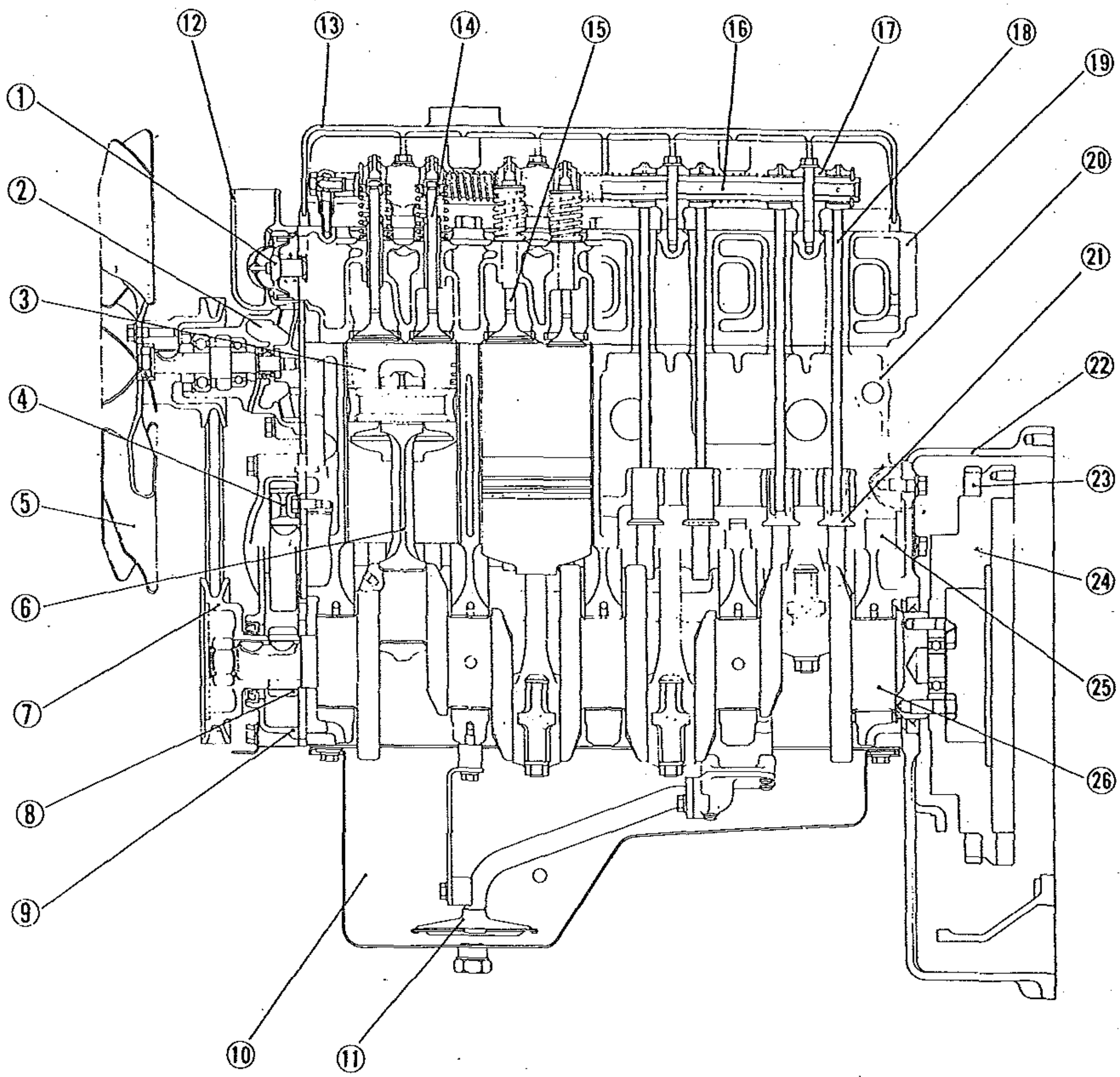
1-Water pump	6-Oil pipe	11-Fuel inlet
2-Fan	7-Fuel feed pipe	12-Adjusting lever
3-Fan belt	8-Fuel filter	13-Starter
4-Fuel injection pump	9-Rocker cover	
5-Fuel feed pump	10-Governor	

Right-side view



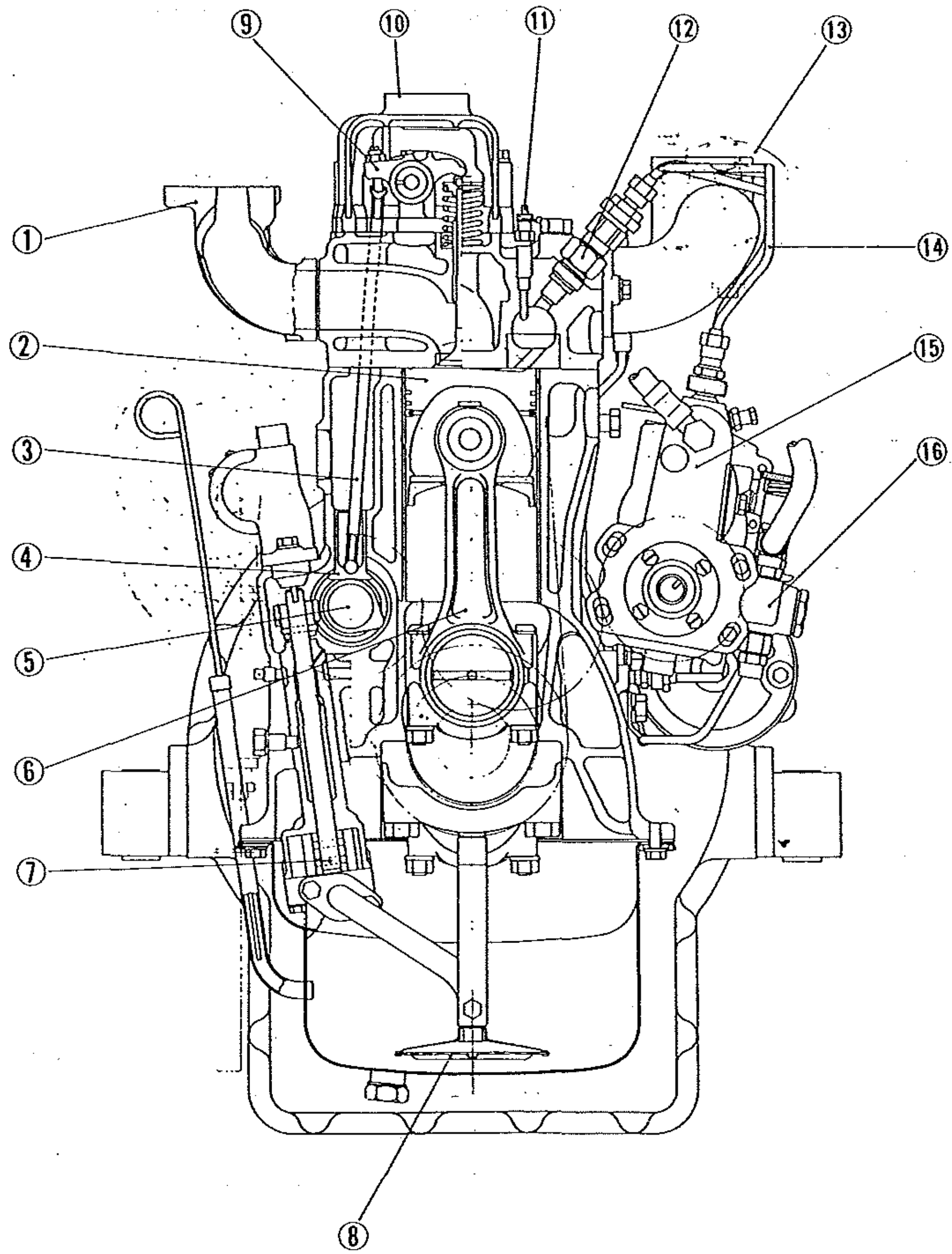
1-Cylinder head	7-Oil filler	13-Timing gear case
2-Crankcase	8-Thermostat	14-Mounting bracket
3-Service meter	9-Oil pipe	15-Oil level gauge
4-Flywheel housing	10-Fan	16-Drain plug
5-Exhaust manifold	11-Alternator	17-Oil pan
6-Rocker cover	12-Alternator bracket	

Longitudinal cross section



1-Thermostat	8-Crankshaft gear	15-Intake valve	22-Flywheel housing
2-Water pump	9-Timing gear case	16-Rocker shaft	23-Flywheel ring gear
3-Piston	10-Oil pan	17-Rocker bracket	24-Flywheel
4-Camshaft gear	11-Oil strainer	18-Valve push rod	25-Camshaft
5-Fan	12-Elbow	19-Cylinder head	26-Crankshaft
6-Connecting rod	13-Rocker cover	20-Crankcase	
7-Crankshaft pulley	14-Exhaust valve	21-Tappet	

Transverse cross section



1-Exhaust manifold	5-Camshaft	9-Rocker arm	13-Fuel filter
2-Piston	6-Connecting rod	10-Oil filler	14-Fuel injection pipe
3-Valve push rod	7-Oil pump	11-Glow plug	15-Fuel injection pump
4-Tappet	8-Oil strainer	12-Oil injection nozzle	16-Fuel feed pump

Specifications

General data	Model designation		S4E
	Type		Water-cooled, 4-stroke cycle, in-line, turbulence-chamber type diesel
	Number of cylinders		4
	Bore x stroke, mm (in.)		94 x 94 (3.701 x 3.701)
	Piston displacement, cc (cu in.)		2609 (159)
	Compression ratio		19 : 1
	Firing order		1 - 3 - 4 - 2
	Direction of rotation		Clockwise as viewed from timing gear case side
	Fuel		ASTM No. 2-D diesel fuel
	Crankcase lubricating oil		API service classification CC - class
	Dimensions	Overall length, mm (in.)	813 (32)
		Overall width, mm (in.)	512 (20-1/8)
		Overall height, mm (in.)	741 (29-1/8)
	Weight (dry), kg (lb)		290 (639)
			DD model / DPS model
	Maximum output, PS/rpm		35/2400 / 37/2400
	Maximum torque, kg-m (ft-lb)/rpm		14.5 (104.9)/1200 / 15.5 (112.1)/1200
	Compression pressure, kg/cm² (psi) (rpm)		20 (284.4) (150 ~ 200), minimum
	Minimum speed, rpm		650 ~ 700
	Maximum speed, rpm		2640
	Cylinder sleeve		Dry type, special cast iron
	Number of piston rings	Compression rings	2
		Oil	1 (with spring expander)
	Valve arrangement		Overhead type
	Valve timing	Intake valves	
		Open	30° before TDC
		Close	50° after BDC
		Exhaust valves	
		Open	74° before BDC
		Close	30° after TDC
	Valve clearance	Intake, mm (in.)	0.25 (0.0098) (cold)
		Exhaust, mm (in.)	0.25 (0.0098) (cold)
	Starting system		Starting motor
Fuel system	Fuel feed pump	Model	ND - EP/KS22A
		Manufacturer	Nippon Denso
		Cam lift, mm (in.)	6 (0.236)
	Fuel injection pump	Model	PES4A65B
		Manufacturer	Nippon Denso
		Plunger diameter, mm (in.)	6.5 (0.256)
		Plunger lead	Right hand
		Cam lift, mm (in.)	8 (0.315)

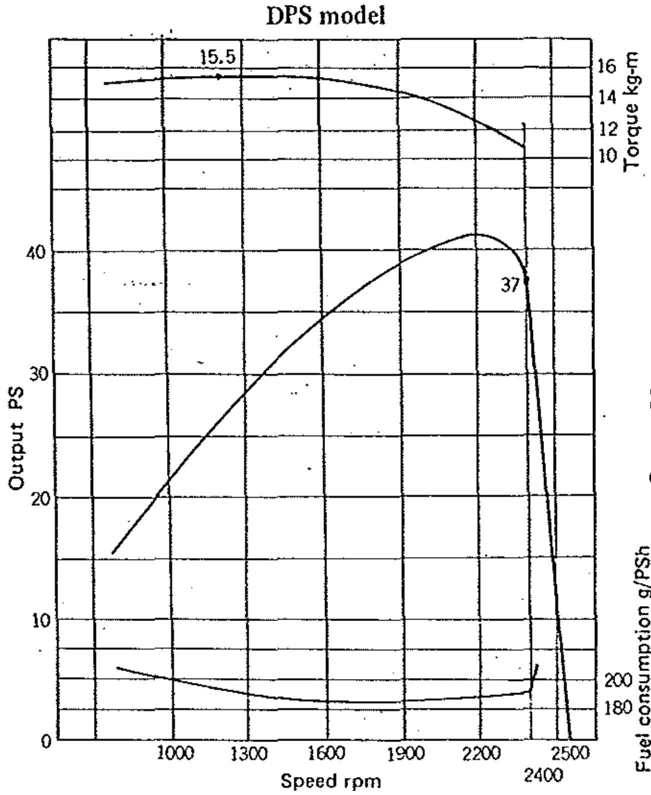
Fuel system — cont.	Injection timing		25 ± 1° before TDC
	Governor	Type Model Manufacturer	Centrifugal, flyweight, all-speed type RSV Nippon Denso
	Injection nozzles	Manufacturer Nozzle holder Nozzle tip Type Spray hole diameter, mm (in.) Spray cone angle Injection pressure, kg/cm^2 (psi)	Nippon Denso Bosch type, KCA17SD Bosch type, ND – DN0SD Throttle type 1 (0.039) 0° 120 (1706) ± 5 (71)
	Fuel filter	Filter element Manufacturer	Paper-element type Nippon Rokaki
Lubrication system	Capacity	Oil pan, liter (gal) Oil filter, liter (gal)	7.0 (1.8) 0.67 (0.18)
	Oil pressure	When operating, kg/cm^2 (psi) When idling, kg/cm^2 (psi)	3 ~ 4 (42.7 ~ 56.9) 1.0 (14.2), minimum
	Oil pump	Type Speed ratio to crankshaft Displacement, liter (cu in.)/min/rpm	Trochoid type 1/2 19.2 (1172)/2400 (engine speed), minimum Oil temperature: 50°C (122°F) Discharge pressure: 3 kg/cm^2 (42.7 psi)
	Oil filter	Type	Paper element type
	Relief valve	Type Relief pressure kg/cm^2 (psi)	Piston-valve type 3 ± 0.3 (42.7 ± 4.3)
Cooling system	Capacity (excl. radiator), liter (gal)		4.6 (1.2)
	Water pump	Type Speed ratio to crankshaft Displacement, liter (cu in.)/min/rpm	Centrifugal type 1.2 : 1 100 (6103)/2520 (pump speed)
	Belt	Type Manufacturer	Low-edge cog B-type "V" belt Mitsuboshi Belt
	Thermostat	Type Manufacturer Valve opening temperature, °C (°F)	Wax type Fuji Seiko 76.5 ± 2° (169.7 ± 3.6°F) (Fully opens at 90°C (194°F))
	Fan	Type Number of blades Outside diameter, mm (in.) x pitch Speed ratio to crankshaft	Steel blade, pusher type 6 380 (14.96) x 30° 1.2 : 1

Electrical equipment	Voltage		24 V
	Polarity		Negative
	Glow plugs	Type Rated voltage-current Resistance value (at normal temperature)	Sheathed type 22.5 volts - 4.8 amperes 4.5 ± 0.5 ohms
	Starter	Model Manufacturer Type Voltage - output Pinion/ring gear (No. of teeth)	M005T27671 Mitsubishi Electric Pinion-shift type 24 volts - 3 kilowatts 11/132
	Alternator	Model Manufacturer Type Voltage - current Rated voltage generating speed, rpm Rated output generating speed, rpm Maximum permissible, rpm Speed ratio to crankshaft	$AP4012B_1$ Mitsubishi Electric 3-phase, enclosed type 24 volts - 12.5 amperes 1100 1900 7000 1.68
	Regulator unit	Model Manufacturer Type Voltage regulator cut-in voltage Safety relay cut-in voltage	$RMS4227C_9$ Mitsubishi Electric Voltage regulator 27.5 ~ 30.5 volts at 3000 rpm (alternator speed) 5 volts, max.

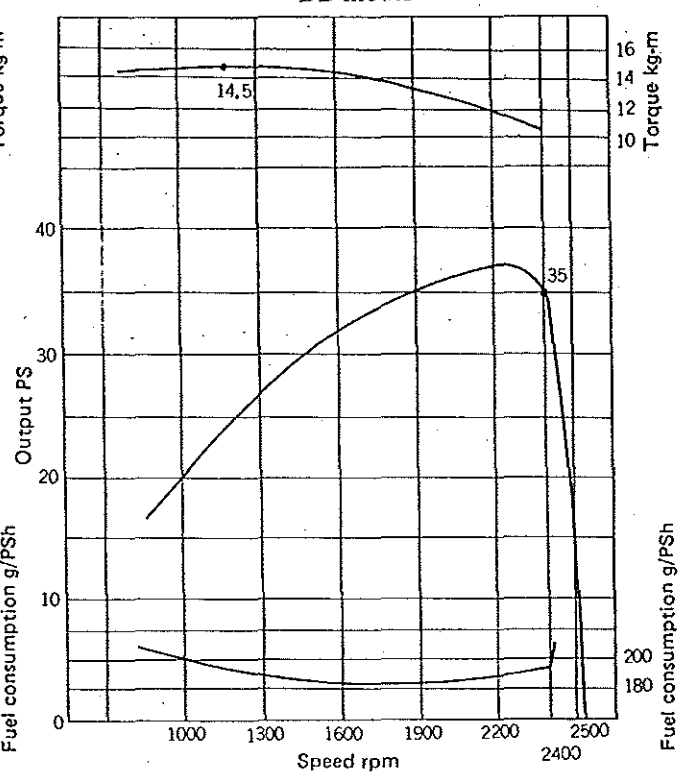
Performance curves

Fully equipped (with fan, alternator and air cleaner)
Corrected to standard conditions [760 mmHg (29.9 in. Hg) pressure, 20°C (68°F) temperature and 65% humidity]

DPS model

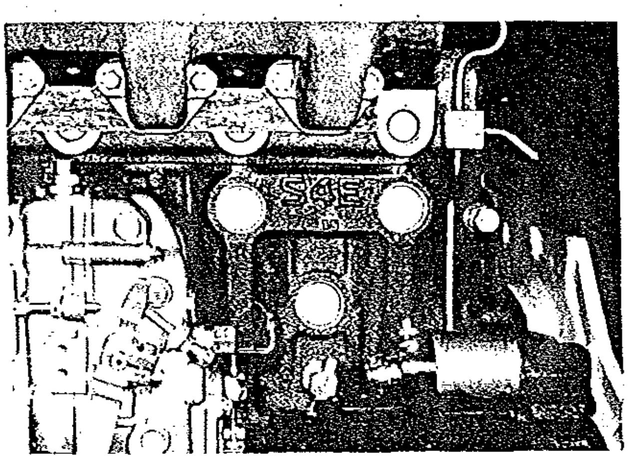


DD model



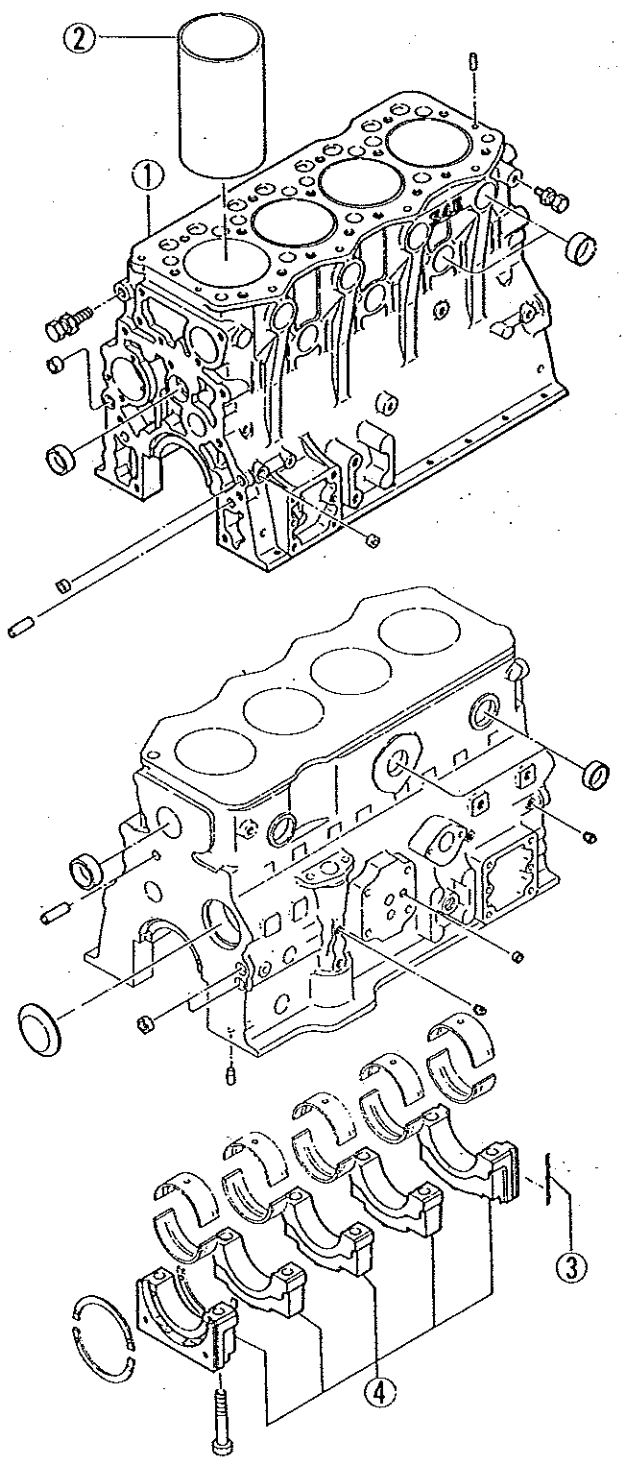
Location of engine serial number

The engine serial number is embossed on the upper left hand side, directly above the starting motor, as shown below.



Engine serial number

Crankcase



1-Crankcase 3-Side seal
2-Cylinder sleeve 4-Bearing caps

Crankcase and cylinder block

Crankcase

The crankcase and cylinder block are in one, shaped as a single casting, into which the cylinder sleeves made of a special cast iron are press-fitted. The sleeves are of "dry" type: they are not in direct contact with engine coolant.

The crankcase as a whole is designed for high rigidity; the strength built into it is calculated to withstand, with an ample margin, the severe cyclic stress of complex nature imparted by the internal running parts.

These stresses vary from one part of the crankcase to another as in any diesel engine; the needed rigidity and durability are secured by the skirt section, which is sized more substantial and extending far below the level at which conventional-design crankcases are terminated to mate with the oil pan.

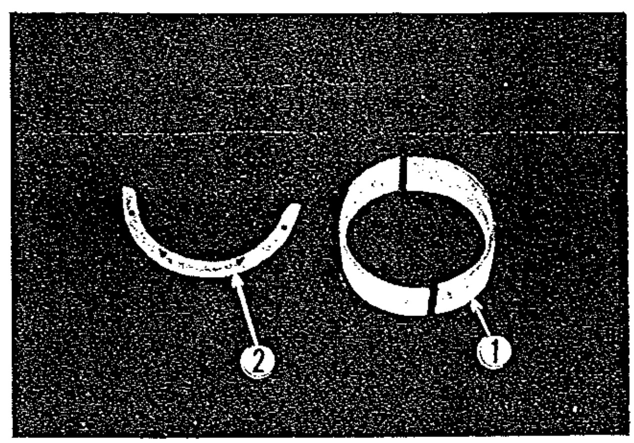
Each main bearing cap is fitted into and held by the crankcase, thus providing a more reliable support for the crankshaft at five places along its length.

Main, thrust and big-end bearings

The five main bearings are of shell type, each consisting of two half shells, there being no distinction between the two: each may be located on top or bottom at the time of bearing installation in engine reassembly.

Crankshaft thrust is taken up at No. 5 journal. Three bearing plates, each in the form of half-ring, are used: two on the rear and one on the bottom front side of No. 5 bearing. These thrust plates are held in place by spring pins.

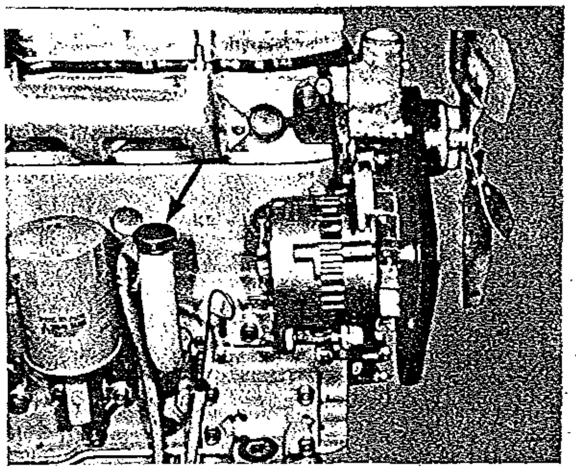
Connecting-rod bearings too are of shell type, each shell being of tri-metal design. The shell is essentially a kelmet metal fused to a steel backing base and covered by an overlay of a lead-tin alloy deposited by plating.



1-Main bearing 2-Thrust bearing

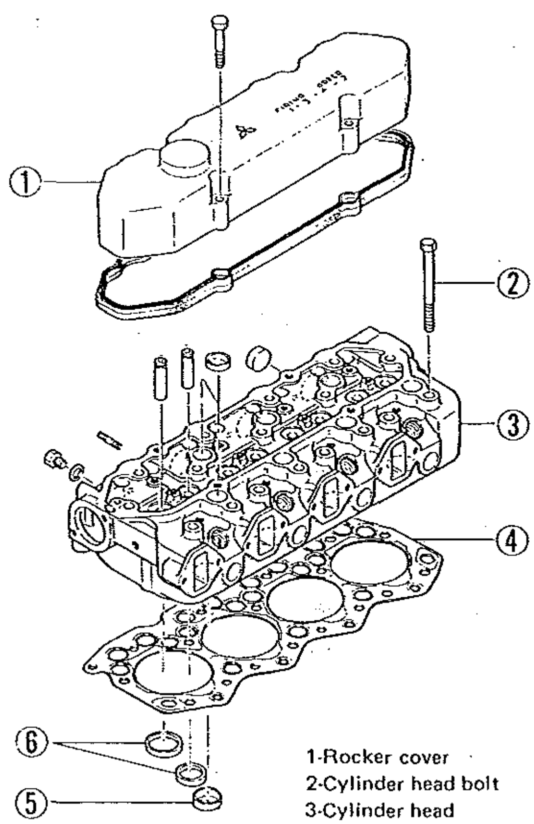
Air breather

The breather for letting fresh air into and letting out fumy air from the crankcase is located on the right-hand side of the engine. It prevents the pressure inside the crankcase from building up and thus minimizes the amount of lube oil getting into the combustion chambers.



Air breather

Cylinder head



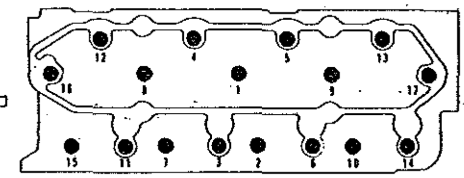
1-Rocker cover
2-Cylinder head bolt
3-Cylinder head
4-Gasket
5-Precombustion chamber jet
6-Valve seat

Cylinder head

Cylinder head

The cylinder head is a single-piece casting, elaborately jacketed for improved cooling and also for greater structural rigidity. Exhaust ports, intake ports and precombustion chambers, each numbering four, are cast out inside the head. The exhaust ports open out to the right, and the intake ports to the left.

A total of 17 bolts secure the cylinder head to the cylinder block. The positions of these bolts are sequentially referred to in the tightening procedure, and are numbered sequentially, starting with "1" and ending with "17" as shown.



Tightening sequence

Precombustion chambers

The precombustion chamber is formed with a cast-out space and an orifice piece – precombustion chamber jet – fitted into the cylinder head from its gasketed side. The shapes of the piston crown and the communicating orifice are such as to produce good turbulence even when the engine is running slowly. The glow plug, sticking out into the ante chamber – precombustion chamber – right beside the injection nozzle is a starting aid in cold weather.

Cylinder head gasket

The gasket for sealing the joint between cylinder head and cylinder block is essentially an asbestos insulator sandwiched between two thin steel sheets, with its combustion chamber holes being edged in apron fashion by stainless steel grommets. The bottom surface in contact with the cylinder block is coated with a special sealing compound for improved sealing effect.

Rocker cover

The rocker cover is aluminum alloy in material.

Valves, valve seats and springs

The intake valve has its disc sized as large as possible for increased suction efficiency.

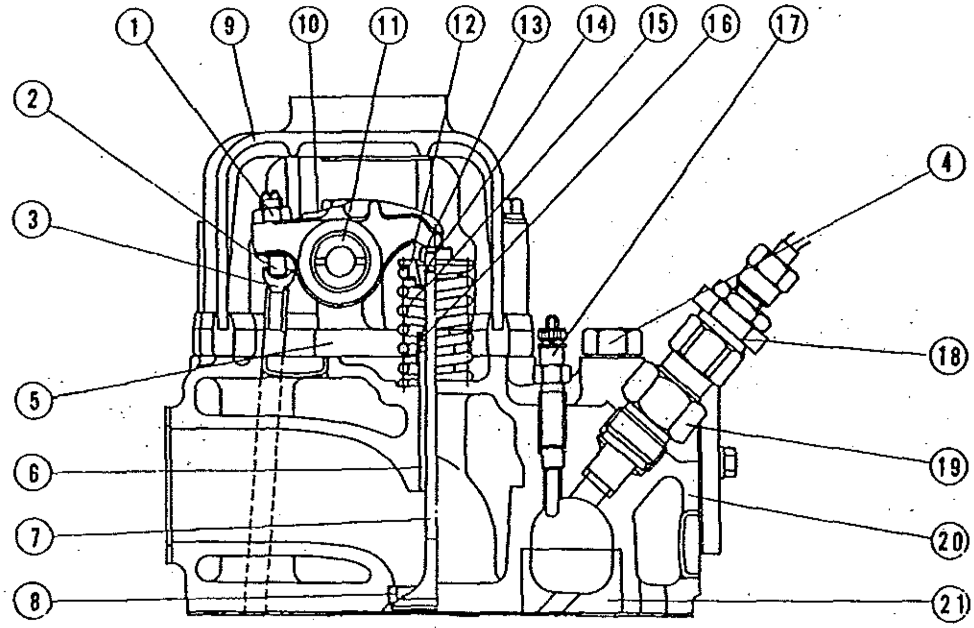
The material of valves is heat-resistant steel having good hot-hardness. This steel used in exhaust valves is of a special kind having extra high resistance to high-temperature creeping, burning and oxidation, fatigue and thermal shock.

Each valve guide is fitted with a stem seal to prevent lube oil from entering the combustion chamber.

A special heat-resistant material of high-durability type is used in the valve seats of both intake and exhaust valves.

Each valve is loaded by a single coil spring, whose turns are spaced apart with equal pitch.

The valve stem end is capped; the cap is in contact with the rocker arm and serves as the wearing member.

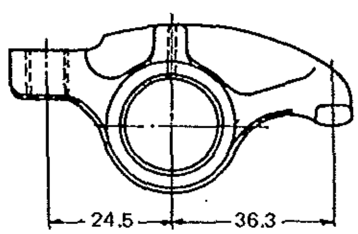


1-Lock nut	8-Valve seat	15-Spring
2-Adjusting screw	9-Rocker cover	16-Valve stem seal
3-Valve push rod	10-Rocker arm	17-Glow plug
4-Cylinder head bolt	11-Rocker shaft	18-Fuel leak-off pipe
5-Rocker bracket	12-Spring retainer	19-Nozzle
6-Valve guide	13-Valve cap	20-Cylinder head
7-Exhaust valve	14-Valve cotters	21-Precombustion chamber jet

Cylinder head — Cross section

Rocker arms, shaft and brackets

The rocker arm is a forging. Its tip for pressing down the valve stem is induction-hardened for increased resistance to wear. Its bore for admitting the rocker shaft is bushed; the bushing is lead bronze in material.



Rocker arm

The rocker shaft is hollow; one end of it is plugged while the other end admits lube oil for lubricating the rocker arms. The external surface of this shaft is hardened by nitriding at low temperatures.

The four rocker brackets are alluminum alloy castings shaped identically.

Main moving parts

Crankshaft

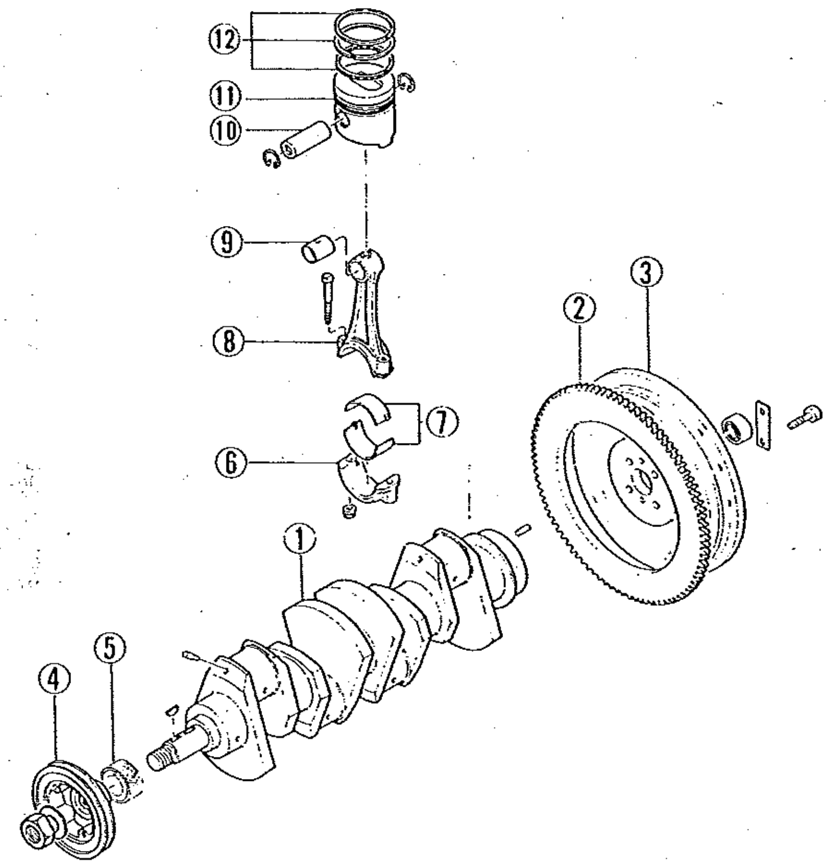
The crankshaft is a single-piece forging complete with balance weights. Its journals and crankpins are sized large to increase its rigidity, and are case-hardened by induction heating.

Flywheel

The cast-iron flywheel carries the pilot ball bearing for holding the forward end of clutch shaft. The flywheel is doweled to the crankshaft and secured by four bolts.

Ring gear

The ring gear is of a high carbon steel, its gears are hardened by induction heating. The ring itself is shrink-fitted to the flywheel. There are 132 gear teeth, each tooth being chamfered at its end facing the starter drive pinion in order to facilitate the meshing action of the pinion.



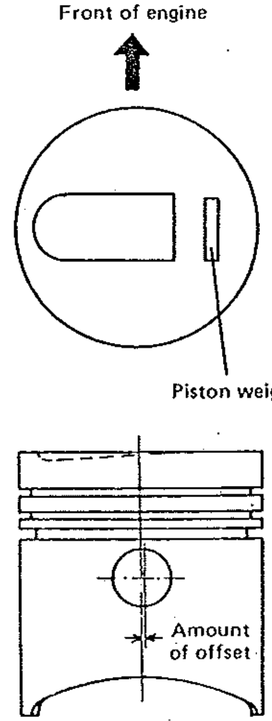
1-Crankshaft
2-Ring gear
3-Flywheel
4-Crankshaft pulley
5-Crankshaft gear
6-Connecting rod bearing cap
7-Connecting rod bearing (shells)
8-Connecting rod
9-Piston pin bushing
10-Pinton pin
11-Piston
12-Piston rings

Main moving parts

Pistons

The pistons are of an aluminum alloy. The piston crown is recessed in such a way as to promote turbulence in both precombustion chamber and main chamber. As seen in side view, the piston is slightly tapered to present an increasingly large diameter toward its skirt; and, as seen in plan view, it is slightly oval. These two features are calculated to compensate its roundness for unequal thermal expansion at the operating temperature.

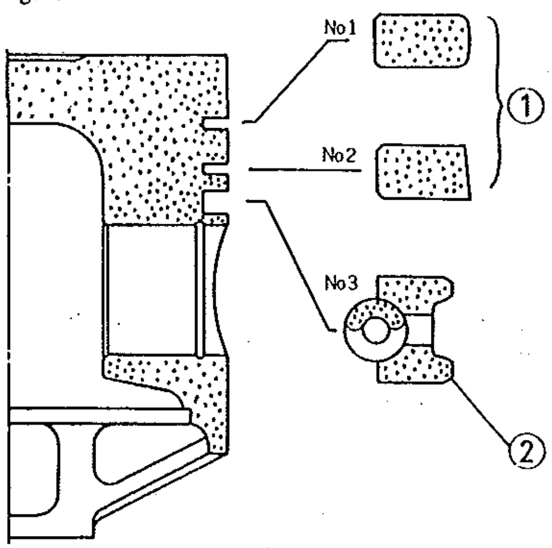
The piston pin hole has its axis slightly offset toward anti-thrust side in order to minimize piston noise. Each piston has its weight indicated on its crown by punching. All four pistons are required to have the same weight within a given tolerance so that the vibration of the main moving parts during operation will be minimized.



Piston weight marking and pin hole offset

Piston rings

Each piston is fitted with three rings: two compression rings (Nos. 1 and 2 as counted from top) and one oil ring. No. 1 ring and oil ring have their faces chrome-plated. No. 2 ring is tapered. An expander coil is provided inside the oil ring to augment its elastic strength.



1-Compression rings 2-Oil ring

Piston rings

Piston pins

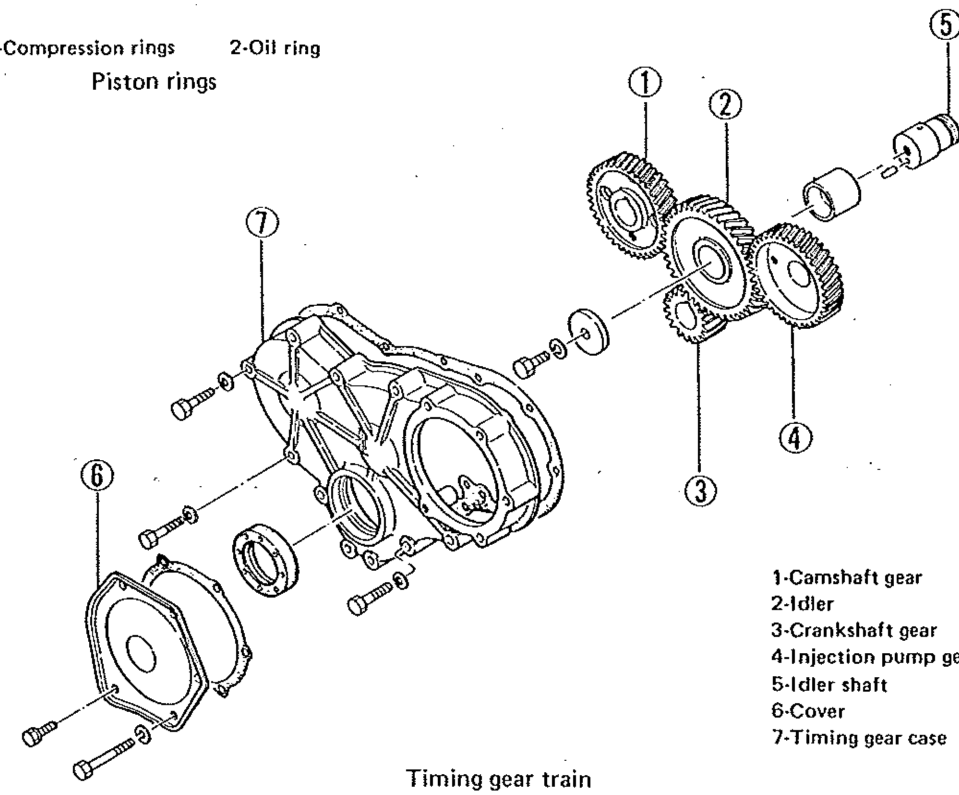
The piston pin is hollow. Its sliding surface is case-hardened by carburization. It is fitted to the piston and carries the small end of the connecting rod in "full floating" manner. The pin inserted into the piston is retained in place by a snap ring fitted into the pin hole at each end.

Connecting rods

The connecting rod is a die forging, shaped to present an "I" cross section in its shank in order to minimize its own mass and yet to retain large strength necessary for withstanding the high compressive force exerted by the piston and also the complex bending stress. Its minimized mass reduces the stresses due to its own inertia.

A lead bronze bushing is press-fitted into its small end. A kelmet bearing is used in the big end to cope with the high bearing load to which the big end is subjected.

Timing gear train



1-Camshaft gear
2-Idler
3-Crankshaft gear
4-Injection pump gear
5-Idler shaft
6-Cover
7-Timing gear case

Timing gear train

Timing gear case

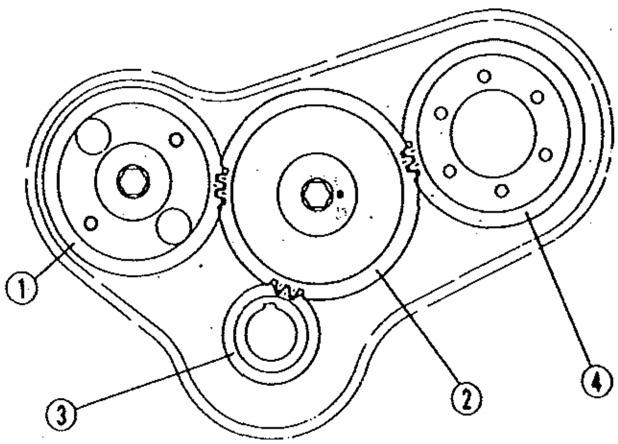
To the front end face of crankcase is attached a large mounting plate called the front plate. To this plate is bolted the timing gear case, in which the timing gears are housed.

The front plate is doweled to the crankcase by two pins. The fuel injection pump is mounted on the front plate. Thus, the position of the injection pump relative to the engine is determined by these two dowel pins.

The forward end of crankshaft extends through the timing gear case to drive the cooling fan through crankshaft pulley. An oil seal is provided in the timing gear case to prevent oil from leaking along this part of crankshaft. The oil seal is doweled to take a given position.

Timing gears

Helical gears made of high carbon steel are used to drive injection pump and camshaft from crankshaft through an idler. The teeth of these gears are finished by shaving for increased durability and high machining accuracy. Because of helical mesh, these gears run quietly and assure accurate timing action.



1-Camshaft gear (No. of teeth: 38)
2-Idler (No. of teeth: 43)
3-Crankshaft gear (No. of teeth: 19)
4-Injection pump gear (No. of teeth: 38)

Timing gear configuration

Camshaft

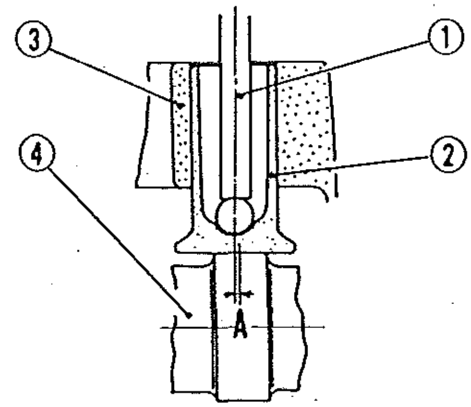
The camshaft is a high carbon steel in material, and its cam surfaces are chill hardened.

The front journal has an oil hole, through which the lube oil under pressure flows from crankcase toward the valve mechanism over the cylinder head. A part of this oil lubricates the thrust face of camshaft.

Tappets

The tappet is of flat type and shaped pot-like to admit the push rod into its hollow. It is cast iron in material; its cam-riding face is hardened by chilling. This design provides a lightweight tappet, resistant to wear and strong and thus suited to high-speed operation. All tappets, regardless of whether they are for intake valves or exhaust valves, are identical and, therefore, identified by the same part number.

The axis of the push rod is slightly offset from the center of the cam. This offset is calculated to cause the tappet to rotate during operation and thus to prevent its cam-riding face from wearing unevenly.



1-Valve push rod
2-Tappet
3-Crankcase
4-Camshaft
A-Amount of offset

Tappet — Cross section

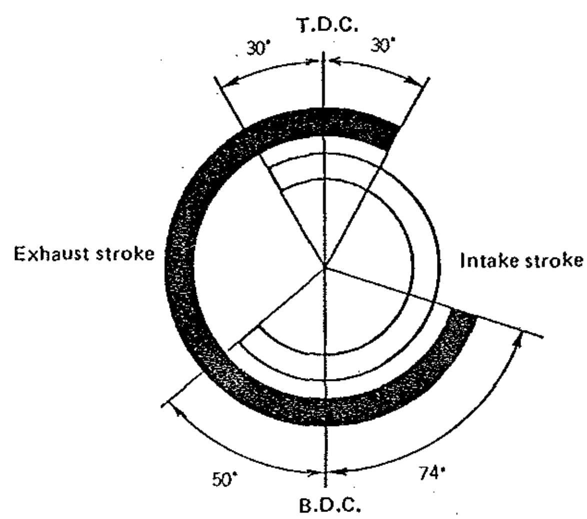
Valve push rods

Made from carbon-steel pipe stock, the push rods has a steel ball welded to its bottom end and a caved-in piece welded to its top end. By the steel ball, the push rods stands on the spherical seat provided in the tappet and, by the caved-in top end, it bears against the adjusting screw threaded in the rocker arm. These contacting ends are hardened by carburization.

Valve timing and valve lash

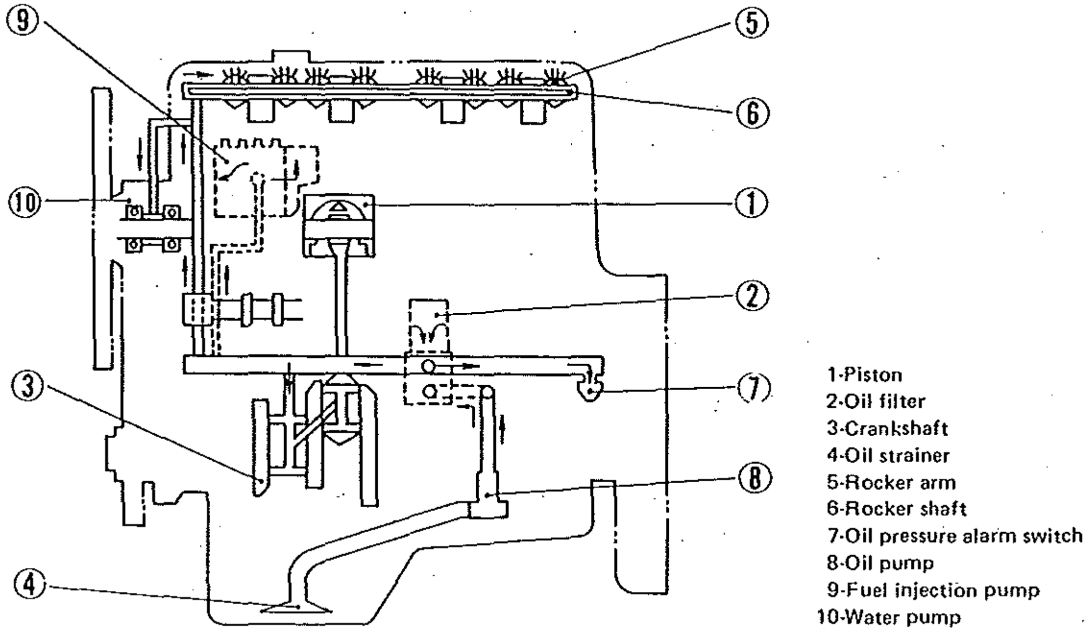
Valve lash is prescribed to be 0.25 mm (0.0098 in.) (cold) for both intake and exhaust valves, and the valve mechanism is timed to actuate the valve as follows:

INTAKE VALVES	.....	open at 30° B.T.D.C.
		close at 50° A.B.D.C.
EXHAUST VALVES	...	open at 74° B.B.D.C.
		close at 30° A.T.D.C.



Valve timing diagram

Lubrication system



Lubrication oil circuit

Lube oil circulation

A trochoid rotary pump draws oil in the oil pan and delivers it under pressure to a full-flow oil filter, from which the cleaned oil is forwarded into the oil gallery inside the crankcase. From the gallery, the oil is distributed to the various parts of the engine. The pump is driven from the camshaft.

The oil filter is of a cartridge type containing a replaceable element through which the oil is forced. The element becomes increasingly dirty as the solid particles accumulate on and in its texture, thereby increasing the difference in pressure between inlet side and outlet side. The element is to be replaced before the differential pressure rises to a level at which the valve located in the bypass passage opens to allow the oil to bypass the element and flow directly into the oil gallery.

The bypass valve is an emergency means; it opens to avoid any critically reduced supply of lube oil to the running parts of the engine.

Oil pan

The oil pan is a sheetmetal vessel shaped deeper in its front part to provide an oil sump. The oil sump is so located because of its position in the machine. The oil level gauge is located at its right-hand side.

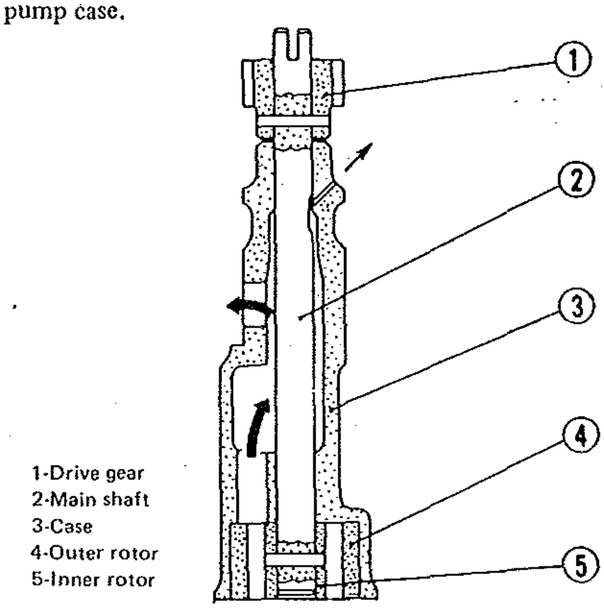
The gasket, through which the oil pan is attached to the crankcase, is of rubberized cork.

Oil strainer

The strainer is a metal screen fitted to the suction side of the oil pump. It serves the purpose of preventing any large-size solid particles from entering the pump.

Oil pump

The pump is located inside the crankcase at its right-hand rear portion. Its main shaft is driven from the skew gear formed of the camshaft. Being a trochoidal rotary pump, it has two rotors, inner and outer. Inner rotor is mounted on the shaft and drives outer rotor inside the pump case.



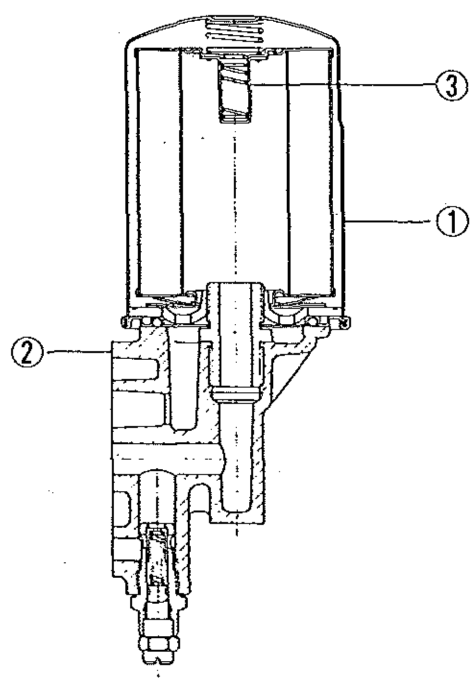
Oil pump — Cross section

It is a positive displacement pump with its rotors in trochoidal mesh. This mesh is relatively free of abrasive action and enables the rotors to serve long and keeps up its pumping performance. Its design performance is as follows:

Pump speed	Displacement	Discharge pressure
1200 rpm	19.2 liters (1172 cu in.)/minute	3 kg/cm^2 (43 psi) at 50°C (122°F)

Oil filter

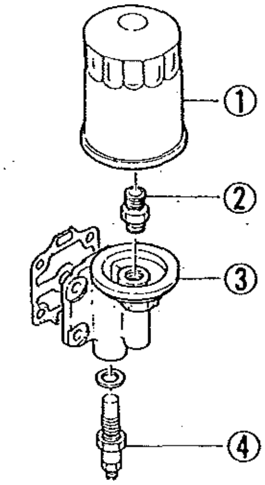
The filter is mounted on the right-hand side of crankcase at its center part. The valve mentioned above for letting the oil bypass the element is actually a relief valve located in the center portion of the element. This valve is set to open when the differential pressure across the element rises to 1.0 ± 0.2 kg/cm^2 (14.2 ± 2.8 psi); when the valve opens, the oil flows directly from inlet side to outlet side. The filter element must be serviced regularly or before the element becomes so dirty as to actuate this bypass valve.



1-Element 3-Bypass valve
2-Bracket

Oil filter — Cross section

The oil filter head has a built-in relief valve operating in response to the oil pump discharge pressure. This valve starts relieving when the pressure rises to 3 ± 0.3 kg/cm^2 (43 ± 4.3 psi), thereby bleeding the excess oil to the oil pan and limiting the pressure of oil reaching the engine oil gallery to a constant level.



1-Element
2-Center screw
3-Bracket
4-Relief valve

Oil filter

Fuel system

Fuel circuit

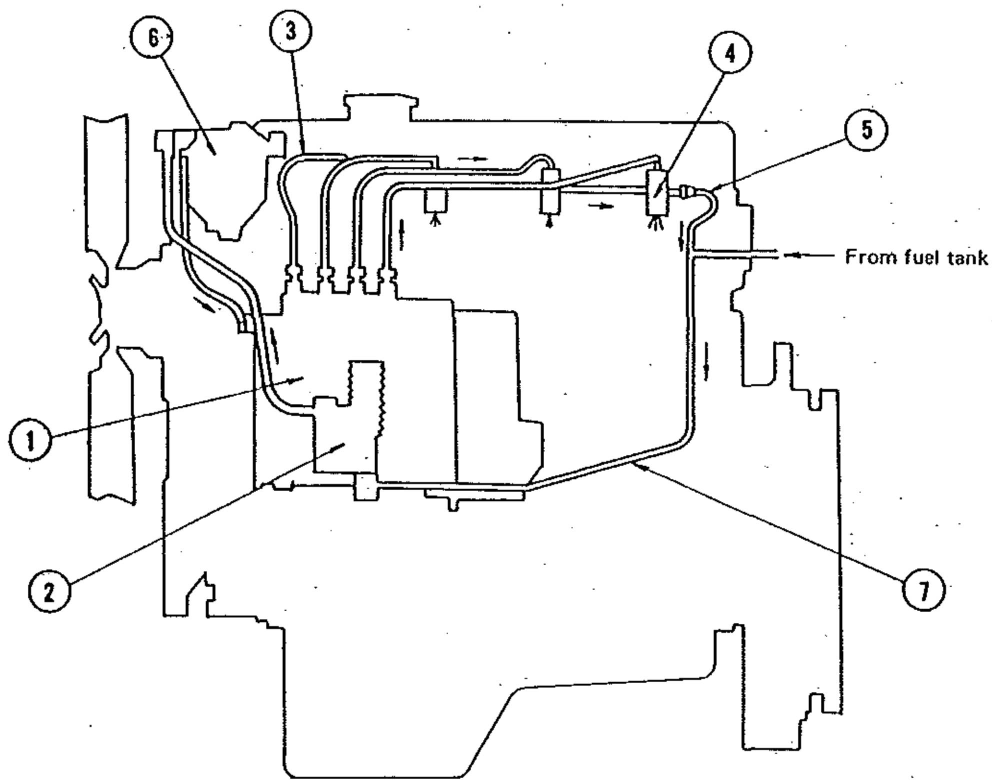
The fuel feed pump, mounted on the fuel injection pump body and forming a part of the injection pump unit, draws fuel from the fuel tank and delivers it through the fuel filter to the gallery inside the injection pump.

The injection pump is of individual plunger type, consisting of four plunger pump elements which are driven from a common camshaft. Each pump element delivers, intermittently, a shot of high-pressure fuel oil to its injection nozzle through its own injection pipe. These shots are synchronized to the diesel cycle in each cylinder and timed by the setting of the timing mechanism.

"Injection quantity," or the amount of fuel delivered uniformly by the four pump elements to the engine through their injection nozzles, is controlled from the accelerator through a linkage and automatically adjusted by the injection pump governor on the basis of engine speed and load requirements.

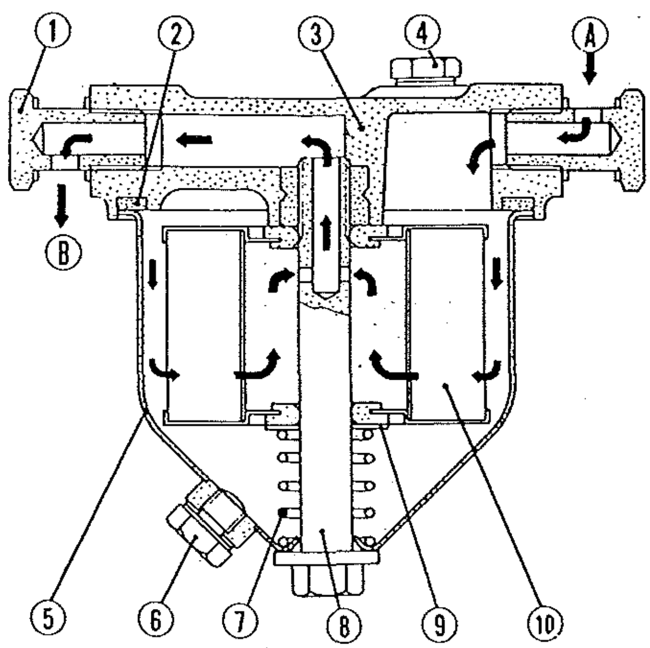
Each injection nozzle is spring-loaded to spray fuel at pressures not lower than 120 kg/cm^2 (1706 psi). A part of each shot of fuel reaching the nozzle returns to fuel feed pump through a leak-off pipe common to all four nozzles. The injection nozzle is of throttle type (as distinguished from standard type), and sprays fuel in atomized form into the precombustion chamber.

The governor built in the injection pump body is a mechanical all-speed governor, which limits the maximum and minimum engine speeds and actuates the control rack of the injection pump to maintain a constant engine speed under varying load condition at a speed level proportional to the position of the accelerator.



Fuel circuit

Fuel filter



Fuel filter – Sectional view

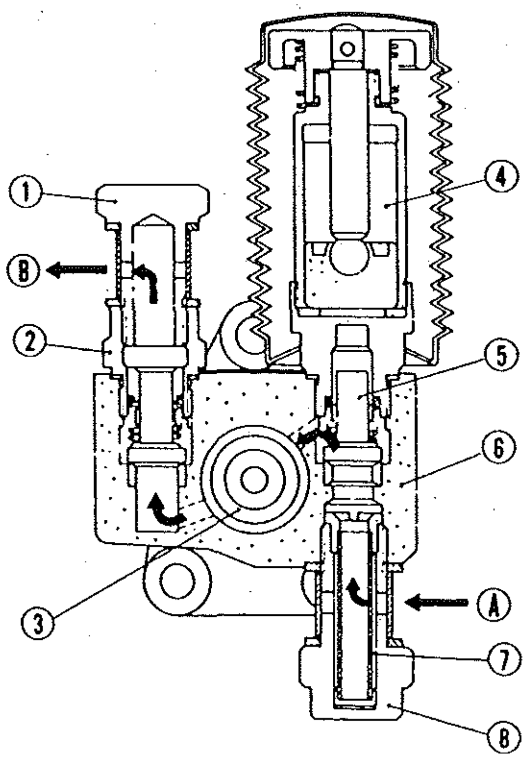
The fuel filter is located forward of the intake manifold. Its filtering element is made of a special paper designed to provide high filtering performance and large capacity.

Total area of filtration	850 cm^2 (132 sq in.)
Filtering element mesh	2 microns (μ)

Fuel feed pump

The camshaft in the bottom section of the injection pump has an eccentric cam besides the cams for actuating the individual pump elements. By this eccentric cam, the pumping plunger of the feed pump is actuated to draw fuel through the inlet strainer and forward it with a discharge pressure limited to 2 kg/cm^2 (28.4 psi) to the injection pump.

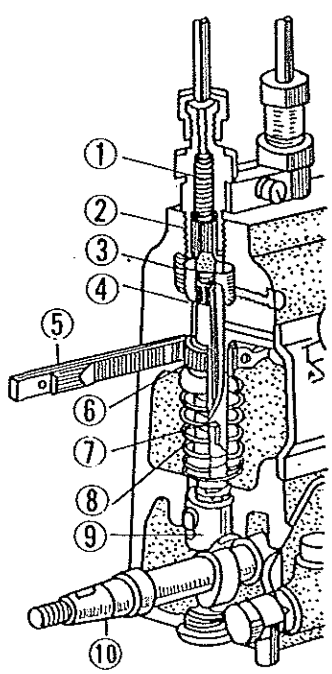
A means of manually priming the fuel circuit ahead of the feed pump is provided in this pump. It consists of a plunger and a knob. Pushing the knob in rapid repetition sends the fuel forward. The fuel circuit from the feed pump through the fuel filter to the injection pump can be primed in this manner. This feature is utilized also in bleeding air out of the fuel circuit.



1-Hollow screw　6-Feed pump housing
2-Valve support　7-Gauze filter
3-Piston spring　8-Hollow screw
4-Priming pump　A-From fuel tank
5-Check valve　B-To fuel filter

Fuel feed pump — Cross section

Fuel injection pump



1-Valve spring
2-Delivery valve
3-Cylinder
4-Plunger
5-Control rack
6-Control pinion
7-Control sleeve
8-Plunger spring
9-Tappet
10-Camshaft

Fuel injection pump

(1) Description

The pump body is an aluminum alloy casting and houses all the moving parts of pump elements and the camshaft. The governor housing is attached to one end of the pump body.

The camshaft is supported by two tapered roller bearings. Like the engine camshaft, it has four cams, one for each pump element, and is driven from the crankshaft through a train of gears arranged for a gear ratio of 2 to 1. For each two rotations of crankshaft, the injection pump camshaft rotates once.

The pump element consists of a plunger, barrel (cylinder), tappet, plunger spring, control pinion and spring-loaded delivery valve. The tappet rides on the cam and pushes the plunger upward for each rotation of camshaft. As the plunger rises, the fuel in the barrel becomes compressed and is forced out through the delivery valve into the injection pipe. The upward plunger stroke, effective in compressing or pressurizing the fuel, is variable, and is varied by means of the control rack and pinion in the manner to be explained later.

The delivery valve, through which a shot of fuel is forced out into the injection pipe by each upward motion of the plunger, is essentially a check valve having a special function of quickly reducing the line pressure the moment the plunger begins to descend. This quick relief of line pressure is necessary to prevent the injection nozzle from dribbling at the end of each injection. How this is accomplished will become clear.

Injection pump data

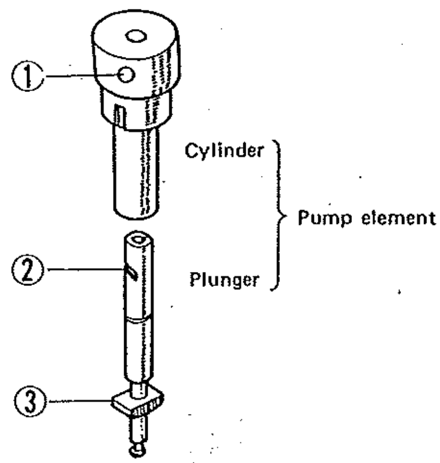
Cam lift	8 mm (0.315 in.)
Plunger diameter	6.5 mm (0.256 in.)
Delivery valve dia.	6 mm (0.236 in.); retraction volume 51 mm^3 (0.003 cu in.)/stroke
Injection order	1 – 3 – 4 – 2
Injection interval	90° ± 30′

(2) Pumping action

a. Pump element construction

The principal parts of the pump element are the cylinder (barrel) and plunger, as shown in this perspective view. Both are machined to extremely close tolerances; the plunger slides up and down in the bore of the cylinder with such a small radial clearance as to make the fit virtually oil-tight.

The two – cylinder and plunger – are selectively combined during manufacture and must be handled as an inseparable pair.



1-Feed hole
2-Control groove
3-Driving face

Pump element

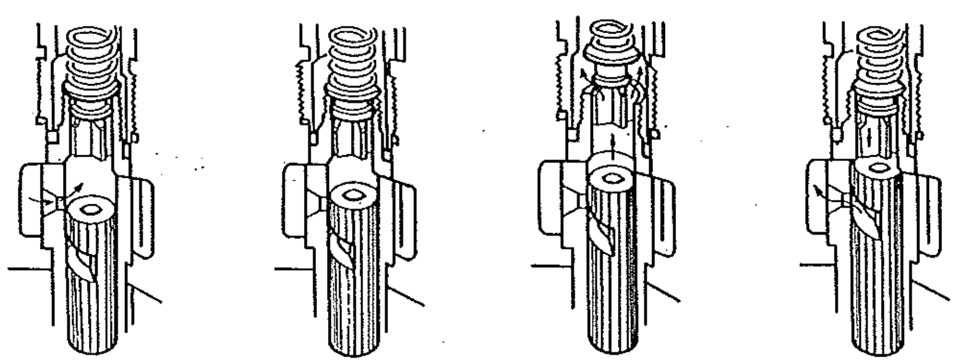
A helical slot is milled in the top portion of the plunger. Called the control groove, this slot is communicated to the space above the plunger through a center hole (or a vertical groove in other designs).

The cylinder has a feed hole, through which the internal space is communicated to the fuel chamber or gallery outside. Fuel (under pressure) flows through this hole when the plunger is down. As the plunger rises, its top portion covers up the feed hole and, from this moment on, the plunger compresses the fuel above it until the control groove meets the hole. Effective stroke refers to that length of the plunger that keeps the feed hole covered during the upward stroke. This length or stroke can be increased or decreased by angularly displacing the plunger.

b. Pump element operation

The following description is referenced to the four cutaway views below:

1. BOTTOM OF STROKE: Fuel flows into the inside space – delivery chamber.
2. BEGINNING OF PRESSURIZATION: The cam pushes up the plunger and, as it rises, its top portion covers the feed hole.
3. FUEL DELIVERY: Fuel is compressed; it forces the delivery valve against its spring to unseat the valve. From this moment, the fuel in the line from delivery valve to injection nozzle is pushed by the plunger.
4. END OF EFFECTIVE STROKE: Pressurization ceases and the delivery valve seats itself under the force of its spring. This valve has an annular recess. As the valve comes down, a small amount of fuel becomes trapped and is extracted from the injection line, so that the pressure ahead of the valve drops very sharply to enable the injection nozzle to snap into closed position. The amount of fuel so drawn back is called "extraction volume," an important factor of fuel injection.



(1) Bottom of stroke (2) Beginning of pressurization (3) Fuel delivery (4) End of effective stroke

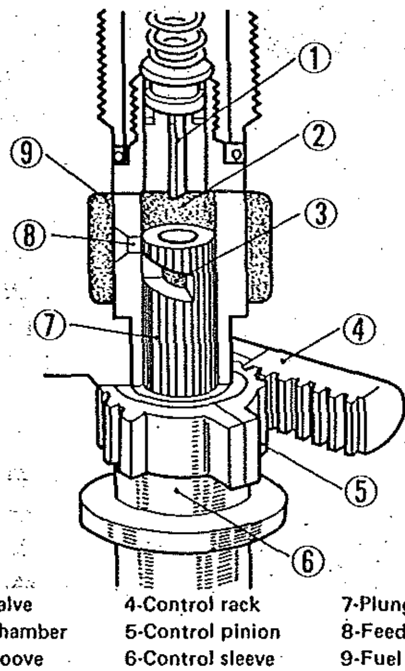
Pump element operation

(3) Injection quantity control

a. Plunger rotating mechanism

The control sleeve, around which the control pinion is fastened, surrounds the lower portion of the cylinder (barrel). The sleeve has two nocks or slots in its bottom end; the driving face or flange formed of the plunger is engaged with these slots, so that the plunger rotates as the sleeve is turned.

The slots are long enough to permit the drive face or flange to slide vertically for full plunger stroke. The control pinion is engaged with the teeth of control rack.

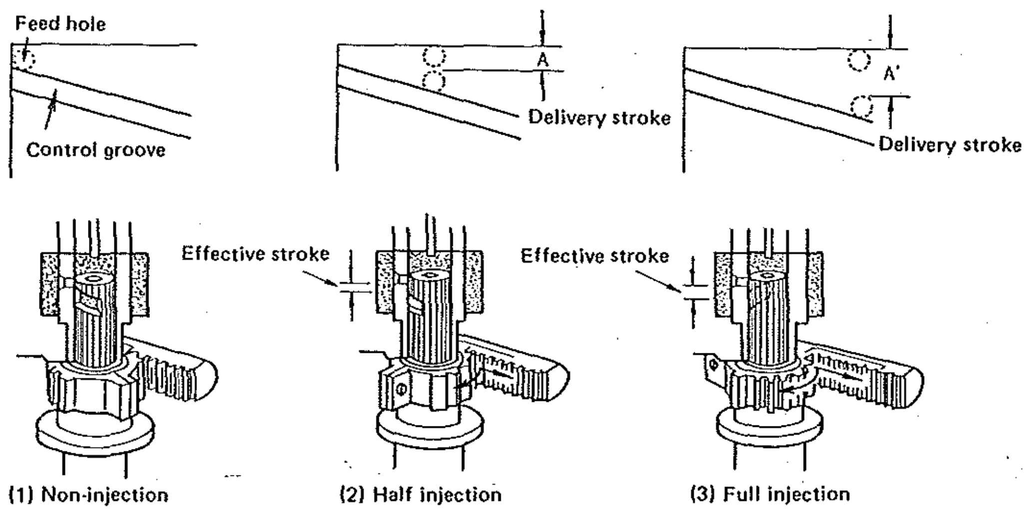


Plunger rotating mechanism

b. Control action

The amount of fuel delivery, or injection quantity, per stroke is determined primarily by the effective pumping stroke of the plunger. The control groove milled out in the plunger being slanted, turning the plunger around its axis changes its effective stroke, and this turning is effected by moving the control rack.

How the effective stroke is varied is illustrated in three views of the plunger, cylinder, control pinion and rack:

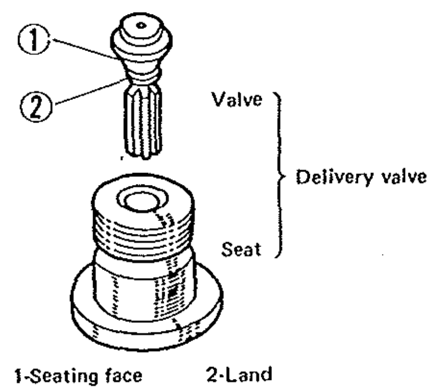


Injection quantity control

(4) Delivery valve

The seat of the delivery valve takes its position right above the barrel and is held down tight by the screw-in pipe connection. The valve has its guide portion fitted into the bore of the seat, and is capable of moving vertically. A coil spring urges the valve downward to keep the valve in contact with the seat face by its conical face.

It should be noted that a land is formed of the valve, a little above its guide portion, forming an annular recess between it and the cone. This recess assumes importance in regard to "extraction volume," mentioned previously.



Delivery valve

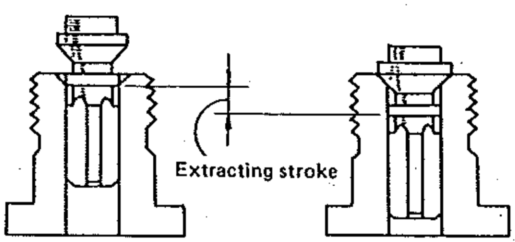
a. Check valve action

During normal operation, the valve spring keeps the valve seated when the plunger is in non-injection position or, if it is in injecting position, when it is moving on downward stroke. As the plunger pressurizes the fuel in delivery chamber to overcome the force of valve spring, the valve unseats and lets out the high-pressure fuel into the injection pipe.

b. Retracting action

Consider the downward movement of the delivery valve following the end of fuel pressurization. The land enters the bore of the seat as the valve goes down, so that the delivery chamber becomes isolated from the injection pipe. The further downward movement of the land draws a small amount of fuel from the pipe and, when the valve cone has seated fully, this fuel is in the annular recess (called "extraction volume").

By this extraction, which occurs within a flash of moment, the injection pipe becomes instantly de-pressurized, thereby enabling the injection nozzle to snap into closed position and thus preventing the secondary injection or dribbling from occurring after each fuel injection.



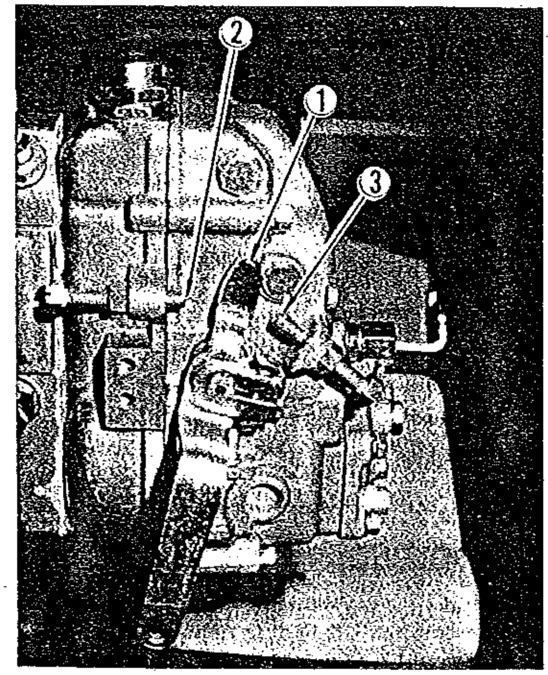
(1) Beginning of extracting action (2) End of extracting action

Type RSV governor

(1) Description

By type, the governor is a mechanical flyweight governor; by function, it is an all-speed governor operating in response to changes in engine speed to actuate the control rack in order to maintain engine speed at a constant level proportional to the set position of the accelerator. This governor function is in sharp contrast to that of a minimum-speed maximum-speed governor, whose control action is to limit the lowest and highest speeds of the engine, leaving the control of intermediate speeds to the operator.

The RSV governor too limits the lowest and highest speeds to provide a speed range over which it performs the governing action mentioned above. These limits, as well as its speed regulation, can be changed by means of adjusting lever and screws.



1-Adjusting lever 3-Idling set screw
2-Maximum speed stop screw

Governor

To make full use of the advantages inherent in this governor, it is well to know its characteristics, which may be summarized as follows:

(a) Compact and lightweight

(b) Automatic supply of excess fuel for starting

(c) Adjustable speed range and regulation for adapting the engine to each type of duty

(d) Maximum injection quantity for each speed level can be adjusted to suit what the engine demands, by adding an adaptor spring.

(2) Basic rules on governor setting

The governor is factory-sealed. Do not break the seal in an attempt to change the settings of critical parts unless you are qualified to do so.

1. Maximum speed stopper is set to supply the right amount of fuel to the engine at the upper limit of the speed range. Disturbing this setting is likely to result in lack of output power or in overspeeding.

2. Full load stopper is set to supply the right amount of fuel for full-load operation. Disturbing this setting is likely to result in lack of output power or in dirty or black exhaust smoke.

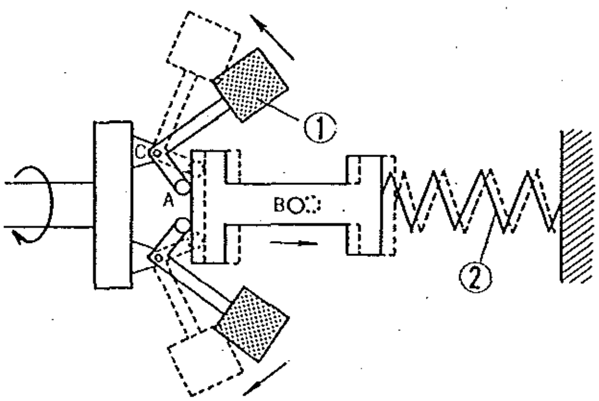
Adjusting screw for the swiveling lever is set at the position to which it has been backed away by 24 notches (6 rotations) or less from fully run-in position. Never try to back it away more than 24 notches or the adjusting screw will come off eventually to create a hazardous condition. (Refer to the part dealing with the adjustment of speed regulation.)

Unless you have overhauled RSV governors many times and can remember the overhauling procedure, be sure to refer to the disassembling and assembling procedures outlined in the latter section of this manual if you are to overhaul them.

Never re-use circlips, "E" rings and "O" rings removed in disassembly. Use new parts in reassembly.

(3) Operating principles

The fundamental principles of a flyweight governor are schematically illustrated here. Arms (A) of flyweights, pivoting around point (C), push on the spring-backed block, whose key point is indicated as (B). The push is due to the centrifugal force of revolving flyweights.



1-Flyweights　　2-Spring

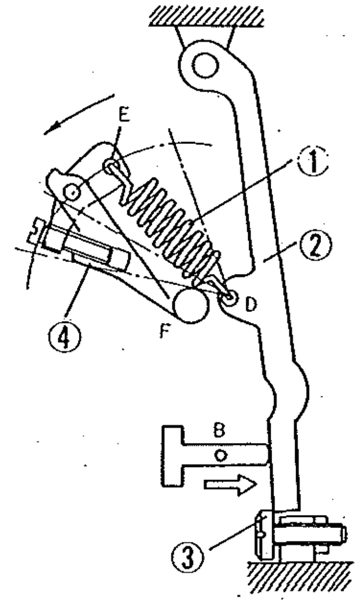
Principle of governing action

When the revolving speed is constant, the push is in balance with the counter-force exerted by the compressed spring. This is an equilibrium condition. When the speed increases, for instance, the whole system seeks a new equilibrium, relocating point (B) and block to the dot-line position.

In the injection pump, point (B) is connected through a linkage to the control rack; the rack is pulled or pushed to vary the injection quantity, thereby lowering or raising the engine speed.

(4) Control spring

It will be recalled that the spring rate (or constant) is the force required to stretch or compress it by unit length. Of course, this force is in the axial direction. For the tension lever, that part of the spring rate of the control spring, effective for pulling this lever, can be changed by angling the spring. Swiveling lever is the means of angling.



1-Control spring　　3-Full-load stopper
2-Tension lever　　4-Swiveling lever

Control spring operation

Note that hook hole (E) is in the arm of swiveling lever, and that this arm can be turned down (to reduce the tensile preload on control spring) or up (to increase the preload) by means of the adjusting screw. Thus, that component of the spring force acting on point (D) to turn tension lever can be set initially by positioning swiveling lever and also its adjusting screw. Our interest is not in how much force control spring exerts to tension lever but rather in that part of this force effective in turning the lever around its pivot point up above.

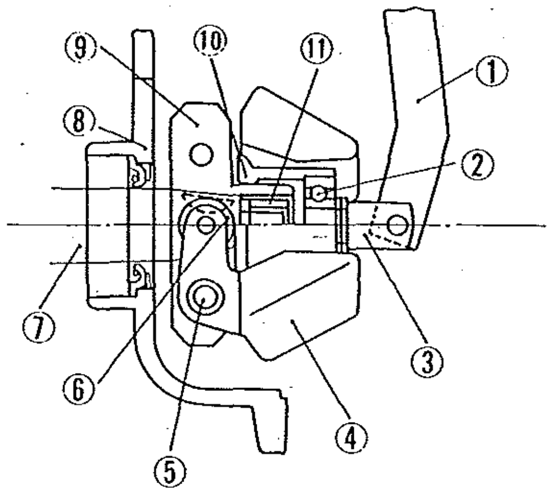
This arrangement of control spring (1) relative to tension lever (2) explains why, in the RSV governor, there is no need of using more than one control spring to change the governed speed (the speed which the governor operates to maintain) and to increase or decrease the speed regulation (or speed droop).

Note, also, that the block with its point (B) exerts push to tension lever in the direction of the arrow; this push is opposed by the pull of control spring. This opposing pull can be increased or decreased by turning the swiveling lever around its pivot (F). If tension lever happens to be off and away from full-load stopper, the increase or decrease of this pull (against a given push of the block) causes the control rack to move inward or outward, thus varying the rate of fuel injection to raise or lower the engine speed; consequently the push increases or decreases to introduce a new equilibrium.

(5) **Construction details**

a. Flywheight device

The two flyweights are mounted on bushing keyed to camshaft and secured by round nut. Since each flyweight can turn around the shaft, and because its inner tip has a roller, these two symmetrically arranged flyweights are capable of pushing on the flanged face of sleeve by their rollers through rolling contact.



1-Guide lever	7-Camshaft
2-Ball bearing	8-Governor housing
3-Control block	9-Camshaft bushing
4-Flyweights	10-Governor sleeve
5-Weight supporting shaft	11-Round nut
6-Roller	

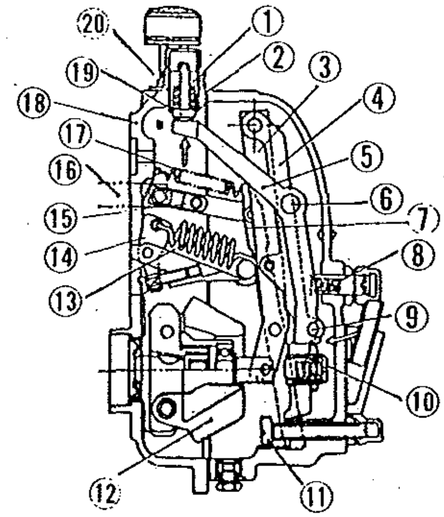
Flyweights and related parts

Sleeve is arranged to slide axially along bushing and rotate around control block, there being provided a ball bearing between sleeve and block. The outer end of block is pinned to guide lever.

Thus, flyweights spread apart more or less depending on the running speed of camshaft, and push control block (toward the right in the illustration) more or less through sleeve. In other words, the rotating speed is translated into a linear force and hence a resultant linear movement of block by the medium of centrifugal force in opposition to the force of springs.

b. Levers and springs

We are now to see how the speed-dependent movement of guide lever is transmitted to the control rack of the injection pump. To do so, we must take note of levers and springs intervening in this transmission. To be examined are these levers and springs: adjusting screw related to torque control lever, torque spring on adjusting screw; guide lever; tension lever; control lever; idling spring; adaptor spring; control spring; swiveling lever; start spring.



1-Adjusting screw	11-Full-load stopper
2-Torque spring	12-Flyweights
3-Guide lever	13-Control spring
4-Tension lever	14-Swiveling lever
5-Torque control lever	15-Shackle
6-Pin A	16-Control rack
7-Control lever	17-Start spring
8-Idling spring	18-Governor housing
9-Tension lever pin	19-Adaptor
10-Adaptor spring	20-Lock nut

Governor — Cross section

All these levers are movable, each being pivoted to the stationary part of the governor at its top or bottom end and pinned to another lever at its other end or intermediate point.

Tension lever and guide lever are pendent from a common pivot shaft (lever supporting shaft). Control lever pivots on a fork joint (stationary) by its bottom end, and its intermediate point is pinned to a halfway point of guide lever, whose bottom end is pinned to the control block, as mentioned before.

The top end of control lever is linked to control rack through shackle. Control spring is hooked between swiveling lever and tension lever. Start spring is hooked between the top end of control lever and a stationary anchor point. Adaptor spring is mounted inside the tension lever, and opposes the control block. Idling spring is mounted in the governor housing as if it were a cushion for the tension lever.

The shaft by which the swiveling lever turns extends through the housing and, outside the housing, is gripped by the adjusting lever. Turning this lever turns the swiveling lever inside. It is to this adjusting lever that the accelerator (lever or pedal) is linked; and it is by turning this adjusting lever that the governed speed is manually raised or lowered. Once the adjusting lever is set, the governor operates to maintain a constant speed corresponding to the position of the adjusting lever.

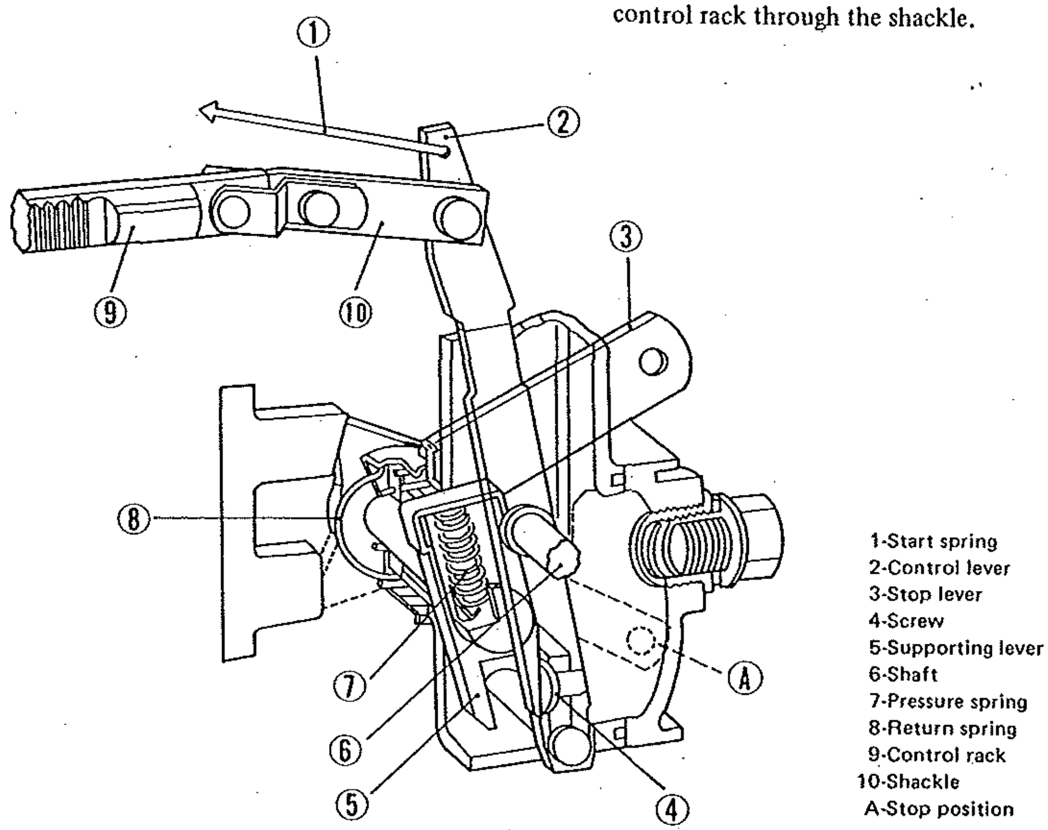
The angular range of the adjusting lever is limited by the maximum speed stopper at the upper end of the range and by the stop adjust screw.

How these levers and spring cooperate will become clear in the subsequent description of the governor operation in three parts: ENGINE STARTING, IDLING CONTROL and MAXIMUM SPEED CONTROL. Before we consider the operation, we shall discuss a special device – STOP DEVICE.

c. Stop device

In the standard RSV governor, which is not equipped with the stop device, turning the swiveling lever all the way to reduce the preload (by control spring) to zero causes the control lever to pull the control rack outward, thereby reducing the fuel injection to zero. This is the way a running engine is stopped.

The stop device, if provided, makes it possible to pull the control rack directly and independently of the adjusting lever (outside) and swiveling lever (inside). This device consists of a stop lever, a supporting lever, two springs and a screw, all associated with the control lever connected to the control rack through the shackle.



Stop device

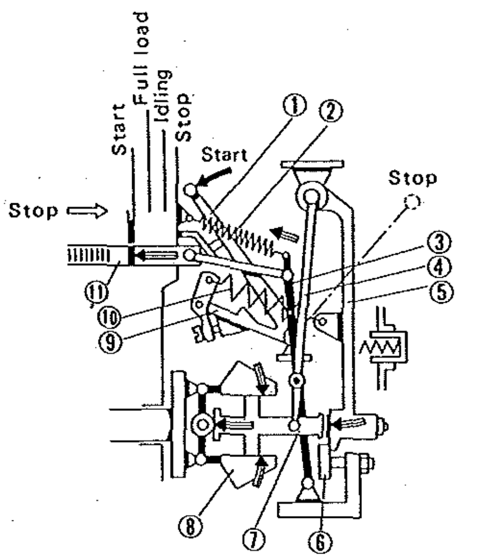
Pushing down the stop lever to its stop position (A) tilts the control lever outward and thus pulls the control rack to its non-injection position. This actuation is direct and fast.

In the standard-specification RSV governor, the adjusting lever is turned to bear against the stop adjust screw (both being located outside the governor housing) to stop the engine. Where the stop device is fitted to the governor, the stop adjust screw may be so positioned as to limit the lowest idling speed (beyond which the engine should stall). How the stop device operates will become clear later in the paragraph explaining this device again in reference to a schematic side view of the governor.

(6) Governor operation

a. Engine starting

Suppose the accelerator is a pedal. Depressing the pedal turns down adjusting lever (shown as integral part of the swiveling lever in the schematic side view) toward the left, and pulls tension lever up against full-load stopper, pushing control block and governor sleeve.



1-Adjusting lever
2-Start spring
3-Control lever
4-Guide lever
5-Tension lever
6-Full-load stopper
7-Control block and governor sleeve
8-Flyweights
9-Swiveling lever
10-Control spring
11-Control rack

Engine starting

By this movement, guide lever and control lever tilt to the left, pushing the control rack to its starting position. This pushing action is assisted by start spring; this spring is designed to urge the control lever toward the left with a relatively small force.

When control rack is in its starting position, the injection pump delivers more fuel than is needed for full-load operation. The excess fuel is needed to help the engine fire up more easily.

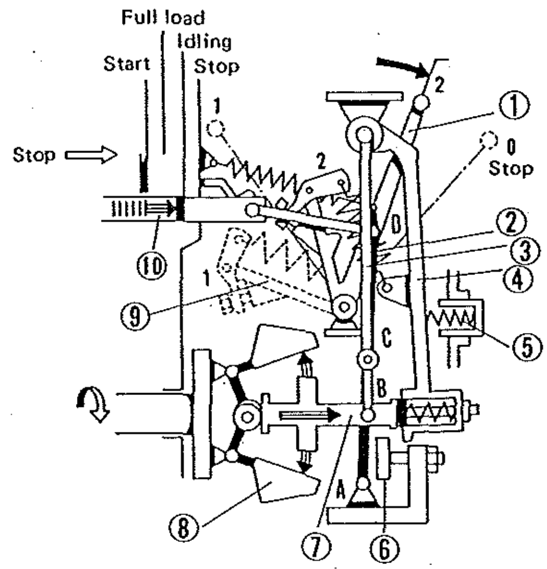
b. Idling control

As the engine fires up, the operator would release the pedal; this makes the swiveling lever and adjusting lever move back to idling position to reduce the pull on tension lever and allow control lever to be tilted back by the push exerted by revolving flyweights upon control block. Control rack is therefore pulled out to idling position, at which the pump delivers fuel at a rate sufficient for keeping the engine idling.

Under the conditions indicated, an idling equilibrium is established between control block on the one hand and the total force of idling sub-spring and control spring, plus start spring.

"Idling" presupposes that the engine is not carrying any load. With the adjusting lever (and hence the swiveling lever, too) kept in the idling position mentioned above, the governor maintains a constant engine speed (so-called "idling speed") by responding automatically to any tendency of the speed to rise or fall and acting to cancel off this tendency by moving the control rack. Suppose, now, that some load is put on the engine.

The engine will then slow down and the flyweights contract, reducing the push of control block to allow the control rack to be pushed in. Consequently, the rate of fuel injection increases to raise the speed, and this increases the push exerted by the control block. In no time, the governor reaches an equilibrium state and the speed settles again at a constant level. This new level, however, is slightly below the previous one (because of the speed regulation) and, if it is too low, could cause the engine to stall.

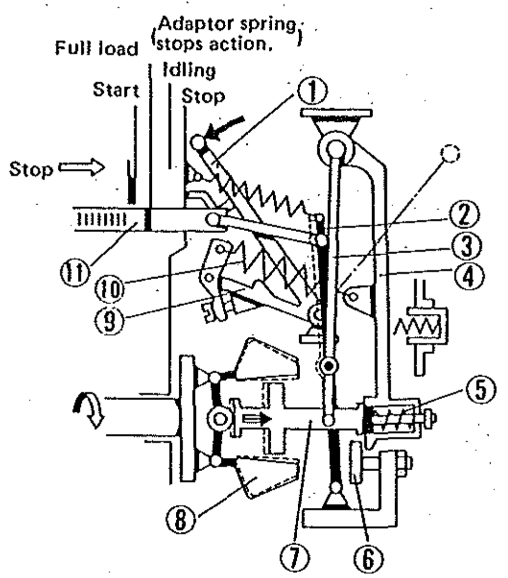


1-Adjusting lever
2-Control lever
3-Guide lever
4-Tension lever
5-Idling sub-spring
6-Full-load stopper
7-Control block
8-Flyweights
9-Swiveling lever
10-Control rack

Idling control

c. Maximum speed control

Let us assume that the engine is idling with the adjusting lever bearing against the idling set screw: the adjusting lever is in idling position. If the lever is moved gradually toward the maximum speed stopper, the pull by the control spring increases gradually and, through the process of action and reaction involving the tension lever and control block, the control rack moves inward, increasing the fuel injection gradually to raise the engine speed. As the adjusting lever meets the full load stopper, the control block will be pushing the tension lever with a greater force, keeping the lever off the full load stopper. Thus, the control rack is prevented from moving too far inward beyond its "idling" position.



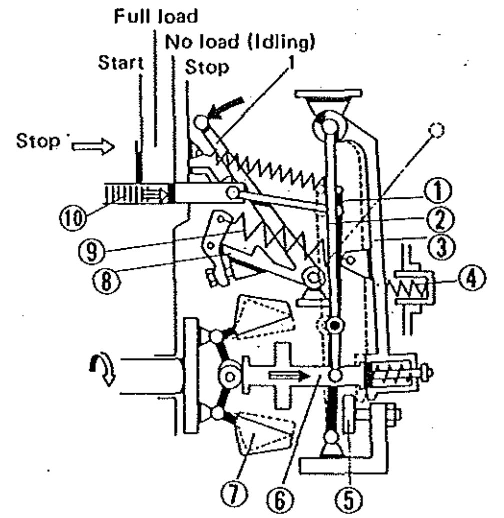
1-Adjusting lever
2-Control lever
3-Guide lever
4-Tension lever
5-Adaptor spring
6-Full-load stopper
7-Control block
8-Flyweights
9-Swiveling lever
10-Control spring
11-Control rack

Maximum speed control

(7) **Speed regulation and adaptor spring action**

One way of considering the effect of full engine load on its speed is to see what would happen when the load is increased gradually under the last-mentioned condition of the governor; namely, the adjusting lever is up against the maximum speed stopper and the tension lever is off the full-load stopper (with the flyweights spread wide apart). As the load increases, the engine slows down, and the tension lever closes in on the full-load stopper, causing the control rack to move in the direction for increasing fuel injection quantity. As the engine slows down still further because of the increasing load, the push by the control block against the tension lever diminishes further and, finally, the tension lever touches the full-load stopper.

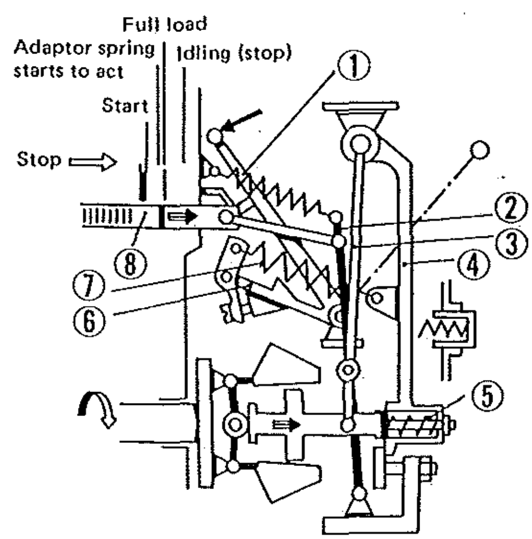
The final speed, it must be noted, is lower than the original no-load speed by several percent despite the fact that the adjusting lever has been kept at the position limited by the maximum speed stopper. This difference in speed between no-load condition and full-load condition is due to the speed droop (or speed regulation) characteristic inherent in the governor of this type. "Speed droop" is desirable for the stability of an engine working under variable load condition.



1-Control lever
2-Guide lever
3-Tension lever
4-Idling sub-spring
5-Full-load stopper
6-Control block
7-Flyweights
8-Swiveling lever
9-Control spring
10-Control rack

No-load condition (transition from "full-load")

After the tension lever touches the full-load stopper, what if the load on the engine increases to lower its speed and causes the flyweights to contract? The tension lever can no longer push back the control block; the control lever would be unable to push the control rack inward to increase the rate of fuel injection. This condition is avoided by means of the adaptor spring built in the tension lever.



1-Adjusting lever
2-Control lever
3-Guide lever
4-Tension lever
5-Adaptor spring
6-Swiveling lever
7-Control spring
8-Control rack

Adaptor spring

Under the full-load condition, the tension lever behaves as if it were rigid and the control block is opposed by the adaptor spring. In other words, the state of equilibrium is produced by the adaptor spring and the control block. If the speed falls due to a rise in load, then the adaptor spring pushes the block to the left, causing the control rack to move inward, thus increasing the delivery of fuel to the engine.

Consider the reverse case: the load is decreased on the engine running slow with full load. In this case, the control block keeps on pushing the adaptor spring to prevent the speed from rising and, after compressing this spring fully, touches the tension lever. From this point onward, the block pushes the lever away from the full-load stopper as the load keeps decreasing.

(8) **Adapting injection quantity to engine**

The true function of the adaptor spring can be appreciated when the two important characteristics of a diesel engine and also of a plunger-type injection pump are recalled.

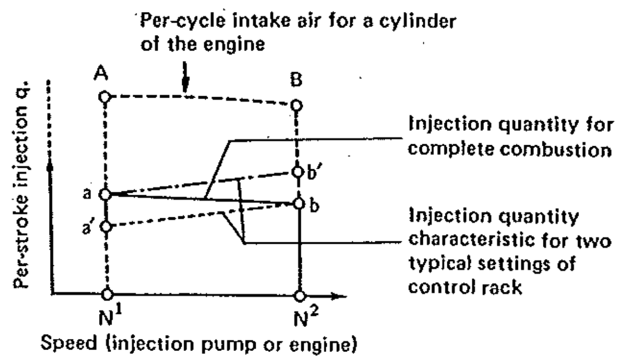
The amount of fuel delivered per stroke by the plunger in the pumping element is theoretically constant when the plunger is in a given angular position (with the control rack held in one position), regardless of its reciprocating speed (dependent on engine speed). Actually, this amount decreases as the speed rises. The reason is that the leakage of fuel, though extremely small, through the sliding clearance around the plunger decreases as the speed rises.

On the other hand, the amount of intake air drawn into each cylinder of a diesel engine is theoretically constant and equal to the "swept volume" of the cylinder; actually, this amount increases as the speed of the engine rises. The reason is that air has mass and takes a definite time to flow.

As long as the amount of air drawn into the cylinder is sufficiently large for the amount of fuel sprayed into it, there is practically no problem: the fuel will burn completely and the exhaust smoke will be clean. However, under full-load condition and, consequently, with a large amount of per-stroke fuel injected, a question has to be asked: is there a sufficient amount of excess air in the drawn-in air?

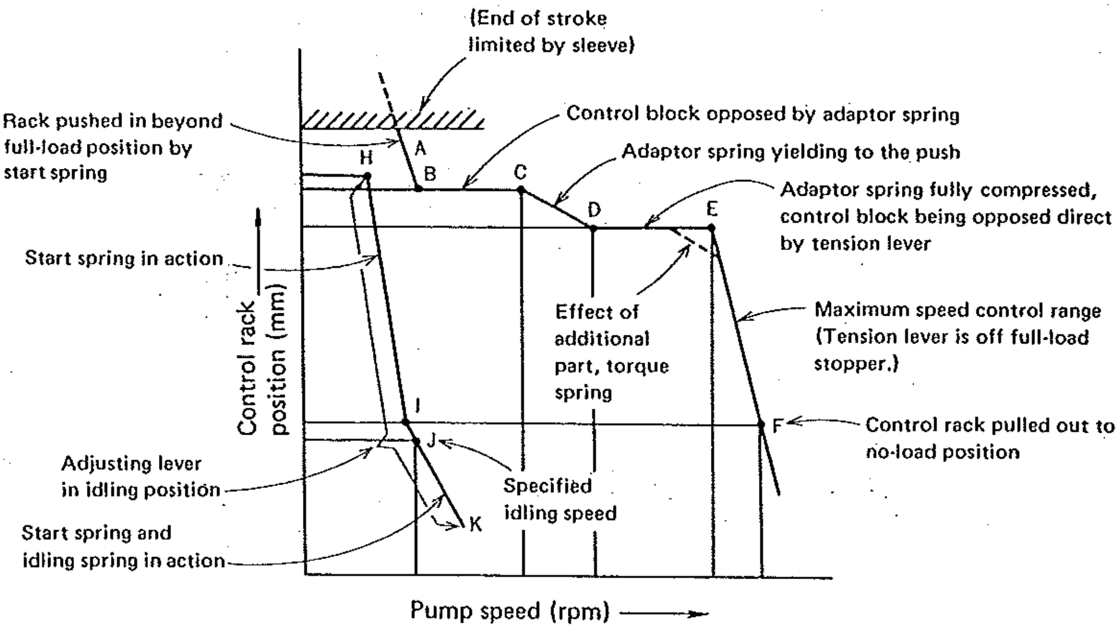
To summarize, where the control rack is held steady and the speed is increased, fuel injection quantity increases but intake air decreases. Under full-load condition, the "smoke limit" would be exceeded to result in a dirty exhaust smoke. To avoid this situation, the control rack must be pulled outward to decrease injection quantity, that is, the control block must be allowed to move toward the tension lever instead of being stopped by this lever. This requirement is met by the adaptor spring.

The graph shown here explains how the adaptor spring adapts injection quantity to the available air in the engine:



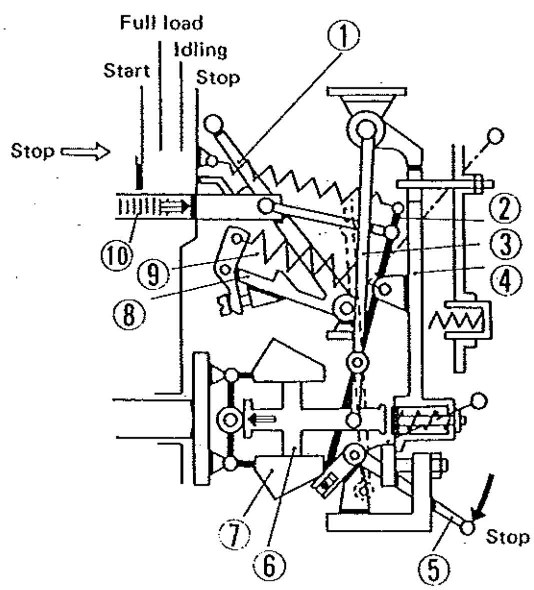
This graph assumes that the control rack of the injection pump is set for maximum injection quantity. Curve a – b′ represents one setting, and curve a′ – b another. With curve a – b′, injection quantity would too much at speed N^2 but just right at speed N^1. With curve a′ – b, the quantity would be just right at speed at N^2 but too little at N^1. What is desired for the air curve A – B is the modified curve a – b, which can be produced by causing the control rack to be pulled out by a small amount as the speed rises under full-load condition. The adaptor spring makes this possible.

(9) Governor characteristic



(10) Stopping the engine with stop lever

The stop device, mentioned in CONSTRUCTION DETAILS, is shown schematically, as associated with the bottom end of the control lever. With the stop lever in normal position, the control lever has its bottom end at the position for normal governor operation. Pushing down the stop lever tilts the control lever to pull the control rack all the way out to the non-injection position, thereby causing the engine to stop.



1-Adjusting lever	6-Control block
2-Control lever	7-Flyweights
3-Guide lever	8-Swiveling lever
4-Tension lever	9-Control spring
5-Stop lever	10-Control rack

Stopping the engine with stop lever

Injection nozzle and nozzle holder

Referring to the cross section of the nozzle, the internal space of the nozzle and holder is filled with fuel. The leakoff line for passing the fuel back to feed pump is connected to nozzle holder. The leakoff passage drilled out in the holder is communicated to the space above distance piece, in which pressure spring is contained to load upon pressure pin.

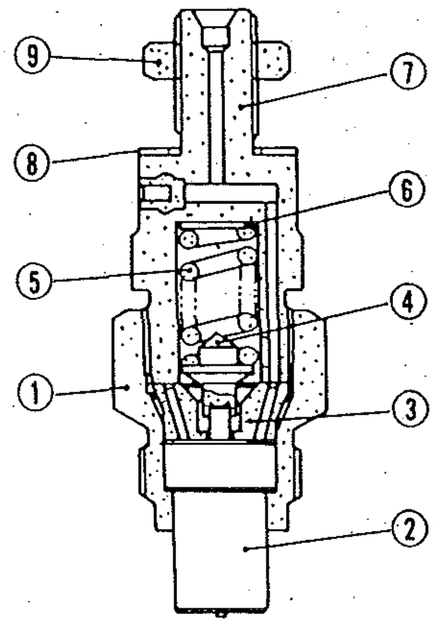
The fuel inlet, to which the injection pipe (not shown) is connected, is provided in the holder. The inlet passage extends through the nozzle holder and opens out at the pressure chamber formed in the tip of injection nozzle. The needle valve has its conical face exposed to the fuel in the pressure chamber.

In operation, a shot of high-pressure fuel reaches the pressure chamber in the form of a pressure rise, causing the needle to unseat so that the fuel is forced out through the orifice into the precombustion chamber.

The pressure at which the needle unseats itself is determined by the compressed state of pressure spring. This preload can be varied for adjustment by changing the thickness of washer. The internal mating faces as well as the threaded portions are finished to extremely close tolerances to ensure the high oil-tightness required of this injecting unit.

Injection nozzle tip

Type	NP-DN0SD
Opening pressure	120 ± 5 kg/cm^2 (1706 ± 71 psi)
Angle of fuel spray	0 deg.

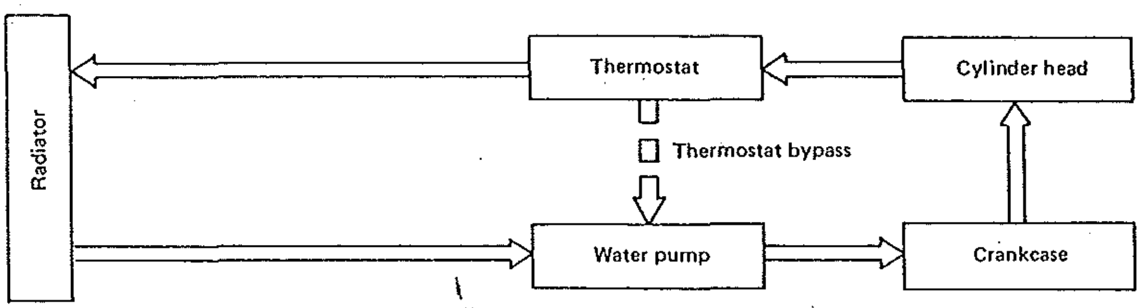


1-Retaining nut
2-Nozzle tip
3-Distance piece
4-Pressure pin
5-Pressure spring
6-Washer
7-Nozzle holder
8-Gasket
9-Nut

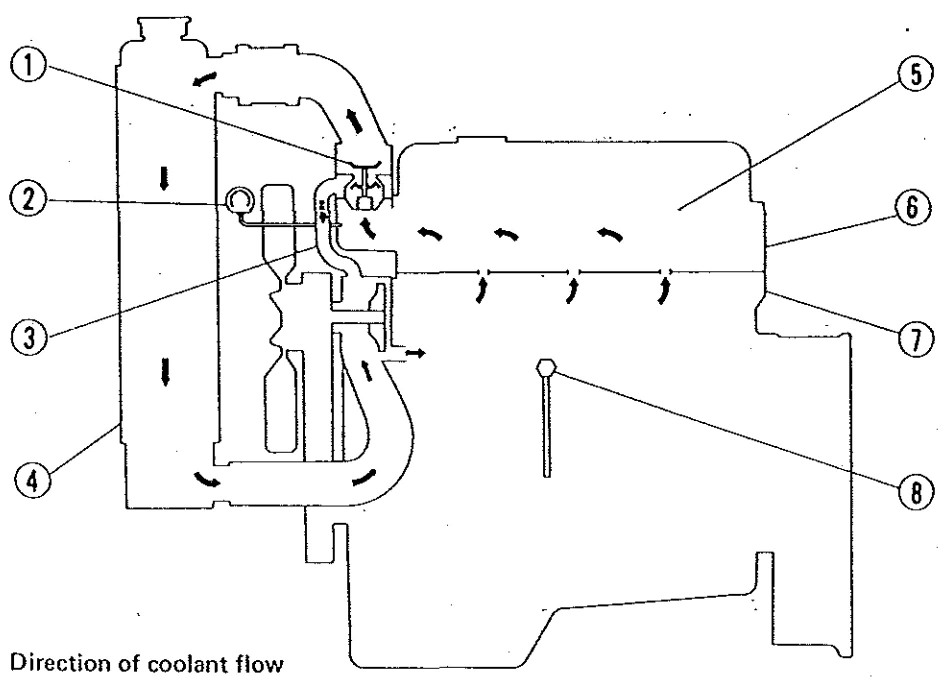
Injection nozzle — Cross section

Cooling system

Description



Cooling system block diagram



1-Thermostat
2-Water temperature gauge
3-Bypass hose
4-Radiator
5-Water jacket
6-Cylinder head
7-Crankcase
8-Drain plug

Direction of coolant flow

Referring to the diagram, above, the coolant is set in forced recirculation by the water pump, which is a centrifugal pump driven by cooling-fan belt. The pump draws coolant from the lower tank section of radiator (4) and forwards it to the water inlet of crankcase (7).

Upon entering the middle section of the crankcase, coolant flows in the jacket to cool the cylinders; then it rises into jacket (5) of cylinder head (6) to cool the combustion chambers and areas around the intake and exhaust valves. From the forward end of the cylinder head, the coolant, now hot because it has taken as much heat as it can, flows into the inlet of thermostat (1).

The thermostat, responding to coolant temperature, controls the flow of coolant toward the radiator upper tank. When coolant temperature is low as when the engine has just been started up from cold state, the thermostat valve remains closed and all of the coolant is diverted back to the water pump inlet through bypass hose (3): under this condition, radiator (4) is bypassed by the coolant.

As the rising coolant temperature reaches 76.5°C (169.7°F), the thermostat valve begins to open increasingly wide and the coolant begins to flow to radiator (4) at a rising rate of flow, with a corresponding decreases in the amount of coolant being bypassed. As the temperature reaches 90°C (194°F), the valve becomes full open, shutting off the bypass passage.

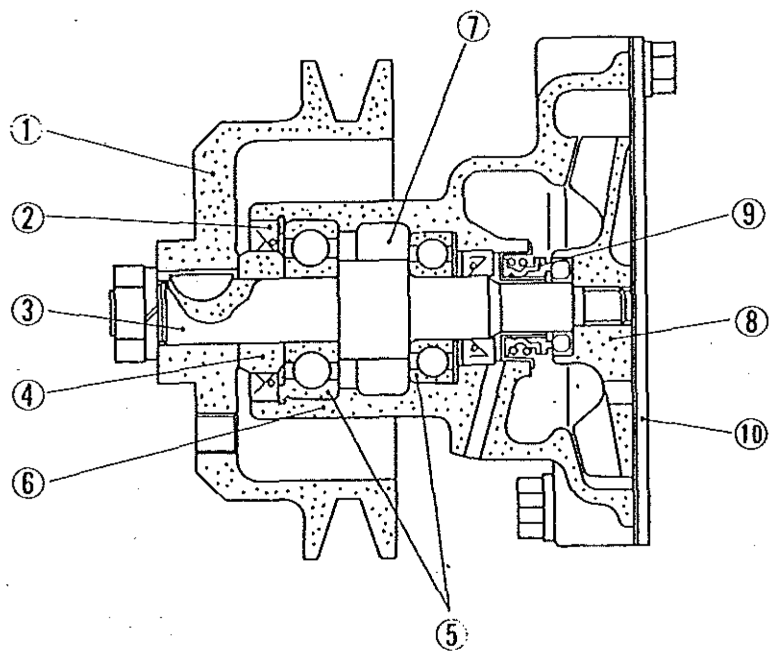
The probe for temperature gauge (2) is installed in the coolant outlet of cylinder head. It is with the signal produced by this probe that the gauge (located at the control station) operates.

Water pump

Pump case (6) is secured to cylinder block through cover plate (10). Pump shaft (3) is supported by two ball bearings (5) having a large bearing capacity. Lube oil is supplied under pressure from engine main oil gallery into space (7) formed around shaft between the two bearings.

Two oil seals (2) contain the oil so admitted to lubricate the ball bearings. Unit seal (9) prevents coolant from leaking out along the shaft. Impeller (8) is threadedly mounted on the inner end of the shaft, and pulley (1) is keyed to the outer end.

Crankshaft pulley and pump pulley (1) are in the speed ratio of 1 to 1.2. The pump capacity is 100 liters (6103 cu in.)/minute at 2520 pump rpm.

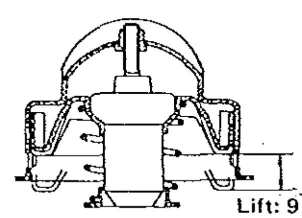


1-Pulley
2-Oil seal
3-Shaft
4-Spacer
5-Ball bearings
6-Case
7-Space filled with lube oil
8-Impeller
9-Unit seal
10-Cover plate

Water pump — Cross section

Thermostat

The thermostat is of wax type, designed to start opening its valve at 76.5 ± 2°C (169.7 ± 3.6°F) of rising temperature and open it fully at 90°C (194°F), lifting it off the seat by 9 mm (0.35 in.) (maximum lift).



Cooling fan

The cooling fan has 6 blades and drives air against the core of the radiator. It is secured to the front end of the water pump pulley. Its outside diameter is 380 mm (14.96 in.); the pitch angle of its blade is 30 deg.

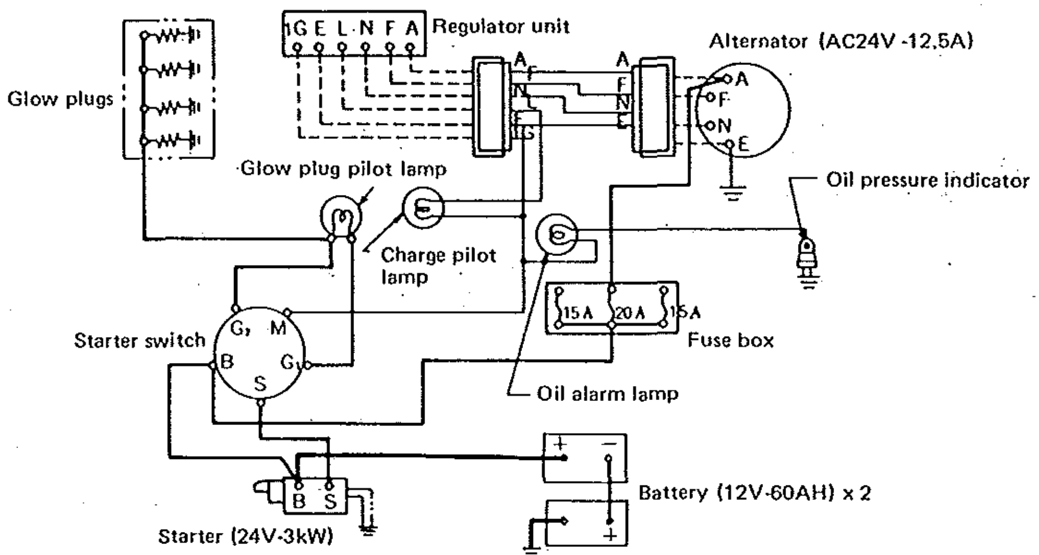
Fan belt

A single low-edge cog belt of Type B is used to transmit drive from crankshaft pulley to pump pulley. Its length is 41 inches (1047 mm).

Electrical equipment

Major equipment specifications

Equipment	Type	Make
Starter	M005T27671	Mitsubishi Electric
Alternator	AP4012B1.	Mitsubishi Electric
Regulator unit	RMS4227C9	Mitsubishi Electric
Glow plugs	Sheathed type	Hiyoshi Denso



Circuit diagram

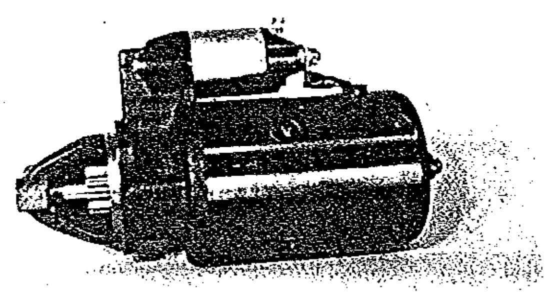
Starter

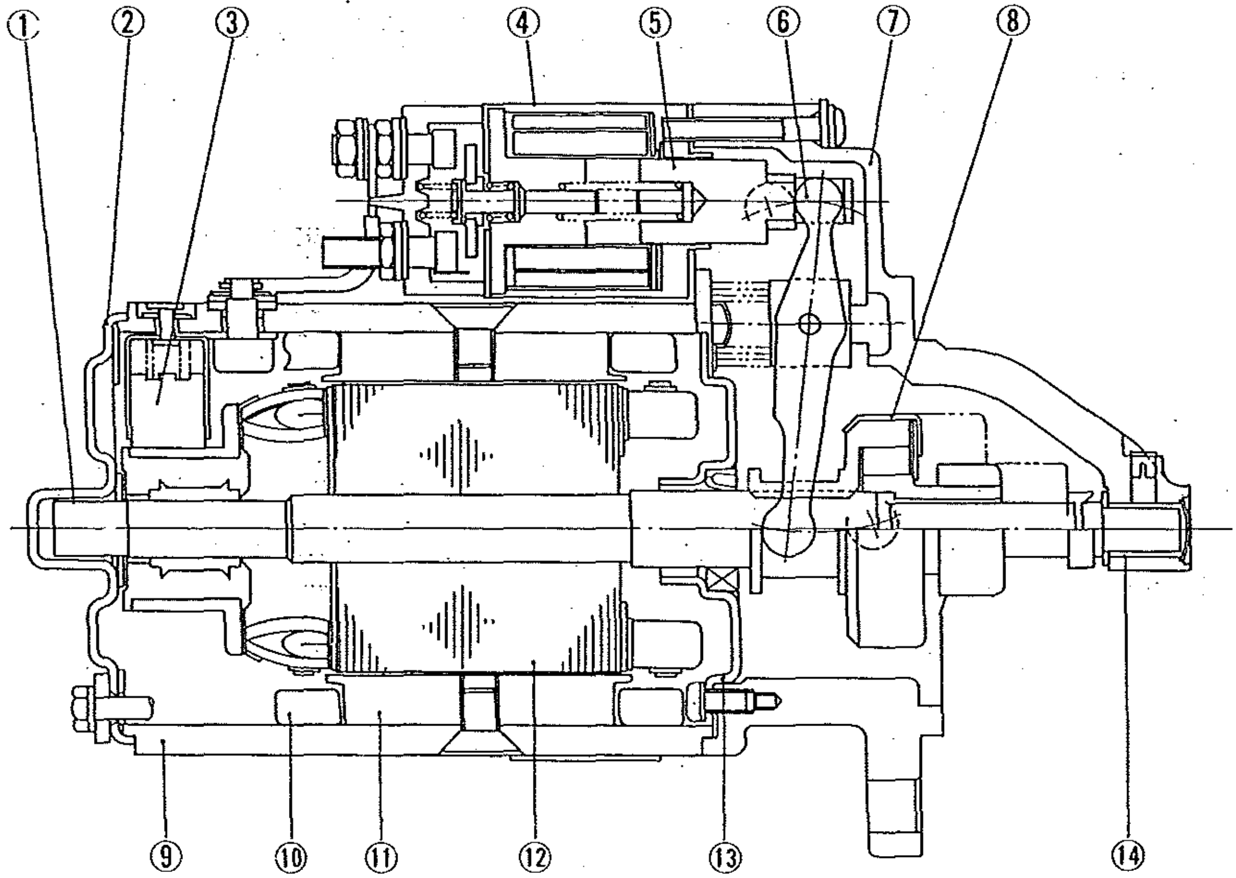
(1) Specifications

Item	Specification
Motor type	Lever-shift pinion type with over-running clutch, built on totally-enclosed water-proof DC motor, M005T27671, compound wound
Voltage	24 volts
Output	3 kW
Yoke dia.	118 mm (4.646 in.)
Rating	30 seconds
Rotation	Clockwise as viewed from pinion side
Weight	Approximately 12.5 kg (27.6 lb)
No-load characteristic	4500 rpm, drawing not more than 50 amperes, at 23 volts
Locked-rotor characteristic	Developing 4.0 kg-m (29 ft-lb) and drawing not more than 700 amperes at 9 volts
Switch-on voltage	16 volts, maximum

(2) Construction

The motor enclosure is of totally-enclosed type, designed tight against oil and water. The following cross section shows that the starter motor consists of three components: DC motor, engaging mechanism comprising an overrunning clutch, a shift lever and a pinion, and magnetic switch for actuating the lever.

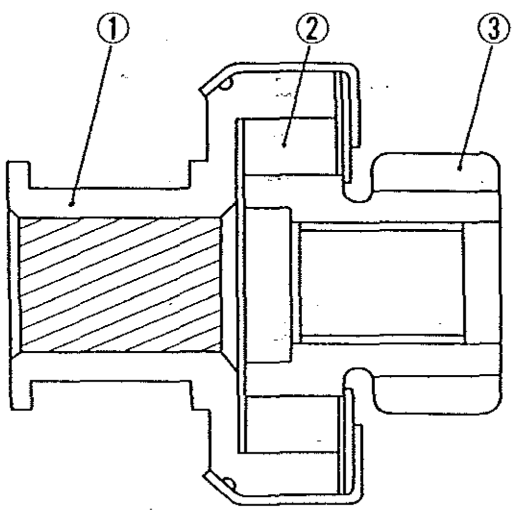

Starter



1-Bushing	5-Plunger	9-Yoke	12-Armature
2-Rear bracket	6-Lever	10-Field coil	13-Center bracket
3-Brush	7-Front bracket	11-Pole piece	14-Bushing
4-Switch	8-Overrunning clutch		

Starter – Cross section

(3) Overrunning clutch



1-Splined sleeve 2-Roller 3-Pinion

Overrunning clutch – Cross section

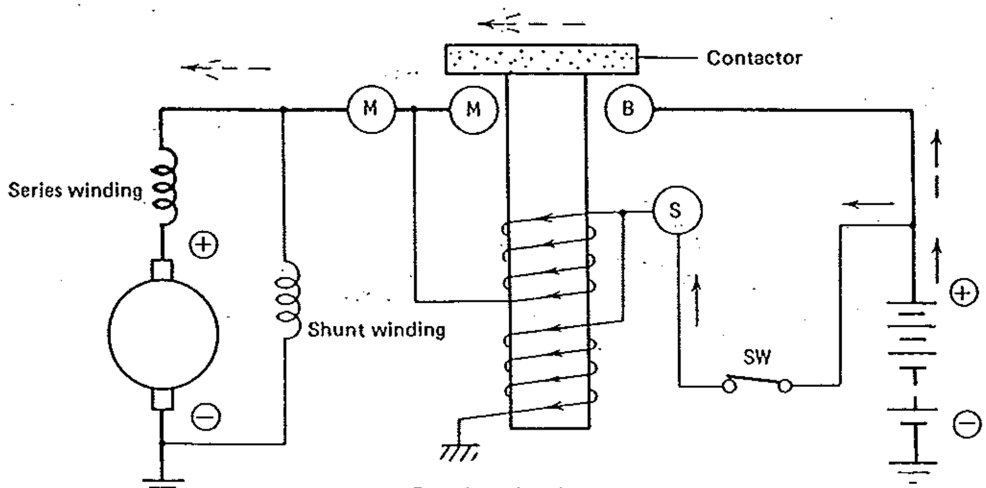
The inner race is integral with pinion (3), and the outer race presenting five cams is integral with splined sleeve (1). The sleeve is engaged with the splined part of the shaft, there being 10 splines. Five clutch rollers (2) are distributed around the inner race, each being pressed against the cam by a spring.

The splined sleeve is capable of sliding axially along the shaft and, when it does slide, the whole clutch moves axially. As the motor shaft rotates, the sleeve revolves with the shaft (when the sleeve is prevented from advancing any further with the pinion meeting the stopper) to drive the pinion in mesh with the ring gear of the flywheel. Under this condition, the rollers (2) are seized between inner race and cams. If the flywheel ring gear drives the pinion (after the firing up of the engine), rollers (2) become released and "freewheel" between inner race and outer race: under this condition, no drive is transmitted from engine side to the starter.

The shift lever, extending from the magnetic switch, embraces the splined sleeve (1) by its forked end. The top end of this lever is held by the magnetic switch plunger; and the middle part is pinned. As the plunger jumps inward upon energization of the switch coil, the lever tilts to push the clutch toward the ring gear. When this lever-shifting action occurs in actual starting up of the engine, the motor will be rotating rather slowly to advance the clutch by the screw action due to the helical splines. Thus, the pinion advances rotatingly to mesh into the ring gear.

(4) **Starter operation**

How the starter is operated to crank the engine will be explained sequentially in reference to this schematic diagram of the starter circuit:



Starting circuit diagram

a. Turning on the switch energizes the two coils of the magnetic switch. The initial current from the battery flows in these two coils, one of which is connected in series with the motor, so that the motor begins to run but slowly because the initial current is rather small. In the meantime, the two coils pull in the plunger to push the overrunning clutch toward the ring gear. The clutch slides along the helical splines and, for the reason already stated, advances smoothly to mesh its pinion with the ring gear.

b. As the pinion meshes into the ring gear fully, the plunger is allowed to move in all the way, making its contactor to close, thereby permitting full current to flow through terminals (M) (B) into the motor. Consequently, the motor runs with full force to crank the engine. Under this condition, the coil in series with the motor is shunted so that practically no current flows in this coil, but the other coil (connected between terminal (S) and ground) remains energized to hold the plunger in pulled-in position.

c. Turning off the switch (key switch) upon firing up of the engine de-energizes the holding coil, so that, by the force of the return spring, the plunger snaps back to the original position, thus disrupting the motor current and pulling the pinion away from the ring gear. The motor will coast before coming to a halt: the counter-electromotive force (reverse voltage) occurring in the motor during this coasting helps the plunger move outward.

Alternator and regulator unit

(1) **Alternator specifications and data**

The alternator is complete with a rectifier.

Item	Specification
Type	Enclosed-type alternator, AP4012B1
Rated output	24 volts, 12.5 amperes
Ground	Negative ground
Outside diameter	128 mm (5.039 in.)
Rotating direction	Clockwise as viewed from pulley side
Weight	6.4 kg (14.1 lb)

(2) **Regulator specifications and data**

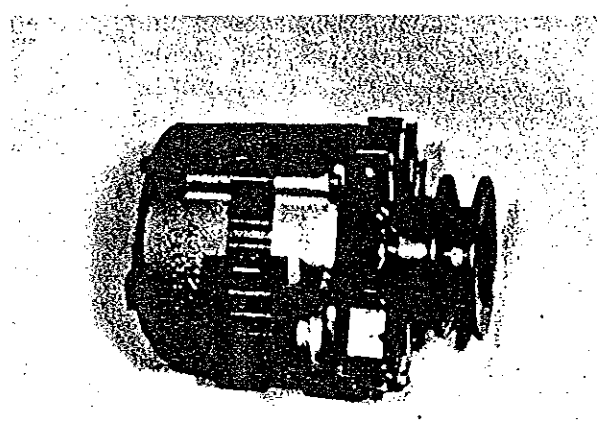
Item	Specification
Type	Two-element type RMS4227C9
Elements	Voltage regulator, and safety relay (w/lamp)
Weight	0.45 kg (1 lb)

(3) **Alternator construction**

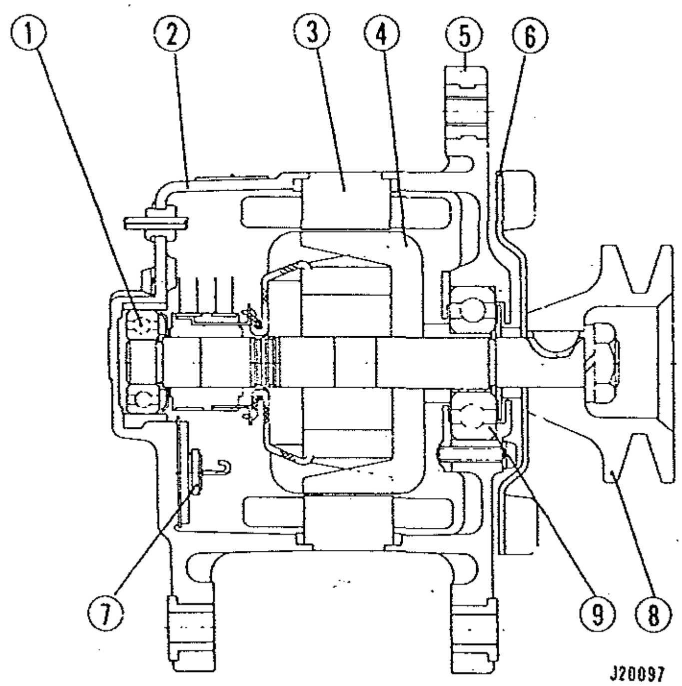
The alternator enclosure is of enclosed type. The field is a single coil mounted on the shaft and surrounded by two multi-pole magnets; excitation current is supplied through slip rings to the coil.

The armature coils are in three groups connected to provide a three-phase armature, and are mounted in the laminated core secured to the casing. Thus, the armature is stationary and the field is rotary. The rotor shaft is driven from the engine through the belt and pulleys.

The three-phase output leads of the armature are tied to the six-diode rectifier mounted inside the casing: three diodes are soldered to the positive heat sink and the other three to the negative heat sink. Cooling is made by the fan from outside.



Alternator



1-Bearing
2-Rear bracket
3-Stator coil
4-Rotor
5-Front bracket
6-Fan
7-Diode
8-Pulley
9-Bearing

Alternator — Cross section

(4) Charging system operation

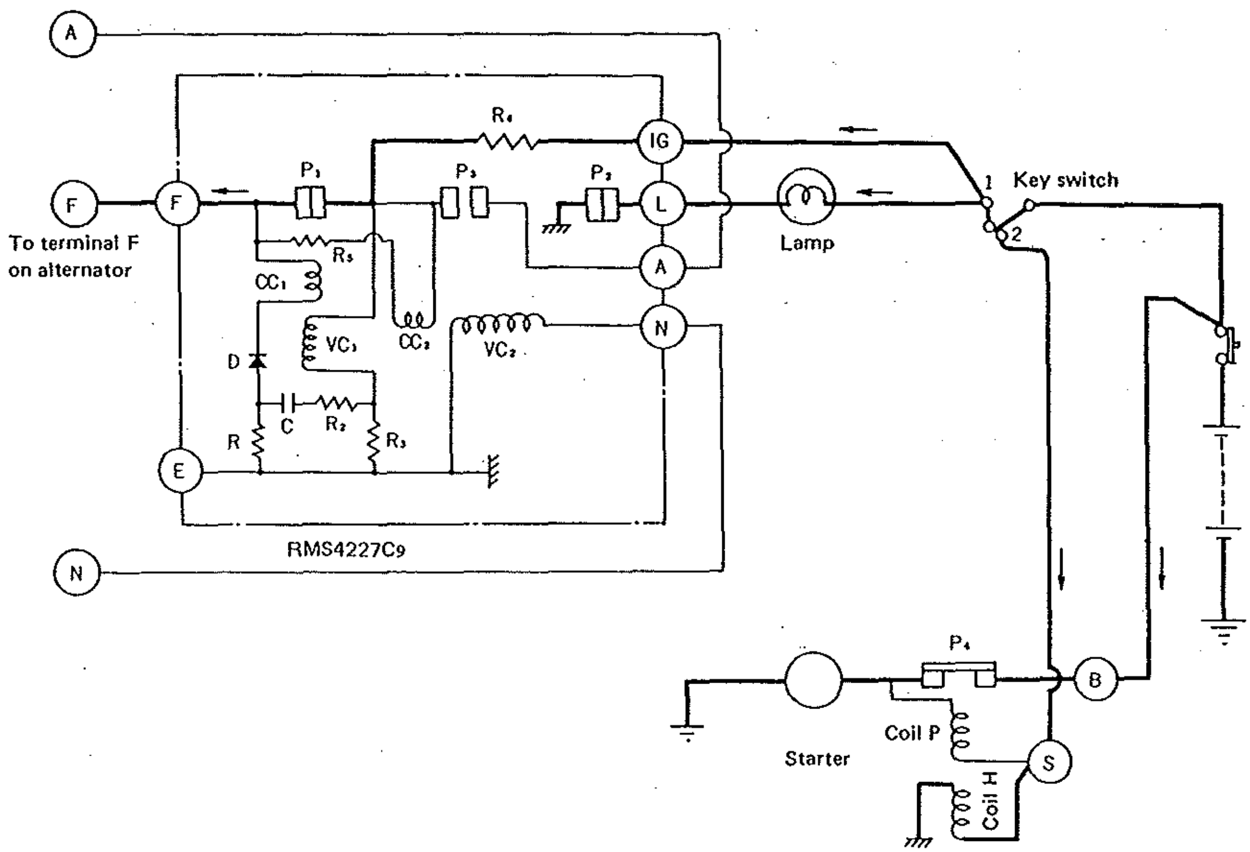
The first of the two circuit diagrams to follow shows how the current flows from the battery when the key switch is turned on for starting up the engine. The second shows the flow of current for charging the battery. In these diagrams, attention should be directed to voltage coils VC_1 and VC_2 and current-coils CC_1 and CC_2, the four coils of the regulator unit.

VC_1 and CC_1 actuate points P_1; VC_2 and CC_2 actuate points P_2 and P_3. The energizing current of a voltage coil is dependent on voltage; that of a current coil (which is connected as a shunt coil) is depending on current.

In these diagrams, the alternator unit (not shown) is represented by its three terminals (A) (F) (N). DC output voltage is available between terminal (A) and ground. Another voltage occurs between terminal (N) – neutral point of the rectifier – and ground. Terminal (F) is for receiving field excitation current from the terminal (A) of the alternator unit itself or, at engine starting, from the battery.

a. Engine starting
With the battery switch closed, turning on the key switch (by moving it to position 1) allows current to flow from the battery to the alternator field and also to the lamp. Field current at this time is small because of resistor R_4. The lamp burns to tell that the alternator is not generating power.

Turning the key switch to position 2 connects the battery to the starter to crank the engine through the sequence of actions already described.



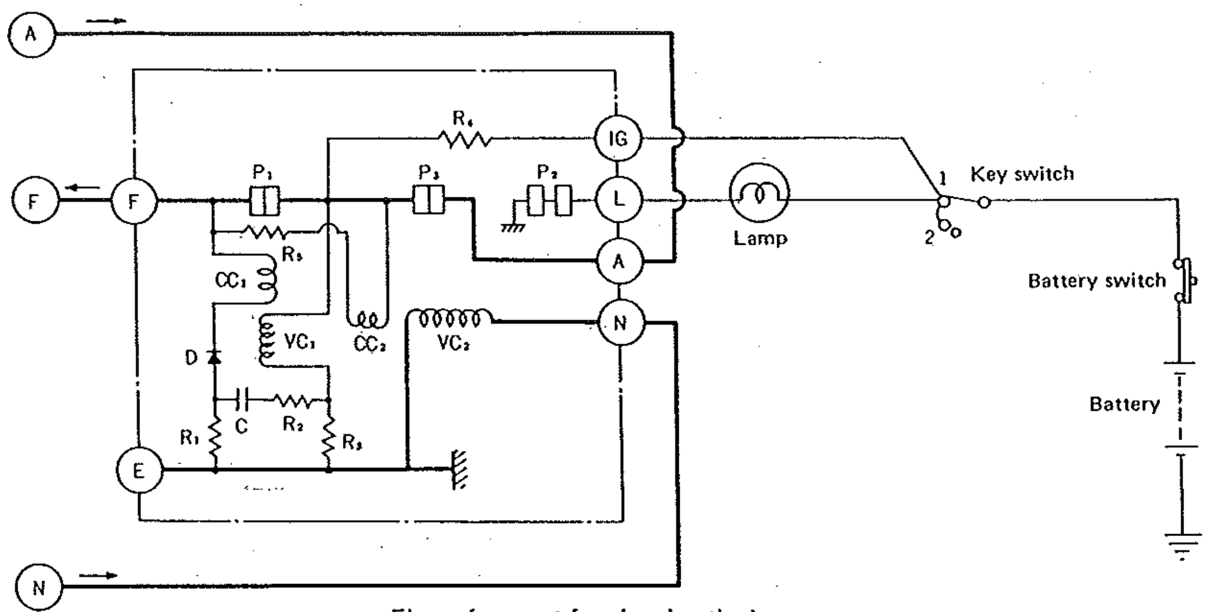
Flow of current for starting the engine

Under this condition, points P_1, P_2 and P_3 remain in the indicated state by their springs. Current flows in VC_1 but it is too small to be of any consequence.

b. Normal charging operation
As the engine starts up, the alternator unit begins to develop output voltage, so that VC_2 becomes energized (by the voltage between terminal (N) and ground (E), as mentioned before) to open points P_2 and put out the lamp.

The output current of the alternator unit flows through point P_3 toward the battery and toward the alternator field through points P_1 when the output voltage is up at the normal level.

If this voltage rises above the predetermined level, the current in VC_1 increases to open points P_1 against its spring, so that field current has to flow through resistor R_5 and is therefore smaller than before: this reduces the output voltage of the alternator unit. Actually, points P_1 open and close in rapid succession to regulate the voltage at a relatively constant level.



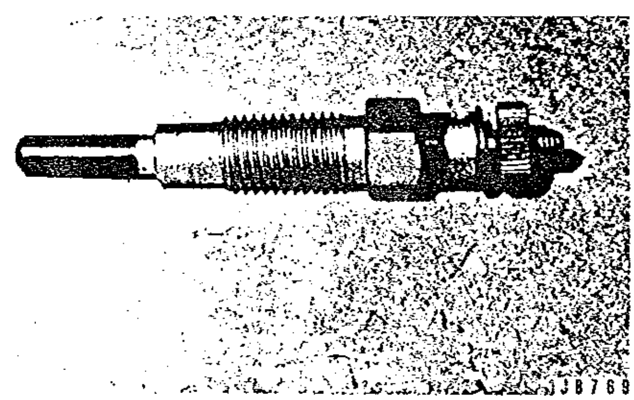
Flow of current for charging the battery

c. Auxiliary circuits

Capacitor C and resistor R_2 are for absorbing the surge that occurs when points P_1 open. They prevent arcing from jumping between the contacting faces of points P_1.

Current coil CC_1 assists VC_1 in closing and opening points P_1 sharply so that the output voltage will be free from excessive ripples.

Current coil CC_2 and resistor R_5 pass some current for the alternator field when points P_1 are open: they prevent the voltage from fluctuating so widely as to cause the lamp to flicker.



Glow plug

Glow plugs

Each precombustion chamber of the engine has a glow plug. The plug is a starting aid and serves to warm up the chamber by "glowing" red with electricity supplied from the battery. It is of a sheathed type in construction.

The four glow plugs, one for each cylinder, are connected in parallel between the preheating line and ground. Failure of one plug, therefore, does not cut out the other three.

MAINTENANCE AND ADJUSTMENT

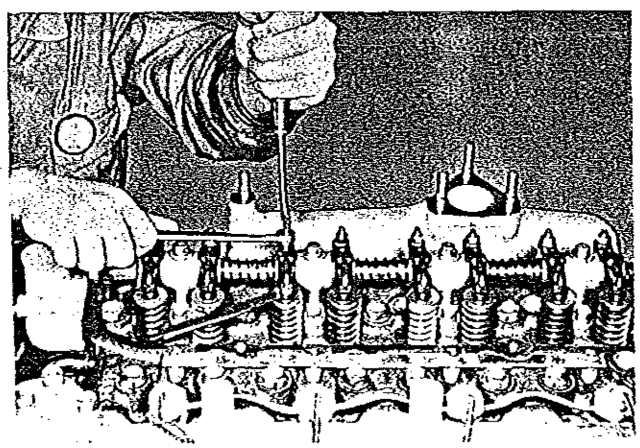
Inspection and adjustment of engine proper

Valve clearance adjustment

The valve clearance specification for this engine is 0.25 mm (0.0098 in.) for both intake and exhaust valves. This value assumes that the engine is at normal temperature, there being no temperature difference throughout the body of the engine. The checking and adjusting procedure is as follows:

(1) Rotate the crankshaft slowly to bring the piston in No. 1 cylinder to Top Dead Center (TDC). This can be accomplished by observing rocker arms of No. 4 cylinder. As you turn the crankshaft, exhaust-valve rocker arm of this cylinder rises: stop turning the crankshaft just when intake-valve rocker arm begins to go down after exhaust valve rocker arm has come up all the way. Under this condition, adjust valve clearance in the usual manner on intake and exhaust valves of No. 1 cylinder, intake valve of No. 2 cylinder, and exhaust valve of No. 3 cylinder.

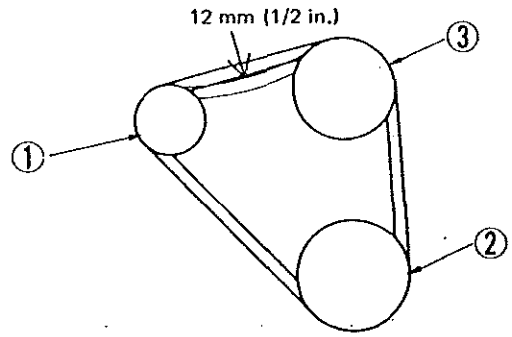
(2) Turn the crankshaft one complete rotation (360°), and hold it there. Adjust the clearance on intake and exhaust valves of No. 4 cylinder, exhaust valve of No. 2 cylinder, and intake valve of No. 3 cylinder.



Adjusting valve clearance

Fan belt tesion adjustment

Give a thumb pressure to the middle section of the belt between alternator pulley and water pump pulley, and see how much this portion of the belt deflects by measuring with a rule. The deflection should be 12 mm (1/2 in.): if not, loosen the mounting bolts of the alternator holder to displace the holder in order to tighten or slacken the belt. After obtaining the prescribed amount of deflection, be sure to tighten the bolts good and hard.



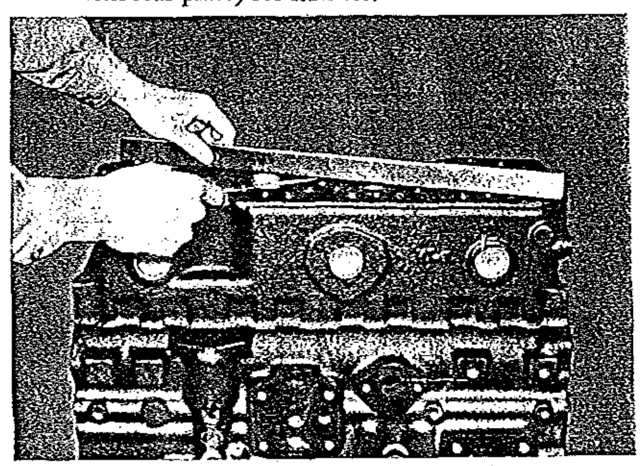
1-Alternator pulley
2-Crankshaft pulley
3-Fan pulley (water pump pulley)

Fan belt tension

Crankcase

Crankcase inspection

(1) Inspect the outside and inside surfaces for evidence of cracking. Visually examine the cylinder bores for scuffing, rusting, erosion or any abnormal wear. Using a straightedge, check the top face (for mating with cylinder head), front face (for mating with front plate) and rear face (for mating with rear plate) for flatness.



Checking crankcase top for flatness

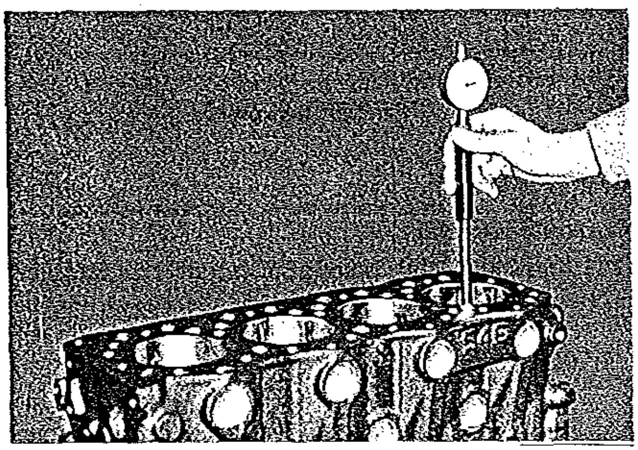
(2) Make sure that the top face of the crankcase is flat within the repair limit specified below. If the limit is found to be exceeded, reface the top by using a surface grinder to make it flat within the specified flatness. Be careful not to remove any more stock than is necessary; if a stock of more than 1 mm (0.039 in.) has to be ground off, then the crankcase is done for.

Unit: mm (in.)

Item	Standard	Repair limit
Flatness of crankcase top face	0.05, max. (0.002)	0.2 mm (0.008)

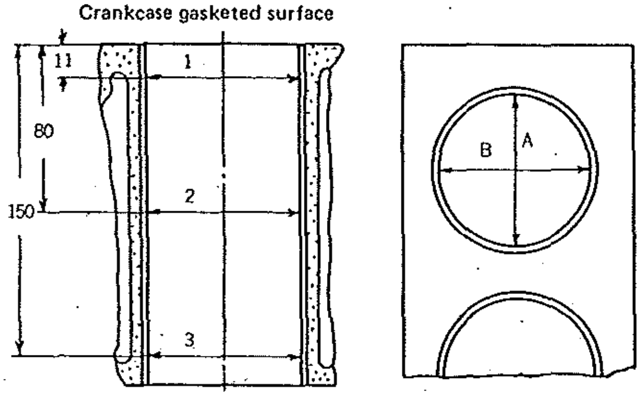
Cylinder sleeve inspection

(1) Using a cylinder gauge, take I.D. measurements in two directions (parallel and transverse to crankshaft axis) on each cylinder sleeve, at three places indicated below; and, from the six measurements taken, determine the amounts of wear (in comparsion with the specifications, listed below) and of uneven wear to see if the repair is exceeded; if so, rebore the sleeve to the next oversize.



Taking I.D. measurements on cylinder sleeves

Crankcase gasketed surface



Positions for checking sleeve bore diameter

Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Cylinder sleeve I.D.	$94^{+0.035}_{-0}$ ($3.701^{+0.0014}_{-0}$)	+0.20 (+0.008)	+1.20 (+0.047)
Out-of-round	0.015 (0.0006), max.		
Taper	0.015 (0.0006), max.		

