M9961-H11341

SERVICE MANUAL

MARINE DIESEL ENGINE

4LHA-STE/STZE/STP/STZP
4LHA-DTE/DTZE/DTP/DTZP
4LHA-HTE/HTZE/HTP/HTZP

M9961-H11341

YANMAR

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MODEL 4LHA-STE/STZE/STP/STZP
4LHA-DTE/DTZE/DTP/DTZP
4LHA-HTE/HTZE/HTP/HTZP

YANMAR DIESEL ENGINE CO.,LTD.

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FORWARD

This service manual has been compiled for engineers engaged in sales service, inspection and maintenance. Accordingly, descriptions of the construction and functions of the engine are emphasized in this manual while items which should already be common knowledge are omitted.
One characteristic of a marine diesel engine is that its performance in a vessel is governed by its applicability to the vessel's hull construction and its steering system.
Engine installation, fitting out and propeller selection have a substantial effect on the performance of the engine and the vessel. Moreover, when the engine runs unevenly or when trouble occurs, it is essential to check a wide range,of operating conditions—such as installation on the hull and suitability of the ship's piping and propeller—and not just the engine itself. To get maximum performance from this engine, you should completely understand its functions, construction and capabilities, as well as proper use and servicing.
Use this manual as a handy reference in daily inspection and manintenance,and as a text for engineering guidance.

Model **4LHA-STE/STZE,DTE/DTZE,HTE/HTZE**
4LHA-STP/STZP,DTP/DTZP,HTP/HTZP

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CHAPTER 0

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1. For Safe Servicing

- Most accidents are caused by failing to observe basic safety rules and precautions. To prevent accidents, it is important to recognize the signs of approaching problems, and eliminate the problems in the early stage before they can cause accidents.
  Please read this manual carefully before starting repairs or maintenance to fully understand safety precautions and appropriate inspection and maintenance procedures. Attempting a repair or maintenance job without sufficient knowledge may cause an unexpected accident.

- It is impossible to cover every possible danger in repair or maintenance in the manual. Sufficient consideration for safety is required in addition to the matters marked ⚠ CAUTION. Especially for safety precautions in a repair or maintenance job not described in this manual, receive instructions from a knowledgeable leader.

- Safety marks used in this manual and their meanings are as follows:

⚠ DANGER	**DANGER indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.**
⚠ WARNING	**WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.**
⚠ CAUTION	**CAUTION indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.**

- Any matter marked [NOTICE] in this manual is especially important in servicing. If not observed, the product performance and quality may not be guaranteed.

2. Precaution For Safe Servicing

(A) Service Shop (place)

WARNING

● Place allowing sufficient ventilation

Jobs such as engine running, part welding and polishing the paint with sandpaper should be done in a well-ventilated place.

[Failure to Observe]

Very dangerous for human body due to the possibility of inhaling poisonous gas or dust.

CAUTION

● Sufficiently wide and flat place

The floor space of the service shop for inspection and maintenance should be sufficiently wide and flat without any holes.

[Failure to Observe]

An accident such as a violent fall may be caused.

CAUTION

● Clean, orderly arranged place

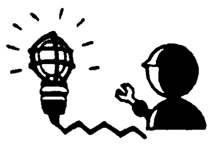
No dust, mud, oil or parts should be left on the floor surface.

[Failure to Observe]

An unexpected accident may be caused.

CAUTION

● Bright, safety illuminated place



The working place should be illuminated sufficiently and safely.

For a job in a dark place where it is difficult to see, use a portable safety lamp.

The bulb should be covered with a wire cage for protection.

[Failure to Observe]

The bulb may be broken accidentally causing ignition of leaking oil.

CAUTION

● Place equipped with a fire extinguisher

Keep a first aid kit and fire extinguisher close at hand in preparation for fire emergencies.

(B) Working Wear

⚠ CAUTION

● Wears for safe operation

Wear a helmet, working clothes, safety shoes and other safety protectors suited to the job. It is especially important to wear well-fitting work clothes.

[Failure to Observe]

A serious accident such as trapping by a machine may occur.

(C) Tools to be Used

⚠ WARNING

● Appropriate holding and lifting

Never operate when the engine is supported with blocks or wooden pieces or only with a jack.
To lift and hold the engine, always use a crane with a sufficient allowance in limit load or a rigid jack.

[Failure to Observe]

A serious accident may occur.

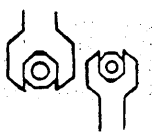
⚠ WARNING

● Use of appropriate tools

Use tools appropriate for the jobs to be done. Use a correctly sized tool for loosening or tightening a machine part.

[Failure to Observe]

A serious injury or engine damage may occur.



(D) Use of Genuine Parts, Oil and Grease

⚠ CAUTION

● Always use genuine parts.

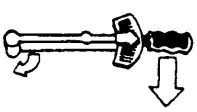
[Failure to Observe]

Shortening of engine life or an unexpected accicdent may arise.

(E) Bolt and Nut Tightening Torque

⚠ WARNING

● Always tighten to the specified torque if designated in the manual.



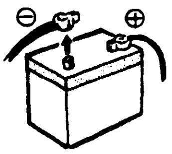
[Failure to Observe]

Loosening or falling may cause parts damage or injury.

(F) Electrical Parts

⚠ WARNING

● Harness short-circuit



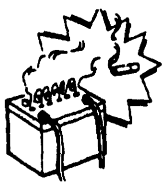
Disconnect the battery negative ⊖ terminal before starting the service job.

[Failure to Observe]

Short-circuiting of a harness may occur to start a fire.

⚠ WARNING

● Battery charging



Since flammable gas is generated during battery charging, keep anything which could cause a fire away from the battery.

[Failure to Observe]

Explosions may occur.

⚠ WARNING

● Battery electrolyte

Since the electrolyte is diluted sulfuric acid, do not let it be splashed onto the clothes or skin.

[Failure to Observe]

The clothes or skin may be burnt.

(G) Waste Treatment

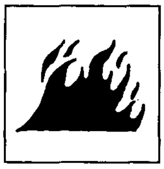
⚠ CAUTION

Observe the following instructions with regard to waste disposal.
Negligence of each instruction will cause environmental pollution.

- Waste fluids such as engine oil and cooling water shall be discharged into a container without spillage onto the ground.
- Do not let waste fluids be discharged into the sewerage, a river or the sea.
- Harmful wastes such as oil, fuel, solvents, filter elements and battery shall be treated according to the respective laws and regulations.
  Ask a qualified collecting company for example.

(H) Handling the Product

⚠WARNING



● Supplying the Fuel

When supplying the fuel, always keep any fire source like a cigarette or match away.

[Failure to Observe]
A fire or explosion may arise.

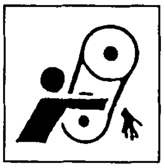
⚠WARNING

● Pay attention to hot portions.

Do not touch the engine during running or immediately after it is stopped.

[Failure to Observe]
Scalding may be caused by a high temperature.

⚠WARNING



● Pay attention to the rotating part.

Never bring clothes or a tool close to the rotating part during engine running.

[Failure to Observe]
Injury may be caused by entrapping.

⚠CAUTION

● Safety Label Check

Pay attention to the product safety label.
A safety label (caution plate) is affixed on the product for calling special attention to safety.
If it is missing or illegible, always affix a new one.

California Proposition 65 Warning

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

California Proposition 65 Warning

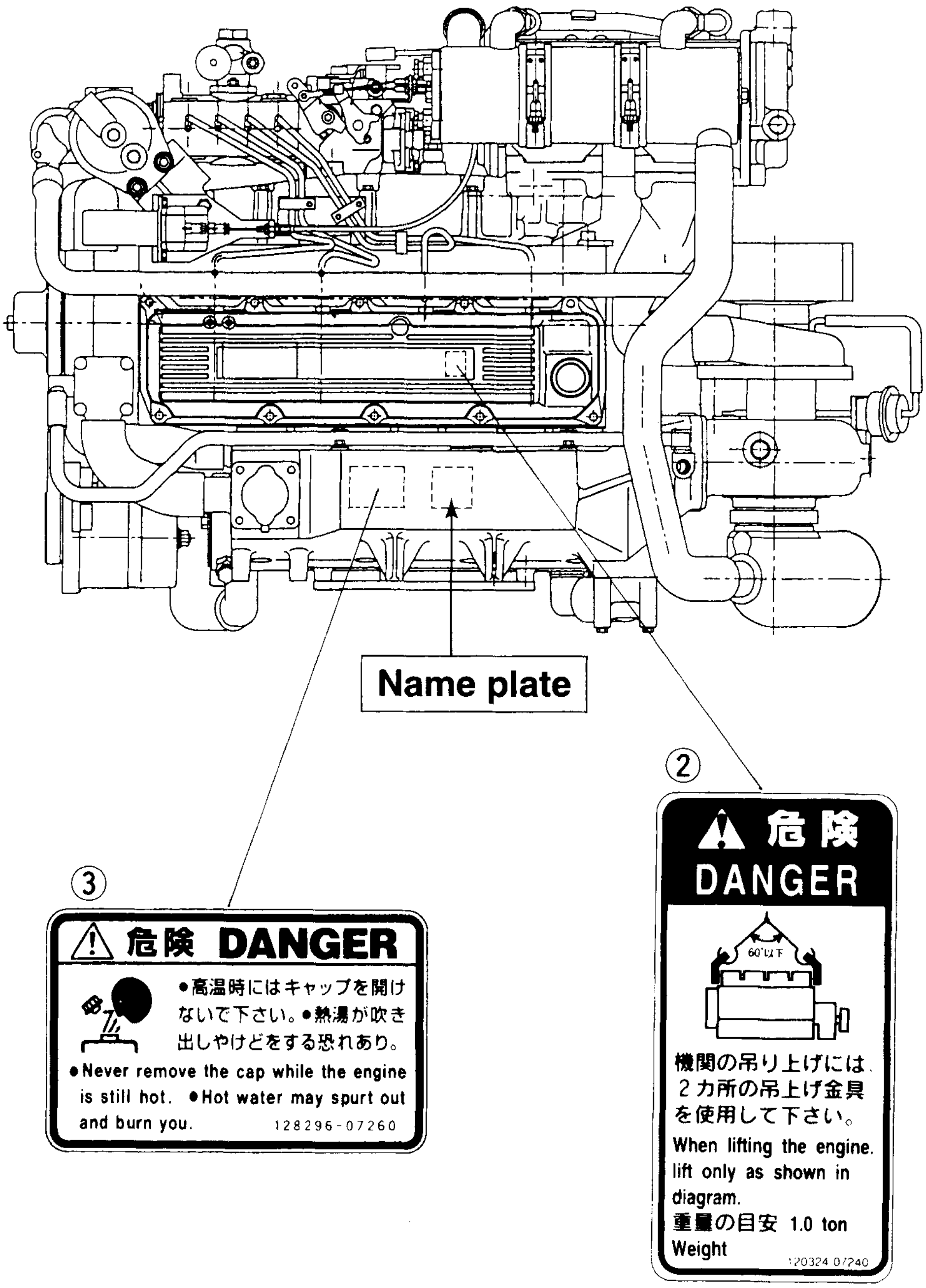
Battery posts, terminals, and related accessories contain lead and lead compounds, chemicals known to the State of California to cause cancer and reproductive harm.

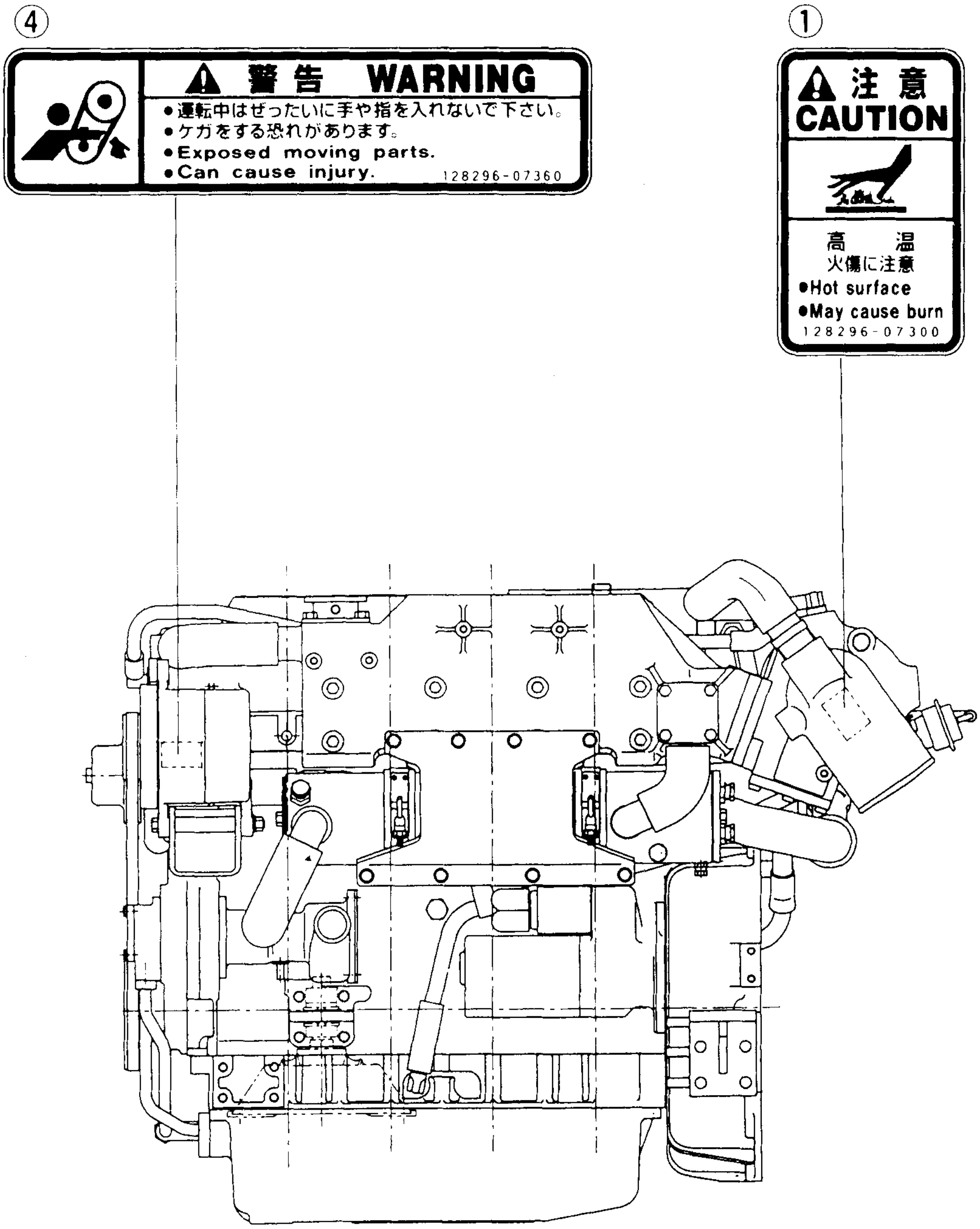
3. Location of Product Safety Labels

To insure safe operation, warning device labels have been attached. Their location is shown in the drawings below and the next page. Keep the labels from becoming dirty or torn and replace them if they are lost or damaged. Also, replace labels when parts are replaced, ordering them in the same way as for the parts

Warning device labels, Parts numbers

No.	Part Code No.
①	128296-07300
②	120324-07240
③	128296-07260
④	128296-07350




④
警告 WARNING
●運転中はぜったいに手や指を入れないで下さい。
●ケガをする恐れがあります。
●Exposed moving parts.
●Can cause injury.
128296-07360
①
注意
CAUTION
高 温
火傷に注意
●Hot surface
●May cause burn
128296-07300

CHAPTER 1

GENERAL

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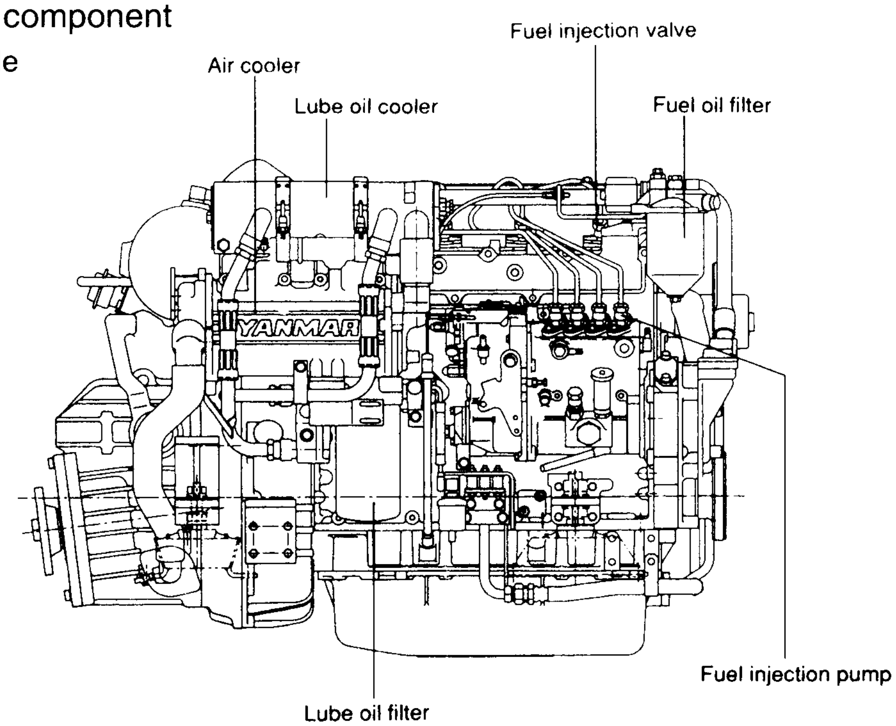
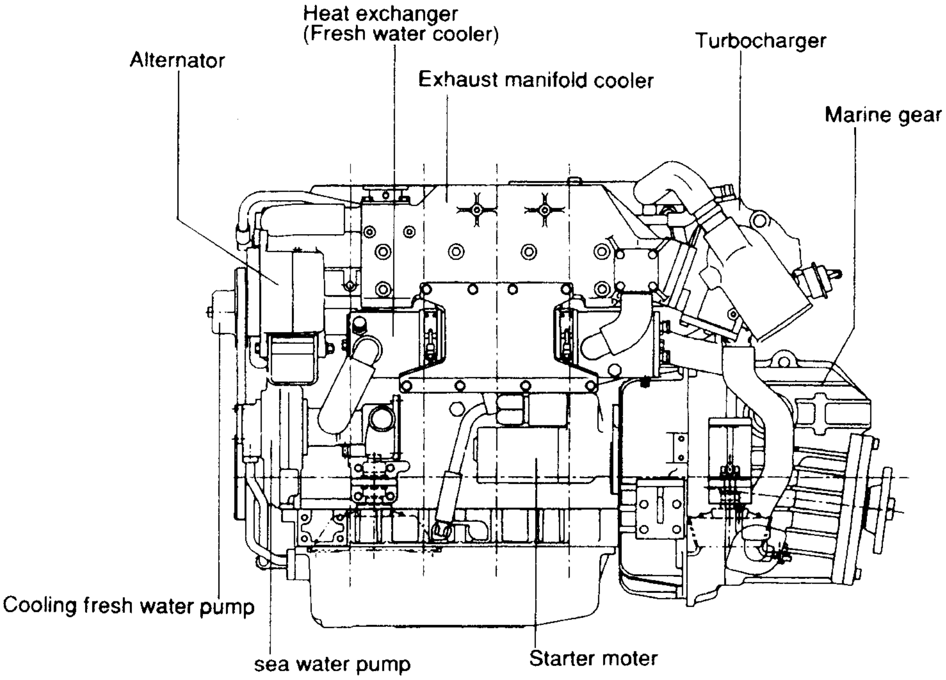
1. Exterior Views

1. Location of component

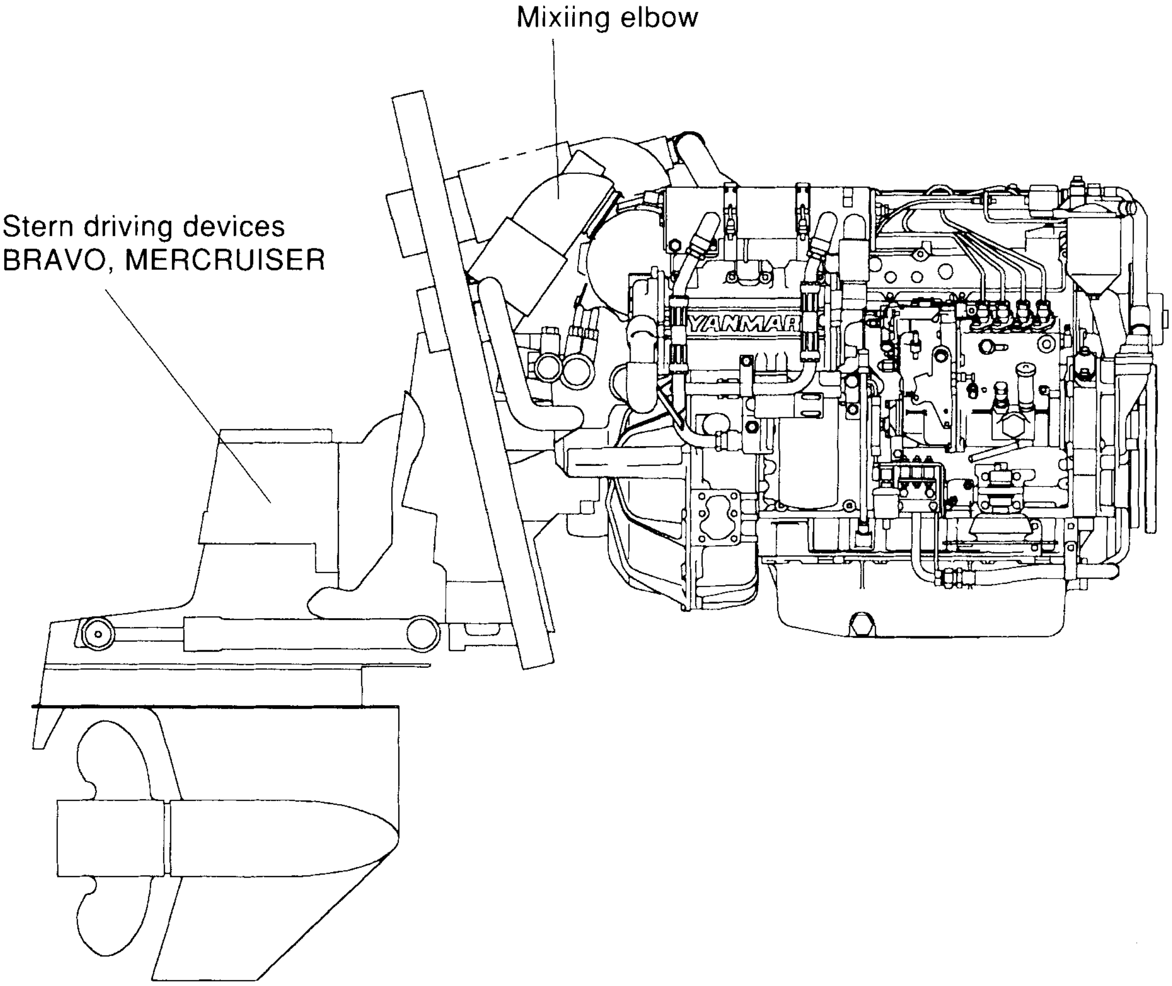
● F. I. Pump side



● Exhaust side

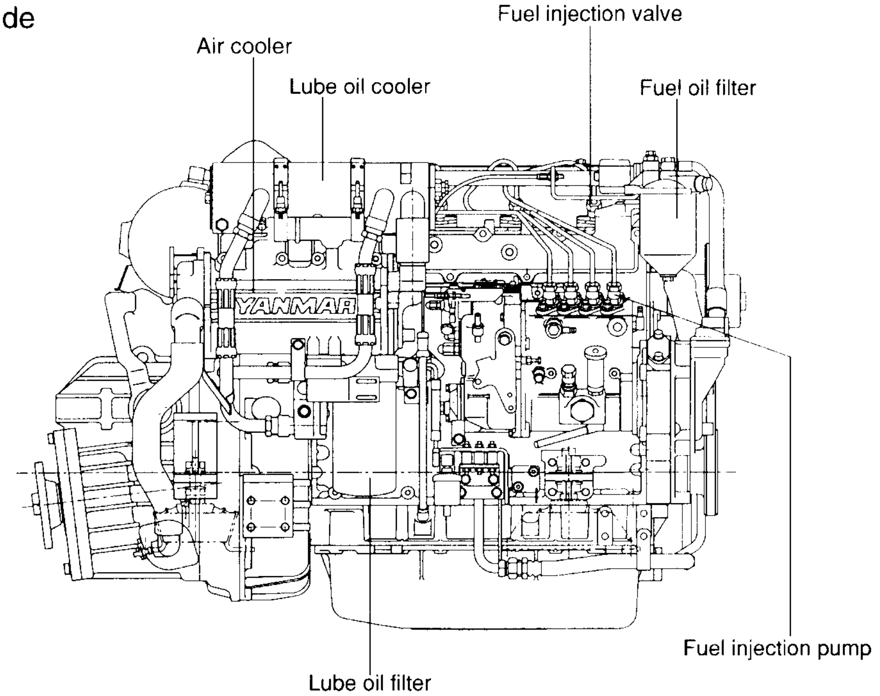


[Note] Above drawings show the 4LHA-STE/STP engines.

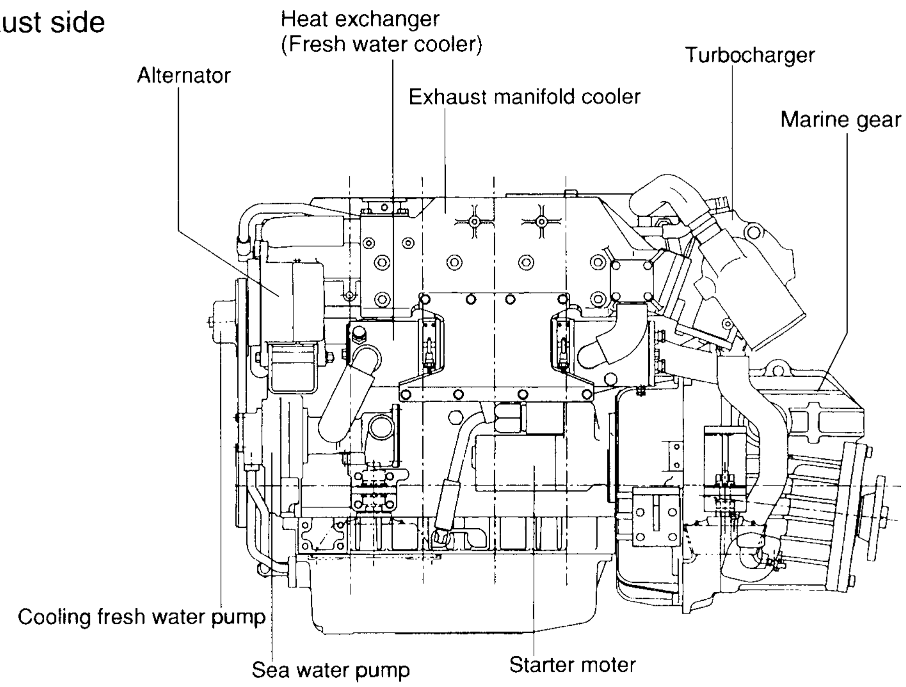


[Note]
Above drawings show the 4LHA-STZE/STZP engines

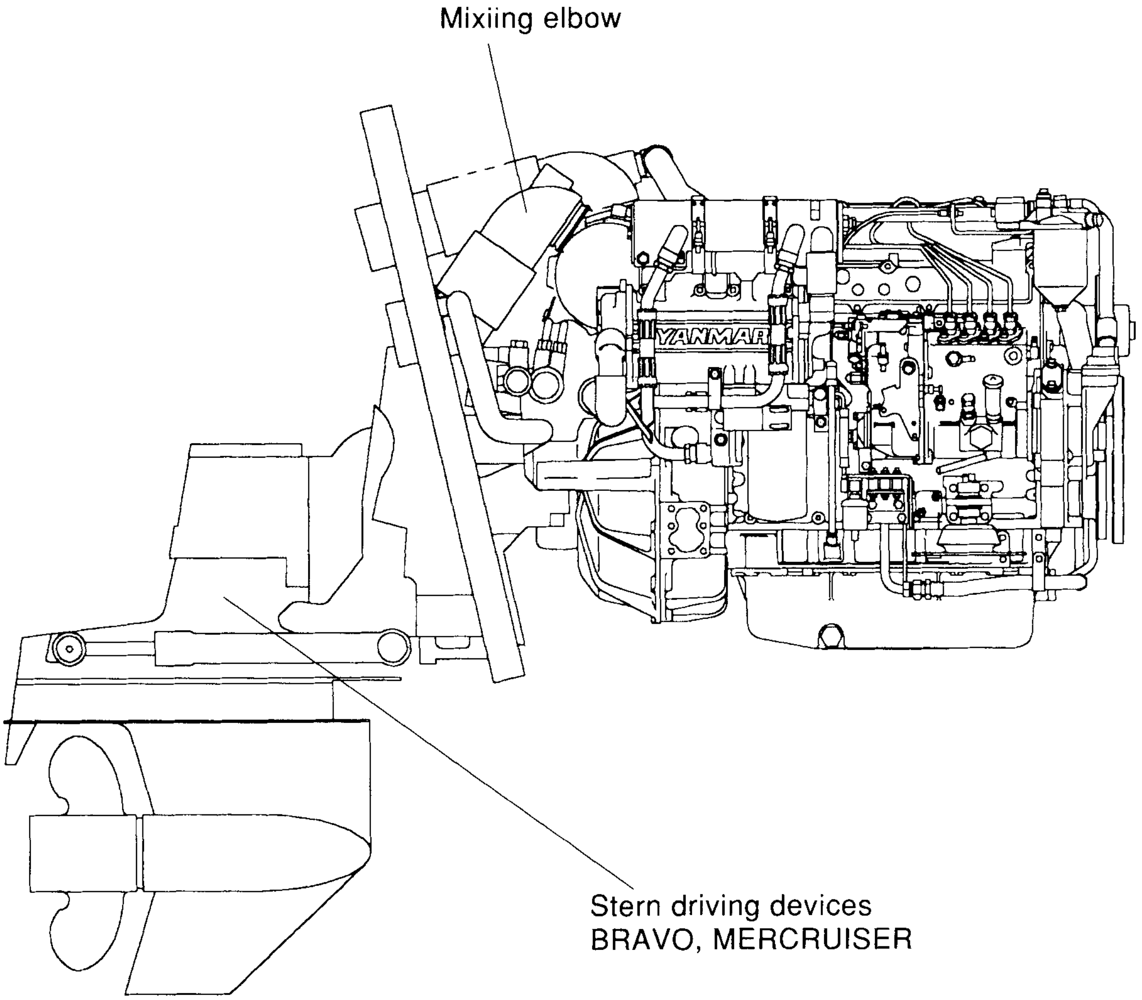
● F. I. Pump side



● Exhaust side

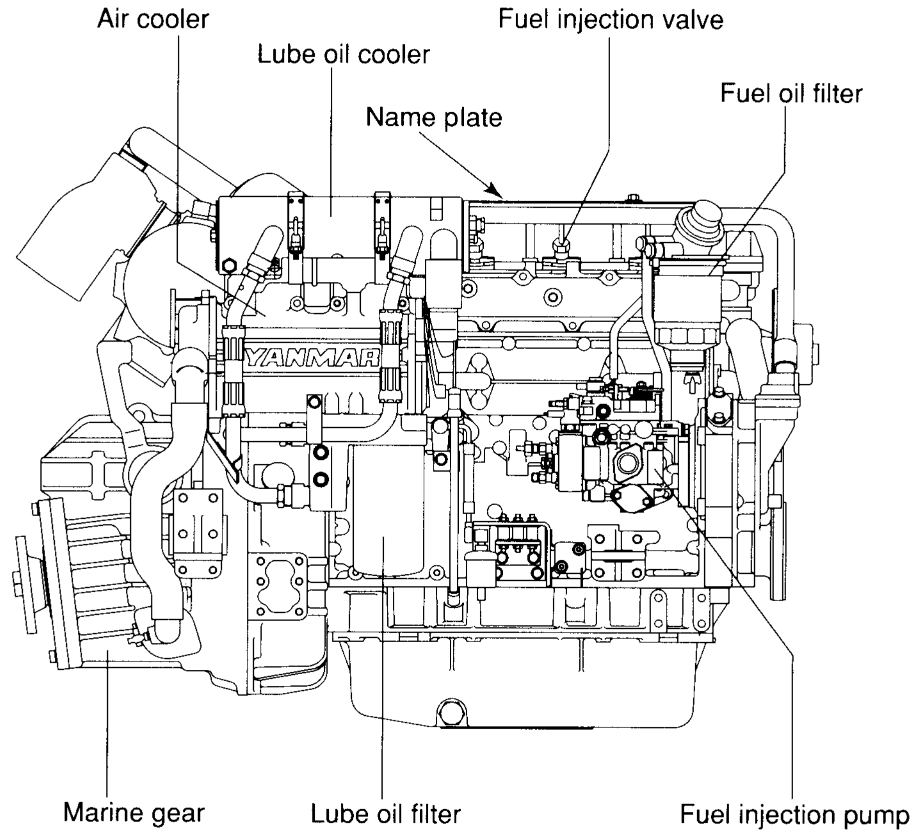


[Note] Above drawings show the 4LHA-DTE/DTP engines.

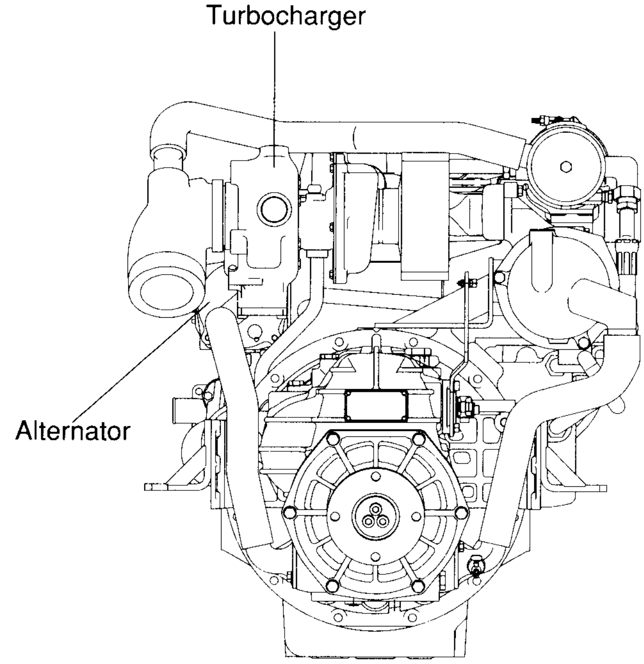


[Note] Above drawings show the 4LHA DTZE/DTZP engines.

● F. I. Pump side

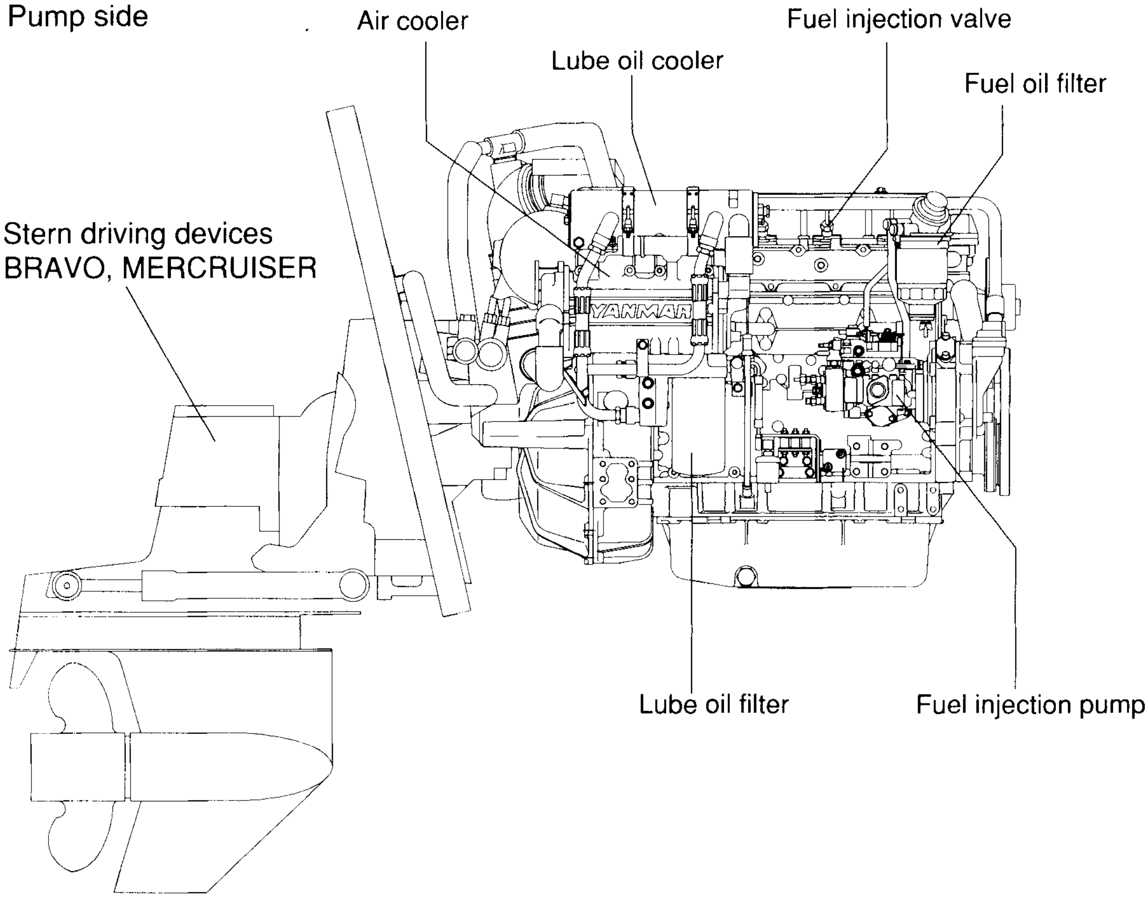


● Clutch side

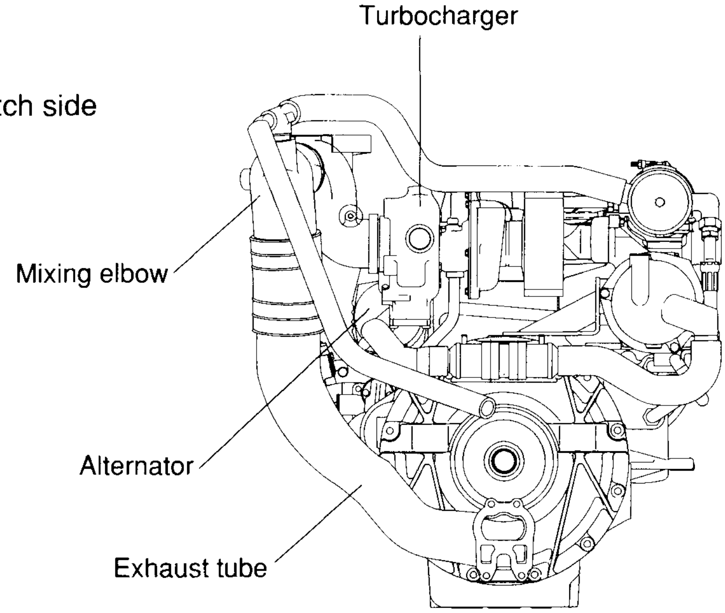


[Note] Above drawings show the 4LHA HTE/HTP engines.

● F. I. Pump side



● Clutch side



[Note] Above drawings show the 4LHA HTZE/HTZP engines.

2. Specifications

Engine Model			4LHA-STZE	4LHA-STE
Type			Vertical 4-cycle water cooled diesel engine	
Combustions system			Direct injection	
Aspiration			Turbocharger with air cooler	
Number of cylinders			4	
Bore×stroke		mm (in.)	100×110(3.94×4.33)	
Displacement		ℓ (cu.in.)	3.455(210.82)	
One hour rating output (DIN6270B)	Output /crankshaft speed	kW/rpm (HP/rpm)	169 ⁄ 3300 (230⁄3300)	
	Brake mean effective pressure	MPa (kgf/cm²)	1.78(18.2)	
	Piston speed	m/sec(ft/sec)	12.10(39.70)	
Continuous rating output (DIN6270A)	Output /crankshaft speed	kW/rpm (HP/rpm)	140⁄3100 (190⁄3100)	
	Brake mean effective pressure	MPa (kgf/cm²)	1.57(16.0)	
	Piston speed	m/sec(ft/sec)	11.0(36.09)	
Compression ratio			15.2	
Fire order			180° 180° 180° 180° 1 - 3 - 4 - 2 - 1	
Fuel injection pump			Inline type, YPES-4AL	
Fuel injection timing (b.T.D.C)		degree	13° ± 1°(FID)	
Fuel injection pressure		MPa (kgf/cm²)	$26.5^{+0.98}_{-0}$ (270^{+10}_{-0})	
Fuel injection nozzles			Hole type model YDLLA-PL	
Direction of rotation	Crankshaft		Counter-clockwise viewed from stem	
	Propeller shaft		Clockwise or counter clockwise	
Power take off			Full power flywheel side	
Cooling system			Fresh water : Centrifugal pump Sea−water : Rubber impeller pump	
Lubrication system			Forced lubrication with trochoid pump (2pump type)	
Starting system	Starting motor		DC 12V,2.5kW	
	AC generator		12V,55A	
Turbo-charger	Type		RHC61W (IHI make)	
	cooling system		Water cooling	
Air cooler System	Type		Sea−water cooled, plate fin type	
Lubricating oil capacity min./max.		ℓ (quart)	5/13(5.29/13.74)	
Cooling water capacity (Fresh water)	Fresh water tank	ℓ (quart)	14(14.8)	
	Sub tank	ℓ (quart)	0.8(0.85)	
Engine lube oil requirment		———	A.P.I CD Class	
Fuel recomended		———	Diesel fuel Cetane value :over 45	
Fresh water capacity		ℓ (quart)	Engine:15 Sub tank:0.8	
Idle speed Low/High		rpm	750/3700	

<table>
<tr><td colspan="3">Engine Model</td><td colspan="3">4LHA-STZE</td><td>4LHA-STE</td></tr>
<tr><td rowspan="5">Marine gear system</td><td colspan="2" rowspan="2">Model</td><td colspan="3">MERCRUSER</td><td rowspan="2">HURTH-HSW630A1</td></tr>
<tr><td>Bravo 1</td><td>Bravo 2</td><td>Bravo 3</td></tr>
<tr><td colspan="2">Reduction(Forward／Reverse)</td><td>1.36/1.36
1.50/1.50
1.65/1.65</td><td>1.50/1.50
1.65/1.65
1.81/1.81
2.00/2.00</td><td>1.36/1.36
1.50/1.50
1.65/1.65
1.81/1.81
2.00/2.00</td><td>1.22/1.21
1.56/1.58
2.04/2.10
2.52/2.53</td></tr>
<tr><td colspan="2">Lube oil requirment</td><td colspan="3">Qick silver high-performance gear lube</td><td>ATF II -D</td></tr>
<tr><td>Lubricating oil capacity min/max</td><td>ℓ (quart)</td><td>2.0(2.11)</td><td>3.0(3.17)</td><td>2.0(2.11)</td><td>-/3.0(-/3.17)</td></tr>
<tr><td></td><td>Clutch Mass</td><td>kg(lb)</td><td>88(184)</td><td>94(207)</td><td>98(216)</td><td>44(97)</td></tr>
<tr><td rowspan="3">Dimensions</td><td>Overall length</td><td>mm(in.)</td><td colspan="3">1039(40.9)</td><td>1059(41.7)</td></tr>
<tr><td>Overall width</td><td>mm(in.)</td><td colspan="3">714(28.1)</td><td>686(27.0)</td></tr>
<tr><td>Overall height</td><td>mm(in.)</td><td colspan="3">782(30.8)</td><td>741(29.2)</td></tr>
<tr><td colspan="2">Engine mass with clutch(dry)</td><td>kg(lb)</td><td>473(1043)</td><td>479(1056)</td><td>483(1065)</td><td>410(904)</td></tr>
</table>

Engine model		4LHA-STP	4LHA-STZP
Type		Vertical water cooled 4-cycle diesel engine	
No. of cylinders		4	
Bore × Stroke mm		100×110	
Displacement ℓ		3.455	
Fuel stop power at crankshaft kw(hp)/rpm		*177 (240) / 3300 **169 (230) / 3300	
Cont. power at crankshaft. kw(hp)/rpm		140 / (190) / 3100	
High idling rpm		3700 ± 25	
Low idling rpm		750 ± 25	
Combustion system		Direct injection	
Starting system		Electric starting (12V-2.5kW)	
Charging system kg		Regulator built in Alternator DC12V-55A	
Cooling system		Constant high temperature fresh water cooling (2 systems : sea & fresh water)	
Lubrication system		Forced lubrication system with trochoidal gear pump	
Direction of rotation		Counter-clockwise (viewed from flywheel side)	
Lube oil capacity	All ℓ	13.0	
	Oil pan ℓ	10.0	
Cooling water capacity ℓ		15 (Engine) , 0.8 (Sub-tank)	
Turbocharger	Model	RHC61W (IHI made)	
	Type	Water cooled turbine housing	
Dimensions (L×W×H) (gear less) mm		1001×686×741	1039×714×782
Dry mass (gear less) kg		365	385
Recommended battery capacity		12V×120Ah	
Recommended type of remote control handle		Single lever type only	
Engine installation style		On the flexible engine mount	

(Note) 1. Rating condition : ISO 3046-1, 8665 2. 1hp = 0.7355 kW
3. Fuel condition : Density at 15℃ = 0.860, Fuel oil temperature *: 25℃ at the fuel injection pump inlet
**: ISO 8665 (Fuel oil temp. 40℃ at the fuel injection pump inlet)

• Marine gear (Option)

Model	HURTH HSW630A1	MERCRUISER		
		Bravo X-1	Bravo X-2	Bravo X-3
Type	8° down Hydraulic	Stern drive		
Available engine	4LHA-STP	4LHA-STZP		
Reduction ratio HSW630A1 : Ahead/Astern Bravo X-1,2,3 : Both Ahead and Astern	1.22/1.21	1.36	1.50	1.36
	1.56/1.58	1.50	1.65	1.50
	2.04/2.10	1.65	1.81	1.65
	2.52/2.53		2.00	1.81
			2.20	2.00
				2.20
For further detail, refer to the maker's manual				

			4LHA-DTZE	4LHA-DTE
Engine Model			4LHA-DTZE	4LHA-DTE
Type			Vertical 4-cycle water cooled diesel engine	
Combustions system			Direct injection	
Aspiration			Turbocharger with air cooler	
Number of cylinders			4	
Bore×stroke		mm (in.)	100×110(3.94×4.33)	
Displacement		ℓ (cu.in.)	3.455(210.82)	
One hour rating output (DIN6270B)	Output /crankshaft speed	kW/rpm (HP/rpm)	140 ／ 3300 (190／3300)	
	Brake mean effective pressure	MPa (kgf/cm²)	1.47 (15.0)	
	Piston speed	m/sec(ft/sec)	12.10(39.70)	
Continuous rating output (DIN6270A)	Output /crankshaft speed	kW/rpm (HP/rpm)	116／3100 (158／3100)	
	Brank mean effective pressure	MPa (kgf/cm²)	1.29 (13.2)	
	Piston speed	m/sec(ft/sec)	11.0(36.09)	
Compression ratio			15.8	
Fire order			180° 180° 180° 180° 1 － 3 － 4 － 2 － 1	
Fuel injection pump			Inline type, YPES-4AL	
Fuel injection timing (b.T.D.C)		degree	12° ± 1°(FID)	
Fuel injection pressure		MPa(kgf/cm²)	$24.5^{+0.98}_{0}$ (250^{+10}_{0})	
Fuel injection nozzles			Hole type model YDLLA-PL	
Direction of rotation	Crankshaft		Counter-clockwise viewed from stem	
	Propeller shaft		Clockwise or counter clockwise	
Power take off			Full power flywheel side	
Cooling system			Fresh water : Centrifugal pump Sea－water : Rubber impeller pump	
Lubrication system			Forced lubrication with trochoid pump (2pump type)	
Starting system	Starting motor		DC 12V,2.5kW	
	AC generator		12V,80A	
Turbo-charger	Type		RHC61W (IHI make)	
	cooling system		Water cooling	
Air cooler System	Type		Sea－water cooled, plate fin type	
Lubricating oil capacity min./max.		ℓ (quart)	5/13(5.29/13.74)	
Cooling water capacity (Fresh water)	Fresh water tank	ℓ (quart)	15(15.9)	
	Sub tank	ℓ (quart)	0.8(0.85)	
Engine lube oil requirement		——	A.P.I CD Class	
Fuel recomended		——	Diesel fuel Cetane value :over 45	
Idle speed Low/High		rpm	750/3700	

Engine Model			4LHA-DTZE			4LHA-DTE
Marine gear system	Model		MERCRUSER			HURTH-HSW450A2
			Bravo 1	Bravo 2	Bravo 3	
	Reduction（Forward／Reverse）		1.36/1.36 1.50/1.50 1.65/1.65	1.50/1.50 1.65/1.65 1.81/1.81 2.00/2.00	1.36/1.36 1.50/1.50 1.65/1.65 1.81/1.81 2.00/2.00	1.26/1.26 1.51/1.51 2.03/2.03 2.43/2.43
	Lube oil requirment		Qick silver high-performance gear lube			ATF Ⅱ-D
	Lubricating oil capacity min/max	ℓ (quart)	2.0(2.11)	3.0(3.17)	2.0(2.11)	2.0(2.11)
	Clutch Mass	kg(lb)	88(184)	94(207)	98(216)	28(61.7)
Dimensions	Overall length	mm(in.)	1039(40.9)			937(36.9)
	Overall width	mm(in.)	787(31.0)			686(27.0)
	Overall height	mm(in.)	830(32.7)			741(29.2)
Engine mass with clutch(dry)		kg(lb)	476(1049)	388(855)	388(855)	398(877.4)

Engine model		4LHA-DTP	4LHA-DTZP
Type		Vertical water cooled 4-cycle diesel engine	
No. of cylinders		4	
Bore × Stroke mm		100×110	
Displacement		3.455	
Fuel stop power at crankshaft kw(hp)/rpm		*147 (200) / 3300 **140 (190) / 3300	
Cont. power at crankshaft. kw(hp)/rpm		116 / (158) / 3100	
High idling rpm		3700 ± 25	
Low idling rpm		750 ± 25	
Combustion system		Direct injection	
Starting system		Electric starting (12V-2.5kW)	
Charging system		Regulator built in Alternator DC12V-55A	
Cooling system		Constant high temperature fresh water cooling (2 systems : sea & fresh water)	
Lubrication system		Forced lubrication system with trochoidal gear pump	
Direction of rotation (crankshaft)		Counter-clockwise (viewed from flywheel side)	
Lube oil capacity	All	13.0	
	Oil pan	10.0	
Cooling water capacity		15 (Engine), 0.8 (Sub-tank)	
Turbocharger	Model	RHC61W (IHI made)	
	Type	Water cooled turbine housing	
Dimension (L×W×H) (gear less) mm		937×686×741	1039×787×830
Dry mass (gear less) kg		365	388
Recommended battery capacity		12V×120Ah	
Recommended type of remote control handle		Single lever type only	
Engine installation style		On the flexible engine mount	

(Note) 1. Rating condition : ISO 3046-1, 8665 2. 1hp = 0.7355 kW
3. Fuel condition : Density at 15℃ = 0.860, Fuel oil temperature *: 25℃ at the fuel injection pump inlet
**: ISO 8665 (Fuel oil temp. 40℃ at the fuel injection pump inlet)

• Marine gear (Option)

Model	HURTH HSW450A2	MERCRUISER		
		Bravo X-1	Bravo X-2	Bravo X-3
Type	8° down Hydraulic	Stern drive		
Available engine	4LHA-DTP	4LHA-DTZP		
Reduction ratio (Both ahead and astern)	1.26	1.36	1.50	1.36
	1.51	1.50	1.65	1.50
	2.03	1.65	1.81	1.65
	2.43		2.00	1.81
			2.20	2.00
				2.20
For further detail, refer to the maker's manual				

Engine Model		4LHA-HTZE	4LHA-HTE
Type		Vertical 4-cycle water cooled diesel engine	
Combustion system		Direct injection	
Aspiration		Turbocharger with air cooler	
Number of cylinders		4	
Bore×stroke	mm (in.)	100×110(3.94×4.33)	
Displacement	ℓ (cu.in.)	3.455(210.82)	
One hour rating output (DIN6270B) — Output/ crankshaft speed	kW/rpm (HP/rpm)	110 ⁄ 3300 (150⁄3300)	
One hour rating output (DIN6270B) — Brake mean effective pressure	MPa (kgf/cm^2)	1.16 (11.8)	
One hour rating output (DIN6270B) — Piston speed	m/sec. (ft/sec.)	12.10(39.70)	
Continuous rating output (DIN6270A) — Output/ crankshaft speed	kW/rpm (HP/rpm)	91.2/3100 (124/3100)	
Continuous rating output (DIN6270A) — Brake mean effective pressure	MPa (kgf/cm^2)	1.02 (10.4)	
Continuous rating output (DIN6270A) — Piston speed	m/sec. (ft/sec.)	11.4 (37.4)	
Compression ratio		16.2	
Fire order		1 —(180°)— 3 —(180°)— 4 —(180°)— 2 —(180°)— 1	
Fuel injection pump		Distributor type, VE-HDI	
Fuel injection timing (b.T.D.C)	degree	6° ± 1°(FIT)	
Fuel injection pressure	MPa (kgf/cm^2)	$20.6^{+0.98}_{-0}$ (210^{+10}_{-0})	
Fuel injection nozzles		Hole type model YDLLA-P	
Direction of rotation — Crankshaft		Counter-clockwise viewed from stem	
Direction of rotation — Propeller shaft		Clockwise or counter clockwise	
Power take off		Full power flywheel side	
Cooling system		Fresh water : Centrifugal pump Sea-water: Rubber impeller pump	
Lubrication system		Forced lubrication with trochoid pump	
Starting system — Starting motor		DC 12V,2.5kW	
Starting system — AC generator		12V,80A	
Turbo-charger — Type		RHC 61W (IHI make)	
Turbo-charger — Cooling system		Water cooling	
Air cooler System — Type		Sea-water cooled, plate fin type	
Lubricating oil capacity min./max.	ℓ (quart)	5/13(5.29/13.74)	
Cooling water capacity (Fresh water) — Fresh water tank	ℓ (quart)	14(14.8)	
Cooling water capacity (Fresh water) — Sub tank	ℓ (quart)	0.8(0.85)	
Engine lube oil requirment	——	A.P.I CD Class	
Fuel recomended	——	Diesel fuel Cetane value :over 45	
Fresh water capacity	ℓ (quart)	Engine:15 Sub tank:0.8	
Idle speed Low/High	rpm	750/3700	

Engine Model			4LHA-HTZE			4LHA-HTE	
Marine gear system	Model		MERCRUSER			HURTH-HSW450A2	KM5A
			Bravo 1	Bravo 2	Bravo 3		
	Reduction (Forward /Reverse)		1.36/1.36 1.50/1.50 1.65/1.65	1.50/1.50 1.65/1.65 1.81/1.81 2.00/2.00	1.36/1.36 1.50/1.50 1.65/1.65 1.81/1.81 2.00/2.00	1.26/1.26 1.51/1.51 2.03/2.03 2.43/2.43	2.57/2.57 2.07/2.07 1.46/1.46
	Lubricating oil capacity min/max	ℓ (quart)	2.9 (3.1)	3.7 (3.9)	2.9 (3.1)	2.0 (2.11)	2.1/1.8 (2.2)(1.9)
	Clutch Mass	kg	88	94	98	28	48
Dimensions	Overall length	mm (in.)	1039(40.9)			937(36.9)	1058(41.65)
	Overall width	mm (in.)	756(29.76)			686(27.0)	681(26.81)
	Overall height	mm (in.)	830(32.7)			741(29.2)	741(29.17)
Engine mass with clutch (dry)		kg	476	482	486	388	408

Engine model		4LHA-HTP	4LHA-HTZP
Type		Vertical water cooled 4-cycle diesel engine	
No. of cylinders		4	
Bore × Stroke mm		100×110	
Displacement		3.455	
Fuel stop power at crankshaft kw(hp)/rpm		*118 (160) / 3300 **113 (154) / 3300	
Cont. power at crankshaft. kw(hp)/rpm		91.2 / (124) / 3100	
High idling rpm		3700 ± 25	
Low idling rpm		750 ± 25	
Combustion system		Direct injection	
Starting system		Electric starting (12V-2.5kW)	
Charging system		Regulator built in Alternator DC12V-55A	
Cooling system		Constant high temperature fresh water cooling (2 systems : sea & fresh water)	
Lubrication system		Forced lubrication system with trochoidal gear pump	
Direction of rotation (crankshaft)		Counter-clockwise (viewed from flywheel side)	
Lube oil capacity	All	13.0	
	Oil pan	10.0	
Cooling water capacity		15 (Engine) , 0.8 (Sub-tank)	
Turbocharger	Model	RHC61W (IHI made)	
	Type	Water cooled turbine housing	
Dimensions (L×W×H) (gear less) mm		937×681×741	1039×777×830
Dry mass (gear less) kg		360	388
Recommended battery capacity		12V×120Ah	
Recommended type of remote control handle		Single lever type only	
Engine installation style		On the flexible engine mount	

(Note) 1. Rating condition : ISO 3046-1, 8665 2. 1hp = 0.7355 kW
3. Fuel condition : Density at 15°C = 0.860, Fuel oil temperature *: 25°C at the fuel injection pump inlet
**: ISO 8665 (Fuel oil temp. 40°C at the fuel injection pump inlet)

• Marine gear (Optional)

Model	HURTH HSW450A2	MERCRUISER Bravo X-1	MERCRUISER Bravo X-2	MERCRUISER Bravo X-3
Type	8° down Hydraulic	Stern drive		
Available engine	4LHA-HTP	4LHA-HTZP		
Reduction ratio (Both ahead and astern)	1.26	1.36	1.50	1.36
	1.51	1.50	1.65	1.50
	2.03	1.65	1.81	1.65
	2.43		2.00	1.81
			2.20	2.00
				2.20
For further detail, refer to the maker's manual				

3.Service Standards

		4LHA-STE,-DTE,-HTE
Normal Lub. Oil press. At Max. output	MPa(kgf/cm2)	0.34~0.44(3.5~4.5)
Valve clearance in/Ex.	mm	0.1/0.5
Fuel injection timing	deg.	b.T.D.C.12
Fuel injection pressure	MPa(kgf/cm2)	$24.5^{+0.98}_{0}$ (250^{+10}_{0})

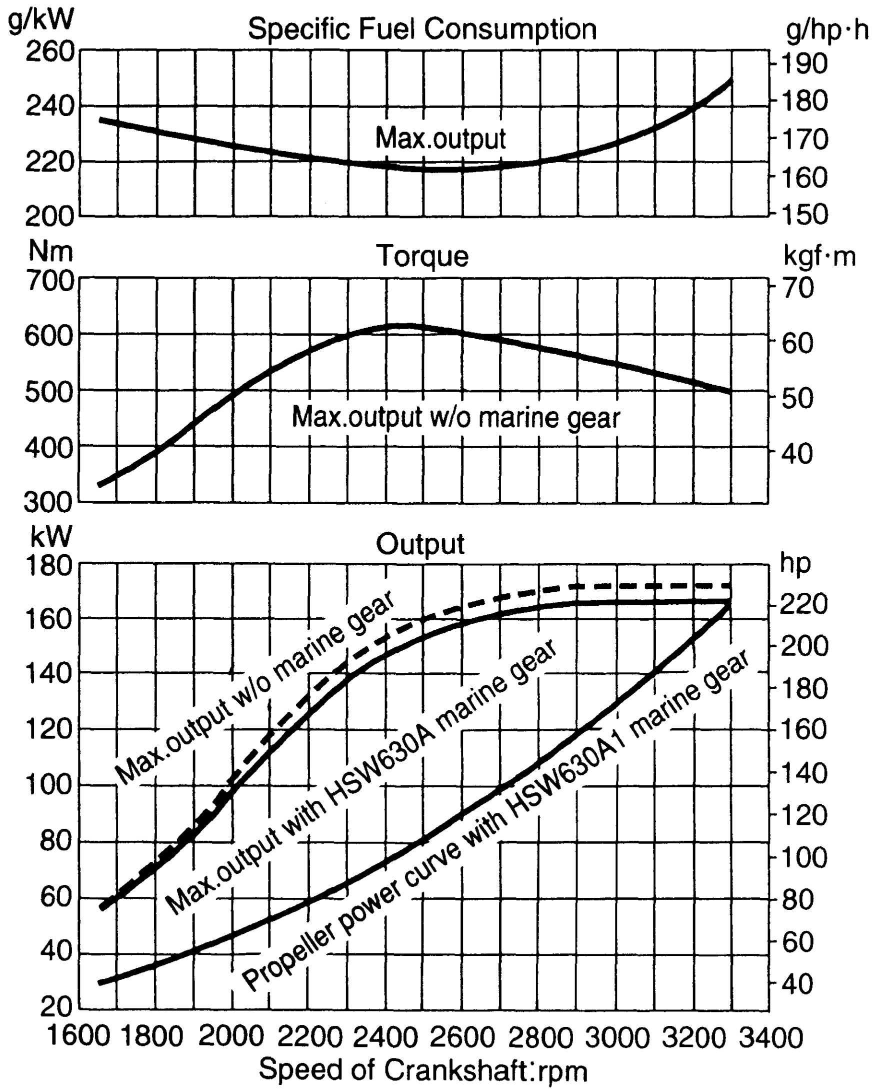
Tightening torque of bolts and nuts

Unit:N(kgf)·m

	Bolt & Nut size	Tightening Torque	Wrench
		4LHA-STE,-DTE,HTE	
Cylinder head bolt	M13×1.5	1st:108(11) 2nd:167(17) 3rd:186(19)	17mm
Connecting rod bolt	M11×1.0	113~123(11.5~12.5)	17mm
Main bearing cap bolt	M14×1.5	186~206(19~21)	19mm
Crank shaft V-pulley clamp bolt	M14×1.5	108~127(11~13)	——
Flywheel clamp bolt	M14×1.5	186~206(19~21)	——
Fuel injection nozzle clamp nut	M6×1.0	5.9~6.9(0.6~0.7)	——
Fuel injection driving gear,clamp nut	M14×1.5	——	
	M18×1.5	118~137(12~14)	——

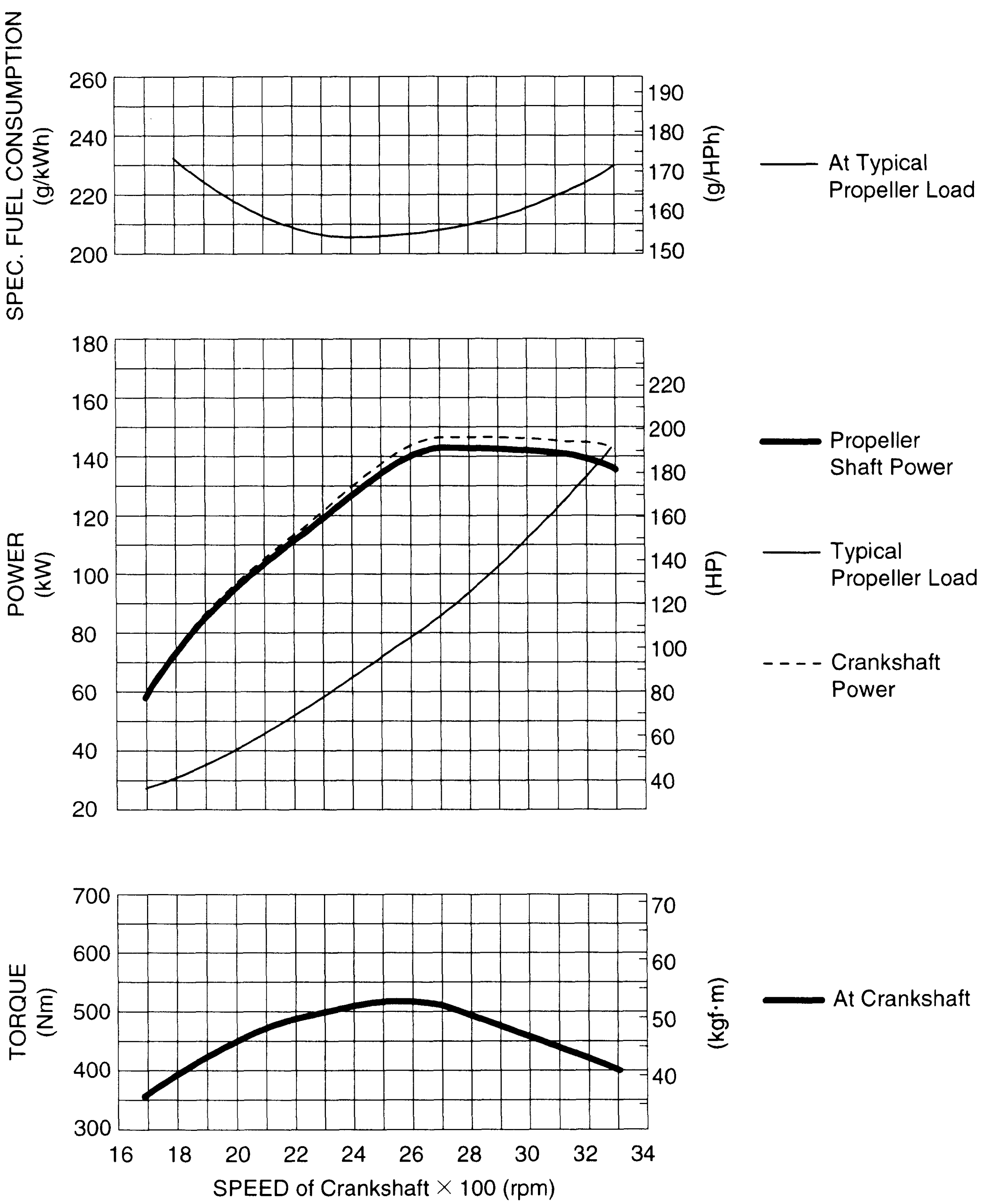
4. Performance Curve

4LHA-STE



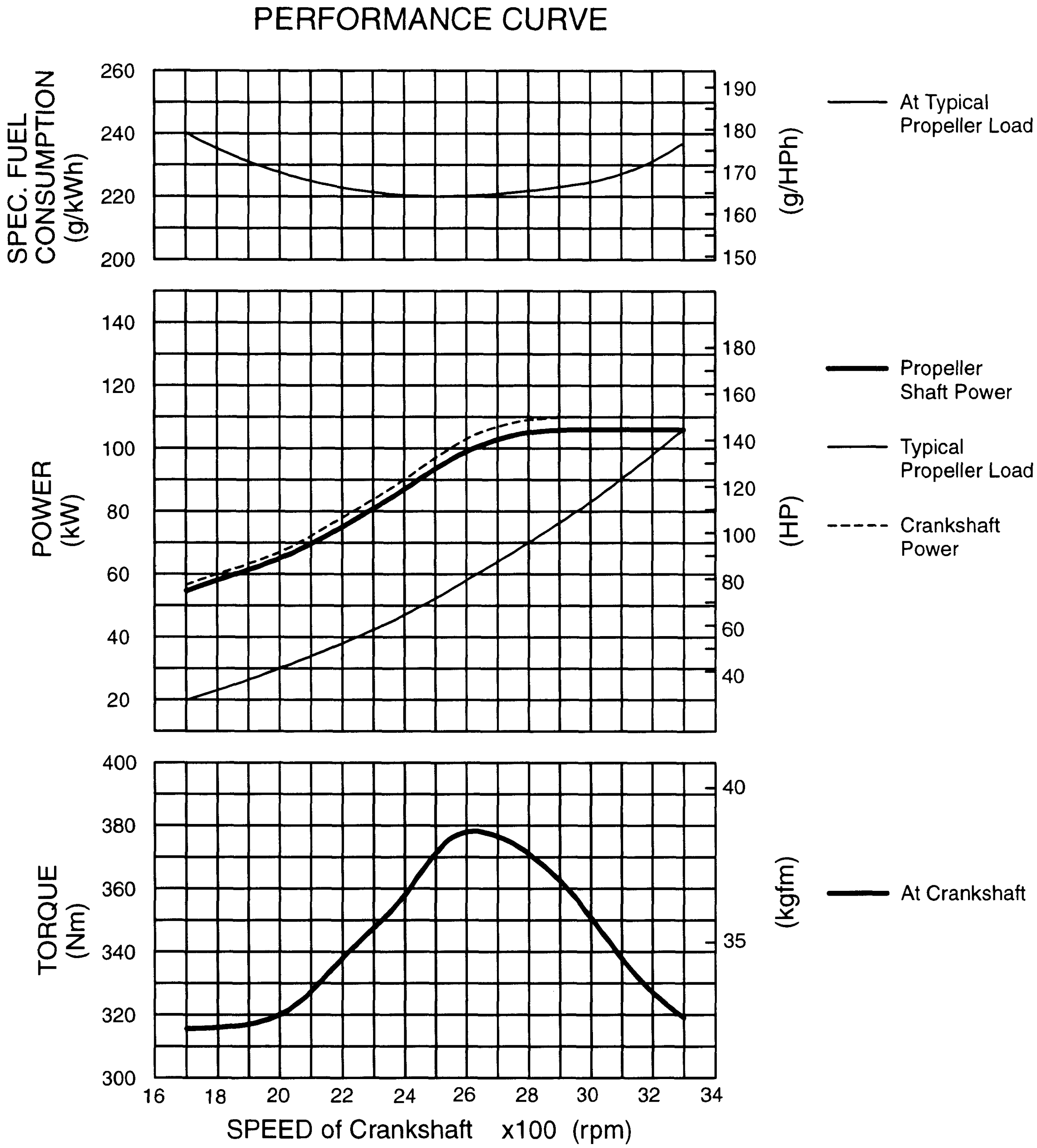
Note:Above data are measured at crankshaft and show the averege performance as tested at our laboratory.

4LHA-DTE



Note:Above data are measured at crankshaft and show the averege performance as tested at our laboratory.

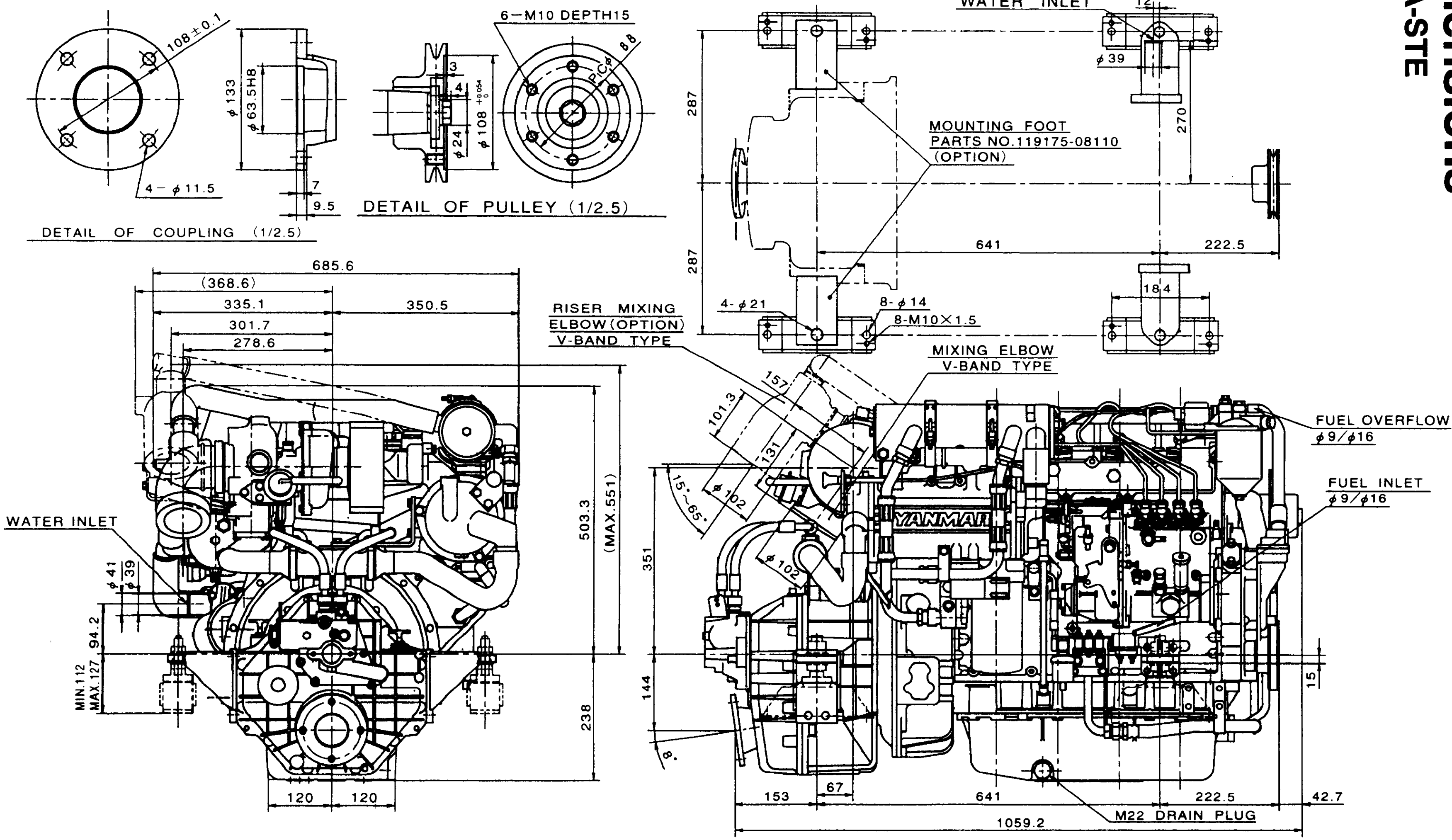
4LHA-HTE



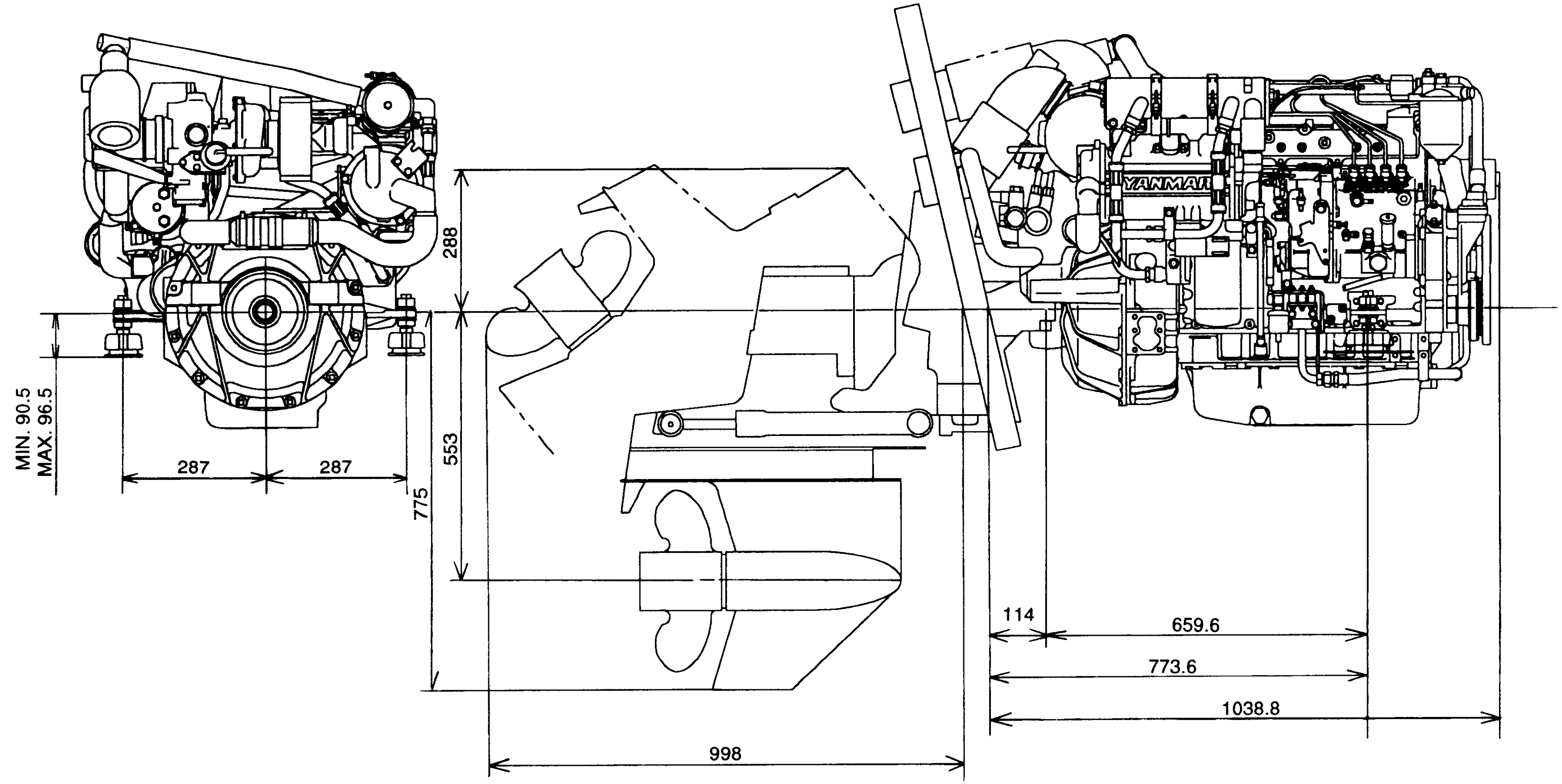
[Note] Above data are mesuned at crankshaft and show the averege performance as testedat our laboratoly.