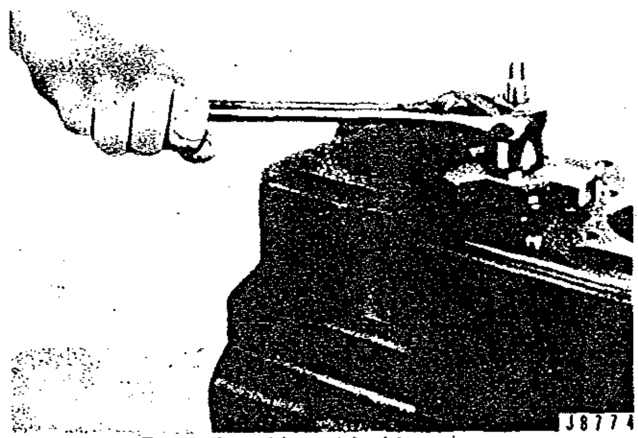
NOTE: "Taper" refers to the parallelness of bore wall.

(2) Two oversizes are provided for: +0.25 and +0.5 mm (0.0098 and 0.0197 in.). After reboring, be sure to hone the bore to the specified oversize accurate within plus 0.035 mm (0.0014 in.) or minus 0 mm. Machining the bores of all four sleeves to the same oversize is preferred. (Pistons and piston rings are available for the two oversizes.)

(3) If any sleeve bore is unevenly worn, determine the oversize, to which the sleeves are to be rebored, on the basis of the maximum wear noted. This will ensure perfect roundness in the oversized bores.

NOTE

If the cylinder sleeves are found in good condition, with the wear far less than the repair limit, it is permissible rebuild the engine with replacement piston rings. In such a case, be sure to ream off the "ridge" and, as necessary, hone the bore.



Removing ridge with ridge reamer

Cylinder sleeve replacement

A cylinder sleeve badly scuffed or worn down beyond the service limit must be replaced by a new one and, in such a case, it is not necessary to replace the other sleeves.

If, however, the cylinder hole becomes damaged in the process of removing a sleeve, then the hole must be rebored for repair and, only in such a case, all the four sleeves must be replaced. The procedure of replacing the cylinder sleeve is as follows:

(1) Set the boring machine on the crankcase, and center it on the sleeve by referring to the lower part of the sleeve which is least subject to uneven wear.

(2) Operate the machine to cut the sleeve until its wall thickness decreases to about 0.5 mm (0.0197 in.)

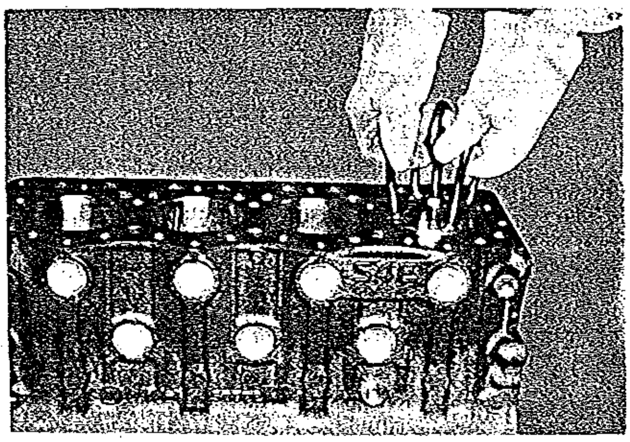
(3) Taking care not to damage the cylinder hole,

break the sleeve and take it out of the hole.

(4) Take measurements on the diameter of the cylinder hole and also on the O.D. of the replacement sleeve; and, from these measurements, see if an interference anywhere between 0.08 and 0.145 mm (0.00315 and 0.00571 in.) is available in the fit to be made; if not, try another sleeve to meet this interference requirement.

(5) With a proper replacement sleeve having been selected, heat the crankcase in a bath of oil to about 300°C (572°F). Using the sleeve installer and hydraulic press, push the sleeve into the crankcase in one stroke, making sure that the top end of sleeve becomes flush with the gasketed surface (top) of crankcase.

(6) Hone the installed sleeve to the standard I.D., that is, 94 plus 0.035 mm or minus 0 mm (3.701 plus 0.0014 in. or minus 0 in.).



Replacing sleeve

Unit: mm (in.)

Item	Standard diameter
Cylinder hole diameter	$98^{-0.010}_{-0.045}$ ($3.858^{-0.00039}_{-0.00177}$)

For replacement sleeves, be sure to use the parts with this part number:

Unit: mm (in.)

Part number	O.D.	I.D.
34407–00300	$98^{+0.10}_{+0.07}$ ($3.858^{+0.0039}_{+0.0028}$)	$93^{+0}_{-0.2}$ ($3.66^{+0}_{-0.0079}$)

Main bearing inspection

(1) Inspect each main bearing for evidence of wiping or fatigue failure, for scratches by dirt particles imbedded and for improper seating on the bore (bearing cap). On the basis of findings, determine whether the bearing should be replaced or not.

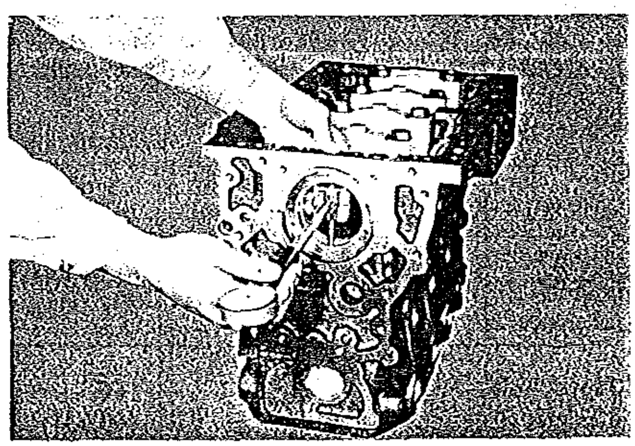
(2) Check each main bearing to be used in engine reassembly to see whether it will provide the specified radial clearance. This can be accomplished in this manner.

Install the main bearings on the crankcase, less the crankshaft, securing each bearing cap by tightening its bolts to 10.4 kg-m (75.2 ft-lb), and read the diameter in the two directions (A) (B), indicated below. Mike the journal and, from these readings, compute the radial clearance.

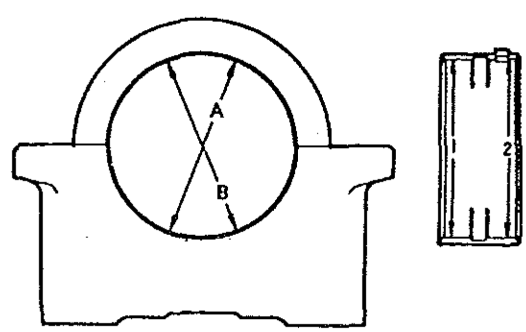
Unit: mm (in.)

Item	Standard	Repair limit
Radial clearance between main bearing and journal	0.05 ~ 0.115 (0.0020 ~ 0.0045)	0.20 (0.008)

If the computed clearance exceeds the limit, replace the bearing or regrind the journal and use the next undersize bearing. Two undersizes are available for this purpose: 0.25 and 0.50 mm (0.0098 and 0.0197 in.).

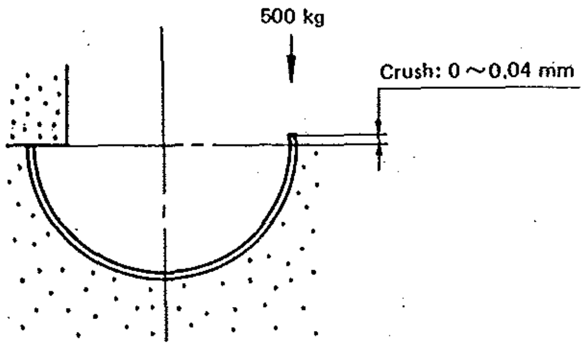


Measuring main bearing I.D.



Positions for miking main bearing

(3) Check each main-bearing shell for "crush." Shells found to be loose in the bore or have an excessive crush must be replaced. A crush of up to 0.04 mm (0.00157 in.), which will yield to a load of 500 kg (1102.5 lb), is prescribed.



Main bearing crush

Tappet and tappet hole inspection

(1) Inspect the riding face of each tappet for wear, contact pattern and crack. Replace defective tappets.

(2) Check the radial clearance of the tappet in the hole against the repair limit, indicated below. If the limit is exceeded, then replace the tappet. If the hole is worn down so much as to provide an excessive radial clearance even with a new tappet, the crankcase must be replaced.

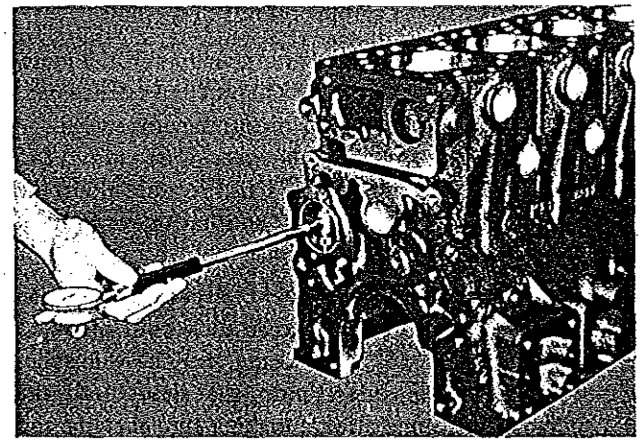
Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Tappet-to-hole clearance	0.035 ~ 0.086 (0.0014 ~ 0.0034)	0.12 (0.0047)	+0.1 (hole) (+0.004)
Tappet hole diameter	$22^{+0.021}_{-0}$ $(0.8661^{+0.00083}_{-0})$		+0.1 (+0.004)

Camshaft hole inspection

(1) Inspect the inside surface of each hole for wear and scratch.

(2) Mike the I.D. of respective holes and also the camshaft journals and, from the readings taken, compute the radial clearance available on each journal. If the clearance exceeds the limit, insert bushing or replace camshaft to reduce the clearance to the specification.

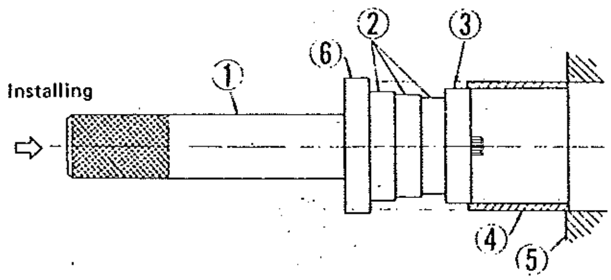


Miking camshaft hole

Unit: mm (in.)

Item		Standard	Repair limit	Service limit
Clearance of journal in hole		0.04 ~ 0.09 (0.0016 ~ 0.0035)	0.15 (0.0059)	
Bushing Hole	Nos. 1 and 2	$54^{+0.060}_{-0}$ $(2.126^{+0.00236}_{-0})$		
	No. 3	$53^{+0.060}_{-0}$ $(2.087^{+0.00236}_{-0})$		
Journal O.D.	Nos. 1 and 2	$54^{-0.04}_{-0.06}$ $(2.126^{-0.00157}_{-0.00236})$		−0.1 (−0.0039)
	No. 3	$53^{-0.04}_{-0.06}$ $(2.087^{-0.00157}_{-0.00236})$		−0.1 (−0.0039)

(3) To install the camshaft bushings, use a group of drivers (puller, 30091-07300, adaptors, 30891-04500 and 30891-04600) after boring the ID of camshaft holes in the crankcase up to 57 mm ± 0 (2.244 ± 0 in.).



1-Handle 4-Bushing
2-Spacer plates 5-Crankcase
3-Pilot plate 6-Drive plate

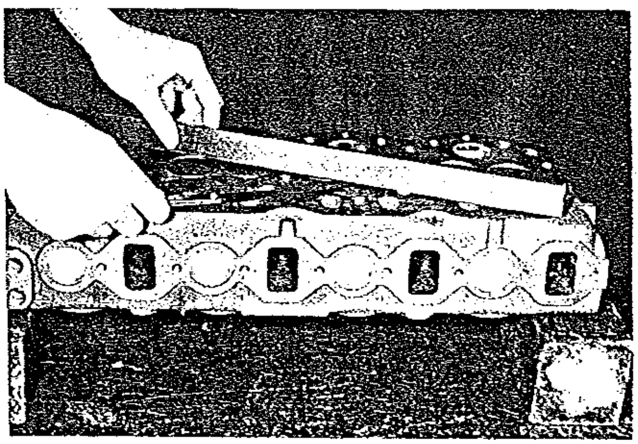
Use of bushing driver

Cylinder head

Cylinder head inspection

Check the gasketed surface of the cylinder head for flatness by using a straightedge and thickness gauge as in the case of checking the crankcase surfaces. This check is to be made with the precombustion jets removed.

Use a surface grinder to reface the cylinder head, as necessary, to the specified flatness.



Checking cylinder head face for flatness

Unit: mm (in.)

Item	Standard	Repair limit
Flatness of gasketed surface of cylinder head	0.05 (0.002), max.	0.2 (0.008)

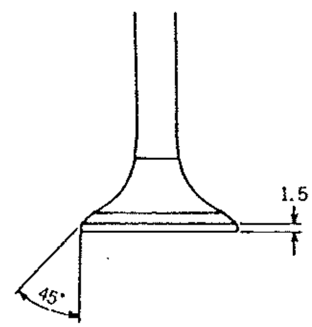
Valves and valve seat

(1) Inspection

De-carbon valve stems and seats; inspect both for wear and evidence of burning. Provided that the wear is within the service limit, grind smooth the seating face of each valve, removing the wear groove, if any, and finishing it to the specified angle of 45 deg. For this service, use a valve refacer.

Unit: mm (in.)

Item		Standard	Service limit
Valve stem diameter	Intake	$8^{-0.045}_{-0.060}$ ($0.315^{-0.00177}_{-0.00236}$)	−0.1 (−0.004)
	Exhaust	$8^{-0.060}_{-0.075}$ ($0.315^{-0.00236}_{-0.00295}$)	−0.15 (−0.0059)
Valve head thickness		1.5 (0.059)	1.2(0.0472) after refacing



Valve head thickness

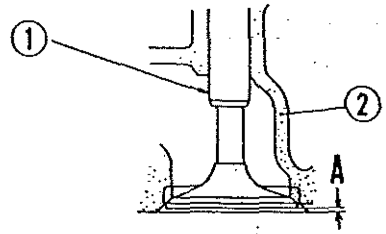
(2) Valve replacement

(a) Replace valves whose stems are found to have worn down to the service limit or head thickness is down to 1.2 mm (0.0472 in.) or under after refacing.

(b) Any valve showing evidence of cracking particularly in the head part must be replaced.

(c) "Valve sinkage" refers to a head face being below the combustion chamber surface, as shown, and is prescribed to be not greater than 1.3 mm (0.051 in.), the standard sinkage being 0.7 ± 0.2 mm (0.028 ± 0.008 in.). If the limit is reached, replace the valve or seat.

(d) Replace valve caps found excessively worn at the top face.



1-Valve A-Sinkage
2-Cylinder head
Valve sinkage

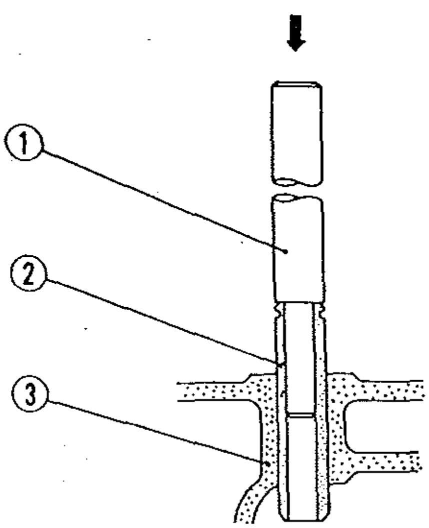
(3) Valve guide replacement

Unit: mm (in.)

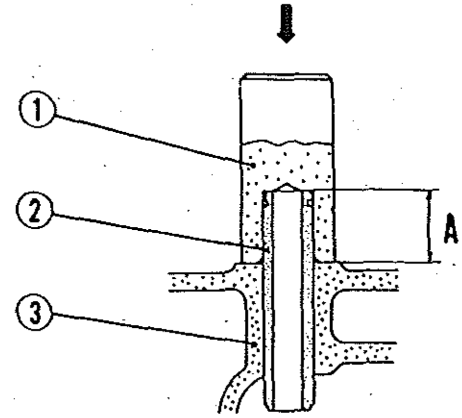
Item		Standard	Service limit
Valve stem clearance in valve guide	Intake	0.055 ~ 0.085 (0.0022 ~ 0.0033)	0.15 (0.0059)
	Exhaust	0.070 ~ 0.100 (0.0028 ~ 0.0039)	0.20 (0.0079)
Guide length outside hole		17 ± 0.3 (0.669 ± 0.012)	

Where the stem-to-guide clearance is found to have exceeded the service limit, both valve and guide must be replaced. Apart from this clearance, check each guide to see if its I.D. near each end has enlarged and, if so, replace it.

Valve guides are press-fitted. To remove them, use a press and a drift, which is a special tool called the guide remover (31391-10500); to install, use the installer (34491-00400), another special-tool drift.



1-Remover 2-Guide 3-Cylinder head
Removing valve guide

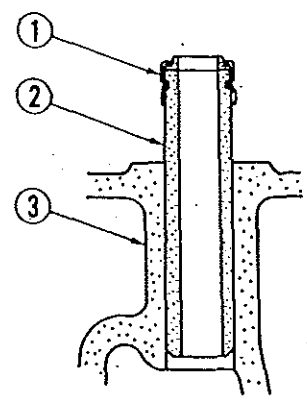


1-Installer 3-Cylinder head
2-Guide A-Guide length outside hole
Installing valve guide

(4) Valve stem seal replacement

The valve stem seals should be replaced if the engine disassembled shows evidence of lube oil leaking into the combustion chambers along valve stems. The seal can be readily removed. When putting on a new seal, make sure that it fits snugly into the annular groove provided in the valve guide end.

If a valve has to be drawn out for one reason or another in the engine in regular use, be sure to have a replacement stem seal on hand for that valve. This is because the seal lip is certain to get scarred by the sharp-edged stem end.



1-Stem seal 2-Guide 3-Cylinder head
Valve stem seal replacement

(5) Valve seat refacing

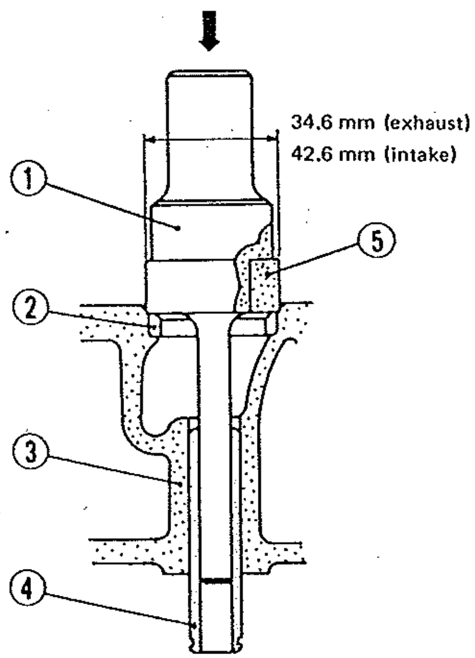
A valve seat badly worn or coarsened must be refaced by grinding in place. Use a valve seat grinder or a seat cutter and 400-grit emery cloth. Care must be exercised in using the seat cutter so that the cut will be even all around. After cutting, pinch the 400-grit emery cloth between the cutter and the seat and grind the seat face smooth.

Before installing the valve, lap the valve and seat, using the lapping compound. Check for contact pattern after lapping, using a paste of red lead to visualize the pattern. The pattern should be uniform and continuous.

(6) Valve seat removal and installation

To remove the valve seat, thin it in place by cutting with a rotary cutter, and break it loose with a chisel, taking care not to nick the counterbore in which the seat is seized by expansion fitting.

To insert the replacement seat, chill it first to about –80°C (–112°F). This low temperature can be reached by immersing the seat in a pool of either or alcohol and by placing dry ice in the pool. Force the chilled seat into the counterbore, which has been trimmed clean and smooth, and calk around the seat with the calking tool (31391-13010 for intake valve or 31391-13020 for exhaust valve).



1-Tool body
2-Valve seat
3-Cylinder head
4-Valve guide
5-Calking ring

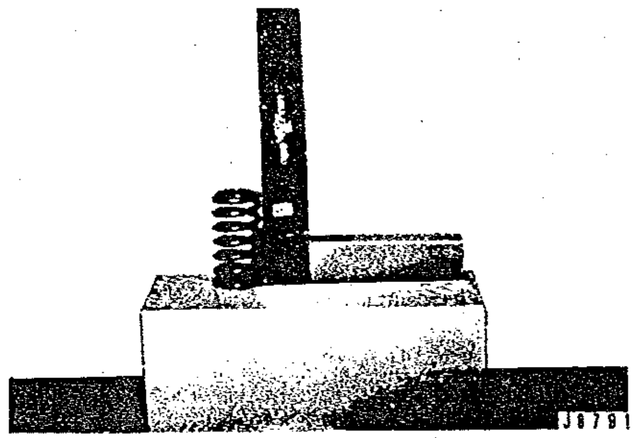
Installing valve seat by using calking tool

Valve spring inspection

Inspect each spring for cracks, and check it for squareness, free length and as-installed length against these specifications:

Unit: mm (in.)

Item	Standard	Repair limit
Valve spring free length	48.85 (1.923)	47.6 (1.874)
Valve spring squareness	0.4/25, max. (0.016/0.98), max.	
As-installed length	43 (1.693)	44 (1.732)



Checking valve spring for squareness

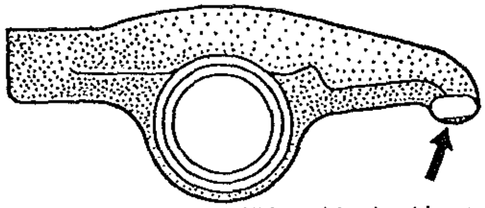
Rocker arm and rocker shaft inspection

(1) The valve-actuating tip of the rocker arm is subject to wear. If the tip face is excessively worn, replace the rocker arm.

(2) Take diameter readings on the bushings and the rocker arm shaft, and compute the radial clearance from these readings. If the limit is exceeded, reduce the clearance by replacing the bushings or rocker arm shaft.

Unit: mm (in.)

Item	Standard	Repair limit
Bushing bore diameter	$20^{+0.021}_{-0}$ $(0.787^{+0.00083}_{-0})$	
Rocker shaft diameter	$20^{-0.016}_{-0.034}$ $(0.787^{-0.00063}_{-0.00134})$	
Shaft clearance in bushing	0.016 ~ 0.055 (0.0006 ~ 0.0022)	0.07 (0.0028)



Rocker arm

(3) Check to be sure that the oil hole drilled out in the rocker arm shaft is clear. When installing replacement bushings, be sure to align the oil holes.

Valve-clearance adjusting screw inspection

Examine each adjusting screw to see if its end face for contacting with the push rod is worn down excessively or if its threads are showing signs of failure; if so found, replace it by a new one.

Push rod inspection

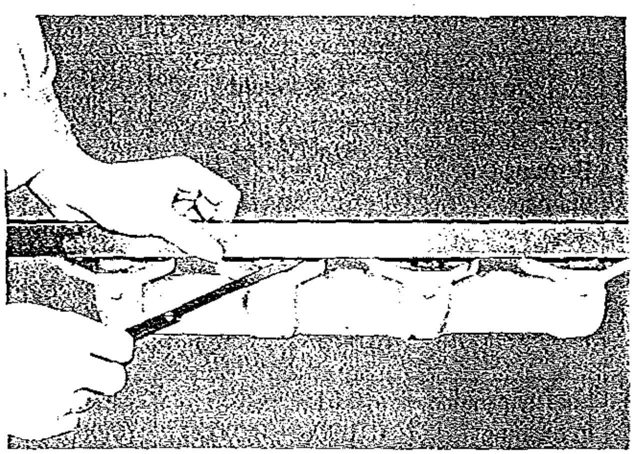
Check push rods for deflection, and inspect them for wear at the end faces for contacting with the tappet and adjusting screw. "Deflection" refers to the runout exhibited by the push rod being rotated with its ends supported by such as "V" blocks.

Unit: mm (in.)

Item	Standard
Push rod distortion	0.4 (0.016), max.

Exhaust manifold inspection

Inspect the manifold flange for cracks and distortion. If the flange faces are warped by more than 0.2 mm (0.0079 in.) when checked as shown, grind them smooth and flat. If any flange is found cracked, replace the manifold.


Checking exhaust manifold flange faces for flatness

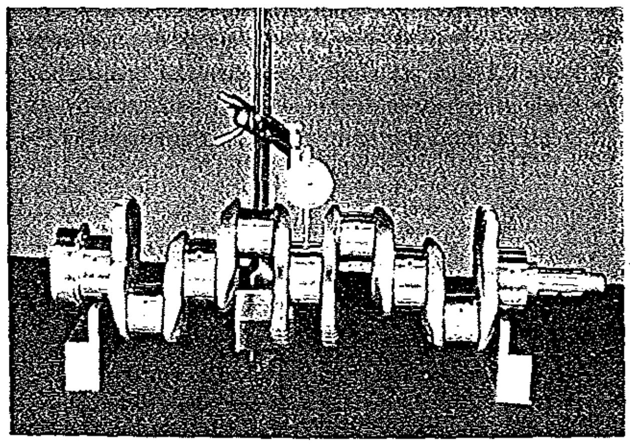
Crankshaft inspection

(1) Crankshaft distortion

Support the crankshaft as shown and roll it to measure its deflection with a dial gauge. "Distortion" is one-half of the deflection (dial gauge reading); if it exceeds the repair limit, reduce it by bending the crankshaft in a press.

Unit: mm (in.)

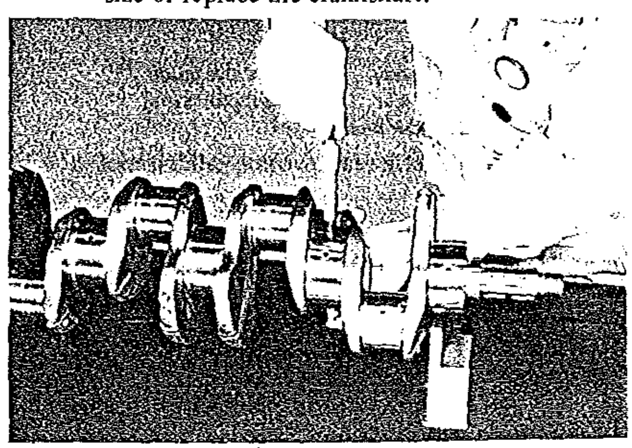
Item	Standard	Repair limit
Crankshaft distortion	0.02 (0.0008), max	0.05 (0.0020)

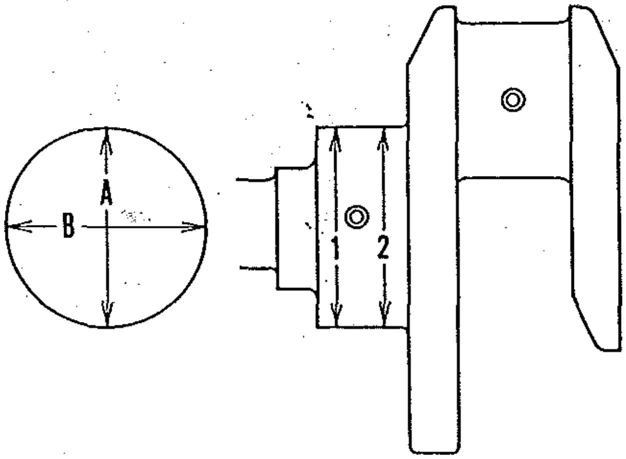

Checking crankshaft for distortion

(2) Journal inspection

(a) Inspect each journal for surface flaws such as roughing, scratches, pitting and burns, and, as necessary, repair the journals by grinding to the next undersize or replace the crankshaft.

(b) Mike each journal to take a total of four readings to determine the wear, out-of-round and taper (cylindricity). If any of the limits is exceeded, repair by grinding to the next undersize or replace the crankshaft.


Miking crankshaft journals



Positions for miking journal

Unit: mm (in.)

Item		Standard	Repair limit	Service limit
Crank-shaft jour-nals	Diame-ter	$75^{-0.030}_{-0.050}$ ($2.953^{-0.00118}_{-0.00197}$)	−0.15 (−0.0059)	−0.9 (−0.035)
	Out-of-round	0.01 (0.0004), max.	0.03 (0.0012)	
	Taper	0.01 (0.0004), max.	0.03 (0.0012)	

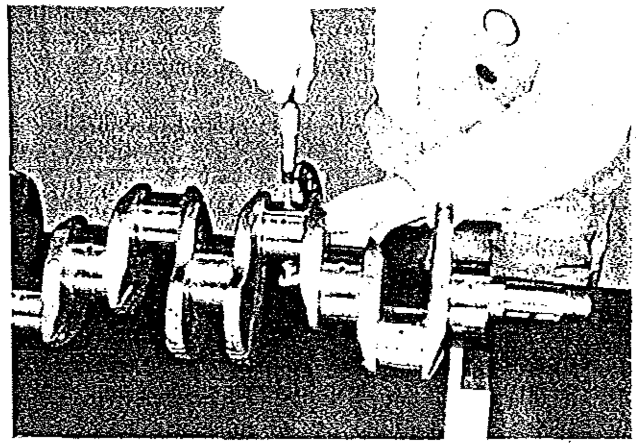
(c) Journal undersizes
For the two undersize main bearings available, the journals are to be ground to these sizes:

Unit: mm (in.)

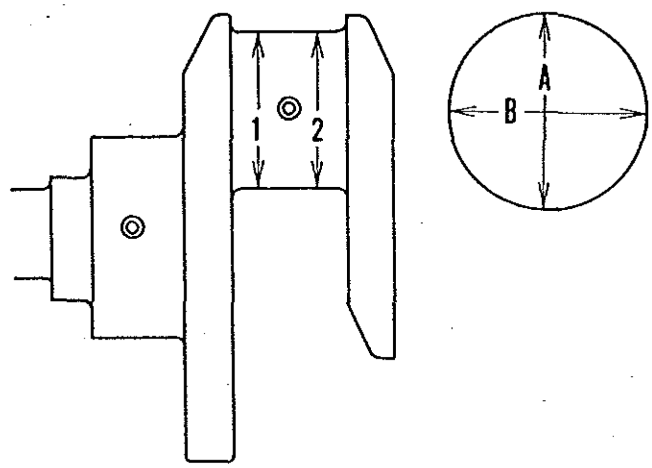
Journal undersize	Journals to be ground to:
0.25 (0.0098)	$74.75^{-0.030}_{-0.050}$ ($2.9429^{-0.00118}_{-0.00197}$)
0.50 (0.0197)	$74.5^{-0.030}_{-0.050}$ ($2.9331^{-0.00118}_{-0.00197}$)

(3) Crankpin inspection

(a) Inspect each crankpin for surface flaws such as roughing, scratches, pitting and burns, and, as necessary, repair the crankpins by grinding to the next undersize or replace the crankshaft.



Miking crankshaft crankpins



Positions for miking crankpin

(b) Mike each crankpin to take a total of four readings to determine the wear, out-of-round and taper. If any of the limits is exceeded, repair by grinding to the next undersize or replace the crankshaft.

Unit: mm (in.)

Item		Standard	Repair limit
Crankpins	Diameter	$58^{-0.035}_{-0.055}$ ($2.283^{-0.00138}_{-0.00217}$)	0.20 (0.00787)
	Out-of-round	0.01 (0.0004), max.	
	Taper	0.01 (0.0004), max.	

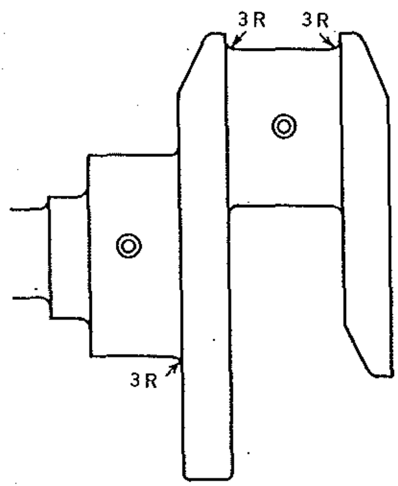
(c) Crankpin undersizes
When grinding the crankpins to the next undersize, be sure to finish each crankpin to the tolerance prescribed for the undersize, which is 0.25mm (0.00984 in.) or 0.50mm (0.01969 in.).

Unit: mm (in.)

Crankpin undersize	Crankpins to be ground to:
0.25 (0.0098)	$57.75^{-0.035}_{-0.055}$ $(2.2736^{-0.00138}_{-0.00217})$
0.50 (0.0197)	$57.50^{-0.035}_{-0.055}$ $(2.2638^{-0.00138}_{-0.00217})$

NOTE

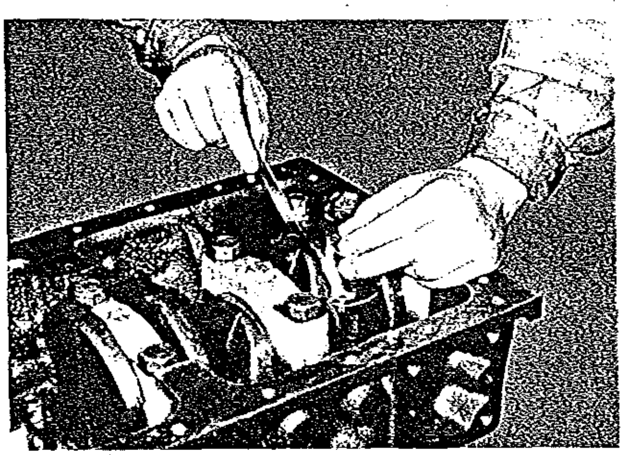
Try to keep the center-to-center distance between journal and crankpin within ±0.05 mm (0.00197 in.) of 47 mm (1.850 in.). When grinding the crankpins to an undersize, be sure to size the corner radius (fillet) to 3 mm (0.118 in.). This applies also to the fillets of journals.



Crankshaft corner radius (fillet radius)

(4) Crankshaft end play

Check the crankshaft for end play, as shown, by using a thickness gauge at the thrust bearing. If a play of 0.3 mm (0.0118 in.) or more is noted, replace the thrust bearing.

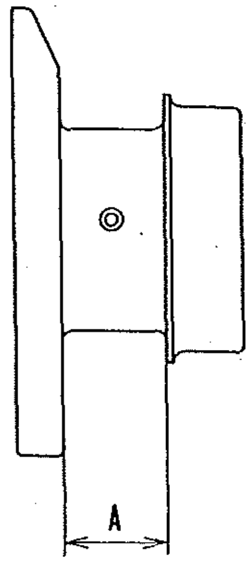


Checking crankshaft end play

Unit: mm (in.)

Item	Standard	Repair limit
Crankshaft end play	0.1 ~ 0.264 (0.00394 ~ 0.01039)	0.3 (0.012)

The end play is due to the difference between the width of thrust bearing and the dimension (A) indicated below:



Journal width for thrust bearing

(5) Oil seal inspection

Inspect each oil seal, and replace it if it is badly worn, damaged or thermally fatigued at the lip surface. An oil seal suspected of poor sealing action evidenced by signs of leakage (noted upon engine disassembly) must be inspected more closely.

(6) Oil seal sleeve inspection

The outside surface of the oil seal sleeve is precision-machined and chrome-plated for greater wear resistance. Be sure to handle the sleeves carefully and protect this surface against damage.

Even a slightest scratch mark, not to mention of a dent or groovy wear, on this surface could result in oil leakage, and a sleeve with such a surface flaw must be replaced.

(7) Replacement of rear oil seal sleeve (for crankshaft gear)

To remove the sleeve, put a chisel to the outside surface of the sleeve and drive it in axial direction to stretch it. This will loosen the sleeve, making it ready to be drawn out. When driving, be careful not to damage the gear.

To install the replacement sleeve, oil its bore and the crankshaft gear, using clean, fresh engine oil; hold the sleeve squarely and drive it into its position, keeping it trued up accurately.

(8) **Inspection of crankshaft keyway and screw threads**

The forward end of the crankshaft is threaded and has a keyway. Visually examine the threads and keyway and, as necessary, repair them.

Pistons and piston rings

(1) **Piston inspection**

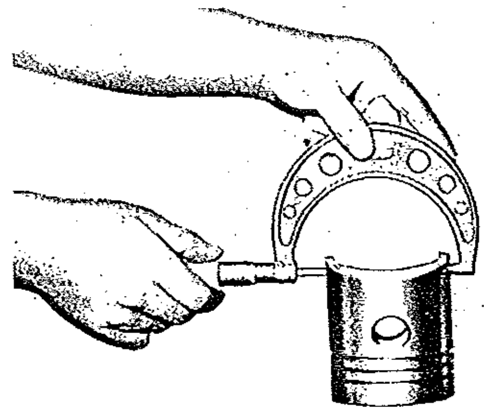
Inspect each piston for any abnormal wear of its sliding surface, for cracks at the crown and for evidence of melting or fusion. Examine the ring grooves for stepped wear and sloped wear. Replace pistons found in bad condition.

(2) **Piston clearance in the bore**

Mike each piston at the positions listed below; and by referring to the bore diameter, previously determined, of its sleeve, compute the radial clearance at each position. If the piston is worn down so much as to exceed the limit [–0.2 mm (–0.0079 in.)] at any of these positions, replace it.

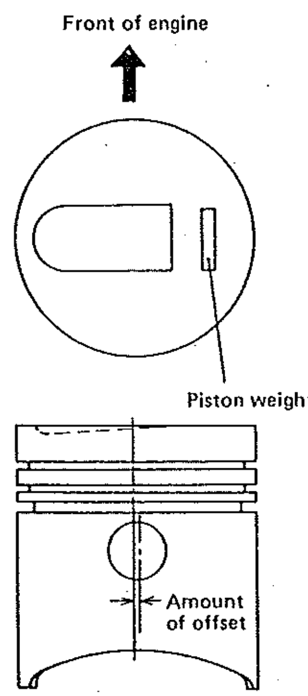
Unit: mm (in.)

Item		Standard	Service limit
Piston diameter (at skirt)	Standard size	93.86±0.015 (3.6953±0.00059)	–0.2 (–0.008)
	0.25-mm (0.0098 in.) oversize	94.11±0.015 (3.7051±0.00059)	
	0.50-mm (0.0197 in.) oversize	94.36±0.015 (3.7150±0.00059)	
Piston clearance in bore	At piston crown	0.615~0.680 (0.02421~0.02677)	0.2 (0.008)
	At No.1 land	0.465~0.530 (0.01831~0.02087)	
	At No.2 land	0.415~0.480 (0.01634~0.01890)	
	Just below oil ring	0.275~0.340 (0.01083~0.01339)	
	17 mm (0.669 in.) below oil ring	0.195~0.260 (0.00768~0.01024)	
	37.5 mm (1.476 in.) below oil ring	0.155~0.220 (0.00610~0.00866)	
	At skirt	0.125~0.190 (0.00492~0.00748)	



J20139

Miking piston



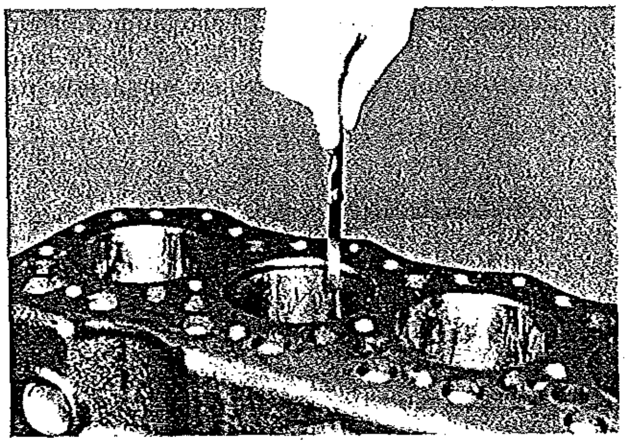
Piston weight marking and pin hole offset

NOTE

Before reassembling the engine, make sure that the four pistons do not differ by plus or minus 3 grams (0.1 oz) from the weight indicated on the crown. If any of the pistons has to be replaced by an oversize piston, replace the other three, too, by those of the same oversize.

(3) **Piston ring gap**

Be sure that each piston ring has its gap within the service limit. Measure the ring gap with a thickness gauge, holding the ring fitted in a new sleeve.



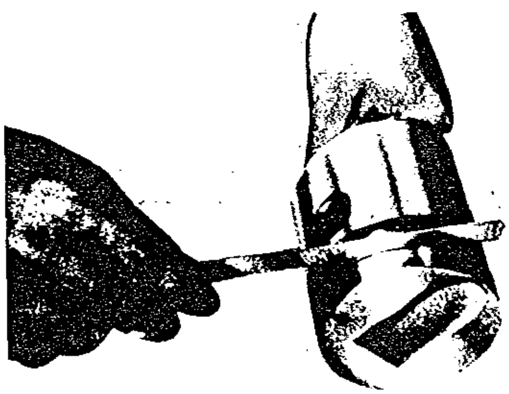
Checking piston ring gap

Unit: mm (in.)

Item	Standard	Service limit
Piston ring gap	0.3 ~ 0.5 (0.0118 ~ 0.0197)	1.5 (0.059)

(4) Piston ring clearance in groove

The clearance between a piston ring and its groove is specified for each. This clearance is dependent on the condition of the ring or the groove, or both. If the reading taken exceeds the repair limit, replace the ring and, if the replacement ring still provides an excessive reading, it means that the groove is worn so much as to require piston replacement.



J8803

Checking piston ring clearance

Unit: mm (in.)

Item		Standard	Repair limit
Piston ring clearance in the groove	No. 1	0.04 ~ 0.08 (0.0016 ~ 0.0031)	0.2 (0.0079)
	No. 2	0.025 ~ 0.060 (0.0010 ~ 0.00236)	0.15 (0.0059)
	No. 3	0.025 ~ 0.060 (0.0010 ~ 0.00236)	0.15 (0.0059)

(5) Pin clearance in piston

Replace the piston or piston pin if the pin clearance, as computed from diameter readings taken on pin hole and pin, exceeds the service limit.

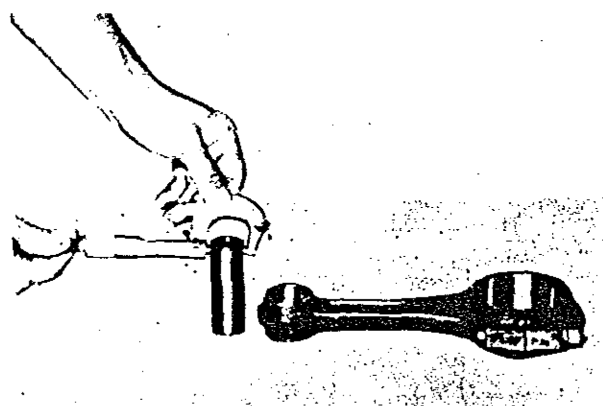
Unit: mm (in.)

Item	Standard	Repair limit
Piston pin diameter	$28^{+0}_{-0.006}$ ($1.102^{+0}_{-0.00024}$)	
Pin clearance in the piston	0 ~ 0.016 (0 ~ 0.0006)	0.05 (0.002)

Connecting rods

(1) Pin clearance in small end

Replace the piston pin or bushing if the pin clearance in the bushing, as computed from diameter readings taken on pin and bushing, exceeds the service limit.



J8804

Miking piston pin

NOTE

To remove the bushing from and install it in the small end, the special tool must be used. Before installing the bushing, be sure to have the oil holes aligned.

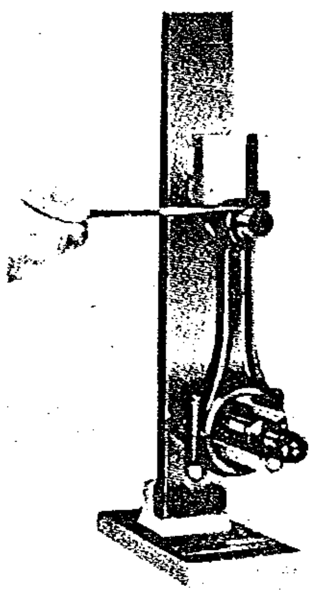
Unit: mm (in.)

Item	Standard	Repair limit
Piston pin diameter	$28^{+0}_{-0.006}$ ($1.102^{+0}_{-0.00024}$)	
I.D. of bushing in small end	$28^{+0.045}_{+0.020}$ ($1.102^{+0.00177}_{+0.00079}$)	
Pin clearance in bushing	0.020 ~ 0.051 (0.0008 ~ 0.0020)	0.08 (0.003)

(2) **Connecting rod alignment and big-end bearings**

(a) Inspect each connecting rod for evidence of cracking, particularly at the corner radius parts of the "I" shank next to the big and small ends and also at the oil hole in the small end. Connecting rods found cracked or suspected of cracking must be replaced.

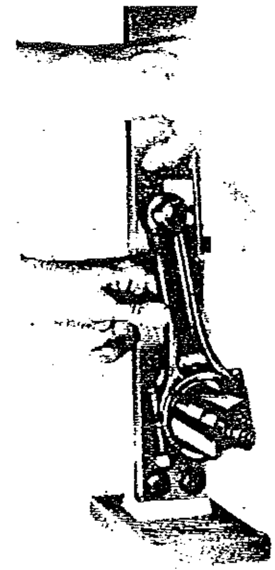
Check each connecting rod for alignment by fitting it to the aligner, as shown, and repair it by cold-working with a press, as necessary. The aligner tells whether the connecting rod is twisted or bent beyond the limit.



Checking connecting rod for bend

Unit: mm (in.)

Item	Standard	Repair limit
Connecting rod alignment (twist and bend)	0.05 (0.002), max.	0.15 (0.006)



J8806

Checking connecting rod for twist

(b) Inspect each big-end bearing for evidence of wiping or fatigue failure, for scratches by dirt particles imbedded in and for improper seating on the bore. Determine whether the bearing should be re-used or replaced on the basis of findings.

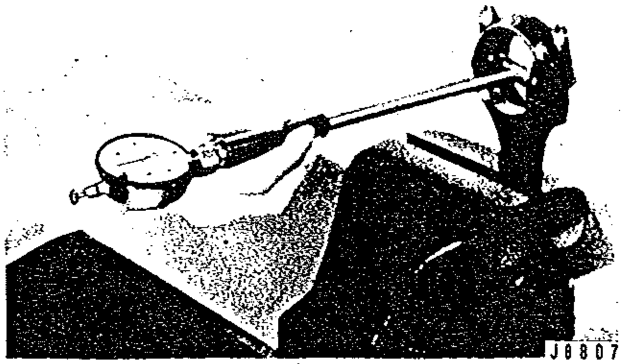
(c) Check the radial clearance between crankpin and bearing; if the repair limit specified below is exceeded by the checked clearance, replace the bearing. Where the crankpin is to be ground to the next undersize, use a replacement bearing of that undersize.

Unit: mm (in.)

Item	Standard	Repair limit
Crankpin diameter	$58^{-0.035}_{-0.055}$ ($2.283^{-0.0014}_{-0.0022}$)	
Radial clearance between bearing and crankpin	0.035 ~ 0.100 (0.0014 ~ 0.0039)	0.20 (0.008)

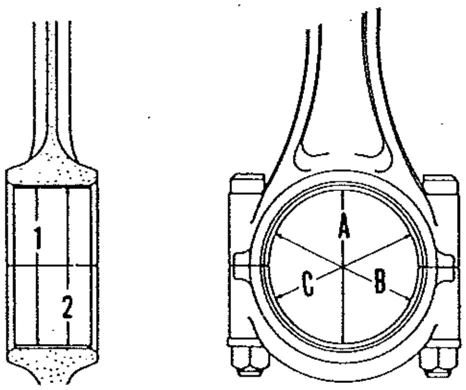
The two bearing undersizes are 0.25 mm (0.00984 in.) and 0.50 mm (0.01969 in.).

As in the case of the main bearing, the clearance is to be determined from the crankpin diameter (determined as described in CRANKPIN INSPECTION) and also the diameter readings taken on the big-end bearing at the positions indicated and in the manner illustrated.



Measuring big-end

The big-end bearing fitted to the connecting rod must be secured by tightening the cap bolts 8.5 ± 0.5 kg-m (61.5 ± 3.6 ft-lb).



Positions for miking big-end bearing

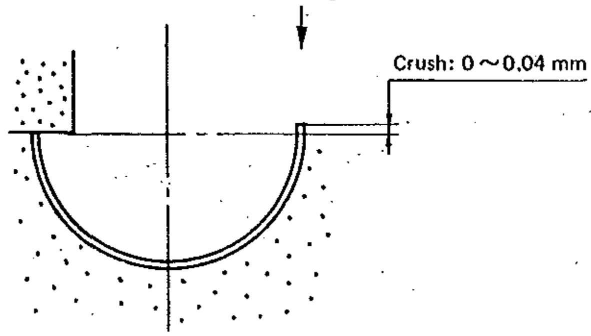
(d) Check the contact pattern of big-end bearing on crankpin by fitting the big end in the normal manner to the crankpin, with the crankshaft laid out on the bench, and by using a paste of red lead or Prussian blue to visualize the contact. Be sure to tighten the cap bolts to the specified torque, that is, 8.5 kg-m (61.5 ft-lb). The contact should occur over at least 75% of the entire surface; if not, replace the bearing.

NOTE

The above job of checking the contact pattern may be eliminated where the crankpin is ground to the specified tolerance and the bearing has been replaced. This is because a replacement bearing is precision-finished to ensure the specified extent of contact.

(e) Check each bearing shell for "crush." Shells found to be loose in the bore or have an excessive crush must be replaced. A crush of up to 0.04 mm (0.0016 in.), which will yield to a load of 350 kg (772 lb), is prescribed. As in the case of the main bearing shells, some "crush" is needed for securing a proper fit, without which the bearing might roll or jump in place, resulting in localized overloading and consequent flaking, burning or fatigue failure.

Check to be sure that the "crush" disappears to allow the bearing cap to mate the big end positively when the cap bolts are tightened to 8.5 kg-m (61.5 ft-lb).

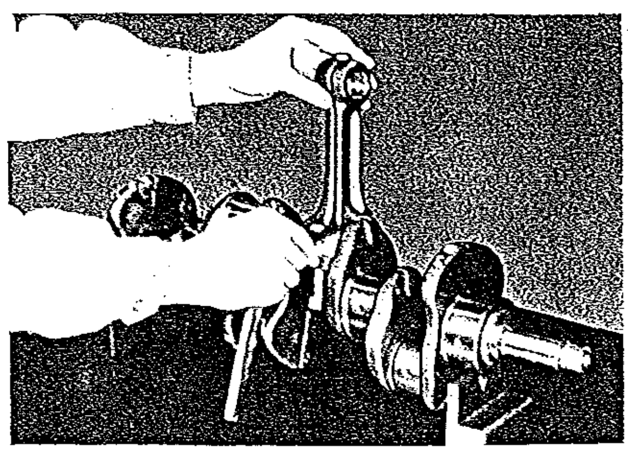


Big-end bearing crush

(f) Check each connecting rod for end play in the manner illustrated, with the cap bolts tightened to 8.5 ± 0.5 kg-m (61.5 ± 3.6 ft-lb). Use a thickness gauge to measure the end play (which is the clearance between big end and crank arm). If the clearance measured exceeds the service limit, replace the connecting rod or big-end bearing.

Unit: mm (in.)

Item	Standard	Service limit
Connecting rod end play	0.15 ~ 0.35 (0.006 ~ 0.014)	0.50 (0.020)



Checking end play of connecting rod

NOTE

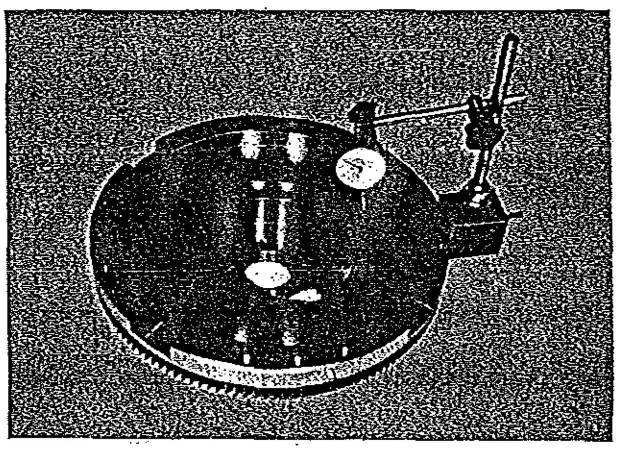
Before reassembling the engine, make sure that the four connecting rods are equal in weight within ±5 grams (±0.18 oz) of the specification weight.

Flywheel inspection

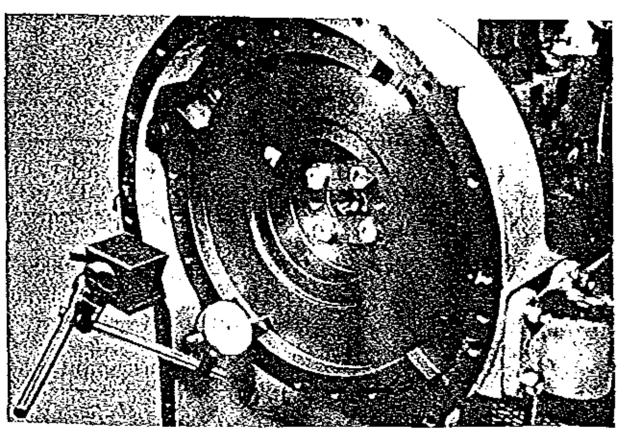
(1) Repair the friction surface of the flywheel if it is found burnt, stepped, or grooved by rivet heads. If this surface is badly worn or damaged, the flywheel must be replaced.

(2) Using a dial indicator, check the friction surface for flatness and face runout. A perfectly flat surface is no guarantee that the surface will not "run out" when it rotates.

Flatness can be checked, as shown, with the flywheel laid on a surface plate. To take the runout reading, secure the flywheel to the crankshaft in the normal manner and roll the crankshaft, with the spindle of the dial indicator put to the surface near its edge.



Checking flywheel for flatness



Checking flywheel for face runout

Unit: mm (in.)

Item	Standard	Repair limit
Flatness of friction surface	0.15 (0.006), max.	0.5 (0.020)
Face runout of friction surface	0.15 (0.006), max.	0.5 (0.020)

(3) Make sure that the flywheel securing bolts are in good condition, with their screw threads showing no signs of stripping. The ring gear with broken or badly worn teeth must be replaced. Clean the bushing for pilot bearing; if the bushing is abnormally worn or showing defective contact pattern, replace it.

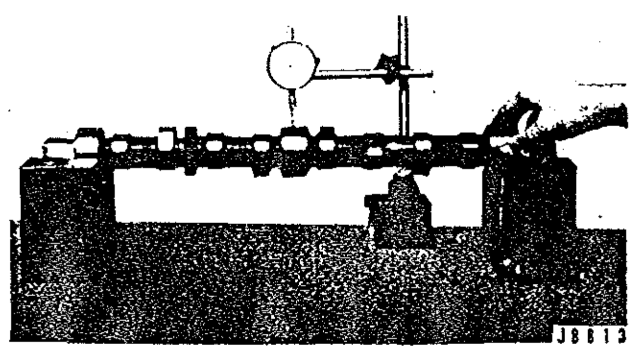
Timing mechanism

Camshaft inspection

(1) Support the camshaft at No. 1 and No. 3 journals by "V" blocks, with the spindle of the dial gauge put to No. 2 journal, and roll the camshaft to measure its distortion (which is one-half of the deflection, that is, the dial gauge indication). Straighten the camshaft in a press or replace it, as necessary.

Unit: mm (in.)

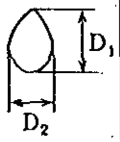
Item	Standard	Service limit
Camshaft distortion	0.02 (0.0008), max.	0.05 (0.0020)



Checking camshaft deflection

(2) Mike each cam of the camshaft to read D_1 (cam height) and D_2 (diameter), and compute the difference between D_1 and D_2. If this difference is less than the service limit, replace the camshaft.

Unit: mm (in.)

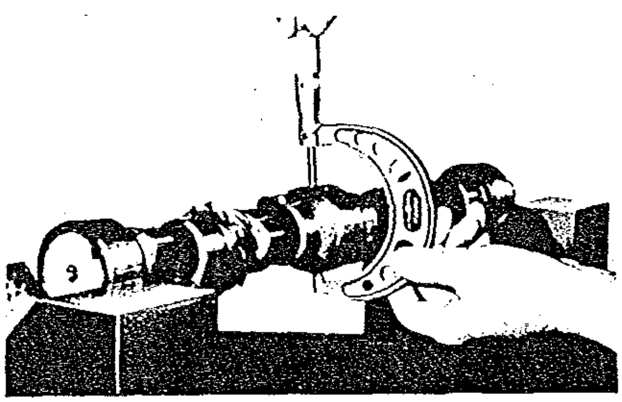
Item		Standard	Service limit
Cam height wear ($D_1 - D_2$) 	Intake cam	D_1 : $46.916^{+0.1}_{-0.3}$ ($1.847^{+0.00394}_{-0.01181}$) $D_1 - D_2 = 6.684$ (0.26315)	$D_1 - D_2 = 6.184$ (0.24346)
	Exhaust cam	D_1 : $45.944^{+0.1}_{-0.3}$ ($1.8088^{+0.00394}_{-0.01181}$) $D_1 - D_2 = 7.344$ (0.28913)	$D_1 - D_2 = 6.844$ (0.26945)

(3) Inspect the camshaft journals for abnormal wear and damage; the camshaft must be replaced if any of its three journals is found in bad condition beyond repair.

(4) Mike each journal of the camshaft in two directions, one being at right angles with another, at two places, front and rear. Measure each camshaft hole in the crankcase. Compute the clearance between the two; if the repair limit is exceeded, bore the hole up to $57H6^{+0.019}_{-0}$ mm ($2.24^{+0.00075}_{-0}$ in.) and insert a bushing to bring it into the standard clearance range.

Unit: mm (in.)

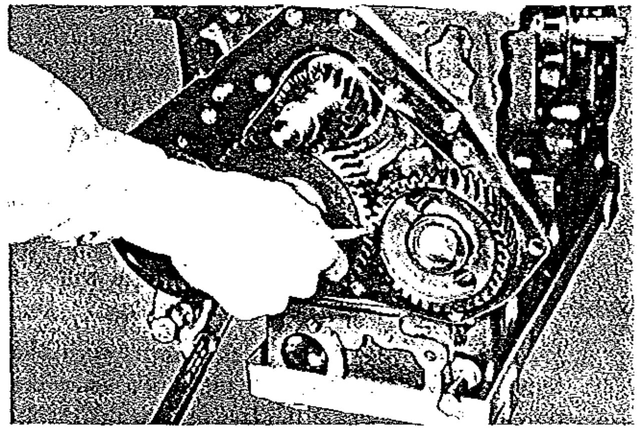
Item		Standard	Repair limit
Camshaft journal O.D.	Nos. 1 and 2	$54^{-0.04}_{-0.06}$	
		($2.126^{-0.0016}_{-0.0024}$)	
	No. 3	$53^{-0.04}_{-0.06}$ ($2.087^{-0.0016}_{-0.0024}$)	
Camshaft journal-to-hole clearance		0.04 ~ 0.09 (0.0016 ~ 0.0035)	0.15 (0.0059)



Miking camshaft journals

Timing gear inspection

(1) Be sure that the backlash in each mesh is within the repair limit. If the limit is exceeded, reduce the backlash by replacing the worn gear. To measure backlash, use a thickness gauge: put the gauge squarely into between two gear teeth.



Checking timing gear backlash

Unit: mm (in.)

Item	Standard	Repair limit
Backlash	0.07 ~ 0.20 (0.0029 ~ 0.0079)	0.25 (0.0098)

(2) Check the radial clearance between idler bushing and shaft by miking. Compute the clearance from the readings taken and, if the repair limit is exceeded, replace the bushing.

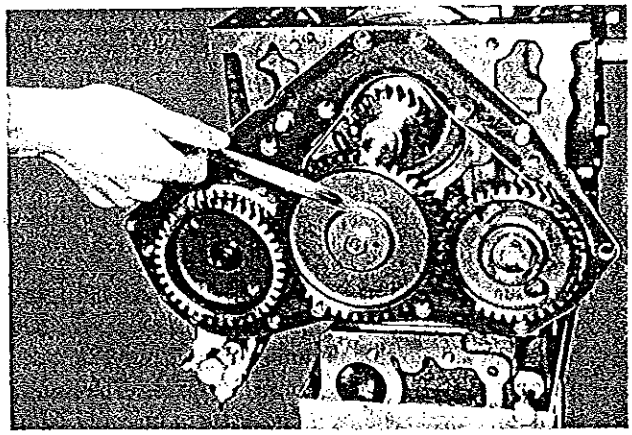
Unit: mm (in.)

Item	Standard	Repair limit
Idler bushing I.D.	$36^{+0.025}_{-0}$ ($1.417^{+0.00098}_{-0}$)	
Idler shaft O.D.	$36^{-0.025}_{-0.050}$ ($1.417^{-0.00098}_{-0.00197}$)	
Bushing-to-shaft clearance	0.025 ~ 0.075 (0.00098 ~ 0.00295)	0.1 (0.0039)

(3) Check the idler end play with a thickness gauge. Replace the thrust plate to reduce the play if the thickness gauge reading exceeds the repair limit.

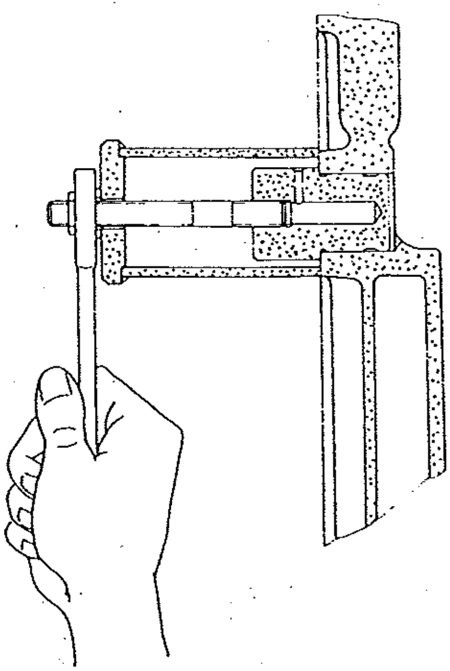
Unit: mm (in.)

Item	Standard	Repair limit
Idler end play	0 ~ 0.1 (0 ~ 0.004)	0.35 (0.0138)



Checking idler end play

(4) If the idler shaft has to be replaced, use the idler shaft puller to remove it, as shown. When installing the replacement shaft, check to be sure that the oil holes are aligned.



Drawing out idler shaft

(5) Inspect the timing gears as follows:

(a) Camshaft gear
Replace the gear if its teeth show evidence of flaking or excessive wear, or if its keyway is galled, worn or otherwise disfigured. Make sure that the camshaft gear as mounted on the camshaft has no more end play than 0.4 mm (0.0157 in.): to check the end play, use a dial gauge. If the reading exceeds the repair limit, replace the thrust plate. (Remember, this gear is shrink-fitted to the camshaft.)

Unit: mm (in.)

Item	Standard	Repair limit
Camshaft end play	0.05 ~ 0.112 (0.00197 ~ 0.00441)	0.3 (0.0118)

(b) Injection pump gear
Inspect the gear teeth for damage and also the mounting bolt holes for malcondition. Replace the gear if found in badly damaged condition.

(c) Crankshaft gear
Replace the gear if its teeth show signs of defective tooth contact, or are excessively worn or otherwise defective.

(d) Idler gear
Inspect the idler gear teeth and, as necessary, replace the gear.

(6) Inspect the gear case for cracks, and for evidence of oil leakage at the part ahead of the crankshaft. A cracked case must be replaced. Inspect the crank pulley, too, examining the condition of the surface in contact with the oil seal and checking the keyway and key for wear. Replace the pulley if found in defective condition.

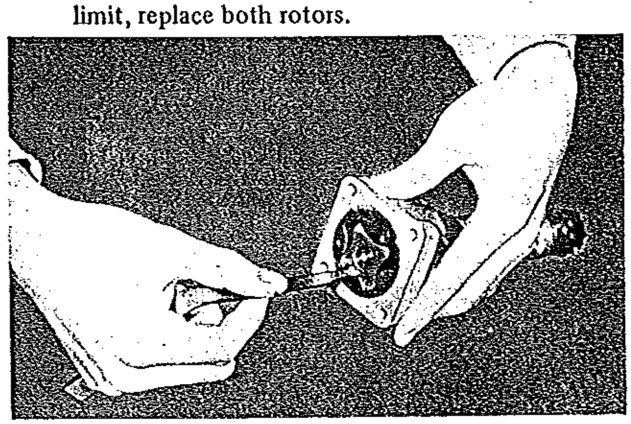
Lubrication system

Oil level check

The oil level gauge is located at the right-hand side of the crankcase, and carries two level marks, upper and lower. The oil pan contains about 7 liters (1.8 gallons) when the oil is up to the upper mark, and about 5.5 liters (1.5 gallons) when it is up to the lower mark. The oil pan should be kept filled to the upper mark.

Oil pump inspection

(1) Running clearance between outer rotor and inner rotor
Using a thickness gauge, check the clearance at various positions. If the reading exceeds the service limit, replace both rotors.



Checking rotor-to-rotor clearance

Unit: mm (in.)

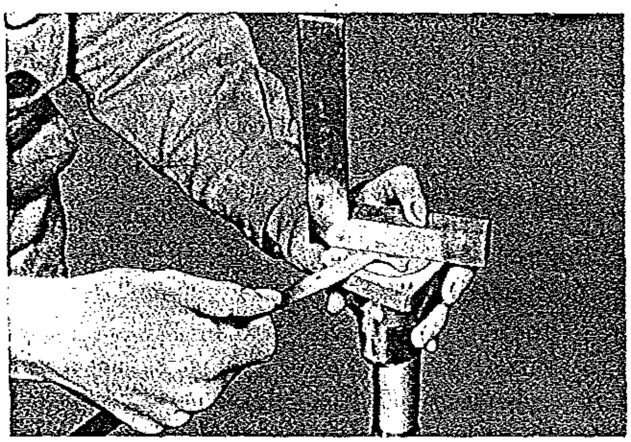
Item	Standard	Service limit
Clearance between inner rotor and outer rotor	0.013 ~ 0.15 (0.0005 ~ 0.0059)	0.25 (0.0098)

(2) **Sliding clearance between rotors and cover**

This clearance is required to be not greater than 0.15 mm (0.00591 in.). If this limit is exceeded, grind off the mating face of the body to reduce the clearance.

Unit: mm (in.)

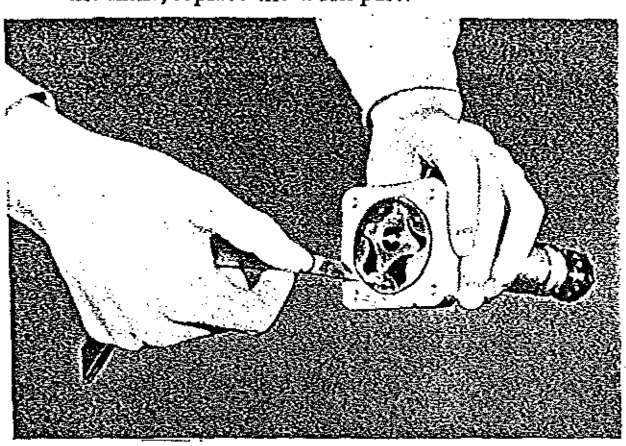
Item	Standard	Repair limit
Clearance between rotors and cover	0.04 ~ 0.09 (0.0016 ~ 0.0035)	0.15 (0.0059)



Checking rotor-to-cover clearance

(3) **Radial clearance between outer rotor and pump body**

Insert a thickness gauge into between outer rotor and body. If the clearance checked is greater than the limit, replace the worn part.



Checking rotor-to-body clearance

Unit: mm (in.)

Item	Standard	Service limit
Clearance between outer rotor and body	0.2 ~ 0.28 (0.0079 ~ 0.0110)	0.5 (0.0197)

(4) **Rotor shaft diameter**

Inspect the shaft for damage, and check it for wear by miking. Determine the available clearance of the shaft in the pump body from the mike readings; if the service limit in terms of clearance value is exceeded or if the shaft is in badly damaged condition, replacement is necessary.

Unit: mm (in.)

Item	Standard	Service limit
Rotor shaft diameter	$13^{+0}_{-0.015}$ ($0.512^{+0}_{-0.00059}$)	
Shaft to body clearance	0.032 ~ 0.074 (0.00126 ~ 0.00291)	0.15 (0.0059)

Oil filter inspection

The filtering element is prescribed to be replaced after each 600 hours of operation or whenever its filtering performance is noted to have deteriorated. Inspect the element to see if it has any signs of rupture or fissure; and if so, replace it by a new one. Visually examine the filter case for distortion and cracks.

Relief valve inspection

First, inspect the valve and valve seat for seating contact, and check its spring for condition. Poor seating can be corrected by lapping. A broken or fatigued spring must be replaced.

Next, check the relief valve for relieving pressure in reference to the specification. Increase or decrease the spring preload, as necessary, to obtain a relieving (opening) pressure within ±0.3 kg/cm^2 (±4.27 psi) of 3 kg/cm^2 (42.7 psi).

Unit: kg/cm^2 (psi)

Item	Standard
Relief valve opening pressure	3 ± 0.3 (42.7 ± 4.27)

Fuel system

Fuel filter inspection

Inspect the filter case and cover for cracks, distortion and damage and also for stripped threads at its threaded part. Replace the case and cover if found in defective condition.

Replace the connector bolts and plug if found with defective threads. The packings removed in disassembly must be discarded: be sure to use new packings in reassembly.

The filtering element is prescribed to be replaced at intervals of 1200 hours, and the filter itself be made free of sludges and condensation by draining at intervals of 300 hours.

NOTE

The filtering element is of paper type not meant to be cleaned by washing. Use a soft-hair brush and compressed air to clean it.

Fuel feed pump inspection

(1) Check valve

Inspect the seating faces of the check valve for wear, and replace parts found in abnormally or excessively worn condition.

(2) Tappet wear

Mike the tappet and tappet hole to determine their diametral wear. Replacement is necessary if the amount of wear noted in comparison with the standard diameter is 0.1 mm (0.004 in.) or more.

Unit: mm (in.)

Item	Standard	Service limit
Tappet diameter	7 (0.276)	0.1 (0.004)
Tappet hole diameter	7 (0.276)	0.1 (0.004)

The overall play of tappet roller pin, involving the pin hole and roller, is prescribed to be not greater than 0.3 mm (0.012 in.). If this limit is exceeded, the whole tappet sub-assembly must be replaced.

Replace the roller if its diameter has worn down to the service limit.

Unit: mm (in.)

Item	Standard	Service limit
Tappet roller O.D.	$15^{+0}_{-0.027}$ ($0.591^{+0}_{-0.00106}$)	−0.075 (−0.00295)

(3) Pump housing damage

Inspect the housing for cracks, broken screw threads and other types of damage and repair or replace it as necessary.

(4) Priming pump wear

Inspect the piston and cylinder for scratch marks, wear and rusting. Check the seating faces of its valve for wear. An excessively worn or damaged seating face must be corrected by replacement.

Fuel feed pump testing

The feed pump is in satisfactory condition when it meets all of the test requirements hereunder enumerated:

(1) Suction performance

The pump should be capable of starting to deliver fuel in 45 seconds of its starting at 150 rpm.

(2) Discharge pressure

Run the feed pump at 600 injection-pump rpm, with the discharge side of the feed pump fully closed. Under this condition, the discharge pressure should be anywhere between 1.8 kg/cm^2 (25.6 psi) and 2.2 kg/cm^2 (31.3 psi).

Unit: kg/cm^2 (psi)

Item	Standard
Feed pump discharge pressure	1.8 ~ 2.2 (25.6 ~ 31.3) at 600 rpm

(3) Capacity test

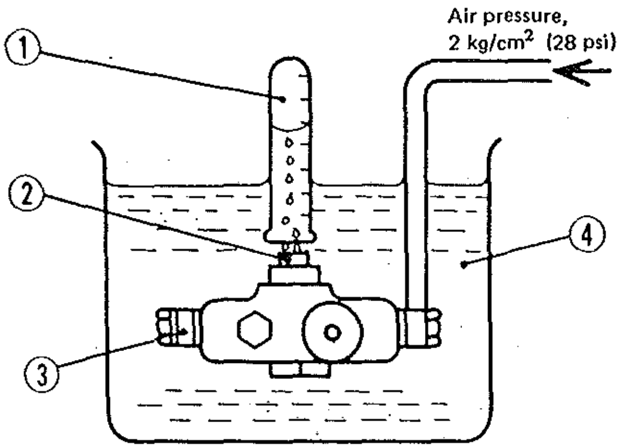
Run the pump at the speed specified below and open the discharge side more or less to hold the discharge pressure at 1.5 kg/cm^2 (21.3 psi) (as read on the test gauge), with a measuring glass cylinder set up to receive the discharged fuel. Under this condition, the pump should deliver at least 900 cc (54.9 cu in.)/minute.

Item	Standard	Repair limit
Feed pump capacity	900 cc (55 cu in.)/minute, minimum at 1000 rpm	600 cc (37 cu in.)/minute, at 1000 rpm

(4) Air-tightness

Immerse the feed pump in a pool of fuel, with its discharge side plugged up. Apply an air pressure of 2 kg/cm^2 (28 psi) to its suction to see if any bubbles come out of the pump. Some air, however, will leak out through the clearance between its pushrod and housing. The pump is sufficiently air-tight if the amount of this leakage (with no leakage from any other part of the pump) is not greater than the value specified.

Item	Standard
Feed pump air-tightness	Not greater than 50 cc (3 cu in.)/minute (with bubbles not larger than 2 mm (0.08 in.) in size)



1-Measuring cylinder 3-Plug
2-Tappet 4-Diesel fuel oil

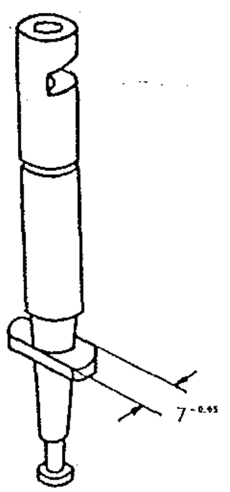
Testing feed pump for air-tightness

If a greater leakage than the specified value occurs, rework the pushrod hole with a burnishing broach to the oversize and replace the pushrod by a new oversize one.

Injection pump inspection

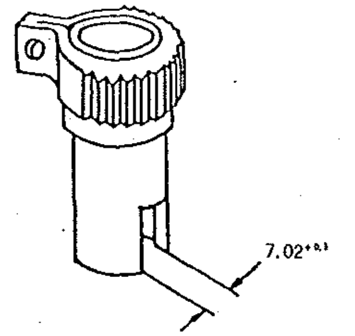
(1) Wear of pumping elements (plunger and barrel)

Mike the width of plunger flange. If this flange is worn down to give a reading less than 6.95 mm (0.2736 in.) [= 7−0.05 mm (0.2756−0.0020 in.)], replace the plunger.



Width of plunger flange

Measure the width of the slot provided in the control sleeve. If this slot is worn down to give a reading greater than 7.02 mm (0.2764 in.), replace the sleeve.



Width of slot in control sleeve

Inspect the sliding surfaces of plunger and barrel for wear, scratch marks and evidence of pitting due to burning. If any defect is noted, replace the whole pumping element (plunger and barrel).

Whether a plunger is worn or not can be told from its appearance. A worn plunger has no surface luster. If any of the four plungers is in defective condition to require replacement, then all four pumping elements (plunger and barrel) should be replaced to ensure the uniform pumping performance for the four injection nozzles. This replacement is necessary also when any of the pumping elements fails to meet the following test requirement on the sliding clearance between plunger and barrel:

Fuel-tightness test on pumping element

After assembling the injection pump, install a test pressure gauge on the delivery valve holder, and run the pump at 200 rpm, with the control rack held in a position for low-load engine operation. The pressure gauge should be capable of indicating up to 300 kg/cm² (4266 psi) or 400 kg/cm² (5688 psi). When operated under these test condition, the pressure gauge should register a pressure not lower then 150 kg/cm² (2133 psi).

Unit: kg/cm² (psi)

Item	Standard	Repair limit
Fuel-tightness of plunger in barrel	150 ~ 200 (2133 ~ 2844) at 200 rpm	150 (2133)

In addition to the above requirement, each pumping element has to meet the following requirement as proof of a proper fit of the plunger in its barrel: Into the barrel removed upon injection pump disassembly, insert its plunger about two-thirds of the way, leaving a third of its length outside the barrel, while holding the barrel horizontal; then angle up the barrel slowly by about 60°. This should cause the plunger to slide in all the way by its own weight to evidence a proper fit. If the plunger goes inward in a free-falling manner or becomes stuck on the way, then the pumping element must be replaced.

Checking pumping element for fit

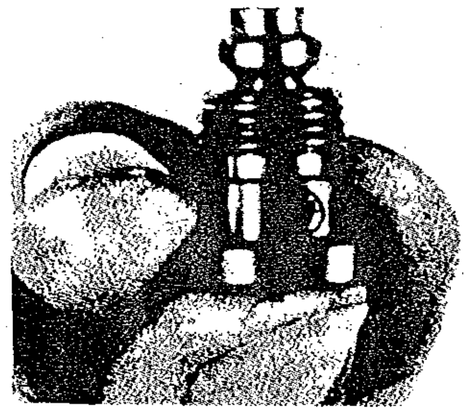
(2) Delivery valve test

Each delivery valve must be tested for seating tightness. Before testing it, inspect its piston, valve seat and other parts for wear. If any part is excessively worn or if the seating contact is defective, replace the valve piston and seat as a unit.

Set up the assembled injection pump on the test stand, with a test pressure gauge installed on the delivery valve holder, as in the fuel-tightness test outlined above. [The gauge should be capable of indicating up to 300 kg/cm² (4266 psi) or 400 kg/cm² (5688 psi)]. Run the pump until the pressure gauge reads slightly above 150 kg/cm² (2133 psi). With a stop watch in the hand, pull the control rack to non-injection position and, at the same time, start clocking the time required by the fuel pressure (ahead of the delivery valve) to fall (due to leakage past the seated valve) 10 kg/cm² (142 psi). If this duration is not less than 5 seconds, then the delivery valve is satisfactorily tight.

Item	Service limit
Seating tightness of delivery valve in terms of duration for a drop of 10 kg/cm² (142 psi) from 150 kg/cm² (2133 psi)	5 seconds, minimum

When the injection pump is in disassembled state, check the fit of the delivery valve piston in the bore by holding the valve with fingers as shown. First, let down the valve all the way into the bore, and give thumb pressure to the bore. This should raise the valve a little and release of thumb pressure should allow it to settle into seated condition; if the valve remains seated without responding to the thumb pressure, its fit in the bore is too loose.



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Checking delivery valve for fit

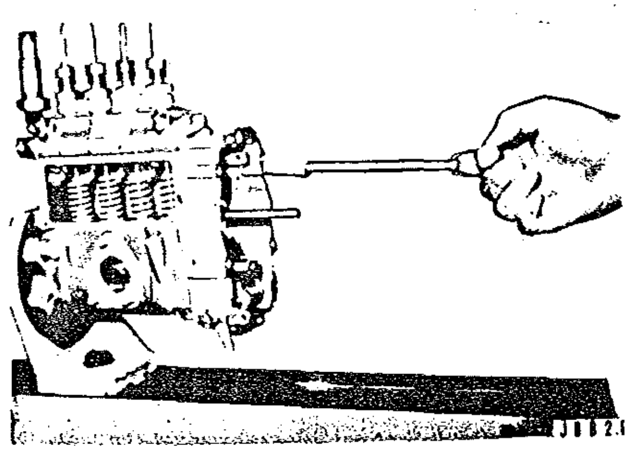
(3) Wear of control rack and pinions

The control rack must be replaced if it is found distorted or bent or its rack teeth are excessively worn. After assembling the injection pump, check each pinion for backlash, and replace pinions found to exceed the service limit on backlash.

Unit: mm (in.)

Item	Standard	Service limit
Pinion-to-rack backlash	0.15 (0.0059)	0.25 (0.0098)

Using a spring scale, check the force necessary to set the control rack in sliding motion. Repair or replace the control rack if it offers a resistance requiring a greater force to overcome than 150 grams (5.25 oz).



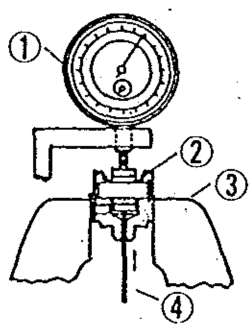
Checking sliding resistance of control rack

Unit: gram (oz)

Item	Standard
Sliding resistance of control rack	Not more than 150 (5.3) as starting pull

(4) Wear of tappets and rollers

The tappet roller consists of roller, roller bushing and pin. The overall wear of these three parts is to be checked by measuring the radial play of the roller with a dial gauge as illustrated. With the tappet sub-assembly held as shown, move the roller up and down with a rod. If a reading greater than 0.3 mm (0.0118 in.) is obtained, replace the whole tappet sub-assembly.



1-Dial gauge 3-Vise
2-Tappet 4-Rod

Checking tapper roller for wear

Mike each tappet and tappet bore to determine the amount of radial clearance between the two. Replacement of worn parts is necessary if the clearance computed from micrometer readings exceeds the service limit.

Unit: mm (in.)

Item	Standard	Service limit
Radial clearance between tappet and tappet bore	0.02 ~ 0.062 (0.0008 ~ 0.00244)	0.25 (0.0098)

Check the outside diameter of each roller; if the reading as referred to the standard O.D. reveals a wear of 0.075 mm (0.00295 in.) or more, replace the whole tappet sub-assembly.

Unit: mm (in.)

Item	Standard	Service limit
Tappet roller O.D.	$17^{\ 0}_{-0.007}$ $(0.669^{\ 0}_{-0.00011})$	–0.075 (–0.00295)

(5) Delivery-valve springs, plunger springs and seats

Springs showing evidence of cracking must be replaced. Measure the free length of each spring; if the spring is found to be shorter by –0.5 mm (–0.020 in.) (plunger spring) or by –1 mm (–0.039 in.) (delivery-valve spring) than the smallest standard length, replace it.

Unit: mm (in.)

Item		Standard	Service limit
Free length of spring	Plunger spring	49^{+1}_{-0} $(1.929^{+0.039}_{-0})$	–0.5 (–0.020)
	Delivery-valve spring	32 ± 0.5 (1.26 ± 0.020)	–1 (–0.04)

Inspect each plunger-spring seat; if the seat is found to have a recess (due to the seating end of the spring) of 0.1 mm (0.0039 in.) or more in depth, replace it.

(6) Wear of camshaft and its tappet roller bearings

Replace the camshaft if any of its cam surfaces is badly worn, grooved or otherwise damaged or if its keyway or threaded end portions are found defective. Mike the major diameter (cam height) of each cam to determine its wear in reference to the standard size and if the amount of wear is noted to exceed the service limit, replace the camshaft.

Unit: mm (in.)

Item	Standard	Service limit
Cam height (major dia.)	$32^{+0.1}_{-0}$ $(1.26^{+0.0039}_{-0})$	–0.2 (–0.0079)

Inspect the tapered roller bearings for wear. A loose, rattling or otherwise defective bearing must be replaced.

(7) Condition of pump housing

Inspect the housing for cracks and examine the threaded parts for damage. If the housing is in cracked or damaged condition or if any of its tappet bore is found to have worn down excessively as a result of the check on the radial clearance of the tappet (in (4) above), replace the housing.

Unit: mm (in.)

Item	Service limit
Pump housing tappet bore	24 – 0.15 (0.945 – 0.0059)

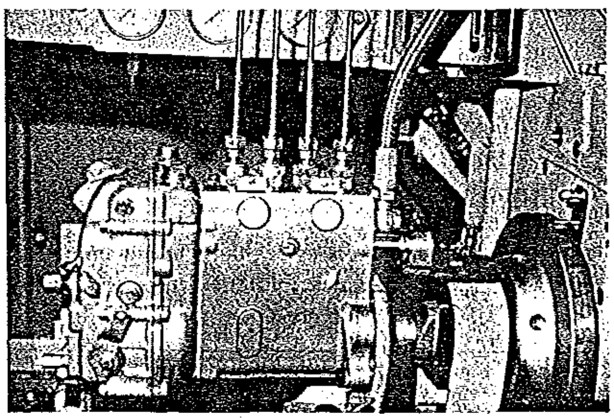
Injection pump testing and adjustment

A diesel engine cannot give the full performance it should be capable of even if it were in its best operable condition, unless the injection pump and governor serving it are equally in best condition. The following testing and adjusting instructions are for making sure that the pump is in such a condition and must be carried out with utmost care. Instructions on the governor will be given separately in the subsequent section.

The tests and adjustments, set forth under three headings, presupposes the use of special servicing equipment – the injection pump tester. It should be borne in mind that the pump and its governor constitute an inseprable set and must be tested and adjusted to meet the specified criteria before installing them on the engine.

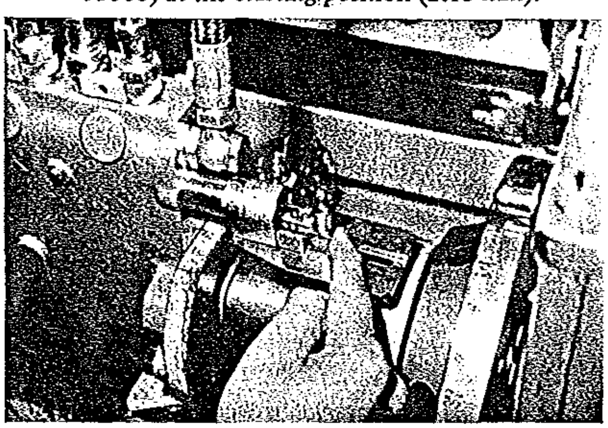
(1) Preparation

(a) Mount the reassembled injection pump on the tester.



Setting up the pump on the tester

(b) Attach the rack position measure. Remove from the governor these parts: maximum speed stopper, stop adjusting screw, idling spring, torque spring and adaptor spring. Push in the control rack toward the governor side as far as it will go, and set the rack position measure (95904-01060) at the starting position (zero mm).



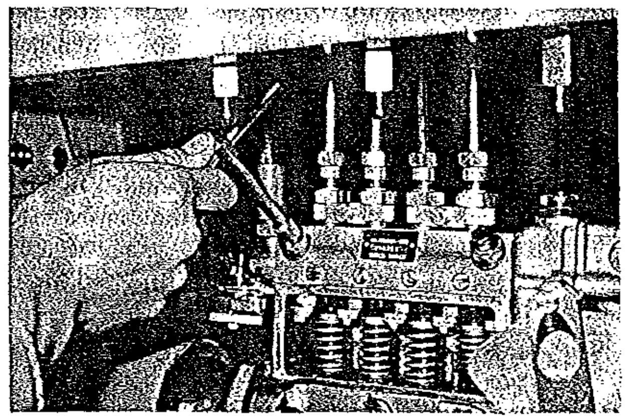
Setting rack measure at 0-mm position

(c) Bleed air out of the injection pump, as follows: First, move the selector lever of the pump tester into "injection" position and turn on the motor switch to start up the motor.

Next, produce the prescribed delivery pressure by means of the pressure adjusting valve. Loosen the air bleeder screw on the pump to let out the trapped air, if any.

NOTE

It is not necessary to "run" the pump in order to bleed air out.

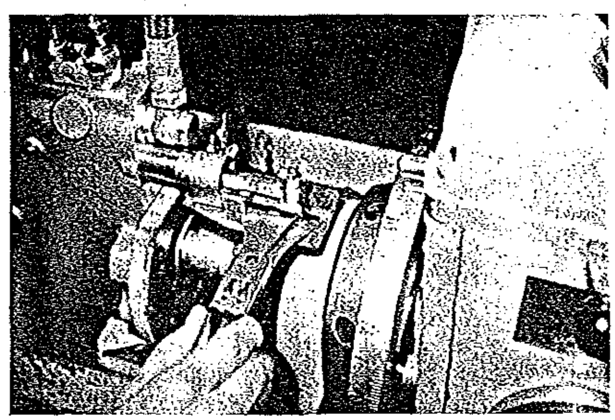


Air bleeding

The pump is now ready for these operations: CONTROL RACK SLIDING RESISTANCE TEST, INJECTION TIMING ADJUSTMENT, and INJECTION QUANTITY ADJUSTMENT.

(2) **Control rack sliding resistance test**

Run the pump at 1000 rpm and measure the resistance with the hand spring balancer. The control rack should be capable of sliding without offering any resistance greater than 50 grams (1.8 ounces).



Checking rack sliding resistance

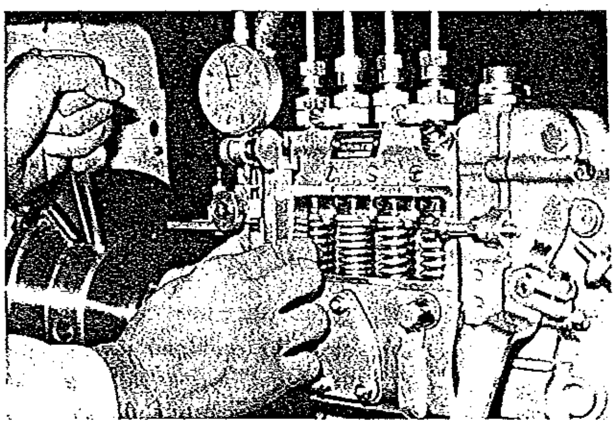
(3) Injection timing adjustment

(a) Pre-stroke adjustment

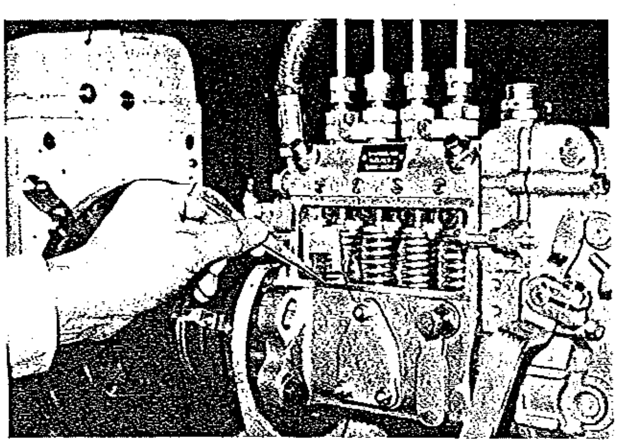
"Pre-stroke" refers to the upward movement of the plunger (and hence of the tappet) and is measured as the distance the tappet travels from its lowest position until the feed hole (in the barrel) becomes closed by the plunger.

Loosen the nozzle holder overflow valve; move the selector lever of the tester to "injection" position; and start running the high-pressure pump of the tester by engaging the clutch; and, with the tappet clearance measuring device (95904-02100) securely installed, turn the camshaft to bring No. 1 plunger to bottom dead center (lowest) position.

From this position of camshaft, rotate it gently in normal direction to raise the tappet (and hence the plunger). In the meantime, fuel will be overflowing. Stop turning the camshaft just when the fuel ceases to overflow, and read the distance traversed by the tappet from its lowest position.



Measuring pre-stroke



Adjusting pre-stroke

Unit: mm (in.)

Item	Standard
Plunger pre-stroke	1.95 ~ 2.0 (0.077 ~ 0.079)

If the reading is not within the standard range, adjust the pre-stroke by repositioning the tappet adjusting bolt vertically with the tappet wrench. Turning this bolt by about a half rotation varies the pre-stroke by about 0.5 mm (0.020 in.). After making this adjustment, be sure to have the lock nut tightened fully.

Check and adjust the other plungers for the prescribed pre-stroke by repeating the foregoing procedure.

(b) Checking and adjusting the angular position of the beginning of injection

The end of pre-stroke corresponds to the beginning of injection: the plunger begins to pressurize the fuel in the barrel when it has just closed the feed hole.

Take the position of No. 1 plunger at its beginning of injection as the reference angular position (0 deg.), and check the angular position at which each of the rest of the plunger begins to inject. Make sure that the beginning of injection comes within the 1 deg. tolerance of the angular value prescribed:

Item	Standard beginning of injection			
	No. 1	No. 2	No. 3	No. 4
Angular spacing of injection timing	0°	89°30' ~90°30'	179°30' ~180°30'	269°30' ~270°30'

Increase or decrease the pre-stroke to bring the beginning of injection, as necessary, into the tolerance allowed. Turning the tappet adjusting

Checking interval between injections

bolt by about a one-fifth (1/5) rotation changes the beginning of injection by about 1 degree.

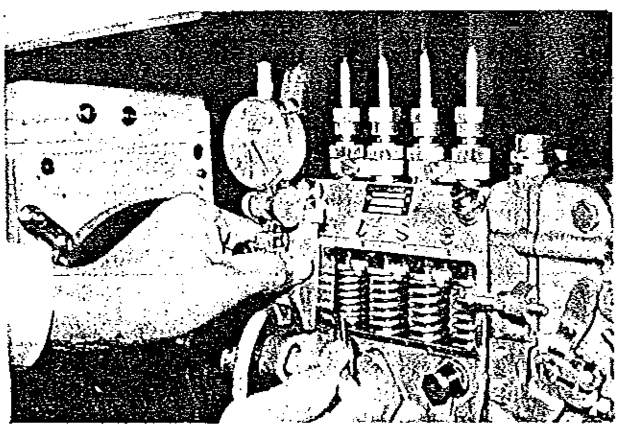
(c) Tappet clearance measurement

By the term "tappet clearance" is meant the marginal upward stroke of the tappet from its top dead center position, through which the tappet can be moved by forcing with a lever. This clearance is prescribed to be not less than the value specified below, and normally should not require any adjustment. Thus, the purpose of this measurement just for making sure that some clearance greater than the specified minimum is available.

Unit: mm (in.)

Item	Standard
Tappet clearance	0.2 (0.0079), minimum

Use the tappet clearance measuring device (95904-02100), as shown, and lever up the tappet which is pushed up all the way by the cam. If the reading happens to be less than the minimum, increase it by means of the tappet adjusting bolt, without causing the injection timing (beginning of injection) to deviate from the 1-deg. tolerance. Increasing the tappet clearance will increase the pre-stroke: be sure not to exceed the upper limit [2.0 mm (0.0787 in.)].



Measuring tappet clearance

The injection is properly timed in the injection pump when all four pumping elements have their pre-stroke and tappet clearance uniformly set to the specifications, with the four angular intervals between successive beginnings of injection are equalized within the given tolerance.

(4) Injection quantity adjustment

"Injection quantity" is expressed in terms of cubic centimeters (cc) of fuel delivered by each pumping element for many strokes of its plunger. This quantity is measured as follows:

Close the nozzle holder overflow valve, so that the injection nozzle will spray out the fuel delivered by its pumping element. Have the high-pressure pump of the tester taken out of service by disengaging its clutch. Keep the selector lever in "injection" position.

NOTES

a) Keep the fuel supply pressure at 2.0 kg/cm^2 (28.4 psi).

b) Be sure to use a measuring cylinder for each pumping element.

c) To empty a measuring cylinder, in to which fuel has been sprayed, be sure to invert the cylinder and keep it in that position for at least 30 seconds before using it for the subsequent measurement.

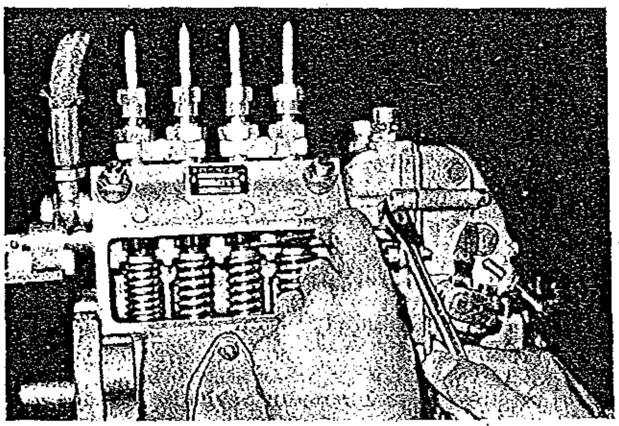
Take three measurements on each pumping element, one measurement for each set of conditions, namely, pump speed, rack position and number of strokes, and compare the measurements taken with the specifications:

Injection quantity specifications

Pump speed rpm	Rack position mm (in.)	Strokes	Injection quantity cc (cu in.)	Difference cc (cu in.)
1000	8.5 (0.335)	200	7.2 ~ 7.8 (0.44 ~ 0.48)	0.4 (0.02)
1000	8.0 (0.315)	200	6.4 ~ 7.0 (0.39 ~ 0.43)	0.4 (0.02)
200	6.0 (0.236)	500	5.0 ~ 8.0 (0.31 ~ 0.49)	1.0 (0.06)

If any pumping element is noted to deliver too much or too little fuel, adjust it to bring its injection quantity into the range specified by displacing the control sleeve relative to the pinion. Loosening the pinion clamp screw allows the sleeve to be rotated in the pinion; turning the sleeve toward the governor side increases the injection quantity, and vice versa.

Be sure to set the pinion and sleeve accurately so that all four pumping elements will deliver the same amount of fuel without exceeding the limit, indicated above, on difference between the largest and the smallest measurement. Be sure to tighten the pinion clamp screw good and hard after adjusting the control sleeve.



Adjusting injection quantity

Governor inspection

Upon disassembling the governor, visually inspect the ball bearing (which is between control block and sleeve as a means of transmitting the push and pull between the flywheel device and the lever mechanism) for wear and damage. Examine the balls and the raceways carefully and, if any abnormal or excessive wear is noted, replace the bearing. Make sure that this bearing is in perfectly good condition: any rattle or abnormal noise is not permitted.

There are a total of five items to be checked and serviced in the governor during the process of reassembly. A repair limit is specified for each and, if the limit is reached, then the part or parts responsible must be repaired or replaced to bring the item (dimension) into the standard dimensional range.

(1) Flyweight inspection

(a) Measure the clearance between the flyweight roller and roller pin. If the limit is reached, replace the flyweight assembly.

Unit: mm (in.)

Item	Nominal diameter	Standard	Service limit
Flyweight roller and roller pin clearance	8 (0.315)	0.025 ~ 0.062 (0.00098 ~ 0.00244)	0.10 (0.00394)

(b) Check the contact surfaces of the flyweight roller and governor sleeve. If any excessive wear or damage is found, replace the flyweight assembly.

Unit: mm (in.)

Item	Nominal diameter	Standard	Service limit
Flyweight roller O.D.	16 (0.63)	$^{0}_{-0.11}$ $\left(^{0}_{-0.0043}\right)$	−0.25 (−0.0098)

(2) Inspection of parts related to control lever

(a) If the control block is worn down at its end and chrome plating is off, replace the control block or guide lever.

(b) Measure the clearance between the holes of the tension lever and guide lever, and supporting lever shaft. If the limit is reached, replace them. If any excessive uneven wear in holes and stepped wear on the shaft are found, replace the supporting lever shaft and levers.

Unit: mm (in.)

Item	Nominal diameter	Standard	Service limit
Tension lever and guide lever holes, and supporting lever shaft clearance	8 (0.315)	0.013 ~ 0.05 (0.0005 ~ 0.0020)	0.10 (0.00394)

(c) Measure the clearance between the schackle pin and control rack hole. If the limit is reached, replace the schackle or control rack.

Unit: mm (in.)

Item	Nominal diameter	Standard	Service limit
Schackle pin and control rack hole clearance	5 (0.197)	0.015 ~ 0.0056 (0.0006 ~ 0.00022)	0.08 (0.0031)

(3) Swiveling lever inspection

Measure the clearance between the swiveling lever shaft and bushing. If the limit is reached, replace the bushing. When replacing the bushing, replace "O" ring and oil seal, too.

Unit: mm (in.)

Item	Nominal diameter	Standard	Service limit
Swiveling lever shaft and bushing clearance	11 (0.433)	0.016 ~ 0.07 (0.0006 ~ 0.0028)	0.15 (0.0059)

(4) Torque control lever inspection

Measure the clearance between the torque control lever bushing and supporting pin. If the limit is reached, replace the lever.

Unit: mm (in.)

Item	Nominal diameter	Standard	Service limit
Torque control lever bushing and supporting pin clearance	8 (0.315)	0.026 ~ 0.056 (0.00102 ~ 0.00220)	0.10 (0.00394)

(5) Spring inspection

When the governor is adjusted, check various springs and determine if they are defective or not. Expecially at disassembly, check them for bent, damage, fatigue and rusting. Check the control spring at its hook part, too. Replace springs found in abnormal condition.

Governor testing and adjustment

As to the meanings of various technical terms used in the following instructions regarding governor performance and adjustments, reference must be had to the governor characteristic curves, below, and to the table of standard adjustment data, carried at the end of this part.

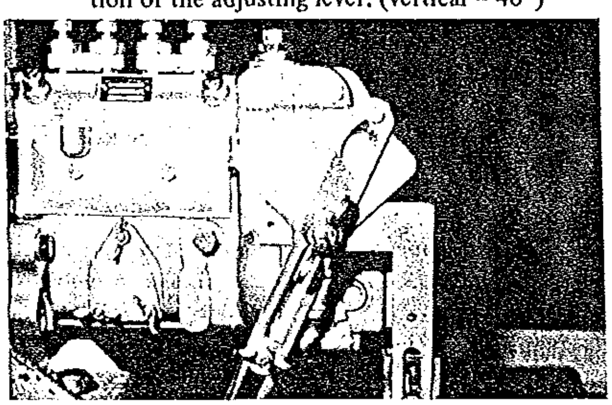
The procedures which follow assume that the injection pump has been properly set for injection timing and injection quantity as outlined in the preceding part, and that the injection pump unit (complete with its governor less the adaptor spring and idling spring) is set on the pump tester.

(1) Governor adjustments

After servicing the governor, securing the prescribed clearances in the various running parts, make four adjustments: adaptor adjustment, maximum-speed control adjustment, low-speed control adjustment and torque spring adjustment. Each adjustment will be explained in reference to the characteristic curves.

(a) Preparation

Install the angular scale plate (protractor) on the governor housing to read the angular position of the adjusting lever. (vertical = 40°)

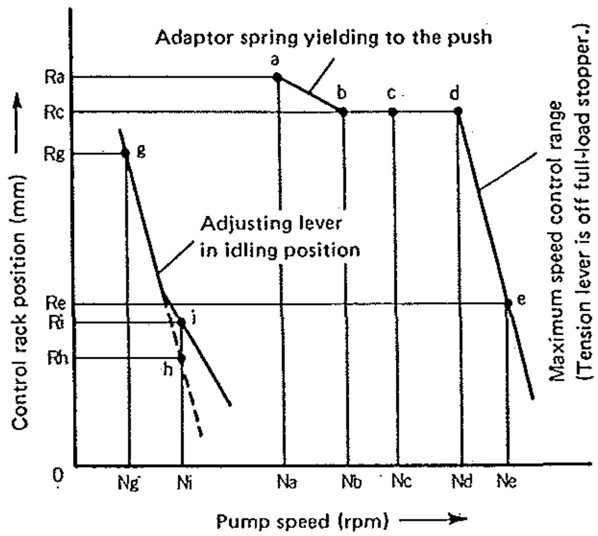


Protractor on governor housing

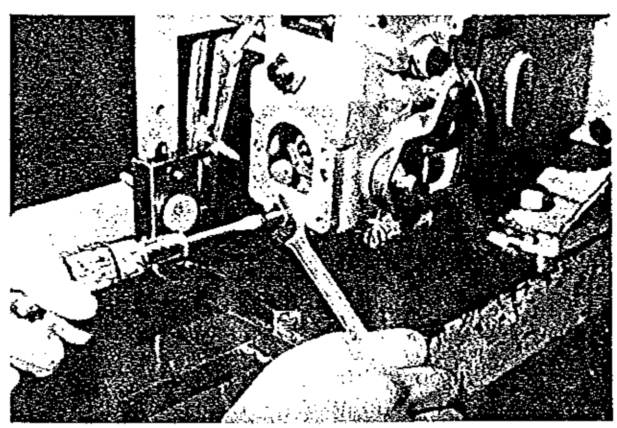
(b) Maximum-speed adjustment

1. Setting the full-load stopper

Run the injection pump at the speed corresponding to "Nc," which is indicated in the characteristic curve diagram. Turn the adjusting lever in the direction for raising the speed: this tensions the control spring, making the control rack move inward. Stop moving the adjusting lever when the rack comes to the position corresponding to "Rc" [= 8.8 ± 0.1 mm (0.346 ± 0.004 in.)], and secure the adjusting lever there tenstatively. Rack position "Rc" is for maximum injection quantity. Bring the full-load stopper into contact with the tension lever under this condition.



Governor characteristic curves



Setting full-load stopper

2. Setting the maximum-speed stopper

Slowly raise the speed from "Nc" to see when the control rack begins to come out (in the direction for decreasing injection quantity). The speed at which this should occur is prescribed to be 1200 rpm (= Nd). This requirement can be met by unlocking the adjusting lever (which was secured in the preceding step), by turning the lever, and by slowly raising the speed. Upon locating that position of adjusting lever at which the control rack begins to come out at 1200 rpm of rising speed, bring the maximum-speed stopper into contact with the lever, thereby setting the maximum-speed position of adjusting lever. The lever angle for this position is prescribed to be $47° \pm 5°$.

3. Speed regulation adjustment

What "speed regulation" signifies was explained previously: it refers to the difference between two governed speeds: no-load speed and full-load speed for a given position of the adjusting lever. It is expressed as a percentage of full-load speed:

Speed regulation

$$= \frac{\text{no-load speed} - \text{full-load speed}}{\text{full-load speed}} \times 100(\%)$$

Generally speaking, the smaller the speed regulation, the better is the engine control; but some regulation is necessary for the sake of running stability and the smallest regulation for the type of all-speed governor as the present one is limited by the governor mechanism. Moreover, each engine runs best when the governor is set to provide the regulation specified for the engine.

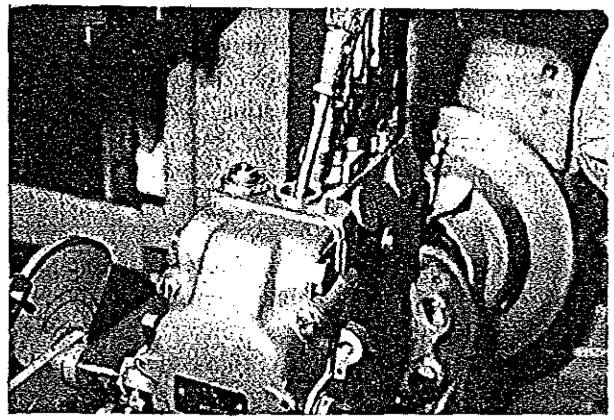
For the maximum speed position of adjusting lever, speed regulation is represented by that portion of the characteristic curve from point "d" to point "e" for the differential speed from "Nd" to "Ne."

In the present governor, the regulation can be changed by means of the adjusting screw provided in the swivel lever. Tightening this screw increases the tension of control spring to reduces the value of regulation, and vice versa. With a small regulation, the curve "d" ~ "e" is sharper and, if it should be too sharp, the governor would become too sensitive.

It is important to note that the speed regulation of an engine unit (complete with its injection pump and governor) is determined not solely by the governor setting but by the characteristics of the engine (which were explained earlier in the discussion of the torque spring). For the present engine, a proper regulation will obtain when the adjusting screw (on the swivel lever) is set as follows:

Drive in the adjusting screw as far as it will go in, and then back it away by four (4) rotations. Four notches of this screw correspond to one (1) rotation.

Backing away the screw increases the regulation (making the curve "d" ~ "e" less sharp). Never back it away by more than 24 notches (6 rotations) or the threaded engagement of the screw will be so small as to invite a hazardous condition.



Setting adjusting screw

4. Re-adjustment of maximum-speed stopper setting

Changing the speed regulation by tightening or loosening the adjusting screw is, in substance, changing the tension of the control spring. For this reason, after each repositioning of the adjusting screw, the position of maximum-speed stopper for determining "Nd" (the speed at which the governor begins to perform its high-speed control action) must be changed to raise or lower "Nd" to a proper level by repeating the process described above.

NOTE

In the table of standard adjustment data, the angular position of the adjusting lever assumes that 40° is vertical.

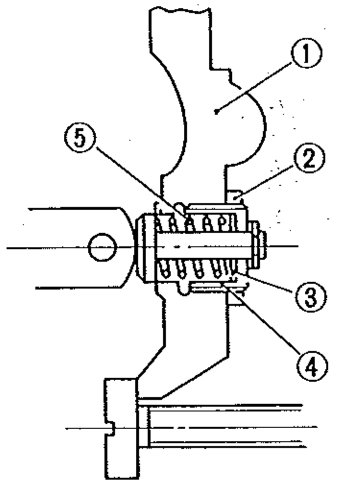
(c) Adaptor adjustment

1. Move the adjusting lever to make it bear against the maximum-speed stopper, and install the adaptor in its normal position in the tension lever.
2. Run the pump at "Na" (= 900 rpm). This should move the control rack inward to the 9.2 ± 0.1 mm (0.362 ± 0.004 in.) position (= Ra); if not, change the thickness of shim plate (3) indicated in this illustration
3. Raise the pump speed from "Na" to "Nb." This

should pull the control rack out to the position "Rc" [= 8.8 ± 0.1 mm (0.346 ± 0.004 in.)]; if not, tighten or loosen adaptor screw (4).

NOTE

The rack movement from "Ra" to "Rc" corresponds to the amount of compression of adaptor spring (5), which is referred to as "adaptor stroke." Tightening (or driving inward) adjusting screw (4) elongates this spring to increase the stroke, and vice versa.



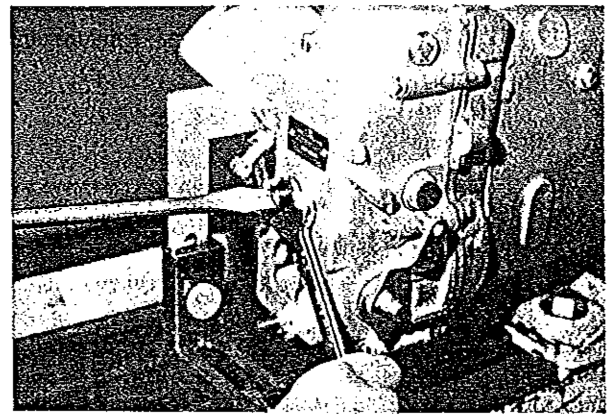
1-Tension lever
2-Lock nut
3-Shim plate
4-Adaptor screw
5-Adaptor spring

Adaptor adjustment

(d) Low-speed control adjustment

This adjustment is related to the low-speed control curve in the diagram given above, and is effected as follows:

1. Run the pump at "Ni" (= 275 rpm), with the adjusting lever bearing against the maximum-speed stopper; turn back the adjusting lever until the control rack comes to "Rh" [= 5.5 ± 0.1 mm (0.217 ± 0.004 in.)]; and secure the adjusting lever there.
2. Install the idling spring. Drive in the adjusting screw of this screw, as shown, until the control rack moves in and comes to "Ri." Be careful not to set this adjusting screw too far inward or the no-load maximum speed will rise too high in operation.
3. Lower the speed to "Ng" (= 200 rpm); this should cause the control rack to move in and comes to "Rg" [= 11.0 mm (0.433 in.) minimum] owing to the action of the idling spring.

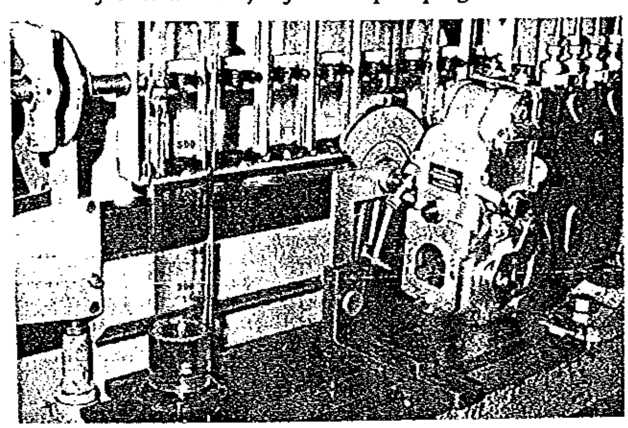


Setting idling spring for low-speed control

4. After completing the foregoing adjustments, stop running the pump and turn the adjusting lever in the stopping direction until the control rack comes to 1 mm (0.0394 in.) position. Set the stop adjusting screw to limit the stopping end of adjusting lever stroke, and secure the screw by tightening its lock nut.

(3) Matching the pump to the engine

After adjusting the governor according to the procedures set forth in (2) above, check the injection quantity by running the injection pump as outlined in (4) INJECTION QUANTITY ADJUSTMENT, INJECTION PUMP TESTING AND ADJUSTMENT. Use a 500-cc (30.5-cu in.) measuring cylinder to receive and collect the fuel delivered by the four pumping elements, with the adjusting lever set at 47° ± 5°. For this test, take two readings, one by running the pump at 900 rpm and the other at 1200 rpm. If the readings differ from the values indicated in the table of standard adjustment data, adjust the pumping elements.



Measuring injection quantity

Table of standard adjustment data

APPLICABLE TO: Injection pump, 090000-9721 (ND-PES4A65B320RND972)

Governor, 090800-4030 (ND-EP/RSV250-1750A2/302ND403)

1. Injection timing adjustment

(1) Direction of rotation: Clockwise as viewed from drive side

(2) Injection order: 1 – 3 – 4 – 2

(3) Interval between successive injections: 90° ± 30′

(4) Pre-stroke: 1.95 ± 0.05 mm (0.077 ± 0.0020 in.)

(5) Tappet clearance: 0.2 mm (0.0079 in.) minimum

2. Injection quantity adjustment

The listed values are based on these conditions: 1) injection nozzles, 093400-0090, 2) nozzle opening (injecting) pressure, 120 kg/cm² (1706 psi), 3) fuel supply pressure, 2.0 kg/cm² (28.4 psi), and 4) high-pressure tester pump, 1.6 mm (0.0630 in.) dia. x 6 mm (0.2362 in.) dia. x 600 mm (23.622 in.).

Pump speed rpm	Rack position mm (in.)	Pumping strokes	Individual injection cc (cu in.)	Permissible difference cc (cu in.)
1000	8.5 (0.335)	200	7.2~7.8 (0.44~0.48)	0.4 (0.02)
1000	8.0 (0.315)	200	6.4~7.0 (0.390~0.43)	0.4 (0.02)
200	6.0 (0.236)	500	5.0~8.0 (0.30~0.49)	1.0 (0.06)

3. Governor adjustment

The listed values are based on these conditions: 1) governed speed range, 275 ~ 1200 rpm, and 2) swivel-lever adjusting screw setting, backed away about four (4) rotations from the fully tightened position.

(1) High-speed control

Lever angle	Speed rpm	Rack position mm (in.)
47° ± 5°	1100	8.2 ± 0.1 (0.3228 ± 0.0039)
	$\boxed{1230}$	$\boxed{7.0 \pm 0.1\ (0.2756 \pm 0.0039)}$
	1290	≦ 4.0 (0.1575)

(2) Low-speed control

Lever angle	Speed rpm	Rack position mm (in.)
High-speed control lever angle MINUS 26° ± 3°	$\boxed{275}$	$\boxed{5.5 \pm 0.1\ (0.2165 \pm 0.0039)}$
	330	5.0 ± 0.1 (0.1969 ± 0.0039) with sub-spring
	200	≧ 11.0 (0.4331)

NOTE: Figures in box $\boxed{\quad}$ are for initial lever setting.

(3) Control by adaptor action

Lever angle	Speed rpm	Rack position mm (in.)
51° ± 5°	400	10.4 ± 0.1 (0.4094 ± 0.0039)
	650	8.8 ± 0.1 (0.3465 ± 0.0039)

(4) Match between injection pump and engine

Lever angle	Pump speed rpm	Total injection qt. cc (cu in.)/500 strokes, 4 cyl.	Remarks
51° ± 5°	600	81 ± 2 (3.1890 ± 0.0787)	With adaptor spring
	1200	62 ± 2 (2.4409 ± 0.0787)	With torque spring

Injection nozzle services

(1) Needle valve and nozzle body

(a) Immerse needle valve and nozzle body in a pool of clean kerosene, insert the valve into the body, and move the valve back and forth to be sure that the sliding contact is smooth without evidencing any excessive clearance. The injection nozzle as a whole must be replaced if the fit is found defective.

(b) Visually examine the nozzle body with a magnifying glass having a power of 4 or 5.

(c) Inspect the needle valve for distortion or damage at its seating part and for wear of its end face in contact with the pressure pin.

(d) Poor seating contact may be corrected, if the defective condition is not advanced too far, by lapping the valve against the seat with a coat of clean lube oil applied to the seating faces. If this does not help, the injection nozzle must be replaced.

(2) Nozzle holder and distance piece

Check the fit between nozzle holder and distance piece and between distance piece and nozzle holder. Determine the quality of the fit from contact patterns obtained with the use of red lead paste: defective fit will be evidenced by an abnormally high rate of return oil (lead-off) flow.

(3) Pressure spring and pressure pin

(a) Replace any pressure spring broken, cracked or otherwise defective, or out of square. Inspect each spring for these defects.

(b) Inspect each pressure pin for wear at its end faces, one for pressure spring and the other for needle valve.

(4) Leak-off pipe packing

If the packing is found in deteriorated condition, replace it.

Injection nozzle testing and adjustment

(1) Injection pressure

The pressure at which the needle valve unseats itself against the force of the pressure spring is referred to as "valve opening pressure" or "beginning-of-injection pressure," but will be called here "injection pressure" for short. The value of this pressure is specified; it is checked and adjusted as follows:

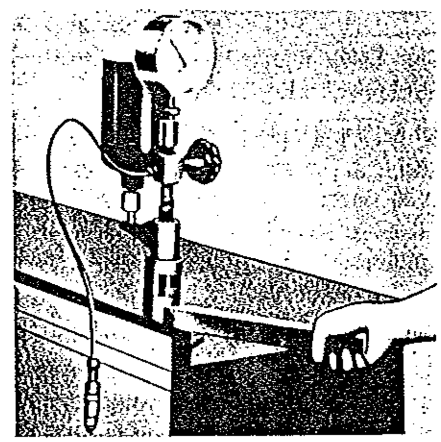
(a) Install the injection nozzle in the nozzle tester, and operate the manual pumping handle of the tester several strokes to prime the nozzle.

(b) Move the lever up and down slowly, completing each up-and-down cycle in about a second, to pressurize the injection nozzle, while observing the indication of the test pressure gauge. As the nozzle begins to spray, the indicating pointer of the gauge being deflected will start perceptively oscillating: read the pressure right then as the injection pressure.

Unit: kg/cm^2 (psi)

Item	Standard	Repair limit
Injection pressure	120 ± 5 (1706.4 ± 71.1)	110 (1564.2), minimum

(c) If the reading taken is below the limit, increase the thickness of the shim used on the pressure spring. Increasing the shim thickness by 0.1 mm (0.0039 in.) raises the injection pressure by about 10 kg/cm^2 (142 psi). Adjusting shim stock for this purpose is available in 20 sizes, from 1.0 mm (0.0394 in.) up to 1.95 mm (0.0768 in.) in increments of 0.05 mm (0.0020 in.) each.

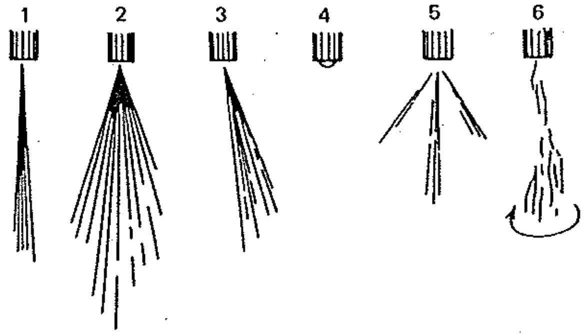


Checking injection pressure on nozzle tester

(2) Spray pattern

The injection nozzles used in the present engine are of throttle type. Some throttling action takes place when the needle valve begins to unseat, thereby limiting the amount of fuel being sprayed out during the initial stage of each fuel injection. Thus, each slug of fuel sprayed out may be regarded as consisting of two parts: initial throttled spray and terminating main spray.

When tested on the nozzle tester, the injection nozzle can be made to produce these two kinds of spray for visual inspection. Initial throttled spray comes about when the tester lever is operated at a rate of 60 cycles per minute (up and down in one second); terminating main spray occurs when the lever is operated rapidly at a rate of, say, 4 to 6 cycles per second.



1-Good
2-Spray cone too large
3-Off-center spray
4-After-dribble
5-Fissured spray
6-Whirling spray

Possible patterns of spray

(a) Initial throttled spray
When the nozzle is producing only this spray, atomization is generally poor and the pattern is rather straight than conical, there being more or less after-dribble, that is, fuel dribbling after injection. All these are due to the fact that the fuel being injected is being throttled by the pintle protruding from the valve.

While the nozzle is making this spray, see if the needle valve chatters in synchronism with the cyclic motion of the lever; if so, then the needle valve is free from any sticking or hitching tendency and, if not, the nozzle and needle valve must be cleaned by washing and re-tested.

Off-center spray or directionally erratic spray, if noted, should be taken to mean that the injection nozzle needs thorough cleaning.

(b) Terminating main spray
With the tester lever operated at a rate of 4 to 6 cycles per second, the initial throttle spray is hardly visible. The spray under this condition may be regarded as main spray.

The main spray should be a good straight cone, about 0° in angle, consisting of finely atomized fuel particles without any large droplets, and should terminate with no dribble at the tip, not to mention of any fuel dripping.

(3) Seating tightness
An injection nozzle tested and adjusted as above, and found to produce a good spray pattern may be re-used in the engine provided that it passes this final test – seating tightness test.

With the injection nozzle mounted on the nozzle tester, raise the pressure slowly to 100 or 110 kg/cm^2 (1422 or 1564 psi) (without exceeding the set pressure of 120 kg/cm^2 (1706 psi), so that the needle valve will not unseat). Hold the pressure and observe the nozzle tip: there should be no evidence of fuel oozing out to form a dribble. If such evidence is noted, then the contacting faces of the needle valve and seat must be repaired by lapping in the manner already suggested or the injection nozzle as a whole must be replaced.

Cooling system

Flushing service

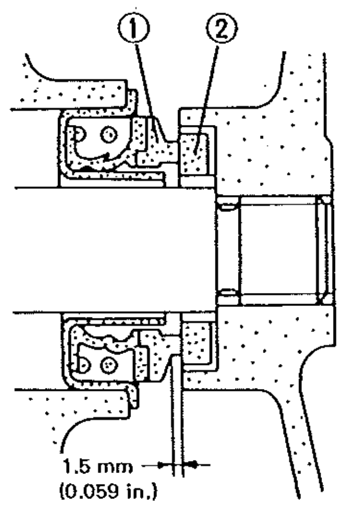
Even drinking water contains one or more substances in extremely small quantities as impurities. In the engine in use, the cooling water deteriorates gradually: the concentrations of impurities increase progressively to form sludges, scales or rust on wet walls inside the engine jackets and in the radiator core to interfere with smooth heat conduction.

Overheating tendency of the engine is often due to its cooling water circuits fouled with scale, sludge or rust formation. For this reason, it is necessary to periodically change the cooling water and, at the same time, flush the cooling system clean. For the cooling water, be sure to use a soft water (drinking water is usually soft).

Water pump services

(1) Check to see if the bearing rattles or develops hitches when the pump shaft is spun by hand; if it does, replacement is necessary.

(2) Inspect the pump impeller for pitting, erosion and breakage; replace the impeller if it is found in bad condition. An impeller found with its front or rear edges showing evidence of rubbing against pump case or rear cover means that the impeller together with the bearing need replacement.



1-Floating seat (carbon)
2-Seal ring (ceramic)

Unit seal

(3) The unit seal must be replaced as a whole if water leakage from it has been complained by the user. Referring to the sectional view of the unit seal, examine floating seat (carbon) (1) and seal ring (ceramic) (2) particularly carefully for wear. If the wear is found excessive, replace the unit seal.

Unit: mm (in.)

Item	Standard	Wear limit
Free-state height of unit seal	21.8 ± 1 (0.858 ± 0.04)	
Floating seat height	1.5 (0.059)	0

(4) Check the fit of pump shaft in the bearing inner race for tightness. If the fit is loose or if the mating faces are badly damaged, replace shaft or bearing or both.

Unit: mm (in.)

Item	Standard	
Fit of pump shaft in bearing inner race	0.001T ~ 0.017T (0.00004T ~ 0.00067T)	(front)
	0.001T ~ 0.017T (0.00004T ~ 0.00067T)	(rear)

(5) Inspect the bore provided in the water pump case for receiving the bearing outer races to see if the bore is damaged; if so, replace the case or the whole pump assembly. Be sure that the bore admits the bearing races with a tight fit.

Unit: mm (in.)

Item	Standard	
Fit of bearing outer races in pump case bore	0.011L ~ 0.025T (0.0004L ~ 0.0010T)	(front)
	0.011L ~ 0.025T (0.0004L ~ 0.0010T)	(rear)

(6) Inspect the threaded portion of the impeller for damage.

Thermostat inspection

Test the removed thermostat to see if it starts opening at 76.5°C ± 2°C (169.7°F ± 3.6°F) of rising temperature and becomes fully open at 90°C ± 2°C (194°F ± 3.6°F). If the difference between these temperature levels is too large, replace the thermostat.

The test is carried out by immersing the thermostat in water contained in an appropriately sized pan and by heating the water with such as an electric stove. Check the rising temperature with a thermometer.

Inspection of fan belt and fan

(1) Inspect the belt for signs of deterioration such as cracks, and check it for permanent stretch. An excessively stretched or cracked belt must be replaced.

(2) Inspect the fan blades for distortion and cracks and replace the fan as necessary.

Electrical equipment

Starter services

(1) **Inspection before disassembly**

(a) Checking the starting circuit for operation

With the starter in place, check to be sure that –

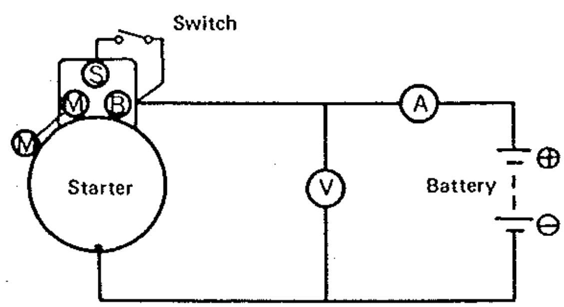
1. The battery is in good condition, with its cell plates showing no evidence of "sulfation" or any other faulty condition, and is in fully charged state.
2. The battery terminal connections are clean and tight.
3. The starter terminal connections are tight.
4. The wires are securely connected to terminals, and are free of any insulation stripping due to fraying, there being no signs of grounding or breaking.
5. The starter switch closes and opens the circuit positively at each position.

Do not jump into a conclusion that the starter is in trouble when the engine refuses to fire up upon cranking: the engine could be in trouble.

(b) No-load test

If the starter is suspected of trouble, take it down from the engine and run a no-load test on it to find out if it is really in trouble.

When removing the starter, be sure to have the battery switch turned off.



No-load test circuit

Here's how to carry out the no-load test: Form a test circuit with a voltmeter and an ammeter, as shown, using a fully charged 24-volt battery; close the switch to run the starter until its speed rises to and above 4500 rpm; and then read the voltmeter and ammeter when the starter is spinning. The ammeter should show that the starter is drawing not more than 50 amperes, with the voltmeter indicating at least 23 volts (at the speed of at least 4500 rpm); if not, estimate the cause of the trouble by consulting the troubleshooting guide, which follows:

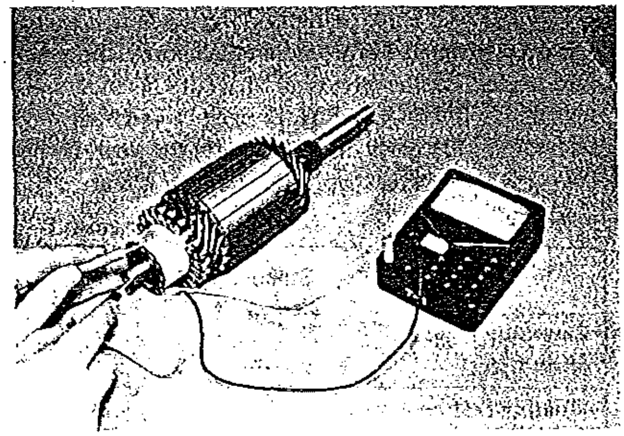
Starter troubleshooting guide

Symptom	Possible cause
Large current and low speed	1. Bearings are dirty, or need lubrication. 2. Rotor (armature core) is rubbing the pole pieces. 3. Grounded coil in the armature or in the field. 4. Short-circuit in the armature coils.
Large current but no speed	1. Magnetic switch is grounded and is not working. 2. Grounded coil in the armature or in the field. 3. Seized bearing.
No current and no speed	1. Open-circuited coil in the armature or in the field. 2. Broken brush pigtail. 3. No conduction between brushes and commutator because of "high mica" condition or dirty commutator surface.
Small current and low speed	Loose coil connection in the field.
Very large current and very high speed	Short-circuited field coil.

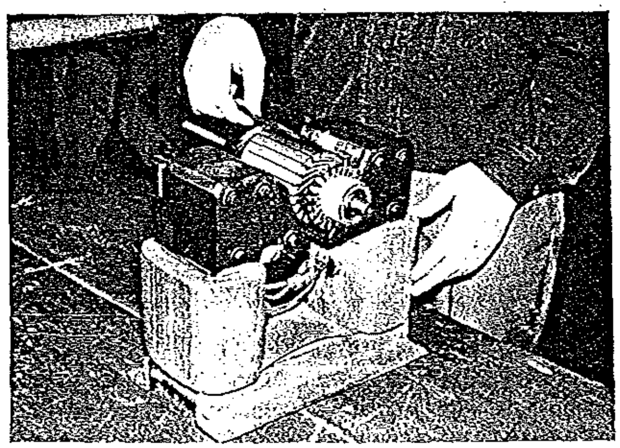
The best way of testing the starter is to run it under loaded condition, but that requires special testing equipment. For ordinary servicing purposes, the no-load test and troubleshooting guide will do.

(2) Inspection after disassembly

(a) Check the armature coils and commutator for ground, open and short. A circuit tester will serve the purpose of checking the coils and commutator for ground and open. To check for short, however, the "growler" must be used.



Testing armature coils and commutator for ground and open



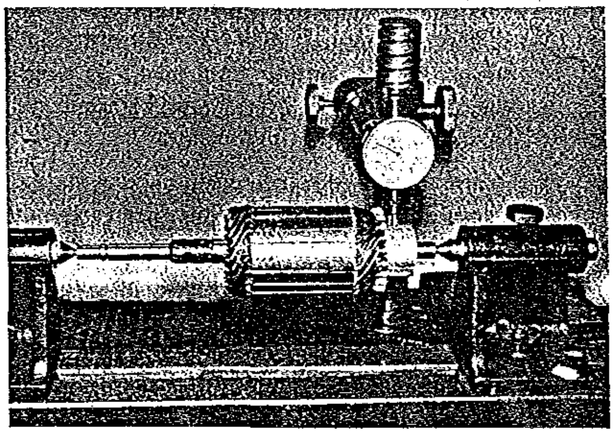
Testing armature for short with growler

(b) Inspect the commutator surface for burning and "high mica" condition. Surface burns can be removed by turning the commutator in a lathe provided that there is enough stock to be removed by machining without exceeding the limit diameter [43.2 mm (1.701 in.)]. "High mica" must be corrected by undercutting the mica between commutator segments. Inspect the risers and, if their solder is found melted, repair them by re-soldering.

Check the commutator for radial runout and, as necessary, repair it by turning in a lathe.

Unit: mm (in.)

Item	Standard	Repair limit	Limit dia.
Commutator runout	0.03 (0.00118)	0.1 (0.0039)	43.2 (1.701)



Checking commutator for runout

(c) One end of the shunt field coil is soldered to the yoke. Undo this soldered connection, and check the positive (+) brush holder for ground by putting one testing prod of a circuit tester (with its selector knob set in the ohmic zone) to the "M" terminal of the starter and the other prod to the field coil: the tester should indicate "continuity." Shift the latter prod to the yoke: the tester should indicate "infinity." This check is for finding whether or not the positive brush holder is satisfactorily insulated. If the insulation is found defective, repair or replace the holder.

(d) Check the brushes for wear. The brush worn down to 13 mm (0.512 in.) in length must be replaced.

Unit: mm (in.)

Item	Standard	Service limit
Brush length	19 (0.748)	13 (0.512)

(e) Replace the rotor if the armature shaft is worn down at any of the three places indicated below; and also replace the bearing if it is so worn that the radial clearance exceeds the upper limit of the range indicated:

Shaft clearance

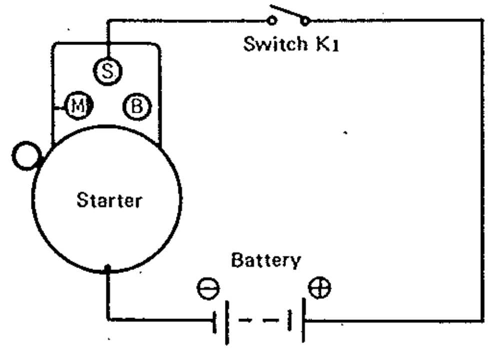
Unit: mm (in.)

Item	Nominal diameter	Standard	Repair limit
Commutator side	14.2 (0.559)	0.034 ~ 0.104 (0.00134 ~ 0.00409)	0.2 (0.0079)
Pinion side	12.2 (0.480)	0.034 ~ 0.104 (0.00134 ~ 0.00409)	0.2 (0.0079)
Center-bracket side	20.3 (0.799)	0.020 ~ 0.353 (0.00079 ~ 0.00139)	

(3) **Testing the reassembled starter**

Upon reassembling the starter, conduct a no-load test in the manner already outlined, and check the magnetic switch and its lever mechanism for pinion shifting action.

To check to see if the pinion plunges forward and recedes properly, open and close the switch (in the test circuit arranged as shown below) repeatedly. The pinion should move back and forth smoothly through its full stroke, without any hitches. If any faulty movement is noted of the pinion, disassemble the shift mechanism and repair it.



Testing circuit for checking pinion shifting action

Having made sure that the pinion moves satisfactorily, close the switch (K_1) to advance the pinion all the way out and hold the switch closed. Under this condition, move back the pinion by giving a light push to it with a fingertip to take up its play, and measure the clearance between pinion and stopper. This clearance should be between 0.5 and 2 mm (0.0197 and 0.0787 in.); if not, increase or decrease the number of washers used in the magnetic switch mounting.

Unit: mm (in.)

Item	Standard
Clearance between pinion and stopper	0.5 ~ 2 (0.0197 ~ 0.0787)

After mounting the starter in place, test it by cranking the engine a second or so about 10 times just to make sure that the pinion meshes with the ring gear properly.

Generating system services

(1) **Cause of poor charging operation**

If the user complains that the battery tends to become overcharged or discharged, check the fan belt for tension and, if the belt is in proper tension, check the wiring connections for tightness. Be sure that there is no open in the charging circuit.

After these two checks, check for each of the four possible causes listed in this guide:

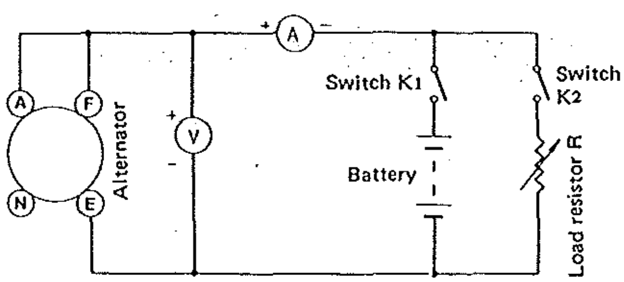
A. The battery tends to become overcharged.	1. Voltage regulator is set to maintain too high a voltage. 2. Voltage coil VC_1 is open-circuited. 3. Resistor R_3 is open-circuited. 4. The battery is internally short-circuited.
B. The battery tends to become discharged.	1. Voltage regulator is set to maintain too low a voltage. 2. Point P_1 or P_2 is not contacting firmly. 3. The alternator is producing not enough power. 4. Too much current is being drawn by one or more electrical loads.

If the cause happens to be 1 "The alternator is producing not enough power," B, then the alternator and its diode rectifier must be tested to ascertain what is preventing the alternator unit from producing enough power.

(2) Alternator tests

(a) Output test

Set up the alternator unit on the test bench and couple the alternator shaft to the variable-speed drive source (motor) of the bench. Make electrical connections to form a test circuit arranged as shown:



Alternator output test circuit

With switch K_1 closed (to energize the alternator field from the battery), drive the alternator by turning on the drive motor, increasing the speed of drive gradually, and observe the indications of the voltmeter and ammeter. Stop increasing the speed when the ammeter indication reaches its zero mark, and open switch K_1: under this condition, the alternator field draws excitation current from the alternator itself (from the DC output terminal of its rectifier) whose output voltage is now high enough to buck the current from the battery.

Raise the speed further until the voltmeter reads 28 volts, and check the speed right then. This speed is the one at which the alternator unit develops the rated voltage, and should be about 1100 rpm.

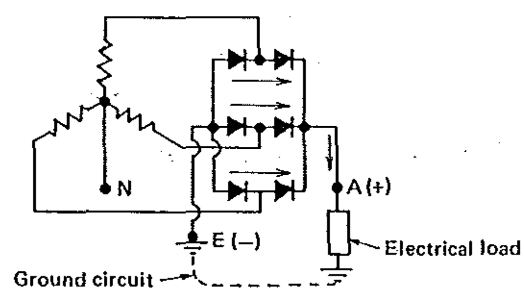
Next, close switch K_2, with the variable load resistor set for maximum resistance (so that no load current will flow). Reduce the load resistance gradually while increasing the speed of drive equally gradually, and read the ammeter at respective levels of rising speed. Compare these readings (output current and speed) with the performance specifications to determine whether or not the alternator unit is capable of the specified output performance.

CAUTION

Be sure to increase the speed and reduce the resistance, both gradually, to avoid rupturing the rectifier diodes and breaking the self-exciting condition of the alternator unit.

(b) Checking the rectifier diodes for open and short

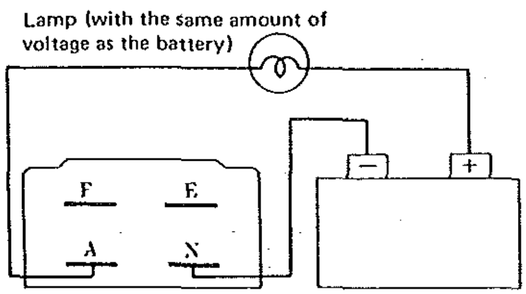
The six diodes of the rectifier are connected, as shown here to pass the current only in the direction (forward) of arrows:



Schematic rectifier connection

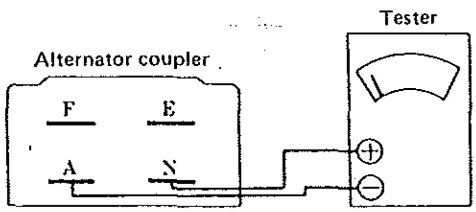
It is obvious from the above schematic diagram that, by biasing each group of three diodes in reverse direction, the shorted (ruptured) condition of one or more diodes can be told: current will flow if any diode is ruptured. If, on the other hand, no current flows when the three are biased in forward direction, it means that all three diodes are open-circuited.

A lamp (2 to 10 watts, 24 volts) and a 24-volt battery with two lead wires will serve the purpose.



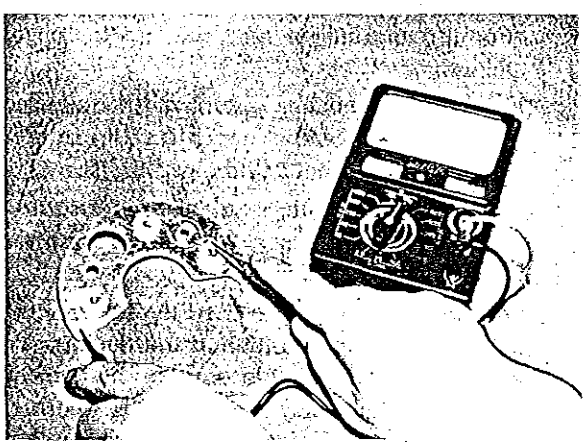
Diode checking arrangement with a lamp

Alternatively, a circuit tester may be used. In this case, bear in mind that the (+) terminal of the tester is connected to the (–) side of its built-in battery and the (–) terminal to the (+) side.



Checking diodes with a circuit tester

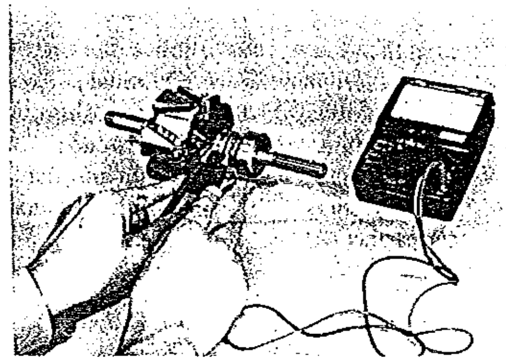
If the foregoing check reveals that the rectifier is in unsatisfactory condition, then check each individual diode for open and short, and also check to be sure that the diodes are not grounded.



Checking diodes for ground

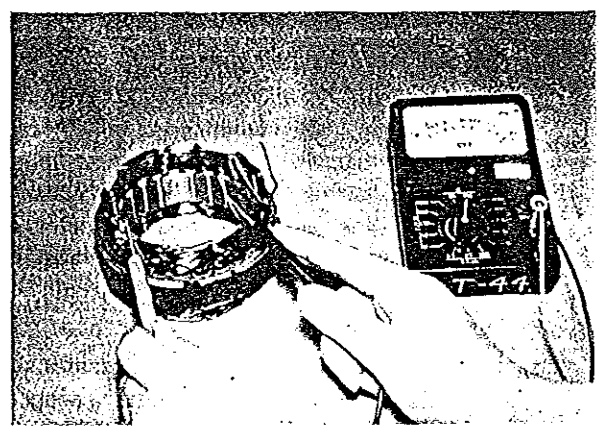
Diodes found short-circuited, open-circuited or ground-circuited by the foregoing methods must be replaced.

(c) Checking the field coils for short through layers
Check the ohmic resistance of field circuit by using the circuit tester, with its testing prods put to the two slip rings. The field coils are in sound condition if a resistance reading of approximately 27 ohms [at 20°C (68°F)] is obtained. A lower reading than this calls for rotor replacement.



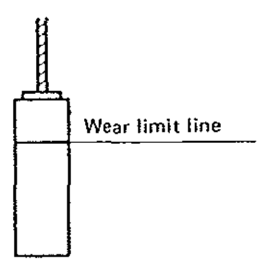
Checking field coils for layer-short

(d) Checking the armature windings for open and ground
Using the circuit tester, check for continuity from and through the neutral point (N) to the end of each winding and also between the windings and the core. An armature found open-circuited or grounded must be replaced.



Checking armature windings for open and short

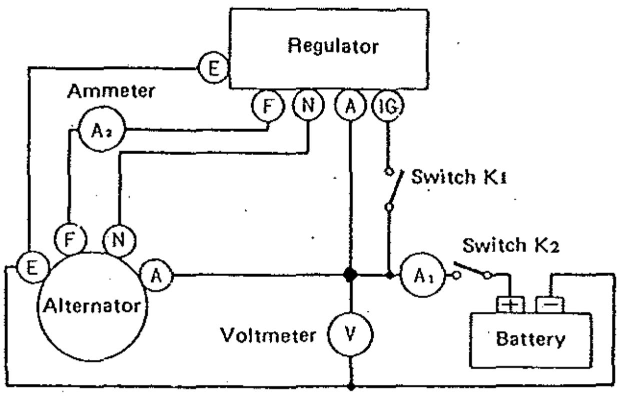
(e) Each brush may be left in service until it wears down to the limit line marked on it. Be sure to use genuine replacement brushes.



Wear limit mark on brush

(3) **Regulator tests and services**

With the alternator unit mounted on the test bench and coupled to the variable-speed drive source (motor), connect the regulator unit, as shown below, with two ammeter A_1 and A_2 and a voltmeter. Be sure to use a fully charged 24-V battery. Before starting the test operation, check to be sure that the resistance inside the regulator unit between terminal IG and terminal F is anywhere between about 35 and 41 ohms. This ohmic value is important: this much resistance means that resistor R_4 is in sound condition and that the point faces of contact P_1 are smooth and closing positively to pass field current properly.



Regulator test circuit

(a) Checking for regulated voltage

Close switches K_1 and K_2 and start driving the alternator. Just when ammeter A_1 indicates zero to signify that the alternator is now in self-exciting condition, open switch K_2. Raise the speed to 3000 rpm and read the voltmeter. The regulator is properly set and working satisfactorily if this reading is between 28.0 and 31.0 volts.

(b) If the indication of ammeter A_2 remains zero, it means 1) contact P_2 is not working properly, or 2) voltage coil VC_2 is open-circuited.

(c) If the voltage read on the voltmeter is outside the range stated above, despite ammeter A_2 showing some field current being supplied to the field, then it means 1) voltage coil VC_1 is open-circuited, 2) resistor R_3 is open-circuited, or 3) contact P_1 is stuck closed with its point faces fused together.

Bench tests

An overhauled engine should be operated on the test bench in order to correctly break it in, to adjust the engine and injection pump and governor for best engine performance, and to quantitatively determine the output power the overhauled engine is capable of.

The test bench is an apparatus complete with a dynamometer. In the following procedures, a standard-type test bench is assumed.

(1) **Breaking in**

Have the engine set up on the bench, and aligned to the dynamometer. Operate the engine for a total of 2 hours according to the schedule indicated below. During this operation, observe the running condition carefully and, if any malcondition is noted to be developing, shut down the engine and take steps to correct it.

Breaking-in schedule

Order	Engine speed (rpm)	Load (PS)	Duration (minutes)
1	1000	0	30
2	1500	7.5	30
3	2000	15	60
4	2500	20	60

Run the engine with (a) lube oil pressure held between 3 and 4 kg/cm^2 (42.7 and 56.9 psi), (b) cooling water temperature held between 75° and 85°C (167° and 185°F), (c) lube oil temperature, as measured in the oil pan complete with a vacuum pump, held between 80° and 90°C (176° and 194°F). While the engine is running, check to be sure that there is no leakage of oil, water or combustion gases, and listen into the engine now and then for abnormal noise.

For this breaking-in run, start up the engine as follows:

(a) Fill up the cooling system and the oil pan, and make sure there is enough fuel. Prime the fuel system, letting out all trapped air, if any.

(b) Use the preheating system to make sure that the glow pilot lamp works. The lamp should glow in about 20 seconds.

(c) With the adjusting lever of the governor moved to the starting position, crank the engine with the starter and, after starting up the engine, move the adjusting lever to its idling position.

(d) With the engine kept in idling condition, inspect for leakage of oil or water, observe the color of exhaust smoke, listen into the engine for abnormal noise, and check lube oil pressure and cooling water temperature.

Until the cooling water temperature rises to its normal operating range, the engine might develop sharp knocking-like sound, but this is no cause for alarm because it will disappear as the temperature rises.

(2) Engine performance tests

Have the air cleaner, vacuum pump, alternator unit and other auxiliary devices mounted on the engine, and test the engine for (a) no-load maximum speed (governor setting), (b) fuel injection (rack setting), and (c) no-load minimum speed (idling setting). Have the dynamometer turned off for these three tests.

(a) Setting the governor (no-load maximum speed test)

Immediately after the breaking-in operation, set the governor to limit the highest speed to 2640 ± 20 rpm. With the governor so set, the engine speed will, as it should, fall to 2400 rpm when full load (rated load) is put on the engine by means of the dynamometer.

(b) Setting the rack (injection quantity test)

Set the rack so that fuel injection quantity will be between 7.6 and 7.8 liters (464 and 476 cu in.) per hour at 1600 engine rpm.

(c) Setting the idling stop screw (no-load minimum speed test)

Set the stop screw so that, when the adjusting lever is turned to bear against this screw, the governor will allow the engine to run at 600 rpm.

(3) Engine output test

Turn on the dynamometer to impose load on the engine running at no-load maximum speed and increase the load until the speed falls to 2400 rpm. Read the dynamometer indication right then. Determine the formal output power by multiplying the reading by this correction factor K:

$$K = \frac{760}{H - Hw}\sqrt{\frac{273 + t}{293}}$$

where H : barometric pressure in mmHg

Hw : partial pressure of H_2O vapor in mmHg

t : room temperature in °C.

DISASSEMBLY AND REASSEMBLY

Hints for facilitating disassembly-reassembly work

Engine disassembly

(a) Orderliness is important. Have work benches and parts trays in good condition, clean and tidy. Washing sinks and pans should be neat and ready for use. Have the disassembled parts placed in respective trays, keeping a group of associated parts in the same tray for easy identification.

(b) Before separating two parts, be sure to make match marks as necessary. Even for those parts to which positional matching is not critical, such marks will facilitate reassembly work.

(c) Signs of some defects or flaws are visible during disassembly but may disappear when the disassembled parts are washed clean. Leave your findings on record when such signs are noted.

(d) Use the right kind of tool for each disassembling job, in order to protect the parts and to speed up the work.

(e) Handle bearings and bushings and the like with care. They are critical parts: a little nick could make them unfit for re-use.

Engine reassembly

(a) Make it a rule not to re-use dirty parts in reassembly. Oil seals and bearings must be particularly clean. Before installing them, be sure to clean the bores for admitting them.

(b) It is a good practice not to re-use those gaskets and sealing members removed from the engine that has been in long service. Use of replacement parts is more economical as far as gaskets and the like are concerned.

(c) Before fitting a running part, be sure to oil its sliding surfaces. Use clean, fresh engine oil.

(d) Have the specified sealing compound on hand. Use of the compound is prescribed for most of sealing parts.

(e) Torque limits are specified for some bolts and nuts. Be sure to use torque wrenches and to refer to the specified values of torque limits.

Engine dismounting and mounting

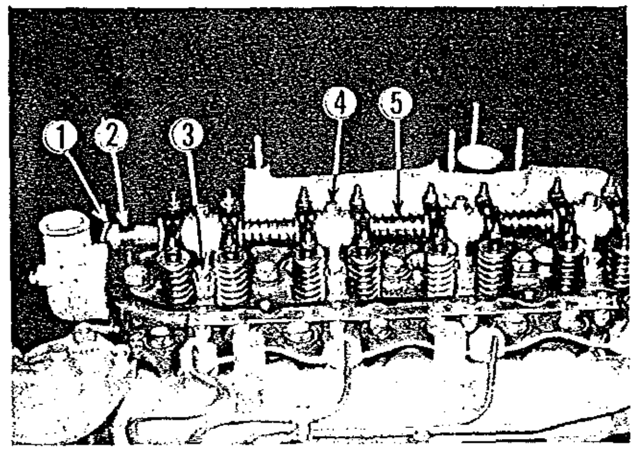
The engine and transmission are to be taken down together from the machine. The two must be combined on the bench and then remounted as a unit. The dismounting and mounting procedures are set forth in another manual.

Rocker arms and rocker shaft

Rocker shaft assembly removal

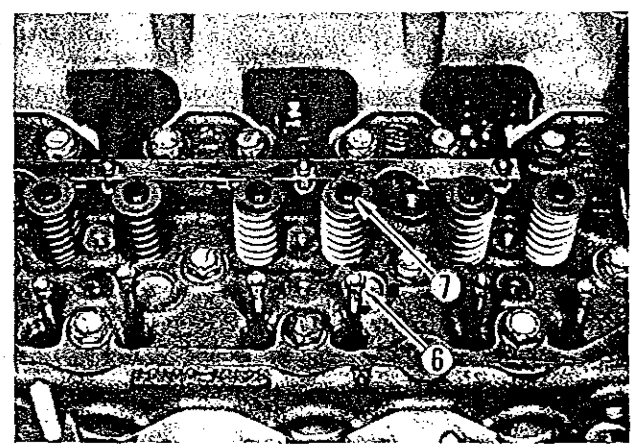
(1) Remove rocker cover and gasket. Remove oil pipe eye bolt (1) and disconnect pipe (2).

(2) Loosen short bolt (3) first and long bolt (4) next on each bracket and, after freeing all four brackets, lift the rocker shaft assembly (5) off the cylinder head.



1-Eye bolt 4-Long bolt
2-Oil pipe 5-Rocker shaft assembly
3-Short bolt

(3) Draw out push rods (6), and remove valve caps (7).



6-Push rod 7-Valve cap

Rocker shaft assembly installation

(1) Insert push rods into respective tappet holes. Mount valve caps on the heads of respective valves. Position the rocker shaft assembly on the cylinder head and make the short bolts and long bolts fingertight.

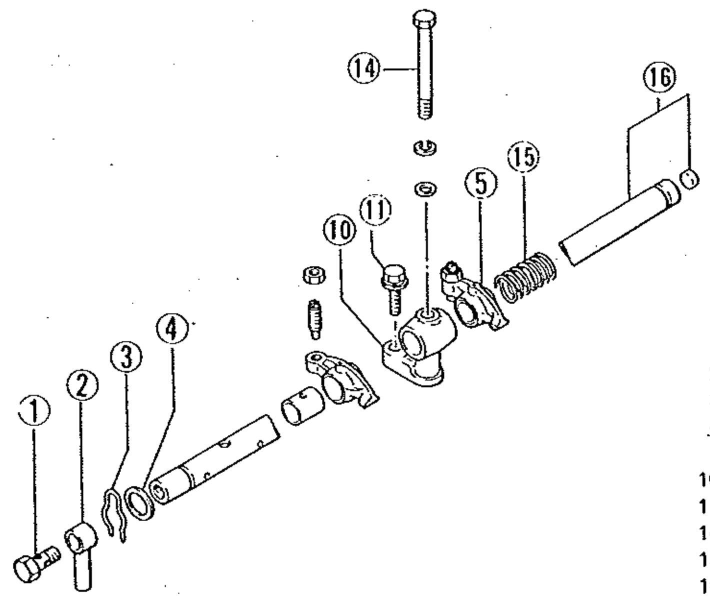
(2) Tighten the 8 short and long bolts to a torque value between 1.5 and 2 kg-m (10.8 and 14.5 ft-lb). Give the final torquing to long bolts first and to short bolts next, making sure that all bolts are tightened equally.

(3) Reconnect the oil pipe and secure the connection by tightening the eye bolt.

Upon starting the reassembled engine for the first time, inspect the rocker shaft assembly, checking for evidence of any loose bolts on the brackets and making sure that the rocker arm mechanism is properly lubricated. Check, also, for abnormal noise, such as valve chatter due to improper valve clearances.

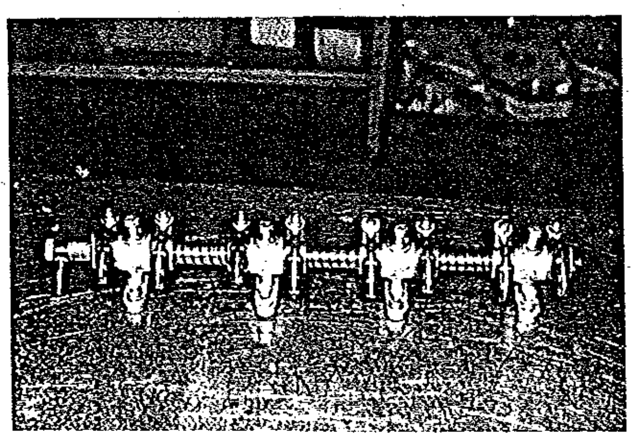
As to the valve clearance, refer to the part dealing with valve clearance adjustment in the latter part of this section. For both exhaust and intake valves, this clearance is prescribed to be 0.25 mm (0.0098 in.) (cold).

Rocker shaft disassembly and reassembly

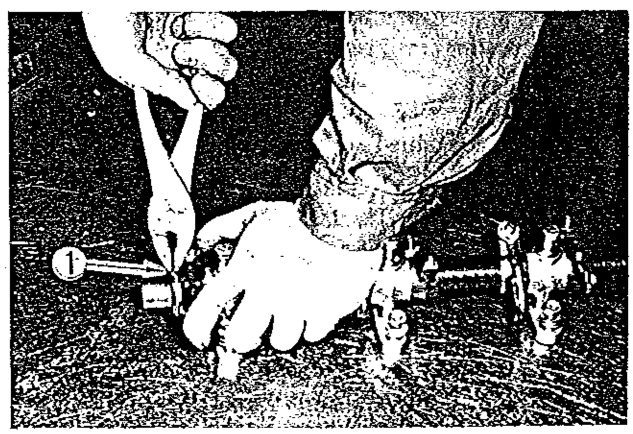


1-Eye bolt
2-Oil pipe
3-Snap ring
4-Washer
5-Rocker arm assembly
10-Bracket
11-Short bolt
14-Long bolt
15-Spring
16-Shaft

Rocker shaft assembly — Exploded view



Rocker shaft assembly



Removing snap ring

(1) To break the rocker shaft assembly, taken off the cylinder head, into its component parts, the first step is to remove snap rings (1), one at each end of the shaft. Pliers must be used to pick out the rings.

(2) Remove washer (4). This permits the assembly to be broken into components: brackets (10), rocker arms (5), springs (15) and shaft (16).

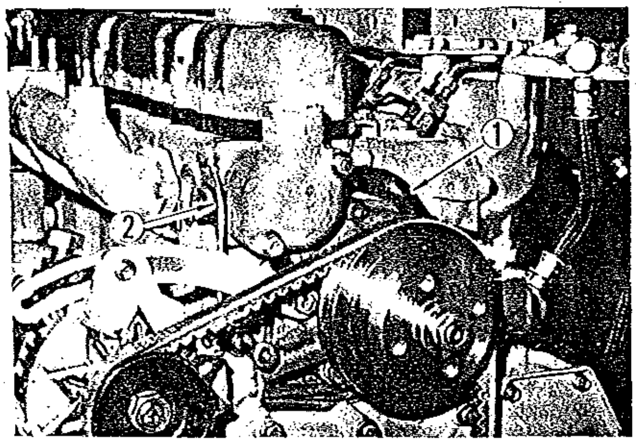
NOTE

Reverse the above sequence of disassembly to rebuild this assembly. Make sure that each rocker arm in place is capable of smooth rocking motion.

Cylinder head

Removal

(1) Disconnect bypass hose (1) and pipe (2). To do so, the thermostat elbow and water pump clamp must be displaced.

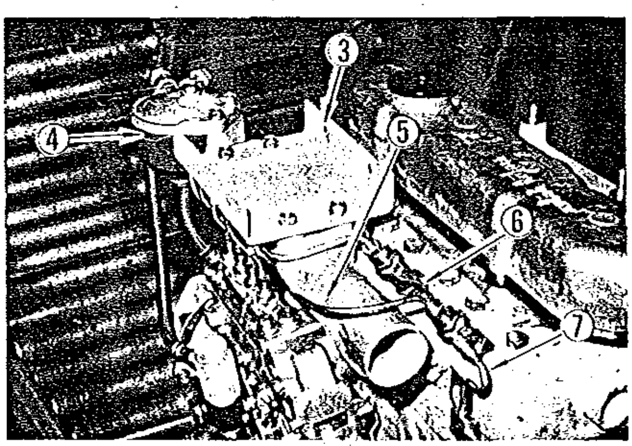


1-Bypass hose 2-Pipe

Removing cylinder head (1)

(2) Remove bracket (3) and fuel filter (4).

(3) Disconnect injection pipes (5), leak-off pipe (6) and return pipe (7).

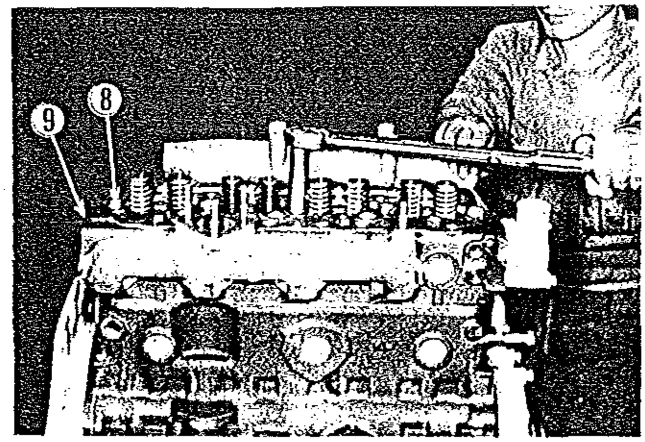


3-Bracket
4-Fuel filter
5-Injection pipe
6-Leak-off pipe
7-Return pipe

Removing cylinder head (2)

(4) Remove rocker cover, and take out the rocker shaft assembly, push rods and valve caps, as described previously.

(5) Remove cylinder head bolts (8). Lift cylinder head (9) straight up to remove it from the block of cylinders and crankcase.



8-Cylinder head bolt 9-Cylinder head

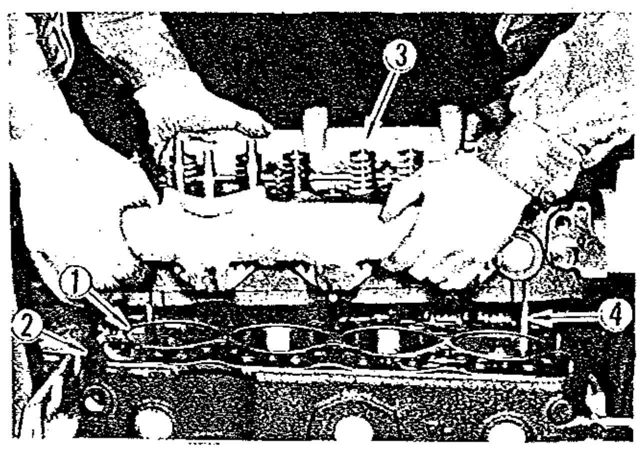
Removing cylinder head (3)

CAUTION

Cover up the open ends of injection pipes and air intake pipe to avoid entry of dirt. When removing the gasket from cylinder head, be careful not to nick or mar the gasketed surfaces of head and block. Read the torque needed to loosen each cylinder head bolt: these readings might help locating the cause of the trouble reported.

Installation

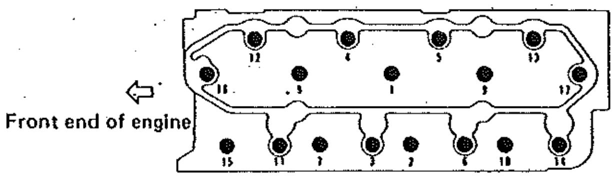
(1) Place new gasket (1) on the block (2), and lower cylinder head (3) squarely onto the gasket. Be sure to have two guide bolts (4) installed so that the gasket in place will not shift.



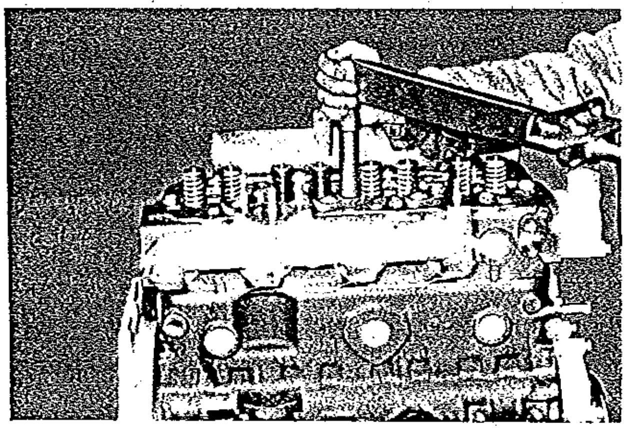
1-Gasket 3-Cylinder head
2-Crankcase 4-Guide bolt (2 pcs)

Installing cylinder head (1)

(2) Using a torque wrench, tighten the cylinder head bolts to 12 ± 0.5 kg-m (87 ± 3.6 ft-lb) in the sequence indicated by the ascending order of numbers, starting with "1."



Tightening sequence



Installing cylinder head (2)

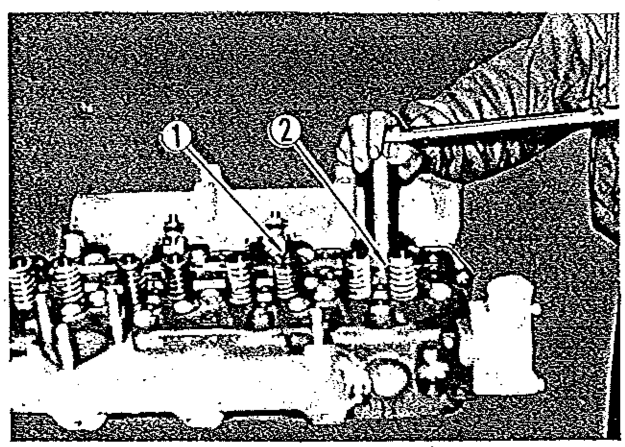
(3) Insert push rods, fit valve caps and install the rocker shaft assembly as described previously.

(4) Reconnect injection pipes, bypass hose and others.

(5) Adjust the valve clearance as prescribed, and mount rocker cover.

Disassembly

(1) Remove nozzle holders (1) and glow plugs (2).

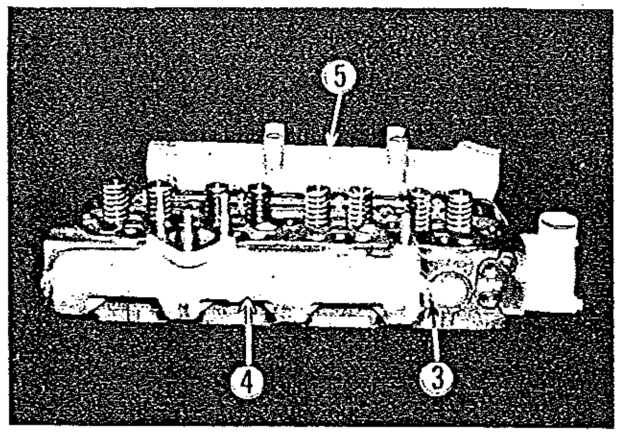


1-Nozzle holder 2-Glow plug

Disassembling cylinder head (1)

(2) Remove nuts (3) securing exhaust manifold (4) to the block. Take off manifold (4).

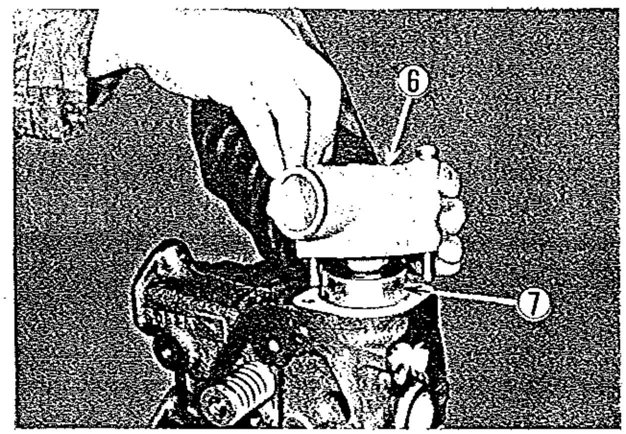
(3) Similarly remove intake manifold (5).



3-Nut 5-Intake manifold
4-Exhaust manifold

Disassembling cylinder head (2)

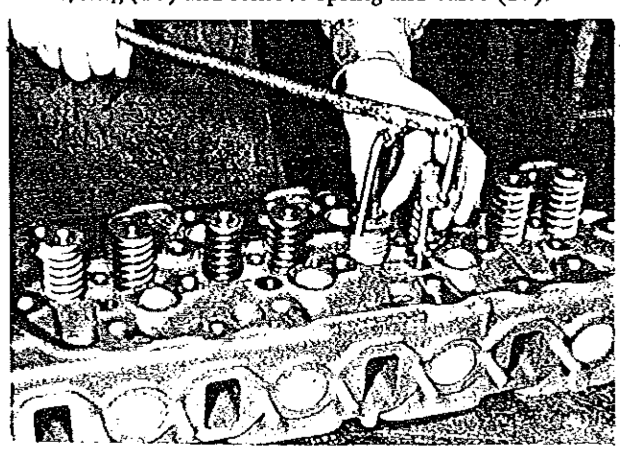
(4) Remove thermostat elbow (6) and take out thermostat (7).



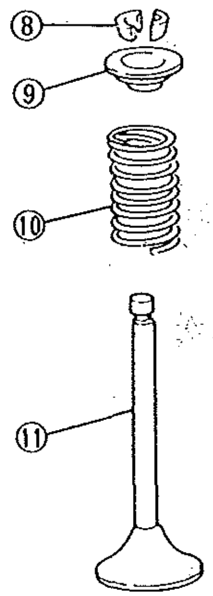
6-Thermostat elbow 7-Thermostat

Disassembling cylinder head (3)

(5) Remove exhaust and intake valves as follows: Compress valve spring by operating the valve lifter, pick out valve cotters (8) and retainer (9), release spring (10) and remove spring and valve (11).



Removing valve cotters



8-Valve cotters
9-Upper retainer
10-Valve spring
11-Valve

Valve — Exploded view

(6) After disassembling the head, de-carbon it thoroughly and clean the threaded holes for glow plugs and nozzle holders by washing. Clean the plugs and holders similarly. Use compressed air to dry washed parts. When washing the nozzle holder units, be careful not to damage their nozzle tips.

NOTES

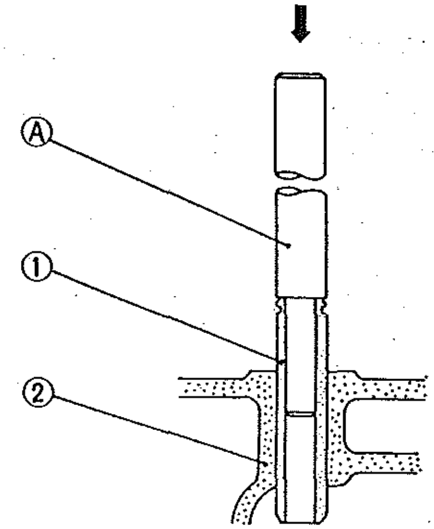
a) Intake and exhaust valves are not marked to identify the respective cylinders they serve. Upon removing each valve, be sure to mark it or otherwise identify it to ensure that it will be restored to the original place of service.

b) The two halves of each valve cotter must be handled as a matched pair for the valve from which it was removed in disassembly.

c) Leave the valve guides in place unless they need replacement.

d) Observe the carboned condition of the combustion chamber surfaces, intake and exhaust ports and valve heads before cleaning them. What is observed is an important symptom for troubleshooting.

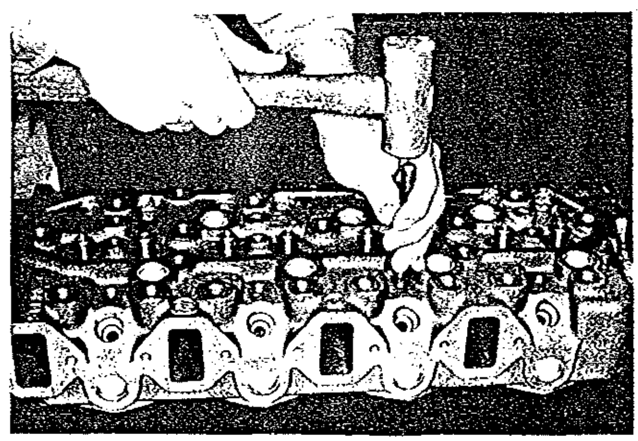
e) To remove the valve guide, be sure to use the valve guide remover (A).



1-Valve guide A-Valve guide remover
2-Cylinder head

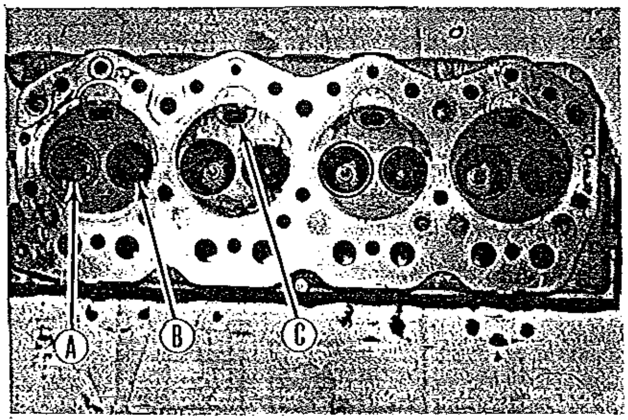
Removing valve guide

f) Leave the precombustion chamber jets in place unless their replacement is necessary. To remove a jet, as when cracks are noted on it, ease the jet out by driving with a flat-faced drift pin inserted through the glow plug hole, as shown:



Removing precombustion chamber jet

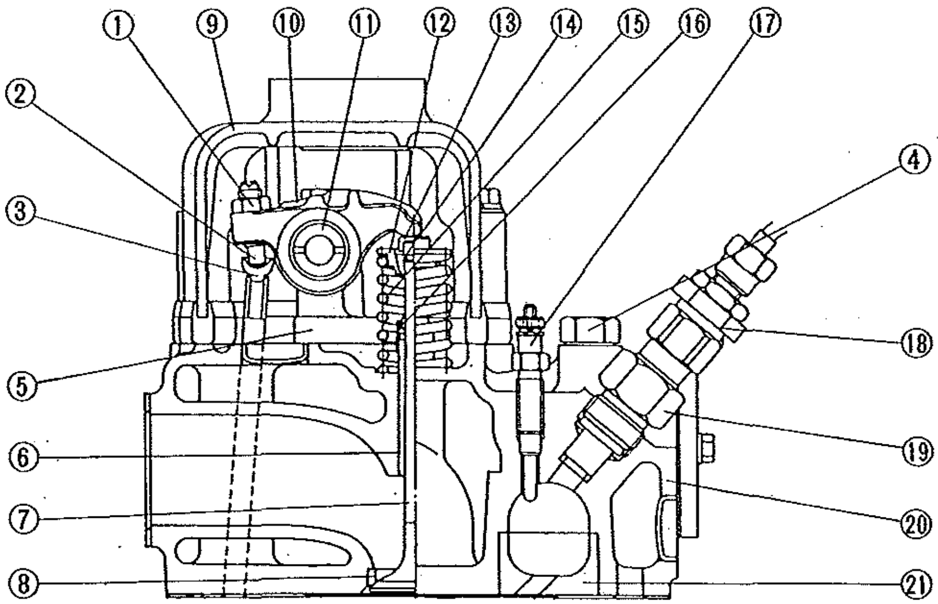
Before installing the jet, wash the precombustion chamber cavity clean, and drive the jet into position, with its orifice pointing to the center of the cylinder.



A-Intake port B-Exhaust port C-Chamber jet
Precombustion chamber jet location

Reassembly

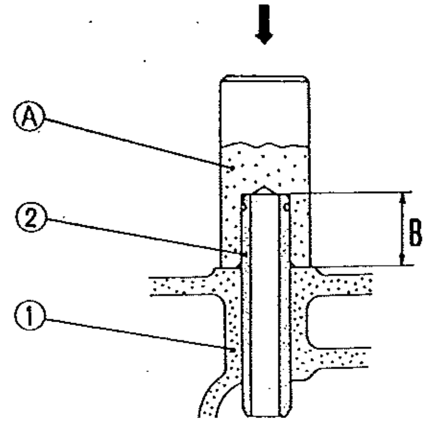
Make sure that all component parts have been serviced or otherwise checked to be in re-usable condition; have them all clean, free of greasy matter. Refer to this cross section in executing the reassembly work:



1-Lock nut
2-Adjusting screw
3-Push rod
4-Cylinder head bolt
5-Rocker bracket
6-Valve guide
7-Exhaust valve
8-Valve seat
9-Cover
10-Rocker arm
11-Rocker shaft
12-Spring retainer
13-Valve cap
14-Valve cotters
15-Spring
16-Stem seal
17-Glow plug
18-Leak-off pipe
19-Nozzle
20-Cylinder head
21-Precombustion chamber jet

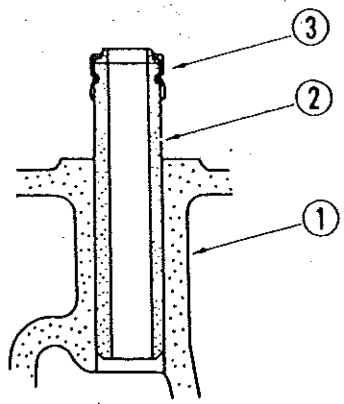
Cylinder head — Cross section

(1) Assuming that the valve guides have been removed, install each guide (2), as shown, with the use of the guide installer (A). After driving the guide in, check to be sure that the dimension (B) measures 17 mm (0.669 in.).



1-Cylinder head
2-Valve guide
A-Valve guide installer
B-Specified length: 17 mm (0.669 in.)

Installing valve guide



1-Cylinder head 3-Stem seal
2-Valve guide
Stem seal

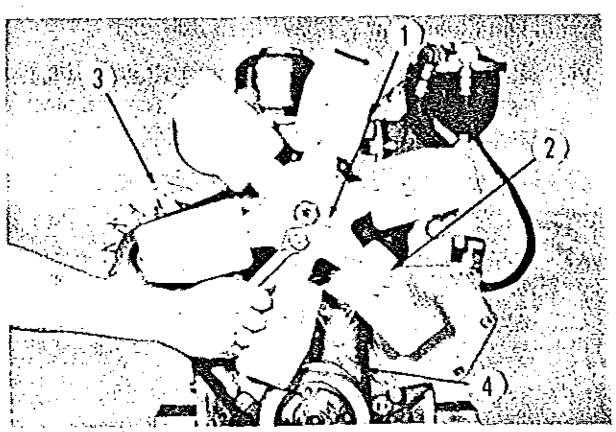
(2) Mount valves (7), springs (15) and retainers (12). Install valve cotters (14) on each valve with the spring compressed by means of the valve lifter. Leave out caps (13), which are to be put on when installing the rocker shaft assembly.

(3) Restore to the cylinder head the thermostat, thermostat cover, nozzle holders, leak-off pipes, glow plugs, connection wires, exhaust manifold and intake manifold.

Timing gears

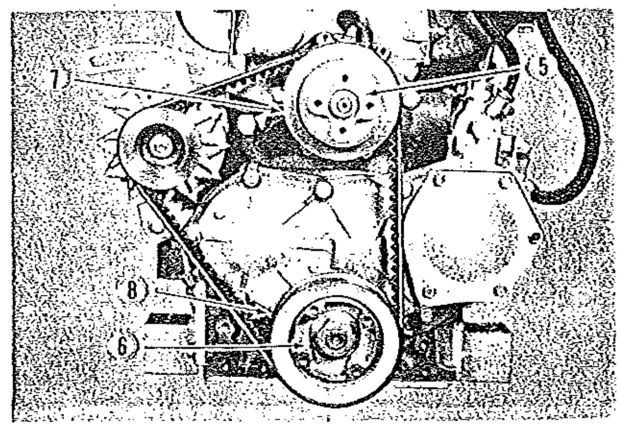
Removal

(1) Remove bolts (1) and take down the fan (2). Loosen bolt (3) securing the adjusting plate to the alternator, and take off fan belt (4).

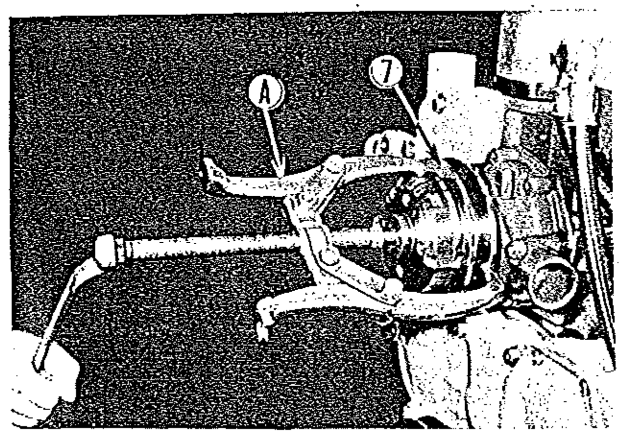


1-Bolt and washer (4 pcs each) 3-Bolt
2-Fan 4-Fan belt
Removing fan

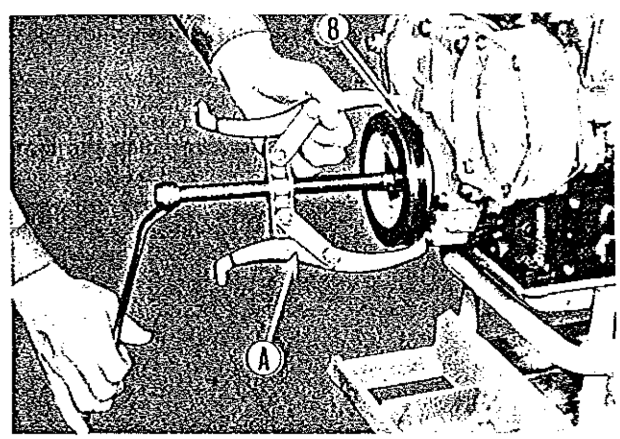
(2) Remove nut (5) on water pump shaft, and nut (6) on crankshaft. From the pump shaft, remove fan spacer and, by using the fan puller (A), draw pump pulley (7). Draw pulley (8) from crankshaft with the puller.



5-Nut and washer 7-Pump pulley
6-Nut and washer 8-Crankshaft pulley
Removing pump pulley and crankshaft pulley

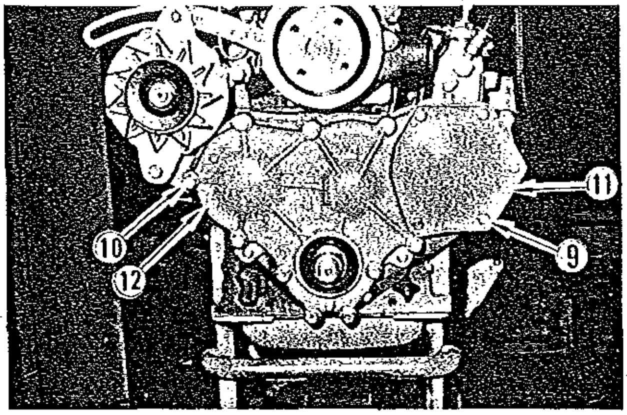


7-Pump pulley A-Puller
Drawing pump pulley off



8-Crankshaft pulley A-Puller
Removing crankshaft pulley

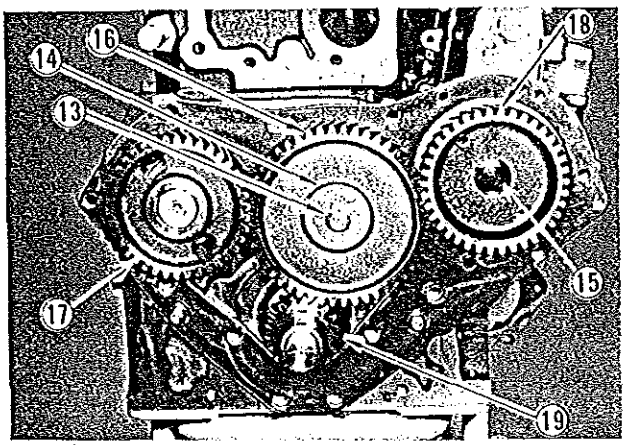
(3) Remove bolts (9) securing the cover (10). Remove bolts (10) securing the timing gear case (12). Take off the cover and gear case.



9-Bolt and washer (5 pcs each)   11-Cover
10-Bolt and washer (9 pcs each)   12-Gear case

Removing timing gear case

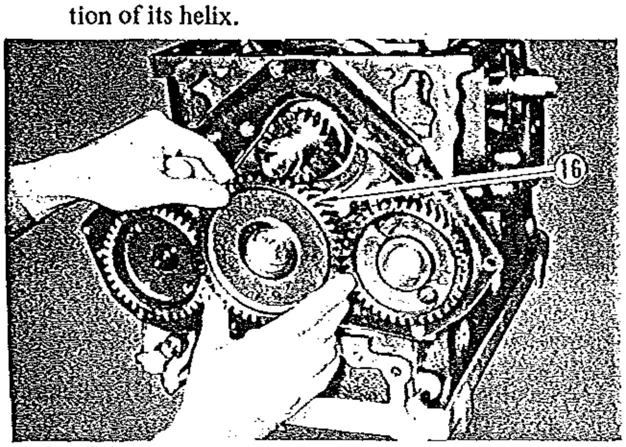
(4) Remove idler bolt (13), thrust plate (14) and injection pump gear nut (15).



13-Bolt   17-Camshaft gear
14-Thrust plate   18-Injection pump gear
15-Nut and washer   19-Crankshaft gear
16-Idler gear

Timing gears

(5) Draw idler gear (16) while twisting it in the direction of its helix.



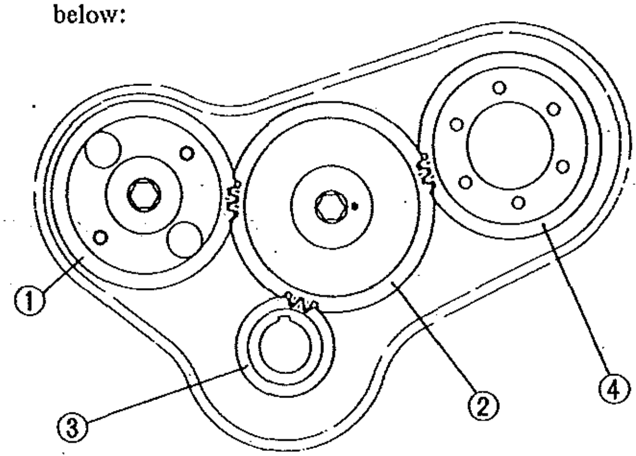
16-Idler gear

Removing idler gear

Leave camshaft gear (17) and injection pump gear (18) in place, unless they have to be serviced or replaced: each gear is to be removed complete with its shaft.

NOTE

Before removing any of the timing gears, be sure to turn over the crankshaft to bring these gears into the position at which the timing marks provided on them meet each other. Removed gears, if any, are to be fitted to take the same angular position, which is illustrated below:



1-Camshaft gear   3-Crankshaft gear
2-Idler gear   4-Injection pump gear

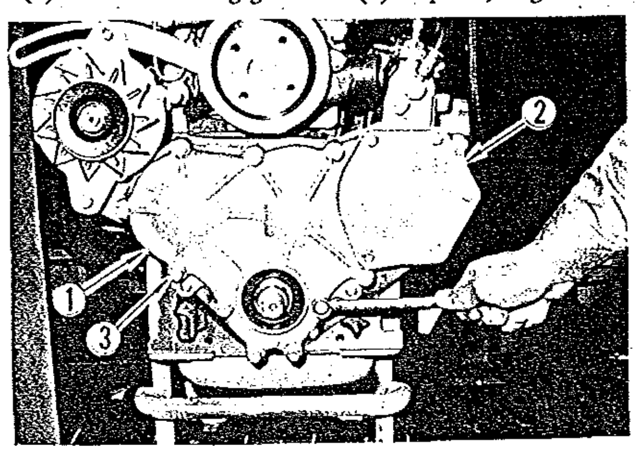
Timing gear match marks meeting each other

Installation

The procedure is generally the reverse of removal. It is assumed here that injection pump gear (4), camshaft gear (1) and idler gear (2) have been removed.

(1) Mount pump gear (4) and camshaft gear (1). Turn these gears while fitting idler gear (2), so that the match marks will meet as shown above.

(2) Position timing gear case (1) in place, as governed

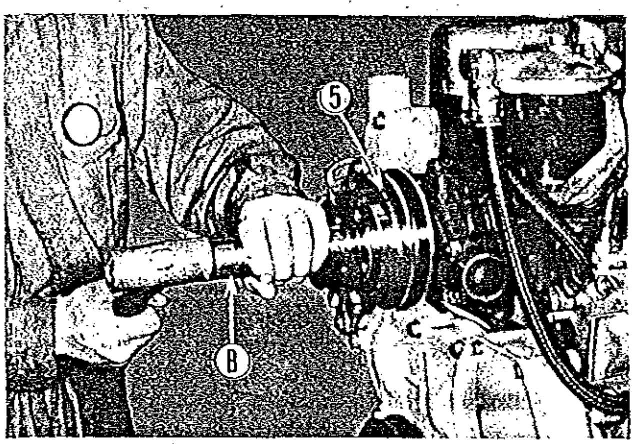


1-Timing gear case   3-Bolt and washer
2-Cover   (13 pcs each)

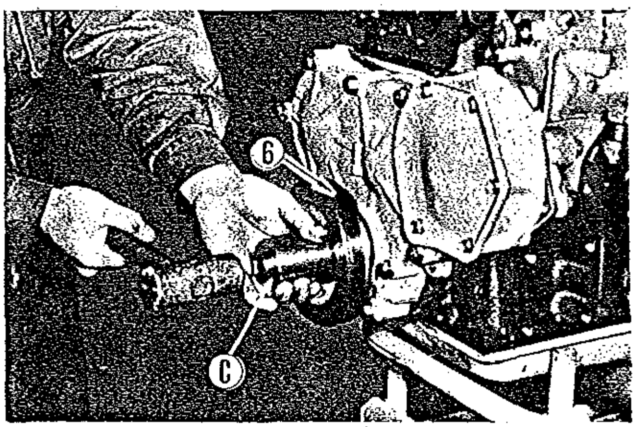
Securing gear case

by the locating pins provided on the front plate, and secure the case by tightening a total of 13 volts. Install injection pump gear cover (2).

(3) Install water pump pulley (5) and crank pulley (6) by driving them onto respective shafts with installers (B) (C).



5-Water pump pulley B-Installer
Installing pump pulley by driving



6-Crank pulley C-Installer
Installing crank pulley by driving

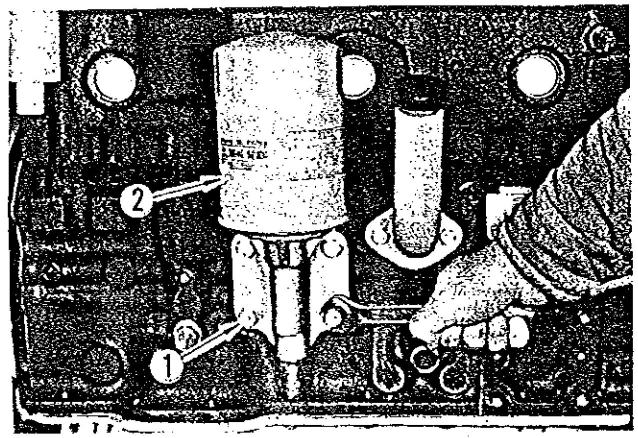
(4) Fit the washer to crank pulley and fasten down the pulley by tightening the nut.

(5) Pass the fan belt around the pulleys and install the cooling fan. Adjust the belt for proper tension as described in the part titled "Fan belt tension adjustment." Belt tension is specified in terms of "belt deflection" and is prescribed to be 12 mm (0.472 in.) (deflection) under thumb pressure.

Lubrication system

Oil filter removal and installation

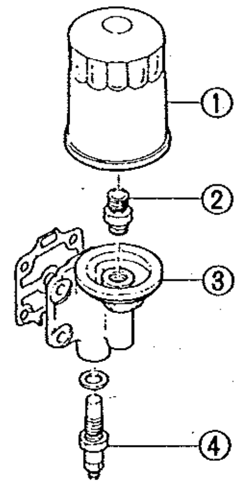
The oil filter is bolted to the crankcase. Removing the four bolts (1) allows the filter (2) to be detached from the engine for removal. When installing the filter, make sure that the seating face is clean and that the packing is in good condition.



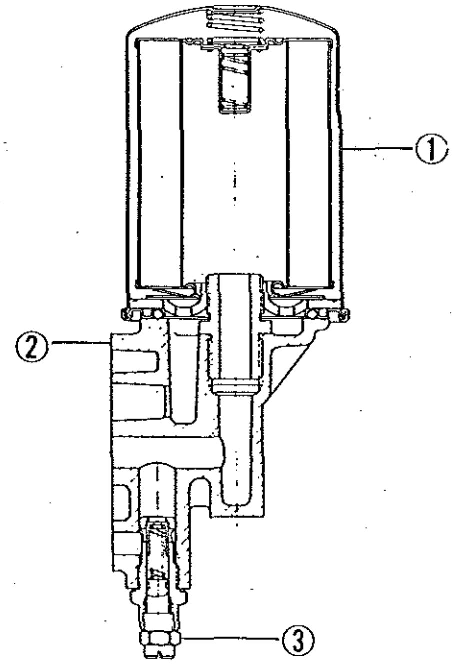
1-Bolt and washer (4 pcs each) 2-Oil filter assembly
Removing oil filter

Oil filter disassembly and reassembly

To disassemble the oil filter, use the oil filter wrench to detach element (1) from filter bracket (3). Removing relief valve (4) from the bracket completes disassembly. To reassemble the oil filter, reverse the disassembling sequence.



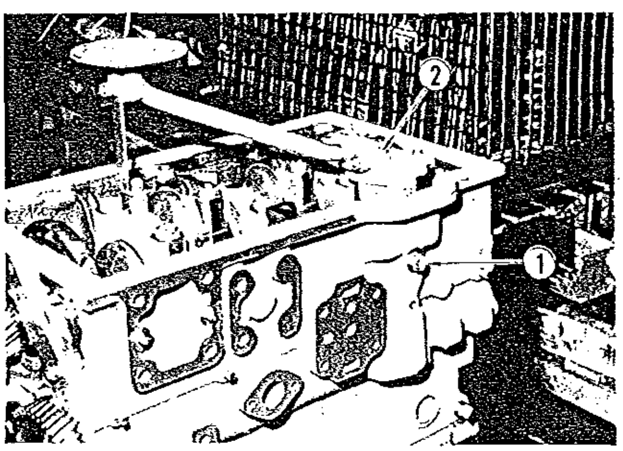
1-Element 3-Bracket
2-Center screw 4-Relief valve
Oil filter — Exploded view



1-Element 3-Relief valve
2-Mounting bracket
Oil filter -- Cross section

Oil pump removal

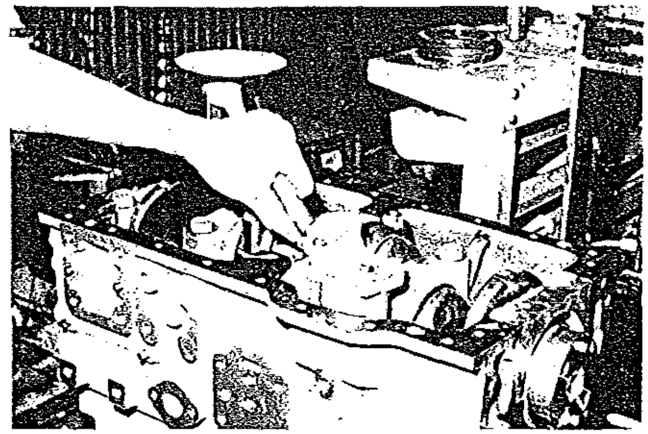
To remove the oil pump, the oil pan must be separated from the crankcase. Before removing the oil pan, be sure to drain it completely. Removing the mounting bolt (1) allows the pump (2) to be pulled out of the crankcase. Reverse this sequence of removal to install the oil pump.



1-Bolt and gasket 2-Oil pump
Removing oil pump

NOTE

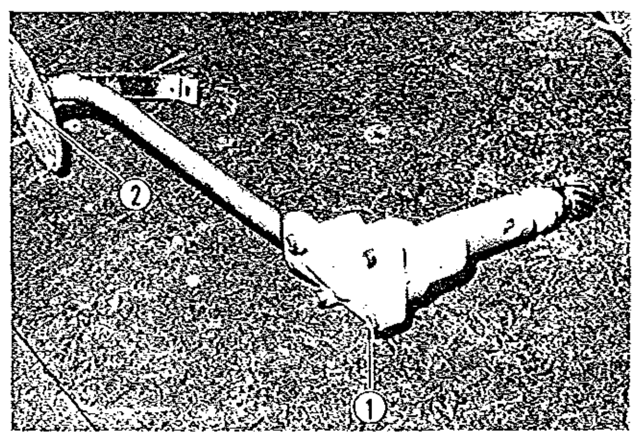
The oil pump will not come off if oil pump drive gear is firmly meshed with camshaft skew gear. While giving a pull to the oil pump, turn over the crankshaft a little to ease the drive gear from the skew gear.



When installing the oil pump, examine the gasket for the mounting bolt. Replace the gasket if it is nicked or otherwise defective.

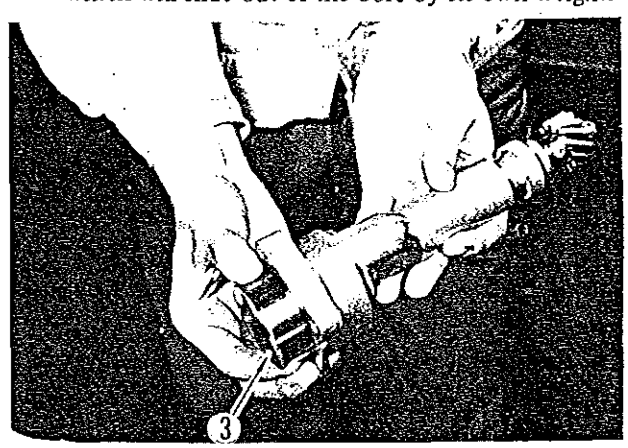
Oil pump disassembly

(1) From the pump, remove oil strainer (2) and pump cover securing bolts (1). Separate the cover.



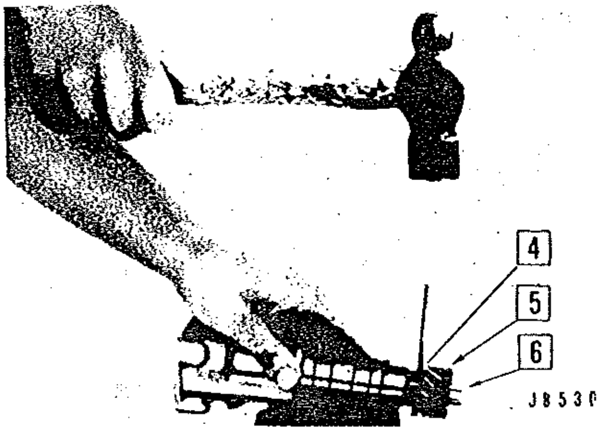
1-Bolt and washer (4 pcs each) 2-Oil strainer
Removing oil strainer

(2) Invert the pump case and catch outer rotor (3), which will slide out of the bore by its own weight.



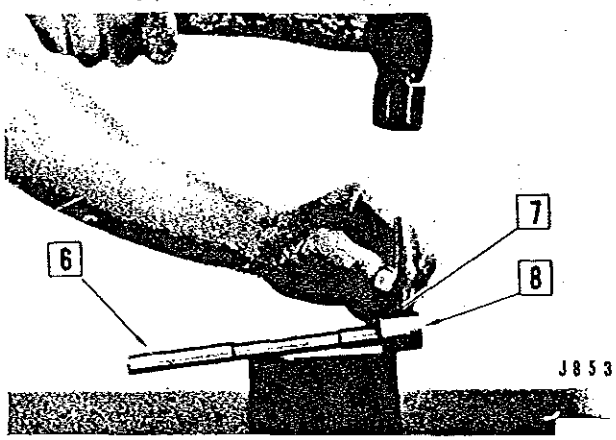
3-Outer rotor
Removing outer rotor

(3) Drive out tapered pin (4) by using a drift, as shown, and pull drive gear (5) off main shaft (6). Draw the main shaft out of the pump case.



4-Tapered pin 6-Main shaft
5-Drive gear
Removing tapered pin

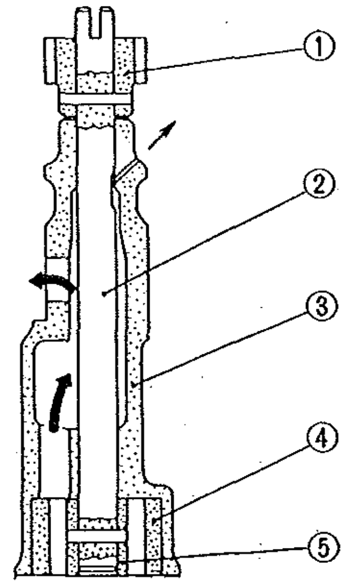
(4) Drive out inner rotor pin (7), and separate main shaft (6) from inner rotor (8).



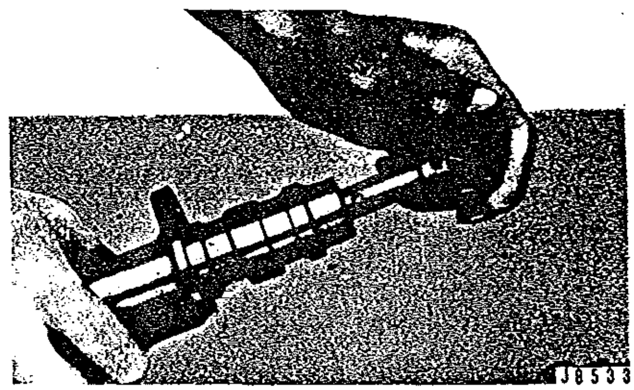
6-Main shaft 8-Inner rotor
7-Inner rotor pin
Removing inner rotor pin

Oil pump reassembly

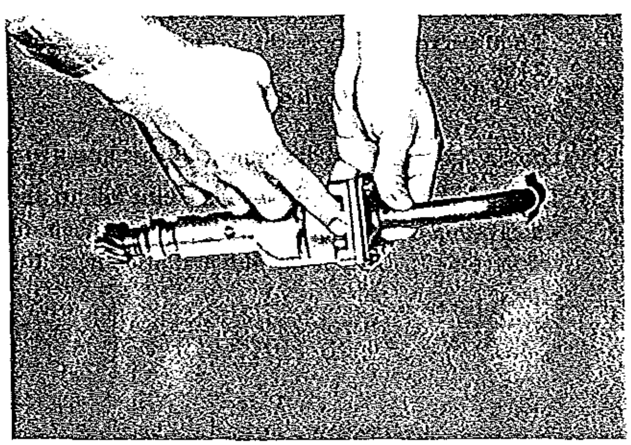
After securing inner rotor to shaft by driving in the pin, insert the shaft into the pump case, and mount the gear on the shaft, locking the gear by driving in the tapered pin.



1-Pump drive gear 4-Outer rotor
2-Main shaft 5-Inner rotor
3-Pump case
Oil pump — Cross section



Mounting drive gear



Fitting cover to case by matching marks

NOTES

a) If main shaft or drive gear has been replaced, a new pin hole must be made by drilling through the gear mounted on the shaft.

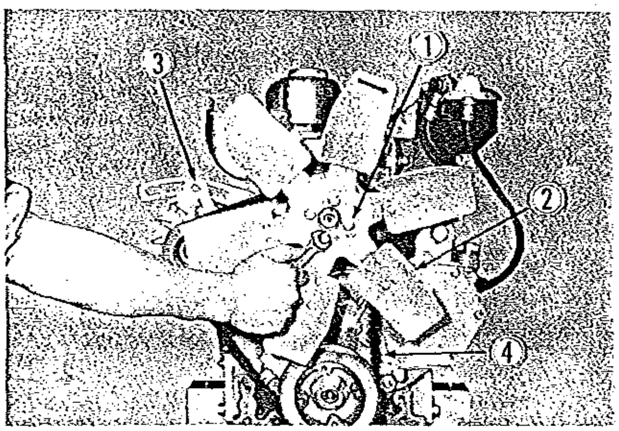
b) After putting on the cover, check to be sure that the match marks are correctly indexed. If the cover is in a wrong position relative to the case, the pump will not draw in oil. Tighten the bolts after checking to be sure that the marks are correctly matched.

c) After reassembling the pump complete with its strainer, immerse the strainer in a pool of oil and run the drive gear by hand to make sure that the pump is capable of sucking oil in.

Cooling system (water pump complete with thermostat)

Water pump removal

(1) Remove four bolts (1) and take off fan (2). Loosen bolt (3) and remove fan belt (4).

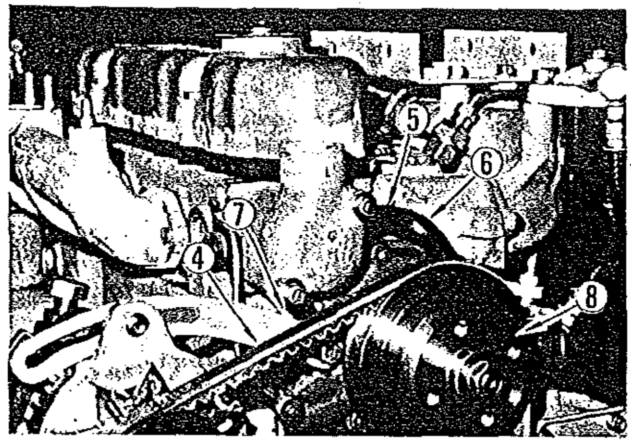


1-Bolt and washer (4 pcs each) 3-Bolt
2-Fan 4-Fan belt

Removing fan

(2) Loosen clamp (5) and disconnect bypass hose (6).

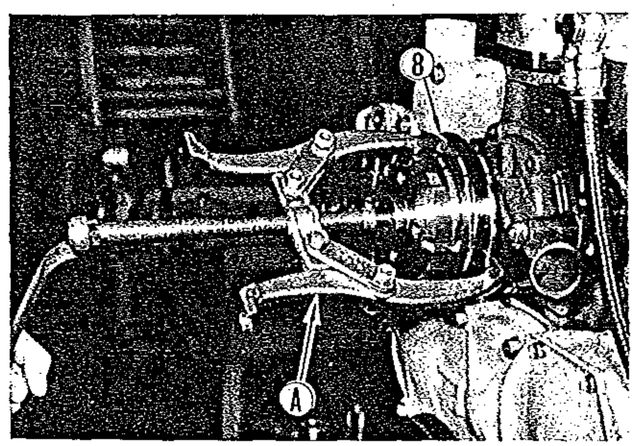
(3) The oil pipe for pressure-feeding lube oil to the water pump is connected to the pump by means of union nut (7). Loosen this nut and disconnect the pipe.



4-Fan belt 7-Union nut
5-Clamp 8-Pulley
6-Bypass hose

Disconnecting hose and pipe

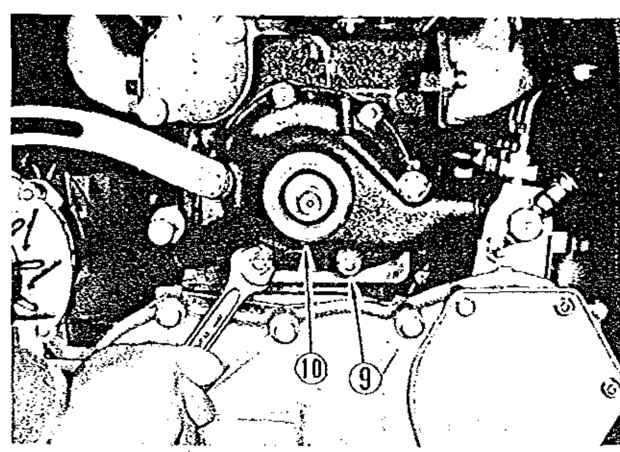
(4) Remove the nut securing pulley (8), and draw the pulley off the shaft by operating puller (A).



8-Pulley A-Puller

Removing pulley

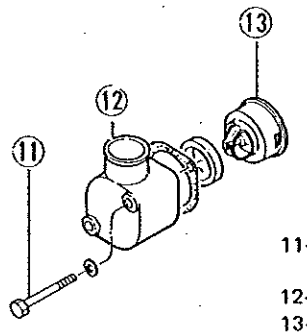
(5) Remove mounting bolts (9) and take off the water pump assembly from the crankcase.



9-Bolt and washer (4 pcs each) 10-Pump assembly

Removing water pump

(6) Remove two bolts (11) securing elbow (12), and take off thermostat (13), as outlined previously.



11-Bolt and washer (2 pcs each)
12-Thermostat elbow
13-Thermostat

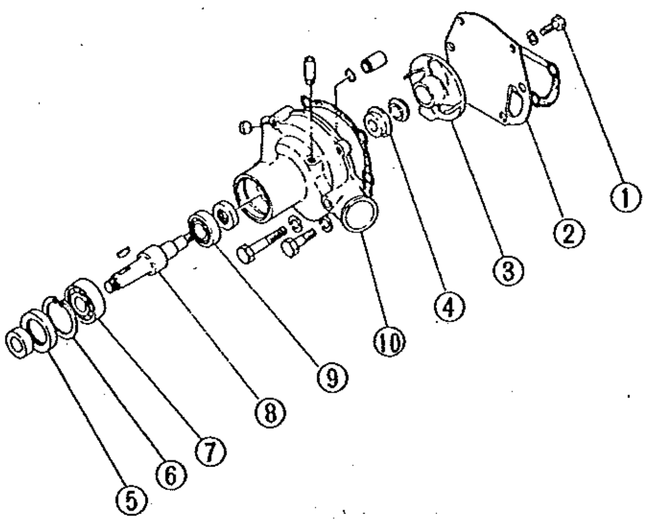
Removing thermostat

Installation is reverse of removal and can be effected by carrying out the foregoing steps in the reverse order. After installing the water pump, be sure to adjust the belt for proper tension.

NOTE

Handle the fan belt with care, keeping it free of any greasy stains. After removing the water pump from the crankcase, be sure to close the water opening of crankcase to avoid entry of dirt.

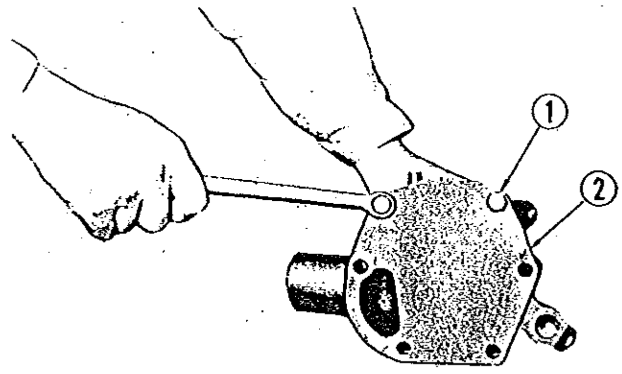
Water pump disassembly



1-Bolt	6-Snap ring
2-Cover	7-Bearing
3-Impeller	8-Shaft
4-Unit seal	9-Bearing
5-Oil seal	10-Pump case

Water pump — Exploded view

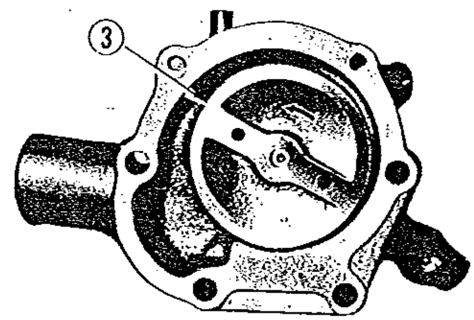
(1) Remove cover (2), which is secured to the pump case by bolts (1).



1-Bolt and washer 2-Cover

Removing pump cover

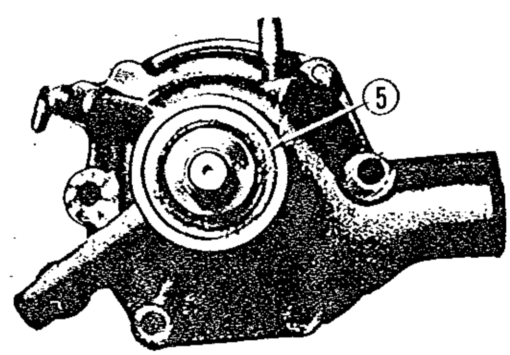
(2) Hold the pump shaft rigidly, and unscrew pump impeller (3) to remove it from the shaft.



Impeller (3) is mounted threadedly on the shaft. The screw threads is of right-hand screw. To remove impeller, turn it in the direction of the arrow.

Removing impeller

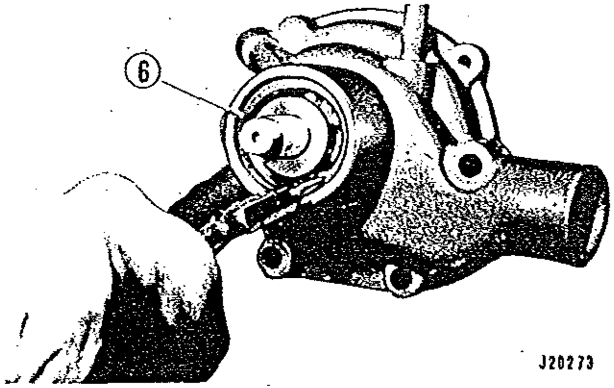
(3) Ease out oil seal (5) from pump case (10).



5-Oil seal

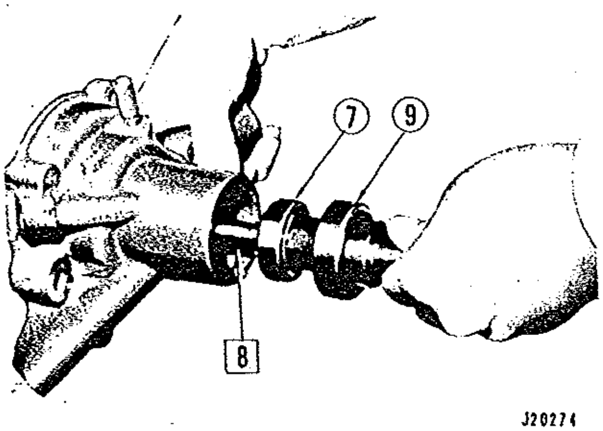
Removing oil seal

(4) Using pliers, pick out snap ring (6) from around the shaft.



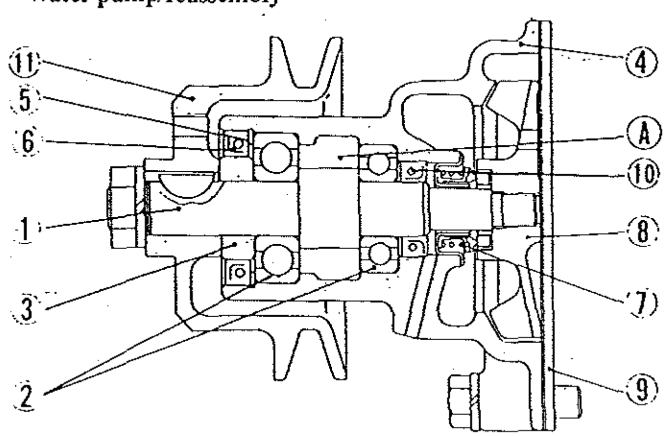
6-Snap ring
Removing snap ring

(5) Draw shaft (8) out from the pulley side of the pump case. Separate the two bearings (7) (9) from the shaft.



7-Bearing 8-Shaft 9-Bearing
Removing shaft

Water pump reassembly



1-Shaft	5-Snap ring	9-Cover
2-Bearings	6-Oil seal	10-Oil seal
3-Spacer	7-Unit seal	11-Pulley
4-Case	8-Impeller	A-Oil cavity

Water pump — Cross section

(1) Fit oil seal (10) into the case (4).

(2) Mount bearings (2) on shaft (1), put on spacer (3) and insert the shaft into the case.

(3) To the pulley side of the pump case, fit snap ring (5).

(4) Attach unit seal (7) to impeller (8), and mount the impeller on the shaft by running the impeller onto the shaft.

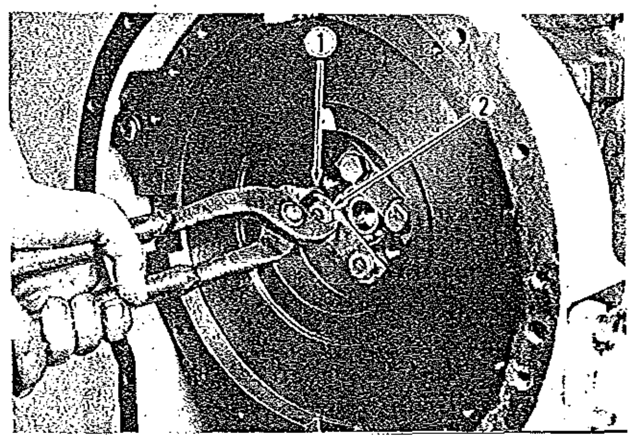
(5) Put on cover (9) and, after fastening it down to the case, check to be sure that the impeller does not rub the cover.

Flywheel and ring gear

Ring gear separation from flywheel

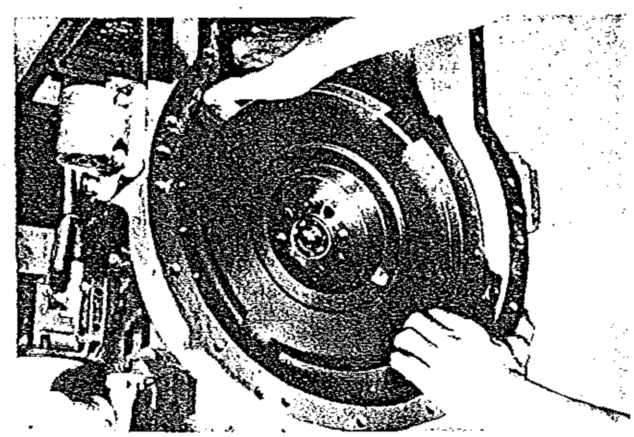
It is assumed here that the clutch has been removed.

(1) Straighten lock washers (1) and remove bolts (2).



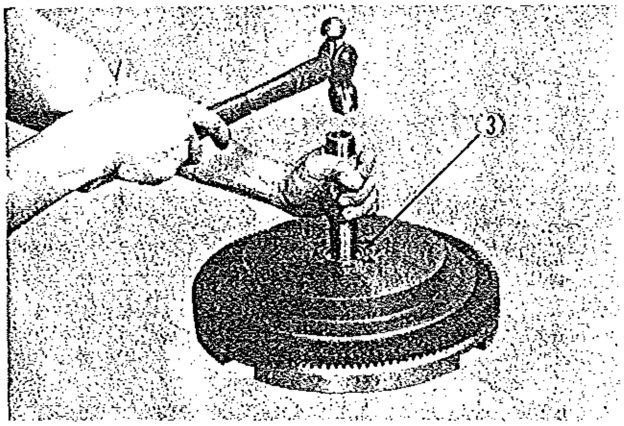
1-Lock washer (2 pcs) 2-Bolt (4 pcs)
Removing flywheel (1)

(2) Hold the flywheel with both hands, as shown, and pull it off crankshaft. Lay the removed flywheel on the bench top.



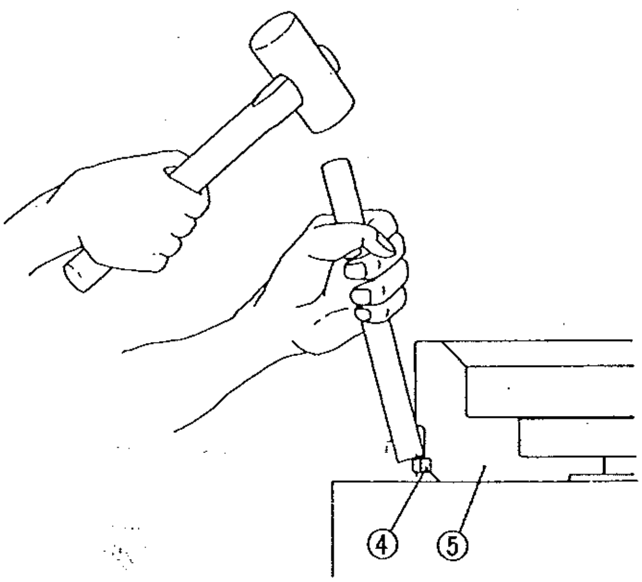
Removing flywheel (2)

(3) Using a drift, drive pilot bushing (3) out.



3-Pilot bushing
Removing pilot bushing

(4) Immerse the flywheel in a hot bath of oil at 100°C (212°F). Keeping the flywheel in this bath for 3 minutes will heat the flywheel uniformly to this temperature. Take out the flywheel, place it on a firm, level working surface, and ease ring gear (4) off flywheel (5) by driving with a drift bar.



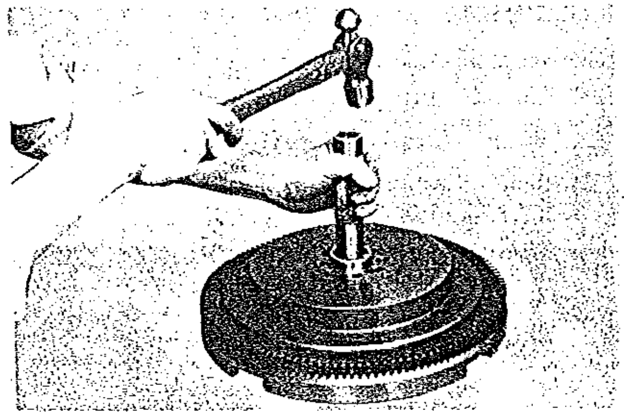
4-Ring gear 5-Flywheel
Removing ring gear

Flywheel reassembly and mounting

(1) Clean the shouldered periphery of the flywheel for receiving the ring gear. Clean the ring gear similarly.

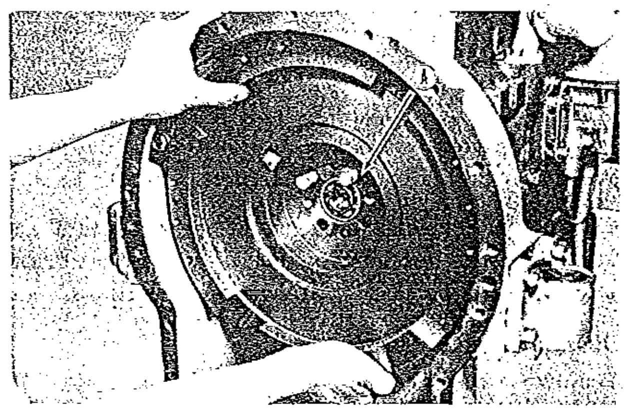
(2) Heat the ring gear to about 100°C (212°F) in a hot bath of oil. Keeping the gear in the 100°C (212°F) bath will heat it uniformly to this temperature. Upon removing the ring gear from the oil bath, fit it to the flywheel, making sure that the ring is seated firmly.

(3) Drive the pilot bushing into the flywheel.



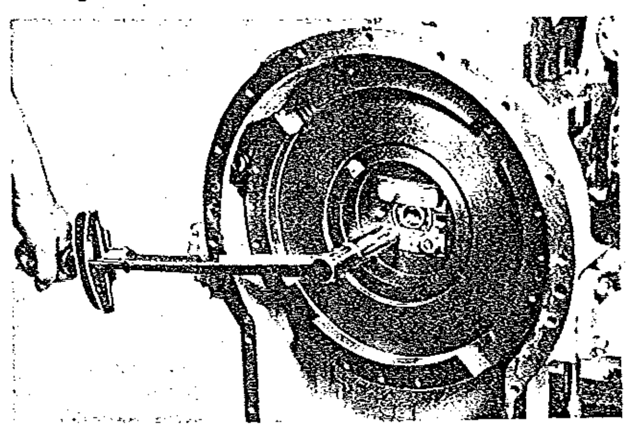
Installing pilot bushing

(4) Screw two guide bolts (A) into the crankshaft end. Hold out the flywheel squarely against crankshaft, positioning it as guided by dowel pins.



A-Guide bolt (2 pcs)
Remove guide bolts after correctly positioning the flywheel.
Fitting flywheel to crankshaft

(5) Put on washers and tighten mounting bolts to secure flywheel to crankshaft. Be sure to torque these bolts to 8.5 ± 0.5 kg-m (61.5 ± 36 ft-lb). Lock the tightened bolts by bending the washers firmly against each bolt head.



Securing flywheel to crankshaft.

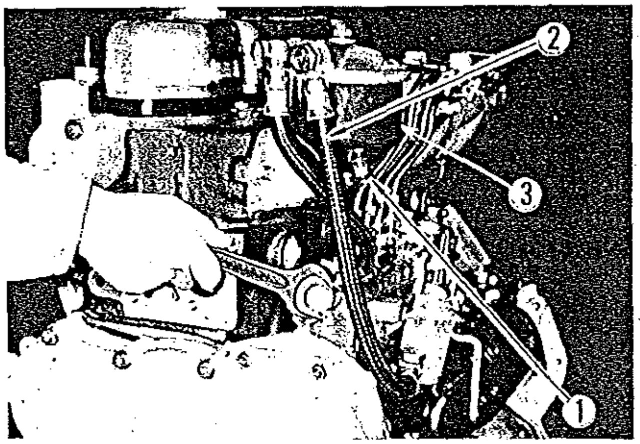
Fuel filter

Removal and installation

(1) Close the fuel supply valve under the fuel tank.

(2) Disconnect fuel feed pipe (2) from filter.

(3) Remove two mounting bolts and take off the fuel filter assembly (3).



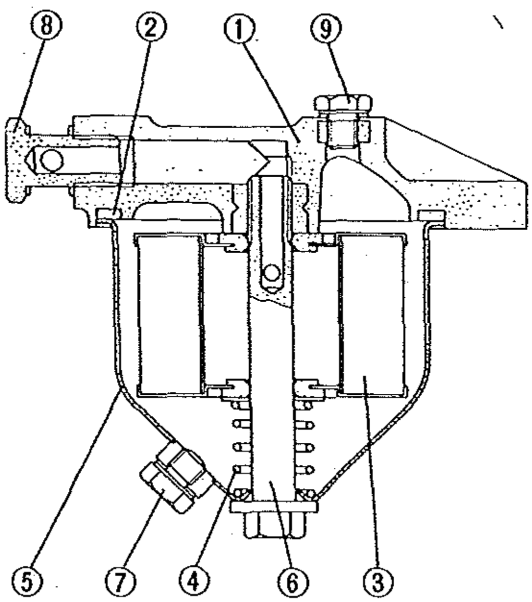
1-Drain plug 3-Filter assembly
2-Fuel feed pipe (2 pcs)

Removing fuel filter

Reverse the foregoing sequence of steps to install the fuel filter. After installing the fuel filter, run the engine and inspect for fuel leakage from pipe connections.

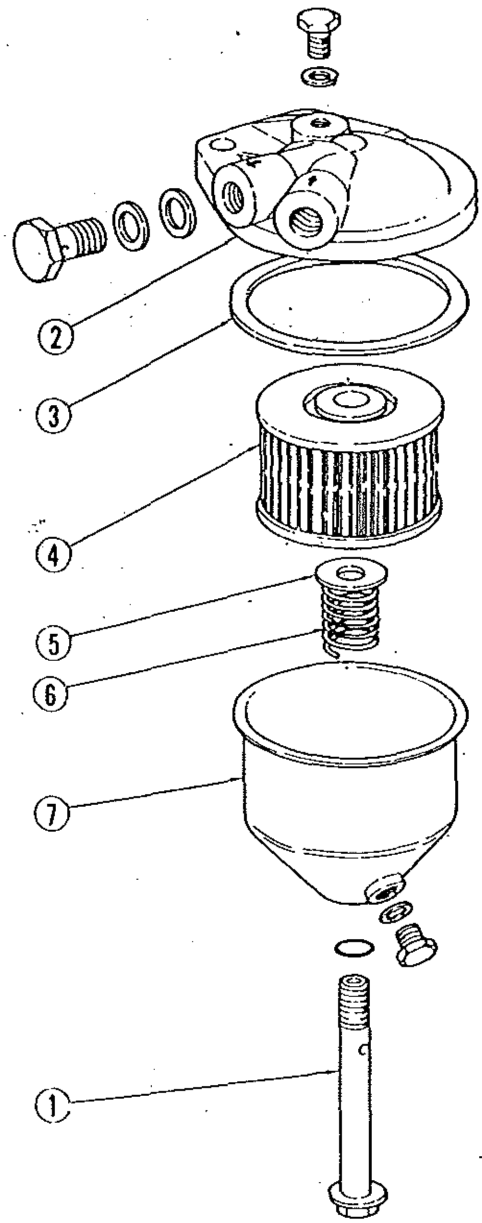
Disassembly and reassembly

The two views of the fuel filter given here are self-explanatory and will serve to explain the methods of disassembly and reassembly:



1-Filter cover 4-Spring 7-Drain plug
2-Gasket 5-Filter case 8-Bolt
3-Element 6-Bolt 9-Air vent plug

Fuel filter — Cross section



Parts are to be taken off one another in the ascending order of reference numbers.

1-Bolt 5-Spring seat
2-Filter cover 6-Spring
3-Gasket 7-Filter case
4-Element

Fuel filter — Exploded view

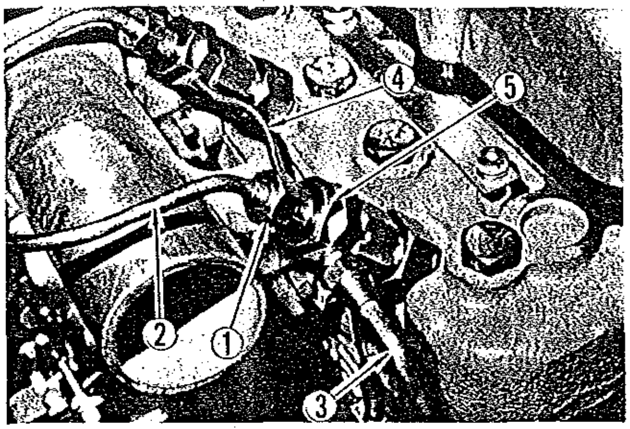
Injection nozzles

Removal and installation

(1) Loosen connector (1) and disconnect injection pipe (2) from the nozzle holder.

(2) Loosen the union nut and disconnect return pipe (3) from the holder.

(3) Remove nut (5) on each nozzle holder and disconnect leak-off pipes (4) interconnecting the holders.



1-Connector (4 pcs) 4-Leak-off pipe
2-Injection pipe 5-Nut (5 pcs)
3-Return pipe

Removing injection nozzle

(4) Put the wrench to the retaining nut, and unscrew the injection nozzle assembly to remove it from the cylinder head. Take off the packing remaining behind on the seating face by plucking with a screwdriver tip. Examine the removed packing to see if it can be re-used.

NOTE

Reverse the foregoing sequence of removing steps to install the injection nozzles, making sure to tighten the nozzle holder in place by torquing its nut to 5 ± 0.5 kg-m (36.2 ± 3.6 ft-lb). After removing each nozzle assembly, be sure to plug up the hole with a wad of cloth to avoid entry of dirt into the cylinder.

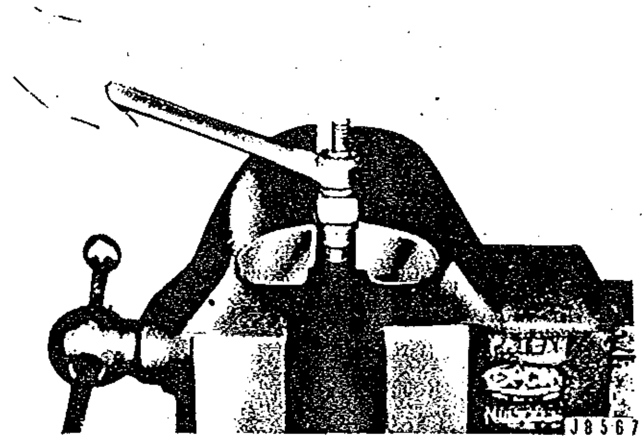
Disassembly

(1) Before disassembly, collect data on the nozzle by testing it for injection pressure (beginning of injection), spray pattern and internal oil-tightness, all in the manner already described. Throughout the disassembly, cleaning and reassembly work, handle each nozzle assembly with care to protect, in particular, the nozzle tip.

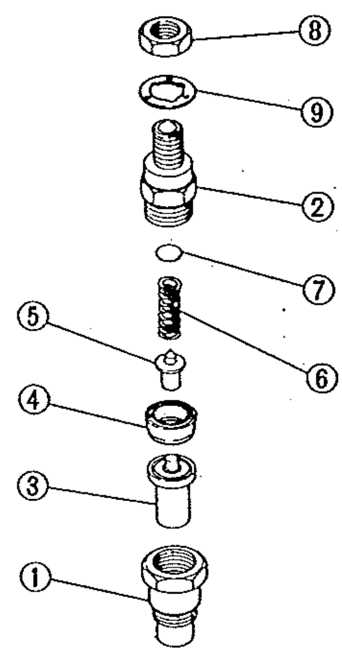
(2) Clamp retaining nut (1) between the jaws of a vise, as shown, put the wrench to the holder and loosen it to separate it from the nut (1).

(3) Take out of the removed holder these parts: nozzle tip (3), distance piece (4), pressure pin (5), spring (6) and washer (7).

Wash the disassembled parts clean with clean kerosine or diesel fuel oil, and dry them with compressed air. Using a wooden scraper, remove carbon: after decarboning, wash the decarboned parts with a more powerful cleaning fluid such as gasoline.



Removing nozzle holder



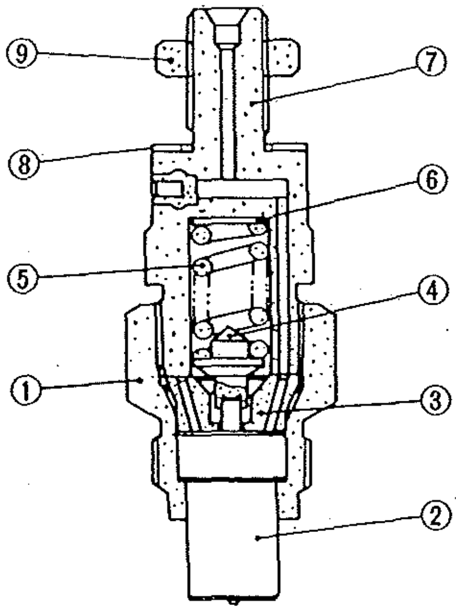
1-Retaining nut 6-Spring
2-Nozzle holder 7-Washer
3-Nozzle tip 8-Nut
4-Distance piece 9-Gasket
5-Pressure pin

Injection nozzle assembly — Exploded view

Reassembly

The reassembling steps are the same as the disassembling steps except that the sequence is reversed, and that the job of fitting a part to another must be carried out in a pool of clean kerosine.

If the needle valve and nozzle proper have to be replaced, be sure to wash the replacement parts in the pool of kerosine after removing their protective film of plastic: wash off the rust-preventive oil from the nozzle proper by stroking the needle valve back and forth in the needle valve stem bore.



1-Retaining nut
2-Nozzle tip
3-Distance piece
4-Pressure pin
5-Spring
6-Washer
7-Nozzle holder
8-Gasket
9-Nut

Injection nozzle — Cross section

Injection pump and governor

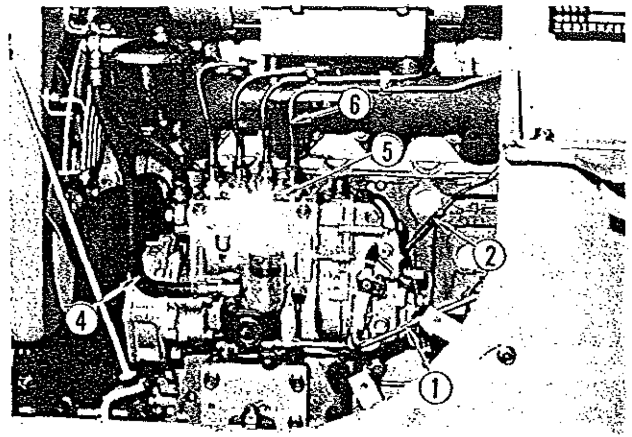
CAUTION

Unless the circumstances require disassembly of the injection pump and its governor, these components should not be disassembled. To overhaul them, special equipment complete with testing devices and special tool is needed. Furthermore, the overhauling work must be performed by a person skilled in this service and in a place specially kept clean.

Removal

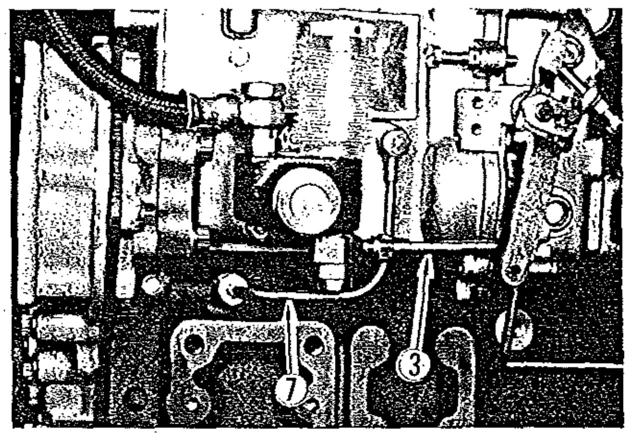
(1) Disconnect control wire (2) from adjusting lever rod (1); and disconnect fuel feed pipe (4) from the pipe joint at injection pump. Similarly disconnect the pipe between fuel filter and injection pump. Remove fuel return pipe (3) by undoing its pipe connections.

At each injection pipe connection on the pump unit, undo connector (5) to disconnect injection pipe (6). Remove oil pipe (7).



1-Adjusting lever rod
2-Control wire
4-Fuel feed pipe
5-Connector
6-Injection pipe (4 pcs)

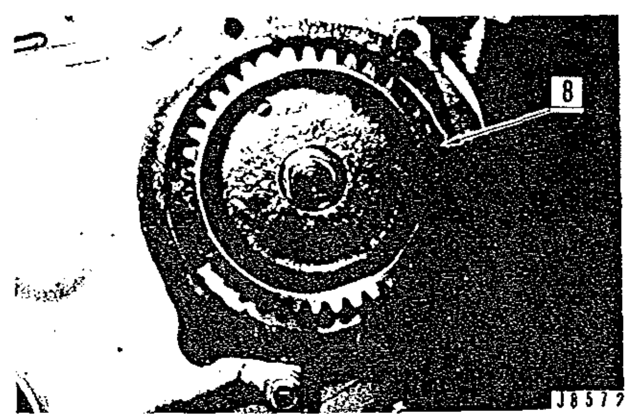
Removing injection pump (1)



3-Return pipe
7-Oil pipe

Removing injection pump (2)

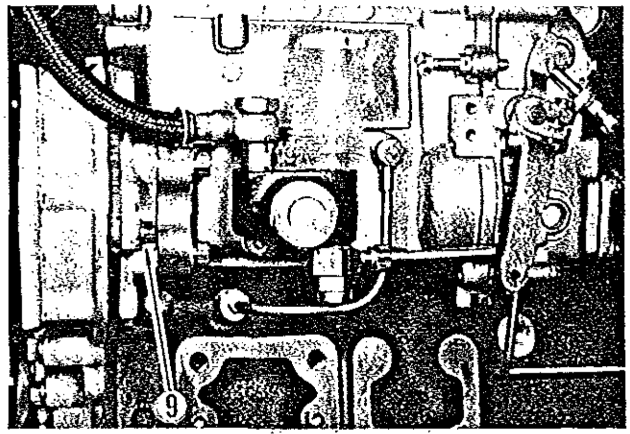
(2) Remove the injection pump gear cover. Turn over engine crankshaft to bring the piston in No. 1 cylinder to top dead center on compression stroke. Look into the timing gear case to check to be sure that the match marks provided on the idler and pump gear are meeting each other correctly.



8-Pump gear

Injection pump gear

(3) Remove bolts (9) securing the mounting flange of the injection pump to the engine front plate, and take down the injection pump unit.



9-Bolt and washer

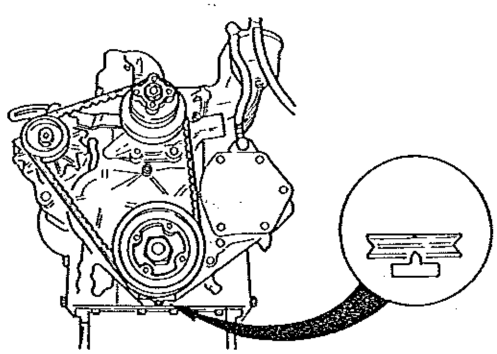
Removing injection pump (3)

Installation

(1) Alignment marks (line marks) are provided on the pump body and mounting flange. Make sure that these marks are lined up. With the pump gear and idler properly positioned in their meshed condition inside the timing gear case, that is, the match marks on these gears indexed to each other, mount the injection pump unit on the engine front plate and secure it by tightening the mounting bolts.

(2) Install fuel feed pipes and lube oil pipe, and reconnect all but No. 1 fuel injection pipe.

(3) Turn over engine crankshaft slowly until the plunger in No. 1 pumping element comes to the position for "beginning of injection." Check to be sure that the timing mark on crank pulley is matched to the mark on the timing gear case; if not, adjust the mounted position of the pump in the following manner:



Setting injection timing

(4) Tilting the pump toward the engine advances the timing, and vice versa. Refer to the graduation marks provided on the edge face of the mounting flange: one division is equivalent to 6 deg. of crank angle.

(5) Having made sure that all timing marks are matched as prescribed and that the beginning of injection is correctly timed (in reference to No. 1 cylinder), reconnect the injection pipe (No. 1). Prime the fuel circuit in the manner previously described: make sure that no air remains trapped in any part of the circuit.

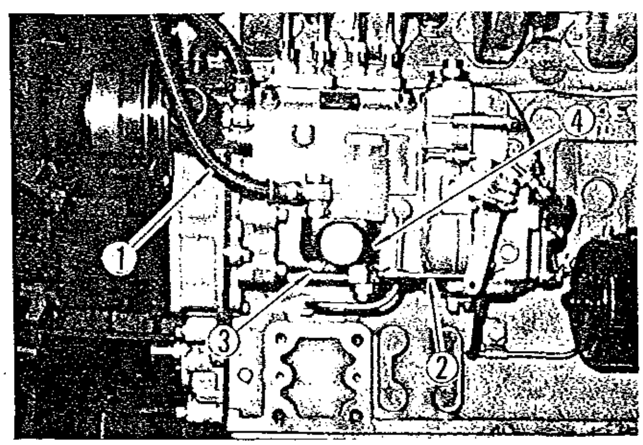
NOTE

Whether the injection pump is correctly installed must be checked by actually running the engine. Run the engine in all speed ranges; listen in for abnormal noise and examine the color of exhaust smoke. Evidence of malconditions noted could be due to mistimed fuel injection.

Feed pump removal and installation

(1) Disconnect fuel feed pipe (1) and return pipe (2).

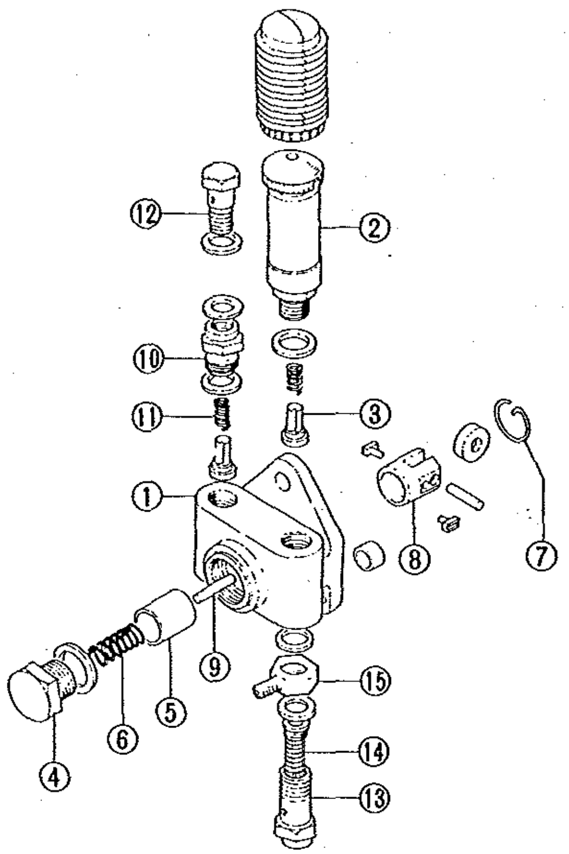
(2) Remove nuts (3) securing the feed pump to the injection pump body, and take off feed pump assembly (4).



1-Fuel feed pipe
2-Return pipe
3-Nut and washer (3 pcs each)
4-Feed pump assembly

Removing feed pump

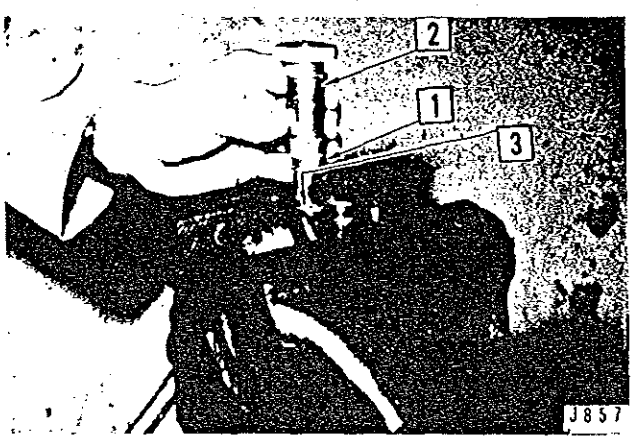
Feed pump disassembly and reassembly



1-Pump housing	9-Push rod
2-Priming pump	10-Valve support
3-Check valve	11-Check valve spring
4-Piston chamber plug	12-Hollow screw
5-Piston	13-Hollow screw
6-Piston spring	14-Gauze filter
7-Ring	15-Nipple
8-Tappet	

Feed pump — Exploded view

(1) Remove priming pump (2), and take out check valve (3).

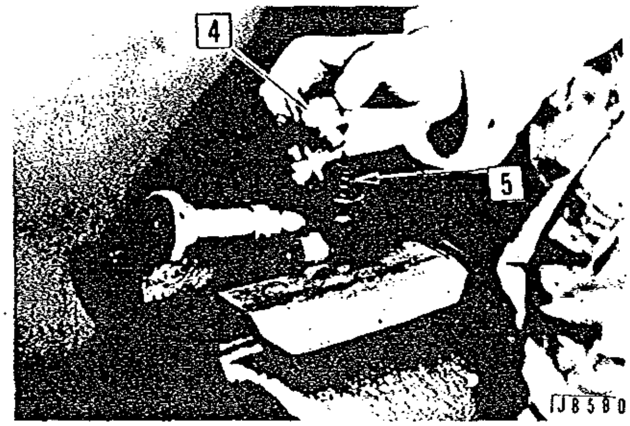


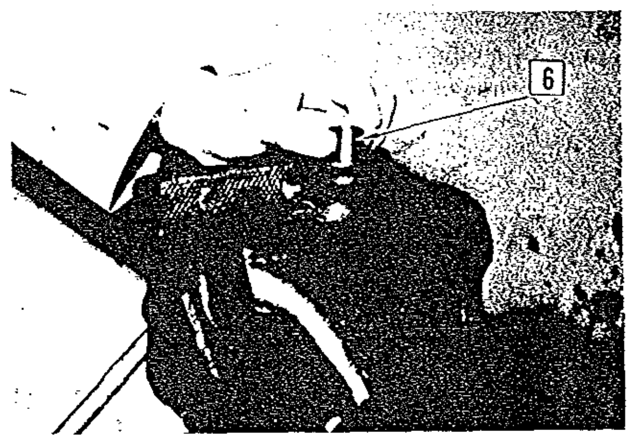
1-Valve holder 3-Check valve
2-Priming pump
Removing priming pump

NOTE

Priming pump is not meant for disassembly: its cylinder and valve holder are integrally combined by using a bonding compound.

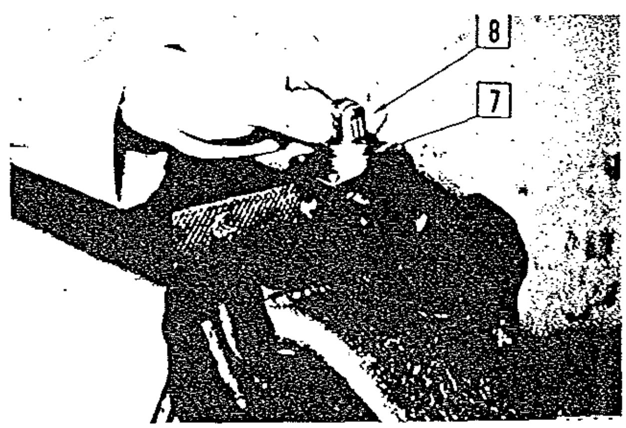
(2) Loosen piston chamber plug (4), pick out piston spring (6), and draw out piston (5).





4-Piston chamber plug 6-Piston spring
5-Piston
Removing feed pump piston

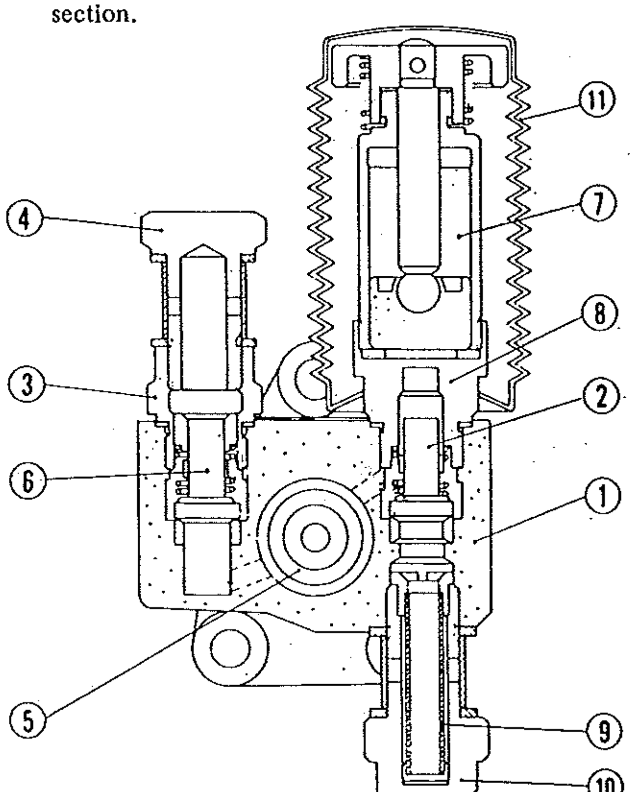
(3) Remove ring (7), and take out tappet (8) and push rod.



7-Spring 8-Tappet
Removing feed pump tappet

NOTE

Assembly is reverse of disassembly. Be sure to correctly assemble by referring to the cross section.



1-Pump housing
2-Check valve
3-Valve support
4-Hollow screw
5-Piston and tappet
6-Check valve
7-Priming pump
8-Valve holder
9-Gauze filter
10-Hollow screw
11-Cover

Feed pump — Cross section

Governor disassembly

The following tools are needed to disassemble and assemble the RSV governor of the injection pump unit:

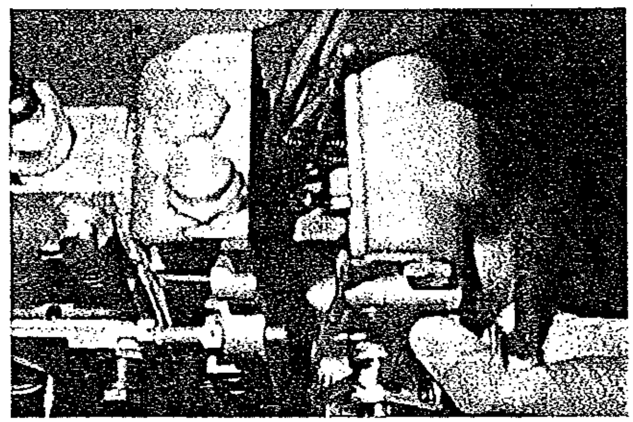
(a) Screwdriver
(b) Wrench set
(c) Long-nose pliers
(d) Special wrench for torquing governor weight round nut
(e) Flyweight extractor
(f) Overhauling tool set

Before starting to disassemble the governor, wash the exterior surfaces of injection pump unit and set up the pump on the bench. Drain lube oil.

(1) Detach and remove the governor cover as follows:

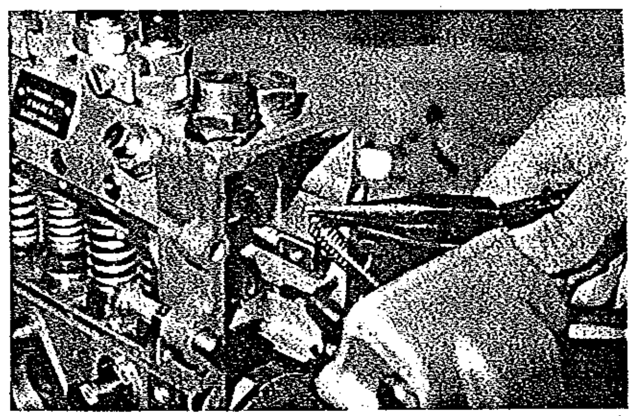
(a) Loosen idle lock nut (1), remove idling sub-spring (2), loosen screws securing cover piece (3), and take off this cover piece.

(b) Remove the six screws (4) securing the governor cover to the housing, and detach the cover by pulling it a little. Insert the screwdriver and move the shackle upward or downward with the tip of screwdriver to undo the pinned connection between control rack and shackle.



Disconnecting shackle from control rack

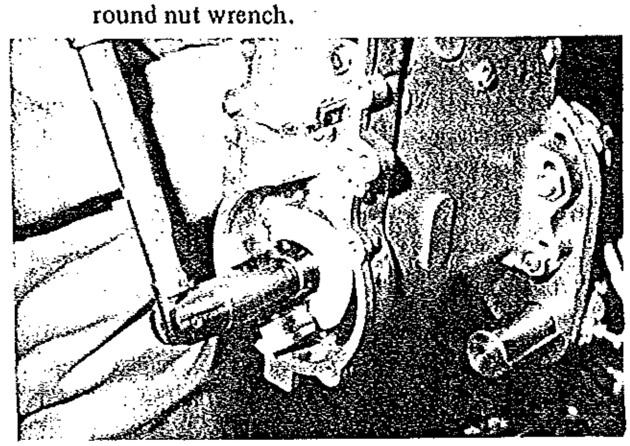
(c) Using the long-nose pliers, unhook the start spring. Remove the governor cover complete with the lever mechanism.



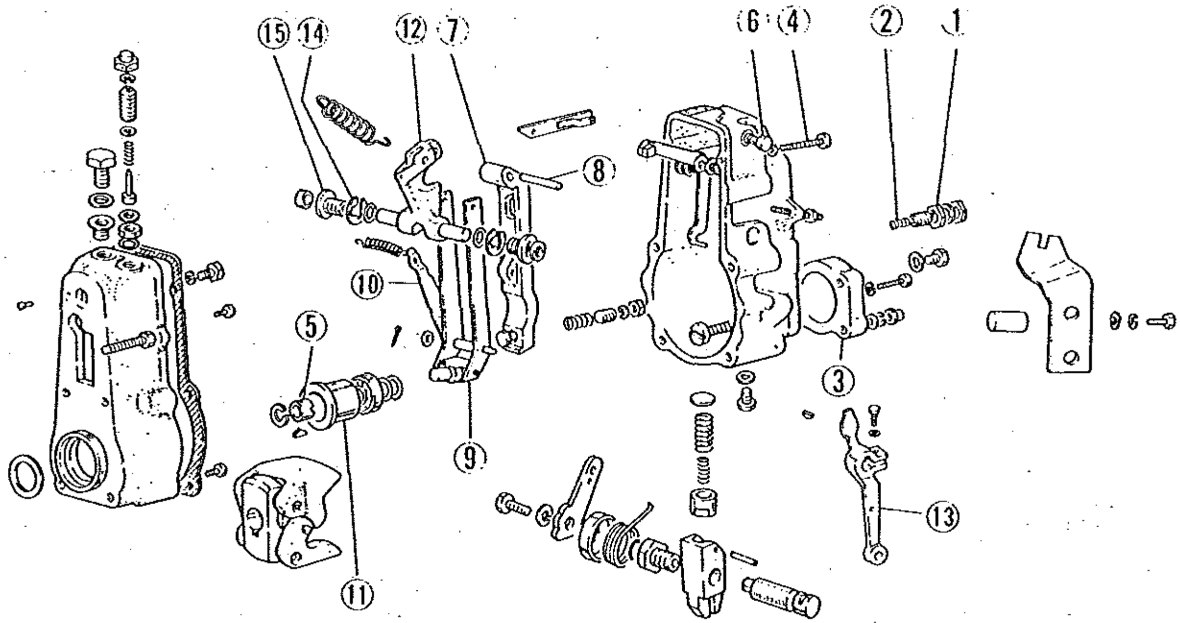
Disconnecting start spring

(2) Remove the flyweights as follows:

(a) Remove round nut (5) by loosening it with the round nut wrench.

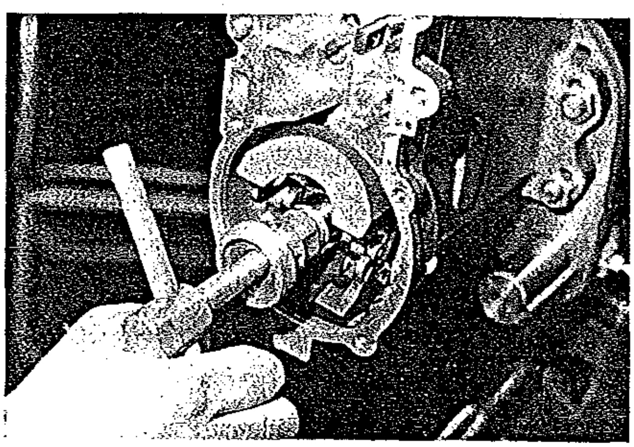


Removing round nut



Governor — Exploded view

(b) Run the flyweight extractor into the threaded hole, as shown, and force the flyweights off the camshaft by jacking action.



Removing flyweights

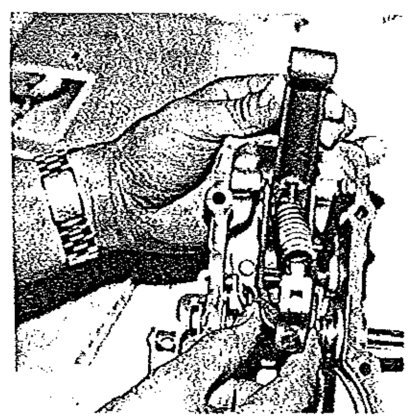
(3) From the removed governor cover, take out the lever mechanism parts, as follows:

(a) Remove two screw plugs (2), and draw out lever supporting shaft (8), on which tension lever (7) is hinged.

(b) Raise the swiveling lever, as shown, take out tension lever (7) and remove control spring.

(c) Take out guide lever (9) together with control lever (10) and governor sleeve (11).

(d) To remove swiveling lever (12), remove adjusting lever (13), pick out snap ring (14), drive out lever bushing (15) to outer side. This permits the lever (12) to come out of the cover.



Removing tension lever

Governor reassembly

Carry out the sequential steps of disassembly in reverse order, adhering to the following instructions:

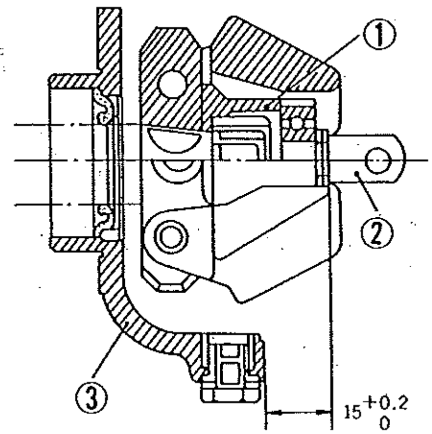
(1) Flyweight mounting

After positioning the flyweights on camshaft, secure it by tightening the round nut to 6 kg-m (43.4 ft-lb). Be sure to place a spring washer under this nut.

(2) Combining governor sleeve and guide lever (floating lever)

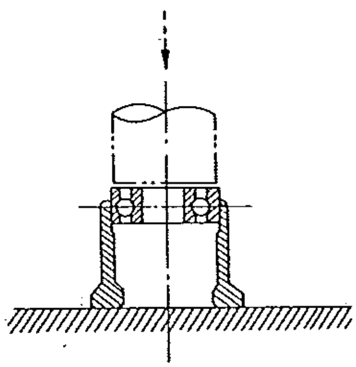
If these two parts have been separated, combine them in the following manner:

Referring to the sketch below, press the ball bearing into the governor sleeve, and press the control block into the bearing, making the flange of the block seat firmly against the inner ring of the bearing. Fit the sleeve (complete with the control block) onto the flyweight support, and measure the distance between the end face of governor housing and the flange of control block. This distance is prescribed to be from 15 mm (0.591 in.) to 15.2 mm (0.598 in.); if not, adjust it by shimming. The shim stock for this purpose is available in three sizes: 0.2 mm (0.0078 in.), 0.3 mm (0.0118 in.) and 0.4 mm (0.0157 in.).

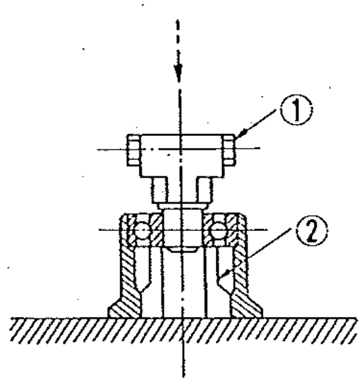


1-Governor sleeve 3-Governor housing
2-Control block

Position of control block



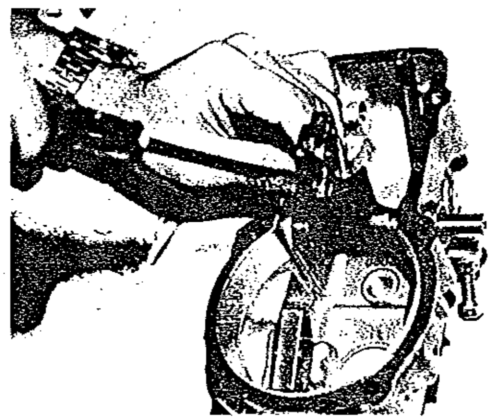
Pressing ball bearing into governor sleeve



1-Control block 2-Inner ring supporting tool

Pressing control block into ball bearing

(3) Check to be sure that the adjusting screw in the swiveling lever is positioned as prescribed; if the screw is too far in or out, adjust it by referring to the value indicated in the list of adjusting standards so that the governor adjusting work to be carried out after reassembly will be made easier.



Checking position of adjusting screw in swiveling lever

(4) Make sure that each lever and link set in position moves smoothly without unduly heavy resistance. After securing the governor cover to the housing, check to be sure that tensioning and relaxing the start spring cause the control rack to slide outward and inward smoothly.

Injection pump disassembly, inspection and reassembly

(1) General rules on work

a. Make a batch of washing fluid available for ready use. For the washing fluid, use clean kerosine or diesel fuel oil.

b. Work in a clean place. The injection pump is a precision-machine component and, as such, abhors dust. After removing it from the engine, wash its exterior clean and inspect for damage: this should be accomplished before starting to disassemble the pump.

c. Some jobs are prescribed to be effected with the use of special tools. Use of common tools is not permitted.

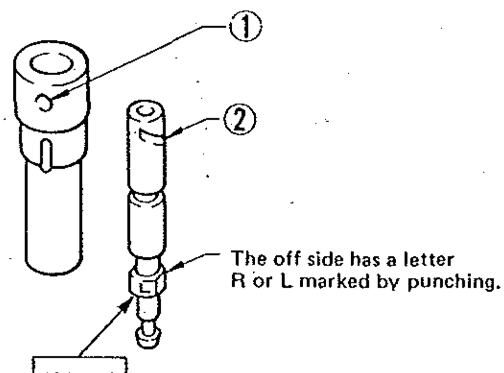
d. Handle each plunger and its cylinder (barrel) as a suit, and each delivery valve with its seat as another suit. Upon removal of these parts, have them set aside as distinct suits identified for the cylinder numbers.

e. When installing the delivery valve holder, be careful not to overtighten it or the pump housing will break. A sticky control rack is often due to an overtightened valve holder. Use a torque wrench, and tighten it to this torque limit:

Unit: kg-m (ft-lb)

Item	Limit
Delivery valve holder tightening torque	2.5 ~ 3.5 (18 ~ 25)

f. Each plunger has its part number punched on its flange. When reassembling the injection pump, be sure to position each plunger so that its punched part faces the front; this means that, with the plunger so positioned, its control groove meets the feed hole. Remember, the adjustability of injection quantity presupposes that all plungers are so positioned in their barrels.



Example of part number

1-Feed hole 2-Control groove

Pumping element parts

g. It is highly essential that the control rack should slide smoothly in place. If any stickiness is noted after reassembly, the pump must be disassembled and reassembled once again. Stickiness of the control rack is often caused by nicks or dents sufferred by the rack, defective rack teeth or pinion teeth, interference between pinion and pump housing, or overtightened delivey valve holders.

h. Axial play is specified for the camshaft. Make sure that it is between 0.03 and 0.05 mm (0.0012 and 0.0020 in.). If too much or too little a play is noted, adjust it by shimming.

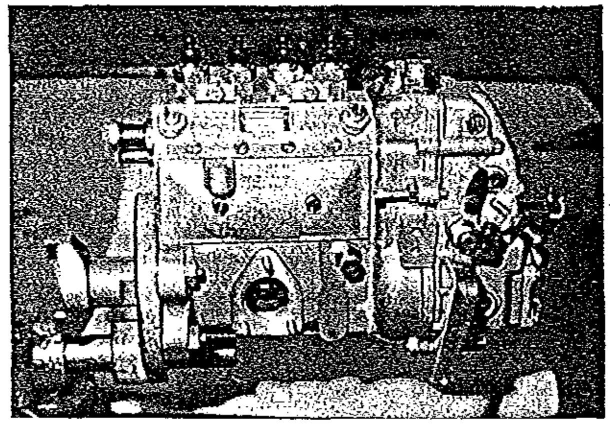
(2) Disassembling procedure

(a) Drain lube oil. Examine the drained oil for evidence of malcondition. Set the injection pump firmly on the work bench, by means of the holding fixture.

Remove the cover plate and look in to see if there are signs of malcondition.

NOTE

Removing one part after another without examining each part critically and heeding to the story each part wants to tell is a wasteful practice and prevents you from taking proper measures necessary for restoring the pump as close to the original condition as possible.



Setting up pump by means of holding fixture

(b) Remove the governor from the pump proper, as in Governor disassembly.

(c) Turn the pump camshaft by hand to "feel" the resistance of camshaft: abnormal resistance means that there is something wrong in the pump. Using a spring balance, measure the sliding resistance of the control rack, and write down the reading for reference. A limit is specified on this resistance:

Unit: gram (ounce)

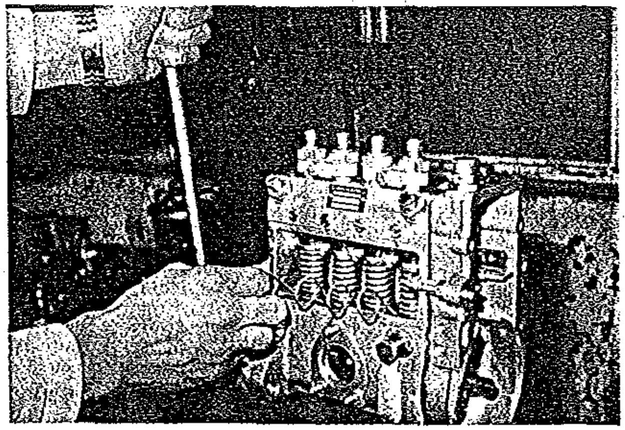
Item	Limit
Sliding resistance of control rack in standstill pump.	150 (5.3)

NOTES

a) A control rack not sliding smoothly could mean that tappets or control sleeves are in bad condition. Check these parts carefully when taking them out in disassembly.

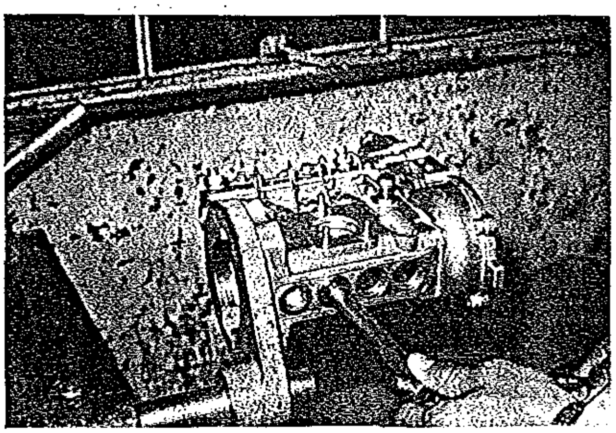
b) Move the control rack all the way in each direction, and note the position of each control pinion for the extreme positions of the rack. Restore these positions at the time of reassembly.

(d) Isolate the four tappets from the cams by holding them in lifted condition. This is accomplished by turning the camshaft by hand to raise each tappet to the highest position and locking the tappet in that position with a tappet insert.



Locking tappets

(e) Lay down the pump and remove the screw plugs, as shown:

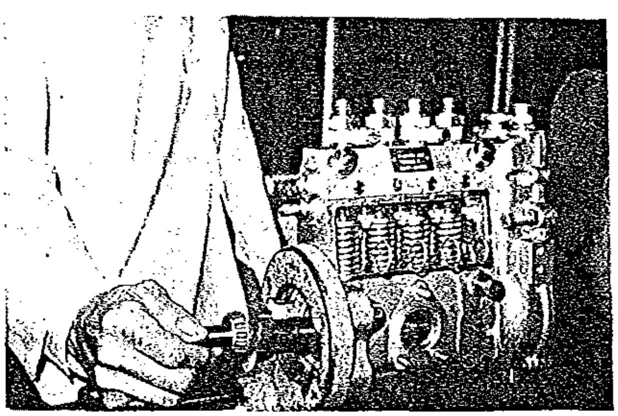


Removing screw plugs

(f) Remove the bearing cover, and draw out the camshaft gently.

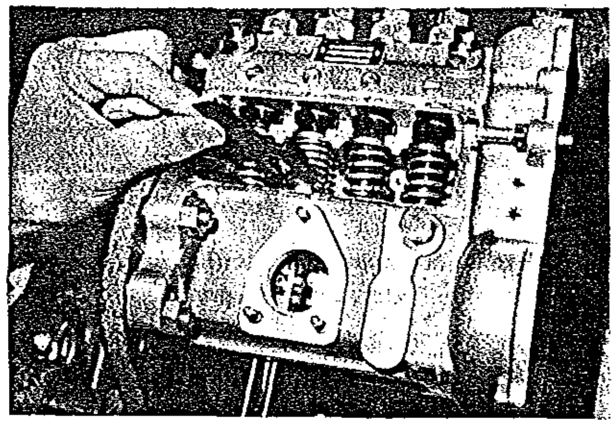
CAUTION

When removing the bearing cover, be careful not to nick or mar the seating faces or oil leakage will develop during operation.



Removing camshaft

(g) Remove the tappet inserts locking the tappets in raised position. To do so, the roller clamp (95905-06030) must be used: insert the clamp through the screw plug hole to pinch the tappet roller, and give a push to the tappet with the clamp to allow the tappet insert to be pulled out.

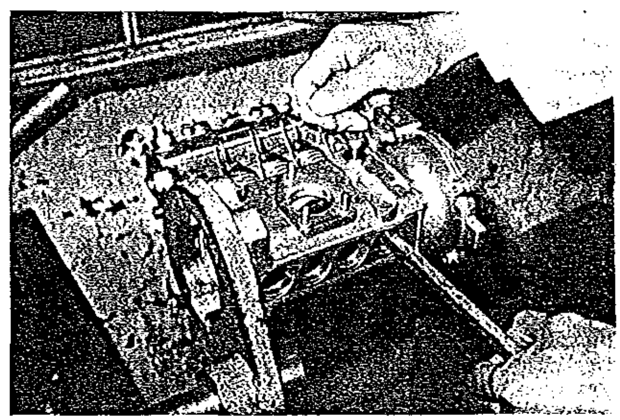


Taking out tappet inserts

(h) Insert the tappet clamp (95905-02030) through bearing hole to pinch the tappet, take off the roller clamp, and remove the tappet. Remove all four tappets in this manner.

NOTE

Tilt down the pump so that the plungers and springs will not fall off.

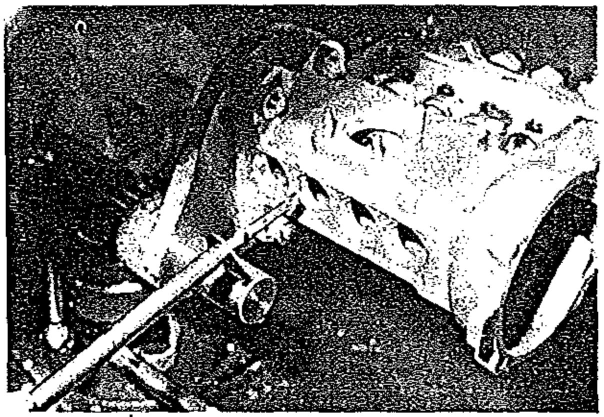


Removing tappets

(i) Remove the plungers and lower spring seats by using the plunger clamp (95905-09030): pinch the lower portion of the plunger with this tool, and draw out the plunger together with its lower spring seat.

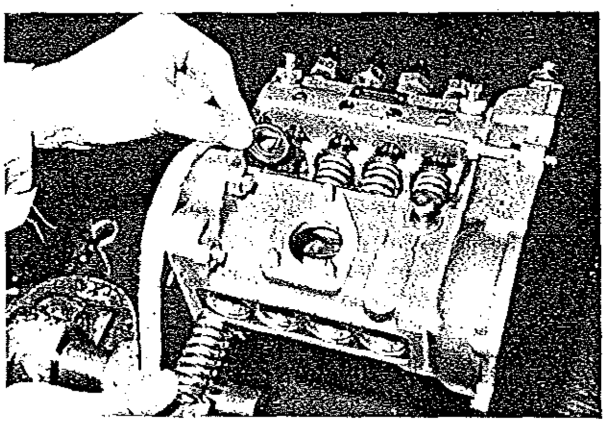
CAUTION

This removal operation must be carried out with great caution to avoid scratching the plunger: pull the plunger straight out.



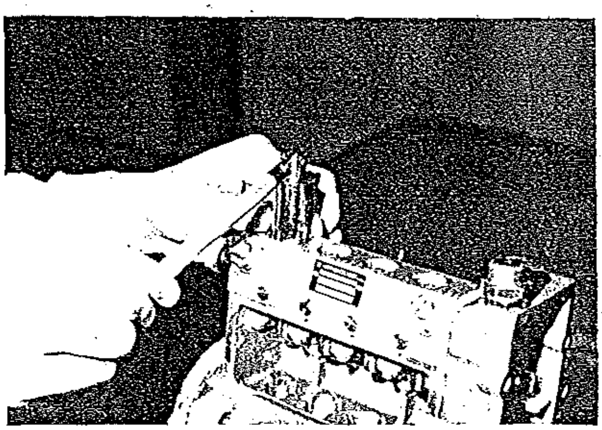
Removing plungers

(j) Draw out each plunger spring, and remove the control sleeve and upper spring seat.



Removing plunger springs and upper seats

(k) Raise the pump body into vertical position. Unscrew and remove the delivery valve holders. Install the extractor and draw out each delivery valve, as shown:

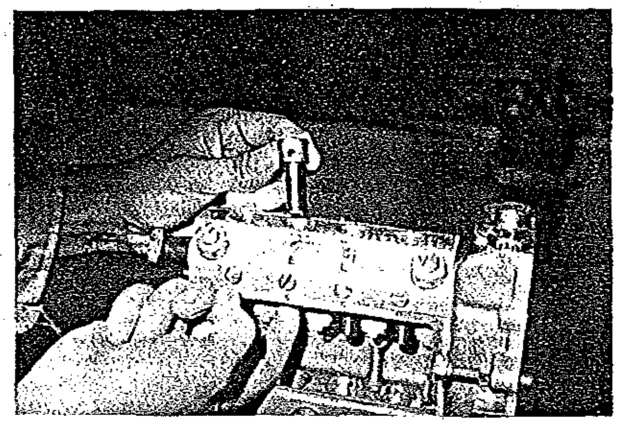


Removing delivery valve

⚠ CAUTION

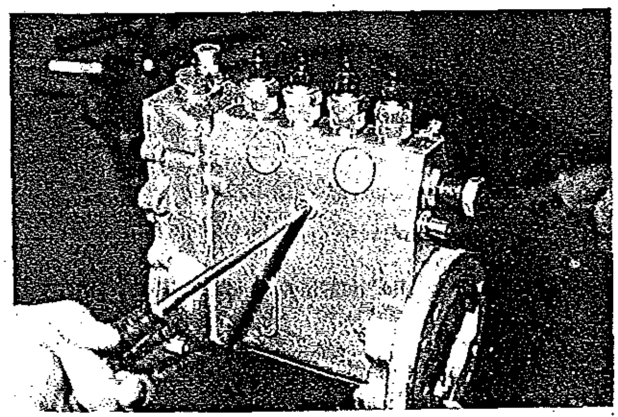
When installing the extractor, be careful not to run down the threaded portion of the extractor too far onto the delivery valve in place.

(l) Take out the cylinder (barrel) from top side by pushing on its bottom.



Removing cylinder

(m) Remove the rack guide screw, and draw out the control rack.



Removing control rack

(3) **Inspection**

Lay out the removed parts in the trays, segregating them in groups, each group for each pumping element and related parts, as identified for the respective reference numbers, No. 1, No. 2, No. 3 and No. 4. Do not disturb the original suits.

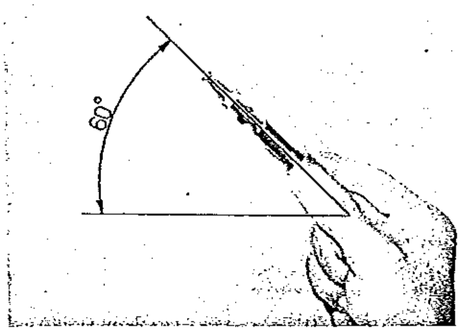
Wash each part clean, and dry it with compressed air, making sure that orifices, screw threads and pockets are all clean.

(a) Pump housing

Inspect each bore, from which the cylinder (barrel) has been drawn out, to see if there is any damage. Check to be sure that the counterbore (into which the shoulder of the cylinder fits) is in good condition to ensure a good oil-tight fit. To repair this counterbore, use the counterbore cutter, one of the special tools for servicing work. Fuel leakage into the camshaft chamber is often due to a defective fit in this counterbore.

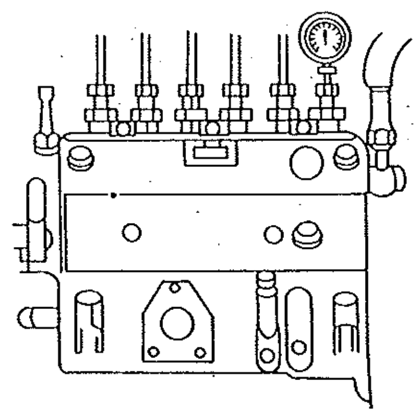
(b) Pumping elements

1. If any scratch or scoring is noted on the cylinder bore under visual examination, replace it together with its plunger.
2. Each suit of cylinder and plunger must be checked for the tightness of sliding fit by testing as follows: Hold the cylinder tilted, forming an angle of 60 deg. relative to horizontal, with its plunger inserted into its bore; pull out the plunger about 20 mm (0.8 in.); and release it to see if it slides down smoothly by its own weight. If it does in several angular positions with the cylinder so angled, the fit is satisfactory. Replace the cylinder and plunger as a suit if any stickiness or free-falling sliding motion is noted.



Testing fit of plunger in cylinder

3. Measure the width of plunger flange. If the flange is worn down to 6.95 mm (0.274 in.) or under in width, replace the plunger and cylinder.
4. Oil-tightness test
The cylinder and plunger found to be in satisfactory condition must undergo another test for checking the oil-tightness of sliding fit between cylinder and plunger, after reassembling the injection pump. Before reassembling the pump, make it absolutely sure that the delivery valves are all in satisfactory condition as determined by the methods to be described subsequently.


Delivery valve test

Set up the pump on the tester, and install a test pressure gauge on one of the delivery valve holders. Prime the pump with fuel oil, and drive the pump at 200 rpm, with the control rack locked in idling position. The pressure gauge indication under this running condition tells whether the cylinder and plunger being tested is satisfactory or not: the pressure criteria are as follows:

Unit: kg/cm^2 (psi)

Item	Standard	Service limit
Oil-tightness of sliding fit between cylinder and plunger	150 ~ 200 (2133 ~ 2844) at 200 rpm	150 (2133)

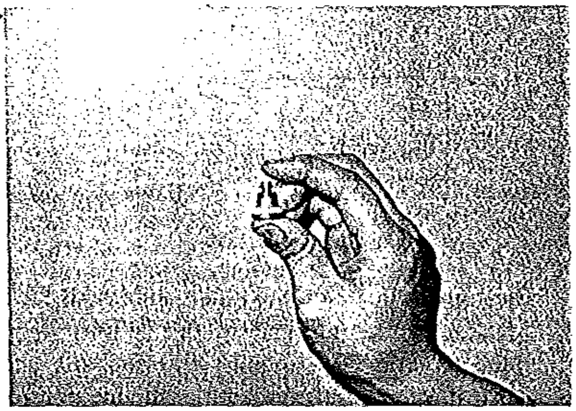
Cylinder-plunger suits not capable of developing at least 150 kg/cm^2 must be replaced. For the test pressure gauge, use one calibrated up to 300 or 400 kg/cm^2 (4266 or 5688 psi).

(c) Delivery valves

1. A delivery valve found with its piston worn excessively or valve seat showing evidence of poor seating contact or damage must be replaced together with its seat.
2. Hold the suit of delivery valve and seat between two fingers, as shown, with the thumb plugging the bottom hole. Pull up the valve and let it go to see if the valve goes down smoothly but becomes arrested as its extraction land closes the bore; if it does, then the suit is satisfactory for the first test. For the second test, push the valve down till it touches the seat, and remove the push to see if the valve springs upward to the arresting position mentioned above; if it does, then the suit is satisfactory for the second test. A valve-seat suit found unsatisfactory in either test must be replaced. Remember, these two tests are meaningful only when the valve

and seat are absolutely clean and oiled adequately to form oil films on their surfaces.

Test each suit of delivery valve and seat in the foregoing manner and, when reassembling the pump, use only those found satisfactory.



Testing delivery valve and seat

3. Oil-tightness test

Test the delivery valve for oil-tightness of its seating contact after checking the cylinders and plungers for oil-tightness by running the reassembled pump at 200 rpm in the manner already described. It is assumed here that the cylinder and plunger served by a particular delivery valve are in good condition with respect to oil-tightness.

Run the pump at 200 rpm in the same testing setup, with the control rack kept in idling position, and, when the pressure gauge indication reaches 150 kg/cm^2 (2133 psi), move the rack into non-injection position ("0" mm) to see if it takes more than 5 seconds for this pressure to fall to 10 kg/cm^2 (142 psi); if it does, then the delivery valve under test is satisfactory.

(d) Control rack and pinions

A control rack in distorted condition or presenting excessive wear on its rack teeth must be replaced. After reassembling the pump, check each pinion for backlash and, as necessary, replace the pinion or control rack, or both, to reduce the backlash to the specification:

Unit: mm (in.)

Item	Standard	Service limit
Rack-to-pinion backlash	0.15 (0.0059)	0.25 (0.0098)

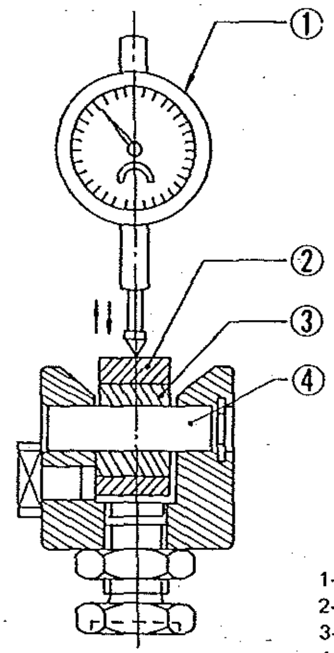
(e) Tappets

Using a dial gauge, read the radial play of the roller of each tappet by moving the roller up and down in the manner illustrated: use a rod to push the roller up from bottom side. If a reading of 0.3 mm (0.012 in.) or more is obtained, replace the whole tappet.

Check the sliding clearance of each tappet in the bore of the housing; tappet replacement is necessary if the clearance noted exceeds the service limit.

Unit: mm (in.)

Item	Standard	Service limit
Tappet-to-bore clearance	0.02 ~ 0.062 (0.0008 ~ 0.00244)	0.25 (0.0098)



1-Dial gauge
2-Roller
3-Roller bushing
4-Pin

Measuring tappet roller paly

(f) Delivery valve springs and plunger springs

Replace badly rusted, cracked or otherwise damaged springs. Springs visibly out of square must be replaced. Check each spring for free-state length, and replace it if the limit, indicated below, is exceeded.

Unit: mm (in.)

Item	Plunger springs		Delivery valve springs	
	Standard	Service limit	Standard	Service limit
Free length of spring	49.0 (1.929)	48.5 (1.909)	32.0 (1.260)	31.0 (1.220)

Inspect each plunger spring seat for depth of its concave; replace the seat if the depth is 0.1 mm (0.004 in.) or over.

(g) Camshaft

Inspect the camshaft for wear of its cam surfaces, of the surfaces of sealed portions in contact with oil seals, and of screw threads at both ends. Inspect, too, for rusting, damage and for keyway deformation. Repair or replace the camshaft depending on the result of inspection.

Check the camshaft for alignment by supporting it with center pins fitted to its end faces, and by measuring the amount of deflection with a dial gauge. A camshaft exhibiting a deflection of 0.15 mm (0.0059 in.) or over at its middle section must be straightened in a press or replaced by a new one.

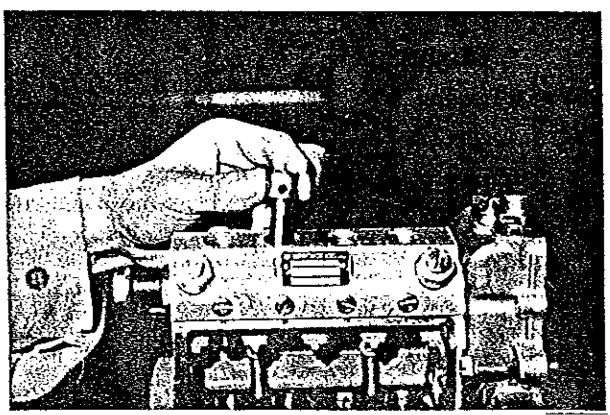
(4) Assembly

(a) Install the cylinders (barrels), positioning each cylinder angularly as guided by the locating pin and positioning groove.

CAUTIONS

a) These cylinders are meant for thumb-pressure fit. Never attempt to drive them into the bores with such as a mallet.

b) After fitting each cylinder into the bore, making it seat firmly in place, check to be sure that it will not rotate when turned with a finger.

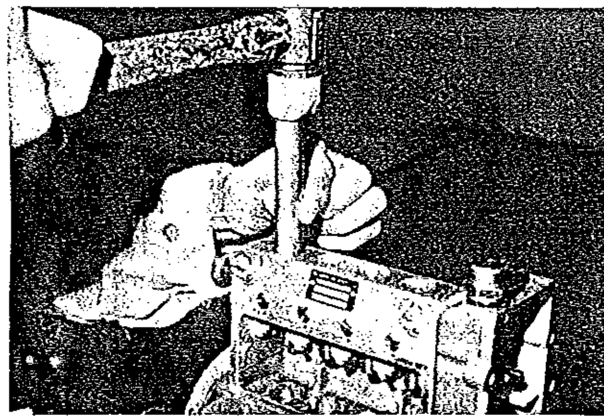


Installing pumping element cylinder

(b) Fit a new valve gasket to the delivery valve, and insert it into bore. Drive down the delivery valve by using a drift, as shown, making the seat meet the top of the cylinder to present an oil-tight face-to-face contact. Only light blows are needed to the end of the drift.

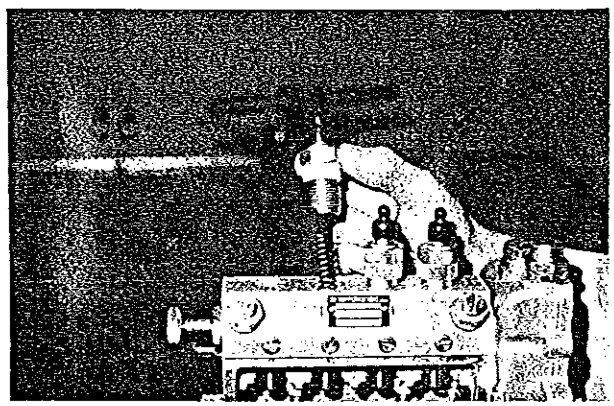
CAUTION

Take every precaution to avoid dust particles getting into between cylinder and delivery valve seat.



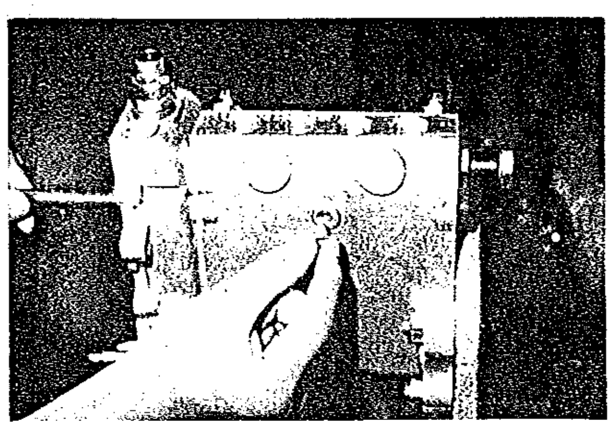
Driving in delivery valve seat

(c) Insert the spring, and run in the delivery valve holder and tighten the holder tentatively.



Installing holder

(d) Position the control rack in place, and install the guide screw.



Fitting guide screw

CAUTIONS

a) Make sure that the guide screw installed is located accurately inside the groove provided in the rack. Tightening this screw located off the groove is liable to bend the rack.

b) After installing the rack, check to be sure that it is capable of smooth movement through its entire stroke.

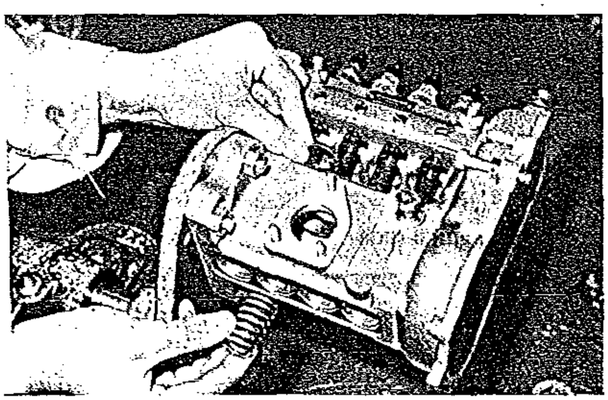
(e) Lay down the pump, and fit control pinions and sleeves to barrels, making sure that each pinion is so positioned that the adjusting hole provided in the control sleeve points to the pinion clamp screw.

NOTES

a) Move the rack back and forth to rotate the control pinions similarly, and check to be sure that each pinion is accurately meshed with the rack teeth.

b) Check, also, to see that each pinion is accurately centered to the control rack when the rack is in its center position, so that moving the rack from this position to each stroke end rotates the pinion by an equal amount.

(f) Install upper spring seats and plunger springs. Using the plunger clamp, fit the lower spring seat to each plunger, and insert the plunger into the barrel.



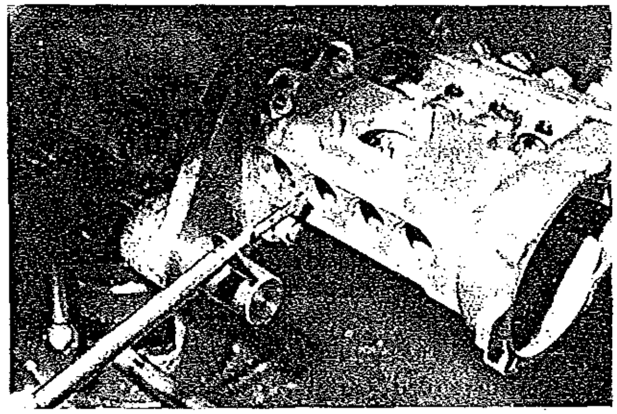
Inserting upper spring seat and plunger spring

NOTES

a) Be sure to hold each plunger true and square and insert it straight into the barrel.

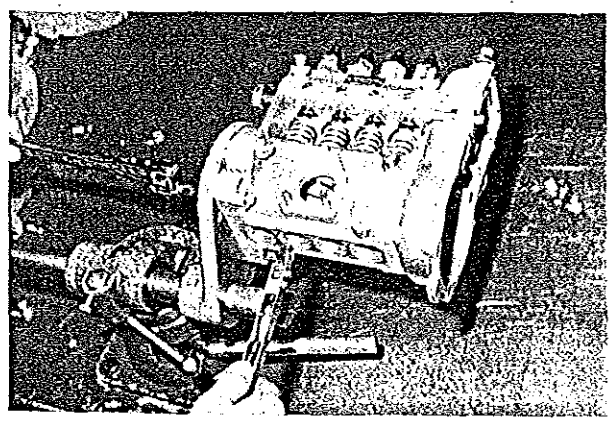
b) Remember, the driving face (on which a number is marked by punching) of each plunger comes on top side: if not, the helical groove of the plunger will not meet the feed hole and this defeats the adjustability of injection quantity.

c) After inserting the cylinder, position its lower spring seat in such a way that the seat will not fall off.



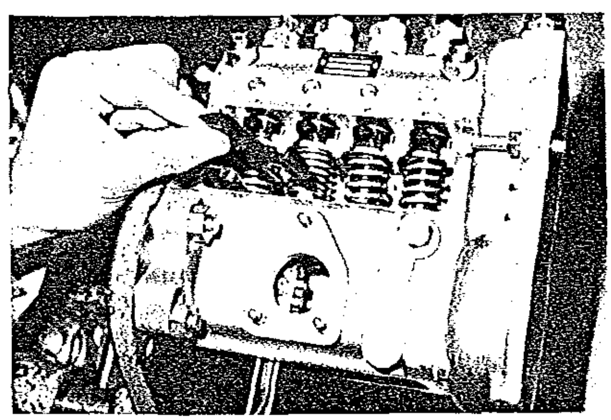
Inserting plunger

(g) Pick up the tappet with the tappet clamp, feed the tappet into the camshaft chamber and insert it into the bore.



Inserting tappet

Match the plunger driving face to the notches cut out in the control sleeve, push up the tappet and hold it there by means of the tappet insert. With the tappet so held, move the rack



Fitting tappet insert to hold up tappet

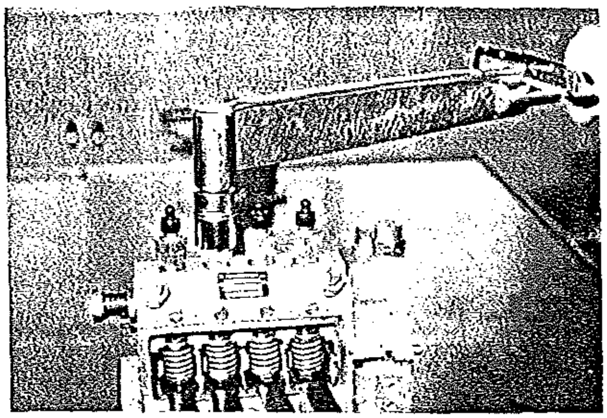
to be sure it slides smoothly. Install all four tappets in this manner, making sure each time that the rack moves smoothly.

(h) Using the torque wrench, tighten the delivery valve holders to this torque value:

Item	Standard
Delivery valve holder tightening torque	2.5 ~ 3.5 kg-m (18 ~ 25 ft-lb)

NOTE

After tightening up each delivery valve holder, move the rack to see if this tightening has adversely affected the ability of the control rack to slide smoothly.



Tightening delivery valve holder

(i) Install the lock plate for locking the delivery valve holders in place. Using the spring balance, check the sliding resistance of the control rack. The rack is required to slide with a push or pull of not greater than 150 grams (5.3 ounces).