5. Dimensions
4LHA-STE

Example of setup with HSW630A1 Hurth marine gear/



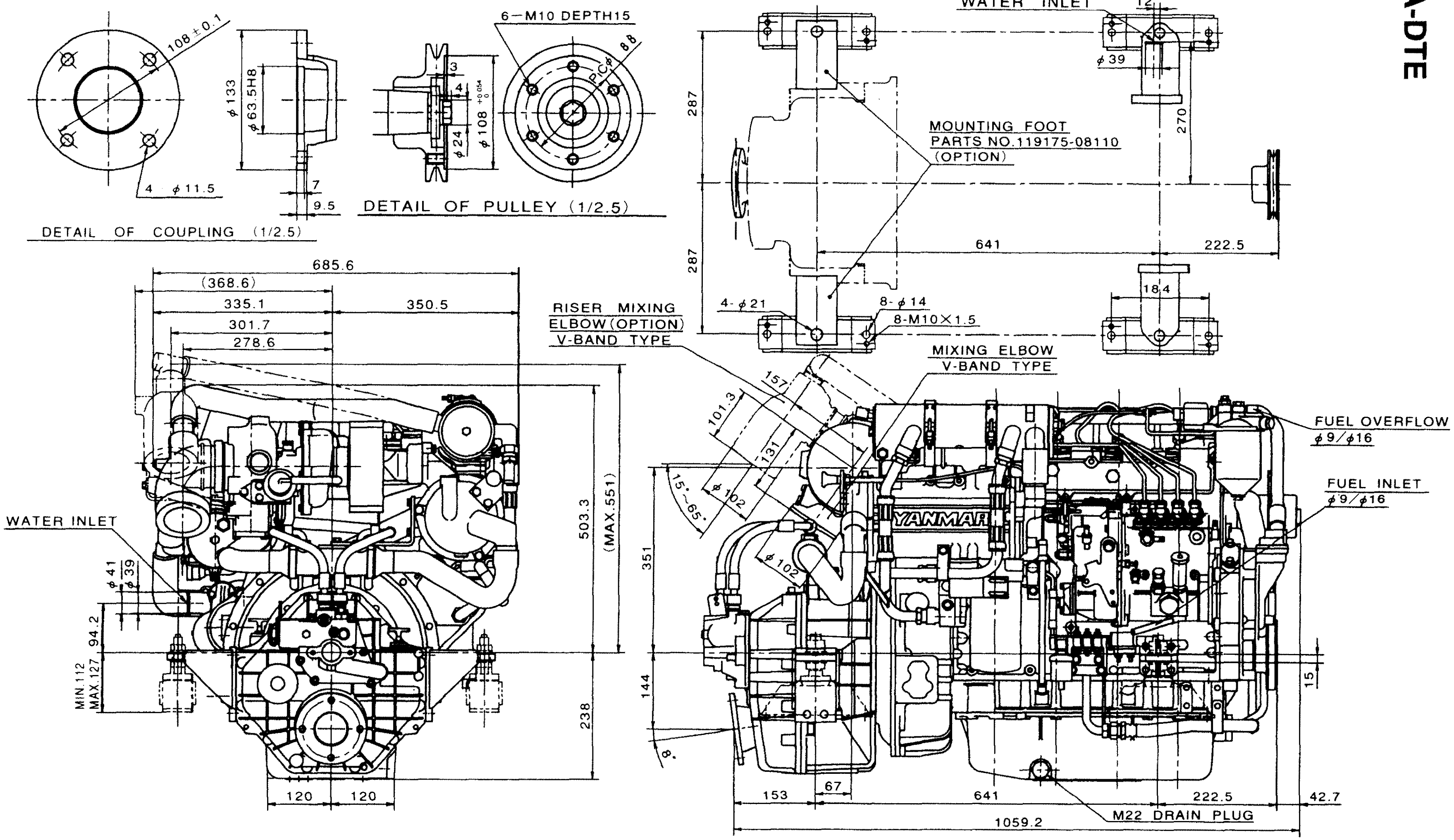
4LHA-STZE



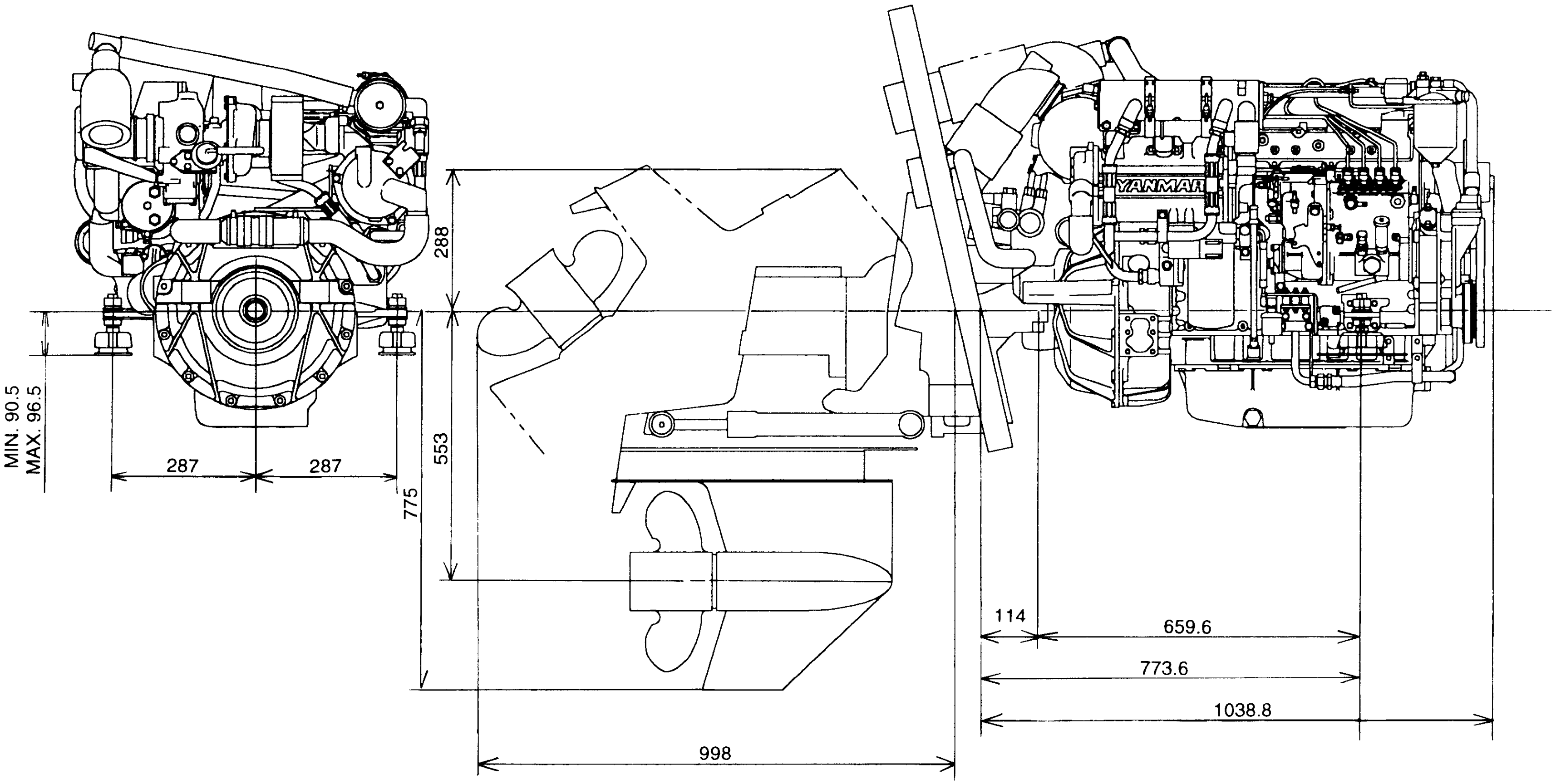
[NOTE] Dimensions of the engine are the same with 4LHA-STE

4LHA-DTE

Example of setup with HSW450A2 Hurth marine gear/



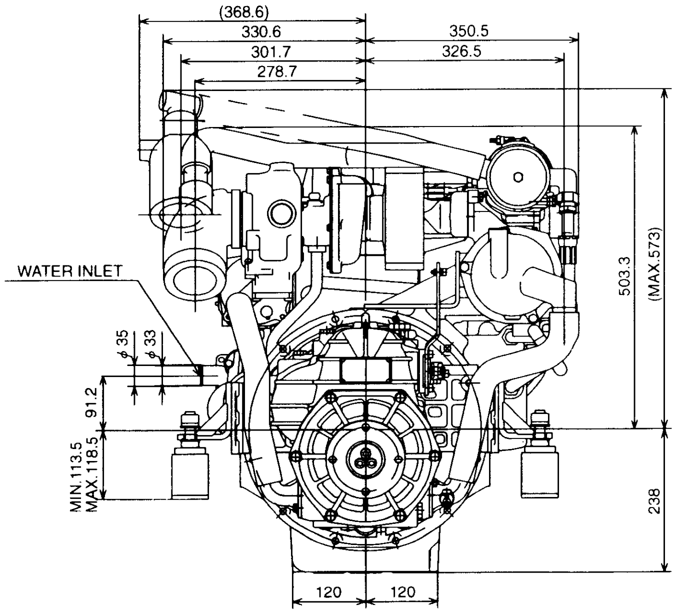
4LHA-DTZE

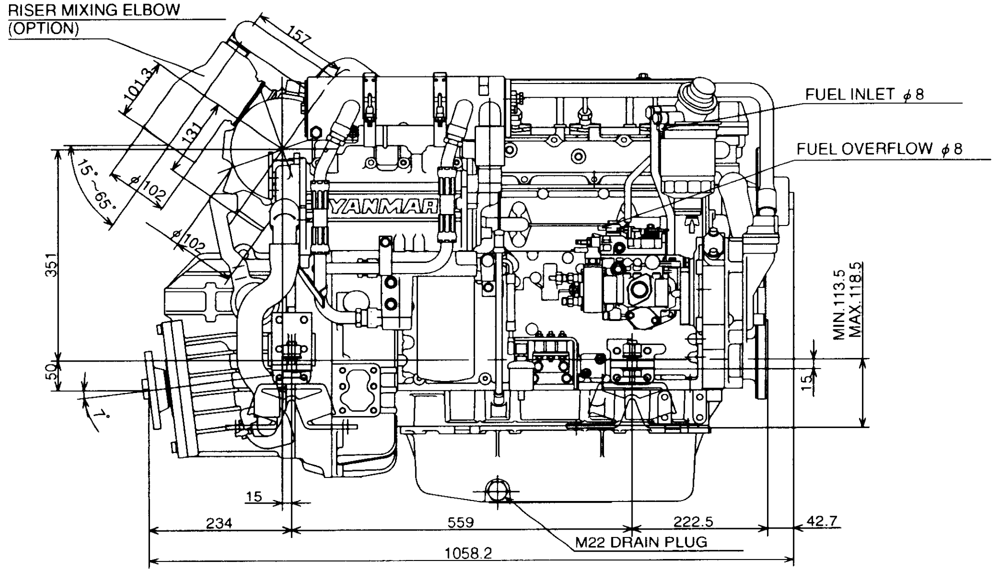


[NOTE] Dimensions of the engine are the same with 4LHA-DTE

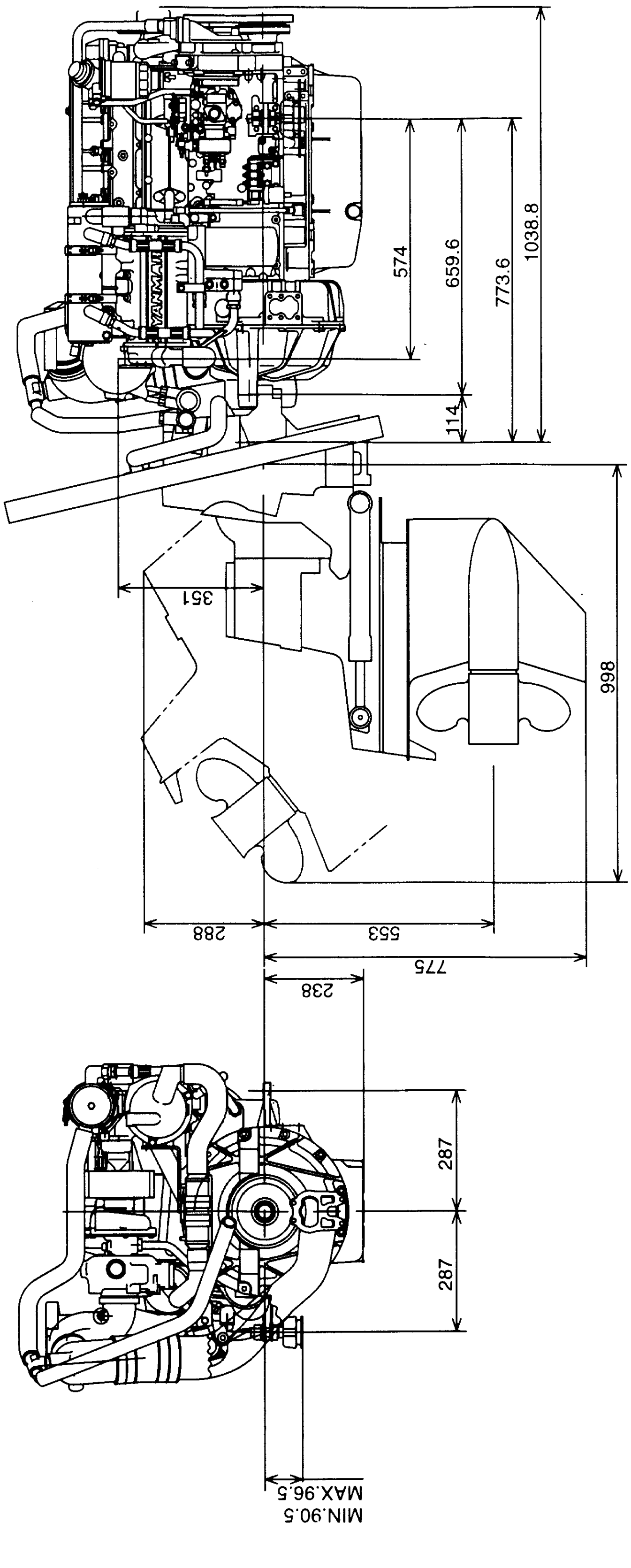
4LHA-HTE

Example of set up with KM5A





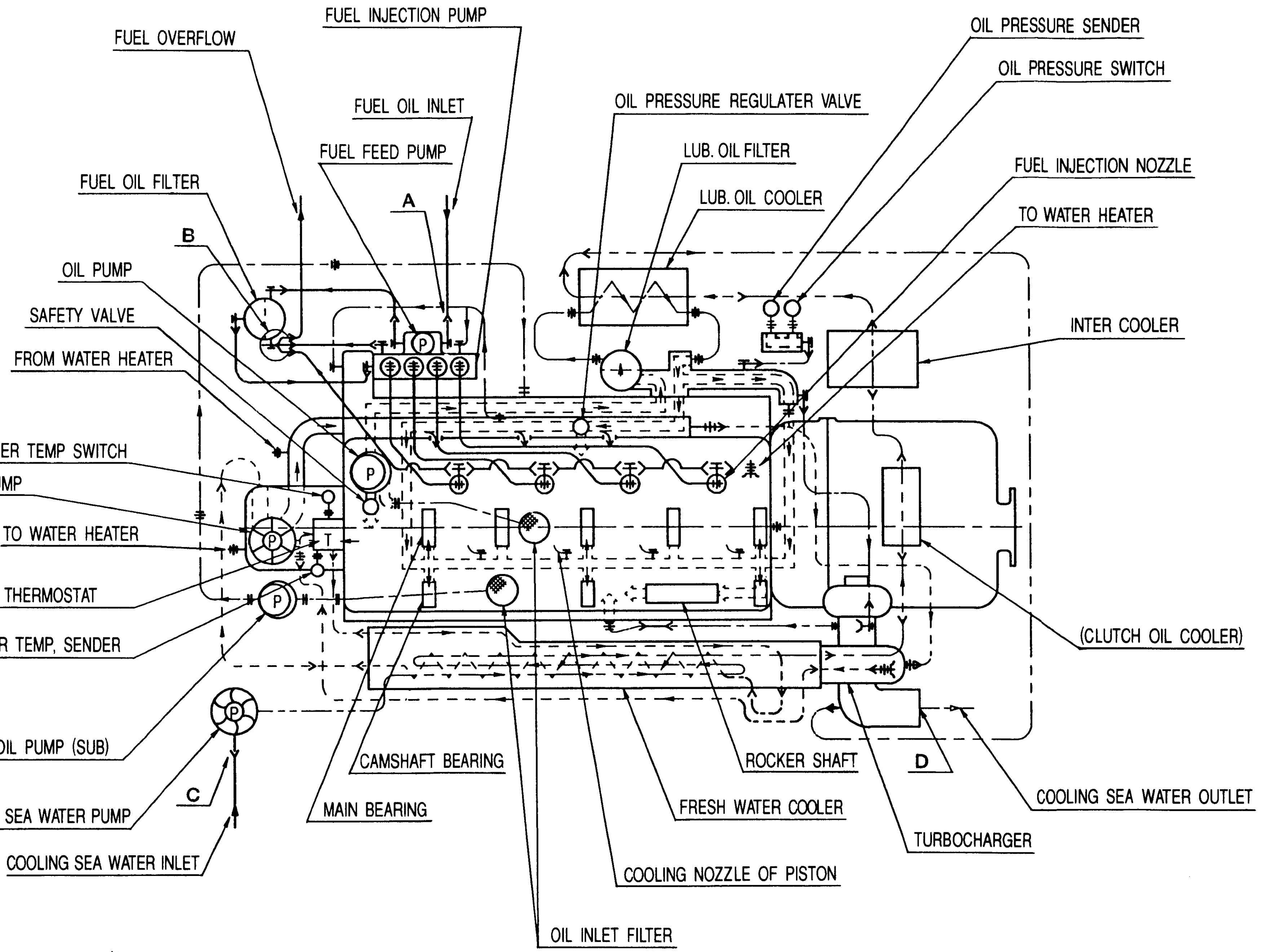
4LHA-HTZE

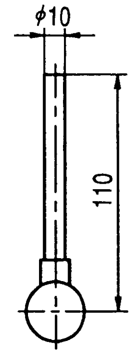


[Note] Dimensions of the engine are the same with 4LHA-HTE

6. Piping Diagrams
4LHA-STE

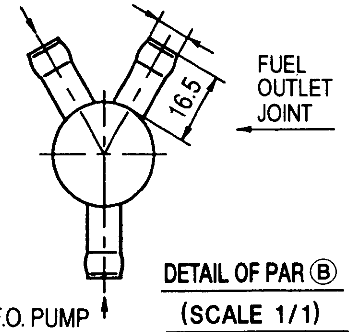
MARKS OF PIPING	NAME
—✱—	(UNION) SCREW JOINT
—▮—	FLANGE JOINT
—T—	EYE JOINT
—<—	NSERTION JOINT
= = = = =	DRILL HOLE
- - - - -	COOLING FRESH WATER PIPING
— - —	COOLING SEA WATER PIPING
— - —	LUB. OIL PIPING
———	FUEL. OIL PIPING





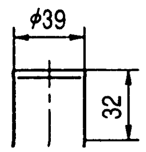
DETAIL OF PAR Ⓐ
(SCALE 1/2)

From F.O. NOZZLE

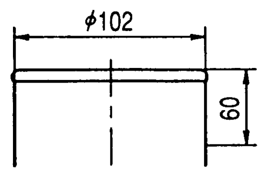


From F.O. PUMP

DETAIL OF PAR Ⓑ
(SCALE 1/1)



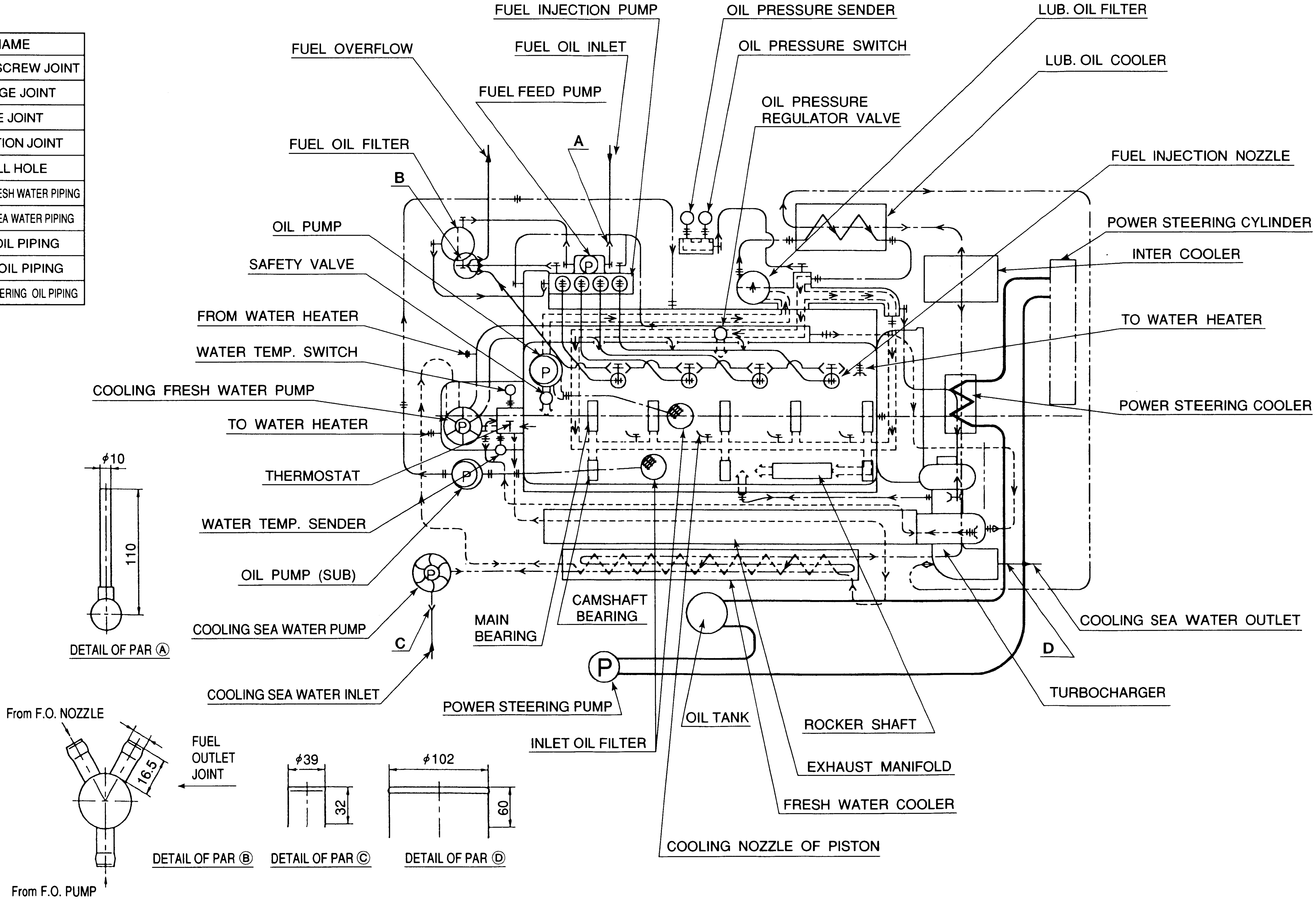
DETAIL OF PAR Ⓒ
(SCALE 1/2)



DETAIL OF PAR Ⓓ
(SCALE 1/2)

4LHA-STZE

MARKS OF PIPING	NAME
─┼┼─	(UNION) SCREW JOINT
─╫─	FLANGE JOINT
─┬─	EYE JOINT
─<──	NSERTION JOINT
==========	DRILL HOLE
....	COOLING FRESH WATER PIPING
─ ─ ─ ─	COOLING SEA WATER PIPING
── ─ ──	LUB. OIL PIPING
────	FUEL. OIL PIPING
━━━━	POWER STEERING OIL PIPING



DETAIL OF PAR Ⓐ

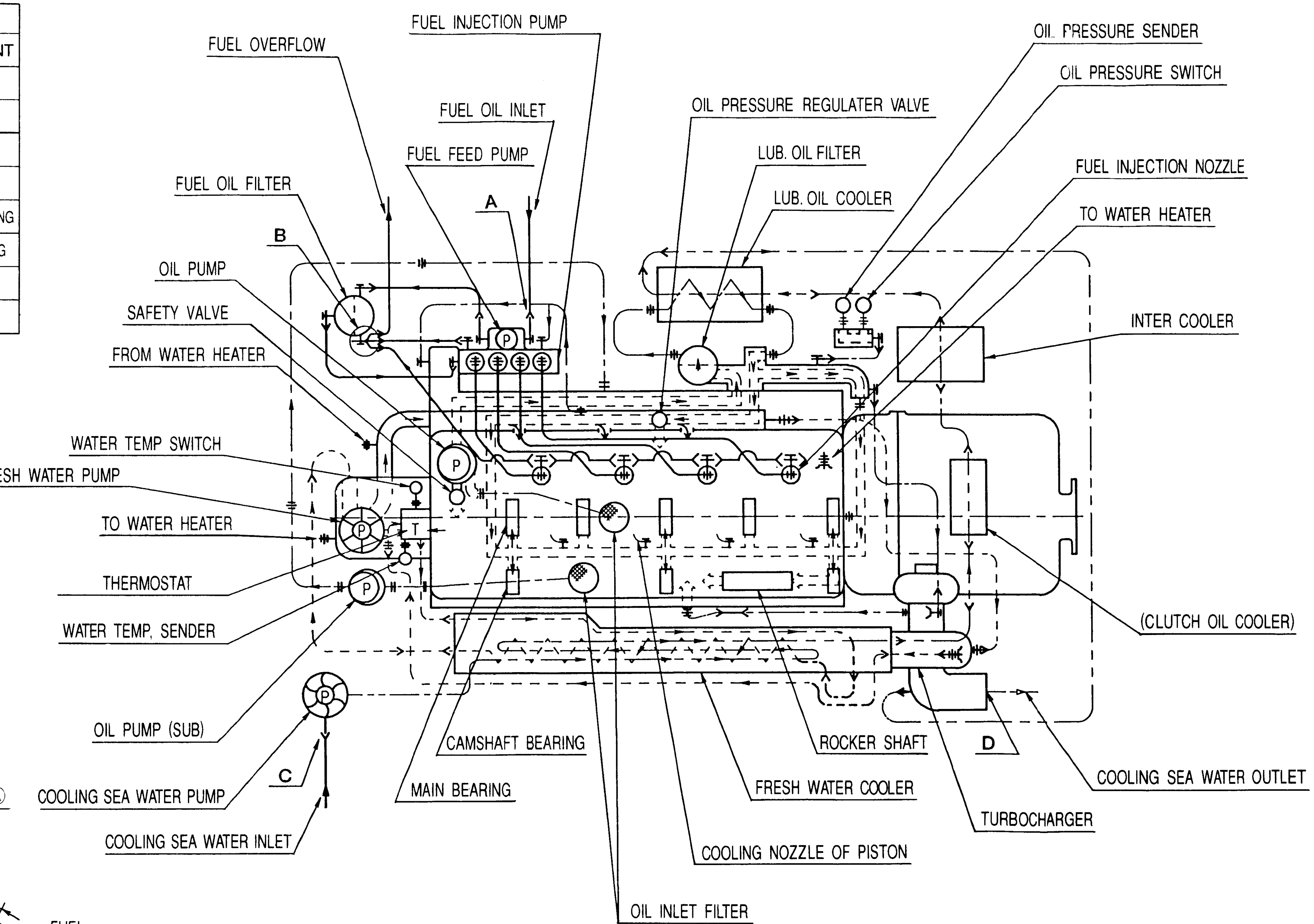
DETAIL OF PAR Ⓑ

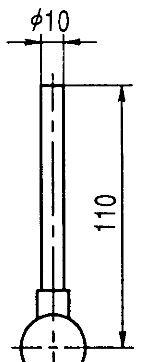
DETAIL OF PAR Ⓒ

DETAIL OF PAR Ⓓ

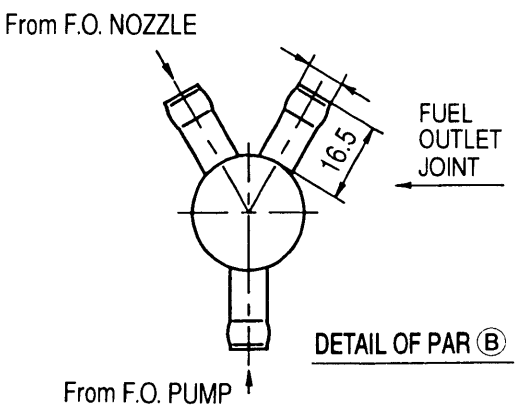
4LHA-DTE

MARKS OF PIPING	NAME
—╫—	(UNION) SCREW JOINT
—┼—	FLANGE JOINT
—┬—	EYE JOINT
—<—	NSERTION JOINT
= = = = =	DRILL HOLE
- - - - -	COOLING FRESH WATER PIPING
— — — —	COOLING SEA WATER PIPING
— - —	LUB. OIL PIPING
———	FUEL. OIL PIPING

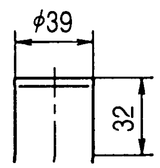




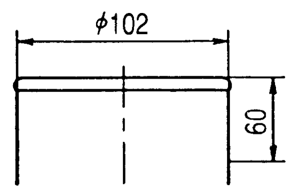
DETAIL OF PAR Ⓐ



DETAIL OF PAR Ⓑ



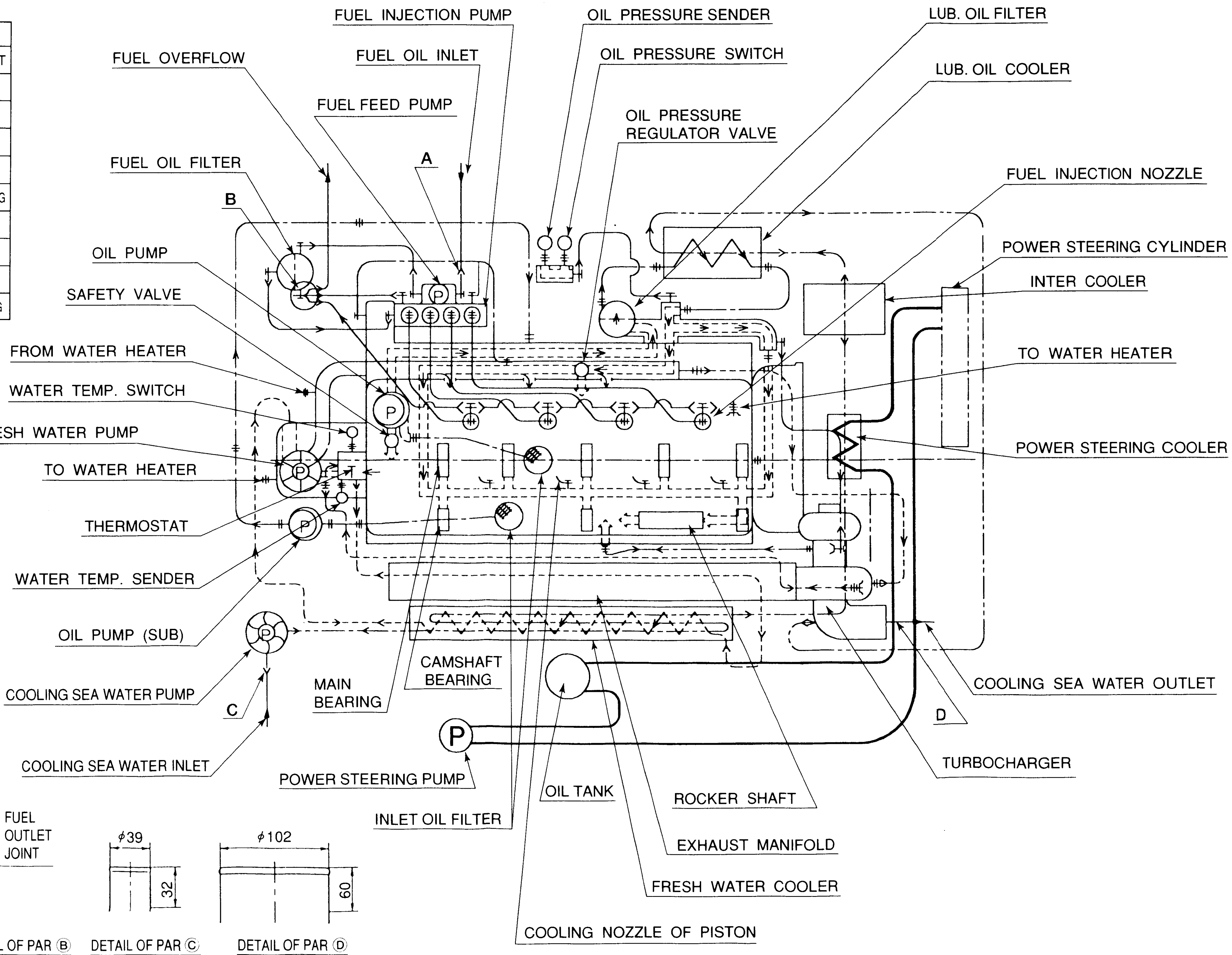
DETAIL OF PAR Ⓒ

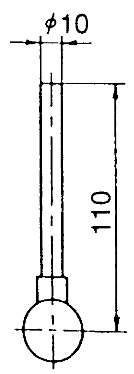


DETAIL OF PAR Ⓓ

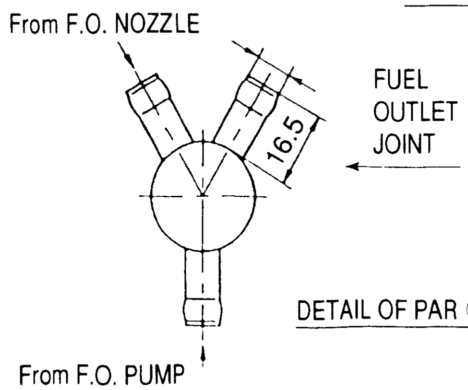
4LHA-DTZE

MARKS OF PIPING	NAME
—⊣⊢—	(UNION) SCREW JOINT
—‖—	FLANGE JOINT
—T—	EYE JOINT
—<—	NSERTION JOINT
==========	DRILL HOLE
----------	COOLING FRESH WATER PIPING
— - —	COOLING SEA WATER PIPING
— - - —	LUB. OIL PIPING
———	FUEL. OIL PIPING
━━━	POWER STEERING OIL PIPING





DETAIL OF PAR Ⓐ



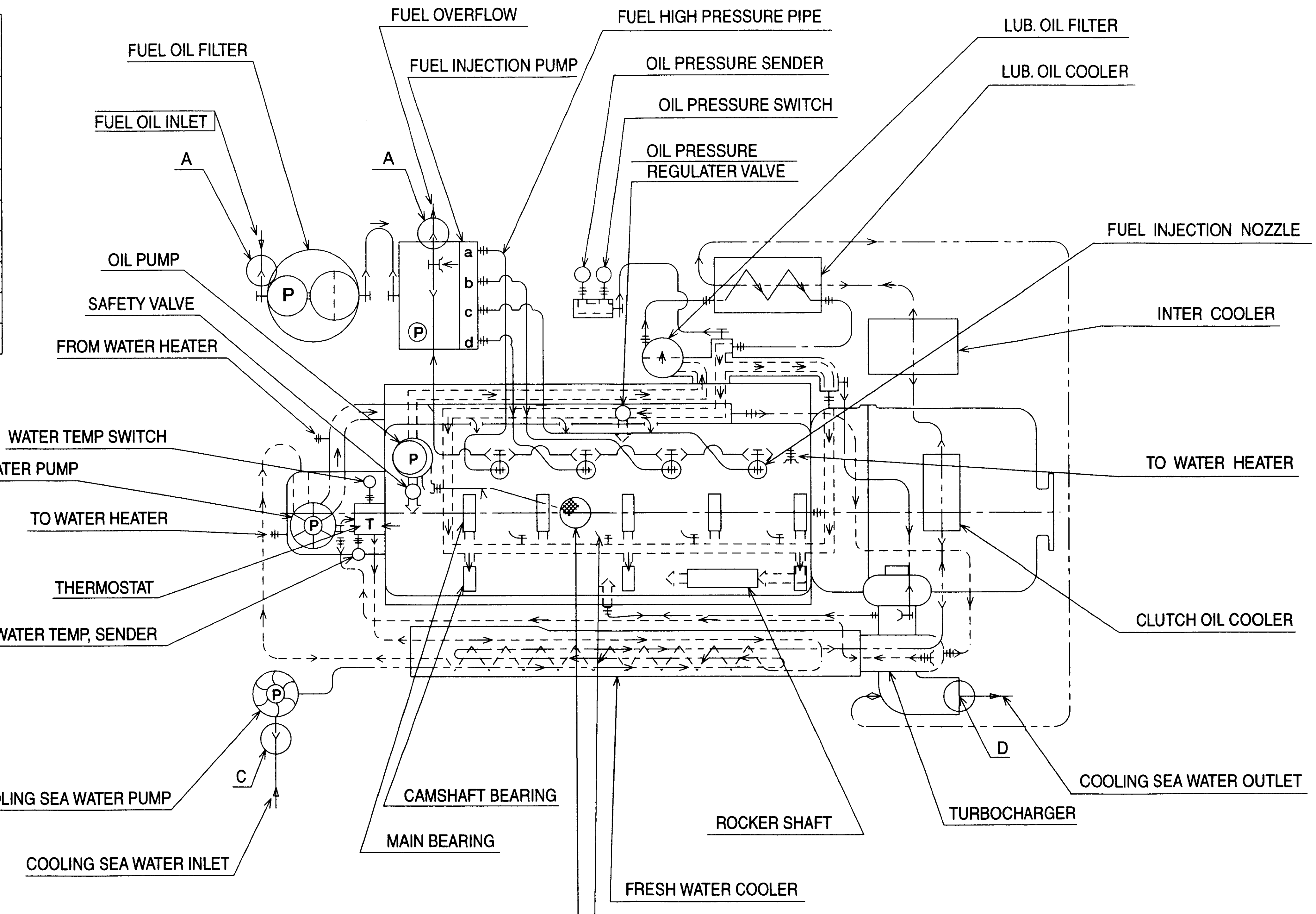
DETAIL OF PAR Ⓑ

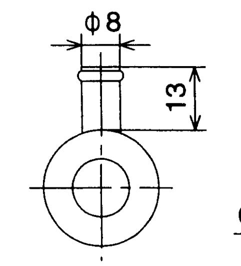
DETAIL OF PAR Ⓒ

DETAIL OF PAR Ⓓ

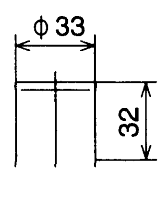
● 4LHA-HTE

MARKS OF PIPING	NAME
—‖‖—	(UNION) SCREW JOINT
—‖—	FLANGE JOINT
—T—	EYE JOINT
—<—	INSERTION JOINT
= = = =	DRILL HOLE
- - - - -	COOLING FRESH WATER PIPING
— - — -	COOLING SEA WATER PIPING
— - - —	LUB, OIL PIPING
———	FUEL, OIL PIPING

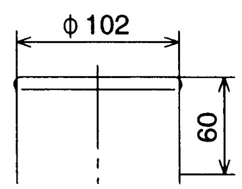




DETAIL OF PART Ⓐ
(SCALE 1/1)



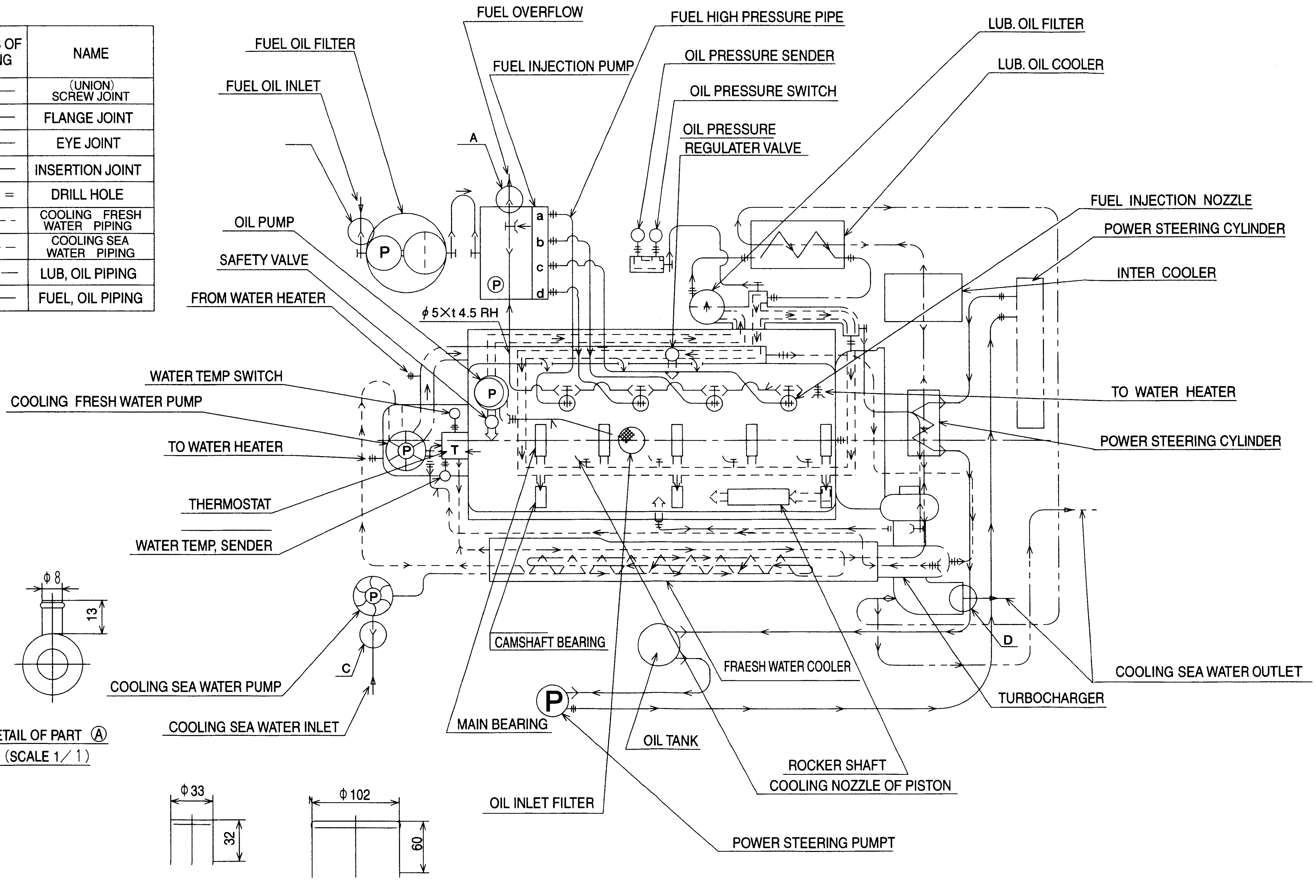
DETAIL OF PART Ⓒ



DETAIL OF PART Ⓓ

● 4LHA-HTZE

MARKS OF PIPING	NAME
—+—	(UNION) SCREW JOINT
—‖—	FLANGE JOINT
—T—	EYE JOINT
—<—	INSERTION JOINT
= = = =	DRILL HOLE
- - - - -	COOLING FRESH WATER PIPING
— - - —	COOLING SEA WATER PIPING
— - —	LUB, OIL PIPING
———	FUEL, OIL PIPING



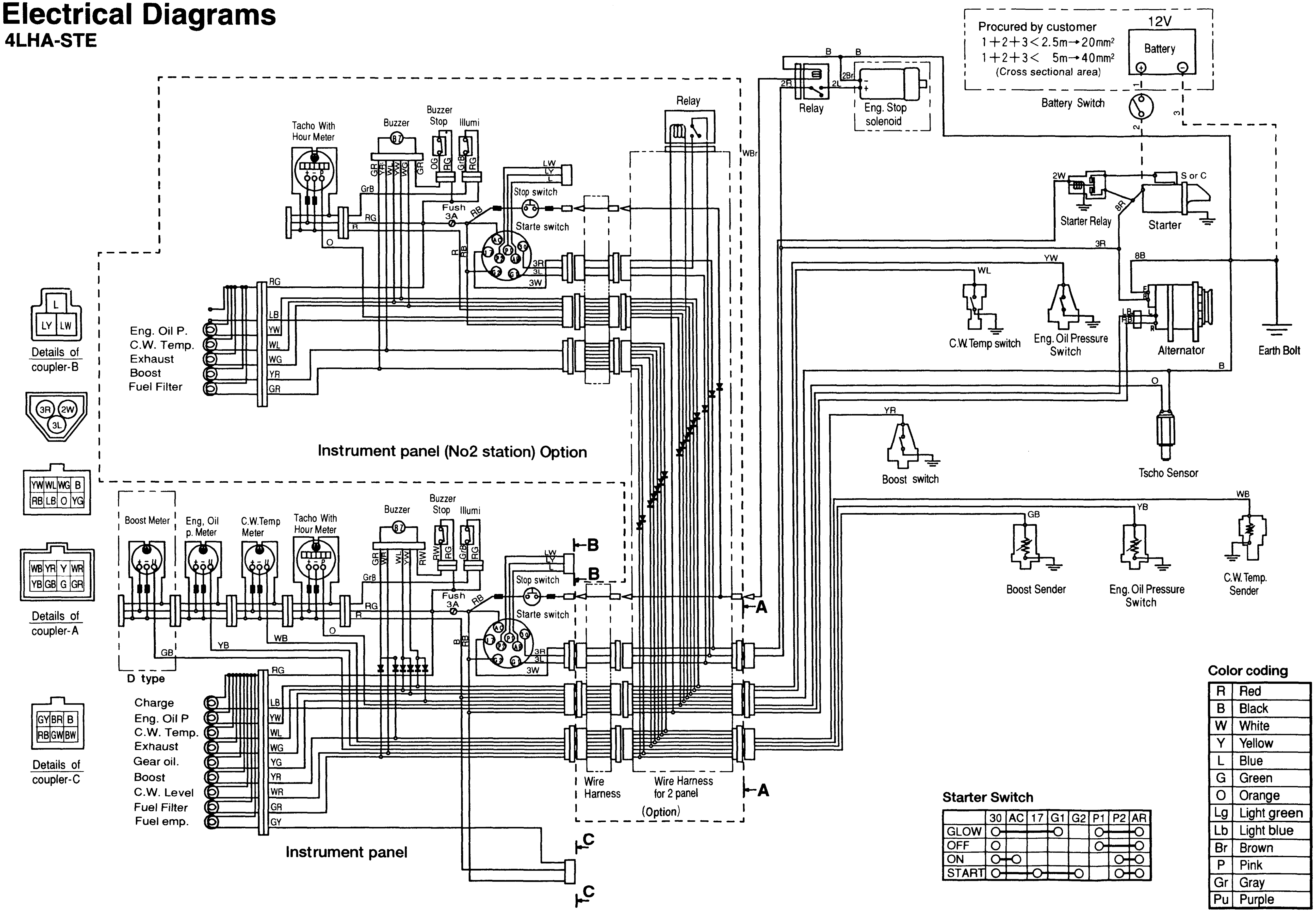
DETAIL OF PART Ⓐ
(SCALE 1/1)

DETAIL OF PART Ⓒ
(SCALE 1/2)

DETAIL OF PART Ⓓ
(SCALE 1/3)

7. Electrical Diagrams

4LHA-STE



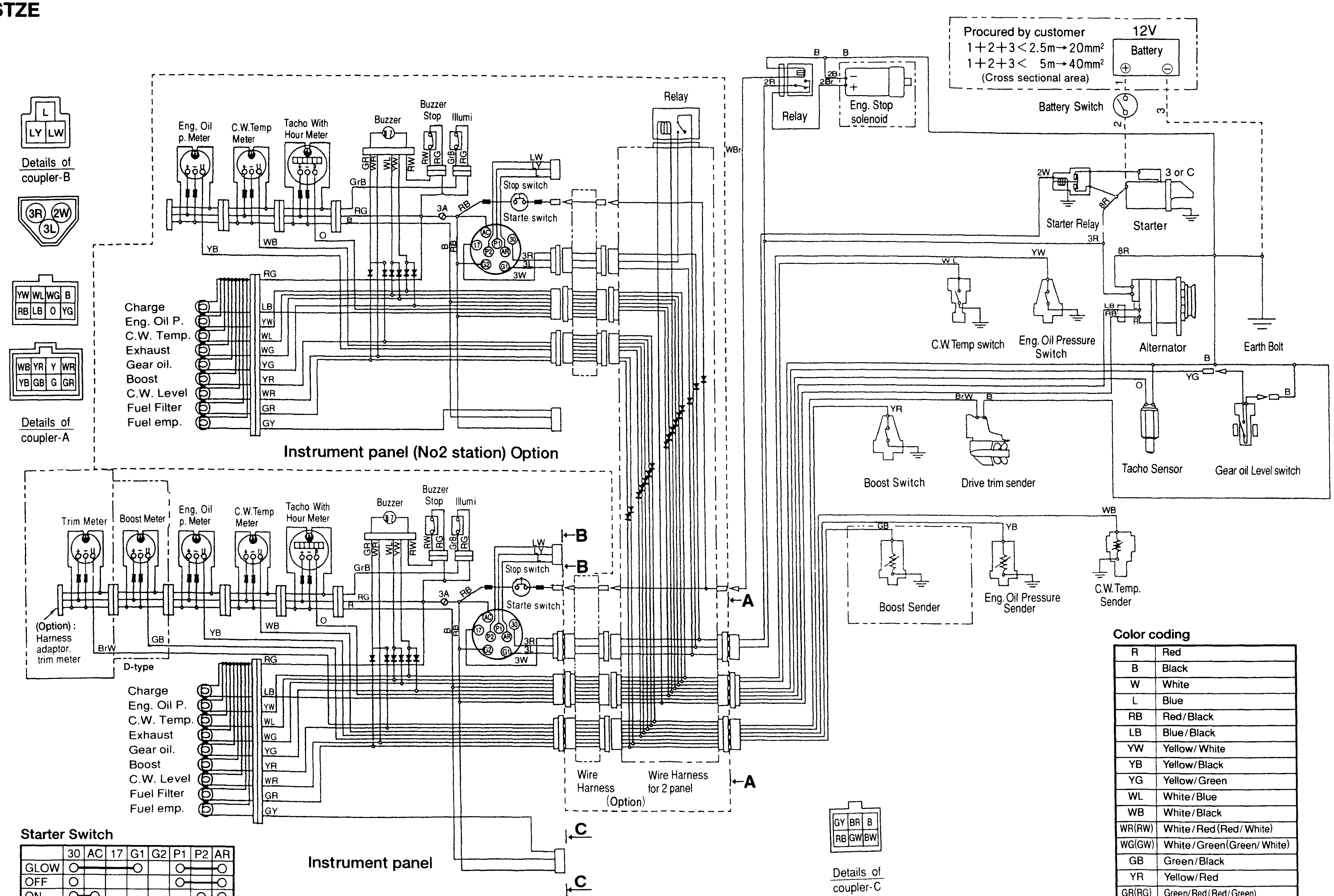
Starter Switch

	30	AC	17	G1	G2	P1	P2	AR
GLOW	O			O		O		O
OFF	O					O		O
ON	O	O					O	O
START	O		O		O		O	O

Color coding

R	Red
B	Black
W	White
Y	Yellow
L	Blue
G	Green
O	Orange
Lg	Light green
Lb	Light blue
Br	Brown
P	Pink
Gr	Gray
Pu	Purple

4LHA-STZE



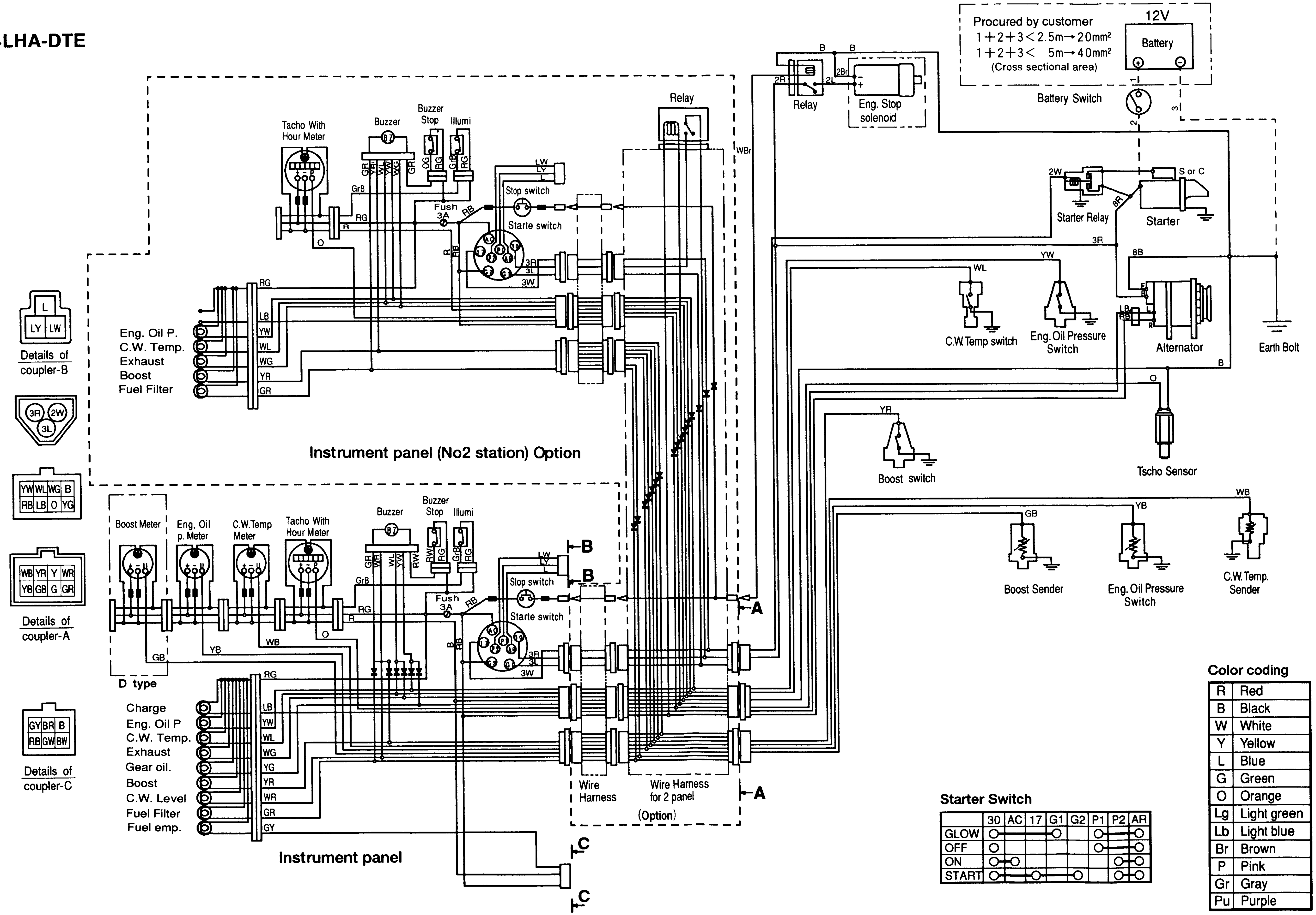
Starter Switch

	30	AC	17	G1	G2	P1	P2	AR
GLOW	O	—	—	O		O	—	O
OFF	O					O	—	O
ON	O	O					O	O
START	O	—	O	—	O		O	O

Color coding

R	Red
B	Black
W	White
L	Blue
RB	Red/Black
LB	Blue/Black
YW	Yellow/White
YB	Yellow/Black
YG	Yellow/Green
WL	White/Blue
WB	White/Black
WR(RW)	White/Red(Red/White)
WG(GW)	White/Green(Green/White)
GB	Green/Black
YR	Yellow/Red
GR(RG)	Green/Red(Red/Green)
O	Orange
BrW	Brown/White
WBr	White/Brown

4LHA-DTE



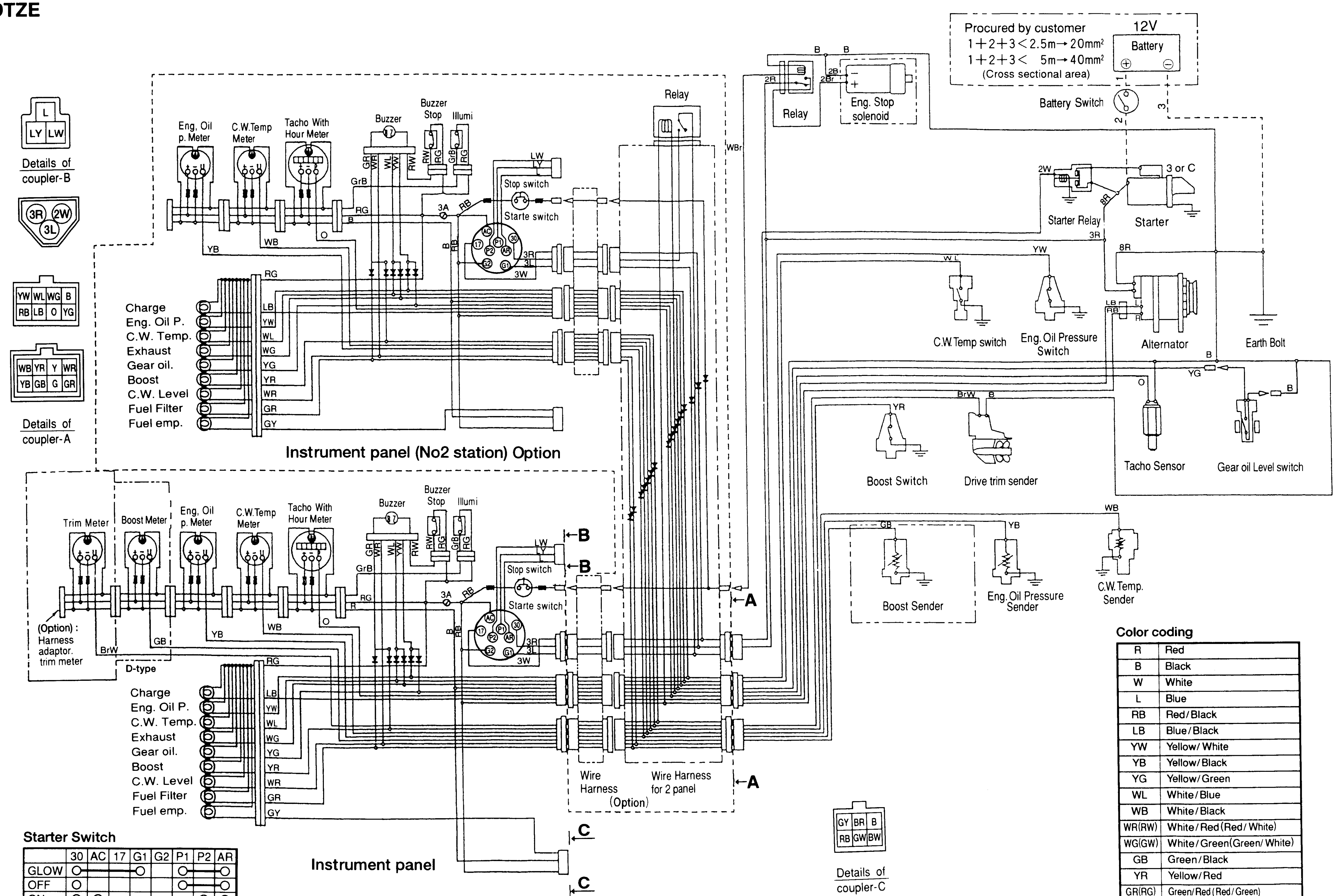
Starter Switch

	30	AC	17	G1	G2	P1	P2	AR
GLOW	○			○		○		○
OFF	○					○		○
ON	○	○					○	○
START	○		○		○		○	○

Color coding

R	Red
B	Black
W	White
Y	Yellow
L	Blue
G	Green
O	Orange
Lg	Light green
Lb	Light blue
Br	Brown
P	Pink
Gr	Gray
Pu	Purple

4LHA-DTZE



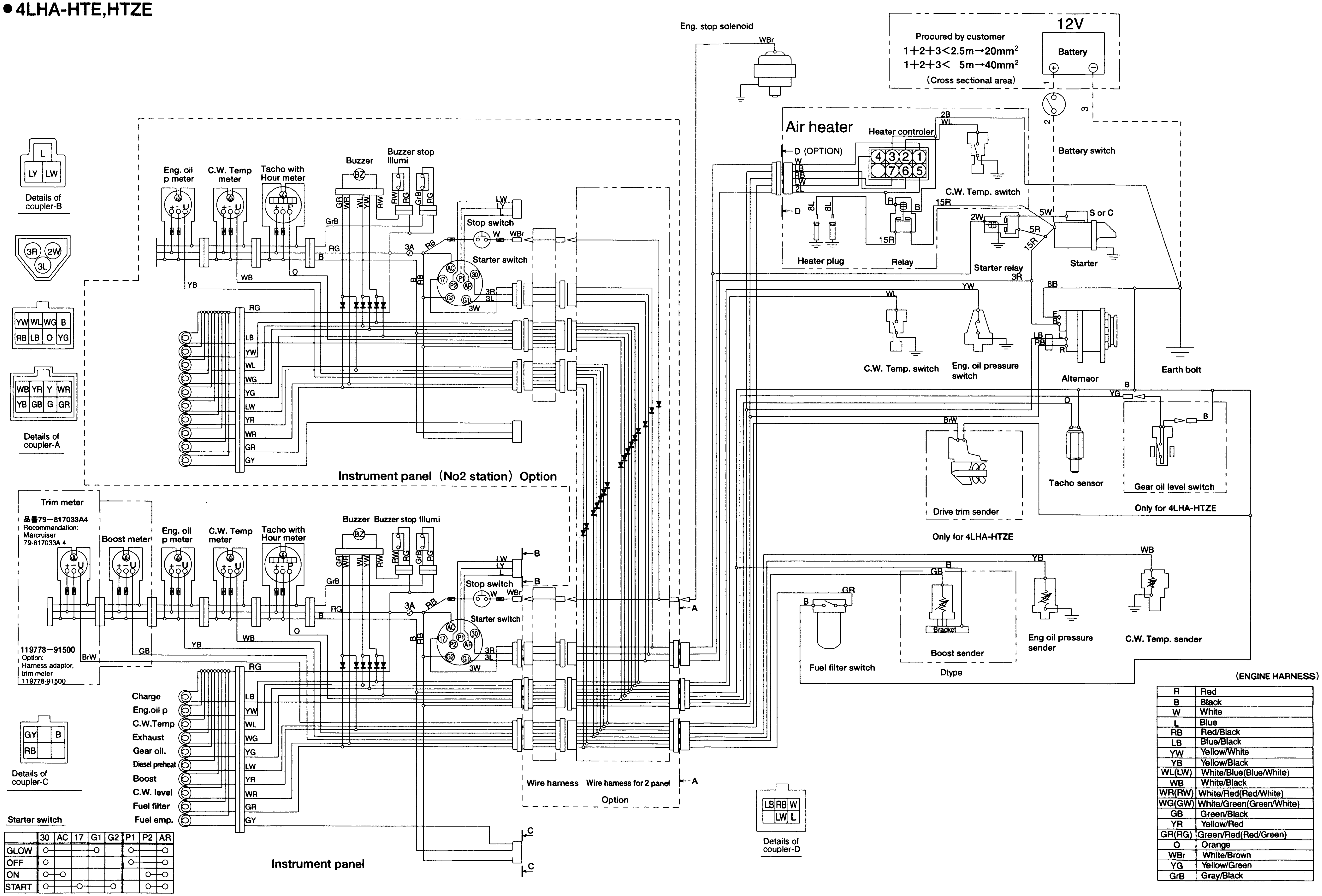
Starter Switch

	30	AC	17	G1	G2	P1	P2	AR
GLOW	O			O		O		O
OFF	O					O		O
ON	O	O					O	O
START	O		O		O		O	O

Color coding

R	Red
B	Black
W	White
L	Blue
RB	Red/Black
LB	Blue/Black
YW	Yellow/White
YB	Yellow/Black
YG	Yellow/Green
WL	White/Blue
WB	White/Black
WR(RW)	White/Red (Red/White)
WG(GW)	White/Green(Green/White)
GB	Green/Black
YR	Yellow/Red
GR(RG)	Green/Red (Red/Green)
O	Orange
BrW	Brown/White
WBr	White/Brown

• 4LHA-HTE,HTZE



Starter switch

	30	AC	17	G1	G2	P1	P2	AR
GLOW	o			o		o		o
OFF	o					o		o
ON	o	o					o	o
START	o		o		o		o	o

(ENGINE HARNESS)

R	Red
B	Black
W	White
L	Blue
RB	Red/Black
LB	Blue/Black
YW	Yellow/White
YB	Yellow/Black
WL(LW)	White/Blue(Blue/White)
WB	White/Black
WR(RW)	White/Red(Red/White)
WG(GW)	White/Green(Green/White)
GB	Green/Black
YR	Yellow/Red
GR(RG)	Green/Red(Red/Green)
O	Orange
WBr	White/Brown
YG	Yellow/Green
GrB	Gray/Black

CHAPTER 2

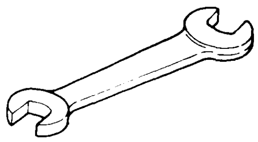
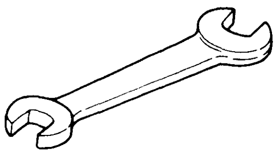
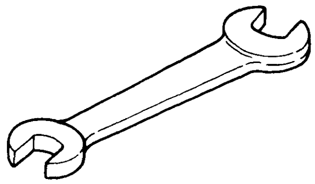
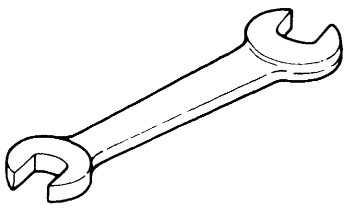
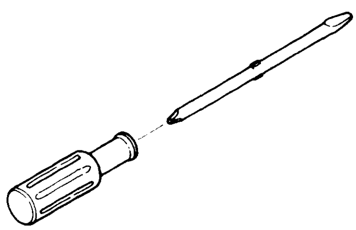
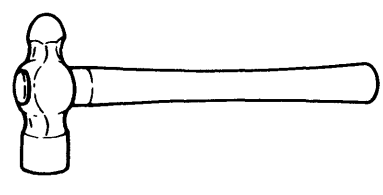
BASIC ENGINE

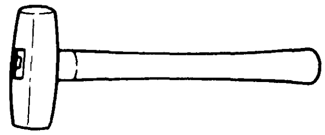
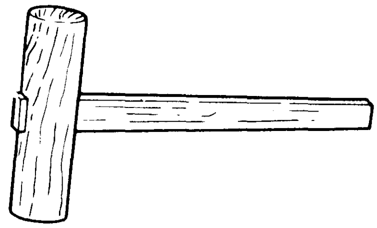
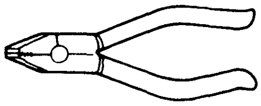
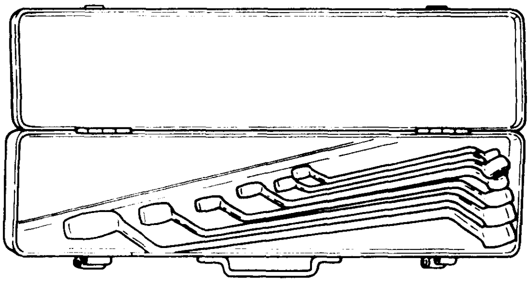
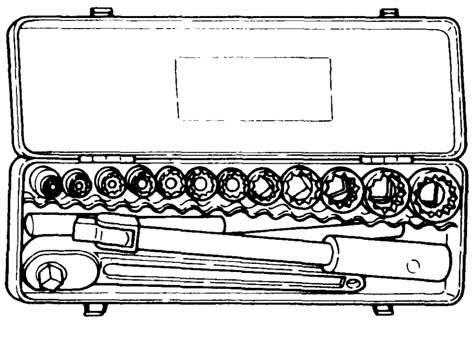
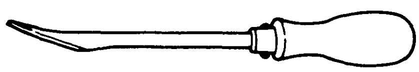
1. Disassembly and Reassembly Tools 2-1
2. Cylinder Block 2-9
3. Cylinder Liners 2-12
4. Cylinder Head 2-14
5. Piston and Piston Pins 2-21
6. Connecting Rod 2-25
7. Crankshaft and Main Bearing 2-28
8. Camshaft and Tappets 2-32
9. Timing Gear 2-35
10. Flywheel 2-36

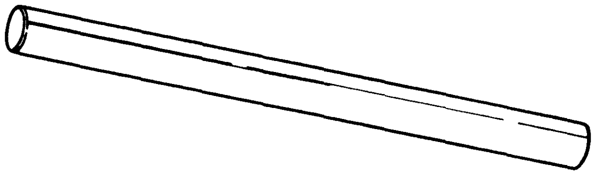
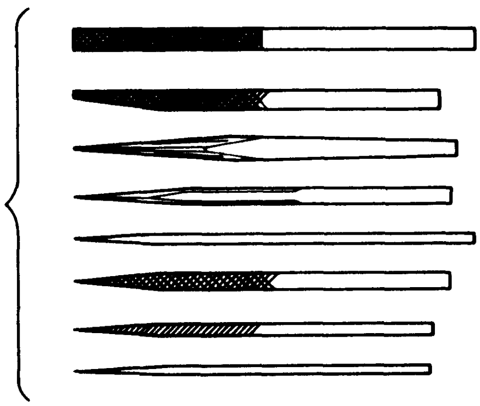
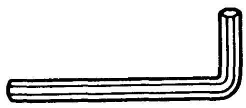
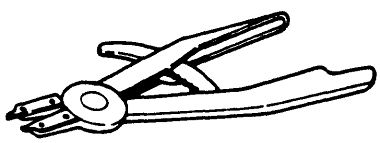
1. Disassembly and Reassembly Tools

The following tools are required when disassembling and reassembling the engine.
Please use them as instructed.

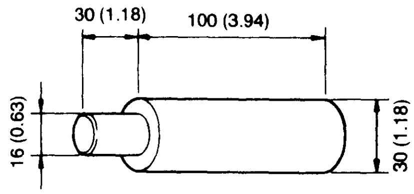
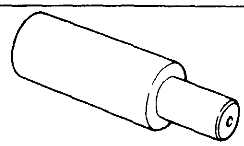
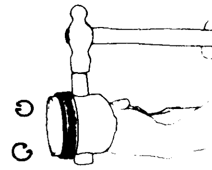
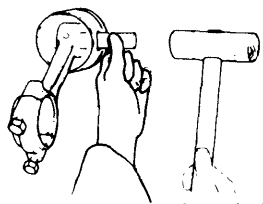
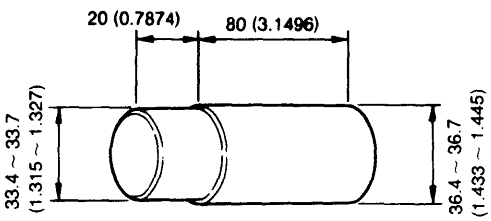
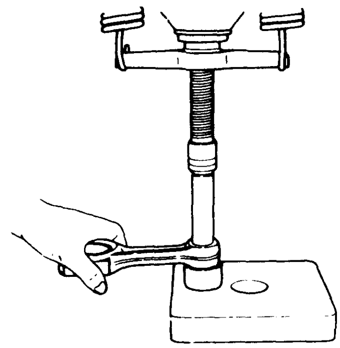
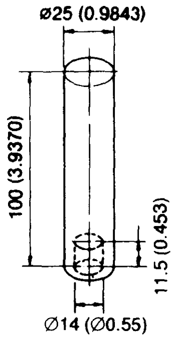
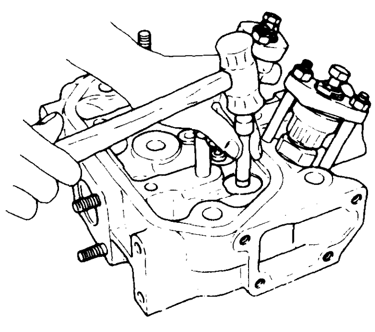
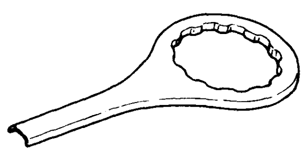
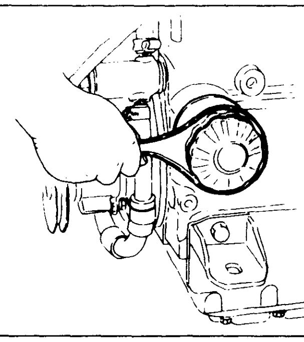
1-1 General Handtools

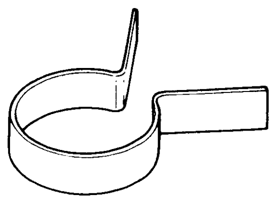
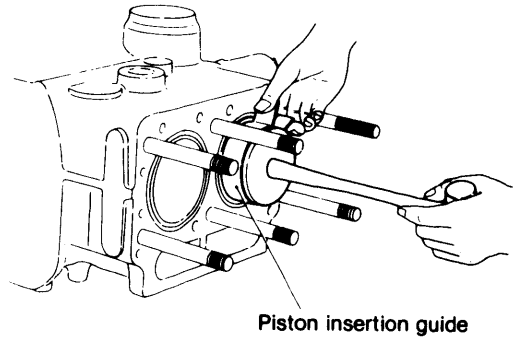
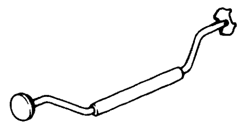
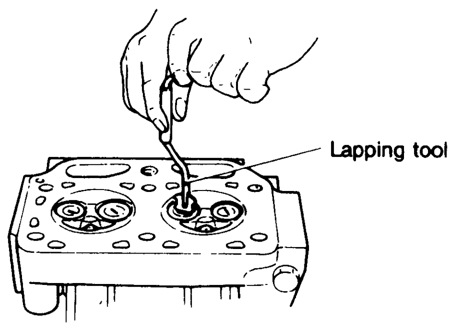
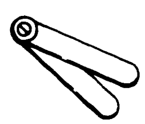
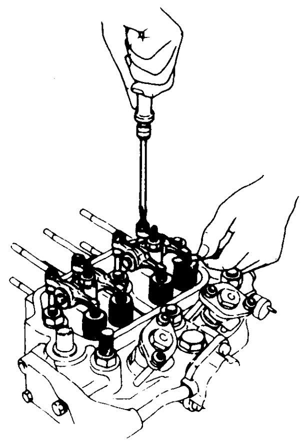
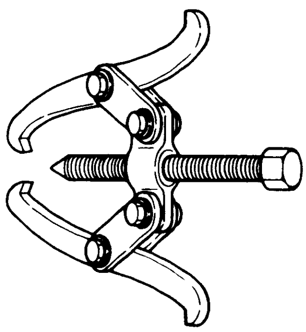
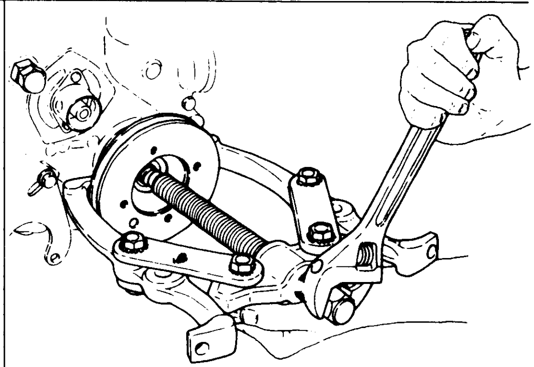
Name of tool	Illustration	Remarks
Wrench		Size: 10 × 13
Wrench		Size: 12 × 14
Wrench		Size: 17 × 19
Wrench		Size: 22 × 24
Screwdriver		
Steel hammer		Local supply

Name of tool	Illustration	Remarks
Copper hammer		Local supply
Mallet		Local supply
Nippers		Local supply
Pliers		Local supply
Offset wrench		Local supply 1 set
Box spanner		Local supply 1 set
Scraper		Local supply

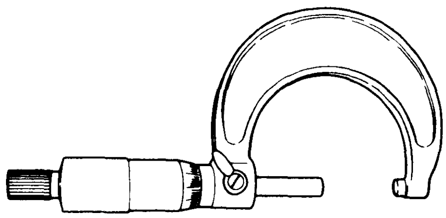
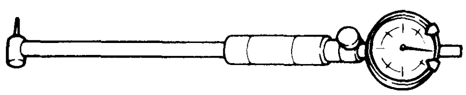
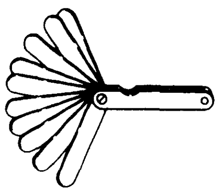
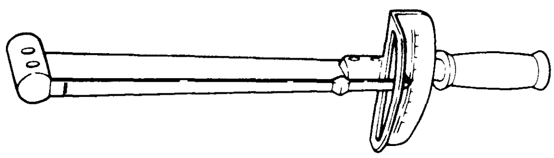
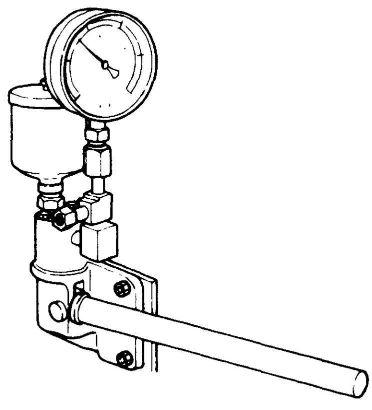
Name of tool	Illustration	Remarks
Lead rod		Local supply
File		Local supply 1 set
Rod spanner for hexagon socket head screws		Local supply Size: 6mm (0.2362in.) 8mm (0.3150in.) 10mm (0.3937in.)
Starling Pliers Hole type Shaft type	 S—0  H4 ~ H8 S = Hole type H = Shaft type	Local supply

1-2 Special Handtools

Name of tool	Shape and size	Application
Piston pin insertion/ extraction tool	mm (in.)  	 Piston pin extractor  Extraction of piston pin  Insertion of piston pin
Connecting rod small end bushing insertion/ extraction tool	mm (in.)  	 Extraction
Intake and exhaust valve guide insertion tool	mm (in.)  	
Lubricating oil No.2 filter case remover		

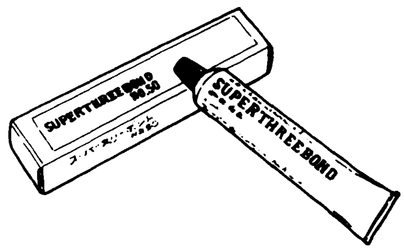
Name of tool	Shape and size	Application
Piston ring compressor		
Valve lapping handle		
Valve lapping powder		
Feeler gauge		
Pulley puller	 Local supply	 Removing the coupling

1-3 Measuring Instruments

Name of tool	Shape and size	Application
Vernier calipers		0.05mm (0.0020in.), 0 ~ 150mm (0 ~ 5.9055in.)
Micrometer		0.01mm (0.0004in.) 0 ~ 25mm (0 ~ 0.9843in.), 25 ~ 50mm (0.9843 ~ 1.9685in.), 50 ~ 75mm (1.9685 ~ 2.9528in.), 75 ~ 100mm (2.9528 ~ 3.9370in.), 100 ~ 125mm (3.9730 ~ 4.9213in.). 125 ~ 150mm (4.9213 ~ 5.9055in.).
Cylinder gauge		0.01mm (0.0004in.), 18 ~ 35mm (0.7087 ~ 1.3780in.), 35 ~ 60mm (1.3780 ~ 2.3622in.), 50 ~ 100mm (1.9685 ~ 3.9370in.).
Thickness gauge		0.05 ~ 2mm (0.0020 ~ 0.0787in.)
Torque wrench		0 ~ 127N·m (0 ~ 13kgf·m)
Nozzle tester		0 ~ 49.0 MPa (0 ~ 500 kgf·cm²)

1-4 Other

Supplementary packing agent

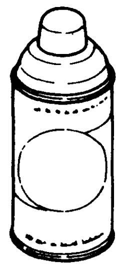


Type	Use
"Three Bond 3B8-005"	White. Since "Three Bond 3B8-005" is a non-organic solvent, it does not penetrate asbestos sheets made principally or completely of asbestos. Always use it with grey asbestos sheet packing for complete oil tightness When "Three Bond 3B8-005" is difficult to obtain, use silicon nonsolvent type "Three Bond No.50."
"Three Bond No. 50"	Grey. Silicon non-solvent type liquid packing. Semidry type packing agent coated on mating faces to prevent oil and gas leakage. Does not penetrate asbestos sheet and assures complete oil tightness.
"Three Bond No. 1"	Reddish brown. Paste type wet viscous liquid packing. Ideal for mating faces which are removed but reinstalled. Particularly used to prevent water leakage and to prevent seizing of bolts and nuts.

Products of Three Bond Co,, Ltd.

The surface to be coated must be thoroughly cleaned with thinner or benzene and completely dry. Moreover, coating must be thin and uniform.

Paint

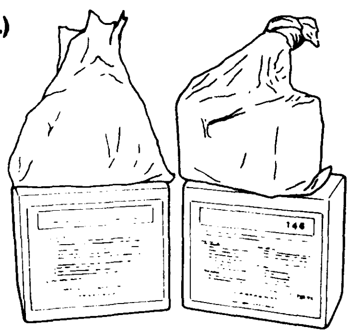


Color spray

Only Metallic Ecole Silver is used on this engine.

Wipe the surface to be painted with thinner or benzene, shake the spray can well, push the button at the top of the can and spray the paint onto the surface from a distance of 30 ~ 40 cm.

Yanmar cleaner (Ref.)



Cooling passage cleaner is mixed by adding one part "Unicon 146" to about 16 parts water (specific gravity ratio). To use, drain the water from the cooling system, fill the system with cleaner, allowing it to stand overnight (10 ~ 15 hours). Then drain out the cleaner, refill the system with water, and operate the engine for at least one hour.

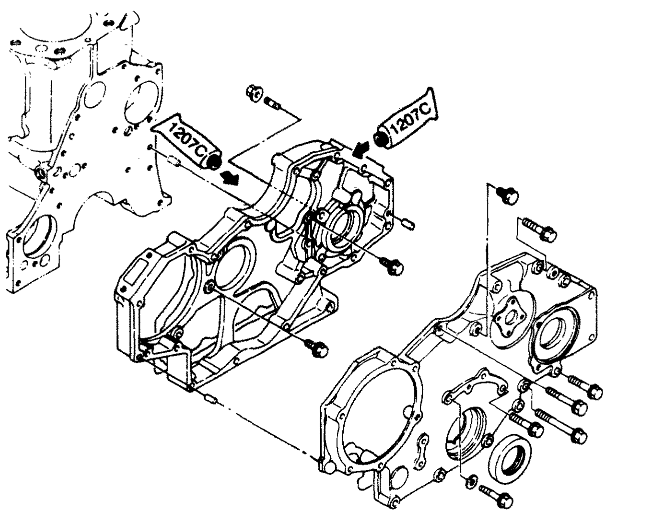
NEJI LOCK SUPER 203M: a locking agent for screws (Ref.)

For coating on screws and bolts to prevent loosening, rusting, and leaking. To use, wipe off all oil and water on the threads of studs, coat the threads with screw lock, tighten the stud bolt, and allow them to stand until the screw lock hardens. Use screw lock on the oil intake pipe threads, oil pressure switch threads, fuel injection timing shim faces, and front axle bracket mounting bolts.

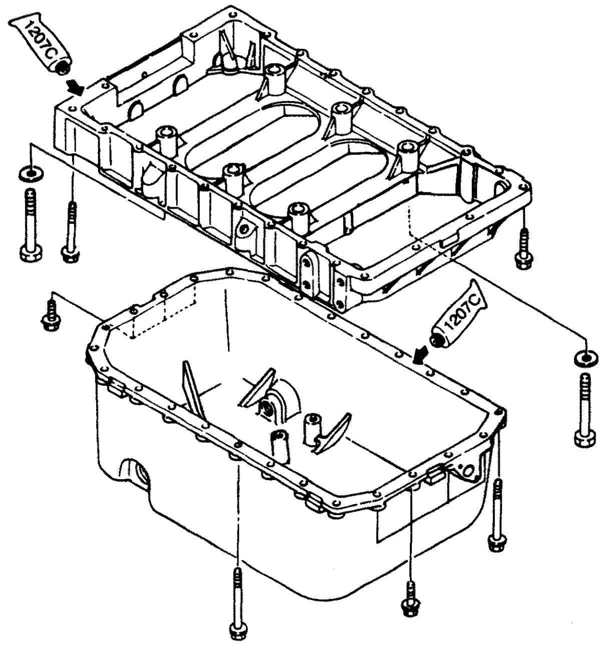
1-5 Using liquid gasket

The liquid gasket (Three Bond 1207C: part No. 977770-01212) is used in this 4LHA series for the following parts.
Clean the sealing faces thoroughly with a scraper and apply the liquid gasket evenly.

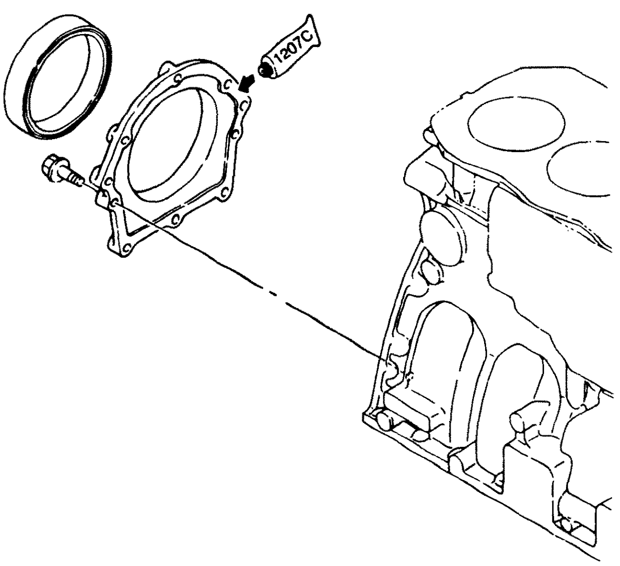
(1) Gear housing



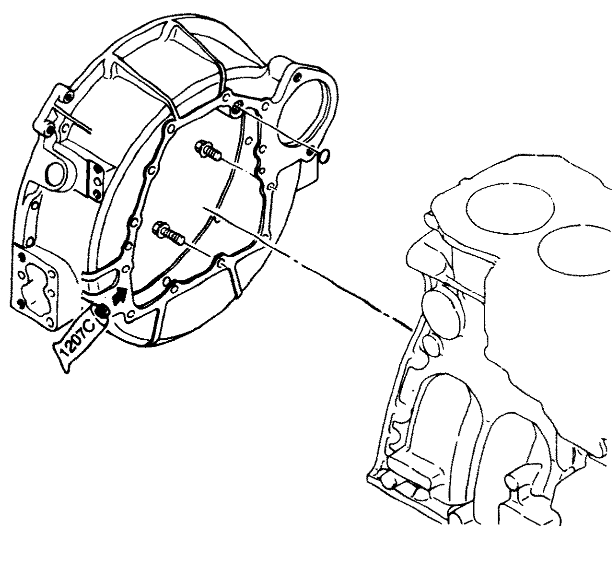
(3) Lube oil sump



(2) Oil seal housing

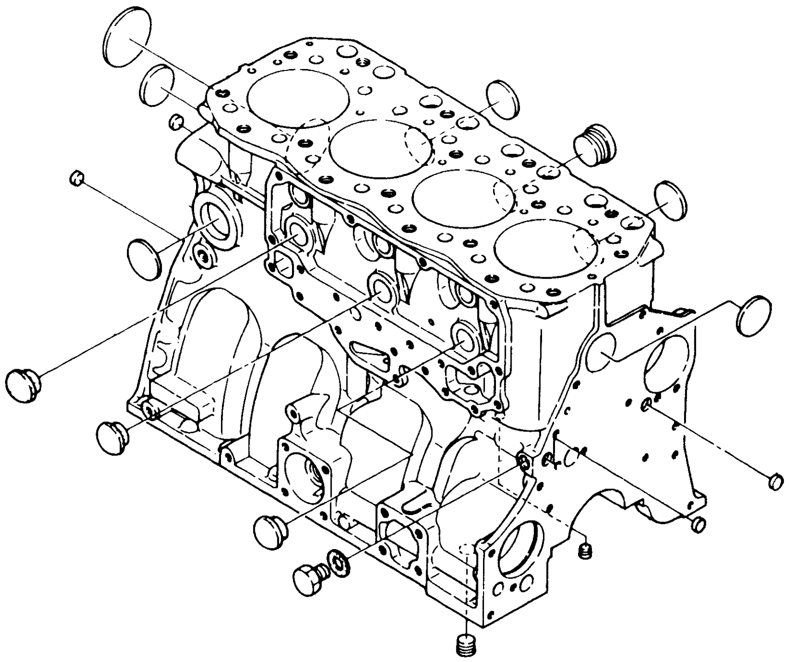


(4) Flywheel housing



2. Cylinder Block

The cylinder block is a thin-skinned, (low-weight), short skirt type with rationally placed ribs. The side walls are wave-shaped to maximize rigidity for strength and low noise.



2-1 Inspection of parts

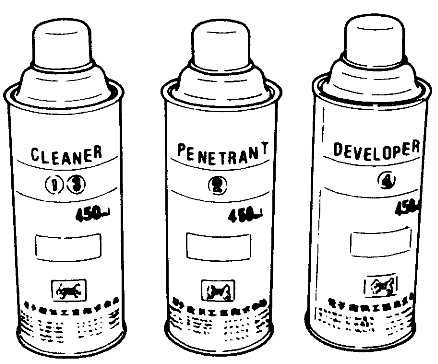
Make a visual inspection to check for cracks on engines that have frozen up, overturned or otherwise been subjected to undue stress. Perform a color check on any portions that appear to be cracked, and replace the cylinder block if the crack is not repairable.

2-2 Cleaning of oil holes

Clean all oil holes, making sure that none are clogged up and the blind plugs do not come off.

Color check kit
Part code No. 97550-004560

	Quantity
Penetrant	1
Developer	2
Cleaner	3

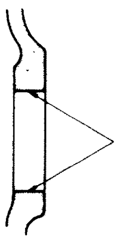
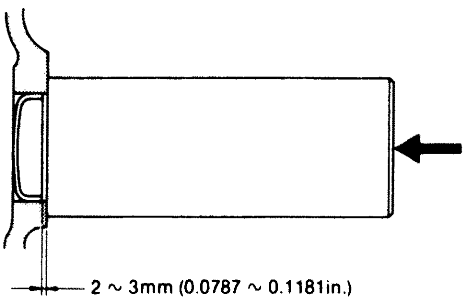


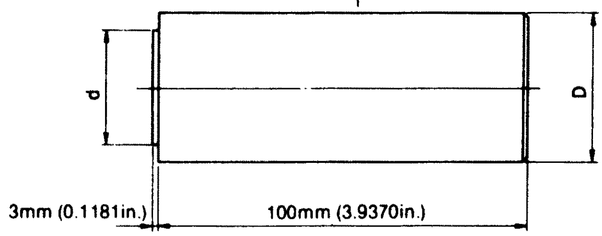
2-3 Color check procedure

(1) Clean the area to be inspected.
(2) Color check kit
The color check test kit consists of an aerosol cleaner, penetrant and developer.
(3) Clean the area to be inspected with the cleaner.
Either spray the cleaner on directly and wipe, or wipe the area with a cloth moistened with cleaner.
(4) Spray on red penetrant
After cleaning, spray on the red penetrant and allow 5 ~ 10 minutes for penetration. Spray on more red penetrant if it dries before it has been able to penetrate.
(5) Spray on developer
Remove any residual penetrant on the surface after the penetrant has penetrated, and spray on the developer. If there are any cracks in the surface, red dots or a red line will appear several minutes after the developer dries.
Hold the developer 300 ~ 400mm (11.8110 ~ 15.7480in.) away from the area being inspected when spraying, making sure to coat the surface uniformly.
(6) Clean the surface with the cleaner.

NOTE: Be sure to read the instructions for the color check kit before use.

2-4 Replacement of cup plugs

Step No.	Description	Procedure	Tool or material used
1.	Clean and remove grease from the hole into which the cup plug is to be driven. (Remove scale and sealing material previously applied.)		•Screw driver or saw blade •Thinner
2.	Remove grease from the cup plug.	Visually check the nick around the plug.	•Thinner
3.	Apply Threebond No. 4 to the seat surface where the plug is to be driven in.	Apply over the whole outside of the plug.	•Threebond No. 4
4.	Insert the plug into the hole.	Insert the plug so that it sits correctly.	
5.	Place a driving tool on the cup plug and drive it in using a hammer.  *Using the special tool, drive the cup plug to a depth where the edge of the plug is 2mm (0.0787in.) below the cylinder surface.	Drive in the plug parallel to the seating surface.	•Driving tool •Hammer

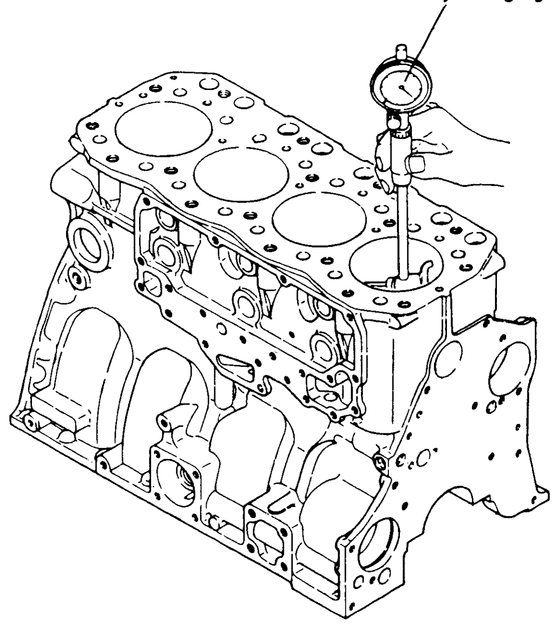


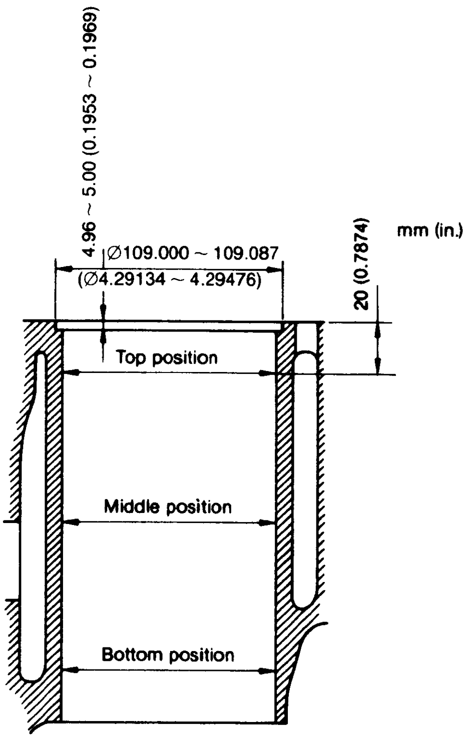
mm (in.)