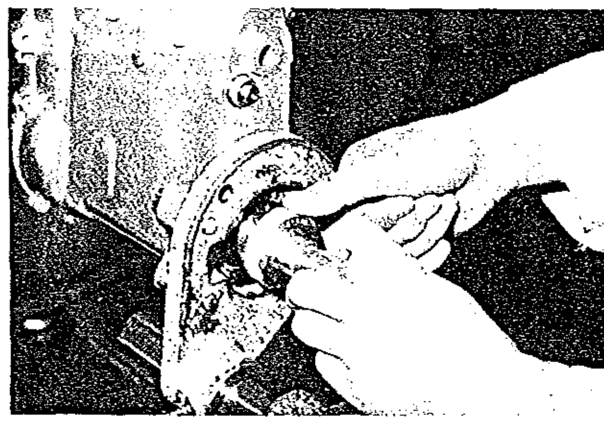
Checking sliding resistance of control rack

(j) Apply engine oil to the camshaft, and install it, positioning it in place with the marked end face coming on the drive side.

(k) Put on the bearing cover tentatively, and check the axial play of the camshaft by using the camshaft clearance gauge (95905-01080). If the play noted is off the range indicated below, reduce or increase it into the specified range by shimming: shim stock for this purpose is available in six thicknesses, 0.10 mm (0.0039 in.), 0.12 mm (0.0047 in.), 0.14 mm (0.0055 in.), 0.16 mm (0.0063 in.), 0.18 mm (0.0071 in.) and 0.50 mm (0.0197 in.). So that the camshaft will not be so displaced by shimming to one side as to offset the cams from the tappets, try to use equal amounts of shim on both sides.

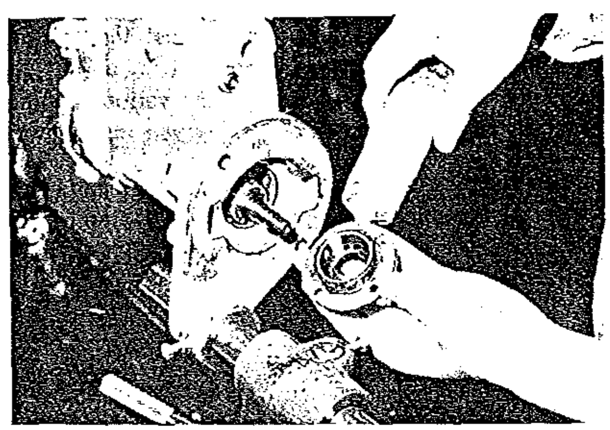
Unit: mm (in.)

Item	Standard
Camshaft bearing axial play	0.03 ~ 0.05 (0.0012 ~ 0.0020)



Checking camshaft axial play

(l) Having properly installed the camshaft, apply BOND to the bearing cover and secure it permanently to the pump body, with an "O" ring set in the joint.



Applying BOND to bearing cover

CAUTIONS

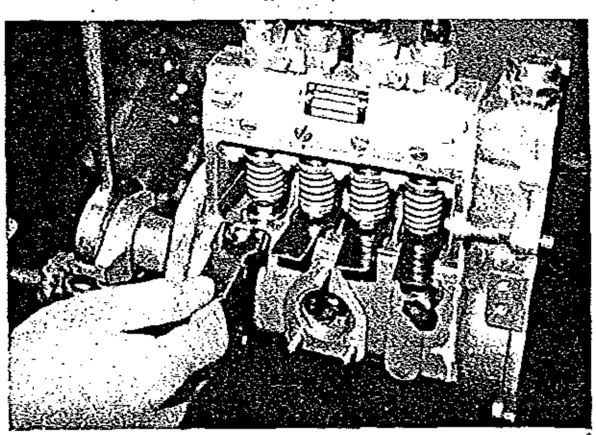
a) Do not apply BOND to the "O" ring.

b) Be sure that the ventilating hole of the cover comes on top side.

(m) Install the screw plugs, tightening each plug to this torque value:

Item	Standard
Screw plug tightening torque	5.5 ~ 7.5 kg-m (39.8 ~ 54.2 ft-lb)

(n) Remove the tappet inserts one after another while turning over the camshaft. For the last time, check to be sure that the control rack is capable of smooth sliding movement, and check its sliding resistance to see and confirm that a force not greater than 150 grams (5.3 ounces) will move the camshaft.



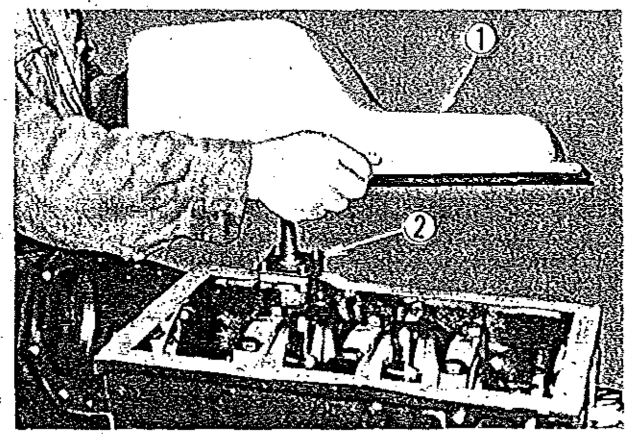
Removing tappet inserts

Engine proper

Disassembly

Drain out engine oil and coolant. Wash the exterior surfaces of the engine clean, and set it up on the disassembly stand. After removing the various components attached to the engine proper, proceed as follows:

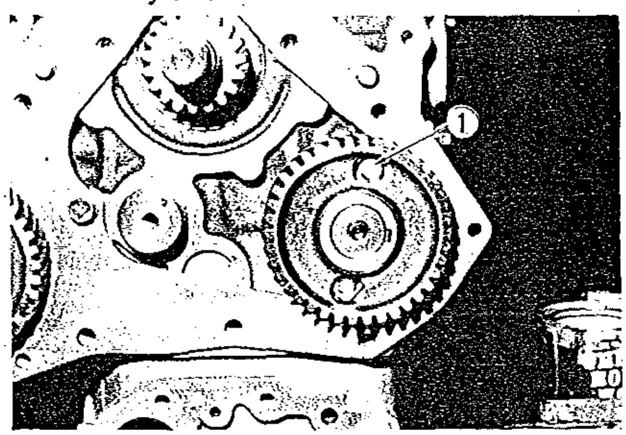
(1) Remove a total of 24 bolts securing oil pan (1) to crankcase, and take off the oil pan. Remove oil pump (2) as outlined in OIL PUMP REMOVAL.



1-Oil pan 2-Oil pump
Removing oil pan

(2) Remove the idler gear in the timing gear train.

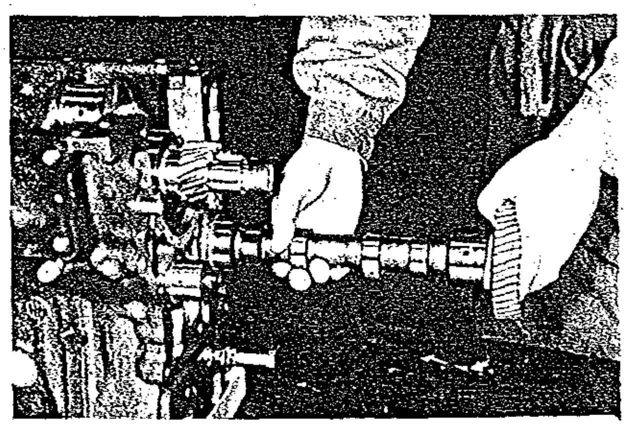
(3) Turn camshaft gear, bringing its two holes to top and bottom to expose bolts (1) securing thrust plate. Remove bolts (1), and draw the camshaft assembly out.



1-Bolt and washer (2 pcs each)
Removing camshaft (1)

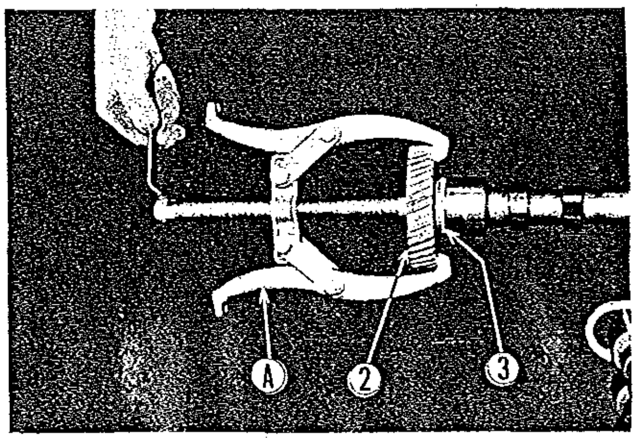
NOTE

Remove the tappets after drawing out the camshaft.



Removing camshaft (2)

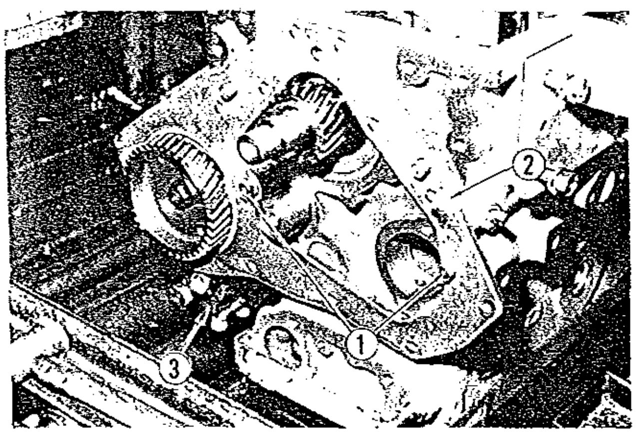
Using the puller (A), extract gear (2) from the camshaft. Remove thrust plate from the camshaft.



2-Gear A-Puller
3-Thrust plate

Removing gear from camshaft

(4) Remove bolts (1) securing the front plate (2) to crankcase, and take off the plate. The injection pump unit (3) comes off as mounted on the front plate.



1-Bolt and washer (2 pcs each) 3-Injection pump unit
2-Front plate

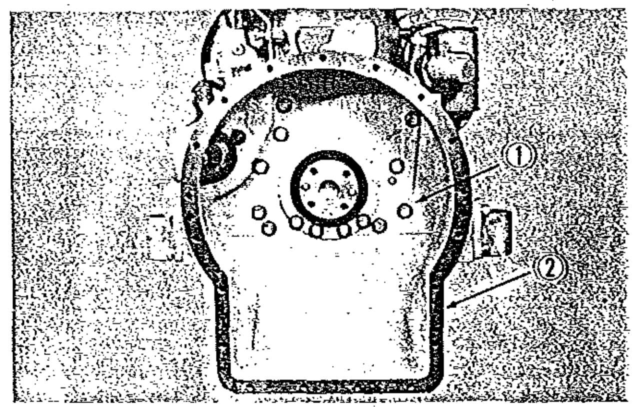
Removing front plate

(5) Remove the flywheel.

(6) Remove bolts (1) securing the rear housing (2) to the rear plate, and take off the housing.

⚠ CAUTION

Exercise caution not to damage the oil seal fitted to the rear housing.

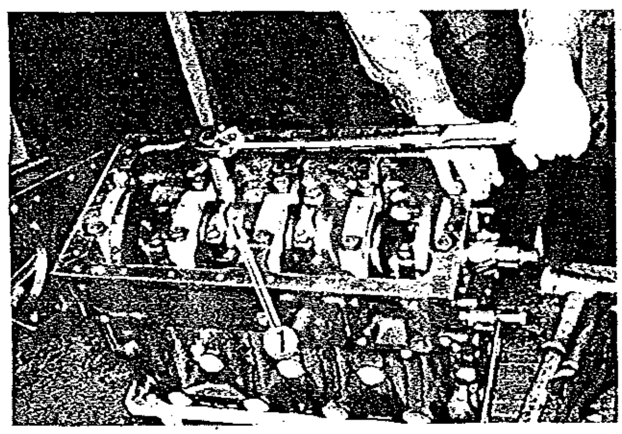


1-Bolt 2-Rear housing

Removing rear housing

(7) Remove connecting rods, pistons and crankshaft, as follows:

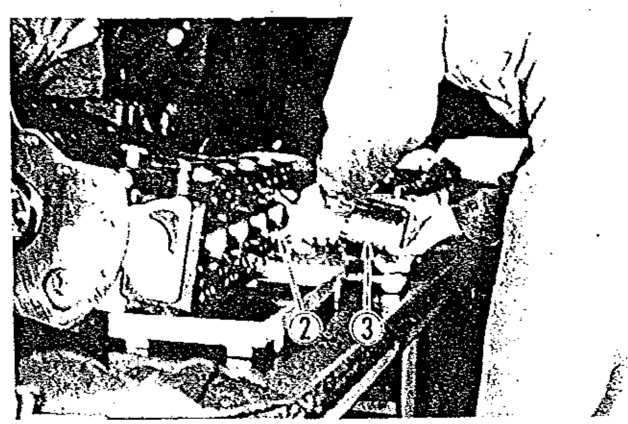
(a) Remove 8 nuts fastening down the connecting rod caps, two nuts on each cap. Take off caps (1) complete with bearings.



1-Cap

Loosening connecting rod cap nuts

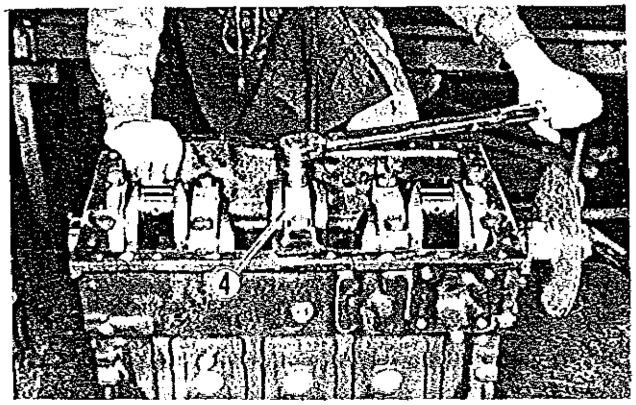
(b) Lay down the crankcase, and draw out each piston and connecting rod.



2-Connecting rod 3-Piston

Drawing out piston and connecting rod

(c) Raise the crankcase (bringing crankshaft to top side). Remove 10 bolts securing the main bearing caps, two bolts on each cap. Take off caps (4) complete with bearings.



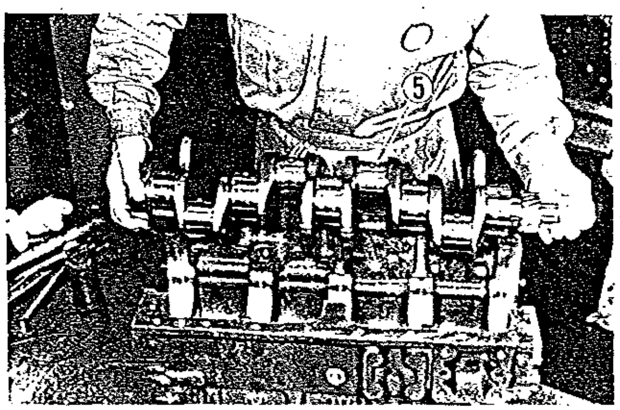
4-Main bearing cap
Loosening main bearing cap bolts

CAUTIONS

a) Handle the bearings carefully to avoid damage. Tag or otherwise identify each bearing shell and set aside the shells in identified groups so that each will be restored to its original location in reassembly.

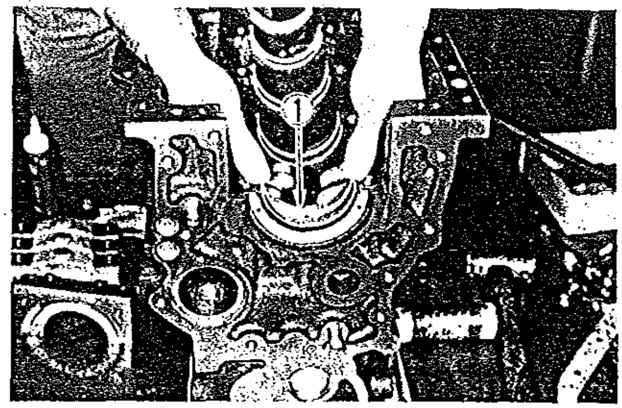
b) Remember, No. 1 and No. 5 bearings have two side seals each.

(d) Lift the crankshaft (5) off and out of crankcase, as shown.

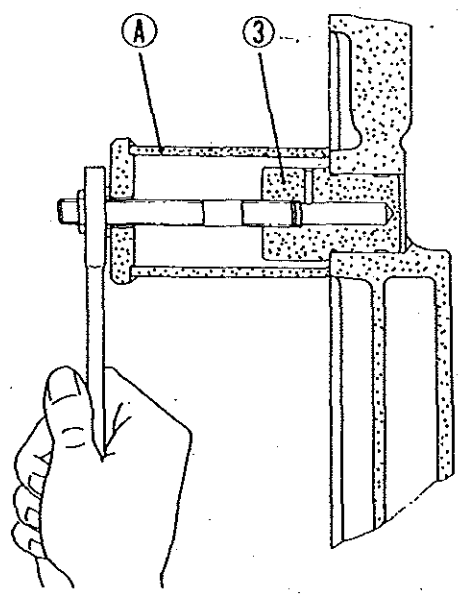


5-Crankshaft
Removing crankshaft

(8) Remove the remaining main bearing shells (1). The idler shaft need not be removed unless to do so is absolutely necessary; the puller (A) must be used to draw out this shaft.

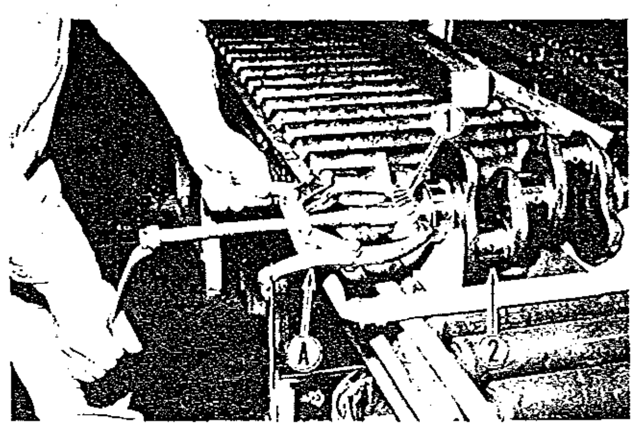


1-Bearing shell
Taking off main bearing shells



3-Idler shaft A-Idler shaft puller
Drawing out idler shaft

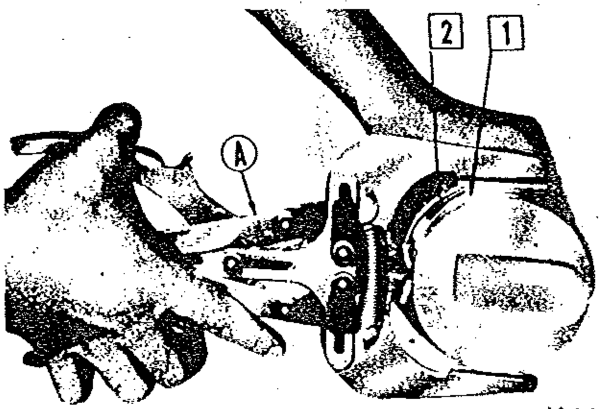
(9) Using the special tool (A), extract crankshaft gear (1) from the removed crankshaft (2).



1-Gear 2-Crankshaft A-Puller
Removing crankshaft gear

(10) From each piston, separate its connecting rod, as follows:

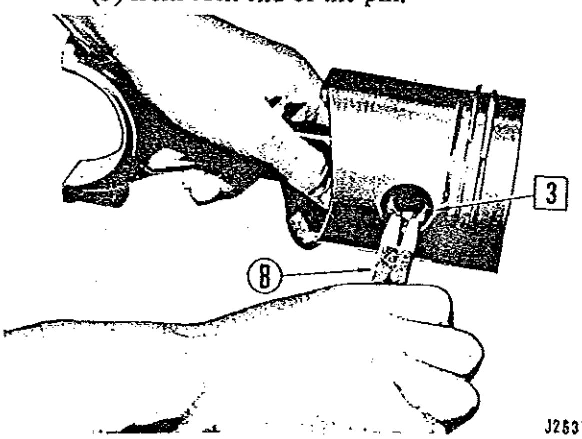
(a) Using the piston ring tool (A), remove compression rings (1) and oil ring (2). Pick out oil ring spring with fingers.



1-Compression rings 2-Oil ring A-Piston ring tool

Removing piston ring

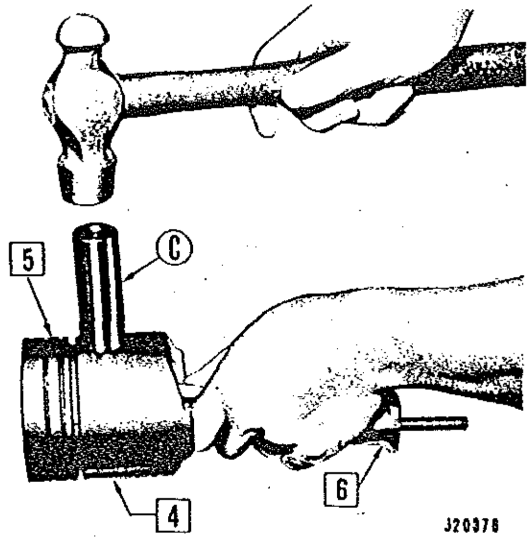
(b) Using the snap ring tool (B), remove snap ring (3) from each end of the pin.



3-Snap ring (2 pcs) B-Snap ring tool

Removing snap ring

(c) Remove pin (4) by driving it out with a drift (special tool) (C), as shown:



4-Pin 6-Connecting rod
5-Piston C-Drift

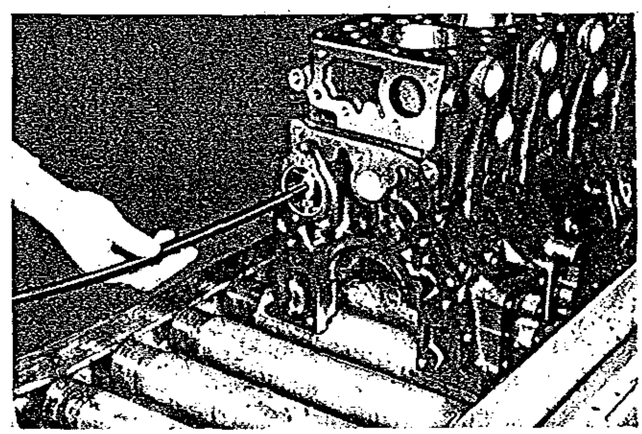
Removing piston pin

(d) From the small end of connecting rod, remove the bushing.

NOTE

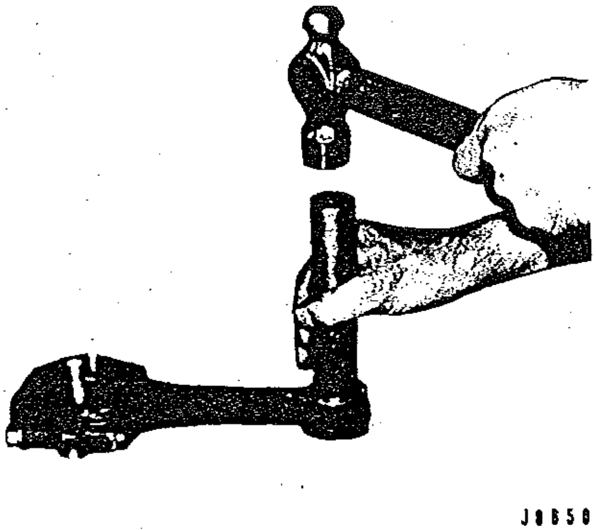
Wash the disassembled parts clean, and decarbon them.

(11) Clean the crankcase by washing it in a bath of caustic soda solution or cleaning solvent, removing grease and grime from all surfaces in and out. Clean oil drillings and holes with a long-handle brush. After washing, dry it with steam or compressed air.

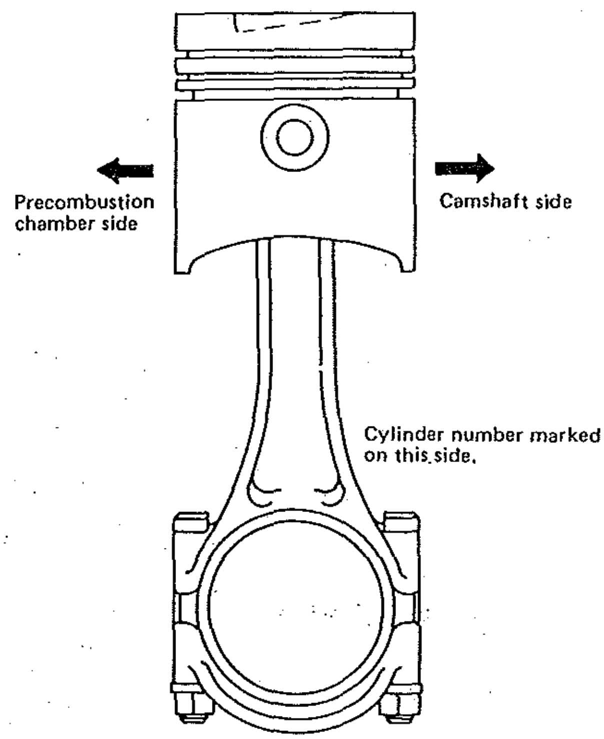


Reassembly

(1) Fit the bushing into the small end of each connecting rod by driving it in with a drift, making sure that the oil hole provided in the bushing meets the hole provided in the small end.



Fitting bushing into small end

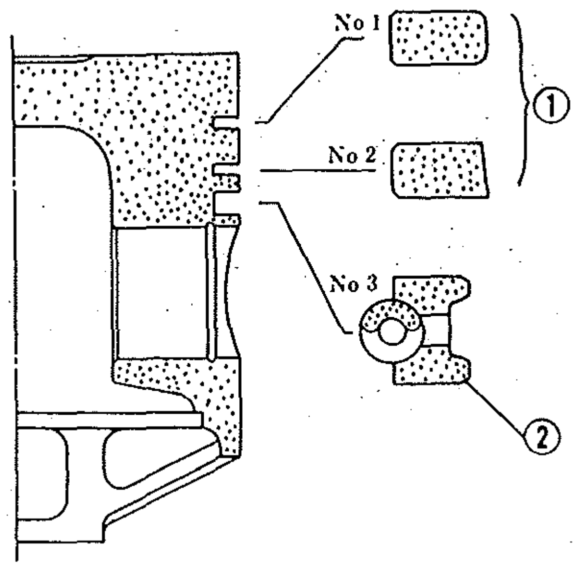


Combining piston and connecting rod

Have a snap ring fitted to one end of the piston pin hole, insert the small end into the piston, aligning the bushing to the pin hole, and insert the pin gently into the pin hole through the bushing from the end at which the snap ring is to be installed.

Be sure that, with the small end connected to the piston, the big end has its match mark located on the camshaft side, that is, opposite to the pre-chamber side. Secure the pin in place by fitting the other snap ring. The pin and pin hole are sized for loose fit and, therefore, the pin should go into the hole when given thumb pressure. This insertion will be made easier by having the piston warmed up in advance.

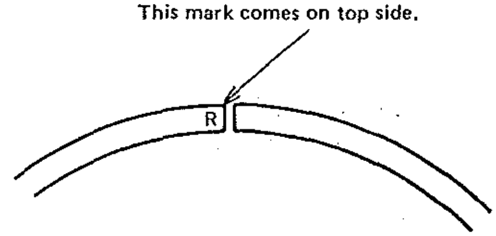
Using the piston ring tool, fit the piston rings (two compression rings and one oil ring) to the piston.



1-Compression rings 2-Oil ring
Installing piston rings

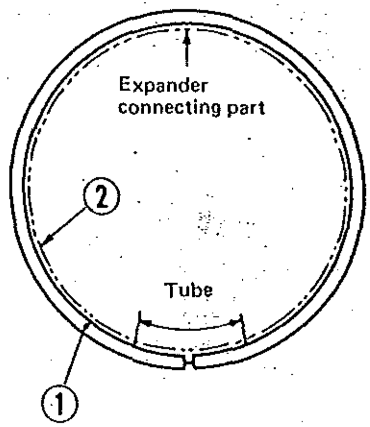
NOTE

No. 2 ring has "R" mark on its top side. Be sure that this side is on top when the ring is in the groove.



"R" mark on No. 2 piston ring

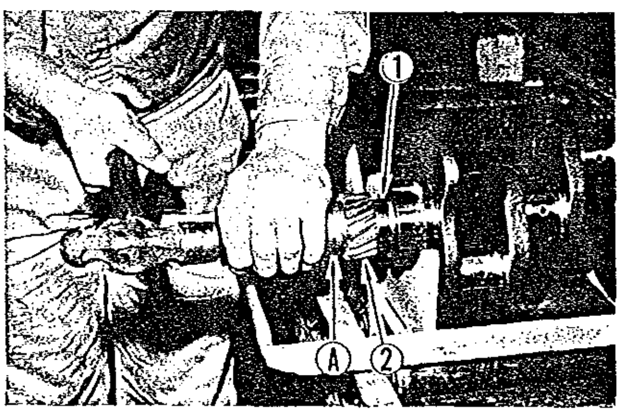
When installing No. 3 (oil) ring, be sure to combine ring (1) and expander (2) by matching the ring ends to the tube.



1-Oil ring 2-Expander

Combining oil ring with expander

(2) After combining the connecting rods with their pistons, to which rings are fitted, insert woodruff keys (1) to the keyway provided in the forward end of crankshaft, and mount gear (2) on this end by driving it in with the installer (A). (This job will be easier if crankshaft gear (2) is heated hot.)

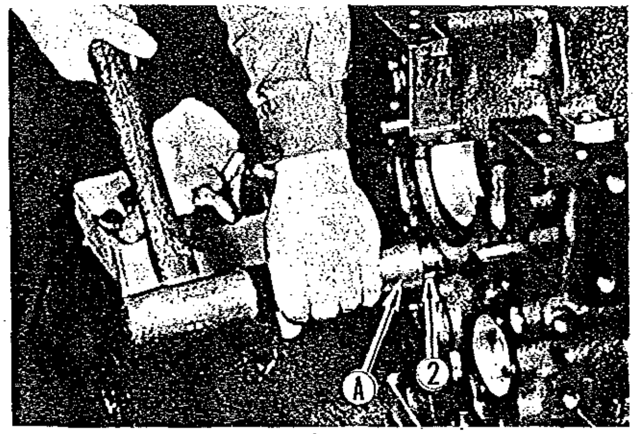


1-Woodruff key (2 pcs) A-Installer
2-Crankshaft gear

Driving gear onto crankshaft

(3) Fit the thrust plate to camshaft, and press camshaft gear onto camshaft. Have the gear heated hot to facilitate the job.

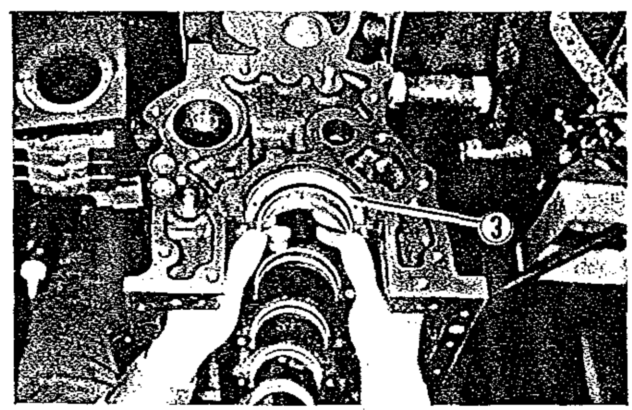
(4) Install idler shaft (2) by driving it into the crankcase with the installer (A), as shown:



2-Idler shaft A-Installer

Installing idler shaft

(5) Position the tappets in the respective tappet holes. Lightly oil the seats of main bearings, and fit the upper bearing shells to the seats, making sure that the tab formed of the shell fits snugly into the recess provided in the seat. Fit thrust plate (3) to the rear side of the seat.

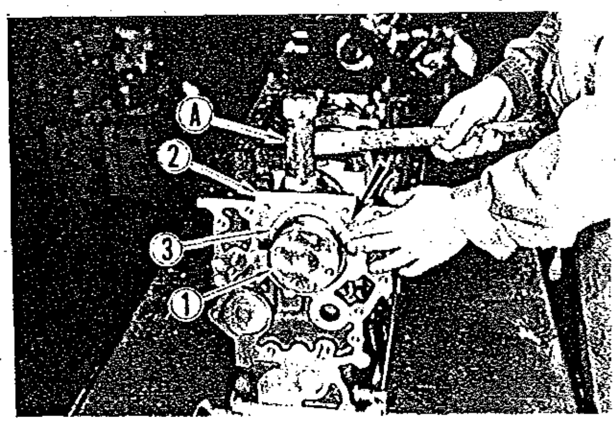


3-Thrust plate

Fitting upper bearing shells

(6) Install the crankshaft, as follows:

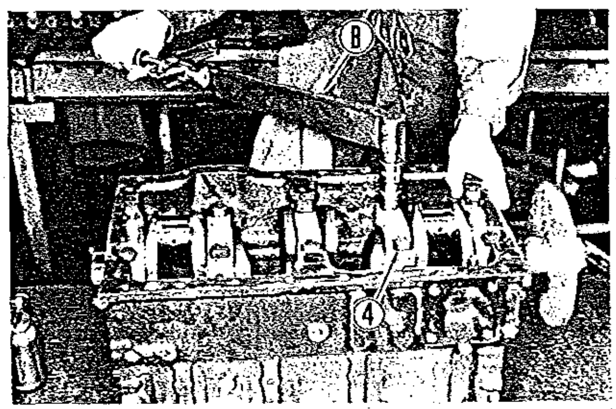
(a) Lower crankshaft in level position and rest it on the five upper shells, which have been lightly oiled. Oil the five bearing caps, and fit the lower bearing shells, which have been oiled similarly. To the mating face of each cap, apply SUPER THREE BOND No. 10. Taking care not to damage thrust plates (3), put on No. 5 cap (2) and settle it firmly in place by tapping on it with a mallet (A). Put on No. 1, No. 2, No. 3 and No. 4 caps, and run down the bearing caps. Make sure that the outer end faces of No. 5 and No. 1 caps are flush with the outer faces of crankcase. (The face to be flush is indicated by the arrow.)



1-Crankshaft 3-Thrust plate
2-No. 5 bearing cap A-Mallet

Fitting bearing caps

(b) Using a torque wrench, tighten the 10 cap bolts equally, tightening each just a little at a time, to the final torque value of 10 to 11 kg-m (72 to 80 ft-lb).



4-Cap bolt (10 pcs) B-Torque wrench

Securing main bearing caps

NOTE

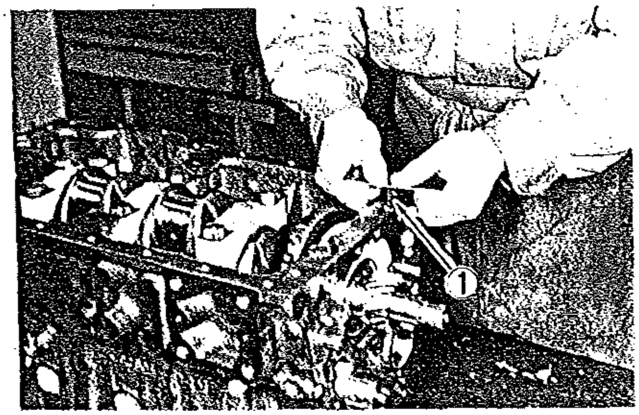
Re-check to be sure that No. 1 and No. 5 caps have their outer end faces flush with crankcase end faces.

(c) Using a dial gauge, check the crankshaft end play to be sure it is within the specified range. Adjust the play, as necessary, by replacing thrust plates.

Unit: mm (in.)

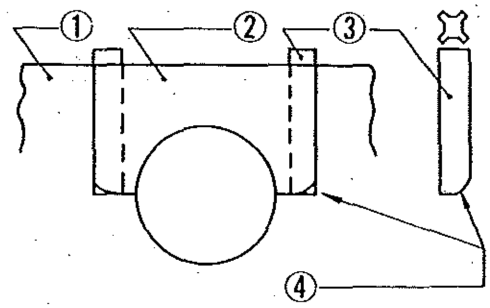
Item	Standard	Repair limit
Crankshaft end play	0.10 ~ 0.264 (0.0039 ~ 0.01039)	0.30 (0.012)

(7) Apply SUPER THREE BOND No. 10 to cap seals (1), and insert the seals into bearing cap grooves at No. 1 and No. 5 main bearing cap.



1-Cap seal

Fitting cap seal



1-Crankcase 3-Cap seal
2-Main bearing cap 4-Rounded corner of cap seal

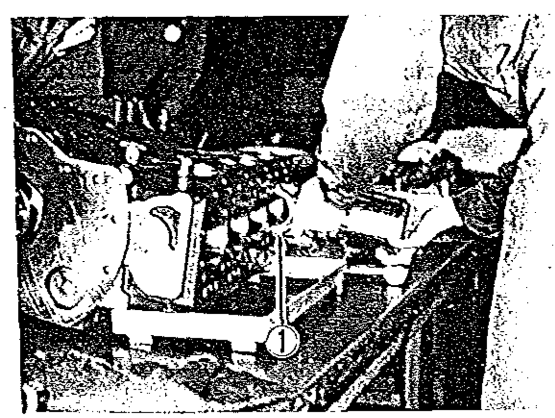
Position of cap seal in groove

CAUTIONS

a) Be sure to insert each cap seal with its round end foremost, bringing the rounded corner on outer side.

b) After pushing in the cap seal, give a full thumb pressure to its end to settle it in place, taking care not to bend the seal. Never drive the seal with such as a hammer.

(8) Lay down the crankcase, and insert the piston-and-rod combinations, as shown. At the crankshaft

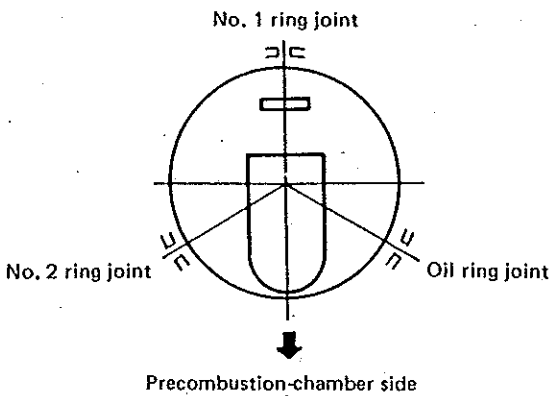


1-Connecting rod bearing

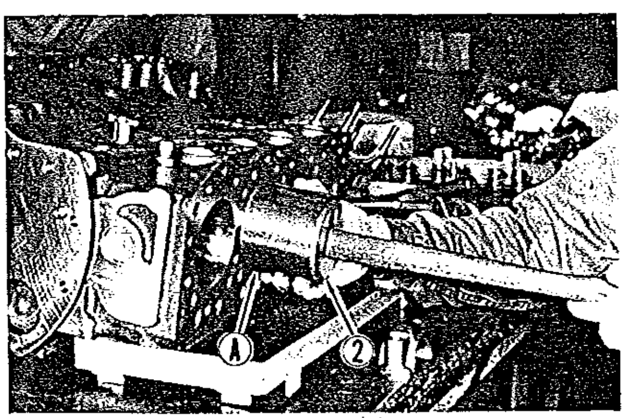
side, fit bearing shells to the big ends and to the caps, oiling the shells as in the case of main bearing shells. Have the pistons and piston rings adequately oiled.

(a) Distribute the ring joints, as shown, and feed the piston into the cylinder by using the piston guide (A), positioning the piston in such a way that the match mark provided on the connecting rod comes on camshaft side.

(b) Secure the four caps by tightening the 8 cap nuts to 8.5 ± 0.5 kg-m (61.5 ± 3.6 ft-lb).



Configuration of piston ring joints

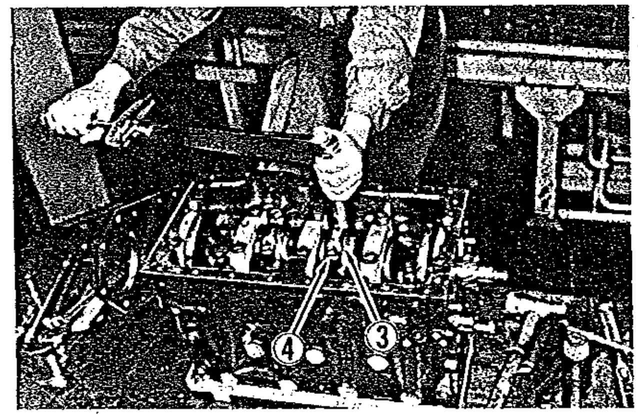


2-Piston A-Piston guide

Inserting piston

NOTE

Before inserting the piston-and-rod combinations into the cylinders, have the cap bolts studded in the big ends. Be sure to match each cap to its big end as governed by the marks.



3-Cap 4-Nut (8 pcs)

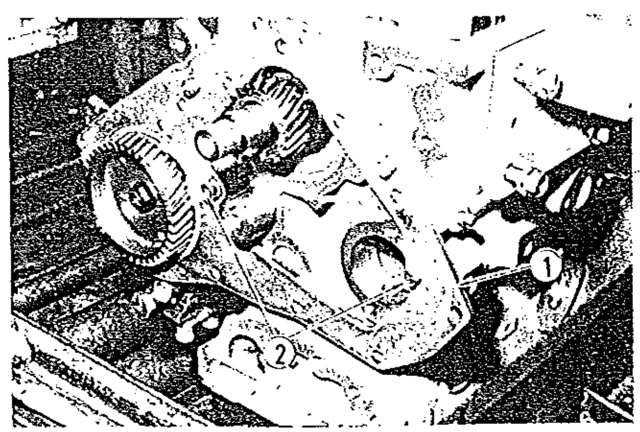
Tightening big-end cap nuts

(9) Check the side play of each connecting-rod big end by barring it to one side and inserting a thickness gauge into the clearance. If the clearance (side play) measured exceeds service limit, the bearing shells or connecting rod must be replaced.

Unit: mm (in.)

Item	Standard	Service limit
Big end side play	0.15 ~ 0.35 (0.0059 ~ 0.0138)	0.50 (0.020)

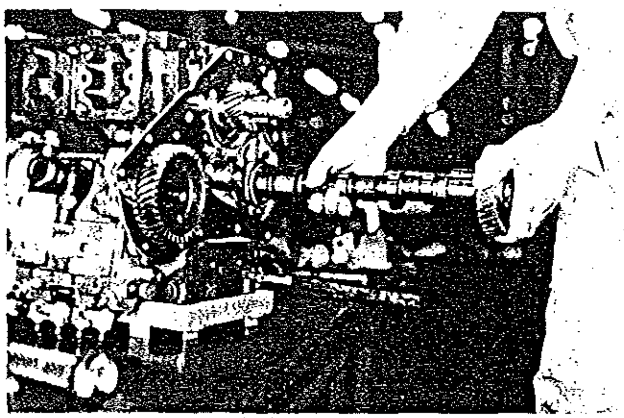
(10) Attach the front plate (1) (on which the injection pump is mounted), and secure the plate to crankcase by tightening its two mounting bolts (2) to 2.1 kg-m (15.2 ft-lb).



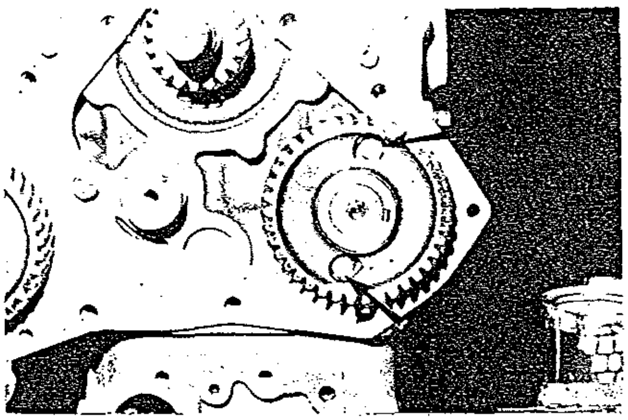
1-Front plate 2-Bolt (2 pcs)

Securing front plate to crankcase

(11) Insert the camshaft gently into crankcase. Secure the camshaft thrust plate to crankcase by tightening its bolts with the wrench put to each bolt head through the hole provided in camshaft gear: the holes are indicated by the arrows.



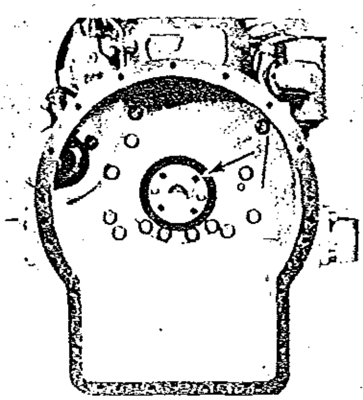
Installing camshaft



Securing camshaft thrust plate to crankcase

(12) Fit the oil pump assembly to crankcase. Make sure that drive gear and camshaft gear are correctly meshed. Secure the pump in place as outlined in OIL PUMP INSTALLATION.

(13) Position the oil pan on crankcase, and secure it by tightening its mounting bolts evenly: there are 24 bolts to be tightened.

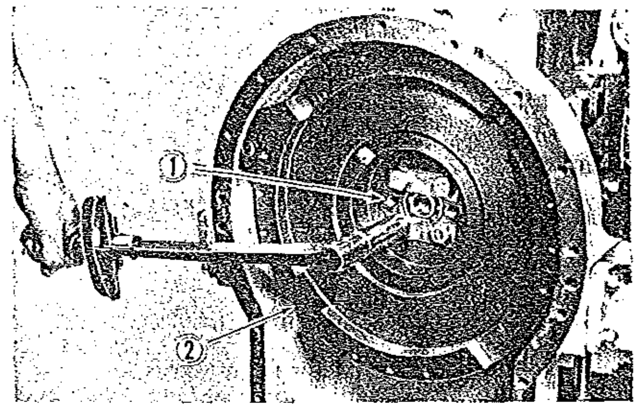


Oil seal in rear housing

CAUTION

When fitting the rear housing to the rear plate, be careful not to allow the oil seal lip to fold over, making its spring to come off. The lip portion is indicated by the arrow.

(14) Drive dowel pin (1) into crank gear. Drive ball bearing into flywheel (2). Secure flywheel to crankshaft through the crank gear by tightening the four mounting bolts to 8.5 ± 0.5 kg-m (61.5 ± 3.6 lb-ft), with the lock washers inserted under bolt heads. Lock the bolts securely by bending the washers positively.



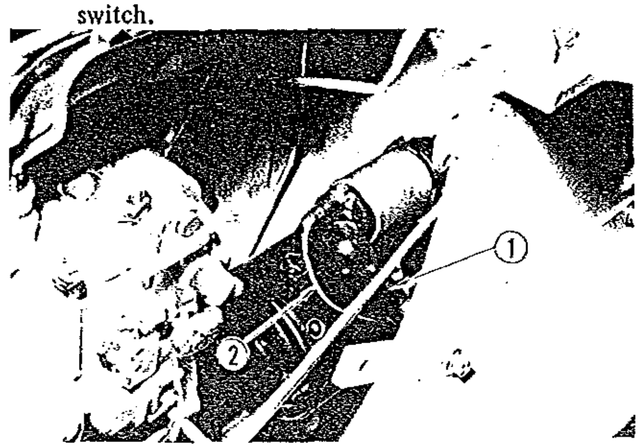
1-Dowel pin 2-Flywheel

Installing flywheel

Starter

Removal and installation

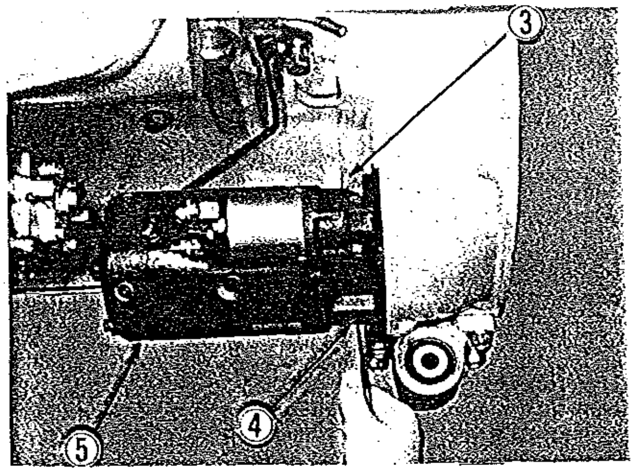
(1) Disconnect from the starter the lead wire (1) connecting starter to the battery. Disconnect, also, the two wires (2) connecting starter to the starter switch.



1-Starter-to-battery wire 2-Starter-to-switch wire (2 pcs)

Disconnecting electrical wires from starter

(2) Remove mounting nut (3) and bolt (4). Take down the starter assembly (5) from the engine.

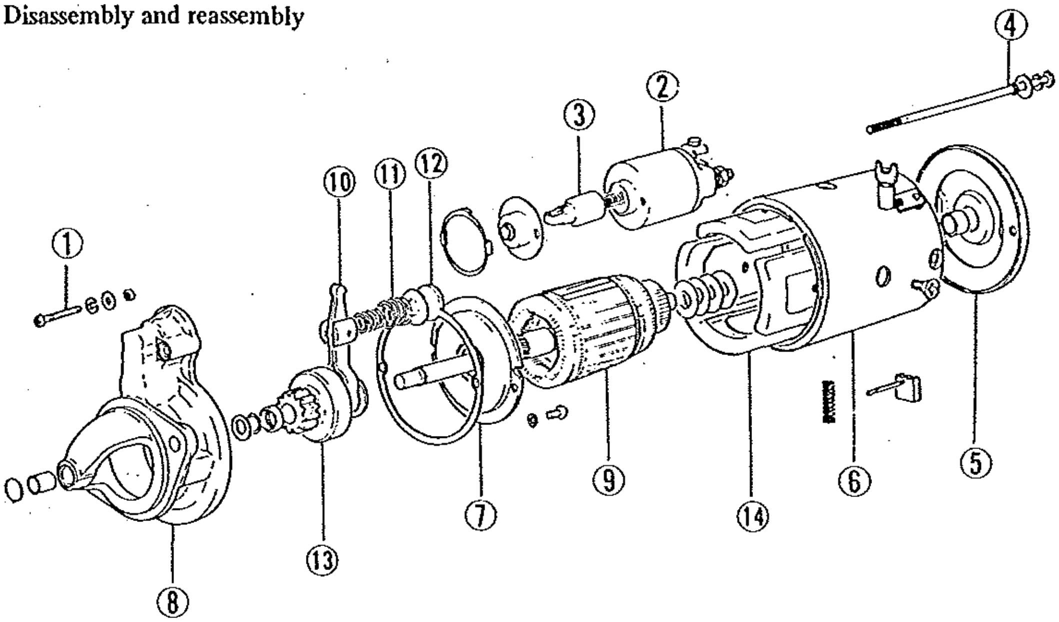


3-Nut and washer 4-Bolt and washer 5-Starter assembly
Removing starter

NOTE

To install the starter, carry out the above two steps in reverse order.

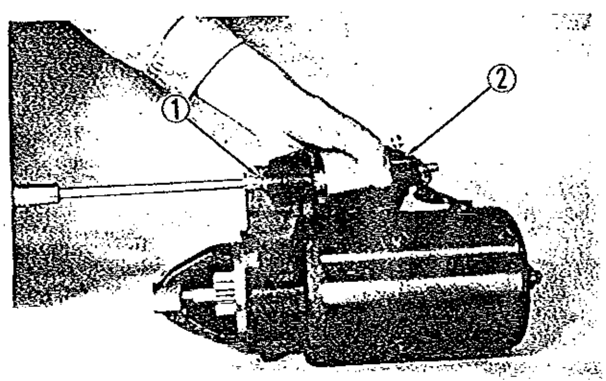
Disassembly and reassembly



1-Bolt and washer (2 pcs each)
2-Switch
3-Plunger
4-Bolt and washer (2 pcs each)
5-Rear bracket
6-Yoke
7-Center bracket
8-Front bracket
9-Armature
10-Lever
11-Lever spring
12-Rubber packing
13-Overrunning clutch
14-Pole piece

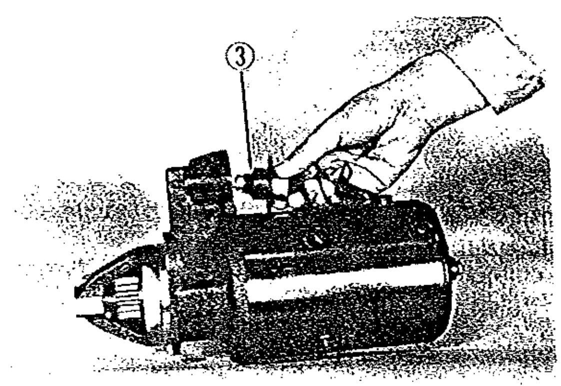
Starter — Exploded view

(1) Remove two bolts (1) securing the magnetic switch to front bracket (8), and take off the switch (2).



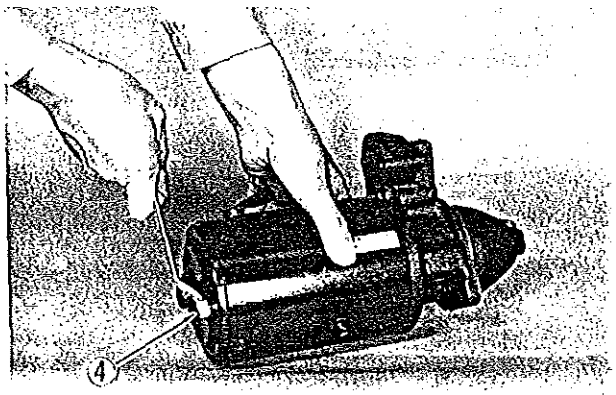
1-Bolt and washer (2 pcs each) 2-Magnetic switch
Removing magnetic switch

(2) From front bracket (8), remove plunger (3) complete with rubber cover.



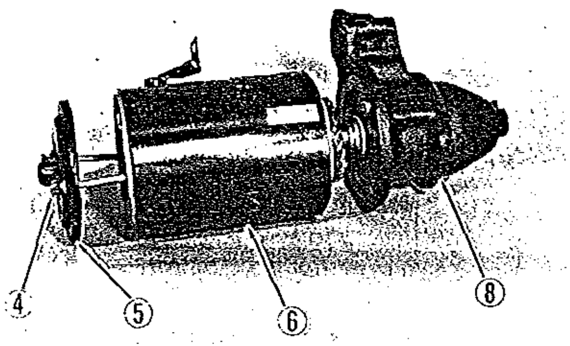
3-Plunger with rubber cover
Removing plunger

(3) Remove two bolts (4) from rear bracket (5).



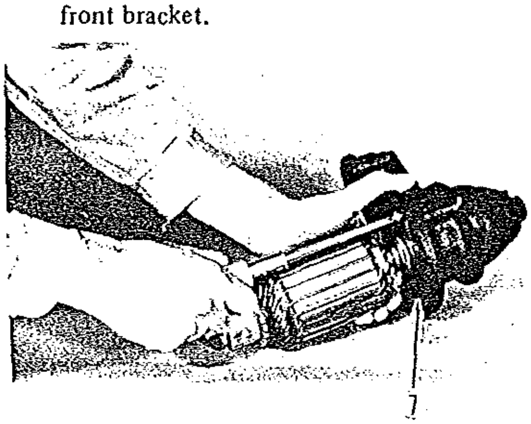
4-Bolt (2 pcs)
Removing bolts securing rear bracket

(4) Detach front bracket (8) from yoke (6) by tapping lightly on the bracket. Separate rear bracket (5) from yoke (6).



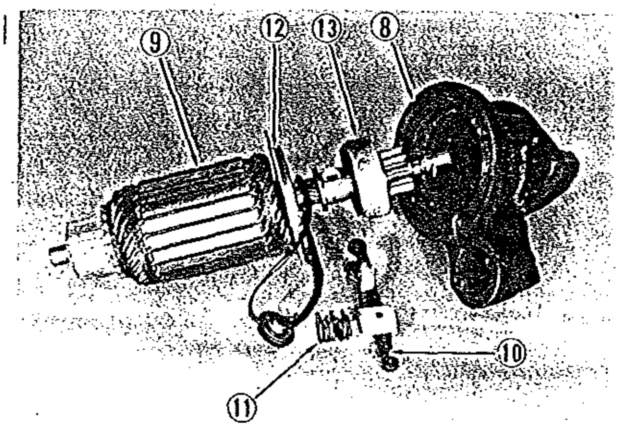
4-Bolt (2 pcs) 6-Yoke
5-Rear bracket 8-Front bracket
Separating brackets from yoke

(5) Take out front bracket complete with rotor and pinion from yoke. Remove center bracket (7) from front bracket by removing the bolts securing it to front bracket.



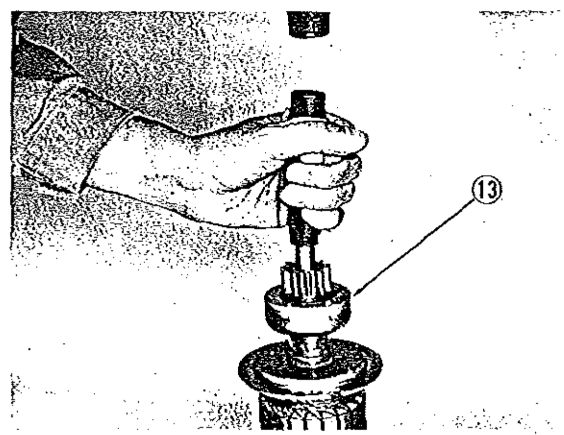
7-Center bracket
Removing center bracket

(6) From front bracket (8), draw out the rotor, that is, armature (9), rubber packing (12), lever (10), spring (11), overrunning clutch (13) complete with pinion.



8-Front bracket 11-Lever spring
9-Armature 12-Rubber packing
10-Lever 13-Overrunning clutch
Separating front bracket from rotor

(7) Remove overrunning clutch (13) from armature (9).



13-Overrunning clutch
Removing clutch from armature

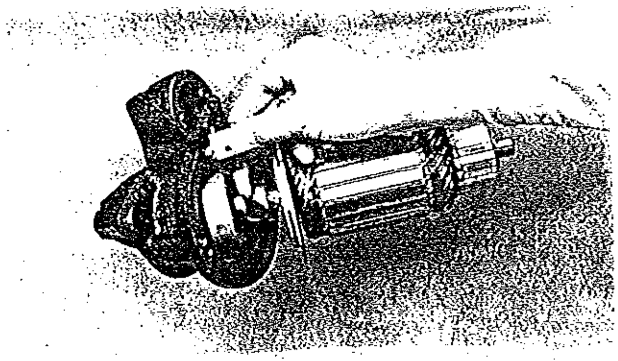
CAUTION

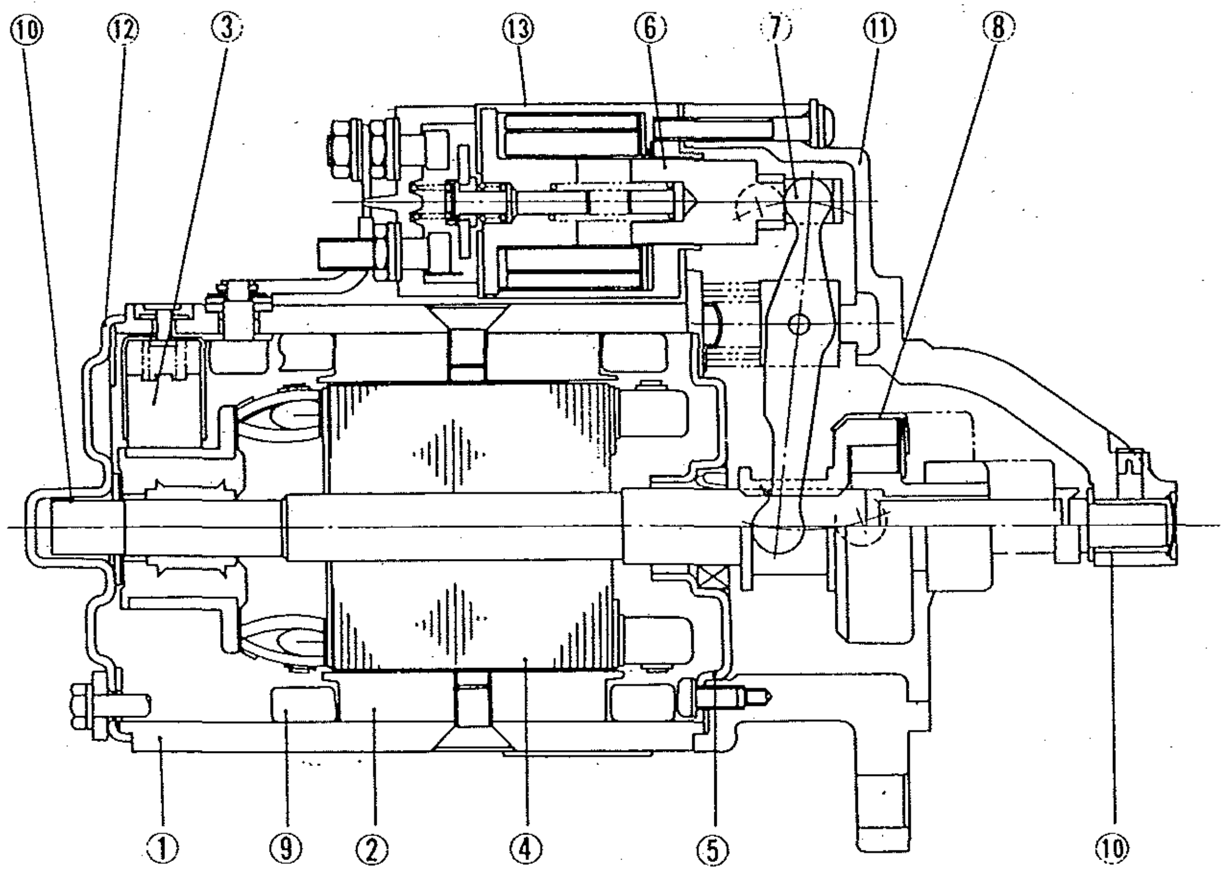
Before drawing off the center bracket, tape the splined portion of the shaft so that the oil seal will not suffer damage as the bracket is moved along the shaft for removal.

(8) To reassemble the starter, reverse the foregoing sequence of disassembling steps and refer to the following cross section:

CAUTION

When installing the lever, be careful not to position it the other way around. The correct position is clearly recognizable in the cross section.





1-Yoke
2-Pole piece
3-Brush
4-Armature
5-Center bracket
6-Plunger
7-Lever
8-Overrunning clutch
9-Field coil
10-Bearing
11-Front bracket
12-Rear bracket
13-Magnetic switch

Starter — Cross section

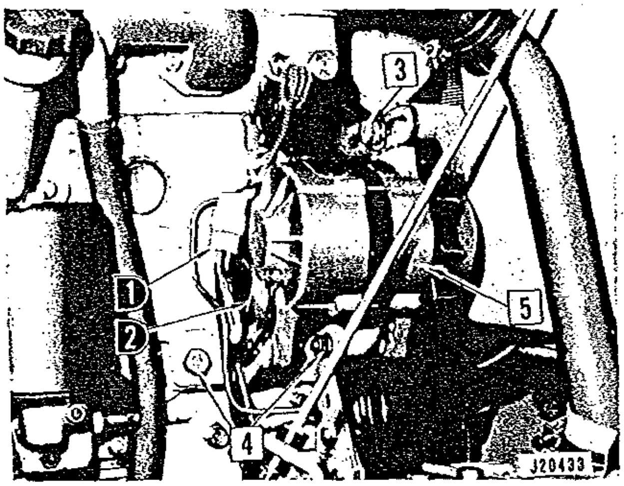
Alternator and regulator unit

Alternator removal and installation

(1) Disconnect wires between alternator and regulator unit and disconnect ground harness (2). Loosen adjusting plate bolt (3) and remove fan belt.

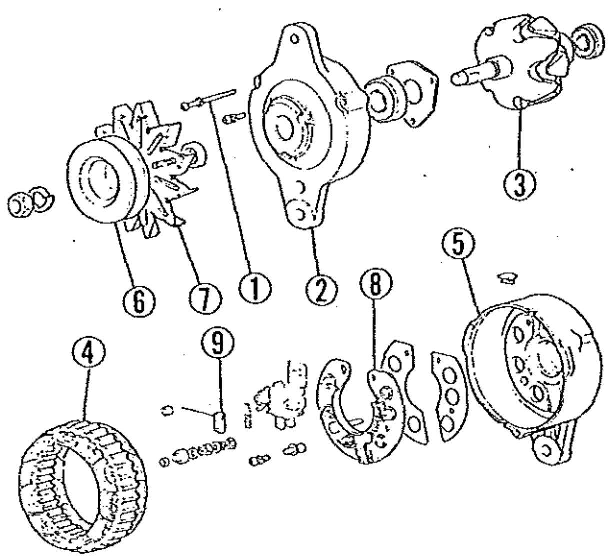
(2) Loosen alternator bracket bolts (4) and remove alternator assembly (5) from engine.

(3) To install the alternator, follow the reverse of removal procedure.



1-Wires between alternator and regulator unit
2-Ground
3-Adjusting plate bolt and washer
4-Bolts, nuts and washers (2 pcs each)
5-Alternator assembly

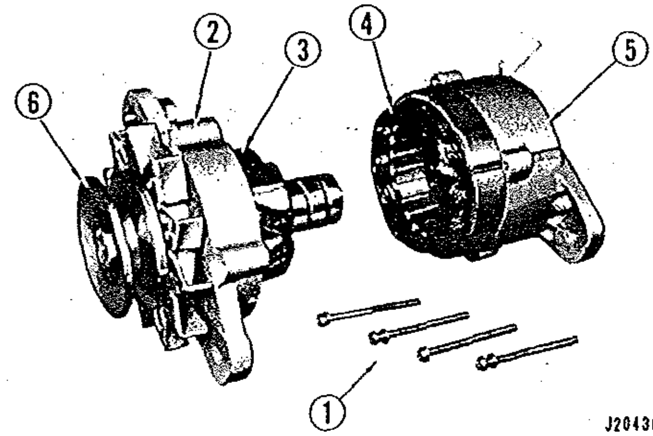
Alternator disassembly and reassembly



1-Bolt (3 pcs) 4-Stator coil 7-Fan
2-Front bracket 5-Rear bracket 8-Diode
3-Rotor 6-Pulley 9-Brush

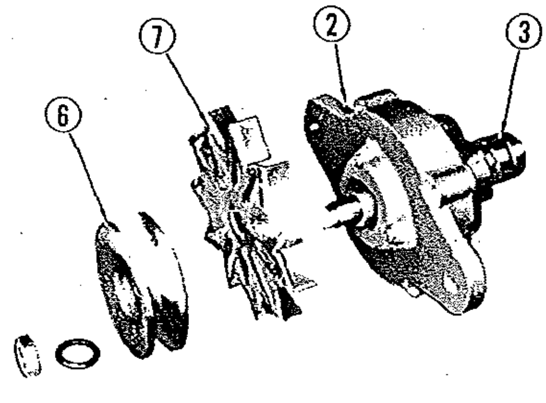
Alternator — exploded view

(1) Pulling out through bolts (1) will permit removal of rotor (3) (with front bracket and pulley) and stator coil (4) (with rear bracket).



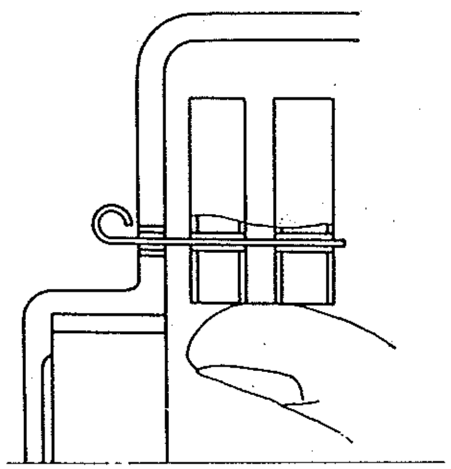
1-Bolt (3 pcs) 4-Stator coil
2-Front bracket 5-Rear bracket
3-Rotor 6-Pulley

(2) Hold rotor in a vice and remove pulley by loosening pulley clamping nut.



2-Front bracket 6-Pulley
3-Rotor 7-Fan

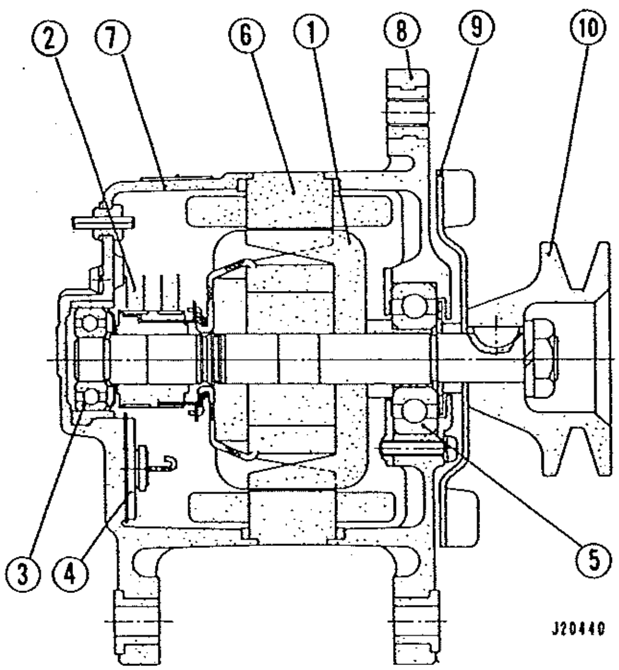
(3) Assemble alternator in the reverse order of disassembly. Place brush in brush holder and secure it by passing a pin through a small hole vacated by removing screw as shown. After assembly, be sure to pull out the pin.



(4) Apply a coating of sealer to the mating surfaces between the stator and rubber packing and those between the front and rear brackets and rubber packing.

NOTE

Care should be taken to install the rubber packing to the stator properly.

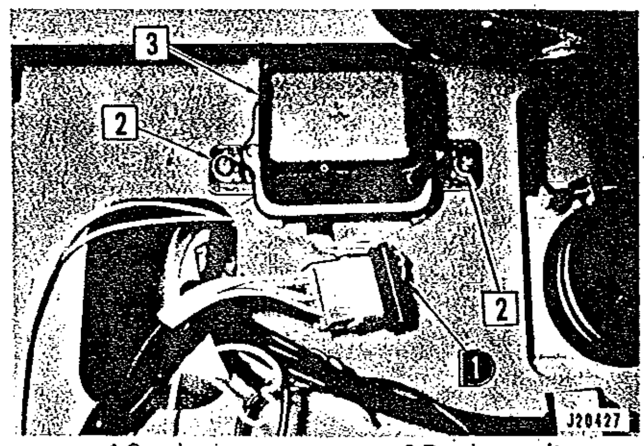


1-Rotor
2-Brush
3-Bearing
4-Diode
5-Bearing
6-Stator coil
7-Rear bracket
8-Front bracket
9-Fan
10-Pulley

Alternator assembly

Regulator unit removal and installation

The regulator unit is mounted on the inboard side of the dashboard. To remove the regulator unit, undo the coupler (1), remove mounting screws (2) and detach it from the dashboard. Reverse these steps to install the regulator unit.

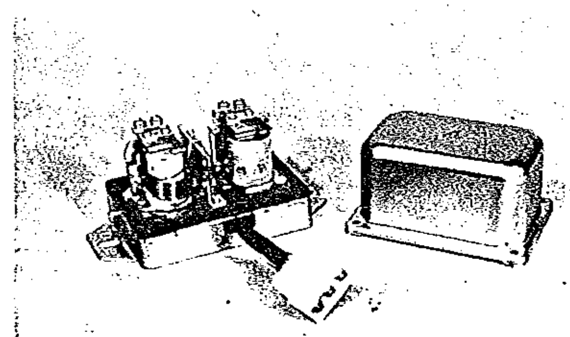


1-Coupler
2-Mounting screw (2 pcs)
3-Regulator unit

Regulator unit in place

Regulator unit disassembly and reassembly

For the purpose of servicing the regulator unit, the only thing to be done is to remove its cover. Its internals are not meant for disassembly.

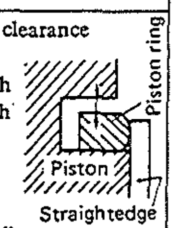


Regulator unit — Disassembled view

MAINTENANCE STANDARDS

MAINTENANCE STANDARDS

Unit: mm (in.)

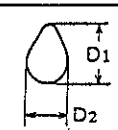
Group	Part or item			Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
General	Maximum rpm (no-load)			2640, max.				Adjust governor.	
	Minimum rpm (no-load)			650 ~ 700					
	Compression pressure			20 kg/cm^2 (284.4 psi), min. (at 150 ~ 200 rpm)	16 kg/cm^2 (227.5 psi)				Oil and water temperatures: 20 ~ 30°C (68 ~ 86°F)
	Engine oil pressure			3 ~ 4 kg/cm^2 (43 ~ 57 psi) (at 1500 rpm)	2 kg/cm^2 (28.4 psi)				Oil temperature: 70°C (158°F)
				1.0 kg/cm^2 (14.2 psi) min. (at idle speed)	0.5 kg/cm^2 (7.1 psi)				
	Valve timing	Intake valves	Opens	30° BTDC	±3°				
			Closes	50° ABDC					
		Exhaust valves	Opens	74° BBDC					
			Closes	30° ATDC					
	Beginning of injection			25° ± 1 (Crank angle)					
Main moving parts	Cylinder sleeves	I.D.		94 (3.701)	+ 0.035 ~ 0 (+0.0014 ~ 0)	+0.20 (+0.008)	1.20 (0.047)	Hone sleeve to 0.25 (0.0098) or 0.50 (0.0197) oversize with prescribed tolerance. Oversize pistons and piston rings should be used.	Four sleeves should be finished to the same oversize. Hone cylinder bore to $98^{-0.010}_{-0.045}$ $(3.858^{-0.00039}_{-0.00177})$ and heat the crankcase. Press sleeves into crankcase and machine each sleeve I.D. to assembly standard.
		Out-of-roundness			0.015 (0.0006), max.				
		Taper							
	Pistons, protrusion above crankcase gasketed surface				0.35 ~ 0.75 (0.0138 ~ 0.0295)			Check bearing clearance.	
	Piston rings and ring grooves	No. 1 compression ring		2.0 (0.079)	0.04 ~ 0.08 [0.0016 ~ 0.0031]	0.20 [0.0079]		Use pistons by replacing piston rings up to service limit. Replace pistons when service limit is reached.	(1) Ring side clearance Measure side clearance with ring kept flush with second land.  (2) Replace oil ring together with expander.
		No. 2 compression ring			0.025 ~ 0.060 [0.0010 ~ 0.0024]	0.15 [0.0059]			
		Oil ring		4.0 (0.157)					

Unit: mm (in.)

Group	Part or item		Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Main moving parts	Piston ring gaps	No. 1 compression ring		[0.30 ~ 0.50 (0.0118 ~ 0.0197)]	[1.5 (0.059)]			When oil ring is compressed to 94 (3.701).
		No. 2 compression ring						
		Oil ring						
	Piston pins	Clearance in pistons	28 (1.102)	[0 ~ 0.016 (0 ~ 0.0006)]	[0.05 (0.002)]		Use pistons by replacing piston pin, up to repair limit.	
		Clearance in connecting rod bushings		[0.020 ~ 0.051 (0.0008 ~ 0.0020)]	[0.08 (0.003)]		Replace pistons or bushings. (Ream if necessary.)	
	Pistons, variance in weight per engine			± 3g (± 0.1 oz)				
	Connecting rods	Variance in weight per engine		± 5g (± 0.18 oz)				
		Clearance on crankpin O.D. (big end bearing I.D.) (in two directions at right angles to each other with bearing in place)	58 (2.283)	[0.035 ~ 0.100 (0.0014 ~ 0.0039)]	[0.20 (0.008)]		Use connecting rods by replacing bearings, up to repair limit. Regrind crankpins and use undersize bearings when repair limit is reached.	Cap must be installed with marks on cap and rod on the same side.
		End play	40 (1.575)	[0.15 ~ 0.35 (0.006 ~ 0.014)]		[0.50 (0.020)]	Replace connecting rods or bearings.	
		Bent and twist		0.05 (0.002)	0.15 (0.006)			
	Crankshaft	Center-to-center dimension between journals and crankpins	47 (1.850)	± 0.05 (± 0.002)				
		Parallelism between crankpins and journals		0.01 (0.0004), max as runout				
		Out-of-roundness of crankpins and journals		Variance in dia.: 0.01 (0.0004), max	0.03 (0.0012)			
		Taper of crankpins and journals						
		Fillet radius	3 (0.12)	± 0.2 (0.008)				
		Variance in crankpin angles		± 20′				

Main moving parts	Crank-shaft	Runout (measured with 1st and 4th journals held in "V" blocks		0.02 (0.0008), max	0.05 (0.0020)		Straighten or replace crankshaft.	
	Main bearings	Clearance on crankshaft journal (in two directions at right angles to each other with bearing in place)	75 (2.953)	0.05 ~ 0.115 [(0.0020 ~ 0.0045)]	0.20 [(0.008)]	−0.9 (−0.035) (at crankshaft journal O.D.)	Replace bearings unless repair limit is reached. Regrind crankshaft journals and use undersize bearings 0.25 (0.0098) or 0.50 (0.0197) when repair limit is reached.	Replace crankcase and bearing caps as an assembly.
		Crankshaft end play	2.45 (0.097)	0.1 ~ 0.264 [(0.0039 ~ 0.01039)]	0.30 [(0.012)]		Replace thrust bearing.	
	Flywheel, face runout and flatness			0.15 (0.006), max	0.50 (0.020)			Install dial gauge to flywheel and measure face runout with respect to flywheel housing rear face.
Cylinder head	Crankcase, warpage on gasketed surface			0.05 (0.002), max	0.2 (0.008)		Regrind if warpage is minor.	
	Cylinder head	Warpage of gasketed surface		0.05 (0.002), max	0.2 (0.008)		Regrind if warpage is minor.	
		Valve seat angle	45°					
		Valve sinkage	0.7 (0.028)	±0.2 (±0.008)	1.3 (0.051)			
		Valve seat width	1.2 (0.047)	±0.14 (±0.0055)	1.6 (0.063)			
	Valve guides, protrusion above cylinder head gasketed surface		17 (0.669)	±0.3 (±0.012)				
	Cylinder head gasket, as-installed thickness		1.4 (0.055)	±0.05 (±0.002)				
Timing gear train	Valves	Clearance of valve stem in guide — Intake valves	8 (0.315)	0.055 ~ 0.085 [(0.0022 ~ 0.0033)]		0.15 [(0.0059)]	Replace both valve guide and stem when service limit is reached.	
		Clearance of valve stem in guide — Exhaust valves	8 (0.315)	0.070 ~ 0.100 [(0.0028 ~ 0.0039)]		0.20 [(0.0079)]	Replace both valve guide and stem when service limit is reached.	
		Margin	1.5 (0.059)			1.2 (0.0472) after refacing		
		Sinkage	0.7 (0.028)	±0.2 (±0.008)		1.3 (0.051)		
		Face runout of head		0.03 (0.0012), max (perpendicular to valve face)				

Unit: mm (in.)

Group	Part or item			Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Timing gear train	Valve springs	Free length		48.85 (1.923)		47.6 (1.874)			
		As-installed length		43 (1.693)		44 (1.732)		Adjust by means of shim(s) when repair limit is reached.	
		Squareness			0.4 (0.016)/25 (0.98), max.				Squareness of each end with respect to center line.
	Valve clearance			0.25 (0.0098) (cold setting)					0.25 clearance may also be obtained by warm setting if intake and exhaust valves are at the same temperature.
	Tappets, fit in crankcase			22 (0.8661)	0.035 ~ 0.086 [(0.0014 ~ 0.0034)]	0.12 [(0.0047)]	+0.10 (+0.004) (at tappet hole dia.)	Replace tappet unless repair limit is reached.	
	Valve push rods, bend				0.4 (0.016), max.				
	Rocker arms, fit on rocker shaft			20 (0.787)	0.016 ~ 0.055 [(0.0006 ~ 0.0022)]	0.07 [(0.0028)]		Replace bushing unless repair limit is reached.	
	Camshaft	Clearance of No. 1 journal in hole		54 (2.126)	0.040 ~ 0.090 [(0.0016 ~ 0.0035)]	0.15 [(0.0059)]		Install bushing when repair limit is reached. (Ream if necessary.)	
		Clearance of No. 2 journal in hole							
		Clearance of No. 3 journal in hole		53 (2.087)					
		Clearance of thrust plate on thrust journal		5 (0.197)	0.05 ~ 0.112 [(0.0020 ~ 0.0044)]	0.3 [(0.0118)]		Replace thrust plate.	
		Cam height	Intake	46.916 (1.8471)	$^{+0.1}_{-0.3}$ $\left(^{+0.00394}_{-0.01181}\right)$ D_1-D_2 = 6.684 (0.26315)		D_1-D_2 = 6.184 (0.24346)	Replace camshaft.	
			Exhaust	45.944 (1.8088)	$^{+0.1}_{-0.3}$ $\left(^{+0.00394}_{-0.01181}\right)$ D_1-D_2 = 7.344 (0.28913)		D_1-D_2 = 6.844 (0.26945)		
		Cam dia.		40.232 (1.5839)					
		Runout			0.02 (0.0008), max.	0.05 (0.0020)		Straighten or replace.	
	Idler	Clearance of bushing on shaft		36 (1.417)	0.025 ~ 0.075 [(0.00098 ~ 0.00295)]	0.1 [(0.0039)]		Replace bushing.	
		End play			0 ~ 0.1 [(0 ~ 0.004)]	0.35 [(0.0138)]		Replace thrust plate.	

Timing gear train	Idler	Clearance of shaft in bore in crankcase	30 (1.181)	0.009T ~ 0.045T [0.00035T ~ 0.00177T]				
		Timing gear, backlash		0.07 ~ 0.20 (0.0028 ~ 0.0079)	0.25 (0.0098)		Replace gear.	
Lubrication system	Oil pump	Clearance of main shaft in body	13 (0.512)	0.032 ~ 0.074 [0.00126 ~ 0.00291]		0.15 [0.0059]	Replace pump case.	
		Clearance of outer rotor in body	50 (1.969)	0.20 ~ 0.28 [0.0079 ~ 0.0110]		0.5 [0.0197]		
		Rotor and cover end play	30 (1.181)	0.04 ~ 0.09 [0.0016 ~ 0.0035]	0.15 [0.0059]		Reface case cover or case.	
		Inner rotor and outer rotor clearance		0.013 ~ 0.15 [0.0005 ~ 0.0059]		0.25 [0.0098]		
	Relief valve	Relief pressure	3.0 kg/cm² (42.7 psi)	± 0.3 kg/cm² (± 4.27 psi)				Oil pressure varies 0.15 kg/cm² (2.133 psi) per 1 (0.04) of shim thickness.
Cooling system	Water pump bearings	Clearance of outer race in pump casing	47 (1.850)	0.011L ~ 0.025T [0.0004L ~ 0.0010T]			Replace pump case or pump assembly.	
			40 (1.575)					
		Clearance of inner race on pump shaft	17 (0.669)	0.001T ~ 0.017T [0.00004T ~ 0.00067T]				
		Radial play		0.010 ~ 0.025 [0.00039 ~ 0.00098]		0.045 [0.00177]	Replace bearing.	Replace bearing when it does not rotate smoothly.
				0.010 ~ 0.022 [0.00039 ~ 0.00087]				
		Spacer, I.D.		0.001T ~ 0.017T [0.00004T ~ 0.00067T]				
		Water pump impeller, vane-to-casing clearance (front and rear sides)	0.5 ~ 1 (0.020 ~ 0.039)				Replace impeller or bearing if vanes are binding.	
	Unit seals	Carbon protrusion	1.5 (0.059)		0			1-Floating seat (carbon) 2-Seal ring (ceramic)
		Height (free length)	21.8 (0.858)	± 1 (± 0.04)				
	Thermostat	Valve opening temperature	76.5°C(169.7°F)	± 2°C (± 3.6°F)				
		Valve lift	9 (90°C) [0.35 (194°F)]					

Unit: mm (in.)

Group	Part or item		Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Cooling system	Belt, tension		Deflection: 12 (0.472)					
Fuel system	Injection nozzles	Injection pressure	120 kg/cm² (1706.4 psi)	±5 kg/cm² (±71.1 psi)	110 kg/cm² (1564.2 psi), min.		Adjust by means of shim(s).	Injection pressure varies 10 kg/cm² (142.2 psi) per 0.1 (0.004) of shim thickness.
		Spray angle	0°				Test by means of hand tester, using diesel fuel at, 20°C or 68°F approx. If spray pattern is improper even after nozzle is washed in clean kerosene, replace nozzle tip.	Spray of fuel oil should be uniform and consist of fine droplets.
		Needle valve seat oil-tightness	Seat shall show no sign of leakage under a pressure of 100 kg/cm² (1422 psi).				Wash needle valve seat or replace nozzle tip.	Replace nozzle tip when needle surface is scratched or scored.
	Fuel feed pump	Clearance of tappet roller pin in pin hole	7 (0.276)	[0.013 ~ 0.071 (0.0005 ~ 0.0028)]		Total play: [0.3 (0.0118), max.]		
		Clearance of tappet roller on roller pin		[0.033 ~ 0.085 (0.0013 ~ 0.0033)]				
		Roller OD	15 (0.591)	0 ~ −0.027 (−0.00106)	−0.0075 (−0.00295)			
		Airtightness	No parts shall show sign of leakage. Leakage between rod housing should be not more than 50 cc (3 cu in.)/min.		See Assembly Standard.			Close pump discharge port with a plug. Apply an air pressure of 2 kg/cm² (28 psi) to the pump, and keep the pump immersed in diesel fuel longer than 1 minutes.
		Number of strokes for pumping (priming pump)		25, max.	30			Operate priming pump handle at a speed of 60 strokes/minute. Check the number of strokes requied for making the pump start dischaging at a head of 1 meter.
		Number of strokes for pumping		45 seconds, max.	50 seconds			Operate injection pump at 150 rpm to check the length of time required for the feed pump to start discharging.

Fuel system	Fuel feed pump	Capacity		900 cc (55 cu in.)/min, min.	600 cc (37 cu in.)/min, min.			Check displacement with injection pump operated at 1000 rpm with a discharge pressure of 1.5 kg/cm^2 (21 psi).
Fuel system	Fuel injection pump	Cam height	32 (1.260)	0 ~ +0.1 (0 ~ +0.0039)		−0.2 (−0.0079)	Replace camshaft.	Check cam surface for condition.
Fuel system	Fuel injection pump	Axial play of camshaft bearing		[0.03 ~ 0.05 (0.0012 ~ 0.0020)]	[0.1 (0.004)]		Adjust by means of shim.	
Fuel system	Fuel injection pump	Clearance of tappet pin in tappet (hole)	7 (0.276)	[0.013 ~ 0.050 (0.0005 ~ 0.0020)]				
Fuel system	Fuel injection pump	Clearance of tappet floating bushing on tappet pin	7 (0.276)	[0.033 ~ 0.078 (0.0013 ~ 0.0031)]		Total play: [0.3 (0.0118), max.]	Replace tappet complete.	
Fuel system	Fuel injection pump	Clearance of tappet roller on floating bushing	11 (0.433)	[0.050 ~ 0.097 (0.0020 ~ 0.0038)]				
Fuel system	Fuel injection pump	Tappet roller OD	17 (0.669)	0 ~ −0.027 (0 ~ −0.0011)		−0.075 (−0.00295)		
Fuel system	Fuel injection pump	Plunger springs: Free length	49 (1.929)	+1 ~ 0 (+0.039 ~ 0)		−0.5 (−0.020)		
Fuel system	Fuel injection pump	Plunger springs: As-installed length	44 (1.732)					
Fuel system	Fuel injection pump	Backlash between pinion and rack		[0.15 (0.0059)]		[0.25 (0.0098)]		
Fuel system	Fuel injection pump	Rack sliding resistance	150 g (5.3 oz) with pump at standstill 50 g (1.8 oz) with pump running at 1000 rpm					
Fuel system	Fuel injection pump	Free length of delivery valve spring	32 (1.26)	±0.5 (±0.02)		−1 (−0.04)		
Fuel system	Fuel injection pump	Plunger pre-stroke	1.95 (0.077)	±0.05 (±0.002)				
Fuel system	Fuel injection pump	Fuel injection quantity	(see table below)					Mount injection pump on pump tester and allow pump to inject.

Pump speed rpm	Rack position mm	Strokes mm	Injection quantity cc (cu in.)	Variance cc (cu in.)
1000	8.5 (0.335)	200	7.2 ~ 7.8 (0.44 ~ 0.48)	0.4 (0.02)
1000	8.0 (0.315)	200	6.4 ~ 7.0 (0.39 ~ 0.43)	0.4 (0.02)
200	6.0 (0.236)	500	5.0 ~ 8.0 (0.31 ~ 0.49)	1.0 (0.06)

Unit: mm (in.)

Group	Part or item		Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Fuel system	Fuel injection pump	Fuel injection quantity	Test conditions Nozzle tip: ND - DN0SD Injection pipe: 6 x 1.6 x 600 (1/4 x 1/16 x 23-5/8) Injection pressure: 120 kg/cm^2 (1706.4 psi) Delivery pressure: 2.0 kg/cm^2 (28.44 psi) Test oil: ASTM Diesel fuel No. 2					
	Mechanical governor	Clearance of swiveling lever shaft in bushing	11 (0.433)	[0.016 ~ 0.07 (0.0006 ~ 0.0028)]		[0.15 (0.0059)]		Replace bushing or swivel lever. Replace "O" ring and oil seal when replacing bushing.
		Clearance of tension lever or guide lever support pin in pin hole	8 (0.315)	[0.013 ~ 0.05 (0.0005 ~ 0.0020)]		[0.10 (0.00394)]		Replace pin and lever if pin hole is worn abnormally or worn to show any stepped portion.
		Clearance of control lever shaft bushing on shackle connecting pin	5 (0.197)	[0.005 ~ 0 (0.0002 ~ 0)]		[0.10 (0.0039)]		Replace control lever or shackle.
		Clearance of shackle pin in control rack hole		[0.015 ~ 0.056 (0.0006 ~ 0.0022)]		[0.08 (0.0031)]		Replace shackle or control rack.
		Guide lever and control block						Replace control block or guide lever if chromed tip of control block is worn down.
		Control spring						Replace spring if hook is badly worn.
		Flyweight roller O.D.	16 (0.630)	−0.11 ~ 0 (−0.0043 ~ 0)		−0.25 (−0.0098)		Replace flyweight.
		Clearance of flyweight roller on roller pin	8 (0.315)	[0.025 ~ 0.062 (0.00098 ~ 0.00244)]		[0.10 (0.00394)]		
		Clearance of torque control lever bushing on support pin		[0.026 ~ 0.056 (0.00102 ~ 0.0022)]				Replace lever.

Step	Item	Adjusting lever angle	Pump rpm Np. rpm	Control rack position RW. mm
1	High-speed control	47° ± 5°	1100 1230 1290	8.2 ± 0.1 (0.3228 ± 0.0039) at full-load stopper 7.0 ± 0.1 (0.2756 ± 0.0039) at initial lever setting ≦ 4.0 (0.1575)
2	Control by adaptor action	51° ± 5°	400 650	10.4 ± 0.1 (0.4094 ± 0.0039) 8.8 ± 0.1 (0.3465 ± 0.0039)

Fuel system

Mechanical governor

3	Low-speed control	High-speed control lever angle MINUS 26° ± 3°	200 275 330	$\geqq$ 11 (0.4331) 5.5 ± 0.1 (0.2165 ± 0.0039) at initial lever setting 5.0 ± 0.1 (0.1969 ± 0.0039) with sub-spring
4	Matching with engine	Adjusting lever angle	Pump rpm Np. rpm	Total injection qt. cc (cu in.)/ 500 strokes, 4 cyl.
		51° ± 5°	600 1200	81 ± 2 (3.1890 ± 0.0787) with adaptor spring 62 ± 2 (2.4409 ± 0.0787) with torque spring
5	Stop lever operation	The stop lever must operate piecisely. When the stop lever is pulled with the high-speed control lever at VII, Np = 1200 rpm, the rack must be drawn up to Rw = 0 mm		

Electrical equipment

Starter

No-load operation			Load operation			Magnetic switch operating voltage	
Voltage (V)	Current (A)	Rpm	Voltage (V)	Current (A)	Torque	Switch IN	Switch OFF
23	50, max.	4500, min.	9	700, max.	4 kg-m (29 ft-lb), min.	16V, max.	When circuit is opened.

Shaft		Metal	Intermediate metal	Commutator O.D. service limit	Brush		
		Rear / Front	Bracket shaft		Height	Wear	Spring compression, kg (lb)
Rear	$14.2^{-0.050}_{-0.077}$ $(0.559^{-0.0020}_{-0.0030})$	$14.2^{+0.027}_{-0.016}$ $(0.559^{+0.0011}_{-0.0006})$	$20.6^{+0.02}_{-0.08}$ $(0.811^{+0.0008}_{-0.0031})$	43.2 (1.701)	19 (0.75) Service limit: 13 (0.51)	6 (0.236)	2 (4.4) Service limit: 1.5 (3.3)
Front	$12.2^{-0.050}_{-0.077}$ $(0.480^{-0.0020}_{-0.0030})$	$12.2^{+0.027}_{-0.016}$ $(0.480^{+0.0011}_{-0.0006})$	$20.3^{0}_{-0.033}$ $(0.799^{0}_{-0.0013})$	2 (0.079)			

Alternator

No-load operation (battery connected)			Load operation (battery + resistance load 12.5A connected)		
Terminal voltage (V)	Current (A)	Rpm	Terminal voltage (V)	Current (A)	Rpm
28	0	1100, max.	28	12.5	1900, max.

Ball bearings		Field resistance 20°C (68°F)
Rear	#6201	27 (Ω)
Front	#6303	

Unit: mm (in.)

Group	Part or item	Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Electrical equipment	Regulator unit						

	Voltage regulator	Lamp relay
Air gap	1.0 ~ 1.4 (0.039 ~ 0.055)	0.9 ~ 1.4 (0.035 ~ 0.055)
Contact point gap	0.3 (0.012), min	0.75 ~ 1.1 (0.030 ~ 0.043)
Back gap	0.75 ~ 1.1 (0.030 ~ 0.043)	
No-load voltage (V)	27.5 ~ 30.5 at 3000 rpm (alternator speed)	
Cut-out voltage (V)		6.5 ~ 7.5
Cut-in voltage (V)		5, max.

TIGHTENING TORQUE

Unit: kg-m (ft-lb)

Item	Torque	Item	Torque
Cylinder head bolts	12 ± 0.5 (87 ± 3.6)	Oil pan drain plug	10.0 ± 0.5 (72.3 ± 3.6)
Main bearing cap bolts	10.4 ± 0.5 (75.2 ± 3.6)	Oil pump connector	5.5 ± 0.5 (39.8 ± 3.6)
Connecting rod cap bolts	8.5 ± 0.5 (61.5 ± 3.6)	Nozzle holder retaining nuts	5.0 ± 0.5 (36.2 ± 3.6)
Flywheel bolts	8.5 ± 0.5 (61.5 ± 3.6)	Injection pump delivery valve holders	3.0 ± 0.5 (21.7 ± 3.6)
Camshaft thrust plate bolts	1.8 ± 0.5 (13 ± 3.6)	Flywheel housing bolts	3.5 ± 0.5 (25.3 ± 3.6)
Front plate bolts	1.8 ± 0.5 (13 ± 3.6)		
Timing gear case bolts	3.5 ± 0.5 (25.3 ± 3.6)		
Crankshaft pulley nut	40 ± 0.5 (290 ± 3.6)		
Idler thrust plate bolt	3.5 ± 0.5 (25.3 ± 3.6)		
Oil pan bolts	0.7 (5.1)		

APPLICATION OF SEALERS

Apply to:	Mating part	Sealer
Main bearing caps	Crankcase bearing caps	SUPER THREE BOND No. 5
Side seals	Crankcase bearing caps	SUPER THREE BOND No. 5

TROUBLESHOOTING

TROUBLESHOOTING CHART (1)

	Complaint / Possible cause	Engine will not start						Glow plugs do not glow red	Glow plugs glow red too early	Engine lacks power			Abnormal exhaust smoke			Engine knocks excessively	Engine is noisy	Engine runs rough	Engine hunts	
		Engine turns but does not start			Starting motor does not turn sufficiently to crank engine	Engine does not turn				A little exhaust smoke	Too much whitish exhaust smoke	Too much black exhaust smoke	When idling	When operating					When idling	When operating
		No exhaust smoke	A little exhaust smoke	Too much exhaust smoke		Engine can be cranked manually	Engine cannot be cranked manually							Whitish exhaust smoke	Black exhaust smoke					
Fuel system	Insufficient fuel supply to injection pump	O	O	—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—
	Greater variance of injection quantity	—	—	O	—	—	—	—	—	—	—	O	O	—	O	O	—	O	O	O
	Defective injection pump seals	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Insufficient injection quantity	O	O	—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—
	Excessive injection quantity	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	—
	Improper fuel spray from injection nozzles	—	—	O	—	—	—	—	—	—	—	O	O	—	O	O	—	O	O	O
	Excessive fuel return from injection nozzles	—	O	—	—	—	—	—	—	O	—	—	—	—	—	—	—	O	O	—
	Injection timing too advanced	—	—	O	—	—	—	—	—	—	—	O	—	—	O	O	—	—	—	—
	Injection timing too retarded	—	—	O	—	—	—	—	—	—	O	—	O	O	—	—	—	O	O	—
	Defective auto timer	—	—	—	—	—	—	—	—	—	—	O	O	—	O	O	O	—	—	—
	Defective governor control spring	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Maladjusted governor damper spring	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	O
	Engine speed too low	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—
	Failure of engine to stop properly	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Poor grade of fuel oil	—	—	O	—	—	—	—	—	—	O	O	O	O	O	O	—	—	—	—
	Fuel viscosity too high	O	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lubrication system	Poor grade of oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Oil viscosity too high	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Oil viscosity too low	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	—	—
	Low oil pressure	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Excessive oil leakage	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pumping up of oil	—	—	—	—	—	—	—	—	—	—	—	—	O	O	O	—	—	—	—
	Clogged oil filter	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Defective oil bypass alarm or lamp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Defective oil indicator switch or lamp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Air system	Insufficient air	—	—	O	—	—	—	—	—	—	—	O	—	—	O	—	—	—	—	—
	Poor compression	—	—	O	—	—	—	—	—	—	O	O	O	O	O	O	—	O	O	O
	Low pressure at high atmospheric temperature (or altitude)	—	—	—	—	—	—	—	—	—	—	O	—	—	O	—	—	—	—	—

(● For detailed information refer to the separate chart.)

Engine vibrates excessively	Engine stalls	Poor response for deceleration	Engine does not pick up speed	Engine operates at high speeds but fails to stop	Engine turns in reverse direction	Excessive fuel consumption	Excessive oil consumption	Oil is diluted by fuel	Water in oil	Excessive blow-by	Defective lubrication system			Abnormal water temperature rise		Defective alternator		Remedy
											When engine stops, warning lamp does not come on	Warning lamp comes on at low-speed operation	Warning lamp comes on at high-speed operation	Water temperature too high (Engine overheats)	Water temperature too low	Indicator lamp does not come on when engine stops	Indicator lamp comes on at high-speed operation	
—	O	—	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●
O	O	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	Check and replace if necessary.
—	O	—	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	O	—	O	—	—	—	—	—	O	—	—	—	●
O	O	—	—	—	—	O	—	O	—	—	—	—	—	—	—	—	—	●
—	O	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	Replace nozzle tips.
O	O	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	●
—	O	—	—	—	—	O	—	—	—	—	—	—	—	O	—	—	—	●
—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	
—	—	O	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Check and replace spring if necessary. Then adjust governor setting on bench.
—	O	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Adjust.
O	O	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	—	Adjust idling set bolt. Hold lever in STOP position.
—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	—	
—	O	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Use fuel for cold weather.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Use good quality oil.
—	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	Use proper viscosity oil.
—	—	—	—	—	—	—	O	—	—	O	—	O	—	—	—	—	—	Use proper viscosity oil.
—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	—	●
—	—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	Retighten and replace packing if necessary.
—	—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	Change element and oil.
	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	Check and replace if necessary.
—	—	—	—	—	—	—	—	—	—	—	O	O	—	—	—	—	—	Check and replace if necessary.
—	O	—	O	—	—	O	—	—	—	—	—	—	—	—	—	—	—	●
—	O	—		—	—	O	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	O	—	—	—	—	—	—	—	O	—	—	—	(Adjust full-load setting of governor.)

Possible cause \ Complaint		Engine will not start — Engine turns but does not start — No exhaust smoke	Engine will not start — Engine turns but does not start — A little exhaust smoke	Engine will not start — Engine turns but does not start — Too much exhaust smoke	Engine will not start — Starting motor does not turn sufficiently to crank engine.	Engine will not start — Engine does not turn — Engine can be cranked manually	Engine will not start — Engine does not turn — Engine cannot be cranked manually	Glow plugs do not glow red	Glow plugs glow red too early	Engine lacks power — A little exhaust smoke	Engine lacks power — Too much whitish exhaust smoke	Engine lacks power — Too much black exhaust smoke	Abnormal exhaust smoke — When idling	Abnormal exhaust smoke — When operating — Whitish exhaust smoke	Abnormal exhaust smoke — When operating — Black exhaust smoke	Engine knocks excessively	Engine is noisy	Engine runs rough	Engine hunts — When idling	Engine hunts — When operating
Cooling system	Engine is too cold.	—	—	O	O	—	—	—	—	—	—	—	O	—	—	O	—	—	—	—
Cooling system	Radiator dissipates heat excessively	—	—	—	—	—	—	—	—	—	O	—	O	O	—	O	—	—	—	—
Cooling system	Insufficient coolant	—	—	—	—	—	—	—	—	—	—	O	—	—	O	—	—	—	—	—
Cooling system	Failure of radiator to dissipate heat properly	—	—	—	—	—	—	—	—	—	—	O	—	—	O	—	—	—	—	—
Cooling system	Water leak through cylinder head gasket	—	—	—	—	—	—	—	—	—	O	—	O	O	—	—	—	O	—	—
Cooling system	Cracks in crankcase water jacket	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective starter switch	—	—	—	—	O	—	O	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective starter magnetic switch	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective starting motor	—	—	—	O	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective starting motor free wheel	—	—	—	O	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective flywheel ring gear and pinion	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Battery voltage drop	—	—	O	O	O	—	O	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Open circuit in glow plugs or pilot lamp	—	—	O	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Short circuit in glow plugs	—	—	O	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective alternator	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective alternator relay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Improper wiring	—	—	O	O	O	—	—	O	—	—	—	—	—	—	—	—	—	—	—
Main moving parts	Jammed moving parts	—	—	—	O	—	O	—	—	—	—	O	—	—	O	—	O	O	—	—
Main moving parts	Worn cylinders, pistons or piston rings	—	—	O	—	—	—	—	—	—	O	—	O	O	—	O	O	—	—	—
Main moving parts	Sticking piston rings	—	—	O	—	—	—	—	—	—	O	—	O	O	—	O	—	—	—	—
Main moving parts	Excessive main bearing clearance	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—
Main moving parts	Loose connecting rod cap bolts	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—
Main moving parts	Interference between valve and piston	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	O	—	—	—
Main moving parts	Broken valve springs	—	—	O	—	—	—	—	—	—	O	—	O	O	—	—	O	O	O	O
Main moving parts	Excessive valve clearance	—	—	—	—	—	—	—	—	—	—	O	—	—	O	—	O	O	O	O
Main moving parts	Foreign substances in cylinders	—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	O	—	—	—
Main moving parts	Excessive gear backlash	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—

(● For detailed information refer to the separate chart.)

Engine vibrates excessively	Engine stalls	Poor response for deceleration	Engine does not pick up speed	Engine operates at high speeds but fails to stop	Engine turns in reverse direction	Excessive fuel consumption	Excessive oil consumption	Oil is diluted by fuel	Water in oil	Excessive blow-by	Defective lubrication system			Abnormal water temperature rise		Defective alternator		Remedy
											When engine stops, warning lamp does not come on	Warning lamp comes on at low-speed operation	Warning lamp comes on at high-speed operation	Water temperature too high (Engine overheats)	Water temperature too low	Indicator lamp does not come on when engine stops	Indicator lamp comes on at high-speed operation	
—	O	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	Heat oil pan from bottom side at starting. After starting, warm up engine thoroughly.
—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	O	—	—	●
—	—	—	—	—	—	—	O	—	—	O	—	O	—	O	—	—	—	●
—	—	—	—	—	—	—	O	—	—	O	—	O	—	O	—	—	—	●
—	—	—	—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	Retighten and replace gasket if necessary.
—	—	—	—	—	—	—	—	—	O	—	—	—	—	—	—	—	—	Replace crankcase.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Check for connections and repair. Replace if necessary.
—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace if necessary.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace starter if necessary.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace ring gear. Replace pinion.
—	—	—	—	—	O	—	—	—	—	—	O	—	—	—	—	O	—	Recharge or replace battery. If necessary heat it.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace copper packings and if necessary glow plugs.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	Replace alternator if necessary.
—	—	—	—	—	O	—	—	—	—	—	—	—	—	—	—	O	O	Adjust or replace.
—	—	—	—	—	—	—	—	—	—	—	O	—	—	—	—	O	—	Connect wires properly.
—	O	—	O	—	—	O	O	—	—	O	—	—	—	O	—	—	—	●
—	O	—	—	—	—	O	O	O	—	O	—	—	—	—	—	—	—	Repair or replace.
—	O	—	—	—	—	O	O	O	—	O	—	O	O	—	—	—	—	Repair or replace.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Check and replace bearing(s) with undersize one(s) if necessary.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Retighten.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Re-time timing gear train or adjust valve sinkage properly.
O	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace.
O	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Adjust valve clearance to 0.25 mm (0.0098 in.).
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace gears or idler bushing.

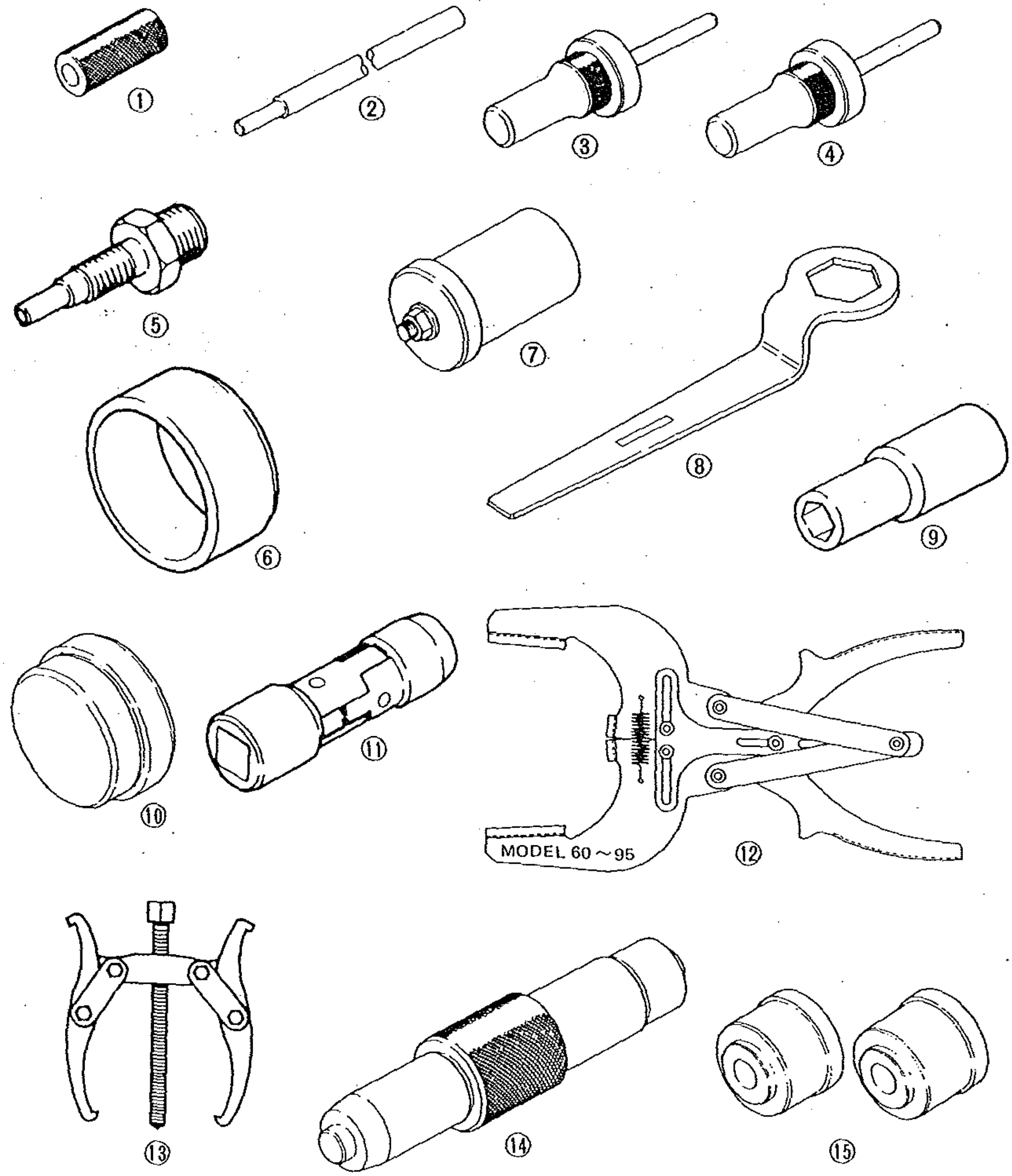
TROUBLESHOOTING CHART (2)

Possible cause		Remedy
Poor fuel supply to fuel injection pump	Closed fuel tank supply cock	Open the cock.
	No fuel in tank	Fill fuel tank.
	Clogged fuel lines	Repair or clean fuel pipes with air.
	Air in fuel system	Retighten connections or replace fuel pipes.
	Clogged fuel feed pump inlet strainer	Remove and clean strainer.
	Defective fuel feed pump	Repair.
	Leaky fuel lines or connections	Retighten connections.
	Clogged fuel filter	Disassemble and clean filter.
	Air in fuel system	Bleed air out of fuel system
Greater variance of injection quantity	Jammed plungers	Replace plungers.
	Jammed tappets	Replace tappets.
	Worn plungers	Replace plungers.
	Worn tappet cams	Replace tappet cams.
	Worn bearings	Replace bearings.
	Worn or broken plunger springs	Replace plunger springs.
	Loose plunger pinions	Reinstall properly by matching marks.
	Defective delivery valves	Replace valves.
	Worn or broken delivery valve springs	Replace valve spring.
Insufficient injection quantity	Governor stop lever link is binding.	Straighten link, placing lever in neutral position.
	Control rack is sticky.	Relubricate or repair.
	Jammed plungers	Replace plungers.
	Jammed tappets	Replace tappets.
	Worn plungers	Replace plungers.
	Worn tappet cams	Replace tappet cams.
	Worn bearings	Replace bearings.
	Loose plunger pinions	Reinstall properly by matching marks.
	Improper full-load setting of governor	Adjust governor setting on bench.
Excessive injection quantity	Stop lever jammed in "increase" position.	Repair lever link, placing lever in neutral position.
	Improper full-load setting of governor	Adjust governor setting on bench.
	Loose plunger pinions	Reinstall properly by matching marks.

Possible cause		Remedy
Improper fuel spray from injection nozzles	Sticking needle valve in one or more nozzles	Repair and replace nozzles if necessary.
	Damaged nozzle tip seats	Repair and replace seats if necessary.
	Worn or broken nozzle springs	Replace nozzle springs.
	Too low an injection pressure	Adjust pressure to 120^{+10}_{0} kg/cm^2 (1706.4^{+142}_{0} psi) on nozzle tester by inserting shim(s).
	Carbon deposited on packings at nozzle tips	Remove carbon.
Injection timing too advanced	Improper installation of fuel injection pump	Re-time properly by tilting injection pump away from engine.
	Incorrect installation of timing gears	Re-time timing gear train.
Injection timing too retarded	Improper installation of fuel injection pump	Re-time properly by tilting injection pump toward engine.
	Incorrect meshing of timing gears	Re-time timing gear train.
	Worn cams, tappets or bearings in fuel injection pump	Replace.
Poor grade of fuel		Use good-quality fuel.
	Water in fuel	Use good-quality fuel.
Low oil pressure	Lack of oil in oil pan	Add oil to prescribed level.
	Air in oil strainer	Replace damaged pipes or packings. Retighten loose connections if any.
	Defective oil pump	Repair.
	Clogged fuel lines	Clean.
	Defective oil pressure regulating valve	Repair and replace if necessary
	Clogged oil filter	Change element and oil.
	Leak in lubricating system	Repair.
Pumping up of oil	Excessive oil in oil pan	Drain oil to lower oil level.
	Worn cylinders, pistons or piston rings	Repair and replace parts if necessary
	Sticking piston rings	Repair and replace damaged rings if necessary.
	Worn valve guides	Replace valve guides.
	Prolonged operation under no load	Overhaul engine if oil-laden gases are exhausted.
Insufficient air	Clogged air cleaner (Paper element type)	Clean and replace element if
	Clogged air cleaner (Oil bath type)	Wash interior.
	Clogged intake manifold	Check and clean.

Possible cause		Remedy
Poor compression	Defective valve seats	Repair.
	Sticking valve stems	Repair and replace valve stems if necessary.
	Failure of rocker arms to lift valves	Adjust valve clearance to 0.25 mm (0.0098 in.).
	Worn cylinders, pistons or piston rings	Repair and replace parts if necessary.
	Sticking piston rings	Replace damaged rings.
	Exhaust gases leak through cylinder head gasket	Retighten and replace gasket if necessary.
	Worn or broken valve springs	Replace springs.
	Insufficient torque of starting motor (at starting)	Replace parts.
Insufficient coolant	Insufficient coolant	Add water to prescribed level.
	Overheating	
	Water leaks from unit seal of water pump	Replace seal.
	Crack in crankcase water jacket	Replace crankcase.
	Water leaks from other parts	Check and repair.
Failure of radiator to dissipate heat properly	Air in cooling system	Bleed air by loosening air bleed plug, drain plug, or hose clamp.
	Rust and scale deposited in radiator	Flush.
	Dust and dirt around radiator	Flush.
	Slippage of fan belt	Adjust belt tension.
	Inoperative thermostat (kept closed)	Replace.
Radiator dissipates heat excessively	Extremely low atmospheric temperature	
	Uncovered radiator	Cover radiator.
	Inoperative thermostat (kept open)	Replace.
Jammed moving parts	Sticking cylinders, pistons or piston rings	Repair and replace if necessary.
	Sticking main bearings and crankpin bearings	Repair and replace if necessary.
	Sticking cam bushing and idler bushing	Repair and replace if necessary.

SPECIAL SERVICE TOOLS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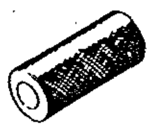
Ref. No.	Part number	Tool	Qt.	Used for:
1	34491-00400	Valve guide installer	1	Valve guide installation
2	31391-10500	Valve guide remover	1	Valve guide removal
3	31391-13010	Valve seat caulking tool (intake valve)	1	Valve seat installation and caulking
4	31391-13020	Valve seat caulking tool (exhaust valve)	1	Valve seat installation and caulking
5	30691-11100	Adaptor	1	Test pressure gauge installation
6	34491-00200	Piston guide	1	Piston installation
7	MH061077-01	Idler shaft puller	1	Idler shaft removal
8	30691-11800	Cranking handle	1	Engine cranking
9	34491-00300	Socket	1	Camshaft thrust plate removal and installation
10	34491-00100	Cylinder sleeve installer	1	Cylinder sleeve installation
11	30091-01101 or commercially-available	Universal extension	1	Injection pump removal and installation
12	31391-12900 or commercially-available	Piston ring tool	1	Piston ring removal and installation
13	64309-12900 or commercially-available	Puller assembly	1	Removal of crankshaft gear, camshaft gear, crankshaft pulley and water pump pulley
14	30091-07300	Idler bushing puller	1	Idler and camshaft bushing removal and installation
15	30891-04500 30891-04600	Adaptors	2	Idler and camshaft bushing removal and installation

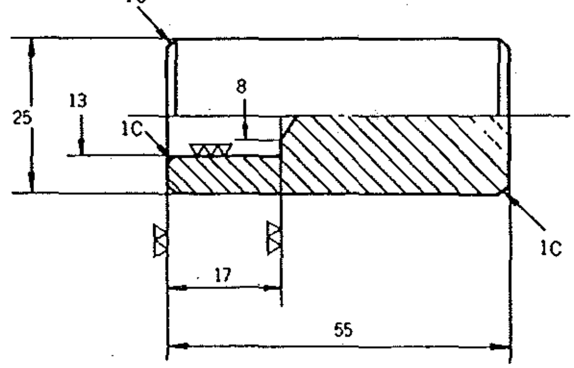
Tool application chart

	Part No.	Tool	Installing valve guides	Removing valve guides	Installing and caulking intake valve seat	Installing and caulking exhaust valve seat	Installing test pressure gauge	Inserting pistons into cylinders	Drawing out idler shaft	Turning over crankshaft	Installing and removing camshaft thrust plate	Installing cylinder sleeves	Tightening rocker bracket bolts (short)	Installing and removing fuel injection pump	Removing and installing piston rings	Removing crankshaft gear	Removing camshaft gear	Removing crankshaft pulley	Removing water pump pulley	Removing and installing idler shaft bushing	Removing and installing camshaft bushings when necessary
1	34491-00400	Valve guide installer	1																		
2	31391-10500	Valve guide remover		1																	
3	31391-13010	Valve seat insert caulking tool (intake valve)			1																
4	31391-13020	Valve seat insert caulking tool (exhaust valve)				1															
5	30691-11100	Adaptor					1														
6	34491-00200	Piston guide						1													
7	MH061077-01	Idler shaft puller							1												
8	30691-11800	Cranking handle								1											
9	34491-00300	Socket									1		1								
10	34491-00100	Cylinder sleeve installer										1									
11	30091-01101 or commercially-available	Universal extension												1							
12	31391-12900 or commercially-available	Piston ring tool													1						
13	64309-12900 or commercially-available	Puller assembly														1	1	1	1		
14	30091-07300	Idler bushing puller																		1	1
15	30891-04500 30891-04600	Adaptors																		1	1

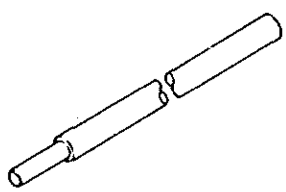
Valve guide installer and remover

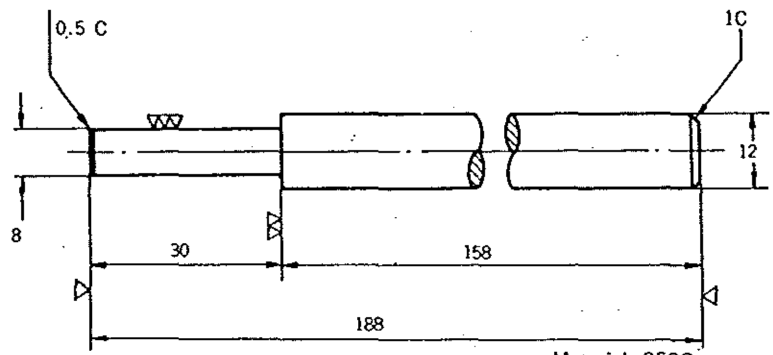
The installer is for use in driving the valve guide into the guide hole in such a way that the guide will take its prescribed position. The remover is for driving the guide out of the hole.





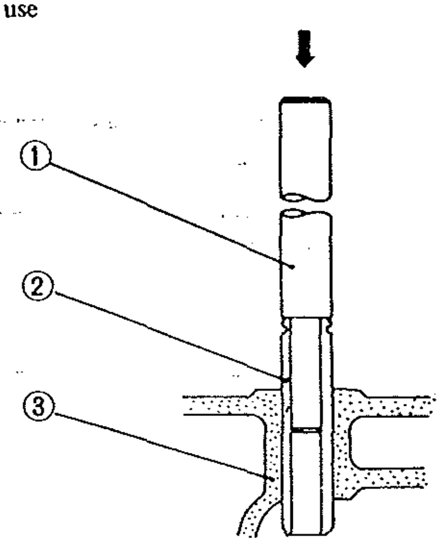
Valve guide installer (part number: 34491-00400)





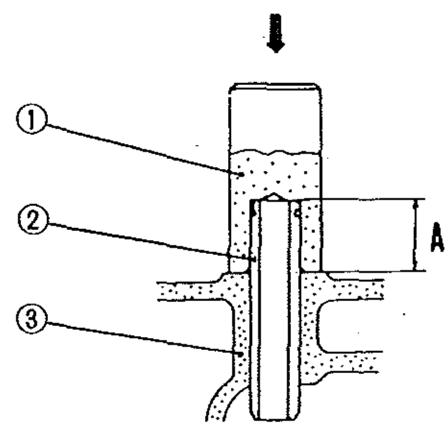
Valve guide remover (part number: 31391-10500)

How to use



1-Remover 3-Cylinder head
2-Valve guide

Removing valve guide

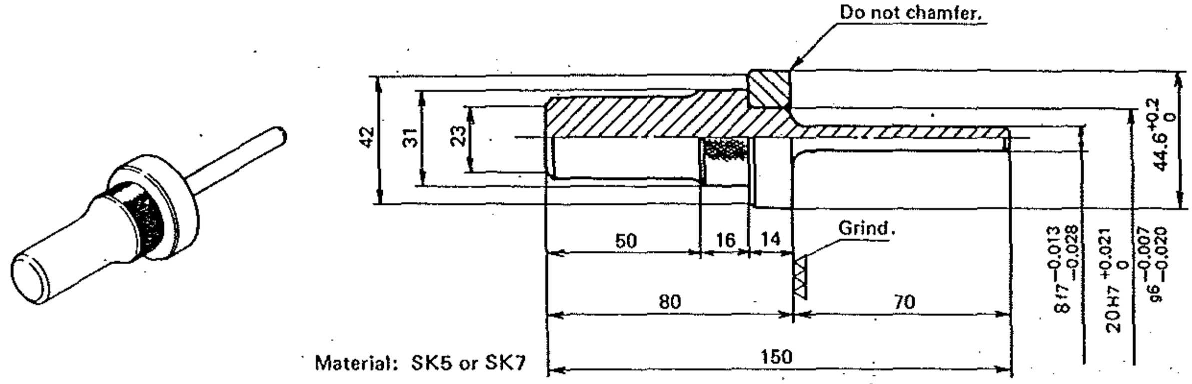


1-Installer 3-Cylinder head
2-Valve guide A-17mm (0.67 in.)

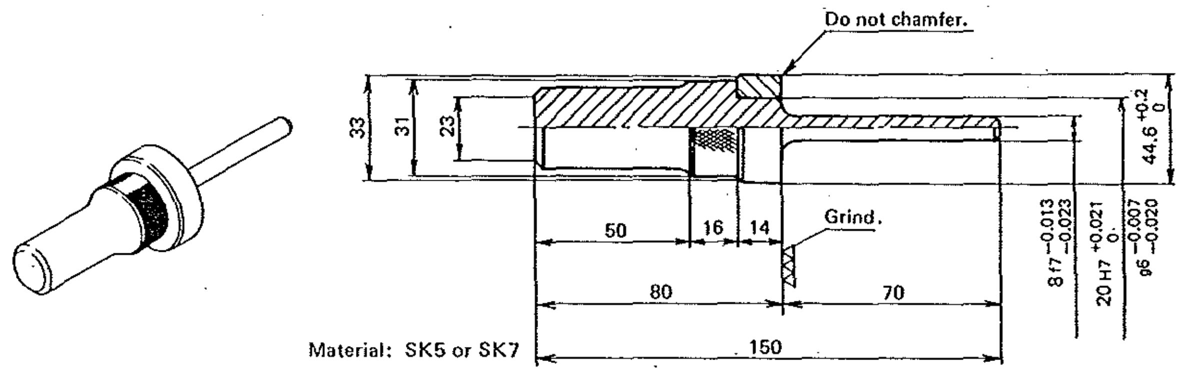
Installing valve guide

Valve seat caulking tools

These tools are for use in driving valve seat (2) into cylinder head (3) and, after fitting the valve, in caulking the peripheral edge of the valve. There are two caulking tools, one for intake valve and the other for exhaust valve. Each comes with a caulking ring, and is to be used in two directions, one for driving and the other for caulking.

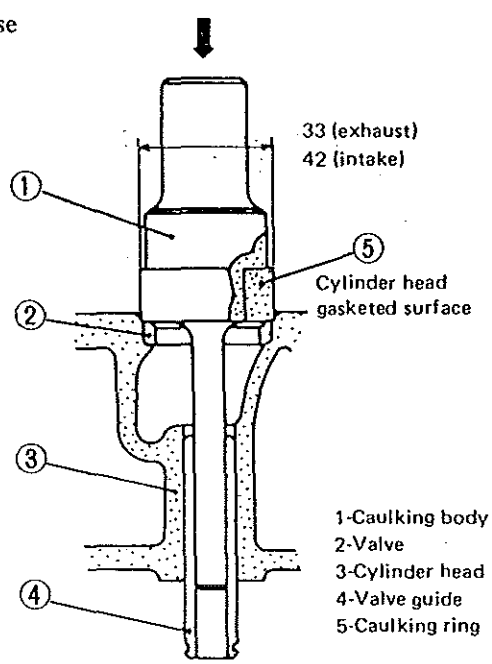


Valve seat caulking tool (intake valve) (part number: 31391-13010)



Valve seat caulking tool (exhaust valve) (part number: 31391-13020)

How to use

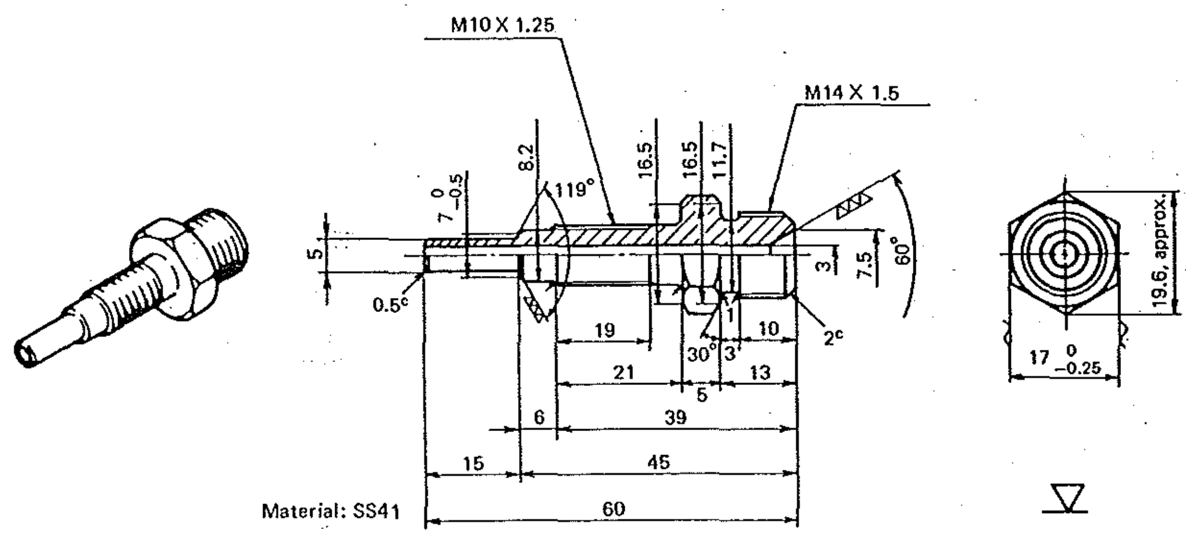


Installing and caulking valve seat

Ref. No.	Part number	Tool	
3	31391-13010	Valve seat caulking tool	(intake valve)
4	31391-13020	Valve seat caulking tool	(exhaust valve)

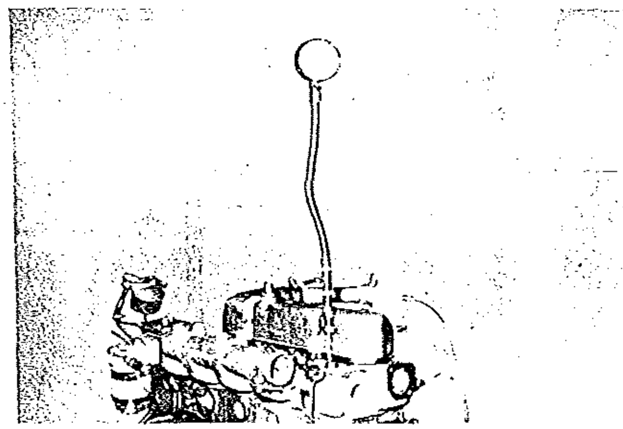
Adaptor

This is a connection fitting to be used in installing the test pressure gauge in the glow plug hole for the purpose of reading the compression pressure.



Adaptor (part number: 30691-11100)

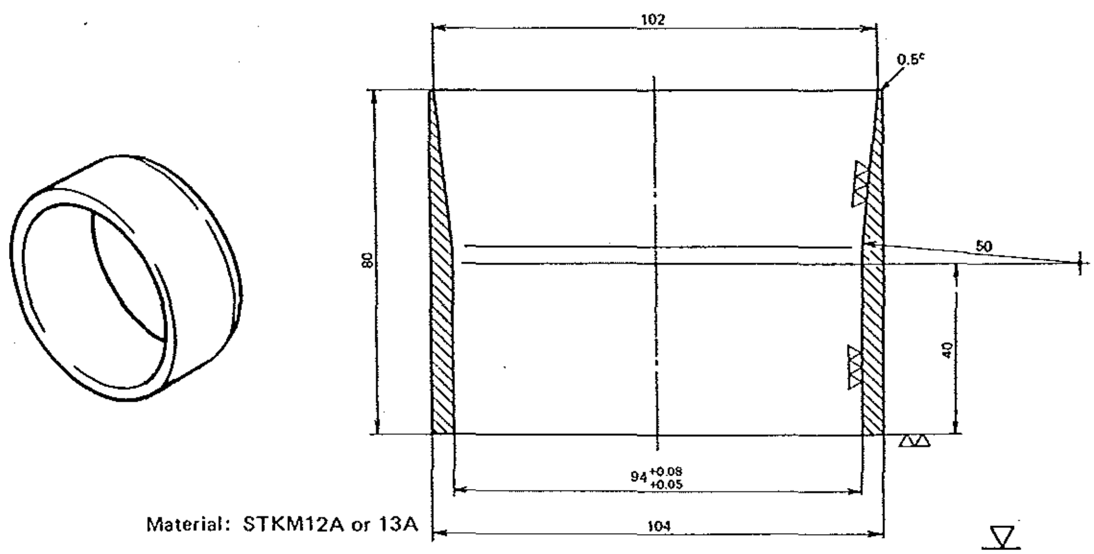
How to use



Test pressure gauge installed with the adaptor

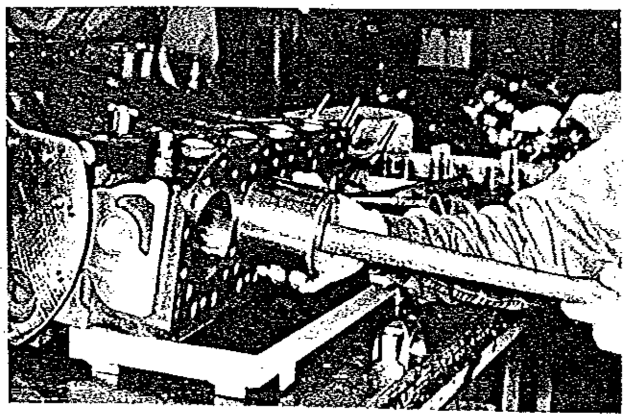
Piston guide

Use this tool when inserting the piston into cylinder. It protects pistons and piston rings against damage, and facilitates the feeding in of the piston.



Piston guide (part number: 34491-00200)

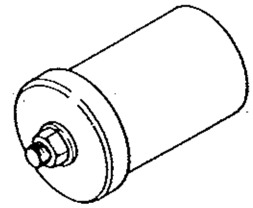
How to use

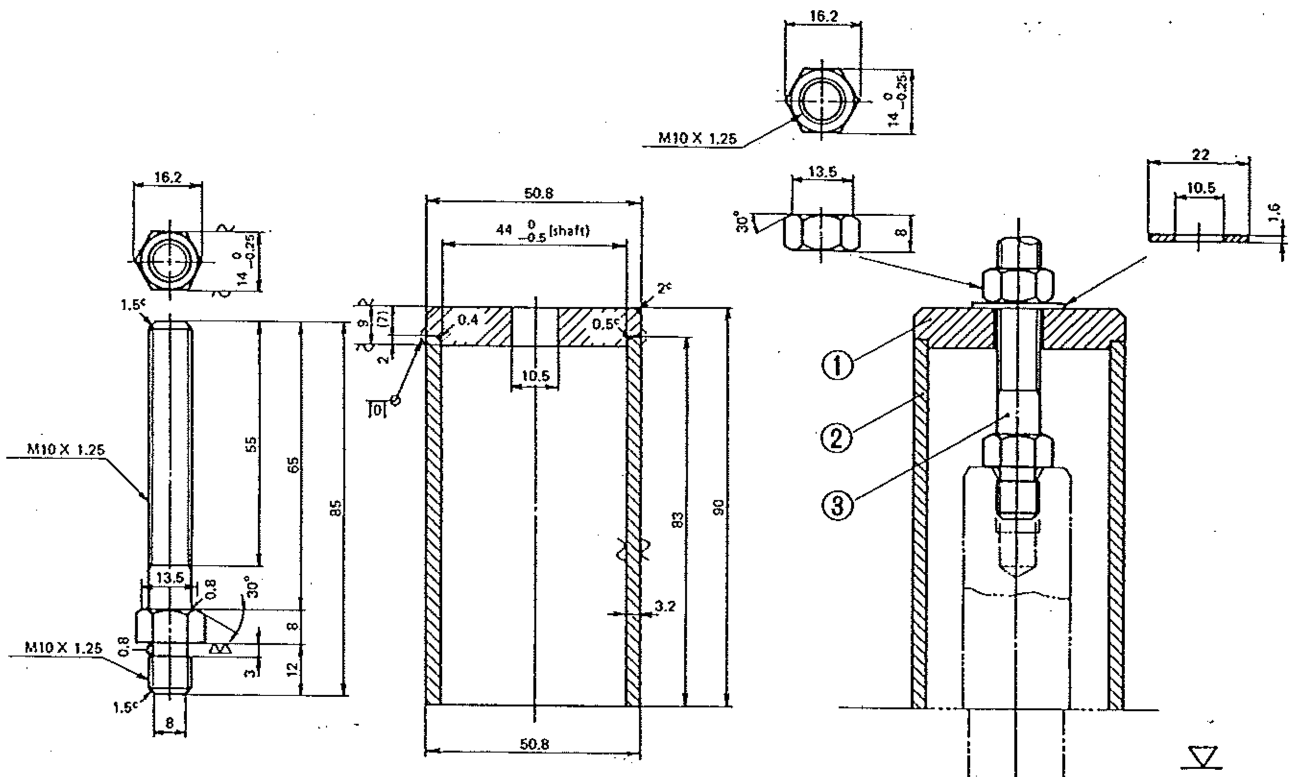


Inserting piston into cylinder

Idler shaft puller

For drawing out the idler shaft, one of the timing gear parts.





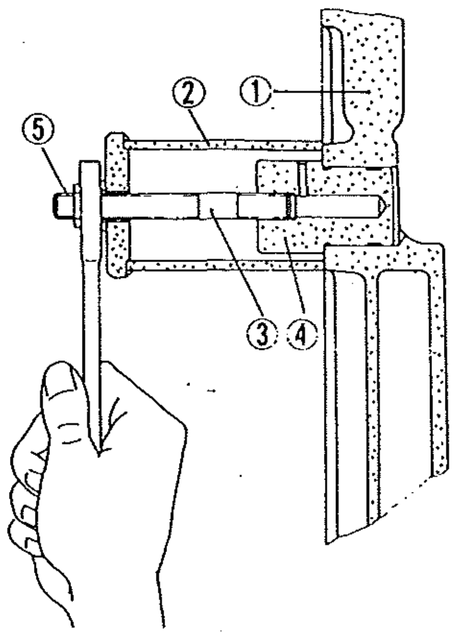
Detail 3 ▽
Material: S43C

Details 1, 2 ▽
Material:
1-STKM11A
2-SS00P

Idler shaft puller (part number: MH061077-01)

How to use

Set the puller over the idler shaft (4), run the stud (3) into the shaft, and drive nut (5) to force the shaft out by jacking action.

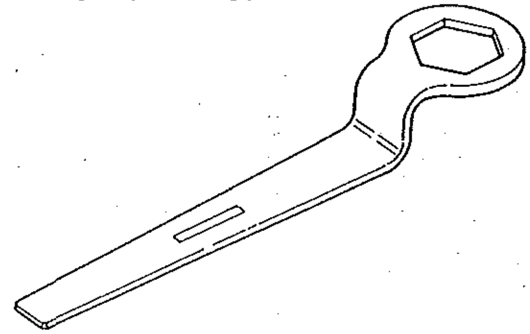


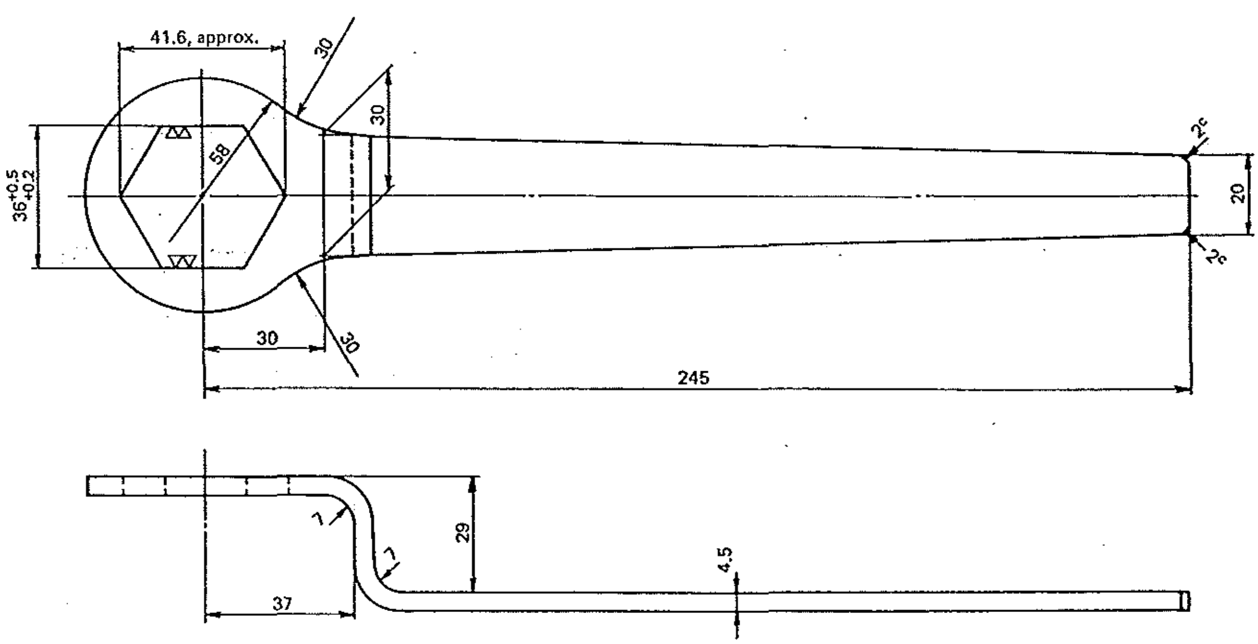
1-Crankcase
2-Puller
3-Stud (M10)
4-Idler shaft
5-Nut

Removing idler shaft

Cranking handle

This tool is for turning over crankshaft, as in valve clearance adjustment and others. Its hexagonal hole fits the crank pulley securing nut.

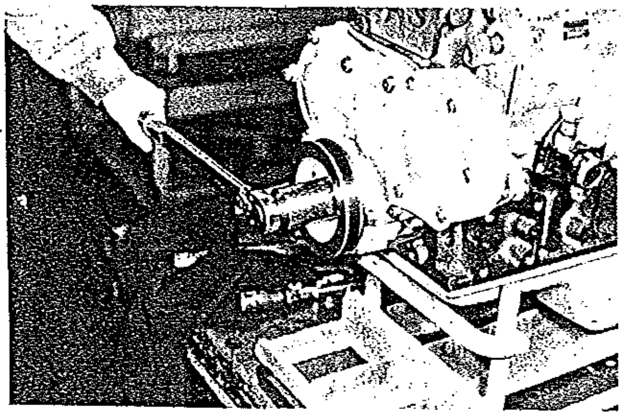




Material: SS41

Cranking handle (part number: 30691-11800)

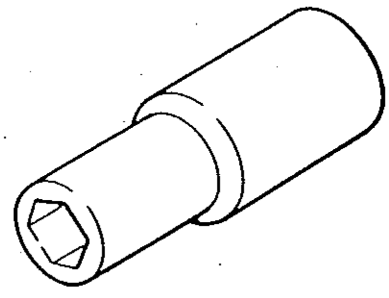
How to use

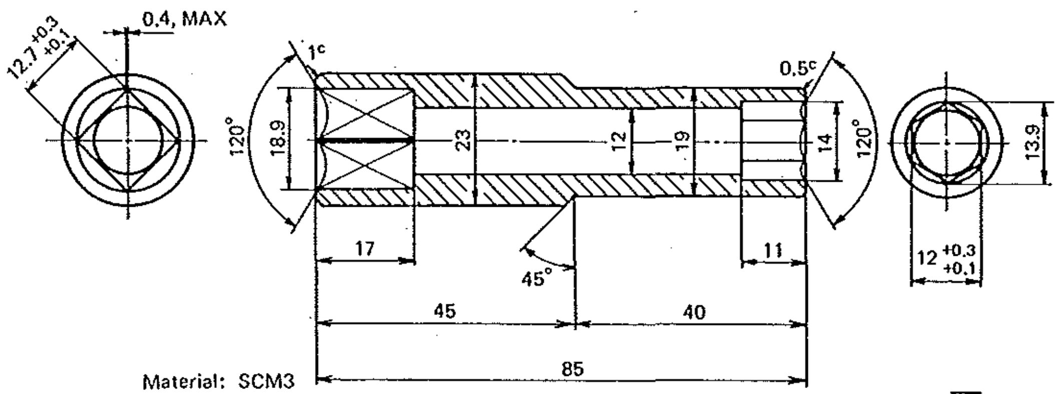


Turning over crankshaft

Socket

This tool is for use in tightening the bolts to secure the camshaft thrust plate (through the holes provided in camshaft gear), and also the shorter ones of the bolts for securing the rocker brackets. It can be used in torquing the glow plugs, too.

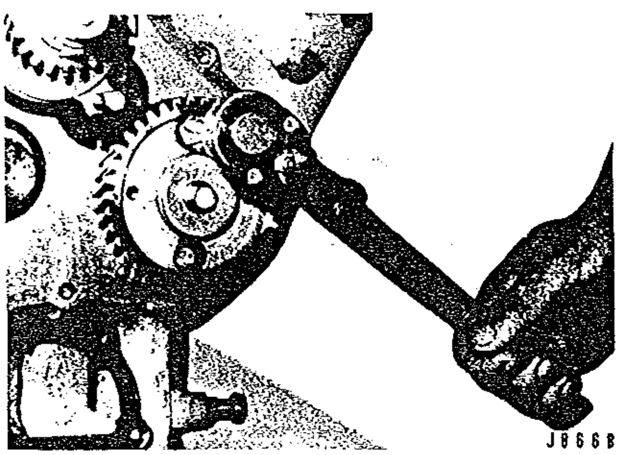




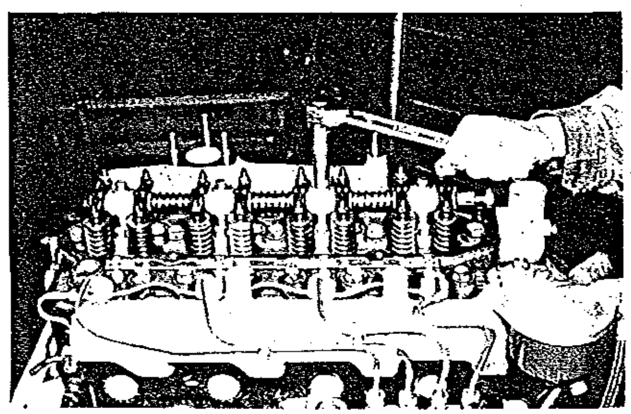
Material: SCM3

Socket (part number: 34491-00300)

How to use



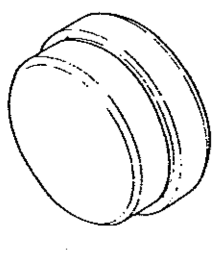
Securing the camshaft thrust plate

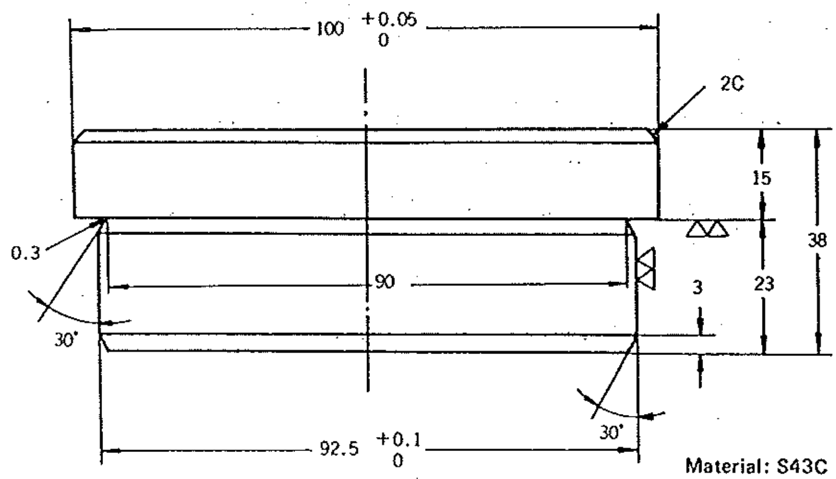


Tightening shorter bolt on rocker bracket

Cylinder sleeve installer

For use in driving replacement sleeve into the cylinder.

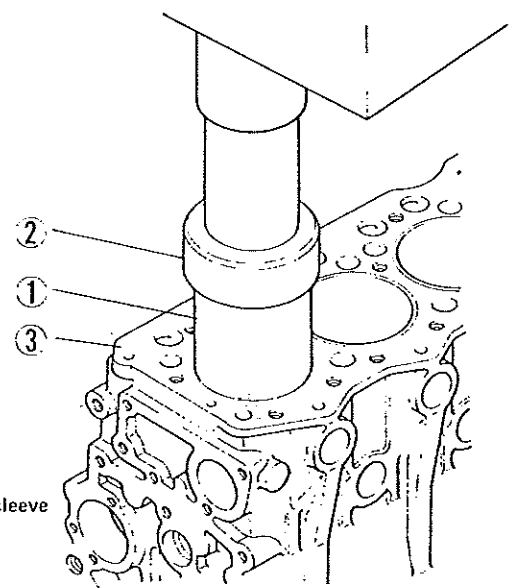




Cylinder sleeve installer (part number: 34491-00100)

How to use

Insert the sleeve installer (2) into sleeve (1), and push on the top end of the installer with a press arbor to force the sleeve into cylinder (3).

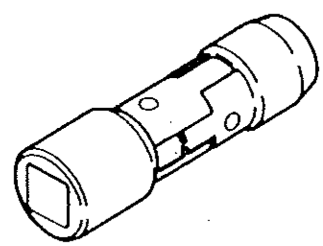


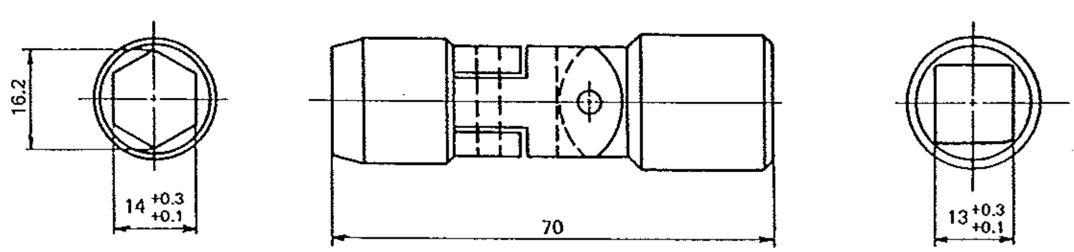
1-Cylinder sleeve
2-Installer
3-Cylinder

Pressing replacement sleeve into cylinder

Universal extension

The fuel injection pump unit is mounted on engine front plate, as secured by two bolts. This extension tool is for bringing the wrench head to these bolts.

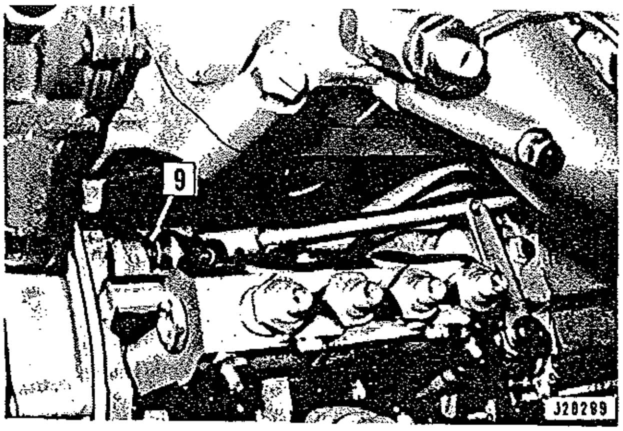




Material: SK7

Universal extension (part number: 30091-01101)

How to use

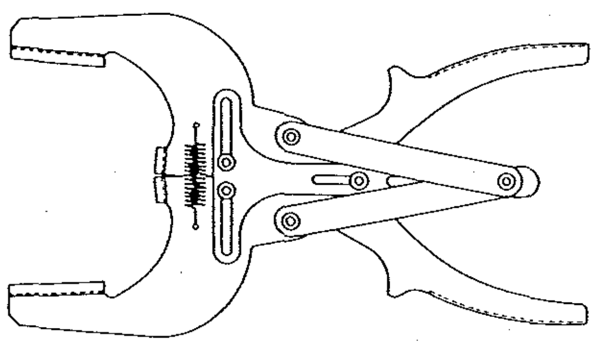


9-Bolt and washer

Tightening injection pump mounting bolts

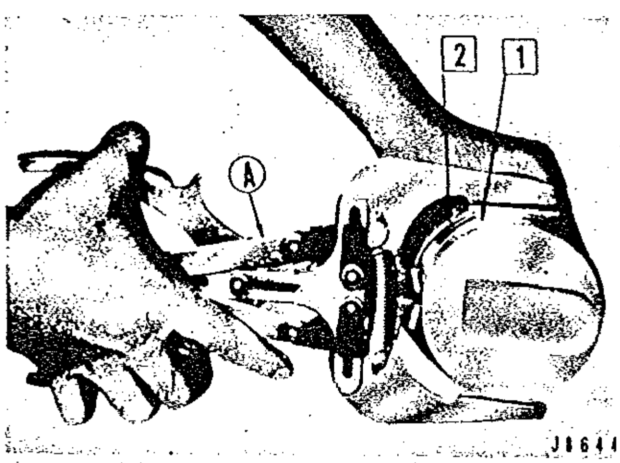
Piston ring tool

For use in fitting piston rings to and in removing them from the piston.



Piston ring tool (part number: 31391-12900)

How to use

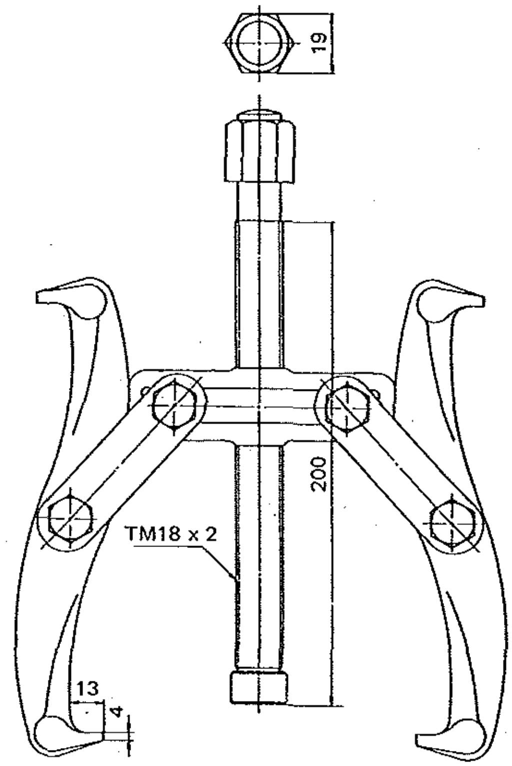


1-Compression rings
2-Oil ring
A-Piston ring tool

Removing piston rings

Puller assembly

For use in removing crankshaft pulley, water pump pulley, crankshaft gear, camshaft gear and injection pump gear.

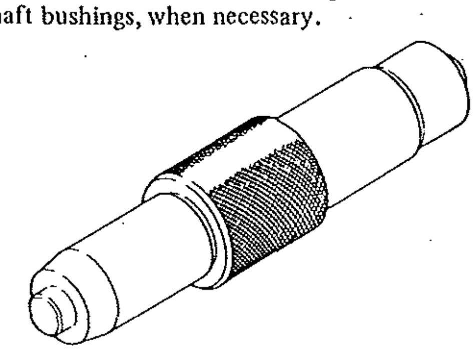


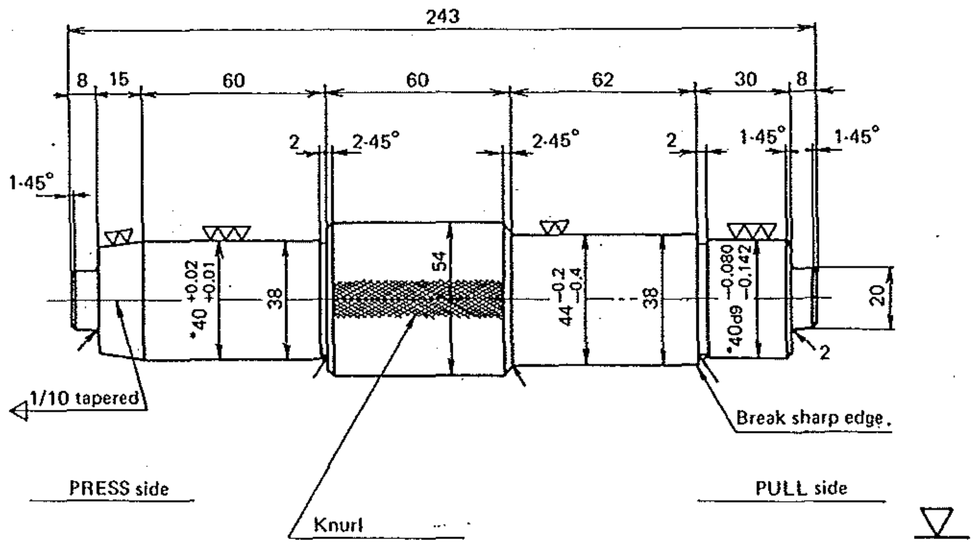
Size of pulley to clamp
Diam. (MIN) X Width (MAX)
40 mm X 110 mm
150 mm X 80 mm

Puller assembly (part number: 64309-12900)

Idler bushing puller

For use in removing and installing idler bushing and camshaft bushings, when necessary.





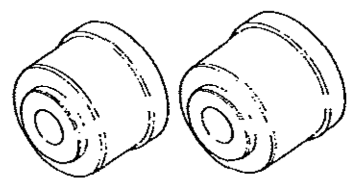
Material: SK7

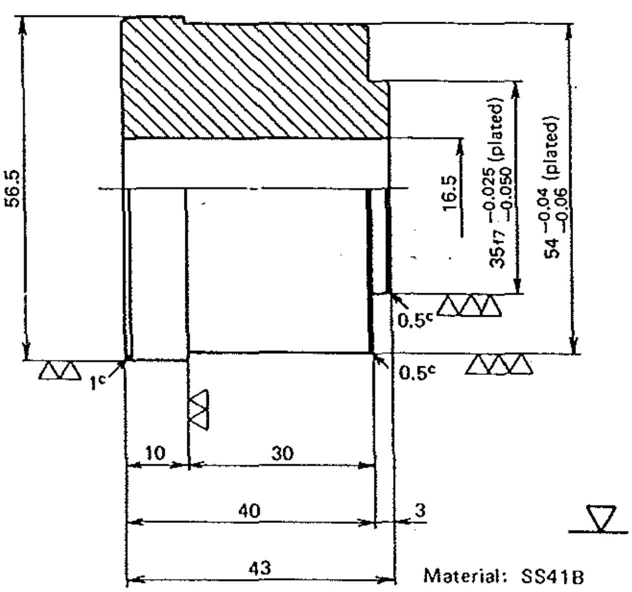
NOTES: 1. * indicates dimensions after plating.
2. Quench and temper (HRC 40 ~ 50).

Idler bushing puller (part number: 30091-07300)

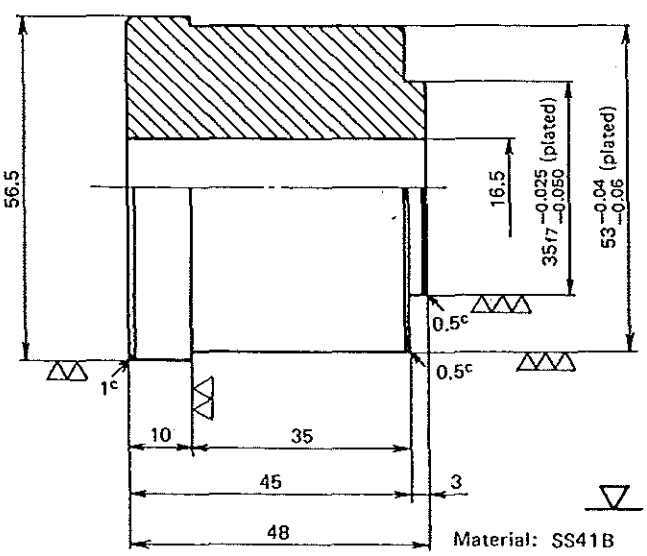
Adaptor

For use in removing and installing idler bushing and camshaft bushings, when necessary.





(part number: 30891-04500)



(part number: 30891-04600)

Adaptors

Printed in Japan

SERVICE MANUAL

MITSUBISHI
TRACTOR
TRACTOR SHOVEL

BD2F
BS3F

DIRECT POWERSHIFT TRANSMISSION

OPERATING PRINCIPLE
TESTING AND ADJUSTMENT
MAINTENANCE STANDARDS
DISASSEMBLY AND REASSEMBLY

MITSUBISHI
HEAVY INDUSTRIES, LTD.

FOREWORD

This service manual has instructions and procedures for the subject on the front cover. The information, specifications, and illustrations used in this manual are based on information that was current at the time this issue was written.

Correct servicing will give this machine a long productive life. Before attempting to start a test, repair or rebuild job, be sure that you have studied the respective sections of this manual, and know all the components you will work on.

Safety is not only your concern but everybody's concern. Safe working habits cannot be bought or manufactured; they must be learned through the job you do. By learning what CAUTION or WARNING symbol emphasizes, know what is safe – what is not safe. Consult your foreman, if necessary, for specific instructions on a job, and the safety equipment required.

NOTES, CAUTIONS and WARNINGS

NOTES, CAUTIONS and WARNINGS are used in this manual to emphasize important and critical instructions. They are used for the following conditions:

NOTE .... An operating procedure, condition, etc., which it is essential to highlight.

⚠ CAUTION .... Operating procedures, practices, etc., which if not strictly observed, will result in damage to or destruction of machine.

⚠ WARNING .... Operating procedures, practices, etc., which if not correctly followed, will result in personal injury or loss of life.

TABLE OF CONTENTS

OPERATING PRINCIPLE

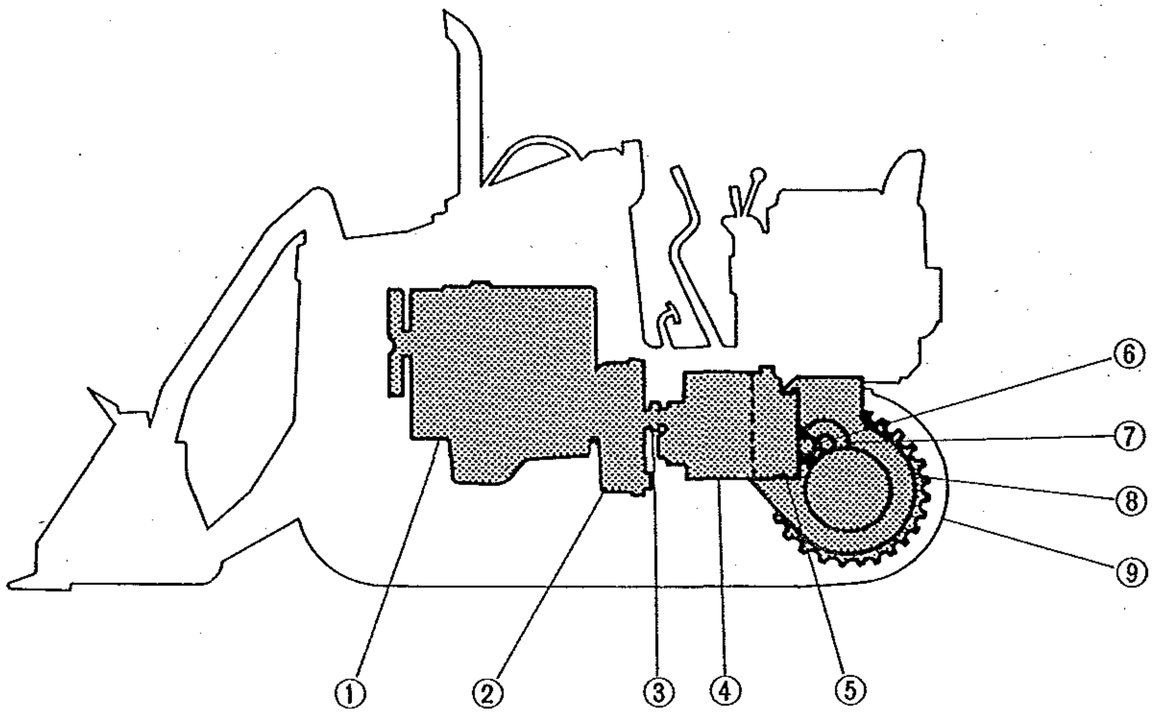
DESCRIPTION

Power developed by engine (1) is conveyed through damper (2) and propeller shaft (3) to transmission (4). In the transmission, power is modified in terms of speed and torque through the combination of multi-disc hydraulic clutches and planetary gears providing two forward speeds and two reverse speeds.

From the transmission output shaft, power flows to final drive gears (8), right and left, through single-stage-reduction transfer gear (5), bevel gear (6) and steering clutches (7), right and left. Two tracks (9) are driven by the final drive gears.

The engine and damper case are coupled together integrally. Four rubber mounts of anti-vibration sleeve type are used to support the engine at four places. Specifically, the engine crankcase rests on these mounts, two on each side.

The transmission and transfer gear are housed in a single case. This case is rigidly bolted to the front face of the steering clutch case.



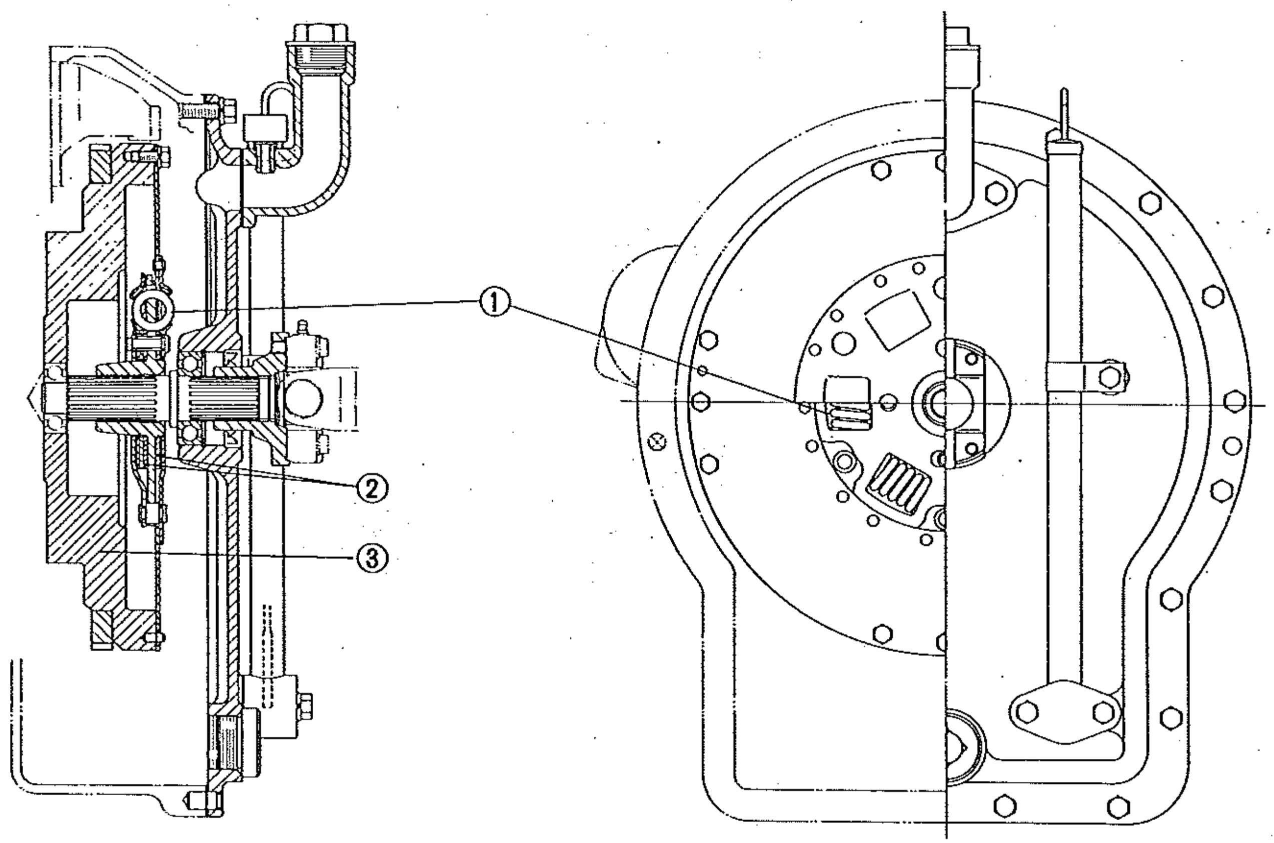
1-Engine
2-Damper
3-Propeller shaft
4-Transmission
5-Transfer gear
6-Bevel gear
7-Steering clutch
8-Final drive gear
9-Track

DAMPER

The damper resembles a conventional disc clutch; it has a hub splined to the shaft and a disc bolted to the flywheel and carrying friction plates (2) and coil springs (1).

Six coil springs (1), arranged in circular direction, are located between the disc and the friction plates (2) forming two sets, and serve to absorb torsional shocks.

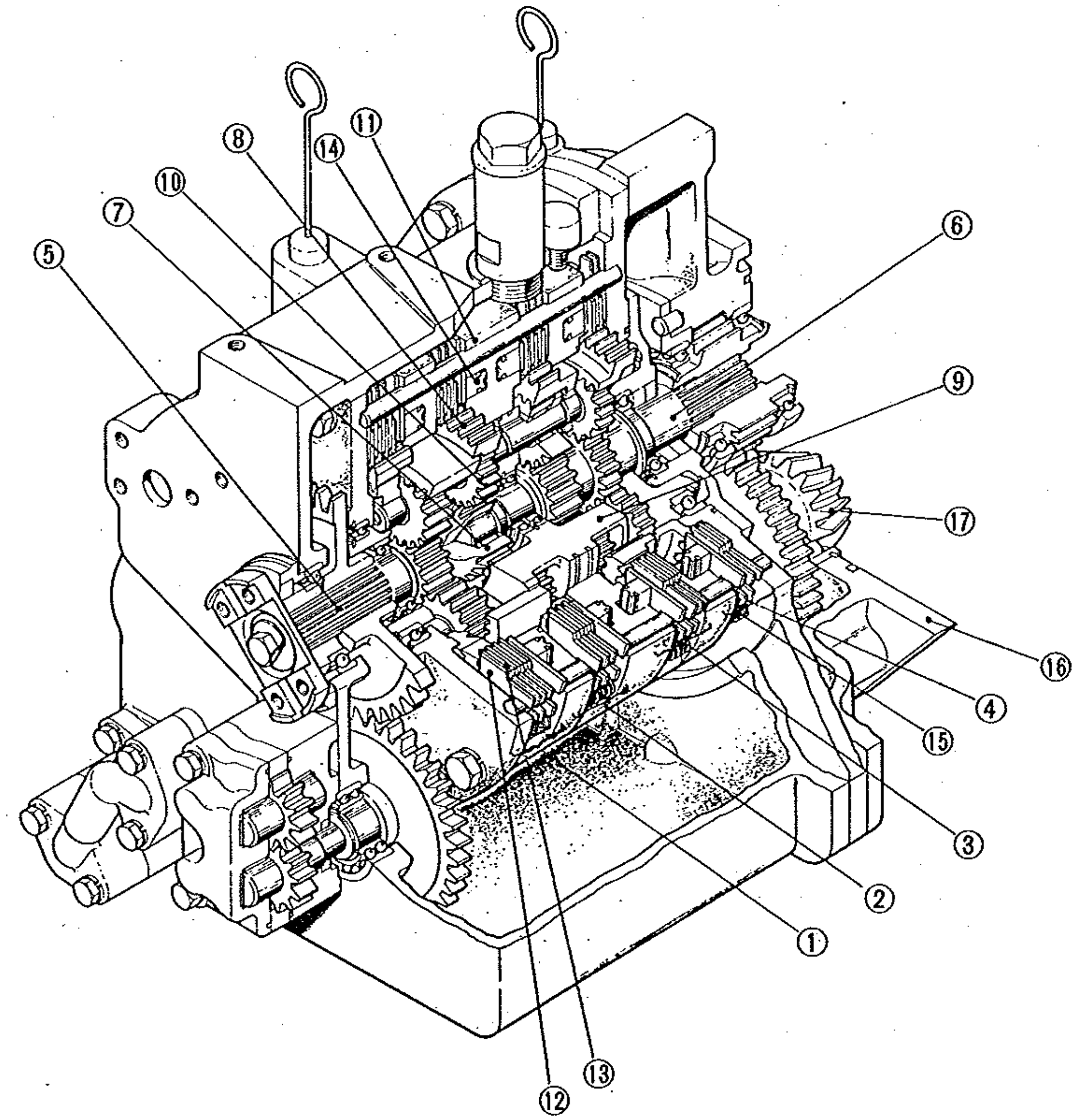
The shocks contemplated in the design of this damper come in two directions: from the engine as when the engine is quickly accelerated or decelerated and from the ground through the power line. By absorbing these shocks, the damper protects gears, bearings and shafts.



1-Coil spring 2-Friction plate 3-Flywheel

TRANSMISSION

The principal working parts of the transmission are four sets of epicyclic (planetary) gearing, each set being complete with a multi-disc hydraulic clutch, a control valve unit (not shown in the below cutaway view), an oil pump and filter, and two shafts (input and output).



1-REVERSE clutch	7-Sun gear	13-Mating plate
2-FORWARD clutch	8-Ring gear	14-Piston
3-SECOND (high) clutch	9-Carrier	15-Return spring
4-FIRST (low) clutch	10-Planet gear	16-Transfer gear
5-Input shaft	11-Housing	17-Bevel pinion gear
6-Output shaft	12-Friction plate	

Operation

To understand how power flows from input shaft to output shaft in the transmission, it is necessary to bear in mind the relative motions of the sun gear, planet gears or pinions and ring gear.

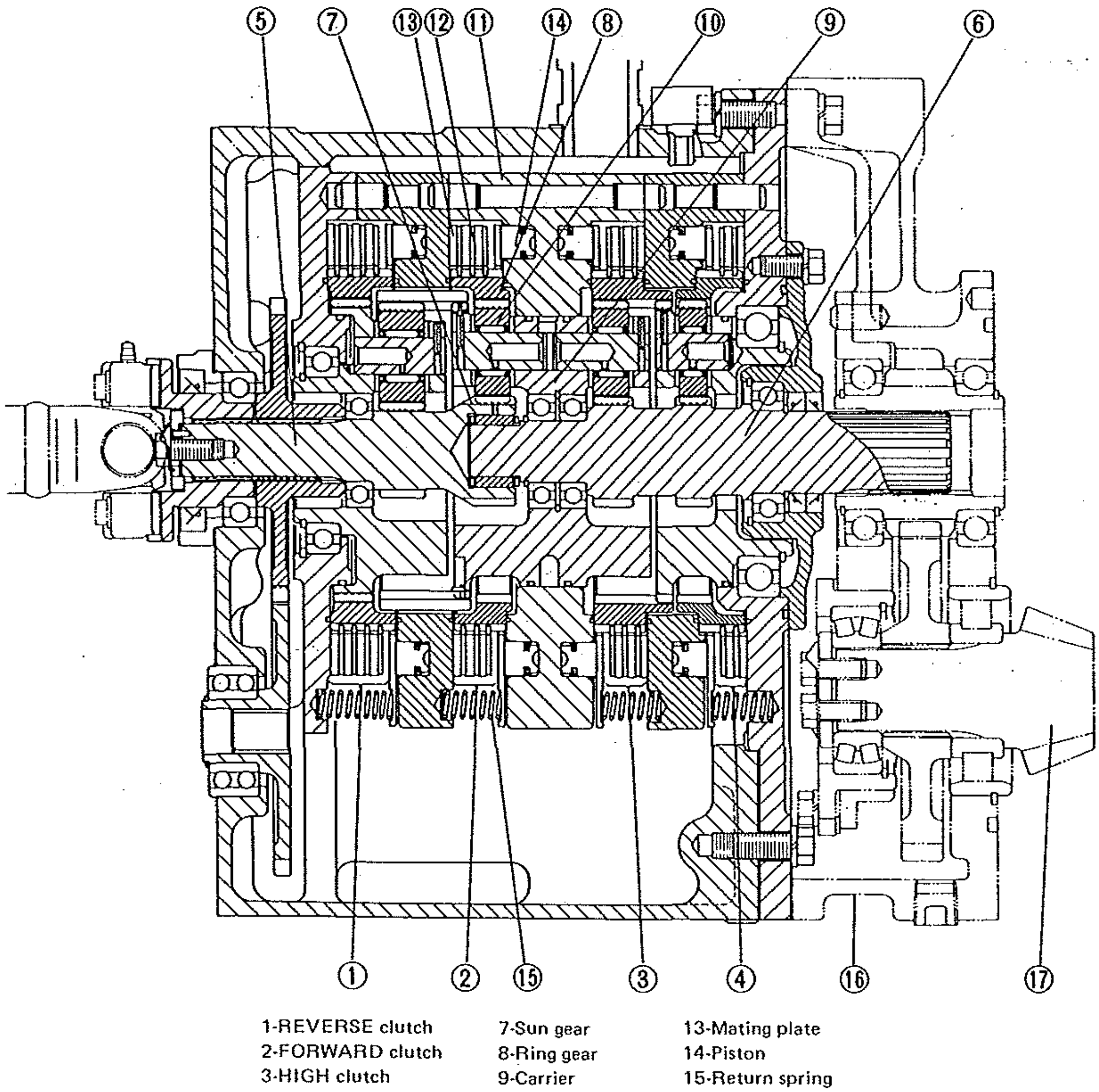
The sun gear rotates; the carrier revolves; and the planet gears rotate on their own shafts or pins and revolve with the carrier, on which they are mounted.

(1) With the sun gear driving the planet gears, the carrier revolves in the direction of sun gear rotation if the ring gear is held standstill. In other words, the directions of carrier and sun gear are the same.

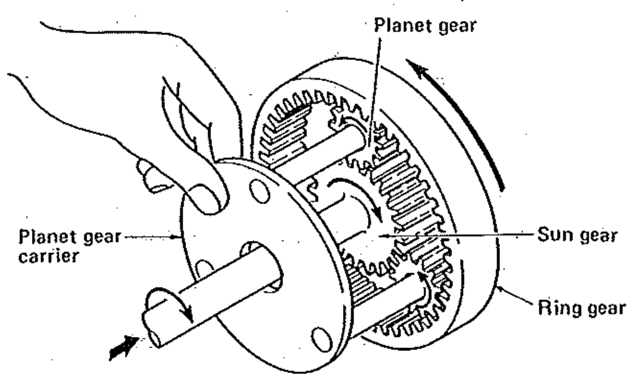
(2) If the carrier is held standstill, the ring gear revolves counter to the direction of sun gear rotation.

There are four sets of planet gears, three for each set. There are five ring gears, of which one is a link between REVERSE planet gears and FORWARD carrier. FORWARD carrier and HIGH carrier may be regarded as constituting a single integral piece. HIGH ring gear links HIGH planet gears to LOW carrier.

In the clutch, friction plates are engaged with external splines of the ring gear, and mating plates (stationary) with internal splines of the housing. The pressure plate is next to the piston.



1-REVERSE clutch
2-FORWARD clutch
3-HIGH clutch
4-LOW clutch
5-Input shaft
6-Output shaft
7-Sun gear
8-Ring gear
9-Carrier
10-Planet gear
11-Housing
12-Friction plate
13-Mating plate
14-Piston
15-Return spring
16-Transfer case
17-Bevel pinion gear



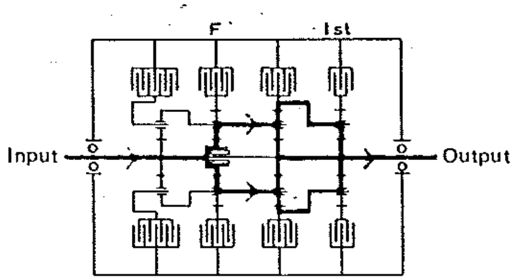
Planet gearing in reverse operation

The longitudinal cross section of the transmission, shown above, serves to explain the flow of power for FORWARD LOW drive. Assume that input shaft (5) is running. FORWARD and LOW clutches are engaged, so that their ring gears are seized and do not revolve. Sun gear (7) will drive pinions (10) and, since ring gear (8) is seized, carrier (9) will revolve in normal direction (which is the same as that of sun gear).

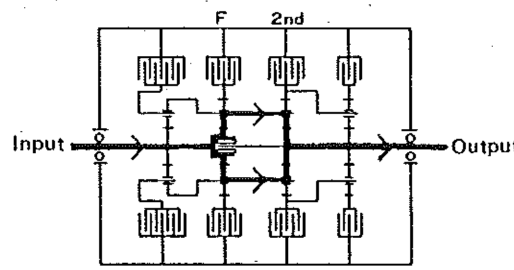
Carrier (9), HIGH pinions, HIGH ring gear (free) and LOW carrier revolve together, in the direction of input shaft. Since LOW ring gear is seized, LOW pinions have to "walk" on the internal teeth of this ring gear; they rotate on their own pins. By this rotation, they necessarily drive LOW sun gear on output shaft. Consequently, output shaft rotates in the direction of input shaft but with a reduced speed.

If HIGH clutch is engaged, instead of LOW clutch as above, HIGH ring gear remains standstill, so that HIGH (2nd) pinions have to drive HIGH sun gear on output shaft. By the same token, output shaft runs in the direction of input shaft but with a slightly higher speed than before (FORWARD LOW).

The two modes of power flow just explained are schematically shown in these diagrams:

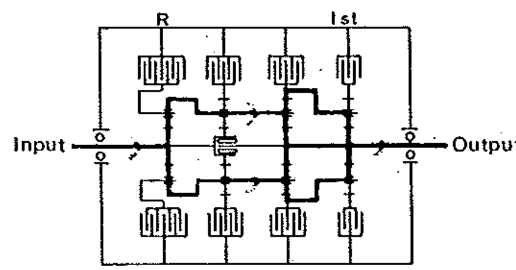


FORWARD LOW drive

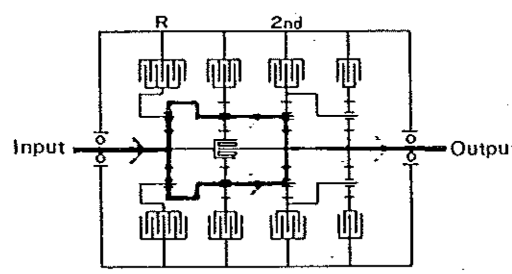


FORWARD HIGH drive

Let's see what happens if REVERSE clutch is engaged (with FORWARD clutch disengaged), with input shaft running as before. In this case, REVERSE carrier is now seized and remains standstill. Its pinions meshed with linking ring gear drive FORWARD carrier (9) in reverse direction. Why reverse? Recall rule (2). What were said of HIGH and LOW planetary gear sets in connection with FORWARD drive apply to REVERSE drive.



REVERSE LOW drive



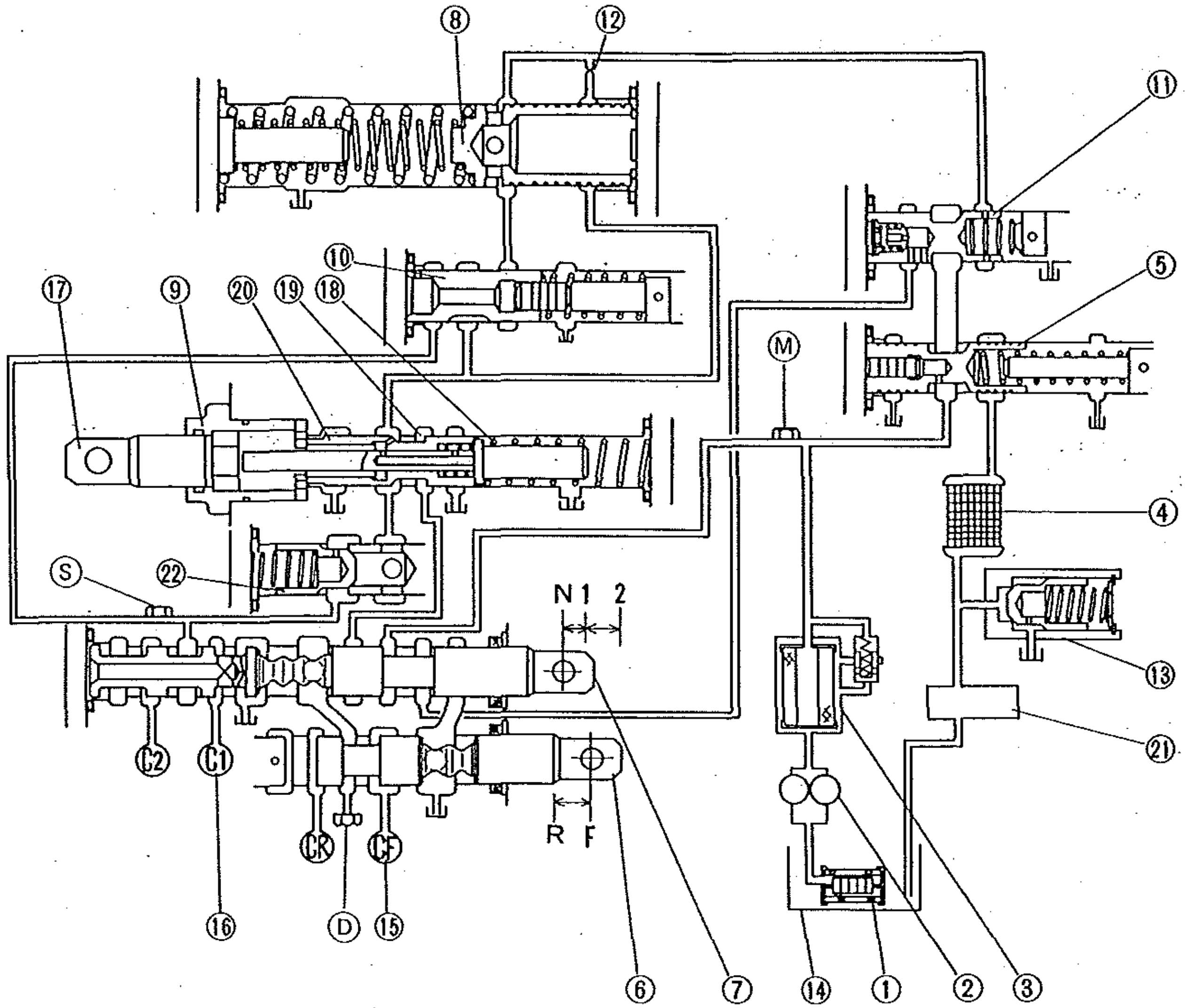
REVERSE HIGH drive

Note that the inner end of output shaft is piloted in input shaft. The outer end of output shaft carries the transfer pinion meshed with the transfer gear, which is splined to the shank of bevel pinion.

"To engage the clutch" is to admit, through the control valve, pressurized oil into the chamber back of the piston. By the admitted oil, the piston pushes on its pressure plate to compact the friction plates and mating plates together. "To disengage the clutch" is to relieve this pressure; when the pressure is removed from the piston, return springs push the piston back to loosen the stack of plates.

How the pressurized oil is selectively directed by the control valve unit to the respective transmission clutches is the main point of the subsequent topic.

Hydraulic control circuit for the transmission



1-Strainer with magnet
2-Oil pump
3-Oil filter
4-Oil cooler
5-Main relief valve
6-Directional selector valve
7-Speed selector valve
8-Accumulator valve
9-Clutch valve
10-Pilot valve
11-Safety valve
12-Main orifice
13-Lubrication relief valve
14-Transmission oil pan
15-FORWARD clutch piston chamber
16-LOW clutch piston camber
17-Clutch valve plunger
18-Return spring
19-FORWARD-REVERSE oil port
20-Clutch valve spool
21-Lubrication circuit
22-Check valve

Hydraulic circuit diagram

Oil filter (3) is installed on the front face of transmission case. If the differential pressure across its element rises to and above 2.0 kg/cm^2 (28.4 psi), a warning lamp lights up and the bypass circuit opens to pass the oil around the element, thus ensuring the adequate oil supply to the control valve unit.

Oil pump (2) is driven from transmission input shaft; it is mounted on the front end of transmission case.

The control valve unit comprises main relief valve (5), directional selector valve (6), speed selector valve (7), accumulator valve (8), clutch valve (9), pilot valve (10) and safety valve (11).

Oil cooler (4) is located at the lower section of the radiator.

Before we go into the discussion of the functional aspects of control valve unit, it may be proper to take note of the purposes served by main components of control valve unit.

MAIN RELIEF VALVE (5): Discharge pressure of oil pump is limited by this valve.

ACCUMULATOR VALVE (8): The rise of oil pressure in the clutch piston chamber upon shifting the control lever is cushioned by this valve to smoothen clutch engagement.

CLUTCH VALVE (9): Oil pressure in the piston chamber of an engaged clutch is reduced by means of this valve when inching action is desired. This valve helps the engine avoid stalling in the event of overloading or quick halting.

PILOT VALVE (10): This valve directs the full discharge flow from oil pump to directional selector valve (6) to improve the response of clutch valve (9).

SAFETY VALVE (11): It is by this valve that the engine is prevented from starting up if the transmission control lever is in LOW (FIRST) or HIGH (SECOND).

Gear shifting

"Gear shifting" may be a wrong term for this DPS transmission for the selective cutting-in of epicyclic gear sets is accomplished by selectively engaging hydraulic clutches, but the term will be used to conform to convention.

How the valves mentioned above operate will be described on the assumption that the control lever is shifted into FORWARD LOW from neutral. We will start out with the building up of normal oil pressure in the circuit.

As the engine starts up (with speed selector valve (7) in neutral position), oil pump (2) begins to deliver oil. This oil (actually oil pressure) reaches selector valve (7) through filter (3), relief valve (5), safety valve (11), main orifice (12), accumulator valve (8) and clutch valve (9).

As the pressure builds up in this path, accumulator valve (8) moves to the end of its stroke against the force of springs: this action is equivalent to pressure accumulation. Consequently, pilot valve (10) moves against its spring to form a circuit bypassing the main orifice (12).

If the pressure rises to and above 20 kg/cm^2 (284 psi), relief valve (5) bleeds out the excess pressure, spilling the oil out toward the oil pan (14) through oil cooler (4). Similarly, if the pressure in the lubrication circuit (21) rises to and above 1.4 kg/cm^2 (20 psi), relief valve (13) operates to relieve the excess pressure, thus preventing an excessive oil flow in the lubrication circuit.

Now, we operate the control lever to shift selector valve (6) into FORWARD and selector valve (7) into LOW. The moment the lever is so shifted, the pressure accumulated in valve (8) applies through clutch valve (9) and a port of valve (7) to piston chambers (15) (16) designated as (CF) and (C1), respectively.

Following this, the spring pushes back accumulator valve (8), so that the oil flows through the oil hole provided in valve (8) and direct into the piston chambers, thereby expediting the pressure build-up in these chambers: this may be spoken of as "rapid filling up of the piston chambers with oil."

[With the pushing back of valve (8), pilot valve (10) too yields to its spring force and moves back to block the circuit bypassing main orifice (12).]

As chambers (15) (16) get filled up, pressure begins to rise again to force valve (8) to push its spring. Consequently, the path of oil changes in this valve: instead of flowing through the bypass oil hole, the oil starts flowing through main orifice (12). Because of "throttling action" of this orifice, the final pressure build-up in the piston chambers is slowed down: this action is spoken of as "modulation." In each clutch, the piston exerts the initial engagement force with this "modulated" pressure.

The clutches are now fully engaged. Accumulator valve (8) moves farther to the end of its stroke and, concurrently, pilot valve (10) compresses its spring and, by this compression movement, opens the bypass circuit to apply the full main pressure to the clutch pistons. Thus, the clutches become fully engaged to seize and hold FORWARD ring gear and LOW ring gear: power now begins to flow in the manner illustrated in the "FORWARD LOW drive" diagram.

To summarize, oil pressure is applied to the piston chamber in three steps: 1) Full-flow oil is supplied to the piston chamber (to result in a drop in main pressure); 2) the subsequent pressure build-up in the chamber is "modulated" or slowed down as the clutch begins to engage fully; and 3) full main pressure applies to keep the clutch engaged. This sequence holds true for the other three modes, too, of shifting, namely, FORWARD HIGH, REVERSE LOW and REVERSE HIGH.

Inching operation

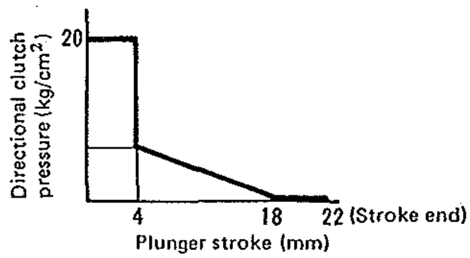
Clutch plunger (17) is connected to the clutch pedal. An inching operation (for driving the machine extremely slowly) is controlled by means of this plunger to reduce the pressure in the FORWARD or REVERSE clutch chamber, without affecting the main pressure applying to the HIGH or LOW clutch chamber. How this is accomplished will be explained by assuming that both FORWARD clutch and LOW clutch are in full engagement (in sequel to the foregoing description of "gear shifting" to FORWARD LOW).

As you push inward plunger (17) against its spring, spool (20) begins to throttle port (19). (This port is for FORWARD and REVERSE clutches.) At the same time, plunger (17) opens its drain port, so that the pressure in FORWARD clutch chamber leaks out. By throttling port (19) and opening the drain port more or less, you can control the chamber pressure within the range from 5 kg/cm^2 (71 psi) down to 0 kg/cm^2. This is for permitting clutch plates to slip more or less.

Consider speed selector valve (7) under this condition: this valve is on the upstream side of clutch valve spool (20). For this reason, the above movement of clutch valve (9) due to the actuation of plunger (17) does not affect the full main pressure applying to LOW clutch chamber, so that this clutch remains engaged.

If you should depress the clutch pedal all the way, port (19) becomes closed and, with the drain port wide open, the pressure in FORWARD clutch chamber falls to zero, thereby disengaging this clutch. Under this condition, the flow of power through the transmission is interrupted.

This graph illustrates the change in a directional clutch chamber (FORWARD or REVERSE) pressure as a function of plunger (17) stroke.



Clutch valve characteristic

The graph tells that, if the plunger is pulled out (by releasing the clutch pedal), the chamber pressure will jump from 4 to 20 kg/cm^2 (57 to 284 psi) (full main pressure). This rise (which is needed when you want to quickly re-engage the clutch) occurs when plunger (17) is quickly pulled out, because the bypass circuit through accumulator valve (8) and pilot valve (10) is wide open. The moment the plunger moves out, the full main pressure applies through this bypass circuit to FORWARD clutch chamber. If, on the other hand, plunger (17) is slowly pulled out, valve (8) and valve (10) jointly perform "modulation," as explained before, to allow the clutch to engage gradually.

Safety interlock between engine starting and transmission

The function of safety valve (11) built in the control valve unit is to prevent the machine from rolling off upon starting up the engine when the transmission control lever is off neutral. Were it not for this feature, the machine could suddenly jerk in standing position as the engine is started up.

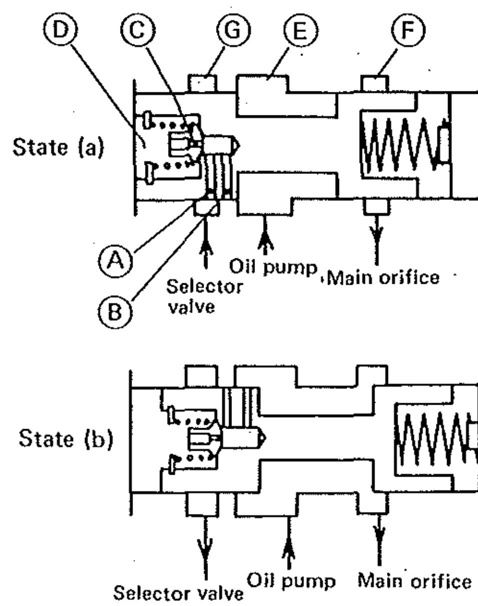
Note the schematic (a), in which safety valve (10) is shown in "blocking" state, the state prior to the starting up of the engine. Ports (E) and (F) are not in communication, so that the oil pump discharge pressure does not reach the main orifice (12). In other words, the pressure for engaging the directional and speed clutches is not available to the selector valves (6) (7). Port (G) is communicated to one of the ports of speed selector valve (7).

Starting up the engine (with the control lever in any of the operating position) results in a rise of pressure in the line (from oil pump) to port (E). As you shift the control lever back to neutral, selector valve (7) displaces itself to neutral position, and communicates the oil pump discharge line to port (G) through its ports. Oil pressure thus applied to port (G) pressurizes the chamber (D) through orifice (A) and check valve (C). Consequently, the valve shifts into state shown in the schematic (b).

In the new state, port (E) and port (F) are communicated so that the pump discharge pressure applies to the selector valves (6) (7) through the normal path. The transmission can now be controlled in the usual manner.

Shifting the control valve to an operating position (with the engine running in the normal manner) displaces the selector valve (7) and bleeds out the pressure applying to port (G), but safety valve (11) remains in state (b) because its check valve (C) stays seated to trap the pressure in chamber (D), to which the pressure in port (E) applies through orifice (B). It will be seen that, as long as the pump is running, safety valve (11) stays in state (b).

After the engine is shut down, it takes some time for safety valve (11) to return to state (a) from state (b). Re-starting the engine immediately or re-starting before valve (11) has returned to state (a) is liable to jolt the machine because of the connection explained above. This means that the transmission control lever should be shifted back to neutral before stopping or re-starting the engine.



Safety valve operation

TESTING AND ADJUSTMENT

TROUBLESHOOTING

Trouble in the DPS transmission shows up in one or more symptoms. What symptoms to contemplate and how to cope with each are tabulated in TROUBLESHOOTING GUIDE.

In the "Remedy" column of the TROUBLESHOOTING GUIDE, suggested measures are in many cases disassembly, repair, replacement, or adjustment, or any combination of these. These measures are meaningful only when the serviceman is versed with various methods of testing and inspection. Along the line of this thought, the methods of tests and adjustments are annexed to the GUIDE to cover 1) DPS transmission proper, 2) control valve unit, 3) transmission oil pump, 4) steering clutch and brake control, 5) clutch pedal and 6) DPS control lever.

Troubleshooting guide

Symptom	Possible cause	Remedy
Drive is lost on one or more gears.	A. Low oil pressure.	
	1) Not enough oil in the oil pan.	1) Refill.
	2) Loose, broken or maladjusted control linkage.	2) Repair or readjust.
	3) Damaged oil pump.	3) Overhaul or replace.
	4) Air is being sucked into pump.	4) Check packed joint in pump suction and repair or replace.
	5) Internal oil leakage in control valve unit due to wear or failure of sealing members such as piston seals and "O" rings.	5) Disassemble and repair or replace defective parts.
	6) Main relief valve is internally dirty with alien matters stuck in sliding clearance, or is out of adjustment.	6) Overhaul. Correct its pressure setting.
	7) Oil is too low in viscosity.	7) Use Class CD oil (engine oil) of API classification, whose viscosity rating is SAE 10W.
	B. Mechanical failure.	
	1) Broken transmission shaft.	1) Disassemble and replace.
	2) Seized or bound clutch piston, friction plates or mating plates, resulting in reduced clutch capacity.	2) Disassemble, repair or replace.
	C. Malfunctioning neutral safety valve.	Overhaul or replace.
Transmission clutches grab, resulting in jumping start or jolt on gear shifting.	1) Accumulator valve is not working as it should.	1) Disassemble and repair or replace.
	2) Pilot valve is malfunctioning.	2) Disassemble and repair or replace.
	3) Oil viscosity is too high.	3) Use SAE 10W oil.
Slow standing start or slow response of transmission to shifting.	1) Clogged orifice in control valve unit.	1) Disassemble and clean.
	2) Not enough oil in the oil pan.	2) Refill.
	3) Control linkage out of adjustment.	3) Readjust.
	4) Air is being sucked into oil pump, due to loose packed joint in suction line.	4) Retighten or replace packing.
	5) Faulty seal ring on clutch piston.	5) Disassemble and replace.
	6) Damaged "O" ring in the path of oil to clutch piston.	6) Disassemble and replace.

Symptom	Possible cause	Remedy
Not enough output.	1) Engine is not delivering enough power.	1) Re-tune the engine.
	2) Not enough oil in transmission oil pan.	2) Refill.
	3) Air is being sucked into oil pump.	3) Check the packed joint and replace packing as necessary.
	4) Sticking or bound spool in main relief valve.	4) Disassemble and repair or replace.
	5) Weakened spring in main relief valve.	5) Disassemble and replace the spring.
	6) Worn-down oil pump.	6) Replace.
	7) Strainer or filter is clogged.	7) Clean or replace.
	8) Badly worn clutch piston ring or "O" ring.	8) Disassemble and replace.
	9) Water in oil.	9) Change oil.
	10) Control linkage out of adjustment.	10) Readjust.
	11) Slipping clutches due to low main pressure.	11) Readjust.
	12) Damaged clutch piston.	12) Disassemble and replace.
	13) Dragging wheel brakes.	13) Readjust.
Transmission does not shift into neutral, or remains on even when clutch pedal is pressed fully.	1) Control linkage out of adjustment.	1) Readjust.
	2) Burnt clutches.	2) Disassemble and replace burnt parts.
	3) Clutch piston, friction plates or mating plates are bound.	3) Disassemble, repair or replace.
	4) Clutch valve is seized and does not move into draining position.	4) Disassemble, repair or replace.
	5) Oil level too high or too low.	5) Adjust to the prescribed level.
Abnormal oil temperature rise.	1) Air is being drawn into oil circuit.	1) Retighten joints and connections, replace gaskets, or check oil level and add oil, as necessary.
	2) Water in oil.	2) Change oil.
	3) Burnt or worn bearings.	3) Disassemble and repair or replace.
	4) Indicating instrument out of order.	4) Replace.
	5) Dragging clutches.	5) Replace friction and mating plates.
	6) Clutch valve linkage out of adjustment.	6) Readjust.
	7) Dragging wheel brakes.	7) Readjust.
	8) Continuous overloading of the machine.	8) Avoid abusive use of the machine.
Loss of safety function of the hydraulic interlock (safety valve).	1) Safety valve is not functioning.	1) Disassemble and repair or replace.
	2) Shift control linkage out of adjustment.	2) Readjust.

Symptom	Possible cause	Remedy
Main pressure is too high. (This is not a symptom; it is a finding obtained by checking with pressure gauge.)	1) Main relief valve is out of adjustment. 2) Internal oil passage in main relief valve is clogged. 3) Bound or sticking main relief valve. 4) Wrong kind of hydraulic oil.	1) Overhaul and adjust. 2) Overhaul and clean. 3) Overhaul. 4) Use oil meeting the specifications.
Transmission responds too slow to shifting. (This is the symptom of main pressure being too low.)	1) Clogged oil strainer or filter. 2) Worn-down oil pump. 3) Main relief valve out of adjustment. 4) Bound or sticking main relief valve. 5) Air is being drawn into oil circuit. 6) Oil leakage from loose joint or connection.	1) Clean or replace. 2) Replace. 3) Readjust. 4) Overhaul. 5) Retighten joints and connections, replace gaskets, or add oil to oil pan. 6) Inspect and repair, replacing "O" rings and seals as necessary.
Clutch oil pressure is abnormally low when clutch pedal is in released condition. (This is not a symptom; it shows up as slow response of transmission or as slipping clutch.)	1) Main pressure too low. 2) Sticking spool in clutch valve. 3) Clutch pedal control linkage is out of adjustment.	1) Refer to the procedure immediately above. (Transmission responds too slow to shifting.) 2) Overhaul. 3) Readjust.
Clutches grab even when clutch pedal is pressed gently.	1) Clutch pedal control linkage is out of adjustment. 2) Clutch valve out of order. 3) Pilot valve is malfunctioning.	1) Readjust. 2) Overhaul. 3) Overhaul.
Machine picks up speed too slowly even when clutch pedal is released sharply.	1) Clutch pedal control linkage is out of adjustment. 2) Clutch valve is out of order. 3) Pilot valve is malfunctioning.	1) Readjust. 2) Overhaul. 3) Overhaul.

TESTING AND ADJUSTMENT

How to test the DPS transmission proper, in the event of any of the transmission difficulties listed in TROUBLESHOOTING GUIDE, will be described. Each test is for narrowing the scope of investigation, and is based on taking pressure readings at the control valve unit.

Preliminary steps

Inspection

(1) Make sure the oil is up to level in the transmission oil pan.

(2) Inspect the transmission and oil lines for oil leakage and correct or repair leaking points, if any.

(3) Be sure that the clutch pedal linkage and control lever linkage are in good adjustment.

Driving test

Drive the machine in the normal manner and try all modes of operation, namely, standing start, inching, acceleration, deceleration, braking, etc., in order to verify the difficulties complained of by the user.

NOTE

To find whether transmission clutches are in slipping condition or not, proceed as follows:

a) Start up the engine and keep brake applied by locking the brake pedal in depressed condition.

b) Pick up speed and shift the lever to F2 (FORWARD HIGH).

c) If the engine stalls upon shifting, it means that F2 clutch is not slipping.

d) Repeat step b) for the other gear positions.

To double-check, see how long it takes for the machine to come to a complete standstill. If it takes longer than 3 seconds or if the machine continues to roll, it means that clutch is slipping.

Trouble diagnosis by oil pressure readings

The following information augments the TROUBLE-SHOOTING GUIDE, and teaches, on the basis of pressure reading, more specific possible causes. Three test pressure gauges are needed: one for M port, one for D port and one for S port of the control valve unit, on which threaded plugs are provided. Remove these plugs and tie the pressure gauges to the threaded holes at which the pressures of the three ports can be sensed.

1. If the transmission refuses to shift:

Operating difficulty and pressure	Possible maldondition	Remedy
1) No shift to FORWARD or REVERSE, or to HIGH or LOW. M port pressure: Normal D and S port pressures: Abnormally low [not higher than 10 kg/cm^2 (142 psi)]	a) Ruptured clutch piston sealing. b) Ruptured control valve gasket. c) Absence of "O" ring or broken "O" ring in the pipe between transmission case and clutch housing. d) Oil hole blanking ball is off.	a) Disassemble, and replace. b) Disassemble, and replace. c) Disassemble, and install "O" ring or replace broken one. d) Fit ball by driving.
2) No shift to all gears. M, D and S port pressures: All low [not higher than 10 kg/cm^2 (142 psi)]	a) Broken oil pump. b) Clogged oil passage between strainer and pump, between pump and line filter or between filter and control valve; or leakage c) Sticky or binding main relief valve.	a) Replace. b) Investigate and clean clogged part by flushing; or repair leaking point. c) Disassemble, and clean.

Operating difficulty and pressure	Possible cause	Remedy
3) No shift to all gears. M port pressure: Normal D and S port pressures: Both gone (0 kg/cm^2)	Neutral safety valve in malcondition due to weakened spring, foreign matter stuck on valve seat, or sticky valve.	Disassemble, clean by washing, and repair or replace. Weakened spring must be replaced.
4) No shift to FORWARD or REVERSE, or to HIGH or LOW. M, D and S port pressures are all normal.	Clutch plates are burnt or the friction-material surfaces are lost due to peeling. If FORWARD clutch plates are burnt and seized: Machine rolls off on F1 and F2 but engine stalls on R1 and R2. If LOW (1st) clutch plates are burnt and seized: Machine rolls off on F1 and R1 but engine stalls on F2 and R2.	Disassemble, and replace.

2. If the machine jerks on shifting:

Operating difficulty and pressure	Possible cause	Remedy
1) Indicating hand of pressure gauge jumps momentarily from 0 to 20 kg/cm^2 (284 psi) on shifting to any gear.	Accumulator valve is sticking, or orifice is clogged.	Wash valve body, check the bore for damage and, as necessary, repair valve and bore to make the valve move smoothly.
2) Indicating hand of pressure gauge jumps momentarily from 0 to 20 kg/cm^2 (284 psi) on shifting to some gears.	a) Clutch piston is sticking. b) Accumulator valve is sticking, or orifice is clogged.	a) Disassemble and repair or replace. b) Refer to 1) above.

3. If the transmission responds too slowly to shifting:

NOTE: Normally the machine rolls off within 0.5 second in standing start.

Operating difficulty and pressure	Possible cause	Remedy
1) Lag is large in shifting from N to 1 and from N to 2, but is normal in shifting from 1 to 2 and 2 to 1. Indicating hand takes 2 seconds or more in deflecting from 0 to 20 kg/cm^2 (284 psi).	a) Sticking accumulator valve. b) Weakened spring of accumulator valve.	a) Refer to 2.1), above. b) Replace.
2) Indicating hand takes longer time than normal to deflect from 0 to 20 kg/cm^2 (284 psi) upon shifting to some gears.	a) Broken clutch sealing. b) Absence of "O" ring or damaged "O" ring in the pipe between transmission and clutch housing.	a) Disassemble and replace. b) Disassemble and install "O" ring or replace broken one.

4. **If the transmission responds erratically to the clutch pedal:**

Operating difficulty and pressure	Possible cause	Remedy
1) With the pedal depressed, the clutch remains engaged.		
A. Pressures at M, S and D ports are all normal.	A. Clutch plates in FORWARD or REVERSE clutch are seized.	A. Disassemble and replace.
B. M and S port pressure: Both normal D port pressure: Does not drop to 0 kg/cm^2.	B. a) Maladjusted control linkage. b) Clutch valve out of order.	a) Readjust. b) Overhaul.
2) Releasing the pedal after fully depressing causes the machine to jerk in standing start. M and S port pressure: Both normal D port pressure: Rises but not smoothly as the pedal moves in releasing direction.	Clutch valve is sticking. NOTE: If 8-mm (0.31-in.) dia. rod is positioned the other way around, the clutch valve will not function properly.	Disassemble and clean by washing. Replace 3-piece spool as necessary. Be sure the 8-mm (0.31-in.) dia. rod is correctly positioned.
3) Releasing the pedal quickly fails to make the machine pick up speed quickly: the machine starts off slowly.		
A. M port pressure: Normal D port pressure: Changes in the normal manner. S port pressure: Momentarily drops upon releasing but returns to 20 kg/cm^2 (284 psi)	A. Foreign matter stuck on check valve seat, or sticking check valve.	A. Disassemble and clean.
B. M port pressure: Normal D port pressure: Changes in the normal manner. S port pressure: Normal (does not drop).	B. Pilot valve is sticking. NOTE: Be sure the slug is correctly positioned. With the slug mispositioned, the pilot valve behaves as it were sticky.	B. Wash valve body. Check accumulator valve orifice for damage. Replace valve and body as necessary.

5. If the transmission overheats easily or does not give enough output power:

Operating difficulty and pressure	Possible cause	Remedy
1) Overheating tendency		
A. Pressures at M, D and S ports are all normal or slightly lower.	A. a) Too much oil in the oil pan. b) Not enough oil in the oil pan.	a) Lower the oil level. b) Raise the oil level.
B. Pressures are normal at all ports.	B. a) Clutch plates are tending to seize. b) Mechanical damage inside the transmission.	a) Disassemble and replace. b) Overhaul.
2) Not enough output power		
A. Pressure are low at all ports, M, D and S.	A. Not enough oil in the oil plan.	Add oil.
B. Pressure are normal at all ports.	B. a) Engine is to blame. b) Mechanical damage inside the transmission.	a) Re-tune the engine. b) Overhaul.

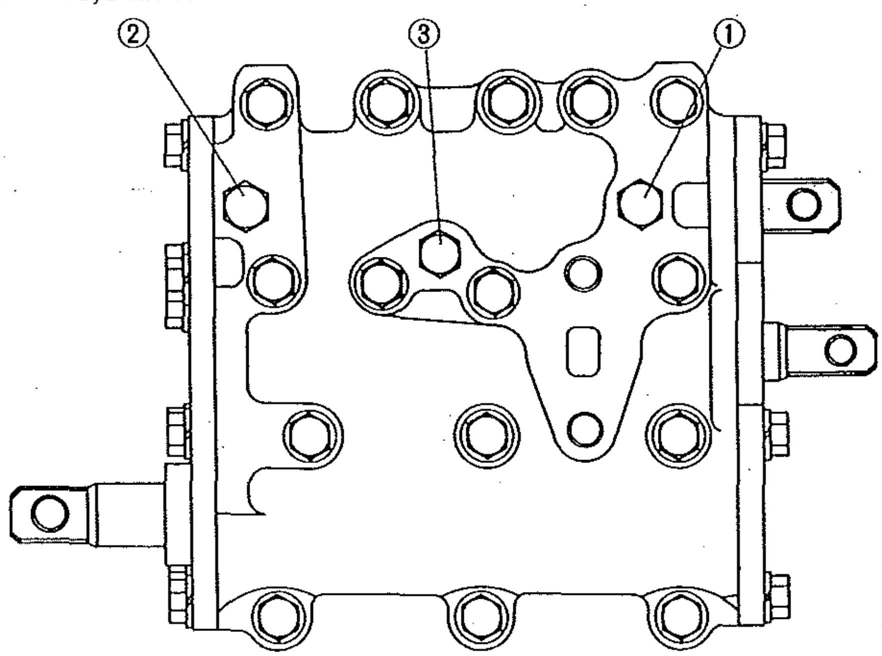
NOTE: Normal steady-state pressure is prescribed to be 20 kg/cm^2 (284 psi) for the three ports, M, D and S. An abnormally high steady-state pressure means (1) the main relief valve being sticky, or (2) the spring of this valve being weakened.

Testing the control valve unit

The following procedure is for determining whether the control valve unit is operating properly, without regard to the transmission, by checking the oil pressure at the three ports mentioned previously. Connect three pressure gauges to the threaded holes provided in the valve unit body. These holes are normally closed with plug screws indicated as 1, 2 and 3.

NOTE

When running the transmission and control valve unit on the bench in order to break it in, be sure to form an oil cooler bypassing circuit by connecting the two flexible hoses, one leading to the cooler inlet and one leading from the cooler outlet.



Connection 3 for D port: Pressure for FORWARD and REVERSE clutches
Connection 1 for M port: Main oil pressure
Connection 2 for S port: Pressure for HIGH and LOW clutches

Pressure designation	Port and gauge connection	Pressure requirement
Main pressure	M port; PF 1/8" connection with "O" ring	With engine running at high idling speed and control lever kept in neutral, this pressure is required to be within this range: 18 ~ 22 kg/cm² (256 ~ 313 psi) If not, adjust the setting of main relief valve by increasing or decreasing the thickness of its shim.
High and low clutch pressure	S port; PF 1/8" connection with "O" ring	With engine running at high idling speed, this pressure is required to remain at a level not lower by 2 kg/cm² (28.4 psi) maximum than the main pressure.
Forward and reverse clutch pressure	D port; PF 1/8" connection with "O" ring	With engine running at high idling speed, this pressure is required to take the following value: 0 kg/cm² for both clutches with control lever in neutral. 2 kg/cm² (28.4 psi) or less below the main pressure, with control lever in HIGH or LOW.
Shifting clutch pressure	S port NOTE: This pressure is transient. It is to be checked when the lever is shifted from neutral to any gear, or from one gear to another.	Clutch pressure is required to change between the two values stated above, namely, 0 kg/cm² and a level 2 kg/cm² (28.4 psi) or less below the main pressure, in the stated period of time:

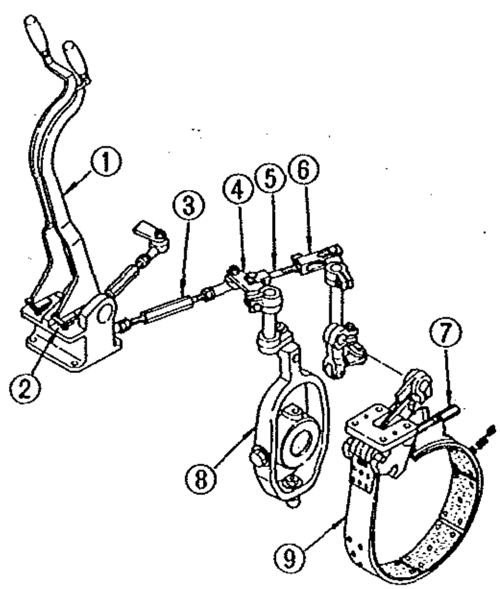
Shifting	Time
N to LOW	1.4 ± 0.2 seconds
HIGH ⇄ LOW	0.4 ± 0.2 second

Bench test criteria for transmission oil pump

Direction of rotation	Clockwise (as viewed from drive gear side)
Hydraulic oil	Engine oil, SAE 10W, 50° ± 5°C (122° ± 9°F)
Pump drive speed	2000 rpm
Discharge flow and pressure	32 liters (1953 cu in.)/minute at 20 kg/cm² (284 psi)

Adjustment of control linkage for steering clutches

The steering clutch lever controls both clutch and brake on each side. The linkage must be so set that, as the lever is pulled through its full stroke, the clutch becomes disengaged or released first and the brake applies next. These requirements, in terms of the position of the lever tip as measured from the edge of the dashboard, are specified.



1-Steering clutch lever
2-Stopper bolt
3-Rod
4-Lever
5-Rod
6-Clevis
7-Adjusting nut
8-Clutch yoke
9-Brake band

Lever position for releasing the clutch

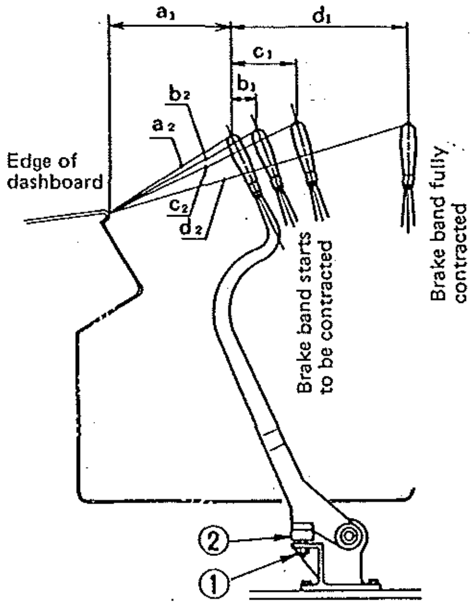
Model	a_1 (horizontal)	a_2 (edge-to-tip)
BS3F	221 mm (8-3/4 in.)	289 mm (11-3/8 in.)
BD2F	239 mm (9-3/8 in.)	295 mm (11-5/8 in.)

(1) How to adjust distance a_1 or a_2

(a) Remove floor plate. Loosen lock nut (1).

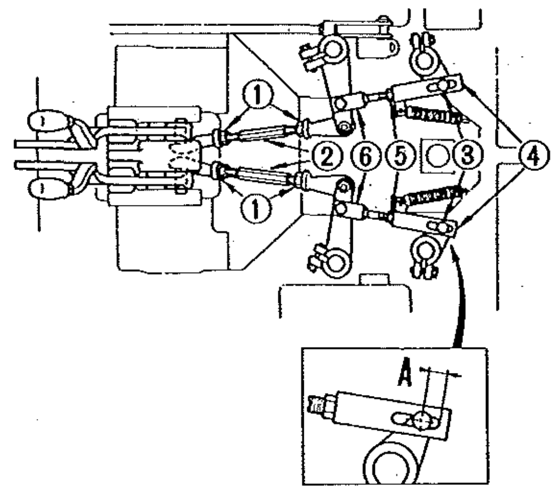
(b) Turn stopper bolt (2) to adjust the distance between dashboard edge to lever tip.

(c) Tighten lock nut (1) securely.



(2) How to adjust clutch lever play and distance b_1, b_2, c_1, c_2, d_1 and d_2:

The following tabulated procedure assumes that the requirement on distance a (for clutch releasing position) is accurately satisfied.



Unit: mm (in.)

Step	Lever position	Lever stroke: Horizontal	Lever stroke: Edge-to-tip	Operating effort	Adjusting method
1	Lever play	b_1 35 ~ 40 (1-3/8 ~ 1-5/8) [40 (1-5/8) preferred]	$b_2 - a_2$ 30 ~ 35 (1-1/8 ~ 1-3/8)	1 ~ 2 kg (2.2 ~ 4.4 lb)	Loosen nut (1), turn rod (2) to adjust, and tighten nut (1).
2	Brake adjusting nut setting (Refer to the part for steering brakes.)				
3	Start of braking	c_1 145 ~ 155 (5-3/4 ~ 6-1/8) [150 (5-7/8) preferred]	$c_2 - a_2$ 125 ~ 135 (4-7/8 ~ 5-3/8) [130 (5-1/8) preferred]	5 ~ 7 kg (11 ~ 15 lb)	Pull lever till brake band begins to move. Loosen lock nut (5) to bring pin to end of slot in clevis (4), and turn rod (6) to adjust. Tighten lock nut (5). With clutch just released, dimension (A) should be about 15 mm (5/8).
4	Brake fully applied	d_1 350 ~ 360 (13-3/4 ~ 14-1/8) [355 (14) preferred]	$d_2 - a_2$ 315 ~ 325 (12-3/8 ~ 12-3/4) [320 (12-5/8) preferred]	8 ~ 11 kg (18 ~ 24 lb)	The stroke stated on the left should result, with steps 1, 2, and 3 having been correctly carried out.

Adjustment of steering clutch brakes

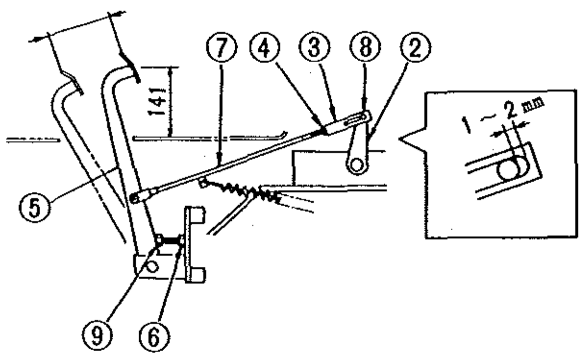
Brake is applied by depressing brake pedal (5) to turn lever (2) through rod (7). The angular stroke of lever (2) will increase as the lining of the brake band wears down progressively, and this increase of the stroke shows up as an increase in the pedal stroke.

The proper stroke of lever (2), as measured at its tip, is about 33 mm (1-1/4-in.). To reduce the stroke, bring the brake band close to the drum by tightening adjusting nut (1) (shown in the photo). The methods of setting this nut (1) and of adjusting the brake pedal for play and stroke are as follows:

Setting the adjusting nut (1)

(1) Tighten the nut to lock. Tightening torque of about 2 ± 0.5 kg-m (14.5 ± 3.6 lb-ft) will be required.

(2) Back off the nut by two rotations plus 3 or 5 flats. This will produce a proper band-to-drum clearance.



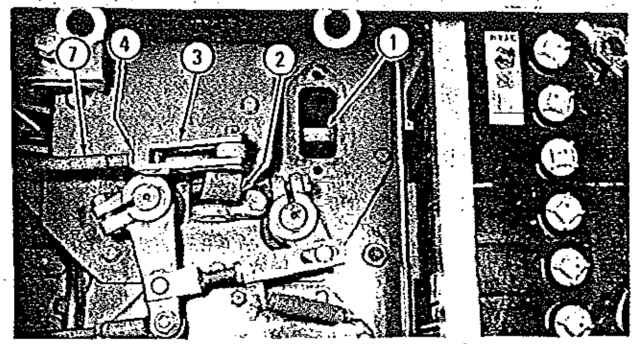
Brake pedal adjustment

(1) Loose lock nut (4).

(2) Loosen lock nut (6) and tighten or loosen adjusting nut (9) to locate the pedal at the height of clutch pedal.

(3) Shorten or elongate rod (7) to produce a clearance of 1 to 2 mm (0.04 to 0.08 in.) between clevis pin (8) and end of slot (see the magnified view). Be sure that the distance between this pin and that on the other end of rod (7) is 571 mm (22.48 in.).

(4) After making these adjustments, check to be sure that lock nuts are tight.



Checking pedal stroke and operating effort

With steps (1) and (2) properly carried out, the pedal should have the following pedal play and stroke and its operating effort should vary as indicated:

Pedal stroke	Operating effort
Play: 3 ~ 6 mm (1/8 ~ 1/4 in.)	1 ~ 2 kg (2.2 ~ 4.4 lb)
Full braking: 110 ~ 125 mm (4-3/8 ~ 4-7/8 in.) [117 mm (4-5/8 in.) preferred]	10 kg (22 lb), maximum

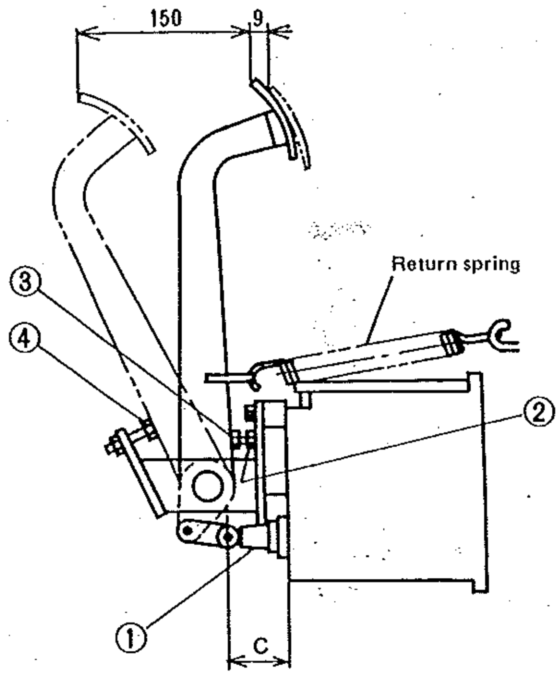
If the checked values are at variance with these values, carry out steps (1) and (2) once more.

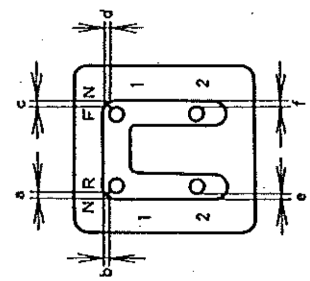
Clutch pedal adjustment

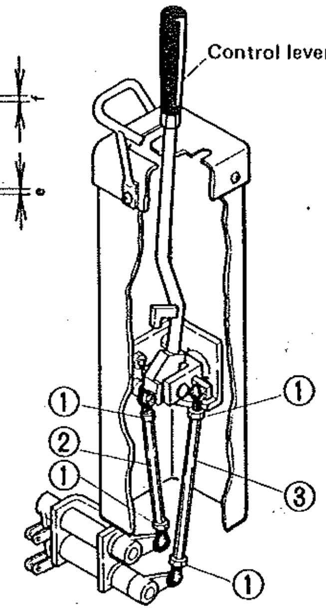
(1) Loosen lock nut (2), run in adjusting bolt (3) to lock, and measure dimension (C), which is the maximum extension of clutch valve plunger (1) and is required to be 55 mm (2.17 in.). This requirement is met by the design of the clutch valve.)

(2) Depress the pedal by 9 mm (3/8 in.), and back off adjusting bolt (3) until the bolt barely touches the pedal arm.

(3) The pedal is now held at the position 9 mm (3/8 in.) in from the original. From this position (backed by the adjusting bolt), depress the pedal 150 mm (5-7/8 in.), and set stopper bolt (4) to bear against the pedal arm.







DPS control lever adjustment

(1) Move the control lever to NR, and measure the clearances (a) and (b). These clearances should be between 0.5 and 2 mm (0.02 and 0.08 in.). Move the lever to FN, and check the clearances (c) and (d). These too should be between 0.5 and 2 mm (0.02 and 0.08 in.).

(2) Move the lever to R2 and to F2 to make sure that the clearances(e) and (f) measure between 0.5 and 2 mm (0.02 and 0.08 in.).

(3) If any of the six clearances is off the stated range, loosen four lock nuts (1), and shorten or elongate rods (2) and (3). To gain access to these parts, remove the control-box side cover and the cover under the left-hand fender (in BS3F) or the platform Re (in BD2F).

(4) After adjusting, tighten the lock nuts and re-check the clearances to be sure that they are not affected by the tightening of lock nuts.

MAINTENANCE STANDARDS

BOLT TIGHTENING TORQUE

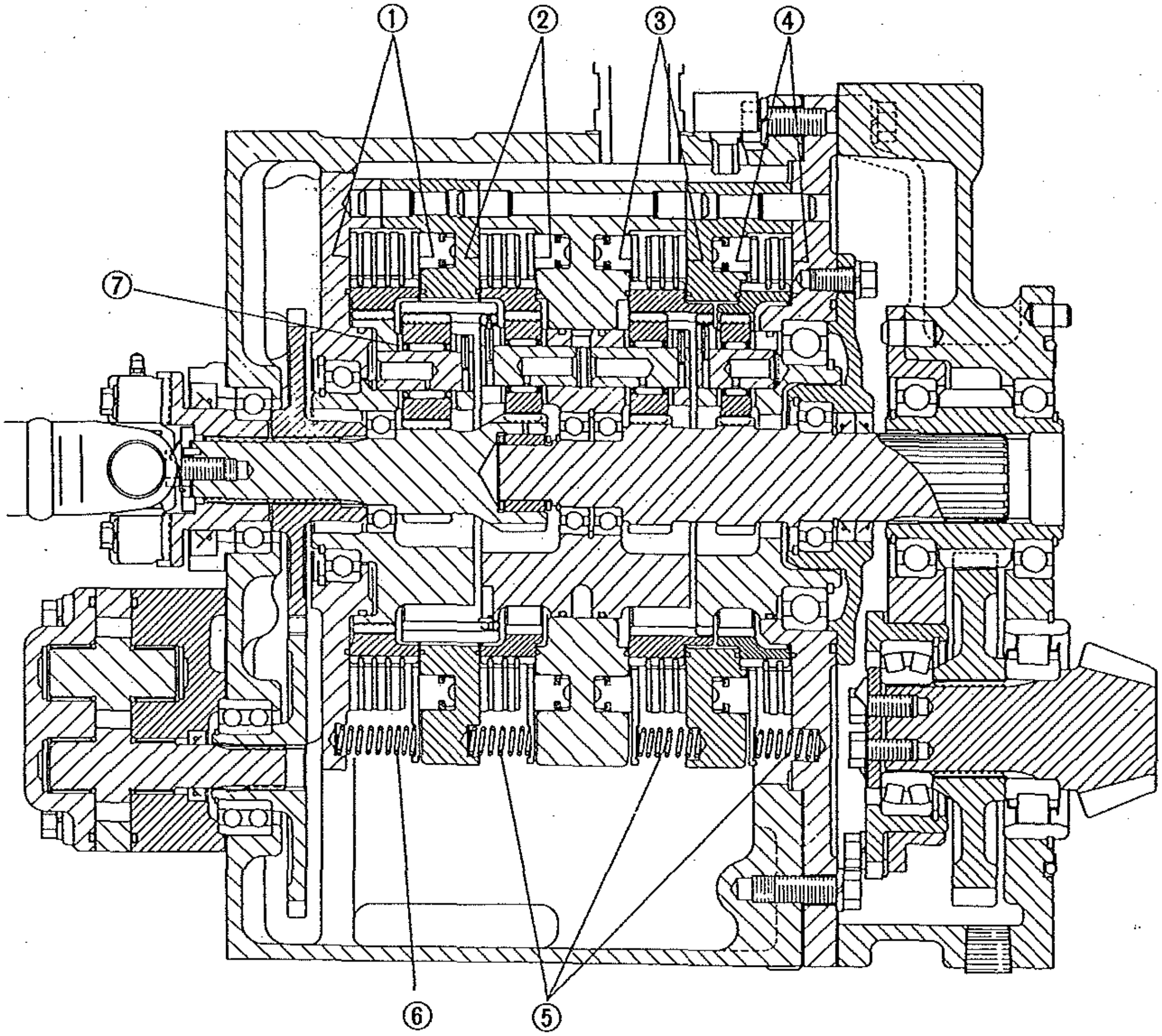
Unit: kg-m (lb-ft)

M 8	1.7 ± 0.2 (12.3 ± 1.4)	PF1/8	2 ± 0.2 (14.5 ± 1.4)
M10	3.4 ± 0.4 (24.6 ± 2.9)	PF1/4	4 ± 0.4 (28.9 ± 2.9)
M12	6.1 ± 0.6 (44.1 ± 4.3)	PF1/2	10.4 ± 1 (75.2 ± 7.2)
M36	51.8 ± 1.5 (374.7 ± 10.8)	PT1/2	10.4 ± 1 (75.2 ± 7.2)

TRANSMISSION

Unit: mm (in.)

Ref. No.	Item		Standard	Tolerance	Service limit
1	Total thickness of reverse clutch (new) (five plates and four discs)		27.7 (1.091)	±0.8 (±0.031)	26.1 (1.028)
2	Total thickness of forward clutch (new) (four plates and three discs)		21.57 (0.8492)	±0.62 (±0.0244)	20.4 (0.803)
3	Total thickness of 2nd-speed clutch (new) (four plates and three discs)		21.57 (0.8492)	±0.62 (±0.0244)	20.4 (0.803)
4	Total thickness of 1st-speed clutch (new) (three plates and two discs)		15.44 (0.6079)	±0.44 (±0.0173)	14.6 (0.575)
	Thickness of new disc		2.95 (0.1161)	±0.10 (±0.0039)	2.45 (0.0965)
	* Verify items 1 thru 4 and thickness of each disc.				
5	Clutch piston return spring	Length under test force	29 (1.14)		
		Test force	6.01 kg (13.25 lb)	±0.5 kg (±1.1 lb)	5 kg (11 lb)
		Free length after test	33 (1.30)		
		Outside diameter	12.5 (0.492)		
6	Clutch piston return spring	Length under test force	36 (1.42)		
		Test force	6.6 kg (14.55 lb)	±0.5 kg (±1.1 lb)	5.5 kg (12.1 lb)
		Free length after test	41 (1.61)		
		Outside diameter	13.5 (0.531)		
7	Thickness of thrust washer		2 (0.08)	±0.05 (±0.0020)	1.8 (0.071)



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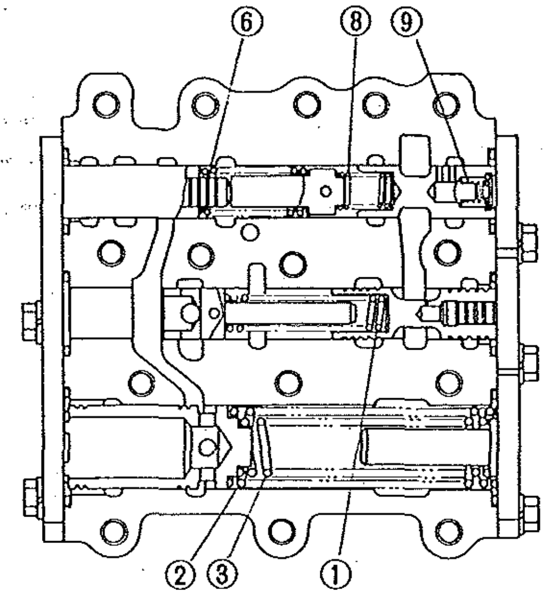
TRANSMISSION CONTROL VALVE

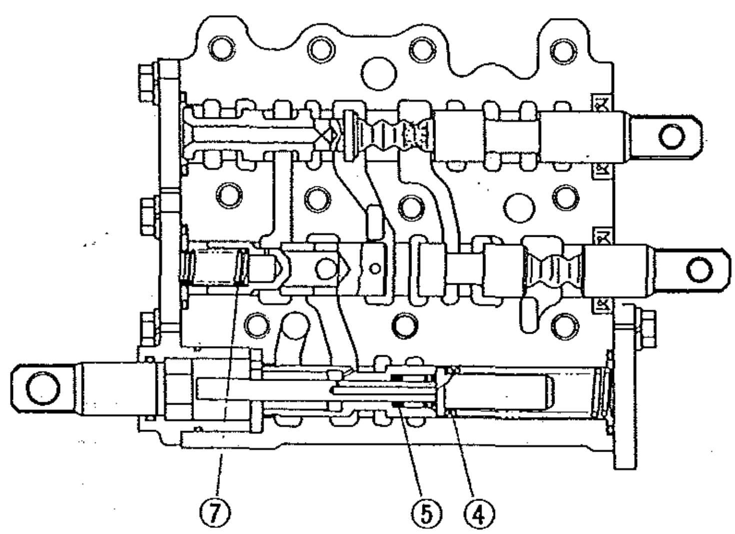
Unit: mm (in.)

Ref. No.	Item		Standard	Tolerance	Service limit
1	Main relief valve spring	Length under test force	55 (2.17)		
		Test force		8.0 ± 0.5 kg (17.6 ± 1.1 lb)	6.5 kg (14.3 lb)
		Free length after test	84 ± 2 (3.3 ± 0.08)		
		Outside diameter	13.3 (0.524)		
2	Accumulator valve spring (outer)	Length under test force	59 (2.32)		
		Test force		34.6 ± 1.5 kg (76.3 ± 3.3 lb)	30 kg (66 lb)
		Free length after test	113.5 (4.468)		
		Outside diameter	30.5 (1.201)		
3	Accumulator valve spring (inner)	Length under test force	60 (2.36)		
		Test force		23 ± 2 kg (50.7 ± 4.4 lb)	20 kg (44 lb)
		Free length after test	99 (3.90)		
		Outside diameter	22.4 (0.882)		
4	Clutch valve return spring	Length under test force	62 (2.44)		
		Test force		6.5 ± 0.6 kg (14.3 ± 1.3 lb)	5.3 kg (11.7 lb)
		Free length after test	95 (3.74)		
		Outside diameter	18.5 (0.728)		
5	Clutch valve spring	Length under test force	17 (0.67)		
		Test force		6.0 ± 0.3 kg (13.2 ± 0.7 lb)	5.0 kg (11.0 lb)
		Free length after test	31 (1.22)		
		Outside diameter	11.4 (0.449)		
6	Pilot valve spring	Length under test force	37 (1.46)		
		Test force		16.0 ± 0.5 kg (35.3 ± 1.1 lb)	13 kg (28.7 lb)
		Free length after test	64 (2.52)		
		Outside diameter	18.3 (0.720)		
7	Check valve spring	Length under test force	25 (0.98)		
		Test force		0.12 ± 0.01 kg (0.26 ± 0.02 lb)	0.09 kg (0.20 lb)
		Free length after test	33 (1.30)		
		Outside diameter	13.3 (0.524)		
8	Safety valve spring	Length under test force	17 (0.67)		
		Test force		2.83 ± 0.2 kg (6.24 ± 0.4 lb)	2.5 kg (5.5 lb)
		Free length after test	33.5 (1.319)		
		Outside diameter	13.2 (0.520)		

Unit: mm (in.)

Ref. No.	Item		Standard	Tolerance	Service limit
9	Damping valve spring	Length under test force	8.9 (0.350)		
		Test force		0.23 ± 0.02 kg (0.51 ± 0.04 lb)	0.18 kg (0.40 lb)
		Free length after test	19 (0.75)		
		Outside diameter	7.5 (0.295)		





DISASSEMBLY AND REASSEMBLY

TRANSMISSION

Removal

Preparatory steps

(a) Removal of floor plate.

(b) Taking down of the seat and seat support.

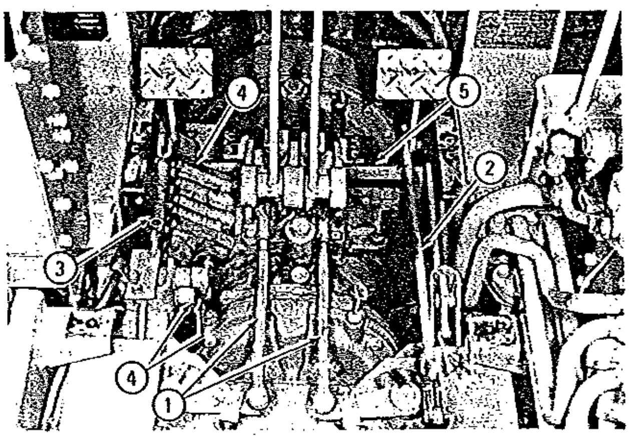
(1) Disconnect and remove two steering clutch lever rods (1).

(2) Disconnect and remove brake pedal rod (2).

(3) Remove return spring (3) urging the brake pedal.

(4) Undo three connections at plungers (4) of DPS control valve unit.

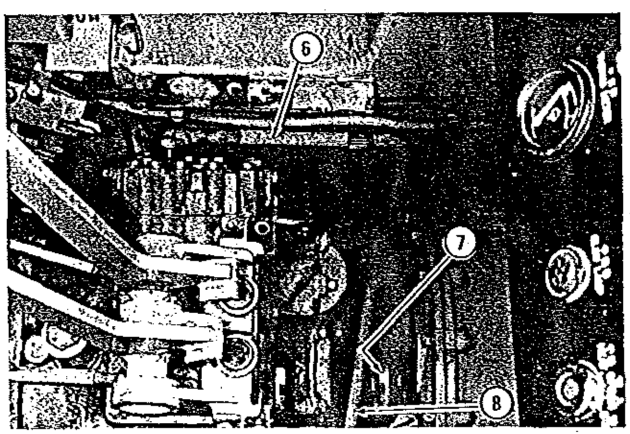
(5) Remove pedal bracket assembly (5).



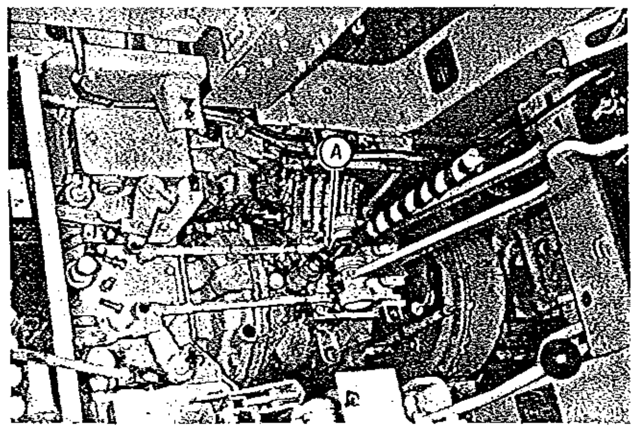
(6) Disconnect oil pipe (6).

(7) Disconnect and remove universal joint (7).

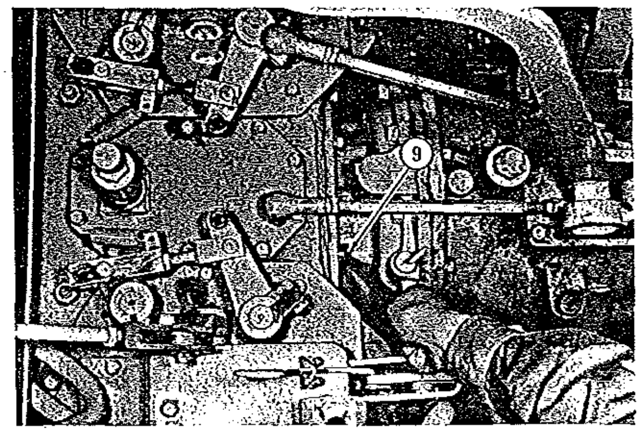
(8) Disconnect oil pipe (8).



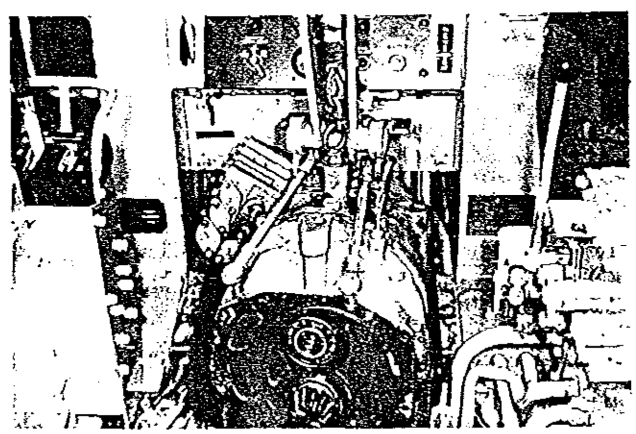
(9) Hitch a lifting sling (A) to the transmission case, and tension the sling to take up the weight of the transmission.



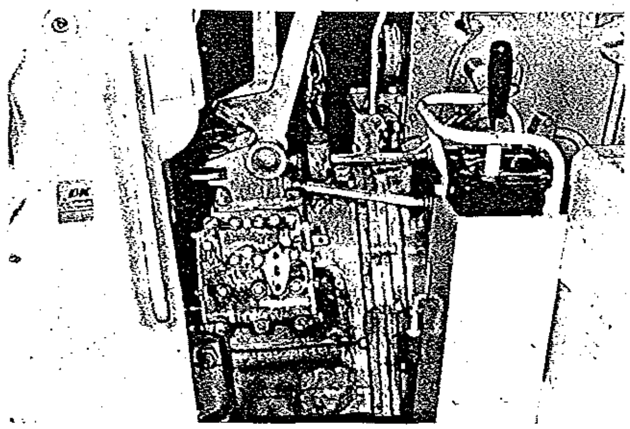
(10) Remove eight bolts (9) fastening the transmission case to the steering clutch case.



(11) Detach the transmission from the clutch case, and move the former out in forward direction.



(12) Lift the transmission out of the machine.



Disassembly

Preparatory steps

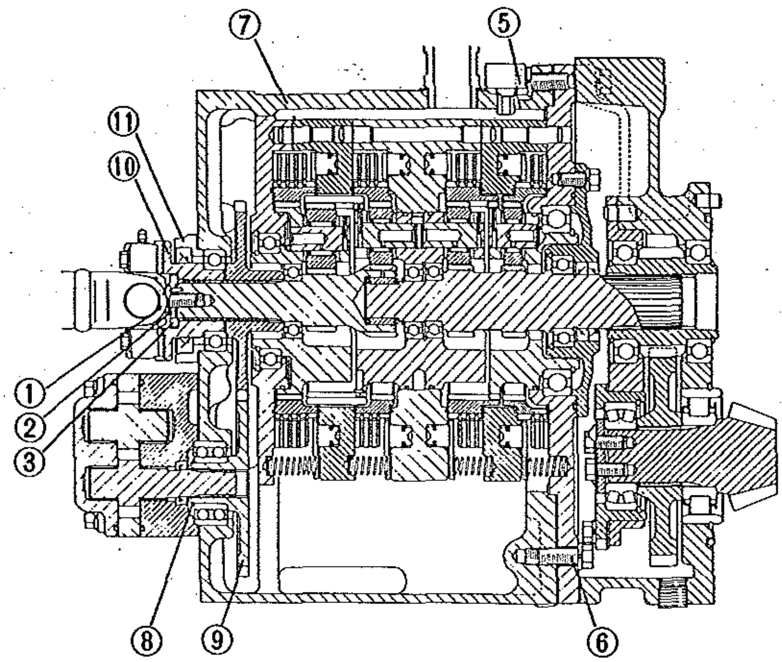
(a) Have the transfer gear assembly removed.

(b) Remove oil filter.

(c) Remove the transmission control valve unit.

(d) Remove oil pump.

(e) Remove magnet strainer.



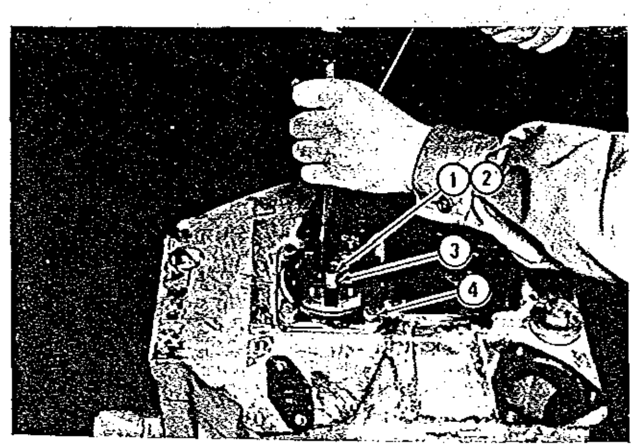
1-Lock washer
2-Bolt
3-Washer
5-Bolt
6-Bolt
7-Transmission case
8-Snap ring
9-Pump driven gear
10-Flange
11-Seal cover

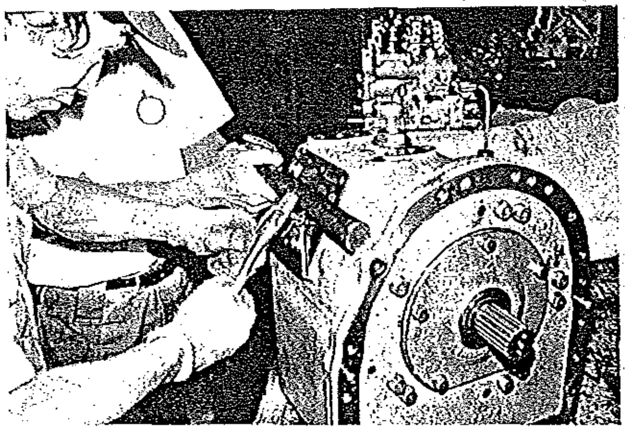
Transmission case and flanged end disassembly

(1) Remove four joint pipes, using a hook, pliers and rod, from the seating face, from which the control valve unit has been taken off. The pipes are indicated by arrows (in the second photo).

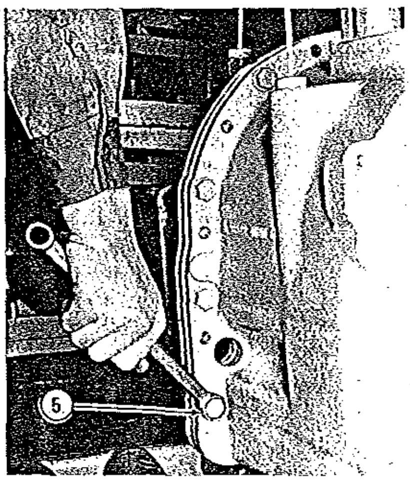
(2) Bend down lock washer (1), and remove bolt (2) and washer (3).

(3) Remove bolts (4) securing the splined flange piece.



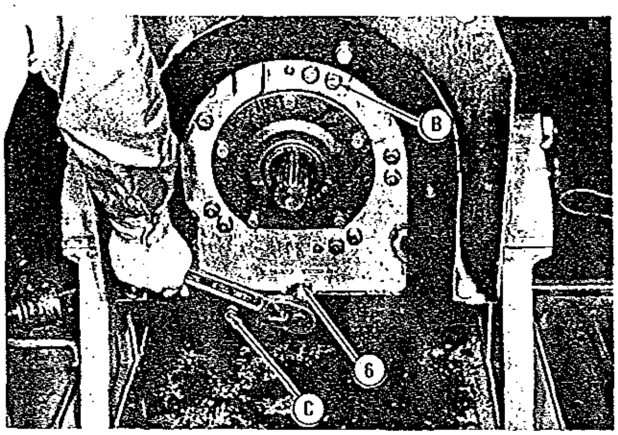


(4) Remove eight bolts fastening the case to the flanged end. The bolts are indicated as (5).

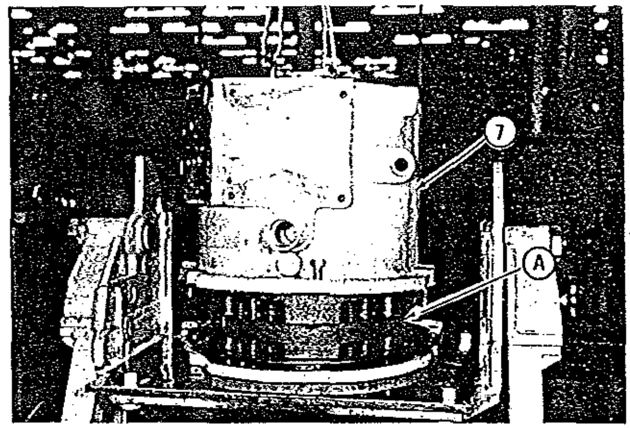


(5) From the flanged end plate, remove bolt (6) securing the plate to the transmission case.

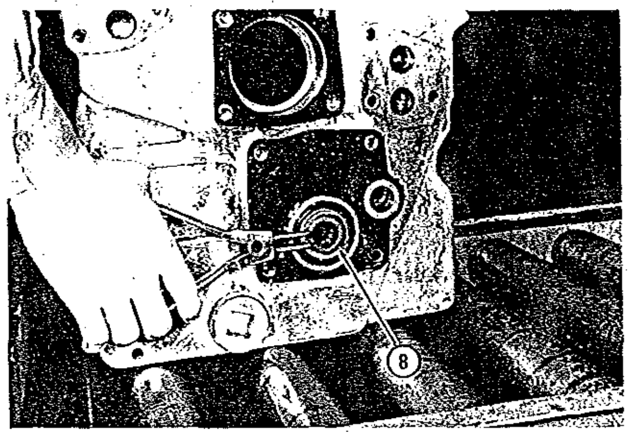
(6) Run jacking bolts (B) (C) into the end plate, detaching the case from the plate.



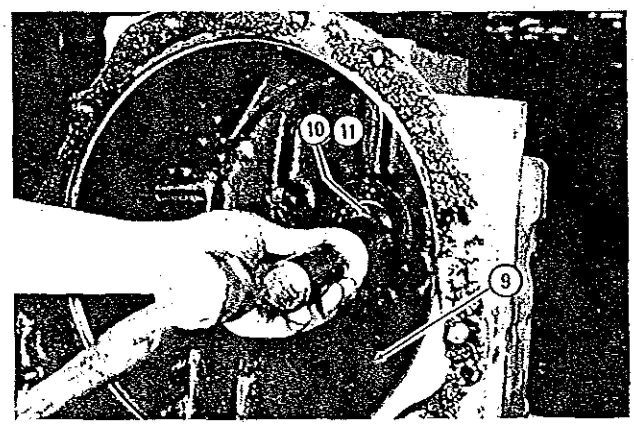
(7) Lift transmission case (7) off, leaving behind the clutch assembly (A) standing on the end plate.



(8) Pick out snap ring (8) from pump driven gear.



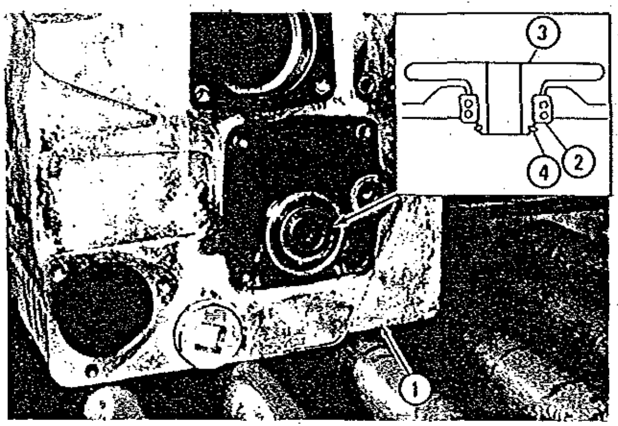
(9) By driving from inside the case, force out flange piece (10). Remove seal cover (11), and take out driven gear (9).



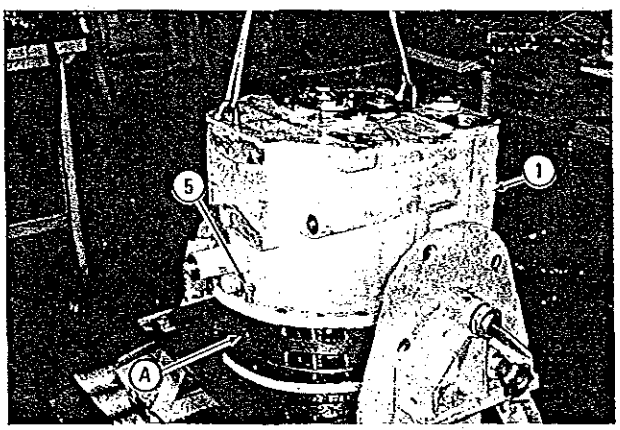
Transmission case and flanged end reassembly

(1) At the front end, install ball bearing (2) in the case (1).

(2) While exerting a push to the ball bearing (2), force driven gear (3) from inside into the bearing by driving, and put on snap ring (4).



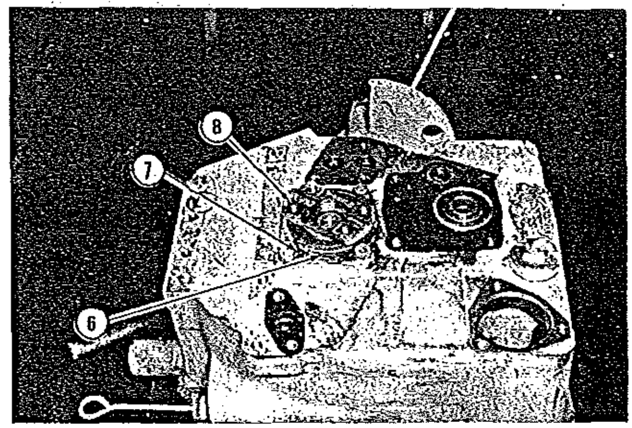
(3) Lower the transmission case (1) onto clutch assembly (A) standing on the flanged end plate, and fasten the case to the plate by bolting. There are eight bolts (5) to be tightened.



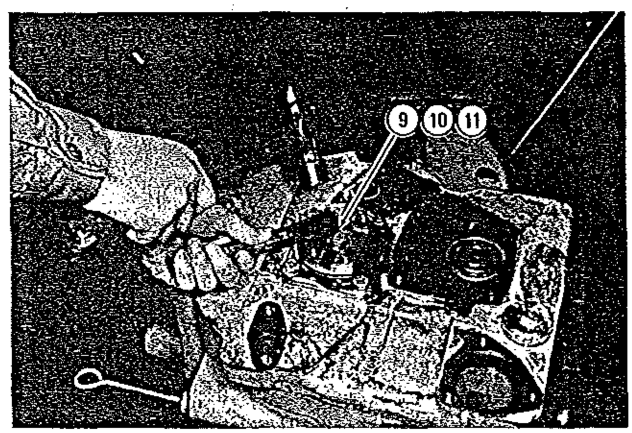
(4) Install the input-shaft ball bearing by driving it into the case.

(5) Fit the oil seal into seal cover (6) by driving, install the cover and secure it to the case by tightening its four bolts (7).

(6) Install the splined flange piece (8), driving it into the bearing; and put on "O" ring.

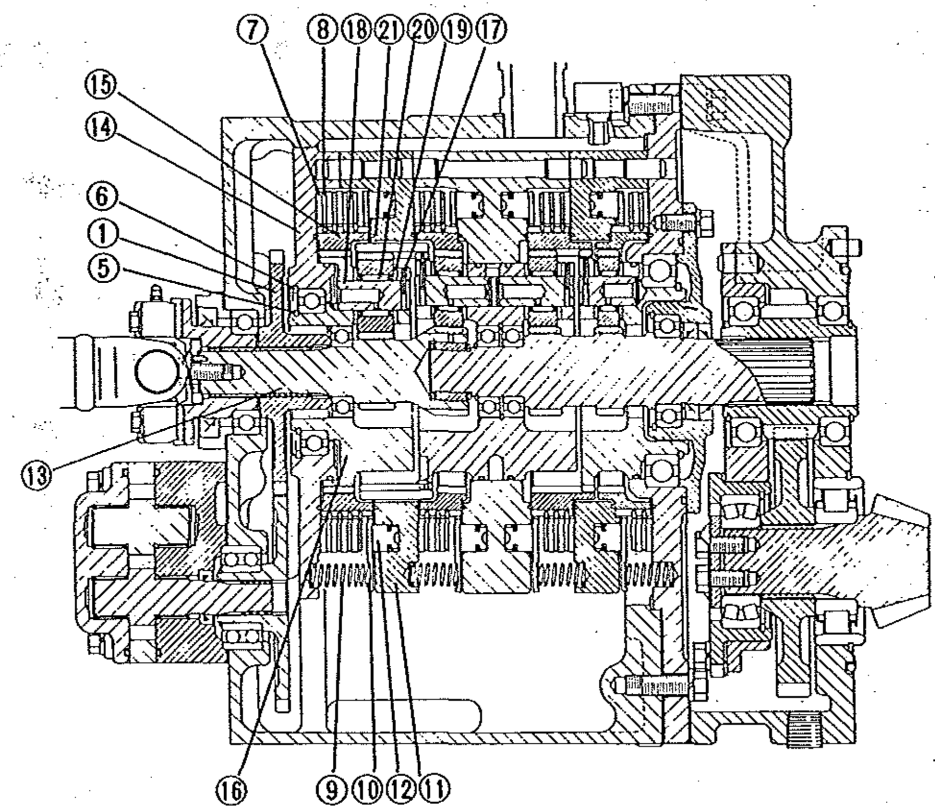


(7) Fit washer (9) and lock washer (10) to the end face of input shaft, run bolt (11) into the shaft and, after tightening the bolt good and hard, lock it by bending the tongue of lock washer.



(8) Install the four joint pipes in the seat for the control valve unit. Be sure to use a new seal on each joint pipe.

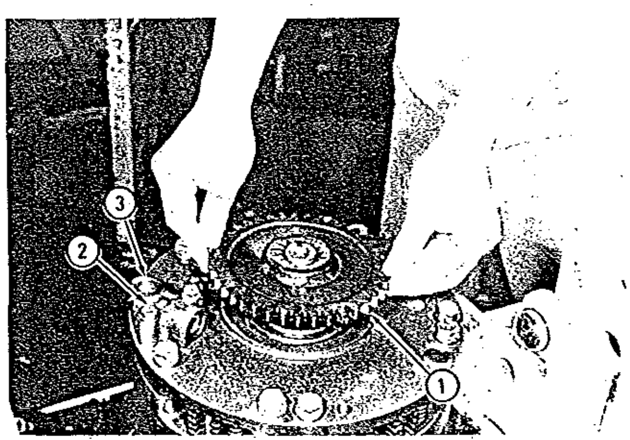
REVERSE section disassembly

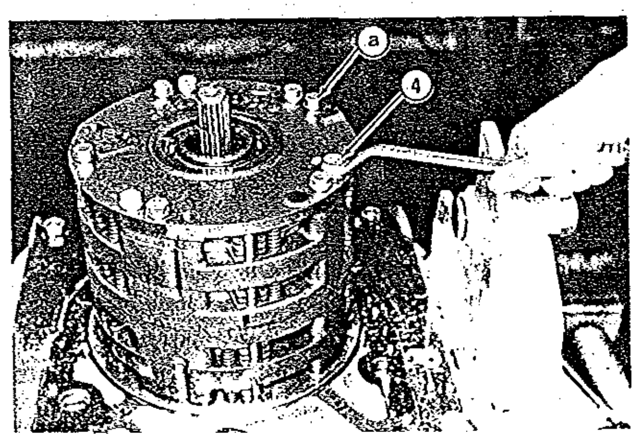


1-Pump drive gear
5-Snap ring
6-Snap ring
7-Mating plate
8-Friction plate
9-Return spring
10-Pressure plate
11-Piston housing
12-Piston
13-Input shaft
14-End housing
15-Ring gear
16-Planet carrier
17-Spring pin
18-Planet pin
19-Thrust washer
20-Needle bearing
21-Planet gear

(1) From input shaft, pull off pump drive gear (1).

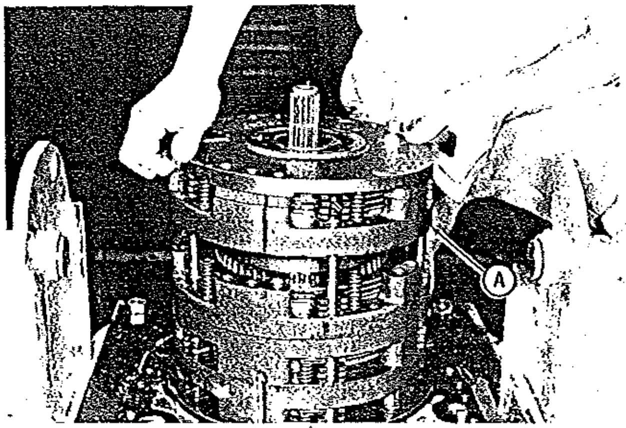
(2) Remove bolts (2), and take off lubricating valve assembly (3).





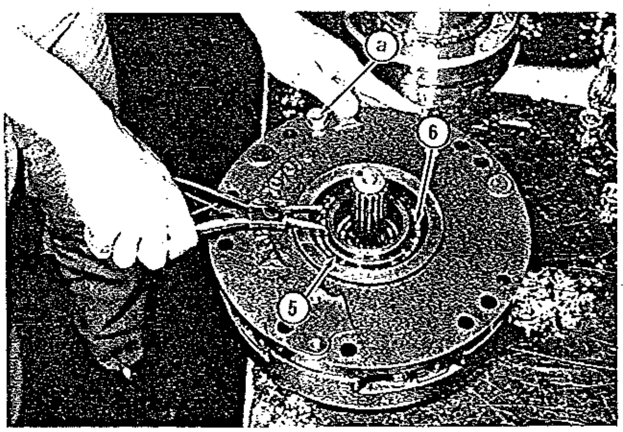
(3) Remove bolts (4). Leave one of these nine bolts (4) in place. The bolt to be left is indicated as (a).

(4) Lift off the REVERSE section (A). This section comprises piston housing R, epicyclic gear sub-assembly R.



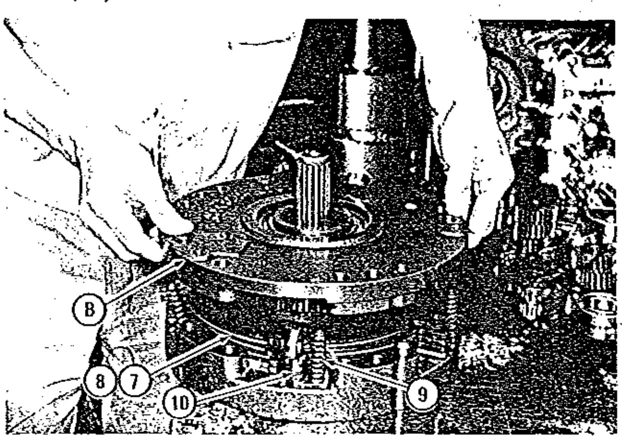
(5) Pick out snap rings (5) (6) retaining the ball bearing in place.

(6) Remove the remaining bolt (a).

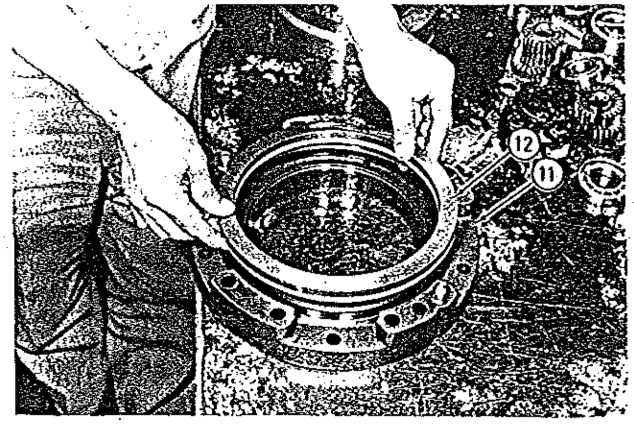


(7) Lift off the combination (B) comprising the end housing and epicyclic gear sub-assembly R.

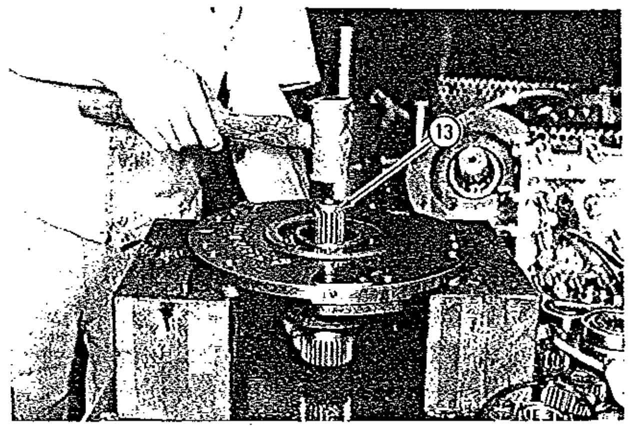
(8) Take out four mating plates (7), four friction plates (8), five return springs (9) and pressure plate (10).



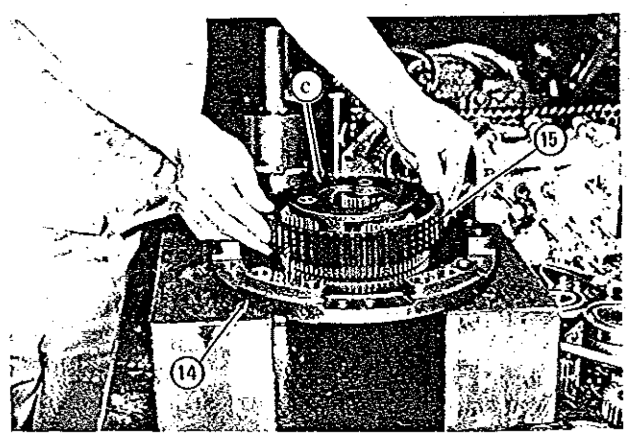
(9) Pick out piston (12), complete with piston seal, from piston housing (11).



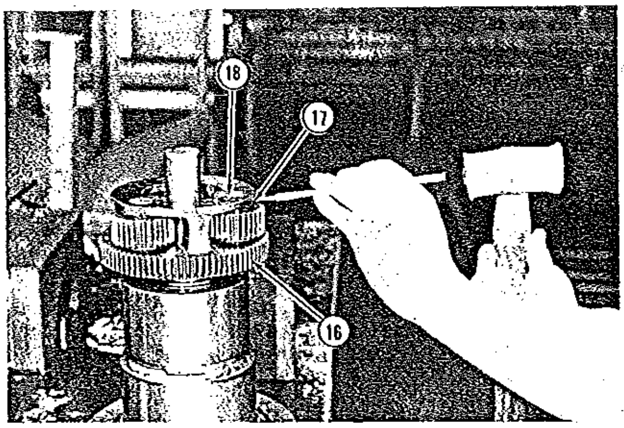
(10) Remove input shaft (13) from epicyclic gear sub-assembly R by driving the shaft.



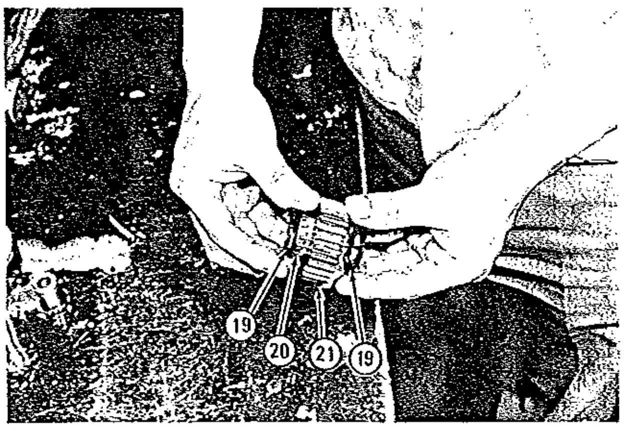
(11) Remove ring gear (15) and planet carrier R (C) from end housing (14).



(12) Using a proper drift, remove three spring pins (17) by driving each out of planet carrier R (16).



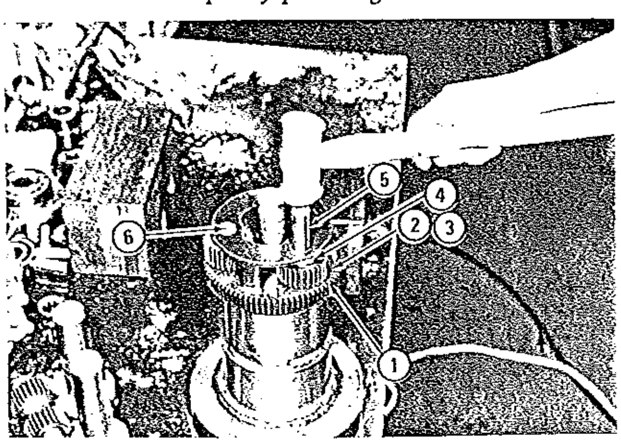
(13) Disassemble each planet into thrust washer (19), needle bearing (20) and gear (21) by pulling its pin (18) out of the carrier.



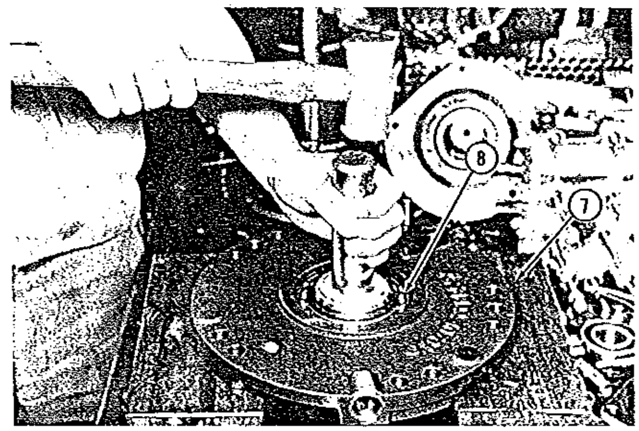
REVERSE section reassembly

(1) Install the three planets in planet carrier R (1) by locating three gears (2), needle bearings (3) and thrust washers (4) inside the carrier and by inserting three pins (5), one into each gear (2). Be sure to position pin (5) in such a way that its oil hole will point to the center of the carrier.

(2) Drive spring pin (6) into the carrier at each planet, and lock the pin by punching its end.



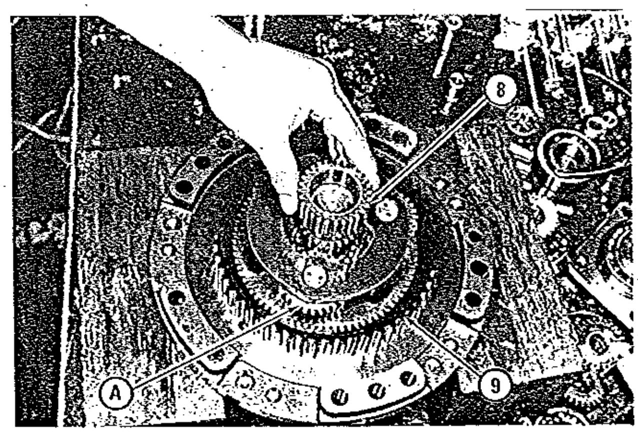
(3) Fit ball bearing (8) to end housing (7) by driving, and install the "O" ring on the back of end housing.



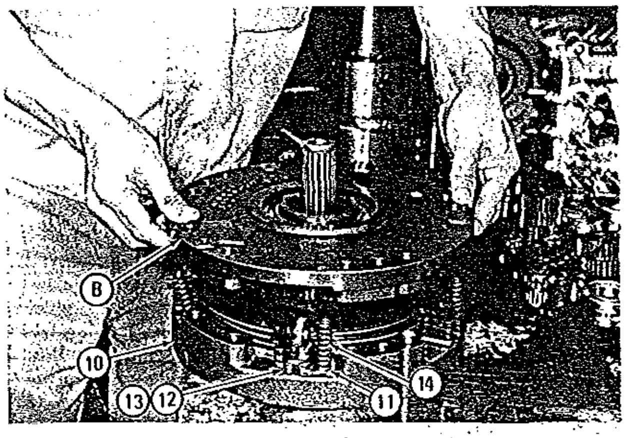
(4) Fit the planet carrier R (complete with planets) to end housing (7).

(5) Mount the ball bearing next to the sun gear of input shaft (8), and insert the shaft into the carrier.

(6) Feed ring gear (9) onto the carrier, making sure that the gear slides smoothly onto the toothed periphery of carrier.

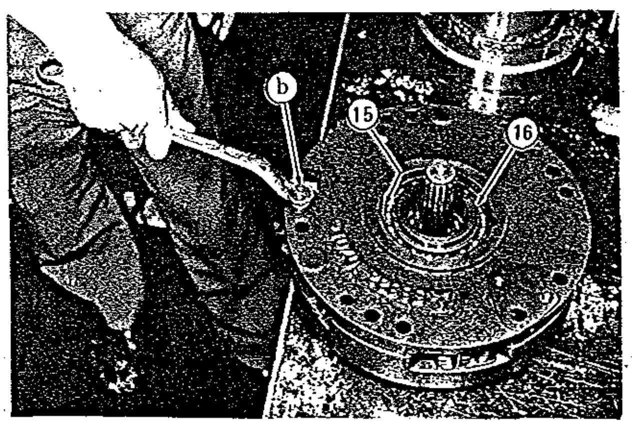


(7) Install piston (complete with piston seal), followed by pressure plate (11), in piston housing (10), and stack friction plates (12) and mating plates (12) alternately.



(8) Set up five return springs (14) on the pressure plate in place, and put on the combination (B) of end housing and epicyclic gearing. Fasten the two together by tightening only one bolt (b).

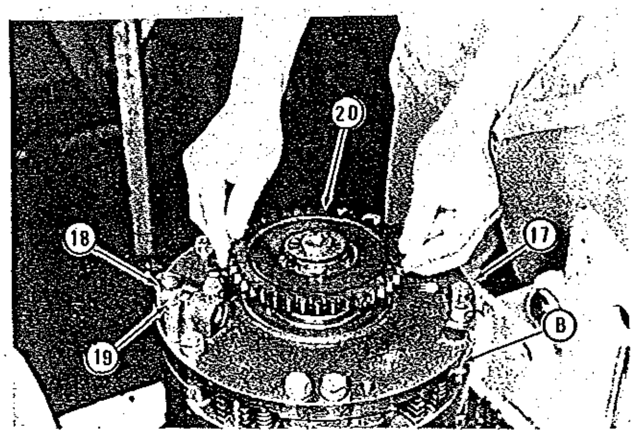
(9) Install two snap rings (15) (16) to retain the ball bearing (between end housing and carrier). This completes reassembly of the REVERSE section.



(10) Place the REVERSE section (B) on the FORWARD-HIGH section, and secure the former to the latter by tightening eight bolts (19).

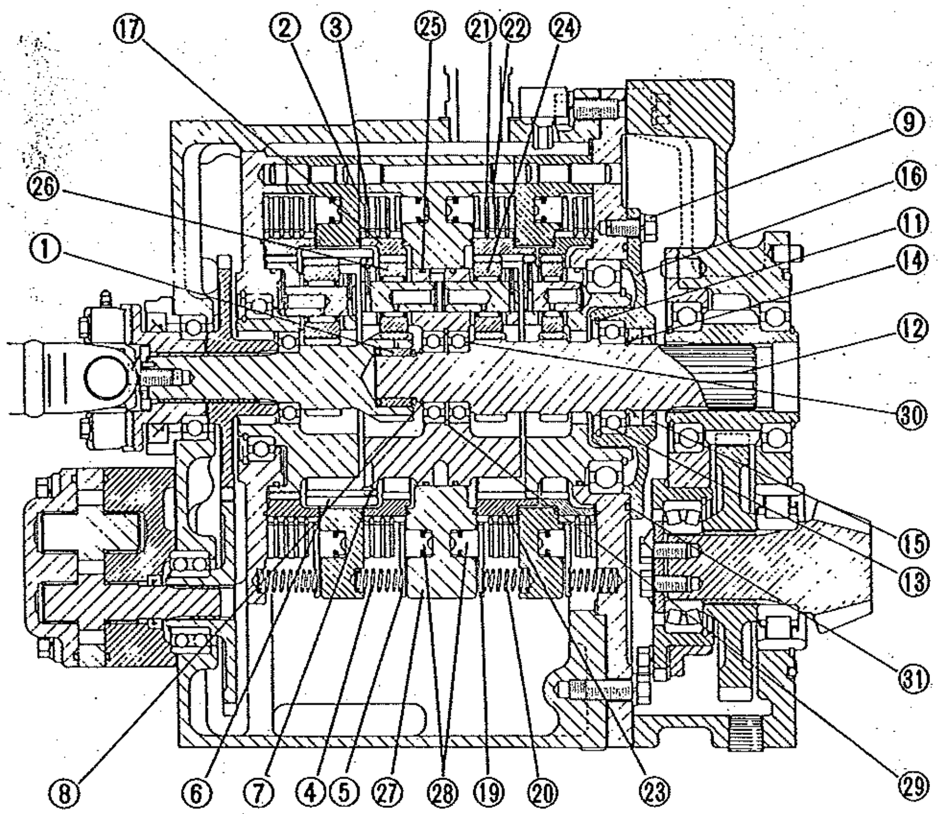
(11) Install lubricating valve (18), and secure it with two bolts (19) to end plate.

(12) Feed pump drive gear (20) onto the splined input shaft, setting the gear snugly with its bottom end bearing against the inner race of ball bearing.



FORWARD-HIGH section disassembly

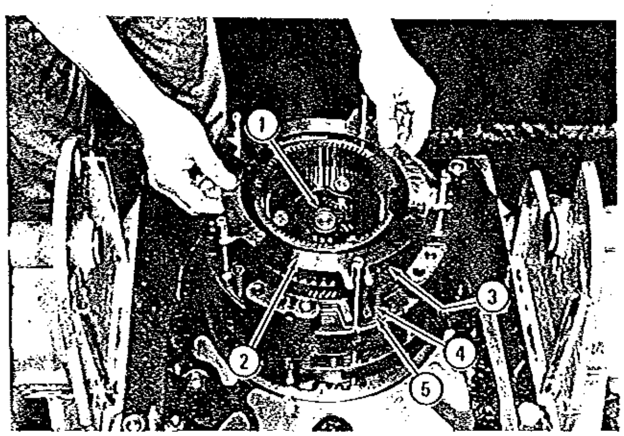
This section comprises two clutches, two epicyclic gearings and one carrier common to the two. (The procedure to follow assumes that the REVERSE section has been removed.)



1-Needle bearing
2-Mating plate
3-Friction plate
4-Return spring
5-Pressure plate
6-Linking ring gear
7-Snap ring
8-Snap ring
9-Bolt
11-Snap ring
12-Output shaft
13-Ball bearing
14-Snap ring
15-Oil seal
16-Bearing case
17-FORWARD ring gear
19-Pressure plate
20-Return spring
21-Friction plate
22-Mating plate
23-HIGH ring gear
24-HIGH planet gear
25-Carrier seal
26-FORWARD planet gear
27-Piston housing
28-Piston
29-Ball bearing
30-Ball bearing
31-"O" ring

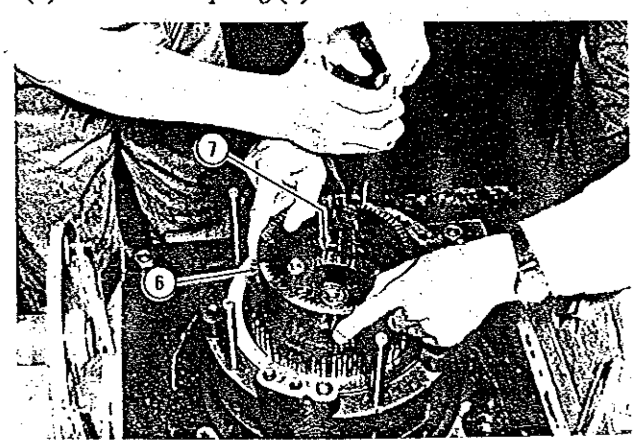
(1) From the top end of output shaft, remove needle bearing (1).

(2) From the piston housing (common to FORWARD and HIGH clutches), take out three mating plates (2), three friction plates (3), five return springs (4) and pressure plate (5). These parts are for FORWARD.

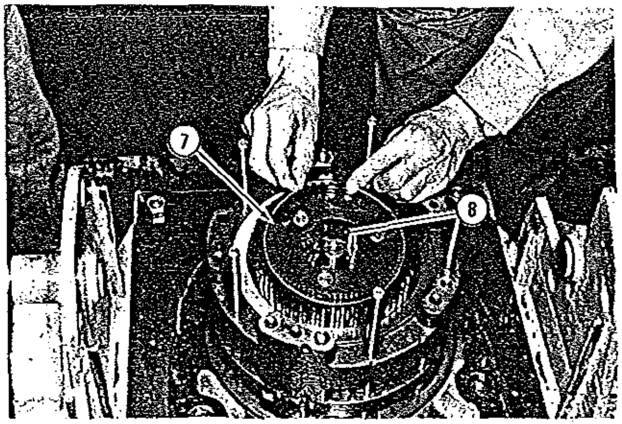


(3) Squeeze snap ring (7), as shown, and take off ring gear (6). This gear is that which links REVERSE planets to FORWARD carrier.

(4) Pick out snap ring (7).

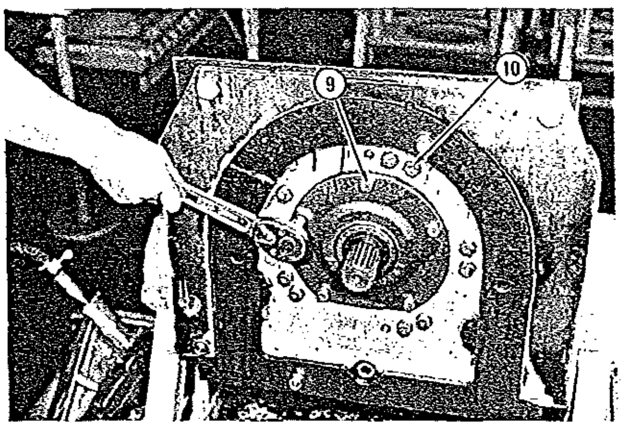


(5) Remove snap ring (8) from output shaft.

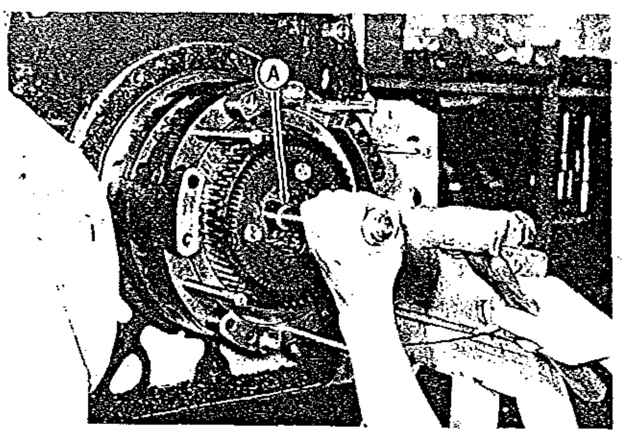


(6) Remove five bolts (9) securing the bearing case to the case cover.

(7) Remove nine bolts (10) holding piston housing to the case cover.

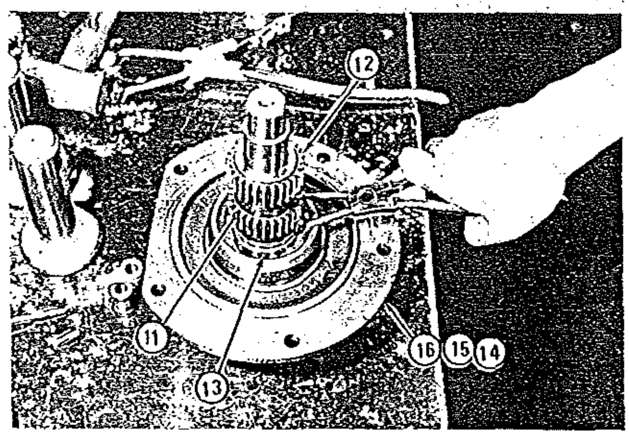


(8) Drive out shaft (A). The shaft will move out together with ball bearing and bearing case.

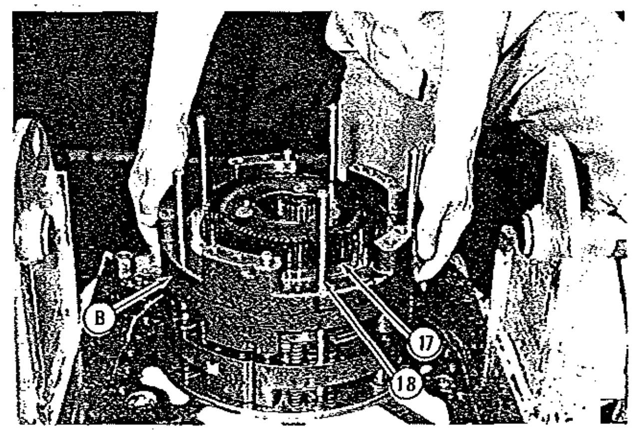


(9) Disassemble the combination of output shaft and bearing case, as follows:

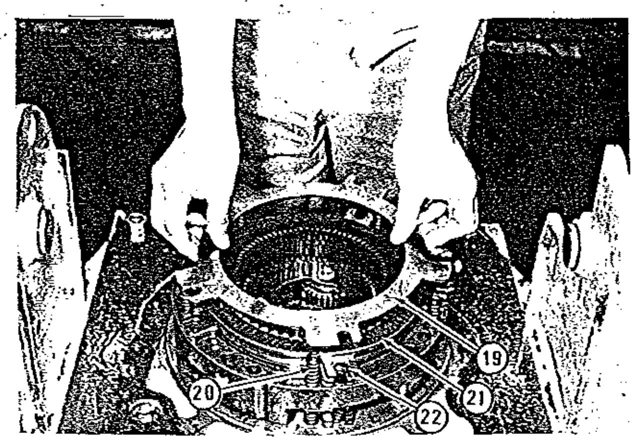
Remove snap ring (11), draw the shaft (12) off, remove ball bearing (13), snap ring (14) from shaft, and take off two oil seals (15) from bearing case (16).



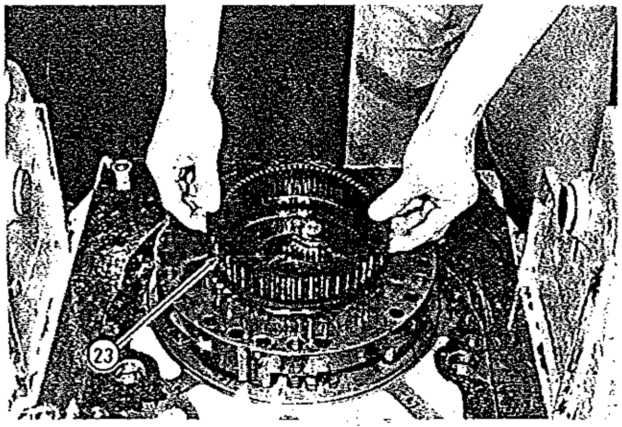
(10) Lift the combination (B) of piston housing and FORWARD-HIGH epicyclic gearings, complete with ring gear (17). Remove five clutch pins (18).



(11) Take out pressure plate (19), five return springs (20), three friction plates (21) and three mating plates (22). These parts are for HIGH. The HIGH piston will have stayed in the piston housing just removed.



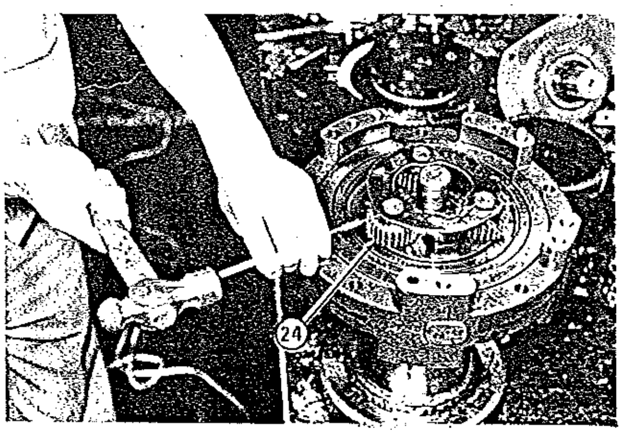
(12) Take out ring gear (23) remaining in the LOW section. This gear is that which links HIGH planets (24) to LOW carrier.



(13) Disassemble the HIGH epicycle gearing, which is on the piston housing removed. The disassembling method is similar to that already explained for REVERSE epicyclic gearing. This disassembly starts out with driving out of three spring pins locking the planet pins to the carrier.

NOTE

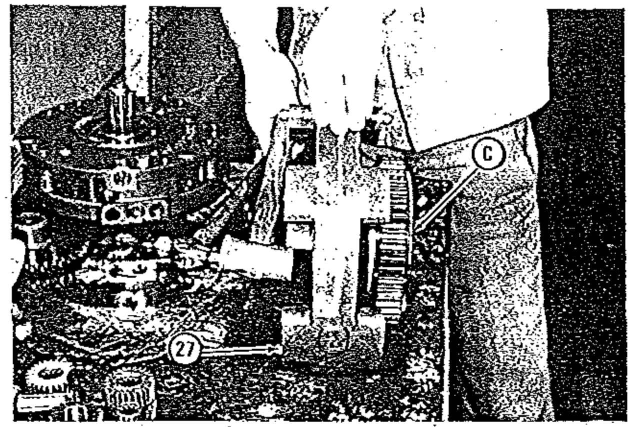
Removal of pins from planets (24) will be made easier if a soft-metal hammer is used to tap on the carrier around each pin: the reaction due to this tapping facilitates easing out of the planet pin.



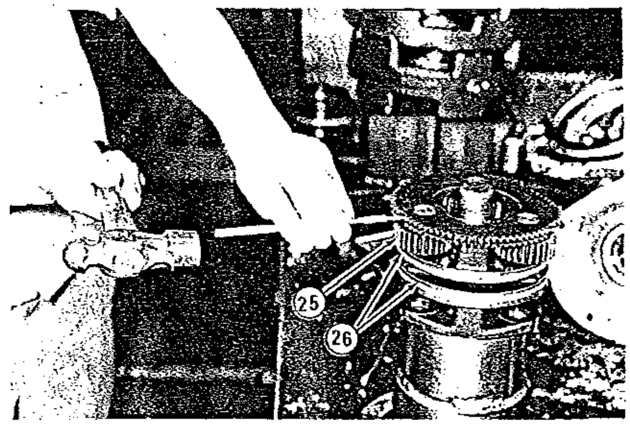
(14) Drive out of the piston housing (27) the common carrier. The carrier comes off complete with the FORWARD epicyclic gearing (C).

NOTE

Give a mark to the piston housing in order to identify its FORWARD side and HIGH side.



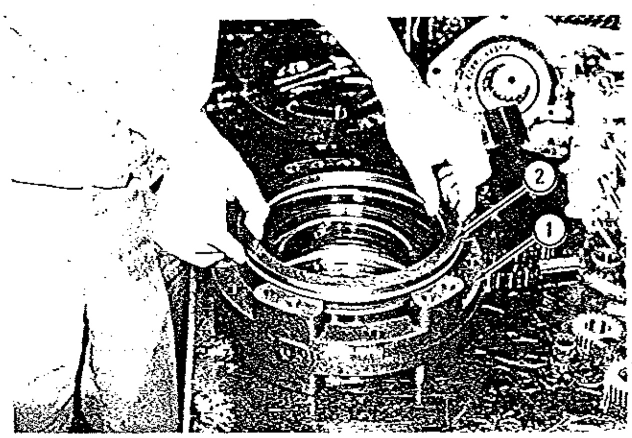
(15) Remove two carrier seals (25), and disassemble the epicyclic gearing into three planet gears (26).



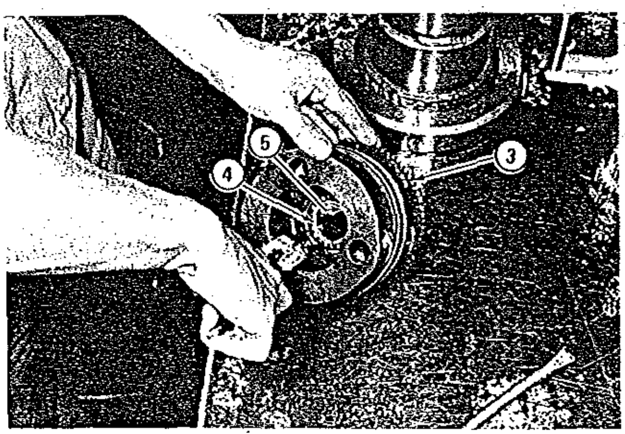
(16) From the piston housing, take out two pistons (28).

FORWARD-HIGH section reassembly

(1) Set the two pistons (2), each complete with piston seal, in the clutch portions of piston housing (1).



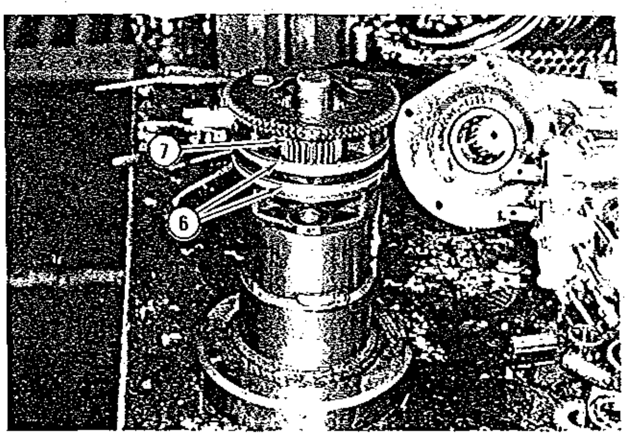
(2) To the common carrier (3) bore, fit snap ring (4) and install two ball bearings (5) by driving, one bearing on each side of the snap ring.