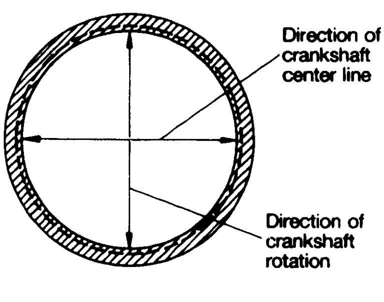
Plug dia.	d	D
Ø14	Ø13.9 ~ 14.0 (Ø0.547 ~ 0.551)	Ø20 (Ø0.79)
Ø40	Ø39.9 ~ 40.0 (Ø1.571 ~ 1.575)	Ø50 (Ø1.97)

2-5 Cylinder bore measurement

Measure the bore diameter with a cylinder gauge at the positions shown in the figure.
Replace the cylinder bore when the measured value exceeds the wear limit. Measurement must be done in at least 3 positions as shown in the figure, namely, the top, middle and bottom positions in both directions along the crankshaft rotation and crankshaft center lines.







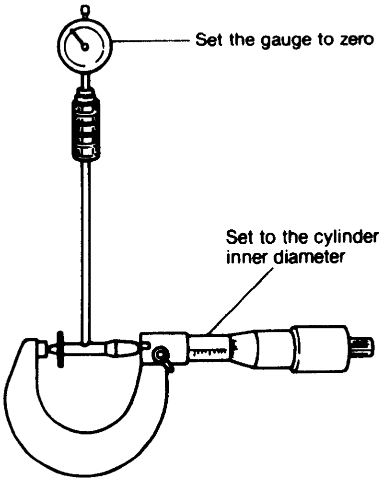
mm (in.)

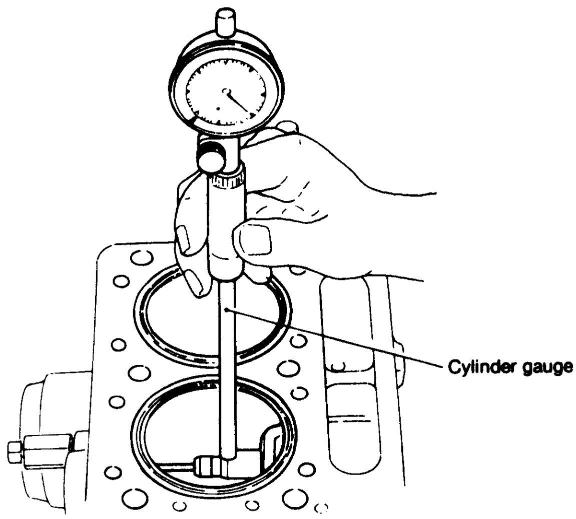
	Standard	Wear limit
Cylinder bore dia.	Ø103.00 ~ 103.03 (Ø4.0551 ~ 4.0563)	Ø103.06 (Ø4.0575)
Cylinder roundness	0 ~ 0.01 (0 ~ 0.0004)	0.02 (0.0008)

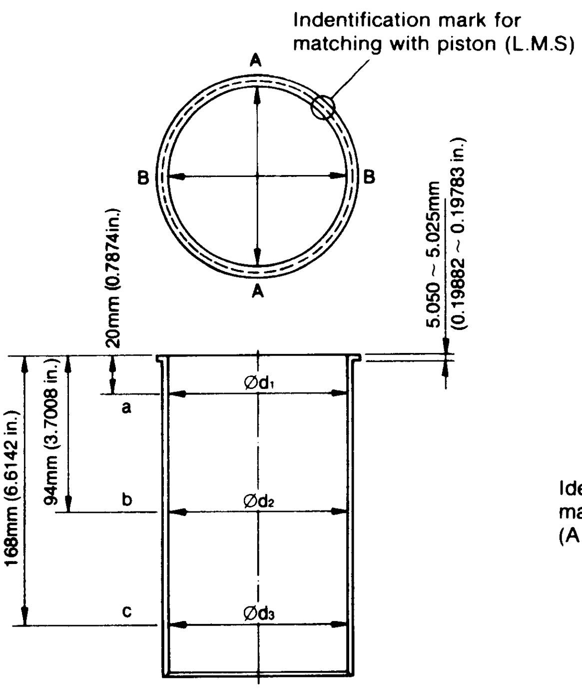
3. Cylinder Liners

3-1 Measuring cylinder liners

Measure the inner diameter of each cylinder with a cylinder gauge and replace the cylinder liner if it exceeds the wear limit.







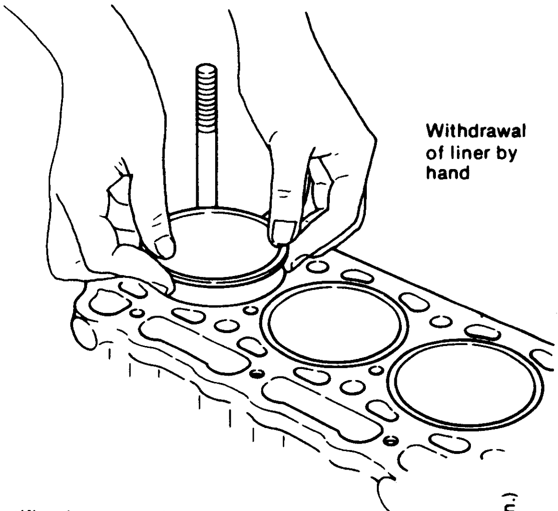
mm (in.)

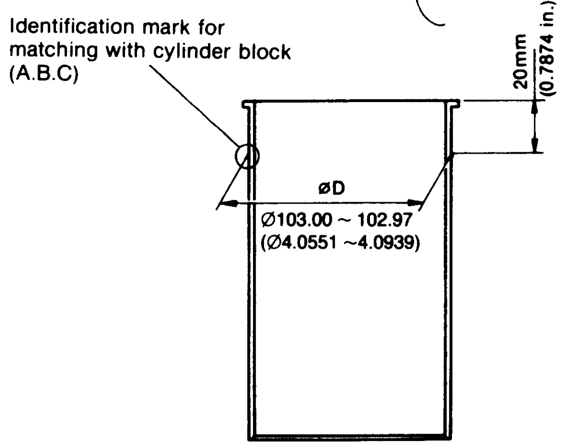
	Standard	Wear limit
Cylinder liner	Ø100.00 ~ 100.03 (Ø3.9370 ~ 3.9382)	Ø100.15 (Ø3.9429)

NOTE: (1) Be sure to measure A-A, B-B and a, b and c
(2) Be sure that d_1, d_2, d_3 are accurate to within 0.02mm (0.0008 in.).

3-2 Inserting cylinder liners

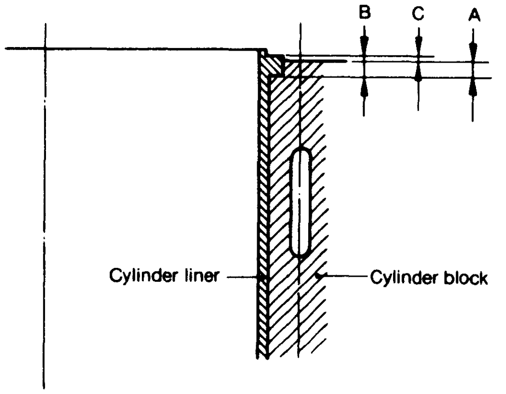
Coat the outside of the liner with oil, and insert lightly by hand. Do not tap with a wooden hammer as this may deform the liner.





3-3 Measuring cylinder liner projection

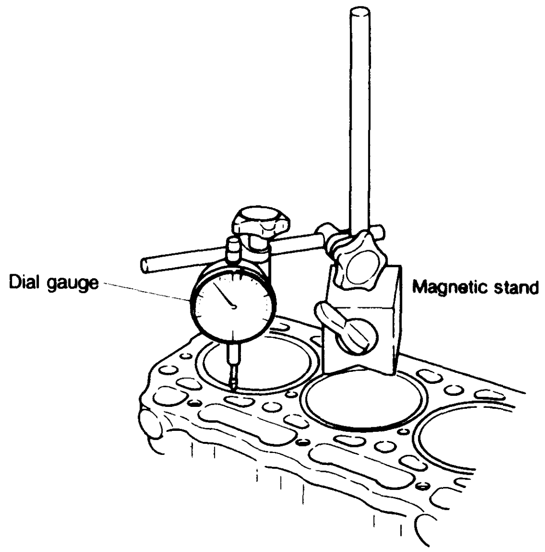
Make sure the cylinder liner flange projects only slightly above the block.



mm (in.)

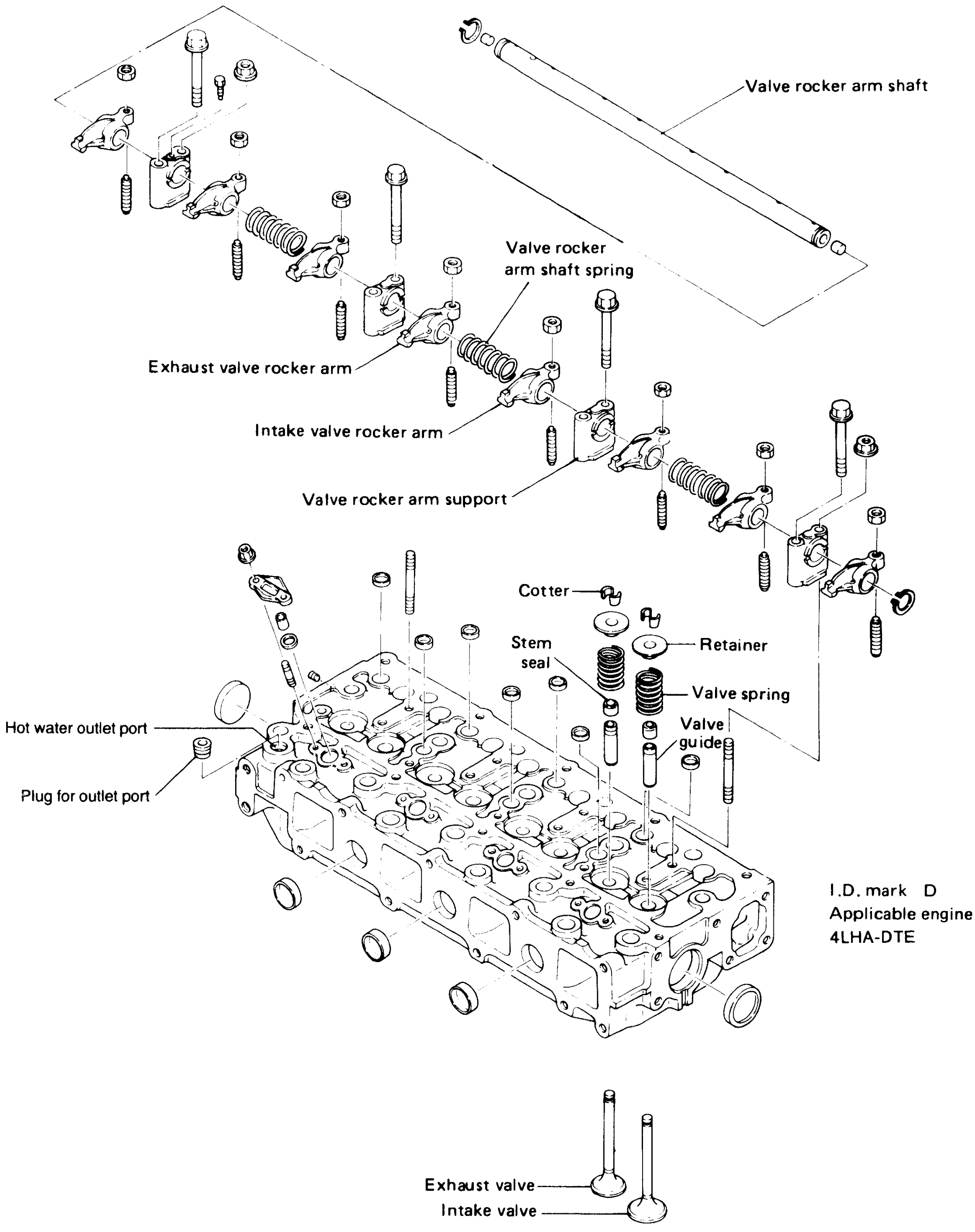
A	5.00 ~ 4.96 (0.1969 ~ 0.1953)
B	5.050 ~ 5.025 (0.19882 ~ 0.19783)
C	0.025 ~ 0.090 (0.00098 ~ 0.00354)

NOTE: Excessive cylinder liner projection is frequently caused by incomplete removal of the rust on the ledge (Part D of figure) of the cylinder block.



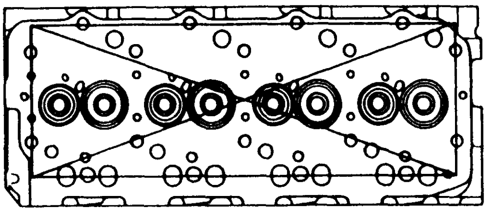
4. Cylinder Head

The cylinder head has a 4-cylinder integral construction.
The area between the intake port and exhaust port is cooled by a water jet.



4-1 Inspecting the cylinder head

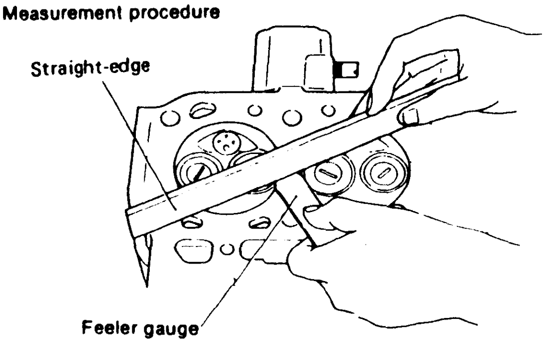
The cylineder head is subjected to severe operating conditions with repeated high pressure, high temperature and cooling. Thoroughly remove all the carbon and dirt-after disassembly and carefully inspect all parts.



4-1.1 Distortion of the combustion surface

Carefully check for cylinder head distortion as this leads to gasket damage and compression leaks.
(1) Clean the cylinder head surface
(2) Place a straight-edge along each of the four sides and diagonal. Measure the clearance between the straight-edge and combustion surface with a feeler gauge.

Measurement procedure

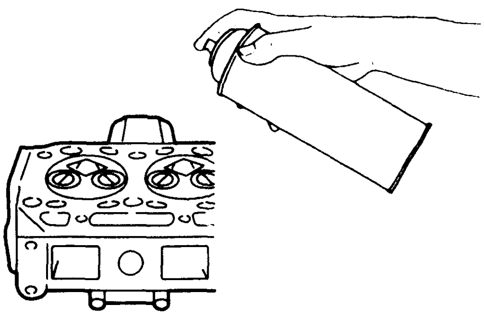


mm(in.)

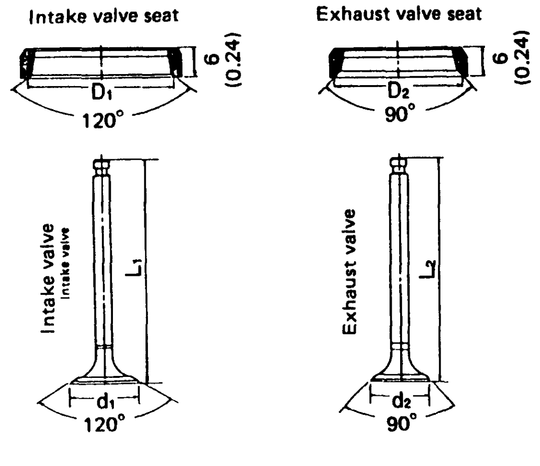
	StandardWear	limit
Cylinder head distortion	0.05 or less (0.002)	0.2(0.0079)

4-1.2 Checking for cracks in the combustion surface

Remove the fuel injection nozzle, intake and exhaust valve and clean the combustion surface. Check for discoloration or distortion and conduct a color check test to check for any cracks.



Standard dimension

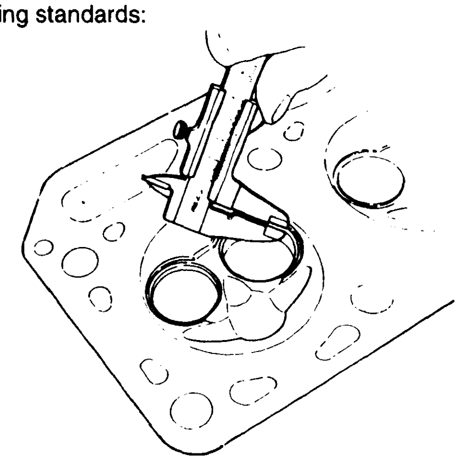


mm (in.)

		4LHA-HTE	4LHA-DTE
Valve seat	Intake D_1	42.5(1.67)	45.5(1.79)
	Exhaust D_2	37.0(1.46)	39.0(1.54)
Valve	Intake d_1	43.5(1.71)	46.0(2.56)
	Exhaust d_2	37.5(1.48)	39.5(1.56)
Length of valve	Intake L_1	121.0(4.76)	121.5(4.78)
	Exhaust L_2	121.0(4.76)	122.0(4.80)

4-1.3 Checking the intake and exhaust valve seats

Check the surface and width of the valve seats.
If they are too wide, or if the surfaces are rough, correct to the following standards:



Seat angle	Intake	120°
	Exhaust	90°

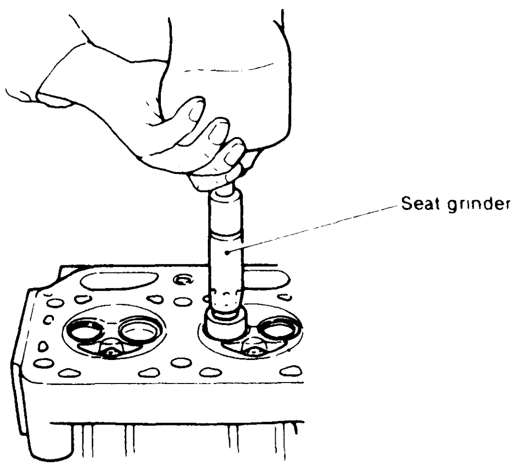
mm(in.)

Seat width	Standard	Wear limit
Intake	1.38-1.62 (0.0543-0.0638)	2.12(0.0835)
Exhaust	2.015-2.227 (0.0793-0.0877)	2.73(0.1075)

4-2 Valve seat correction procedure

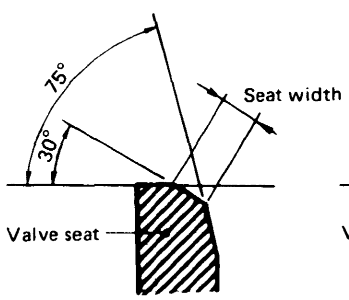
The most common method for correcting unevenness of the seat surface with a seat grinder is as follows:

(1) **Use a seat grinder to make the surface even.**
First, use a 70° grinder, then grind the seat to the standard dimension with a 15° grinder.

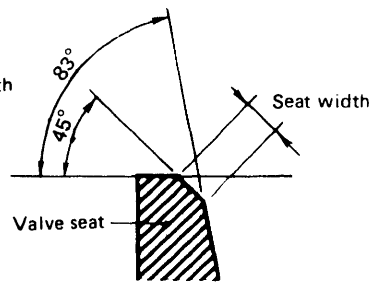


Seat grinder	Intake valve	30°
	Exhaust valve	45°

NOTE: When seat adjustment is necessary, be sure to check the valve and valve guide. If the clearance exceeds the tolerance, replace the valve or the valve guide, and then grind the seat.

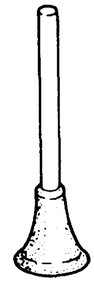


Intake valve seat



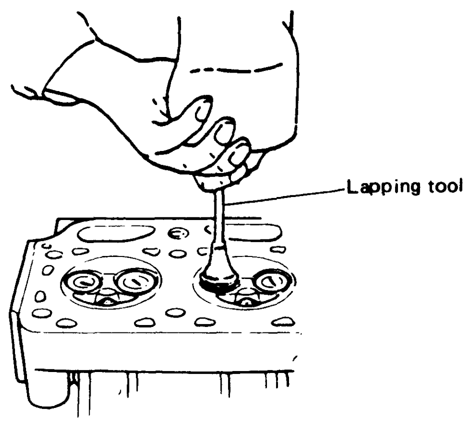
Exhaust valve seat

(2) Knead oil into the valve compound and finish the valve seat with a lapping tool.
(3) Final finishing should be done with oil only.



Lapping tool
Use a rubber cap type lapping tool for cylinders without a lapping tool groove slit.

NOTE: Clean the valve and cylinder head with light oil or the equivalent after valve seat finishing is completed, and make sure that there are no grindings remaining.

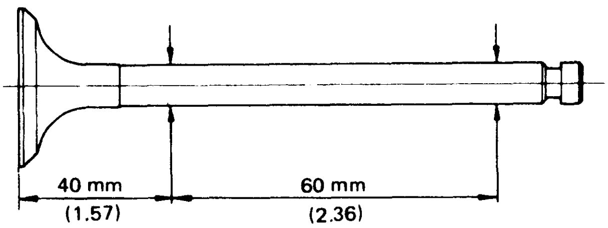


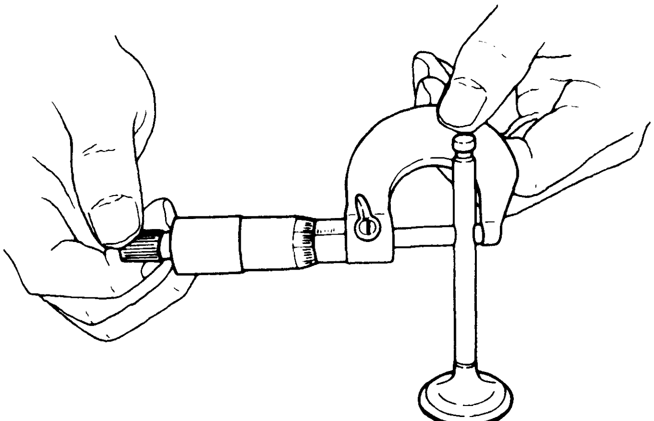
NOTE: 1. Insert adjusting shims between the valve spring and cylinder head when seats have been refinished with a seat grinder.
2. Measure valve distortion after valve seat refinishing has been completed, and replace the valve and valve seat if it exceeds the tolerance.

4-3 Intake/exchaust valves, valve guides

4-3.1 Wearing and corrosion of valve stem

Replace the valve if the valve stem is excessively worn or corroded.





mm (in.)

Valve stem outside dia.	Standard	Wear limit
Intake	8.96 – 8.975 (0.3528 – 0.3533)	8.9 (0.3504)
Exhaust	8.94 – 8.955 (0 352 – 0.3526)	8.9 (0.3504)

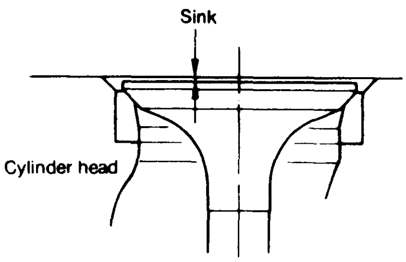
4-3.2 Inspection of valve seat wear and contact surface

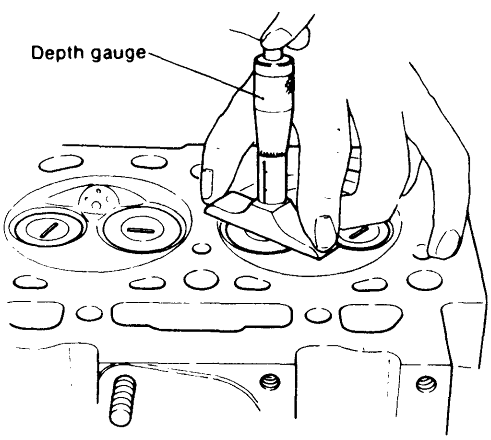
Inspect for valve seat scratches and excessive wear. Check to make sure the contact surface is normal. The seat angle must be checked and adjusted if the valve seat contact surface is smaller than the width of the valve seat.

Note: Bear in mind that the intake and exhaust valves have different diameters.

4-3.3 Valve sinking

Over long periods of use and repeated lappings, combustion efficiency may drop. Measure the sinking distance and replace the valve and valve seat if the valve sink exceeds the tolerance.





mm (in.)

	Standard	Wear limit
Valve sink	0.2 – 0.4 (0.0079 – 0.0157)	1.8 (0.0709)

4-3.4 Valve guide

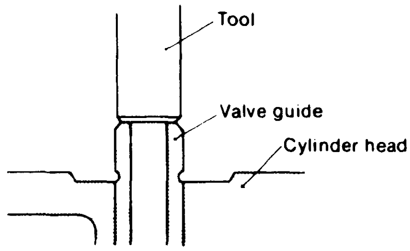
(1) Measuring inner diameter of the valve guide.
Measure the inner diameter of the valve guide and replace it if it exceeds the wear limit.

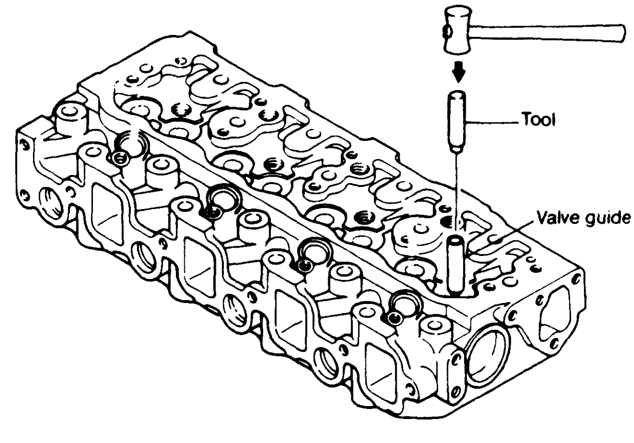
mm (in.)

		Standard	Wear limit
Valve guide inside dia.	Intake	9.00 – 9.015 (0.3543 – 0.3549)	9.1 (0.3583)
	Exhaust	9.00 – 9.015 (0.3543 – 0.3549)	9.1 (0.3583)

NOTE: The inner diameter standard dimensions assume a pressure fit.

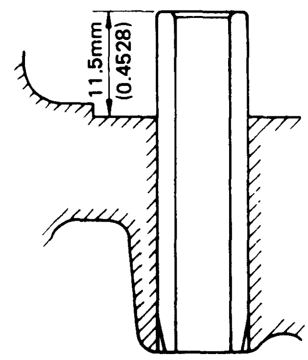
(2) Replacing the valve guide
Use the insertion tool and tap in the guide with a mallet.



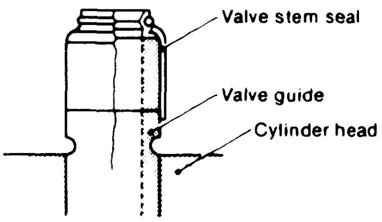


The intake valve guide and exhaust valve guide are of different shapes/dimensions. The one with a groove around it is the exhaust valve guide and the one without is the intake valve guide.

(3) Valve guide projection
The valve guide should project 11.5 mm from the top of the cylinder head.



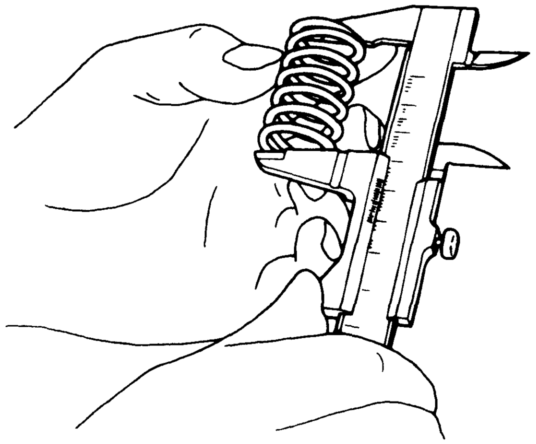
(4) Valve stem seals
The valve stem seals in the intake/exhaust valve guides cannot be re-used once they are removed—be sure to replace them.
When assembling the intake/exhaust valves, apply an adequate amount of engine oil on the valve stem before inserting them.



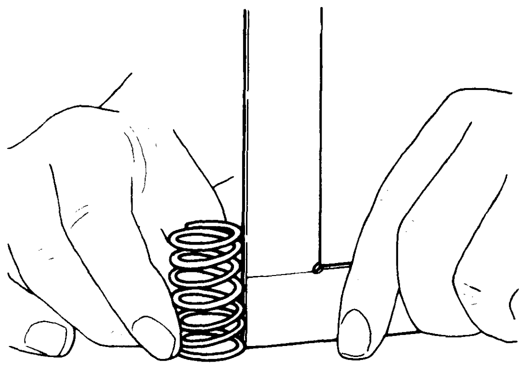
4-4 Valve springs

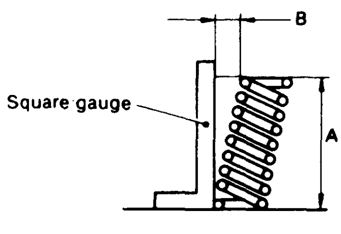
4-4.1 Checking valve springs

(1) Check the spring for scratches or corrosion.
(2) Measure the free length of the spring.

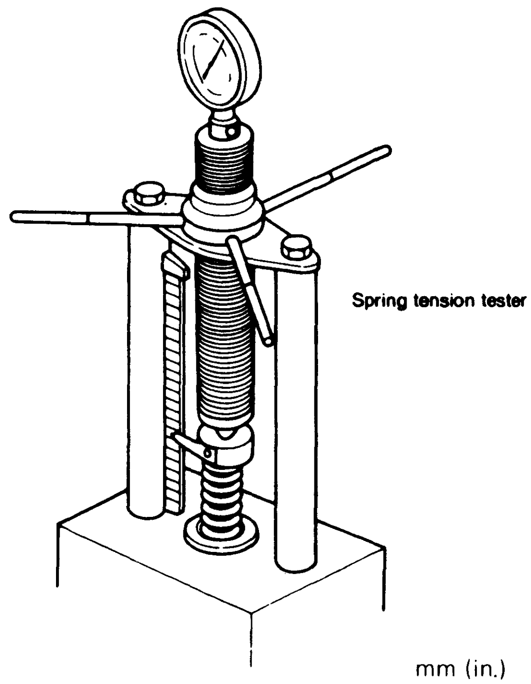


(3) Measure inclination.





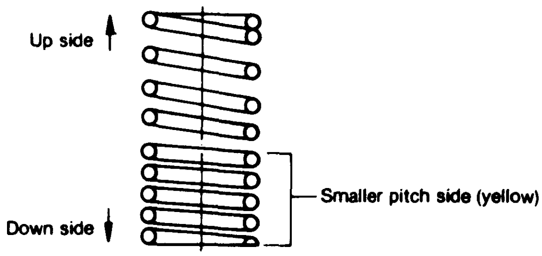
(4) Measure spring tension.



mm (in.)

Valve spring		Standard	Wear limit
Free length	mm (in.)	43 (1.6929)	42.5 (1.6732)
Inclination	mm (in.)	–	1.2 (0.0472)
Tension (When compressed 1 mm)	N (kgf)	25.4 (2.59)	–

Assembling valve springs
The side with the smaller pitch (painted yellow) should face down (cylinder head).



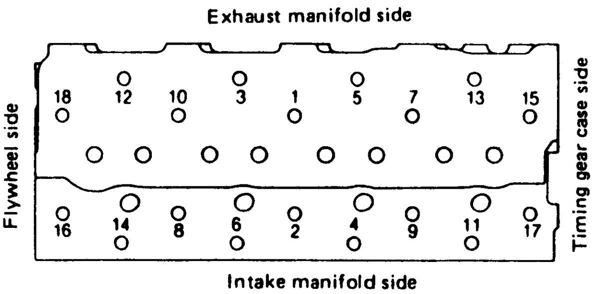
NOTE: The pitch of the valve spring is not even. The side with the smaller pitch (yellow) should face down (cylinder head) when assembled.

(5) Spring retainer and spring cotter
Inspect the inside face of the spring retainer, the outside surface of the spring cotter, the contact area of the spring cotter inside surface and the notch in the head of the valve stem. Replace the spring retainer and spring cotter when the contact area is less than 70%, or when the spring cotter has been recessed because of wear.

4-5 Assembling the cylinder head

Partially tighten the bolts in the specified order and then tighten to the specified torque, being careful not to distort the head.

(1) Clean out the cylinder head bolt holes.
(2) Check for foreign matter on the cylinder head surface where it comes in contact with the block.
(3) Coat the head bolt threads and nut seats with lube oil.
(4) Use the positioning pins to line up the head gasket with the cylinder block.
(5) Match up the cylinder head with the head gasket and mount.



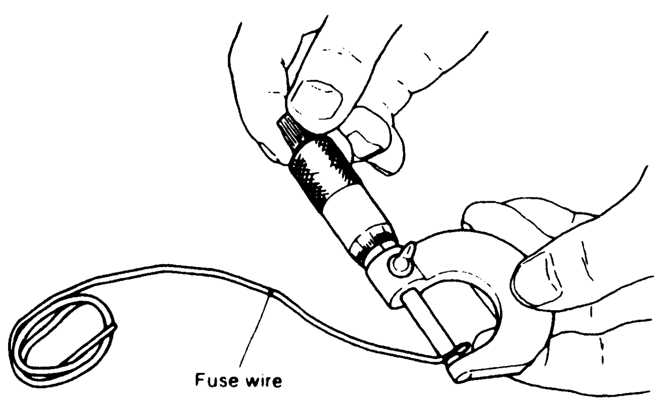
4 Cylinder engine

kg-m(ft.lb)

	First	Second	Final
Tightening torque	5 (36.17)	10 (72.35)	15-17 (108.52-123)

4-6 Measuring top clearance

(1) Place a high quality fuse (ϕ1.5mm (0.0591in.), 10mm(0.3937in.)long) in three positions on the flat part of the piston head.
(2) Assemble the cylinder head gasket and the cylinder block and tighten the bolts in the specified order to the specified torque.
(3) Turn the crank, (in the direction of engine revolution), and press the fuse against the piston until it breaks.
(4) Remove the head and take out the broken fuse.
(5) Measure the three positions where each fuse is broken and calculate the average.
(0.71~0.75mm(0.0280~0.0295in.) is ideal.



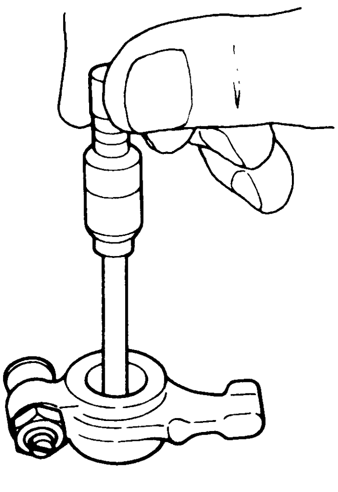
mm

Topclearance	4LHA-HTE,-STE	0.71-0.89
	4LHA-DTE	0.81-0.99

4-7 Intake and exhaust valve arms

Valve arm and valve arm bushing wear may alter opening/closing timing of the valve, and may in turn affect engine performance according to the extend of the change.

(1) Valve arm shaft and valve arm bushing
Measure the outer diameter of the shaft and the inner diameter of the bearing, and replace if wear exceeds the limit.



mm (in.)

	Standard	Wear limit
Intake and exhaust valve rocker arm shaft outside dia.	18.459 – 18.479 (0.7267 – 0.7275)	18.35 (0.7224)
Intake and exhaust valve rocker arm bushing inside dia. (assembled)	18.50 – 18.52 (0.7283 – 0.7291)	18.60 (0.7323)
Valve rocker arm shaft and bushing clearance at assembly	0.021 – 0.061 (0.0008 – 0.0024)	–

Replace the valve arm shaft bushing if it moves and replace the entire valve arm if there is no tightening clearance.

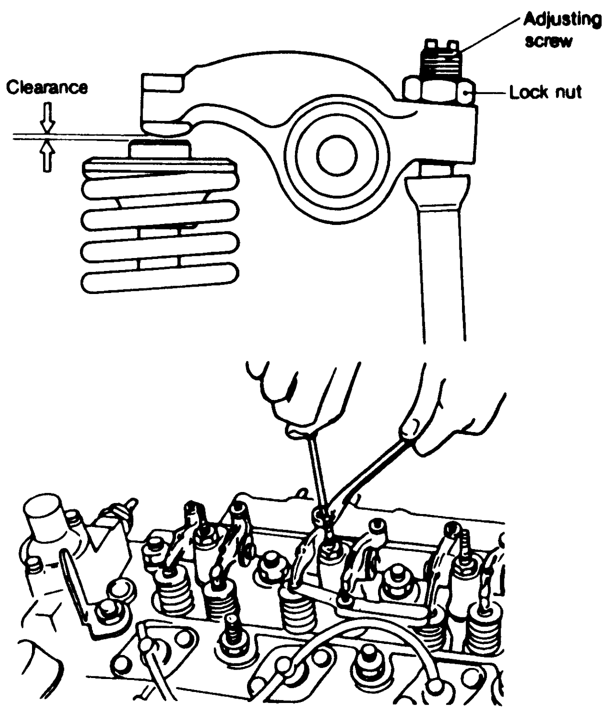
(2) Valve arm spring
Check the valve arm spring and replace it if it is corroded or worn.
(3) Valve arm and valve top retainer wear
Inspect the contact surface of the valve arm and replace it if there is abnormal wear or flaking.
(4) Inspect the contact surface of the valve clearance adjustment screw and push rod and replace if there is abnormal wear or flaking.

4-8 Adjustment of valve head clearance

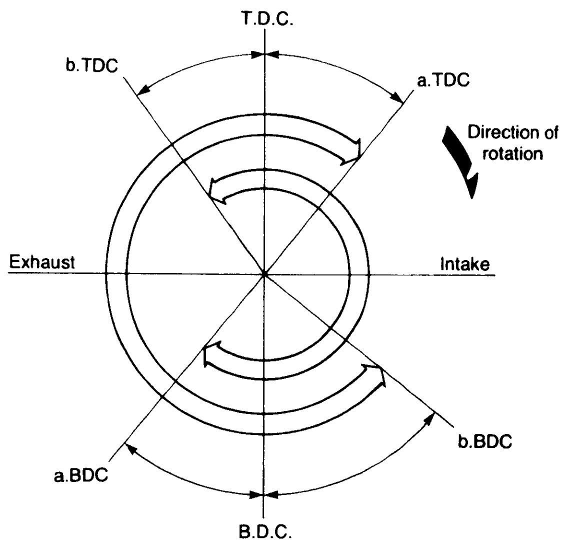
(1) Make adjustments when the engine is cool.

mm (in.)

Intake valve clearance	0.1 (0.004)
Exhaust valve clearance	0.3 (0.012)



(2) Be sure to adjust the opening and closing angles for both the intake and exhaust valves when reassembling the timing gear.



Degree

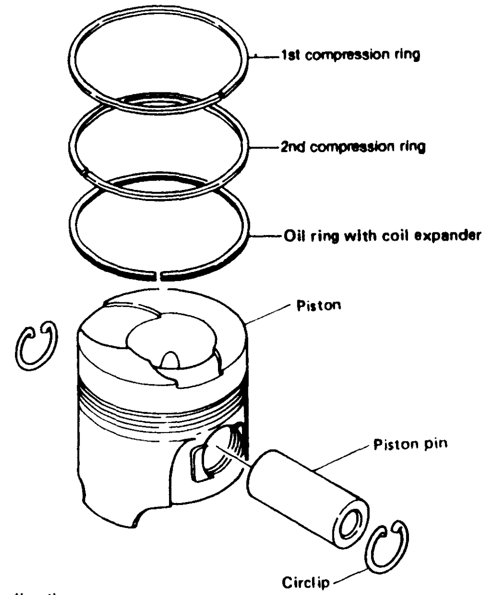
Intake valve open	b. TDC	59±5
Intake valve closed	a. BCD	63±5
Exhaust valve open	b. BDC	58±5
Exhaust valve closed	a. TDC	46±5

5. Piston and Piston Pins

The piston is made of an aluminum alloy with low thermal expansion.
There is a clearance between the outside diameter of the piston and the inside diameter of the cylinder. The clearance is an important factor that has influence on the lubricosity between the piston and cylinder, lubricating oil consumption and the noise level of the cylinder.
In Yanmar enjines, both piston and cylinder have identfication marks to ensure proper clearance between the piston and cylinder on their respective top surfaces.
In the Yanmar factory, the piston is assembled into a cylinder block with the same identfication mark.
The following shows the possible combinations of identification marks for the piston and cylinder block.

		Identification of piston			
		L	ML	MS	S
Cylinder block	L	○	○	×	×
	M	×	○	○	×
	S	×	×	○	○

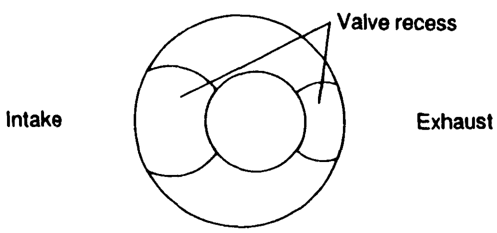
Note 1: ○....Fixed
×....Do not fix

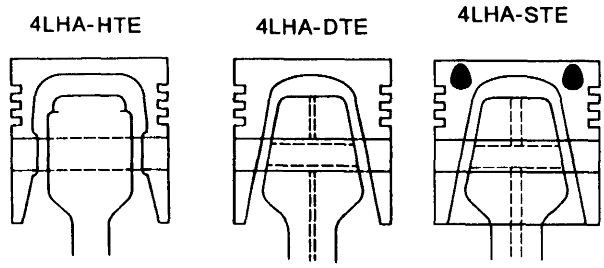


Piston application

mm(in.)

		4LHA-HTE	4LHA-DTE
Valve recess	Intake	46.5(1.83)	49.0(1.93)
	Exxhaust	40.5(1.59)	42.5(1.67)





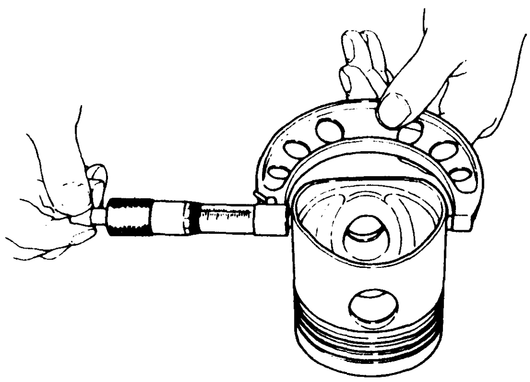
5-1 Piston

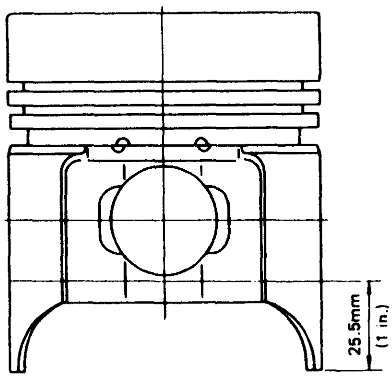
5-1.1 Piston head and combustion surface

Remove the carbon that has accumulated on the piston head and combustion surface, taking care not to scratch the piston. Check the combusion surface for any damage.

5-1.2 Measurement of piston outside diameter/inspection

(1) Replace the piston if the outside of the piston or ring grooves are worn.
(2) Measure the piston O.D. 25.5mm (1 in.) from the bottom at right angles to the piston pin.



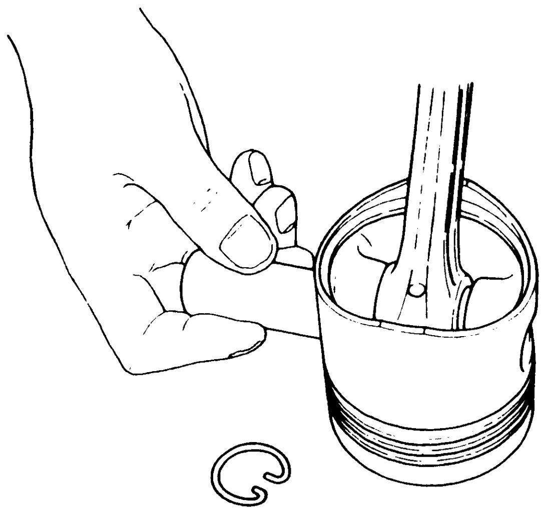


mm(in.)

	Standard	Wear limit
Piston outside dia.	99.895-99.925 (3.9329-3.9341)	99.79 (3.9287)

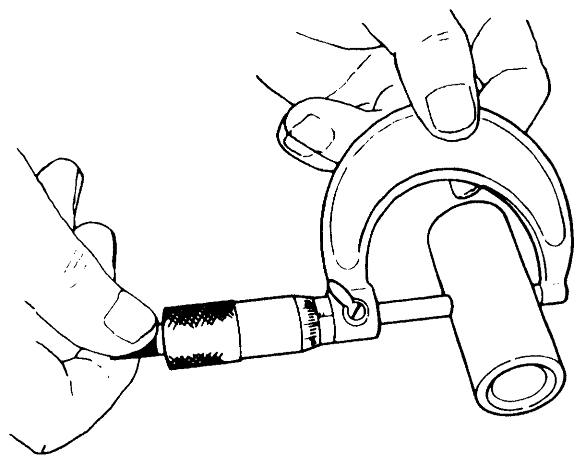
5-1.3 Replacing the piston

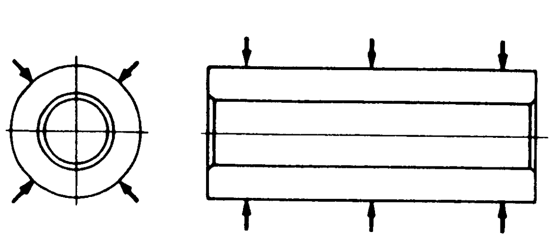
A floating type piston pin is used in this engine. The piston pin can be pressed into the piston pin hole at room temperature (coat with oil to make it slide in easily).



5-2 Piston pin

Measure the outer diameter and replace the pin if it is excessively worn.





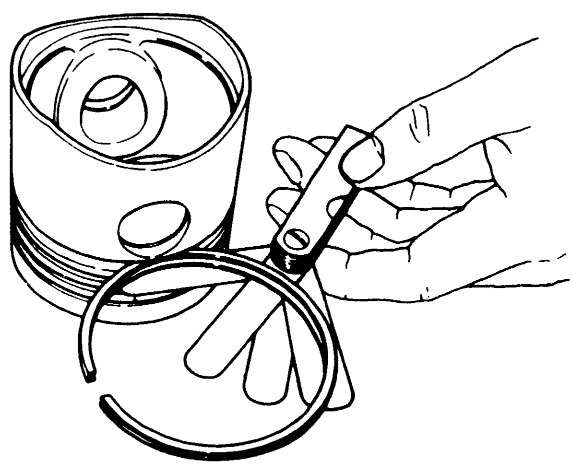
	4LHA-HTE	4LHA-DTE
Piston pin insertion hole dia.	34.00-34.011 (1.3386-1.3390)	37.00-37.011 (1.4567-1.4578)
Piston pin outside dia.	33.989-34.00 (1.3381-1.3386)	36.989-37.00 (1.4563-1.4567)
Standard clearance	0-0.022 (0-0.0009)	0-0.022 (0-0.0009)

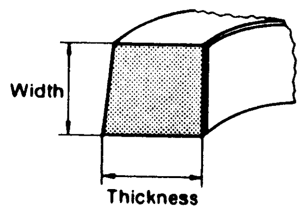
5-3 Piston rings

There are 2 compression rings and 1 oil ring.
The absence of an oil ring on the piston skirt prevents oil from being kept on the thrust surface and in turn provides good lubrication.

5-3.1 Measuring the rings

Measure the thickness and width of the rings, and the ring-to-groove clearance after installation. Replace if wear exceeds the limit.



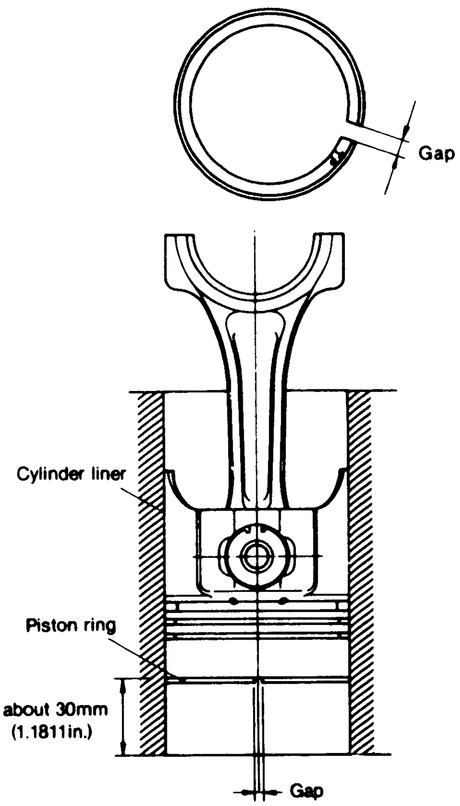


mm (in.)

		Standard	Wear limit
First piston ring	Groove width	**2.095 – 2.110 (0.0825 – 0.0831)**	–
	Ring width	**1.975 – 1.990 (0.0778 – 0.0783)**	–
	Groove and ring clearance	**0.105 – 0.135 (0.0041 – 0.0053)**	**0.15 (0.0059)**
Second piston ring	Groove width	**2.045 – 2.060** (0.0805 – 0.0811)	–
	Ring width	**1.975 – 1.990 (0.0778 – 0.0783)**	–
	Groove and ring clearance	**0.055 – 0.085 (0.0022 – 0.0035)**	0.15 (0.0059)
Oil ring	Groove width	3.020 – 3.035 (0.1189 – 0.1195)	–
	Ring width	2.92 – 2.99 (0.1169 – 0.1177)	–
	Groove and ring clearance	0.030 – 0.065 (0.0012 – 0.0026)	0.15 (0.0059)

5-3.2 Measuring piston ring gap

Press the piston ring onto a cylinder and measure the piston ring gap with a gauge.
Press on the ring about 30 mm (1.1811 in.) from the bottom of the cylinder.

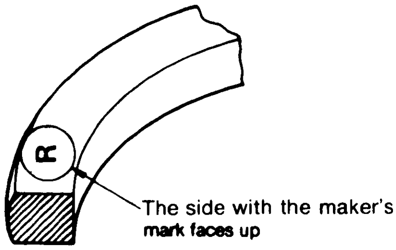


mm (in.)

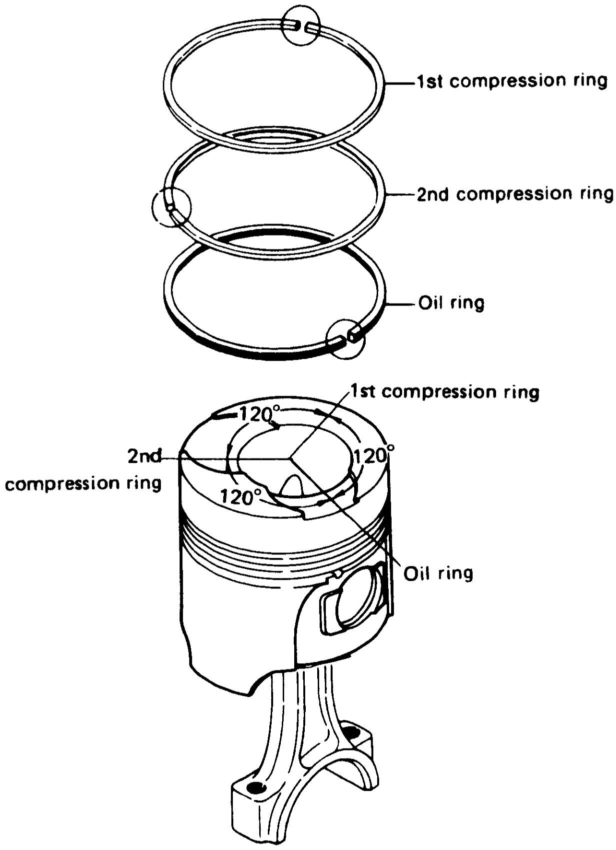
	Standard	Wear limit
First piston ring gap	0.25 – 0.40 (0.0098 – 0.0157)	1.5 (0.0591)
Second piston ring gap	0.25 – 0.40 (0.0098 – 0.0157)	1.5 (0.0591)
Oil ring gap	0.3 – 0.5 (0.0118 – 0.0197)	1.5 (0.0591)

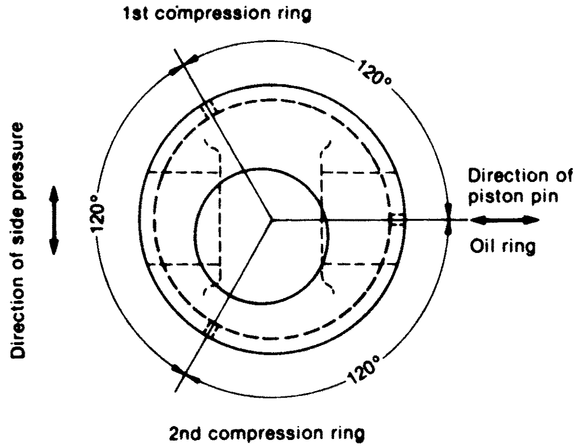
5-3.3 Replacing the piston rings

(1) Thoroughly clean the ring grooves when replacing piston rings.
(2) The side with the manufacturer's mark (near piston ring gap) should face up.

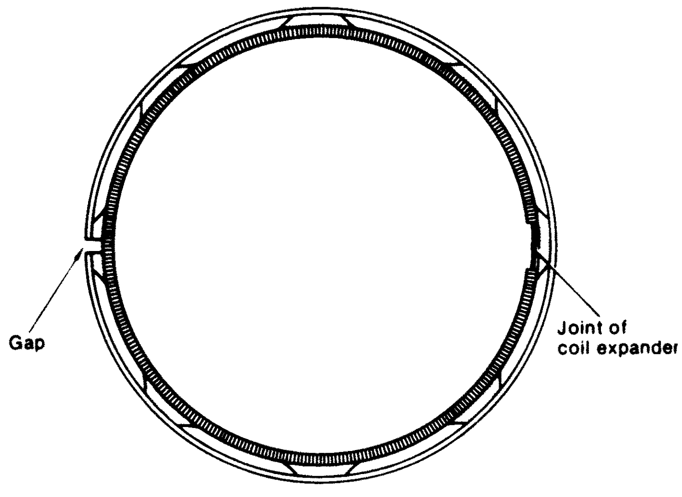


(3) After fitting the piston ring, make sure it moves easily and smoothly.
(4) Stagger the piston rings at 120° intervals, making sure none of them line up with the piston.



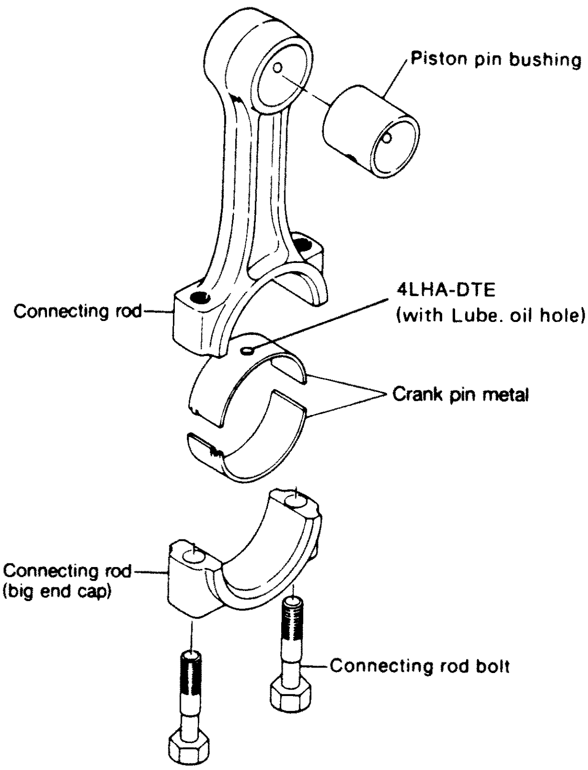


(5) The oil ring is provided with a coil expander. The coil expander joint should be opposite (staggered 180°) the oil ring gap.



6. Connecting Rod

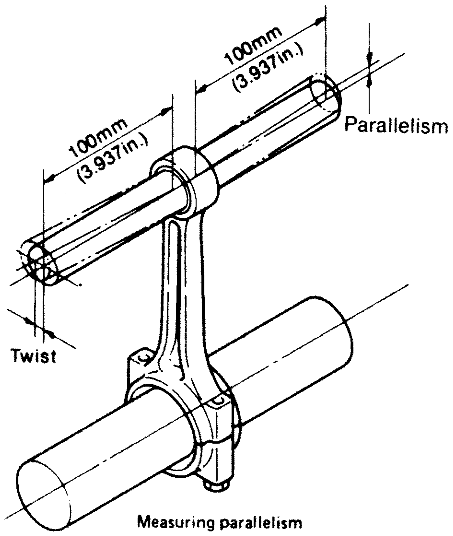
The connecting rod is made of high-strength forged carbon steel.
The large end with the special aluminum-alloy metal can be separated into two and the small end has a copper alloy coil bushing.



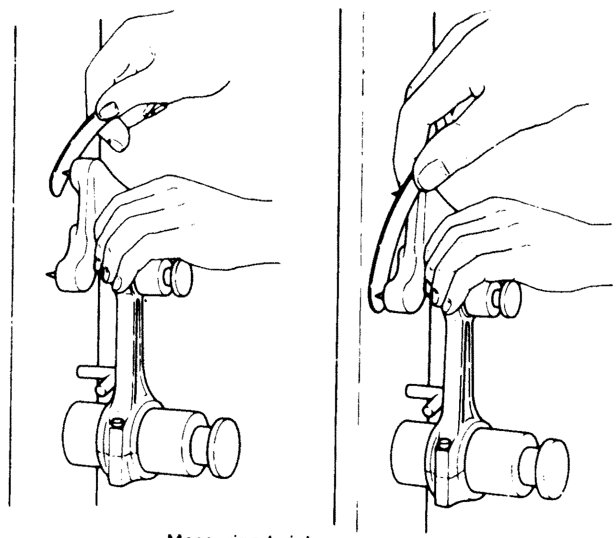
6-1 Inspecting the connection rod

6-1.1 Twist and parallelism of the large and small ends

Insert the measuring tool into the large and small ends of the connecting rod. Measure the extent of twist and parallelism and replace if they exceed the tolerance.



Measuring parallelism

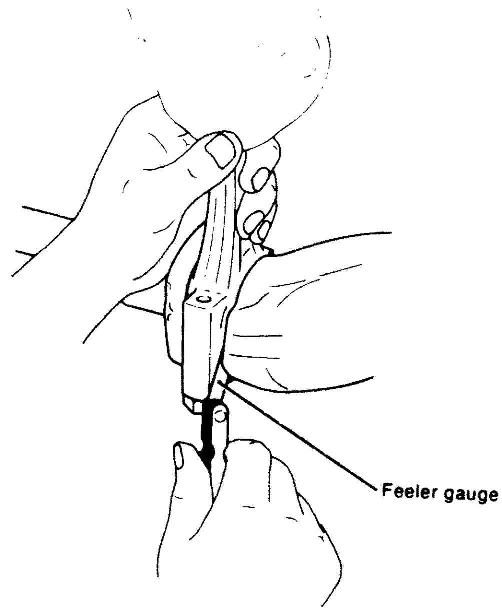

Measuring twist

mm (in.)

	Standard	Wear limit
Connecting rod twist and parallelity	0.05/100 or less (0.0020/3.94)	0.2 (0.0079)

6-1.2 Checking thrust clearance

Fit the respective crank pins to the connecting rod and check to make sure that the clearance in the crankshaft direction is correct.



mm (in.)

	Standard	Wear limit
Connecting rod side clearance	0.2 – 0.4 (0.079 – 0.0157)	0.45 (0.0177)

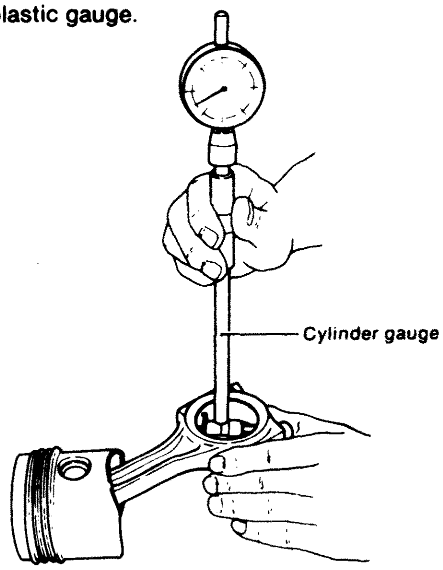
6-2 Crank pin bushing

6-2.1 Checking crank pin bushing

Check for flaking, melting or seizure on the contact surface.

6-2.2 Measuring crank pin oil clearance

Use a plastic gauge.



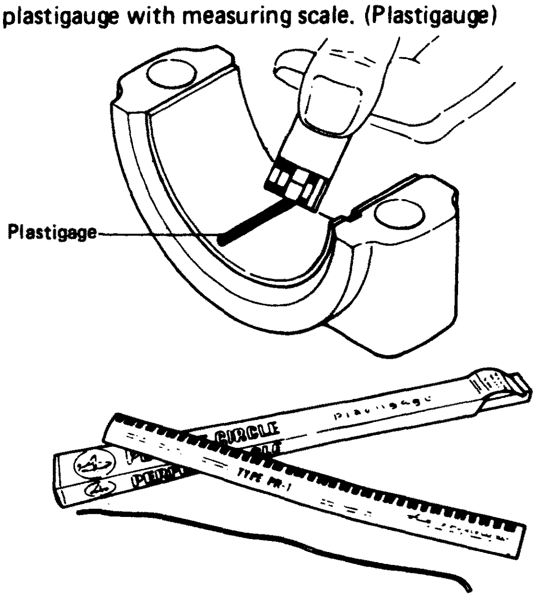
Procedure

(1) Use the press gauge (Plastigage) for measuring oil clearance in the crank pin.
(2) Mount the connecting rod on the crank pin (tighten to specified torque).

N(kgf)·m

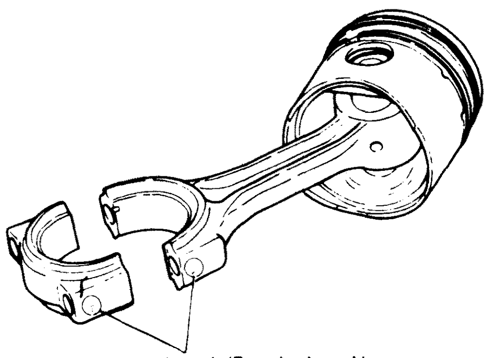
Connecting rod tightening torque	118 (12)

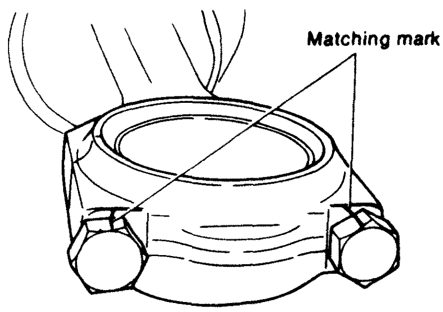
(3) Remove the connecting rod and measure the broken plastigauge with measuring scale. (Plastigauge)



6-2.3 Precautions for replacement of crank pin bushing

(1) Wash the crank pin bushing.
(2) Wash the large end cap, mount the crank pin bushing and make sure that it fits tightly on the large end cap.
(3) When assembling the connecting rod, match up the large end and large end cap number. Coat the bolts with engine oil and gradually tighten them alternately to the specified torque.
If a torque wrench is not available, make match marks on the bolt heads and large end cap (to indicate the proper torque position) and retighten the bolts to those positions.

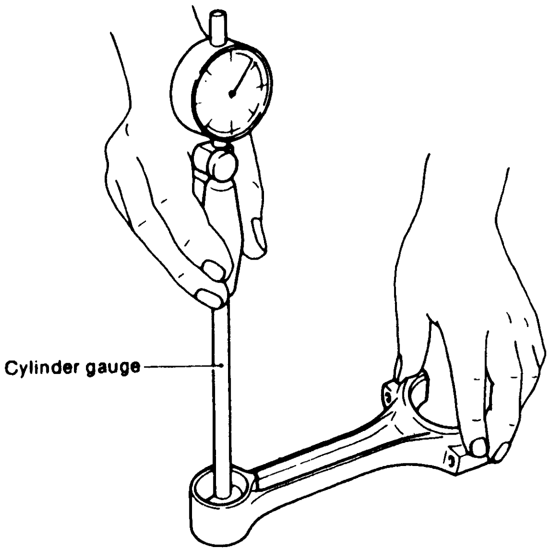




(4) Make sure there is no sand, metal cuttings or other foreign matter in the lube oil, and that the crankshaft is not scratched. Take special care in cleaning the oil holes.

6-3 Piston pin bushing

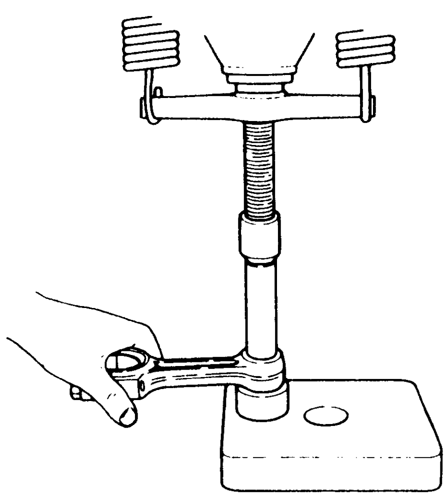
(1) Measuring piston pin clearanoe
Excessive piston pin bushing wear may result damage to the piston pin or the piston itself.



mm(in.)

Piston	4LHA-HTE		4LHA-DTE,-STE	
	Standard	Wear limit	Standard	Wear limit
Piston pin bushing inside dia.	23.04-34.05 (1.3398-1.3406)	34.10 (1.3425)	37.03-37.05 (1.4579-1.4587)	37.10 (1.4606)
Piston pin and bushing oil cleareance	0.030-0.061 (0.0012-0.0024)	–	0.030-0.061 (0.0012-0.0024)	–

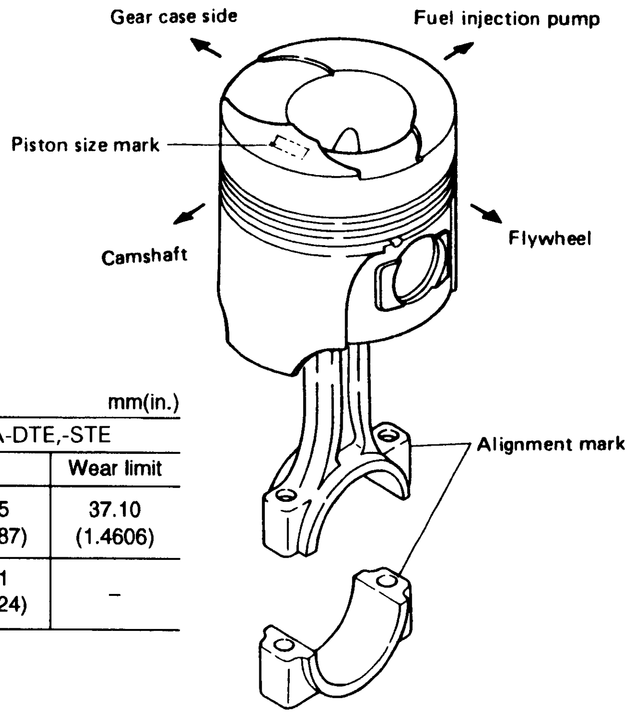
(2) Replacing piston pin bushing
1)When the bushing for the connecting rod piston pin is either worn out or damaged, replace it by using the "piston pin extracting tool" installed on a press.



NOTE: Force the piston pin bushing into position so that its oil hole coincides with the hole on the small end of the connecting rod.

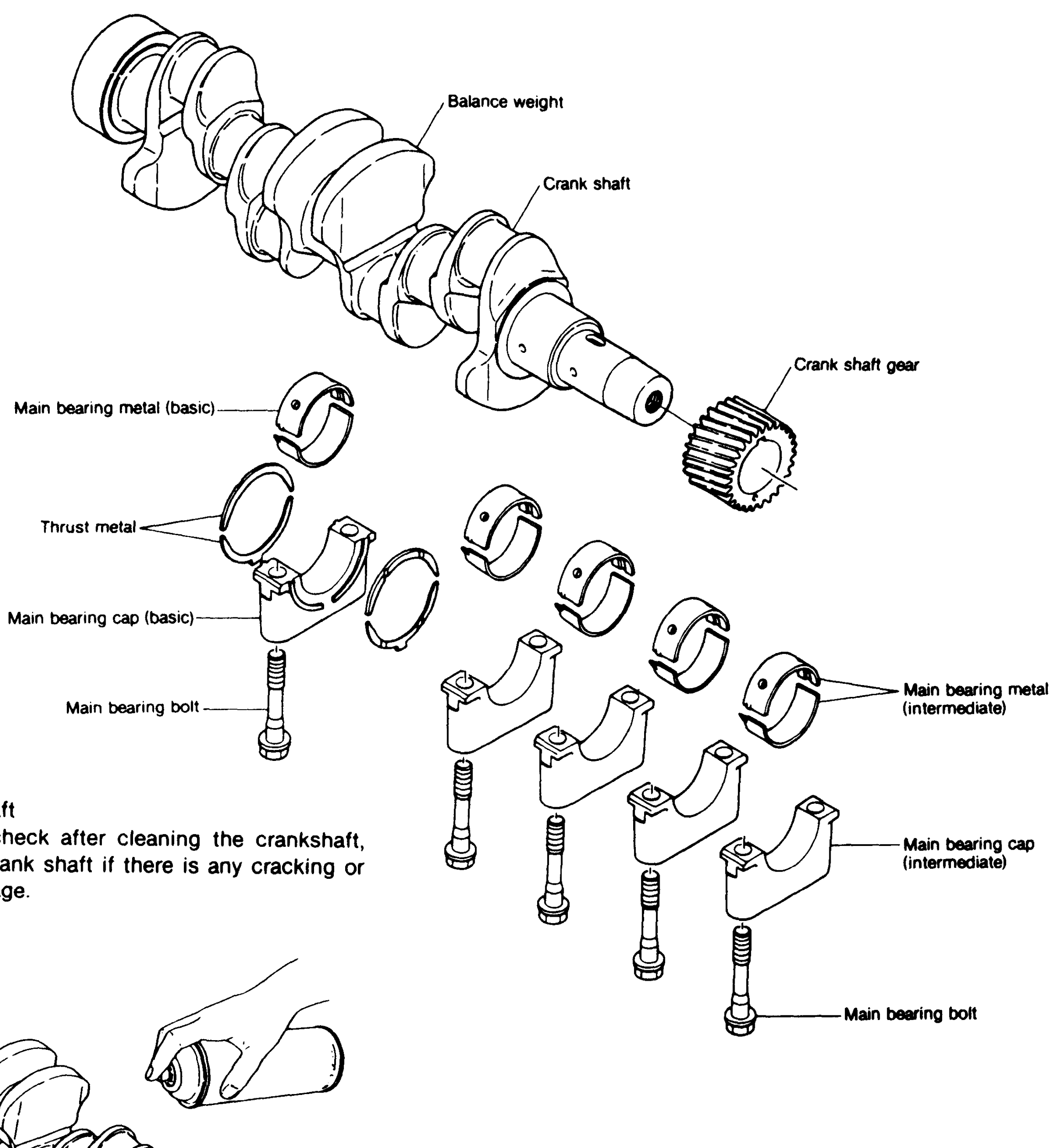
6-4 Assembling piston and connecting rod

The piston and connecting rod should be assembled so that the match mamk on the connecting nod large end faces the fuel injection pump side and the combustion chamber above the piston is close to the fuel injection pump.



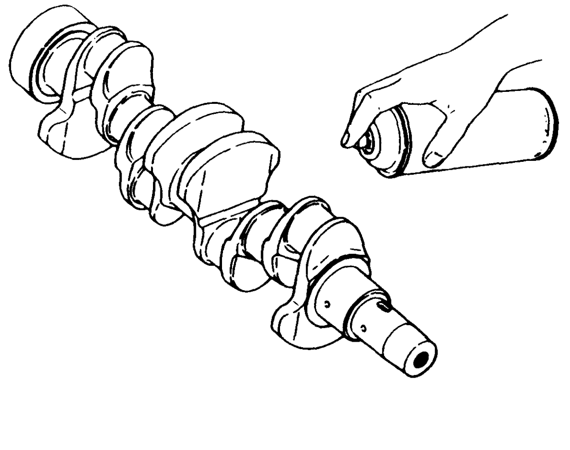
7. Crankshaft and Main Bearing

The crank pin and crank journal have been high-frequency hardened for superior durability, and the crankshaft is provided with four balance weights for optimal balance. The crankshaft main bearing is of the hanger type, with the upper metal (cylinder block side) provided with an oil groove, and with no oil groove on the lower metal (bearing cap side). The bearing cap (location cap) of the flywheel side has a thrust metal which supports the thrust load.

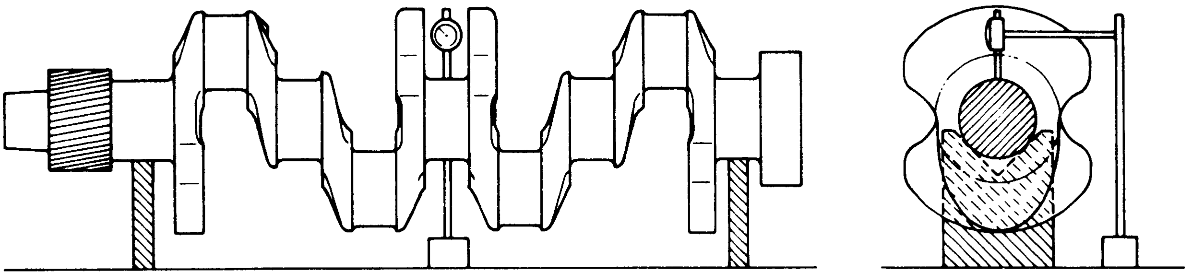


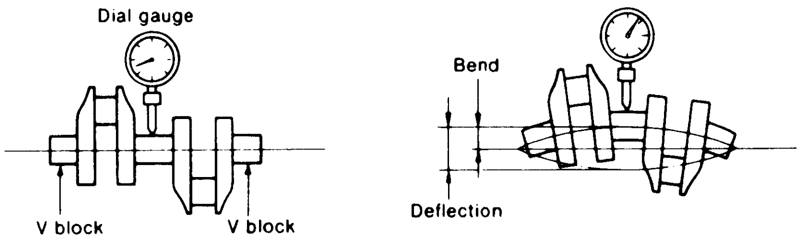
7-1 Crankshaft

(1) Color check of shaft
Perform a color check after cleaning the crankshaft, and replace the crank shaft if there is any cracking or considerable damage.



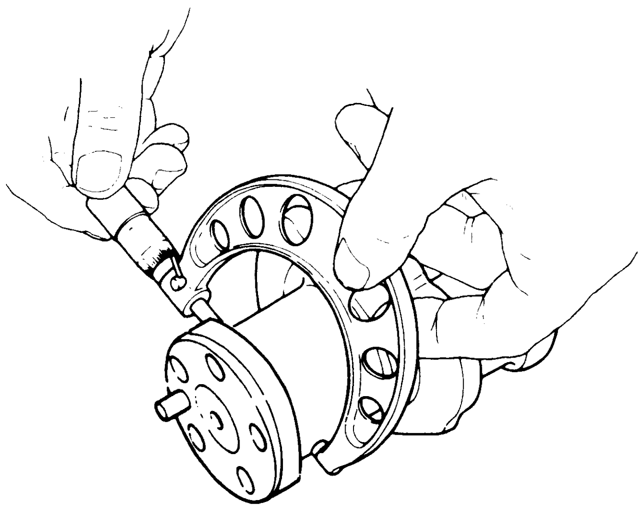
(2) Bending of the crankshaft
Support the crankshaft with V-blocks at both ends of the journals. Measure the deflection of the center journal with a dial gauge while rotating the crankshaft to check the extent of crankshaft bending.

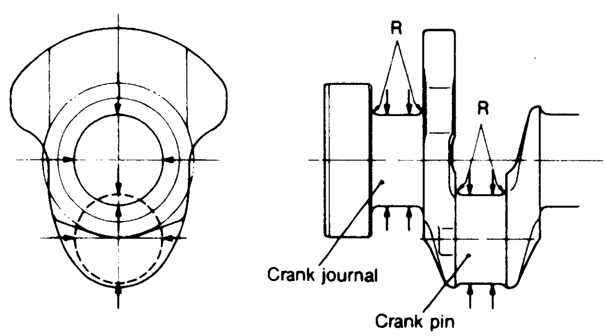




Crankshaft bend	Less than 0.02mm (0.0007 in.)

(3) Measuring the crank pin and journal
Measure the extent of journal wear (roundness, taper). Regrind it to the proper shape if it is within the outer diameter limit, and replace if not.





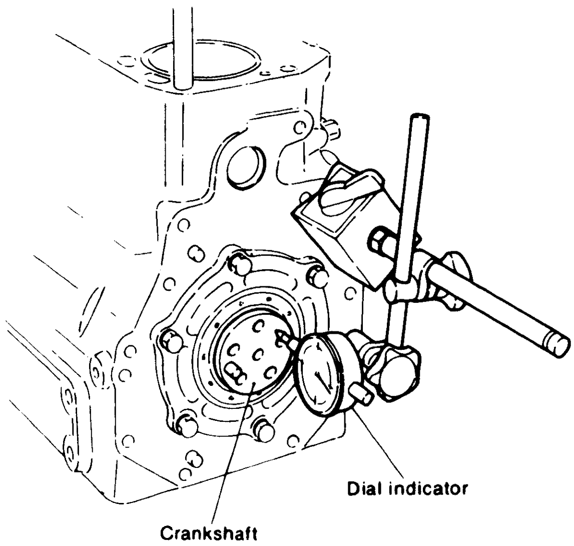
mm (in.)

		Standard	Wear limit
Crank pin	Outside dia.	59.952 – 59.964 (2.3603 – 2.3608)	59.90 (2.3583)
	Bushing inside dia.	60.00 – 60.042 (2.3622 – 2.3639)	60.10 (2.3661)
	Crank pin and bushing oil clearance	0.036 – 0.09 (0.0014 – 0.0035)	–
Crank journal	Outside dia.	69.952 – 69.964 (2.7540 – 2.7545)	69.90 (2.7520)
	Bushing inside dia.	70.00 – 70.045 (2.7559 – 2.7577)	70.10 (2.7598)
	Crank journal and bushing oil clearance	0.036 – 0.093 (0.0014 – 0.0037)	–
Fillet rounding of crank pin and journal		4.0 – 4.3 (0.1575 – 0.1693)	–

(4) Checking side clearance of the crankshaft
After assembling the crankshaft, tighten the main bearing cap to the specified torque, and move the crankshaft to one side, placing a dial gauge on one end of the shaft to measure thrust clearance.
This measurement can also be effected by inserting the gauge directly into the clearance between the thrust bearing and crankshaft thrust surface.
Replace the thrust bearing if it is worn beyond the limit.

mm (in.)

	Standard	Wear limit
Crankshaft side gap	0.132 – 0.223 (0.0052 – 0.0088)	0.29 (0.0114)



7-2 Main bearing

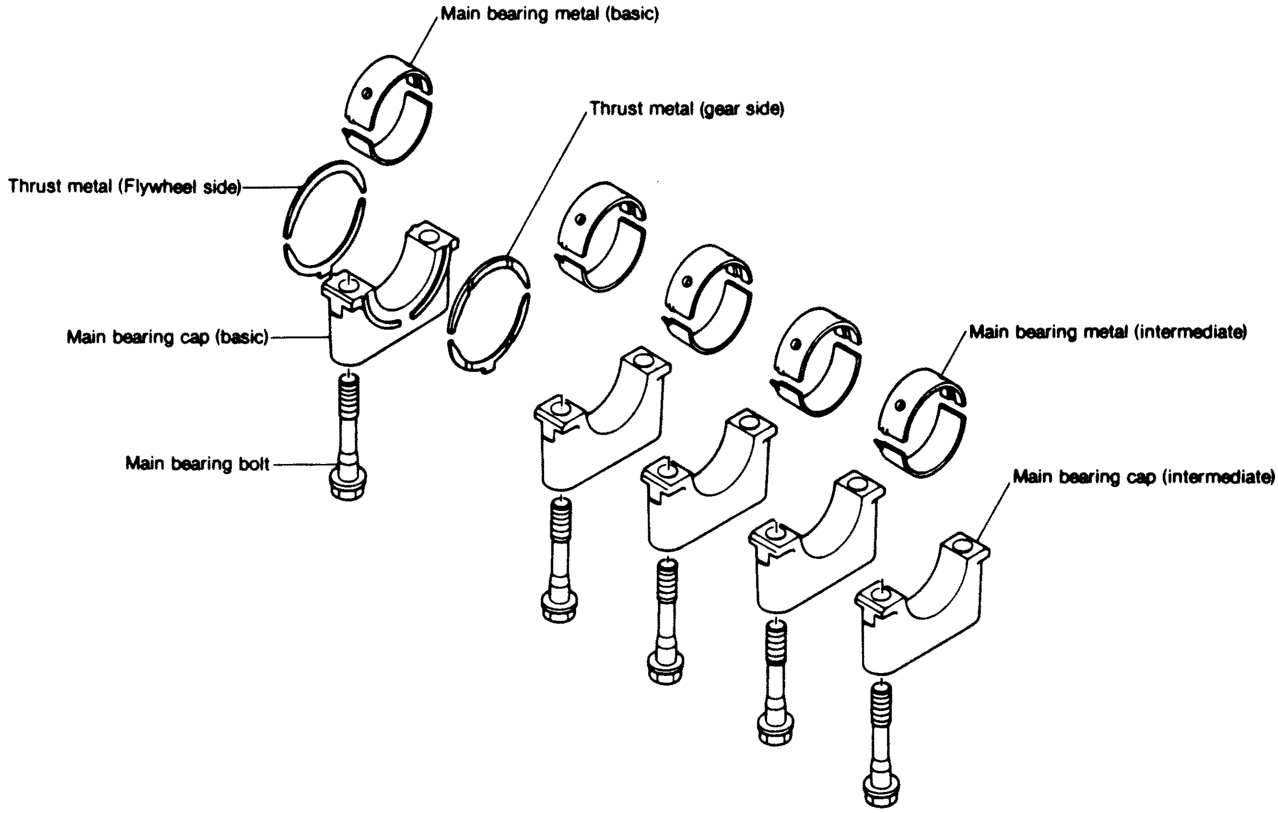
(1) Inspecting the main bearing
Check for flaking, seizure or burning of the contact surface and replace if necessary.

(2) Measuring the inner diameter of metal
Tighten the cap to the specified torque and measure the inner diameter of the metal.

N(kgf)·m

Bearing cap bolt tightening torque	186~206 (19 - 21)

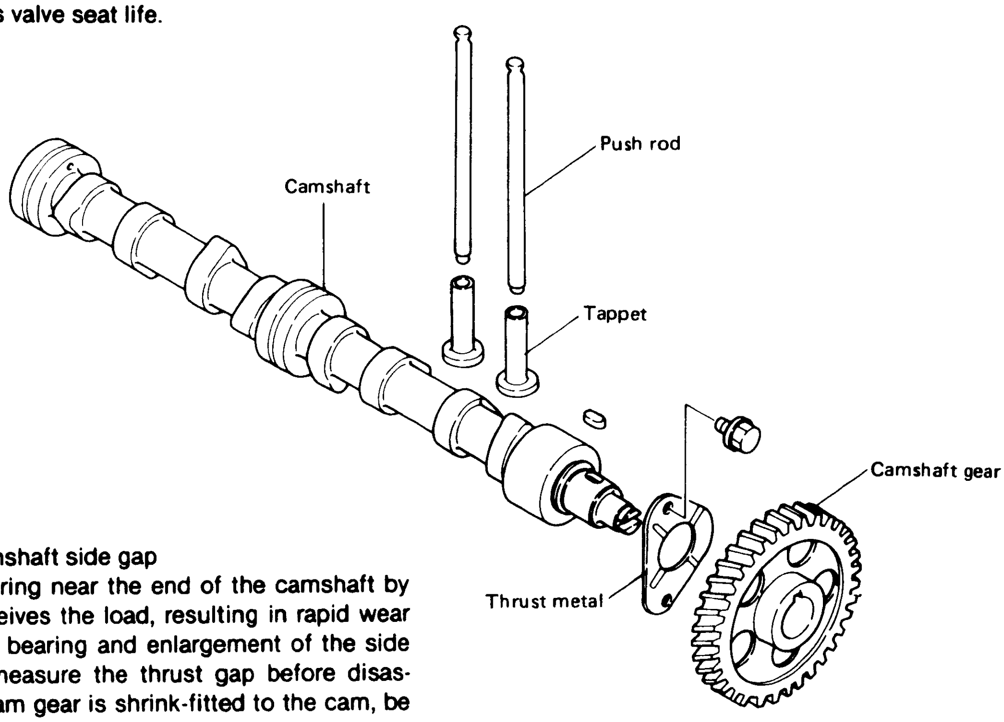
***NOTE:** When assembling the bearing cap, keep the following in mind.*
1) The lower metal (cap side) has no oil groove.
2) The upper metal (cylinder block side) has an oil groove.
3) Check the cylinder block alignment No.
4) The "FW" on the cap lies on the flywheel side.



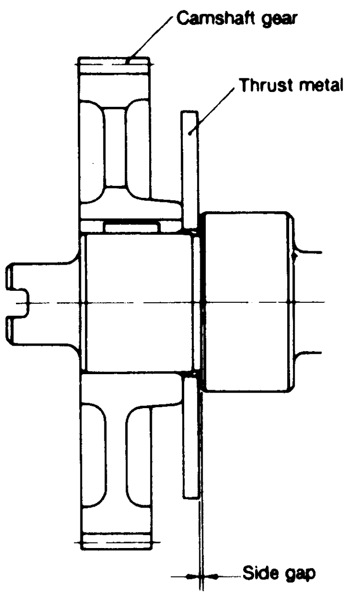
8. Camshaft and Tappets

8-1 Camshaft

The camshaft is normalized and the cam and bearing surfaces are surface hardened and ground. The cams have a curve that minimizes the repeated shock on the valve seats and maximizes valve seat life.