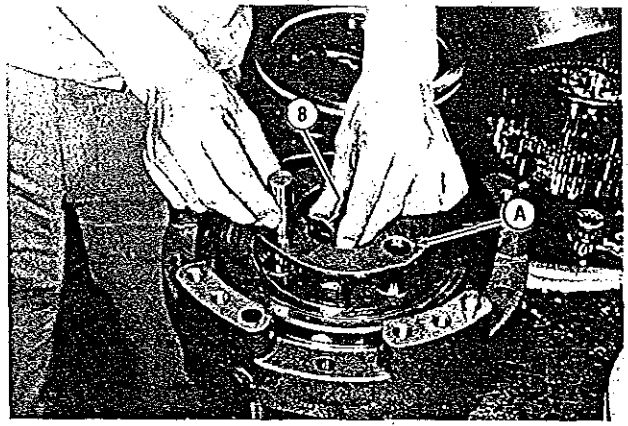
(3) Fit two carrier seals (6) to the carrier, and install FORWARD epicyclic gearing (7). (The installing method is similar to that explained for REVERSE.)

NOTE

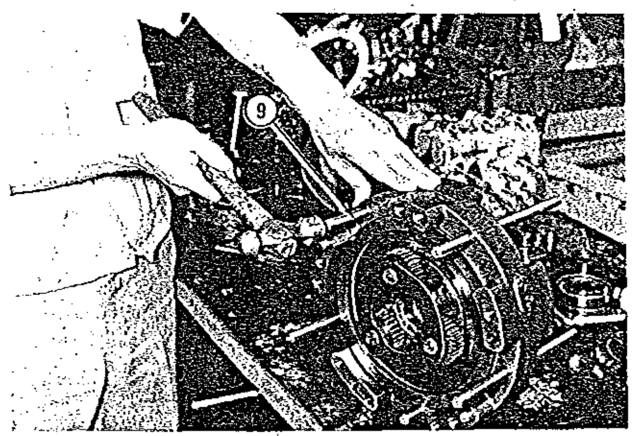
Put on FORWARD ring gear at this time. This ring will not go into position after the carrier has been combined with the piston housing.



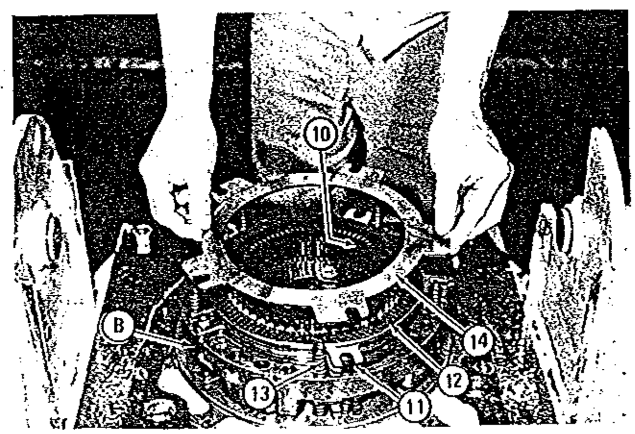
(4) Set the sub-assembly (A) of planet carrier in the common piston housing. (The carrier is now complete with FORWARD epicyclic gearing.) Install three HIGH planet gears (8) on the HIGH side of the carrier.



(5) Insert five piston pins (9) into the common piston housing.

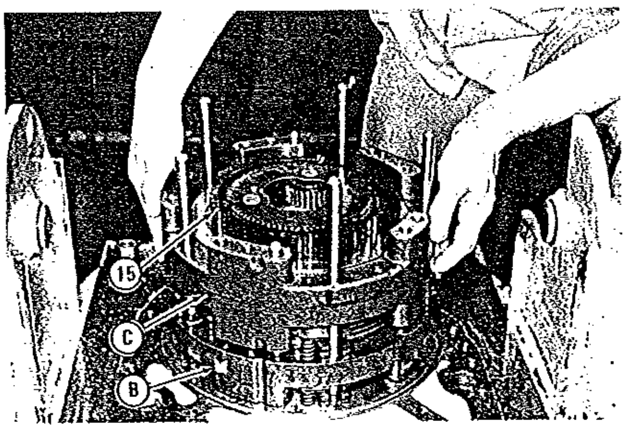


(6) Onto the LOW section (B), install ring gear (10), and place three mating plates (11) and three friction plates (12) alternately; set up five return springs (13) and place pressure plate (14).



(7) Place the FORWARD-HIGH section (C) over the LOW section (B), admitting the clutch plates and ring gear (on the LOW section) smoothly into the FORWARD-HIGH section (C) being lowered.

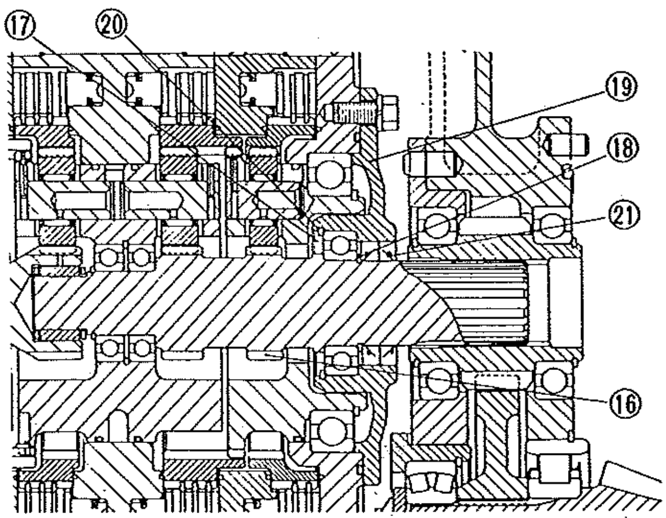
(8) Install ring gear (15).



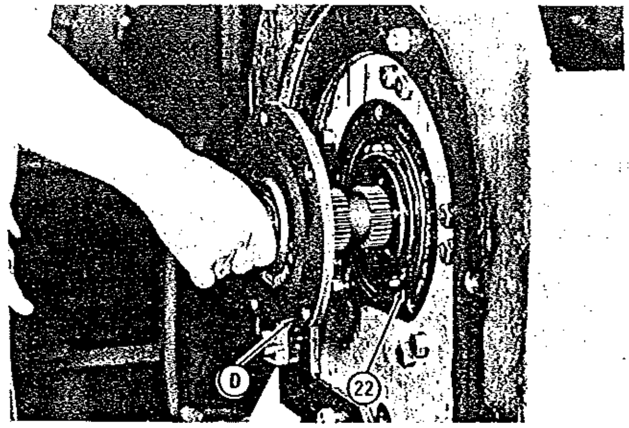
(9) Mount ball bearing (17) on output shaft (16) by driving the bearing to and against the shoulder, and put on snap ring (18).

(10) Insert the output shaft into bearing case (19), and fit snap ring (20) to the case, thereby retaining the ball bearing (17).

(11) Fit two oil seals (21) to the bearing case, making sure that the end faces of each seal are correctly discriminated.

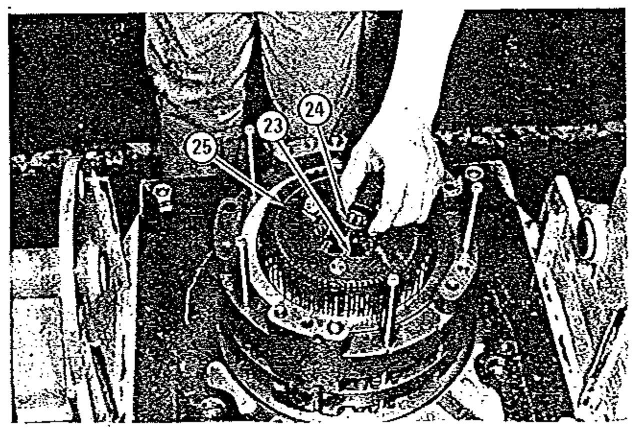


(12) Fit "O" ring (22) to the case cover. Feed the output shaft into the LOW and FORWARD-HIGH sections, and seat the bearing case (D) snugly on the case cover.

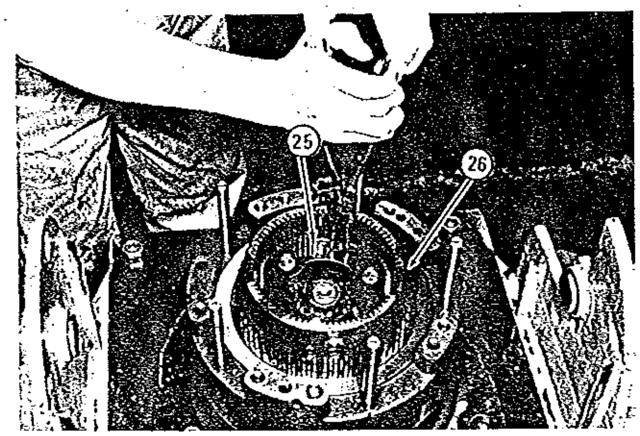


(13) Fit snap ring (23) to the output shaft, and mount needle bearing (24) on the shaft.

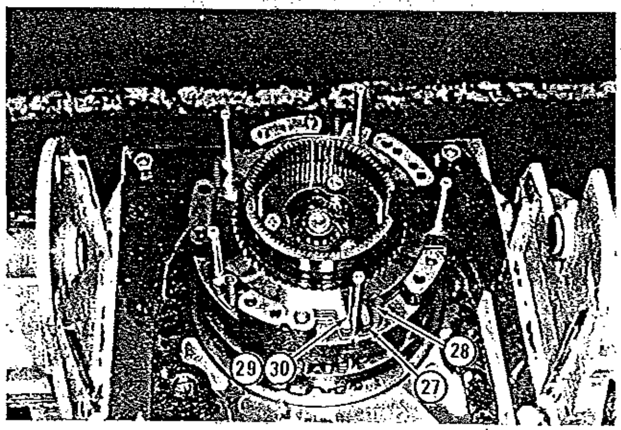
(14) Into the snap ring groove provided in the toothed periphery of carrier, fit snap ring (25). This is FORWARD side of the carrier.



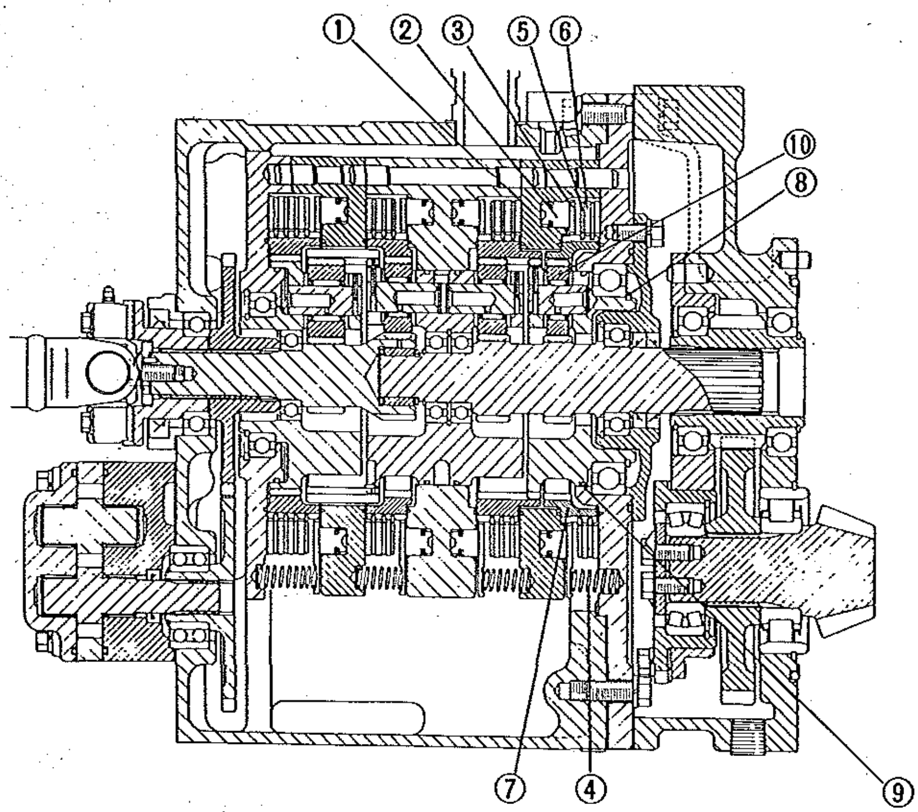
(15) Squeeze snap ring (25) in place and insert the link ring gear (26), making this gear engage smoothly with the carrier teeth. Guide the hook ends of the snap ring into the valleys 5 teeth apart.



(16) Place pressure plate (27) over the FORWARD piston, put on five return springs (28), and stack three friction plates (29) and three mating plates (30) alternately.

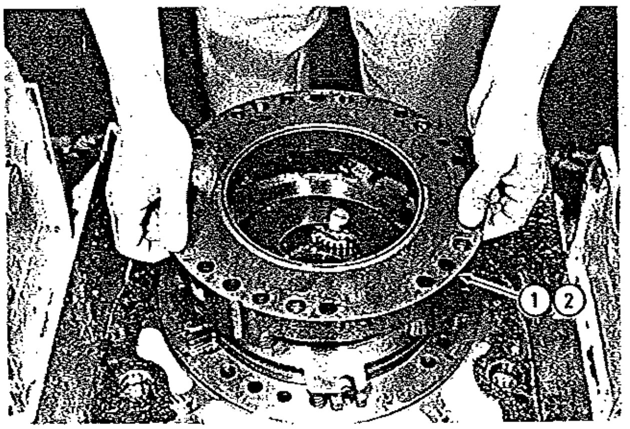


LOW section disassembly

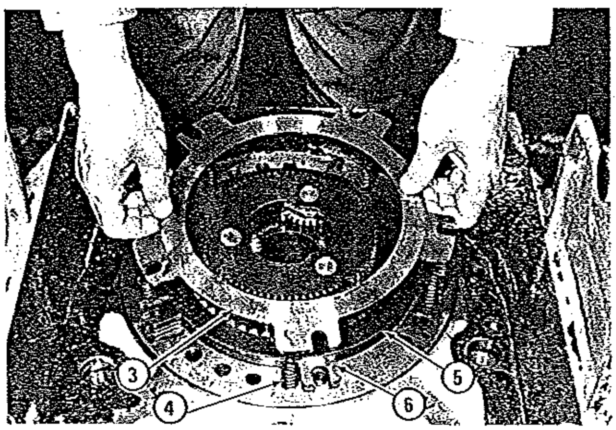


1-Piston housing	6-Mating plate
2-Piston	7-LOW ring gear
3-Pressure plate	8-Snap ring
4-Return spring	9-Carrier seal
5-Friction plate	10-LOW planet gear

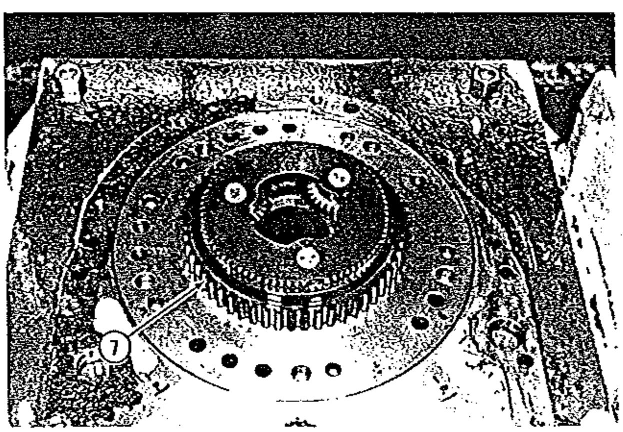
(1) Lift off piston housing (1); piston (2) comes out with the housing.



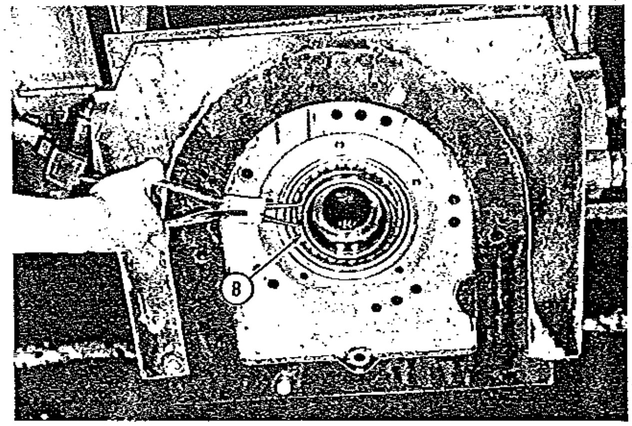
(2) Take out pressure plate (3), five return springs (4), two friction plates (5) and two mating plates (6).



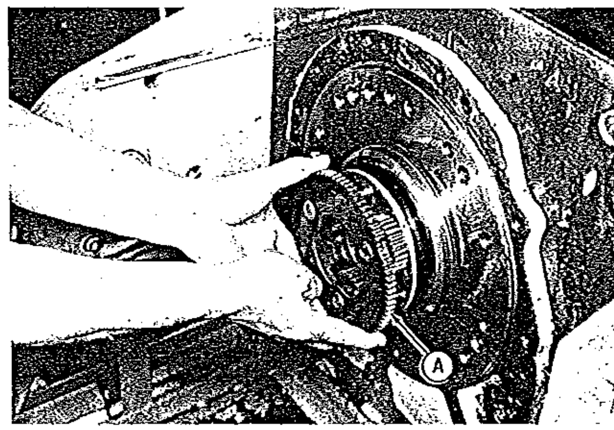
(3) Lift off LOW ring gear (7).



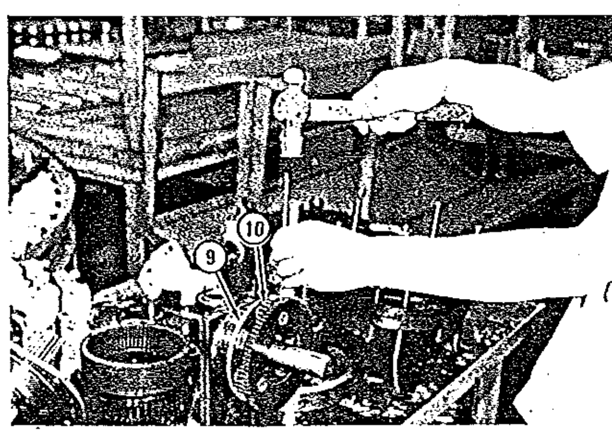
(4) Remove snap ring (8) retaining the ball bearing in place.



(5) From the case cover, remove the epicyclic gear sub-assembly (A).

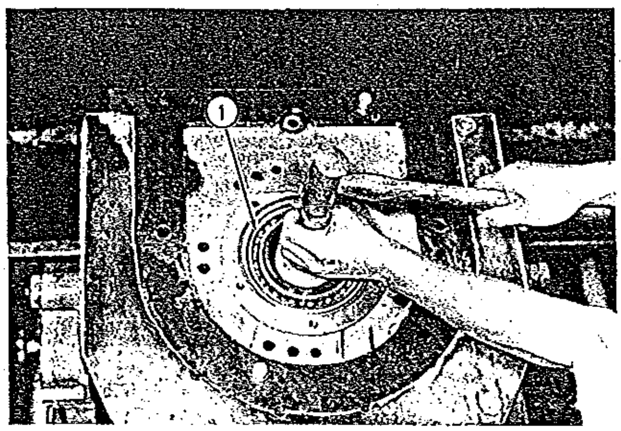


(6) Remove carrier seal (9), and disassemble the epicyclic gearing to take out three planet gears (10).

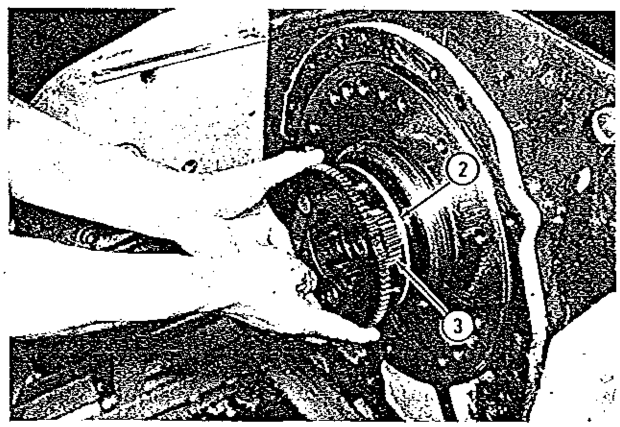


LOW section reassembly

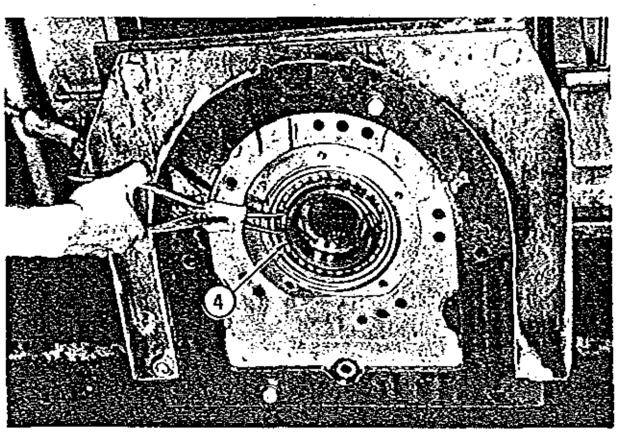
(1) Drive ball bearing (1) into the case cover.



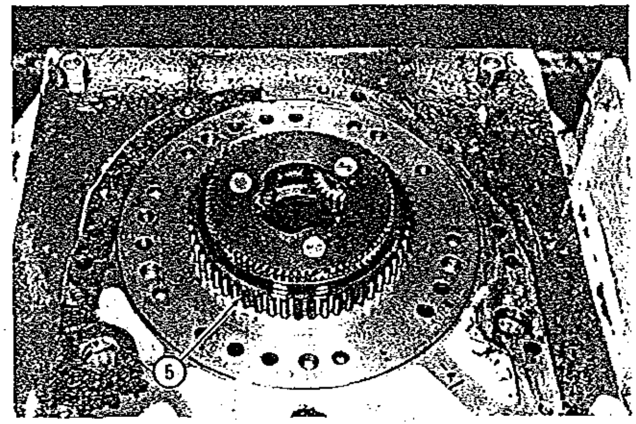
(2) Fit carrier seal (2) to the LOW carrier, and reassemble the epicyclic gearing according to the method already described.



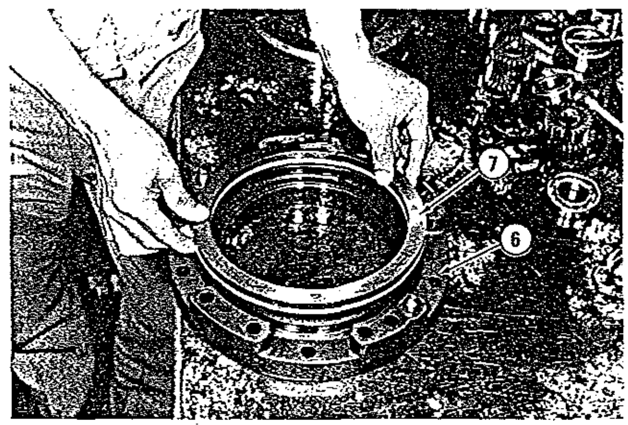
(3) Fit snap ring (4) to the carrier to retain the ball bearing.



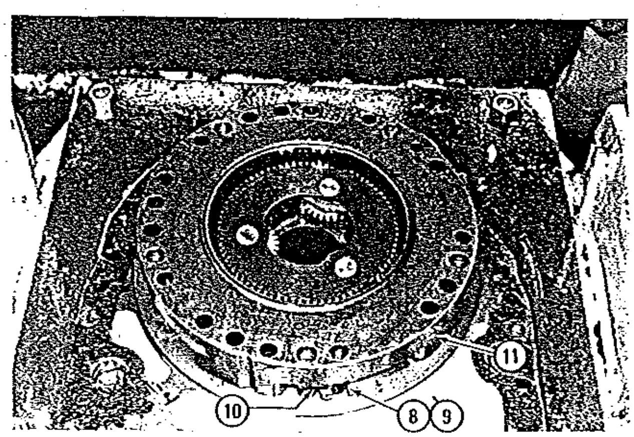
(4) Install ring gear (5), resting it on the case cover.



(5) Insert LOW piston (7) into piston housing (6). Be sure that the piston is complete with seal.

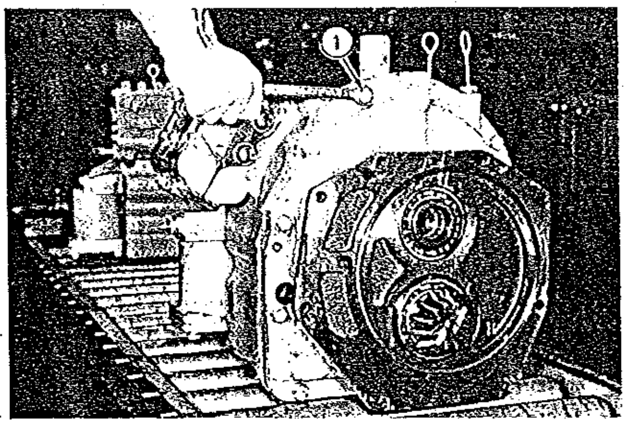


(6) Place two mating plates (8) and two friction plates alternately; set up five return springs (10) and pressure plate (11), on the case cover. Lower the piston housing onto what are on the cover case.

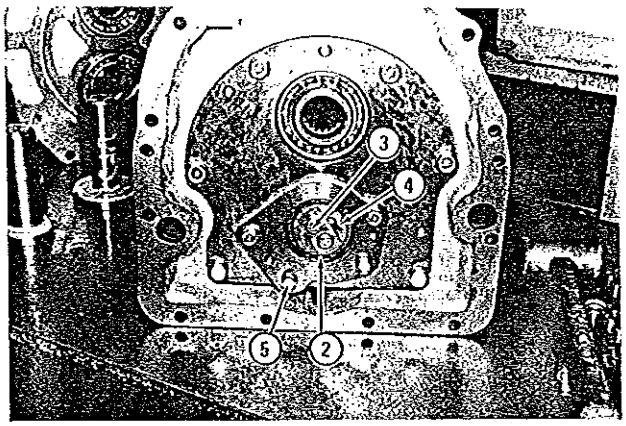


Transfer gear disassembly

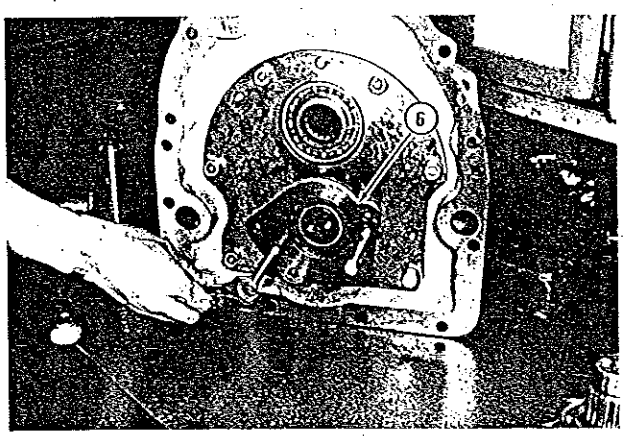
(1) Remove twelve bolts (1) securing the transfer gear assembly to the transmission case.



(2) Bend down the tongues of lock washer (2), remove two bolts (3) and take off washer (4).

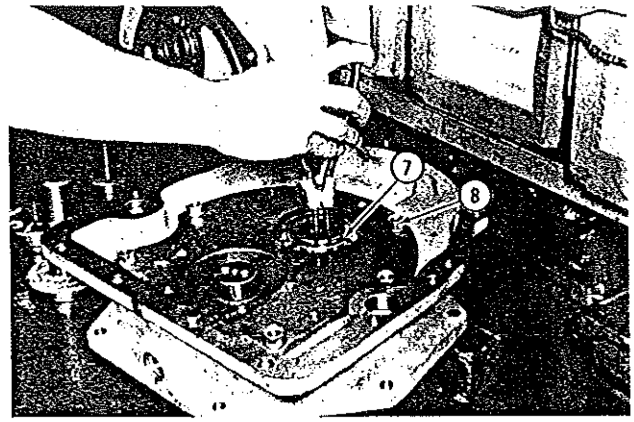


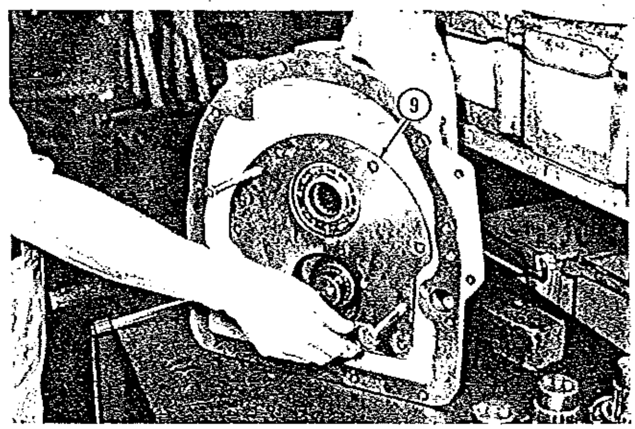
(3) Remove four bolts (5), run in two jacking bolts and force bearing case (6) out.



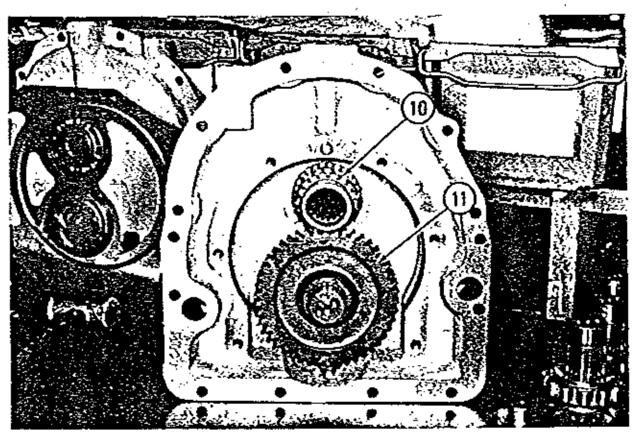
(4) Pick out snap ring (7).

(5) Remove six bolts (8) and take off transfer gear cover (9).

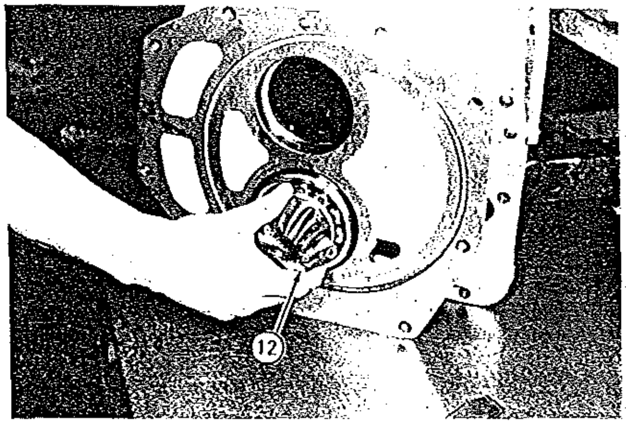




(6) Pull off transfer driven gear (11) from bevel pinion shaft.

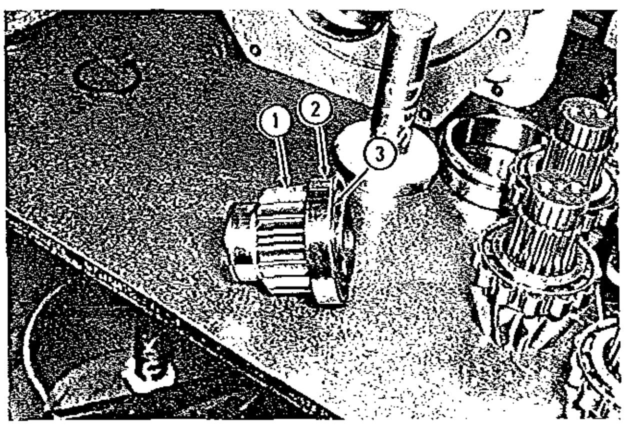


(7) Draw out bevel pinion (12) and drive gear (10) from the transfer gear case.

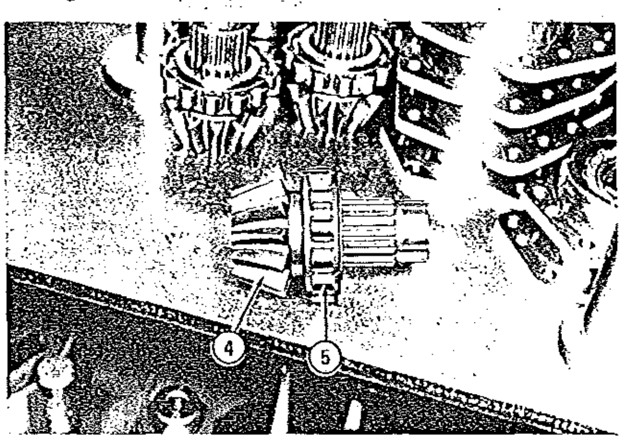


Transfer gear reassembly

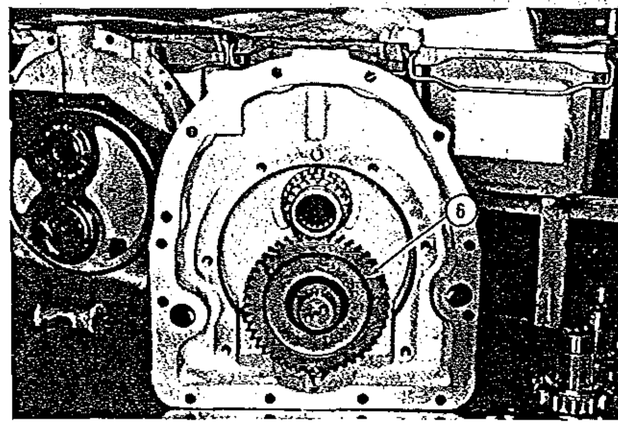
(1) Mount ball bearing (2) on the inner end of transfer drive gear (1), fit snap ring (3), and drive the bearing into the case.



(2) Mount roller bearing (5) on the shank of bevel pinion (4), and drive the bearing into the transfer gear case.

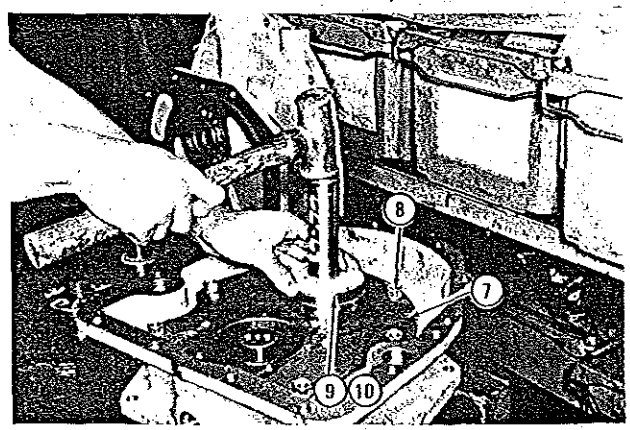


(3) Fit transfer driven gear (6) onto the splined shank of bevel pinion.

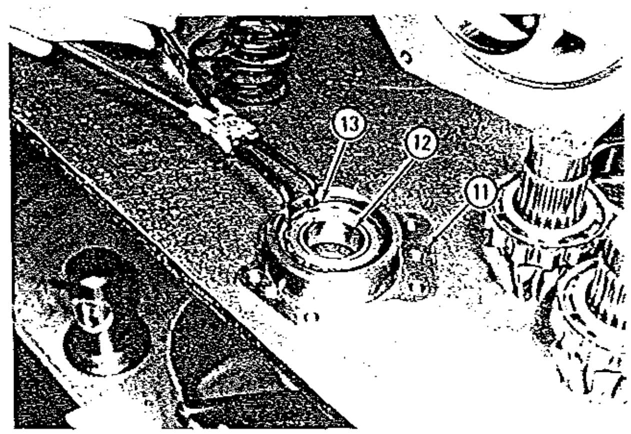


(4) Put on transfer gear cover (7) and secure it to the case by tightening six bolts (8).

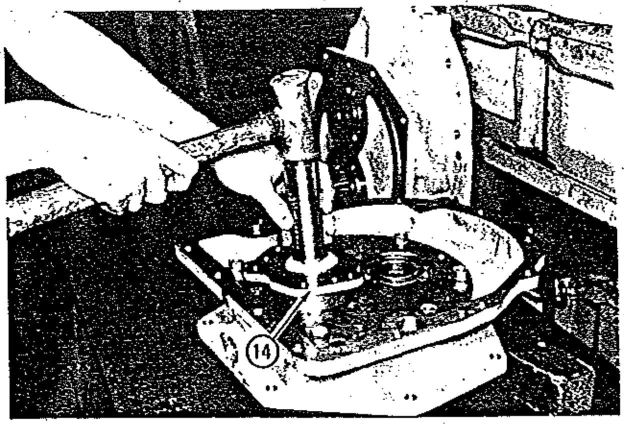
(5) Drive ball bearing (9) into the cover, and retain it by fitting snap ring (10).



(6) Drive ball bearing (12) into bearing case (11), and retain it by fitting snap ring (13).



(7) Put on shim (14), and drive bearing case (11) into the transfer gear case. Secure the bearing case by tightening four bolts.



CAUTION

The distance between the end face of bevel pinion and the outer face of transfer gear case is specified for each transfer gear because of the selective assembly during manufacture of the transfer gear. The specification is formed by a certain value (represented by letter "m" and marked on the end face of the pinion) per cent and 46.2 mm (1.819 in.). The per-cent value is either positive (+) or negative (–). To bring this distance into ±0.1 mm (0.004 in.) of the specification, the thickness of the shim used between bearing case and transfer gear cover must be adjusted.

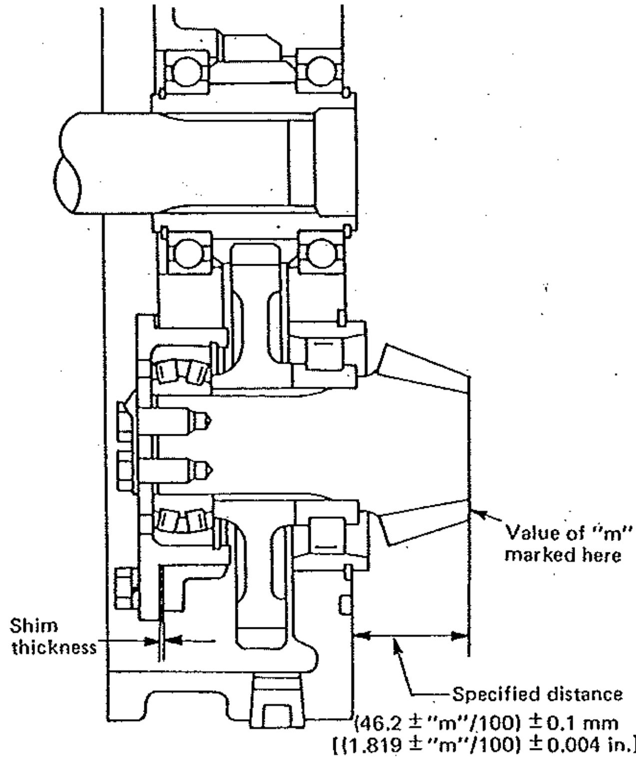
Two shims, 58827-10900 and 58827-11000, each in three sizes are available for use in this adjustment:

58827-10900: 0.1 mm (0.004 in.), 0.4 mm (0.016 in.), 1.0 mm (0.039 in.)

58827-11000: 0.1 mm (0.004 in.), 0.4 mm (0.016 in.), 1.0 mm (0.039 in.)

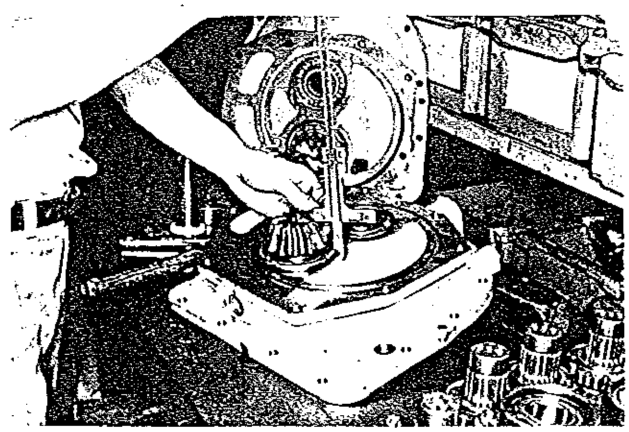
This specification is: 46.2 mm (1.819 in.) – "m"/100 ± 0.1 mm (0.004 in.) if "m" is positive.

46.2 mm (1.819 in.) + "m"/100 ± 0.1 mm (0.004 in.) if "m" is negative.



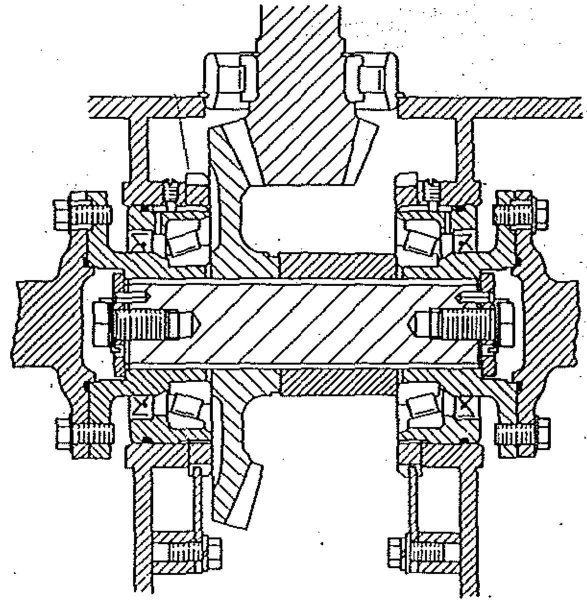
(8) Fit the washer to the end face (inner) of bevel pinion shank, put on lock washer and secure the washer by tightening two bolts. Be sure to lock the bolts by bending the lock washer.

(9) Secure the transfer gear assembly to the transmission case by running in and tightening a total of 12 bolts.



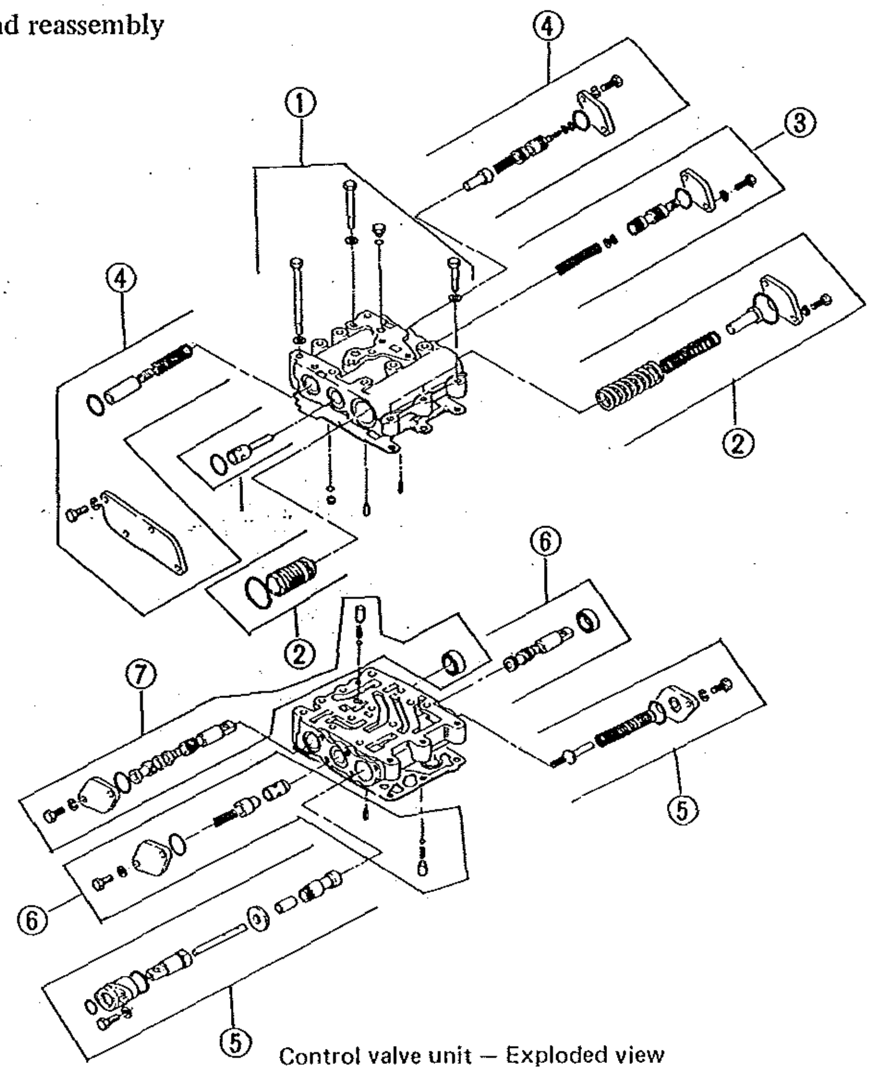
CAUTION

The bevel crown gear to mesh with the bevel pinion comes on the left side as seen in the sectional view. This is a requirement to be met in the DPS transmission. For the DD transmission, the bevel crown gear comes on the right side.



CONTROL VALVE UNIT

Disassembly and reassembly



Control valve unit — Exploded view

Carry out disassembly in the following sequence:

(1) Valve housing removal
(2) Accumulator valve removal
(3). Main relief valve removal
(4) Safety and pilot valve removal
(5) Clutch valve removal
(6) Directional selector valve removal
(7) Speed selector valve removal

Reassembly is the reverse of disassembly.

CAUTIONS

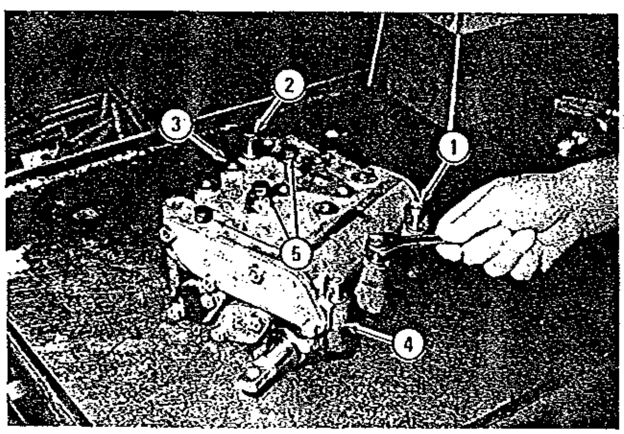
a) The control valve unit is a precision-machined device. Perfect cleanliness is the primary requirement on the place of work; use clean tools, work in clean, dust-free air, and handle the removed internals carefully.

b) In reassembly, be sure to tighten similar bolts equally to avoid distortion of parts in which spools, plungers and valves have to move back and forth by sliding. Binding, sticky or otherwise erratic movement of these sliding members is often due to unequal tightening of bolts and screws.

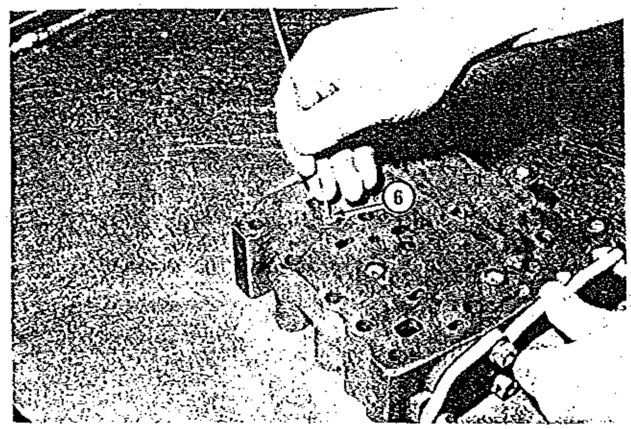
Valve housing disassembly

(1) Remove three bolts (1) and one bolt (2), and take off upper housing (3).

(2) Remove gasket (4) and three plugs (5).



(3) Remove accumulator orifice (6).



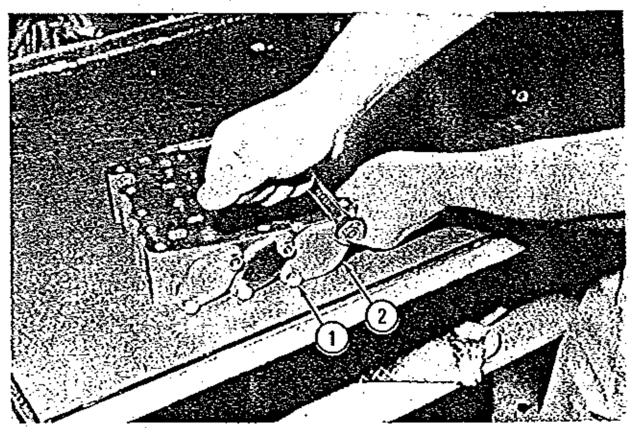
Valve housing reassembly

(1) Install accumulator orifice, plugs and gasket on the housing.

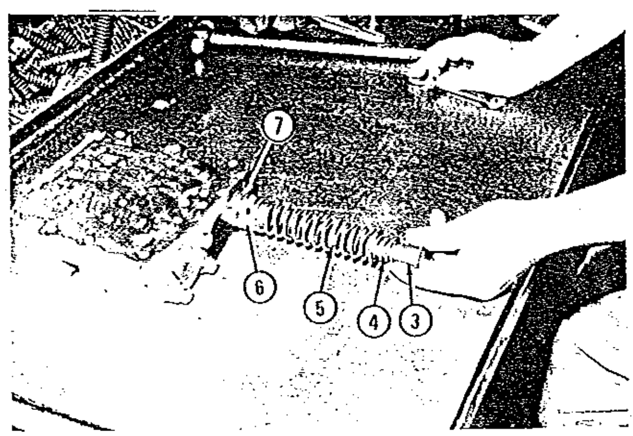
(2) Put on the housing and secure it by tightening the bolts.

Accumulator valve disassembly

(1) Remove two bolts (1) and take off cover (2).



(2) Remove accumulator pin (3), springs (4) (5), valve (6) and "O" ring (7).



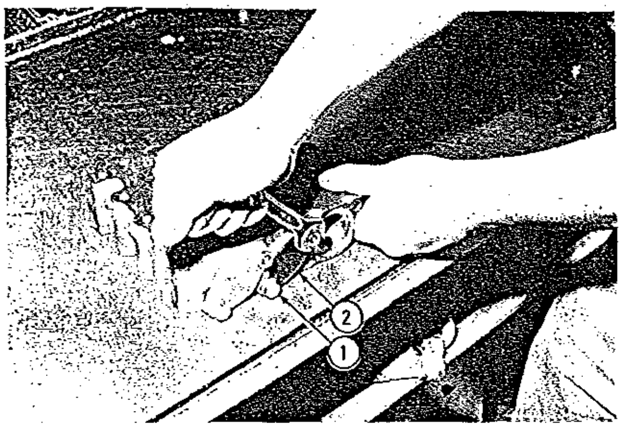
Accumulator valve reassembly

(1) Insert into the housing the accumulator parts in this order: accumulator valve, springs and pin. Put on "O" ring.

(2) Secure cover to the housing.

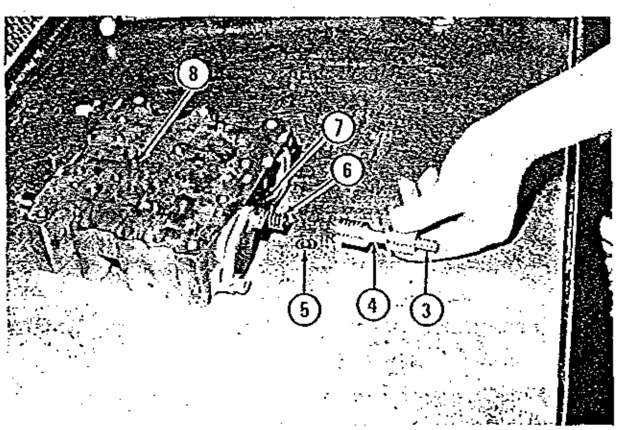
Main relief valve disassembly

(1) Remove two bolts (1), and take off cover (2).



(2) Remove slug (3), main valve (4), shim (5), main spring (6) and "O" ring (7).

(3) While tapping lightly on the housing with such as a wooden mallet, draw out bearing roller (8), and take out check seat.

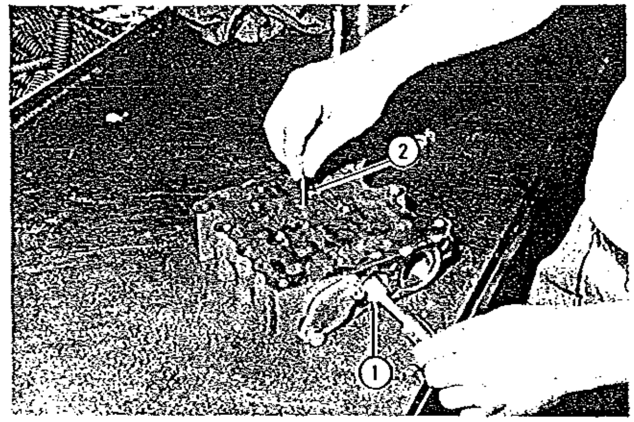


Main relief valve reassembly

(1) Insert check seat (1) into the housing, and secure by installing bearing roller (2).

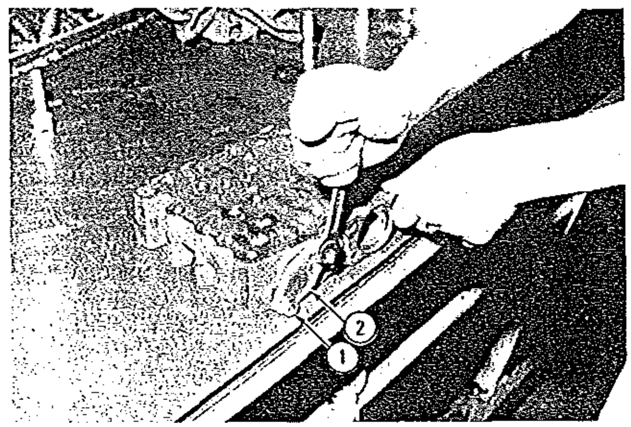
(2) Install main spring, shim, main valve, slug and "O" ring.

(3) Put on the cover.

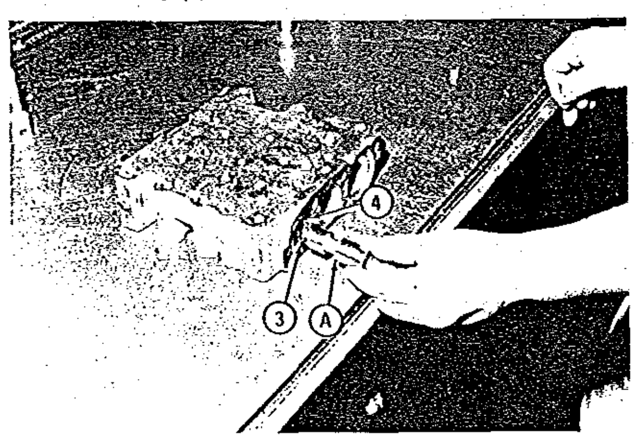


Safety and pilot valve disassembly

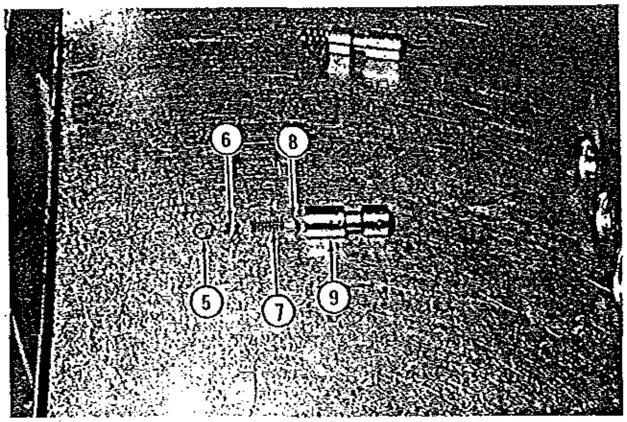
(1) Remove two bolts (1), and take off cover (2).



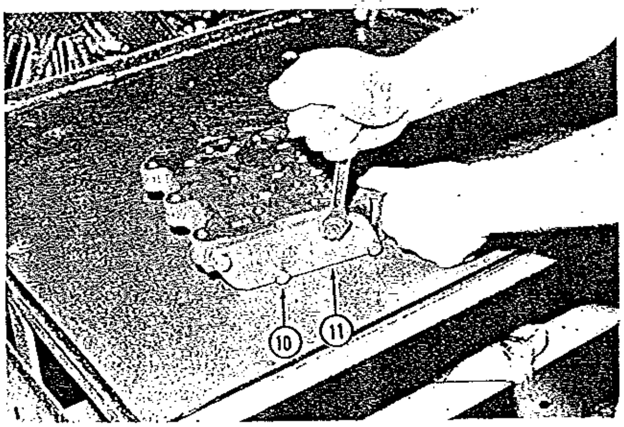
(2) Remove safety valve assembly (A), spring (3) and "O" ring (4).



(3) Disassemble the valve assembly (A) into snap ring (5), spring retainer (6), damping spring (7), damping valve (8) and safety valve (9).

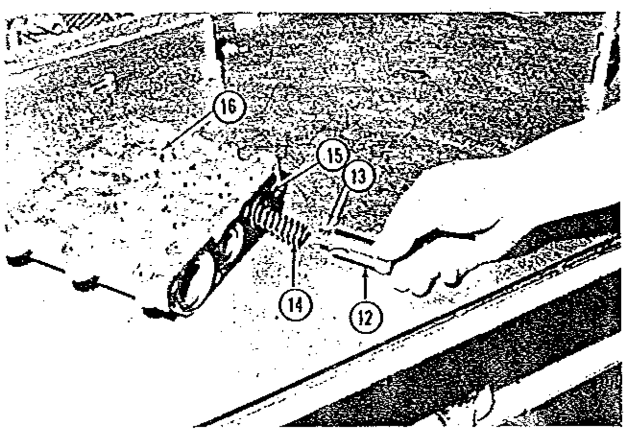


(4) Remove four bolts (10), and take cover (11) off.



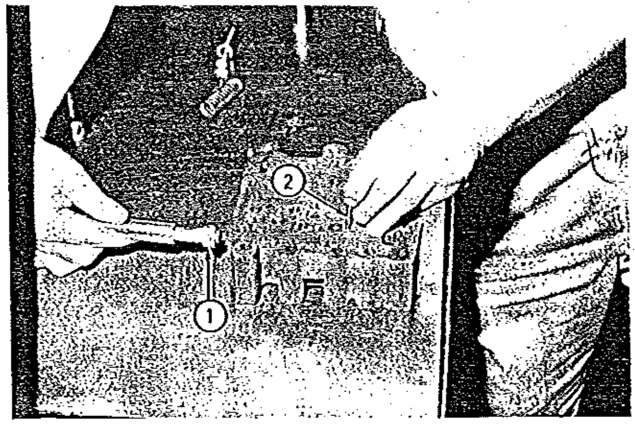
(5) Remove pilot valve (12), slug (13), pilot valve spring (14) and "O" ring (15).

(6) While tapping lightly on the housing with a wooden mallet, draw out bearing roller (16), and remove stopper.



Safety and pilot valve reassembly

(1) Insert stopper (1) into the housing, and secure it by installing bearing roller (2).



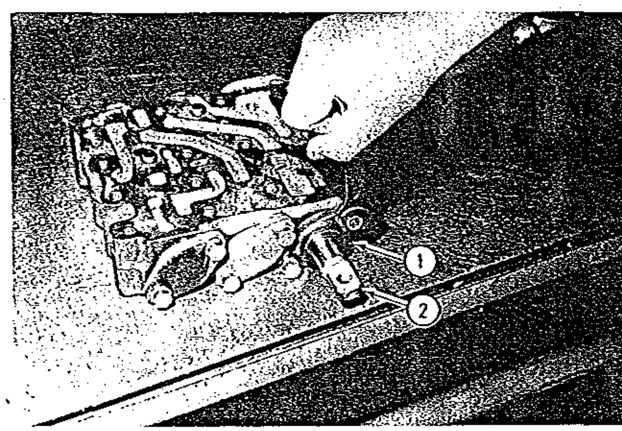
(2) Install pilot valve spring, slug, pilot valve, "O" ring and cover.

(3) Build up the safety valve assembly.

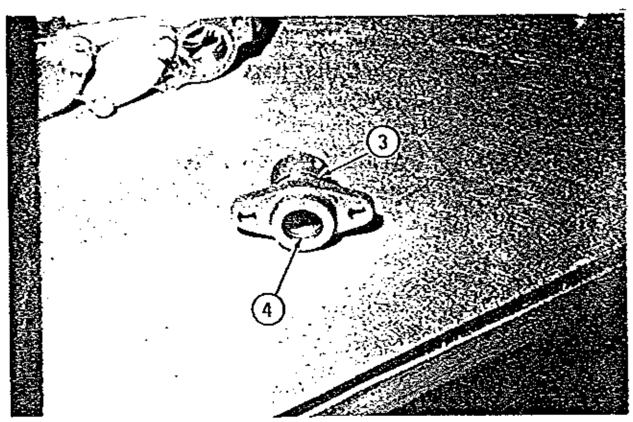
(4) Insert safety valve spring and valve assembly into the housing, and install "O" ring and cover.

Clutch valve disassembly

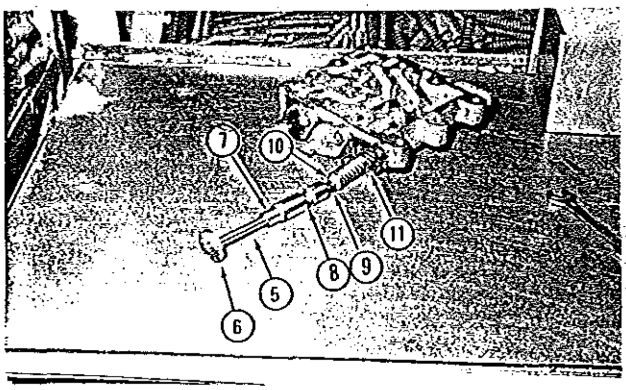
(1) Remove two bolts, and take clutch cover (1) and plunger (2).



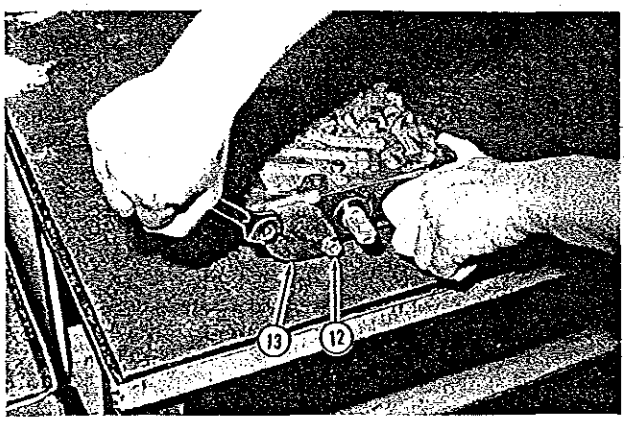
(2) From the clutch cover, remove "O" rings (3) (4).



(3) Remove clutch rod (5), spacer (6), slug (7), valve (8), spring (9), pin (10) and clutch spring (11).



(4) Remove two bolts (12) and take off cover (13).



Clutch valve reassembly

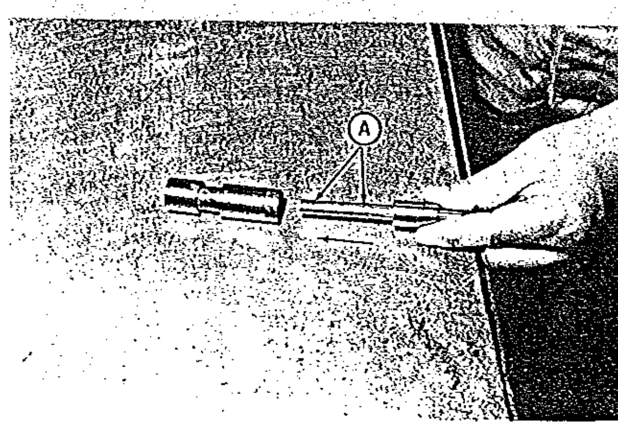
(1) Bolt the cover to the housing.

(2) Insert into the housing the clutch valve parts in this order: clutch spring, pin, spring, valve, slug, spacer and rod.

NOTE

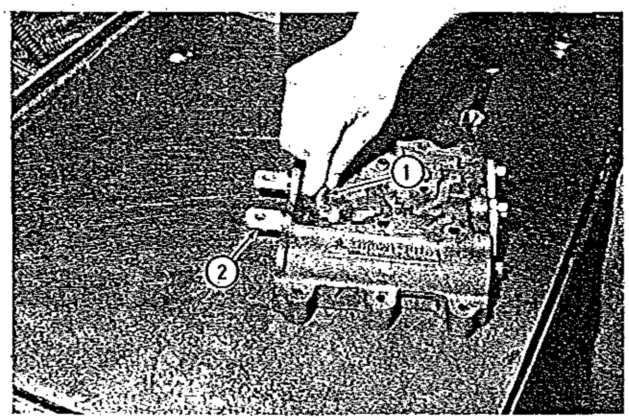
When inserting the clutch rod into the clutch valve, be sure to feed that part of rod having oil holes (A) into the valve.

(3) Fit two "O" rings to the clutch cover, and insert the cover and plunger into the housing.

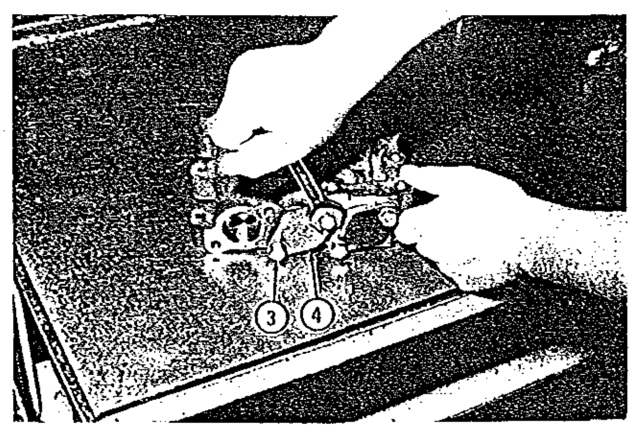


Directional selector valve disassembly

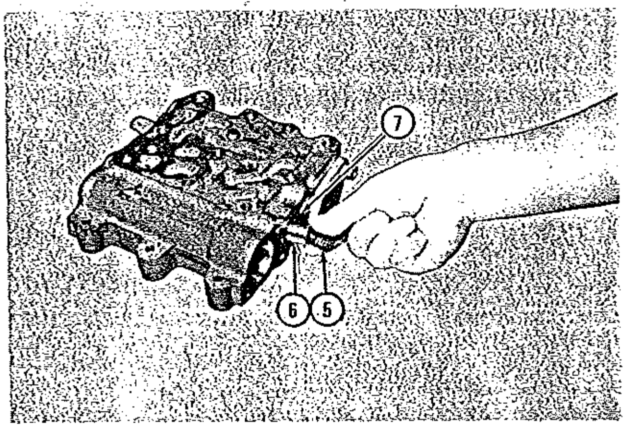
(1) Remove two detent sub-assemblies (1), top and bottom, and pull out selector plunger (2).



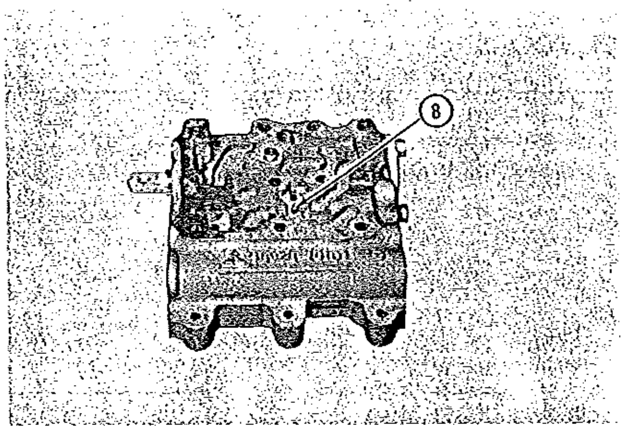
(2) Remove two bolts (3), and take off cover (4).



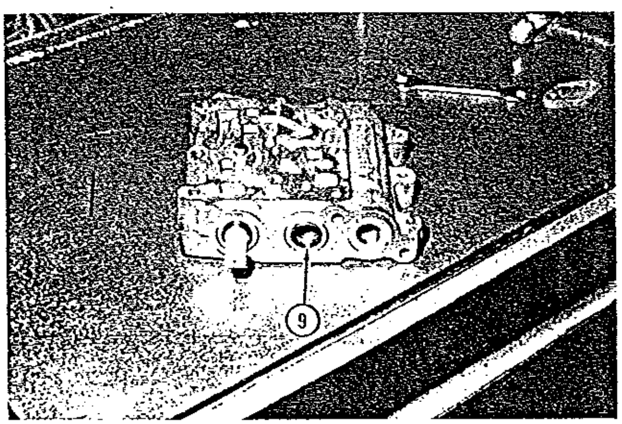
(3) Take out check spring (5), valve (6) and "O" ring (7).



(4) Remove bearing roller (8) and take out the plug.



(5) Remove oil seal (9).



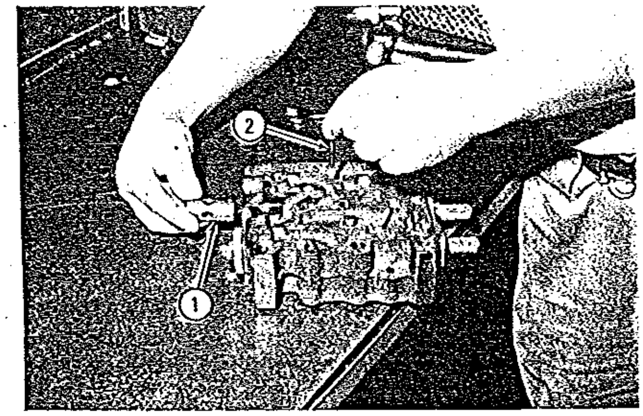
Directional selector valve reassembly

(1) Install the oil seal by driving it into the housing.

(2) Install plug (1), securing it with bearing roller (2), and lock the roller by punching.

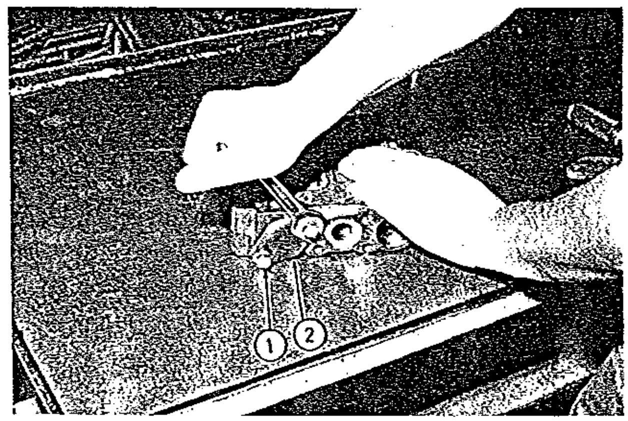
(3) Insert plug, check spring and "O" ring, and put on the cover.

(4) Insert the plunger and install the detent sub-assemblies.

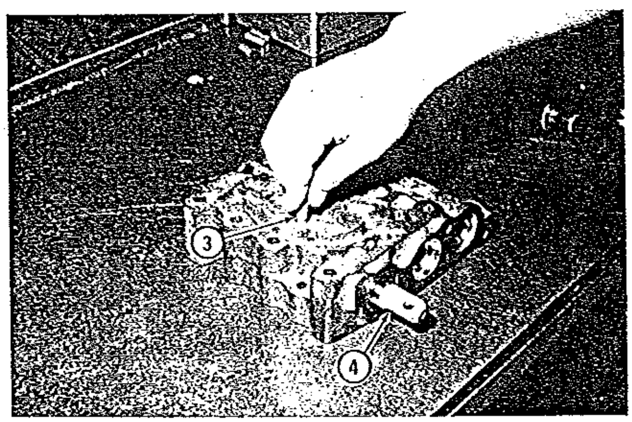


Speed selector valve disassembly

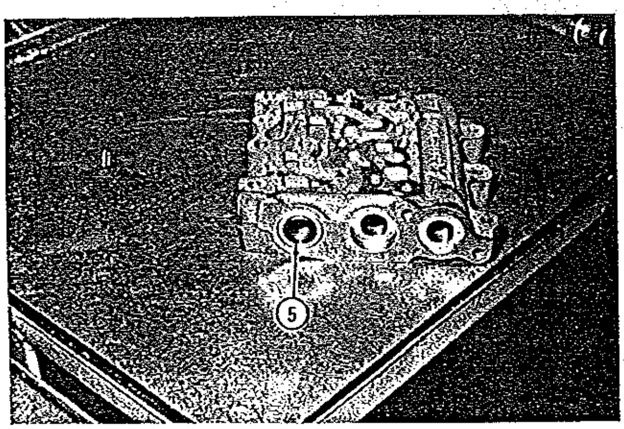
(1) Remove two bolts (1), and take off cover (2).



(2) Remove detent sub-assemblies (3), top and bottom, and take out speed plunger (4) and "O" ring.



(3) Remove oil seal (5).

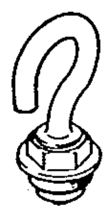
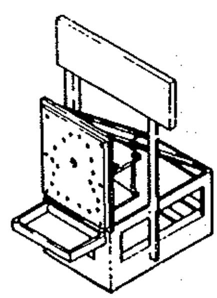


Speed selector valve reassembly

(1) Install the oil seal by driving it into the housing, and insert the speed plunger and fit "O" ring.

(2) Install detent sub-assemblies and put on the cover.

SPECIAL SERVICE TOOLS

Part number	Tool name	Shape	Use
58609-04200	Hook		For lifting clutches
58609-02600	Connector		For connecting test pressure gauges to the control valve unit (with "O" ring, 05500-19008)
58809-10038	DPS driving test bench		For DPS driving test Mount DPS test bench (58809-10038) on PDC test bench (58609-00030).
58609-00030	PDC driving test bench		

Printed in Japan

SERVICE MANUAL

MITSUBISHI TRACTOR TRACTOR SHOVEL

BD2F
BS3F

(DIRECT-DRIVE-TRANSMISSION TYPE)

POWER TRAIN / HYDRAULIC SYSTEM

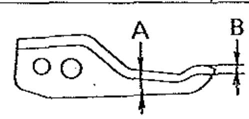
MAINTENANCE STANDARDS

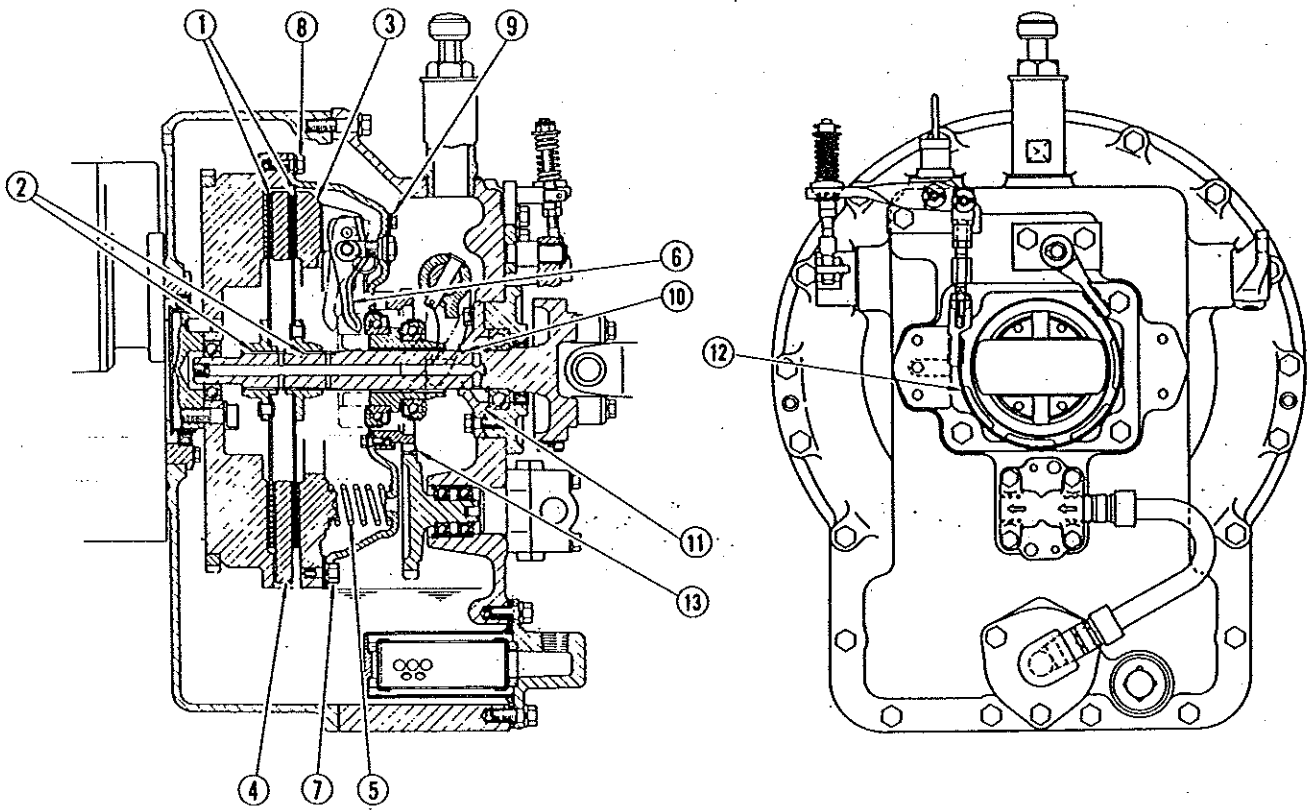
MITSUBISHI
HEAVY INDUSTRIES, LTD.

TABLE OF CONTENTS

FLYWHEEL CLUTCH

Unit: mm (in.)

Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Clutch discs	Facing thickness	5.7 ~ 6.3 (0.224 ~ 0.248)	One side: –0.4 (–0.016) Both sides: –0.8 (–0.031)	
		Runout	Up to 0.7 (0.028), incl	Over 0.7 (0.028)	
2	Hub splines	Minor diameter	26.67 ~ 26.7 (1.0500 ~ 1.0512)		
		Side fit of teeth	0.05 ~ 0.15 (0.0020 ~ 0.0059)	0.3 (0.012)	
3	Pressure plate	Friction surface thickness	20.2 (0.795)	19.7 (0.776), max	
		Friction surface flatness	0.05 ~ 0.15 (0.0020 ~ 0.0059)	0.3 (0.012)	
		Strut bolt holes	10.2 ~ 10.25 (0.402 ~ 0.404)	10.5 (0.413)	
		Release lever pin bushings		See Remarks.	Bushings are said to have reached the service limit if "teflon" overlay coating is worn away.
4	Mating plate	Friction surface thickness	13.0 (0.512)	12.5 (0.492), max	
		Friction surface flatness	0.05 ~ 0.1 (0.0020 ~ 0.004)	0.2 (0.008)	
5	Pressure springs	Free length	70.6 (2.780)	68.5 (2.697)	
		Load to compress spring to initial working length [48.2 (1.898)] kg (lb)	43.5 ± 2.17 (95.9 ± 4.78)	39.2 (86.4)	
		Squareness	Up to 2°	Over 3°	
6	Release levers	Fit on bearing	1.9 (0.075)		A – B = 0.5 (0.020), min
		Stroke	18 (3/4)		
7	Strut bolts	Tightening torque kg-m (lb-ft)	4 ~ 6 (28.9 ~ 43.4)	1 (7.2)	
8	Clutch cover mounting bolts	Tightening torque kg-m (lb-ft)	1.7 (12.3)		
9	Lock plate mounting bolts	Tightening torque kg-m (lb-ft)	0.6 ~ 0.8 (4.3 ~ 5.8)		
10	Seal ring	Surface		Cuts or breakage	
11	Cover	Surface making contact with seal ring		Grooves or scratches	
12	Brake band	Lining thickness		3.0 (0.118), max	
13	Pump drive gear	Backlash with mating gear	0.35 ~ 0.42 (0.0138 ~ 0.0165)	Over 0.7 (0.028)	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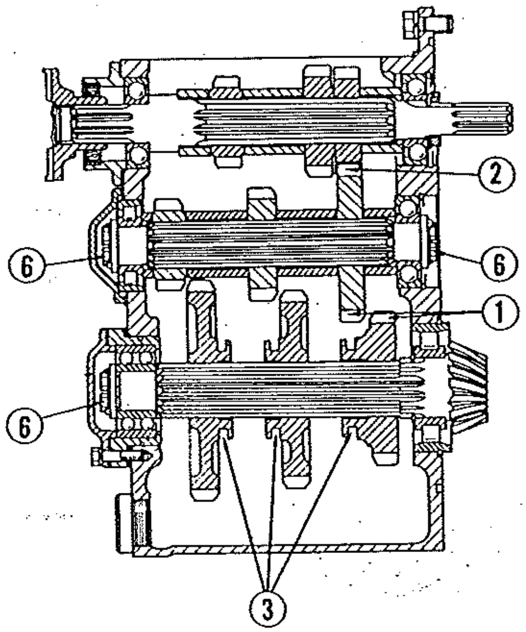
TRANSMISSION (DIRECT DRIVE)

Unit: mm (in.)

Ref. No.	Item		Assembly standard	Service limit	Remarks
1	3rd-speed gears	Backlash with reverse idler	0.12 ~ 0.30 (0.0047 ~ 0.0118)	0.6 (0.024)	
2	Gears other than 3rd-speed gears	Backlash	0.12 ~ 0.28 (0.0047 ~ 0.0110)	0.6 (0.024)	
3	Sliding gears	Width of shifter fork grooves	7.1 ~ 7.2 (0.280 ~ 0.283)	7.7 (0.303)	
4	Shifter shafts	Fit in forks	0.020 ~ 0.062 (0.00079 ~ 0.00244)	0.5 (0.020)	
5	Poppet springs	Free length	62 (2.44)	60.5 (2.382)	
		Load to compress spring to initial working length [55 (2.2)] kg (lb)	9.8 ± 0.49 (21.6 ± 1.08)	7.5 (16.5)	
6	Countershaft end securing bolts/bevel pinion securing bolts	Tightening torque kg-m (lb-ft)	2.7 ± 0.3 (19.5 ± 2.2)		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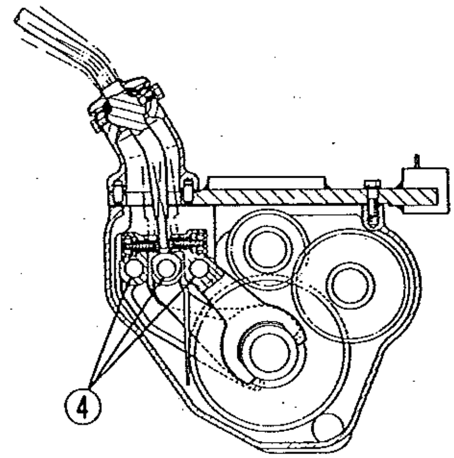
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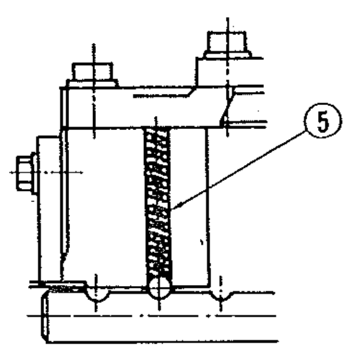
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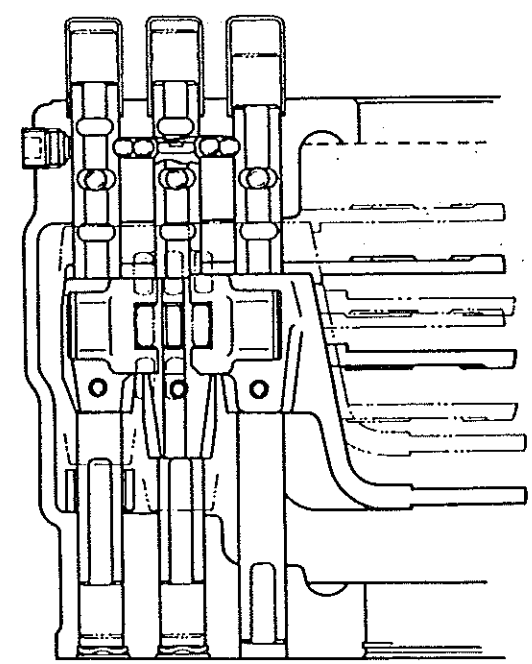
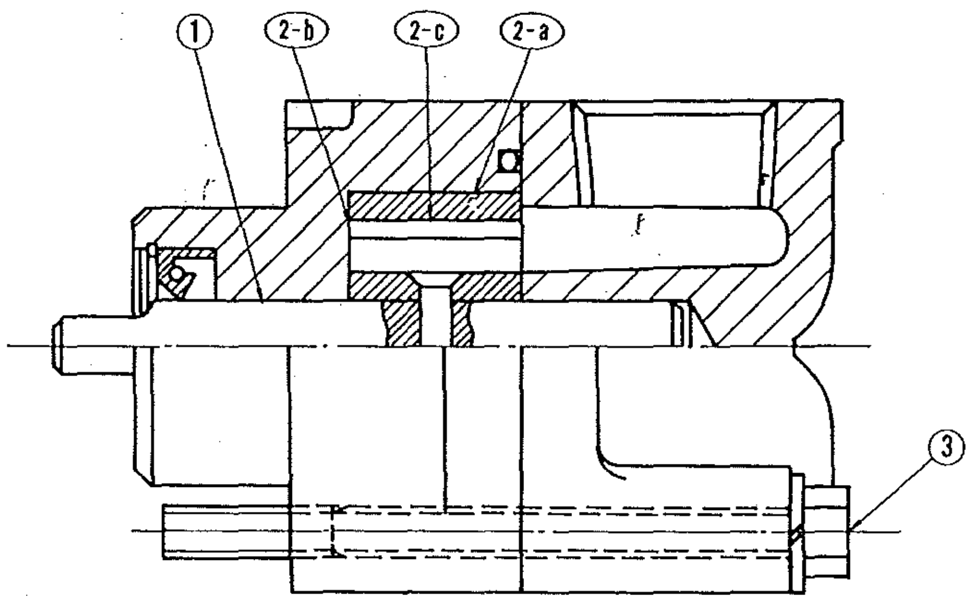


CLUTCH LUBRICATION OIL PUMP

Unit: mm (in.)

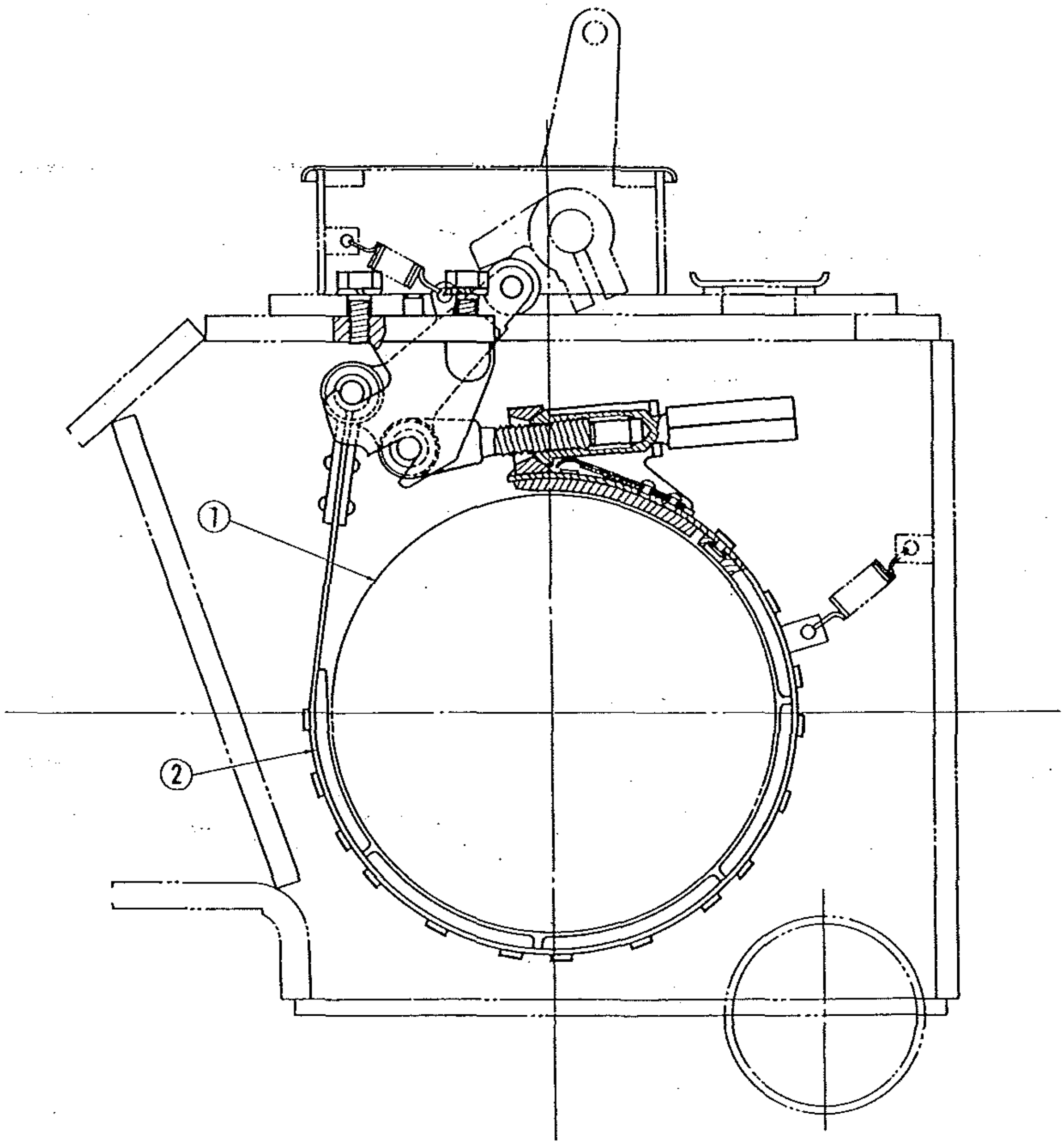
Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Main shaft clearance in pump body			0.100 ~ 0.121 (0.00394 ~ 0.00476)	0.2 (0.008)	
2	Outer rotor and inner rotor	a	Radial fit of outer rotor in pump body	0.200 ~ 0.275 (0.00787 ~ 0.01083)	0.5 (0.020)	
		b	End fit of rotors in pump body	0.04 ~ 0.09 (0.0016 ~ 0.0035)	[0.15 (0.0059)]	
		c	Fit of inner rotor trochoid feeth in outer rotor	0.013 ~ 0.150 (0.00051 ~ 0.00591)	0.25 (0.0098)	
3	Oil pump mounting bolts	Tightening torque kg-m (lb-ft)		1.7 (12.3)		



BRAKE

Unit: mm (in.)

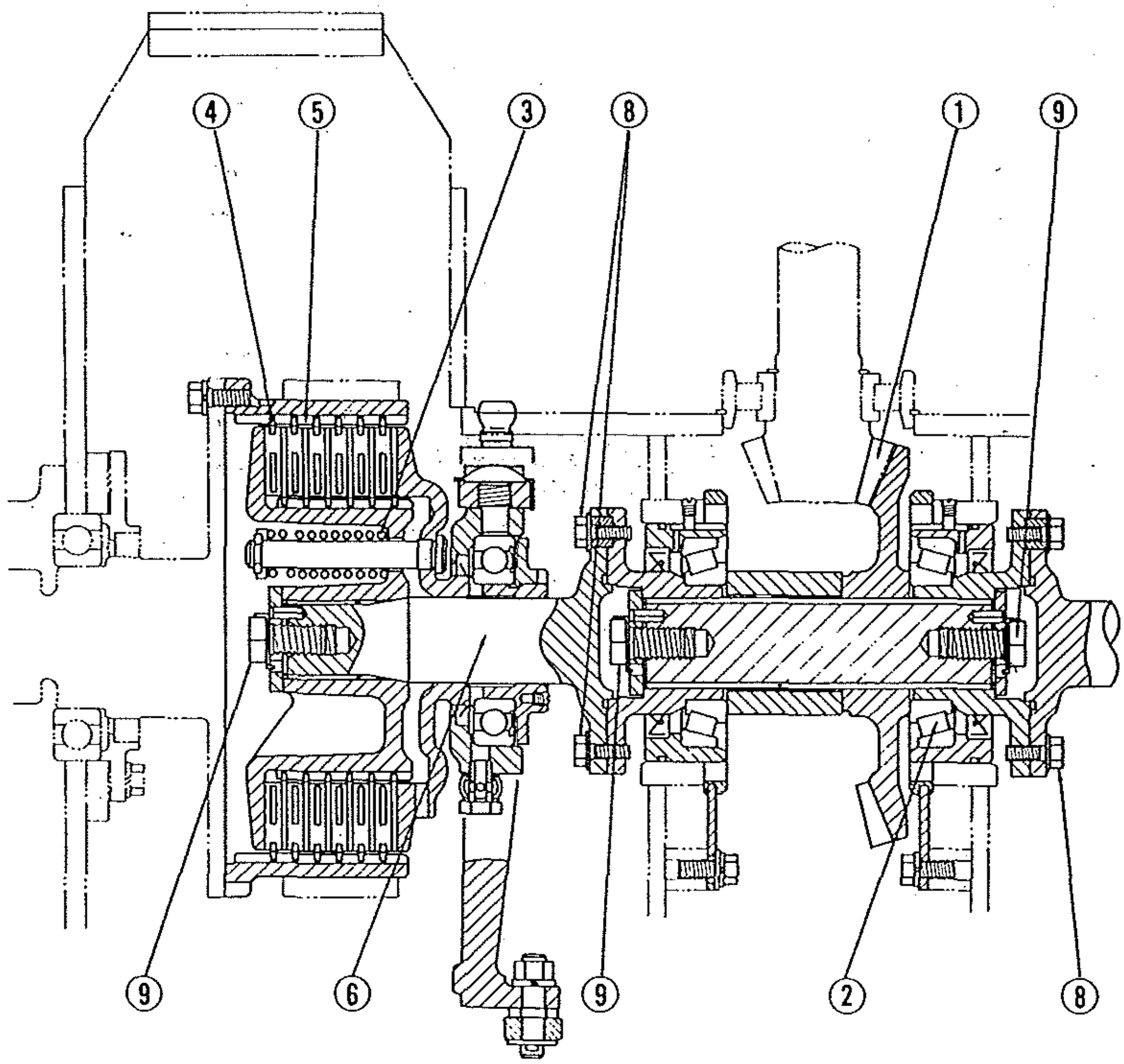
Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Drum	Outside diameter	252 (9.92)	250 (9.84)	
		Clearance in linings	0.8 (0.031)		
2	Linings	Thickness	6.5 (0.256)	4.5 (0.177)	



STEERING CLUTCHES

Unit: mm (in.)

Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Bevel gear	Backlash with pinion	0.15 ~ 0.20 (0.0059 ~ 0.0079)		
2	Tapered roller bearings	Preload (bevel gear) kg-m (lb-ft)	0.7 ~ 0.9 (5.1 ~ 6.5)		
3	Clutch springs	Free length	77.5 (3.051)		
		Load to compress spring to initial working length [63 (2.5)] kg (lb)	65.5 ± 5 (144 ± 11)		
4	Clutch facings	Thickness	8.7 (0.343)	6 (0.24)	
		Backlash with outer drum	0.16 ~ 0.52 (0.0063 ~ 0.0205)	0.8 (0.031)	
5	Clutch plates	Thickness	2.8 (0.110)	2.3 (0.091)	
		Backlash with inner drum	0.14 ~ 0.30 (0.0055 ~ 0.0118)	0.6 (0.024)	
		As-assembled thickness of plates (6 pcs) and facings (6 pcs)	69 (2.72)	66 (2.60)	
6	Clutch shaft	Fit in pressure plate	0.3 ~ 0.375 (0.012 ~ 0.01476)		
7	Lever and roller	Clearance	1.5 (0.059)		
8	Drive shaft/ clutch shaft securing bolts (10-mm diam)	Tightening torque kg-m (lb-ft)	4.2 ± 0.4 (30.4 ± 2.9)		
9	Drive shaft/ clutch shaft securing bolts (16-mm diam)	Tightening torque kg-m (lb-ft)	16 ~ 19 (115.7 ~ 137.4)		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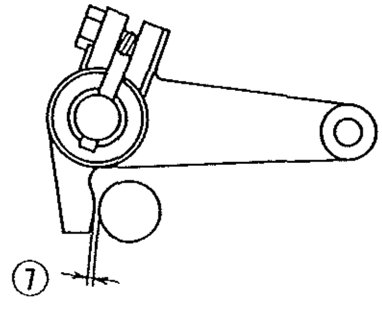
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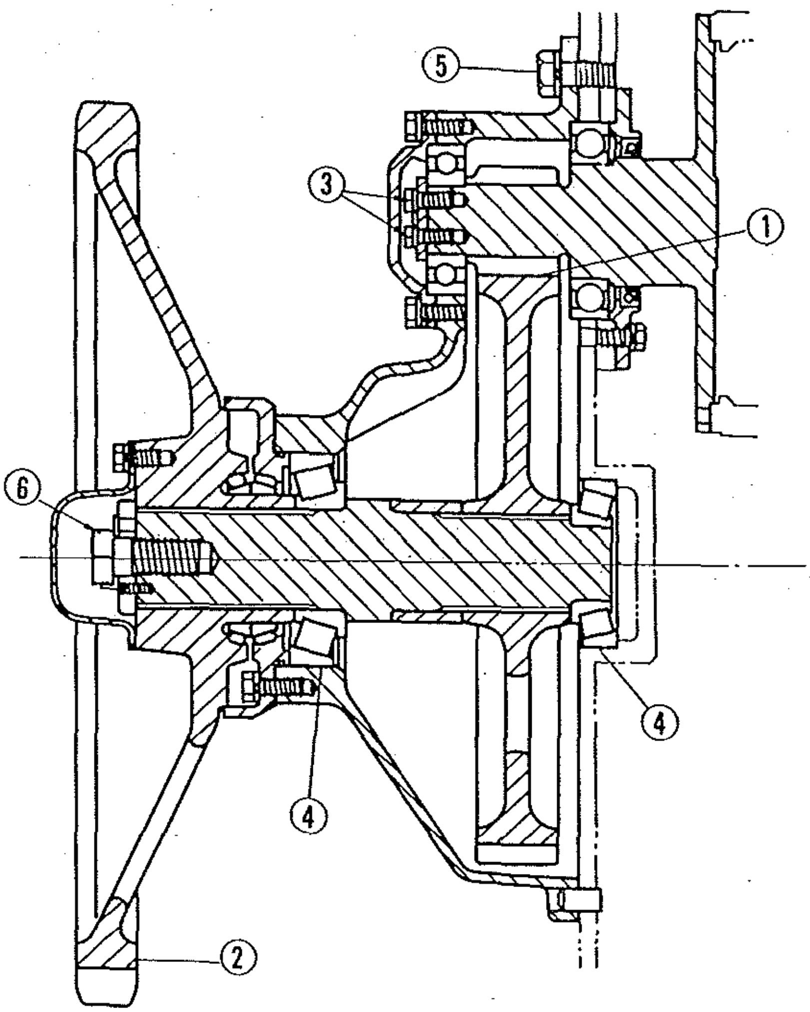
FINAL DRIVES

Unit: mm (in.)

Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Gears	Backlash	0.17 ~ 0.37 (0.0067 ~ 0.0146)	1.0 (0.039)	
2	Sprockets	Tooth width	40 (1.57)	36 (1.42)	
3	Pinion lock plate mounting bolts	Tightening torque kg-m (lb-ft)	4.2 ± 0.4 (30.4 ± 2.9)		
4	Tapered roller bearings	Preload kg-m (lb-ft)	0.29 ~ 0.37 (2.1 ~ 2.7)		
5	Final drive case mounting bolts	Tightening torque kg-m (lb-ft)	8.4 ± 0.8 (60.8 ± 5.8)		
6	Sprocket mounting bolts	Tightening torque kg-m (lb-ft)	55 ± 5 (397.8 ± 36.2)		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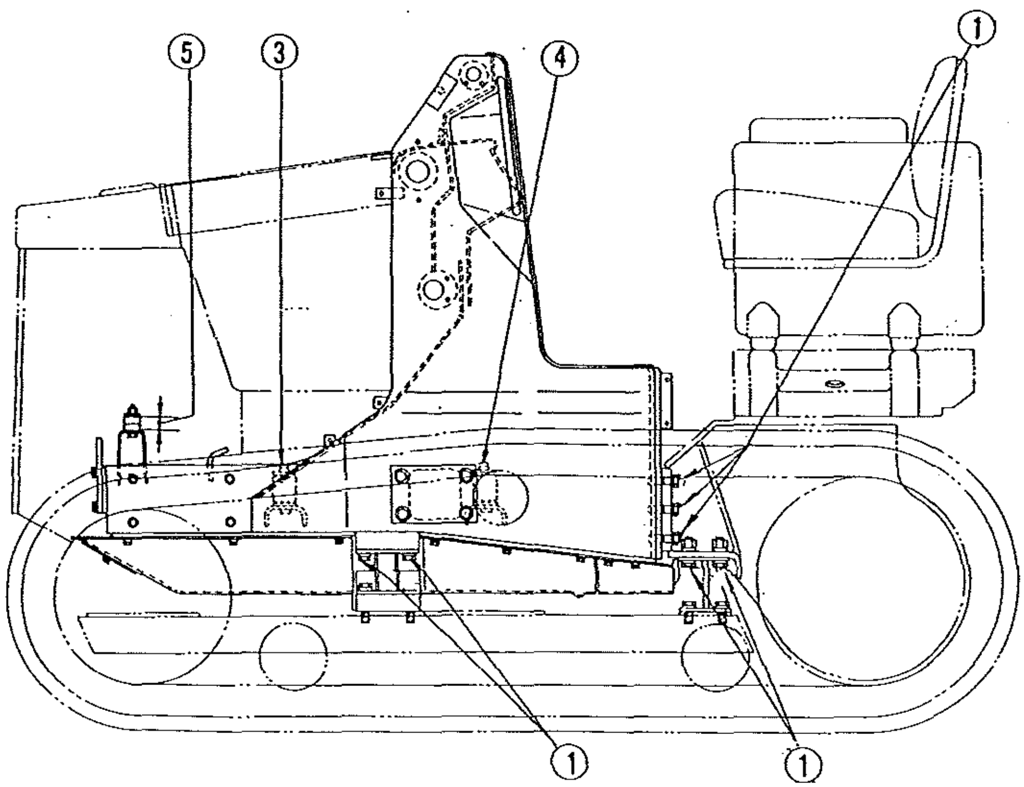
FRAME

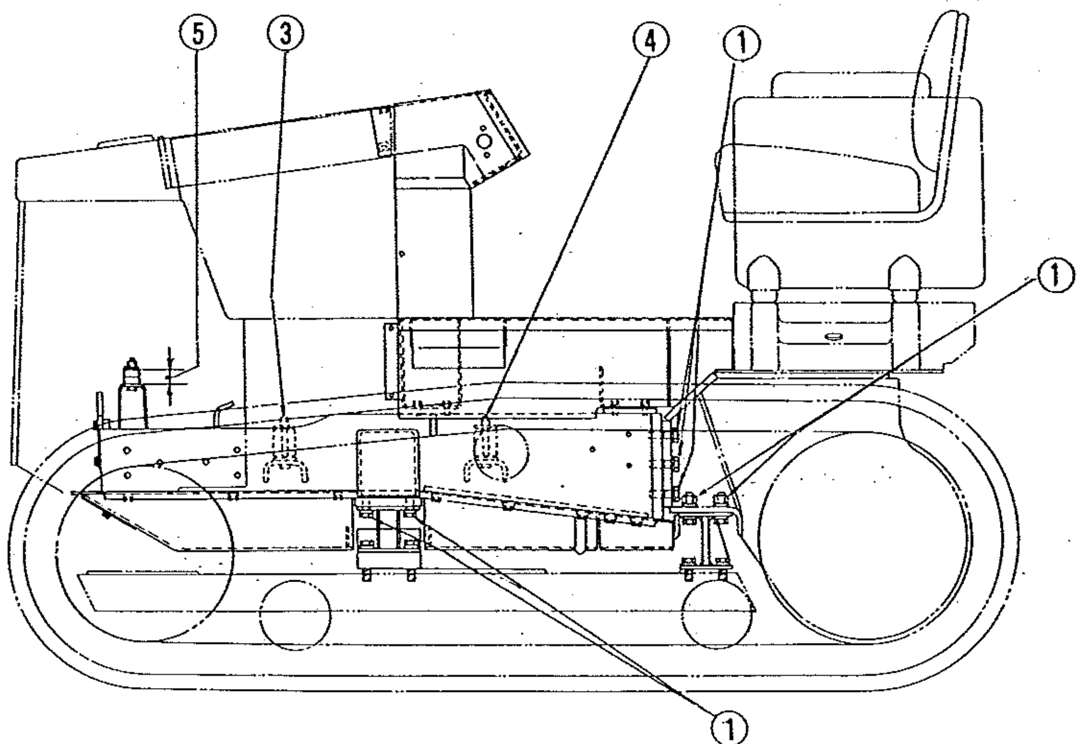
Unit: mm (in.)

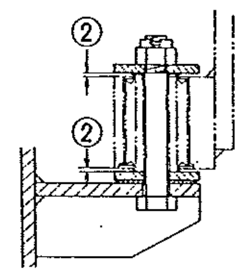
Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Steering clutch case/frame/rigid bar mounting bolts	Tightening torque kg-m (lb-ft)	29 ~ 32 (210 ~ 231)		
2	Engine front mount/flywheel clutch case mount	Bracket-to-stopper clearance	Upper: 1.2 ~ 2.2 (0.047 ~ 0.087) Lower: 1.5 ~ 2.0 (0.059 ~ 0.079)		
3	Engine front mount attaching bolts	Tightening torque kg-m (lb-ft)	15.9 ± 1.6 (115 ± 11.6)		
4	Flywheel clutch case mounting bolts	Tightening torque kg-m (lb-ft)	15.9 ± 1.6 (115 ± 11.6)		
5	Radiator mounting bolts	As-tightened clearance	25.5 (1.004)		
6	Center to center of tracks	Standard models	1200 (47-1/4)	10 (3/8)	Difference between "A" and "B"
		Swamp models	1400 (55-1/8)		
		Super-swamp models	1550 (61)		

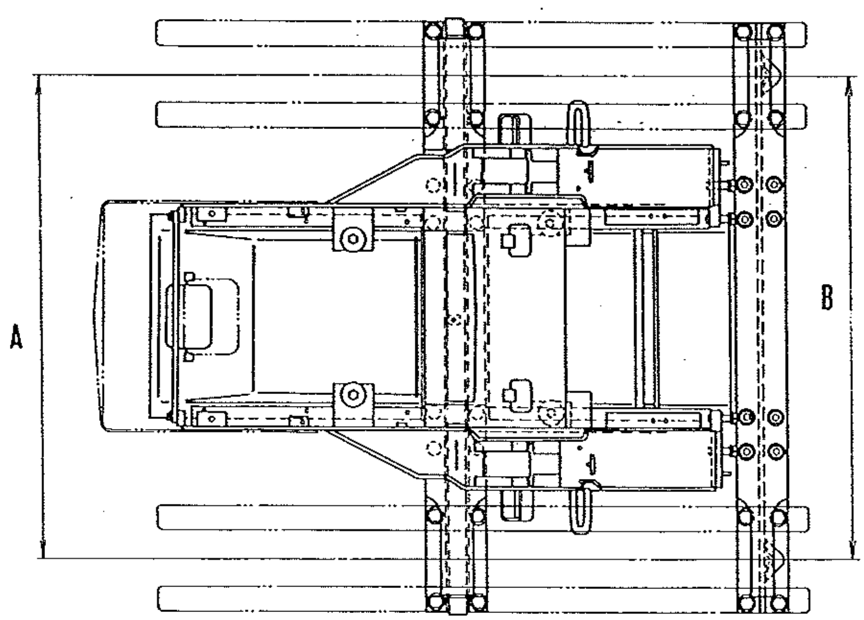
BS3F



BD2F



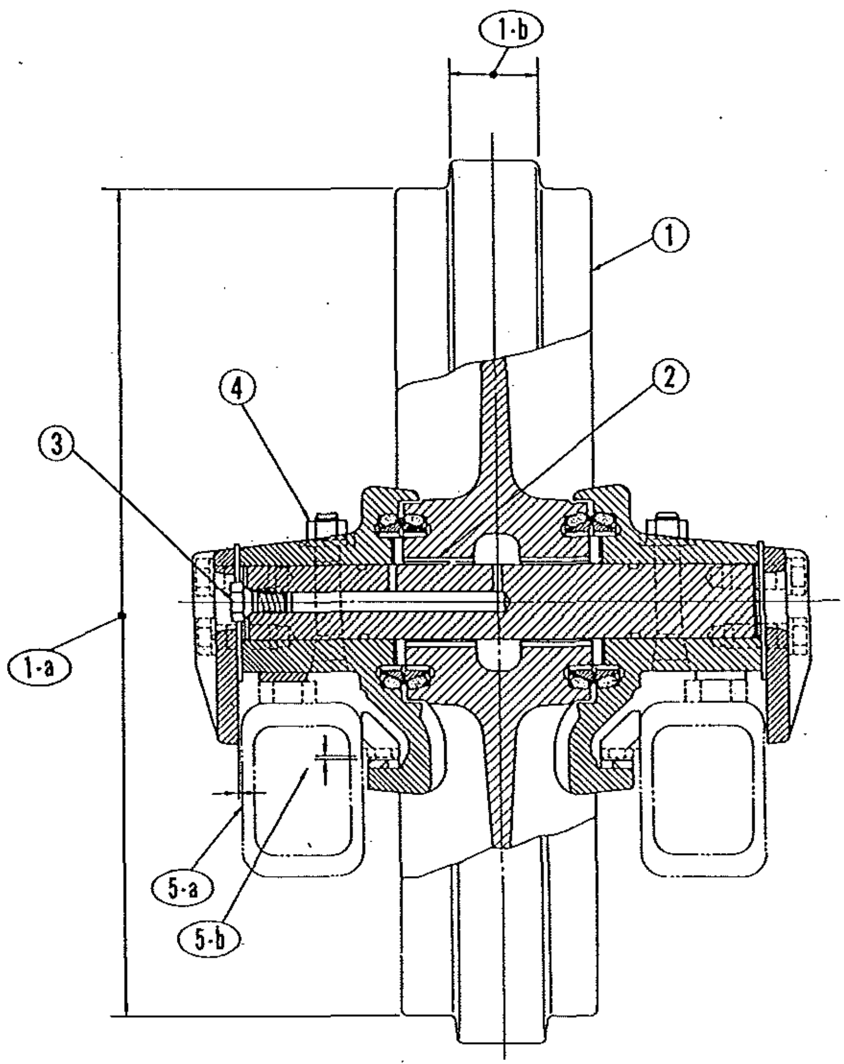




FRONT IDLERS

Unit: mm (in.)

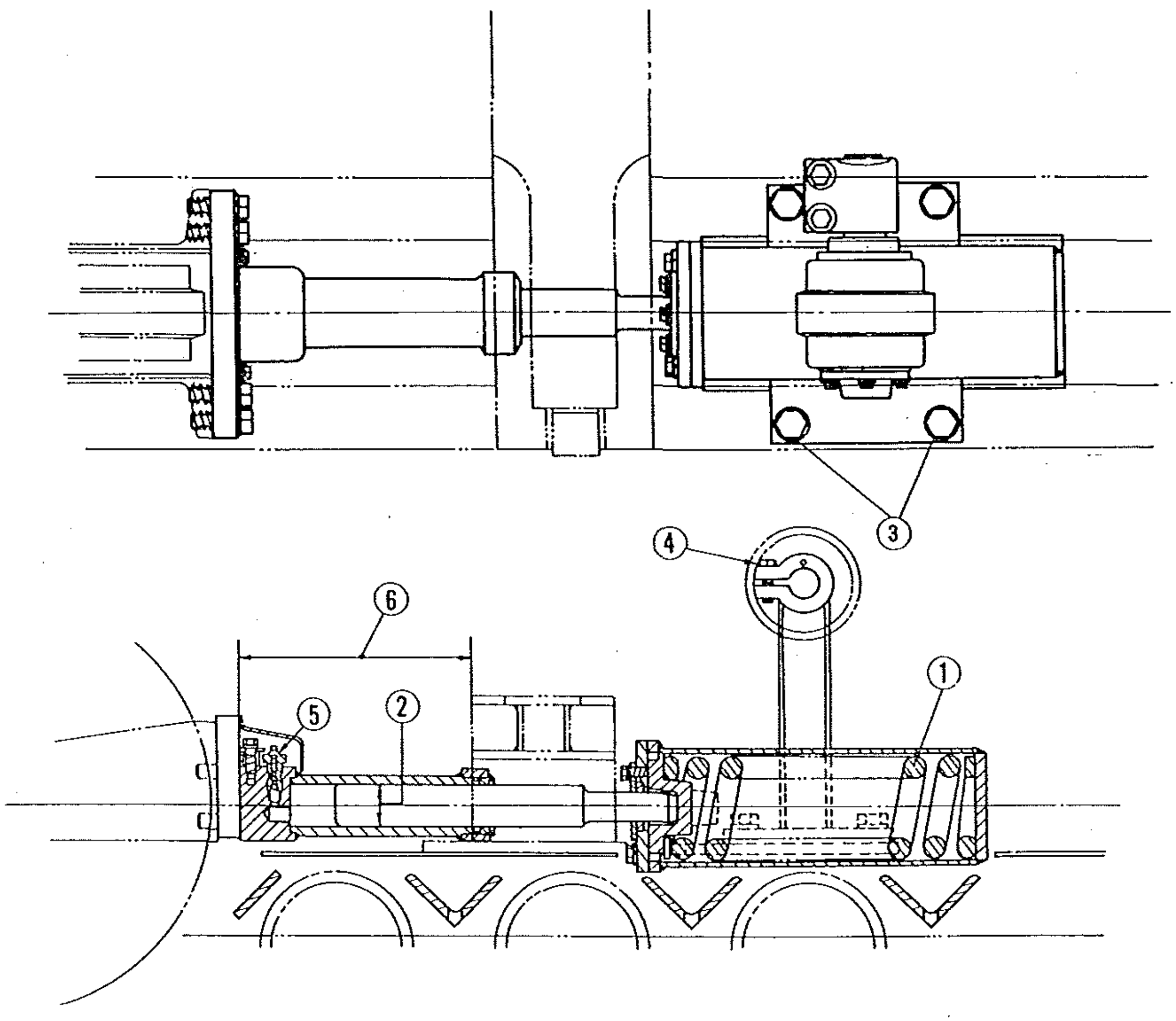
Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Idlers	a	Diameter at (1-a)	420 (16.54)	411 (16.18)	Repair limit: 413 (16.26)
		b	Diameter at (1-b)	42 (1.65)	35 (1.38)	
		Axial play		0.2 ~ 0.25 (0.008 ~ 0.0098)	1.4 (0.055)	
2	Shafts	Fit in bushing		0.155 ~ 0.235 (0.00610 ~ 0.00925)	1.0 (0.039)	
3	Filler plugs	Tightening torque kg-m (lb-ft)		7.6 ± 0.8 (55 ± 5.8)		
4	Bearing-shaft securing taper pin bolts	Tightening torque kg-m (lb-ft)		6.5 ± 0.7 (47 ± 5.1)		
5	Guides/track frames	a	Lateral clearance	1 (0.04)	3 (0.12)	
		b	Vertical clearance	1 (0.04)	3 (0.12)	



RECOIL SPRINGS

Unit: mm (in.)

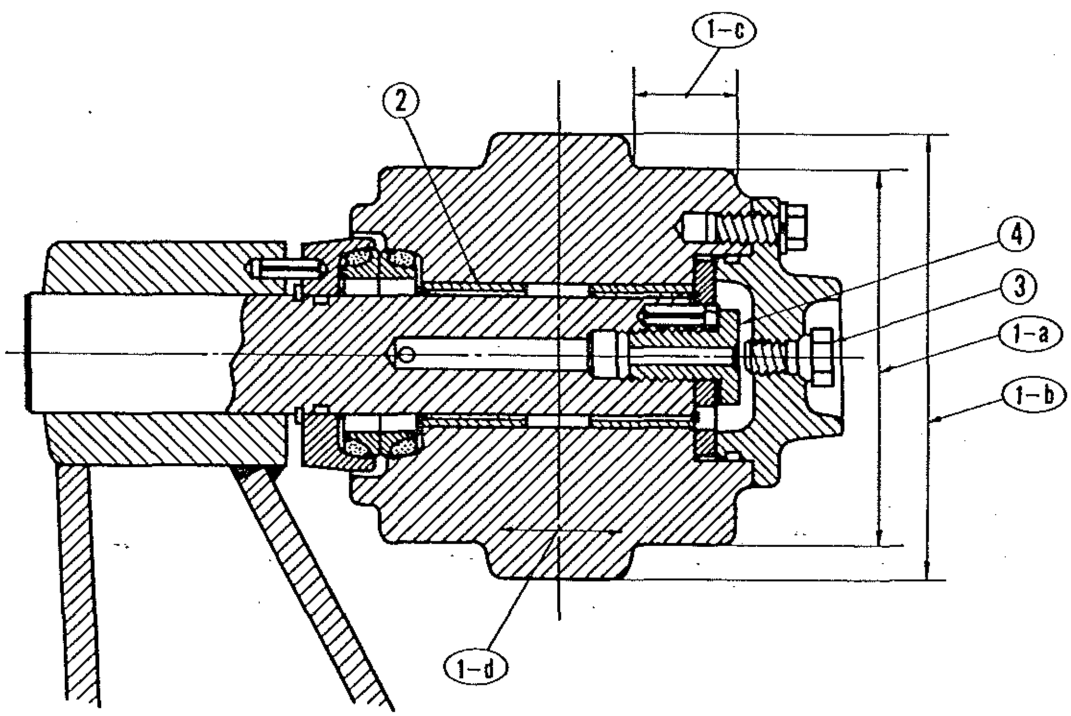
Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Recoil springs	Free length	381.5 (15.020)		
		Load to compress spring to initial working length [326 (12.83)] kg (lb)	2610 ± 210 (5755 ± 463)	2300 (5072)	
2	Cylinders	Fit on piston	0.075 ~ 0.164 (0.00295 ~ 0.00646)	0.8 (0.031)	
3	Track carrier roller bracket mounting bolts	Tightening torque kg-m (lb-ft)	13.5 ± 1.4 (97.6 ± 10.1)		
4	Roller shaft-bracket securing bolts	Tightening torque kg-m (lb-ft)	7.6 ± 0.8 (55 ± 5.8)		
5	Filler valves	Tightening torque kg-m (lb-ft)	3.5 ± 0.4 (25.3 ± 2.9)		
6	Track adjuster cylinders	Adjustment	248.9 (9.800)	316.4 (12.46)	



TRACK CARRIER ROLLERS

Unit: mm (in.)

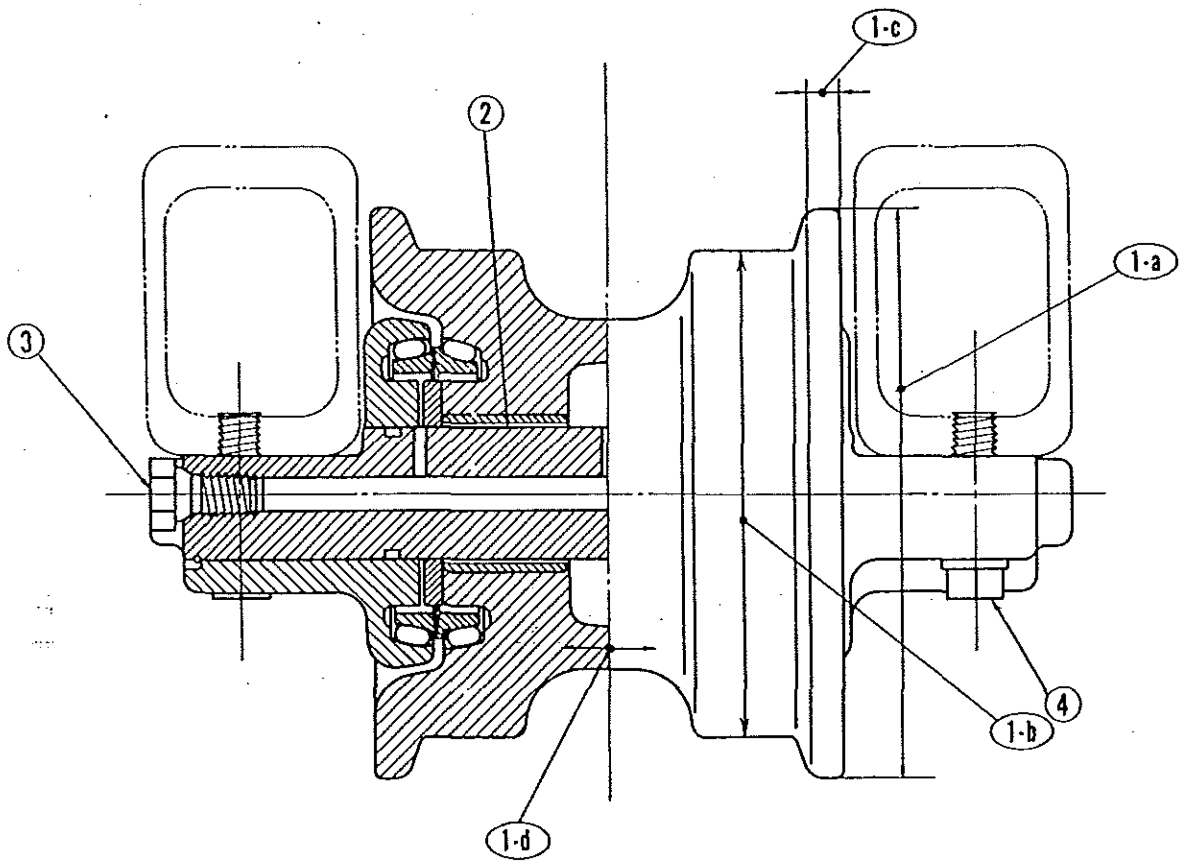
Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Rollers	a	Diameter at (1-b)	130 (5.12)	118 (4.65)	
		b	Diameter at (1-a)	110 (4.33)	98 (3.86)	Repair limit: 102 (4.02)
		c	Width at (1-c)	30 (1.18)	35 (1.38)	
		d	Axial play	0.2 ~ 0.5 (0.008 ~ 0.020)	1.0 (0.039)	
2	Roller shafts	Fit in bushings		0.185 ~ 0.226 (0.00728 ~ 0.00890)	1.6 (0.063)	
3	Filler plug	Tightening torque kg-m (lb-ft)		4.2 ± 0.4 (30.4 ± 2.9)		
4	Roller shaft securing bolts	Tightening torque kg-m (lb-ft)		12.2 ± 1.2 (88.2 ± 8.7)		



TRACK ROLLERS

Unit: mm (in.)

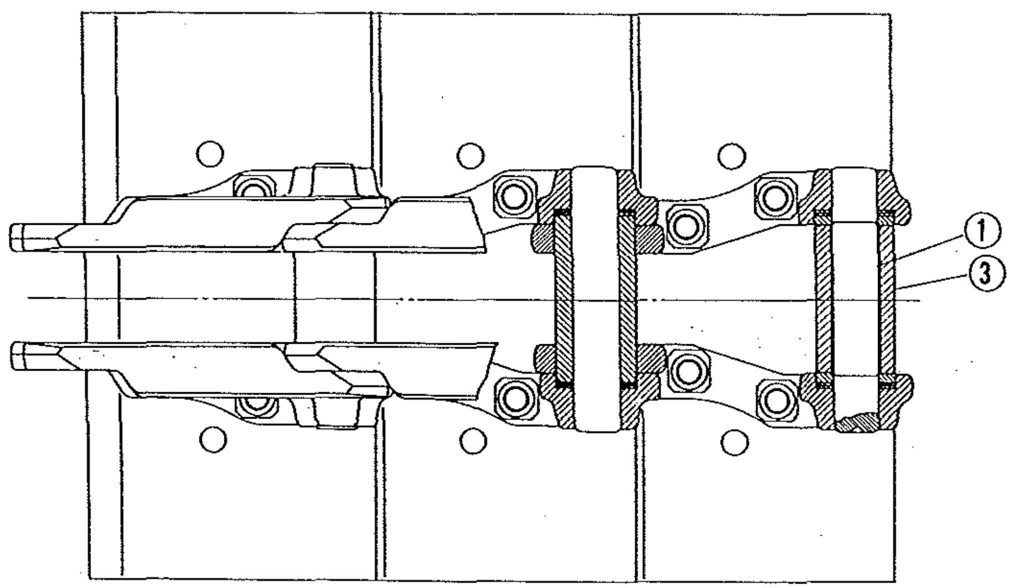
Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Rollers	a	Diameter at (1-a)	164 (6.46)	152 (5.98)	
		b	Diameter at (1-b)	140 (5.51)	128 (5.04)	Repair limit: 132 (5.20)
		c	Flange width	9 (0.35)	4 (0.16)	
		d	Axial play	0.30 ~ 0.90 (0.0118 ~ 0.0354)	1.4 (0.055)	
2	Roller shafts	Fit in bushings		0.2 ~ 0.25 (0.008 ~ 0.0098)	1.6 (0.063)	
3	Filler plugs	Tightening torque kg-m (lb-ft)		7.6 ± 0.8 (55 ± 5.8)		
4	Roller mounting bolts	Tightening torque kg-m (lb-ft)		6 ± 0.6 (43.4 ± 4.3)		

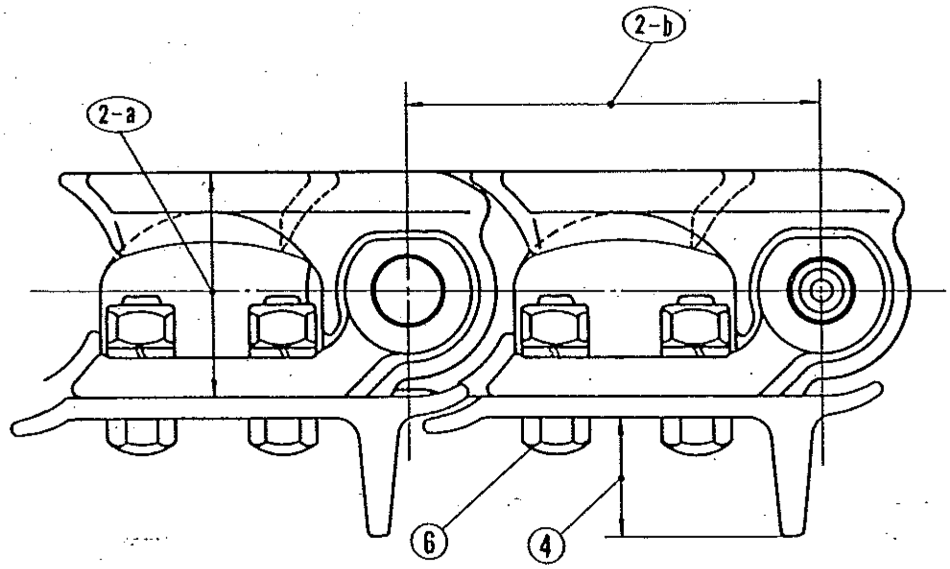


TRACKS

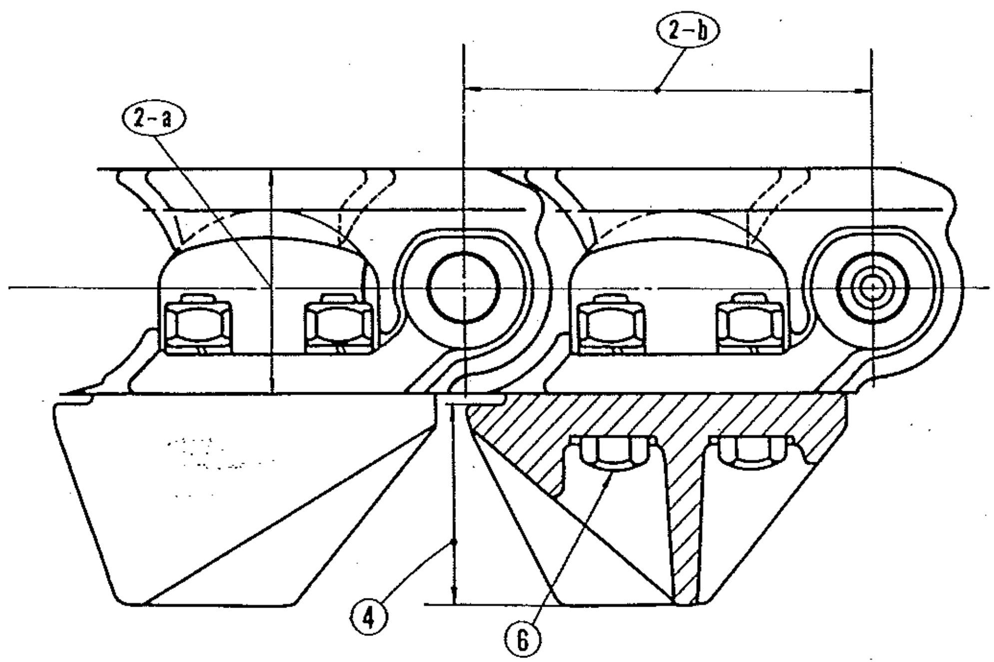
Unit: mm (in.)

Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Bushings	Outside diameter		41 (1.61) (Limit for reversing)	37.2 (1.465)	Limit for reversing: 38 (1.50) (maximum wear)
2	Links	a	Height	75 (2.95)	68 (2.68)	Repair limit: 70 (2.76)
		b	Link pitch	540 (21.3)	550 (21.65)	Limit for reversing: 552 (21.73)
3	Track pins	Fit in bushings		0.45 ~ 0.734 (0.0177 ~ 0.02890)	2.5 (0.098)	
4	Shoes	Grouser height	Standard models	38.5 (1.516) (BD2F)	11 (0.43)	
			Standard models	30 (1.18) (BS3F)	10 (0.39)	
			Swamp models	67.5 (2.657)	55.5 (2.185)	Repair limit: 57.5 (2.264)
			Super-swamp models	57.5 (2.264)	52.5 (2.067)	Repair limit not specified
5	Tracks	Sag		20 ~ 30 (3/4 ~ 1-1/8)		
6	Shoes bolts	Tightening torque kg-m (lb-ft)		17 ~ 20 (123 ~ 145)		





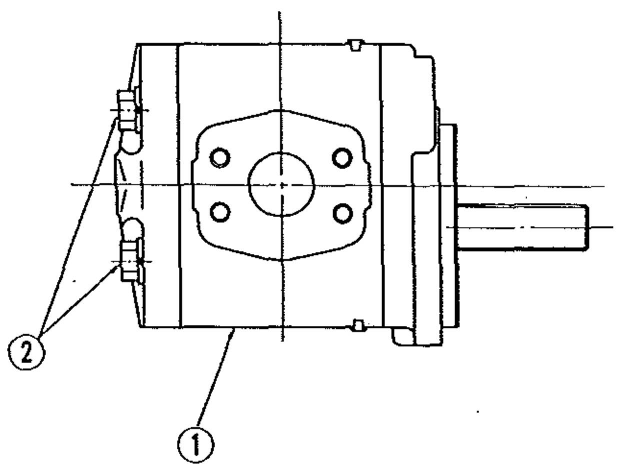
Standard model track

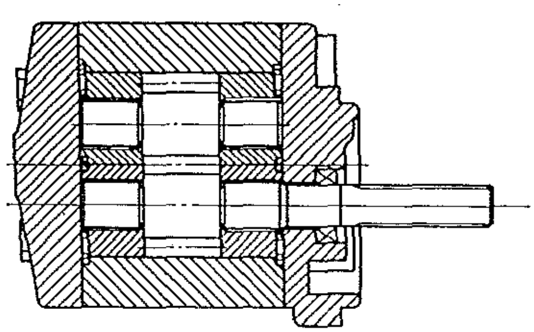


Swamp model/super-swamp model track

HYDRAULIC PUMP

Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Pump performance	BD2F	Rpm	2400		
			Delivery pressure kg/cm^2 (psi)	160 (2275)		
			Capacity liter (cu in.)	64 (3906)		
		BS3F	Rpm	2400		
			Delivery pressure kg/cm^2 (psi)	160 (2275)		
			Capacity liter (cu in.)	64 (3906)		
2	Pump cover mounting bolts	Tightening torque kg-m (lb-ft)		$4.75^{+0.25}_{-0}$ $(34.36^{+1.8}_{-0})$		

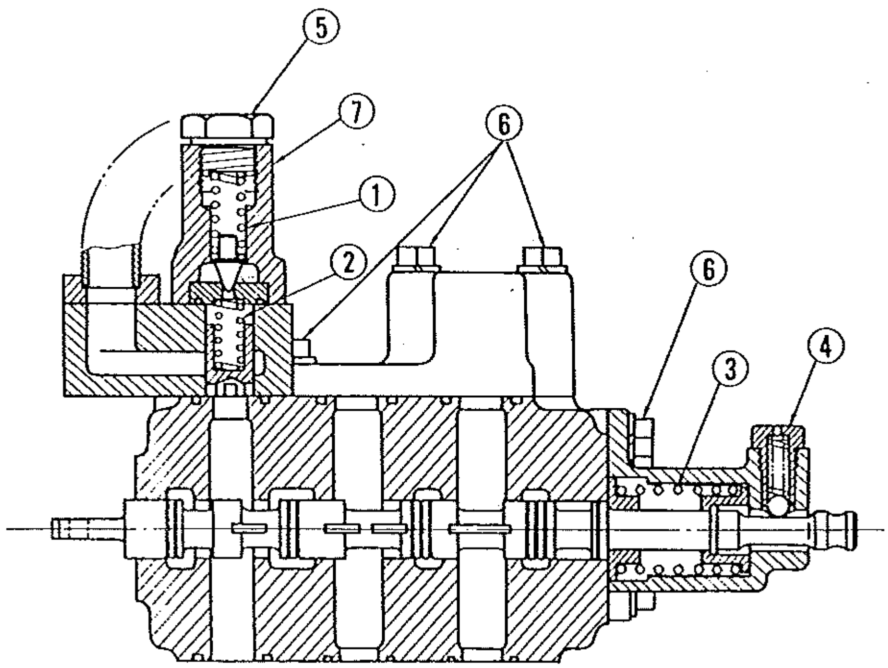




HYDRAULIC CONTROL VALVE (BD2F)

Unit: mm (in.)

Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Pilot valve spring	Free length	42.9 (1.689)		
		Load to compress spring to initial working length [34.1 (1.343)] kg (lb)	24.7 ± 2 (54.5 ± 4.4)		
2	Relief valve spring	Free length	39 (1.54)		
		Load to compress spring to initial working length [26.5 (1.043)] kg (lb)	3.82 ± 0.3 (8.42 ± 0.7)	3 (6.6)	
3	Plunger center spring	Free length	59 (2.32)		
		Load to compress spring to initial working length [46.6 (1.83)] kg (lb)	5.4 ± 0.5 (11.9 ± 1.1)	8 kg/45 mm (17.61 lb/1.85 in.)	
4	Plunger detent plug	Tightening torque kg-m (lb-ft)	75 ± 0.5 (542 ± 3.6)		
5	Relief valve plug	Tightening torque kg-m (lb-ft)	7 ± 0.7 (51 ± 5)		
6	Bolts	Tightening torque kg-m (lb-ft)	4.6 ± 0.5 (33.3 ± 3.6)		
7	Main relief valve performance	Pressure that makes relief valve open kg/cm² (psi)	160 ± 3 (2275 ± 43)		
		Flow rate liter (cu in.)/min	64 ± 3 (3906 ± 183)		



HYDRUALIC CONTROL VALVE (BS3F)

Unit: mm (in.)

Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Pilot valve spring		Free length	42.9 (1.689)		
			Load to compress spring to initial working length [34.1 (1.343)] kg (lb)	24.7 ± 2 (54.5 ± 4.4)		
2	Relief valve spring		Free length	39 (1.54)		
			Load to compress spring to initial working length [26.5 (1.043)] kg (lb)	3.82 ± 0.3 (8.42 ± 0.7)	3 (6.6)	
3	Safety valve spring (inner)	Rod side	Free length	64.9 (2.555)		Pressure setting: 180 kg/cm² (2560 psi)
			Load to compress spring to initial working length [53.7 (2.114)] kg (lb)	19 ± 1.5 (42 ± 3.3)		
		Head side	Free length	64.9 (2.555)		Pressure setting: 140 kg/cm² (1991 psi)
			Load to compress spring to initial working length [56.2 (2.213)] kg (lb)	14.8 ± 1.5 (32.6 ± 3.3)		
4	Safety valve spring (outer)	Rod side	Free length	63.8 (2.512)		Pressure setting: 180 kg/cm² (2560 psi)
			Load to compress spring to initial working length [53.7 (2.114)] kg (lb)	62.9 ± 4.9 (138.7 ± 10.8)		
		Head side	Free length	63.8 (2.512)		Pressure setting: 140 kg/cm² (1991 psi)
			Load to compress spring to initial working length [56.2 (2.213)] kg (lb)	47.3 ± 4.9 (104.3 ± 10.8)		
5	Check valve spring		Free length	34.5 (1.358)		
			Load to compress spring to initial working length [30.5 (1.201)] kg (lb)	0.10 ± 0.01 (0.22 ± 0.02)	0.09 kg/30 mm (0.20 lb/1.18 in.)	
6	Make-up valve (dump) spring		Free length	34.5 (1.358)		
			Load to compress spring to initial working length [30.5 (1.201)] kg (lb)	0.10 ± 0.01 (0.22 ± 0.02)	0.09 kg/30 mm (0.20 lb/1.18 in.)	
7	Make-up valve (lift) spring		Free length	50 (1.97)		
			Load to compress spring to initial working length [36 (1.42)] kg (lb)	0.24 ± 0.04 (0.53 ± 0.09)	0.17 kg/37 mm (0.37 lb/1.46 in.)	
8	Plunger (dump) center spring		Free length	58.5 (2.303)		
			Load to compress spring to initial working length [30 (1.18)] kg (lb)	5.9 ± 0.6 (13.0 ± 1.32)	4 (8.8)	
9	Plunger (lift) center spring		Free length	88.5 (3.484)		
			Load to compress spring to initial working length [46.6 (1.83)] kg (lb)	10.1 ± 1 (22.2 ± 2.2)	8 (17.6)	
10	Plunger detent plug		Tightening torque kg-m (lb-ft)	7.5 ± 0.5 (54.2 ± 3.6)		

<table>
<tr><th>Ref. No.</th><th colspan="3">Item</th><th>Assembly standard</th><th>Service limit</th><th>Remarks</th></tr>
<tr><td>11</td><td>Safety valve body</td><td colspan="2">Tightening torque kg-m (lb-ft)</td><td>20 ± 2
(145 ± 14)</td><td></td><td></td></tr>
<tr><td>12</td><td>Relief valve plug</td><td colspan="2">Tightening torque kg-m (lb-ft)</td><td>20 ± 2
(145 ± 14)</td><td></td><td></td></tr>
<tr><td>13</td><td>Safety valve plug</td><td colspan="2">Tightening torque kg-m (lb-ft)</td><td>20 ± 2
(145 ± 14)</td><td></td><td></td></tr>
<tr><td>14</td><td>Bolts</td><td colspan="2">Tightening torque kg-m (lb-ft)</td><td>4.6 ± 0.5
(33.3 ± 3.6)</td><td></td><td></td></tr>
<tr><td rowspan="2">15</td><td rowspan="2">Main relief valve performance</td><td colspan="2">Pressure that makes relief valve open kg/cm^2 (psi)</td><td>160 ± 3
(2275 ± 42.7)</td><td></td><td></td></tr>
<tr><td colspan="2">Flow rate liter (cu in.)/min</td><td>64 ± 3
(3906 ± 183)</td><td></td><td></td></tr>
<tr><td rowspan="4">16</td><td rowspan="4">Safety valve performance</td><td rowspan="2">Rod side</td><td>Pressure that makes relief valve open kg/cm^2 (psi)</td><td>180 ± 2
(2560 ± 28.4)</td><td></td><td></td></tr>
<tr><td>Flow rate liter (cu in.)/min</td><td>23 ± 2
(1404 ± 122)</td><td></td><td></td></tr>
<tr><td rowspan="2">Head side</td><td>Pressure that makes relief valve open kg/cm^2 (psi)</td><td>140 ± 2
(1991 ± 28.4)</td><td></td><td></td></tr>
<tr><td>Flow rate liter (cu in.)/min</td><td>23 ± 2
(1404 ± 122)</td><td></td><td></td></tr>
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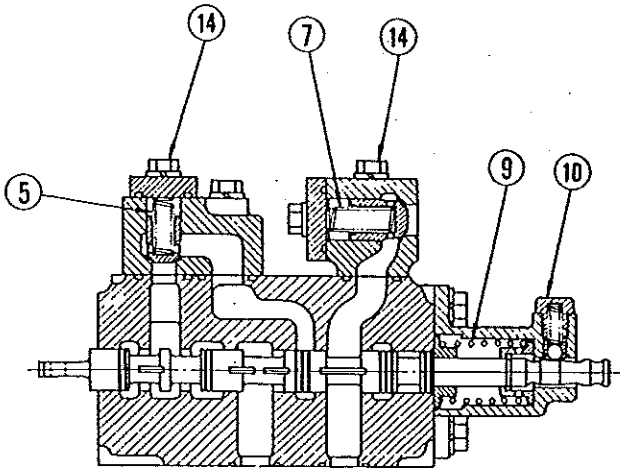
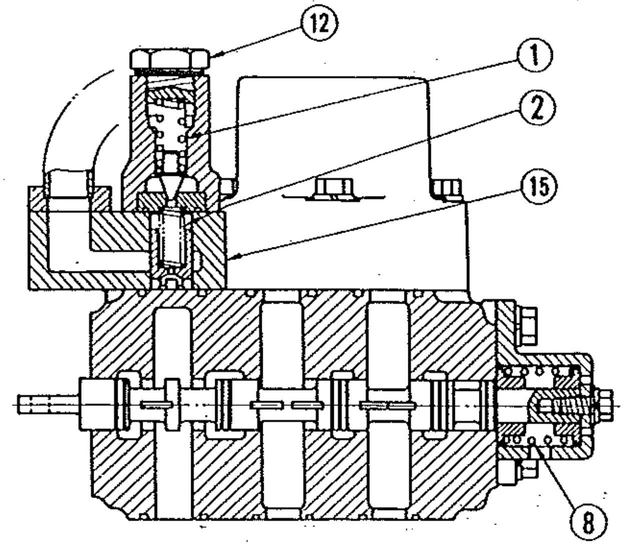
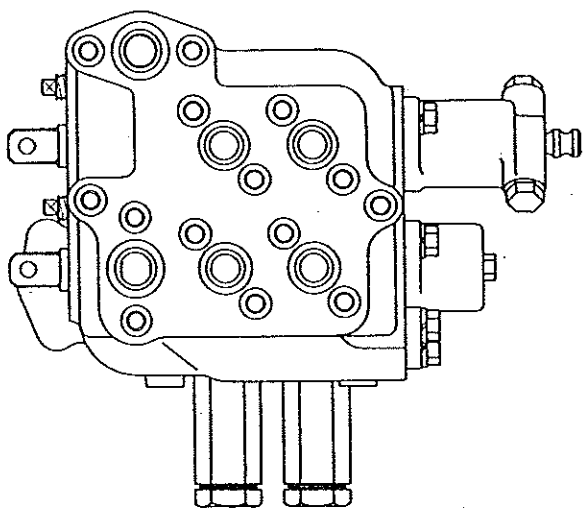
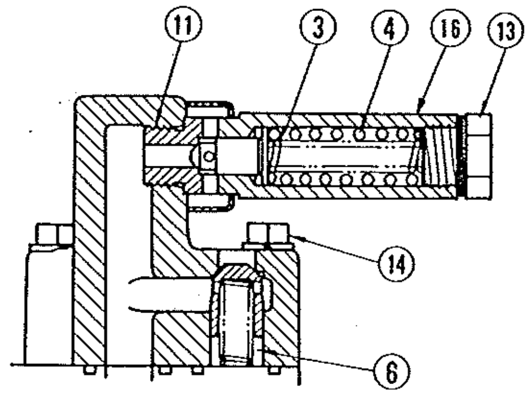


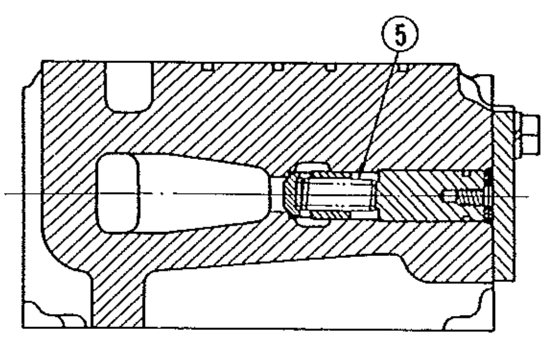




Safety/make-up valve (dump)



Check valve (lift)

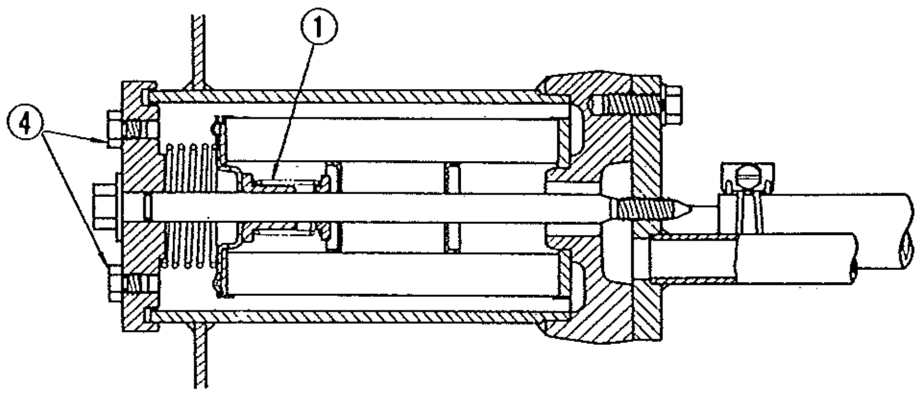


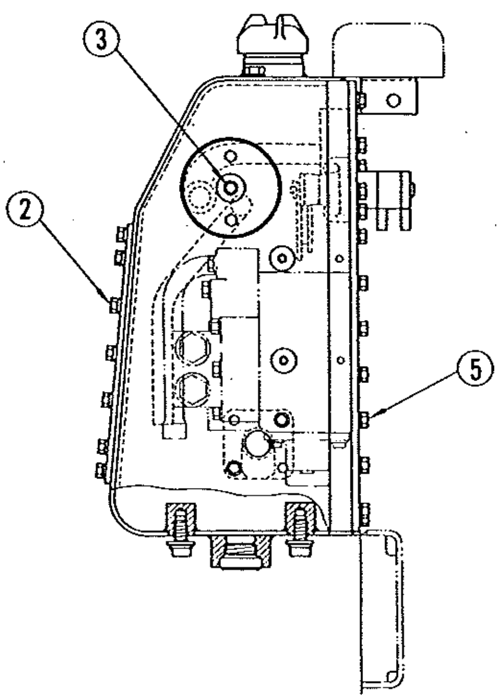
Make-up valve (lift)

HYDRAULIC TANK

Unit: mm (in.)

Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Safety valve spring in filter	Free length	106.2 (4.181)		
		Load to compress spring to initial working length [38 (1.50)] kg (lb)	7.07 ± 0.7 (15.6 ± 1.5)	6 (13.2)	
2	Tank cover mounting bolts	Tightening torque kg-m (lb-ft)	3.5 ± 0.3 (25.3 ± 2.2)		Copper washers are used; they are meant to be replaced each time the bolts are loosened.
3	Filter cover center bolt	Tightening torque kg-m (lb-ft)	4.8 ± 0.5 (34.7 ± 3.6)		
4	Filter bleeder plug/drain plug	Tightening torque kg-m (lb-ft)	2.5 ± 0.2 (18.1 ± 1.4)		
5	Tank cover mounting bolts	Tightening torque kg-m (lb-ft)	3.5 ± 0.3 (25.3 ± 2.2)		

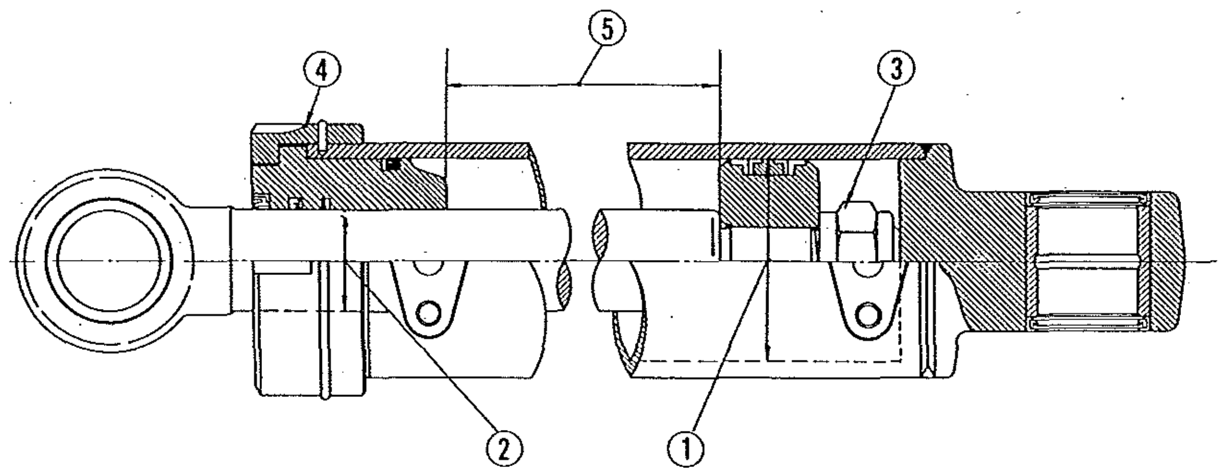




LIFT CYLINDERS (BS3F)

Unit: mm (in.)

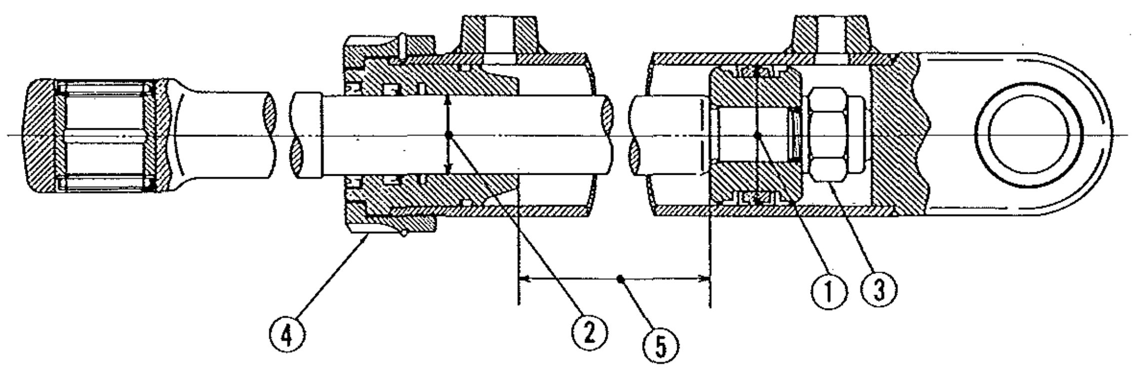
Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Fit of cylinder on piston			0.35 (0.0138)	
2	Fit of guide bushing on piston rod		0.075 ~ 0.139 (0.00295 ~ 0.00547)	0.35 (0.0138)	
3	Piston securing nut	Tightening torque kg-m (lb-ft)	95 ± 5 (687 ± 36)		
4	Gland screw	Tightening torque kg-m (lb-ft)	75 ± 8 (542 ± 58)		
5	Piston rod	Stroke	386 (15.20)		
		Center to center of pins with cylinder fully retracted	700 (27.56)		



DUMP CYLINDERS (BS3F)

Unit: mm (in.)

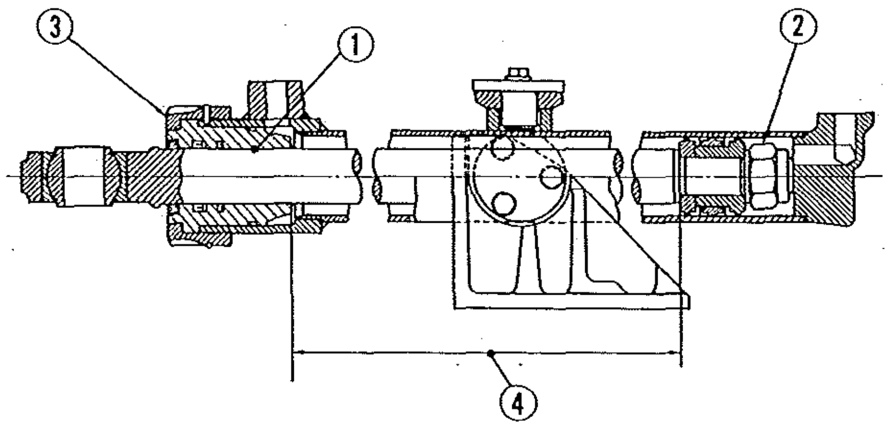
Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Fit of cylinder on piston			0.35 (0.0138)	
2	Fit of guide bushing on piston rod		0.075 ~ 0.139 (0.00295 ~ 0.00547)	0.35 (0.0138)	
3	Piston securing nut	Tightening torque kg-m (lb-ft)	50 ± 2.5 (362 ± 18)		
4	Gland screw	Tightening torque kg-m (lb-ft)	45 ± 4.5 (325 ± 32.5)		
5	Piston rod	Stroke	423.5 (16.67)		
		Center to center of pins with cylinder fully retracted	866.5 (34.11)		



BLADE LIFT CYLINDERS (BD2F)

Unit: mm (in.)

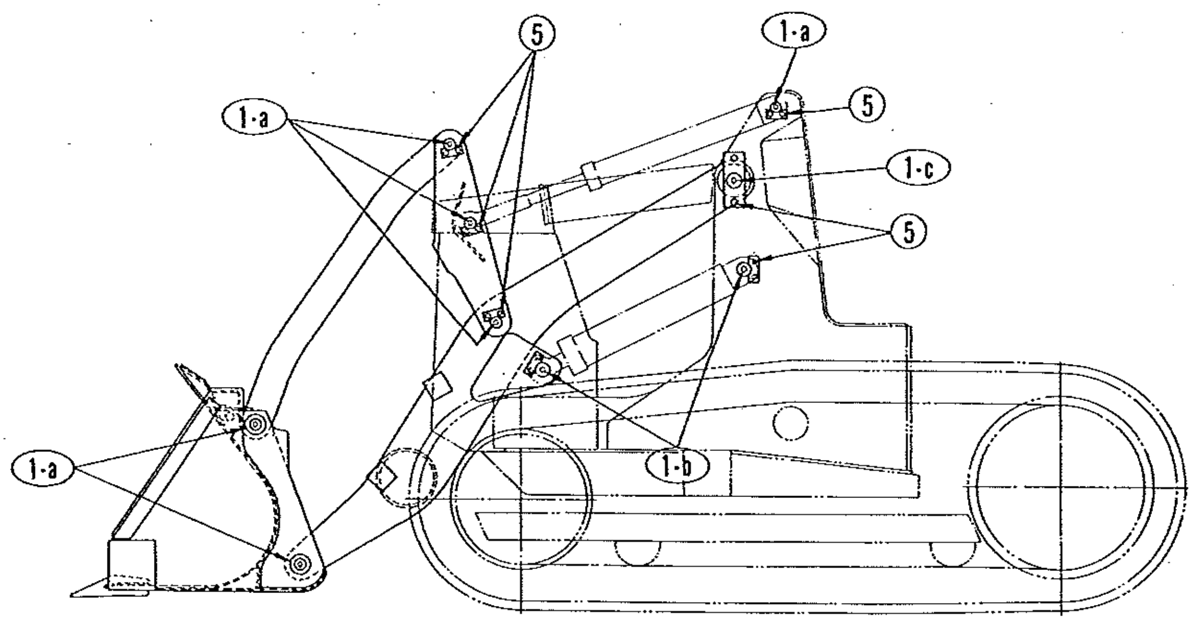
Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Fit of guide bushing on piston rod		0.075 ~ 0.139 (0.00295 ~ 0.00547)	0.35 (0.0138)	
2	Piston securing nut	Tightening torque kg-m (lb-ft)	50 ± 2.5 (362 ± 18)		
3	Cylinder head	Tightening torque kg-m (lb-ft)	45 ± 4.5 (325 ± 32.5)		
4	Piston rod	Stroke	689 (27.13)		
		Center to center of pins with cylinder fully retracted	917 (36.10)		

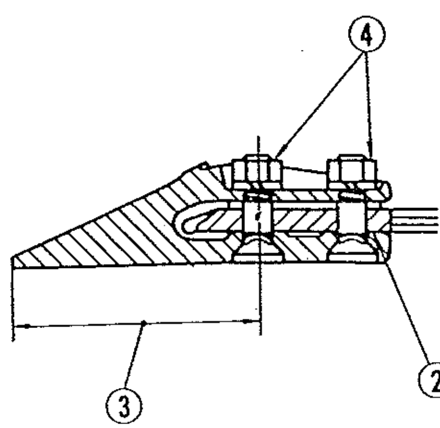


BUCKET AND LINKAGE (BS3F)

Unit: mm (in.)

Ref. No.	Item			Assembly standard	Service limit	Remarks
1	Fit of each pin in bushing	a	35 (1.38)	0.10 ~ 0.175 (0.0039 ~ 0.00689)	0.6 (0.024)	
		b	45 (1.77)	0.10 ~ 0.175 (0.0039 ~ 0.00689)	0.6 (0.024)	
		c	50 (1.97)	0.13 ~ 0.219 (0.0051 ~ 0.00862)	0.6 (0.024)	
2	Cutting edge width			159 (6.26)	120 (4.72)	
3	Tooth length			160 (6.30)	100 (3.94)	
4	Tooth securing bolts	Tightening torque kg-m (lb-ft)		29 ~ 32 (210 ~ 231)		
5	Lock plate mounting bolts	Tightening torque kg-m (lb-ft)		3.5 ± 0.3 (25.3 ± 2.2)		

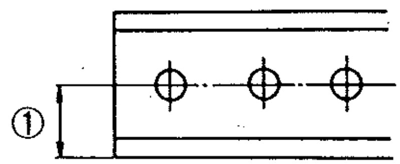


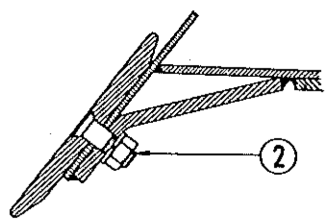


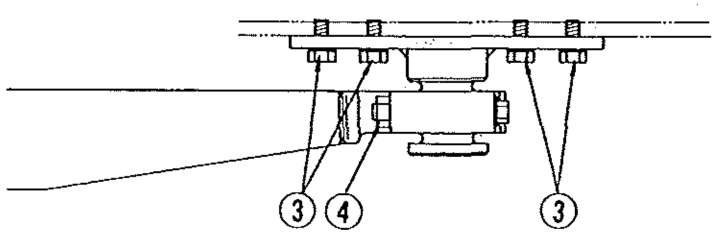
BLADE (BD2F)

Unit: mm (in.)

Ref. No.	Item		Assembly standard	Service limit	Remarks
1	Cutting edges/ end bits	Dimension at (1)	75 (2.95)	45 (1.77)	
2	Cutting edge mounting plow bolts	Tightening torque kg-m (lb-ft)	6.5 ± 0.7 (47.0 ± 5.1)		
3	Trunnion mounting bolts	Tightening torque kg-m (lb-ft)	10.4 ± 1 (75.2 ± 7.2)		
4	Trunnion cap mounting bolts	Tightening torque kg-m (lb-ft)	15.8 ± 1.6 (114.3 ± 11.6)		







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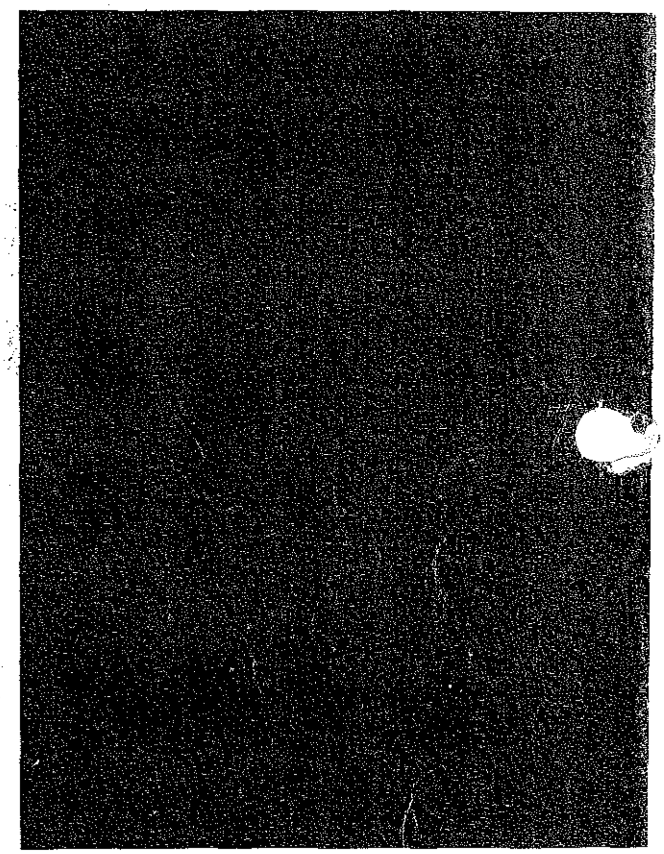


Printed in Japan

SERVICE MANUAL

MITSUBISHI
TRACTOR
TRACTOR SHOVEL

BD2F
BS3F

(DIRECT-DRIVE-TRANSMISSION TYPE)

POWER TRAIN / HYDRAULIC SYSTEM

DISASSEMBLY AND REASSEMBLY

MITSUBISHI
HEAVY INDUSTRIES, LTD.

FOREWORD

This service manual has instructions and procedures for the subject on the front cover. The information, specifications, and illustrations used in this manual are based on information that was current at the time this issue was written.

Correct servicing will give these machines a long productive life. Before attempting to start a test, repair or rebuild job, be sure that you have studied the respective sections of this manual, and know all the components you will work on.

Safety is not only your concern but everybody's concern. Safe working habits cannot be bought or manufactured; they must be learned through the job you do. By learning what CAUTION or WARNING symbol emphasizes, know what is safe – what is not safe. Consult your foreman, if necessary, for specific instructions on a job, and the safety equipment required.

NOTES, CAUTIONS and WARNINGS

NOTES, CAUTIONS and WARNINGS are used in this manual to emphasize important and critical instructions. They are used for the following conditions:

NOTE .... An operating procedure, condition, etc., which it is essential to highlight.

CAUTION .... Operating procedures, practices, etc., which if not strictly observed, will result in damage to or destruction of machine.

WARNING .... Operating procedures, practices, etc., which if not correctly followed, will result in personal injury or loss of life.

January 1978

TABLE OF CONTENTS

Preliminary steps for servicing work

Preliminary steps \ Components to be serviced	Universal joint	Transmission	Transmission control	Brake	Bevel gear	Steering clutch	Steering clutch/ brake control	Final drive	Final-drive pinion	Hydraulic pump	Hydraulic control valve	Tracks	Front idlers	Recoil spring	Track frame	Track rollers	Track carrier rollers
Platform removal	○	○	○				○										
Driver's seat removal		○	○	○	○	○	○		○								
Seat support removal		○	○	○	○	○			○								
Removal of steering clutch and brake pedal		○															
Removal of steering clutch lever assembly		○	○														
Universal joint removal		○															
Transmission oil draining		○															
Removal of steering clutch/brake control rods				○	○	○			○								
Removal of steering clutch case bracket				○	○	○			○								
Draining steering clutch case					○												
Removal of steering clutch assembly					○				○								
Final drive draining								○	○								
Track breaking at master pin								○	○				○				
Hydraulic tank draining										○	○						
Hydraulic tank removal											○						
Track slackening								○	○			○	○	○	○	○	○
Track removal															○		
Disconnecting rigid bar															○		
C frame removal (BD2F)															○		
Track roller guard removal																○	

RADIATOR GUARD AND RADIATOR

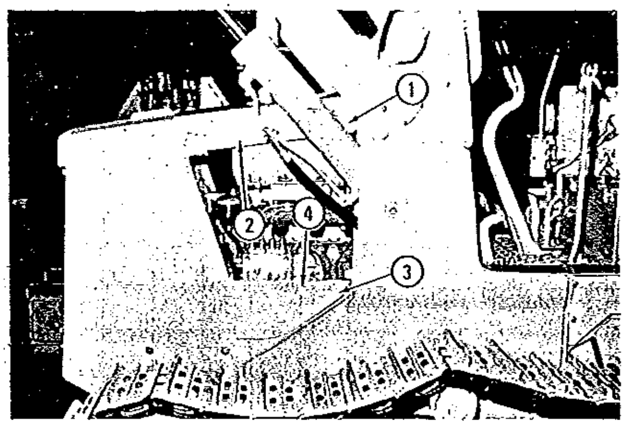
Radiator guard removal (BS3F)

Preparatory step

Raise the bucket all the way, and support the lift cylinders to keep the bucket raised. To support the cylinders, install the brackets, which are among the furnished tools.

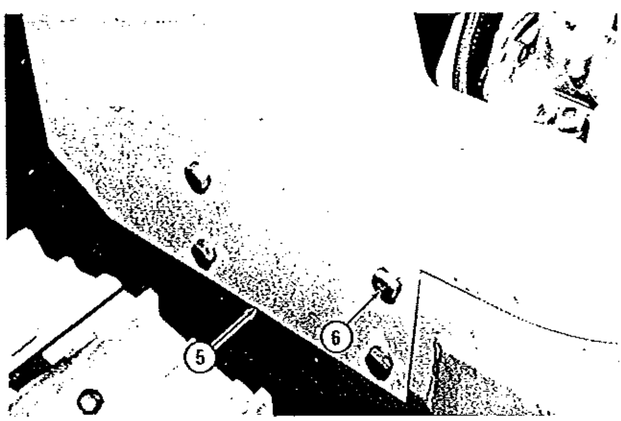
(1) Remove three bolts (1), and take down engine hood (2) complete with muffler pipe.

(2) Remove four bolts (3), two on each side, and take down side guards (4), right and left.



(3) Hitch a sling wire to radiator guard (5) and, by operating the overhead lifter such as a hoist to take up the weight of the guard, hold the guard steady. Remove eight bolts (6), four on each side.

(4) Raise radiator guard (5) just a little in suspended state and shift the guard forward to separate it from the frame.



Radiator guard mounting (BS3F)

Mount the guards by reversing the removal procedure.

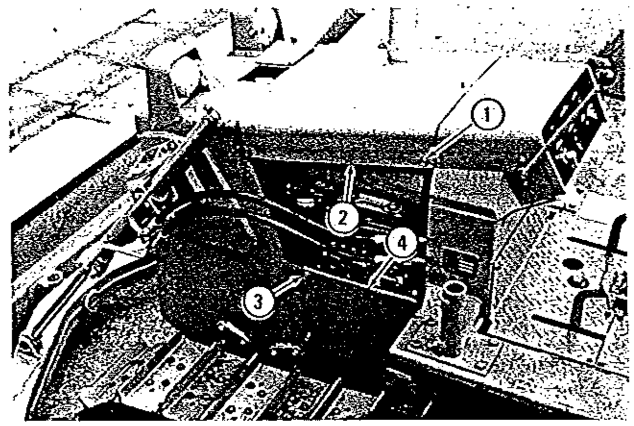
Radiator guard removal (BD2F)

Preparatory step

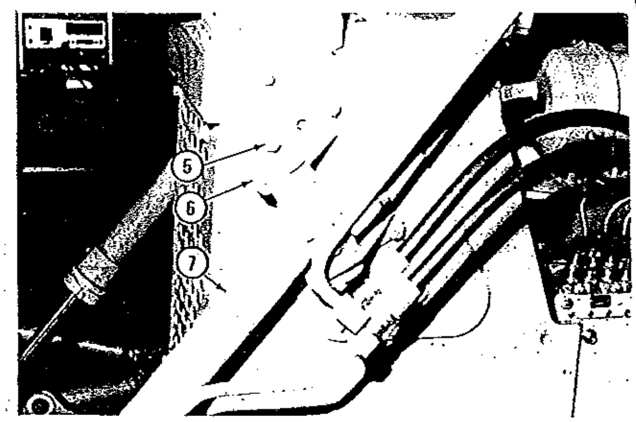
Lower the blade and rest it on the ground.

(1) Remove three bolts (1), and take down engine hood (2) complete with muffler pipe.

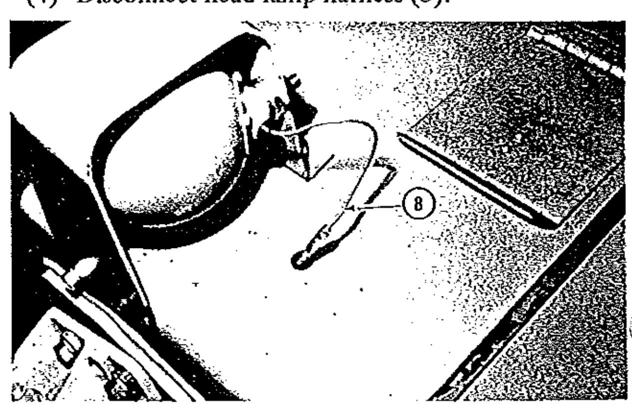
(2) Remove four bolts (3), two on each side, and take down side guards (4), one on each side.



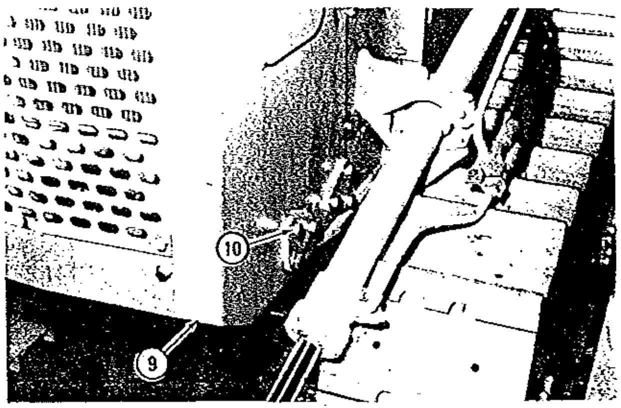
(3) Remove eight bolts (5), four on each side, and take down blade cylinder brackets (6), right and left, each complete with blade cylinder (7).



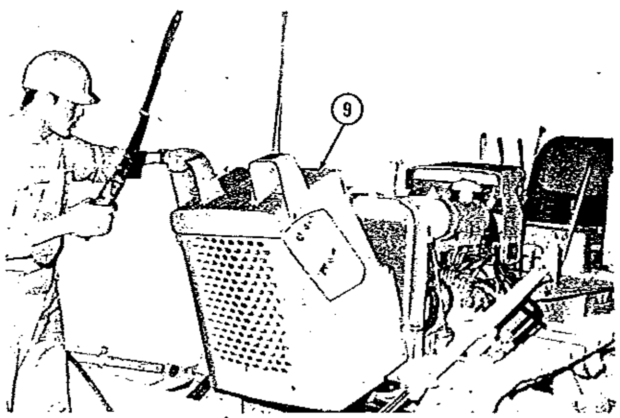
(4) Disconnect head-lamp harness (8).



(5) Keep radiator guard (9) in suspended state, using the hoist and lifting sling, and remove a total of 12 bolts (10), six on each side.



(6) Lift radiator guard (9) just a little and move it forward to sever it from the frame.



Radiator guard mounting (BD2F)

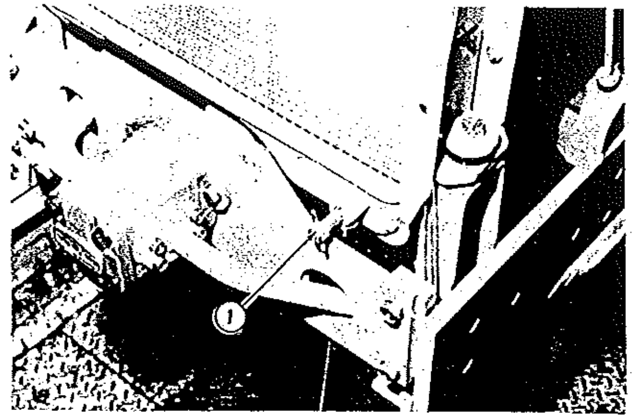
Mount the guards by reversing the removal procedure.

Radiator removal

Preparatory step

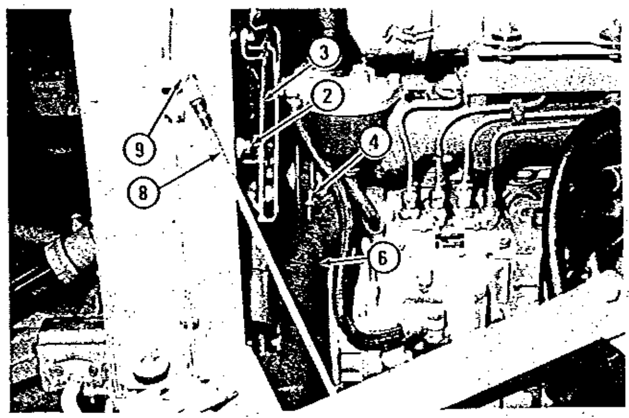
Have the radiator guards taken down.

(1) Loosen drain cock (1) and make the radiator empty of water.

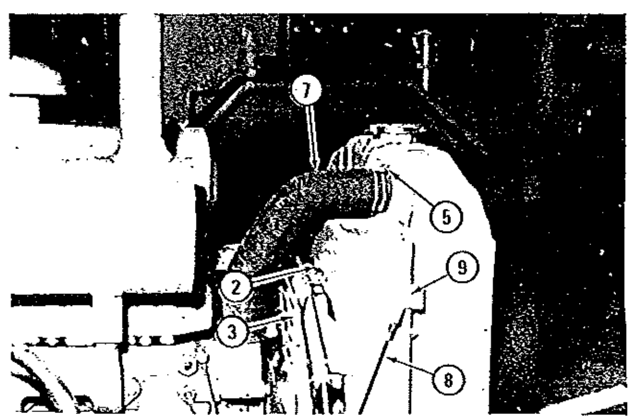


(2) Remove four bolts (2), and take down fan guard (3).

(3) Loosen hose clips (4) (5) and disconnect rubber hoses (6) (7).

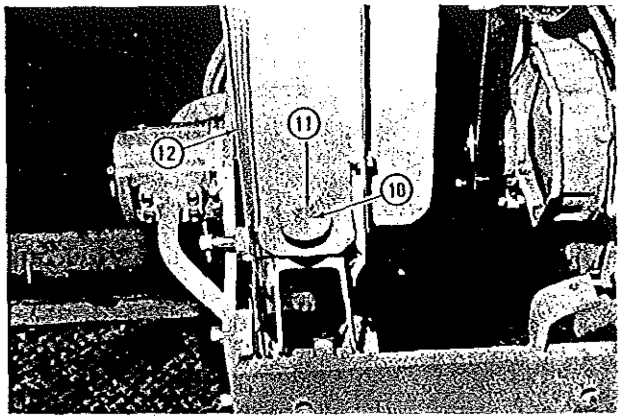


(4) Remove clevis pin (9) from each rod (8), right and left.



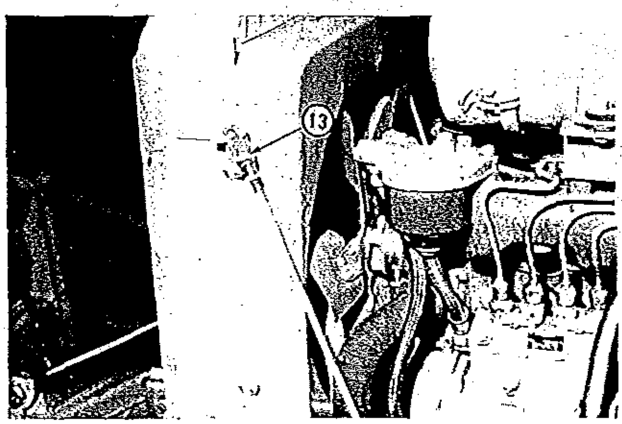
(5) At each side of the radiator, remove slotted nut (10) and mount bolt (11).

(6) Dismount radiator (12).



Radiator mounting

Reverse the removal procedure to mount the radiator. After setting the radiator in place, however, be sure to adjust it, making it trued up relative to the frame by turning two clevises (13), one on each side.



ENGINE

Removal (BD2F)

Preparatory steps

(a) Have radiator guards removed.

(b) Have radiator dismounted.

(c) Remove floor plates (Fr and Re).

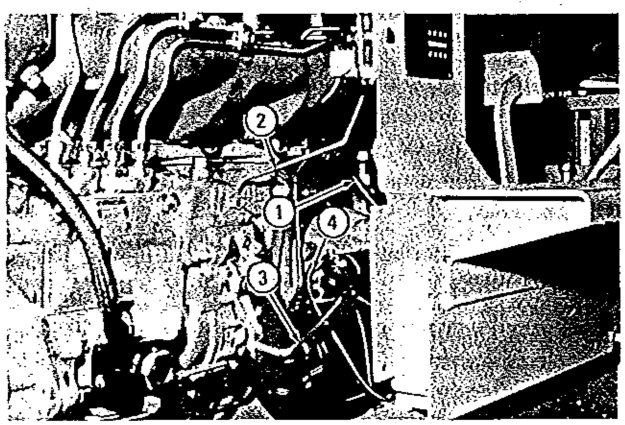
(d) Disconnect cables from the battery.

(e) Remove the universal joint.

(1) Disconnect fuel pipe (1), and make necessary provisions to prevent fuel from leaking out of the pipe.

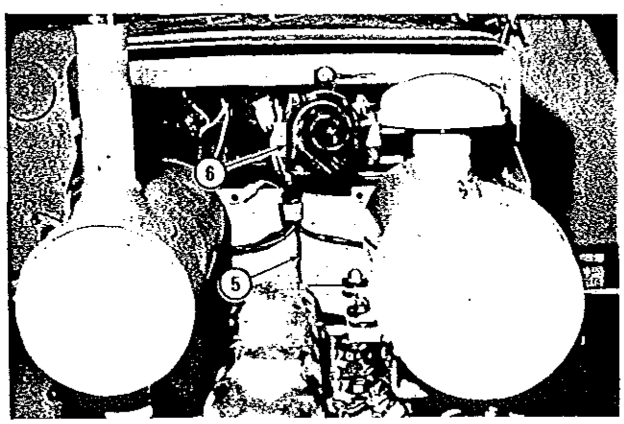
(2) Disconnect control rods (2) (3) from engine side.

(3) Disconnect electrical wire (4) from the starter.



(4) Disconnect glow plug wire (5).

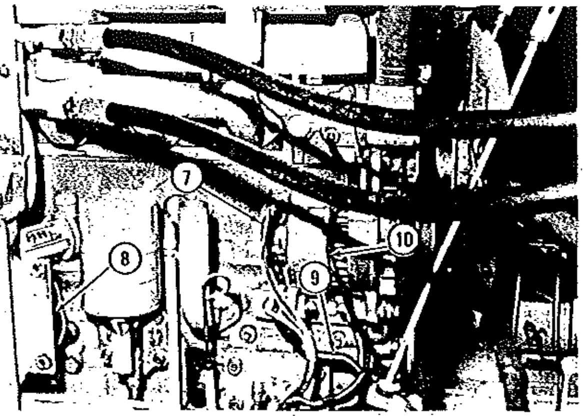
(5) Remove horn (6).



(6) Disconnect alternator wire (7).

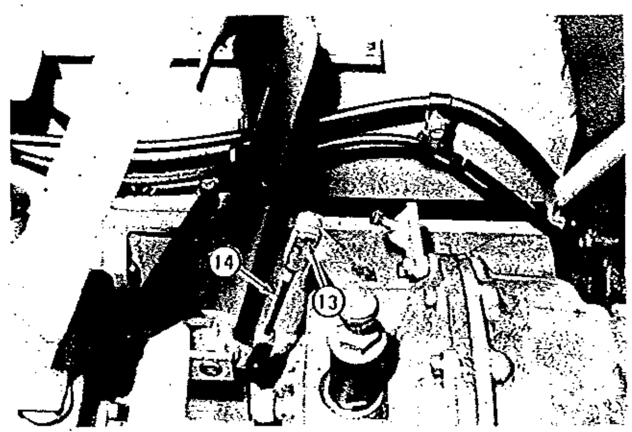
(7) Disconnect oil pressure unit wire (8) and engine grounding wire (9).

(8) Disconnect wire from thermo gauge unit (10).

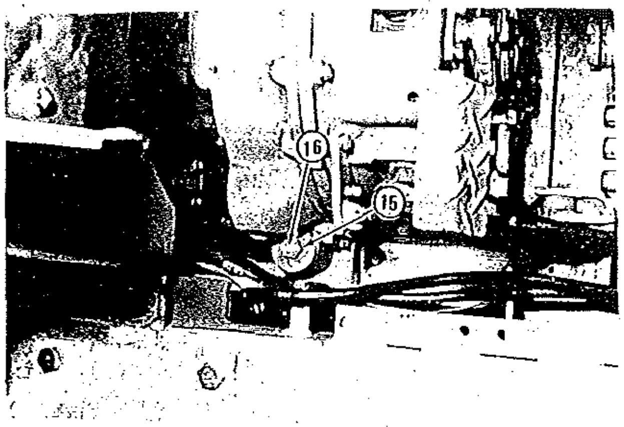


(9) Remove four bolts (11), and take off universal joint (12) in the hydraulic pump drive line.

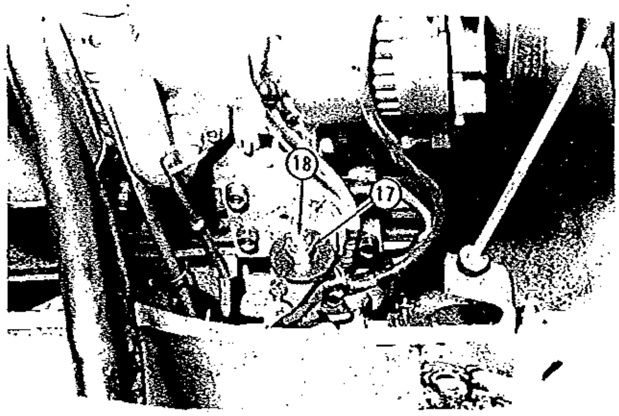
(10) Draw out clevis pin (13), and disconnect rod (14) in the clutch control linkage.



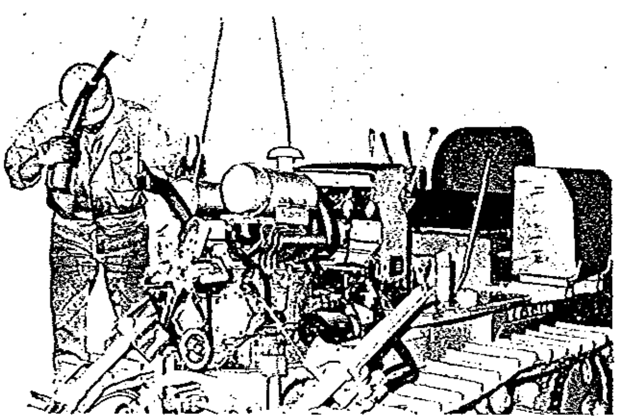
(11) At each side of the clutch case, remove castle nut (15) and mount bolt (16).



(12) Remove castle nut (17) and mount bolt (18) at each side of the engine.



(13) Hitch the lifting sling to the engine securely, hooking the sling ends to the lifting means provided on the engine and lift the engine-and-clutch combination gently. Ease the engine out in suspended state toward front side to remove it from the machine.



Mounting (BD2F)

The following steps must be taken during the sequence of engine mounting steps, which is the reverse of removal.

(1) At each of the four mount brackets, be sure to locate the mount parts as shown here. Note that shim (1) and washer (2) come on bottom side and shim (3) and washer (4) on top side. Just when you have lowered the engine to the mounts, check to be sure that clearance (A) between washer (2) and bracket measures something like 1.5 to 2 mm (0.059 to 0.079 in.). If the clearance is gone (measuring 0 mm) at one or more mounts, replace all four mount brackets.

(2) After installing the two universal joints (one is the joint in hydraulic pump drive line and the other is that which is between clutch and transmission), check to be sure they are nearly horizontal.

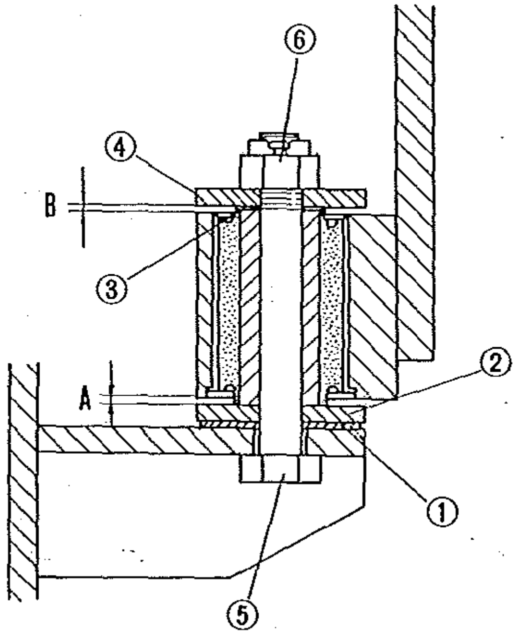
(3) With mount bolt (5) in place, see if clearance (B) is between 1.2 and 2.2 mm (0.047 and 0.087 in.); if not, reduce or increase the thickness of shim (3) to set the clearance within this range at each mount.

(4) Tighten castle nuts (6) to 15.9 ± 1.6 kg-m (115 ± 11.6 lb-ft).

(5) After tightening the four mounts, see if the combination of engine and clutch is tilted under visual observation; if so, check the mounts and brackets and make necessary corrections. Be sure that the combination is trued up and level.

(6) As necessary, use the following replacement parts:

Washers (2) (4):	6-mm (0.24-in.) thickness, 58611-02400
	4-mm (0.16-in.) thickness, 58811-11200
Shim (1):	1-mm (0.04-in.) thickness, 64361-74611
	0.5-mm (0.02-in.) thickness, 64361-74612
Shim (3):	0.5-mm (0.02-in.) thickness, 64361-17156



6
4
B
3
2
A
1
5

UNIVERSAL JOINT

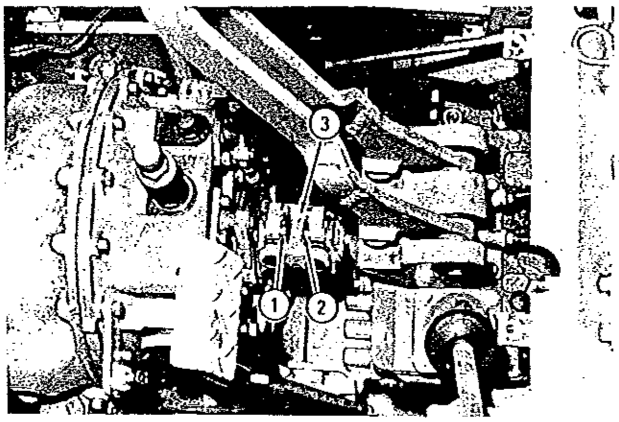
Removal

Preparatory step

Have floor plates (Fr and Re) removed to provide access to the joint.

(1) Remove bolts (1) (2), four each.

(2) Pick out universal joint (3).



Installation

To install the joint, reverse the two sequential steps of removal.

TRANSMISSION

Transmission assembly removal

Preparatory steps

(a) Remove floor plates (Fr and Re).

(b) Remove the under guard.

(c) Drain the transmission.

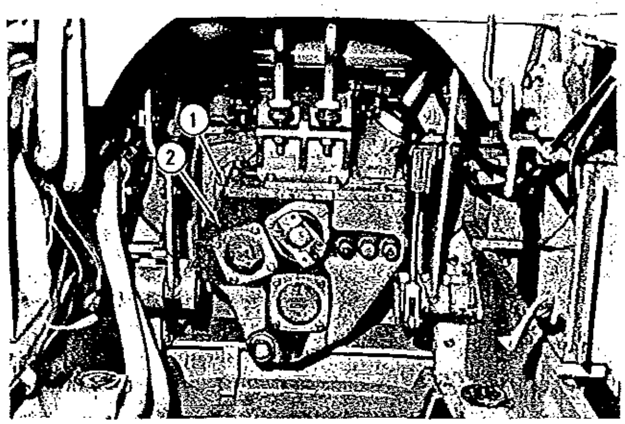
(d) Remove the propeller shaft.

(e) Remove the steering-clutch lever assembly.

(1) The transmission must be lifted with an hoist. Hitch a lifting sling to the transmission case.

(2) With the weight of the transmission taken up by the sling, remove mounting bolts (1) to free it from the steering clutch case.

(3) Lift the assembly (2) out of the machine.



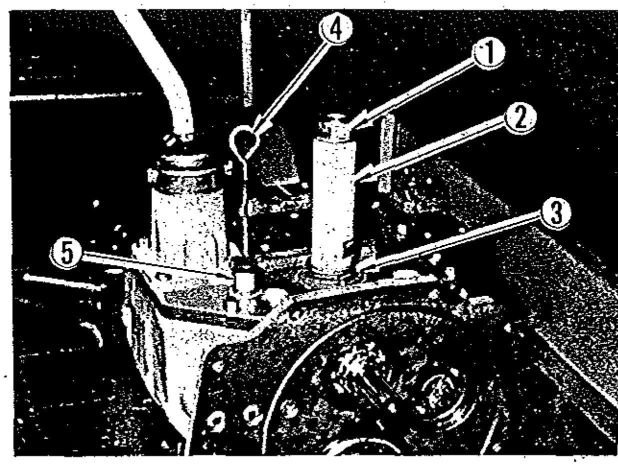
Transmission assembly mounting

Using the hoist and lifting sling, bring the transmission assembly into position, reversing the procedure of removal.

Transmission control lever and cover disassembly

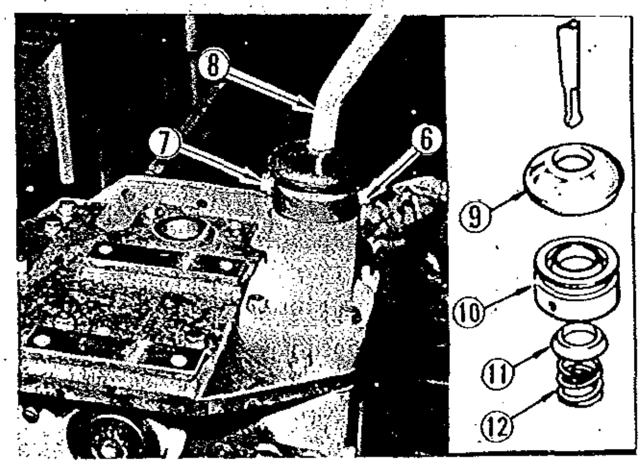
(1) Set up the removed transmission assembly on the work stand or bench. Remove plug (1), plug base (2) and gasket (3).

(2) Take off level gauge (4) and remove pipe (5).



(3) Remove bolts (6) (7) to free control lever (8). Be sure to recover spring washers when removing these bolts.

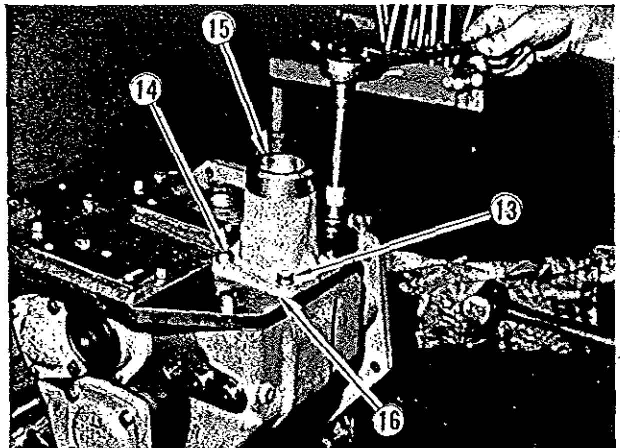
(4) Pull out control lever (8), and separate or take out the parts associated with this lever; namely, dust cover (9), cover (10), retainer (11) and spring (12).



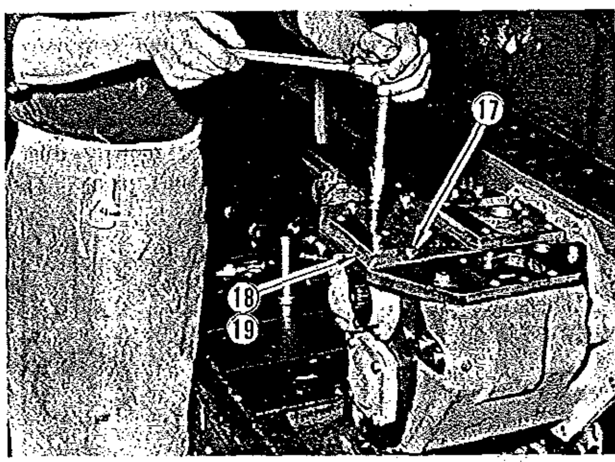
(5) Remove two bolts (13) (on the outer side, each with a spring washer) and two bolts (14) (on the inner side, each with a spring washer). Take off lever case (15) and gasket (16).

NOTE

Outer bolts (13) are longer than inner bolts (14). Be sure to discriminate these two sizes at the time of reassembly.



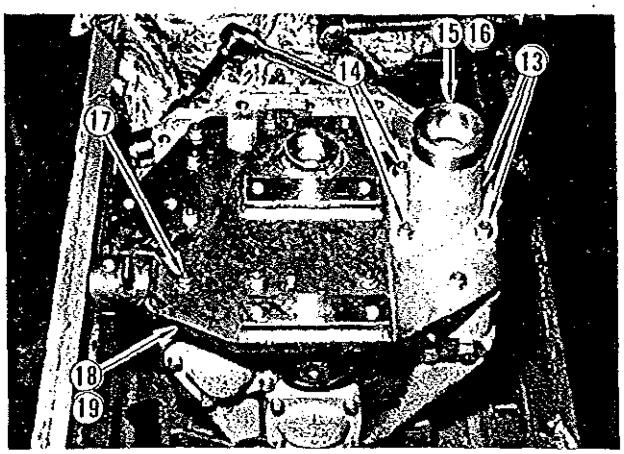
(6) Remove ten bolts (17) and spring washers, and take off transmission cover (18) and gasket (19).



Transmission control lever and cover reassembly

(1) Install cover (18), securing it to the case by tightening bolts (17), each with a spring washer. Be sure to position gasket (19) squarely when placing the cover on the case.

(2) Put on lever case (15) and its gasket (16), and secure the case by tightening bolts (13) (14). Remember, these bolts need spring washers.



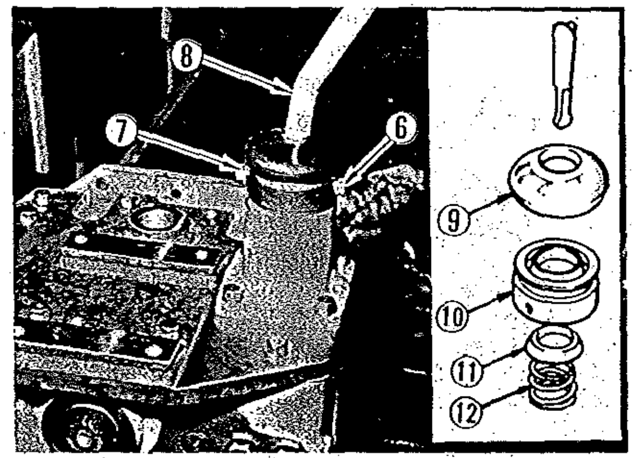
NOTE

Bolts (14) come on the inner side and bolts (13) on the outer side of the case.

(3) Mount spring (12), retainer (11), cover (10) and dust cover (9) on the inner end of control lever (8).

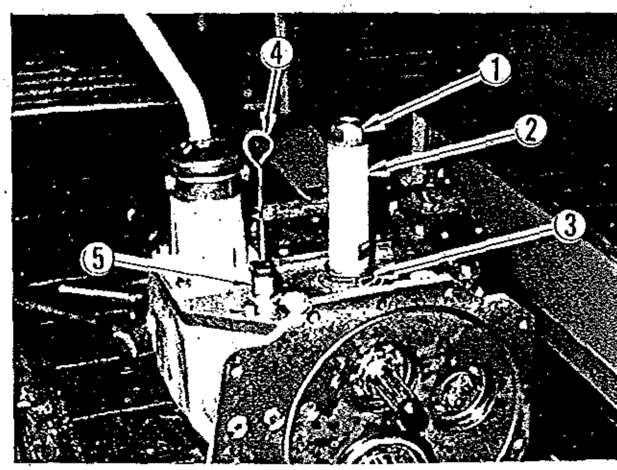
(4) Insert lever (8) into case (15), positioning the lever angularly to bring its pivoting groove to the inner side of the case.

(5) Put on cover (10), and secure it by tightening bolts (6) (7). Use spring washers on these bolts.



(6) Install level gauge pipe (5), using the sealing compound (THREE BOND No. 2) to provide an oil-tight fit. Insert gauge (4).

(7) Install plug base (2) and plug (1), with gasket (3) fitted to the seat.

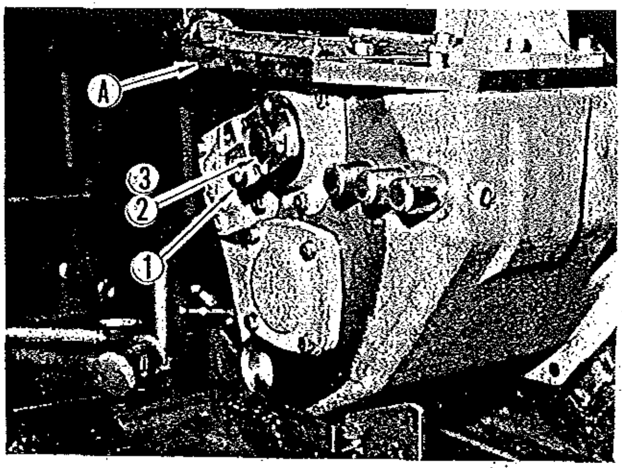


Main drive shaft disassembly

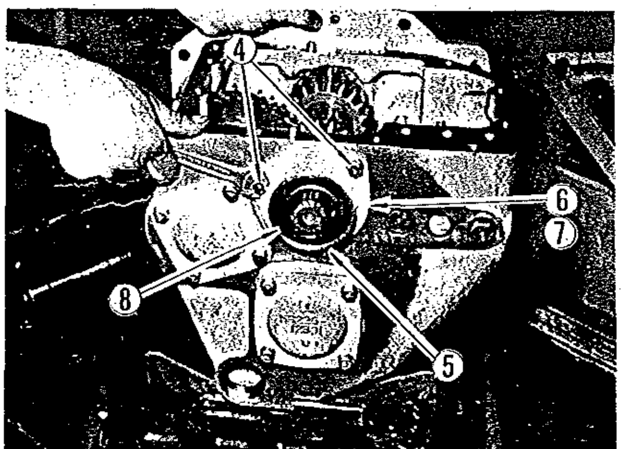
Preparatory step

Have the transmission control lever and cover removed in advance, and proceed as follows:

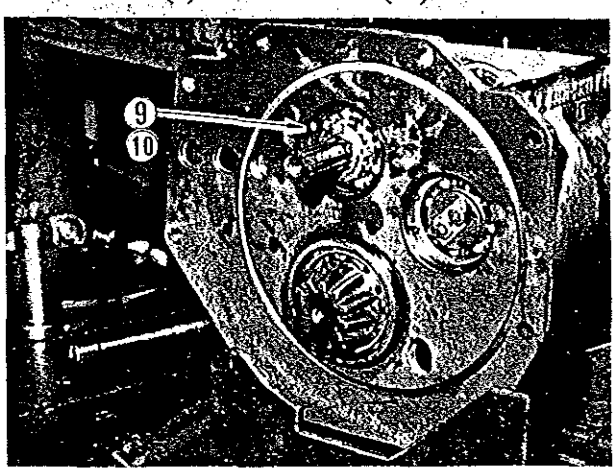
(1) Remove flange (1): this flange is on the input end of main drive shaft, and comes out with expansion plug (2) and snap ring (3). Plug (2) and ring (3) may be removed from the flange, as necessary.



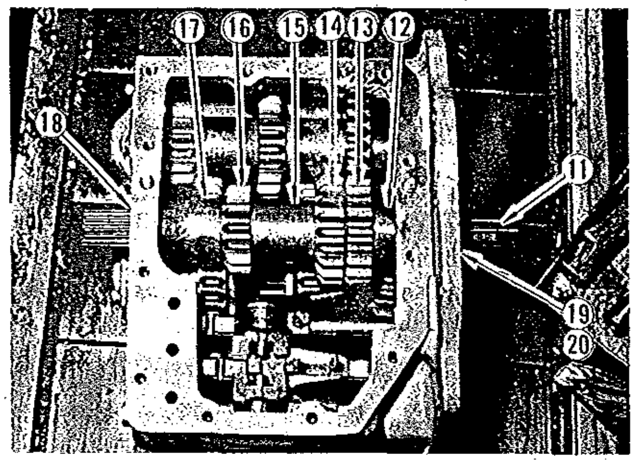
(2) Remove two bolts (4) and one seal bolt (5), that is, a total of three bolts, each with a spring washer, and take off cover (6) and gasket (7). Oil seal (8) may be detached from the cover (6).



(3) From the other end of main drive shaft, remove lock nut (9) and lock washer (10).



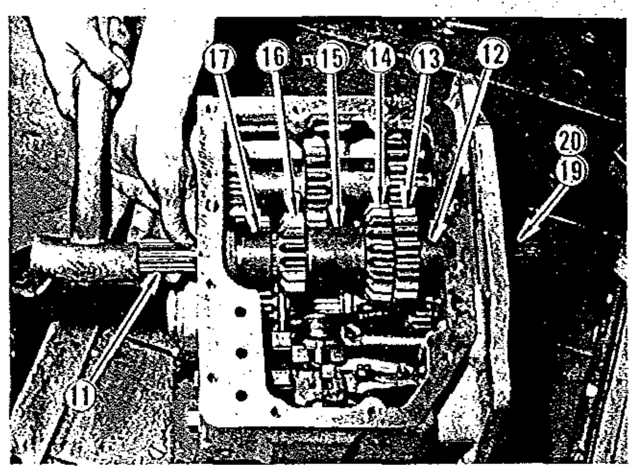
(4) Using a proper drift and hammer, force main drive shaft (11) into the case by delivering the drive to the splined end (on the steering clutch case side) of the shaft. Take out spacer (12), constant mesh gear (13), 1st reverse gear (14), spacer (15), 1st gear (16) and spacer (17). Remove bearing (18) from main drive shaft (11), and snap ring (19) and bearing (20) from the case: these bearings may be left in place unless removal is necessary.



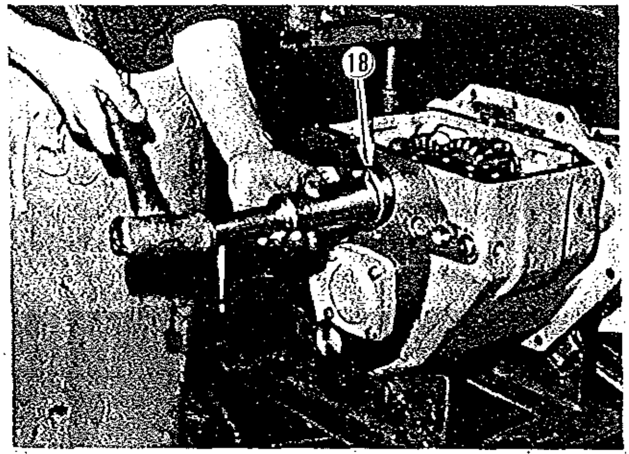
Main drive shaft reassembly

(1) Drive bearing (20) into the case wall (on output side) and fit snap ring (19) to retain this bearing in place.

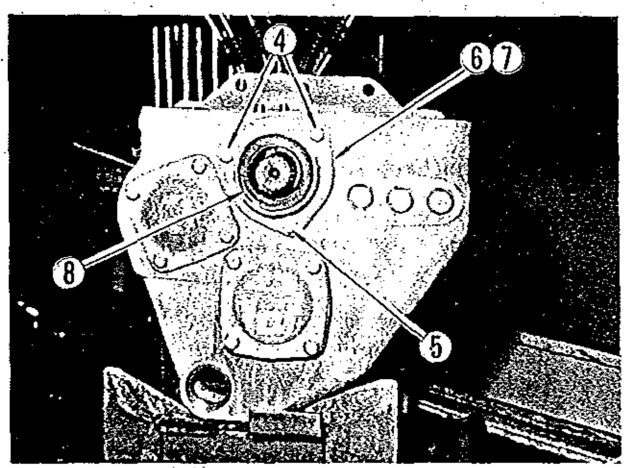
(2) Feed main drive shaft (11) into the case through the hole on input side while mounting thereon spacer (17), 1st gear (16), spacer (15), 1st reverse gear (14), constant mesh gear (13) and spacer (12).



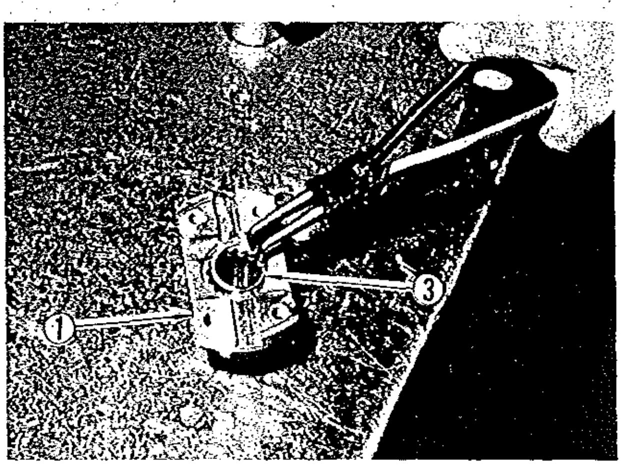
(3) Install bearing (18), as shown.



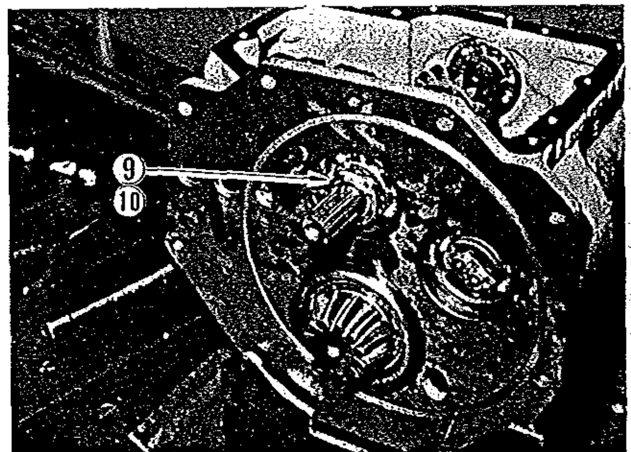
(4) Fit oil seal (8) – properly greased at its lip portion – to cover (6), and install this cover with gasket (7) by tightening bolts (4) (5). Be sure to use a spring washer on each bolt. Remember, seal bolt (5) comes on the bottom side.



(5) Fit snap ring (3) and expansion plug to flange (1), and mount this flange on shaft (11).



(6) Install lock washer (10) and lock nut (9) to secure the bearing and snap ring on the output end of main drive shaft.



Subsequent step

The control lever and cover can now be restored.

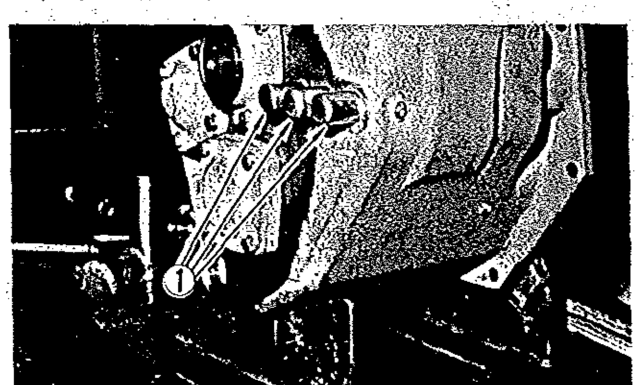
Shift fork disassembly

Preparatory steps

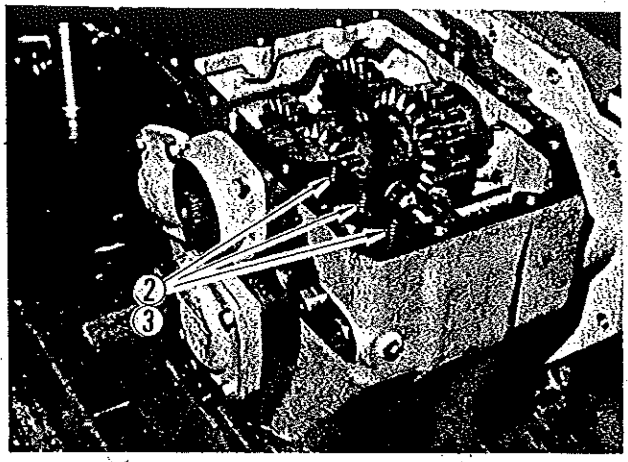
(a) Have the control lever and cover removed.

(b) Remove the main drive shaft.

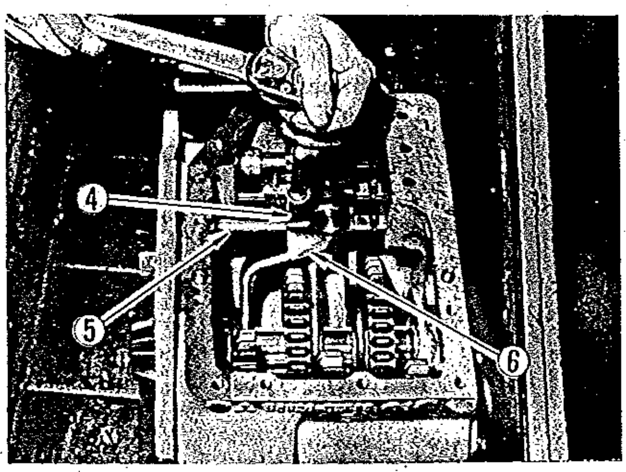
(1) Remove three expansion plugs (1) from the transmission case.



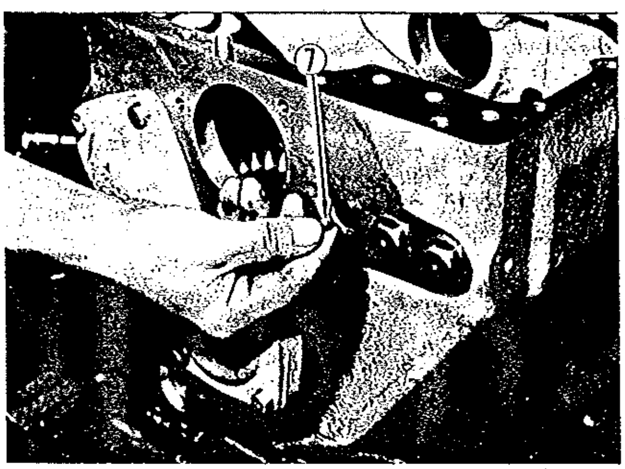
(2) From the top face of the case, remove three springs (2) and three steel balls (3).



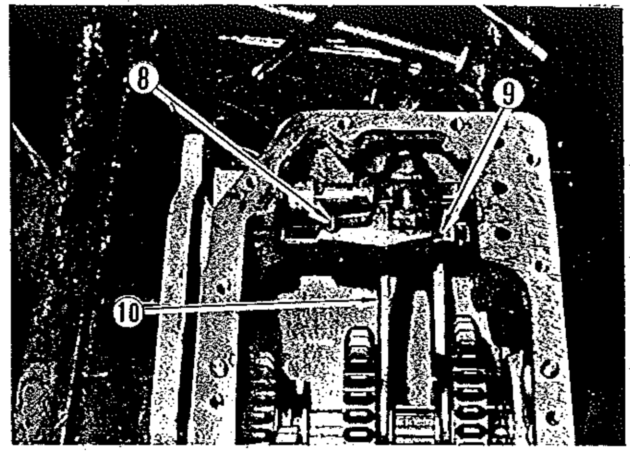
(3) Loosen and remove set screw (4), which secures 3rd shift fork (6) to 3rd shift rail (5). Take out 3rd shift rail and shift fork (6).



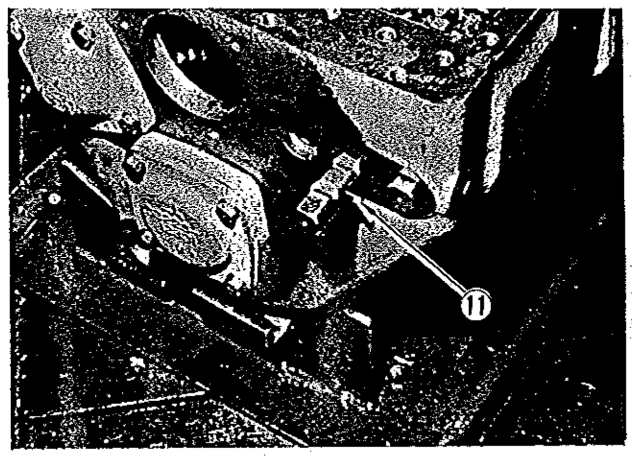
(4) Pick out two steel balls (7) located between 2nd shift rail and 3rd shift rail.



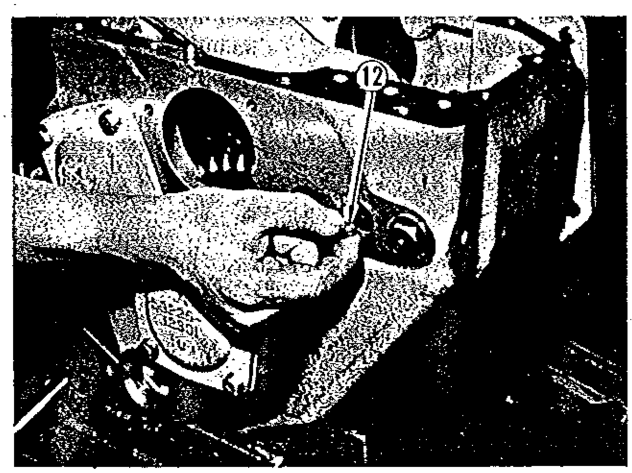
(5) Free 2nd shift fork (10) by removing its set screw (8), and take out 2nd shift rail (9) and fork (10).



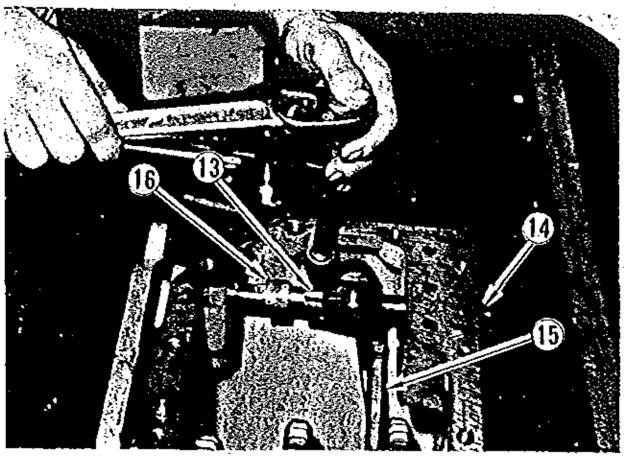
(6) From 2nd shift rail (9), pick out interlock pin (11).



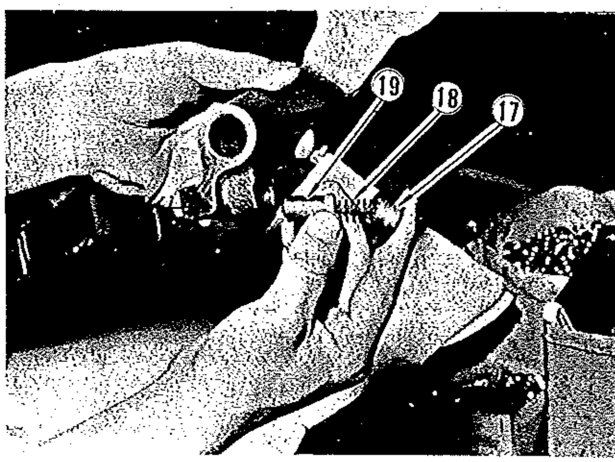
(7) Remove two steel balls (12) located between 2nd shift rail and 1st shift rail.



(8) Free 1st shift fork (15) by removing its set screw (13), and take out 1st shift rail (14), fork (15) and collar (16).

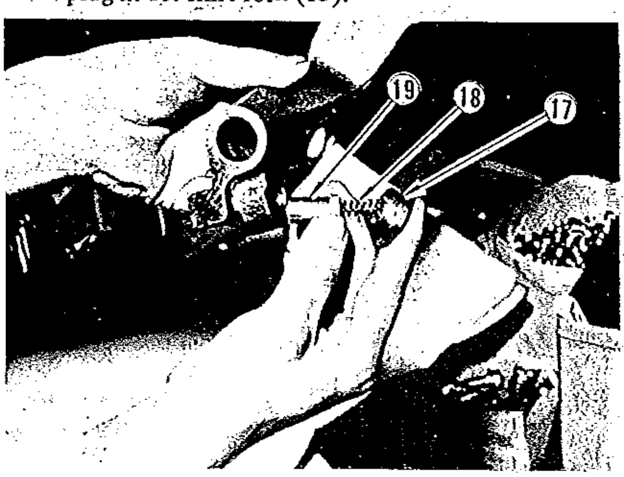


(9) From the removed 3rd and 1st shift forks, remove plug (17), spring (18) and plunger (19).

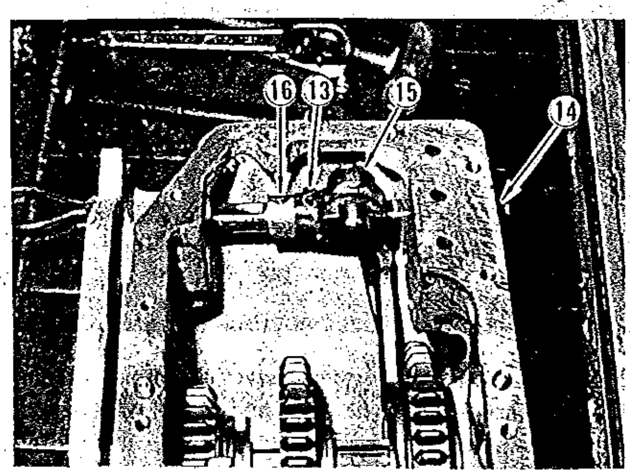


Shift fork reassembly

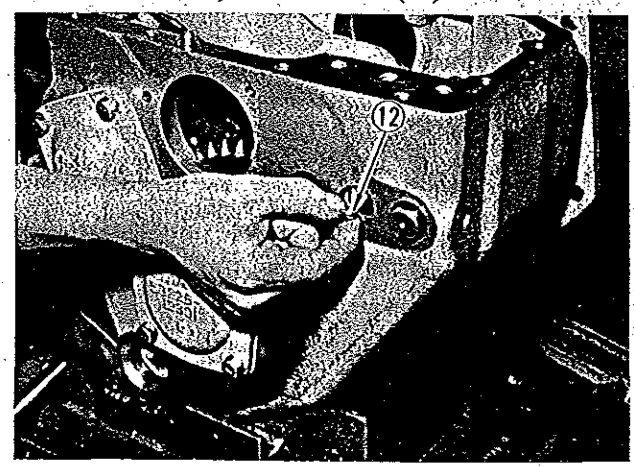
(1) Install plunger (19), spring (18) into 3rd shift fork (6), and run in plug (17) to retain the plunger and spring in the fork. Similarly install the plunger and plug in 1st shift fork (15).



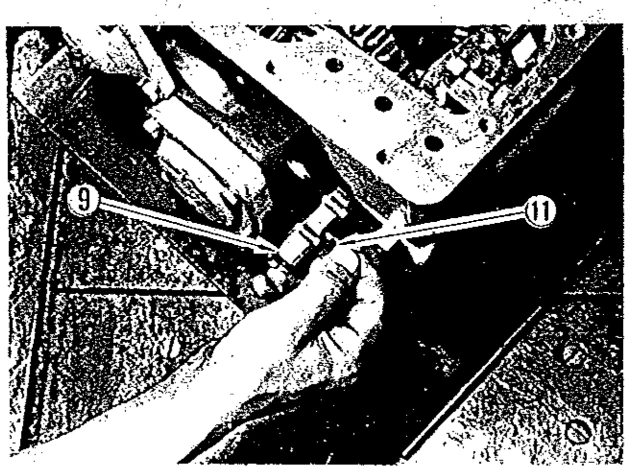
(2) Insert 1st shift rail (14) into the case, mounting thereon 1st shift fork (15) and collar (16). Secure the fork by tightening its set screw (13). Lock the tightened screw (13) to the fork with a wire piece.



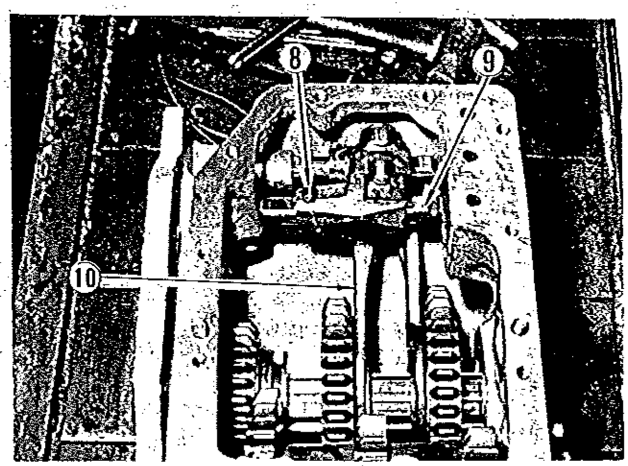
(3) Insert into the ball hole (between 1st shift rail and 2nd shift rail) two steel balls (12).



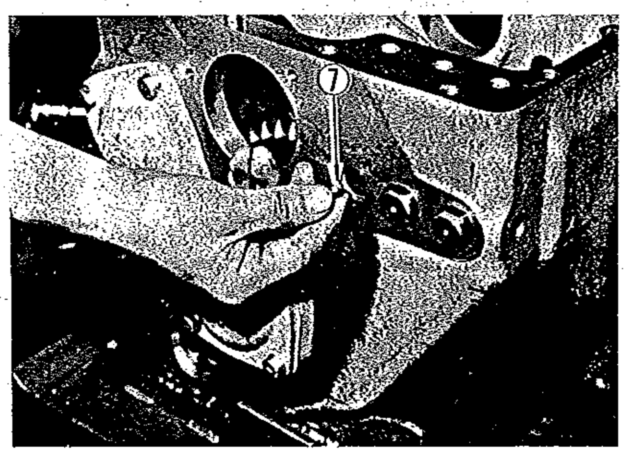
(4) Insert interlock pin (11) into 2nd shift rail (9).



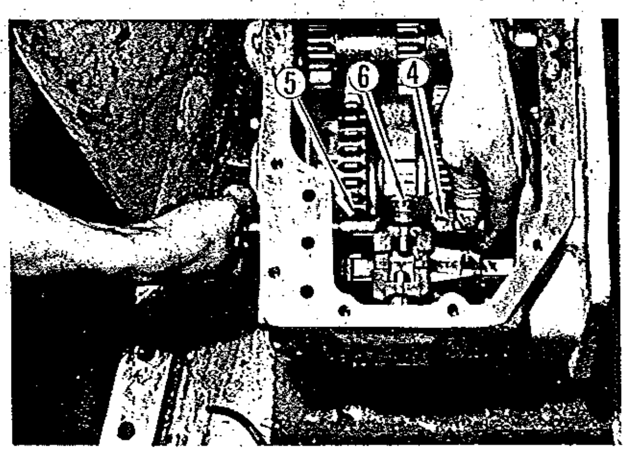
(5) Insert 2nd shift rail (9) into the case, while mounting shift fork (10) on the rail, and secure the fork to the rail by tightening set screw (8). Lock the tightened screw to the fork with a wire piece.



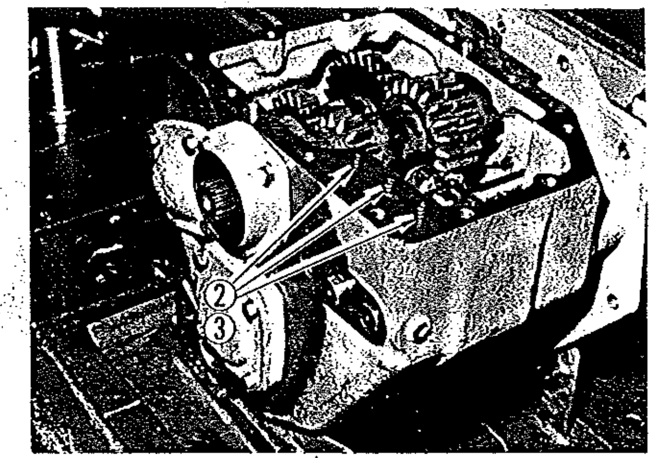
(6) Insert into the ball hole (between 2nd shift rail and 3rd shift rail) two steel balls (7).



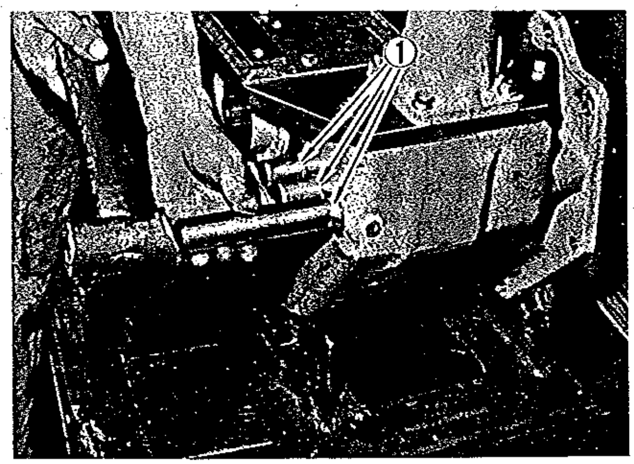
(7) Insert 3rd shift rail (5) into the case, while mounting thereon shift fork (6). Tighten set screw (4) to secure the fork, and lock the screw to the fork with a wire piece.



(8) Place three steel balls (3) and three springs (2) in the holes provided in the top face of the transmission case.



(9) Drive into the case wall three expansion plugs (1), using a proper drift and hammer.



Subsequent step

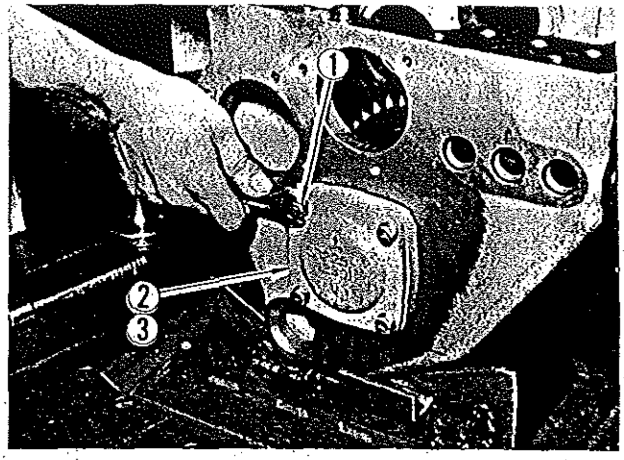
The subsequent work is in two jobs: installing the main drive shaft assembly and reassembling the control lever and cover on the top of the transmission case.

Countershaft disassembly

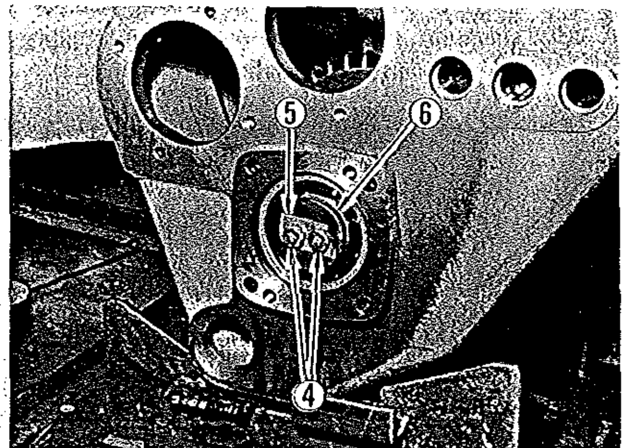
Preparatory step

The following procedure assumes that the control lever and cover are off and that the main drive shaft assembly has been taken out.

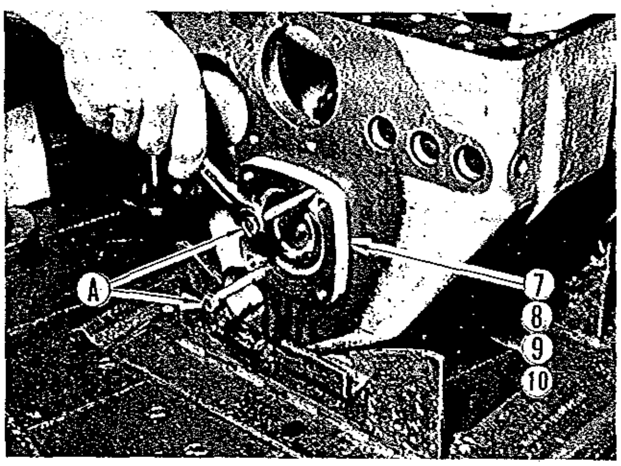
(1) Remove four bolts (1), each provided with a spring washer, and take off cover (2) and gasket (3).



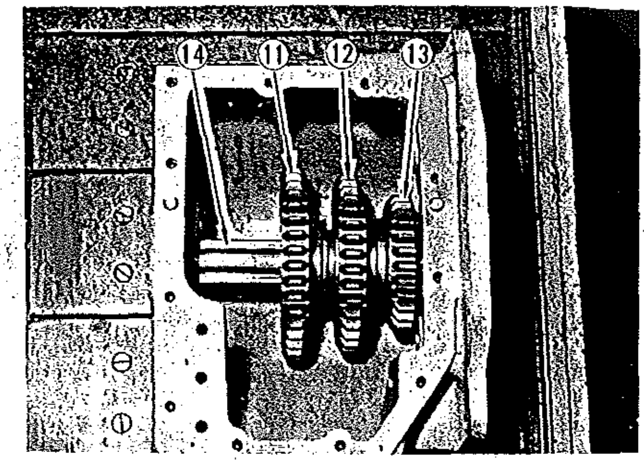
(2) From the end face of bevel gear shaft, remove two bolts (4) and their spring washers, and take off lock plate (5) and washer (6).



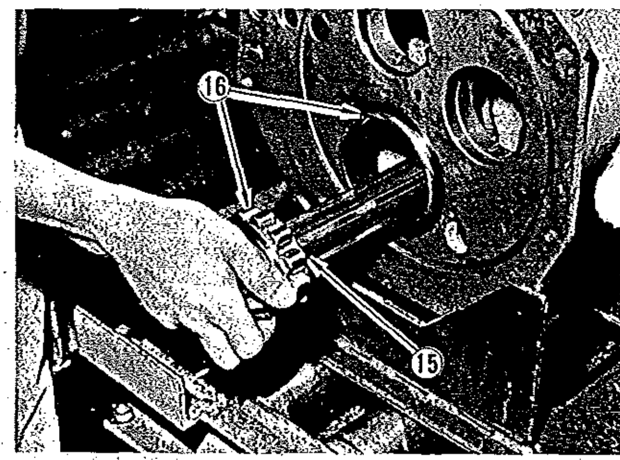
(3) Run in two jacking bolts (A) and force bearing cage (7) off. Remove bearing (8), "O" ring (9) and shim (10) from the cage.



(4) Drive on the end face of bevel gear shaft into the case from the universal joint side (input side) and, while pulling the shaft (14) out through the output-side case wall, take out 1st sliding gear (11), 2nd sliding gear (12) and 3rd sliding gear (13).

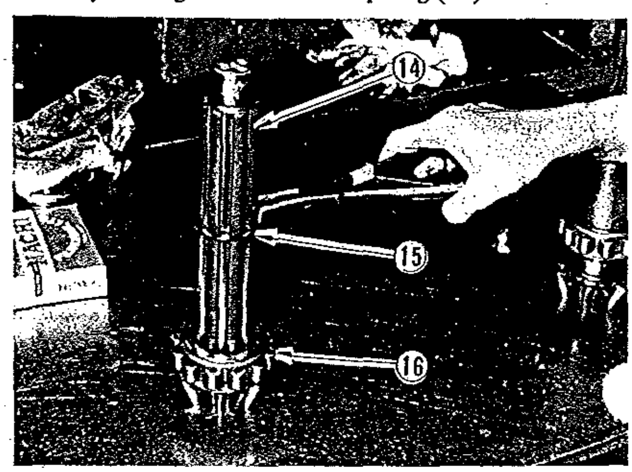


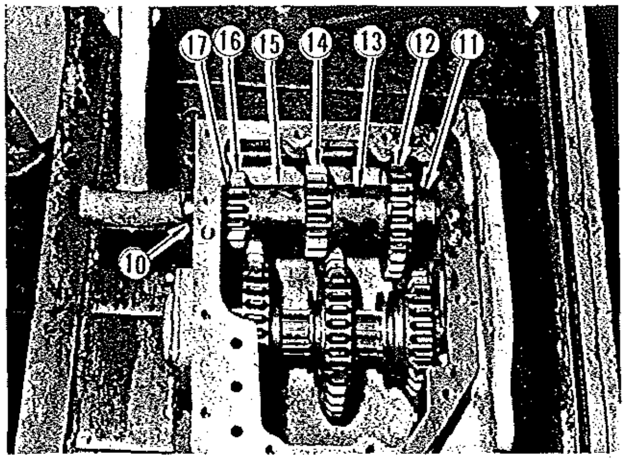
(5) Pick out snap ring (15) off bevel gear shaft (14), and remove the inner race of bearing (16) from the shaft. From the case wall, remove the bearing outer race.



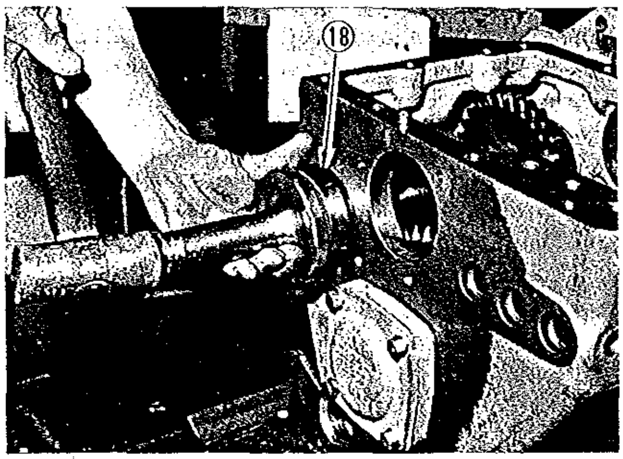
Bevel gear shaft reassembly

(1) Fit bearing inner race (16) to bevel gear shaft (14) by driving the race. Fit snap ring (15) to the shaft.

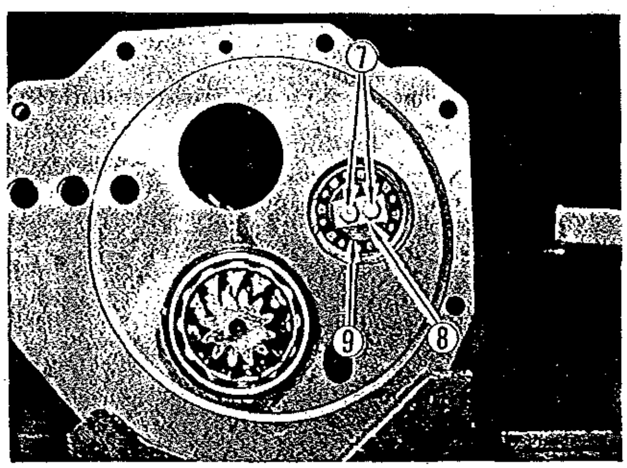




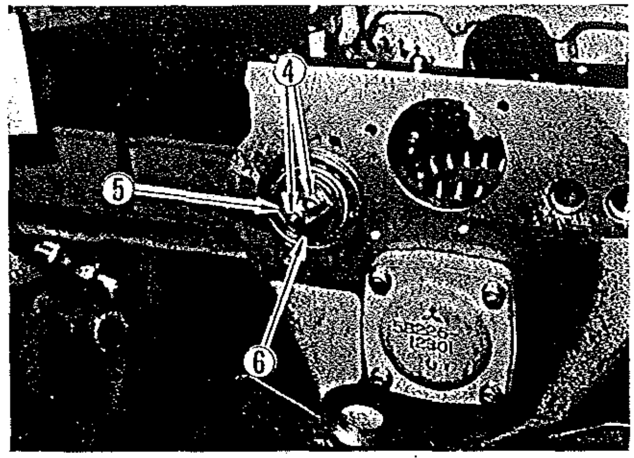
(3) Install bearing (18), as shown.



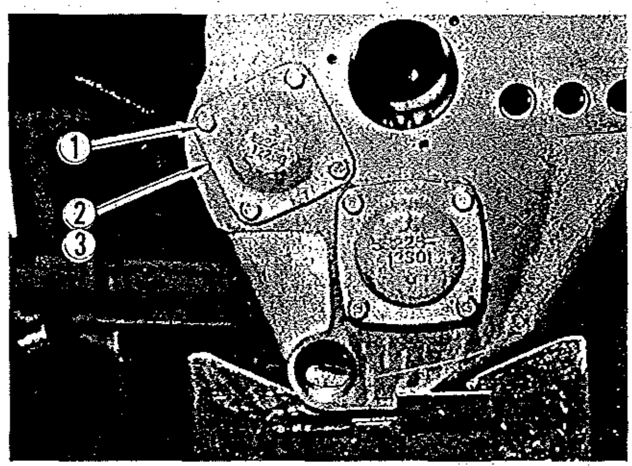
(4) At the steering clutch case side of the case, install washer (9) and lock plate (8) by tightening two bolts (7), and lock these bolts by bending the lock plate.



(5) At the other side, similarly install lock plate (5) and washer (6) on the end face of countershaft. After tightening two bolts (4), be sure to lock them by bending the plate.



(6) Put on gasket (3), place cover (2), and secure the cover to the case by tightening four bolts (1), each with a spring washer, thus completing the reassembly in place of the countershaft.



Subsequent steps

The subsequent jobs are: (a) shift fork reassembly, (b) main drive shaft reassembly, and (c) reassembly of control lever and cover, all in place.

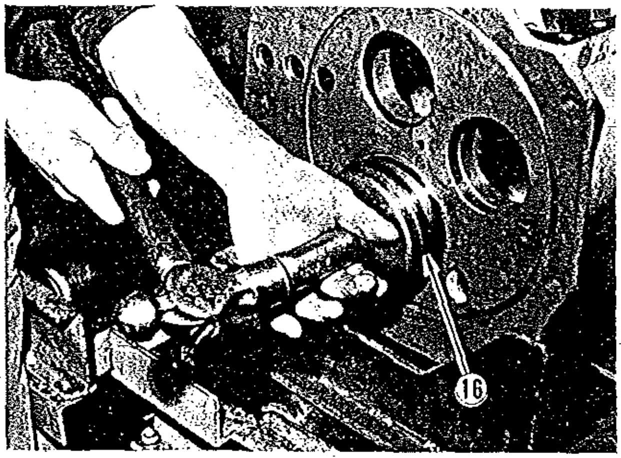
Bevel gear shaft disassembly

Preparatory step

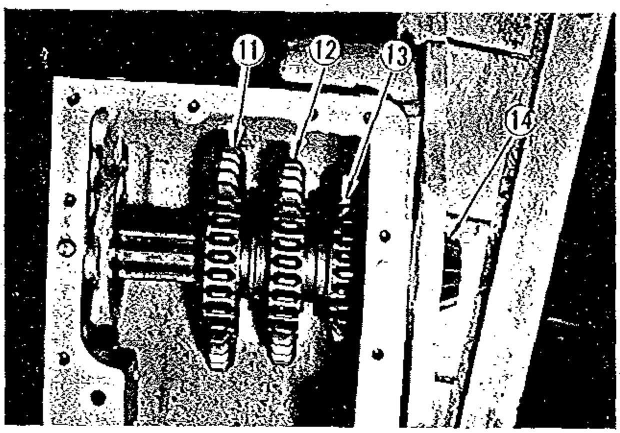
The following procedure assumes that (a) control lever and cover are off, (b) main drive shaft assembly is out, (c) shift forks are out, and (d) countershaft assembly is out, leaving the bevel gear shaft and others in the case.

(1) Remove four bolts (1), each complete with a spring washer. Take off cover and gasket (3).

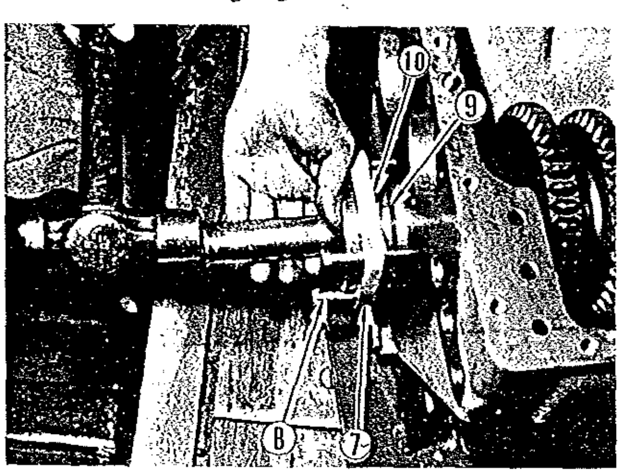
(2) Fit bearing outer race (16) into the bore by driving as shown.



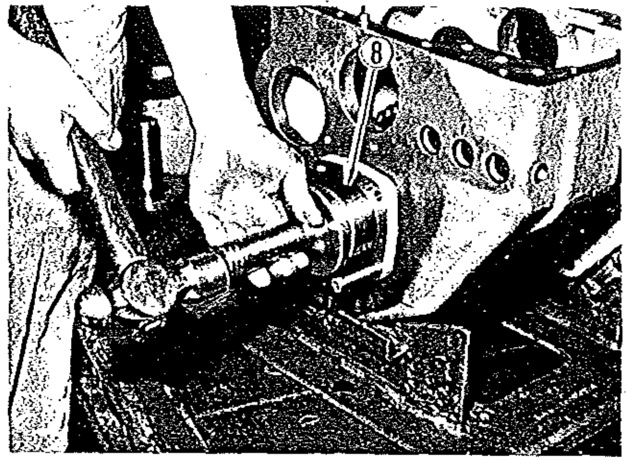
(3) Feed bevel gear shaft into the case through the output-side wall of the case while mounting thereon 3rd sliding gear (13), 2nd sliding gear (12) and 1st sliding gear (11).



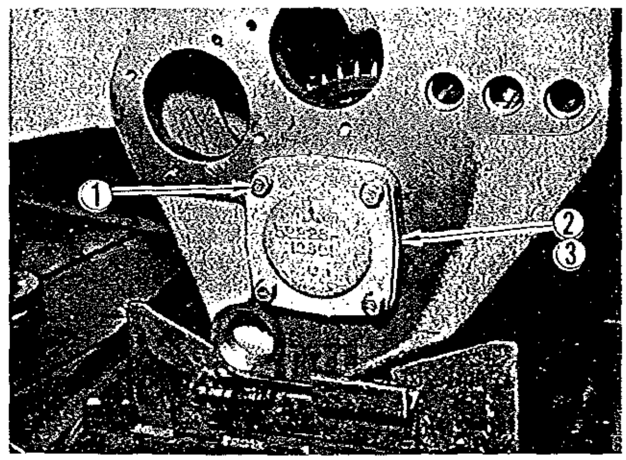
(4) Fit "O" ring (9) and shim (10) to bearing case (7), and position the cage squarely at the bore to force it into the case wall. Be sure to keep the cage trued up by running in four guide bolts (B). These bolts are for aligning the bolt holes.



(5) Using the drift, drive the cage into the case wall.



(6) Fit gasket (3) and put on cover (2). Secure the cover by tightening four bolts (1): a spring washer is provided on each bolt.



FLYWHEEL CLUTCH

Clutch housing assembly and clutch disc assembly removal

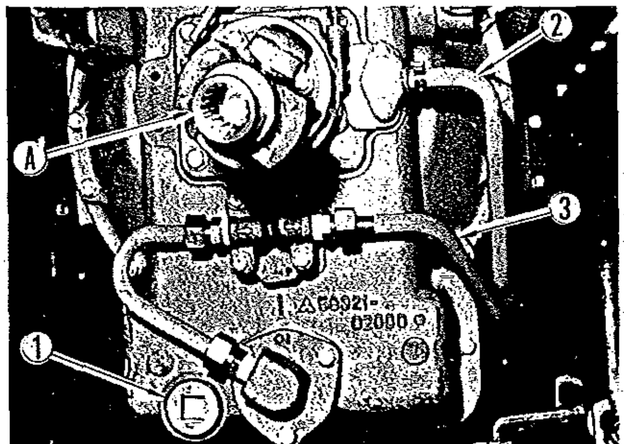
Preparatory step

Have the engine unit (comprising the clutch) taken down from the machine and set on the work stand. The clutch is to be removed from the engine in this condition.

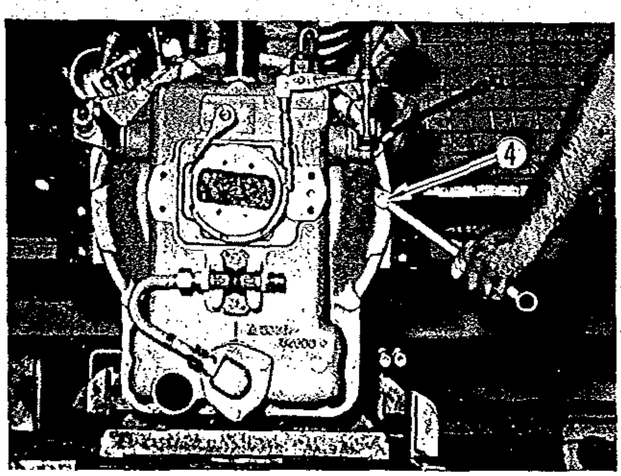
(1) Remove drain plug (1) to empty the clutch of oil.

(2) Remove oil pipes (2) (3). These pipes are associated with the oil cooler.

(3) Remove universal joint assembly (A).

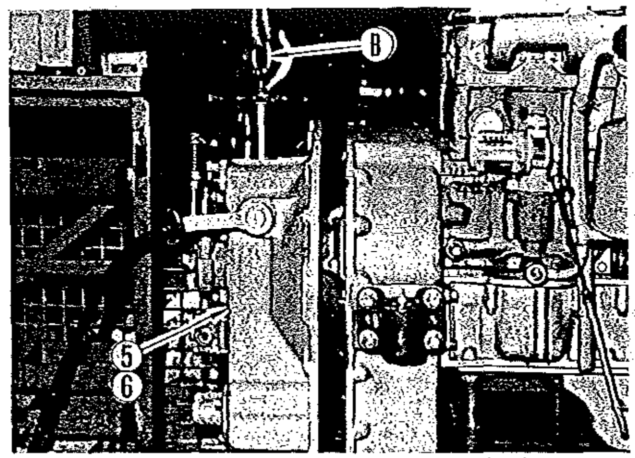


(4) Remove a total of 19 bolts (4) securing clutch housing to flywheel housing. A spring washer is used on each bolt.



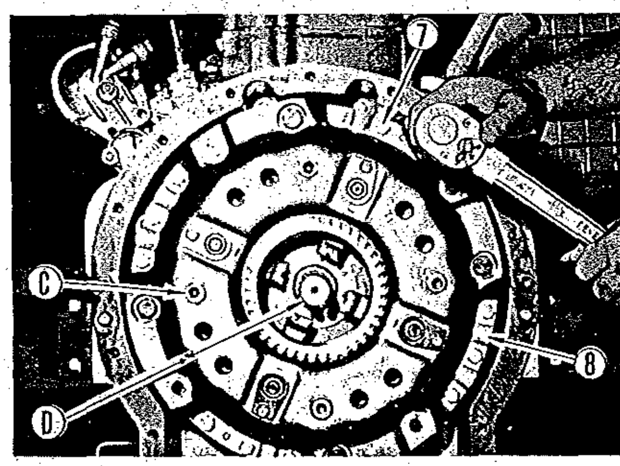
(5) Remove the breather plug and run lifting eye bolt (B) into the plug base.

(6) By operating the hoist, suspend the clutch housing assembly (5) and, in suspended state, sever it from flywheel housing. Take off gasket (6).

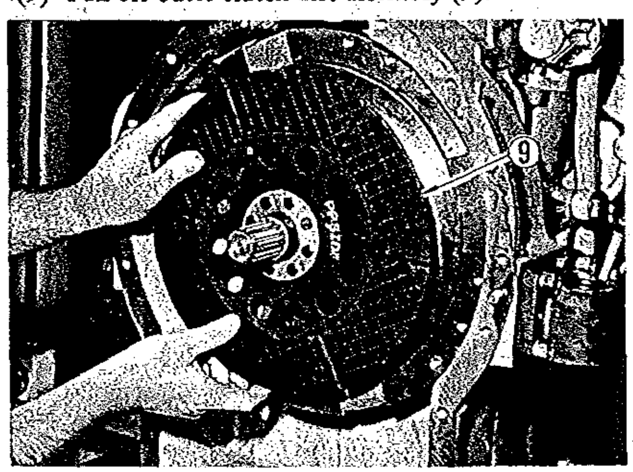


(7) Install four guide bolts (C) by running them into clutch spring holes provided in the clutch cover. Insert clutch disc arbor (D) into the splined hole of the clutch disc hub.

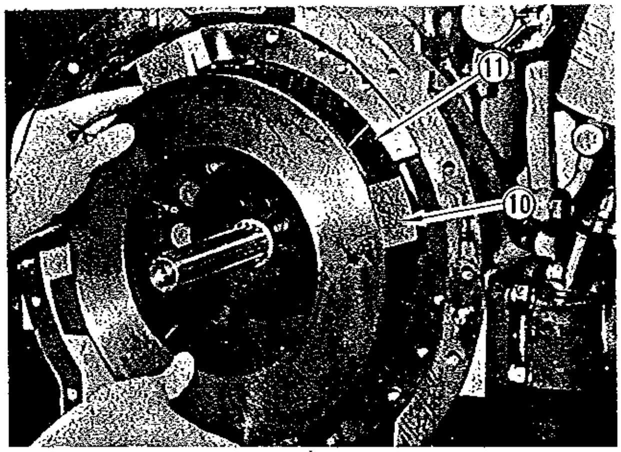
(8) Remove 12 bolts (7) securing the clutch cover to flywheel. A spring washer is on each bolt. Pull off the clutch cover assembly (8).



(9) Pull off outer clutch disc assembly (9).



(10) Pull off mating plate (10) and inner clutch disc assembly (11).



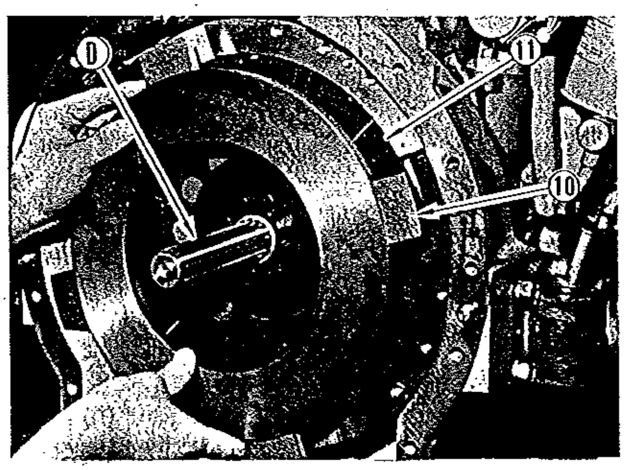
Clutch housing assembly and clutch disc assembly installation

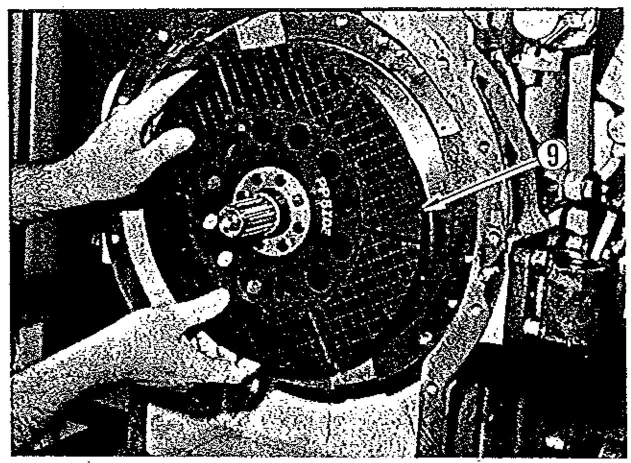
Preparatory step

The clutch alignment arbor used in removing the clutch must be used in installing work in order to align the clutch discs and cover.

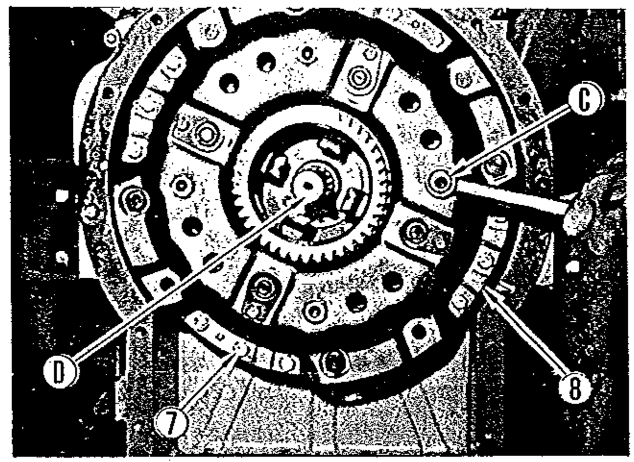
Alignment arbor (D)	58809-15600

(1) Fit alignment arbor (D) to the center of flywheel, and pass inner disc (11), mating plate (10) and outer disc (9) onto the arbor.

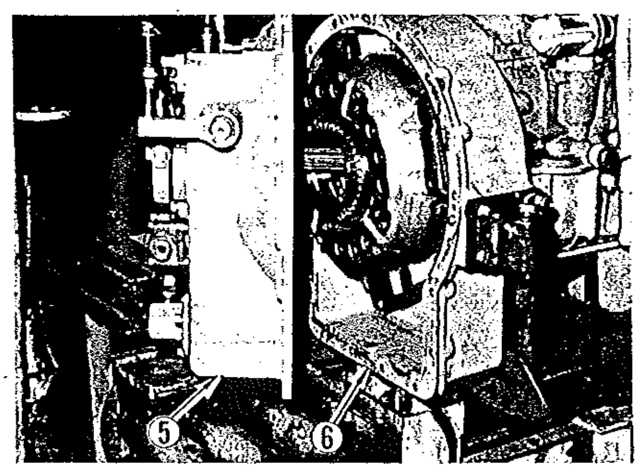




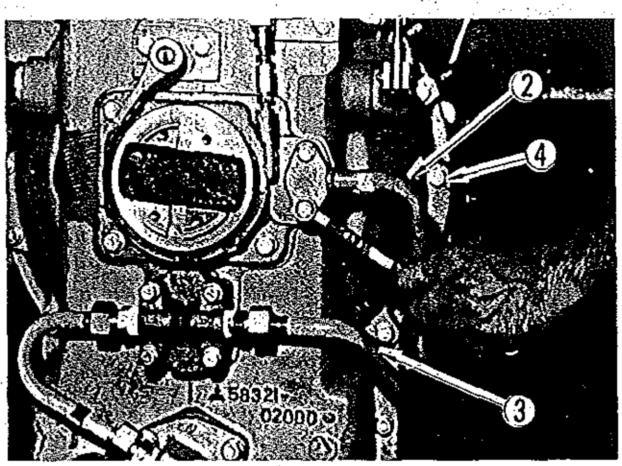
(2) Put on clutch cover assembly (8) and secure it to the flywheel by tightening 12 bolts (7). Be sure to use a spring washer on each bolt. Remove four guide bolts (C), and pull off arbor (D).



(3) Fit gasket (6) to flywheel housing; bring in clutch housing assembly (5) in suspended state; and fit the assembly to flywheel housing through the gasket. Secure the housing (5) by tightening 19 bolts (4), each complete with a spring washer.



(4) Reconnect oil pipes (2) (3).



⚠ CAUTION

Inner clutch disc is marked "FSIDE" and outer clutch disc "PPSIDE." Be sure to distinguish between the two when installing the clutch.

Clutch brake disassembly

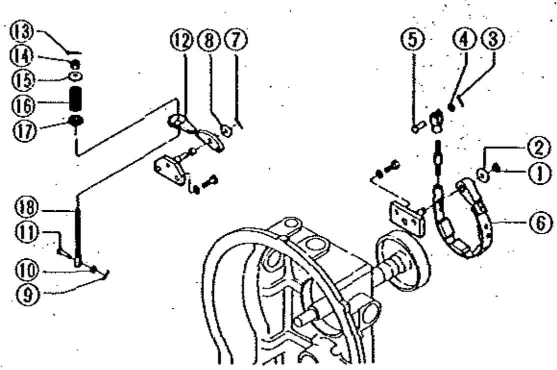
(1) Remove snap ring (1) and plain washer (2) to free the anchored end of brake band (6).

(2) Pull off split pin (3) and remove plain washer (4) and clevis pin (5) to disconnect the band from lever (12). Take off brake band (6).

(3) Pull off split pin (7) and remove plain washer (8) from the pivot shaft of lever (12).

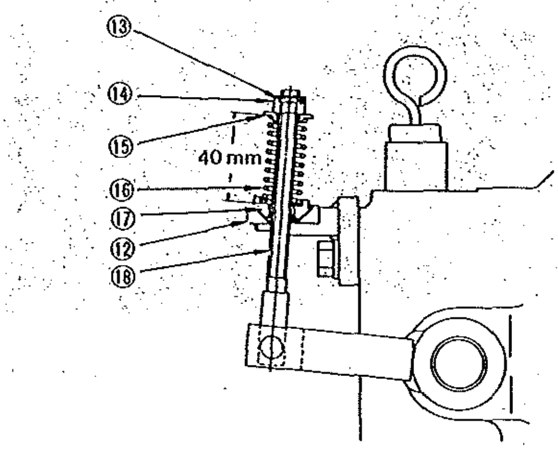
(4) Pull off split pin (9) and remove plain washer (10) and clevis pin (11). Remove brake lever (12), complete with adjusting bolt (18), spring (16) and others.

(5) From brake lever (12), remove split pin (13), slotted nut (14), seat (15), spring (16), seat (17) and adjusting bolt (18).

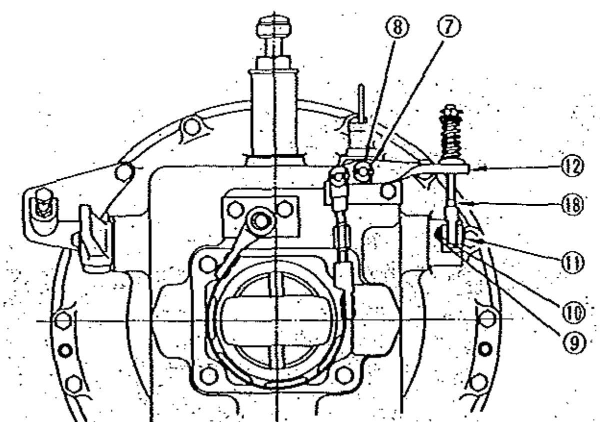


Clutch brake reassembly

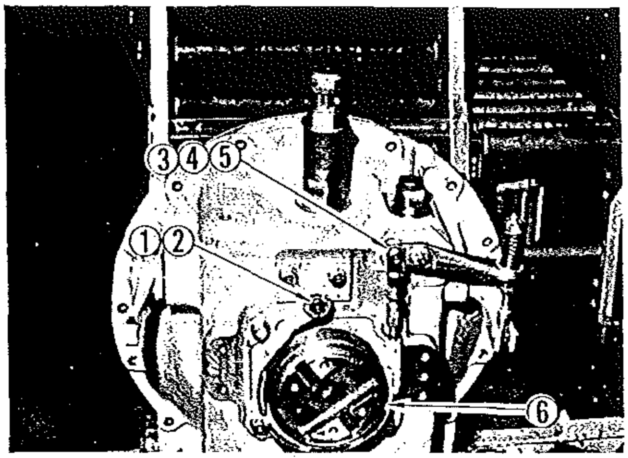
(1) Mount adjusting bolt (18), seat (17), spring (16), seat (15) and slotted nut (14) on the brake lever (12); run down slotted nut to compress the spring to 40 mm (1.57 in.) in length; and lock the nut by inserting split pin (13).



(2) Connect adjusting bolt (18) to the forked lug by means of clevis pin (11) and plain washer (10), locking the washer by inserting split pin (9). Mount brake lever (12) on pivot shaft and retain the lever by fitting plain washer (8) and inserting split pin (7).



(3) Connect the anchor end of brake band (6) to the pivot pin, securing the connection by fitting plain washer (2) and snap ring (1). Connect the other end, clevis end, to lever (12), securing the connection by fitting clevis pin (5), plain washer (4) and split pin (3).

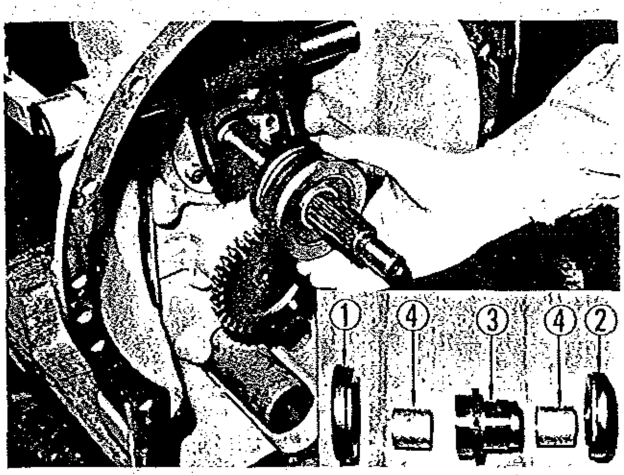


Main drive shaft disassembly

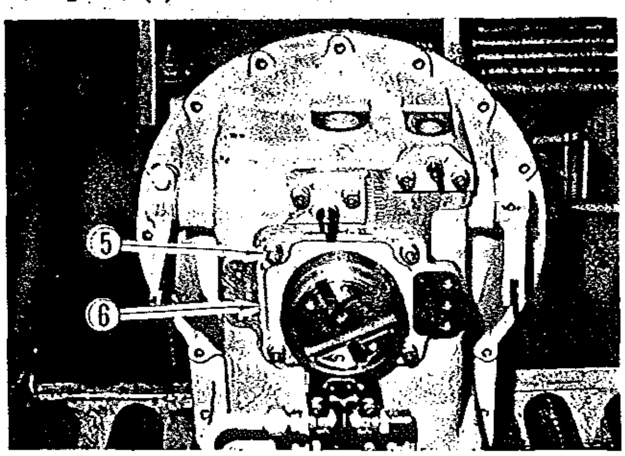
Preparatory step

For this work, have the clutch brake taken down and proceed as follows:

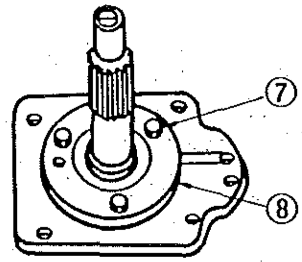
(1) Slide the release bearing assembly off main drive shaft in place. Disassemble this bearing into parts (1) (2), hub (3) and two bushings (4).



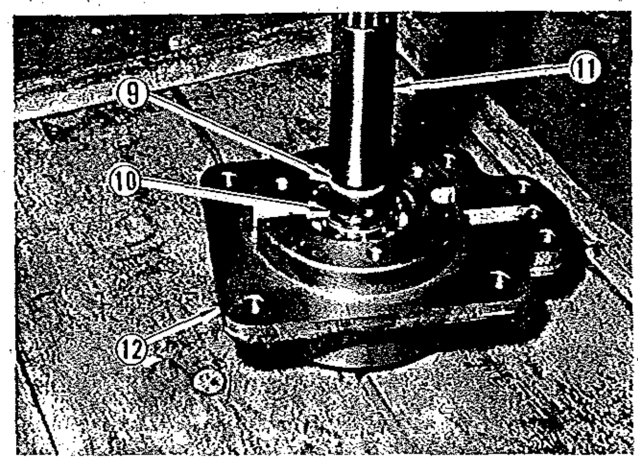
(2) Remove four bolts (5) and their spring washers, and draw out the main shaft assembly. Remove gasket (6).



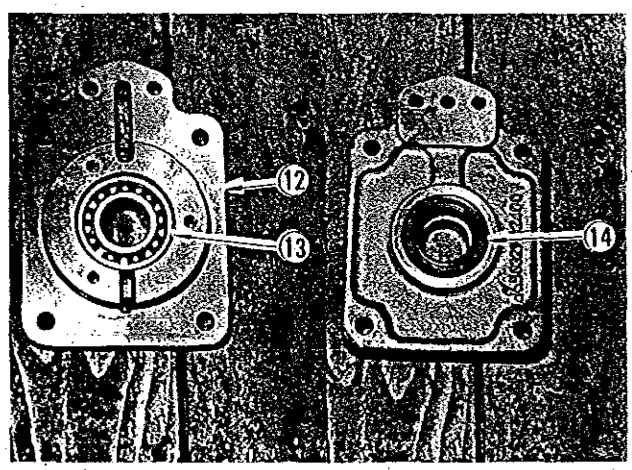
(3) Remove three bolts (7), each complete with a spring washer, and take off cover (8).



(4) Pick out seal ring (9) and snap ring (10), and detach cover (12) from main drive shaft (11).

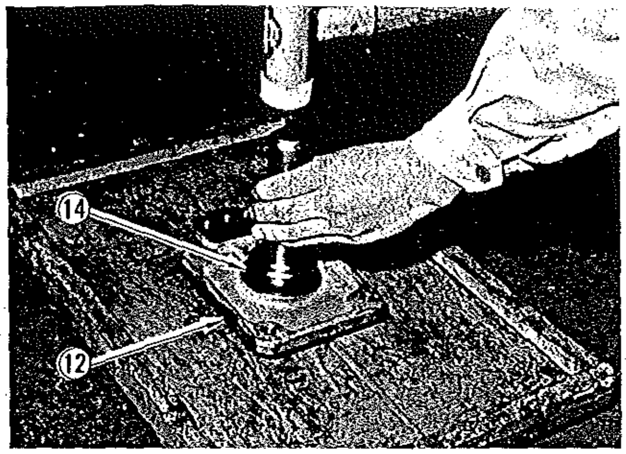


(5) Remove bearing (13) and oil seal (14) from cover (12).

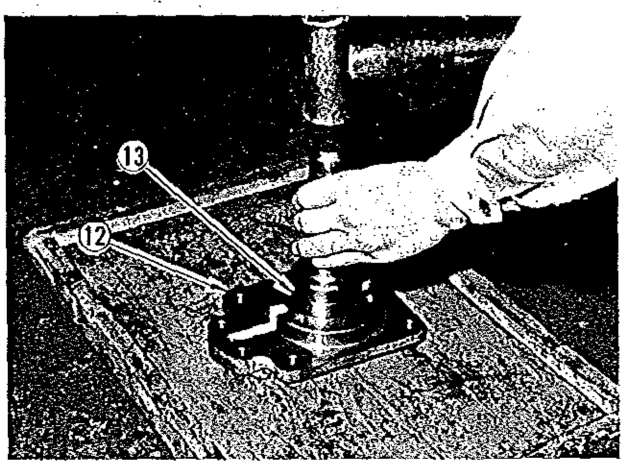


Main drive shaft reassembly

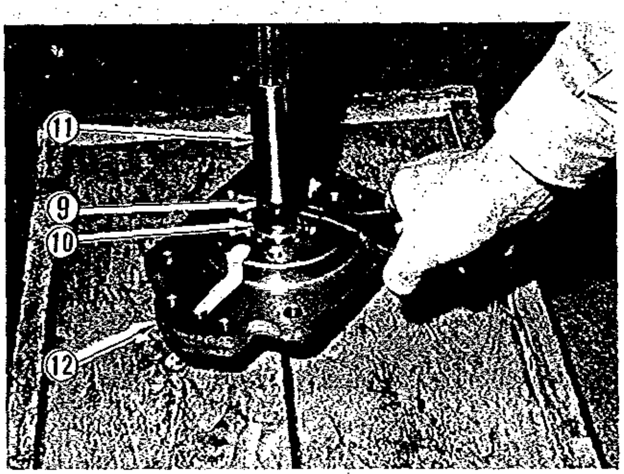
(1) Fit oil seal (14) to cover (12).



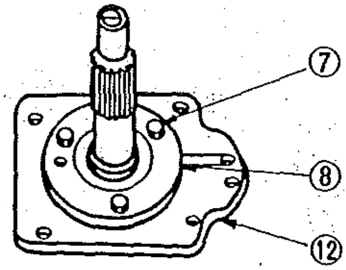
(2) Drive bearing (13) into cover (12).



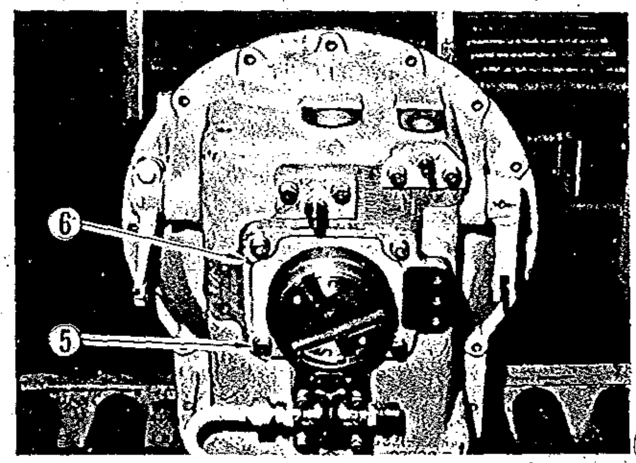
(3) Insert main drive shaft (11) into cover (12), and put on snap ring (10) and seal ring (9).



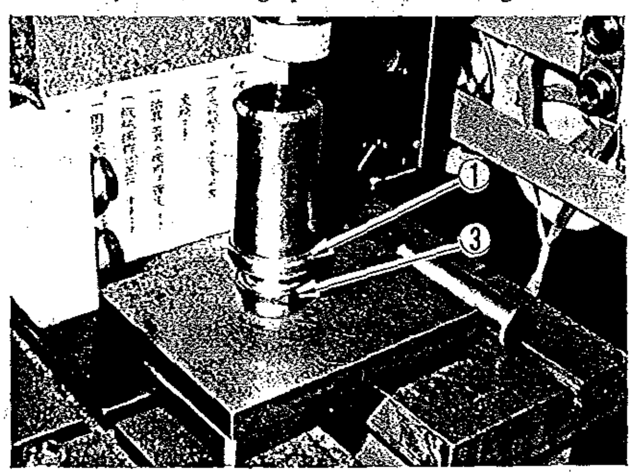
(4) Secure cover (8) to cover (12), locating the oil groove of cover (8) correctly. Be sure to use a spring washer on each bolt (7).



(5) Fit gasket (6) to the mating face of clutch housing, position the main drive shaft assembly in place, and secure the assembly by tightening four bolts (5), using a spring washer on each bolt.



(6) Drive the two bushings into release hub (3), as shown, and combine bearing halves (1) with the hub, thus building up the release bearing.



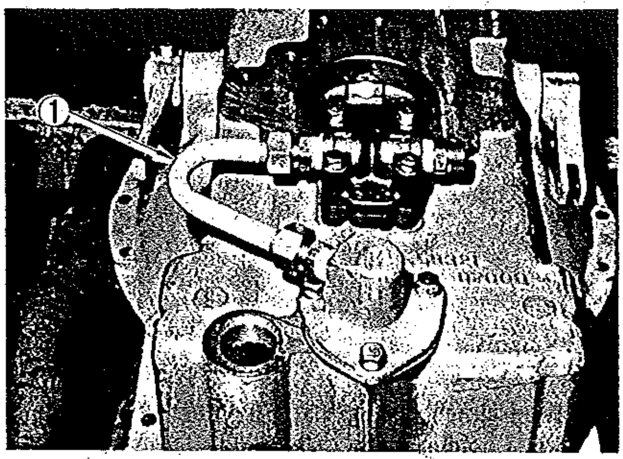
(7) Slide the release bearing onto main drive shaft.

Subsequent step

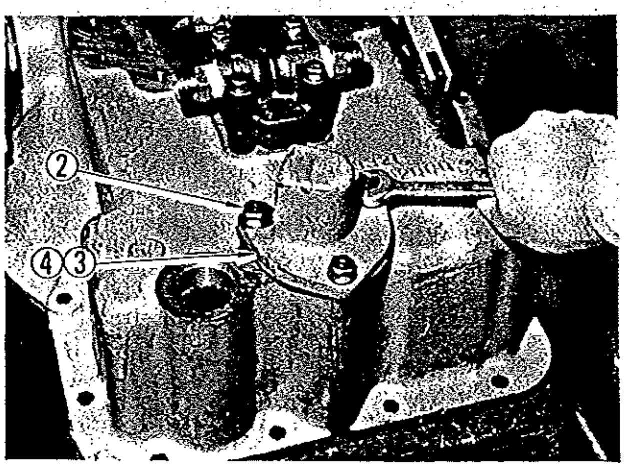
The job to follow this reassembly is the mounting of clutch brake.

Clutch filter and oil pump removal

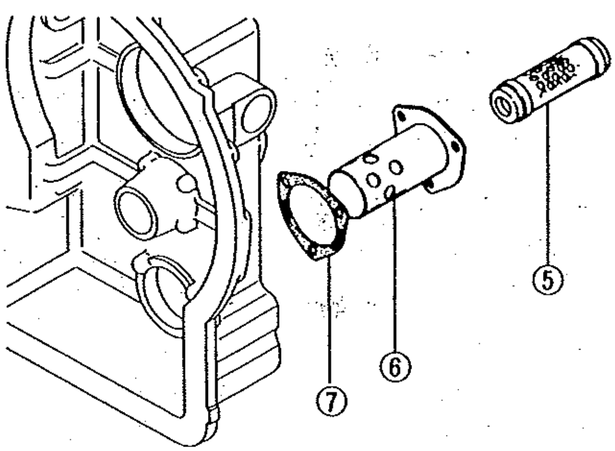
(1) Disconnect and remove suction pipe (1).



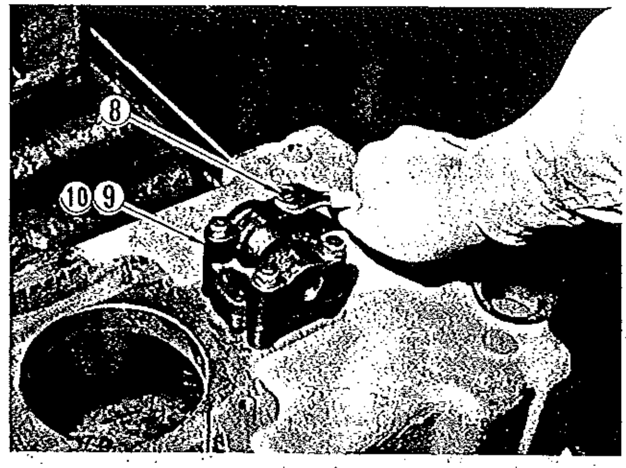
(2) Remove three spring-washered bolts (2) securing the filter cover, and take off filter cover (3) and gasket (4).



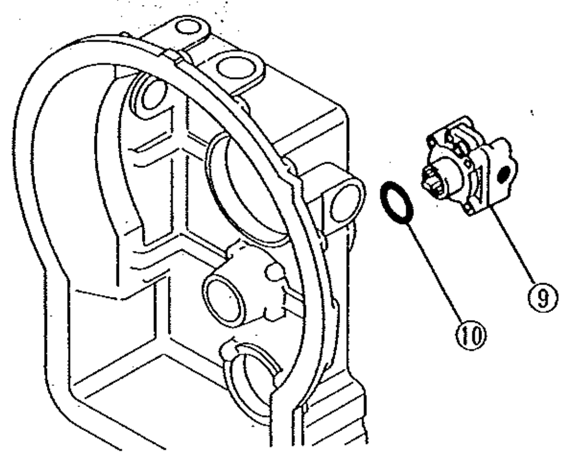
(3) From clutch housing, remove oil filter (5), filter case (6) and gasket (7).



(4) Remove four spring-washered bolts (8) fastening down the pump in place.



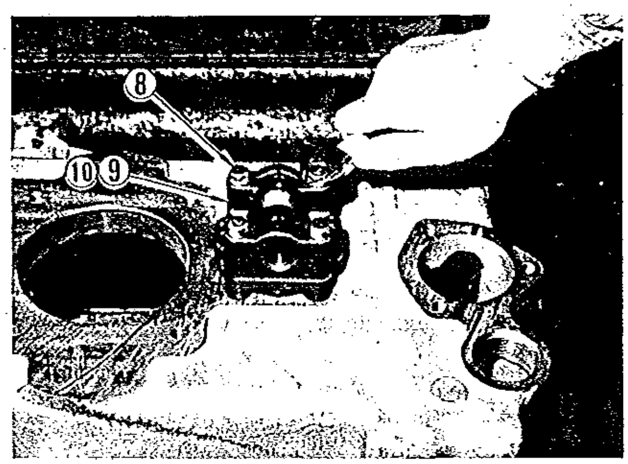
(5) From clutch housing, draw out clutch pump assembly (9) and "O" ring (10).



Clutch filter and oil pump installation

(1) Fit "O" ring (10) to the clutch pump assembly, and fit the assembly to clutch housing.

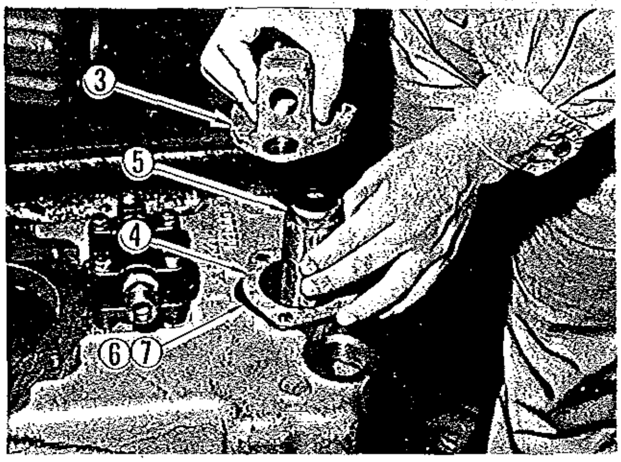
(2) Tighten four spring-washered bolts (8) to secure the clutch pump assembly in place.



(3) Fit gasket (7) to clutch housing, insert filter case (6) and position filter (5) in place.

(4) Fit gasket (4) to case (6), put on cover (3), and secure the cover by tightening three spring-washered bolts.

(5) Reconnect suction pipe (1).



Clutch release shaft and release lever disassembly

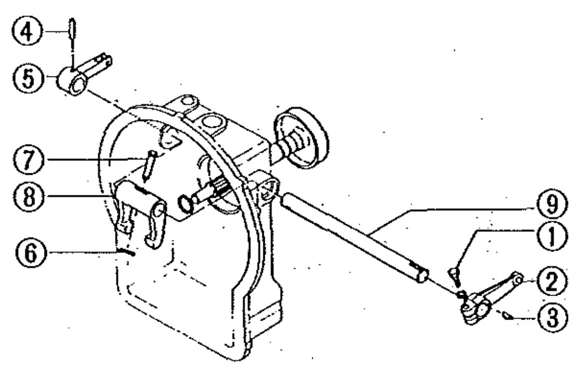
Preparatory step

The following procedure assumes that (a) brake band has been removed and (b) main drive shaft too has been removed.

(1) Remove bolt (1) and its spring washer to loosen the grip of clutch lever (2) upon release shaft (9). Take off lever (2) and recover key (3).

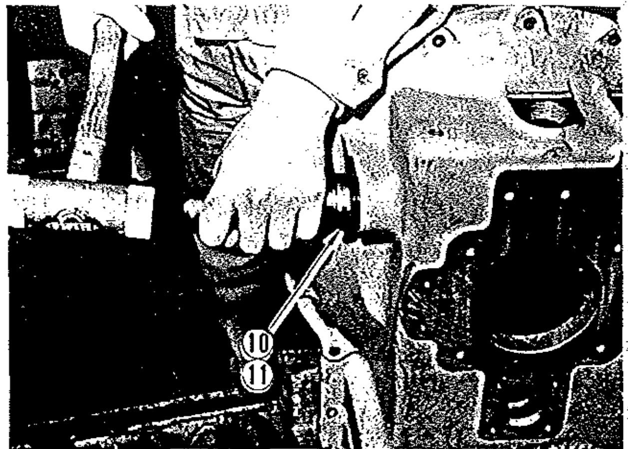
(2) Pull out spring pin (4) and remove lever (5).

(3) Pull out split pin (6) and clevis pin (7). Draw out clutch release shaft (9) while picking up clevis (8).

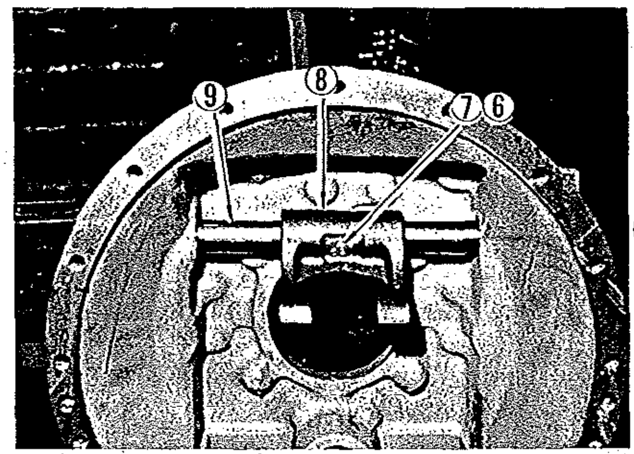


Clutch release shaft and release lever reassembly

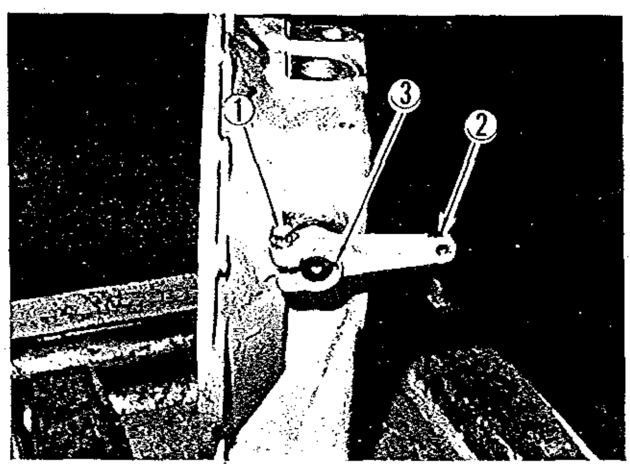
(1) Into each hole, right and left, push needle bearing (10) by driving, and fit oil seal (11), as shown.



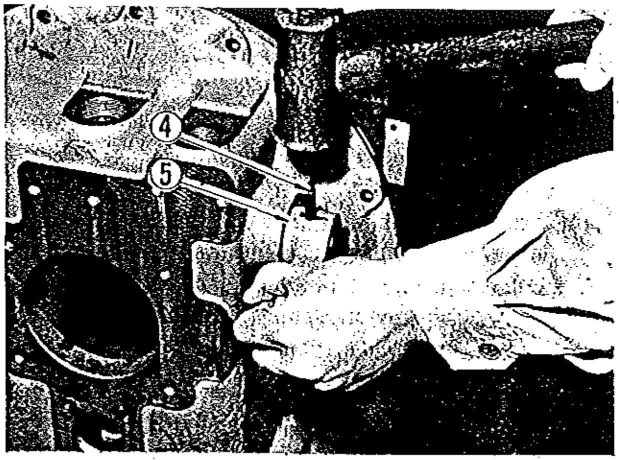
(2) Feed clutch release shaft (9) into clutch housing while holding clevis (8) inside to receive shaft (9). With release shaft (9) held properly by needle bearings, insert clevis pin (7) and lock this pin by using split pin (6).



(3) Drive key (3) into the keyway provided in the clutch release shaft. Fit clutch lever (2) onto the shaft, and tighten bolt (1) to secure the lever positively to the shaft. Be careful not to omit the spring washer for this bolt.



(4) On the other end of the shaft, mount lever (5) and lock it by driving split pin (4).



Subsequent step

The subsequent work is the installation of main drive shaft and brake band.

Clutch cover and pressure plate disassembly

(1) Scribe or otherwise provide match marks across the joint seam between clutch cover (1) and pressure plate (2). Run four guide bolts into the clutch spring holes of clutch cover.

(2) Remove four spring-washered reamer bolts (3) securing strap plates, and take off four washers.

(3) Remove four bolts (5) and their spring washers. Pick out four lock plates (6) from clutch cover (1).

(4) Loosen and remove four nuts (7) by running each off its lever support (15).

(5) Gradually loosen the four guide bolts equally to allow the clutch cover to be pushed away from pressure plate by the force of clutch springs.

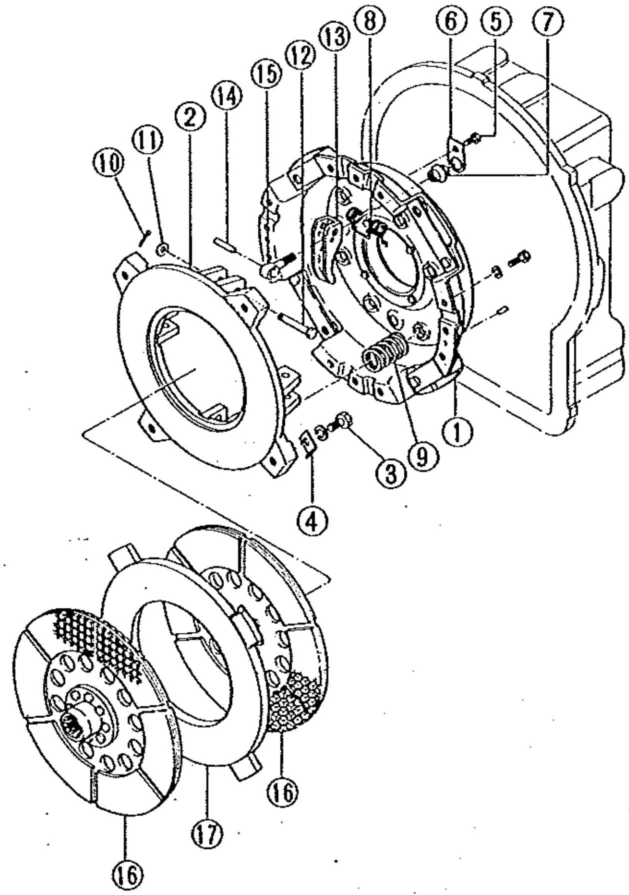
(6) Remove the guide bolts, and take clutch cover (1) off pressure plate (2).

(7) Disengage and remove from the removed clutch cover the return spring (8).

(8) From pressure plate (2), pick out twelve pressure springs (9).

(9) At each release lever (13), remove split pin (10), washer (11) and pin (12), and take out the release lever.

(10) Remove pin (14) and separate lever support (15) from release lever (13).



1-Clutch cover
2-Pressure plate
3-Reamer bolt w/spring washer
4-Washer
5-Bolt w/spring washer
6-Lock plate
7-Nut
8-Return spring
9-Pressure spring
10-Split pin
11-Washer
12-Pin
13-Release lever
14-Pin
15-Lever support
16-Clutch disc assembly
17-Mating plate

Clutch cover and pressure plate reassembly

(1) Combine release levers with lever supports by inserting pin (14) through the pin holes of release lever (13) and lever support (15).

(2) Fit each release lever (13) to the lever boss formed of pressure plate (2); insert pin (12) through the boss and lever; and put on washer (11). Retain and lock the washer (11) by inserting split pin (10). When handling the combination of release lever and support at each boss, be careful not to allow the pin (14) to slip out.

(3) Set new return springs (8) in the clutch cover.

(4) At the spring boss parts formed of pressure plate (2), position twelve pressure springs (9), keeping each spring standing true and square.

(5) Place clutch cover (1) over pressure plate (2), positioning the former by bringing the match marks into alignment.

NOTE

As you put on the clutch cover, check to be sure that the pressure springs fit snugly into their seats formed of the cover.

(6) Insert the four guide bolts, each with a plain washer, into clutch cover (1), and run them into the tapped holes provided in pressure plate (2) at its boss parts.

(7) Tighten the guide bolts gradually and equally to push down the clutch cover.

NOTES

a) While pressing the cover down, be sure to let lever supports (15) come out neatly through the holes provided in spherical seats formed of the clutch cover.

b) Be sure that the return springs (8) are in correct position.

Push down the cover until the strap plates touch the boss parts of pressure plate.

(8) At each strap plate, use a drift pin of about 8 mm (0.32 in.) in diameter to align the hole in strap plate to the tapped hole in pressure plate. Into the aligned hole, insert reamer bolt (3), complete with special washer (4) and plain washer. Tighten the four reamer bolts equally to a torque value between 4 and 6 kg-m (29 and 43 lb-ft).

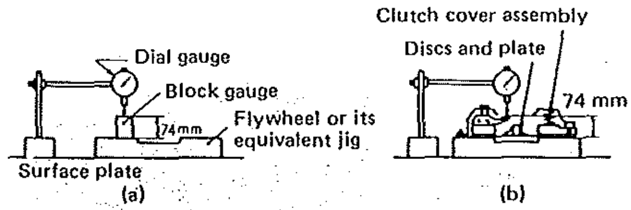
(9) Put nut (7) on each lever support (15), and run down the four nuts (7) until the lever height (defined below) measures about 74 mm (2.91 in.): this is a tentative setting.

Release lever height adjustment

Preparatory step

"Lever height refers to the elevation of the inner tip of release lever above the friction surface of flywheel. The following procedure assumes that the flywheel has been removed from the engine and is now placed on a surface plate.

(1) Rig up a dial gauge, as shown, making sure its supporting fixture is solid and free of any rattle. Place a 74-mm (2.91-in.) block gauge on the flywheel and adjust the dial gauge to read zero mm.



Release lever height adjustment

(2) Stack the two clutch discs and mating plate upon the flywheel, and put on the clutch cover assembly with its pressure plate down. Secure the cover to the flywheel by tightening the twelve bolts, each with a spring washer. Remove the four guide bolts.

(3) Adjust the lever height of each release lever, as follows: Point the dial gauge spindle to the lever tip; read its indication; tighten or loosen the nut (on lever support) until the dial gauge reads zero; and repeat this process on the other three release levers.

Pump the release levers up and down at least 50 times and measure the lever height again. As necessary, adjust the height, making sure the difference between largest reading and smallest reading is not more than 0.7 mm (0.028 in.).

(4) Put on lock plate (6) and secure it to the cover by tightening bolt (5) to 0.6 to 0.8 kg-m (4.3 to 5.8 lb-ft). Be careful not to disturb the nuts.

STEERING CLUTCHES AND BRAKES

Steering clutch and brake assembly removal

Preparatory steps

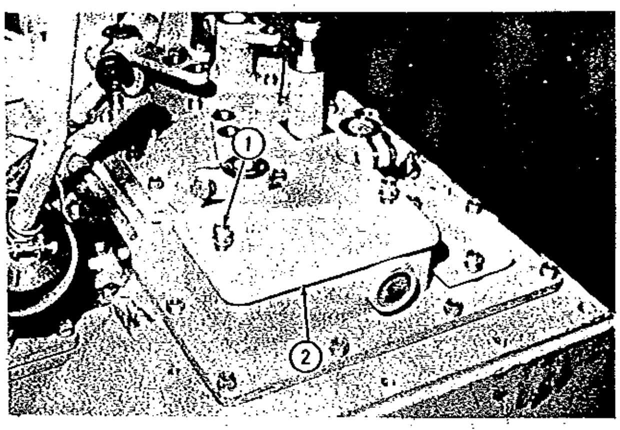
(a) Have the seat and seat bracket dismounted.

(b) Have the brake control rods taken down.

(c) Have the steering clutch control linkage removed.

(d) Take down the battery.

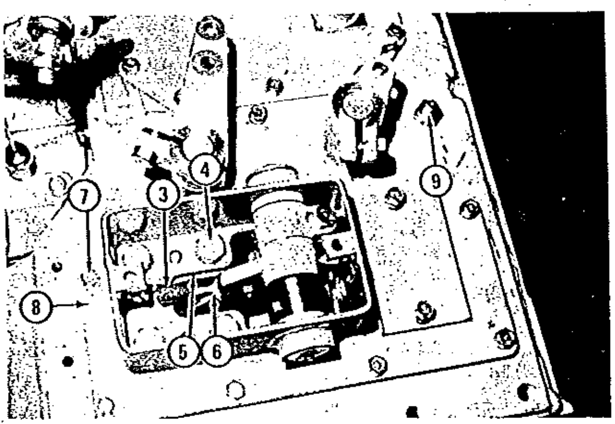
(1) Remove two bolts (1) and take off cover (2).



(2) Remove spring (3) and anchor mounting bolts (4), thus disconnecting anchor (5) and lever (6).

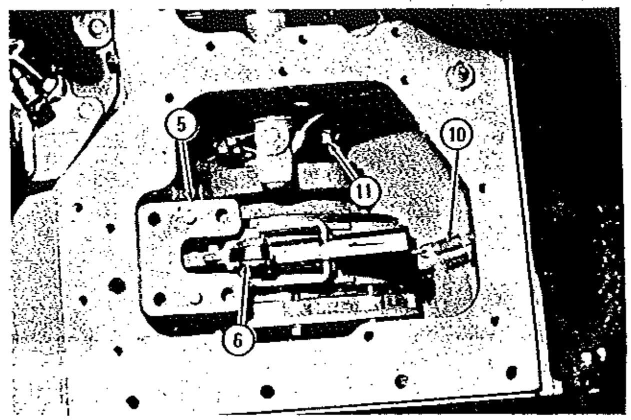
(3) Remove bolts (7) and take off bracket (8).

(4) Remove grease nipple nut (9).

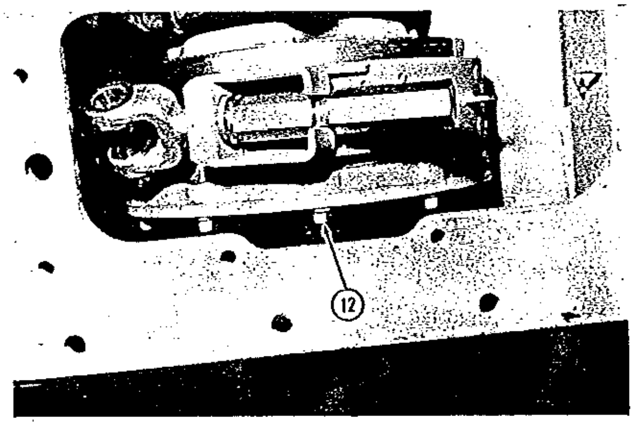


(5) From brake band, remove anchor (5), lever (6) and spring (10).