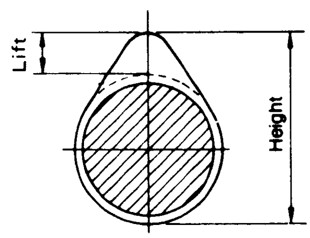
(1) Checking the camshaft side gap
The standard bearing near the end of the camshaft by the cam gear receives the load, resulting in rapid wear of the end of the bearing and enlargement of the side gap. Therefore, measure the thrust gap before disassembly. As the cam gear is shrink-fitted to the cam, be careful when replacing the thrust bearing.



mm (in.)

	Standard	Wear limit
Camshaft side gap	0.05 – 0.20 (0.0020 – 0.0079)	0.29 (0.0114)

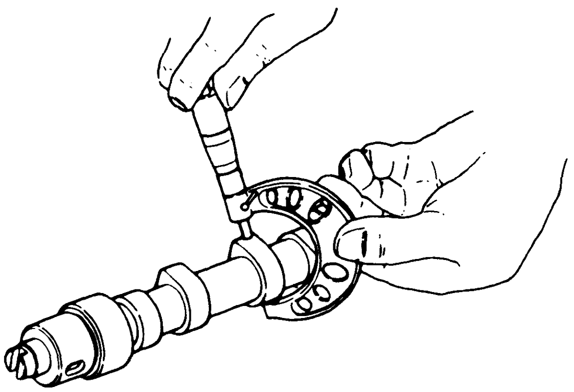
(2) Measure the cam height, and replace the cam if it is worn beyond the limit.



mm (in.)

Cam height	Standard	Wear limit
Intake cam	48.435 – 48.565 (1.9069 – 1.9120)	48.1 (1.9094)
Exhaust cam	48.435 – 48.565 (1.9069 – 1.9120)	48.1 (1.9094)

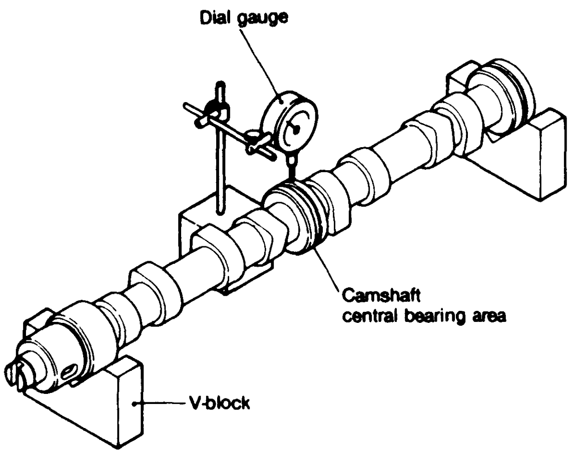
(3) Measure the camshaft outer diameter and the camshaft bearing inner diameter. Replace if they exceed the wear limit or are damaged.



mm (in.)

	Standard			Wear limit
	Gear case side	Intermediate	Flywheel side	
Camshaft journal outside dia.	56.91 – 56.94 (2.2406 – 2.2417)	56.91 – 56.94 (2.2406 – 2.2417)	56.91 – 56.94 (2.2406 – 2.2417)	56.80 (2.2362)
Camshaft journal bushing inside dia.	56.98 – 57.05 (2.2433 – 2.2461)	–	–	57.10 (2.2480)
Cylinder block bearing inside dia.	–	57.00 – 57.03 (2.2441 – 2.2453)	57.00 – 57.03 (2.2441 – 2.2453)	57.10 (2.2480)
Oil clearance	0.04 – 0.14 (0.0016 – 0.0055)	0.06 – 0.12 (0.0024 – 0.0047)	0.06 – 0.12 (0.0024 – 0.0047)	–

(4) Bending of the camshaft
Support both ends of the camshaft with V-blocks, place a dial gauge against the central bearing areas and measure bending. Replace if excessive.



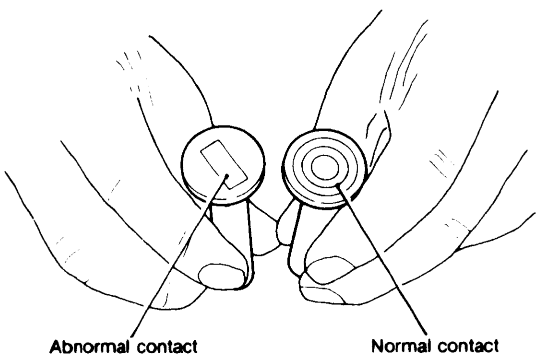
NOTE: The reading on the dial gauge is divided by two to obtain the extent of bending.

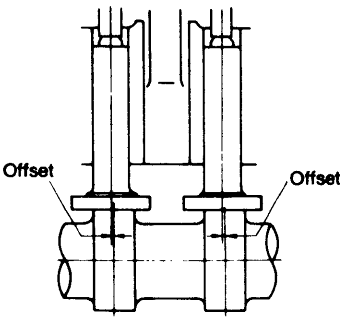
mm (in.)

	Standard	Wear limit
Camshaft deflection	0.02 or less (0.0008)	0.05 (0.0020)

8-2 Tappets

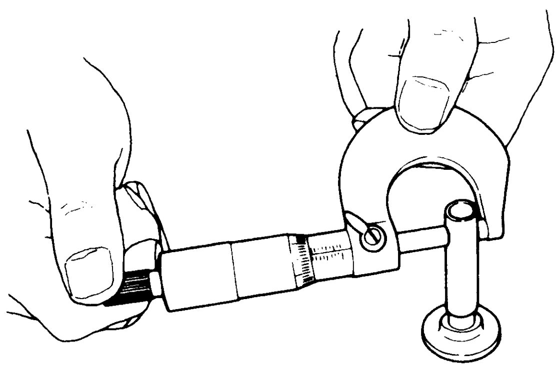
(1) The tappets are offset to rotate during operation and thereby prevent uneven wearing. Check the contact of each tappet and replace if excessively or unevenly worn.





NOTE: When removing tappets, be sure to keep them separate for each cylinder and intake/exhaust valve.

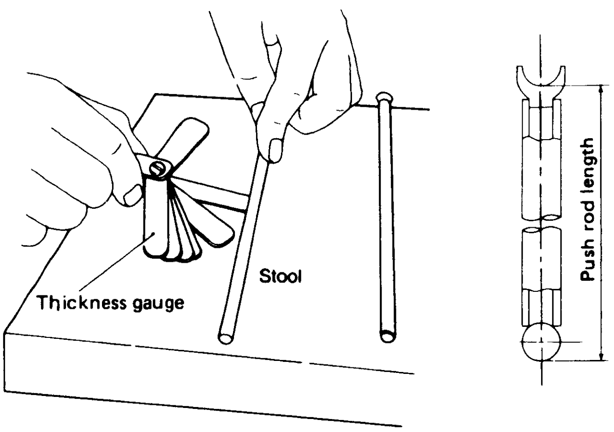
(2) Measure the outer diameter of the tappet, and replace if worn beyond the limit.



mm (in.)

	Standard	Wear limit
Tappet stem outside dia.	14.218 – 14.233 (0.5598 – 0.5604)	14.17 (0.5579)
Tappet guide hole inside dia. (cylinder block)	14.249 – 14.270 (0.5610 – 0.5618)	14.30 (0.5630)
Tappet stem and guide hole oil clearance	0.016 – 0.052 (0.0006 – 0.0020)	–

(3) Measuring push rods.
Measure the length and bending of the push rods.

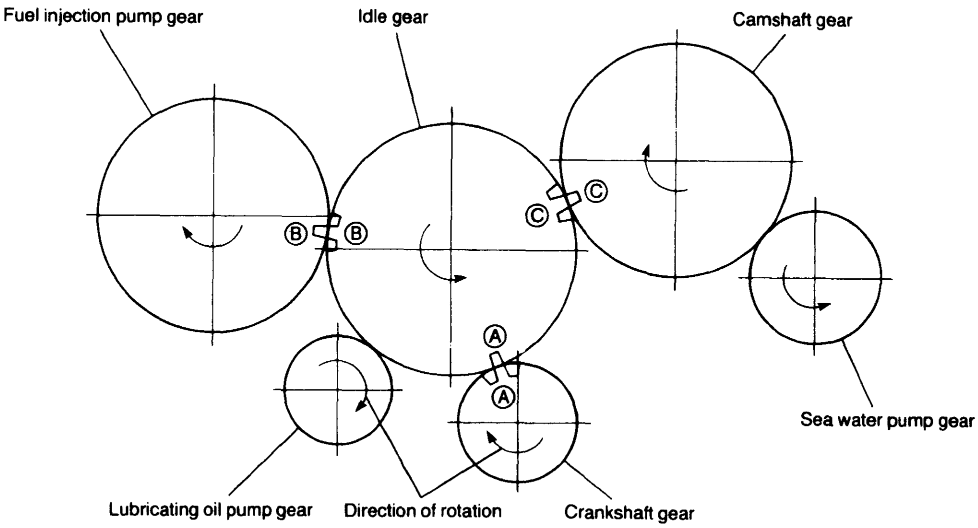


mm (in.)

	Standard	Wear limit
Push rod length	178.25 – 178.75	–
Push rod bend	0.03 or less (0.0012)	0.3 (0.0118)
Push rod dia.	8 (0.3150)	–

9. Timing Gear

The timing gear is helical type for minimum noise and specially treated for high durability.
Match up the timing marks on each gear when assembling (A, B and C).



	Crankshaft gear	Idle gear	Lube oil pump gear	Injection pump gear	Camshaft gear	Sea water pump gear
No. of teeth	24	51	20	48	48	27
Back lash	0.08 ~ 0.16mm(0.0031 ~ 0.0063in.)					

9-1 Inspecting the gears

(1) Inspect the gears and replace if the teeth are damaged or worn.

(2) Measure the backlash of all gears that mesh, and replace the meshing gears as a set if wear exceeds the limit.

*NOTE: **If backlash is excessive, it will not only result in excessive noise and gear damage, but also lead to bad valve and fuel injection timing and a decrease in engine performance.***

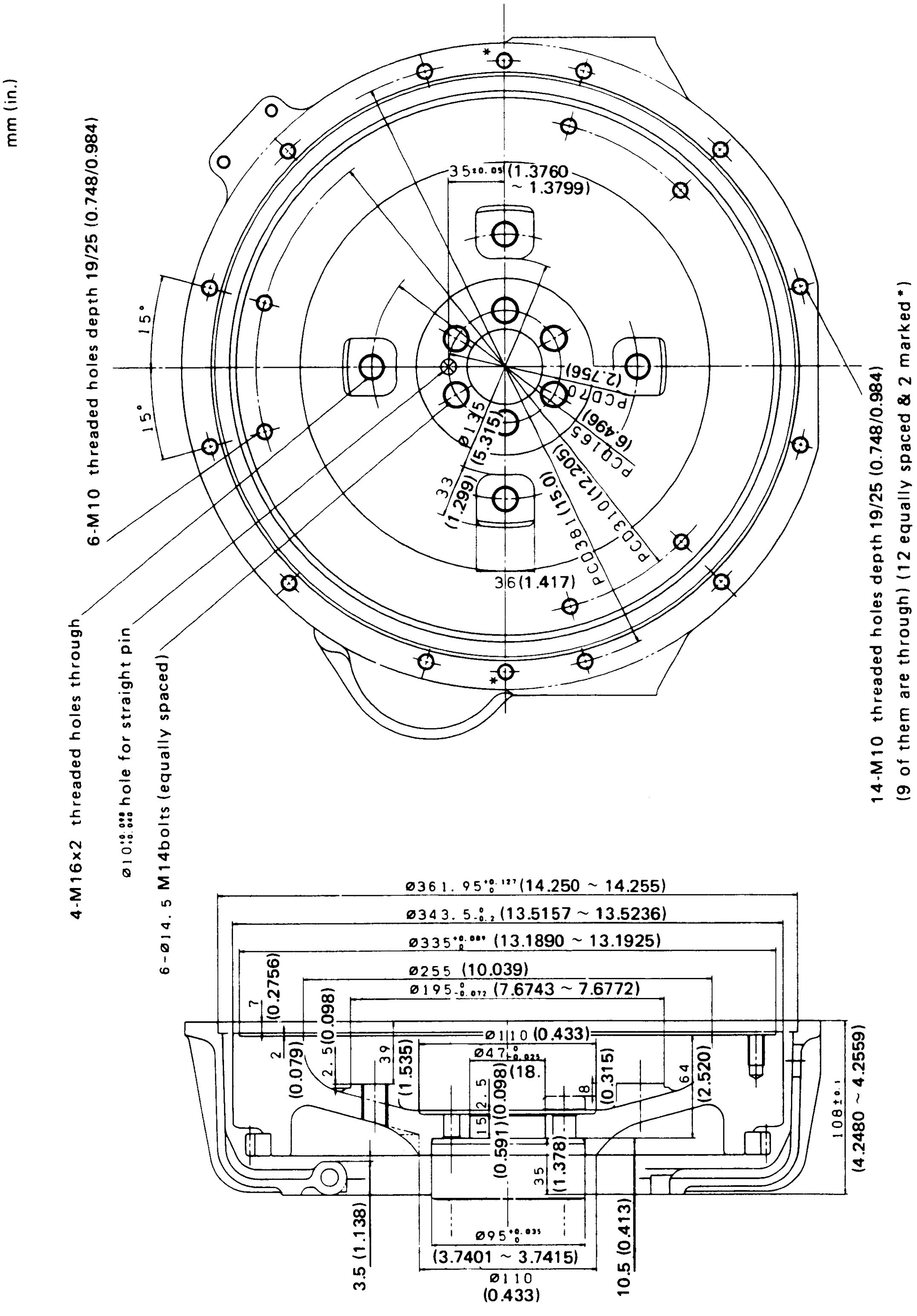
mm (in.)

	Standard	Wear limit
Idle shaft dia.	45.95 – 45.975 (1.8091 – 1.8100)	45.9 (1.8071)
Idle shaft bushing inside dia.	46.00 – 46.025 (1.8110 – 1.8120)	46.09 (1.8146)
Idle shaft and bushing oil clearance	0.025 – 0.075 (0.0010 – 0.0030)	–

(3) Idling gear
The bushing is pressure fitted into the idling gear. Measure the bushing inner diameter and the outer diameter of the shaft, and replace the bushing or idling gear shaft if the oil clearance exceeds the wear limit.
A, B and C are inscribed on the end of the idling gear. When assembling, these marks should align with those on the cylinder block.

10. Flywheel

10-1 Dimensions of flywheel and flywheel housing



CHAPTER 3

FUEL INJECTION EQUIPMENT

3-1. DISTRIBUTOR TYPE

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3. Fuel Injection Pump Outline 3-1-4
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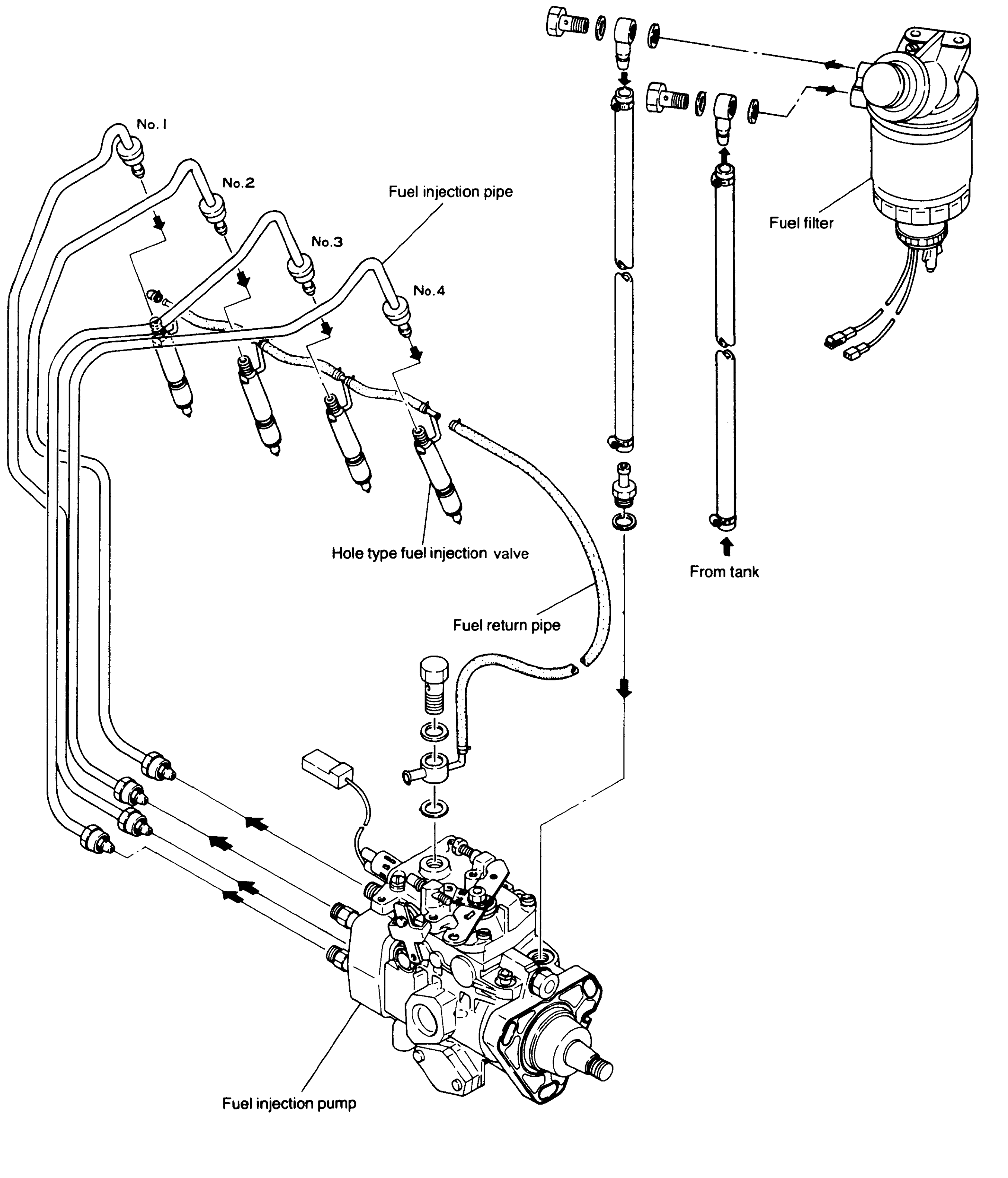
1. Fuel Supply System



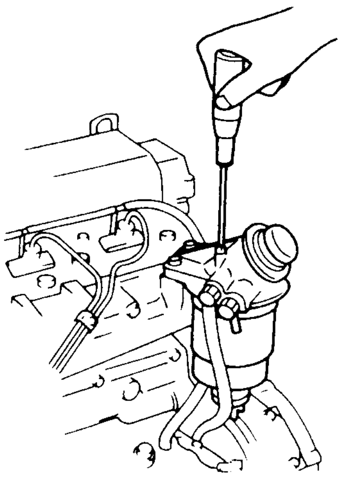
2. Bleeding and Checking Injection Timing

1 . Air bleeding in the fuel system (4LHA-HTE/HTZE/HTP/HTZP)

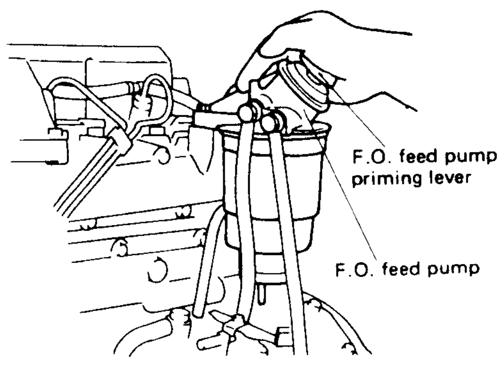
If the engine is operated when the fuel tank is empty, or with the fuel tank outlet cock closed, air is sucked into the fuel oil system, and the engine stops. When this happens, vent the air as follows:

(1) Add fuel to the fuel tank.

(2) Loosen the air-vent screw on the fuel oil filter, and push the fuel feed pump priming lever several times.
When no air is observed in the fuel, tighten the air-vent screw firmly.

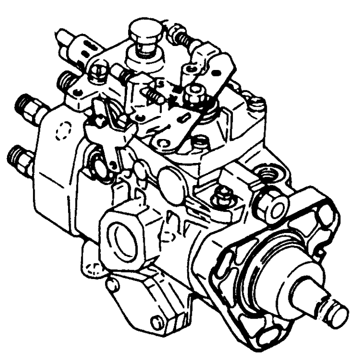


(3) Loosen the hexagonal bolt on the fuel pump. Push the fuel feed pump priming lever to vent the air. After venting the air, firmly tighten the hexagonal bolt.



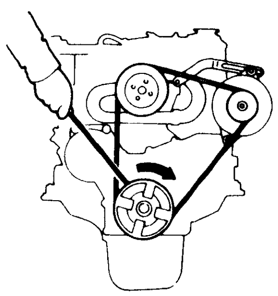
2. Check the fuel injection timing as follows:

(1) Remove the high pressure pipe from the fuel injection pump.



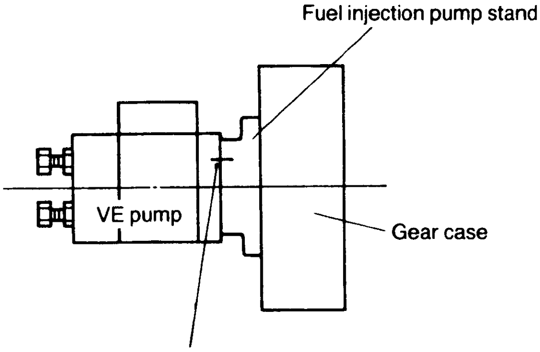
(2) Pull the engine warm up knob out and place the control lever in the "half speed" position.

(3) Insert a turning bar into the hole on the crank pulley on the front side. Crank the engine lightly to check the fuel injection timing.



(4) Timing marks on the flywheel can be seen through the hole on the flywheel housing

NOTE



Make sure that the match marks are aligned.
(With alignment of these marks, injection timing is automatically adjusted)

3. Removal and installation of injection pump

(1) Remove the fuel injection pump gear cover from the timing gear housing cover.

(2) Make mating marks on the idle gear and the injection pump gear using white paint for reinstallation.

(3) Remove the pump drive shaft end nut, the washer, the pump gear from the shaft, three pump retaining bolts, and two pump support bolts.
Remove the injection pump.

NOTE: When removing the pump;

1) Do not drop keys from the drive shaft into the gear housing.

2) Avoid damage to O-rings on the pump.

3) Do not hit the shaft end with a hammer.

(4) When installing the pump, match the mating marks on the bracket and the pump flange.

(5) While aligning the mating marks on the idle gear and the pump gear, install the pump to the pump gear.

(6) Tighten the drive shaft end nut to 69N-m(7kgf-m).

3. Fuel Injection Pump Outline

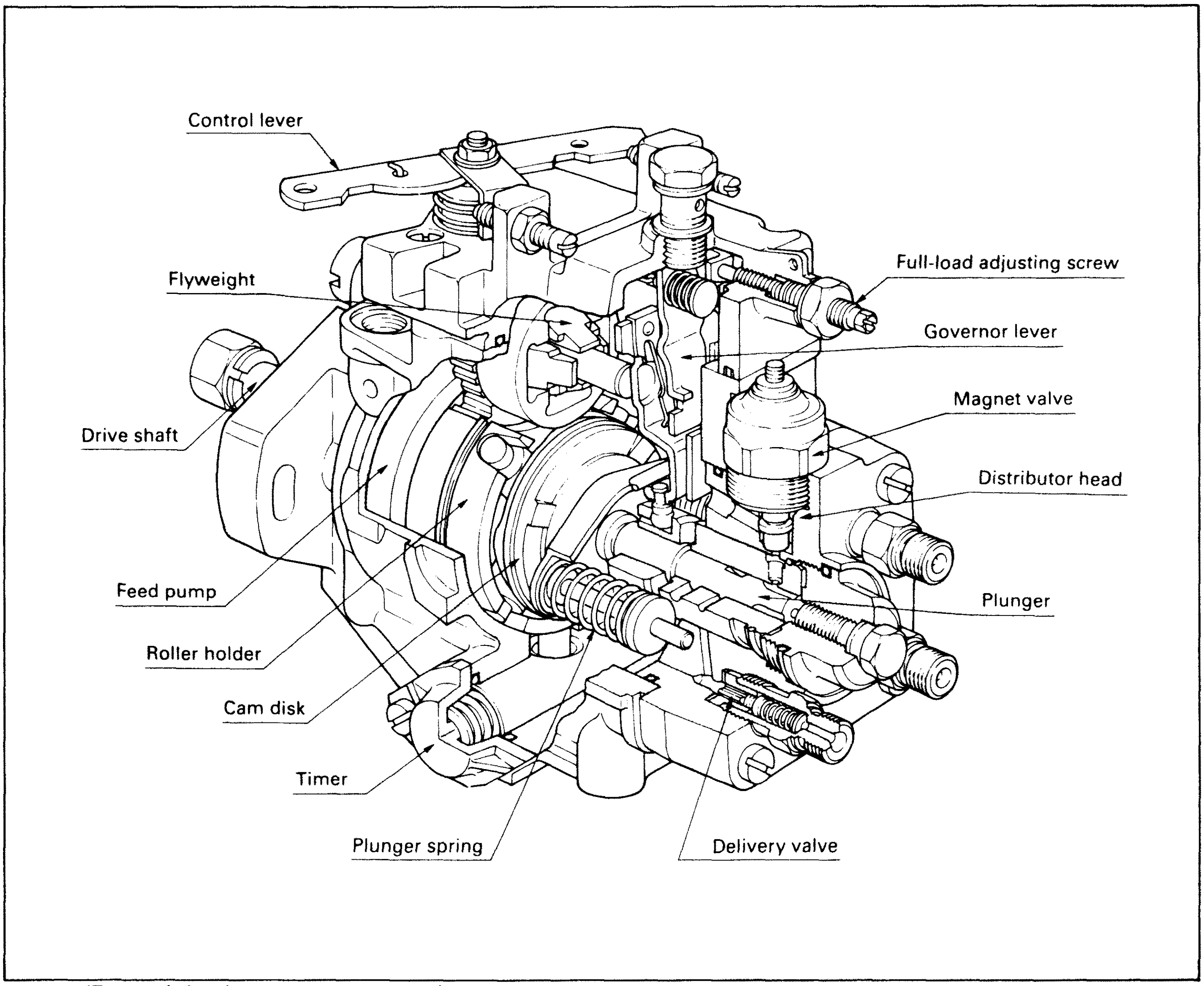


Fig. 1 VE type injection pump construction

With the PE type (in-line type) injection pump, the number of pump elements (plunger assemblies) must be the same as the number of engine cylinders. However, with the VE type (distributor type) injection pump, the number of plungers has no relationship to the number of engine cylinders, and there is only one plunger. This single plunger reciprocates while rotating, and fuel oil is injected into each cylinder through the injection pipes in accordance with the engine's firing order.
As well as this, the governor, timer, feed pump etc. installed on the outside of the PE type injection pump are equipped within the VE type injection pump.

In comparison with the PE type, the VE type injection pump has less than half the number of component parts, and was developed in order to satisfy the need for a small, lightweight and high-speed injection pump.
In response to operator requirements, it was possible to design a pump with acceleration close to that of gasoline vehicles.

4. Fuel System

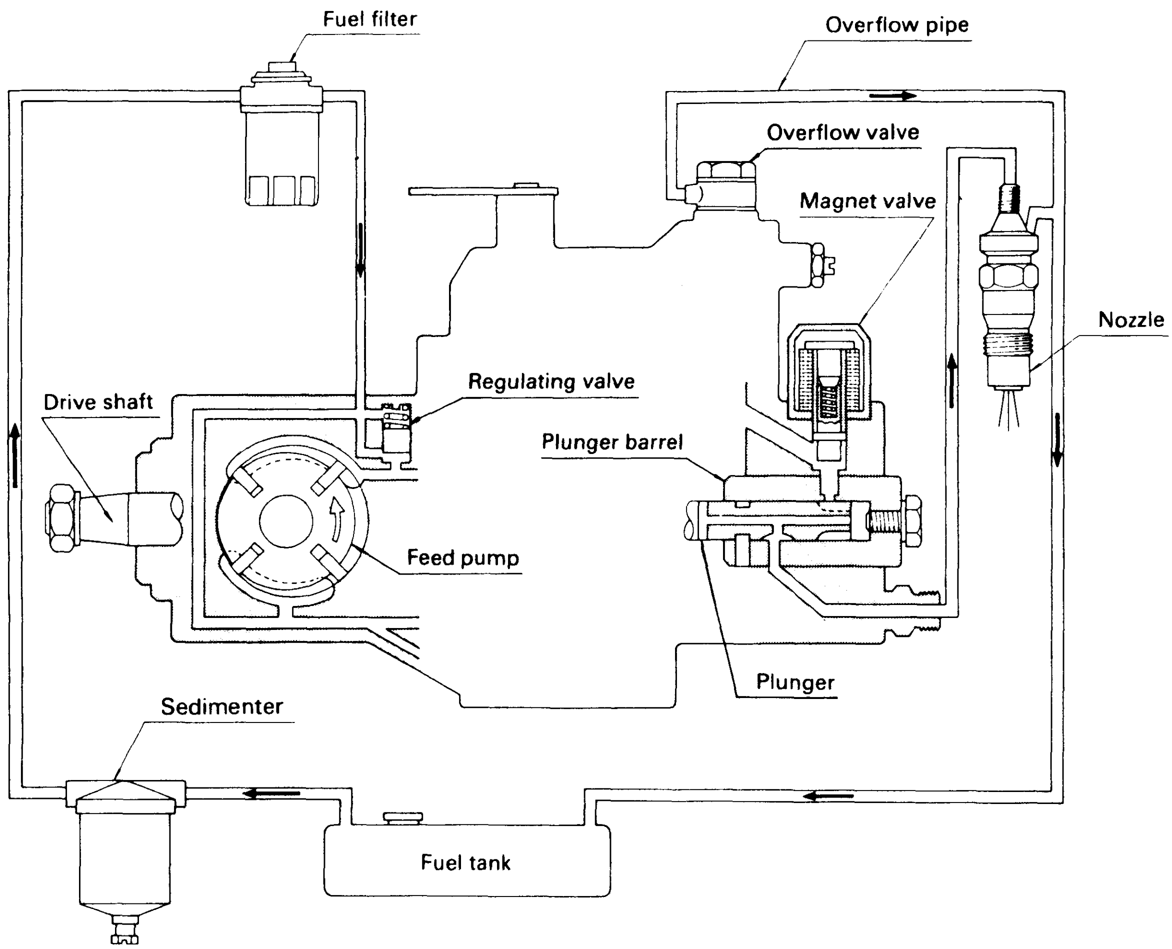


Fig. 2 Fuel system

Figure 2 shows an example of a fuel system.
The injection pump drive shaft is turned by the engine's timing belt (or gear) and fuel oil is drawn by the injection pump's feed pump through the sedimenter and fuel filter to the injection pump's fuel oil inlet.
The fuel filter acts to filter the fuel oil, and the sedimenter is located in the lower portion of the fuel filter to remove moisture from the fuel system.
With drive shaft rotation the fuel oil sucked into the feed pump is pressurized by the feed pump and fills the injection pump chamber. The fuel oil pressure is proportional to drive shaft speed, and when it exceeds a specified pressure excess fuel again returns to the inlet side through a regulating valve located at the feed pump's fuel oil outlet.
The fuel oil in the injection pump chamber flows through the distributor head inlet into the pressure chamber, where plunger rotation and reciprocating motion increase its pressure. The fuel oil is then delivered through the injection pipe to the nozzle and nozzle holder.
An overflow valve located at the top of the injection pump functions to maintain a constant fuel oil temperature in the pump chamber by returning excess fuel oil to the fuel tank.

5. Injection Pump Construction and Operation

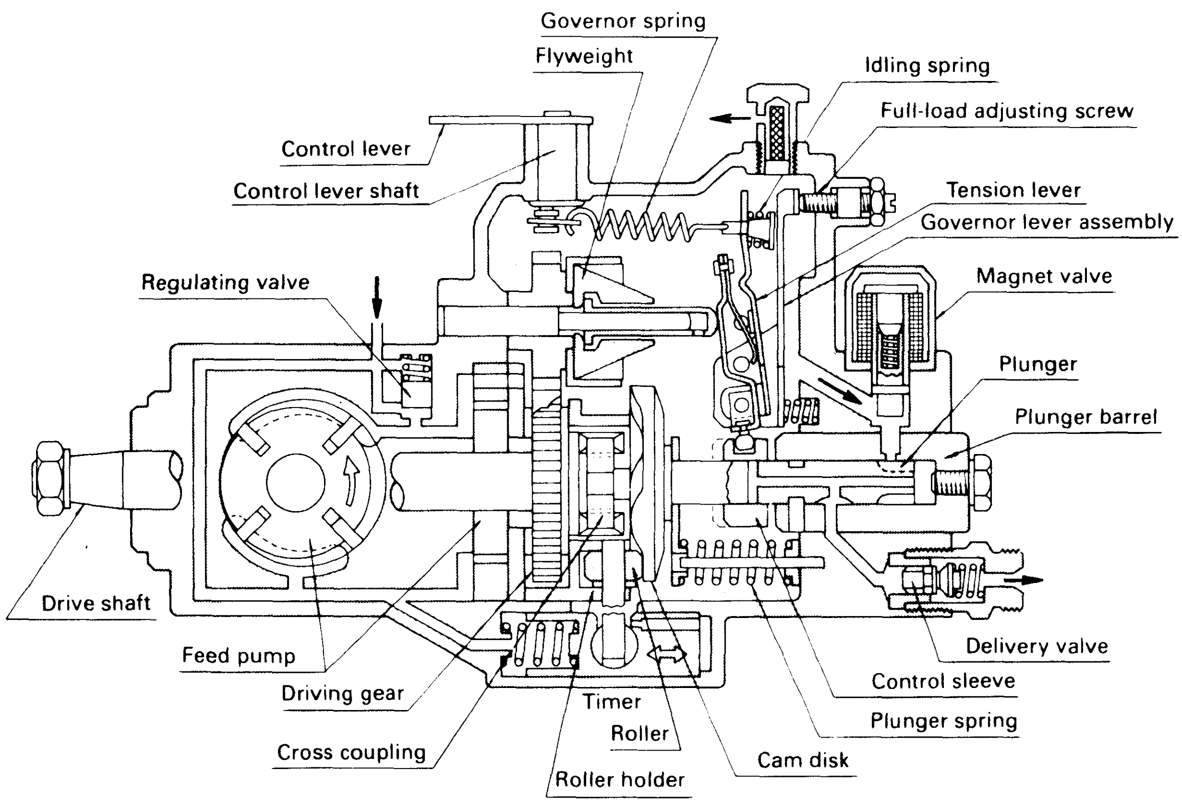


Fig. 3 Cross-sectional view of VE type injection pump

Fuel Delivery

The drive shaft, rotated by the engine's timing belt (or gear), rotates the cam disk through a cross coupling. The cam disk's press-fitted pin fits into a groove in the plunger to rotate the plunger. To reciprocate the plunger, the cam disk is also equipped with the same number of raised face cams, arranged uniformly around the circumference of the cam disk, as the number of cylinders. The cam disk's face cams are always in contact with the roller holder assembly's rollers because the cam disk and the plunger are pressed against the roller holder assembly by the set force of the two plunger springs. Because of this the plunger can follow cam disk movement. Therefore, as the cam disk is rotated on the roller holder assembly by the drive shaft, simultaneous plunger rotation and reciprocating movement is possible.
The roller holder assembly construction is such that it can only rotate in a certain angle range in accordance with timer operation.

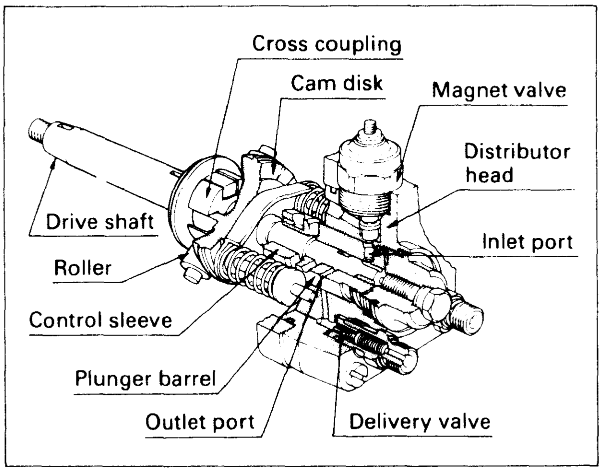


Fig. 4 Cutaway view of fuel delivery

Because the plunger rotates and reciprocates simultaneously, suction of the fuel oil into the pressure chamber, pressurization in the pressure chamber and delivery into the engine cylinder are all possible.

Speed Governing

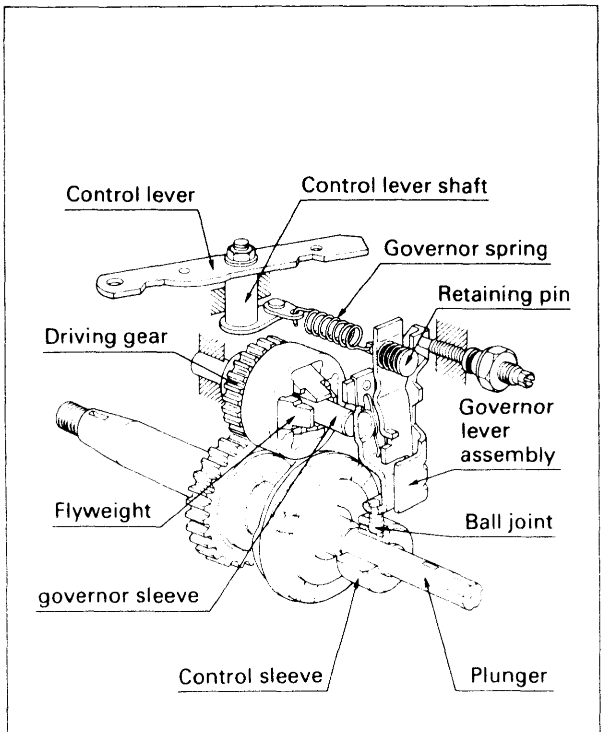


Fig. 5 Cutaway view of speed governing

The governor is located in the upper part of the injection pump chamber. Four flyweights and a governor sleeve are held in the flyweight holder, which is mounted on the governor shaft.
The flyweight holder is rotated and accelerated by the drive shaft gear, through rubber dampers.
The governor lever assembly is supported by pivot bolts in the pump housing, and the ball joint at the bottom of the lever assembly is inserted into the control sleeve, which slides over the outside surface of the plunger. The top of the lever assembly (the tension lever) is connected to the governor spring by a retaining pin, while the opposite end of the governor spring is connected to the control lever shaft. The control lever shaft is inserted into the governor cover and a control lever is attached to the control lever shaft. The accelerator pedal is connected directly to the control lever by a linkage, and the governor spring set force changes in response to the control lever position (i.e. accelerator pedal position).
Injection quantity control is governed by the mutually opposing forces of the flyweights' centrifugal force and the governor spring's set force.
The flyweights' centrifugal force, which changes in response to engine speed, acts on the governor lever through the governor sleeve.
The governor spring's set force, which is dependant on control lever position, i.e. accelerator pedal position, acts on the governor lever through the retaining pin.

Injection Timing Control

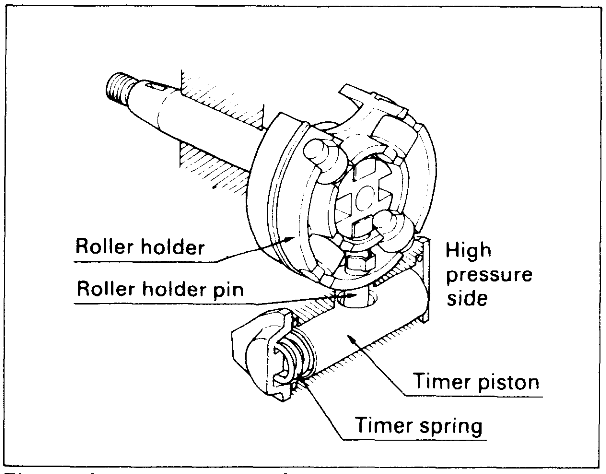


Fig. 6 Cutaway view of injection timing control

The piston is positioned in the center of the timer in the lower part of the injection pump.
On the low pressure side of the timer piston there is a timer spring with a predetermined set force; the pump chamber fuel oil pressure acts on the opposite side (high pressure side). The timer piston position changes in accordance with the balance of these two forces, to rotate the roller holder via the roller holder pin. When the timer piston compresses the timer spring, the injection timing is advanced (the roller holder rotates in the reverse rotation direction), and due to timer piston movement in the opposite direction the injection timing is retarded. Injection timing is controlled by the above.

Feed Pump

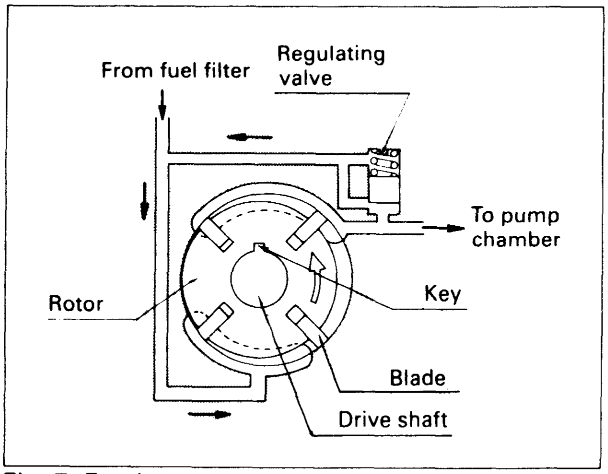


Fig. 7 Feed pump operation

The feed pump comprises a rotor, blades and liner.
Drive shaft rotation is transmitted through a key to rotate the rotor.
The inside circumference of the liner is eccentric to the centre of rotor rotation. Four blades are installed in the rotor. Centrifugal force forces the blades outwards during rotation to contact the inside surface of the liner and form four fuel oil chambers. The volume of these four chambers increases through rotor rotation to suck fuel oil from the fuel tank. Conversely, when the volume of these four chambers decreases fuel oil is pressurized.

Regulating Valve

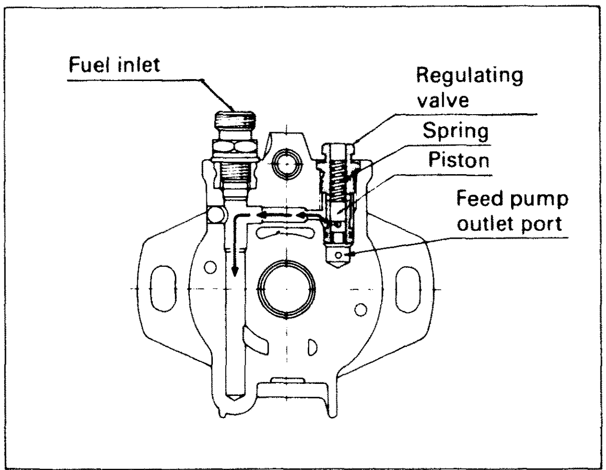


Fig. 8 Regulating valve operation

Feed pump fuel oil delivery pressure increases proportionately with an increase in injection pump speed.
However, the total fuel oil injection quantity necessary for the engine is considerably less than that delivered by the feed pump. Therefore, in order to prevent an excessive increase in the pump chamber pressure caused by the excess fuel oil, and to adjust the pump chamber pressure so that it is usually within the specified limit, a regulating valve is installed near the feed pump outlet. The timer performs timing control using the pump chamber pressure, which is regulated by the regulating valve.

Plunger Operation

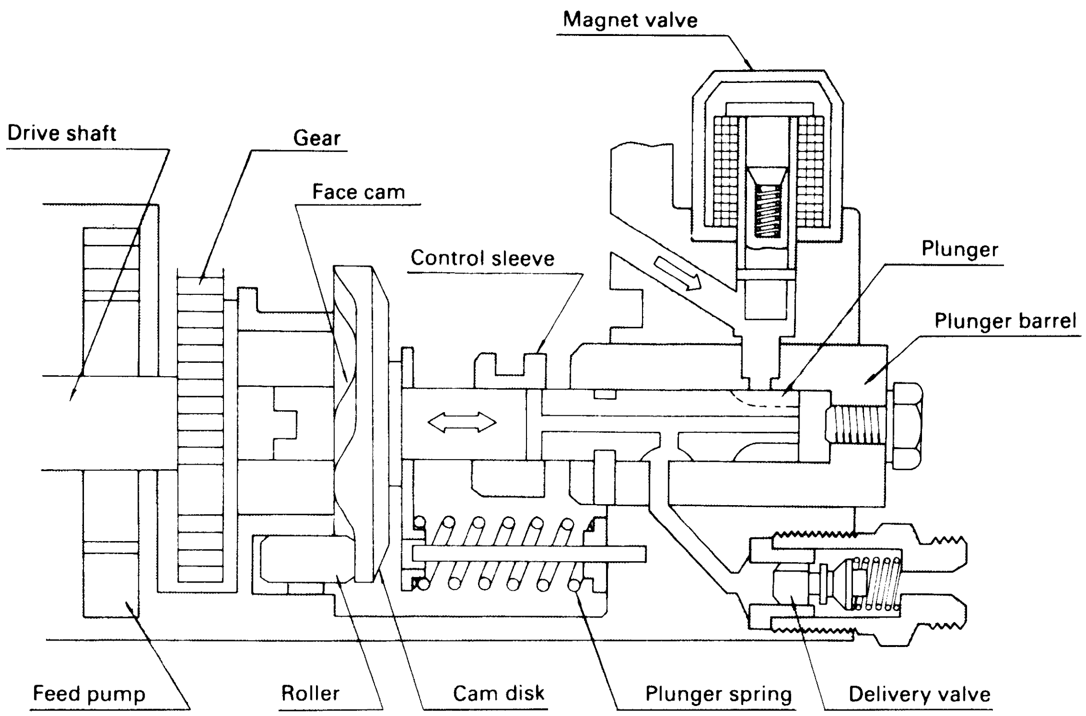


Fig. 9 Plunger operation

The drive shaft drives the feed pump, the cam disk and the plunger simultaneously. Plunger reciprocating movement is accomplished through the movement of the cam disk's face cams over the roller holder assembly's rollers.
When the plunger's inlet slit and the inlet port of the plunger barrel, press-fitted to the distributor headare aligned, fuel oil is sucked into the pressure chamber. After the plunger barrel's inlet port has been closed by the plunger, the plunger rises.
Once the plunger's outlet slit and the plunger barrel's outlet port are aligned, and the pressure chamber pressure exceeds the injection pipe's in-line residual pressure and the delivery valve spring's set force, the delivery valve opens, fuel oil flows to the injection pipe, and is then injected from the nozzle into the engine cylinder.
Then, when the plunger's cut-off port aligns with the control sleeve's end face, plunger fuel delivery is completed.
The plunger barrel has only one inlet port, but it has an outlet port for each engine cylinder.
However, although the plunger has the same number of inlet slits as engine cylinders, it has only one outlet slit and one equalizing slit.

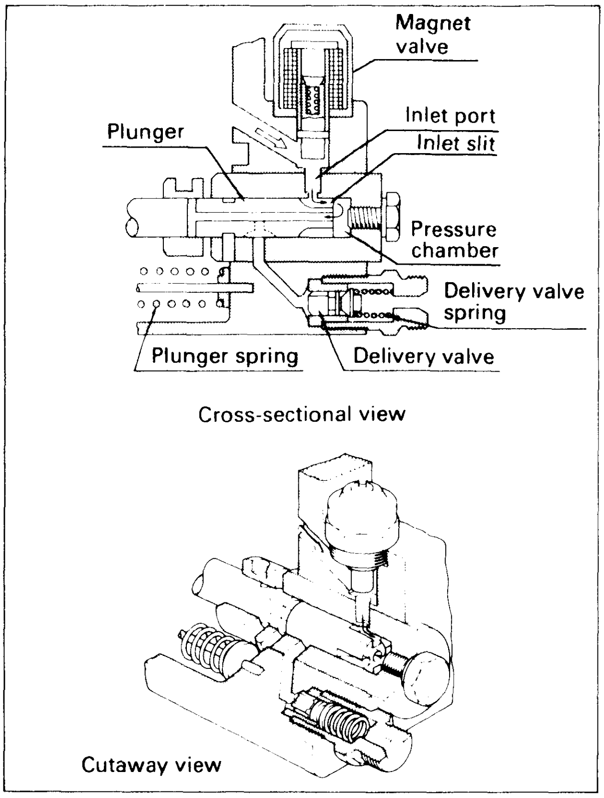


Fig. 10 Plunger operation: suction stroke

Suction stroke

During the plunger's return stroke, when the plunger barrel's inlet port and the plunger's inlet slit are aligned, pressurized fuel oil in the pump chamber is sucked into the pressure chamber. (Fig. 10)

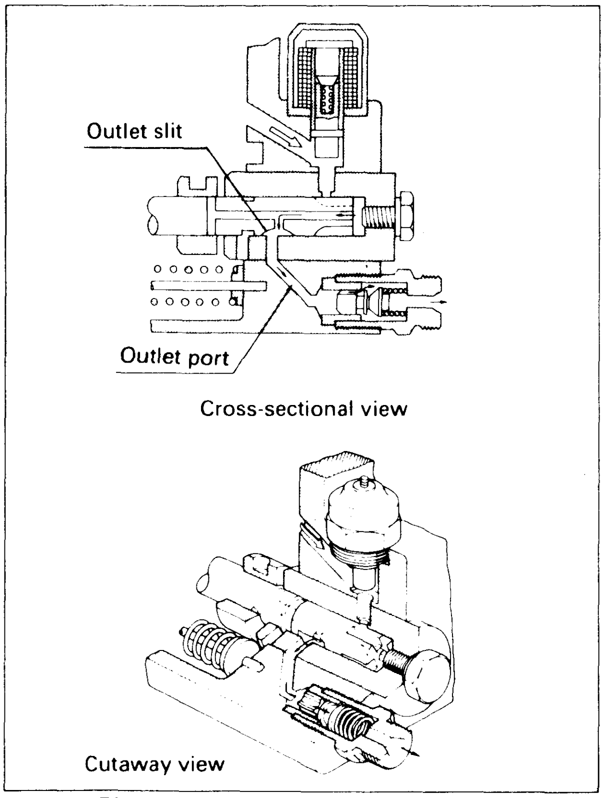


Fig. 11 Plunger operation: delivery stroke

Delivery stroke

As the plunger is rotated and lifted by the cam disk, the plunger's outside face blocks the plunger barrel's inlet port and compression of fuel oil begins. At almost the same time the plunger's outlet slit meets the plunger barrel's outlet port. As a result of this, the fuel oil pressurized by the plunger lift overcomes the set force of the delivery valve spring and the injection pipe's in-line residual pressure, and opens the delivery valve. The fuel oil is then injected through the nozzle and nozzle holder into the engine's combustion chamber. (Fig. 11)

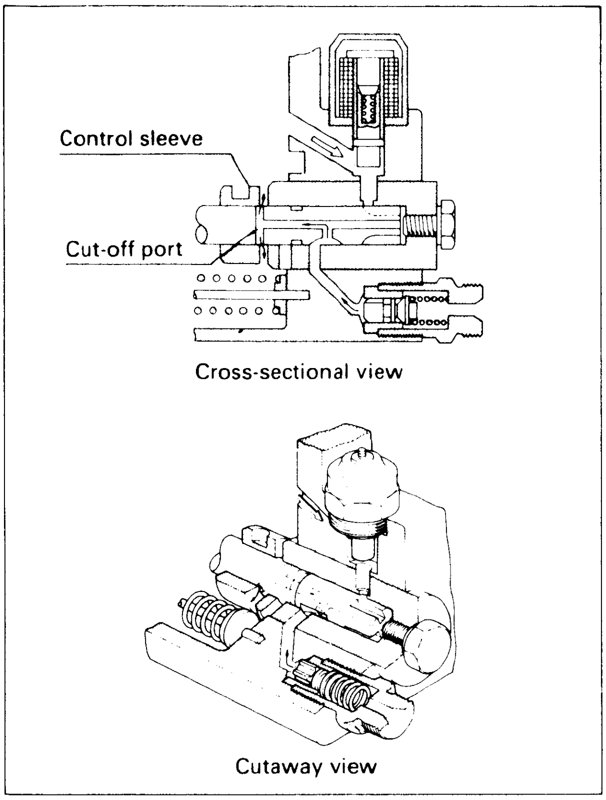


Fig. 12 Plunger operation; end of injection

End of injection

When the end face of the control sleeve meets the plunger's cut-off port, the fuel oil in the plunger (i.e. the pressure chamber), which is at a much higher pressure than that in the pump chamber, returns to the pump chamber through this cut-off port. The pressure then suddenly decreases, the delivery valve is closed by the spring, and fuel oil delivery finishes. These operations occur instantaneously. (Fig. 12)

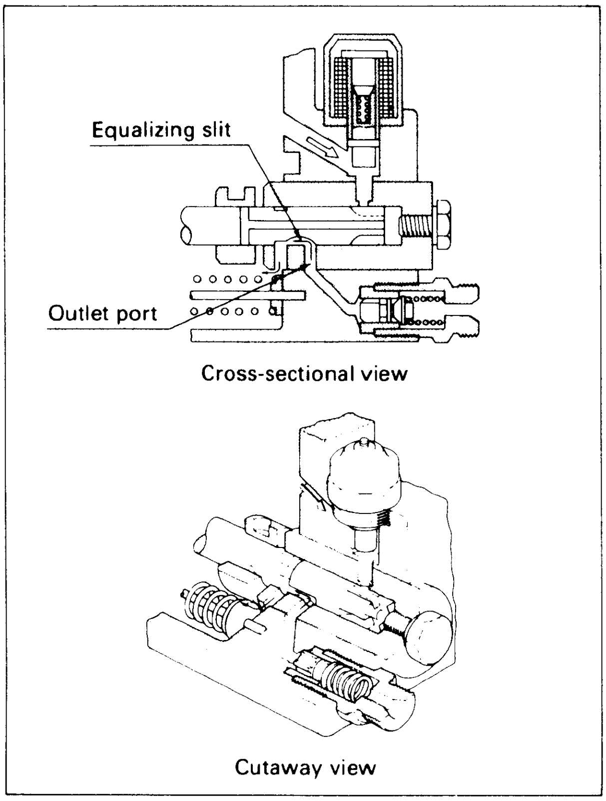


Fig. 13 Plunger operation; equalizing stroke

Equalizing stroke

Following the end-of-injection the plunger rotates 180° and the plunger barrel's outlet port meets the plunger's equalizing slit.
Then, the pressure of the fuel oil in the injection passage between the plunger barrel's outlet port and the delivery valve decreases to that of the fuel oil in the pump chamber.
This stroke equalizes each cylinder's outlet port pressure at injection for every revolution, therefore assuring stabilized injection. (Fig. 13)

The above operations are performed in the order of injection for each (pump) revolution.

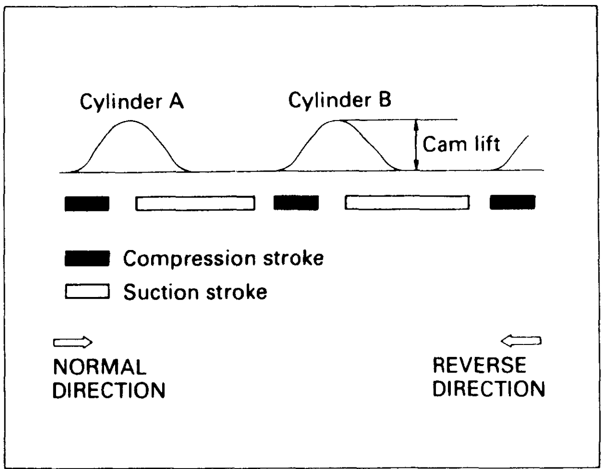


Fig. 14 Plunger strokes for cylinders A and B

Reverse rotation prevention

While the plunger is moving in the normal direction of rotation, the inlet port is open during the plunger's return stroke and sufficient fuel oil is sucked into the pressure chamber. During the compression stroke the inlet port is closed and injection is performed.
However, should the engine rotate in the reverse direction (e.g. when a stationary, parked vehicle begins to roll backwards and the engine is rotated, etc.) the plunger barrel's inlet port and the plunger's inlet slit will align during plunger lift, the fuel oil cannot be pressurized and non-injection will result.
Because of this the engine will immediately stop.

Injection quantity control

Fuel injection quantity is increased or decreased by the effective stroke, which is varied by the position of the control sleeve.

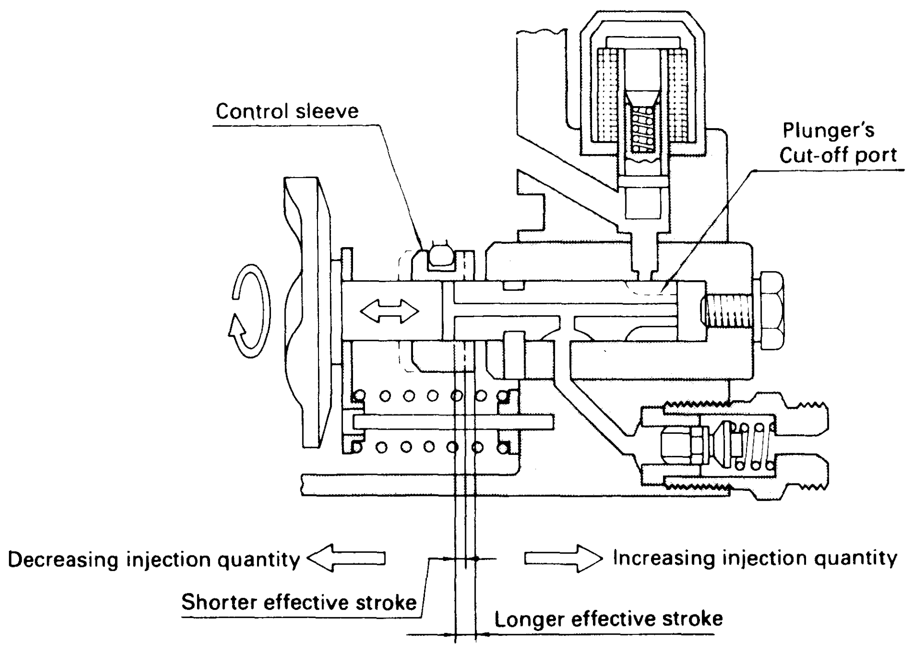


Fig. 15 Plunger's effective stroke

This effective stroke is the plunger stroke from the plunger's cut-off port to the control sleeve's end-face during the delivery stroke, after the plunger barrel's inlet port and the plunger's inlet slit are closed.
It is proportional to the fuel injection quantity.
As can be seen in Fig. 15, control sleeve travel to the left decreases the effective stroke, and conversely control sleeve travel to the right increases the effective stroke and the fuel injection quantity.
Although the beginning-of-injection position is constant, end-of-injection varies according to the control sleeve position. The control sleeve position is determined by the governor.

Delivery Valve and Damping Valve

When the increased fuel oil pressure resulting from the plunger's compression stroke has overcome the delivery valve spring's set force and the injection pipe's in-line residual pressure, the delivery valve opens and fuel oil is delivered to the nozzle holder and the nozzle. (Fig. 16-A)
Then, when nozzle opening pressure is reached, initial injection into the engine cylinder occurs.

When the plunger has lifted and injection has ended, the pressure in the pressure chamber suddenly decreases and the delivery valve spring closes the delivery valve. In order to prevent delayed injection it is necessary to maintain the residual pressure of the fuel oil in the injection pipe for the next injection. The delivery valve functions to prevent reverse fuel oil flow during the plunger's suction stroke.

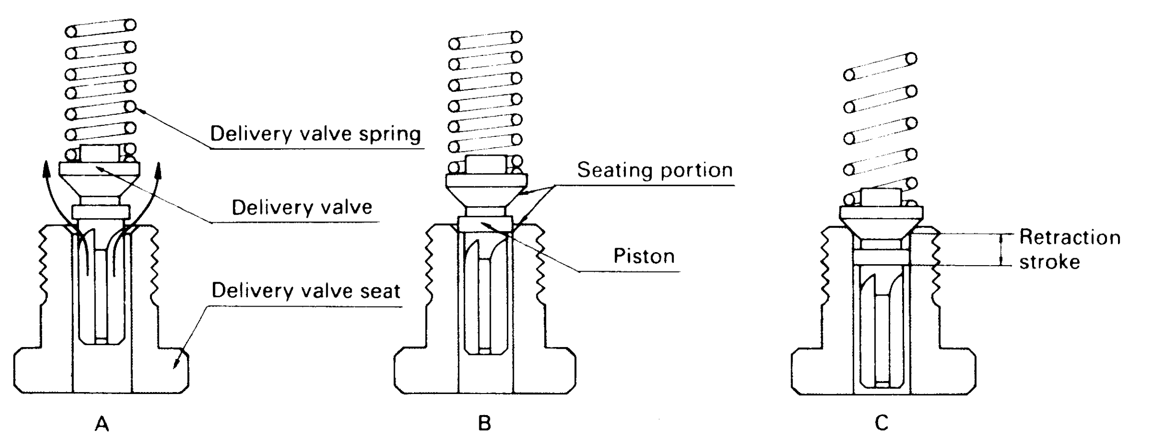


Fig. 16 Delivery valve operation

In the centre of the delivery valve is a piston. After injection has ended and the piston edge is contacting the top of the valve seat (Fig. 16-B), the amount by which the injection pipe's in-line pressure is reduced is proportional to the volume of fuel retracted up to the time that the delivery valve is completely closed.

$$\left[\frac{\pi(\text{piston diameter})^2}{4} \times \text{retraction stroke}\right]$$

Because of this, cut-off of injection occurs immediately after the end-of-injection and subsequent dripping is prevented. (Fig. 16-C)

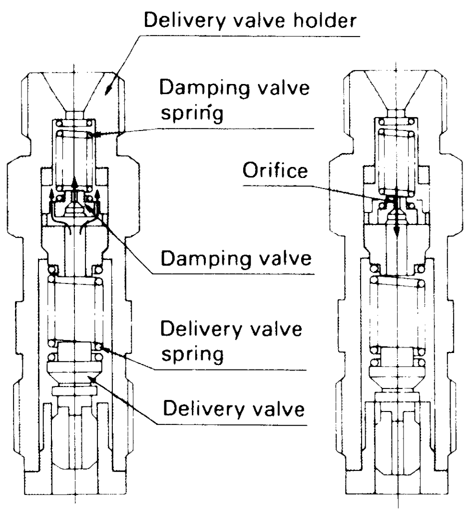


Fig. 17 Damping valve operation

The damping valve is a component of the delivery valve and its construction is shown in Fig. 17.

The damping valve compresses the damping valve spring and opens almost simultaneously with the opening of the delivery valve. Fuel oil delivered by the plunger through the injection pipe is then delivered to the nozzle holder and the nozzle. After the end-of-injection the damping valve is closed more quickly (seated) than the delivery valve by the set force of the damping valve spring.

Following this, because only the retracted fuel oil is returned through the small orifice in the centre of the damping valve up until the time that the delivery valve is seated, a sudden reduction in the injection pipe's in-line pressure can be prevented.

A sudden reduction in pressure may sometimes result in negative pressure, thereby causing cavitation. This may result in corrosion of the injection pipes and finally the danger of pipe breakage.

The damping valve is installed to prevent the above problems.

6. Governing Mechanism

Depending on the purpose of use, mechanical governors (those utilizing a flyweight) are divided into three types:

1. The variable speed governor
2. The combination governor
3. The minimum-maximum speed governor

Variable Speed Governor Construction and Operation

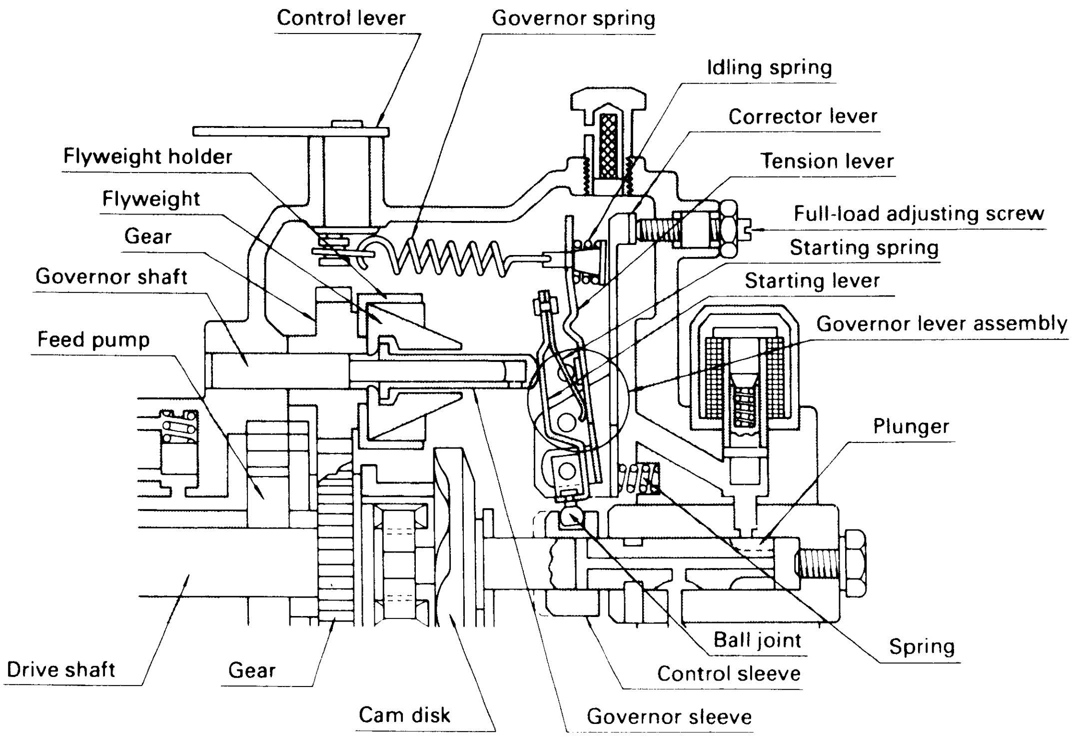


Fig. 18 Variable speed governor construction

The construction of the variable speed governor is shown in Fig. 18.
The rotation of the drive shaft (equipped with two rubber dampers) is conveyed through an acceleration gear to the flyweight holder mounted on the governor shaft.

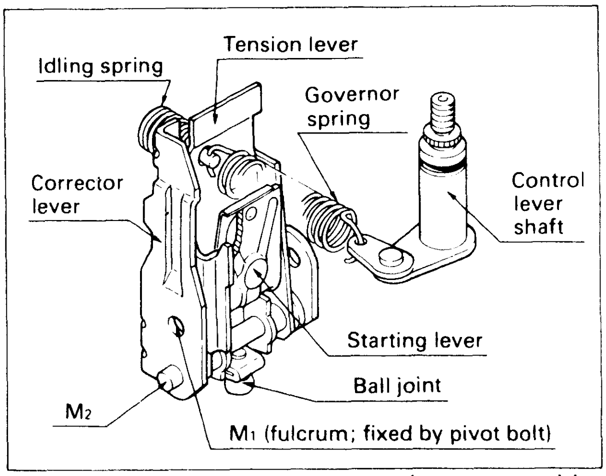


Fig. 19 Variable speed governor lever assembly

Four flyweights are mounted in the flyweight holder, and with rotation these open outward through centrifugal force. This movement moves the governor sleeve in an axial direction, resulting in the governor sleeve pushing the governor lever assembly.
The governor lever assembly consists of the corrector lever, tension lever, start lever, start spring and the ball joint. (Fig. 19)

The corrector lever's fulcrum M_1 is fixed at the pivot bolts in the pump housing and as its bottom portion is being pushed by the springs in the distributor head, and the top portion is being pushed by the full-load adjusting screw, the corrector lever cannot move at all.
The starting lever, separated from the tension lever by the starting spring only at engine starting, moves the governor sleeve to close the flyweights. As a result of this the ball joint at the bottom of the starting lever, pivoting around the tension and starting levers' common fulcrum M_2, can move the control sleeve in the fuel-increase direction (i.e. toward the distributor head side) for engine starting.

During engine operation the starting lever and the tension lever are in contact and move together as a single component. The top of the tension lever is connected to the control lever through the governor spring.
An idling spring is mounted on the retaining pin at the top of the tension lever.
Governor construction is such that governor control over the entire speed range is performed by the operation of all these springs.

Engine starting

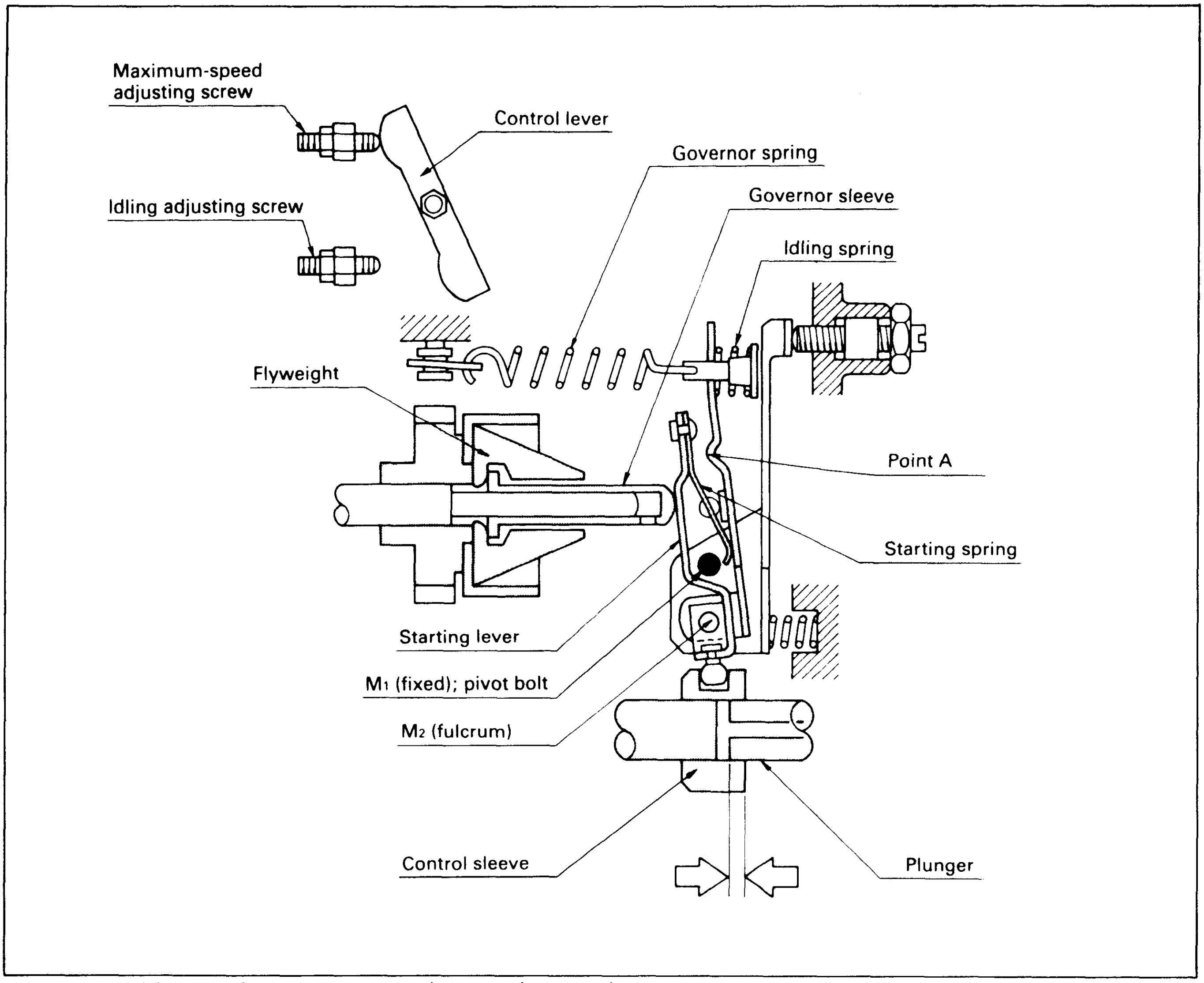


Fig. 20 Variable speed governor operation: engine starting

To improve starting characteristics at engine starting, the normal full-load injection quantity is exceeded and excess fuel for starting is supplied.
When the accelerator pedal is depressed while the engine is stationary, the starting lever is separated from the tension lever by the starting spring and moves to push the governor sleeve.
Because of this the control sleeve is moved to the right (the maximum injection quantity direction; Fig. 20) by the starting lever pivoting around M_2.
Therefore, through lightly depressing the accelerator the engine can be easily started.

After engine starting centrifugal force is generated by the flyweights, the governor sleeve acts to compress the weak starting spring and the starting lever is pressed against the tension lever.
Through this movement the control sleeve is moved in the fuel-decrease direction, injection is returned to the full-load injection quantity range and the supply of excess fuel for starting is completed. Following this, the tension lever and the starting lever, in contact at point A (Fig. 20), move together as a single component.

Idling operation

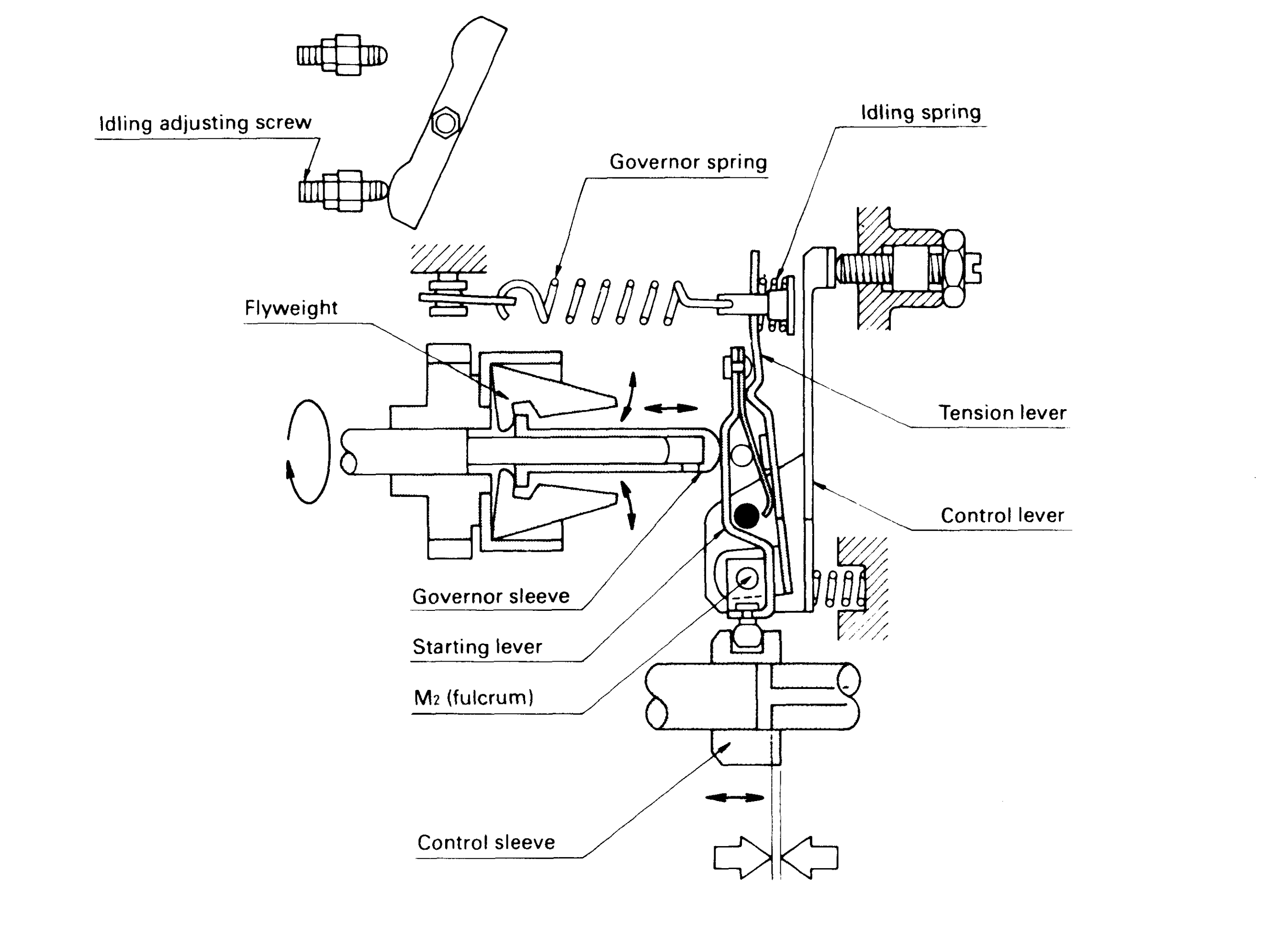


Fig. 21 Variable speed governor operation: idling operation

Once the engine has started the accelerator pedal is returned to its original position. The control lever is also returned to its original position and the governor spring tension becomes "0". The flyweights then open, the starting lever is pressed against the tension lever and compression of the idling spring begins.

The control sleeve then travels in the fuel-decrease direction and stops in the position where the flyweights' centrifugal force and the idling spring force are balanced. In this position stable idling operation can be obtained.

Full-load and no-load maximum speed control

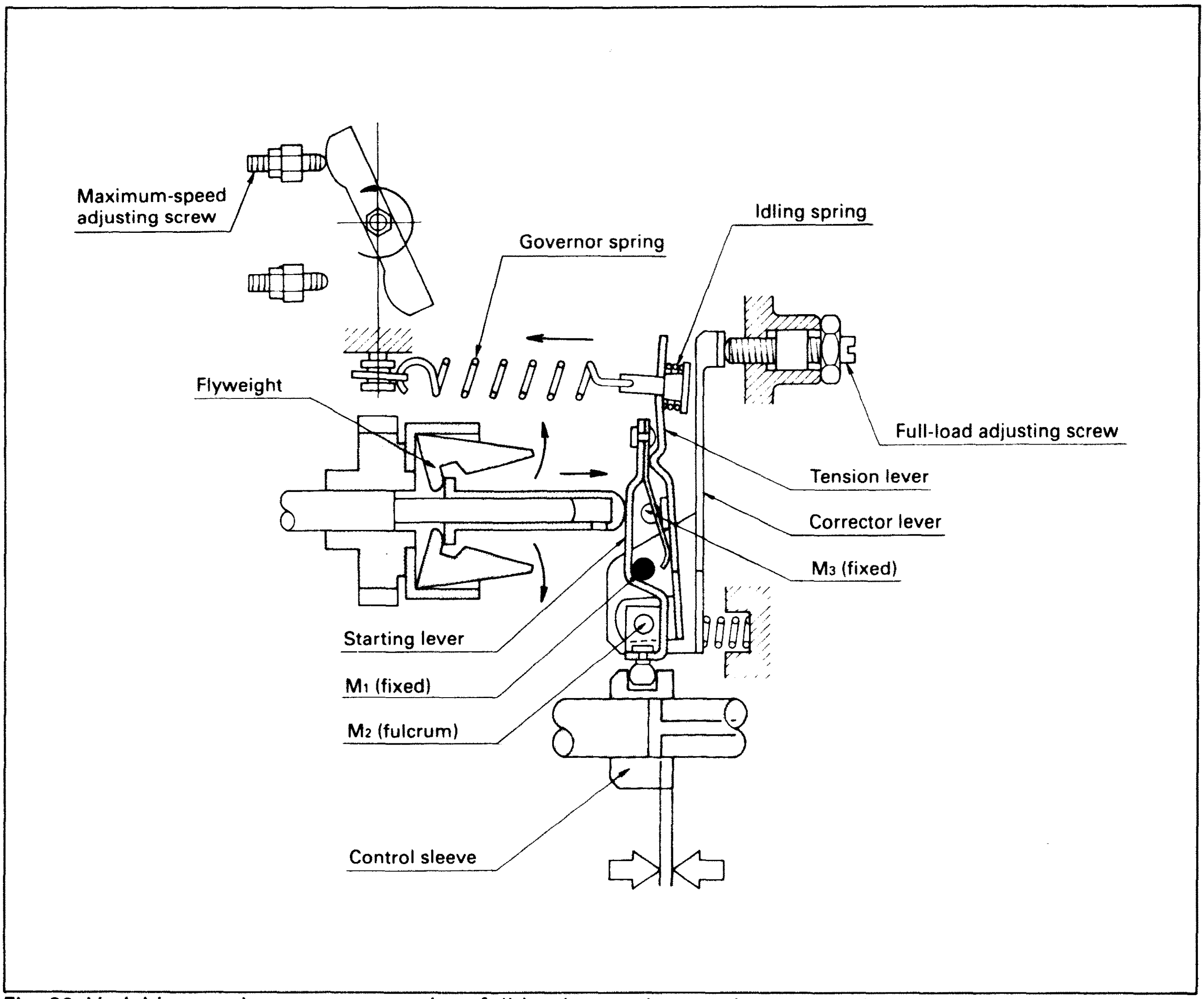


Fig. 22 Variable speed governor operation: full-load operation maximum speed control

When the accelerator pedal is fully depressed and the control lever has contacted the maximum speed adjusting screw, the tension lever contacts the pin (M_3) press fitted to the pump housing (i.e. where the full-load injection quantity is obtained) and can move no further. At this time the governor spring set force is at a maximum. Because of this, the idling spring is fully compressed and the flyweights, being pushed by the governor sleeve, are closed. Then, although the centrifugal force of the flyweights increases with the increase in engine speed, the flyweights cannot move the governor sleeve until the governor spring's set force has been overcome.

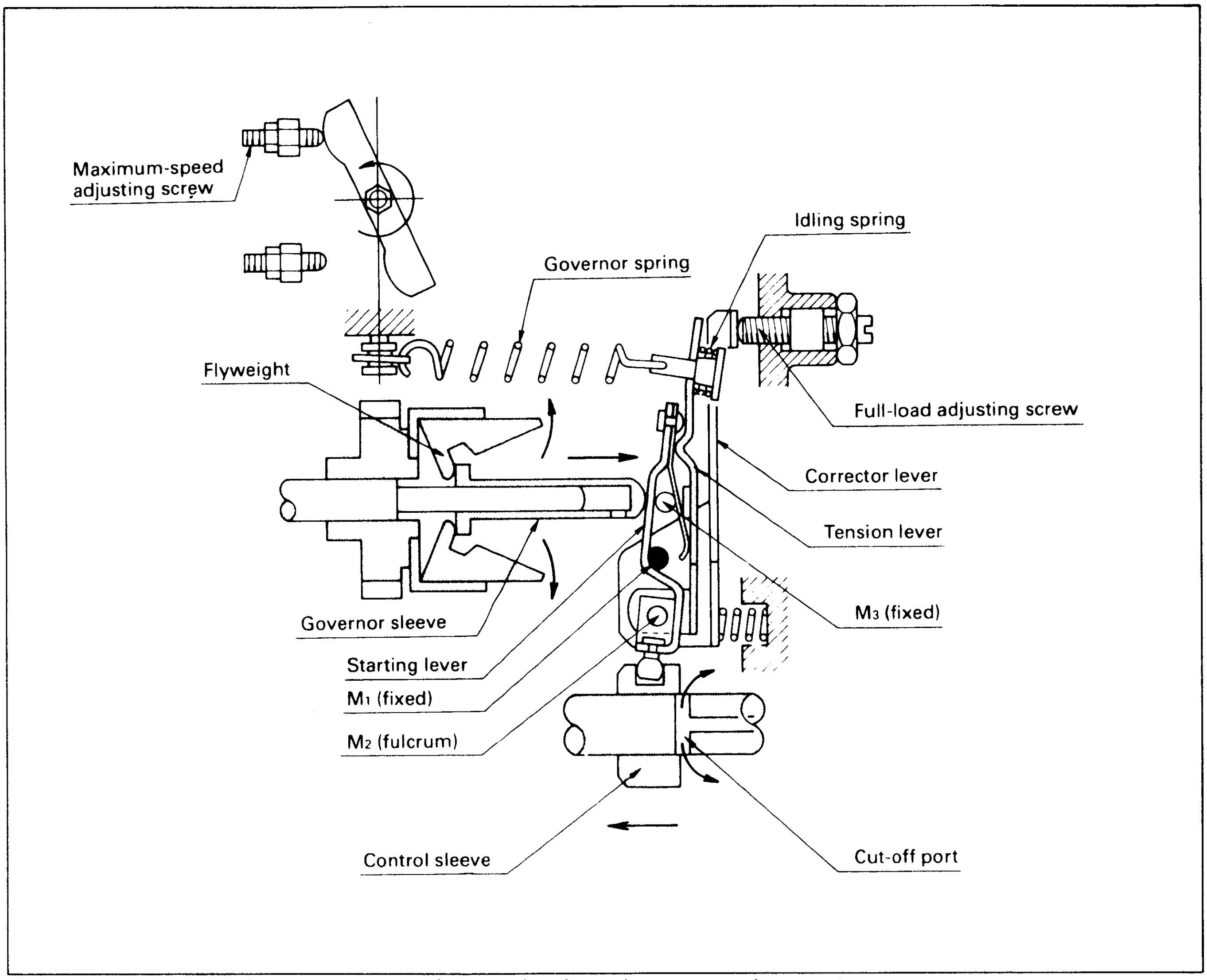


Fig. 23 Variable speed governor operation: no-load maximum speed control

Furthermore, with an increase in engine speed after both are balanced, the flyweights' centrifugal force will overcome the governor spring's set force, and will extend the spring while moving the governor lever assembly.
Therefore, the fuel injection quantity will be decreased and high speed control will be performed so that the specified maximum speed is not exceeded.
When the accelerator pedal is not fully depressed, the governor spring set force may be varied freely so that governor control may be performed in response to partial load conditions.
The full-load injection quantity is determined according to the amount that the full-load adjusting screw is screwed in. When the full-load adjusting screw is screwed in, the corrector lever pivots to the left (Fig. 22; counterclockwise direction) around point M_1 and the control sleeve moves in the fuel-increase direction. Unscrewing the full-load adjusting screw moves the control sleeve in the fuel-decrease direction.

Combination Governor Construction and Operation

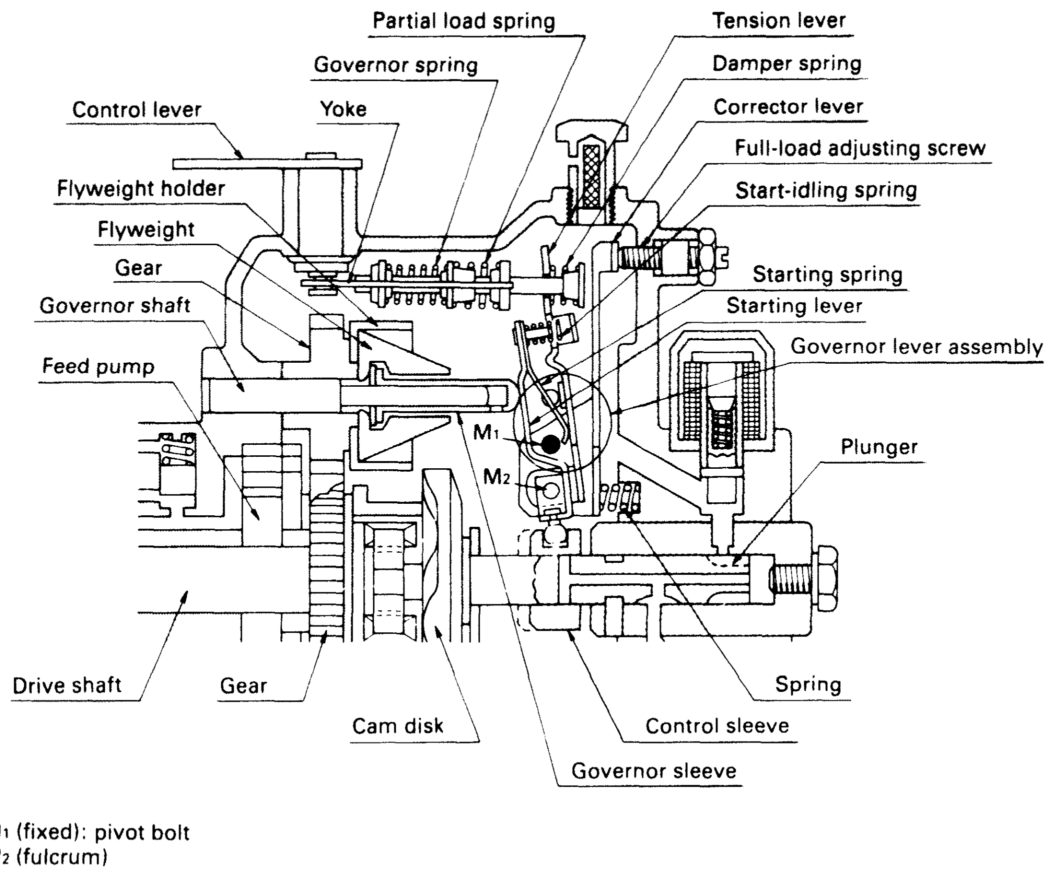


Fig. 24 Combination governor construction

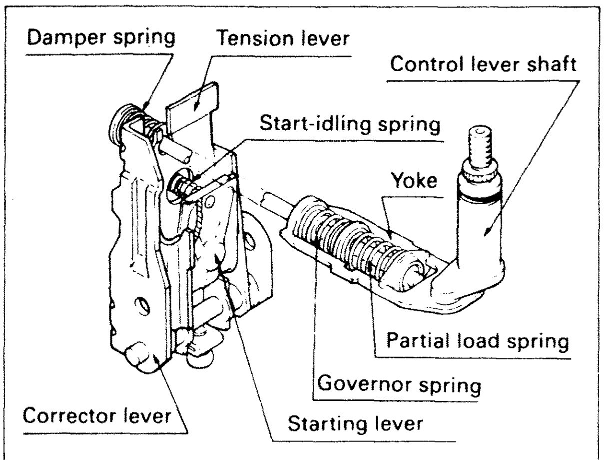


Fig. 25 Combination governor lever assembly

When comparing the construction of the combination governor with that of the variable speed governor, the governor spring and the governor lever assembly of the combination governor differ from those of the variable speed governor.

As shown in Fig. 24 a yoke is attached to the control lever shaft assembly, and the governor spring and the partial load spring, with a preset force, are installed inside the yoke. A damper spring is installed at the end of the yoke.

Idling control is performed by the start-idling spring, which is installed between the top of the tension lever and the starting lever in the governor lever assembly.

Engine starting

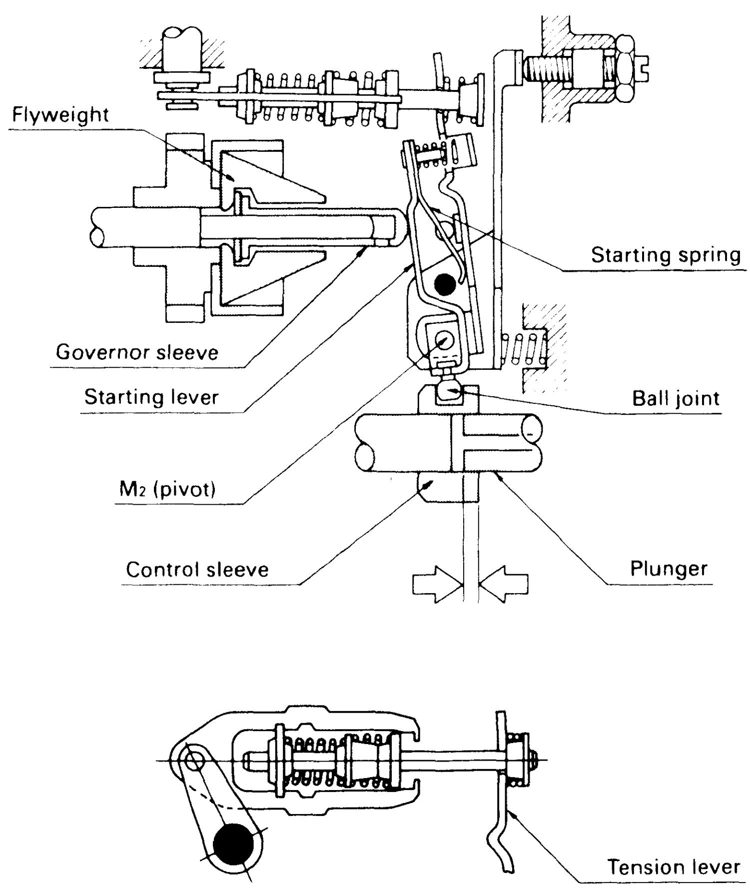


Fig. 26 Combination governor operation: engine starting

Depressing the accelerator pedal lightly at engine starting results in the control lever shaft assembly pulling the tension lever to the left (Fig. 26), and through the action of the starting spring (leaf spring) the starting lever pushes the governor sleeve. Through this movement the ball joint, with point M_2 as the fulcrum, moves the control sleeve to the position where excessive fuel for starting can be obtained, and the engine can be easily started.

Once the engine has been started, the centrifugal force generated by the flyweights pushes the governor sleeve against the weak force of the starting spring. The control sleeve is then moved in the fuel-decrease direction and the supply of excessive fuel for starting is completed.

Idling operation

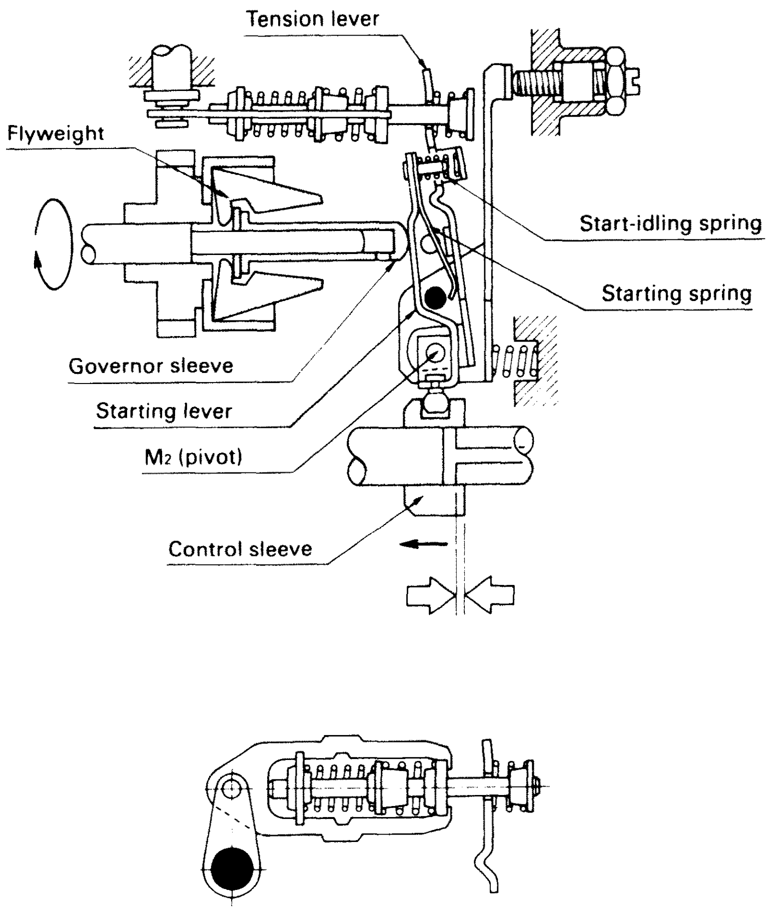


Fig. 27 Combination governor operation: idling operation

On releasing the accelerator pedal the control lever is returned to the idling position and the tension lever is freed.
Through the flyweights' centrifugal force the governor sleeve pushes the starting lever. After the start-idling spring has contacted the tension lever, the combined forces of the start-idling spring and the starting spring balance the flyweights' centrifugal force and the starting lever becomes stationary.
This starting lever movement moves the control sleeve directly in the fuel-decrease direction and stabilized idling operation can begin.

Partial load operation

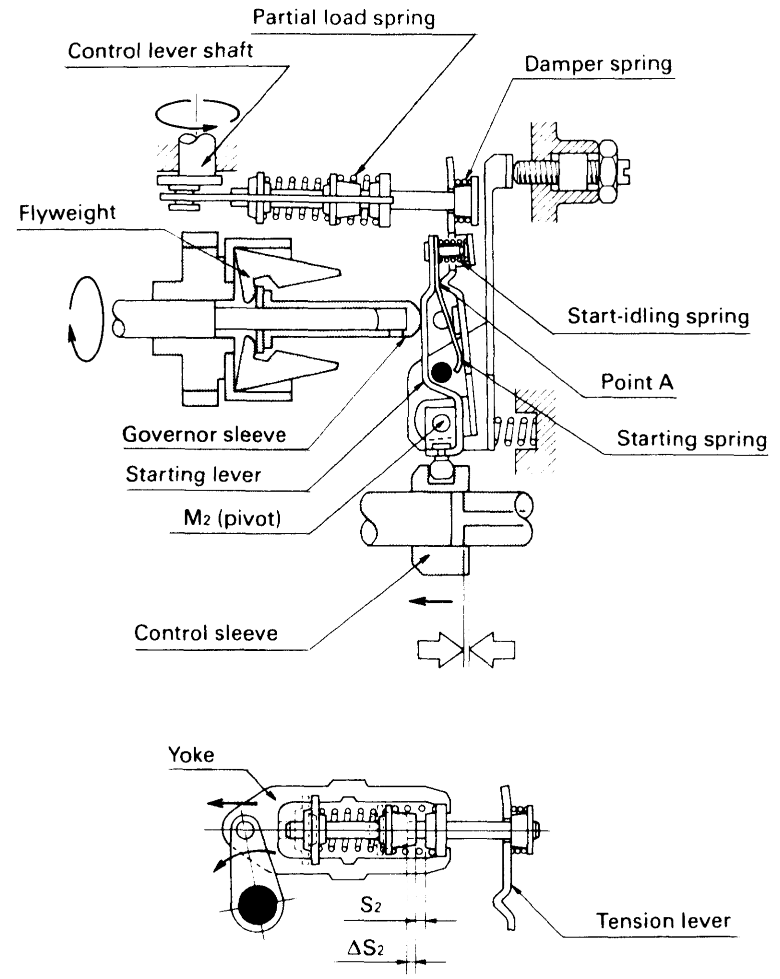


Fig. 28 Combination governor operation: partial load operation

In the speed range exceeding idling the starting spring and the start-idling spring are already compressed, and the starting lever and the tension lever, which are in contact at the convex point A, both move together as one. (Fig. 28)

Therefore, during partial load operation the damper spring and the partial load spring are acted upon by (and oppose) the flyweights' centrifugal force.

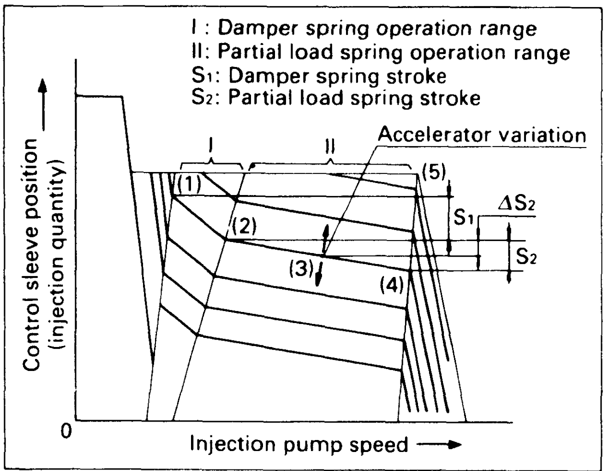


Fig. 29 Combination governor characteristics

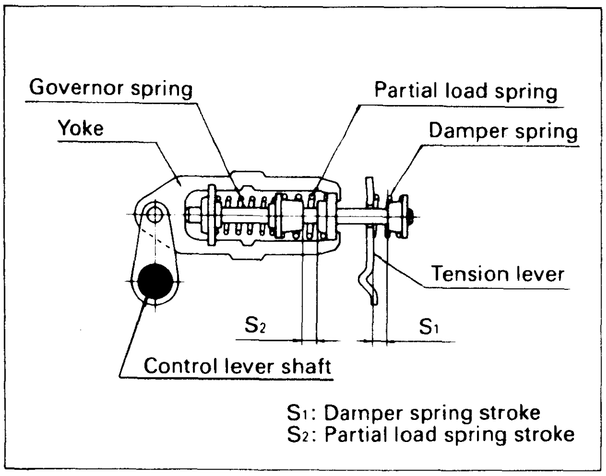


Fig. 30 Control lever shaft assembly

In low speed range I the control sleeve's position is controlled by the balance of the flyweights' centrifugal force and the damper spring force.
(e.g. control sleeve movement from (1) to (2) in Fig. 29)
In the intermediate-high speed range II (where the flyweights' centrifugal force exceeds the damper spring force, but is less than the governor spring's set force) the damper spring is fully compressed, and the partial load spring in the yoke is compressed an amount equal to ΔS_2 (Fig. 29). ΔS_2 varies according to the balance of the flyweights' centrifugal force with each spring's set force (i.e. engine speed and engine load).

If an uphill slope is negotiated after travelling on a level road with the control lever position fixed and the control sleeve positioned at point (3), because the engine speed decreases, the control sleeve position will shift in the direction of point (2) through the action of the partial load spring and the fuel injection quantity will be increased.
Conversely, if a downhill slope is negotiated, the fuel injection quantity will be decreased as engine speed increases.
Furthermore, if the amount that the accelerator pedal is depressed is altered, the control sleeve position will move in the direction of the arrow in Fig. 29.

Full-load and no-load maximum speed control

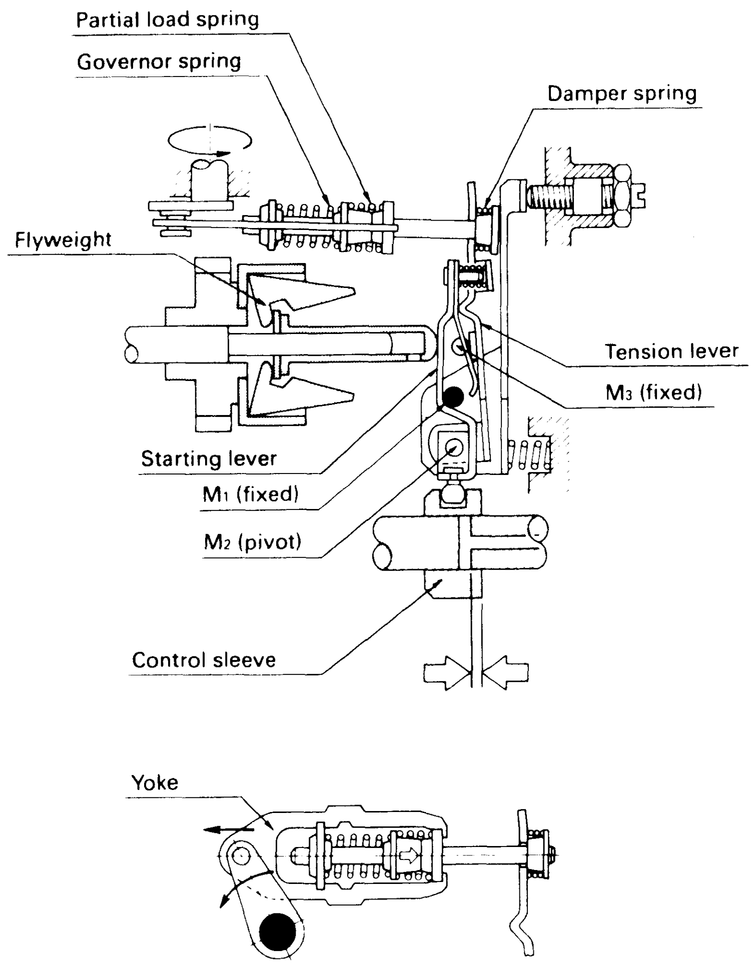


Fig. 31 Combination governor operation: full-load maximum speed operation

On moving the control lever until it contacts the maximum speed stopper bolt, the tension lever contacts the pin (or the stop lever of the BCS or ACS) M_3 press-fitted to the pump housing and can move no further. Consequently, the damper spring and the partial load spring are fully compressed and the control sleeve travels to the position where the full-load injection quantity can be obtained.

Following this engine speed increases and, at the point where the flyweights' centrifugal force balances the combined forces of the yoke springs (point (5) in Fig. 29), the full-load maximum speed of maximum engine output is reached.

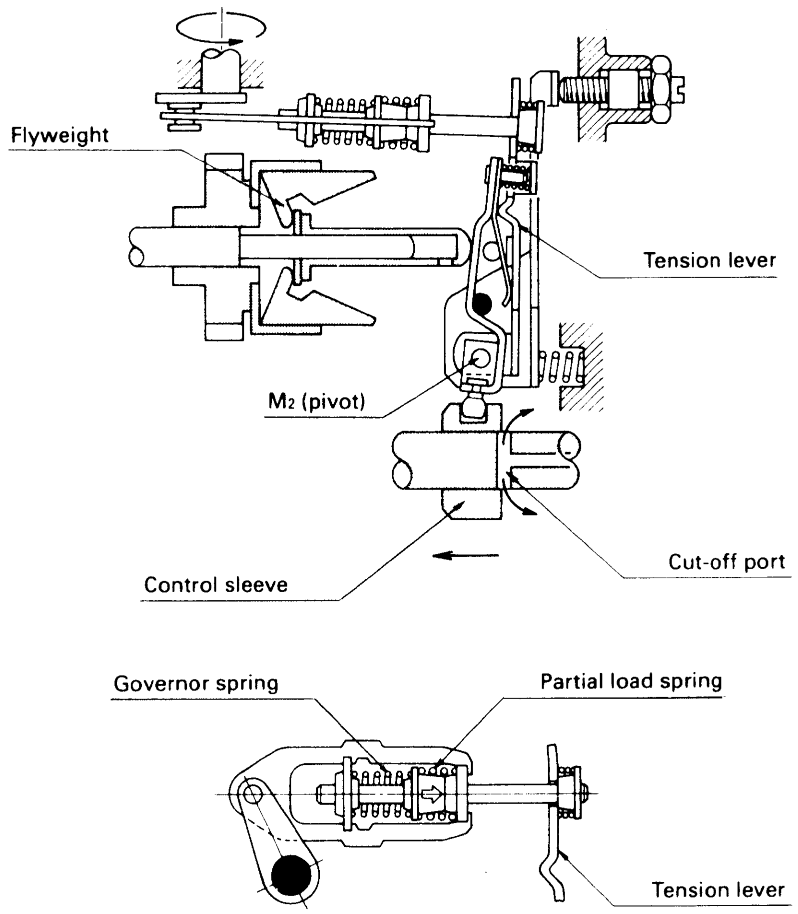


Fig. 32 Combination governor operation: no-load maximum speed control

To prevent the engine from exceeding the specified maximum speed when pump speed increases further, due to variations in load etc, the flyweights begin to compress the governor spring and the tension lever is pivotted clockwise around point M_2 to move the control sleeve in the non-injection direction.
The governor therefore controls the engine speed so that it does not exceed the engine's specified maximum speed.

Variable Speed Governor and Combination Governor

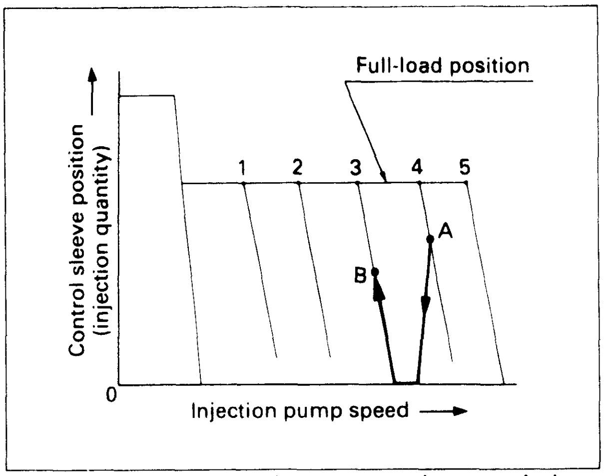


Fig. 33 Variable speed governor characteristics

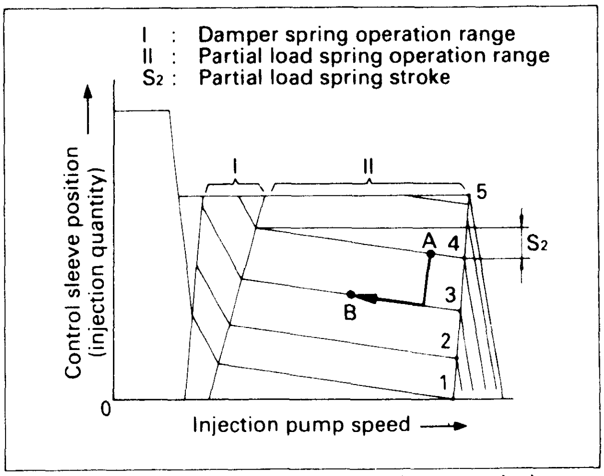


Fig. 34 Combination governor characteristics

The governor spring's set force in a variable speed governor changes in accordance with changes in the accelerator pedal position. (Fig. 33: points 1–5).
For example, when the flyweights' centrifugal force and the governor spring's set force are balanced (Fig. 33; point A) and the accelerator pedal is released a little to decrease speed, the control sleeve will move to the non-injection position as shown by the solid line in Fig. 33. Then, in response to the change in the governor spring's set force (gradient 3), the control sleeve will move in the fuel-increase direction and will stop in the positon where the injection quantity necessary for the load at this time can be obtained (i.e. point B ; the flyweights' centifugal force and the governor spring's set force are balanced). The variable speed governor governs in the engine's all-speed range in response to accelerator pedal position or variations in engine load.

With the combination governor the set force of the partial load spring and the control sleeve position (Fig. 34 : lines 1–5) are varied in response to accelerator pedal position to regulate the fuel injection quantity.
If the accelerator pedal is released slightly to decrease speed during partial load operation (Fig. 34 : point A), when the flyweights' centrifugal force and the partial load spring's set force are balanced, the control sleeve will move from point A to point B, as shown by the solid line in Fig. 34.
As can be seen from the solid line in Fig. 34 showing control sleeve movement when speed decreases, the combination governor's control sleeve travel is less, and the variation in fuel injection quantity is also decreased.
This results in a reduction in the shock caused by sudden variations in fuel injection quantity and an improvement in accelerator "feeling" when speed is reduced.

Governor Equipped with Negative Torque Control Device

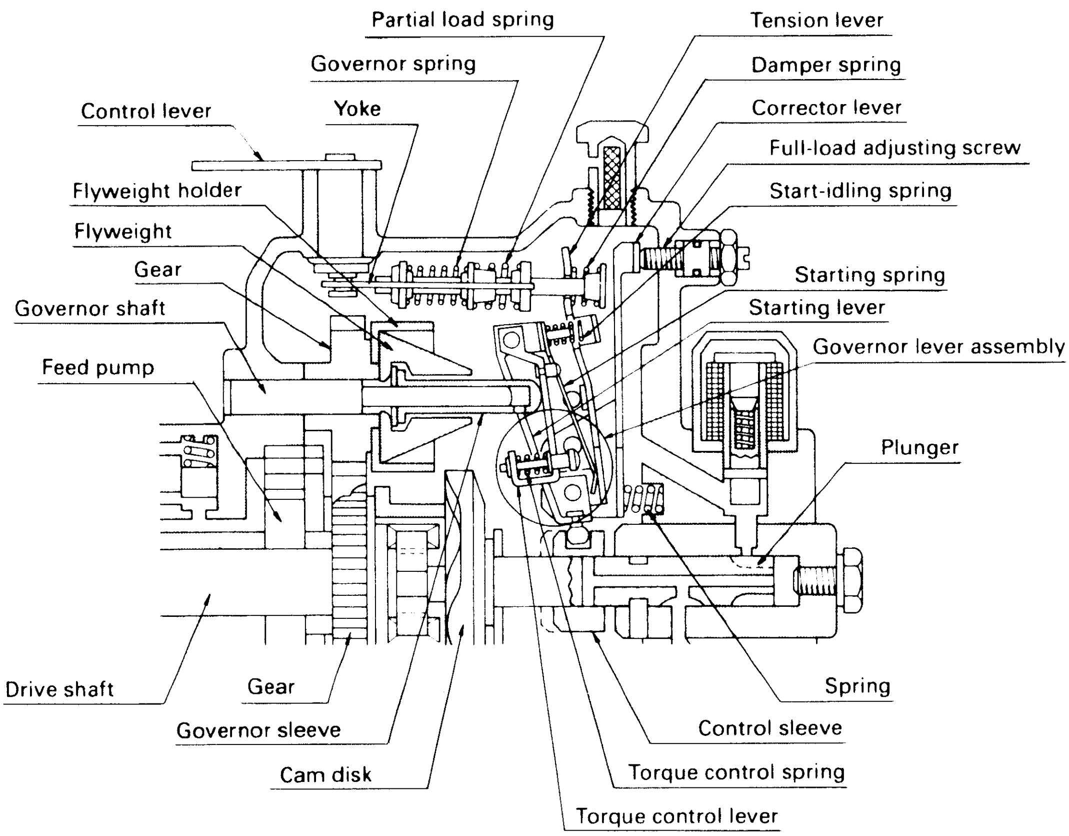


Fig. 35 Construction of governor equipped with negative torque control device

A negative torque control device is provided through the installation of a torque control lever to the governor lever assembly's starting lever.

The torque control lever is fitted with a torque control spring, the set force of which varies according to the torque control stroke.

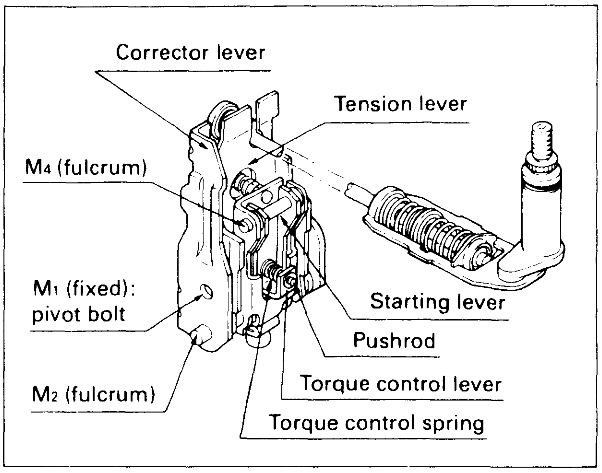


Fig. 36 Governor lever assembly equipped with negative torque control device

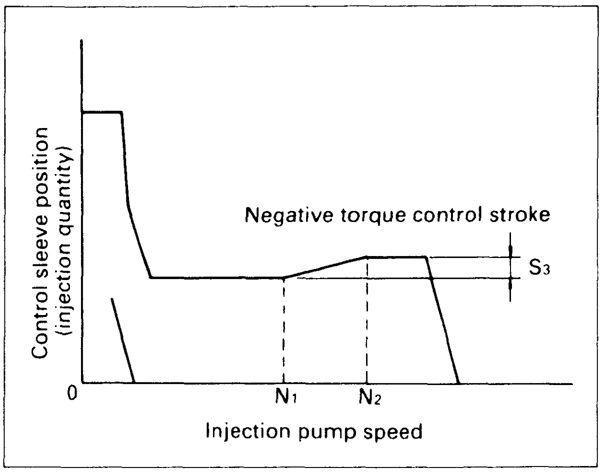


Fig. 37 Negative torque control characteristic

The negative torque control device moves the control sleeve through the torque control stroke (S_3 in Fig. 37) in the governor's intermediate-speed control range to increase the injection quantity in proportion to engine speed and therefore prevent insufficient engine output resulting from insufficient fuel injection at high speeds. (Refer to Fig. 37.)
Figure 37 shows the control characteristics of a combination governor equipped with the negative torque control device.

Engine starting

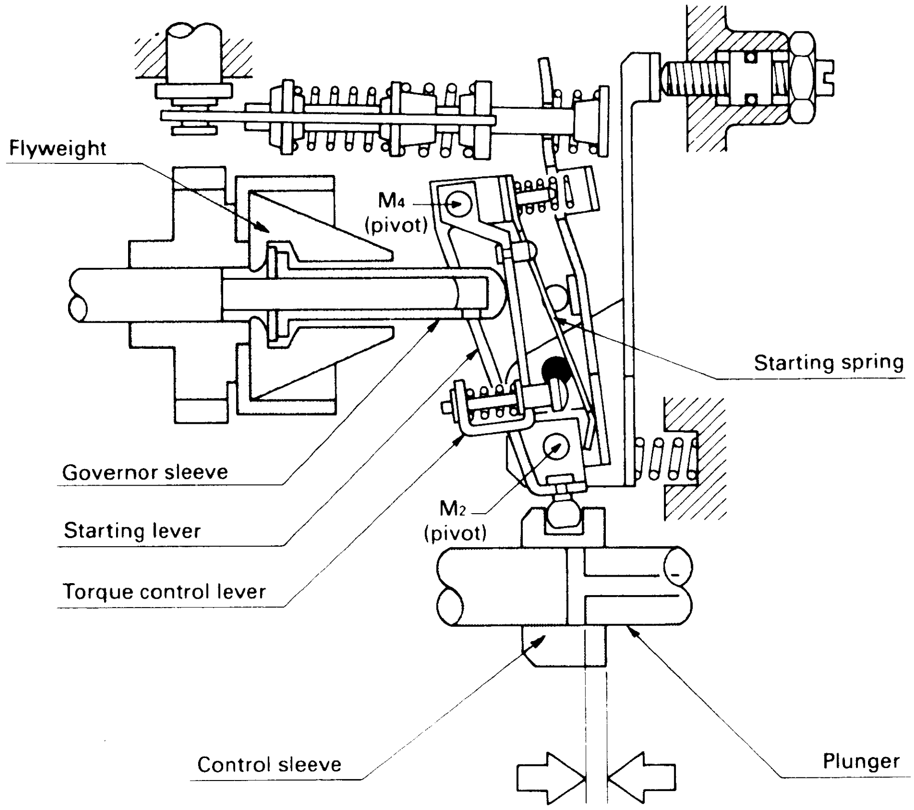


Fig. 38 Operation of governor equipped with negative torque control device: engine starting

As in the variable speed governor or the combination governor, the governor equipped with the torque control device controls starting through the action of the starting spring (a leaf spring) mounted on the starting lever.
At starting the action of the starting spring pivots both the starting lever and the torque control lever (connected at M_4) in a counter-clockwise direction around point M_2, thus moving the control sleeve in the fuel-increase direction to supply a fuel injection quantity sufficient for starting.

Idling operation

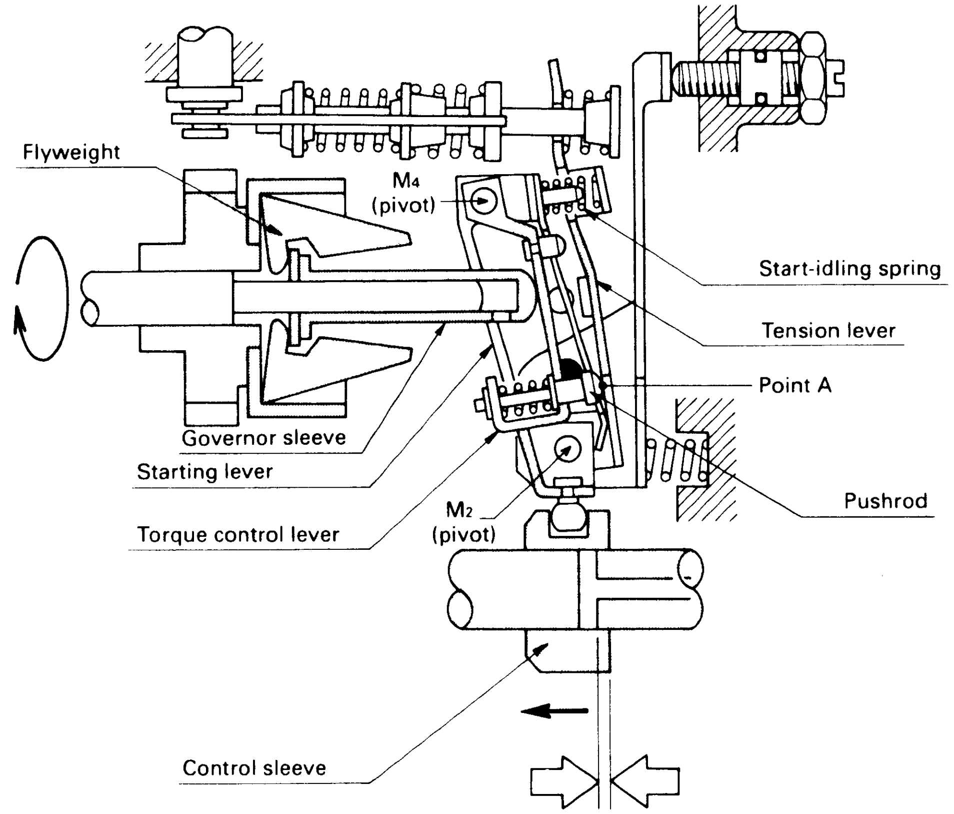


Fig. 39 Operation of governor equipped with negative torque control device: idling operation

On starting, the centrifugal force of the flyweights causes the governor sleeve to move to the right (Fig. 39). The governor sleeve then contacts and moves the torque control lever.
The torque control lever pushrod then contacts the tension lever at point A, and the torque control lever then pivots around point A to compress the start-idling spring until its set force is overcome by the flyweights' centrifugal force. Consequently the starting lever will pivot clockwise around M_2, thus moving the control sleeve in the fuel decrease direction until an injection quantity suitable for idling is attained.

Partial load operation

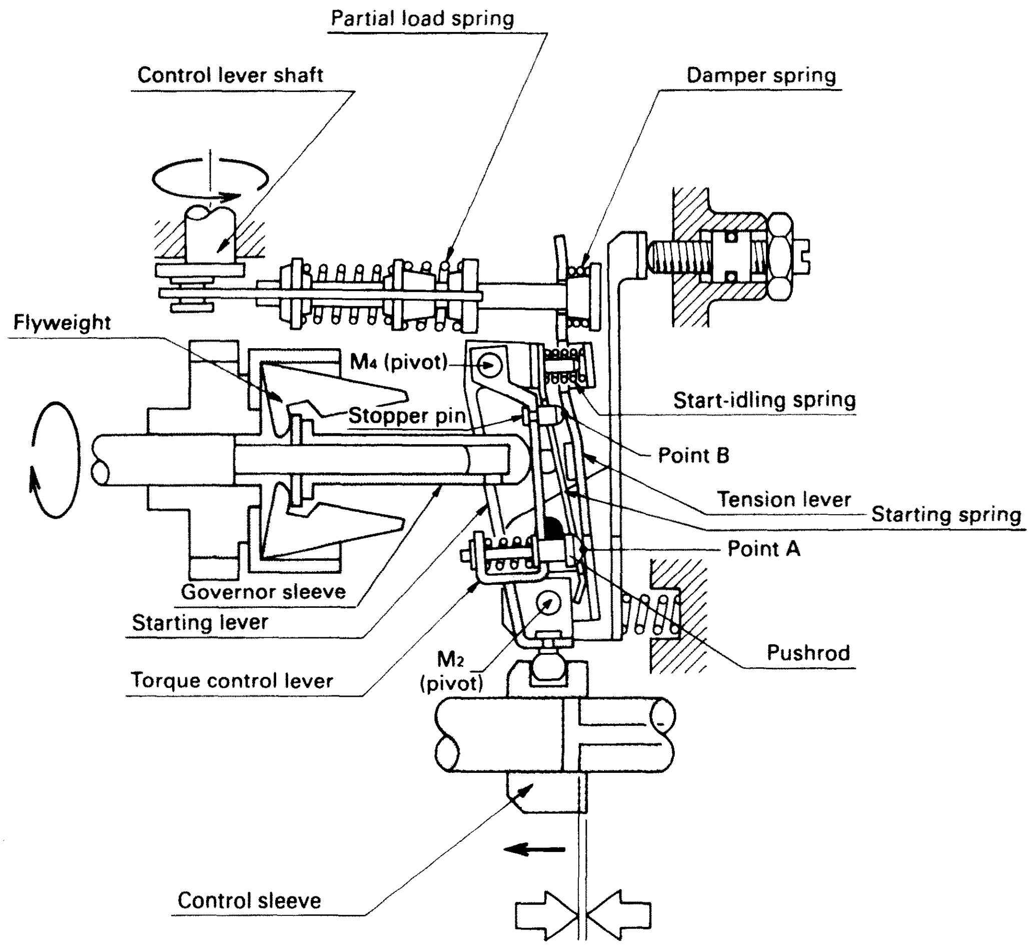


Fig. 40 Operation of governor equipped with negative torque control device: partial load operation

In the speed range exceeding idling operation, and the range where the control lever is positioned between the idling position and the maximum speed position, the starting spring and start-idling spring are already fully compressed, and the torque control lever and the tension lever (which are in contact at points A and B through the torque control lever pushrod and stopper pin), and the starting lever, move together as one (Fig. 40).
Therefore, during partial load operation the damper spring and the partial load spring are acted upon by (and oppose) the flyweights' centrifugal force.
If the speed increases during partial load operation in accordance with a change in the control lever position (i.e. the control sleeve position) after the accelerator pedal is depressed, the consequent increase in the flyweights' centrifugal force moves the governor sleeve to the right, thereby pushing the torque control lever to the right. Then, as the torque control lever, the starting lever and the tension lever behave as one component, movement of the governor sleeve by the flyweights' centrifugal force compresses the damper spring and the partial load spring, and pivots the starting lever around M_2. Thus, the control sleeve is moved to the left to decrease the fuel injection quantity. As a result of this, the speed is decreased to maintain a suitable engine speed, and an injection quantity corresponding to the engine load etc. is obtained at the point where the flyweights' centrifugal force is balanced with the combined forces of the damper and partial load springs.

Full-load maximum speed operation

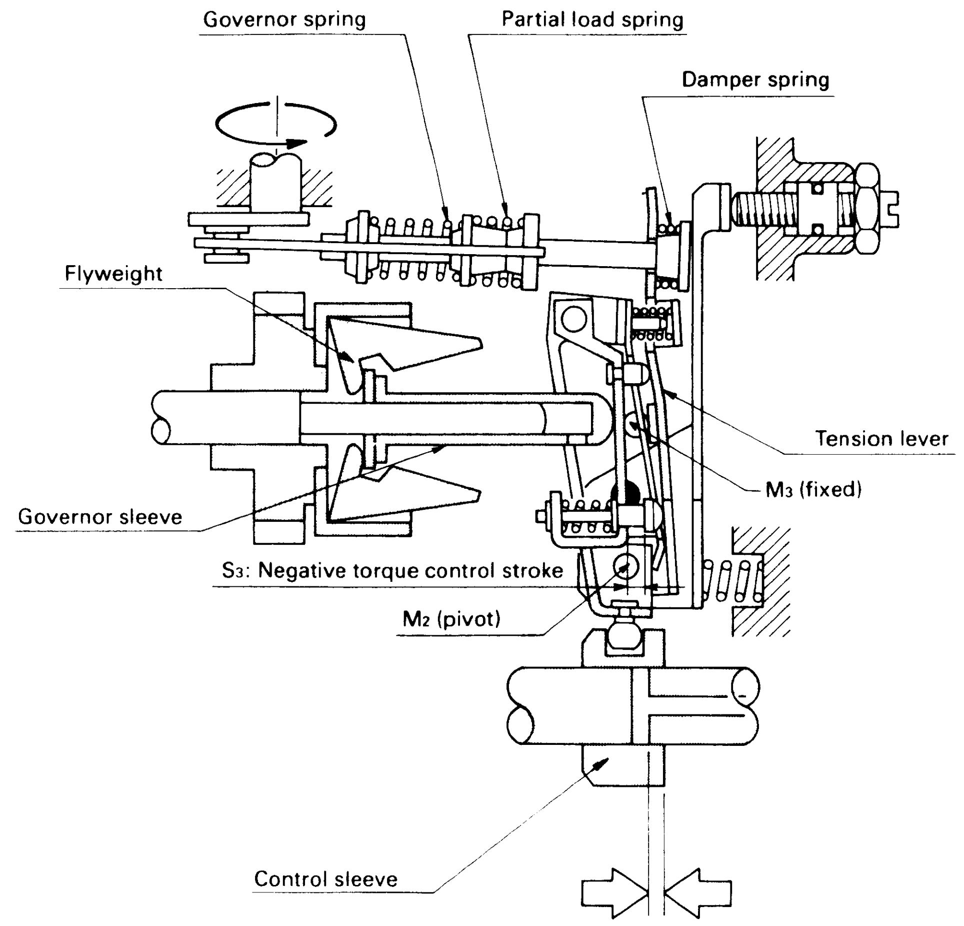


Fig. 41 Operation of governor equipped with negative torque control device: full-load maximum speed operation

When the control lever is moved until it contacts the maximum speed stopper, engine speed is increased until the full-load maximum speed is reached. At this time the yoke is pulled to the extreme left (refer to Fig. 41), the partial load spring is fully compressed, the governor spring is compressed and the tension lever is pulled to the left until it contacts the stopper pin M_3 (i.e. where the full-load injection quantity is obtained).

With an increase in speed the flyweights' centrifugal force increases and the governor sleeves acts to move the tension lever against the force of the governor spring to move the control sleeve and maintain full-load maximum speed operation.

Negative torque control stroke operation

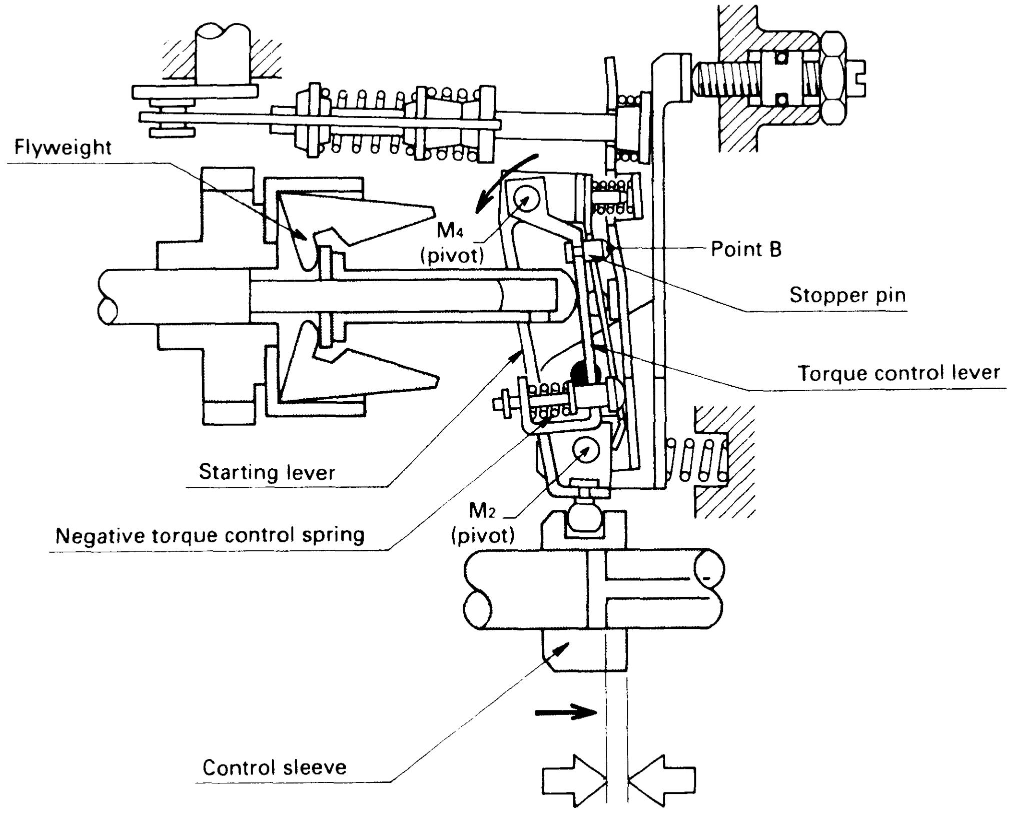


Fig. 42 Operation of governor equipped with negative torque control device: negative torque control stroke operation

When the engine speed exceeds N_1 r.p.m (refer to Fig. 37) the centrifugal force of the flyweights will continue to increase, resulting in compression of the negative torque control spring.
The torque control lever will therefore pivot counterclockwise around point B (the torque control lever stopper pin), pivoting the starting lever counterclockwise around M_2 to move the control sleeve in the fuel-increase direction. The increase in the fuel injection quantity is determined by the negative torque control stroke S_3 (refer to Fig. 41).

No-load maximum speed operation

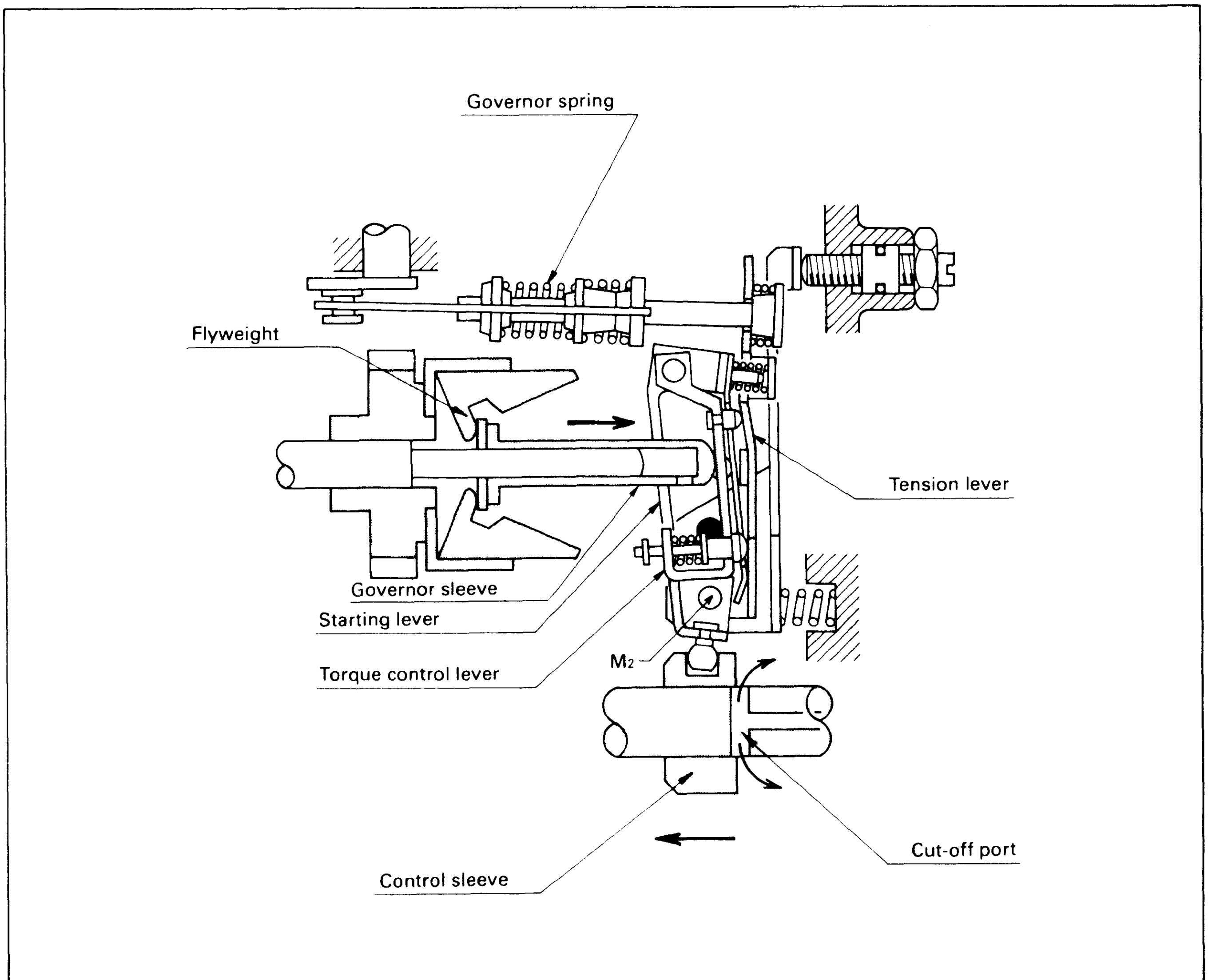


Fig. 43 Operation of governor equipped with negative torque control device: no-load maximum speed control

When the negative torque control stroke is completed and engine speed increases further, the flyweights' centrifugal force will move the governor sleeve to the right (Fig. 43). The starting lever and the tension lever (through the torque control lever) are then moved to compress the governor spring until the governor spring tension is balanced with the flyweights' centrifugal force in the no-load maximum speed position. If engine speed further increases, the control sleeve will move to the left until the plunger's cut-off port enters the pump chamber, resulting in non-injection so that the engine's specified maximum speed will not be exceeded.

7. Timer Construction and Operation

It is well-known that the relationship between fuel injection timing and engine performance (power, exhaust gas, engine vibration) is very important.
If actual fuel injection timing differs only slightly from the standard specified timing, then diesel engine performance will be adversely effected.
Because the ignition lag arising during diesel engine combustion increases as engine speed increases, it is necessary to compensate for this ignition lag by advancing injection timing.
To do this, a timer is installed at the bottom of the injection pump.

Standard Type Timer (Speed Timer)

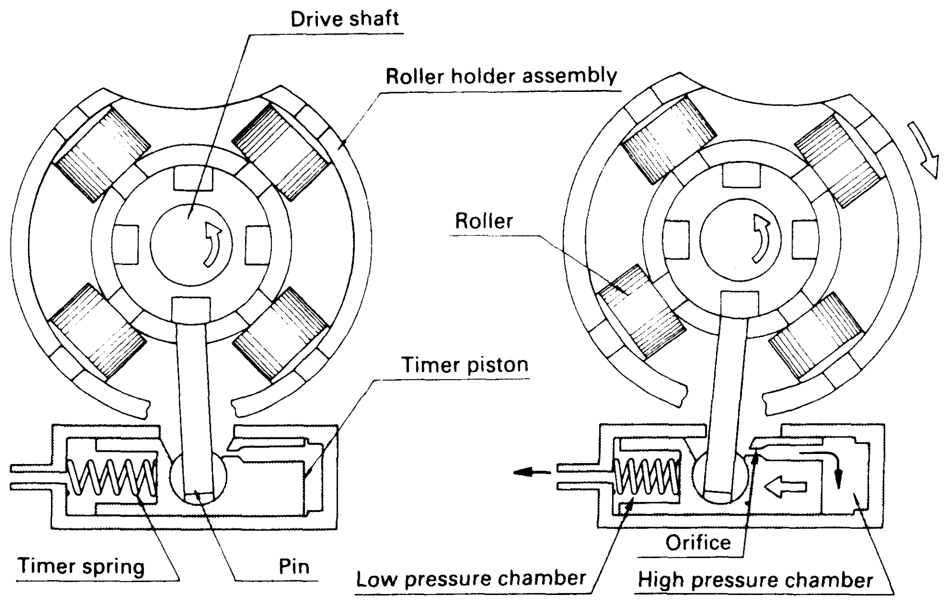


Fig. 44 Speed timer construction and operation

As shown in Fig. 44, a timer spring is installed in the low pressure chamber of the timer. Pump chamber pressure, passing through the timer piston orifice, acts on the high pressure side of the timer piston.
This timer piston orifice acts to prevent timer piston pulsation generated by fuel pressure fluctuations.
Timer piston movement results in the pin moving the roller holder assembly in the direction opposite to injection pump rotation.
When pump chamber pressure exceeds the set force of the timer spring due to an increase in pump speed, the timer piston compresses the timer spring and turns the roller holder assembly in the direction opposite to that of injection pump rotation. With this movement the cam disk's face cams contact the roller holder's rollers more quickly and injection timing is advanced.

When pump speed decreases and the timer spring set force exceeds the pump chamber pressure, the roller holder assembly is moved in the direction to retard injection timing.
Additional devices such as the solenoid timer, cold start device (C.S.D.) and the load timer etc. are also used with this standard-type timer to vary the injection timing in the specified range of engine speeds and loads.

Servo Valve Timer

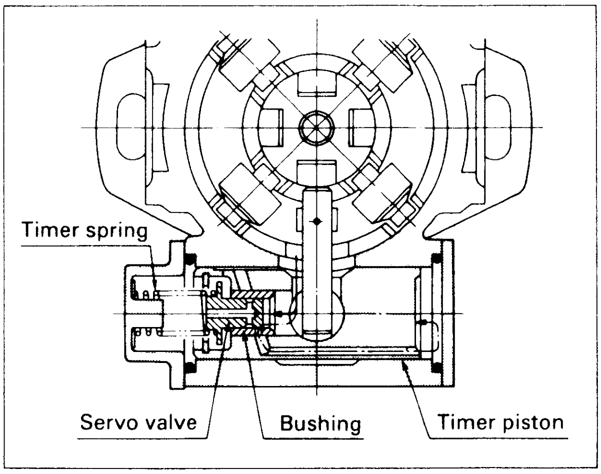


Fig. 45 Servo valve timer construction

As shown in Fig. 45, through the addition of some parts (e.g. servo valve), the alteration of other parts (e.g. timer piston, cover and spring) and alterations to the fuel oil transfer passage, the servo valve timer differs from the standard type timer.
With the servo valve timer, pump chamber pressure does not act directly on the timer's high pressure chamber, but flows through the servo valve before acting on the timer's high pressure chamber.
The timer spring force does not push the timer piston, but pushes the servo valve against pump chamber pressure. The servo valve position depends on the balance of these two opposing forces, and timer characteristics in turn depend on the servo valve position.

For example, if the timer piston is moved in the retard direction by fluctuations in the driving reaction force, the servo valve position will not change, as the pump chamber pressure does not change. The servo valve then functions to compensate for the fluctuations in the driving reaction force by allowing the supply of pump chamber pressure to the high pressure side of the timer piston. The timer piston is therefore returned to its original position. In other words, the timer piston position is dependant on the servo valve position.
From the above, the servo valve timer's absorbing of the effect of the driving reaction force on injection timing can be seen.
As the effective pressure area directly acted upon by the pump chamber pressure decreases, and correspondingly the spring constant decreases, an improvement in response and a decrease in hysteresis can be obtained.

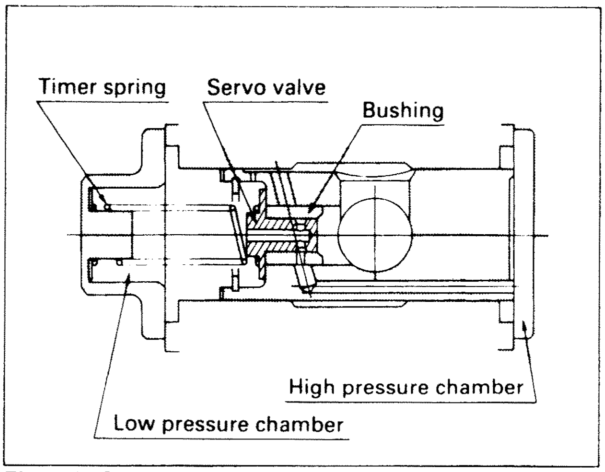


Fig. 46 Servo valve timer operation: when advance angle is "0"

When advance angle is "0" (Low pump chamber pressure)

The pump chamber pressure, compared to the timer spring force, is still low, and the servo valve and the timer piston are pushed fully in the retard direction by the timer spring. The passage between the pump chamber (high pressure side) and the timer's high pressure chamber is closed, and the timer's high pressure chamber is connected to the timer's low pressure chamber (fuel inlet side) by the servo valve.

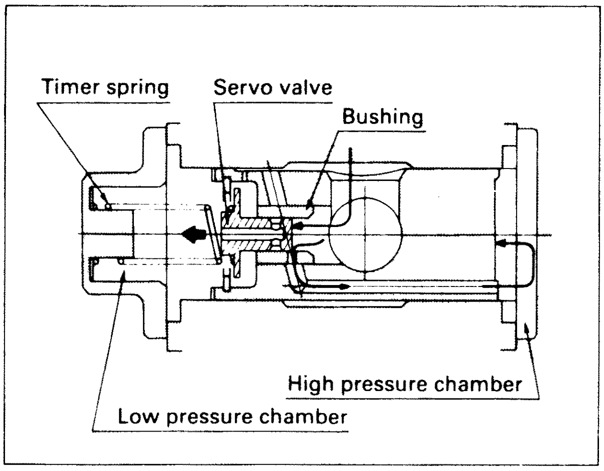


Fig. 47 Servo valve timer operation: when pump chamber pressure has increased

When pump chamber pressure has increased

The pump chamber pressure has increased, the pump chamber pressure exceeds the timer spring set force, and the servo valve has been moved to the left (Fig. 47).
The passage between the pump chamber and the timer's high pressure chamber is open and the pump chamber pressure acts on the timer's high pressure chamber. Due to this the timer piston is moved in the advance direction (to the right in Fig. 47)

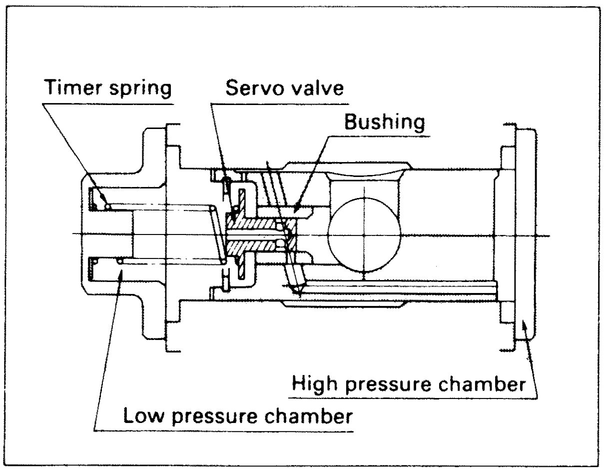


Fig. 48 Servo valve timer operation: stable condition (balanced)

Stable condition (balanced)

The pump chamber pressure and the timer spring force are balanced, and the servo valve is stationary in a suitable position. The timer piston moves until the bushing hole is closed by the servo valve.
When the bushing hole is completely closed, there will be no change in the timer's high pressure chamber pressure and the timer piston will be stationary.

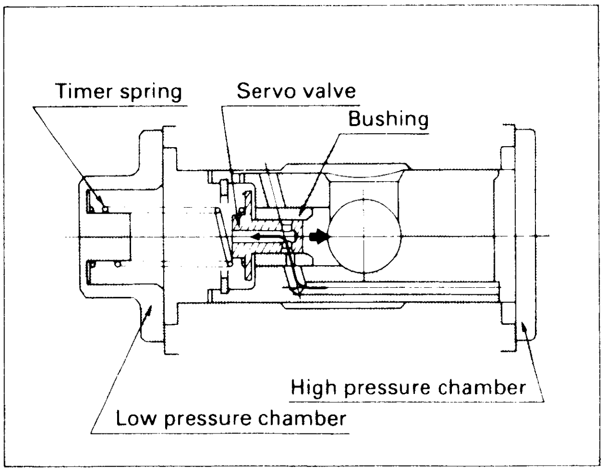


Fig. 49 Servo valve timer operation: when pump chamber pressure has decreased

When pump chamber pressure has decreased

From the stable condition, pump chamber pressure has decreased and the servo valve is moved to the right (Fig. 49) by the timer spring force. The timer's high pressure chamber and the timer's low pressure chamber are connected through the passage in the servo valve. Therefore the timer high pressure chamber's high pressure escapes to the timer's low pressure chamber and the timer piston moves in the retard direction (to the right in Fig. 49), and, as in the above, a stable condition results.

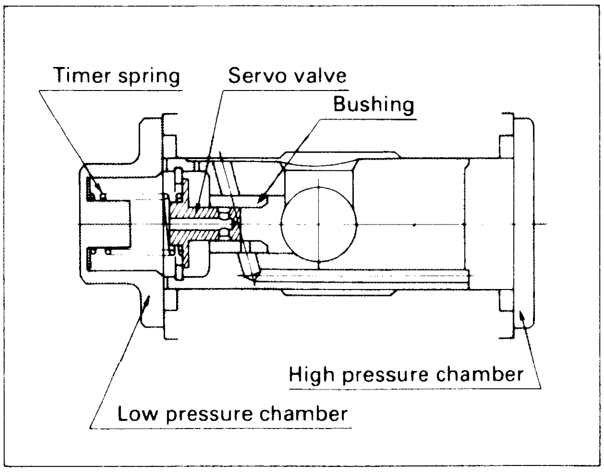


Fig. 50 Servo valve timer operation: maximum advance position

Maximum advance position

As the pump chamber pressure has completely overcome the timer spring force, the timer piston moves until its end face contacts the timer cover's low pressure chamber side. That is, if pump chamber pressure further increases, the timer piston cannot move further in the advance direction. This position is the maximum advance position.
According to the above, if the timer piston is moved through the driving reaction force, operations identical to the above (when pump chamber pressure has increased or decreased) will be repeated until the stable condition is attained.

Load Timer

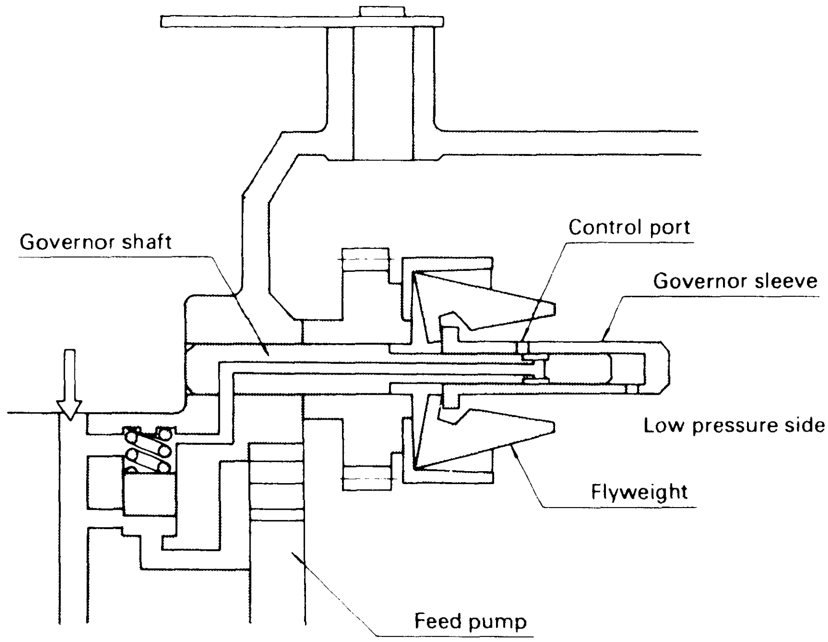


Fig. 51 Load timer construction and operation

The load timer functions to retard injection timing under partial loads in the low and intermediate speed range, and to reduce exhaust emission and engine noise.
With the load timer, the governor sleeve, the governor shaft, and the injection pump housing are specially constructed to facilitate the escape of fuel oil in the injection pump chamber from the governor sleeve control port, through a passage in the governor shaft and pump housing to the low pressure side.
When the flyweights are closed, the control port and the governor shaft passage are not aligned.
When the flyweights begin to open with an increase in the engine speed, the control port and the governor shaft passage barely align and injection pump chamber pressure begins to decrease as the pump chamber fuel oil flows to the fuel inlet (i.e. low pressure side) through this passage. When fully open pressure reduction is complete.
As a result, the timer's advance angle is only retarded an amount equal to the value of the pressure reduction.
Furthermore, the flyweights' (governor sleeve's) position changes in accordance with control lever position (engine load).

8. Magnet Valve

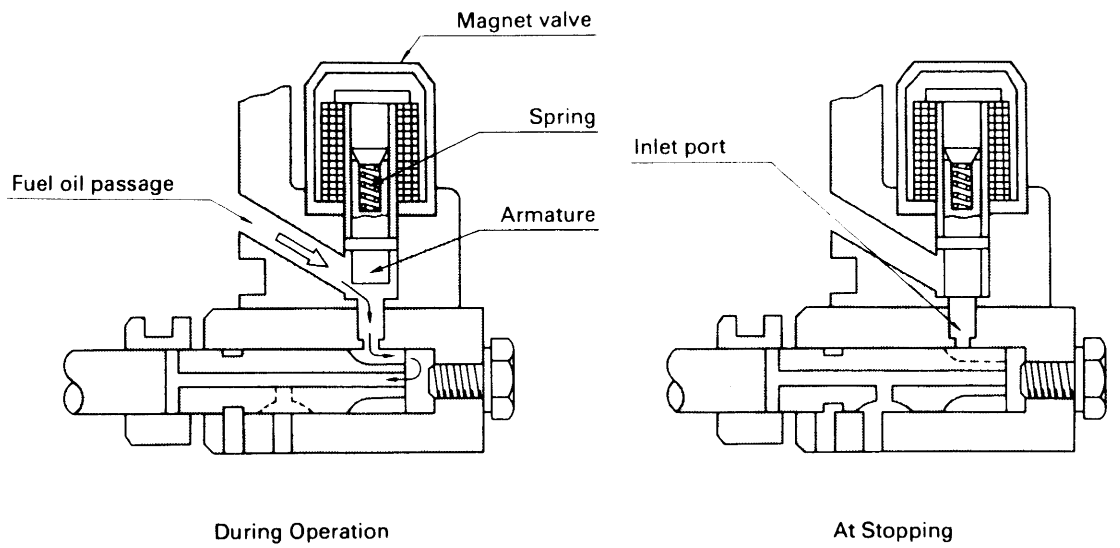


Fig. 52 Magnet valve construction and operation

The magnet valve is turned on and off by the vehicle's ignition switch to open and close the fuel oil passage leading to the plunger barrel's inlet port.
When the ignition switch is ON, current flows through the magnet valve, the armature in the centre of the magnet valve is attracted upwards and fuel oil from the pump chamber is supplied to the plunger barrel's inlet port.
When the ignition switch is turned OFF, the force of the spring inside the armature moves the armature downwards. Therefore, the fuel passage leading to the plunger barrel's inlet port is blocked and, as fuel oil injection to the engine combustion chamber is prevented, the engine can be stopped immediately.

9. Pump Reassembly, Adjustment and Inspection

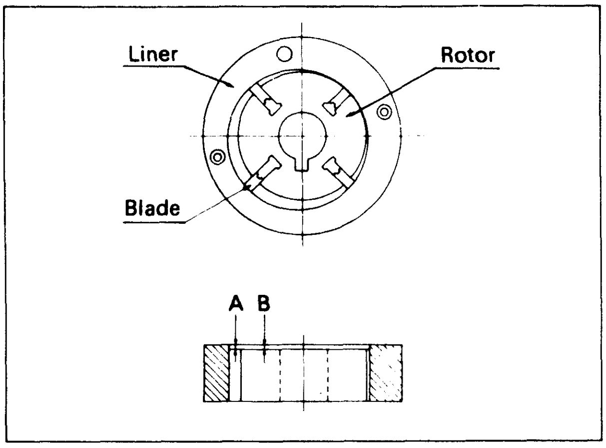


Fig. 1

1. Feed Pump Assembly

Set the rotor and blades inside the liner as a unit, so that their axial clearance will be within the specified tolerance. (The feed pump is delivered as a pre-adjusted assembly.)

Clearance between liner and rotor : A
0.010–0.020 mm.
Clearance between liner and blades: B
0.010–0.020 mm.

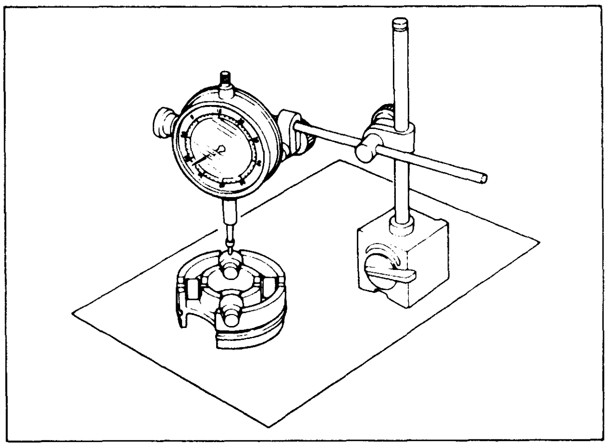


Fig. 2

2. Roller Height

When reassembling the roller holder, select the roller so that the difference in height (See Fig. 2) will be within the specified tolerance. (The roller holder is delivered as a pre-adjusted assembly.)

Difference in roller height:
±0.02 mm.

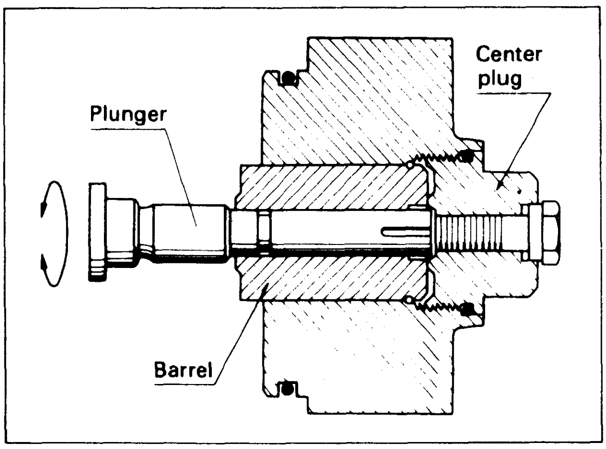


Fig. 3

3. Distributor Head Inspection

a) Plunger barrel movement.
With the center plug tightened to the head at the specified torque 58.8-78.5 N-m(6-8 kgf.m) insert the plunger into the barrel. Confirm that in any position the plunger slides smoothly in the barrel.

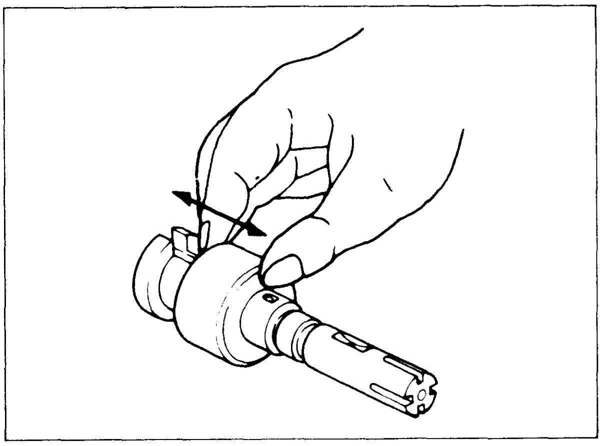


Fig. 4

b) Plunger control sleeve movement
Move the control sleeve 4 mm in an axial direction either side of the cut-off port. Rotate control sleeve and repeat. The control sleeve must slide smoothly in any position.

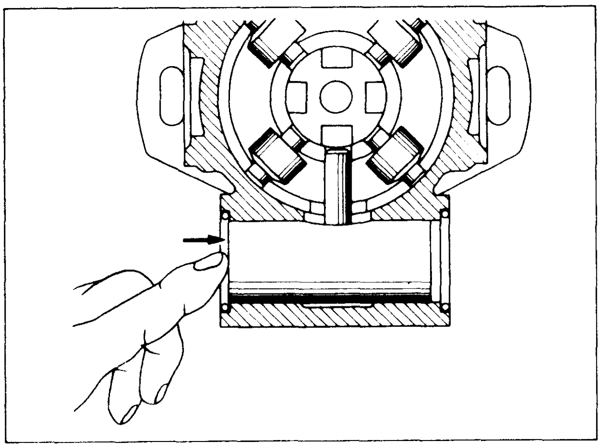


Fig. 5

4. Timer Movement Inspection

Position the plunger in the bottom dead center position. Push the timer piston from the retard side and observe timer movement. The timer must move smoothly. The force required for this movement should not exceed the specified value (Max 1N(0.1 kgf))

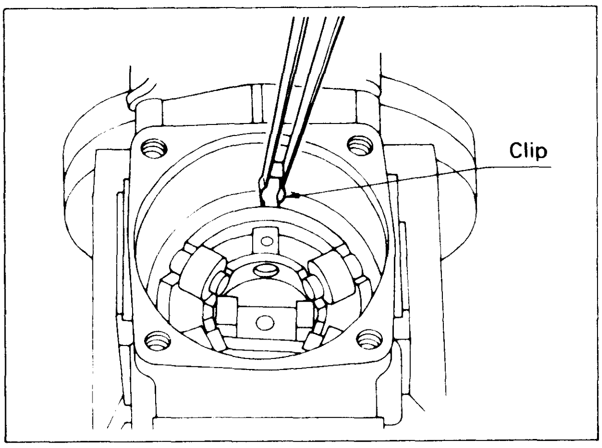


Fig. 6

5. Visual Inspection of Timer Lock Pin

Visually check that the timer connection lock pin [(25) in Fig. 25] is set correctly. Ensure a new clip (26) is installed at every service.

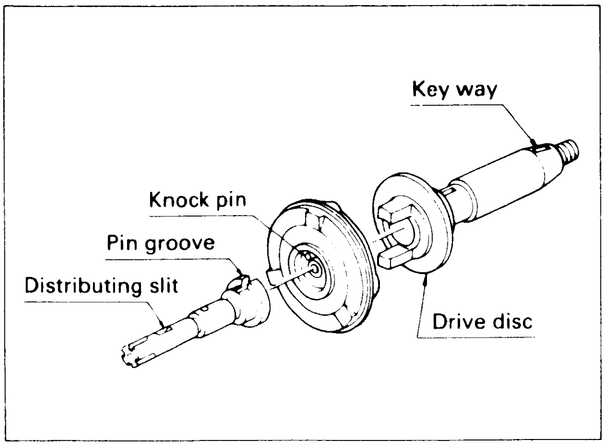


Fig. 7

6. Drive Shaft Key Way and Pin Groove

Visually check that the drive shaft key way and plunger pin groove are properly aligned.

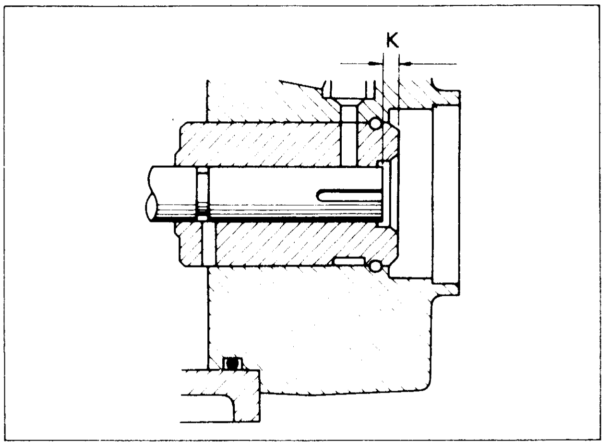


Fig. 8

7. Plunger Position Adjustment

a) VE type pump without plunger pre-stroke
Adjust the plunger position in the distributor head so that the dimension "K" is as specified. "K" is the distance from the end face of the distributor barrel to the plunger tip when the plunger is in the bottom dead center position. Adjust the shim [(52) in Fig. 25] on the plunger bottom, referring to the specified "K" dimension.

Clearance "K": 3.3 $^{\pm 1}$ mm

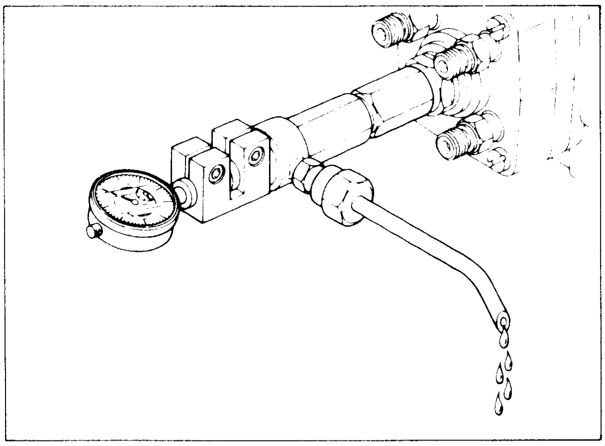


Fig. 9

b) VE type pump with plunger pre-stroke
The plunger position must be adjusted by checking the port closure point hydraulically on a pump test bench..With the plunger in the bottom dead center position, apply feed pressure of 0.02MPa(0.2 kgf/cm^2). Test oil should flow out of the measuring device over-flow tube. Manually rotate the pump in the proper direction. Read the dial indicator when test oil stops flowing, and adjust the shim [(52)in Fig. 25] on the plunger bottom so that the dial reading is as specified.

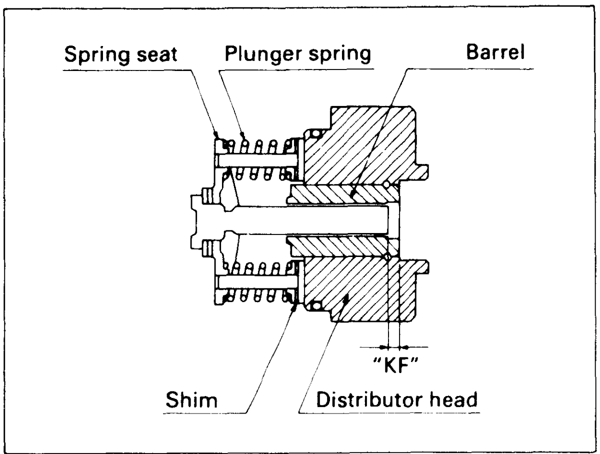


Fig. 10

8. Measurement of Plunger Spring Set Length

Install the plunger and plunger spring in the distributor head without the shim [(48) in Fig. 25]. Push the plunger bottom lightly in an axial direction and measure the dimension "KF". "KF" is the distance from the end face of the distributor barrel to the plunger tip. Adjust the shim (48) refering to the specified "KF" dimension.

Cam Lift (mm)	Dimension "KF" (mm)
3	5.3 $^{\pm.1}$
2.8	5.3 $^{\pm.1}$
2.5	5.3 $^{\pm.1}$
2.2	5.8 $^{\pm.1}$
2.0	6.0 $^{\pm.1}$
1.56	6.64$^{\pm.1}$

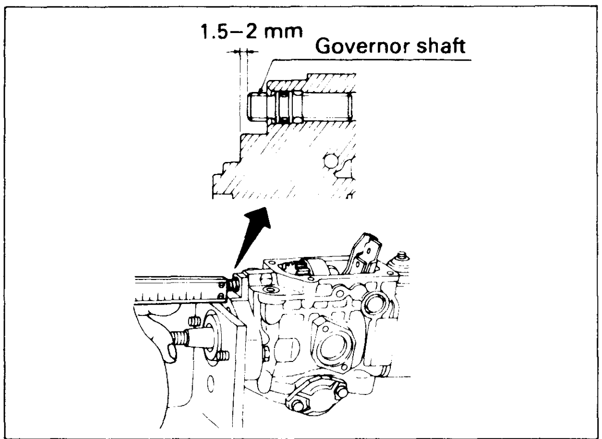


Fig. 11

9. Governor Shaft Installation

Install the governor shaft [(108) in Fig. 25] so that the distance from the end face of the pump housing flange to the governor shaft end face is 1.5–2.0 mm.

For an injection pump installed with a Load Timer, screw in the governor shaft so that the distance from the end of the governor shaft to the pump housing flange surface is 3 mm. After adjustment, tighten the locknut to the specified torque.

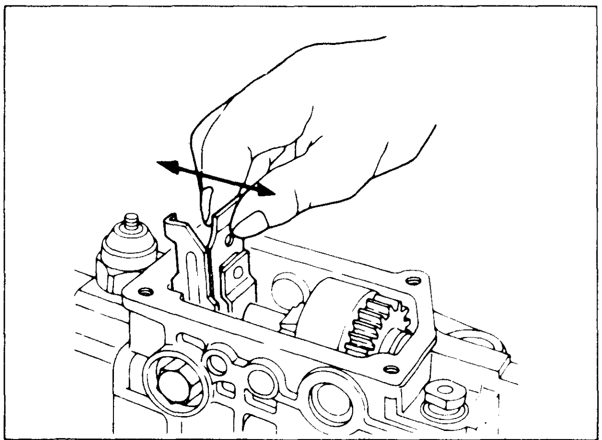


Fig. 12

10. Testing Governor Lever Action

After reassembly, manually check the movement of the start lever, governor lever assembly and control sleeve.

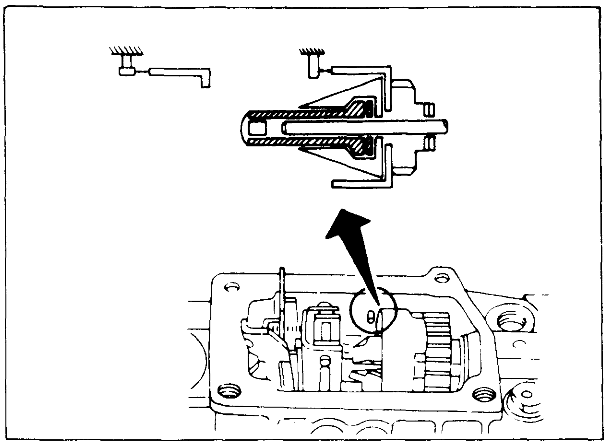


Fig. 13

11. Flyweight Assembly Clearance

Using a thickness gauge measure the clearance between the flyweight holder end face and the stopper pin (marked in Fig. 13.) Adjust the clearance using the shim [(110) in Fig. 25] at the back of the governor flyweight assembly.

Clearance:
With straight pin: $0.15^{+0.2}$ mm
With stepped pin : $0.35^{+0.2}$ mm

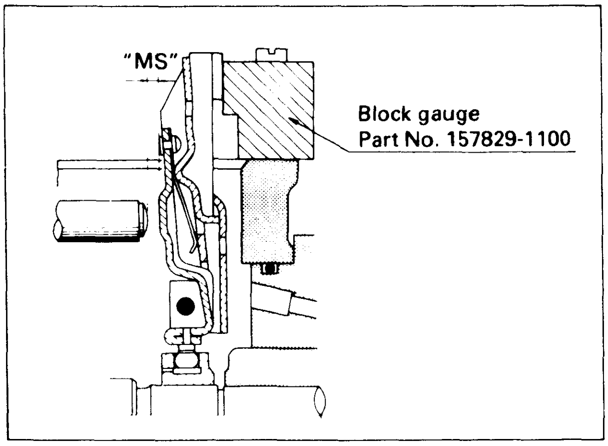


Fig. 14

12. Starting Stroke "MS" Adjustment

"MS" is the distance from the closing plug installed on the governor sleeve to the starting lever, and determines the fuel injection quantity for engine starting. Method of measurement varies, depending on the type of governor lever assembly, as shown below.

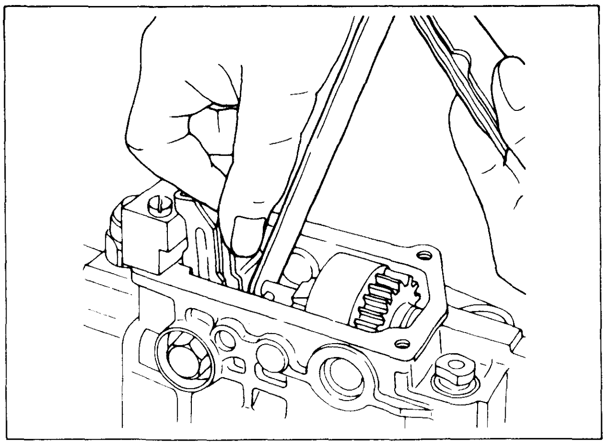


Fig. 15

a) Standard type
Hold the corrector lever against the block gauge (Part No. 157829-1100) installed as shown in Fig. 15, and keep the tension lever against the stopper pin press-fitted into the pump housing.
Then, hold the starting lever against the tension lever with the start spring compressed.
Using a thickness gauge measure dimension "MS"

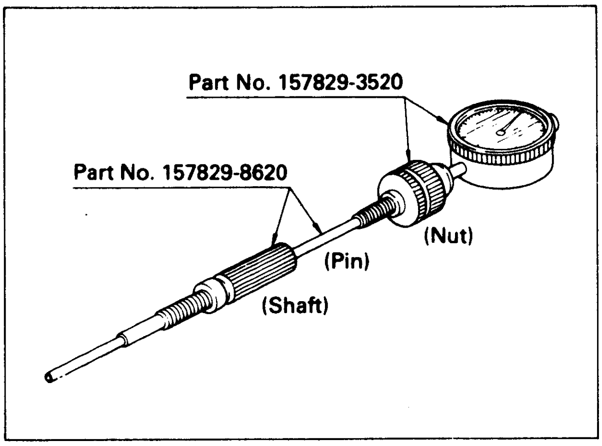


Fig. 16

b) Negative torque control type
(1) Use "MS" measuring device (Part No. 157829-8620), block gauge (Part No. 157829-1100) and Plunger lift stroke measuring device (Part No. 157829-3520.)
Before measurement, the pin of the plunger lift stroke measuring device (Part No. 157829-3520) must be replaced with the pin of the "MS" measuring device (Part No. 157829-8620.)