(6) Remove a total of 8 bolts (11) to sever coupling from clutch shaft.



(7) Remove a total of 20 bolts (12) to undo the flange connection between brake drum and pinion.



NOTE

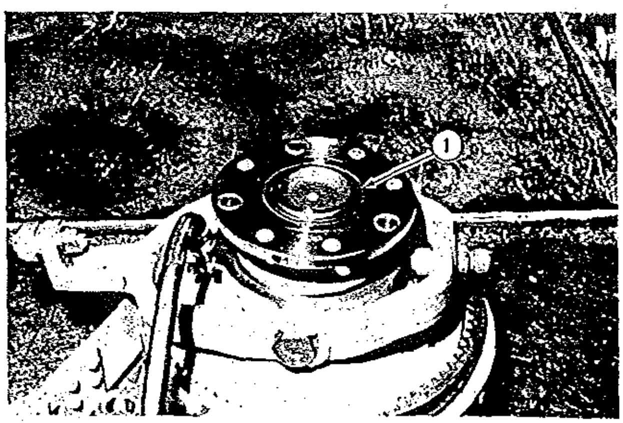
Removal of bolts (11) (12) will be facilitated by pushing the machine to rotate the drive line just a little at a time.

(8) Push clutch shaft toward final drive to undo the spigot fit in the coupling and, under this condition, remove the steering clutch and brake assembly (complete with yoke).

Steering clutch and brake assembly installation

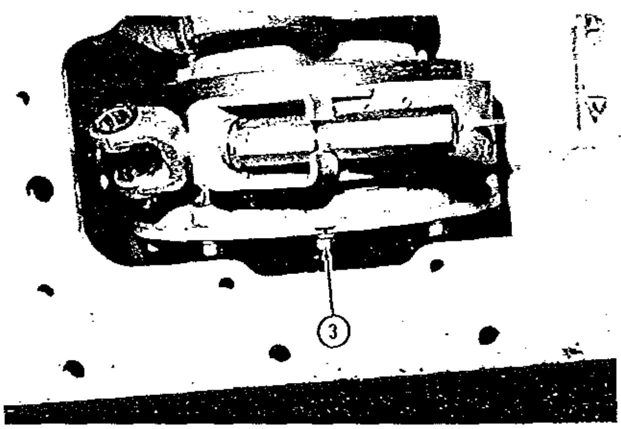
(1) Fit "O" ring (1) to the flange part of clutch shaft. Gently feed the steering clutch and brake assembly into the steering case.

(2) Position the assembly in place, letting the ball stud portion of the yoke enter the boss portion of the case.



(3) Fasten the coupling to clutch shaft by tentatively tightening bolts (2), each with a lock washer.

(4) Secure the pinion flange to brake drum by tightening bolts (3) to 4.3 kg-m (31.1 lb-ft). A spring washer must be used with each bolt (3).



(5) Tighten bolts (2) equally, and bend the tongue of each lock washer.

(6) Install the grease-hose nipple on the case, and secure the nipple by tightening its nut.

(7) Install the coil spring, hooking it to the brake band and to the case.

(8) Connect the lever and anchor to the brake band. Put on the bracket, bolt the anchor, and put on the cover.

Subsequent steps

(a) Installation of the steering clutch control, and clutch adjustment.

(b) Installation of the brake control rods.

(c) Installation of the seat and seat bracket.

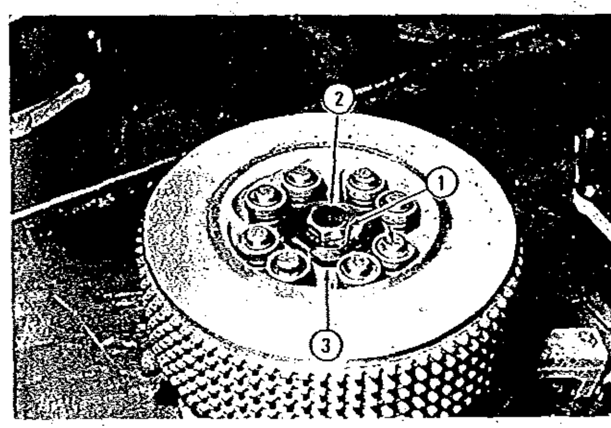
Steering clutch disassembly

Preparatory step

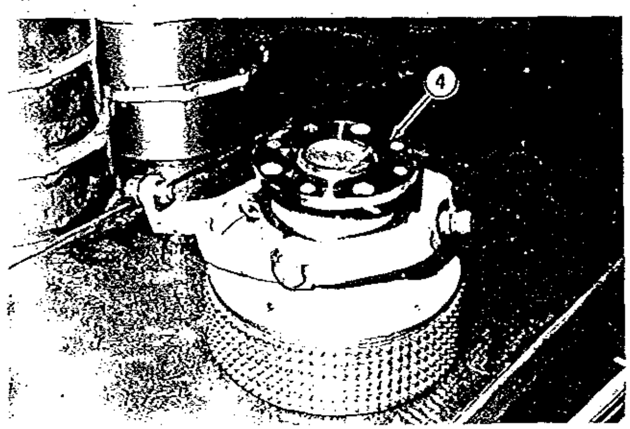
Have the steering clutch severed from the brake drum, and have the below-named tool on hand.

Needed tool	Qt.	Symbol
Steering clutch tool: 58609-01900	1	(A)

(1) Unbend lock washer (1), remove bolt (2) and pick out washer (3).

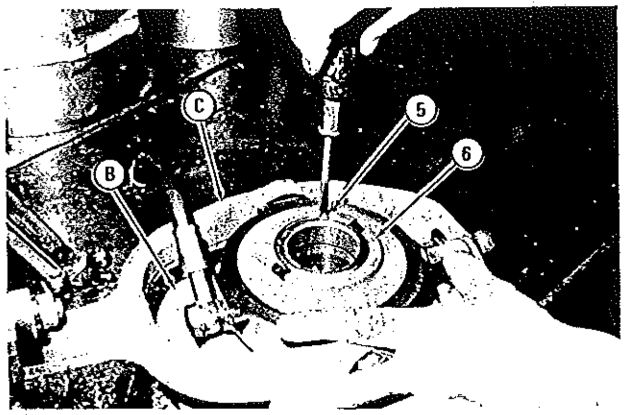


(2) Withdraw clutch shaft (4) from the assembly.



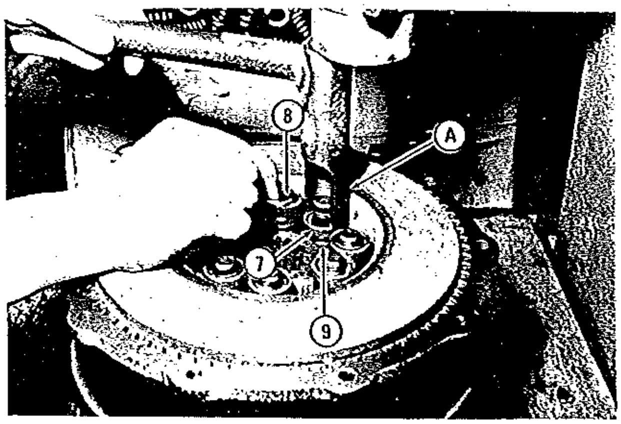
(3) Remove set screw (5), and run out nut (6).

(4) Remove yoke sub-assembly (C) from clutch plate sub-assembly (B).

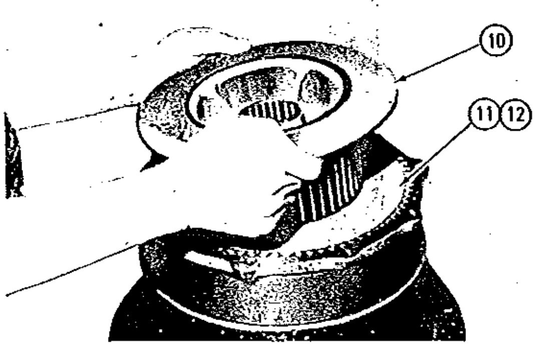


(5) Firmly hold clutch plate sub-assembly. Give a downward push with tool (A) to spring guide (7) to compress the spring and remove retainer (8): repeat this process to remove all retainers (7).

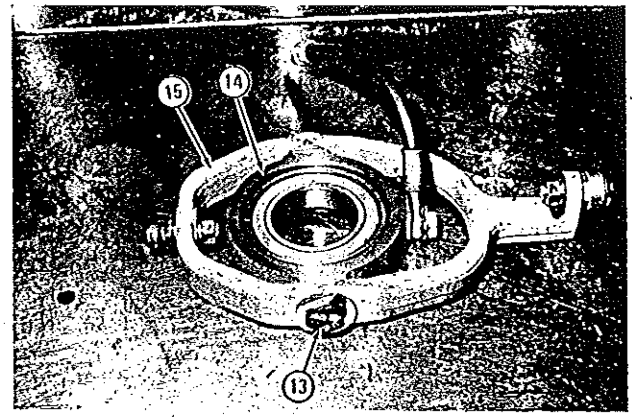
(6) From each guide pin, remove guide (7) and spring (9).



(7) Draw out drum (10), and take out a total of 12 plates (11) (12).



(8) Disassemble the yoke sub-assembly into bolts (13), shifter (14) and yoke (15).

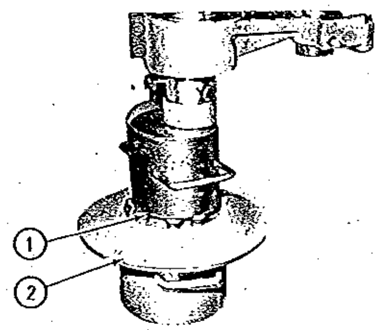


Steering clutch reassembly

Needed tool	Qt.	Symbol
Steering clutch tool: 58609-01900	1	(A)

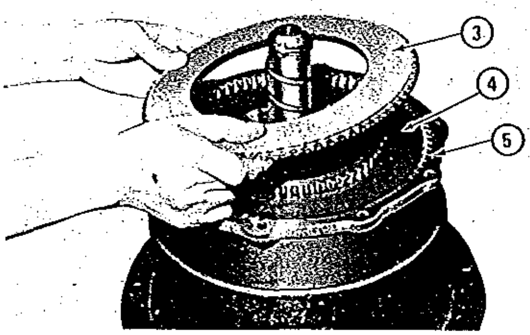
The reassembling procedure is the reverse of the disassembling procedure, but some of the individual steps must be carried out as follows:

(a) Force guide pins (1) into plate (2).



(b) When inserting the two kinds plates into drum (5), be sure to mate the toothed faces of plate (3) and plate (4).

(c) Be sure to use tool (A) when fitting the retainer to each guide pin. Compress the spring with this tool and fit the retainer.



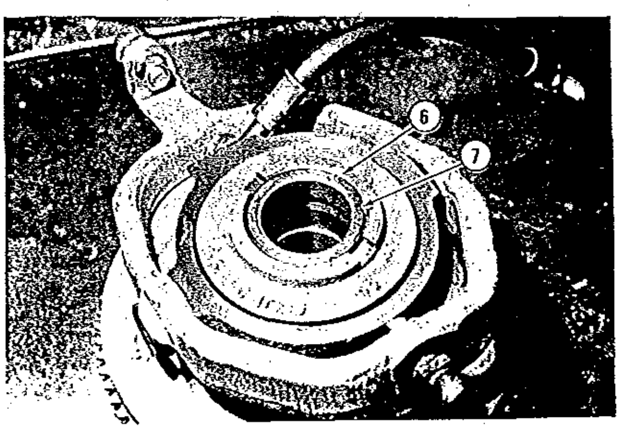
(d) After running in and tightening nut (6) against plate (2), drill and tap a hole anew for the set screw.

Use 5-mm (0.20-in.) drill and make a 14-mm (0.55-in.) deep hole.

Thread with M6 X 1 tap to 10-mm (0.39-in.) depth.

(e) After tightening the set screw to lock the nut, lock the screw by punching at two places.

(f) The tightening torque for the bolts securing the flanged portion of shaft is 17 ± 1.7 kg-m (123 ± 12.3 lb-ft).



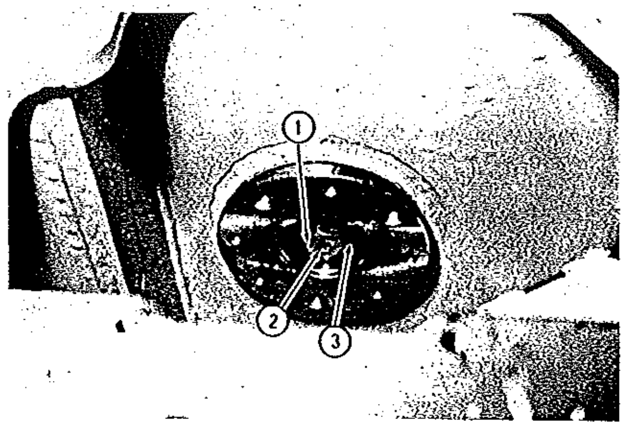
Bevel gear and shaft disassembly

Preparatory step

Have the steering clutch and brake assemblies, right and left, removed in advance, and have the below-named tool on hand.

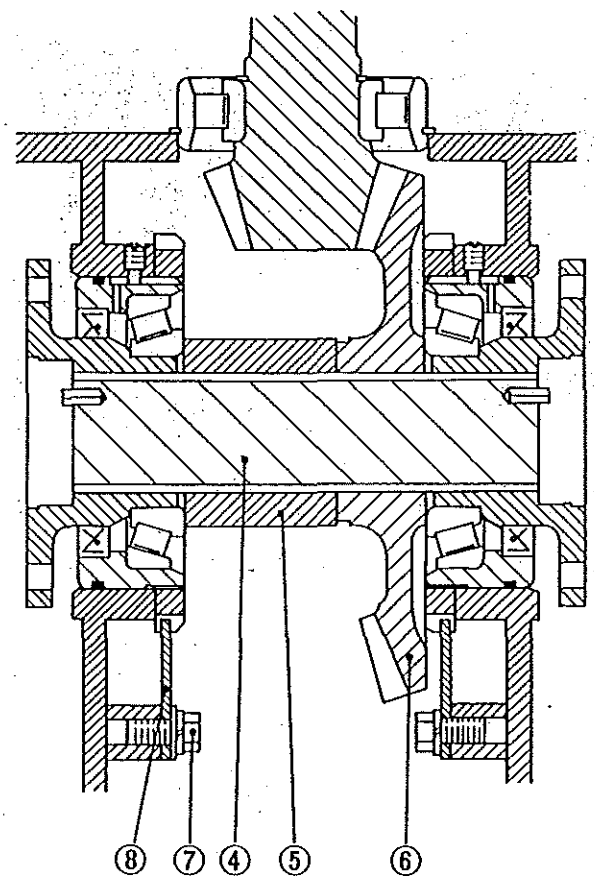
Needed tool	Qt.	Symbol
Wrench: 58809-10200	1	(A)

(1) Unbend lock washer (1). Remove bolt (2) and washer (3). Repeat this at the other end of bevel gear shaft.

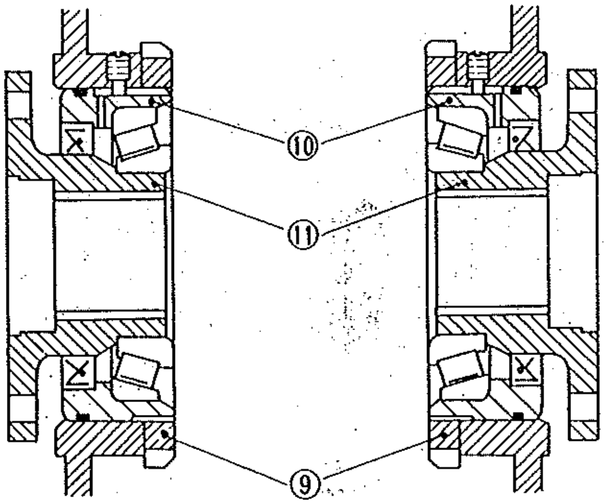


(2) Force out bevel gear shaft (4) by driving with a soft-metal hammer while taking out spacer (5) and bevel gear (6).

(3) Remove bolts (7), each securing locking washer (8). Take out washers (8).



(4) Using wrench (A), loosen nuts (9). Remove nuts (9), bearing cages (10) and coupling (11).

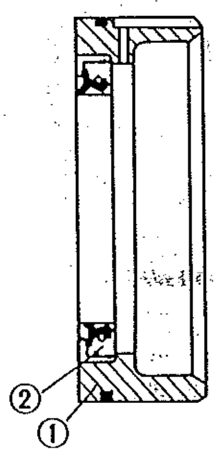


Bevel gear and shaft reassembly

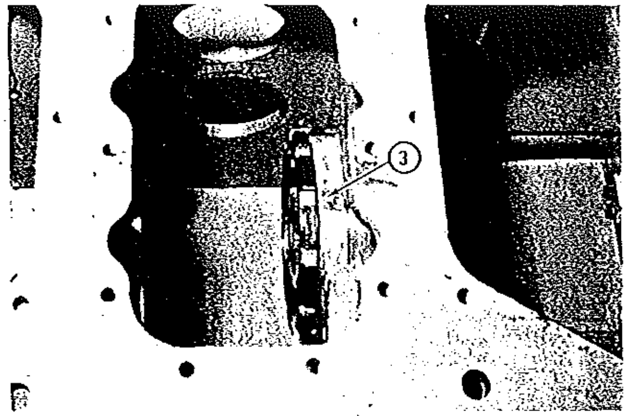
Needed tool	Qt.	Symbol
Wrench: 58809-10200	1	(A)

Reverse the disassembly procedure, and carry out the following instructions:

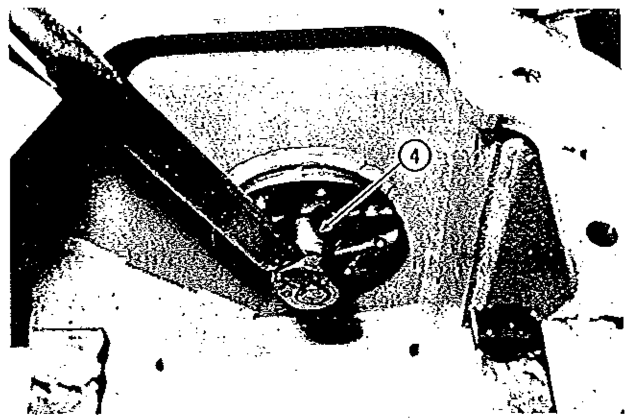
(a) Oil seal (2) is to be pressed into cage (1). Be sure to position the seal as shown, and to fill up the lip space with grease, before fitting it to the cage.



(b) The set screw (3) on each bearing cage must be locked in place by punching at two places.

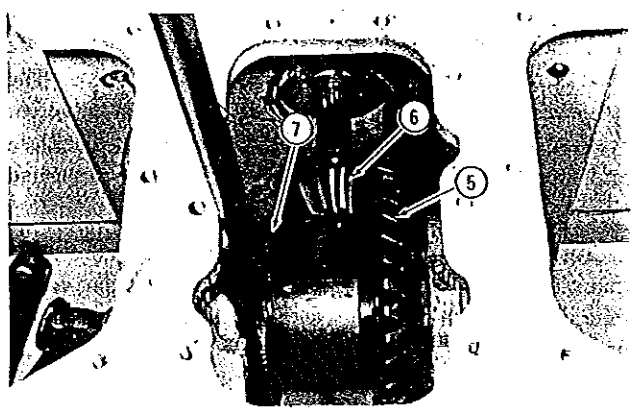


(c) When tightening bolt (4) at each end face of bevel gear shaft, torque it to anywhere between 16 and 19 kg-m (115 and 134 lb-ft).

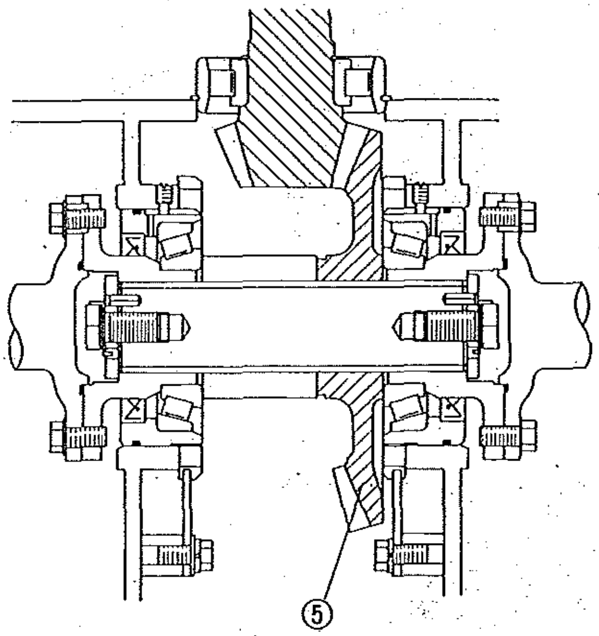


(d) Backlash between bevel gear (5) and pinion (6) is meant to be adjusted by repositioning nuts (7), right and left, in place. This backlash is prescribed to be between 0.15 and 0.20 mm (0.0059 and 0.0079 in.). After adjusting, check to be sure that the tooth contact pattern is satisfactory.

(e) Starting torque is specified for the steering clutch shaft. The specification is 0.72 ~ 0.88 kg-m (5.21 ~ 6.37 lb-ft), and is to be met by making the two nuts (7) more or less tight.



(f) In the direct-drive machines, bevel gear (5) comes on the right, as shown. Experience tells that this requirement is often neglected out of carelessness.



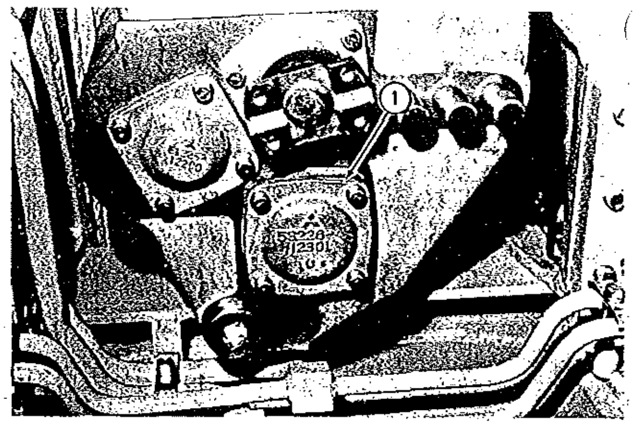
Bevel gear-to-pinion tooth contact adjustment

It is highly essential that bevel gear and bevel pinion should be in a properly meshed condition. Whether the mesh is proper or not can be told from contact patterns to be produced by rolling in the usual manner. For this adjustment, two displacements are involved: displacement of bevel pinion on the one hand and displacement of gear on the other, each along its own axis.

To displace the pinion, increase or decrease the shim (1) between bearing cage and transmission case. To displace the gear, reposition the two adjusting nuts, right and left, on the bearing cages.

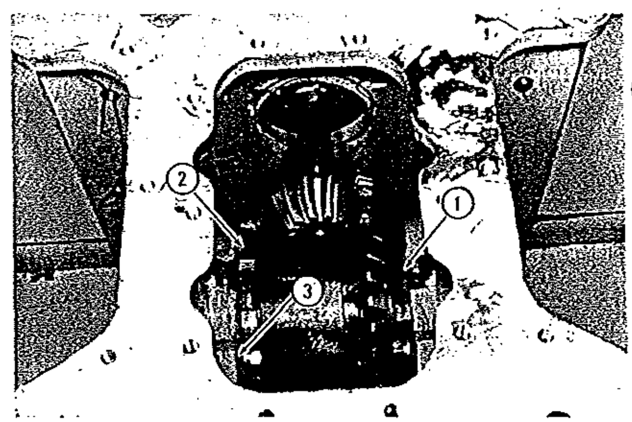
Both backlash and tooth contact pattern can be varied for adjustment by these two displacements. The way the backlash and pattern change for a displacement of pinion or gear, or both, is due mainly to the tolerances within which the related parts are machined during manufacture. Thus, a set of general rules cannot be quantitatively stated for these two adjustments. The procedure is the same for all cases, but a trial-and-error method must be used to obtain the specified backlash and tooth contact pattern in the manner to be described below.

The pinion and gear are selectively combined during manufacture; the two form a set. If either the gear or the pinion has to be replaced, both must be replaced by a new set.

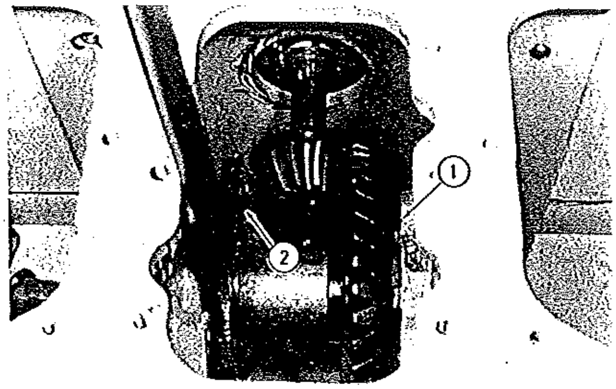


Bevel gear shaft bearing preload adjustment

Backlash adjustment is meaningful only where the two bearings holding the bevel gear shaft are properly tight to produce the specified starting torque – 0.72 ~ 0.88 kg-m (5.21 ~ 6.37 lb-ft) – on steering clutch shaft. Before starting to adjust the backlash, locate the bevel gear tentatively to permit checking, with right-hand nut (1) held steady by means of lock plate (3) and left-hand nut (2) made tentatively tight, both nuts being settled in place.



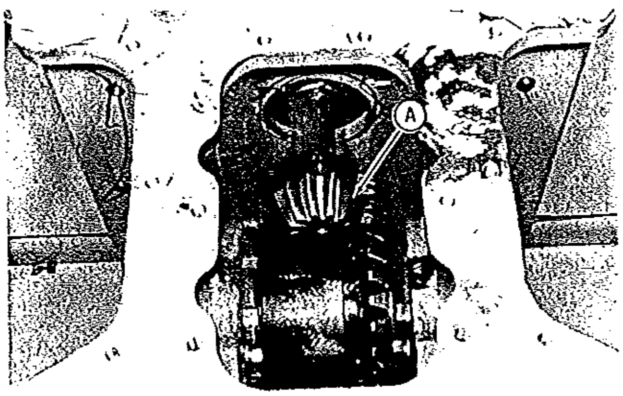
Depending on the starting torque, tighten or loosen the two nuts equally to obtain a torque between 0.72 and 0.88 kg-m (5.21 and 6.37 lb-ft). The torque does not change if one nut is loosened by a certain amount and the other nut is tightened by the same amount. This connection is dealt with further in the section for final drive.



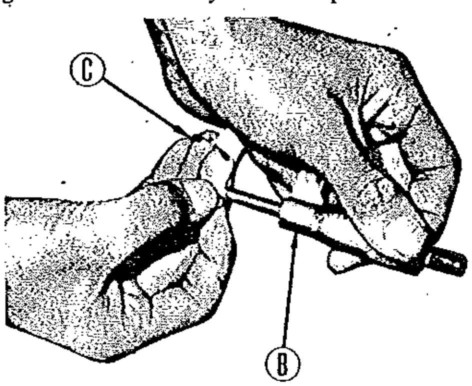
Method of backlash adjustment

Insert a fuse stock piece in the mesh (A) between pinion and gear, and roll the two in the usual manner to flatten the stock piece. Measure the flattened piece (C) with a micrometer (B). Read the backlash in this way at four places equiangularly apart.

Backlash specification	0.15 ~ 0.20 mm (0.0059 ~ 0.0079 in.)



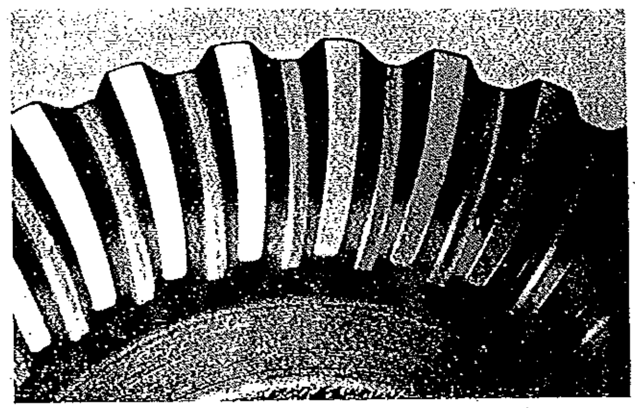
To bring the backlash into this range, loosen one nut and tighten the other by the same amount (so that the bearing preload shall not be disturbed) to displace the gear toward or away from the pinion.



Method of tooth contact adjustment

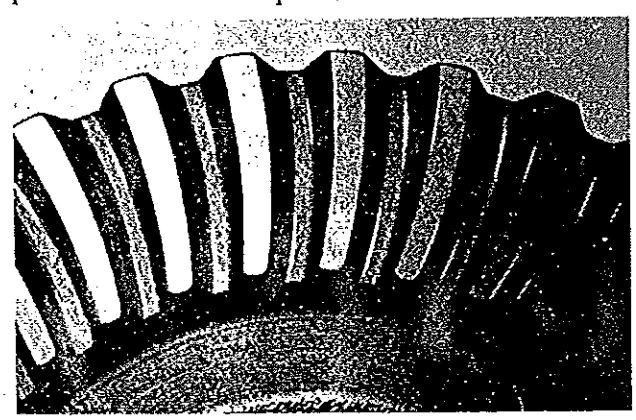
Be sure that the shim (for bevel pinion) is the same as that which was removed in disassembly. Of course, a new shim has to be used in reassembly if a new set of pinion and gear is to be installed. The following method assumes that the pinion and gear have been installed, with a proper backlash produced by the foregoing method.

Bear in mind that a proper backlash adjustment usually brings the pinion and gear into a properly meshed condition. Using a paste of red lead or prussian blue, roll contact patterns according to the standard practice. The mesh is correct and proper if the contact pattern starts faintly from the tooth toe and extends toward the heel, covering about 30% of tooth length. This is a no-load pattern; in operation, the pattern will shift under load to distribute the stress properly for quiet running and long tooth life.



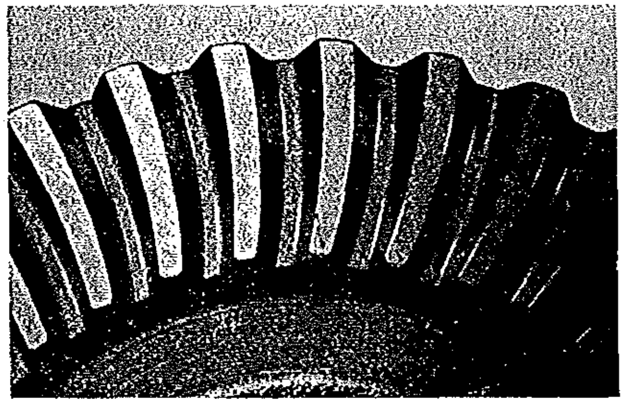
Example A Correct no-load contact pattern

Example B shows a contact pattern suggesting that pinion is backed away too much from bevel gear. The remedy is to increase the thickness of the shim by an amount necessary to relocate the contact pattern to the position shown in Example A.



Example B Incorrect contact pattern due to pinion backed away too much

Example C means that pinion is advanced too much toward bevel gear. In this case, the shim thickness must be reduced to back away the pinion.



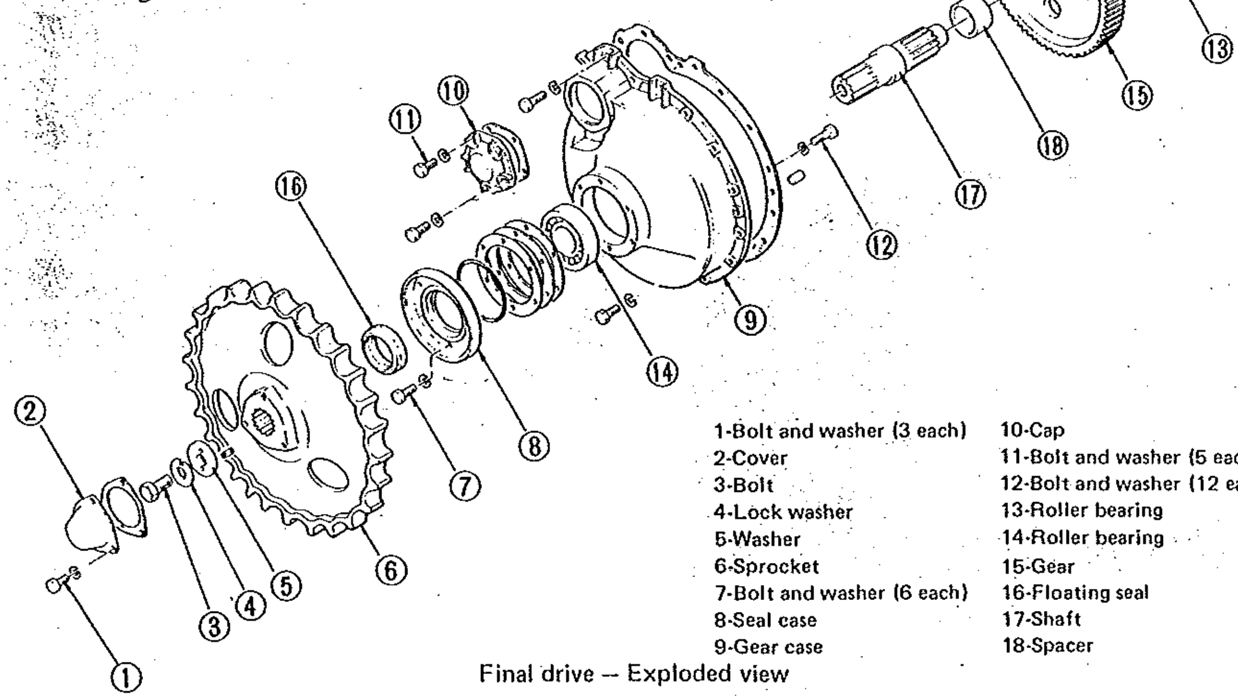
Example C Incorrect contact pattern due to pinion advanced too much

Repositioning the pinion in order to obtain the contact pattern approximating that of Example A necessarily disturbs the backlash adjustment. For this reason, backlash and tooth contact must be adjusted alternately more than once until both become satisfactory.

FINAL DRIVE

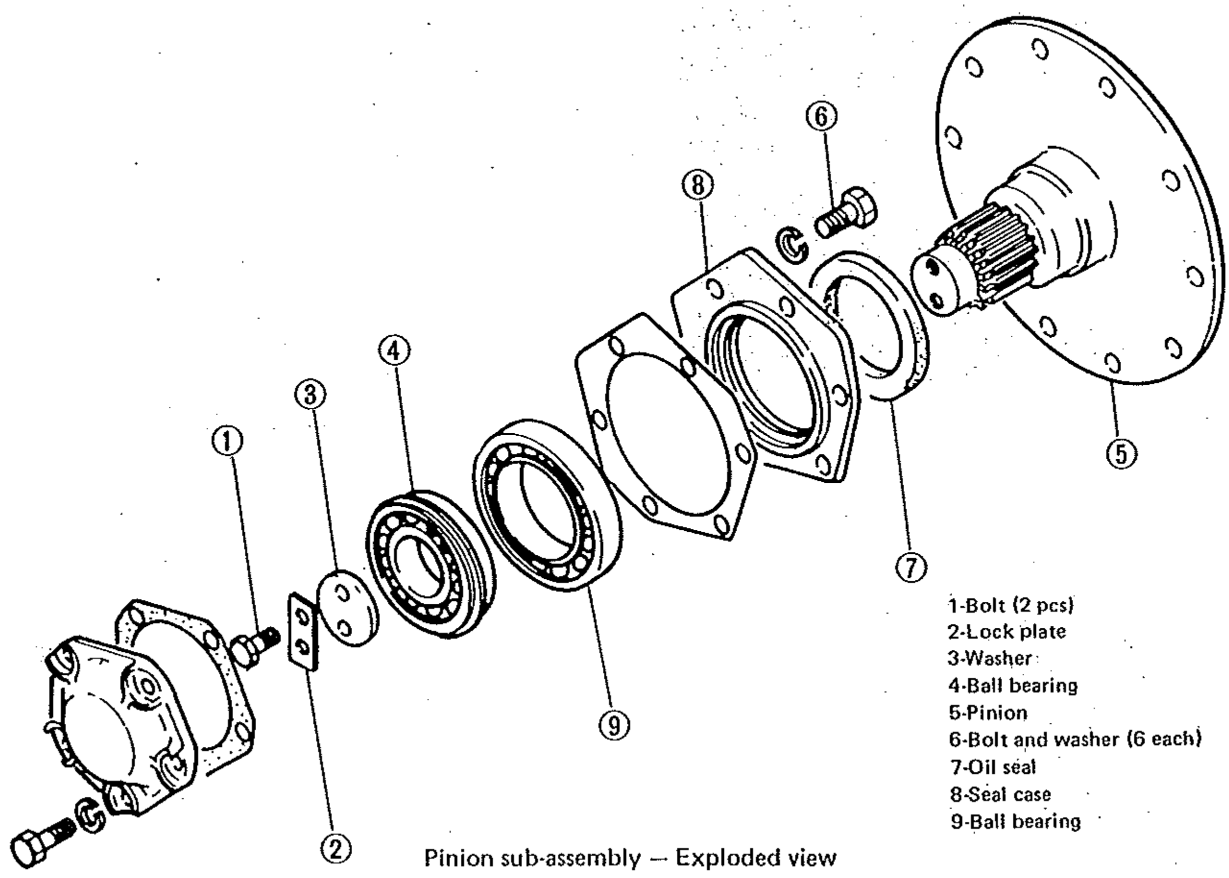
Removal (disassembly)

Two exploded views are sufficiently detailed to illustrate the procedure to be followed in disassembling and reassembling the final drive.



1-Bolt and washer (3 each)
2-Cover
3-Bolt
4-Lock washer
5-Washer
6-Sprocket
7-Bolt and washer (6 each)
8-Seal case
9-Gear case
10-Cap
11-Bolt and washer (5 each)
12-Bolt and washer (12 each)
13-Roller bearing
14-Roller bearing
15-Gear
16-Floating seal
17-Shaft
18-Spacer

Final drive – Exploded view



1-Bolt (2 pcs)
2-Lock plate
3-Washer
4-Ball bearing
5-Pinion
6-Bolt and washer (6 each)
7-Oil seal
8-Seal case
9-Ball bearing

Pinion sub-assembly – Exploded view

Preparatory steps

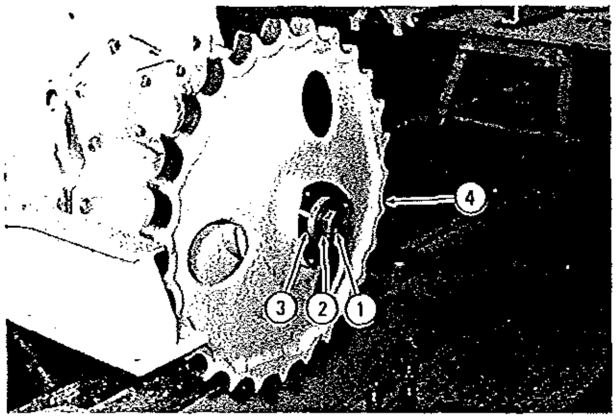
(a) Have the two track chains broken at the master pin.

(b) Drain the final drive case.

(c) Have the steering clutch drums removed.

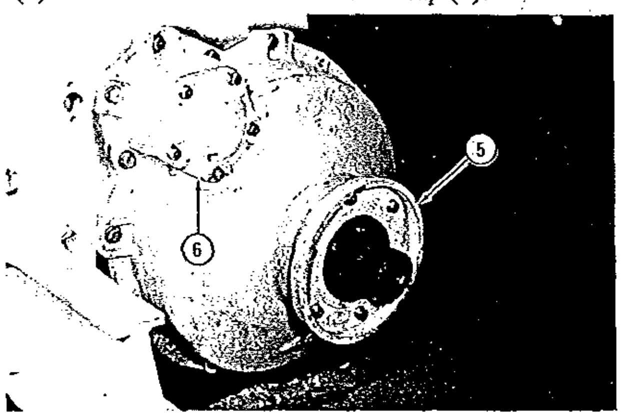
(1) Remove three bolts securing the cover, and pull the cover off.

(2) Remove bolt (1). Take out lock washer (2) and washer (3). Draw sprocket (4) off the shaft.

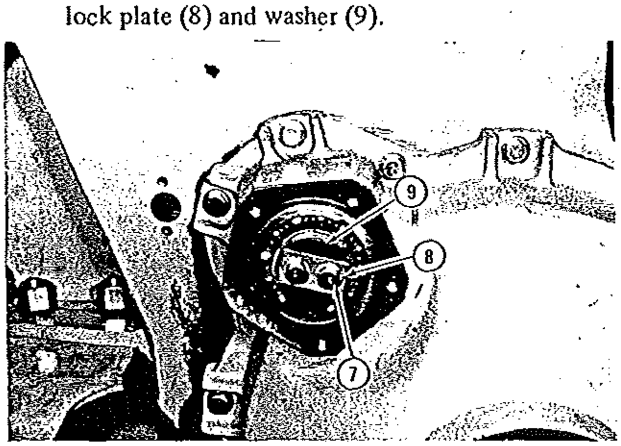


(3) Remove six bolts and take off seal case (5).

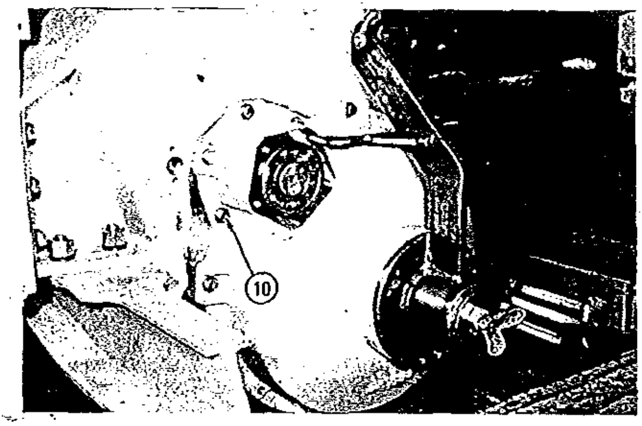
(4) Remove five bolts and take off cap (6).



(5) From the end of pinion, remove two bolts (7), lock plate (8) and washer (9).



(6) Install the lifting tool on the gear case. Remove twelve bolts (10) securing the gear case, and take down the case together with shaft sub-assembly in suspended state.

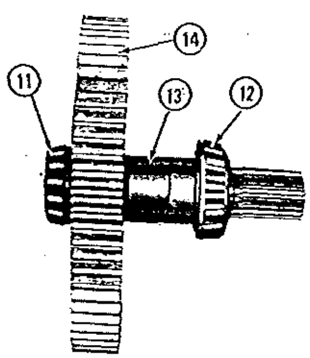


WARNING

As the final drive gear case comes off in suspended state, the gear shaft parts from the clutch case. Unless the lifting tool or its equivalent is used to hold the shaft to the gear case, the shaft sub-assembly might slip off and drop to the floor, resulting in possible personal injury. Use of the lifting tool or its equivalent is mandatory.

(7) Draw out the shaft sub-assembly from the removed gear case.

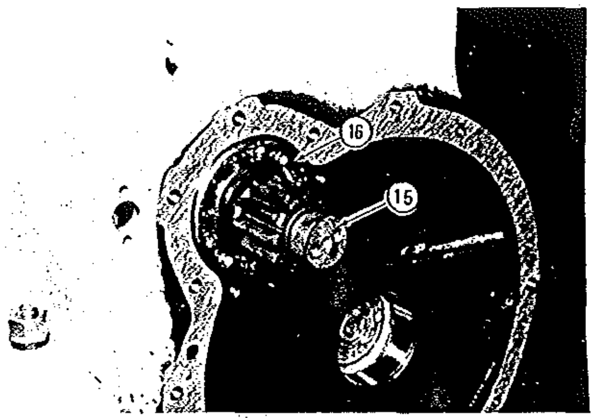
(8) Pull roller-bearing inner races (11) (12) off the shaft, and remove spacer (13) and gear (14).



(9) To remove pinion (15), drive it into the clutch case. For this driving, use a soft-metal hammer.

(10) Detach the seal case, which is secured by six bolts, from the clutch case.

(11) Remove ball bearing (16) from the clutch case.



Installation (reassembly)

(1) Install the ball bearing for pinion in the clutch case, and attach the seal case.

(2) Mount the gear and spacer on the shaft, and drive the two bearing inner races onto the shaft.

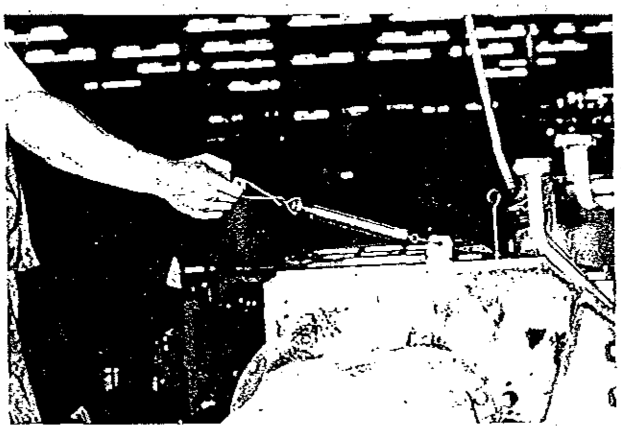
(3) Insert the shaft sub-assembly into the final drive gear case; install the lifting tool on the gear case; and attach it in suspended state to the clutch case.

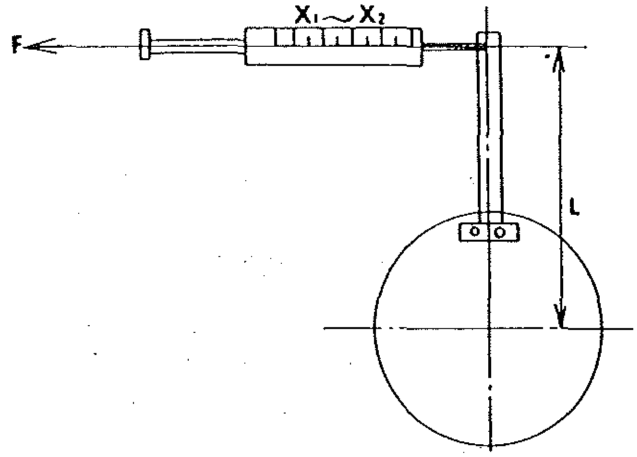
(4) Insert the pinion into the bearing already in place in the clutch case, and install the other bearing on the pinion by driving it onto the pinion.

(5) Fit 1.8-mm (0.071-in.) (standard) thick shim to the gear case, and secure the seal case to the gear case, with the shim in between.

(6) Check the bearing preload on pinion. This preload in terms of starting torque is specified.

Pinion starting torque	0.29 ~ 0.37 kg-m (2.10 ~ 2.68 lb-ft)





Attach an arm to the pinion and hook a spring balance to the arm, as shown. Read the force needed to turn the pinion, and compute the torque on the basis of the scale reading and the length of the arm:

T [kg-m (lb-ft)] = F [kg (lb)] X L [m (ft)]

where L is the radial length, and F is the scale reading.

Examples:

Where L = 0.25 m (0.82 ft), X_1 = 1.16 kg (2.56 lb) and X_2 = 1.48 kg (3.26 lb)

T = 0.29 kg-m (2.10 lb-ft)
= 0.25 m (0.82 ft) X 1.16 kg (2.56 lb) (X_1)

T = 0.37 kg-m (2.68 lb-ft)
= 0.25 m (0.82 ft) X 1.48 kg (3.26 lb)
(L) (X_2)

It will be seen that the starting torque is satisfactory, that is, the bearings are properly preloaded if the force needed to start turning the pinion is anywhere between 1.16 and 1.48 kg (2.56 and 3.26 lb).

(7) After noting that the roller bearings are properly preloaded, mount the sprocket wheel on the shaft.

Subsequent steps

The subsequent jobs are: (a) installation of steering clutch drums, (b) refilling the final drive case, and (c) connection of two track chains.

UNDERCARRIAGE

How to slacken the track chain

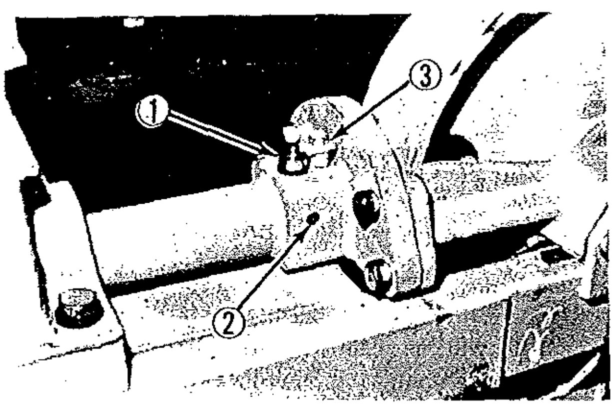
The first step is to clean the idler, removing pebbly muck and dirt, to make sure the front idler is capable of yielding backward. Clean and clear the vent hole provided in the grease cylinder.

⚠ WARNING

Never try to peep into the vent hole and grease valve of the grease cylinder! Be sure that front idler is not pushing back on grease cylinder. Remember, a very high pressure could develop in the grease cylinder.

(1) Very slowly, loosen fill valve (1) by turning it leftwise; this will cause grease to come out of vent hole (2) and, if front idler is pushing backward, the idler will move back because of the relieved pressure.

(2) If there is evidence of pressure remaining high in the grease cylinder, loosen fill valve (1) all the way until it touches the stopper (3). This should relieve the pressure, allowing the track to slacken.

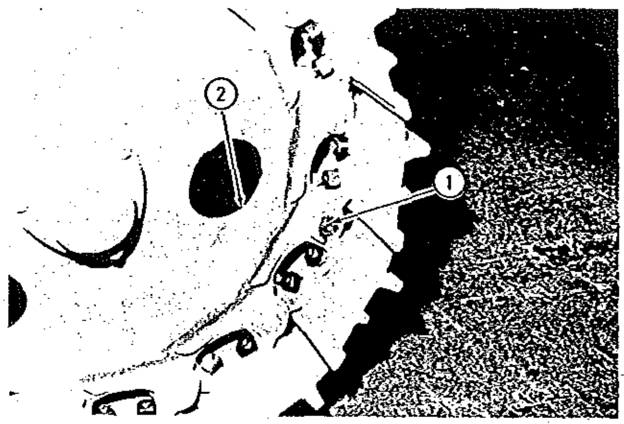


(3) If the track remains tensioned tight, start up the engine and drive the machine back and forth in a jogging manner. This should force the track into slackened state.

(4) Again, if the track still remains tight, chock a piece of wood into between sprocket wheel and track and drive the machine backward just a little. This will pull back front idler to force the grease to come out of vent hole.

Track removal

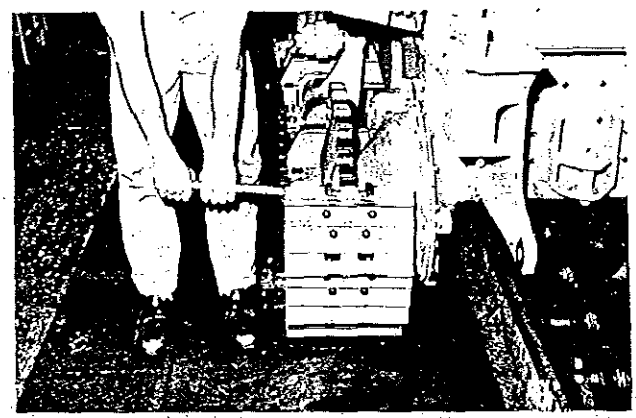
(1) Drive the machine until master pin (1) comes to the rear part of sprocket wheel (2).



(2) Slacken the track as described above.

(3) Using the guide bar, drive the master pin out. Pressing the pin out with a hydraulic ram is preferred, however.

(4) Disconnect the shoe links. Insert a rod into the links and, while holding the rod, roll the machine ahead to spread the tack out on the floor.



Track installation

Assuming that the two tracks are laid out parallel on the floor, with the machine standing astride on these track chains, proceed as follows:

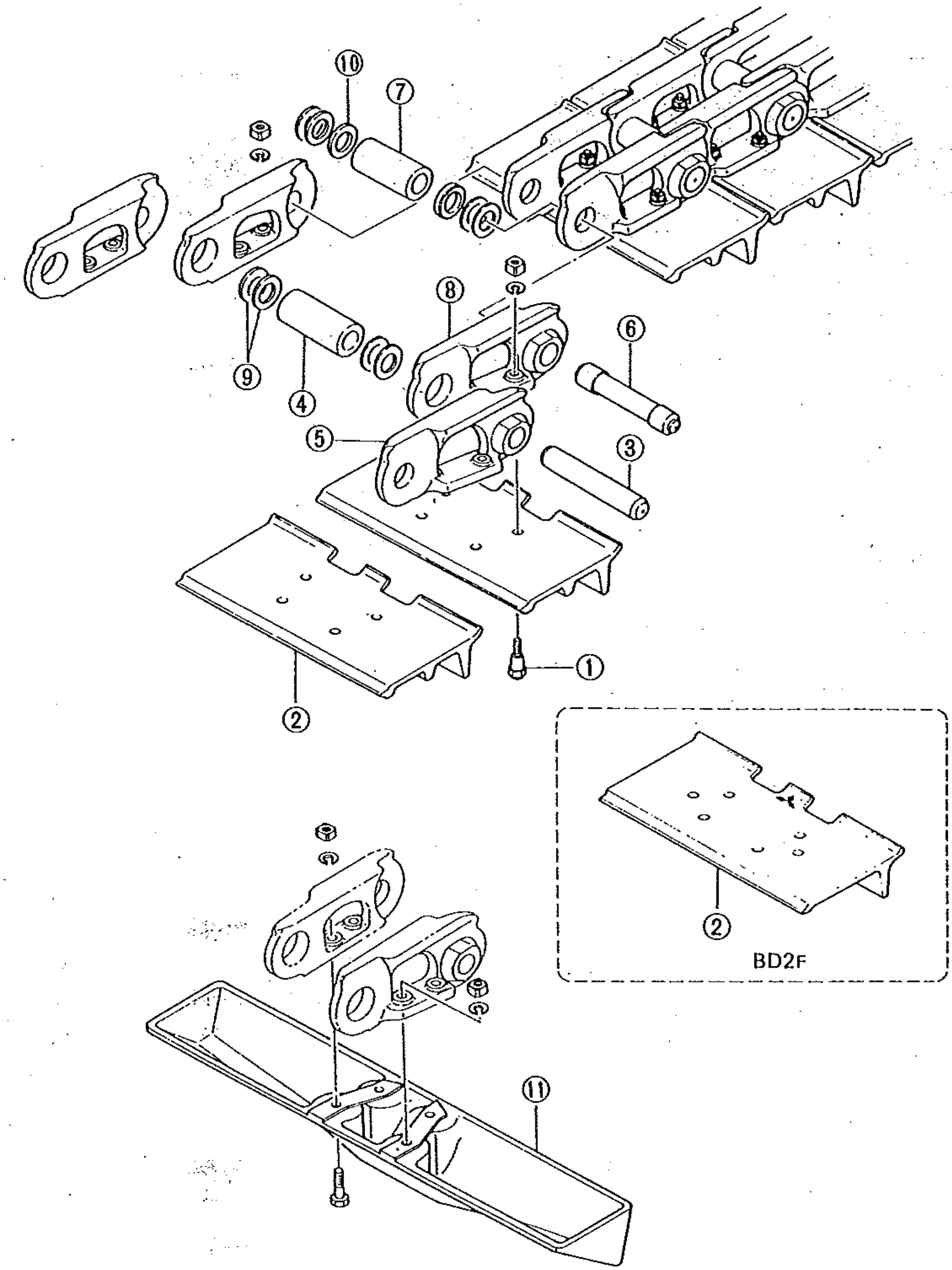
(1) Drive the machine back to the rear ends of tracks.

(2) Insert a bar into the rearmost links and, while holding the rear end firmly against sprocket wheel, roll the machine ahead to carry this end over and along until it comes to the front over front idler.

(3) Reconnect the two ends of the track by driving in the master pin. Repeat the process on the other track, and tension the tracks.

Track disassembly

"Track disassembly" here means no more than disconnecting one pair of links from another.



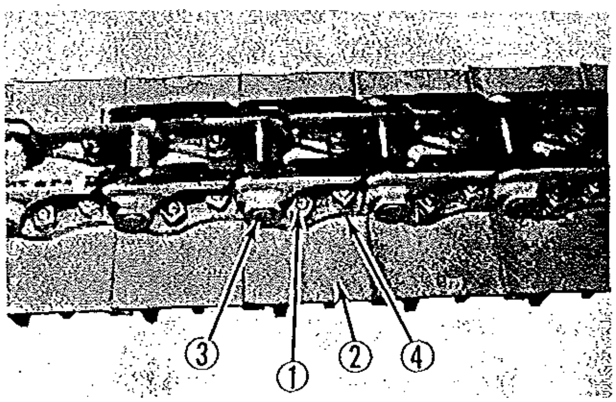
1-Bolt, nut and washer (4 each)
2-Shoe
3-Pin
4-Bushing
5-Link
6-Master pin
7-Master bushing
8-Master link
9-Seal washer
10-Spacer
11-Swamp shoe

Track segment — Exploded view

(1) Remove four bolts (1) and take off shoe (2).

(2) Drive pin (3) out of links (4).

(3) Remove bushing, links, seals, etc.



Track reassembly

(1) Fit seal washers and bushing to the two links. Drive pin into the links.

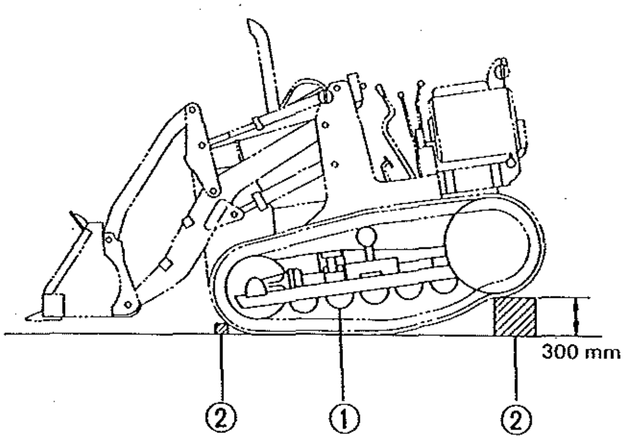
(2) Bolt the shoe to the links.

Track roller removal

Preparatory step

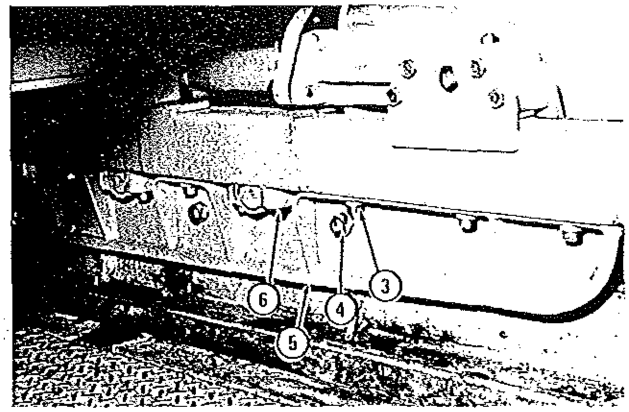
Have the two track chains slackened, and prepare two wood blocks of 300-mm (11-3/4-in.) square section and two small wood blocks for chocking.

(1) Place the two blocks (2) behind the sprockets in a chocking manner, and ride onto these blocks until track rollers (1) float up and away from the track, as shown. Chock the tracks at front end with blocks (2), and apply brake lock.



(2) Take down track roller guard (5) by removing 16 bolts (3) and 4 bolts (4).

(3) Remove four bolts (6) from underside of frame and take down the track roller assembly. Repeat this process at each roller.



Track roller installation

(1) With the machine held in the condition illustrated above, fit each track roller assembly to frame and secure it by bolting.

(2) After installing all track rollers, bolt the guard to the frame, and drive the machine forward out of its chocked condition.

Subsequent step

Tightening the track adjustment.

Track roller disassembly

Preparatory step

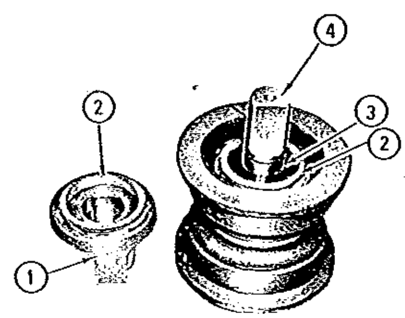
Remove the plug from the end face of the shaft to drain out oil. Be sure that the roller is completely empty of oil, and proceed as follows:

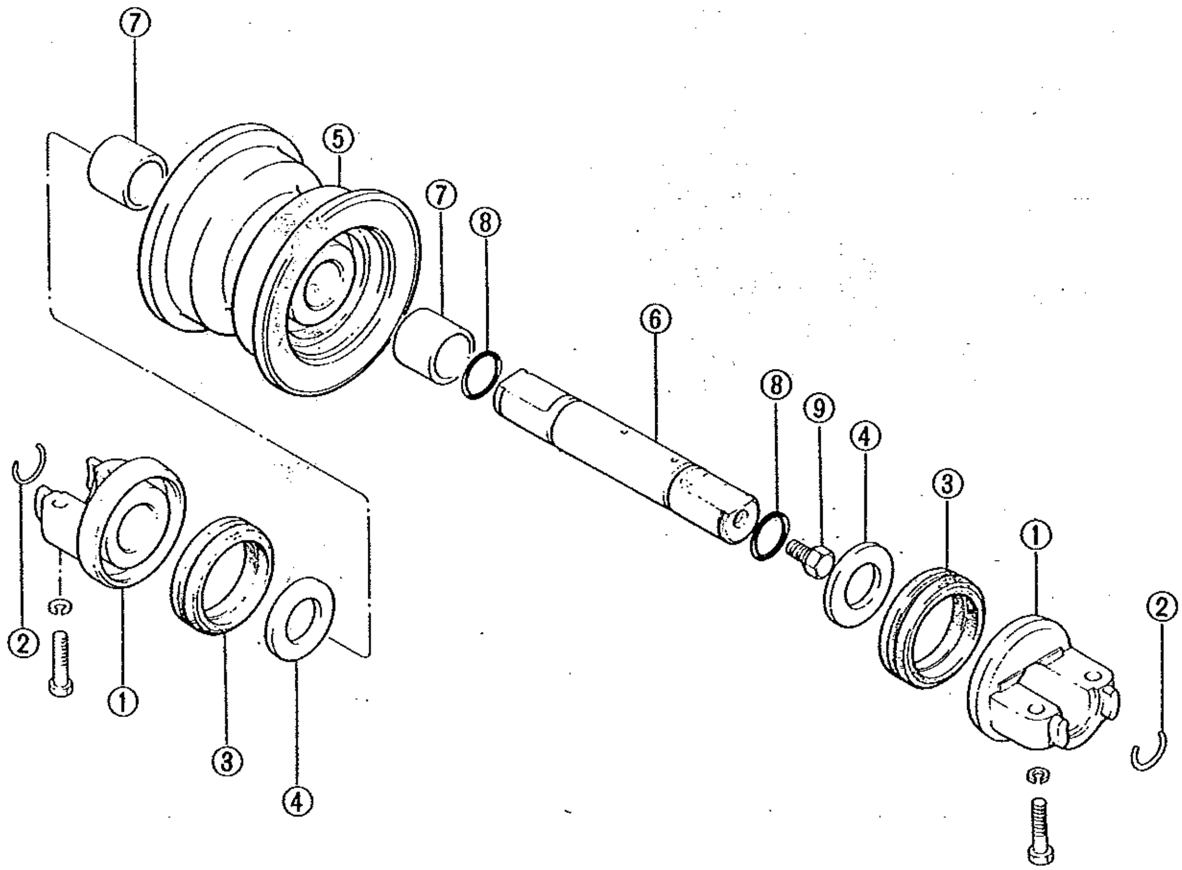
(1) Remove two snap rings, and take off two collars (1).

(2) From collar and roller, pick out floating seal rings (2).

(3) Take out thrust washers (3) and shaft (4).

(4) Remove bushings from the bore of roller.





1-Collar (2 pcs)	4-Thrust washers (2 pcs)	7-Bushing (2 pcs)
2-Snap ring (2 pcs)	5-Flanged roller	8-"O" ring (2 pcs)
3-Floating seal (2 sets)	6-Shaft	9-Plug

Track roller — Exploded view

Track roller reassembly

Tool needed	
Adaptor	58809-15100

(1) Install the two bushings in the bore of flanged roller by driving them in with a soft-metal hammer.

(2) Insert the shaft into the roller.

(3) Fit floating seals and thrust washers to the roller.

⚠ CAUTIONS

a) A properly sized rod or the special installing tool must be used to fit each set of floating seals to the roller. Caution must be exercised not to damage the seals and "O" rings.

b) Never use a screwdriver to fit the seals and washers.

(4) Using a lint-free cloth or a brush and the washing fluid, clean the surface of the steel ring, which is a part of the floating seal set. Make sure that this surface is free of any grime.

(5) Fit the two collars and retain them in place by installing snap rings.

(6) Using the above-named adaptor, charge 60 cc (3.66 cu in.) of oil into the track roller.

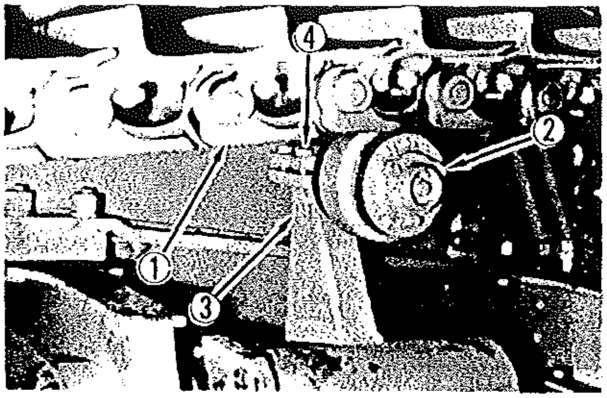
Carrier roller removal

Preparatory step

Have the track chains slackened, and proceed as follows:

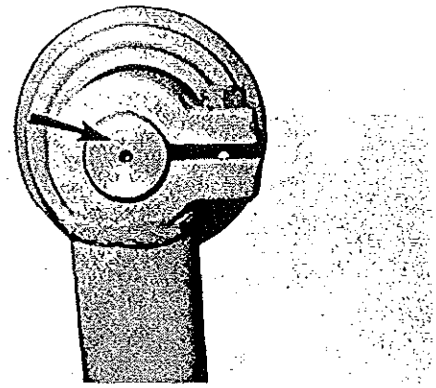
(1) Push up the track above the carrier roller to produce some clearance between track (1) and roller (2).

(2) Loosen two bolts (4), by which the carrier roller bracket (3) is fastened. Take out carrier roller (2).



Carrier roller installation

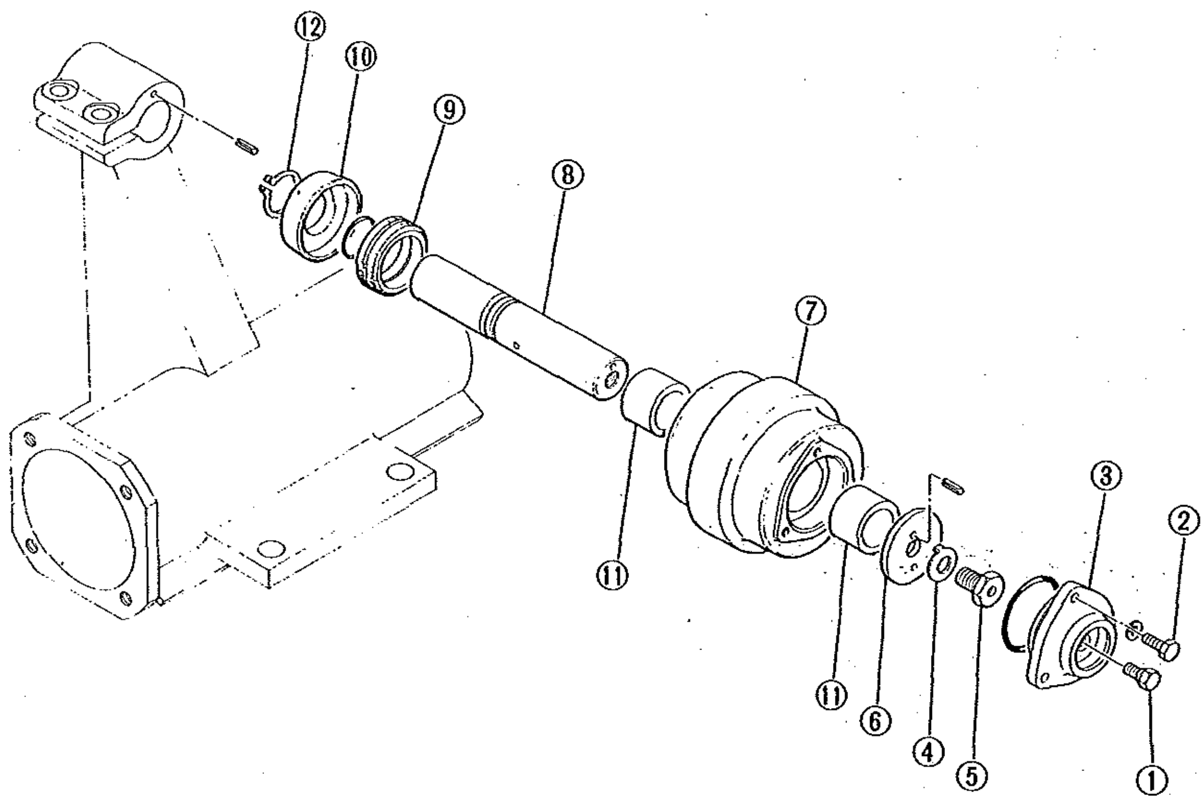
The end face of roller shaft has an arrow mark engraved on it. Insert the shaft into the bracket, pointing the arrow mark upward, as shown, and tighten the two bolts to clamp the shaft.



Carrier roller disassembly

Preparatory step

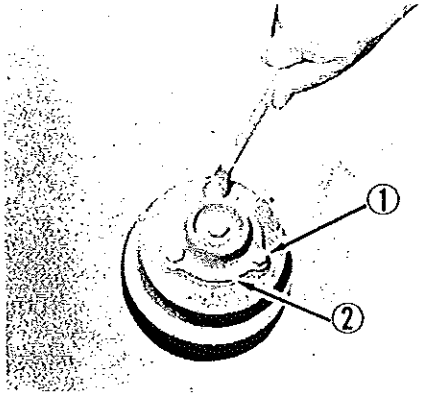
Have the oil inside the roller drained out completely.



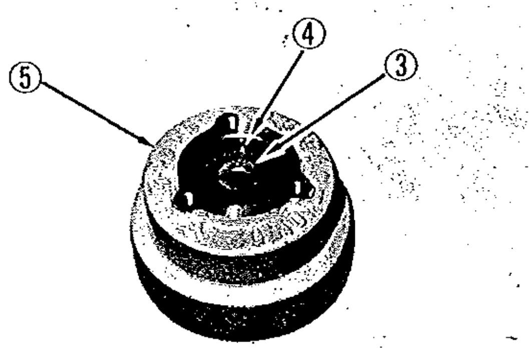
1-Plug	5-Bolt	9-Floating seal
2-Bolt and washer (3 each)	6-Washer	10-Seal support
3-Cover	7-Roller	11-Bushing (2 pcs)
4-Lock washer	8-Shaft	12-Snap ring

Track carrier roller — Exploded view

(1) Remove three bolts (1) and take cover (2) off.



(2) Remove bolt (3), and drive shaft (4) out of roller (5).



(3) Remove the floating seal from the roller and seal support.

(4) Remove the seal support and "O" ring from the shaft.

(5) Remove two bushings from carrier roller.

Carrier roller reassembly

Needed tool	
Adaptor	58609-00300

(1) Fit the two bushings into the bore of flanged roller.

(2) Insert the shaft into roller and lock the shaft in place by tightening the bolt.

(3) Put on the cover.

(4) Install the floating seal and seal support, and retain them by fitting snap ring.

(5) Using the above-named adaptor, charge 75 cc (4.58 cu in.) of oil into the roller through the plug bolt hole. Be sure to tighten the plug bolt good and hard.

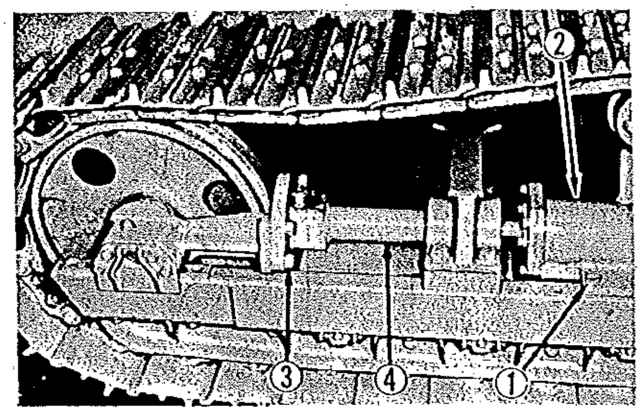
Recoil spring removal

Preparatory step

Have the grease cylinder completely depressurized; the method of relieving the pressure is described under "How to slacken the track chain."

(1) Remove four bolts (1), and dismount carrier roller bracket (2), in the cylindrical base of which is contained the recoil spring.

(2) Remove four bolts (3) to disconnect grease cylinder (4) from front idler yoke, and take out the cylinder.



Recoil spring installation

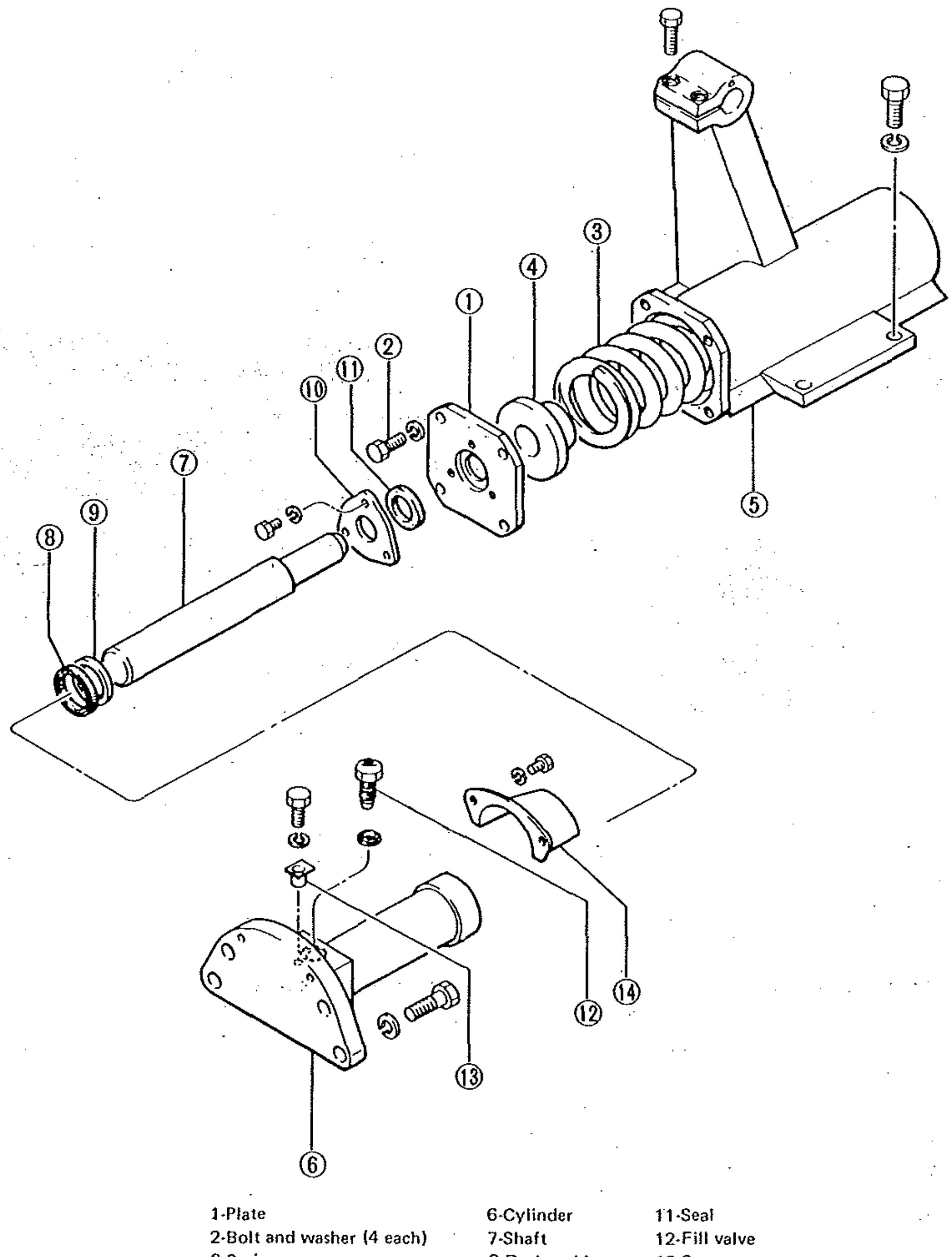
(1) Reconnect the grease cylinder to front idler yoke.

(2) Push the carrier roller bracket, complete with carrier roller, into between frame and track, and secure the bracket to the frame by tightening the four bolts.

Subsequent step

Stretch the track tight by pressurizing the grease cylinder.

Recoil spring disassembly



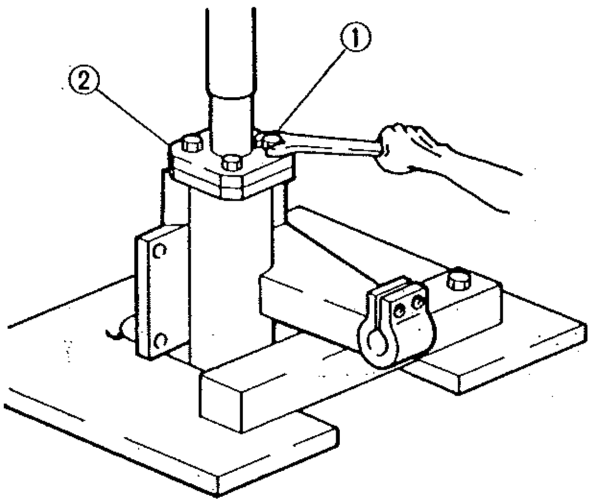
1-Plate	6-Cylinder	11-Seal
2-Bolt and washer (4 each)	7-Shaft	12-Fill valve
3-Spring	8-Rod packing	13-Stopper
4-Spring retainer	9-Dust seal	14-Cover
5-Carrier roller bracket	10-Plate	

Recoil spring assembly — Exploded view

Preparatory step

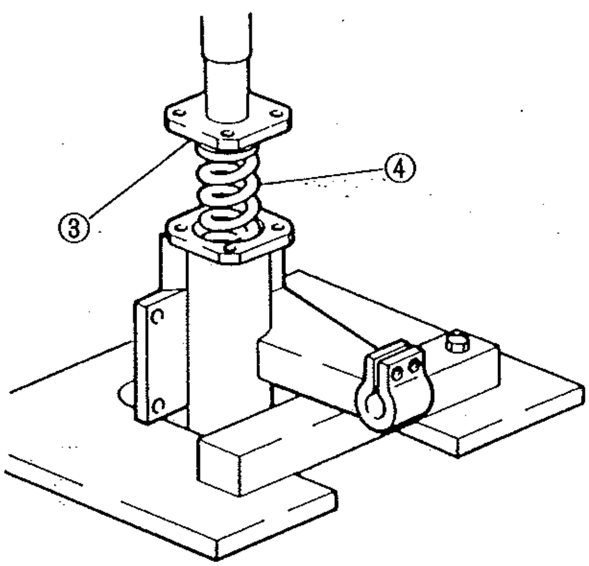
It is assumed that the recoil spring assembly has been taken down and is now set on the bench.

(1) Remove the three bolts securing the guide plate, and take off the plate and seal.



(2) Place the recoil spring assembly in the press, and hold down the head plate (2) with the press arbor, as shown, so that this plate will not jump off by the force of the recoil spring. Remove four bolts (1).

(3) Back off the press arbor gradually to let coil spring (4) expand. Take out plate (2), spring retainer (3) and spring.



(4) Take out the shaft from the cylinder and remove the rod packing and dust seal.

Recoil spring reassembly

(1) Fit the rod packing and dust seal in the cylinder and insert the shaft.

(2) Insert the spring into the carrier roller bracket, and lock the spring in place with the spring retainer and plate by tightening the four bolts. Place the seal and guide plate on it by tightening the three bolts.

Subsequent step

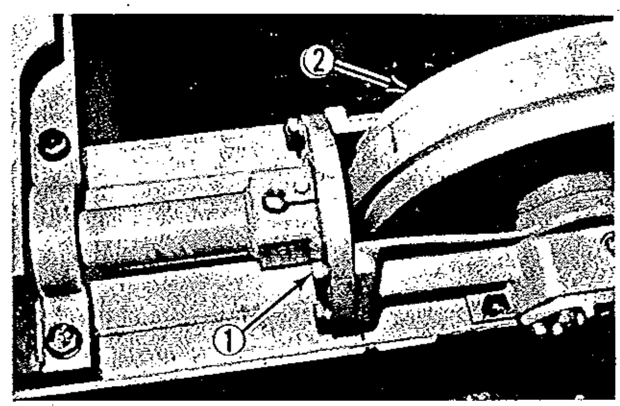
Installation of the track carrier roller.

Front idler removal

Preparatory step

Have the track chain broken at the master pin.

Remove four bolts (1). Using a hoist and lifting sling, suspend front idler (2) in place. With the weight of front idler taken up, push it forward, letting the idler slide out of the frame.

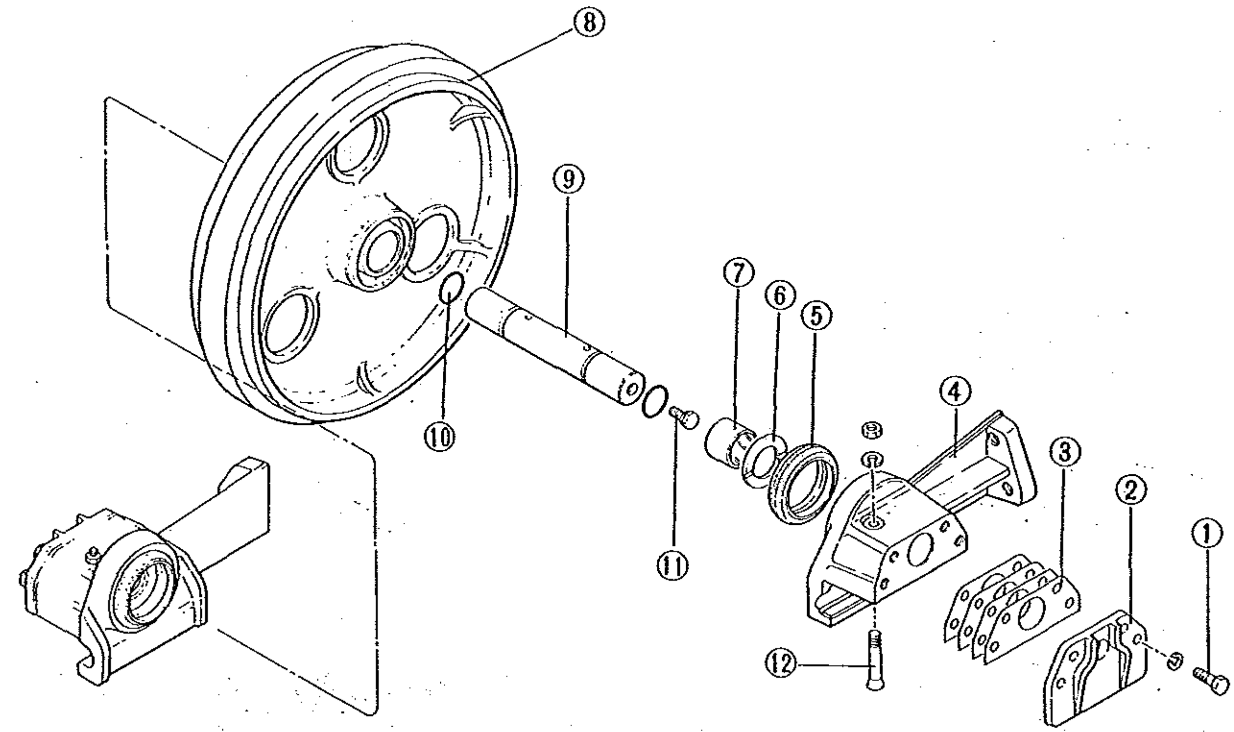


Front idler installation

(1) Bring in the front idler assembly to the front end of the frame, and push it into the frame.

(2) Check the front idler alignment, and connect its bearing parts to the flange behind.

Front idler disassembly



1-Bolt and washer (4 each on eash side)	5-Floating seal (2 sets)	9-Shaft
2-Guide (2 pcs)	6-Thrust washer (2 pcs)	10-"O" ring (2 pcs)
3-Shim (2 sets)	7-Bushing (2 pcs)	11-Plug
4-Bearing (2 pcs)	8-Idler	12-Pin, nut and washer (2 each)

Front idler — Exploded view

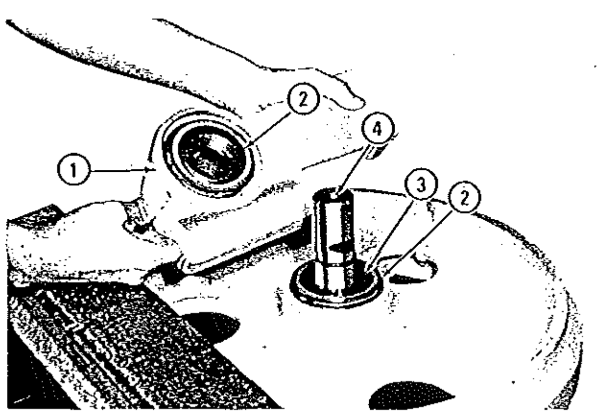
Preparatory step

Have the front idler completely empty of oil.

(1) Remove from each bearing (4) the guide piece (2) and shim (3). Four bolts (1), each with a spring washer, must be removed to do so. (See the exploded view.)

(2) Referring to the photo, remove the locking pin from each bearing (1) to free the bearing from the shaft, and pull the bearing off.

(3) Take out floating seal (2) and thrust washer (3).



(4) Carry out the above steps on the other side, and pull shaft (4) out of the idler.

(5) Drive bushings out of the idler bore.

Front idler reassembly

Needed tool	Qt.	Symbol
Adaptor 58809-15100	1	(A)

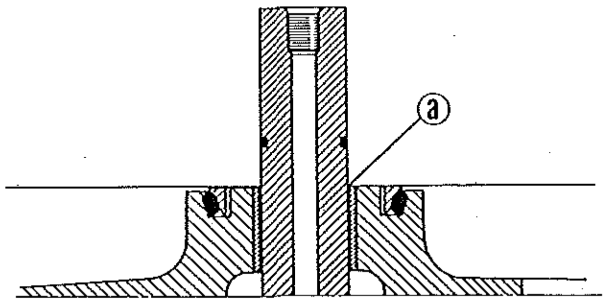
(1) Install the two bushings in the bore of the idler.

(2) Insert the shaft into the idler.

(3) Fit the floating seals. With the shaft held in vertical position, fill oil into the idler by using the adaptor (A). Keep charging the oil until it begins to overflow from the end (a) of the bushing.

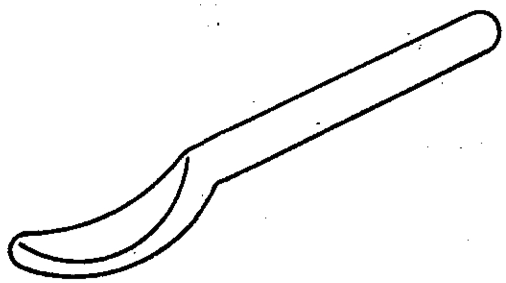
(4) Fit the thrust washers, and mount the two bearings on the shaft.

(5) Bolt the shims and guides to the bearings. Standard shim thickness is 2 mm (0.079 in.).



Floating seal disassembly and reassembly

(1) To pick out a floating seal during disassembly, use a 5-mm (0.20-in.) dia. rod, about 100 mm (3.93 in.) long, whose tip is flattened into a spoon shape with edges dulled by filing. It is possible to pick out the seal with fingers, but this spoon-like tool will facilitate the removal.

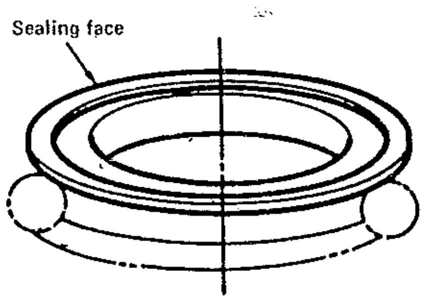


Seal plucking tool

CAUTION

When removing a floating seal, be careful not to strain any part of it. Prying out the seal with a screwdriver is a bad practice. Remember, the floating seal is a precision-machined component.

(2) Each floating seal removed must be handled as a set. After cleaning the seal rings by washing, put the two rings together, face to face, tape them just as carefully.



How to service the floating seal

(1) The two steel rings constituting a floating seal are selectively matched. If either ring is in any of the following conditions, replace the seal as a set:

(a) Broken ring, or chipped or scarred sealing face.

(b) Sealing face not perfectly flat (which is evidenced by rubbing contact pattern).

(c) Pitted or corroded sealing face.

(d) Sealing face with its offset gone due to wear.

(2) Any "O" ring removed in disassembly must not be re-used in reassembly.

(3) WASHING: Clean each removed floating seal by washing. To be washed are the steering rings and collar, and also the steel-bushing seal supports by which the floating seal is held in place. Use a clean washing fluid and a cloth or a brush.

It is permissible to use the washing fluid to clean "O" rings, but do not soak them with the washing fluid. Never leave "O" rings immersed in the fluid.

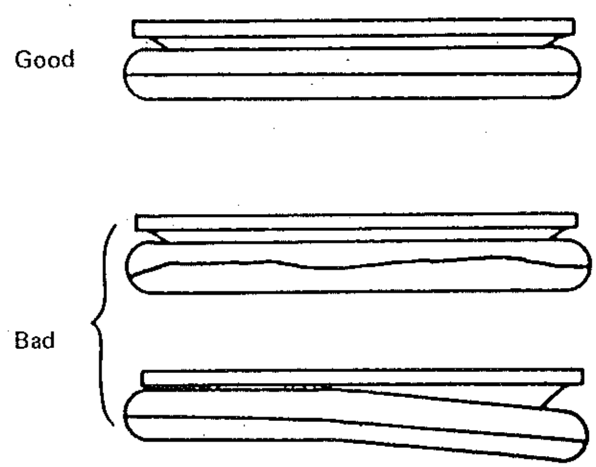
NOTE

A wire brush may be used to rub off grime and rust from the surfaces of the collars and steel-bushing supports. Make sure that the collar is free of any grits. Leaky floating seals are often due to the grits caught between the two sealing faces at the time of seal installation.

After cleaning by washing, make the washed parts and surfaces dry by using compressed air. The surfaces coming into contact with the "O" ring must be particularly dry of washing fluid.

Each replacement floating seal taken out of the package will be found coated with anti-rust oil. Before using the seal, remove its "O" rings, and wash the steel rings clean. Use the washing fluid sparingly on the "O" rings to remove the oil.

(4) "O" RINGS: When fitting the "O" ring to the steel ring, be careful not to scratch its surface with the ring edge. Check to be sure that "O" ring fits to the steel ring snugly and squarely.



HYDRAULIC SYSTEM

Hydraulic pump removal

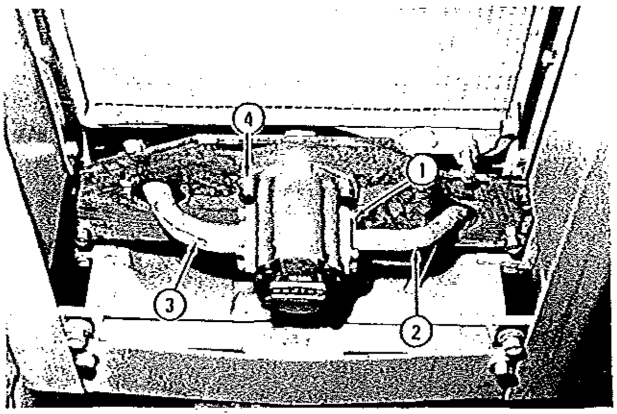
Preparatory steps

(a) Remove the engine-room front guard.

(b) Have the hydraulic oil tank drained completely.

(1) Remove bolts (1), four on each side, and disconnect pipes (2) (3).

(2) Remove two bolts (4), and pull out the hydraulic pump.



Hydraulic pump installation

(1) Bolt the pump to the frame.

(2) Reconnect the two pipes to the pump body.

Subsequent steps

Refilling of the hydraulic oil tank, and installation of the front guard.

Gear pump disassembly

(1) Referring to the exploded view of the gear pump, remove four bolts (1), and take off cover (2) and mounting flange (12).

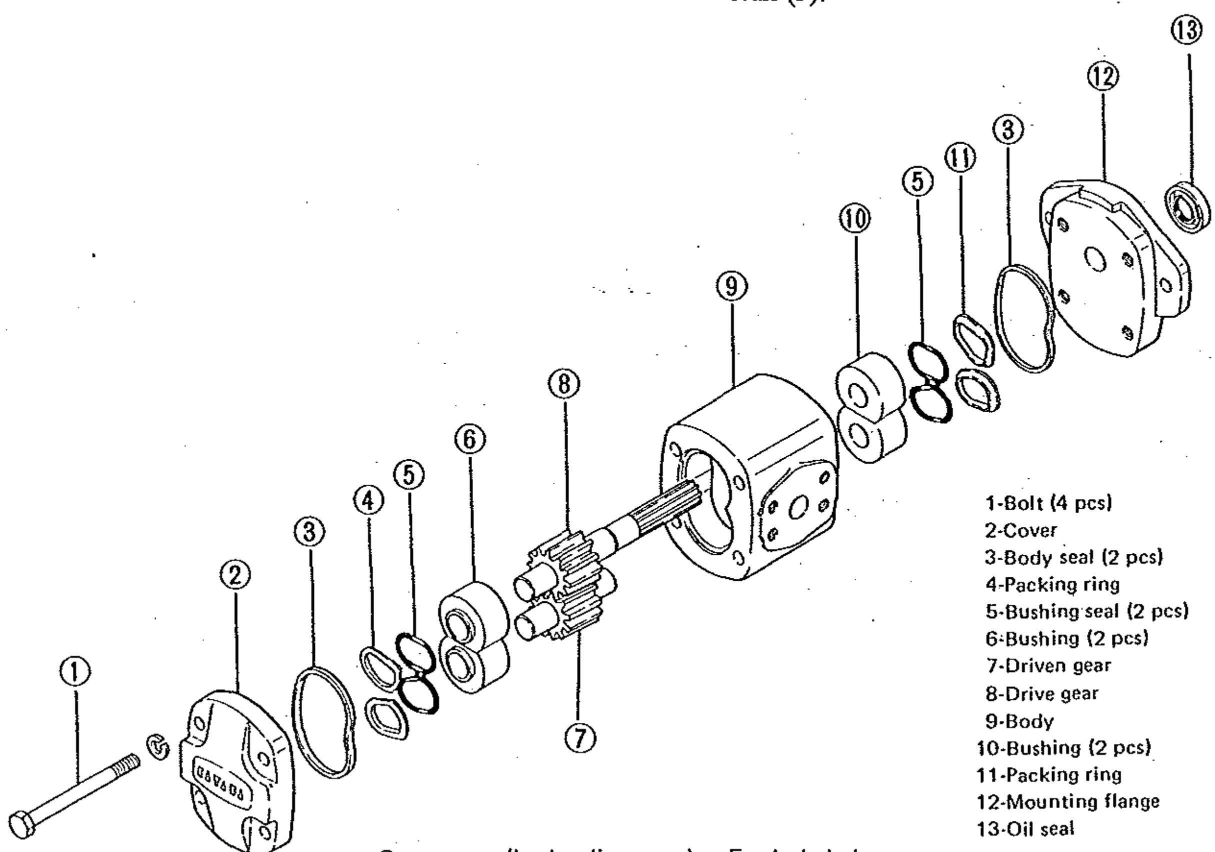
(2) Lay down pump body (9). Pull out drive gear (8) by hand, and remove bushings.

NOTE

If the bushing will not come out, tap on the pump body with a plastic hammer to shake the bushings loose. Be sure to place the pump body on a resilient base and tap lightly.

(3) Pull out driven gear (7) and remove bushings.

(4) From the cover and mounting flange, separate oil seals (3).



1-Bolt (4 pcs)
2-Cover
3-Body seal (2 pcs)
4-Packing ring
5-Bushing seal (2 pcs)
6-Bushing (2 pcs)
7-Driven gear
8-Drive gear
9-Body
10-Bushing (2 pcs)
11-Packing ring
12-Mounting flange
13-Oil seal

Gear pump (hydraulic pump) — Exploded view

(5) Lay out the disassembled parts neatly in the order in which they came out, identifying each for its position in the assembly. Particularly, the shaft and its bushings must be identified positionally by marking or otherwise so that they will resume the exact original condition in reassembly.

Gear pump reassembly

(1) Fit oil seals to the mounting flange and cover.

(2) Attach bushing seals and packing rings to the bushings of the flange side, and insert the bushings into the pump body. Be sure to apply high-grade grease to the bushings before inserting them: this applies equally to the bushings of the other side.

NOTES

a) When inserting the bushings, be sure to hold them squarely to the bore to avoid scuffing.

b) If the OD surface of a bushing is found with scratch marks, smoothen the surface with an oil stone.

(3) Mesh drive gear with driven gear in the same positional relationship as before, and insert them into the pump body.

NOTE

The usual practice is to provide match marks on the end faces of the two gears before drawing them out in disassembly.

(4) Install the other bushings, to which bushing seals and packing rings are attached. Put on the cover and fasten the whole assembly together by tightening the four thru-bolts.

NOTE

Before inserting the drive and driven gears into the bore, have the splined portion of drive gear shaft wrapped with one or two layers of cellophane tape, so that, when the shaft passes through the bushing, it will not damage the bushing seal there.

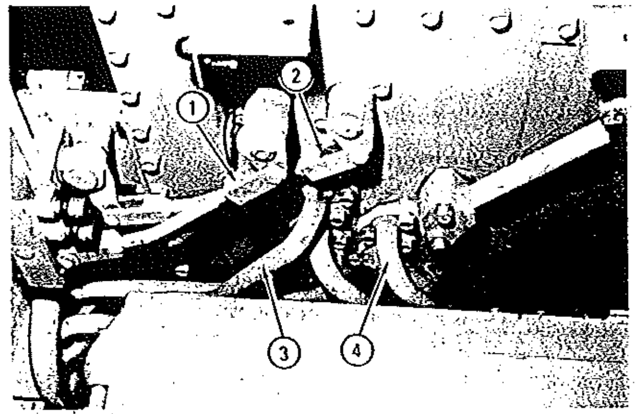
Hydraulic tank removal (BS3F)

Preparatory step

Drain the tank, and have the driver's seat and right-hand arm rest taken down. These two jobs are to precede the following procedure:

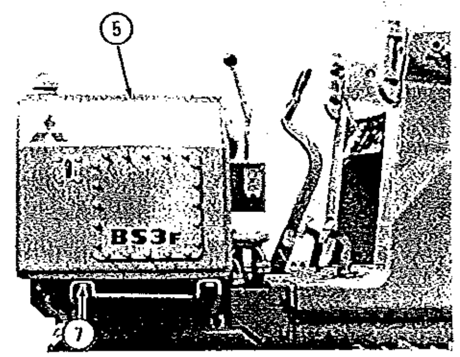
(1) Disconnect lever rods (1) (2) of hydrualic control.

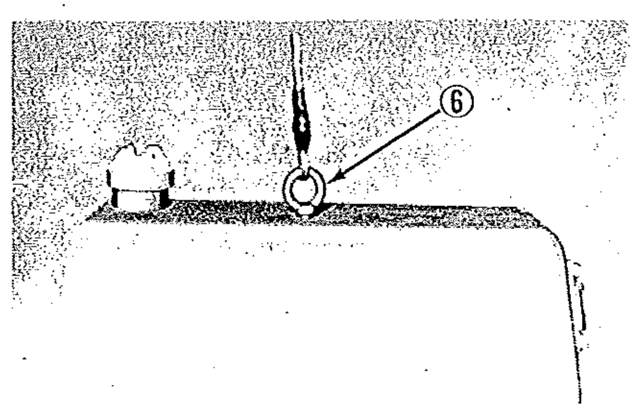
(2) Disconnect two pipes (3) associated with the hydraulic pump, and four pipes (4) leading to hydraulic cylinders from the control valve.



(3) Run eye bolt (6) into the tapped hole (5). Take a hitch on the eye bolt with a lifting sling and operate the hoist to take up the weight of the tank.

(4) Remove four bolts (7), and lift the tank away.





Hydraulic tank installation (BS3F)

(1) Bring the tank over to the fender, and seat the tank snugly.

(2) After securing the tank in place, reconnect the pipes and control lever rods.

Subsequent steps

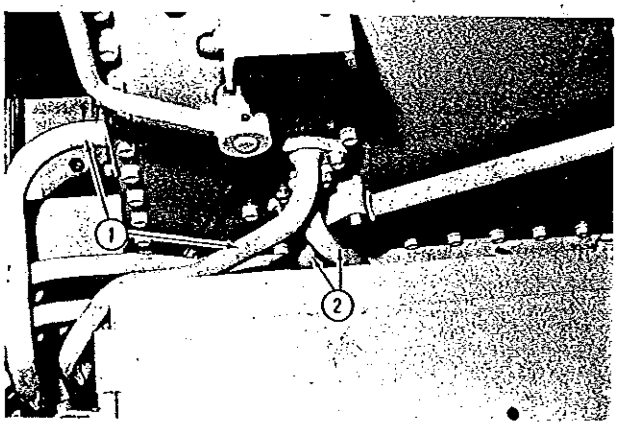
Installation of the right-hand arm rest and driver's seat, and refilling of the hydraulic tank.

Hydraulic tank removal (BD2F)

Preparatory step

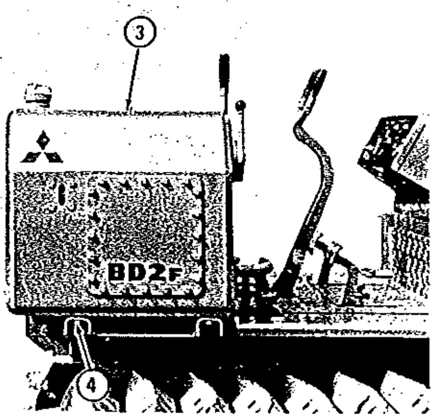
Drain the tank, and have the driver's seat and right-hand arm rest taken down.

(1) Disconnect two pipes (1) associated with the hydraulic pump, and two pipes (2) associated with the control valve.



(2) Run eye bolt (3) into the top of the tank, hitch a lifting sling to the bolt, and operate the hoist to take up the weight of the tank.

(3) Remove four bolts (4), and lift the tank away.

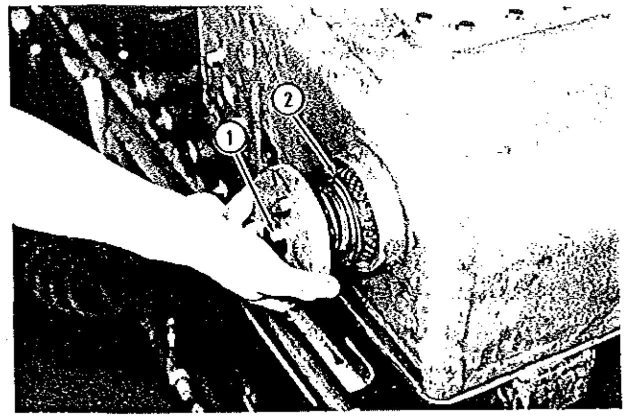


Hydraulic tank installation (BD2F)

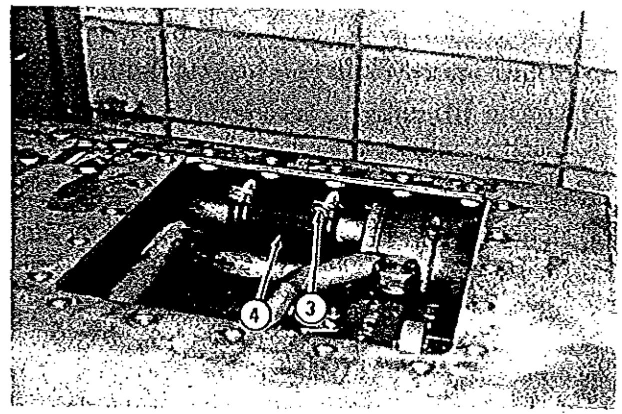
Reverse the removal procedure to remount the tank, and complete the work by installing the driver's seat and arm rest and by filling up the tank.

Hydraulic tank disassembly

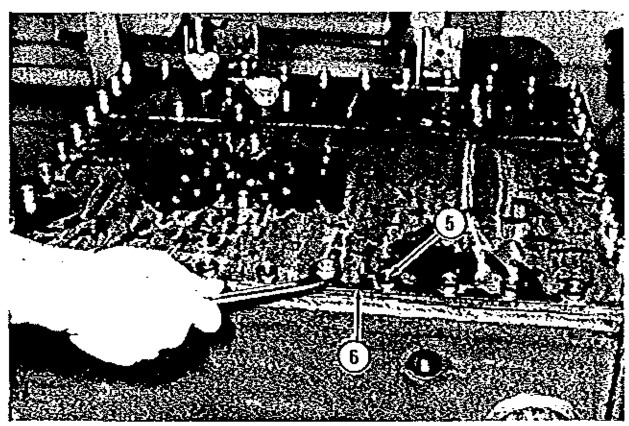
(1) Remove filter stud (1), and take out element (2).



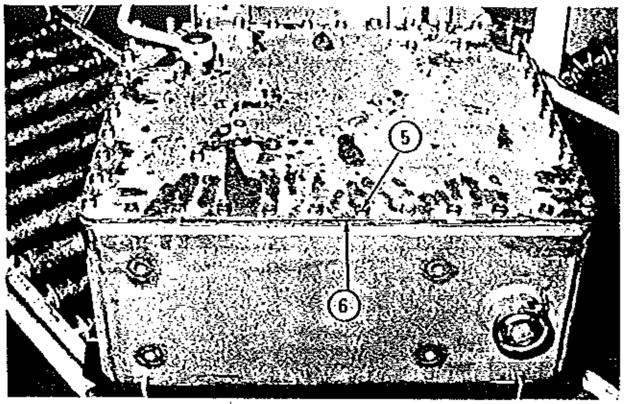
(2) Remove the top cover, loosen clamp (3) and disconnect rubber hose (4).



(3) Remove a total of 40 bolts (5), and take off cover (6).

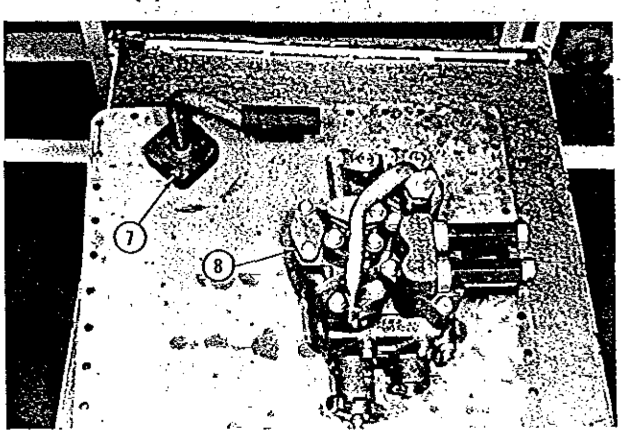


BS3F

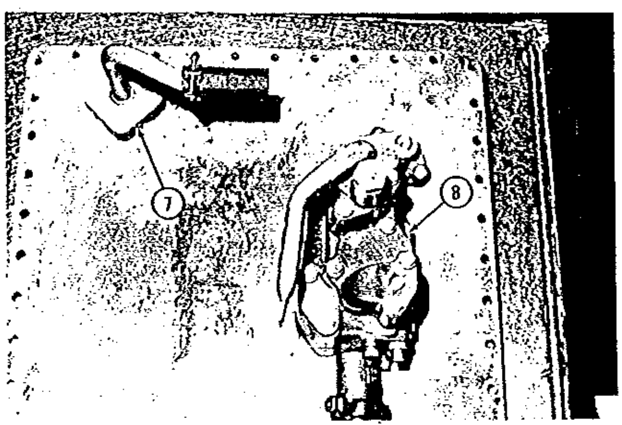


BD2F

(4) Remove pipe (7) and control valve (8) from tank cover (6).



BS3F



BD2F

Hydraulic tank reassembly

(1) Mount the control valve on, and reconnect the pipe to, the tank cover.

(2) Put on the cover, and secure it by tightening 40 bolts.

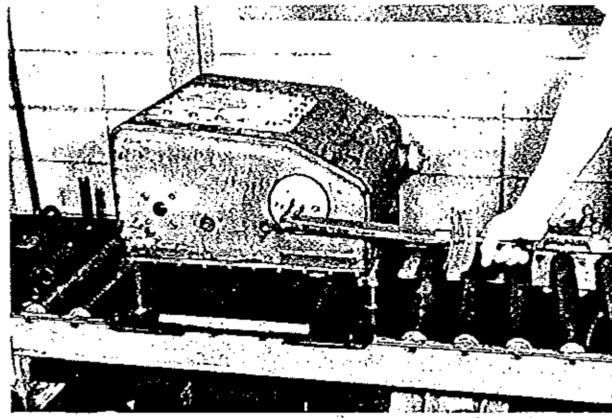
(3) Turn over the tank and reconnect the rubber hose by tightening its clamp. Put on the top cover.

(4) Insert the element and secure it in place by tightening its stud to this torque value:

Filter stud tightening torque	3.5 ± 0.3 kg-m (25.3 ± 2.2 lb-ft)

NOTE

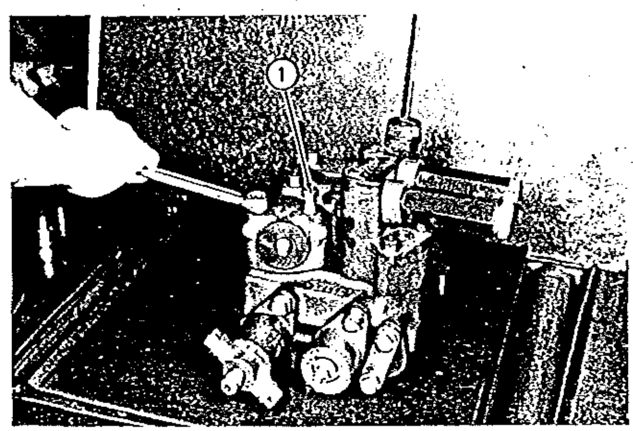
An arrow mark is provided on the element cover. Be sure to position the element so that the arrow will point upward.



Hydraulic control valve disassembly (BS3F)

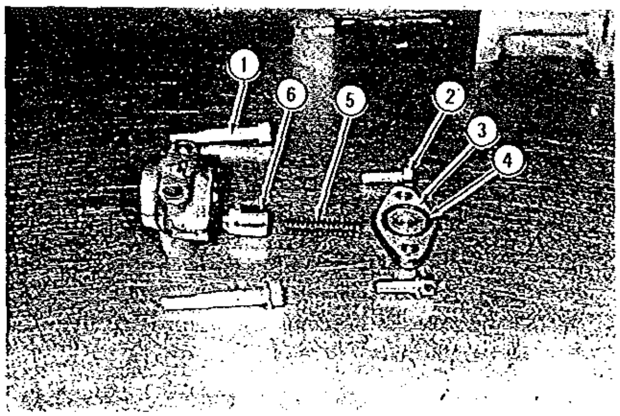
(1) Disassemble the make-up valve in three steps:

(a) Remove two bolts (1), and remove the make-up valve sub-assembly.



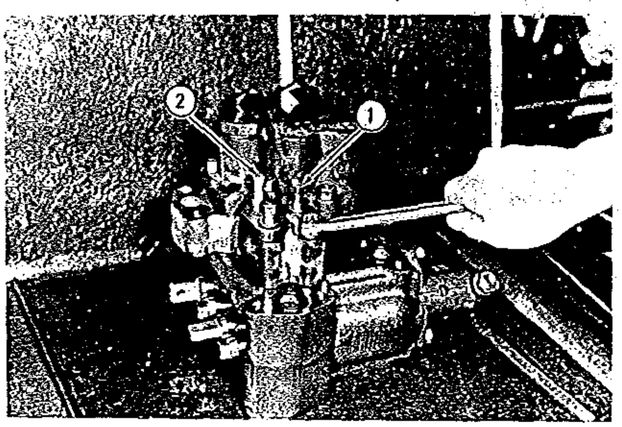
(b) Remove two bolts (2) and detach cover (3).

(c) Take out "O" ring (4), spring (5) and valve (6).

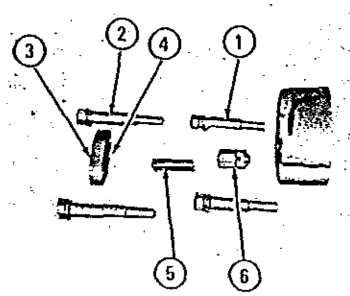


(2) Disassemble the lift-cylinder check valve in two steps:

(a) Remove bolts (1) (2), two each, and take off the check valve sub-assembly.



(b) From the valve body, remove cover (3), "O" ring (4), spring (5) and valve (6).

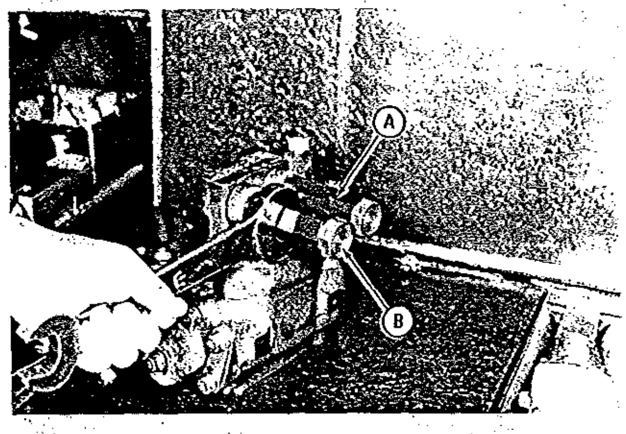


(3) Disassemble safety valve and safety make-up valve as follows:

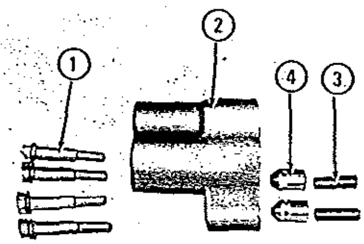
(a) Detach the two safety valve sub-assemblies (A) (B).

NOTE

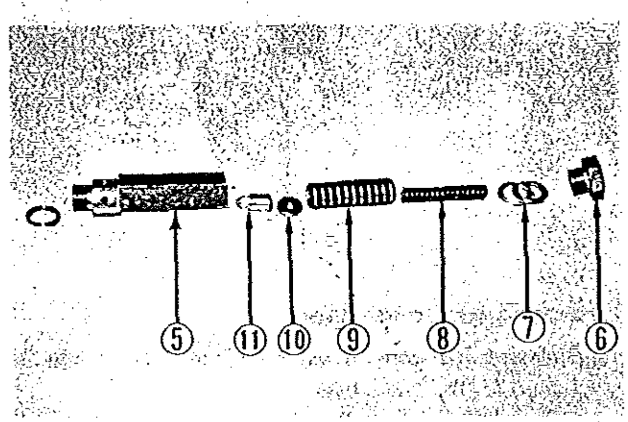
These valves are set to relieve at: 180 kg/cm^2 (2560 psi) in valve (A) and 140 kg/cm^2 (1991 psi) in valve (B).



(b) Remove four bolts (1), and take out valves (4) and springs (3) from body (2).

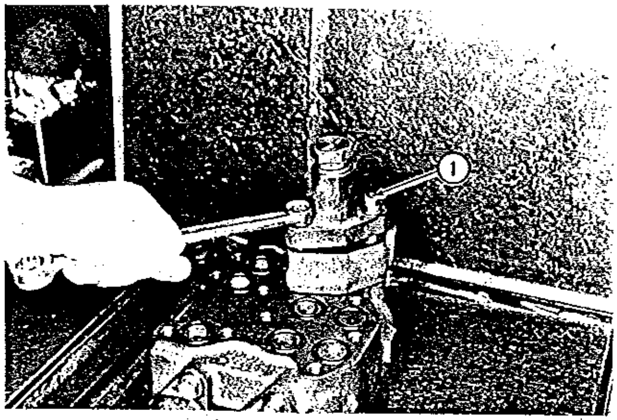


(c) Remove safety valve body (5) and, from the removed body, separate plug (6), shim (7), springs (8) (9), washer (10) and valve (11).

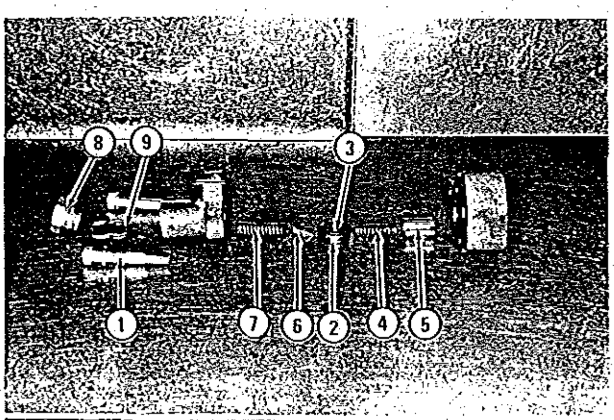


(4) Disassemble the relief and pilot valve sub-assembly, as follows:

(a) Loosen the screw plug, remove two bolts (1), and take off the sub-assembly.

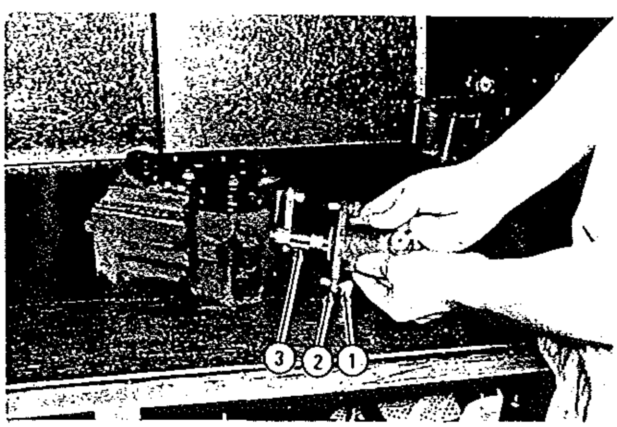


(b) Break down the sub-assembly into these parts: seat (2), "O" ring (3), spring (4), piston (5), valve (6), spring (7), screw plug (8) and shim (9).

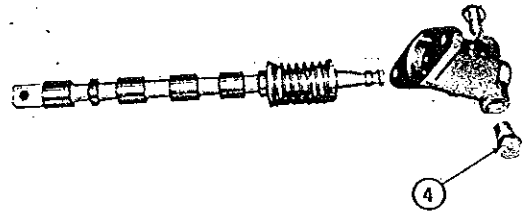


(5) Disassemble the lift-cylinder plunger, as follows:

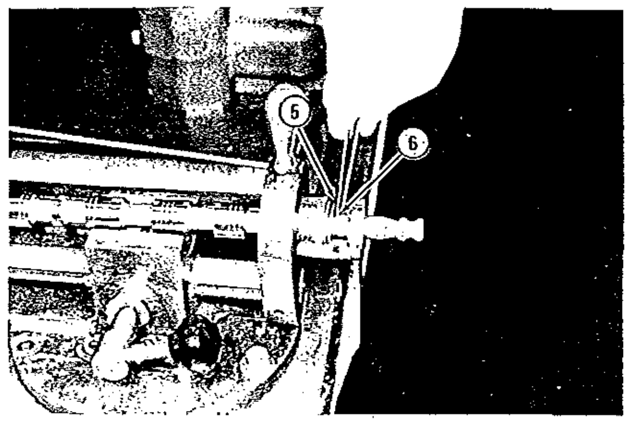
(a) Remove two bolts (1), and take out cap (2) and operating plunger (3).



(b) Remove two plugs (4), and draw plunger out of cap.

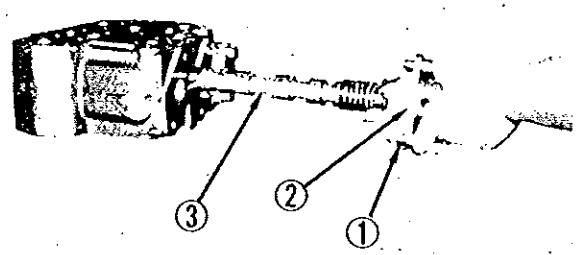


(c) Clamp the plunger steady. While pushing spring retainer (5) to compress the spring, pick washer (6) off the plunger.

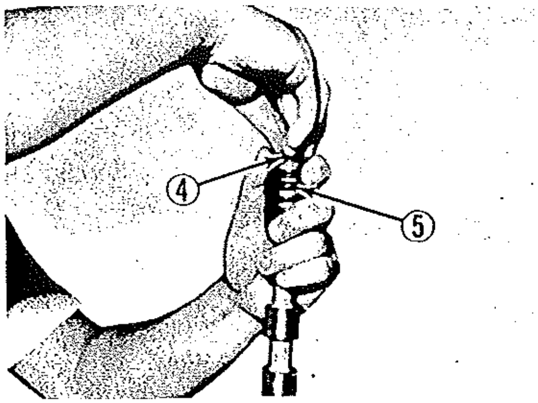


(6) Disassemble the dump-cylinder plunger, as follows:

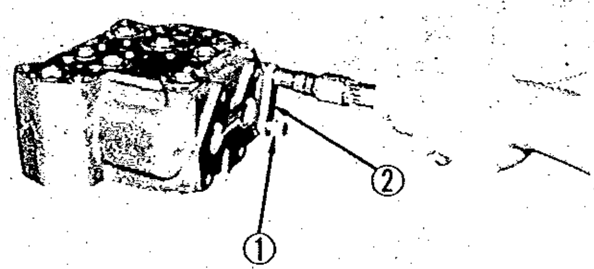
(a) Remove two bolts (1), and take out operating plunger (3) complete with cap (2).

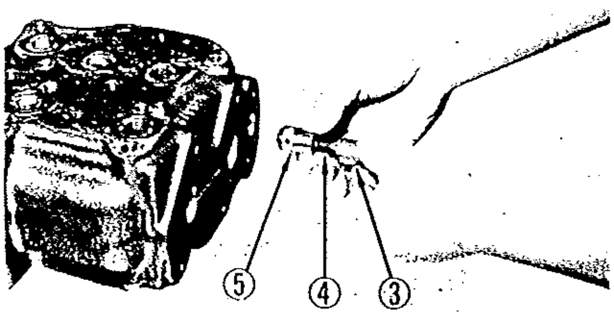


(b) Push down spring (5) with one hand just a little and loosen bolt (4) by the other. Remove bolt (4) from plunger (5).



(7) Disassemble the dump-cylinder check valve by removing two bolts (1) and stopper (2) and taking out plug (3), spring (4) and valve (5).





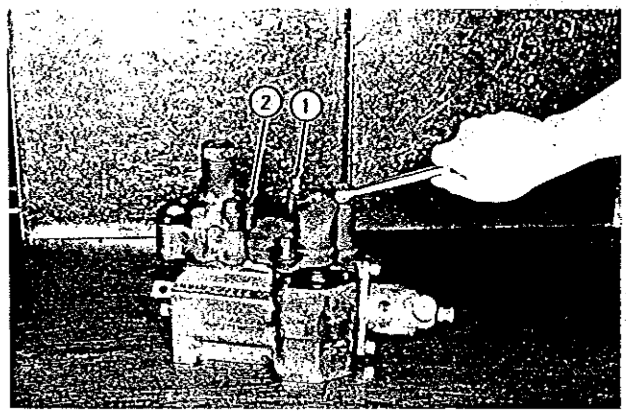
Hydraulic control valve reassembly (BS3F)

Rebuild the hydraulic control valve assembly by installing its components in the following sequence: 1) Dump-cylinder check valve, 2) dump-cylinder plunger, 3) lift-cylinder plunger, 4) relief and pilot valve sub-assembly, 5) safety and safety make-up valve sub-assembly, 6) lift-cylinder check valve, and 7) make-up valve sub-assembly.

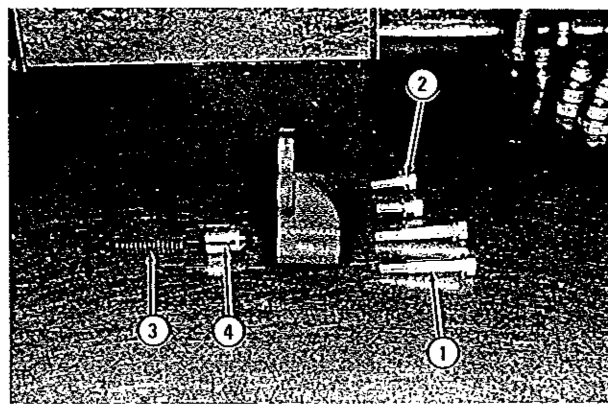
Hydraulic control valve disassembly (BD2F)

(1) Disassemble the make-up valve in two steps:

(a) Remove bolts (1) (2), two each, and take out the make-up valve sub-assembly.



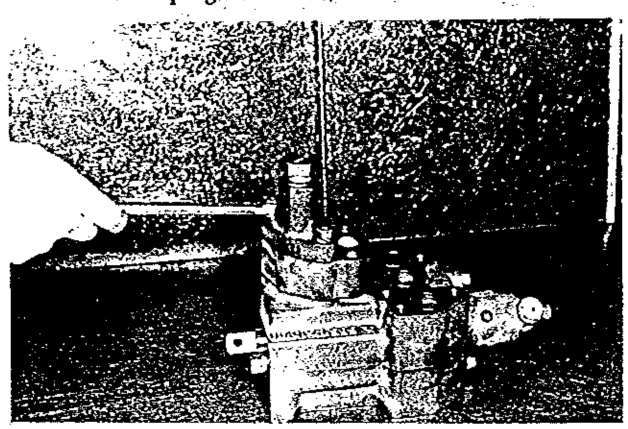
(b) Remove spring (3) and valve (4) from the body.



(2) Disassemble the relief and pilot valve sub-assembly, as in the case of the similar sub-assembly of BS3F, by proceeding as follows:

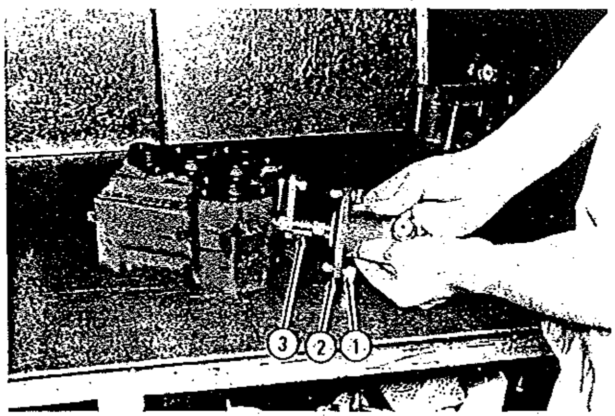
(a) Remove two bolts, and take out the sub-assembly.

(b) Break down the sub-assembly into these parts: seat, "O" ring, spring, piston, valve, spring, screw plug and shim.

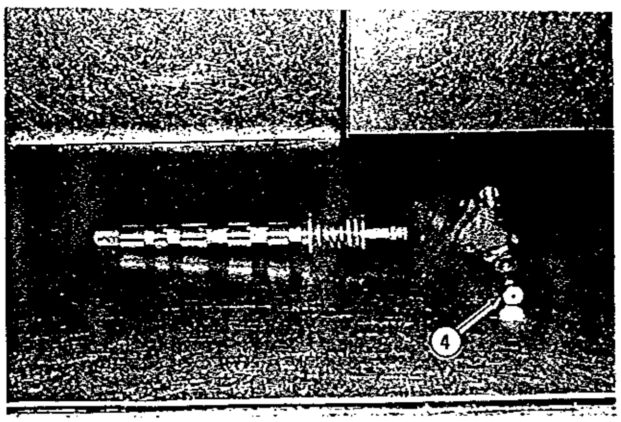


(3) Disassemble the plunger, as follows:

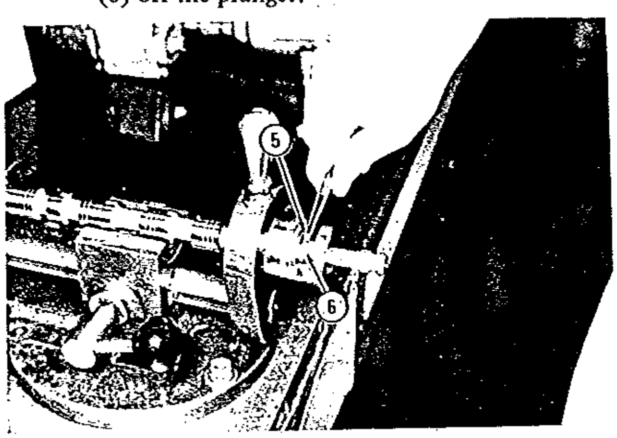
(a) Remove two bolts (1), and take out cap (2) and operating plunger (3).



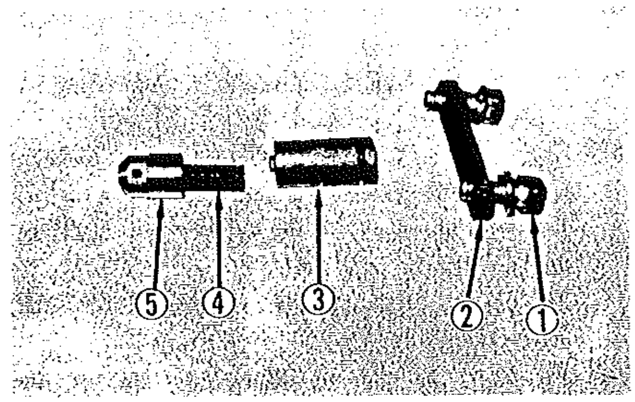
(b) Remove two plugs (4), and draw plunger out of cap.



(c) Clamp the plunger steady. While pushing spring retainer (5) to compress the spring, pick washer (6) off the plunger.



(4) Disassemble the check valve, as in BS3F, by removing two bolts (1) and stopper (2) and taking out plug (3), spring (4) and valve (5).



Hydraulic control valve reassembly (BD2F)

Rebuild the hydraulic control valve assembly by installing its components in the following sequence: 1) check valve, 2) plunger, 3) relief and pilot valve sub-assembly, and make-up valve sub-assembly.

Lift cylinder removal (BS3F)

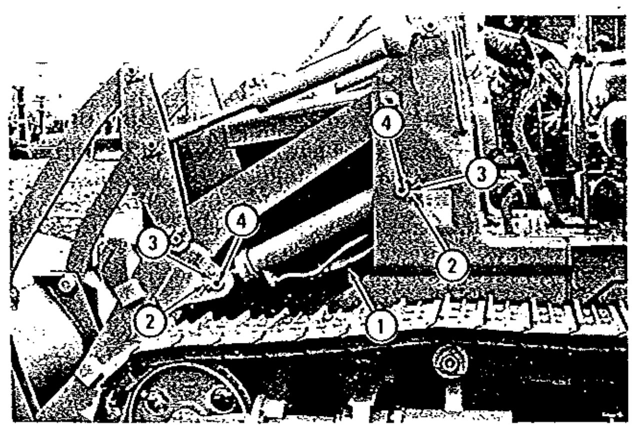
Preparatory step

Have the bucket lowered to and resting on the ground.

(1) Disconnect two pipes (1) and each side of the machine.

(2) Take up the weight of the lift cylinder with a lifting sling and hoist, or tie the cylinder to the arm with a rope.

(3) Remove two bolts (2), front and rear, and take off lock plates (3) and pins (4), and carry the cylinder in suspended state off the machine.



Lift cylinder installation (BS3F)

Install each lift cylinder by reversing the removal procedure. Use of a hoist and lifting sling will facilitate the installing work.

Dump cylinder removal (BS3F)

Preparatory step

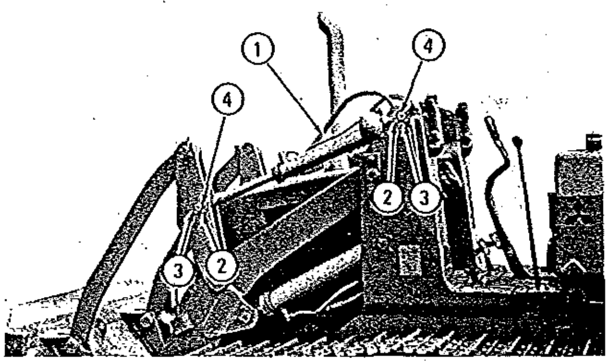
Have the bucket lowered to and resting on the ground.

(1) Disconnect two pipes (1), front and rear, at each side of the machine.

(2) Take up the weight of the cylinder with a lifting sling and hoist.

(3) At each end of the cylinder, remove bolt (2), lock plate (3) and pin (4).

(4) Carry the cylinder in suspended state off the machine.



Dump cylinder installation (BS3F)

Reverse the removal procedure to install the dump cylinder.

Blade cylinder removal (BD2F)

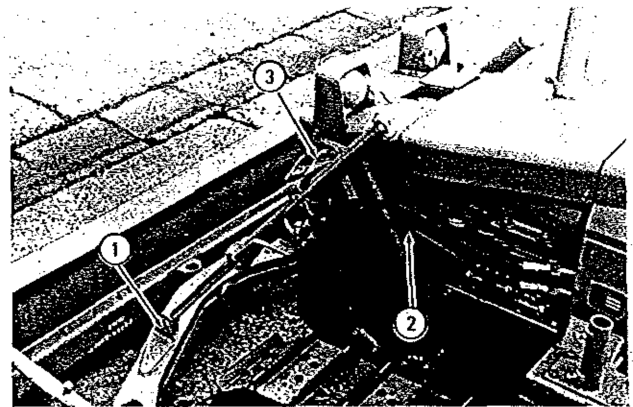
Preparatory step

Have the blade lowered to and resting on the ground.

(1) Remove pin (1) from the rod connection of each cylinder. Operate the hydraulic system to contract the two blade cylinders fully.

(2) Tie the two cylinders respectively with a rope, in order to hold them steady in place.

(3) Disconnect two pipes (2) from each cylinder, and remove four bolts (3). Untie and take off the cylinders.



Blade cylinder installation (BD2F)

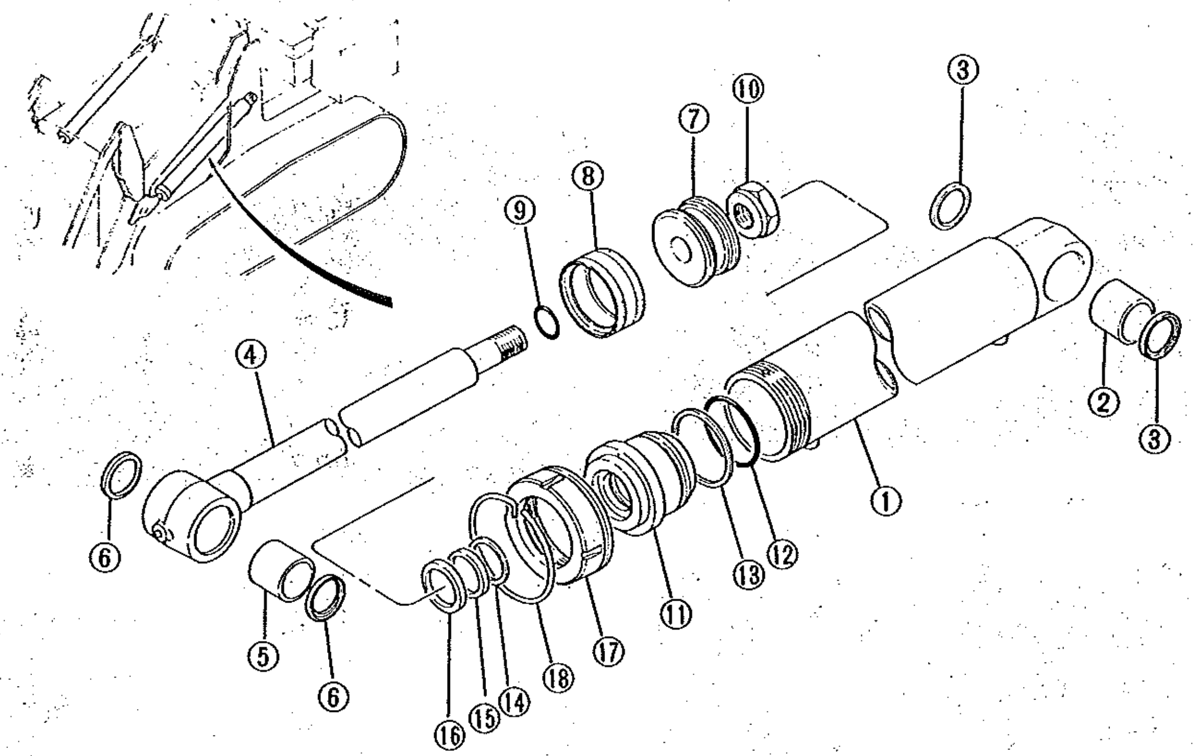
(1) Secure the rear end portion of the cylinder to the radiator guard.

(2) Reconnect the oil pipes to the cylinder.

(3) Extend the rod, and pin its forward end to the "C" frame.

Hydraulic cylinder disassembly

Tool needed	
Hook wrench	58609-01500
Hook wrench	58609-01700



1-Cylinder pipe	7-Piston	13-Back-up ring
2-Bushing	8-Piston seal	14-Buffer ring
3-Dust seal (2 pcs)	9-"O" ring	15-Rod packing
4-Rod	10-Self-locking nut	16-Dust seal
5-Bushing	11-Guide bushing	17-Gland screw
6-Dust seal (2 pcs)	12-"O" ring	18-Ring

Hydraulic cylinder – Exploded view

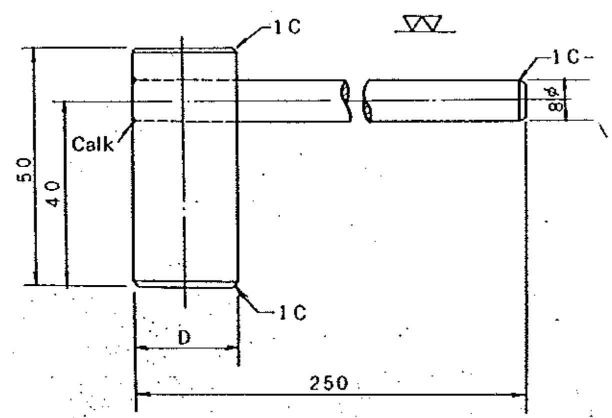
How to fit seal to piston

Preparatory step

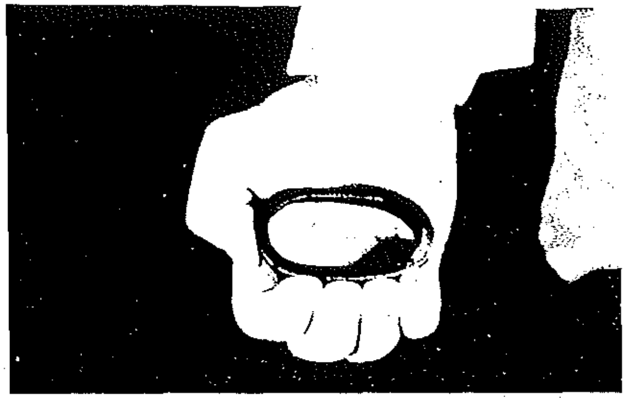
To fit the seal (8) to the piston (7) – shown in the exploded view – a special tool must be used. This tool differs in dimension for different hydraulic cylinders, as follows:

Unit: mm (in.)

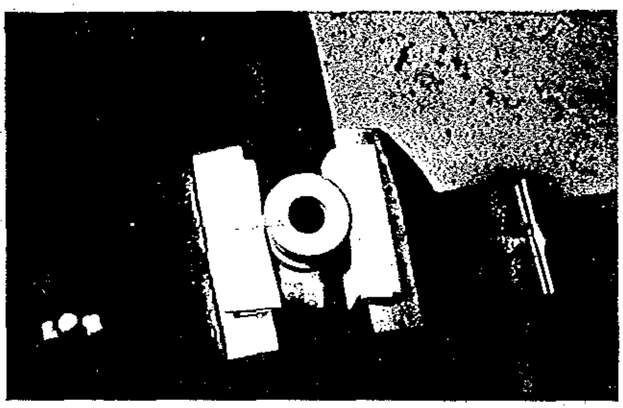
Hydraulic cylinder	Piston ID	Dimension D
Lift cylinder	30 (1.18)	29.5 (1.161)
Blade cylinder	24 (0.94)	23.5 (0.925)



(1) Hold the piston seal in the palm of the hand, and squeeze the seal 3 or 4 times to soften it.

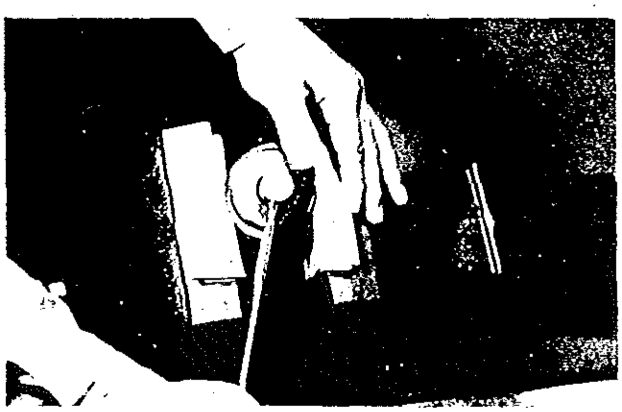


(2) Clamp the piston in the vise, with copper plates in between to protect the piston against denting.

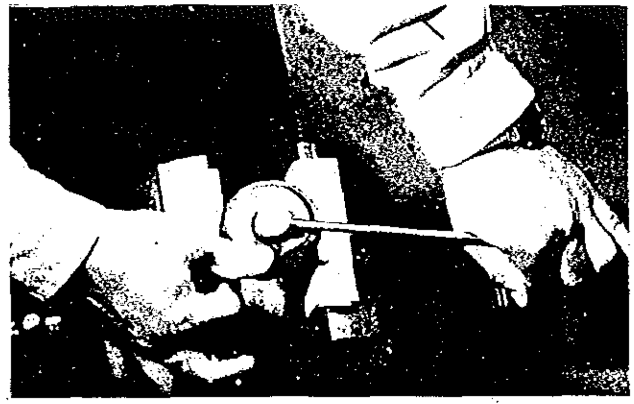


(3) Apply hydraulic oil to the piston seal. Fit a portion of the seal to the seal groove formed of the piston. Insert the tool into the piston.

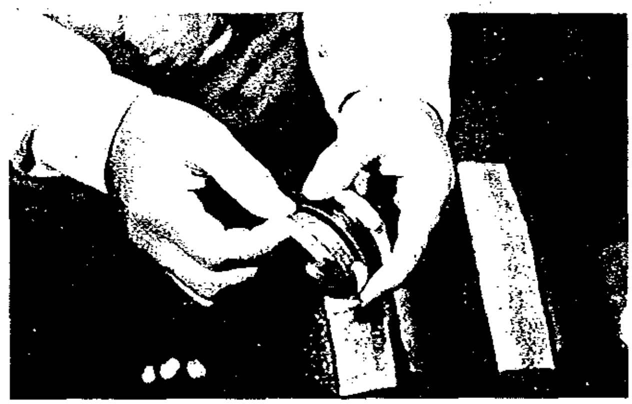
(4) Hold down the seal with the left hand, and slowly turn the arm rod of the tool, letting the rod ride on the seal. A downward push must be maintained on the rod in so turning, in order to force the seal into the groove. In this manner, force about three-quarters of the seal into the groove.



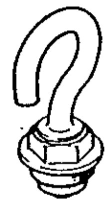
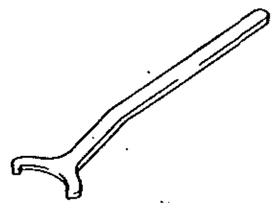
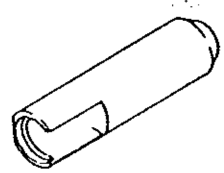
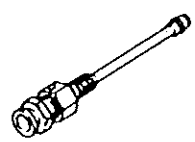
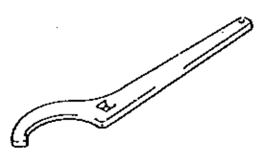
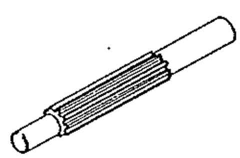
(5) Change the hand, and turn the arm rod in the other direction to force the remaining one-quarter into the groove.

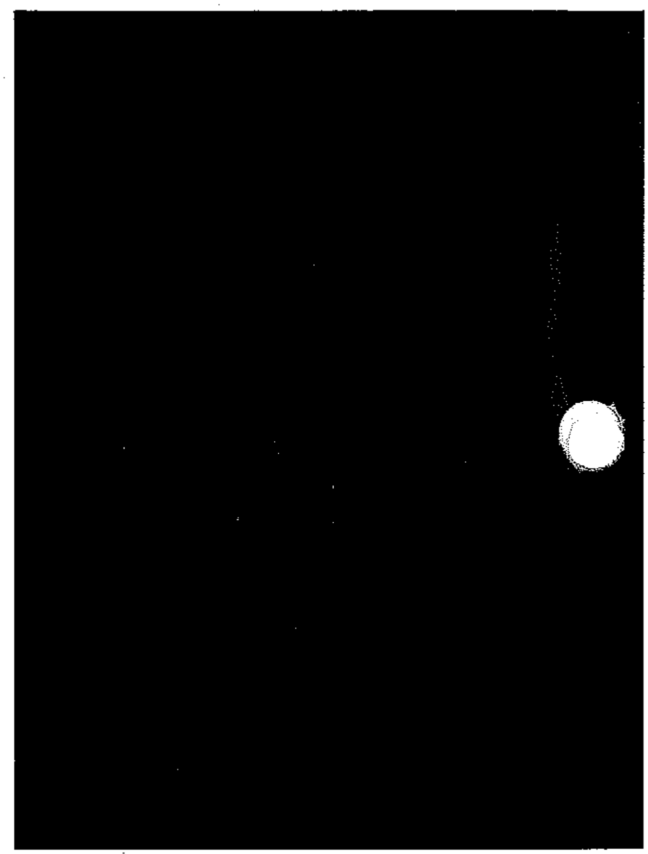


(6) Fit the backup ring to the piston.



SPECIAL SERVICE TOOLS

Part No.	Tool name	Shape	Use
58609–04200	Hook		For lifting the clutch
58809–10200	Wrench		For turning adjusting nuts in bevel gear adjustments
58609–01900	Steering clutch tool		For disassembly and reassembly of steering clutches
58609–00300	Adaptor		For charging oil into carrier rollers
58809–15100	Adaptor		For charging oil into front idlers and track rollers
58609–01500	Hook wrench		For tightening gland screws of dump and blade cylinders
58609–01700	Hook wrench		For tightening gland screws of lift cylinders
58809–15600	Clutch disc arbor		For aligning clutch discs and plates in flywheel clutch services



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