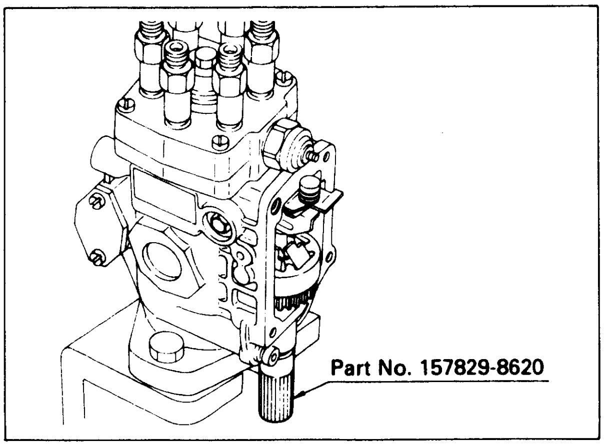


Fig. 17

(2) Position the pump upright, loosen the nut (107) (See Fig. 25) and remove the governor shaft (108).
Install the shaft of "MS" measuring device (Part No. 157829-8620) in place of the governor shaft.
Take care not to drop the washer (111) and shim (110) (See Fig. 25), by holding the flyweight.
For an injection pump installed with a Load Timer, screw in the governor shaft so that the distance from the end of the governor shaft to the pump housing flange surface is 3 mm. After adjustment, tighten the lock-nut to the specified torque.

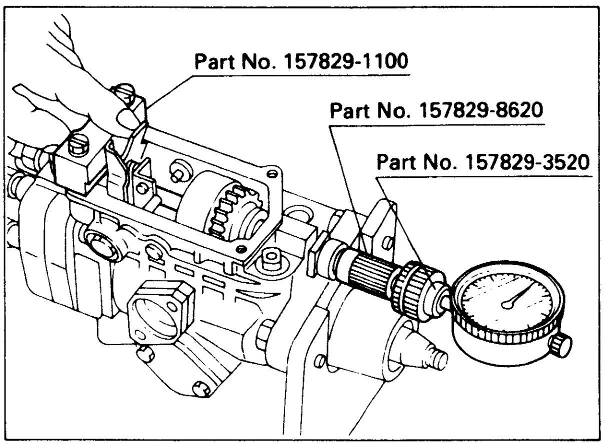


Fig. 18

(3) Install the block gauge (Part No. 157829-1100) as shown in Fig. 18. Insert the pin of the plunger lift stroke measuring device (Part No. 157829-3520) into the measuring device shaft, already fixed in step b-(2). Secure the dial using the nut. To set the dial's zero point, slightly push the dial so that the dial reads between 2 to 3 mm (the tip of the pin touches the rear side of the closing plug.) Ensure the governor sleeve is pushed toward the flyweight side.
Hold the corrector lever against the block gauge, and push the tension lever against the stopper pin, press-fitted into the pump housing. Next, push the sleeve until the start lever contacts the tension lever, and will not move any further.
Next, read the dial and select the proper sized closing plug, to ensure dimension "MS" is as specified.

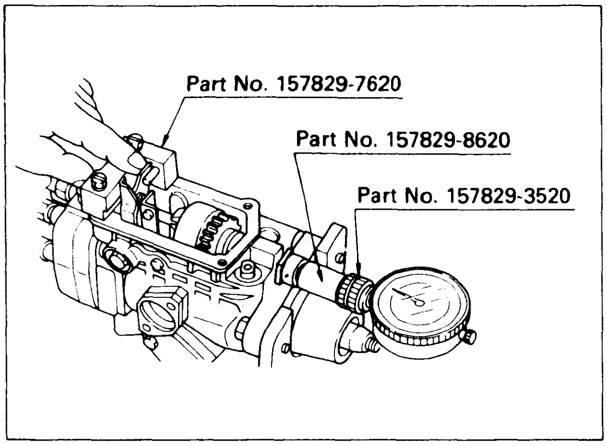


Fig. 19

c) Boost compensator stopper and aneroid compensator type
Install the block gauge (Part No. 157829-7620) as shown in Fig. 19. Insert the pin of the plunger lift stroke measuring device (Part No. 157829-3520) into the device shaft, already fixed in step b-(2). Secure the dial with the nut. To set the dial's zero point, lightly push the dial so that the dial reads between 2 and 3 mm (the tip of the pin touches the rear side of the closing plug.) Ensure the sleeve is pushed toward the flyweight side.
Hold the corrector lever against the block gauge and push the tension lever against the stopper pin press-fitted into the block gauge. Next, push the governor sleeve until the start lever contacts the tension lever, and will not move any further. Then, read the dial and select the proper sized closing plug to ensure that dimension MS is as specified.

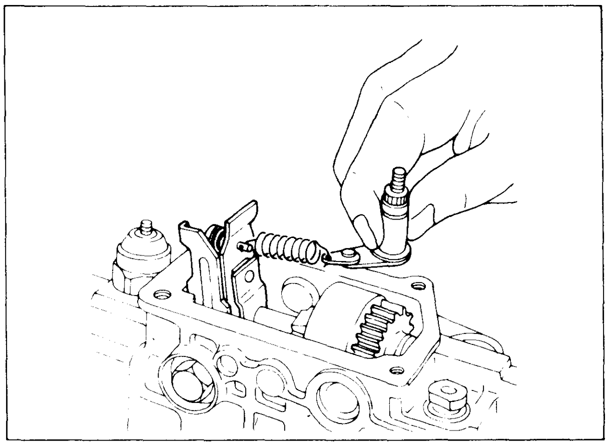


Fig. 20

13. Governor Spring Installation (Variable governor)

Attach the governor spring to the control lever shaft so that the hook faces downward.

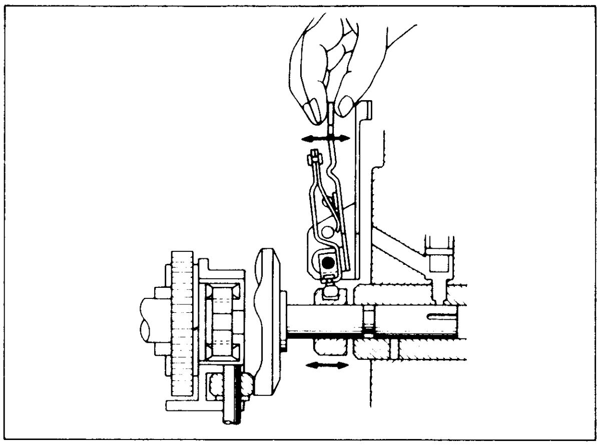


Fig. 21

14. Testing Governor Lever Assembly Movement

Position the cam in the top dead end position, and manually check governor lever assembly (control sleeve) movement. Perform this test over the entire cam profile.

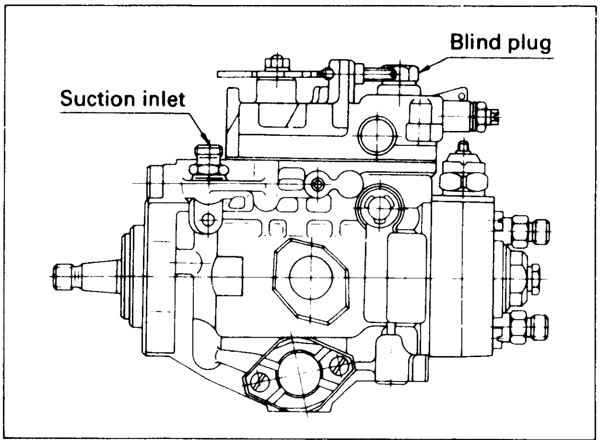


Fig. 22

15. Air-tightness Test

After completion of assembly, perform an air-tightness test as described below.

a) Tightly screw in the pump cover overflow outlet plug (with a gasket).
b) Supply compressd air [approx.0.39MPa(4 kgf /cm^2)] to the pump through the suction inlet.
c) Immerse the pump in light oil.
d) Check for bubbles indicating pump leakage (particularly at the drive shaft oil seal).

16. Handling of O-Rings

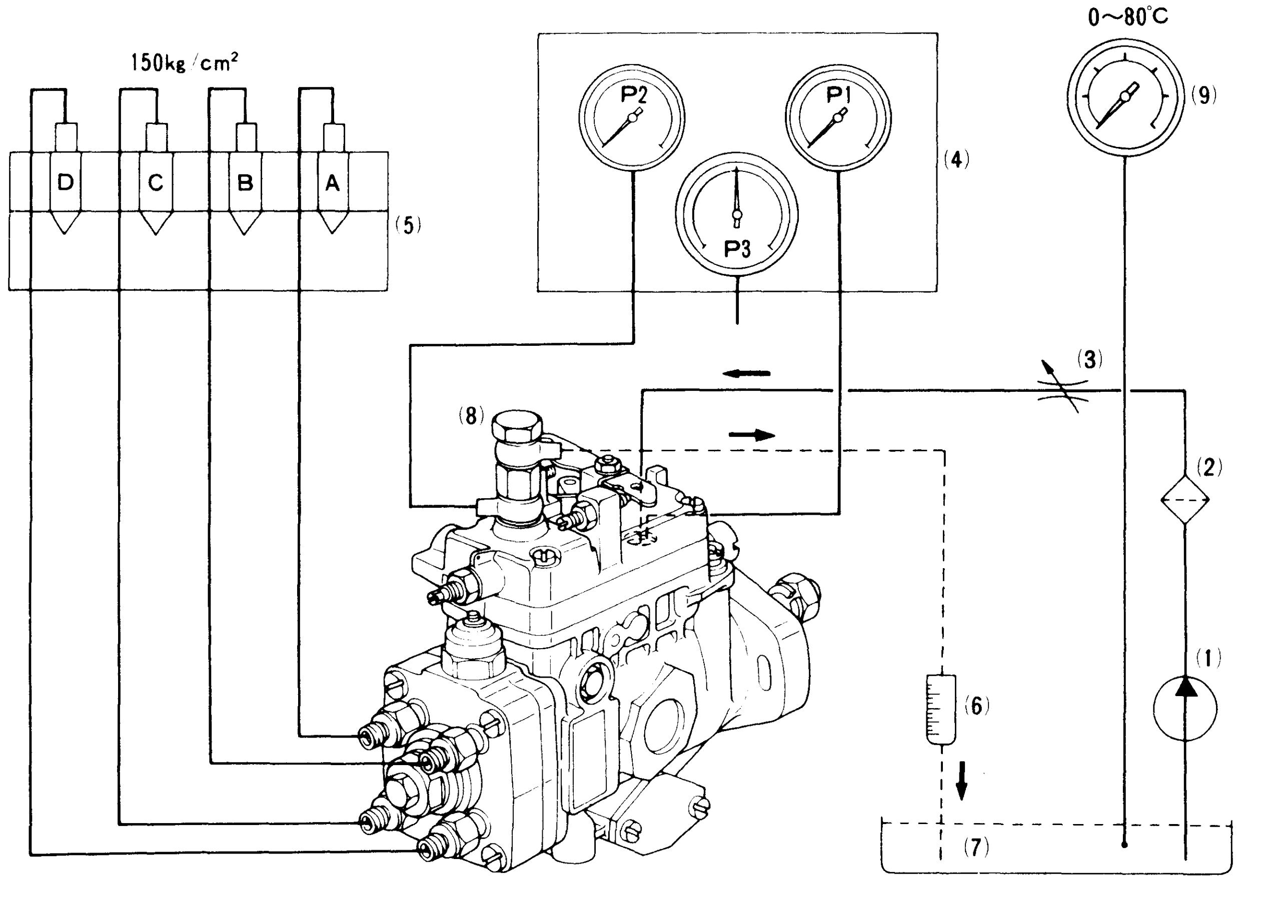
a) Rubber O-rings must be stored unexpanded.
b) When reassembling the pump after test immersion or actual use, replace all O-rings.

10. Test Bench Adjustment of VE Pump

* For adjustment specifications, refer to the individual test standards.

* Adjustment conditions:

Nozzle	: DKKC Part No. 105780-0000 (NP-DN12SD12T)
Nozzle holder	: DKKC Part No. 105780-2080 (EF8511/9A)
Nozzle opening pressure	: 14.7 MPa(150 kgf/cm²)
Injection line	: 6×2−840 mm
Test oil	: SAE Standard Test Oil (SEA J967d) or ISO 4113 test oil
Fuel oil temperature (fuel tank)	: 45^{+5} °C
Supply pressure	: 0.02 MPa(0.2 kgf/cm²)



(1) Pre-supply pump
(2) Filter
(3) Regulator valve inlet
(4) Accumulator
P1: Test oil inlet pressure 0–0.1MPa(0–1 kgf/cm²)
P2: Pump chamber pressure 0–1.47MPa(0–15 kgf/cm²)
P3: Positive & Negative pressure;
Positive: Boost compensator 0–0.2MPa(0–2 kgf/cm²)
Negative: Aneroid compensator 0–101kPa(0–76 cmHg)
(5) Nozzle opening pressure 14.7MPa (150 kgf/cm²)
(6) Measuring cylinder for overflow fuel volume
(7) Fuel tank
(8) Overflow valve
(9) Thermometer(fuel tank)

Fig. 23 TEST BENCH PIPING DIAGRAM FOR PUMP PERFORMANCE TEST

* Warm-up operation: refer to the following:

1. Standard Type VE Pump

Attach the pump to the pump test bench and connect the injection lines.
Using the thermometer (see Fig. 23) measure the fuel oil temperature in the fuel tank. Before starting operation, fill the pump with test oil.

a) Apply the specified voltage to test the pump's magnetic valve.
Fix the control lever in the maximum-speed position.
Operate the pump at the rated speed for approx. 10 minutes.

b) Timer adjustment
Install the timing measuring device and connect the pressure gauge.
Total timer stroke is determined by the timer piston length.
The start of the timer piston stroke depends on the spring tension force and the fuel oil feed pressure; the spring tension force is determined by the shims inside the timer cover. Usually, at least one shim (0.6 mm) is placed on each side of the timer spring.
Adjust the regulating valve so that the timer advances at the specified speed.

c) Supply pressure test
During timing adjustment, the pump chamber pressure must be within the specified range.

d) Full-load fuel injection quantity adjustment
Adjust the full-load fuel injection quantity through the full-load adjustment screw, and by adjusting the tension lever attached to the control sleeve.
Before adjustment, confirm that at the measuring point speed is as specified. Set the control lever to the maximum-speed position by rotating the adjusting screw.
Adjust the full-load point by measuring the fuel injection quantity and referring to the specifications. The measuring point at all speeds must be within the specified range.
The fuel injection quantity for each cylinder must not exceed the specified quantity.

e) Idling adjustment
Adjust the idling fuel injection quantity using the control lever.
The fuel injection quantity for each cylinder must not exceed the specified quantity.

f) Governing adjustment
Adjust the governing performance using the control lever. The governing point is reached when the full-load fuel injection quantity begins to decrease, provided the adjusting screw is set at a position ensuring governor operation.

g) Measurement of overflow quantity
Measure the overflow quantity at the specified speeds using a measuring cylinder.
Compare the measurement with the specified quantities.

h) Measurement of fuel injection quantity for engine starting
Control the starting fuel injection quantity at the specified speeds. Set the control lever to the maximum-speed position to adjust the starting stroke.

i) Control lever angle (see Fig. 24)
Adjust the control lever angles and dimensions given below, referring to the specifications.

- α; Idling position/center position angle
- β; Idling/maximum-speed position angle
- γ; Idling/partial load position angle
- a; Distance from the end of idling stopper to its boss portion
- b; Distance from control lever idling position to maximum-speed stopper
- c; Distance from control lever partial load position to idling stopper

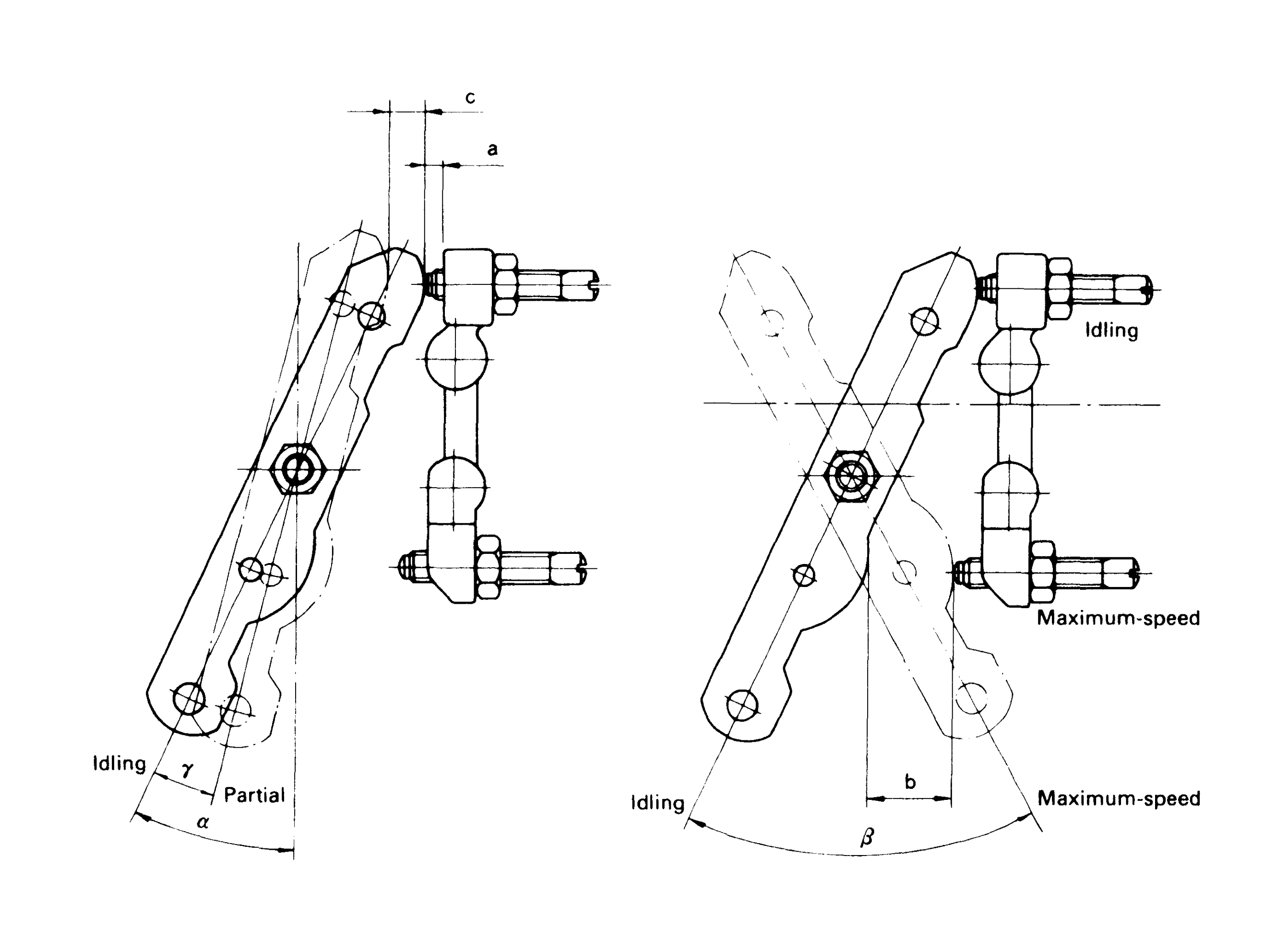


Fig. 24

2. VE Pump Special Specifications

a) Pump equipped with load timer
For a pump equipped with a load timer, move the control lever in the idling direction until the specified fuel injection quantity is reached at the specified test speed, and fix. Then, adjust the governor shaft so that the timer advances as specified.

b) Electrical shut-off
(1) Actuating voltages.
Check, as follows, at speeds as specified in the test standard.
Raise the voltage from 0 volts until the magnet actuates. Note the voltage and compare with the specifications.
(2) Fuel injection stop control
Cut off the voltage at the specified speed and ensure the fuel injection quantity is zero.

11. Troubleshooting

Malfunctions	Causes	Remedies
The engine does not operate		
1. Fuel oil is not injected from the injection pump	1. There is no fuel oil in the fuel tank	Supply fuel and bleed the system
	2. The fuel line from the fuel tank is blocked	Clean or replace
	3. The fuel filter is clogged	Clean or replace
	4. There is air in the fuel filter or the pump chamber	Bleed the system
	5. The accelerator linkage is not properly connected	Repair .
	6. The magnet valve wiring is broken or its armature is sticking	Repair or replace
	7. The feed pump blades are sticking, and therefore not operating	Repair or replace
	8. The drive gear or woodruff key is broken	Replace
2. Injection timing is incorrect	1. The drive gear or belt connections are incorrect	Repair
	2. The injection pump is incorrectly installed on the engine	Repair and adjust injection timing
	3. The roller holder assembly's roller or pin is worn excessively	Replace the assembly
	4. The plunger is worn excessively	Replace the distributor assembly
3. The nozzle does not operate	1. The nozzle or nozzle holder is functioning incorrectly	Inspect, then repair or replace
The engine operates, but only for a short time	1. The pipe(s) to the injection pump is blocked, or the fuel filter is clogged	Clean or replace the pipe(s) or fuel filter
	2. The fuel oil contains air or water	Bleed of air or replace the fuel oil
	3. The feed pump's delivery quantity (or pressure) is insufficient	Repair or replace
The engine "knocks"	1. The injection timing is too advanced	Readjust the timing
	2. The nozzle or nozzle holder is functioning incorrectly	Inspect, then repair or replace

Malfunctions	Causes	Remedies
The engine exhaust contains smoke and the engine "knocks"	1. The injection timing is incorrect	Readjust the timing
	2. The nozzle or nozzle holder is functioning incorrectly	Inspect, then repair or replace
	3. The injection quantity is excessive	Readjust
The engine output is unstable	1. The fuel filter element is clogged and fuel oil delivery is poor	Clean or replace
	2. The amount of fuel or pressure delivered by the feed pump is too little	Inspect and repair
	3. The injection pump is sucking air	Inspect and repair
	4. The regulating valve is stuck in the open position	Replace
	5. The plunger is sticking and does not travel its full stroke	Replace the distributor assembly
	6. The plunger spring is broken	Replace
	7. The control sleeve is not sliding smoothly	Repair or replace
	8. The governor lever is not operating properly or is worn excessively	Repair or replace
	9. The delivery valve spring is broken	Replace
	10. The delivery valve is not sliding properly	Repair or replace
	11. The nozzle or the nozzle holder is not functioning properly	Inspect, and then repair or replace
	12. The injection timing is incorrect	Readjust
Insufficient output		
1. The injection quantity is insufficient	1. The specified full-load injection quantity is not delivered	Readjust
	2. The control lever is not reaching the maximum speed position	Readjust
	3. The governor spring is weak and therefore the governed speed is too low	Replace
	4. The plunger is worn	Replace the distributor assembly
	5. The delivery valve seating portions are damaged	Replace
2. The injection timing is too advanced and the engine is "knocking"		Readjust

Malfunctions	Causes	Remedies
3. The injection timing is too retarded and the engine is overheating or the exhaust contains smoke		Readjust
4. The nozzle or the nozzle holder is not functioning properly		Inspect, and then repair or replace
The engine cannot reach its maximum speed	1. The governor spring is too weak or is improperly adjusted	Readjust or replace
	2. The control lever is not reaching the maximum-speed position	Readjust
	3. The nozzle's injection operation is poor	Repair or replace
The engine's maximum speed is too high	1. The governor spring is too strong or is improperly adjusted	Readjust or replace
	2. The governor flyweights or governor sleeve movement is not smooth	Repair or replace
Idling is unstable	1. The injection quantities are not uniform (the delivery valve is not operating properly)	Inspect or replace
	2. The governor's idling adjustment is improperly adjusted	Readjust
	3. The plunger is worn	Replace the distributor assembly
	4. The plunger spring is broken	Replace
	5. The rubber damper is worn.	Replace
	6. The governor lever shaft pin is worn excessively	Replace
	7. The feed pump blades are not operating properly	Repair or replace
	8. The regulating valve is stuck in the open position	Replace
	9. The fuel filter element is clogged and therefore fuel oil delivery is poor	Clean or replace
	10. The nozzle or the nozzle holder is not functioning properly	Inspect and then repair or replace

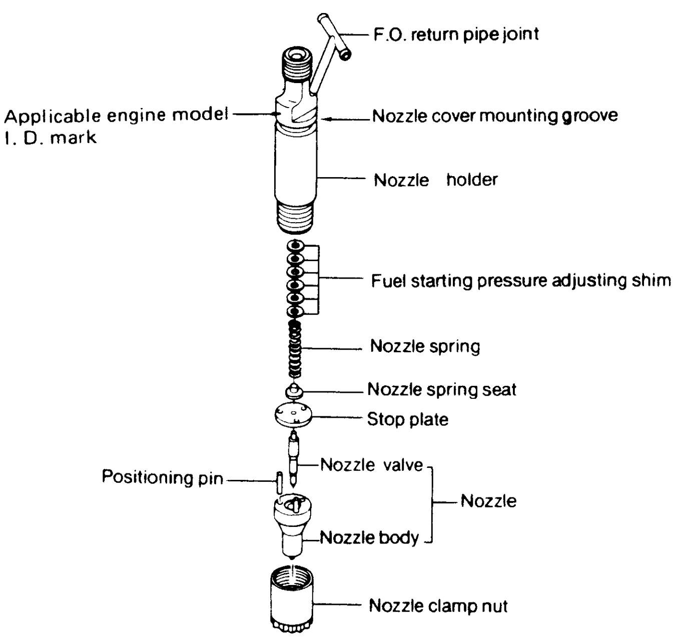
Malfunctions	Causes	Remedies
The engine cannot be stopped	1. The magnet valve armature is stuck in the open position	Repair or replace
	2. Foreign matter is lodged on the magnet valve armature's seating portion	Repair

Note: Main points related to troubleshooting are noted above. Items related to "Additional Devices are not included.

12. Fuel Injection Nozzle

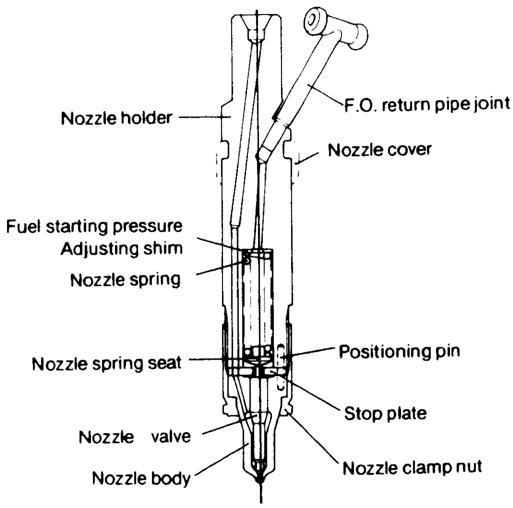
When fuel oil pumped by the fuel injection pump reaches the injection nozzle, it pushes up the nozzle valve (held down by spring), and is injected into the combustion chamber at high pressure.
The fuel is atomized by the nozzle to mix uniformly with the air in the combustion chamber. How well the fuel is mixed with high temperature air directly affects combustion efficiency, engine performance and fuel economy.
Accordingly, the fuel injection nozzles must be kept in top condition to maintain performance and operating efficiency.

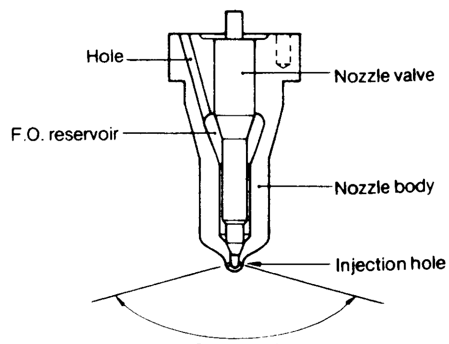
(1) Hole type fuel injection nozzle



12-1 Functioning of fuel injection nozzle

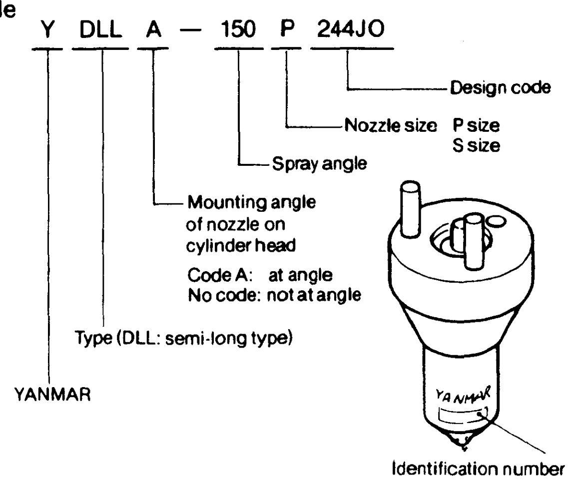
Fuel from the fuel injection pump passes through the oil port in the nozzle holder, and enters the nozzle body reservoir.
When oil reaches the specified pressure, it pushes up the nozzle valve (held by the nozzle spring), and is injected through the small hole on the tip of the nozzle body.
The nozzle valve is automatically pushed down by the nozzle spring and closed after fuel is injected.
Oil that leaks from between the nozzle valve and nozzle body goes from the hole on top of the nozzle spring through the oil leakage fitting and back into the fuel tank.
Adjustment of injection starting pressure is effected with the adjusting shims.





(3) Nozzle body identification number
The type of nozzle can be determined from the number inscribed on the outside of the nozzle body.
1) Hole type fuel injection nozzles

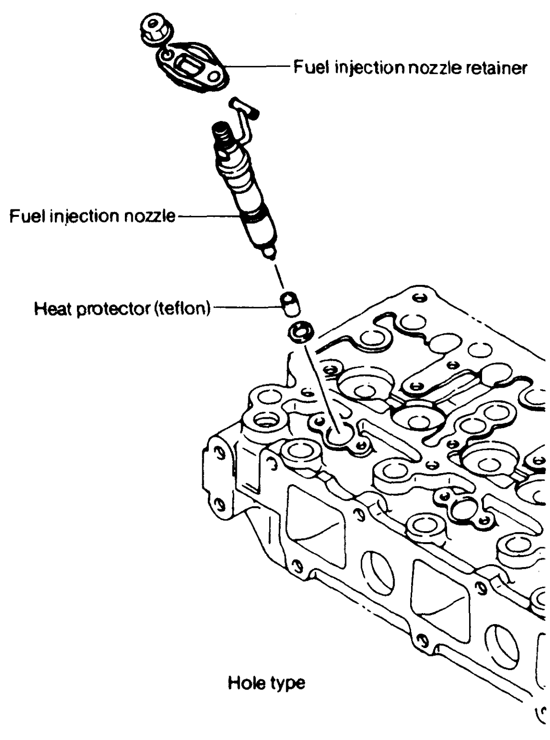
Sample



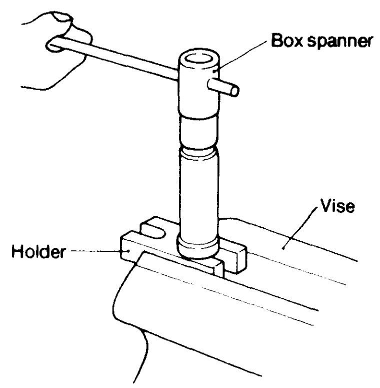
12-2 Fuel injection nozzle disassembly

NOTE: 1. Disassemble fuel injection nozzle in a clean area as for fuel injection pump.
2. When disassembling more than one fuel injection nozzle, keep the parts for each injection nozzle separate for each cylinder (i.e. the nozzle for cylinder 1 must be remounted in cylinder 1).

(1) When removing the injection nozzle from the cylinder head, remove the high pressure fuel pipe, fuel leakage pipe, etc., the injection nozzle retainer nut, and then the fuel injection nozzle.



(2) Put the nozzle in a vise
NOTE: Use the special nozzle holder for the hole type injection nozzle so that the high pressure mounting threads are not damaged.
(3) Remove the nozzle nut



NOTE: Use a special box spanner for the hole type (the thickness of the two nozzle nuts is 15mm (0.5906in.))

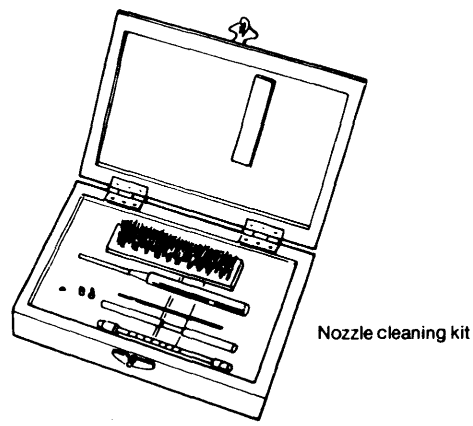
(4) Remove the inner parts

NOTE: Be careful not to loosen the spring seat, adjusting shims or other small parts.

12-3 Fuel injection nozzle inspection

12-3.1 Washing

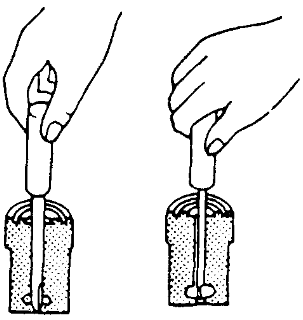
(1) Make sure to use new diesel oil to wash the fuel injection nozzle parts.
(2) Wash the nozzle in clean diesel oil with the nozzle cleaning kit.



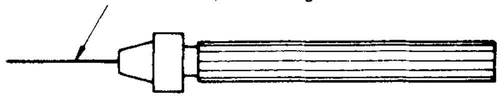
1) Diesel Kiki nozzle cleaning kit:
Type NP-8486B No. 5789-001
2) Anzen Jidosha Co., Ltd. nozzle cleaning kit:
Type NCK-001

(3) Clean off the carbon on the outside of the nozzle body with a brass brush.

(4) Clean the nozzle seat with cleaning spray.



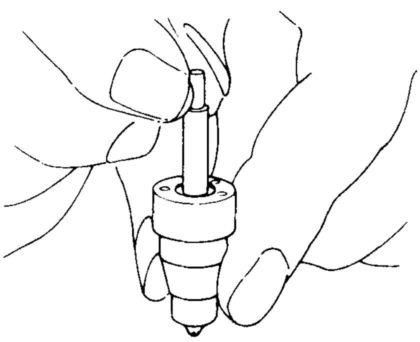
(5) Clean off the carbon on the tip of nozzle with a piece of wood.
(6) Clean hole type nozzles with a nozzle cleaning needle.



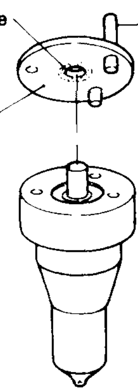
Part code no.	28210-000010

12-3.2 Nozzle inspection

(1) Inspect for scratches/wear
Inspect oil seals for abnormal scratches or wear and replace nozzle if the nozzle sliding surface or seat are scratched or abnormally worn.
(2) Check nozzle sliding
Wash the nozzle and nozzle body in clean diesel oil, and make sure that when the nozzle is pulled out about half way from the body, it slides down by itself when released.
Rotate the nozzle a little; replace nozzle/nozzle body as a set if there are some places where it does not slide smoothly.



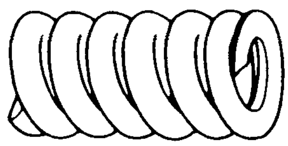
(3) Inspecting stop plate (inter-piece)
Check for scratches/wear in seals on both ends, check for abnormal wear on the surface where it comes in contact with the nozzle; replace if stop plate is excessively worn.



mm (in.)

Nozzle contact surface wear limit	0.1 (0.0039)

(4) Inspecting nozzle spring
Replace the nozzle spring if it is extremely bent, or the surface is scratched or rusted.



(5) Nozzle holder
Check oil seal surface for scratches/wear; replace if wear is excessive.

12-4 Fuel injection nozzle reassembly

The fuel injection nozzle is reassembled in the opposite order to disassembly.
(1) Insert the adjusting shims, nozzle spring and nozzle spring seat in the nozzle holder, mount the stop plate with the pin, insert the nozzle body/nozzle set and tighten the nut.
(2) Use the special holder when tightening the nut for the hole type nozzle as in disassembly.

Nozzle nut tightening torque N-m(kgf-m)

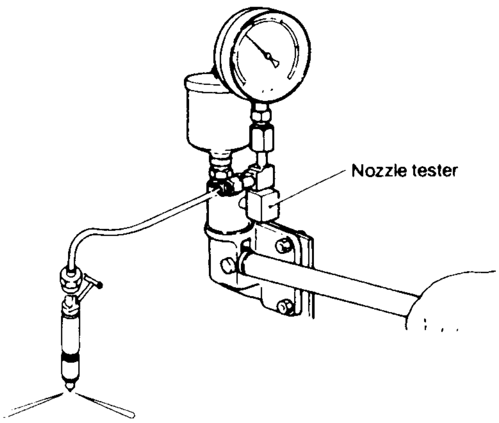
Hole type nozzle	39.2 ~ 44.1 (4 ~ 4.5)

—	4LHA-HTE/HTZA/HTP/HTZP
Nozzle type	140P285 KOT
P / N	119172-53050

12-5 Adjusting fuel injection nozzle

12-5.1 Adjusting opening pressure (4LHA-HTE/HTZA/HTP/HTZP)

Mount the fuel injection nozzle on the nozzle tester and use the handle to measure injection starting pressure, If it is not at specified pressure, use the adjusting shims to increase/decrease pressure.



Injection starting pressure MPa(kgf/cm²)

Injection starting pressure	19.6~20.6 (200~210)

12-5.2 Injection test

After adjusting the nozzle to the specified starting pressure, check the fuel spray condition and seat oil tightness.

(1) Check seat oil tightness

After two or three injections, gradually increase the pressure up to 1.96MPa (20 kgf/cm²) before reading the starting pressure, maintain the pressure for 5 seconds, and make sure that no oil is dripping from the tip of the nozzle.

Test the injection with a nozzle tester; retighten and test again if there is excessive oil leakage from the overflow coupling.
Replace the nozzle as a set if oil leakage is still excessive.

(2) Injection spray condition

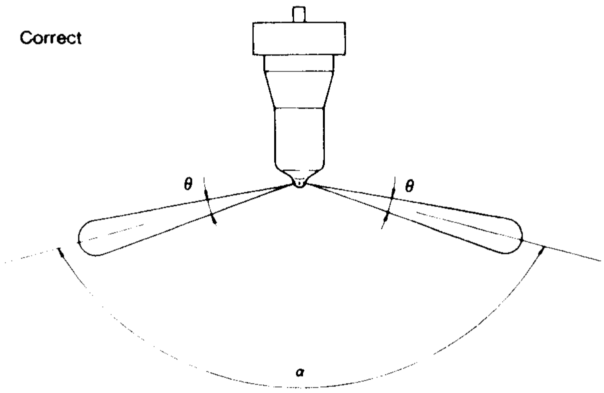
Operate the nozzle tester lever once to twice a second and check for abnormal injection.

1) Hole type nozzles

Replace hole type nozzles that do not satisfy the following conditions:

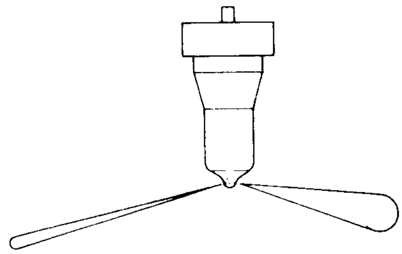
- Proper spray angle (θ)
- Correct injection angle (α)
- Complete atomization of fuel
- Prompt starting/stopping of injection

Correct



Spray from each nozzle hole is uniform

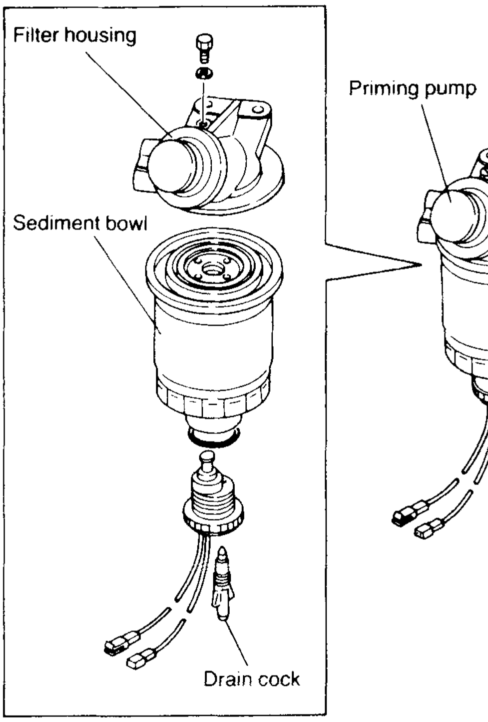
Poor



- Excessive difference in spray angle (θ)
- Excessive difference in injection angle (α)
- Incomplete atomization
- Sluggish starting/stopping of injection

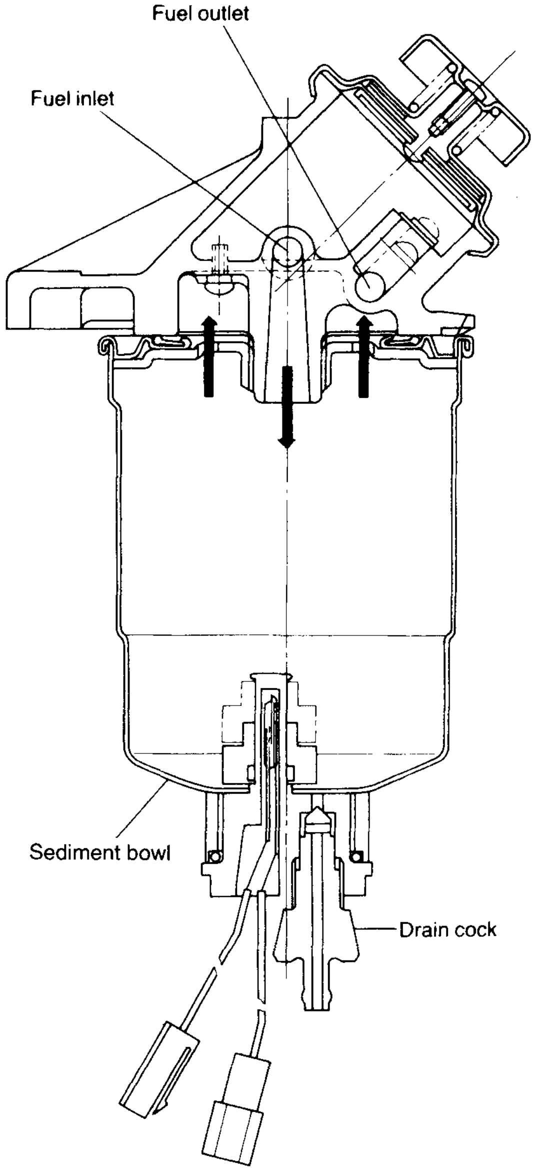
13. Fuel Filter

The fuel filter is installed between the fuel tank and fuel injection pump, and removes dirt/foreign matter and water from the fuel from the fuel tank.
Fuel from the tank enters filter housing inlet and fills the sediment bowl. The fuel is filtered as it passes through the filter element, leaves the housing at outlet, and flows to the fuel injection pump. Sediment and water settle to the bottom of the sediment bowl.



13-1 Maintenance

Every 50 hours operation, remove drain cock and drain sediment bowl.



4LHA-HTE/HTZE/HTP/HTZP

Pre-stroke 0.2				
1. Settings	Pump Speed (rpm)	Settings	Charge-air Press (mmAg)	Difference in delivery (cc)
1.1 Timing device travel	1000	1.1 - 1.5mm	——	——
1.2 Supply pump pressure	1000	0.36–0.42(3.7–4.3) MPa(kgf/cm²)		——
1.3 Full load delivery without charge-air pressure	1000	80.0 – 81.0 cc/100st		4.7
1.3 Full load delivery with charge-air pressure	——	—— cm³/1000st		——
1.4 Idle speed regulation	400	11.0 – 15.0 cm³/1000st		2.5
1.5 Start	100	100.0 – 140.0 cm³/1000st		——
1.6 Full-load speed regulation	1840	13.0 – 19.0 cm³/1000st		——
1.7 Load Timer Adjustment	——	—— cm³/1000st		——

2. Test Specifications		
2.1 Timing device	N = rpm mm	1000 / 1500 1.1 – 1.5 / 2.0 – 2.9
2.2 Supply pump	N = rpm MPa(kgf/cm²)	1000 / 1500 0.36–0.42(3.7 – 4.3) / 0.47–0.53(4.8 – 5.4)
Overflow delivery	N = rpm cm³/10s	1000 45.0 – 88.0

2.3 Fuel deliveries

Speed control lever	Pump Speed (rpm)	Fuel delivery cm³/1000sts	Charge-air press.(mmAg)
End stop	1900 1840 1650 1500 1000	Max. 40 12.5 – 19.5 83.5 – 90.5 84.8 – 91.8 79.5 – 81.5	——
Switch-off	100 400	0 0	——
Idle stop	400 500	11.0 – 15.0 Max. 8.0	——
Partial load	——	——	——
2.4 Solenoid	max. cut-in voltage: 8V 16V test voltage: 12V–14V 24V–26V		

3. Dimensions

Designation	for assembly and adjustment mm
K	3.0 – 3.2
KF	5.4 – 5.6
MS	0.9 – 1.1
α A	21 – 29 deg. mm
β B	35 – 45 deg. mm
γ C	deg. mm

Observations:

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For detail, ask the ZEXEL.

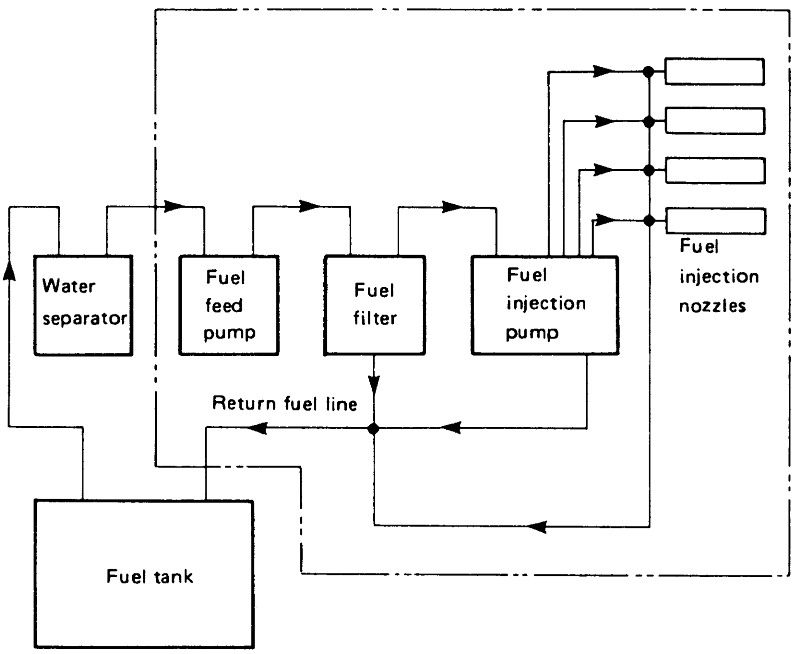
3-2. YPES-AL TYPE

1. Fuel Supply System 3-2-1
2. Disassembly, Reassembly and Inspection of Governor 3-2-15
3. Disassembly, Reassembly and Inspection of Fuel Injection Pump 3-2-21
4. Adjustment of Fuel Injection and Governor 3-2-31
5. Automatic Advancing Timer 3-2-38
6. Fuel Feed Pump 3-2-40
7. Fuel Injection Nozzle 3-2-43
8. Troubleshooting 3-2-48
9. Tools 3-2-50
10. Fuel Injection Pump Specifications 3-2-53
11. Service Data 3-2-54

1. Fuel Supply System

1-1 Fuel supply system

The YPES-AL fuel injection pumps are in-line. The engine gears drive the camshaft via the timing gears. The camshaft then drives the feed pump, pumping fuel from the tank to the filter at a pressure of 0.118(1.2)MPa(kg·f/cm²). The filtered fuel is fed to the reservoir in the pump housing, where the plunger raises its pressure. The fuel then passes through the injection pipe for injection into each cylinder via the fuel injection nozzle.

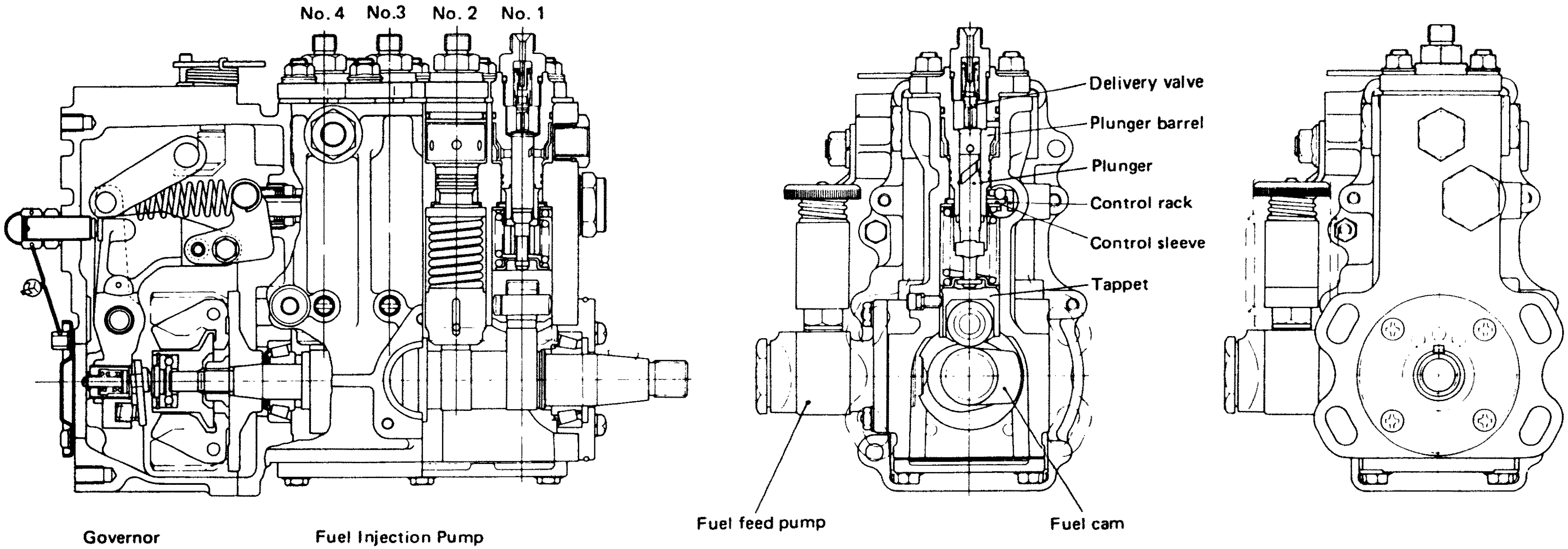


The Model YPES-AL fuel injection pump is an in-line pump with a governor.
A camshaft is built into the pump. There are a drive cam for the fuel feed pump and tappet-drive cams for the plunger.
A pump driving gear is mounted on the drive side of the camshaft, and a governor weight on the opposite side.
As the plunger rises, the fuel oil opens the delivery valve and passes through the high pressure pipe to the fuel injection nozzle.
When the control rack is connected to the governor lever moves, the control sleeve turns the plunger. This changes the point at which the helix (lead groove) opens the port and thereby controls the amount of fuel injected.

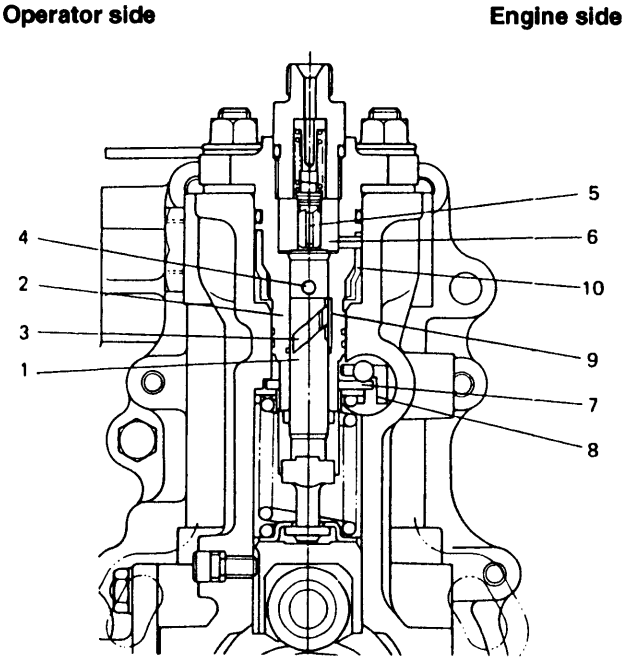
1-2 Fuel injection pump specitications

Type	YPES-AL
Specifications	*See separate service data*

Fuel Injection Pump Construction



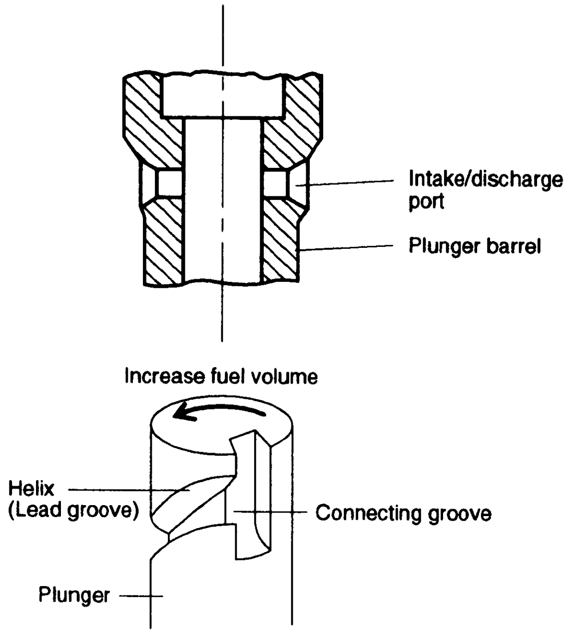
1-3 Functioning of fuel injection pump



1. Plunger
2. Plunger barrel
3. Lead groove
4. Intake port
5. Delivery valve
6. Delivery valve seat
7. Control sleeve
8. Control rack
9. Fuel leak return groove
10. Protector

The fuel injection pump supplies pressurized fuel to the injection nozzles through the action of the plunger. The plunger reciprocates in the plunger barrel with a fixed stroke and is lapped for a precise fit. A lead groove is helically cut in the plunger, and this leads to a connecting groove which rises to the top of the plunger.
The integrate plunger barrel, the plunger barrel and the flange case for the delivery valve holder, equips a port for intake and discharge. The injection volume of individual cylinders can therefore be adjusted by rotating the integrate plunger barrel. The fuel comes through this port into the plunger chamber, is pressurized by the plunger, opens the delivery valve, flows to the fuel injection nozzle through the fuel injection pipe and is injected into the combustion chamaber. Fuel injection ends when the pressurized fuel has been discharged. This happens when the lead groove lines up with the port, (as the plunger rises and the pressure in the fuel injection pipe drops).

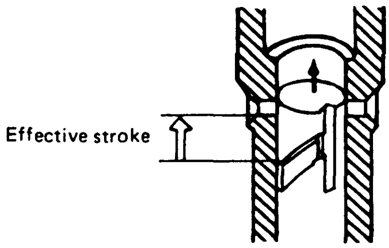
The control sleeve groove is fitted to the plunger flange. The control knob of the control sleeve is inserted in the control rack groove.
The rack controls the plunger, allowing continuous changes in the volume of fuel injected from zero to maximum. A fuel leak return hòle is provided in the plunger barrel. This returns fuel which leaks through the gap between the plunger and the barrel to the fuel lines, preventing dilution of the lubricant in the cam chamber.



1-4 Injection volume control

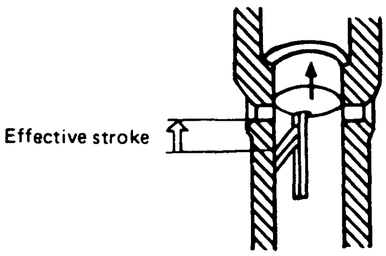
(1) Full injection volume position

When the rack is set at maximum setting, maximum volume of fuel is discharged. Injection occurs when the top of the plunger lines up with the intake port in the barrel. At this time, the lead groove which is positioned at the widest stroke part, lines up with the discharge port, prolonging the injection time and increasing the volume of fuel injected.
This setting is normally used for starting and max. output operation.



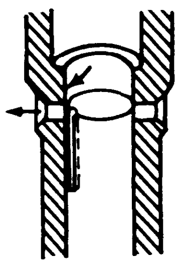
(2) Half injection volume position

Discharge ends earlier as the rack is moved towards zero from the maximum setting.
The fuel injection volume is decreased accordingly.

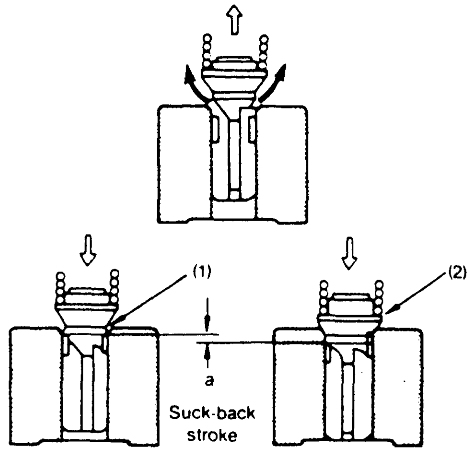


(3) No fuel injection

With the rack set near zero, the intake/discharge port in the barrel is always open, so no fuel is pressurized, (even though the plunger continues to reciprocate).



The delivery valve at the top of the plunger prevents fuel in the fuel injection pipe from flowing back to the plunger chamber and sucks up fuel from the nozzle valve to prevent after-drip.
When the plunger lead lines up with the discharge port of the plunger barrel, the injection pressure drops, and the delivery valve is brought down by the delivery valve spring.



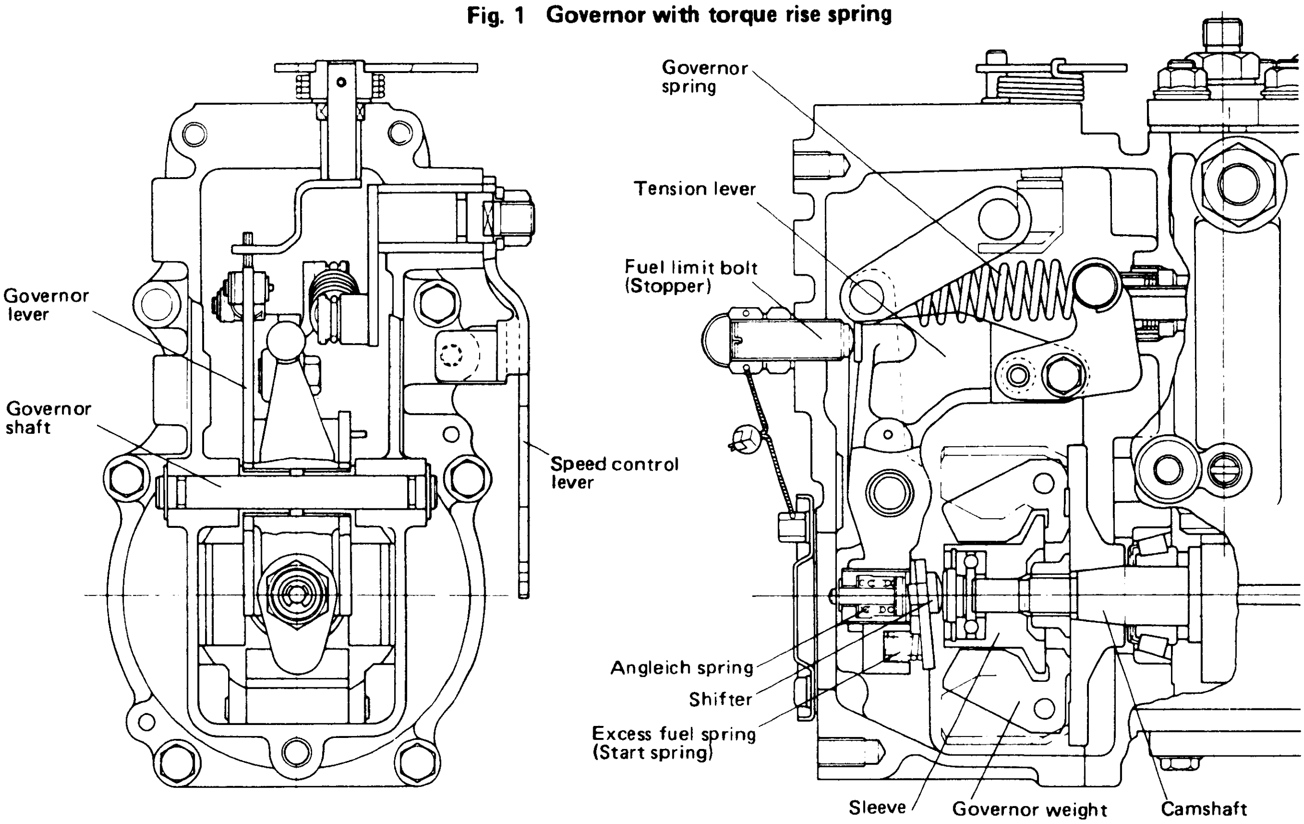
At the same time, the suck-back collar (1) blocks off the fuel injection pipe and the delivery chamber, and the valve continues descending until the seat (2) comes in contact with the barrel. The fuel oil pressure in the fuel injection pipe decreases proportionately with the lowering of the valve (due to increased volume).
This accelerates the closing of the nozzle valve, and sucks up fuel from the nozzle to prevent dripping. The result is a longer nozzle life and improved combustion efficiency.

1-5 Governor construction

Diesel engines are used in extremely varied conditions, with a wide range of loads and rpms. The governor has the important function of controlling the fuel injection quantity. It quickly responds to changes in rpm by adjusting the position of the control rack.

YPES-AL fuel injection pump is equipped with the all speed type governor. The governor is available in 2 types: one has the torque rise spring (angleich spring) (Fig. 1), and the other has the smoke cut spring (angleich spring) (Fig. 2).

Fig. 1 Governor with torque rise spring



The governor weight is mounted on the end of the fuel injection pump cam shaft. It rotates around the governor support pin, driven by the cam shaft, and is forced outwards by the centrifugal force acting on the weight.
The thrust force on the cam shaft due to this centrifugal force acts on the lower part of the tension lever via the sleeve. An excess fuel spring for starting is mounted on the bottom of the tension lever.
One end of the governor spring is hooked to the right upper end of the tension lever, and the other end to the spring lever on the control lever shaft.
The spring lever and control lever are mounted on the same shaft, so by turning the control lever towards full, the governor spring is pulled and the load gradually rises.
The tension lever can move freely around the governor shaft on the player bearing. As the speed increases and the shifter is pushed to the left, the tension lever rotates clockwise. And when the speed falls, the tension lever rotates counterclockwise.

The governor lever rotates smoothly on the same governor shaft. The bottom part of this lever is in contact with the sleeve through the shifter, which is itself in contact with the bottom of the tension lever through the excess fuel spring. It therefore moves with the tension lever according to the rise or fall of the engine speed.
The top of the governor lever is connected to the fuel pump control rack through the governor link. The movement of the lever controls the volume of fuel injected by the pump. As the speed increases, the lever rotates clockwise and moves the control rack to reduce fuel, and when the speed falls the lever rotates counterclockwise to cause the control rack to pass more fuel. Thus, the engine speed is controlled.
The top of the tension lever comes in contact with the stopper built into the top of the governor case to limit the maximum fuel injection volume.

Fig. 2 Governor with smoke cut device

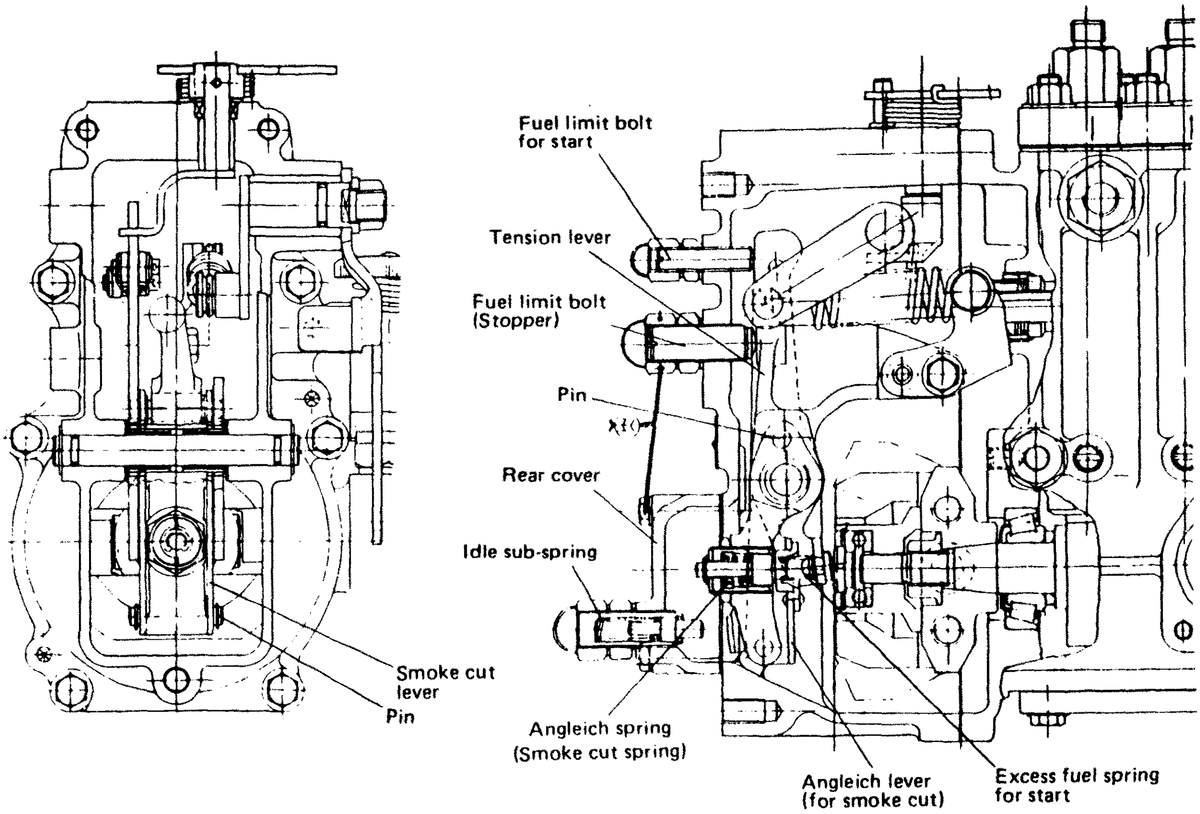
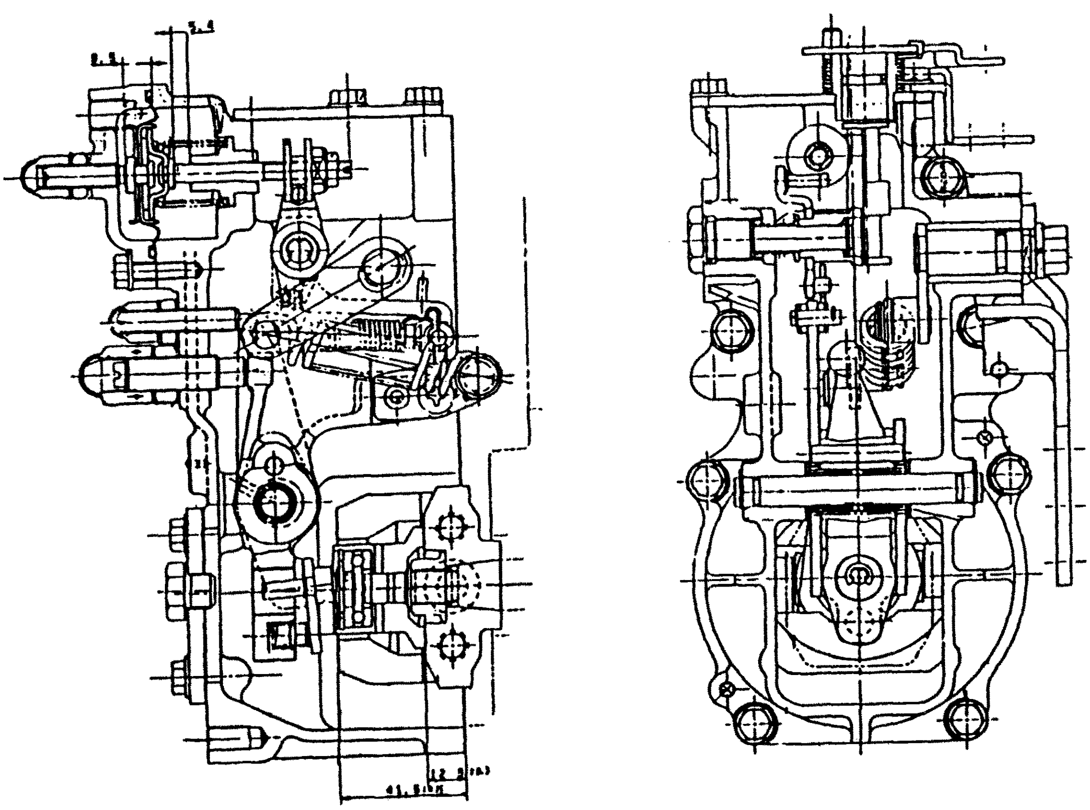


Fig. 3 Governor with smoke cut device

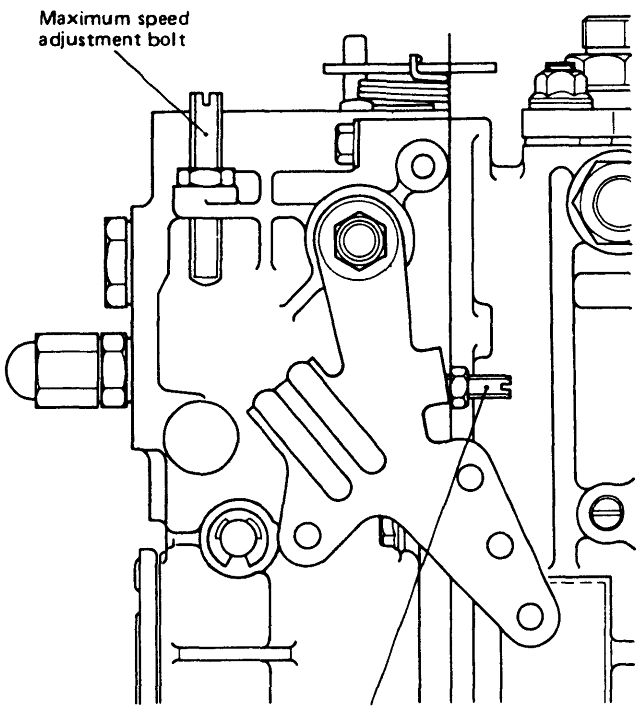


Types of governor according to structure

A number of different governors are equipped with the YPES-AL series fuel injection pump. Each is designed in accordance with individual engine structures and parts.

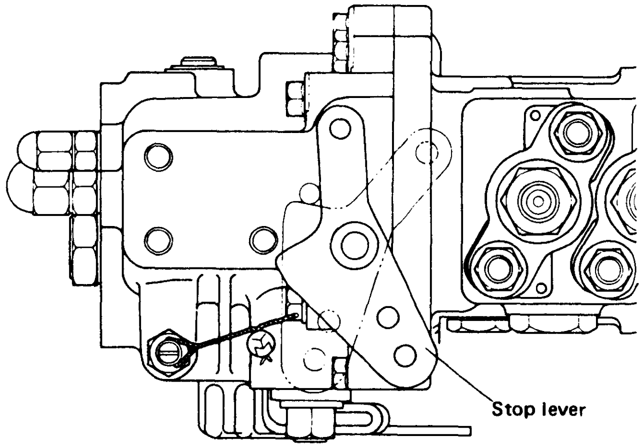
(1) Shape of control and stop levers

The control and stop levers that operate the governor have different shapes depending on engine design and method of attachment, as seen in the pictures below. The motion of the control lever is regulated by the maximum speed adjustment bolt and the idling adjustment bolt. These maintain the necessary engine speed.



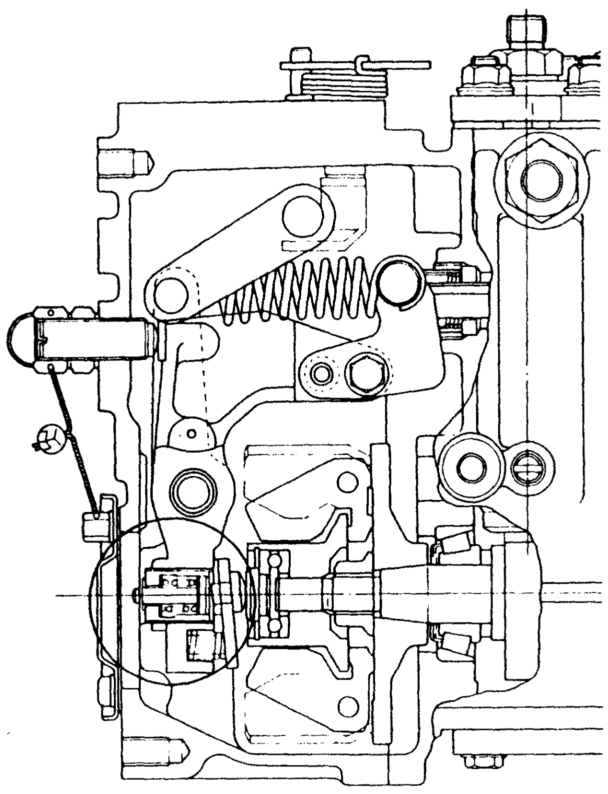
(2) Engine stop device

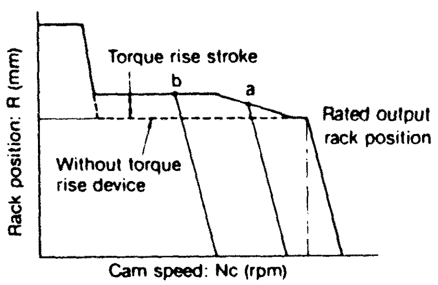
The stop lever can be operated by a push-pull cable, magnetic solenoid or a stop motor. The governor is equipped in one of three designs depending on the intended purpose.



(3) Torque rise equipment

This governor can be equipped with an angleich spring for torque rise.
It is therefore suitable for use with various engines.

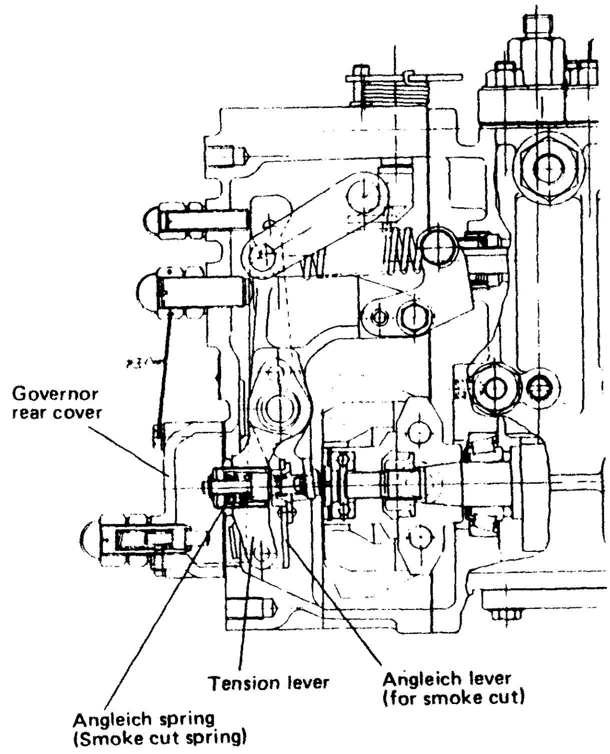


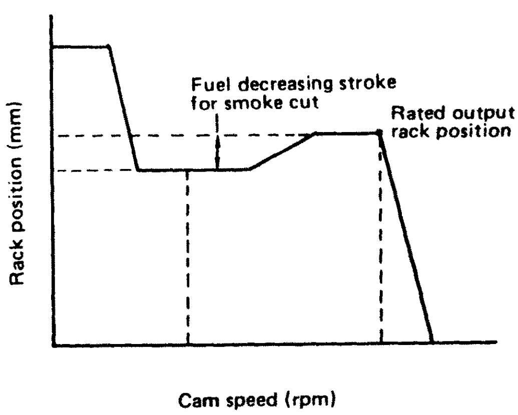


(4) Smoke cut device

(4)-(1) Angleich spring

This governor can be equipped with the smoke cut spring (angleich spring) which reduces injection at low-and middle speed ranges.
The smoke cut spring decreases fuel injection to minimize black smoke, which would otherwise occur just after the engine is started or an idling engine is started rapidly, (the speed control lever is turned to "FULL"), as for a marine engine.





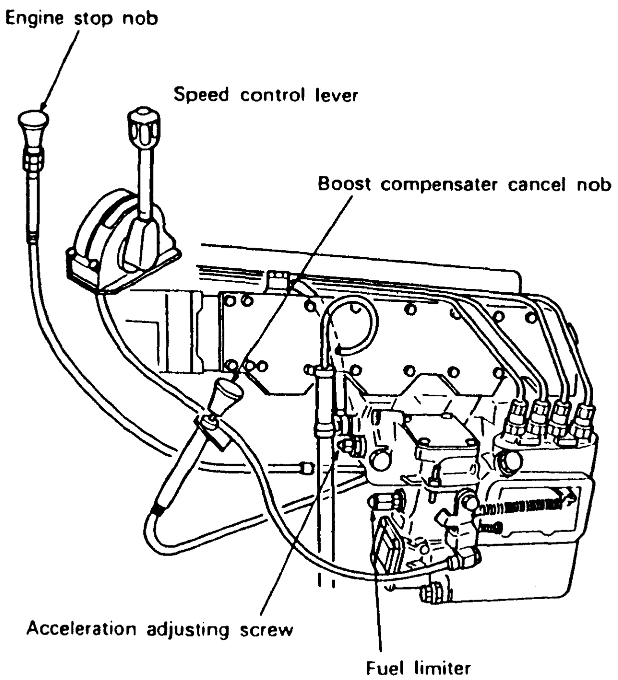
(4)-(2) Boost compensator

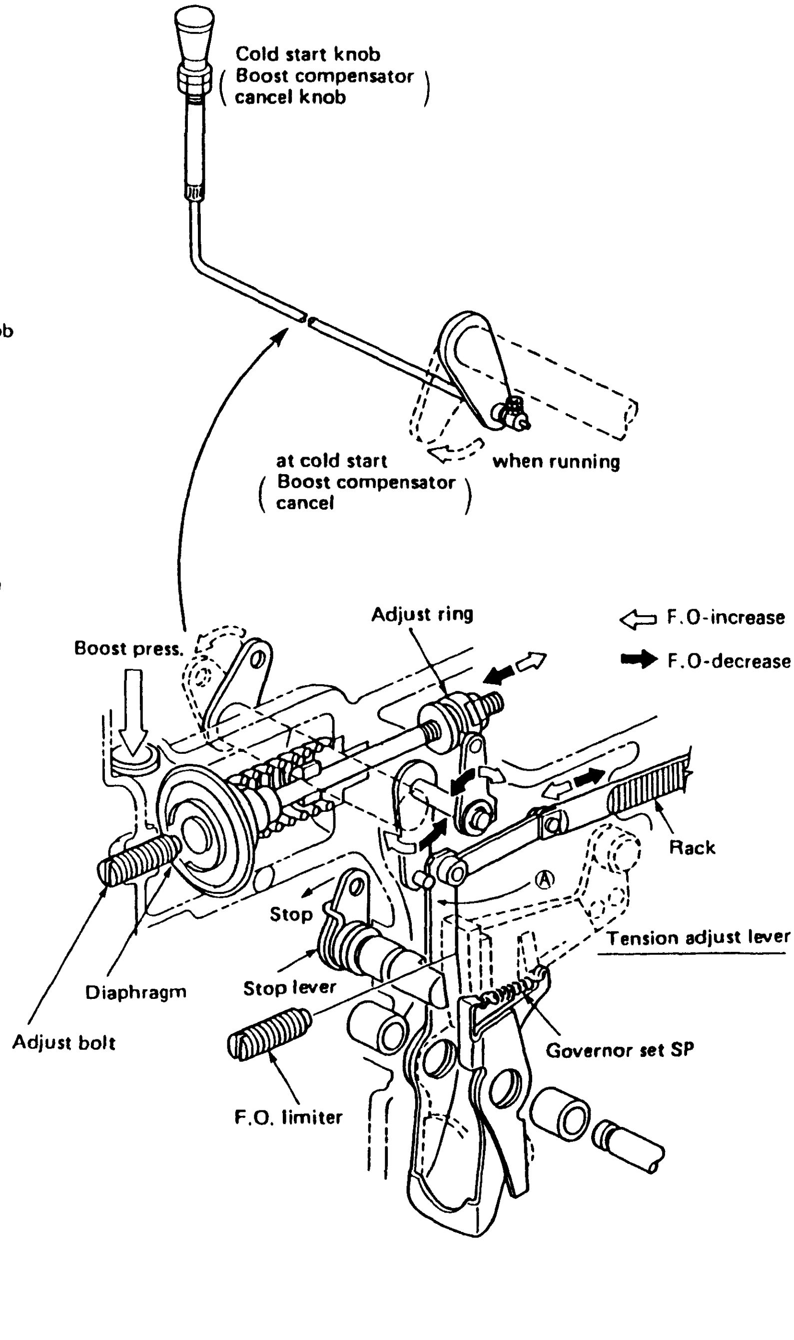
(4)-(2)-(1) Objective of compensator

The boost compensator is a device mounted to the fuel injection pump for engines equipped with a turbocharger. The amount of air sent from the intake manifold by the linking function of the turbocharger increase in proportion to the amount of fuel injected from the injection pump (4LHA-DTE).The boost compensator controls the injection quantity by responding to changes in pressure.

(4)-(2)-(2) Outline of structure and principle of operation

1 When the regulator handle is operated during abrupt acceleration, the control rack moves to the increase side as far as A.
2 Increase of engine speed drive the turbocharger to increase boosting pressure. This boosting pressure pushes the diaphram in the boost compensator, moving the control rack to the fuel increase side by means of the boost compensator lever.



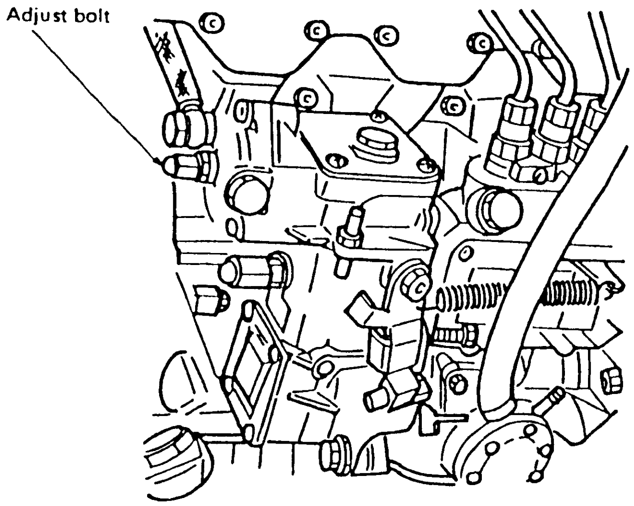


(4)-(2)-(3) Operation of cancel knob

1 Since the boost compensator is the device that limits the fuel injection amount for starting the engine in cold temperatures (below -5° C), it is necessary to cancel the function of the boost compensator and increase the fuel injection amount.
2 If the engine is gard to start in cold temperatures, start the engine by pulling the cancel knob (cold start knob).
3 Once the engine is started, push the knob back into resume the function of the boost compensator.

(4)-(2)-(4) Adjustment of boost compensator

The initial rack of the boost compensator has been adjusted properly at the time of shipment. However, the acceleration can be increased at the request of the customer. Watch the color of the exhaust while making the adjustment.



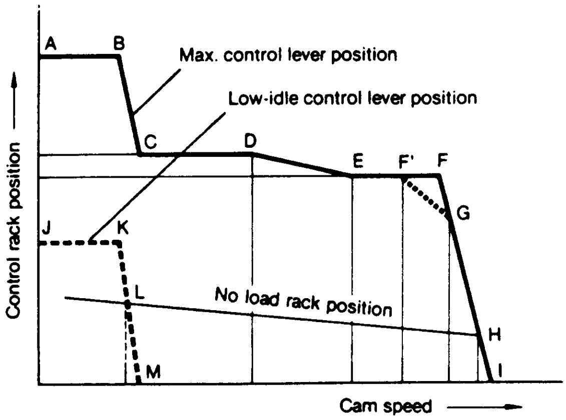
<Procedure>
Remove the cap nut of adjust bolt with the blade-type screw driver.

Right turn	Large effect on boost comp.	• Higher acceleration • More black exhaust
Left turn	Small effect on boost comp.	• Lower acceleration • Less black exhaust

1-6 Function of Governor

(1) Function of governor

The following is a representation of the movement characteristics of the control rack at respective speeds rising from 0, with the governor control lever at the maximum speed position.



A-B: Fuel volume condition during starting. Volume is controlled by excess fuel spring.

B-C: The rack moves to decrease injection after the engine starts and the speed increases, (as the load of the excess fuel spring is overcome by the centrifugal force of the governor weight).

C-D: High torque at low speeds is obtained by increasing the fuel injection volume in keeping with the angleich stroke.

D-E: The condition when the thrust force exceeds the force of the angleich spring on the bottom of the tension lever. This gradually pushes the rack to lower fuel injection as the engine speed increases.

E-F: The condition when both the right and left ends of the shifter come in contact with the sleeve and the bottom of the tension lever, and the control rack is held in the normal position by the stopper, (max. injection volume position on models not equipped with an angleich spring).

F: The point at which the governor spring starts to take effect. This is the rated output of the engine.

F': The point at which the governor starts to take effect on models with a torque spring.

G: Continuous rating point (usually 85–90% injection volume of F point).

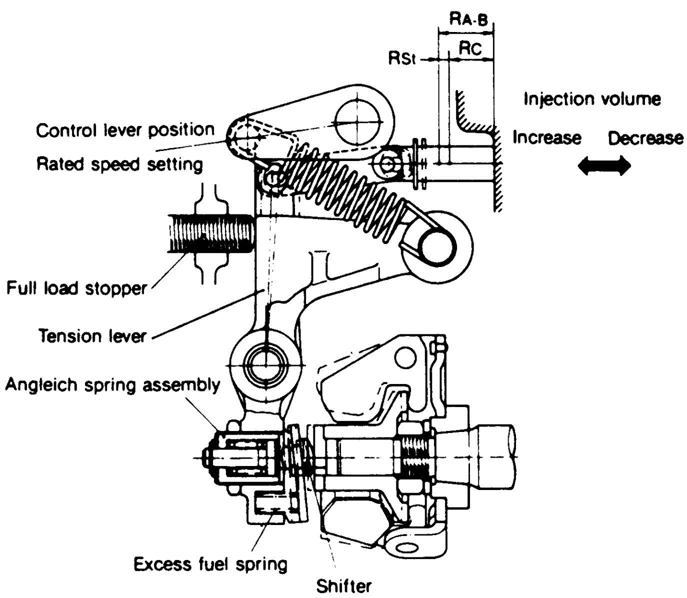
H: No load max. speed

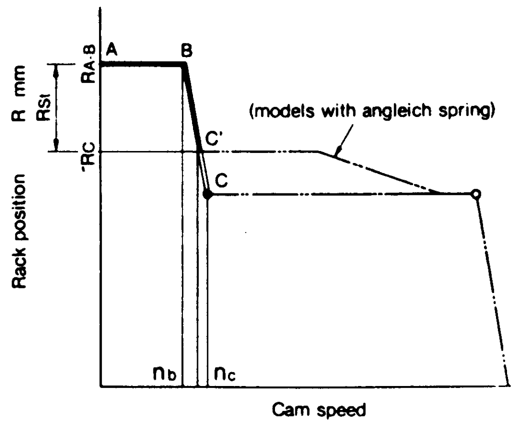
L: Low-idle position

(2) Starting control

Moving the control lever to the max. speed position pulls the governor spring, and moves the tension lever until it comes in contact with the control stopper. When this is done, the excess fuel spring located between the tension lever and governor lever holds the control rack at the max. starting injection volume position $R_{A\text{-}B}$.

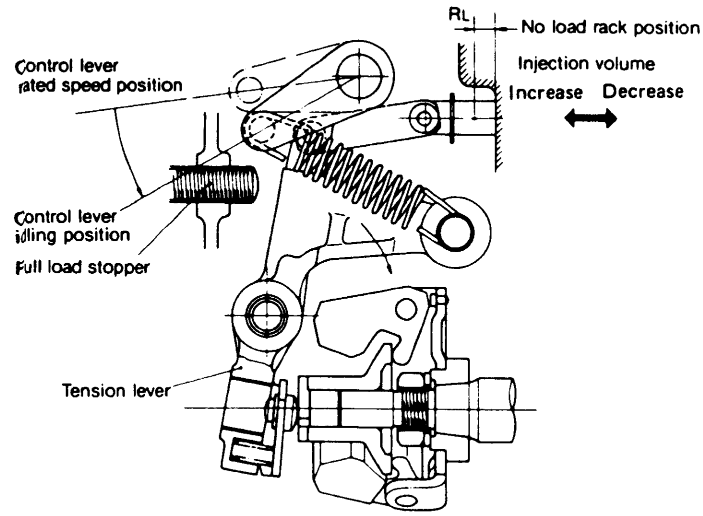
After the engine is started, the excess fuel spring is compressed as the centrifugal force of the governor weight overcomes the set load of the excess fuel spring. As the speed exceeds N_b, the speed changes from B to C' (on models with an angleich spring) or B to C (on models without an angleich spring). The rack reaches the position of Rc, at which the governor lever and tension lever are interlocked.





(3) Idling

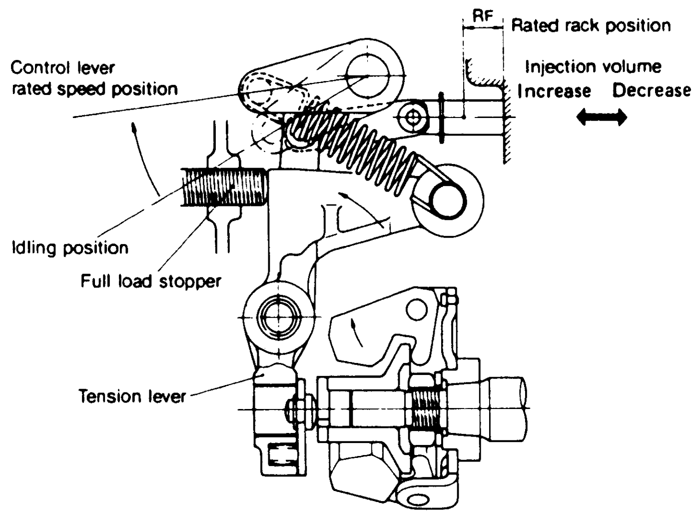
Idling is controlled by the governor and excess fuel springs because this governor is not equipped with an idling spring (however some engines are equipped with an idle control spring for torque decrease). As the control lever is returned to the idling position after engine starting, the governor spring tension falls and the tension lever descends clockwise. The governor weight load keeps the governor spring and the excess fuel spring load in equilibrium to maintain the idling speed at (R_L).



NOTE: Depending on specifications, the governor can be provided with an idling spring.

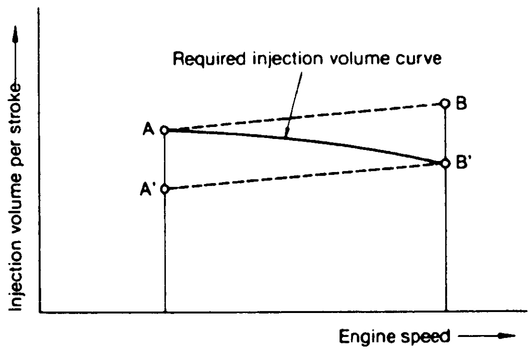
(4) Maximum speed

The angle of the control lever is set for the engine speed. The governor keeps the engine speed constant by the adjusting speed when the load changes.
For example, if the operator moves the control lever with the link from the idling position to max. output, the governor spring tension increases, the tension lever is pulled until it comes in contact with the full load stopper, the movement of the governor lever is transmitted to the control rack via the link, maintaining the full load rack position, and engine speed increases until the governor weight thrust load and governor spring tension come into equilibrium at full load max. speed.



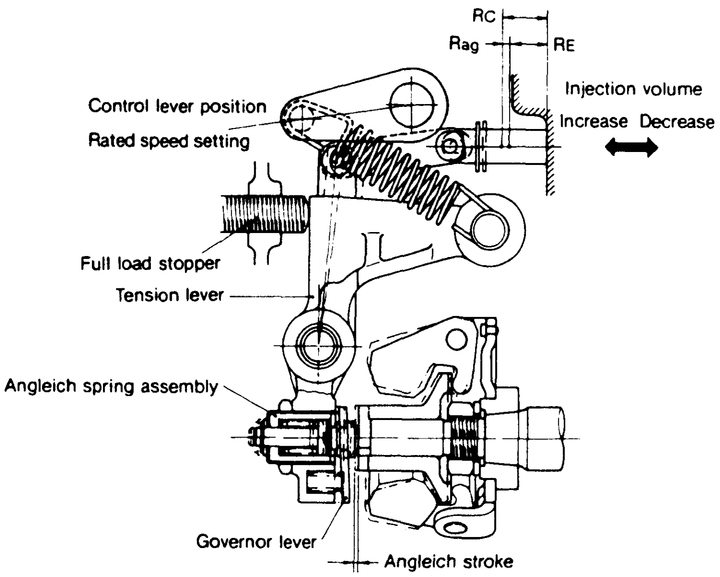
(5) Importance and function of angleich

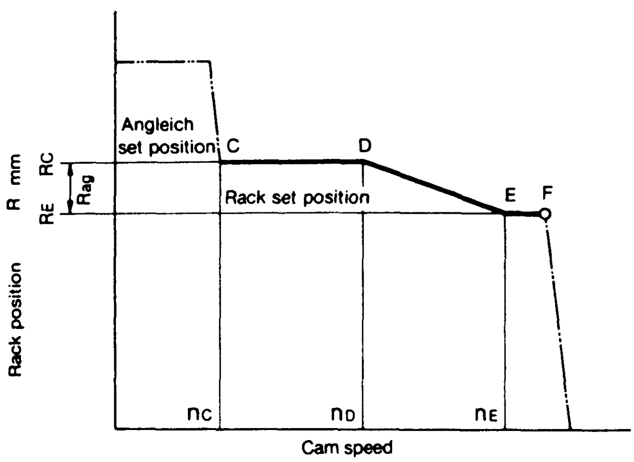
The engine air intake efficiency falls as the speed increases, while the pump injection characteristics tend to rise with speed. Accordingly, the governor must satisfy the injection curves represented in the diagram below in order to obtain sufficient output at low speed, and not to emit black smoke at high speed. The angleich spring was devised to provide for maximum torque at low speed by setting the injection volume at point A, and shifting the injection volume to point B' at high engine speed.

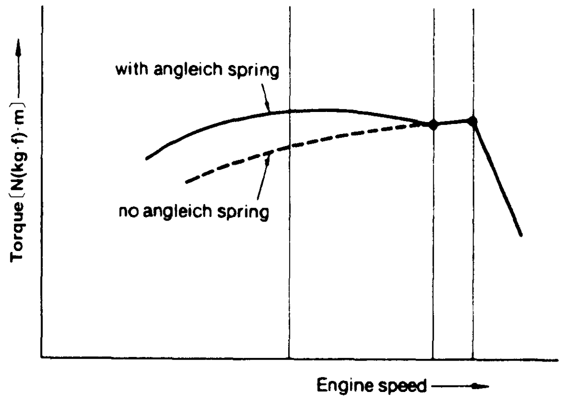


The angleich spring is mounted on the lower part of the tension lever (however some engines are not equipped with an angleich spring, depending on usage and speed range utilized).
If the engine speed is low, the governor weight cannot compress the angleich spring because the angleich spring load is larger than the governor weight thrust load, and the control rack is held at a position (Rc) to increase the injection volume.

Furthermore, the angleich spring is gradually compressed as the engine speed rises. This is because the increased governor weight thrust load exceeds the angleich load before high speed control is effected. When the governor lever and the bottom of the tension lever come into contact (end of angleich stroke), the injection volume is reduced by that amount, and the rack reaches the rated position (RE).



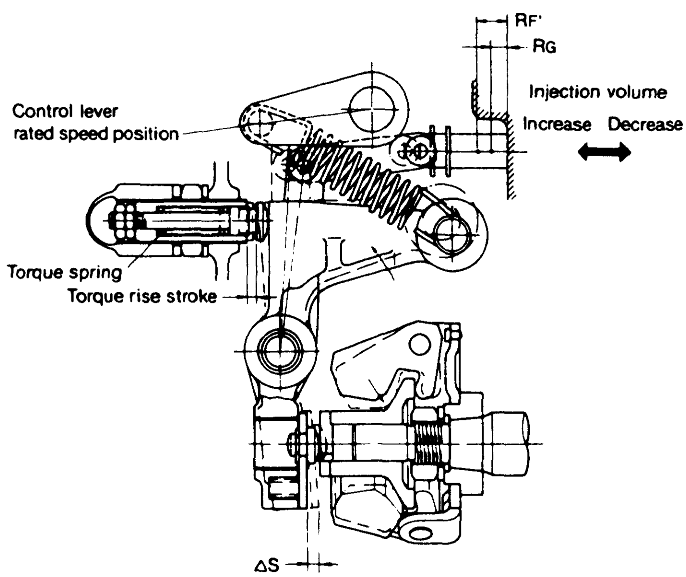


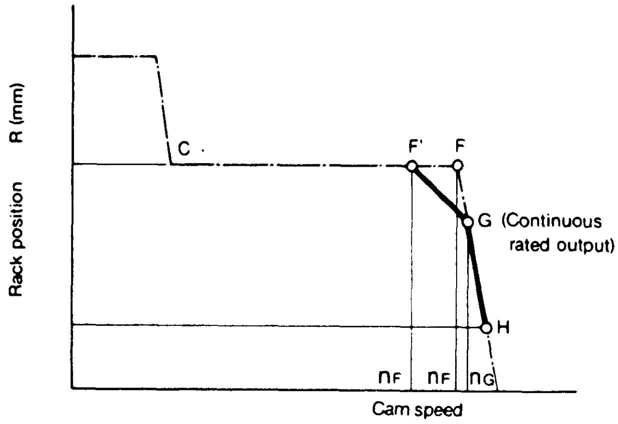


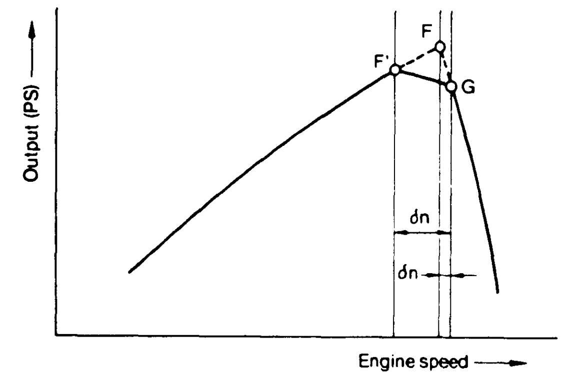
(6) Necessity of torque spring and function

Engines used in construction machinery are subjected to sudden loads which cause a decrease in speed and sometimes result in stopping of the engine. A torque spring is provided to move the control rack for a higher injection volume when engine speed falls. The higher torque can withstand overloads and prevent the engine from stopping. The governor control lever is fixed at point G in the diagram on the right, the continuous rated output position. If the engine is loaded, the tension lever encompasses the torque spring, the control rack comes away from full load stopper, and this fluctuates between G and H according to engine load.

If the load on the engine exceeds the continuous rated output, the speed falls and the governor spring tension exceeds the governor weight thrust load to overcome the torque spring set load. The tension lever then gradually causes the control rack to increase the injection volume. The torque rise stroke ends when the control rack reaches F'.



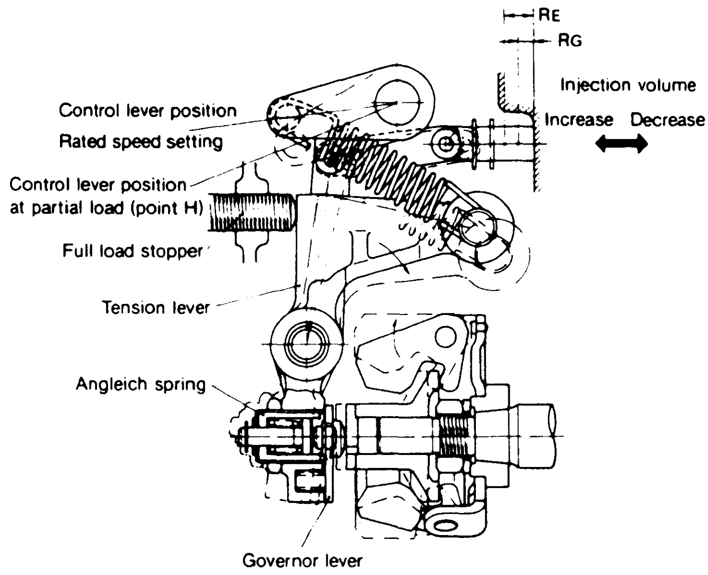


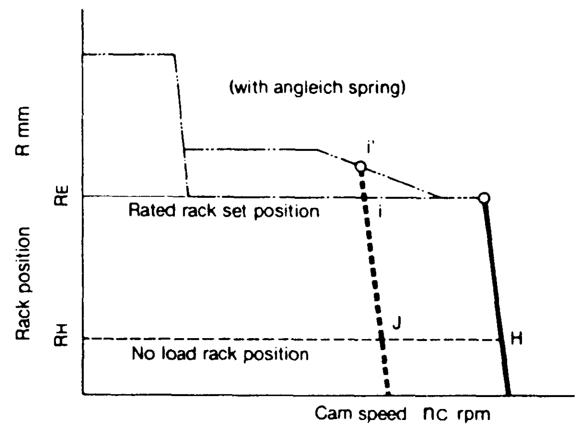


The torque spring thus provides for increasing injection volume as the speed falls. This increases the engine torque and in turn prevents engine stopping due to sudden increases in load. This also contributes to strong engine output characteristics.

(7) No-load maxi'num speed

When the load decreases from full load max. speed and engine speed increases, the increased thrust load of the governor weight acting on the governor spring through the tension lever exceeds the set load of the spring. The tension lever and governor lever descend clockwise; the control rack is pushed to the no-load injection volume position (R_H) and the engine is operated at no-load max. speed.
When the engine is being used at a partial load, the governor spring functions in the same way at a lower speed (i, i''–j) as for full load max. speed, (because the governor spring set load is also smaller).

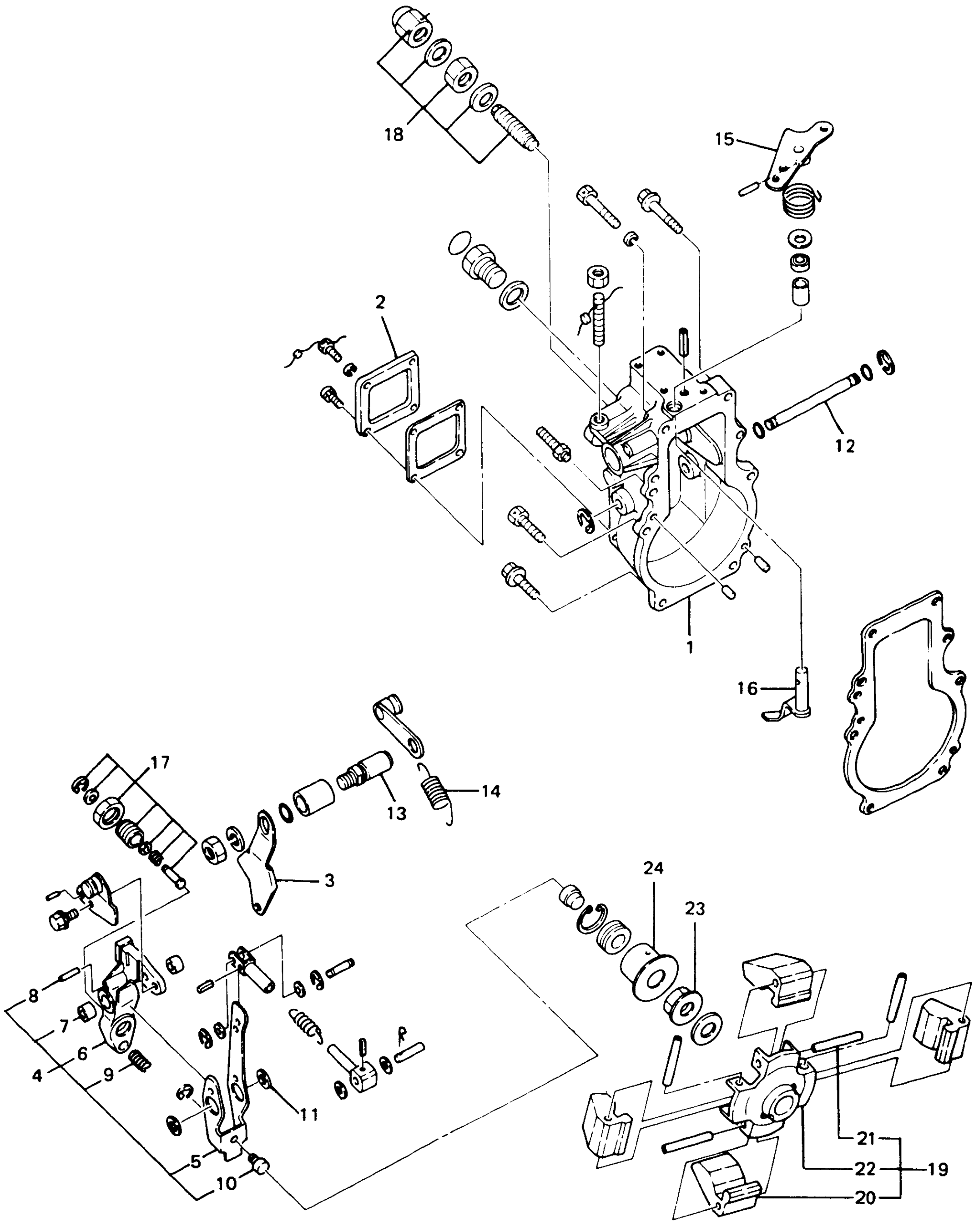




(8) Stopping the engine

The engine stops when you turn the governor control lever all the way to stop.
On engines equipped with a stop device, the engine can be stopped by moving the control rack to the stop position, regardless of the control lever position.

2. Disassembly, Reassembly and Inspection of Governor



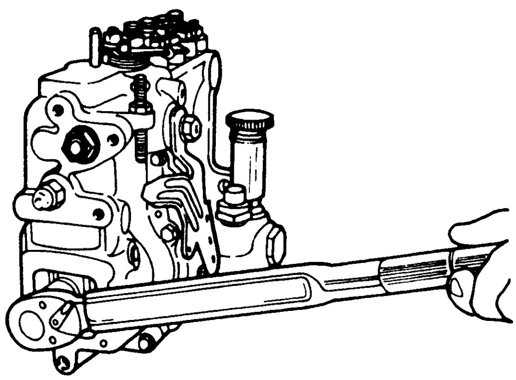
The figure shows the governor with torque rise spring.

1. Governor case
2. Governor case cover
3. Control lever
4. Governor lever assembly
5. Governor lever
6. Tension lever
7. Bushing
8. Spring pin
9. Excess fuel spring
10. Shifter
11. Washer
12. Governor shaft
13. Control lever shaft
14. Governor spring
15. Stop lever
16. Stop lever shaft
17. Angleich spring assembly
18. Fuel stopper assembly (limit bolt)
19. Governor weight assembly
20. Governor weight
21. Pin
22. Governor weight support
23. Governor weight nut
24. Governor sleeve

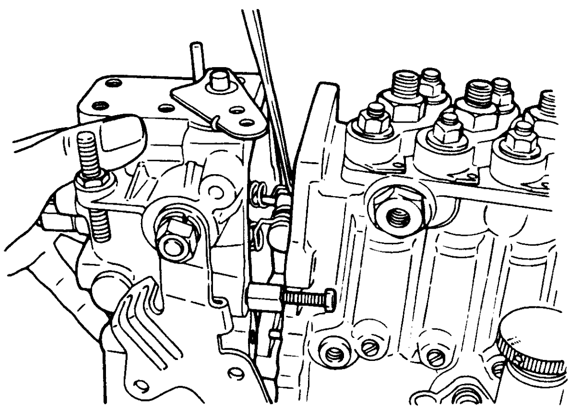
2-1 Governor disassembly

(1) Remove the governor case cover.

(2) Remove the angleich spring assembly.



(3) Remove the governor case bolt. Remove the governor case (parallel pin) from the fuel pump unit while lightly tapping the governor case with a wooden hammer. Make a gap between the governor case and fuel pump by moving only the moving parts of the governor lever.



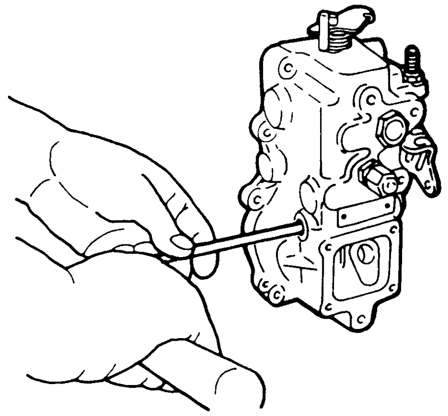
(4) Remove the connecting spring by inserting needle nosed pliers between the fuel pump and governor case.

(5) Slide the governor case and fuel pump apart and pull out the link pin of the fuel control rack.

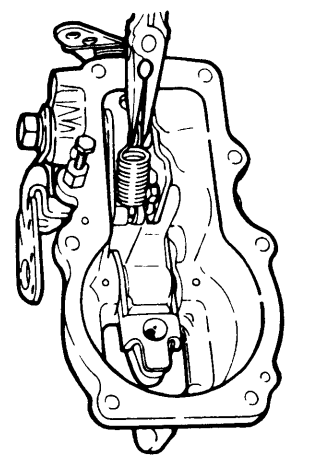
(6) Remove the snap-rings on both ends of the governor lever shaft.

(7) Put a rod (10 mm (0.3937 in.) in dia. or less) in one end of the governor lever shaft, and tap the governor shaft until the O-ring comes out from the other side of the governor case.

(8) After removing the O-ring, lightly tap the end of the shaft from which you removed the O-ring, and remove the governor lever shaft. Then remove the governor shaft assembly and washer.



(9) Unhook the governor spring from the tension lever and control lever shaft.

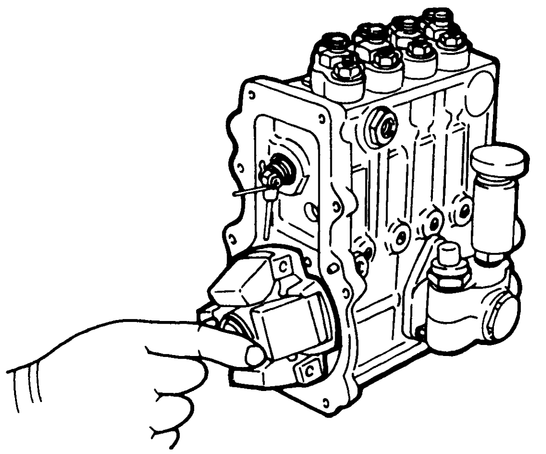


Note: The governor assembly consists of the governor lever, tension lever, bushing, throttle spring and shifter, and is normally not disassembled. The spring pin is removed when you replace the shifter or throttle spring.

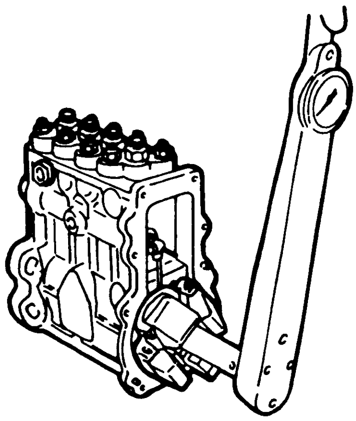
(10) When you need to pull out the control lever shaft, remove the control lever tightening nut, lightly tap the control lever shaft with a wooden hammer, and pull it out from the inside of the governor case.

NOTE: Do not remove the fuel limit nut from the governor case unless necessary.

(11) Pull out the governor sleeve at the end of the fuel camshaft by hand.

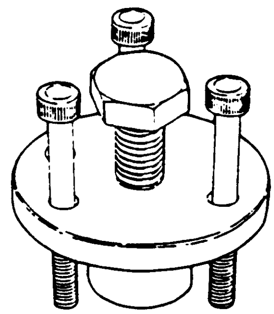


(12) Remove the governor weight nut and washer with a box spanner, stopping it with the hole in the fuel pump coupling or holding the coupling with a vise. Screw the governor weight nut back in, (two or three times).



NOTE: Be careful as the taper fit comes apart after removing the nut --- the governor weight may fly out.

(13) Remove the governor weight assembly from the fuel pump cam. Use the governor weight pulling tools.



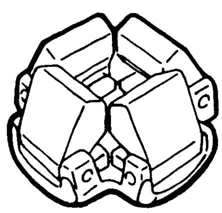
NOTE: The governor weight assembly is made up of the governor weight, support and pin. Do not disassemble.

2-2 Inspection of governor

Inspection of governor weight assembly

Replace if:

(1) It does not open and close smoothly.

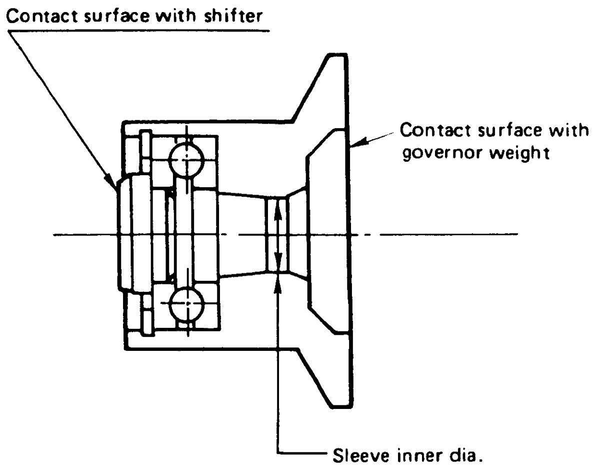


(2) The contact surface with governor sleeve is extremely worn.

(3) The governor weight support/pin is worn or the caulking is loose.

(4) The governor weight support stopper is excessively worn.

Inspection of governor sleeve



Replace if:
(1) The contact surface with the governor weight is worn or there is pitching.
(2) The contact surface with the shifter is considerably worn or there is pitching.
(3) The governor sleeve does not move smoothly above the cam shaft due to governor sleeve inner dia. wear or other reasons.

Inspection of governor lever assembly

(1) Measure the clearance between the governor shaft and bushing, and replace if it exceeds the limit.

mm (in.)

	Standard Dimension	Standard Clearance	Limit
Governor shaft outer dia.	9.986 ~ 9.995	0.065 ~ 0.124 (0.0025 ~ 0.0048)	0.5 (0.0196)
Bushing inner dia.	10.060~10.110		

(2) Inspect the shifter contact surface, and replace the shifter (always disassemble by removing the pin) if it is worn or scorched.
(3) Disassemble and replace excess fuel springs that are settled, broken or corroded by pulling the spring pin.
(4) Check link parts for bends or kinks that will cause malfunctioning, and replace any parts as necessary.

NOTE: 1. Side gap on top of governor lever shaft.

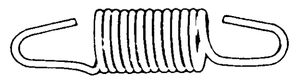
mm (in.)

Standard side gap	0.4 ~ 0.8 (0.0157 ~ 0.0315)

2. Replace the governor lever, tension lever, bushing, shifter and throttle spring as an assembly.

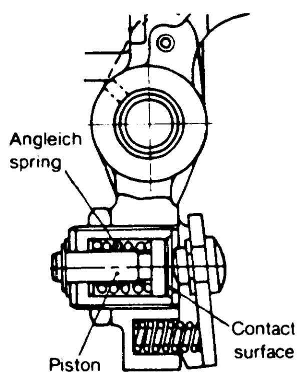
Inspection of springs

(1) Check the governor spring and other springs and replace if they are broken, settled or corroded.
(2) Measure the free length of the governor spring, and replace if it exceeds the limit.
See the service data sheet for the free length of the governor spring.



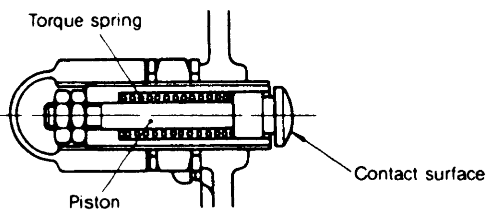
Inspection of angleich spring assembly

Replace if:
(1) There is wear to the sliding surface of the piston or the surface which contacts with the shifter.
(2) If the assembly is broken.



Inspection of torque spring assembly.

Replace if:
(1) The tip of the piston or the contact surface are worn.
(2) The torque spring is broken.

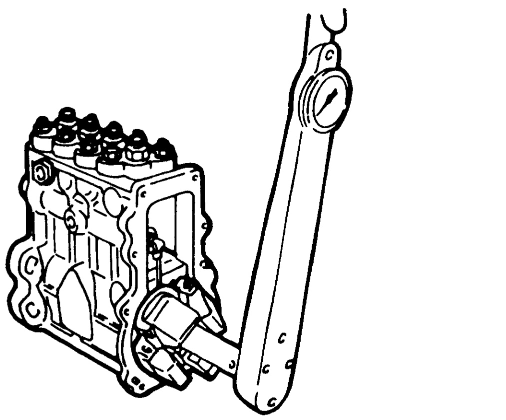


2-3 Assembling the governor

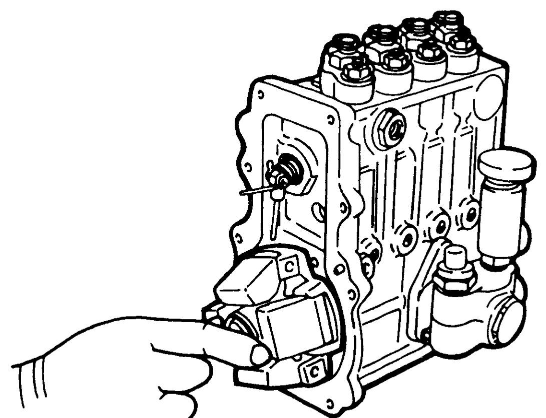
Inspect all parts after disassembly and replace any parts as necessary. Before starting reassembly, clean both the new parts and parts to be reused, and put them in order.
Be sure to readjust the unit after reassembly to obtain the specified performance.

(1) Insert the governor weight assembly to the taper portion at the end of the fuel pump camshaft. Stop it through the hole in the fuel pump coupling or by holding the coupling with a vise. Mount the spacer, and tighten the governor weight nut.

Governor weight tightening torque	39.2 ~ 44.1 (4.0 ~ 4.5) N(kgf)·m



(2) Open the governor weight and insert the sleeve in the end of the fuel pump camshaft.



NOTE: Make sure that the sleeve moves smoothly after insertion.

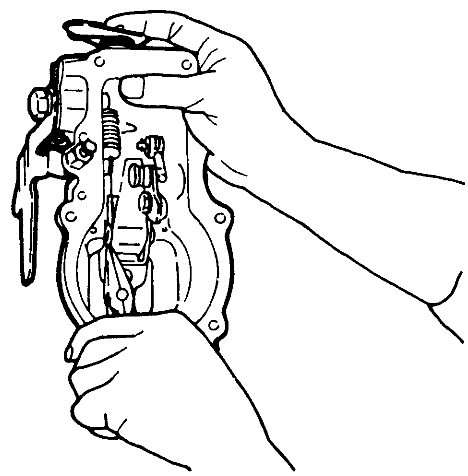
(3) When the control lever shaft has been removed, lightly tap the control lever shaft and washer from inside the governor case, using an appropriate plate.

(4) If the governor has been disassembled, tap in the spring pin.

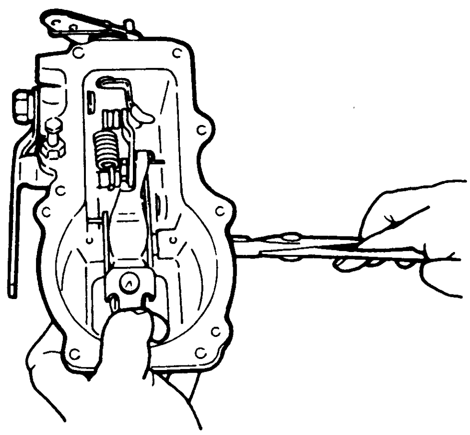
(5) Mount the governor link to the governor lever assembly.

NOTE: 1. Make sure that the correct governor link mounting holes are used, and that it is mounted in the correct direction.
2. Make sure that the governor link moves smoothly.

(6) Hook the governor spring on the control lever shaft and tension lever hooks.



(7) Put the governor lever shaft assembly in the governor case, insert the governor lever shaft until the O-ring groove protrudes from out the opposite side of the governor case, and fit the O-ring.

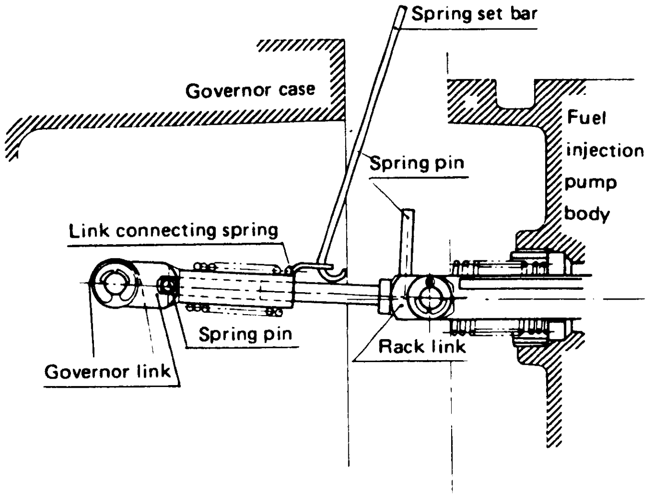


NOTE: 1. *Fit the O-ring to the side you tapped it in from.*
2. *Coat the O-ring with the silicon oil for protection during insertion.*
3. *Don't forget to place washers on both sides of the governor lever.*

(8) After mounting the O-ring, tap the governor lever in the opposite direction, and mount the E-shaped stop rings on the grooves at both ends.

NOTE: After mounting the governor lever assembly, make sure that it moves smoothly.

(9) Insert the rack link in the governor link, hook the link connecting spring on the spring pin of the governor link side with the spring set bar, and connect the governor link with the rack link.



(10) Fit the link connecting spring to the spring pin at the rack link with the spring set bar by pushing the rack link into the governor link.

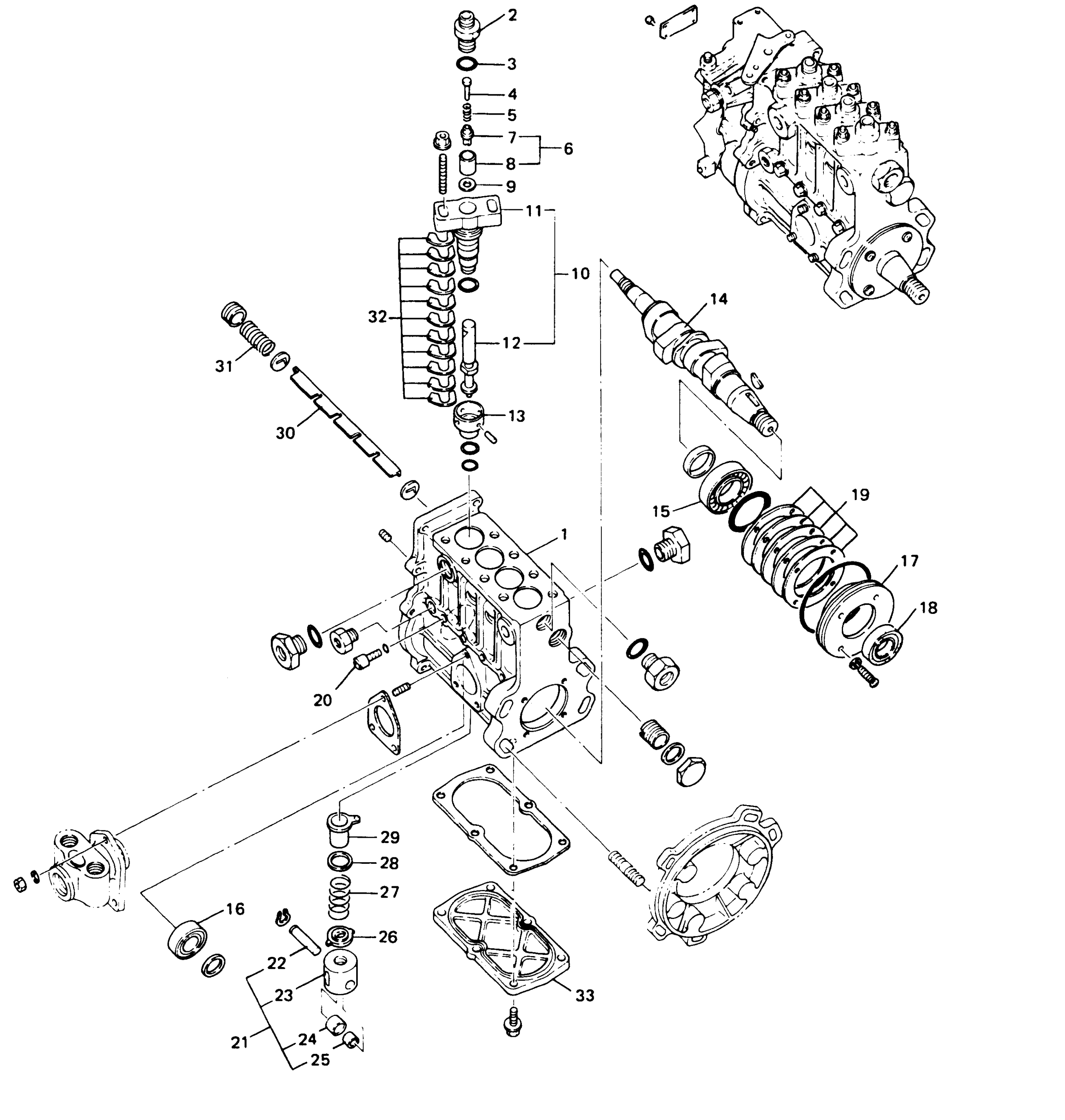
(11) Mount the governor case to the fuel pump unit, lightly tapping it with a wooden hammer, and tighten the bolts.

(12) Mount the governor case cover.

(13) Insert the control lever to the control lever shaft, and tighten the nut.

NOTE: Move the control lever back and forth to make sure that the entire link moves smoothly.

3. Disassembly, Reassembly and Inspection of Fuel Injection Pump



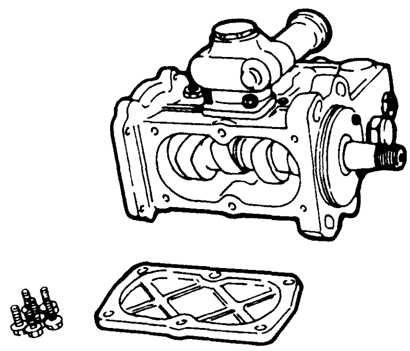
1. Fuel injection pump body
2. Delivery valve holder
3. O-ring
4. Delivery valve stopper
5. Delivery valve spring
6. Delivery valve assembly
7. Delivery valve
8. Delivery valve seat
9. Packing
10. Plunger assembly
11. Plunger barrel
12. Plunger
13. Protector
14. Fuel injection pump camshaft
15. Bearing
16. Bearing
17. Bearing holder
18. Oil seal
19. Adjusting shims
20. Tappet stopper
21. Tappet assembly
22. Pin
23. Roller guide
24. Roller
25. Bushing
26. Plunger spring seat B
27. Plunger spring
28. Plunger spring seat A
29. Control sleeve
30. Control rack
31. Aux. spring
32. Adjusting shims
33. Pump bottom cover

3-1 Disassembly of fuel injection pump

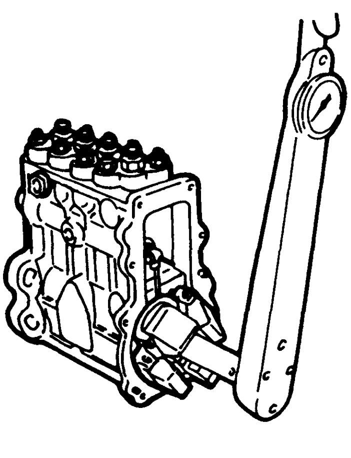
When disassembling the fuel pump, separate the parts for each cylinder and be careful not to get them mixed up.
Be especially careful to keep the plunger/plunger barrel, delivery valve/delivery valve seat and other assemblies separate for each cylinder (the parts of each assembly must be kept together and put back in the same cylinder).

Preparation

1. Wash off the dirt and grease on the outside of the pump with cleaning oil (kerosene or diesel oil) before disassembly.
2. Perform the work in a clean area.
3. Take off the fuel pump bottom cover and remove the lubrication oil.
4. Turn the fuel pump upside down to drain the fuel oil.

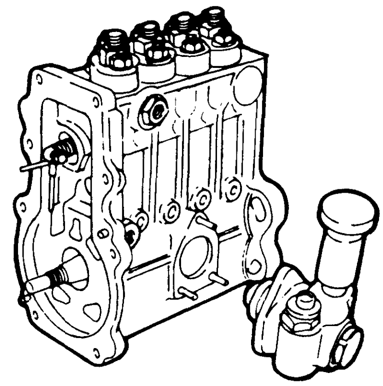


(1) Loosen the nut with a box spanner and take it off. Hold the unit either by the hole in the fuel pump coupling or by placing the coupling in a vice, and take out the governor weight assembly.

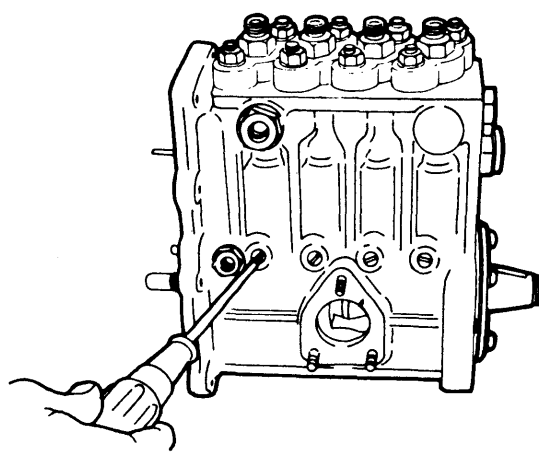


(2) Remove the fuel feed pump.

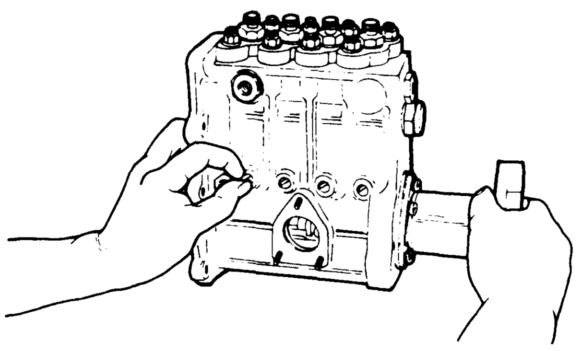
NOTE: Do not disassemble the fuel feed pump. See instructions for fuel feed pump for details.



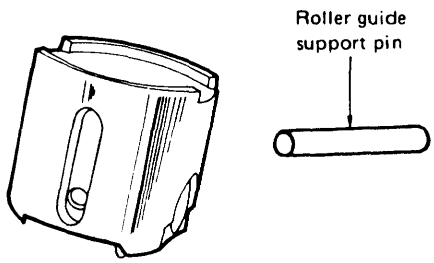
(3) Remove the roller guide clamping bolts.



(4) Turn the camshaft and push the roller guide support pin into the hole on the stopper groove of the roller guide.



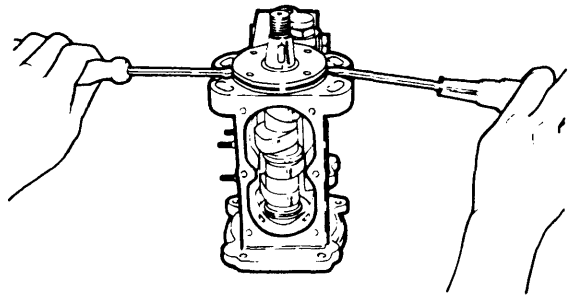
NOTE: If the camshaft does not turn, put double nuts or a coupling on the end of camshaft.



(5) Remove the camshaft woodruff key.

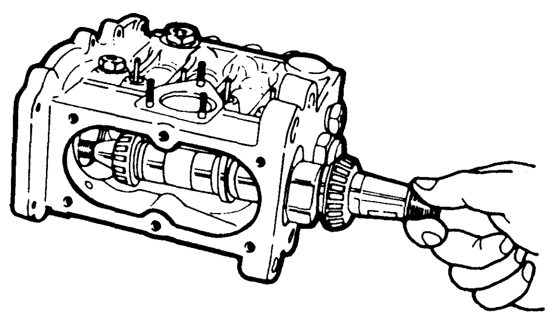
(6) Remove the 4 bolts of the bearing holder.

(7) Place a screwdriver in the two grooves on the camshaft bearing holder mounting surface, and pull out the camshaft bearing holder.

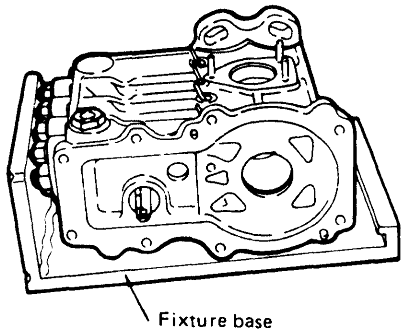


NOTE: 1. Be careful not to damage the oil seal with the threaded part of the camshaft.
2. Be careful not to lose the shims between the pump and bearing holder.

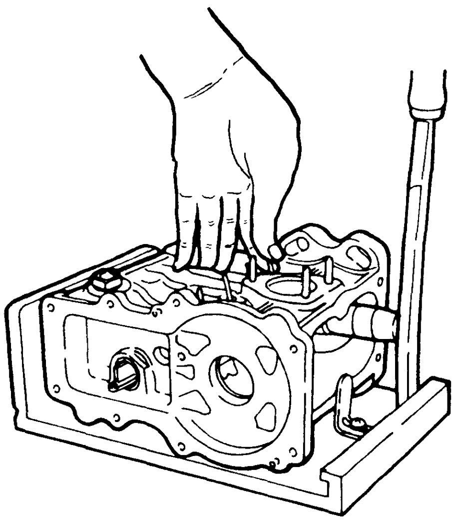
(8) Put a plate against the governor end side of the camshaft and tap it lightly. Pull out the camshaft and drive side bearing.



(9) Install the fuel injection pump on the pump fixture base.

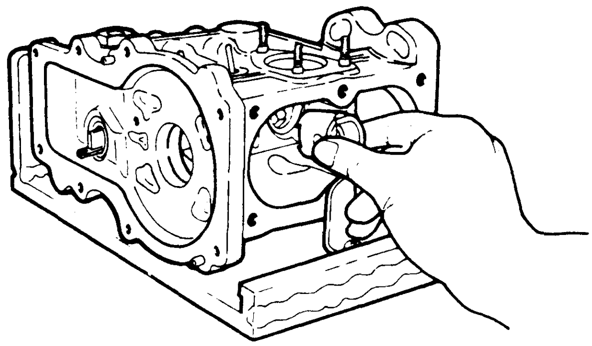


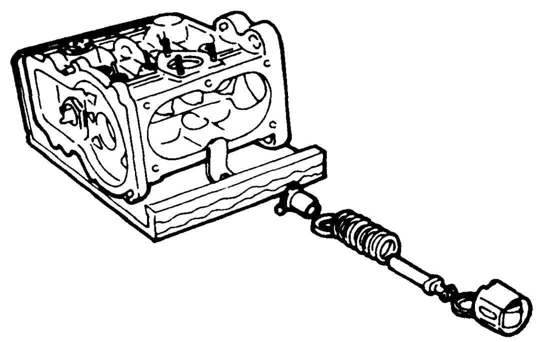
(10) Push the roller guide from underneath with the roller guide push lever and pull out the pushed support pin [item (4)].



NOTE: The plunger spring may make the roller guide and plunger, etc. fly out when the plunger support plate is removed.

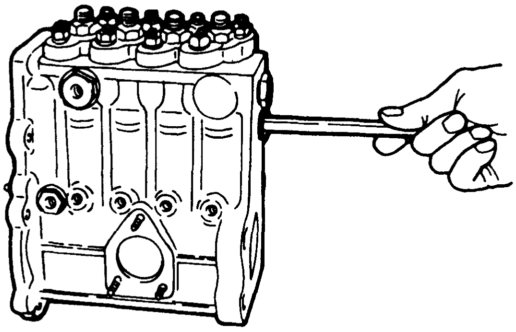
(11) Remove the parts of the roller guide by hand in the following order: plunger spring seat B, plunger, spring, plunger spring seat A and control sleeve.





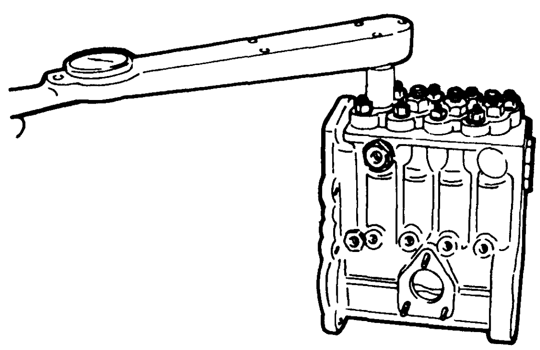
NOTE: All of the roller guides will fall out when the fuel pump is stood up. So, first remove the roller guide support pin and roller guide for one cylinder at a time.

(12) Remove the control rack.



NOTE: Be careful not to lose the spring and seats attached to the control rack.

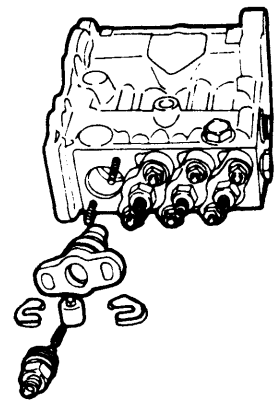
(13) Remove the delivery valve holder.

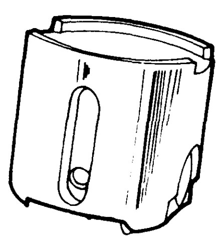


(14) Remove the delivery valve assembly.

NOTE: 1. Be careful not to lose the delivery valve packing, delivery valve spring, delivery valve stopper and other small parts.
2. Keep the delivery valve assemblies for each cylinder clearly separate.

(15) Push up the lower part of plunger barrel from the bottom of the pump, and take out the plunger barrel from the top of pump.



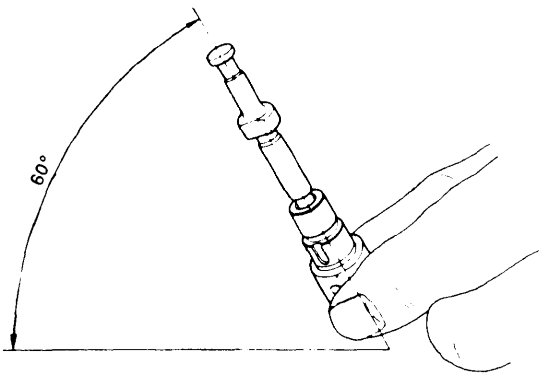


NOTE: Keep each plunger barrel and plunger taken out before as a set.

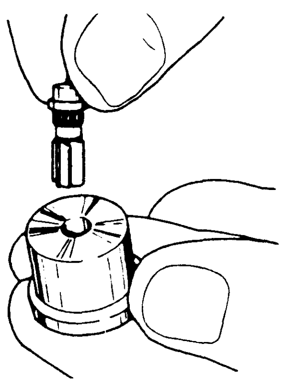
3-2 Inspection of fuel injection pump

(1) Inspection of plunger

1) Thoroughly wash the plungers, and replace plungers that have scratches on the plunger lead or are discolored.
2) The plunger is in good condition if it slides down smoothly when it is tilted at about 60°. Repeat this several times while turning the plunger. Repair or replace if it slides down too quickly or if it stops part way.



(2) Inspection of delivery valve



1) Replace as a set if the delivery valve suck-back collar or seat is scratched, scored, scuffed, worn, etc.
2) The valve is in good condition if it returns when released after being pushed down with your finger (while the holes in the bottom of the delivery guide seat are covered). Replace if necessary.
3) Likewise, the valve should completely close by its own weight when you take your finger off the holes in the bottom of the delivery guide sheet.

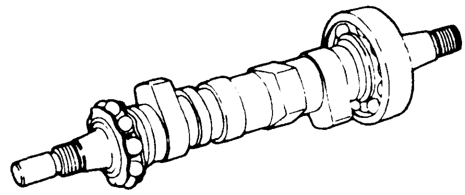
NOTE: When fitting new parts, wash with diesel oil and perform the above inspection.

(3) Inspection of pump

1) Inspect for extreme wear of the roller guide sliding surface. Scratches on the roller pin sliding surface are not a problem.
2) Inspect the plunger barrel seat.
If there are burrs or discoloration, repair or replace as this will lead to dilution of the lubricant.

(4) Inspection of fuel camshaft and bearings

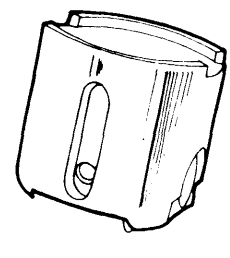
1) Fuel camshaft
Inspect for scratches or wear of camshaft, deformation of key grooves and deformation of screws on both ends, and replace if necessary.
2) Bearings
Replace if the taper rollers or outer race surface are flaked or worn.



NOTE: Replace fuel camshafts and bearings together.

(5) Inspection of roller guide assembly

1) Roller
Replace if the surface is worn or flaked.

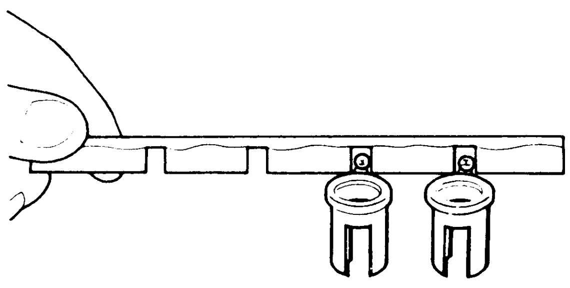


2) Roller guide
Replace if the roller pin hole and the surface in contact with the plunger side is extensively worn or there are many scratches.
3) Replace if the play of the roller guide assembly pin/roller is 0.2 mm (0.0078 in.) or more.
4) Roller pin
Replace the roller pin if its play in the radial direction is great.

(6) Inspection of rack and control sleeve

1) Rack
Inspect the bending of the rack and wear or deformation of its fit with ball of control sleeve.
2) Control sleeve
Inspect for wear or deformation of the ball and fit to the plunger.

NOTE: Rack resistance increases if the fitting or sliding surfaces are not in good working order, and this affects the condition of the engine (rough rpm, over running, etc.)



(7) Inspection of plunger spring and delivery spring

Inspect springs for scratches, cracks, breakage, uneven wear and rust.

(8) Inspection of oil seals

Inspect oil seals to see if they are burred or scratched.

(9) Inspection of roller guide stop

Inspect the side of the tip, replace if excessively worn.

(10) Replacement of O-ring

Replace if they are removed.

3-3 Reassembly of fuel injectio pump

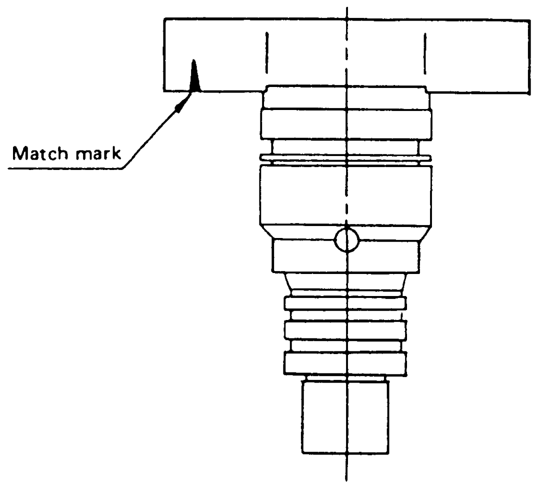
Preparation

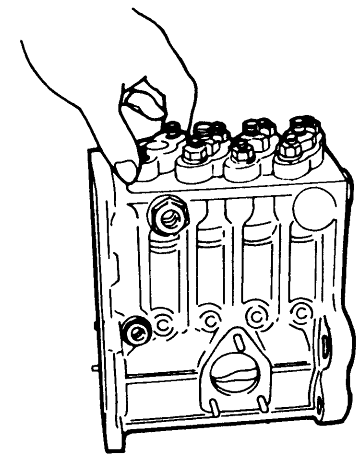
After inspection, arrange and clean all parts.
See Inspection of Fuel Pump for inspection procedure.

(1) Turn the match mark on the flange of plunger barrel to face left from driving side of the pump, insert the plunger barrel from the top of the pump, adjust it with the match mark on pump body, and tighten the nuts.

tightening torque	25.5 ~ 27.5 (2.6 ~ 2.8) N(kgf)·m

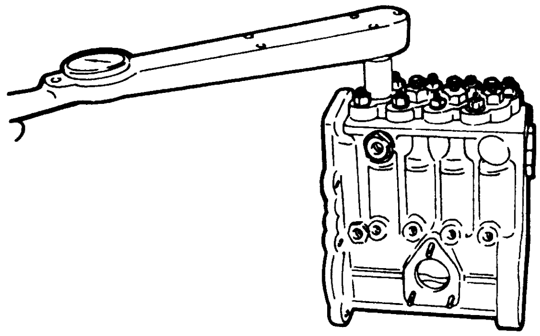
NOTE: Coat the silicon oil with the O-ring.





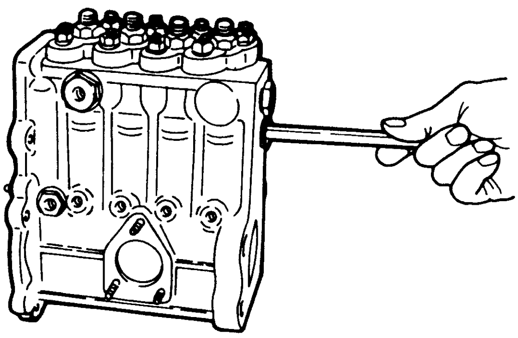
(2) Insert the packing, delivery valve assembly, spring, and stopper from the top of the pump, in that order, and tighten the delivery valve holder.

Delivery value holder tightening torque	39.2 ~ 44.1 (4.0~4.5) N(kgf)·m



(3) Place the control rack.

NOTE: Do not forget the rack Aux. spring.



(4) Place the control sleeve from the bottom of the pump. Make sure the rack moves smoothly through a full cycle.

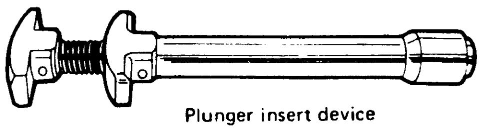
(5) Mount the plunger spring seat A.

NOTE: 1. Be sure to mount the seat A with the hollow side facing down.
2. Check again to make sure that the rack moves easily.

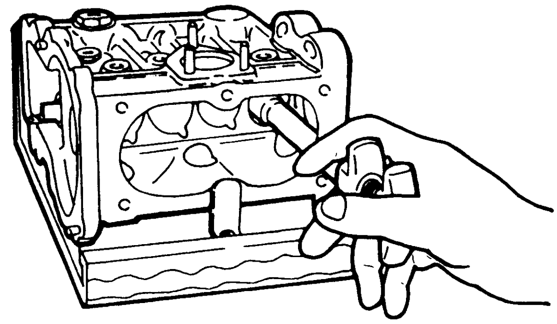
(6) Mount the plunger spring.

(7) Mount the plunger spring seat B on the head of the plunger, and fit the plunger in the lower part of pump. The match mark R-1 on the plunger flange should be on the left as seen from the driving side of the pump.

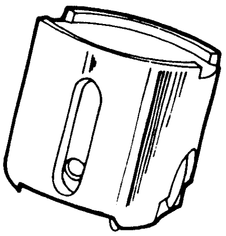
NOTE: This is important, because if the plunger is mounted in opposite direction, the spill way will be reversed.

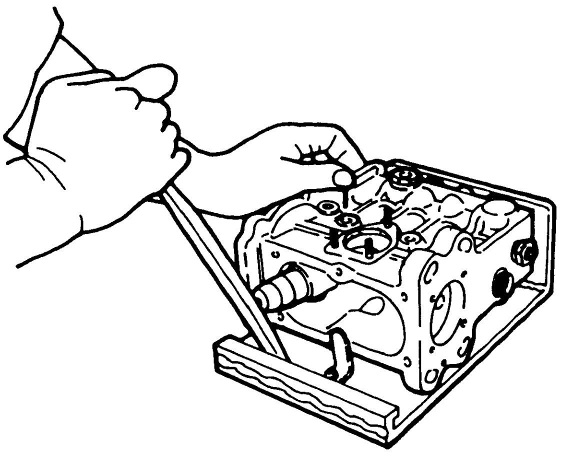


Plunger insert device



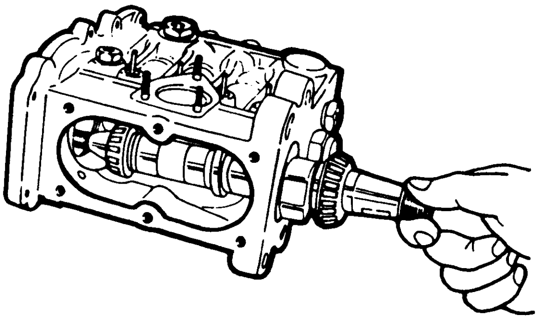
(8) Insert the roller guide, pushing it up from the bottom of the pump with the roller guide push lever, and insert the support pin in the hole on the roller groove.





NOTE: Check the movement of the rack. If the movement is heavy, the plunger spring may be out of place. Insert a screwdriver and bring it to the correct position.
Fit the shims when replacing the roller guide assembly and tighten then lightly.

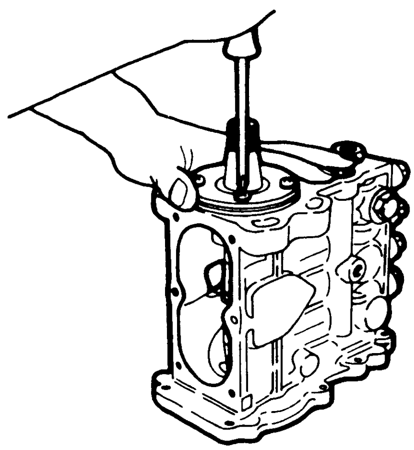
(9) Fit the bearings to both ends of the camshaft, and insert from the driving side.



(10) Fit the oil seal on the inside of the bearing holder and mount the bearing holder.

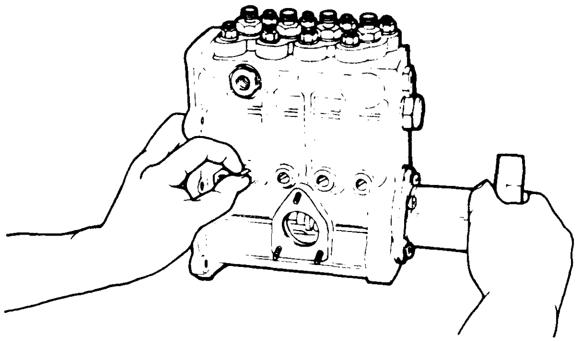
NOTE: Coat the camshaft and the oil seal with silicon oil to prevent the oil seal from being scratched.

tightening torque	5.9 ~ 6.9 (0.6~0.7) N(kgf)·m



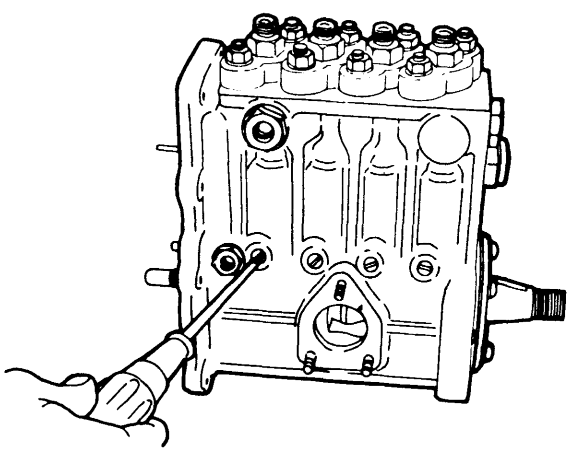
(11) Tap in the camshaft woodruff key.

(12) Mount double nuts or a coupling on the end of the camshaft, and pull out the roller guide support pin as you turn the camshaft.



(13) Make sure that the roller guide stop groove is in the correct position, and tighten the roller guide stop bolts.

tightening torque	5.9 ~ 6.9 (0.6~0.7) N(kgf)·m



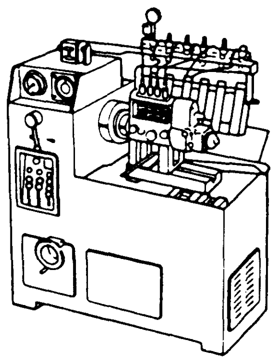
4. Adjustment of Fuel Injection Pump and Governor

Adjust the fuel injection pump after completing re-assembly. The pump itself must be readjusted with a special pump tester when you have replaced major parts such as the plunger assembly, roller guide assembly, fuel camshaft, etc. Procure a pump tester like the one illustrated below.

4-1 Preparations

Prepare for adjustment of the fuel injection pump as follows:

(1) Adjusting nozzle assembly and inspection of injection starting pressure.



MPa(kgf/cm²)

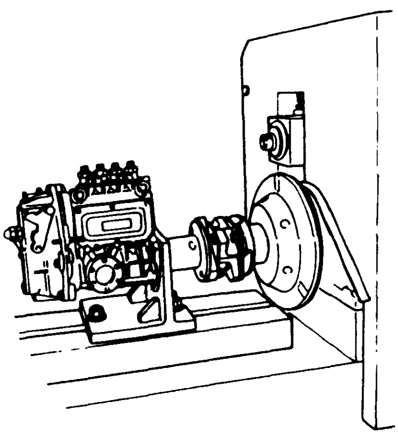
Adjusting nozzle type	*See separate service data*
Injection starting pressure	

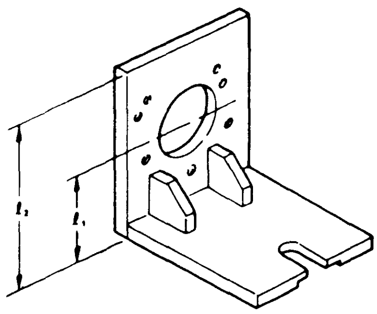
(2) Adjusting injection pipe.

mm (in.)

Inner dia./outer dia. x length	*See separate service data*
Minimum bending radius	25 (0.98)

(3) Mount the fuel injection pump on the pump tester platform.

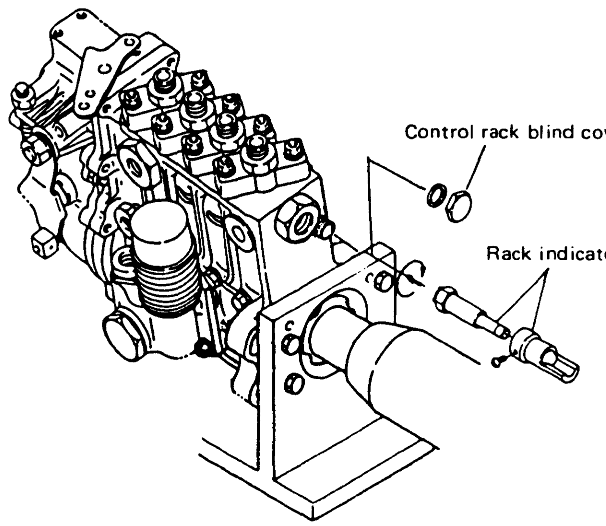


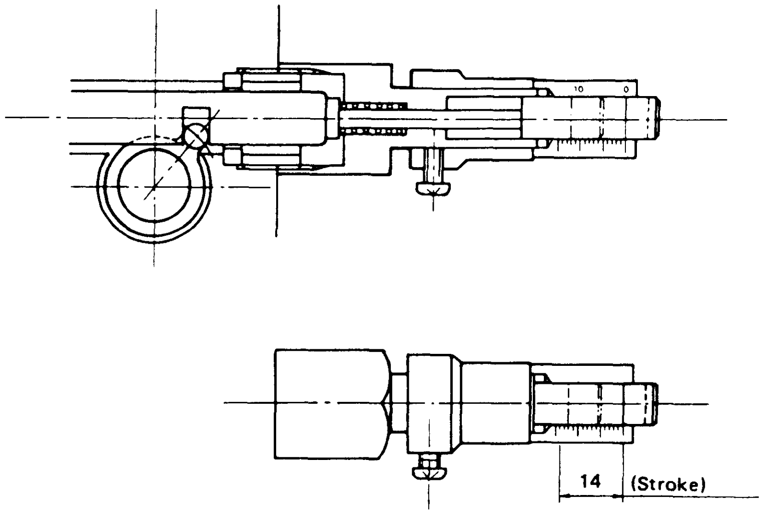


mm (in.)

Tester used	ℓ_1	ℓ_2	Part code number
Yanmar	110 (4.3307)	150 (5.9055)	121978-51010

(4) Remove the control rack blind cover and fit the rack indicator.
Next, turn the pinion from the side of the pump until the control rack is at the maximum drive side position, and set it to the rack indicator scale standard position.
Then make sure that the control rack and rack indicator slide smoothly.



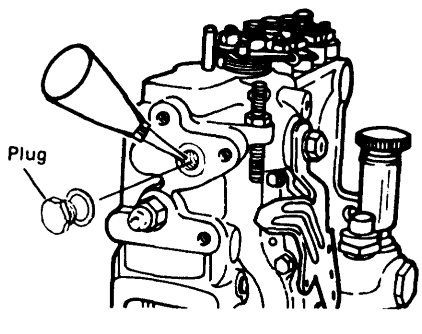


Rack indicator	
Part number	121978-51500

(5) Check the control rack stroke
Make sure the rack position is at 14±0.5 mm on the indicator scale when the governor control lever is set at the maximum operating position. If it is not at this value, change the link connecting the governor and control rack.

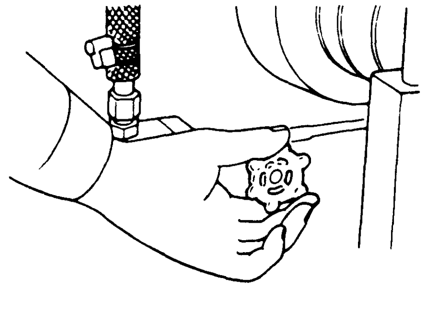
NOTE: Links are available in 1 mm (0.0394 in.) increments.

(6) Remove the plug in the oil filler port of the governor case, and fill the pump with about 400 cm^3 of pump oill or engine oil.



(7) Complete fuel oil piping and operate the pump tester to purge the line of air.

(8) Set the oil feed pressure from the pump tester to the injection pump at the pressure specified in the separate service data sheet.

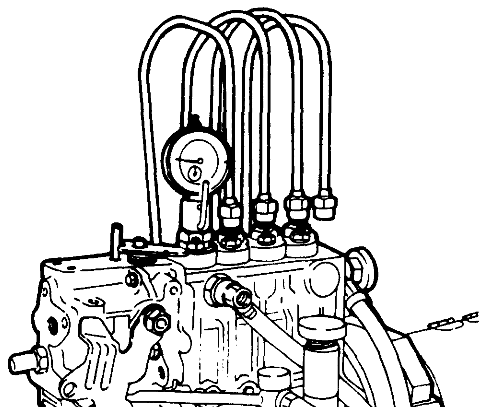


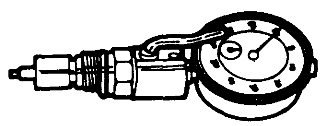
4-2 Adjustment of pre-stroke

(1) Remove the delivery valve holder of No.1 cylinder. Remove the delivery valve spring, delivery valve and gasket.

(2) Screw the pre-stroke measuring device in the screw hole on the top of pump.

(3) Set the control rack to the full throttle position, find the bottom dead center of the plunger while rotating the pump by hand, and set the dial indicator to zero.





Pre-stroke measuring device

(4) Slowly rotate the pump in the normal rotation direction by hand, and measure the plunger lift until fuel flow stops from the overflow pipe on the measuring device.

Pre-stroke	***See separate service data***

(5) If the measured pre-stroke is not standard, adjust by changing the shim thickness between the flange of the plunger barrel and pump body.

mm

Adjusting shims thickness	1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5

(6) Repeat the above procedure to adjust the pre-stroke of each cylinder.

(7) After adjustment is completed, insert the gasket, delivery valve, delivery valve holder and spring. Tighten the delivery valve holder.

Delivery valve holder tightening torque	39.2~44.1(4.0~4.5)N(kgf)·m

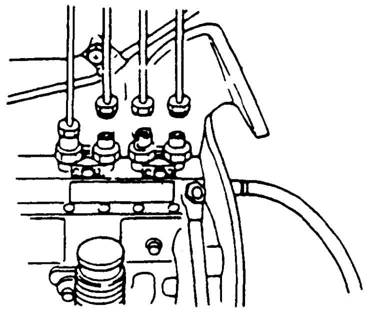
4-3 Adjusting injection timing

After adjusting the pre-stroke for all cylinders, check/adjust the injection timing.

(1) Set the governor control lever in the operating position (bring the plunger to the effective injection range), turn the camshaft clockwise, and check the injection starting time (FID) of cylinder No. 1 (start of fuel discharge from the delivery retainer).

Cylinder No.	Count from the drive side
Direction of rotation	Right looking from drive side

(2) Now set the tester needle on the flywheel scale in a position where it is easy to read, and check the injection timing several times according to the injection order.



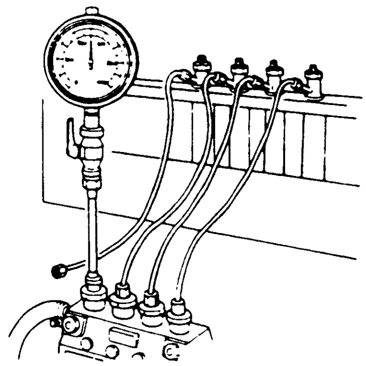
No. of cylinders	3	4
Injection order	1–2–3–1	1–3–4–2–1
Injection interval	120°	90°
Allowable deviation	±30′	

(3) Readjust the pre-stroke of cylinders that are not within the allowable deviation (increasing the adjusting shim thickness makes the injection timing slower, and decreasing makes it faster).
The change in injection timing effected by the adjusting shims is as follows:

Change in shim thickness	Change in injection timing	
	Cam angle	Crank angle
0.1 mm (0.0039 in.)	0.4°	0.8°

4-4 Plunger pressure test

(1) Mount the pressure gauge to the delivery retainer of the cylinder to be tested.



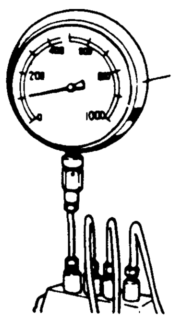
Max. pressure gauge reading	98.1(1,000) MPa(kgf/cm²)
Connecting screw dimensions	M12 x 1.5

(2) Set the governor control lever in the stop position, operate the injection pump at about 200 rpm, and make sure that the pressure gauge reading is 49.0(500)MPa(kgf/cm²) or more. All the time lightly move the control rack towards full throttle (drive side).
Replace the plunger if the pressure does not reach this value.

(3) Immediately release the rack after the pressure has stopped injection.
At the same time, check to see that oil is not leaking from the delivery retainer or fuel injection piping, and that there is no extreme drop in pressure.

4-5 Delivery valve pressure test

(1) Perform the plunger pressure test in the same way, bringing the pressure to about 11.8(120)/MPa (kgf/cm²), and then stopping injection.



(2) After the pressure has risen to the above value, measure the time it takes to drop from 9.81 ~ 8.83 (100 ~ 90) MPa (kgf/cm²).

9.81~8.83(100~90) MPa(kgf/cm²)	5 seconds (to drop 0.98(10)MPa(kgf/cm²)

If the pressure drops faster than this, wash the delivery valve, and retest. Replace the delivery valve if the pressure continues to drop rapidly.

4-6 Adjusting injection volume (uniformity of each cylinder)

The injection volume is determined by the fuel injection pump rpm and rack position. Check and adjust to bring it to the specified value.

4-6.1 Measuring injection volume

(1) Preparation
Set the pump rpm, rack position and measuring stroke to the specified value and measure:

Pump RPM	*See separate service data*
Pump rotating direction	Right looking from drive side
Rack indicator scale reading	*See separate service data*

(2) Measuring injection volume
Measure the injection volume at the standard stroke, and adjust as follows if it is not within the specified value.

Measuring stroke	*See injection pump service data*
Specified injection volume at standard rack position	
Nonuniformity of cylinders	

4-6.2 Adjustment of injection volume

(1) Adjustment of injection volume: loosen the two nuts on the flange of the plunger barrel, and turn the plunger barrel to the right or left.

(2) Measure the injection volume of each cylinder again.
Repeat this process until the injection volume for every cylinder is the same. (within the specified limit)

(3) After completing the measurements, retighten the nuts of plunger barrel flange.

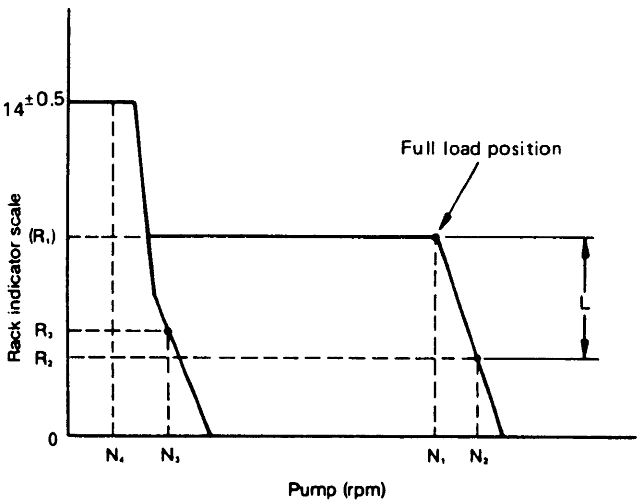
Tightening torque	25.5~27.5(2.6~2.8)N(kgf)·m

(4) If not aligned with the match mark, make a new match mark.

4-7 Adjustment of governor

4-7.1 Adjusting the fuel limit bolt

(1) Adjust the tightness of the fuel limit bolt to bring the rack position to the specified value (R_1) with the governor control lever all the way down towards the fuel increase position. Keep the pump at rated rpm N_1.

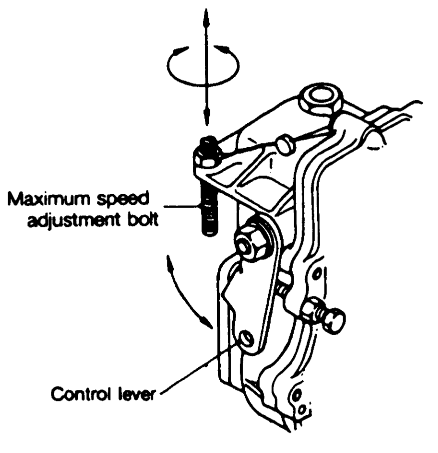


(2) Measure fuel injection volume at rack position (R_1).

(3) If the injection volume is at the specified value, tighten the fuel limit bolt lock nut.

4-7.2 Adjusting RPM limit bolt

(1) Gradually loosen the governor control lever while keeping the pump drive condition in the same condition as when the fuel limit bolt was adjusted, and adjust the tightness of the RPM limit bolt to the point where the rack position just exceeds the specified value (R_1).

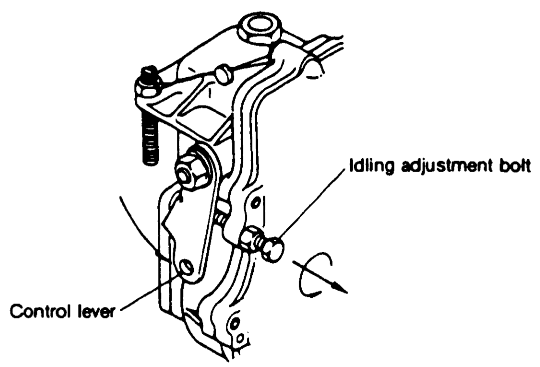


(2) Check maximum RPM at no load
Further increase rpm, and make sure that rack position ($R_2 = R_1 - L$) corresponding to maximum rpm at no load is within specified value (N_2).

No load max. RPM (Pump RPM)	*See separate service data*

4-7.3 Adjusting idling

(1) Maintain the pump rpm at specified rpm (N_3).



Idling rpm (Pump RPM)	*See separate service data*

(2) Measure the injection volume as you lower the governor control lever to the idling position, and adjust the position of the control lever with the idling adjustment bolt to bring it to the specified value.

Measuring stroke	*See separate service data*
Idling injection volume	

4-7.4 Check the injection volume when starting

(1) Make sure the control rack moves smoothly as you gradually reduce idling rpm.

(2) Next fix the governor control lever at full load position with the pump at the specified rpm (N_4). Make sure that the control rack is in the maximum position.
Measure the injection volume and check to make sure it is within the specified value.

For models with a fuel limit bolt for starting, adjust to the specified injection volume with the fuel limit bolt.

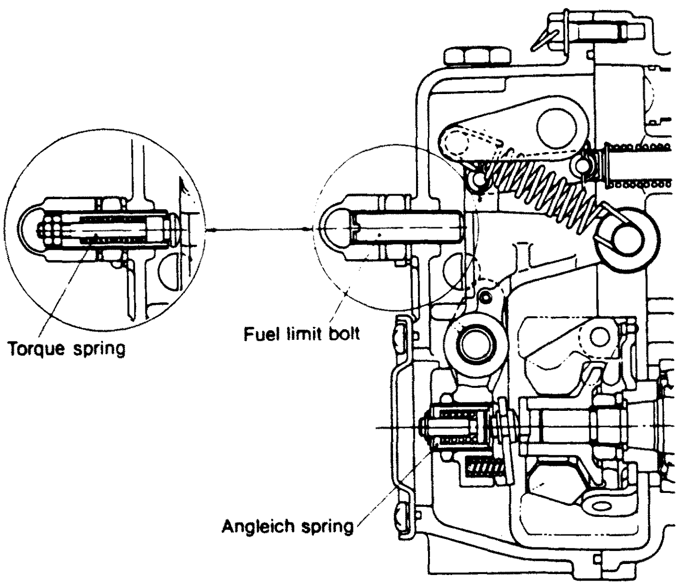
Pump rpm (N_4)	200 rpm
Rack indicator scale	13.5 ∿ 14.5
Measuring stroke	500st
Injection volume	***See separate service data***

4-7.5 Check injection stop

Drive the pump at no load maximum rpm (N_2). With governor control lever in the full load position, operate the stop lever on the governor case, and make sure that injection to all cylinders is stopped.

4-8 Adjustment of torque rise

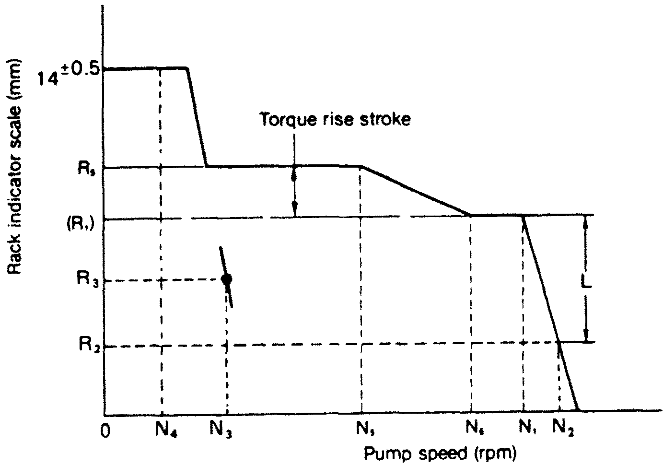
There are some models which obtain torque rise with angleich and torque springs incorporated in the fuel injection pump as an injection volume increasing mechanism.



4-8.1 Models with angleich spring

For models with an angleich spring, perform this adjustment after finishing the speed limit bolt adjustment.

(1) The angleich spring is used as an assembly.
(2) Bring the governor control lever to the full load position, and keep the pump speed at the specified peak torque (N_5).
(3) Remove the governor case cover in this state and screw the angleich spring assembly to the tension lever. Screw in from the contact position with the governor lever (when control lever starts to move), so that the injection volume at torque rise is within the specified values (θ deg.)



(4) After completing the above, tighten the lock nut to the specified torque, and mount the governor case cover.

N(kgf)·m

Lock nut tightening torque	24.5 ~ 29.4 (2.5~3.0)

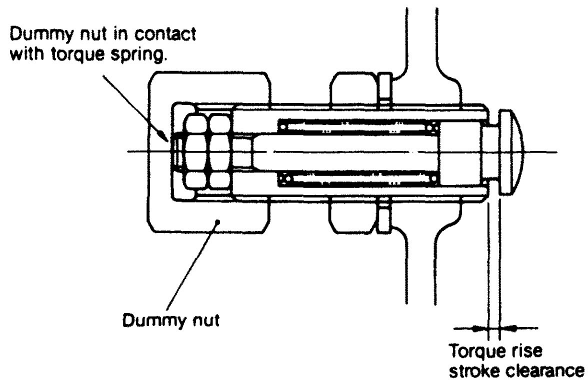
NOTE: Make sure that the angleich bolt does not turn with the locknut during tightening.

(5) Bring the fuel injection pump back to the rated speed. Make sure that the control rack smoothly displaces the torque rise stroke, and that rack position (R_1) and injection value are within the specified value at (N_1) rpm.

4-8.2 Models with torque spring

The torque rise spring is corporated in the fuel limit bolt, and is used as an assembly.

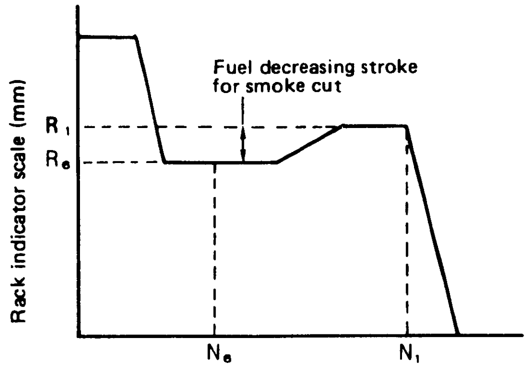
Perform this adjustment after finishing the speed limit bolt adjustment.

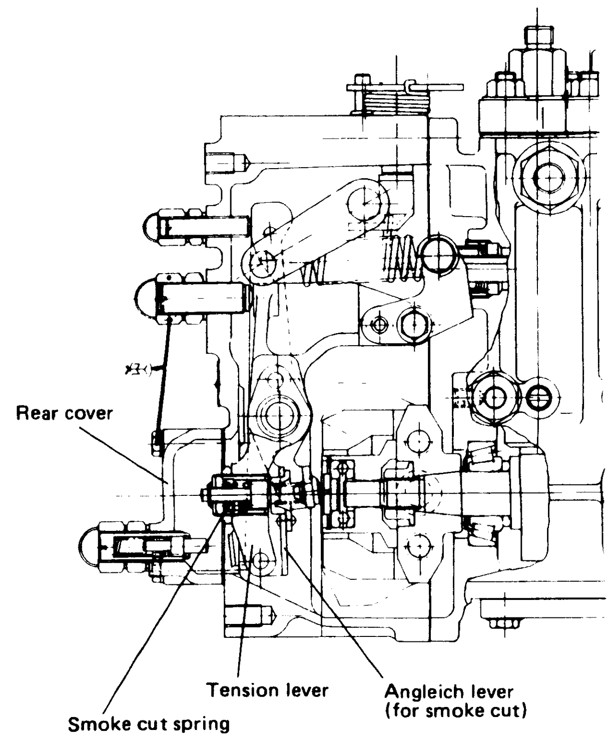


Use the dummy nut during adjustment as shown in the fig., without torque rise stroke, and remove it after completing adjustment.

4.8.3 Smoke cut spring

The smoke cut spring is used in the form of spring loaded assembly.





Smoke cut spring control revolutions	*See separate service data*
Smoke cut spring control injections	

Before Adjusting the smoke cut spring assembly, adjust (1) the fuel limit bolt, and
(2) the revolution limit bolt.

(1) Turn the control lever to "FULL LOAD," and keep the fuel injection pump at the specified smoke cut spring control revolutions (N_6).

(2) Remove the rear cover from the governor. Screw the smoke cut spring assy. in the thread of the tension lever until it comes into contact with the angleich lever. Further screw in the smoke cut spring assy. to the position in which the specified injection is attached (R_6). (The smoke cut lever moves in the direction of "DECREASE of injections").

(3) Tighten the lock nut to the specified tightening torque. Attach the governor rear cover.

Lock nut tightening torque	25.4~29.4(2.5~3.0)N(kgf)·m

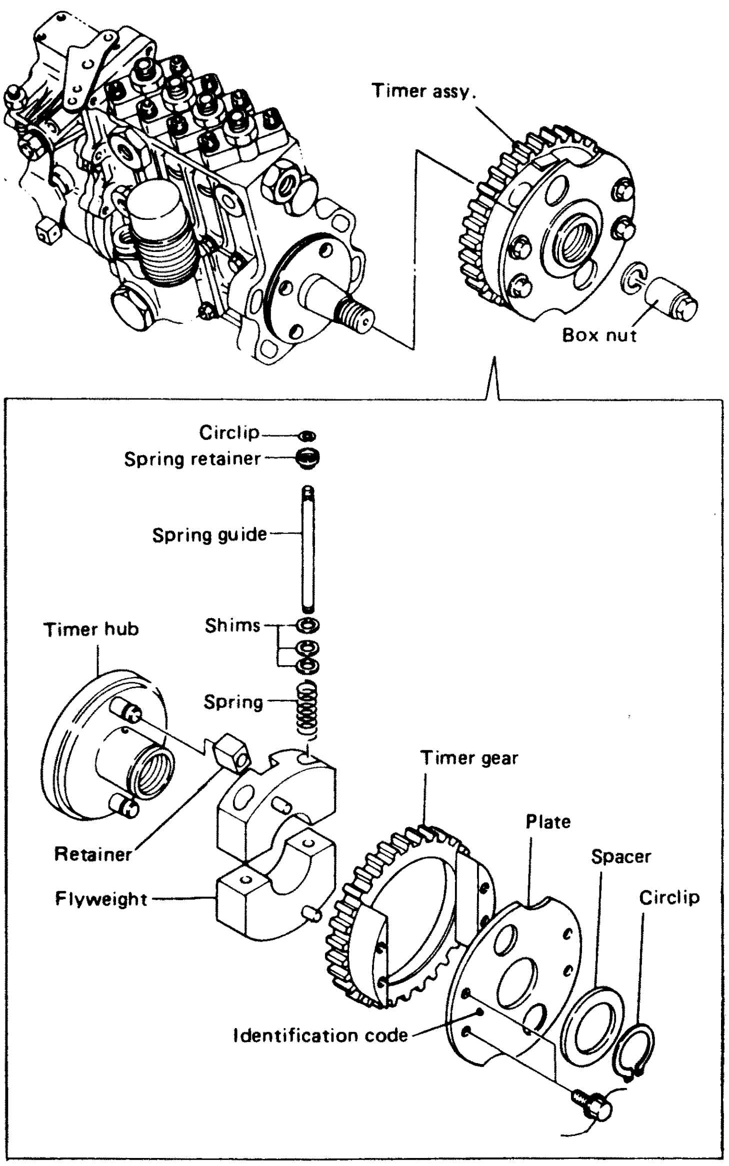
(4) Run the fuel injection pump at the rated revolutions (N_1) once again. Check whether the control rack smoothly changes fuel decreasing strokes. Finally, make sure that rack position (R_1) and injection at revolutions (N_1) meet the specification.

5. Automatic Advancing Timer

5-1 Timer construction

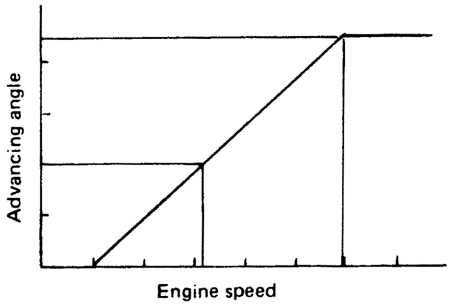
The faster the engine speed, the larger the crank angle is during ignition delay. This results in a delay in ignition time and thus a decrease in engine output. When an engine is used from low to high speed, the injection timing must be changed according to engine speed to maintain it at the optimum timing.
The automatic timer uses centrifugal force to automatically adjust injection timing.

Model Identification code Advanced angle	*See separate service data*



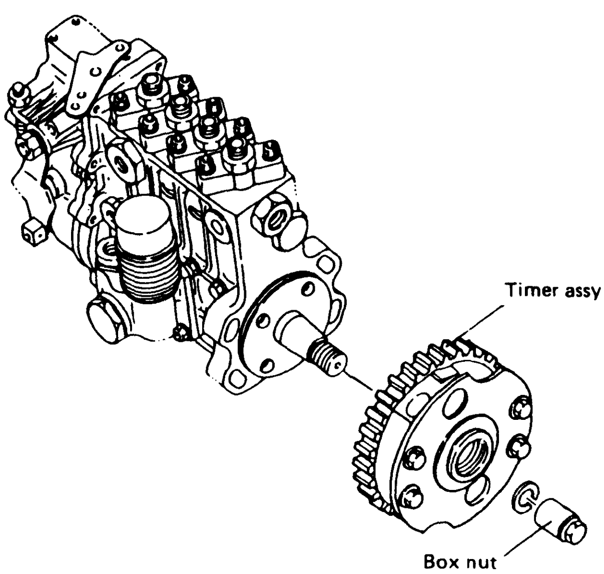
5-2 Function and characteristics of timer

The flyweights are pressed against the center of the flyweight by the springs. As speed increases, the centrifugal force of the two flyweights increases, compresses the timer springs, and the relative position of the timer gear and hub changes according to the function of the retainer guide groove of the weight and the weight guide of the timer gear, changing the injection timing. Accordingly, as the spring is compressed (according to the rise in speed advancing the timing), the advancing angle remains proportional to speed.



The advancing characteristics can be changed by changing the profile of the retainer guide groove of the weight and the spring constant and setting force of the spring

5-3 Timer disassembly



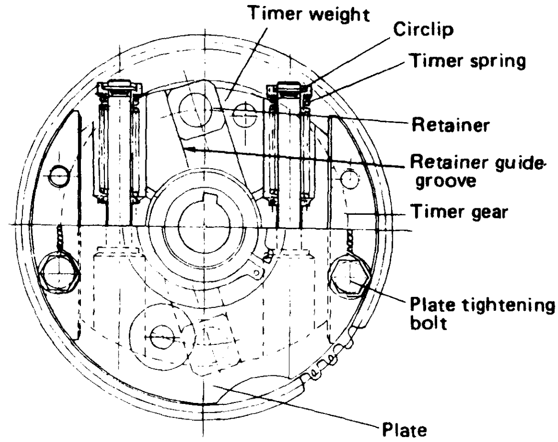
(1) Remove the camshaft box nut.
(2) Use a timer extractor to remove the timer assembly.
(3) The retainers and weights can be removed when you take off the circlip and plate tightening bolts and separate the timer gear and timer hub.

Note: As the advancing angle has been set at the factory, do not disassemble the timer unless necessary.

5-4 Timer inspection

(1) Inspect the timer spring, and replace if there is excessive settling or corrosion.
(2) Inspect the retainer guide groove of the timer weight, retainer, and gear it comes in contact with, and replace if wear is excessive or movement is not smooth.
(3) Inspect the circlip, and replace if there is excessive wear.

Note: Recheck advancing angle when replacing weight or spring, and readjust as necessary with adjusting shims.



5-5 Timer reassembly

(1) Fix the plate by the tightening bolts.

N(kgf)·m

Tightening torque	22.6 ~ 26.5 (2.3~2.7)

(2) Mount the timer assembly on the fuel injection pump camshaft, and tighten the box nut with a socket wrench.

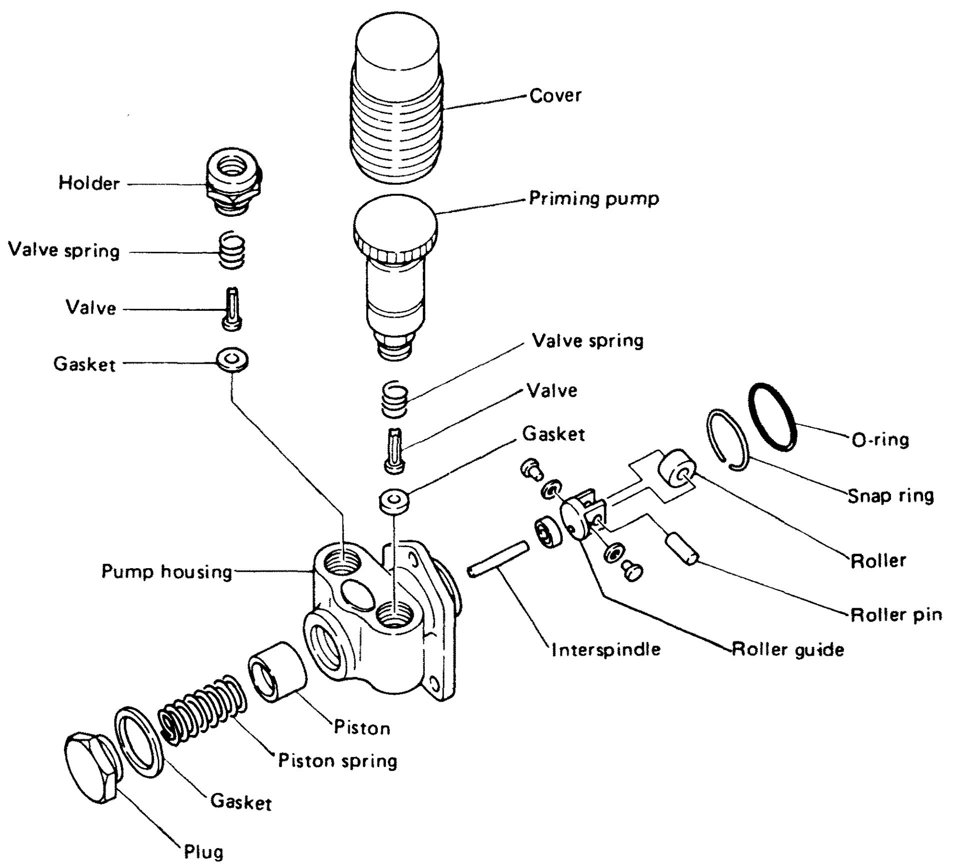
N(kgf)·m

Tightening torque	122.6 ~ 132.4 (12.5~13.5)

6. Fuel Feed Pump

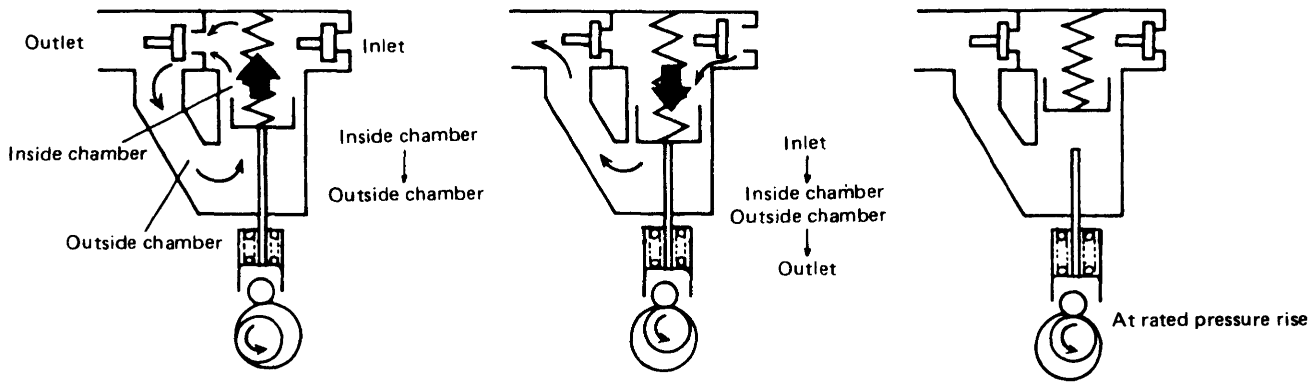
6-1 Fuel Feed Pump Design and Function

The fuel feed pump consists of a priming pump, which extracts air from the fuel system and is used manually to feed fuel while the engine is stopped, and a feed pump, which supplies fuel while the engine is running. The fuel feed pump is driven by an eccentric cam on the fuel camshaft.
When the cam pushes on the piston via the roller guide, the fuel in the piston chamber passes through the discharge valve and flows behind the piston. The suction valve closes under pressure and prevents the fuel from flowing back to the tank.
When the cam is lowered, the piston is pushed back by the piston spring and the fuel behind the piston chamber is forced to the fuel pump. The negative pressure which develops in the piston chamber makes the suction valve open and fills the piston chamber with fuel.



Automatic pressure control mechanism

As the delivery pressure of the fuel pump climbs, the pressure at the back of the piston also rises, overcoming the piston spring force, and hindering the lowering of the piston. Thus, the fuel flow automatically stops, and the fuel pressure is maintained within a fixed range.



When the outside chamber pressure overcomes the piston spring force, the piston is pushed up and separated from the push rod.

6-2 Fuel Feed Pump Disassembly

Follow the procedure below to disassemble the fuel feed pump.

(1) Remove the piston spring stopper plug, and pull out the piston and piston spring.

(2) Remove the snap ring, and pull out the tappet assembly.

(3) Pull out the inter-spindle.

(4) Remove the priming pump.

(5) Remove the discharge valve spring stopper, and remove the valve and spring from inside.

(6) Remove the O-ring.

6-3 Fuel Feed Pump Inspection

(1) Block the priming pump with your finger and check whether the pressed-in piston returns by spring force. If the piston returns, the piston does not have enough negative pressure. Always replace the priming pump as a set.

(2) Check the piston spring for cuts, cracks, uneven wear and rust.

(3) If the piston, inter-spindle, or tappet assembly are extremely worn, replace the part.

(4) Check the contact surface of the valve and valve seat for defects.

(5) When there is play in a valve seat which has been calked into the feed pump body, the whole fuel pump body must be replaced.

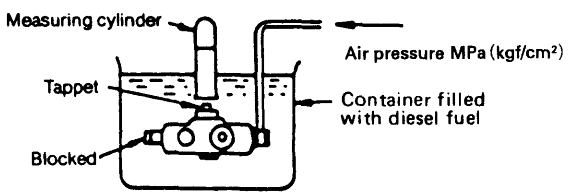
NOTE: Play in the valve seat hinders the opening and closing of the valve, causing insufficient fuel supply and abnormal wear of the tappets and camshaft.

6-4 Fuel Feed Pump Reassembly

(1) To reassemble the fuel feed pump, follow the assembly procedure in reverse order.

(2) When the pump has been reassembled, perform the air-tightness test.

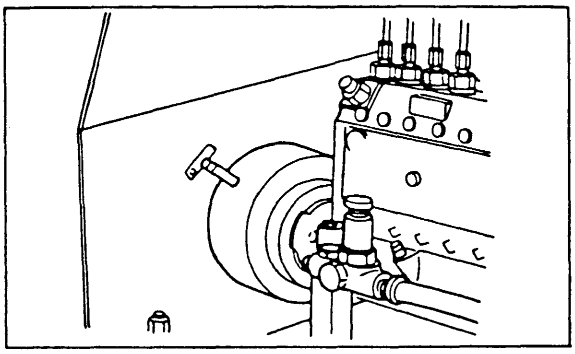
Apply 0.29(3)MPa(kgf/cm²) of air pressure to the discharge outlet of the pump, and check for air leaks from the O-ring. If air is leaking, replace the O-ring.



6-5 Fuel Feed Pump Adjustment

1. Testing procedures for the fuel feed pump

Set the fuel feed pump on the injection pump, and operate the assembled unit on the pump tester.

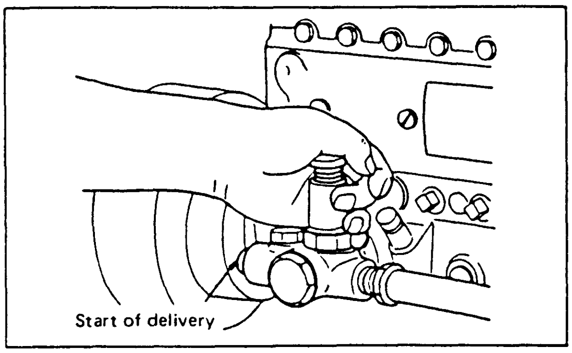


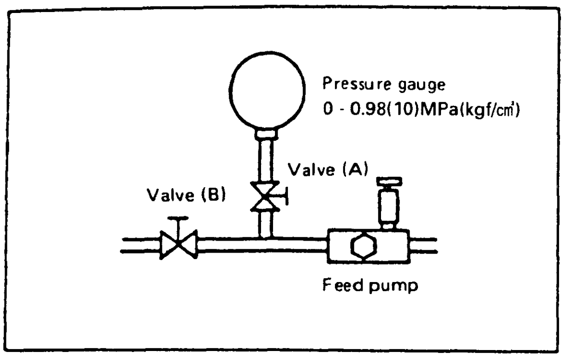
Fuel piping should be provided directly from the tank, not through the delivery pump of the tester.

(1) Suction test for the priming pump

Loosen the handle of the priming pump, and push the handle at 60 – 100 strokes/minute. If fuel comes out of the delivery side of the feed pump after about 30 strokes, the priming pump is normal. If it takes longer, replace the priming pump as a set.

Suction head	1 m	Within 30 strokes
Suction pipe dia.	$\phi 8$	

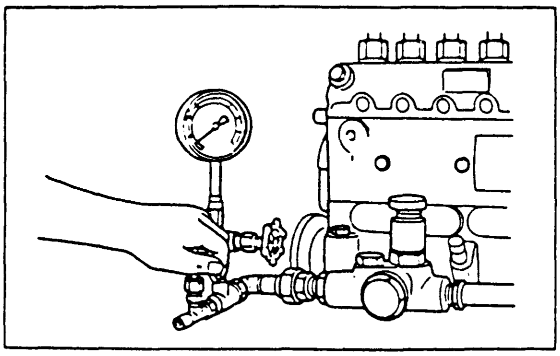




Equipment for feed pump test

(2) Max. delivery feed volume test

You will need the special equipment for conducting max. delivery pressure and delivery volume tests.



Max. delivery pressure test

NOTE: 1. *Do not run the equipment for more than 5 minutes since the fuel injection pump may be damaged if operated in non-injection condition.*

2. *Operate the injection pump at the specified rpm, and read the pressure gauge indicator when valve B is tightened completely. Tighten valve A so that the pressure gauge indicator does not move when the pressure is applied.*

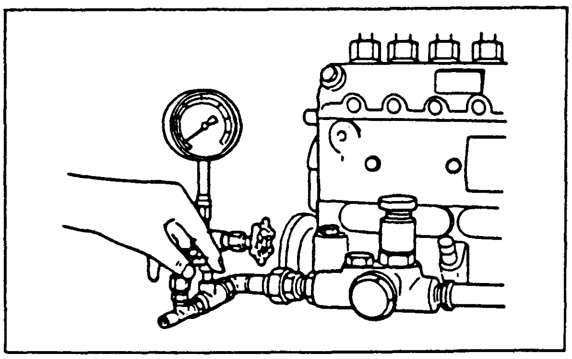
- Volume pressure [MPa(kgf/cm²)] :0.216~0.314(2.2~3.2)
- rpm:600

Replace the piston spring if it is defective.

(3) Delivery test

Operate the fuel injection pump at the specified rpm, open valve (B) until the pressure gauge indicator shows 0.098(1)MPa(kgf/cm²), and measure the delivery rate for one minute.

- Volume (ℓ/min.): over 1.8
- Back pressure [MPa(kgf/cm²)] :0.098(1)
- rpm: 1000



Delivery test

7. Fuel Injection Nozzle

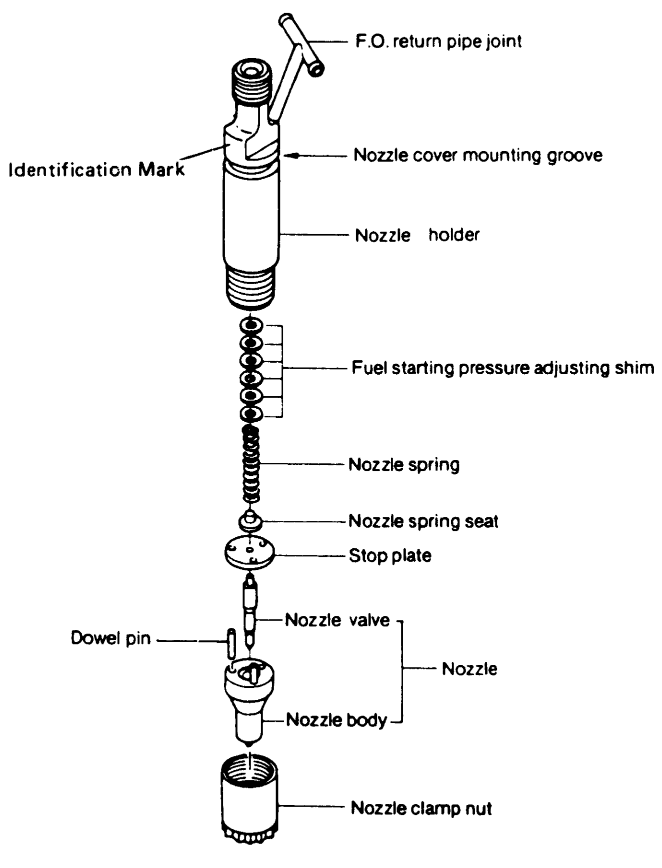
When fuel oil pumped by the fuel injection pump reaches the injection nozzle, it pushes up the nozzle valve (held down by spring), and is injected into the combustion chamber at high pressure.
The fuel is atomized by the nozzle to mix uniformly with the air in the combustion chamber. How well the fuel is mixed with high temperature air directly affects combustion efficiency, engine performance and fuel economy.
Accordingly, the fuel injection nozzles must be kept in top condition to maintain performance and operating efficiency.

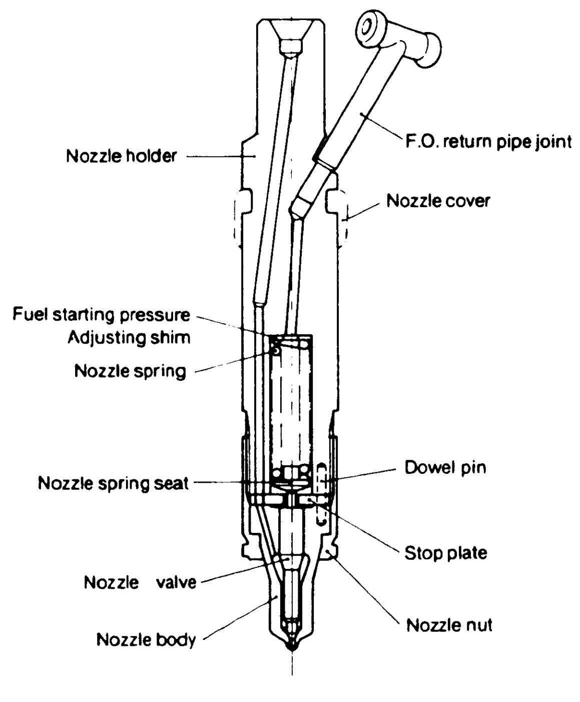
7-1 Functioning of fuel injection nozzle

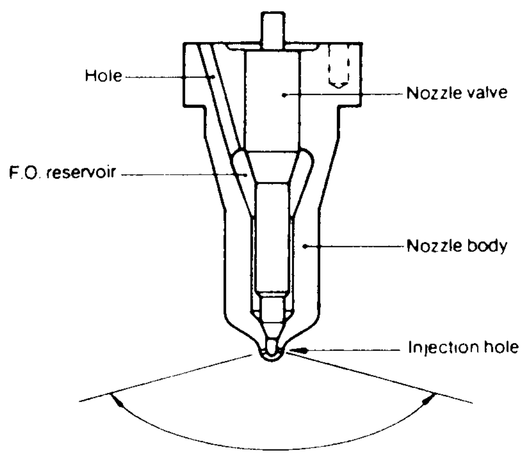
Fuel from the fuel injection pump passes through the oil port in the nozzle holder, and enters the nozzle body reservoir.
When oil reaches the specified pressure, it pushes up the nozzle valve (held by the nozzle spring), and is injected through the small hole on the tip of the nozzle body.
The nozzle valve is automatically pushed down by the nozzle spring and closed after fuel is injected.
Oil that leaks from between the nozzle valve and nozzle body goes from the hole on top of the nozzle spring through the oil leakage fitting and back into the fuel tank.
Adjustment of injection starting pressure is effected with the adjusting shims.

7-2 Type/construction of fuel injection nozzle

(1) Hole type fuel injection nozzle







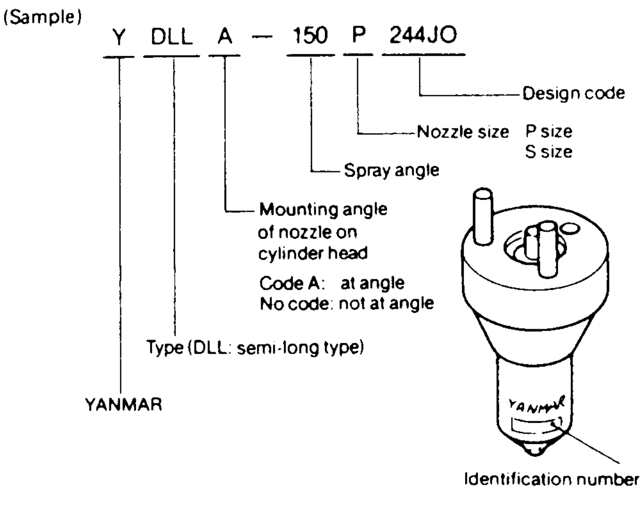
MPa(kgf/cm²)

Nozzle opening pressure	26.5～27.5 (270～280)	23.5～24.5 (240～250)
Nozzle type	140P355KO 5-φ0.35×140°	140P325KO 5-φ0.32×140°
Engine model	4LHA-STE/STZE STP/STZP	4LHA-DTE/DTZE DTP/DTZP

(2) Nozzle body identification number

The type of nozzle can be determined from the number inscribed on the outside of the nozzle body.

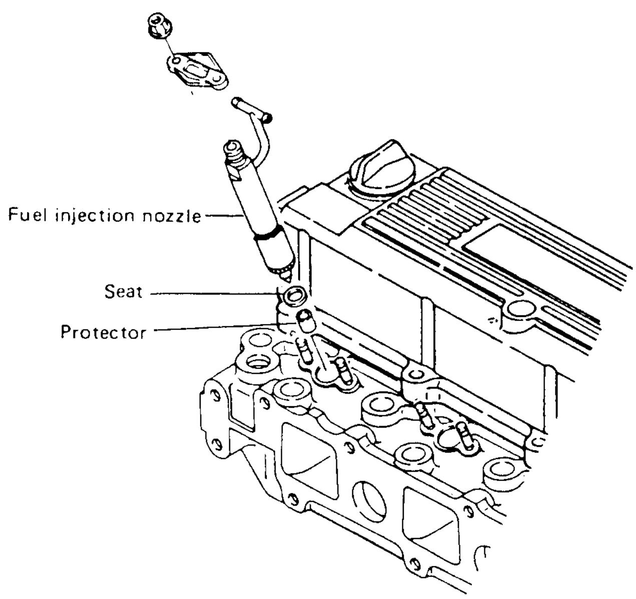
1) Hole type fuel injection nozzles



7-3 Fuel injection nozzle disassembly

NOTE: 1. Disassemble the fuel injection nozzle in a clean area as for fuel injection pump.
2. When disassembling more than one fuel injection nozzle, keep the parts for each injection nozzle separate (i.e. the nozzle for cylinder 1 must be remounted in cylinder 1).

(1) When removing the injection nozzle from the cylinder head, remove the high pressure fuel pipe, fuel leakage pipe, etc., the injection nozzle retainer nut, and then the fuel injection nozzle.

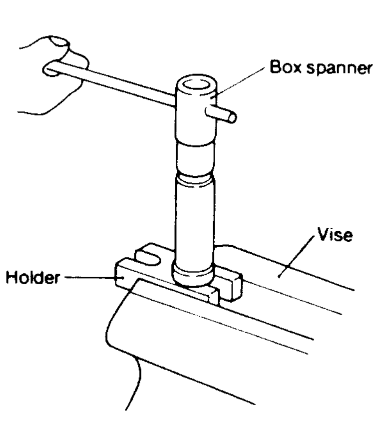


Hole type

(2) Put the nozzle in a vise

NOTE: Use the special nozzle holder for the hole type injection nozzle so that the high pressure mounting threads are not damaged.

(3) Remove the nozzle nut



NOTE: Use a special socket wrench for the hole type (the thickness of the two nozzle nuts is 15 mm (0.5906 in.)).

(4) Remove the inner parts

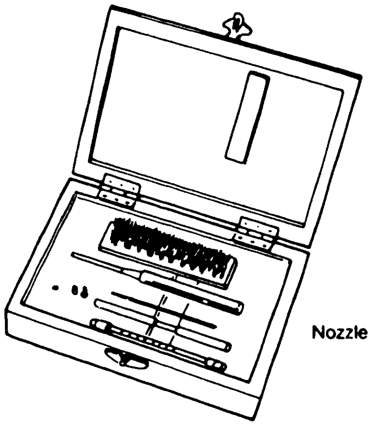
NOTE: Be careful not to loosen the spring seat, adjusting shims or other small parts.

7-4 Fuel injection nozzle inspection

7-4.1 Washing

(1) Make sure to use new diesel oil to wash the fuel injection nozzle parts.

(2) Wash the nozzle in clean diesel oil with the nozzle cleaning kit.

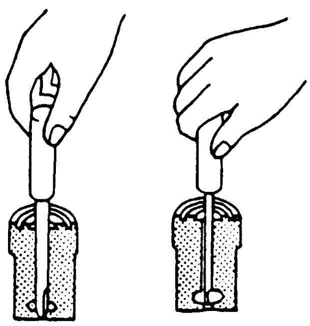


Nozzle cleaning kit

1) Diesel Kiki nozzle cleaning kit:
   Type NP-8486B No. 5789-001
2) Anzen Jidosha Co., Ltd. nozzle cleaning kit:
   Type NCK-001

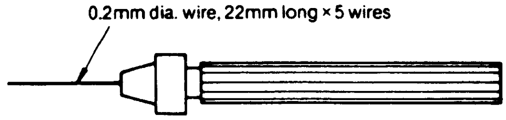
(3) Clean off the carbon on the outside of the nozzle body with a brass brush.

(4) Clean the nozzle seat with cleaning spray.



(5) Clean off the carbon on the tip of nozzle with a piece of wood.

(6) Clean hole type nozzles with a nozzle cleaning needle.



Part code no.	28210-000010

7-4.2 Nozzle inspection

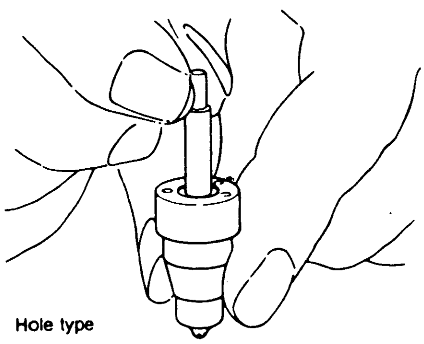
(1) Inspect for scratches/wear

Inspect the oil seals for abnormal scratches or wear and replace the nozzle if the nozzle sliding surface or seat are scratched or abnormally worn.

(2) Check nozzle sliding

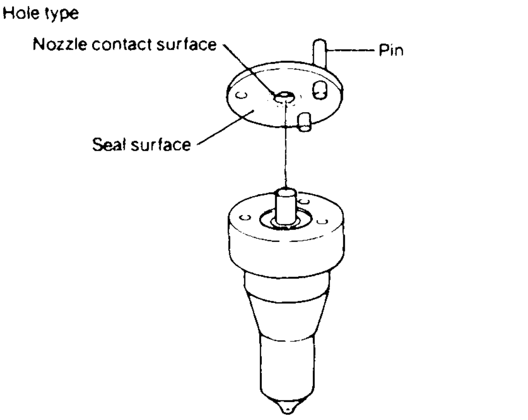
Wash the nozzle and nozzle body in clean diesel oil, and make sure that when the nozzle is pulled out about half way from the body, it slides down by itself when released.

Rotate the nozzle a little; replace the nozzle/nozzle body as a set if there are some places where it does not slide smoothly.



(3) Inspecting the stopper

Check for scratches/wear in seals on both ends, check for abnormal wear on the surface where it comes in contact with the nozzle; replace if the stop plate is excessively worn.

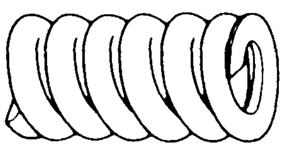


mm (in.)

Nozzle contact surface wear limit	0.1 (0.0039)

(4) Inspecting the nozzle spring

Replace the nozzle spring if it is extremely bent, or if the surface is scratched or rusted.



(5) Nozzle holder

Check the oil seal surface for scratches/wear· replace if wear is excessive.

6-5 Fuel injection nozzle reassembly

The fuel injection nozzle is reassembled in the opposite order to disassembly.

(1) Insert the adjusting shims, nozzle spring and nozzle spring seat in the nozzle holder, mount the stop plate with the pin, insert the nozzle body/nozzle set and tighten the nut.

(2) Use the special holder when tightening the nut for the hole type nozzle, as in disassembly.

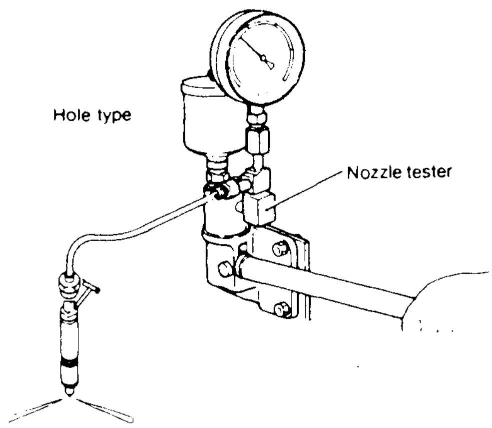
Nozzle nut tightening torque N(kgf)·m

Hole type nozzle	39.2 ~ 44.1(4~4.5)

7-6 Adjusting fuel injection nozzle

7-6.1 Adjusting opening pressure

Mount the fuel injection nozzle on the nozzle tester and use the handle to measure injection starting pressure. If it is not at the specified pressure, use the adjusting shims to increase/decrease pressure.



Injection starting pressure MPa(kgf/cm²)

4LHA-STE/STZE/STP/STZP	4LHA-DTE/DTZE/DTP/DTZP
26.5~27.5 (270~280)	23.5~24.5 (240~250)

7-6.2 Injection test

After adjusting the nozzle to the specified starting pressure, check the fuel spray condition and seat oil tightness.

(1) Checking the seat oil tightness

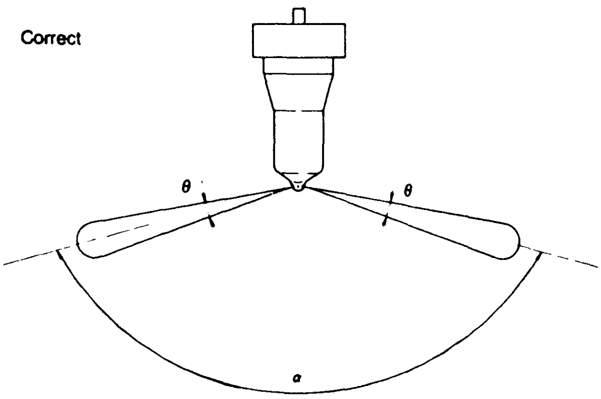
After two or three injections, gradually increase the pressure up to 1.96 (20) MPa(kgf/cm²). Before reading the starting pressure, maintain the pressure for 5 seconds and make sure that no oil is dripping from the tip of the nozzle.
Test the injection with a nozzle tester, retighten and test again if there is excessive oil leakage from the overflow coupling.
Replace the nozzle as a set if oil leakage is still excessive.

(2) Injection spray condition

Operate the nozzle tester lever once or twice a second and check for abnormal injection.

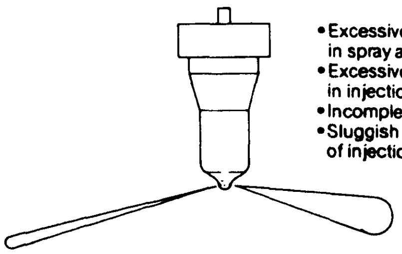
1) Hole type nozzles
Replace hole type nozzles that do not satisfy the following conditions:
- Proper spray angle (θ)
- Correct injection angle (α)
- Complete atomization of fuel
- Prompt starting/stopping of injection

Correct



Spray from each nozzle hole is uniform

Poor



- Excessive difference in spray angle (θ)
- Excessive difference in injection angle (α)
- Incomplete atomization
- Sluggish starting/stopping of injection

8. Troubleshooting

8–1 Troubleshooting of Fuel Injection Pump

Complete repair means not only replacing defective parts, but finding and eliminating the cause of the trouble as well. The cause of the trouble may not necessarily be in the pump itself, but may be in the engine or the fuel system. If the pump is removed prematurely, the true cause of the trouble may never be known. Before removing the pump from the engine, at least go through the basic check points given here.

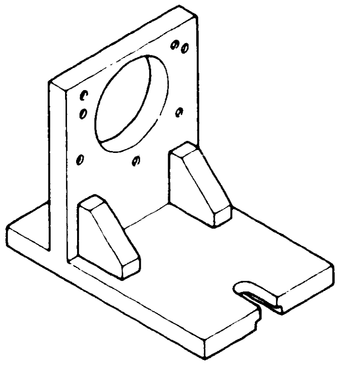
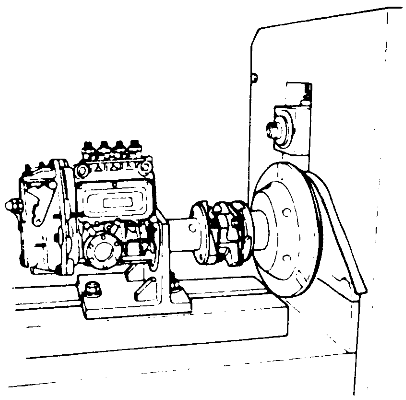
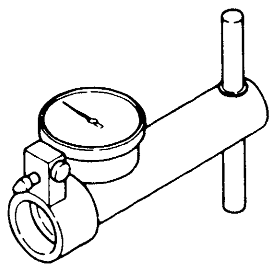
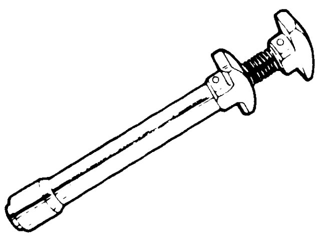
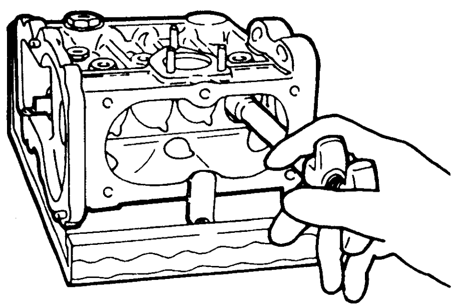
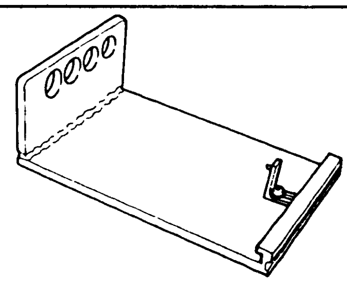
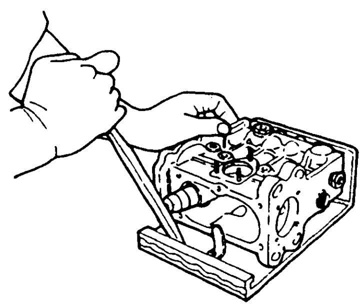
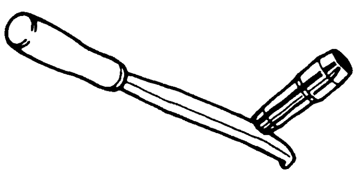
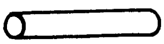
Basic check points
- Check for breaks or oil leaks throughout the fuel system, from the fuel tank to the nozzle.
- Check the injection timings for all cylinders. Are they correctly adjusted? Are they too fast or too slow?
- Check the nozzle spray.
- Check the fuel delivery. Is it in good condition? Loosen the fuel pipe connection at the injection pump inlet, and test operate the fuel feed pump.

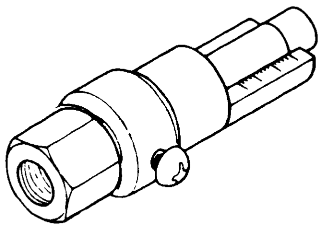
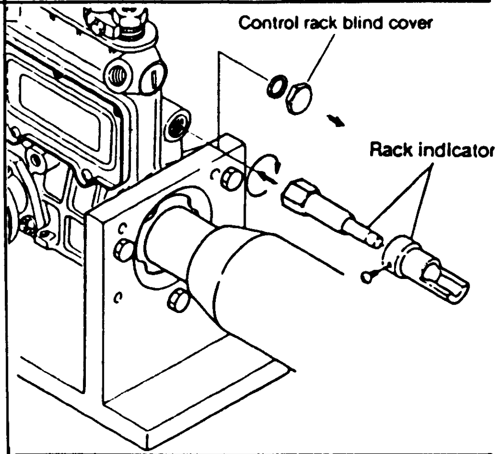
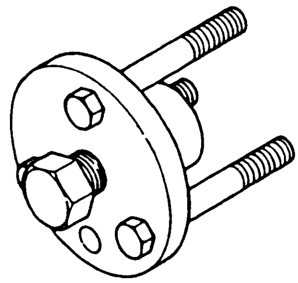
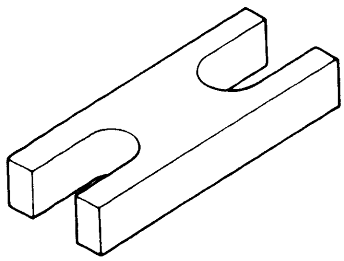
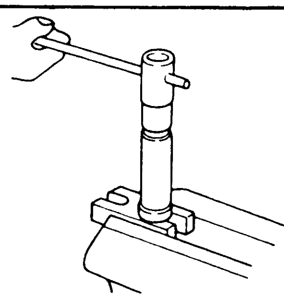
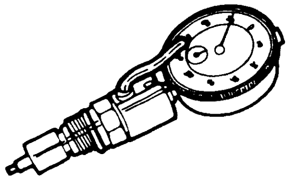
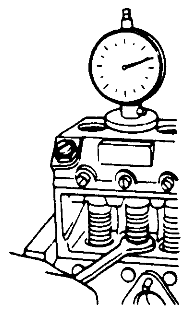
8–2 Major Faults and Troubleshooting

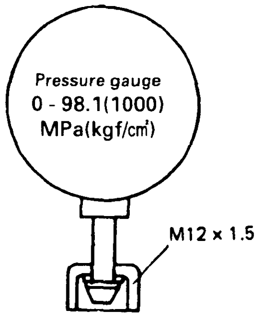
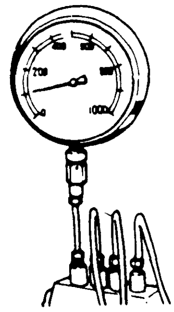
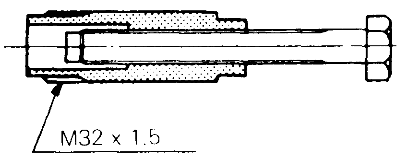
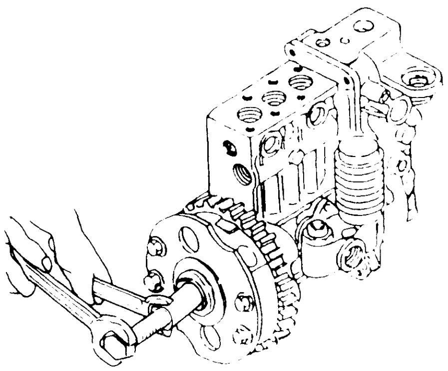
Fault		Cause	Remedy
1. Engine won't start.	Fuel not delivered to injection pump.	(1) No fuel in the fuel tank.	Resupply
		(2) Fuel tank cock is closed.	Open
		(3) Fuel pipe system is clogged.	Clean
		(4) Fuel filter element is clogged.	Disassemble and clean, or replace element
		(5) Air is sucked into the fuel due to defective connections in the piping from the fuel tank to the fuel pump.	Repair
		(6) Defective valve contact of feed pump	Repair or replace.
		(7) Piston spring of feed pump is broken.	Replace
		(8) Inter-spindle or tappets of feed pump are stuck.	Repair or replace
	Fuel delivered to injection pump.	(1) Defective connection of control lever and accel. rod of injection pump.	Repair or adjust
		(2) Plunger is worn out or stuck.	Repair or replace
		(3) Delivery valve is stuck.	Repair or replace
		(4) Control rack doesn't move.	Repair or replace
		(5) Injection pump coupling is damaged, or the key is broken.	Replace
	Nozzle doesn't work.	(1) Nozzle valve doesn't open or close normally.	Repair or replace
		(2) Nozzle seat is defective.	Repair or replace
		(3) Case nut is loose.	Inspect and tighten
		(4) Injection nozzle starting pressure is too low.	Adjust
		(5) Nozzle spring is broken.	Replace
		(6) Fuel oil filter is clogged.	Repair or replace
		(7) Excessive oil leaks from the nozzle sliding area.	Replace the nozzle assembly
	Injection timing is defective.	(1) Injection timing is retarded due to failure of the coupling.	Adjust
		(2) Camshaft is excessively worn.	Replace camshaft
		(3) Roller guide incorrectly adjusted or excessively worn.	Adjust or replace
		(4) Plunger is excessively worn.	Replace plunger assembly
2. Engine starts, but immediately stops.		(1) Fuel pipe is clogged.	Clean
		(2) Fuel filter is clogged.	Disassemble and clean, or replace the element.
		(3) Improper air-tightness of the fuel pipe connection or pipe is broken and air is being sucked in.	Replace packing; repair pipe
		(4) Insufficient fuel delivery from the feed pump.	Repair or replace

Fault		Cause	Remedy
3. Engine's output is insufficient.	Defective injection timing, and other failures.	(1) Knocking sounds caused by improper (too fast) injection timing.	Inspect and adjust
		(2) Engine overheats or emits large amount of smoke due to improper (too slow) injection timing.	Inspect and adjust
		(3) Insufficient fuel delivery from feed pump.	Repair or replace
	Nozzle movement is defective	(1) Case nut is loose.	Inspect and retighten
		(2) Defective injection nozzle performance.	Repair or replace nozzle
		(3) Nozzle spring is broken.	Replace
		(4) Excessive oil leaks from nozzle.	Replace nozzle assembly
	Injection pump is defective.	(1) Max. delivery limit bolt is screwed in too far.	Adjust
		(2) Plunger is worn.	Replace
		(3) Injection amount is not uniform.	Adjust
		(4) Injection timings are not even.	Adjust
		(5) The 1st and 2nd levers of the governor and the control rack of the injection pump are improperly lined up.	Repair
		(6) Delivery stopper is loose.	Inspect and retighten
		(7) Delivery packing is defective.	Replace packing
		(8) Delivery valve seat is defective.	Repair or replace
		(9) Delivery spring is broken.	Replace
4. Idling is rough.		(1) Movement of control rack is defective.	
		1) Stiff plunger movement or sticking.	Repair or replace
		2) Rack and pinion fitting is defective.	Repair
		3) Movement of governor is improper.	Repair
		4) Delivery stopper is too tight.	Inspect and adjust
		(2) Uneven injection volume.	Adjust
		(3) Injection timing is defective.	Adjust
		(4) Plunger is worn and fuel injection adjustment is difficult.	Replace
		(5) Governor spring is too weak.	Replace
		(6) Feed pump can't feed oil at low speeds.	Repair or replace
		(7) Fuel supply is insufficient at low speeds due to clogging of fuel filter.	Disassemble and clean, or replace element
5. Engine runs at high speeds, but cuts out at low speeds.		(1) The wire or rod of the accelerator is caught.	Inspect and repair
		(2) Control rack is caught and can't be moved.	Inspect and repair
6. Engine doesn't reach max. rpm.		(1) Governor spring is broken or excessively worn.	Replace
		(2) Injection performance of nozzle is poor.	Repair or replace
7. Loud knocking.		(1) Injection timing is too fast or too slow.	Adjust
		(2) Injection from nozzle is improper. Fuel drips after each injection.	Adjust
		(3) Injection nozzle starting pressure is too high.	Adjust
		(4) Uneven injection.	Adjust
		(5) Engine overheats, or insufficient compression.	Repair
8. Engine emits too much smoke.	When exhaust smoke is black:	(1) Injection timing is too fast.	Adjust
		(2) Air volume intake is insufficient.	Inspect and repair
		(3) The amount of injection is uneven.	Adjust
		(4) Injection from nozzle is improper.	Repair or replace
	When exhaust smoke is white:	(1) Injection timing is too slow.	Adjust
		(2) Water is mixed in fuel.	Inspect fuel system, and clean
		(3) Shortage of lube oil in the engine.	Repair
		(4) Engine is over-cooled.	Inspect

9. Tools

Name of tool	Shape and size	Application
Pump mounting support for Yanmar tester 121978-51010		
Measuring device (cam backlash) 121978-51050		
Plunger insert 121978-51100		
Pump fixture base 121978-51150		
Roller guide push lever 121978-51250		
Roller guide support pin 121978-51200		

Name of tool	Shape and size	Application
Rack indicator 121978-51500		
Weight extractor 158090-51400		
Nozzle plate 158090-51700		
Prestroke measuring device 121978-51350		

Name of tool	Shape and size	Application
Pressure gauge 121820-92540		
Spring set bar 121978-51610		
Timer extractor 144626-92700		

10. Fuel Injection Pump Specifications

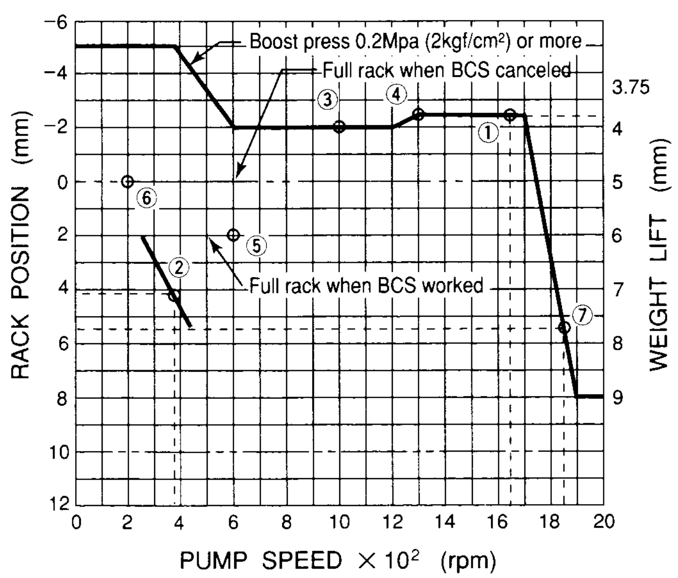
Model				4LHA-STE/STZE/STP/STZP	4LHA-DTE/DTZE/DTP/DTZP
Fuel injection equipment assembly code number			(1) + (2) + (3)	719173 - 51310	719175 - 51310
			(1) + (2) + (3) + (4)	——	
(1)	Fuel injection pump	Assembly code number		119175 - 51000	
		Plunger barrel assembly	Part code number	119593 - 51100	
			Plunger diameter mm	ϕ 9.5	
			Lead angle deg	45° Lower lead (right)	
			Identification number	R7	
		Delivery valve assembly	Part code number	119593 - 51300	
			Suck back volume: Q_R mm³/st	59	
			Angleich cut mm	0.30	
			Identification number	——	
		Camshaft	Part code number	119175 - 51030	
(2)	Governor	Assembly code number		119175 - 61000	
		Governor weight	Part code number (type)	119173-61200 (2 weights)	
		Governor spring	Part code number	119588 - 61700	
			Spring constant N(kgf)/mm	7.55 (0.77)	
			Free length mm	63	
		Smoke cut device	Type	Angleich spring for smoke cut (Inverted angleich)	
			Part code number	119174 - 61550	
		Engine stop device		Pulling stop lever	
(3)	Fuel feed pump		Assembly code number	119593 - 52000	
			Type	Piston type	
(4)	Automatic advancing timer		Assembly code number	D19175-54102	D19588-54100
			Advanced angle: θ cam. deg.	2.5°	2.1°
			Identification number	225	——
Injection order (Count from drive side)				1-3-4-2-1	
Injection interval				90°	
Remarks				Governor with smoke cut device	

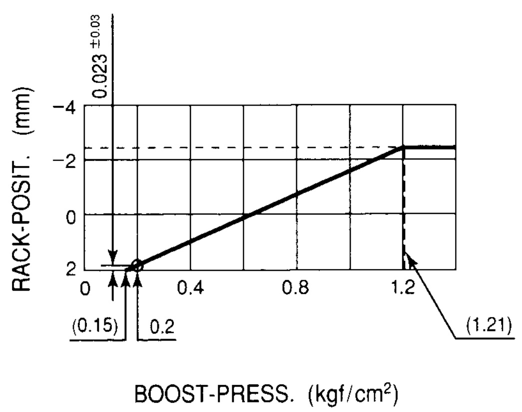
11. Service Data

● 4LHA-STE/STZE/STP/STZP

		Rack position (mm)	Pump speed (rpm)	Calibration data (Manufacturer STD)		Remarks
				Average inject. qty. (mm³/st)	Max. variation between cyls. (%)	
Ajustment of injection quantity	⑥	(0)	200	120±30	——	BCS cancel
	⑤	(2.0)	600	63±3.5	——	BCS works
	③	(−2)	1000	135±3	——	Inverted angleich
	①	−2.5±0.2	1650	130±2	±3	Max. (fuel stop) rating
	②	(4.1)	375	9±3	±1.5	Low idle
	⑦	(5.4)	1850	8~15	——	Max. idle
	④	(2.4)	1300	(Expected 13.5)	——	Measuring point
Test conditions for adjustment inj. pump	Nozzle, nozzle holder assy.			D19175−53200(CL)		——
	Nozzle			5− φ0.35 (YDLLA140P355KO)		——
	Nozzle holder			For 4LHA-STE		——
	Nozzle opening press.			270~280kgf/cm²		——
	Transfer pump press.			4.6kgf/cm²		——
	Injection pipe			φ6.35× φ2×475mm		——
	Test fuel oil			Diesel fuel oil JIS No.2		——
	Fuel temp			40℃		——

● Direction of rotation : Clockwise (viewed from driving side)
● Injection order : 1-3-4-2-1 (No1 from driving side)

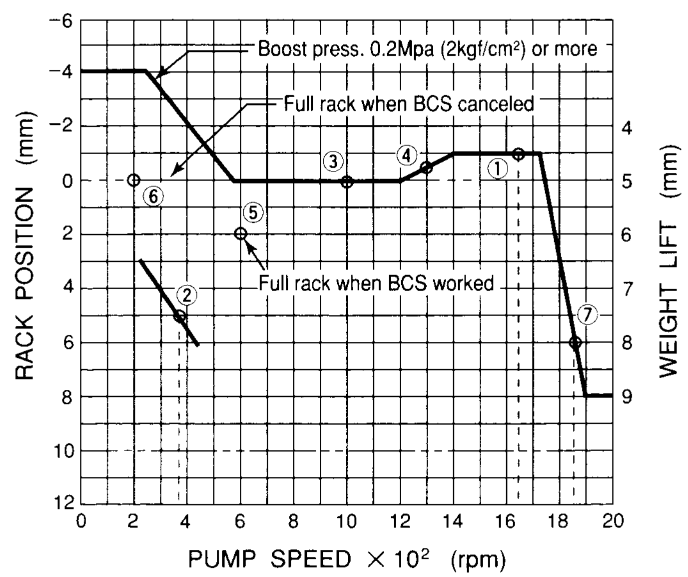


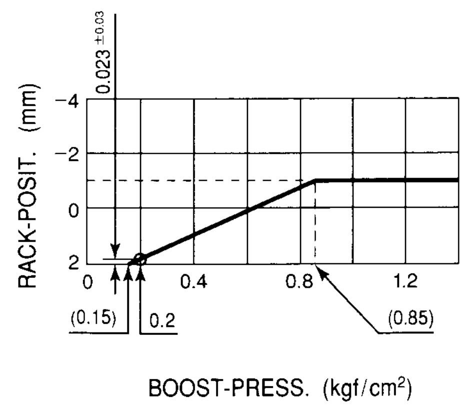


● 4LHA-DTE/DTZE/DTP/DTZP

		Rack position (mm)	Pump speed (rpm)	Calibration data (Manufacturer STD)		Remarks
				Average inject. qty. (mm³/st)	Max. variation between cyls. (%)	
Ajustment of injection quantity	⑥	(0)	200	120±30	——	BCS cancel
	⑤	(2.0)	600	77±3.5	——	BCS works
	③	(0)	1000	115±3	——	Inverted angleich
	①	−1.0±0.2	1650	108±2	±3	Max. (fuel stop) rating
	②	(5.0)	375	9±3	±15	Low idle
	⑦	(6.0)	1850	8~15	——	Max. idle
	④	(−0.5)	1300	(Expected 115)	——	Measuring point
Test conditions for adjustment inj. pump	Nozzle, nozzle holder assy.			D19173−53200		——
	Nozzle			5−0.32 (YDLLA140 P325KO)		——
	Nozzle holder			For TN100		——
	Nozle opening press.			240~250kgf/cm²		——
	Transfer pump press.			4.6kgf/cm²		——
	Injection pipe			φ6.35× φ2×475mm		——
	Test fuel oil			Diesel fuel oil JIS No.2		——
	Fuel temp.			40℃		——

● Direction of rotation : Clockwise (viewed from driving side)
● Injection order : 1-3-4-2-1 (No1 from driving side)





CHAPTER 4

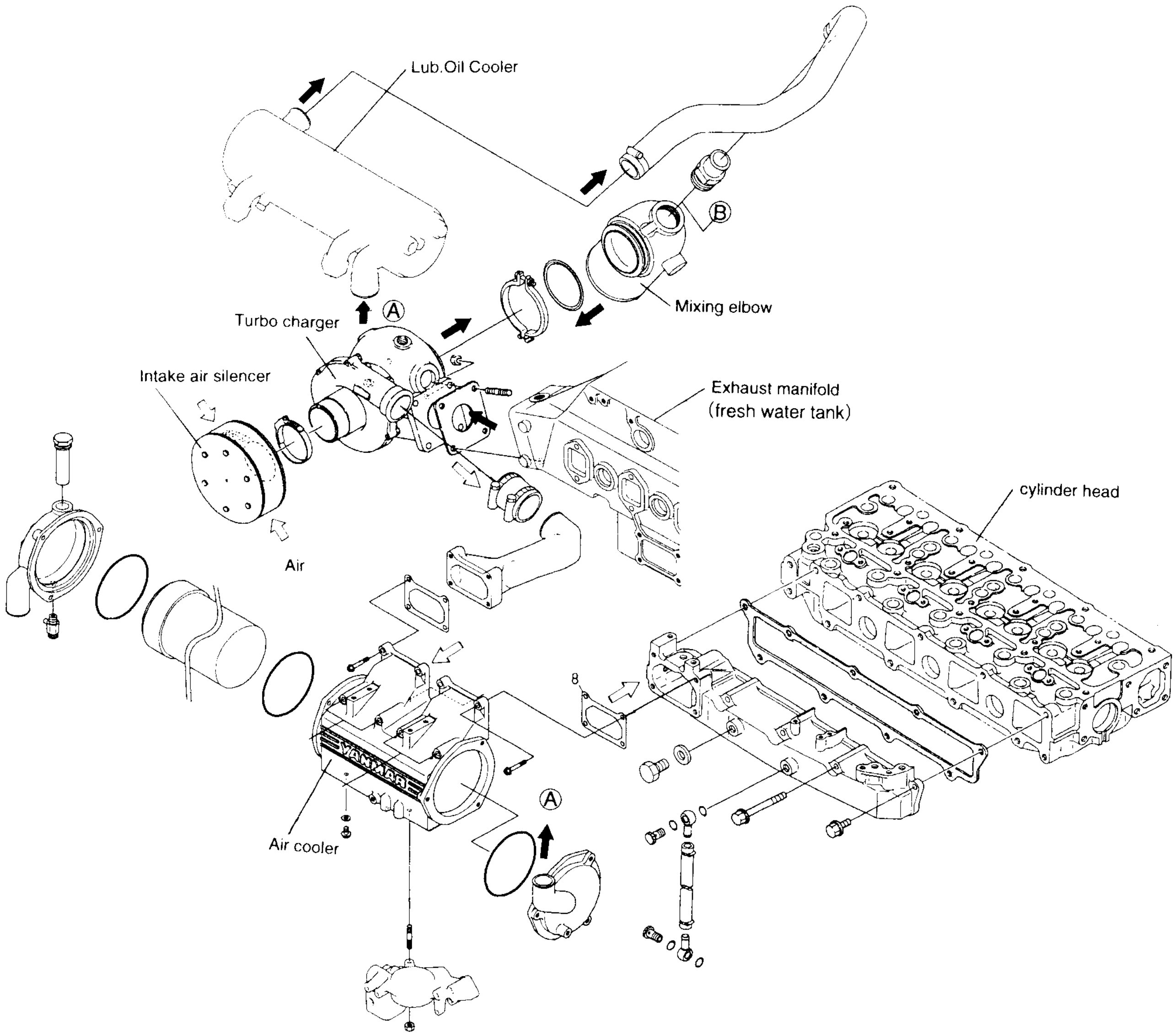
INTAKE AND EXHAUST SYSTEM

1. Intake and Exhaust System.......................................4-1
2. Intake Silencer...4-2
3. Intake Manifold...4-3
4. Turbocharger...4-4
5. Mixing Elbow..4-26
6.Breather...4-27

1. Intake and Exhaust System

1-1 Intake and exhaust system

Air introduced from the intake air silencer passes through the air duct to the air cooler where it is cooled, and is then distributed to each cylinder via the intake manifold.
Exhaust gas goes from heat exchanger (ftesh water tank), through the water-cooled turbocharger to the mixing elbow and is discharged with the sea water.



Air Cooler Specifications

Type	Sea water cooled, plate fin type

NOTE: ⇨ *Charging Air*
➡ *Exhaust gas and Sea-water*

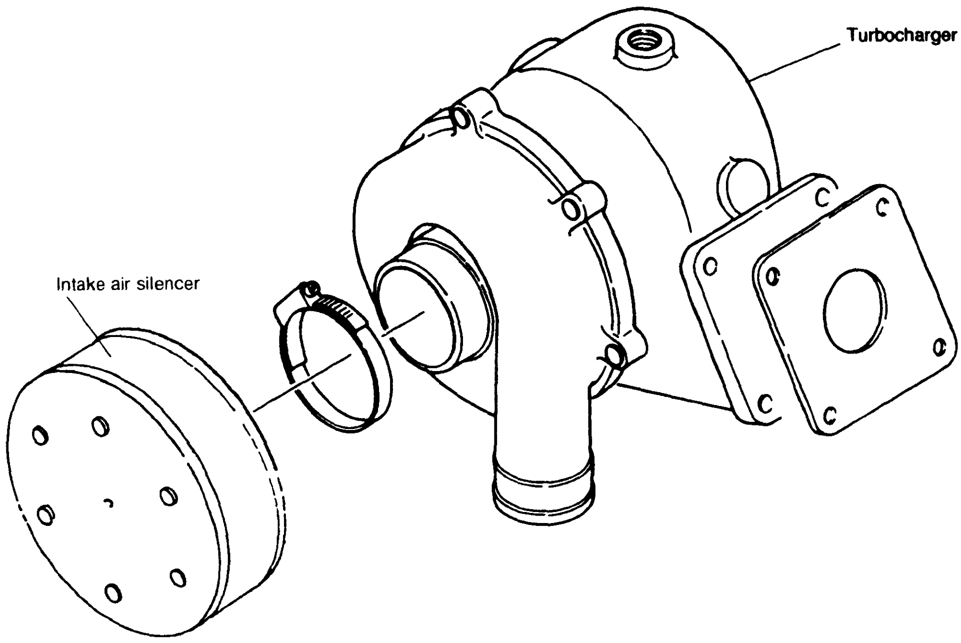
2. Intake Silencer

2-1 Construction

The intake silencer has mesh to reduce noise.

2-2 Intake silencer inspection

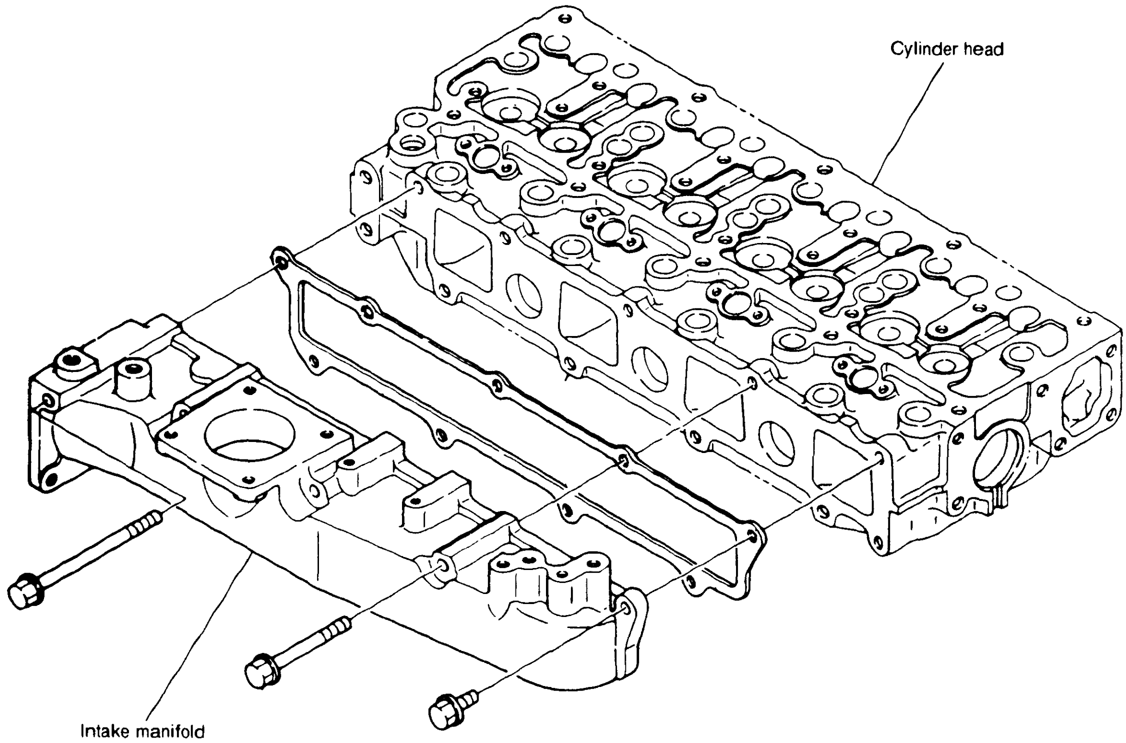
(1) Wash the steel mesh of the intake silencer with a neutral detergent every 300 hours operation. If welds are cracked or corroded, repair or replace as necessary.



3. Intake Manifold

3-1 Inspection

(1) Make sure that air flows through smoothly and clean out any dirt. Replace if it is excessively corroded, cracked or otherwise damaged.
(2) Inspect the gasket packings and replace if damaged.
(3) On models equipped with an air heater between the manifold and coupling, inspect the nickel-chrome wires for breakage, damaged contacts, etc.,



4 Turbocharger

4 - 1 Construction and Function

4 - 1 - 1 Construction and function

(1) Turbine

The exhaust gas coming out of the engine is accelerated of its flowing speed through the nozzle of the turbine housing and blown against the turbine wheel to give the torque to the turbine shaft. This is called the turbine, in which the seal rings and shrouds are built in to prevent adverse influence to the bearings by the gas.

(2) Blower

The compressor impeller mounted on the turbine shaft receives torque from the turbine shaft, sucks the air and compress it to be fed to the air intake pipe. This is called the compressor or blower.

(3) Bearing

1) Thrust bearing
Since thrust force is continuously applied to the turbine shaft, it is designed to prevent the shaft from movement by the thrust.

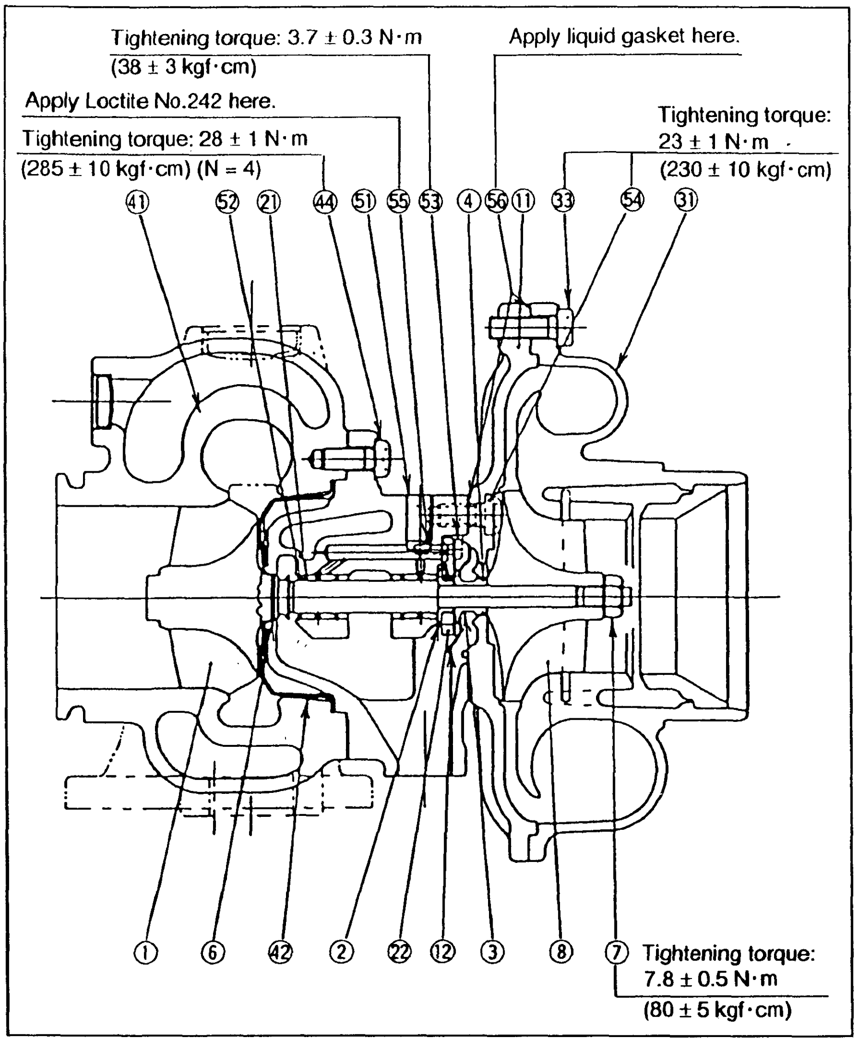
2) Radial bearing
The floating bearing type is adopted. Since this type has double oil film layers at inside and outside surfaces of the bearing, causing the bearing itself to rotate together with the shaft, the slippage speed of bearing is lower than the turbine shaft revolution, thereby, the dynamic stability is improved, when compared with the normal type bearing.

(4) Sealing structure at blower side

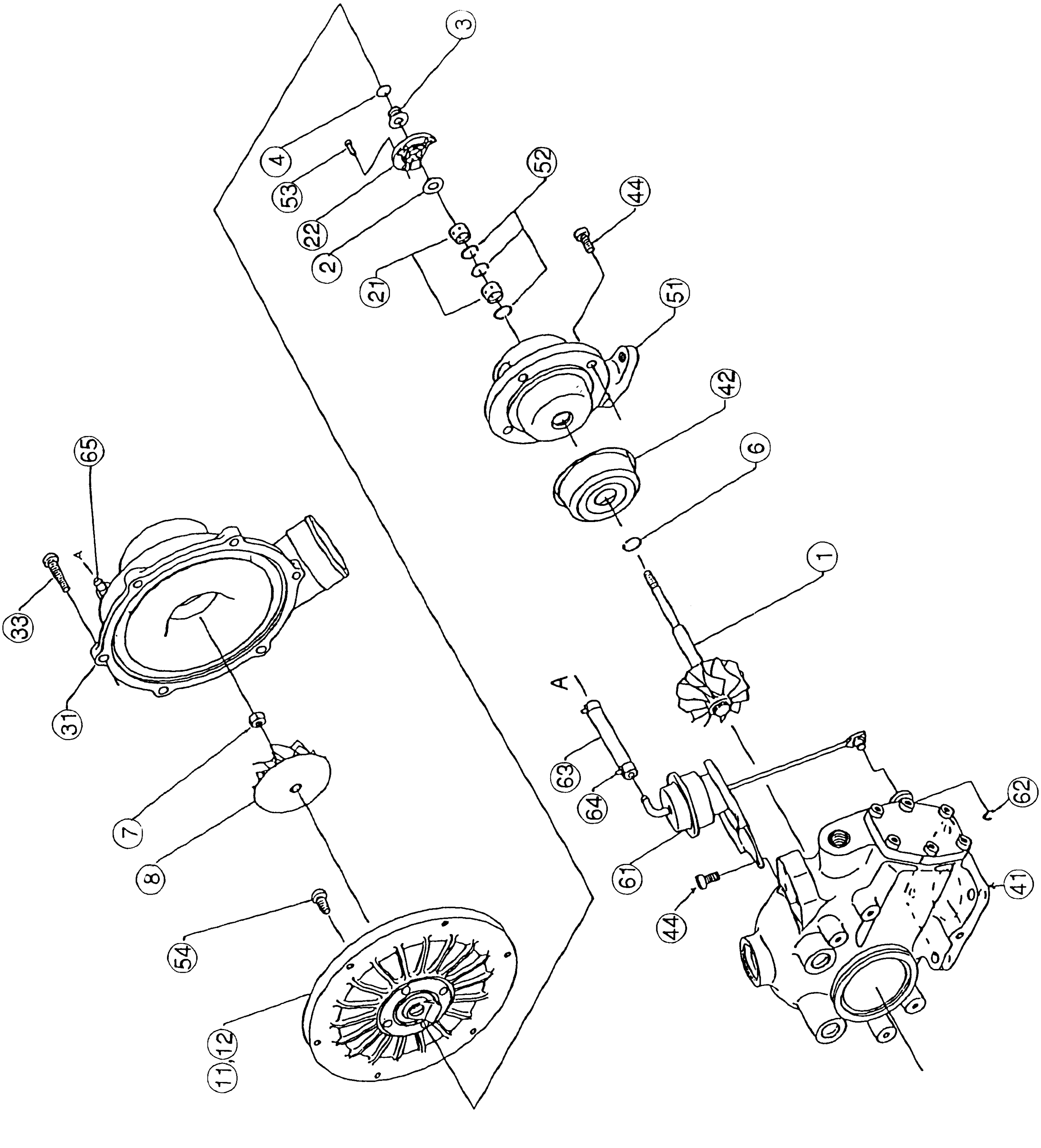
The dual-wall structure is adopted for the rear of compressor housing for preventing leakage of intake air and oil. Further, seal ring and oil defensive plate are provided.

No.	Components	Qty
①	Turbine shaft	1
②	Thrust bushing	1
③	Oil thrower	1
④	Compressor side seal ring	1
⑥	Turbine side seal ring	1
⑦	Shaft end nut	1
⑧	Compressor impeller	1
⑪	Seal plate	1
⑫	Oil defensive plate	1
㉑	Floating bearing	2
㉒	Thrust bearing	1
㉛	Compressor housing	1
㉝	TORX T screw bolt	6
㊶	Turbine housing	1
㊷	Thermal insulation plate	1
㊹	TORX T screw bolt	13
51	Bearing housing	1
52	Retaining ring	3
53	TORX T screw bolt	3
54	TORX T-shape pan head small screw	4
55	Liquid gasket	–
56	Liquid gasket	–
61	Waste gate actuator	1
62	E-type retaining ring	1
63	Boost hose	1
64	Hose clip	2
65	Boost pipe	1

Sectional View (RHC61W model)

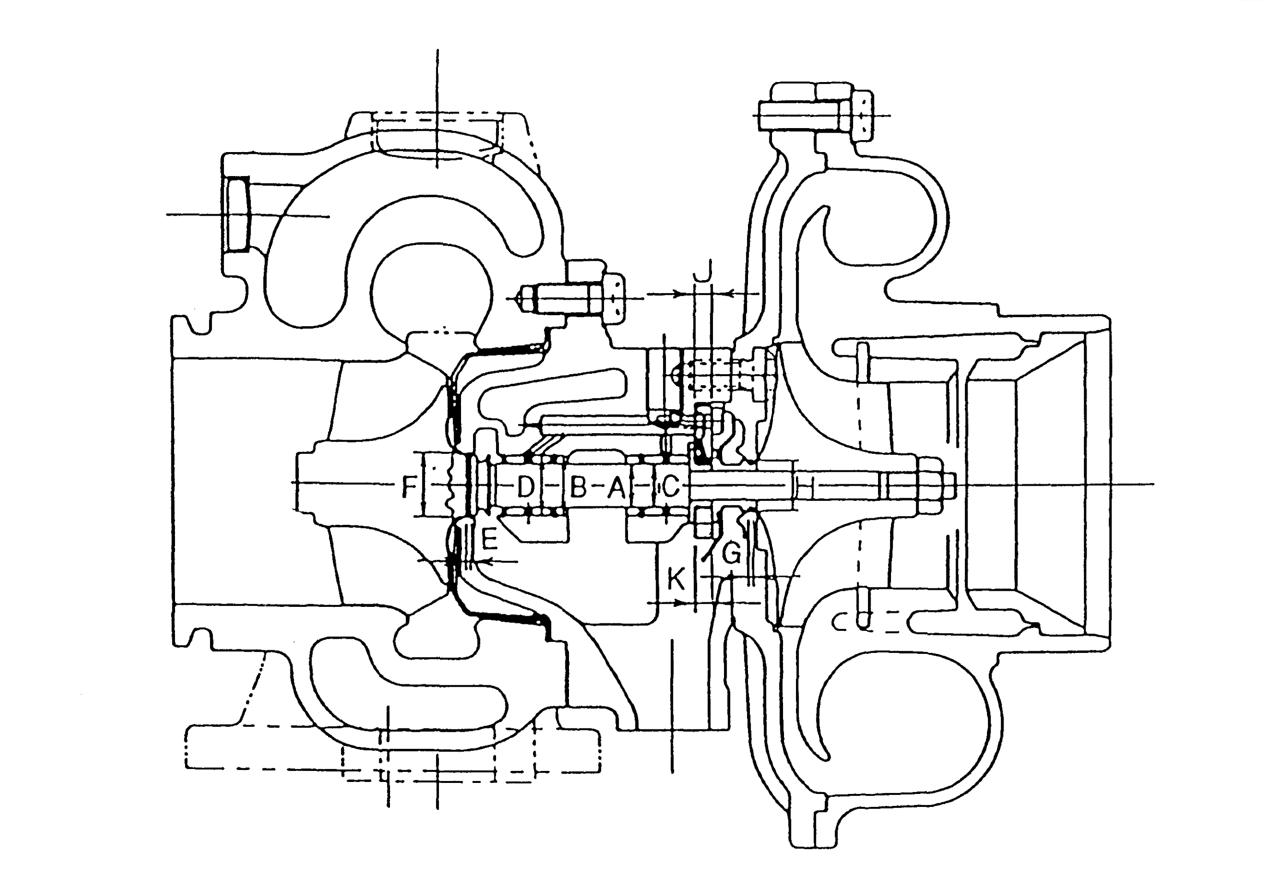


4-2 Components(RHC61W Turbocharger)



4 - 3 Service Specifications

4 - 3 - 1 Service standards



(Unit: mm)

	Inspection item	Usable limit	Remarks
Turbine shaft	Turbine shaft journal outside diameter (A)	11.380	
	Turbine side seal ring groove width (E)	1.330	
	Compressor side seal ring groove width (G)	1.520	
	Turbine shaft runout	0.011	
Bearing	Floating bearing inside diameter (C)	11.460	
	Floating bearing outside diameter (D)	15.980	
	Bearing case inside diameter (B)	16.110	
Thrust bearing	Thrust bearing width (J)	4.280	
	Thrust bushing groove to groove distance (K)	4.480	
Seal ring inserting area	Turbine side (bearing wheel chamber) (F)	17.030	
	Compressor side (seal plate) (H)	14.050	
Turbine shaft play in axial direction		0.110	Service standard: 0.06 to 0.09
Turbine shaft play in radial direction		0.205	Service standard: 0.10 to 0.17

4 - 3 - 2 Nut and bolt tightening torque

Tightening parts	N·m	(kgf·cm)
Turbine housing set bolt (M8)	28 ± 1	285 ± 10
Compressor housing set bolt (M8)	23 ± 1	230 ± 10
Thrust bearing set bolt (M4)	3.7 ± 0.3	38 ± 3
Seal plate set bolt (M8)	23 ± 1	230 ± 10
Compressor impeller set nut (M7) (left-handed thread)	7.8 ± 0.5	80 ± 5
Actuator set bolt (M8)	28 ± 1	285 ± 10
Valve case cover set bolt (M8)	28 ± 1	285 ± 10

4 - 4 Periodic Inspection Procedure

4 - 4 - 1 Periodic inspection intervals

Periodically inspect the turbocharger for the overall conditions and fouling. The checking interval varies with the operating conditions, but refer to the table below as guideline.

—	Inspection interval		
Inspection item	Every 6 months or 1,500 hours	Every 12 months or 3,000 hours	Every 24 months or 6,000 hours
Rotation of turbine shaft	○		
Play of turbine shaft		○	
Overhaul and inspection			○

4 - 4 - 2 Inspection procedure

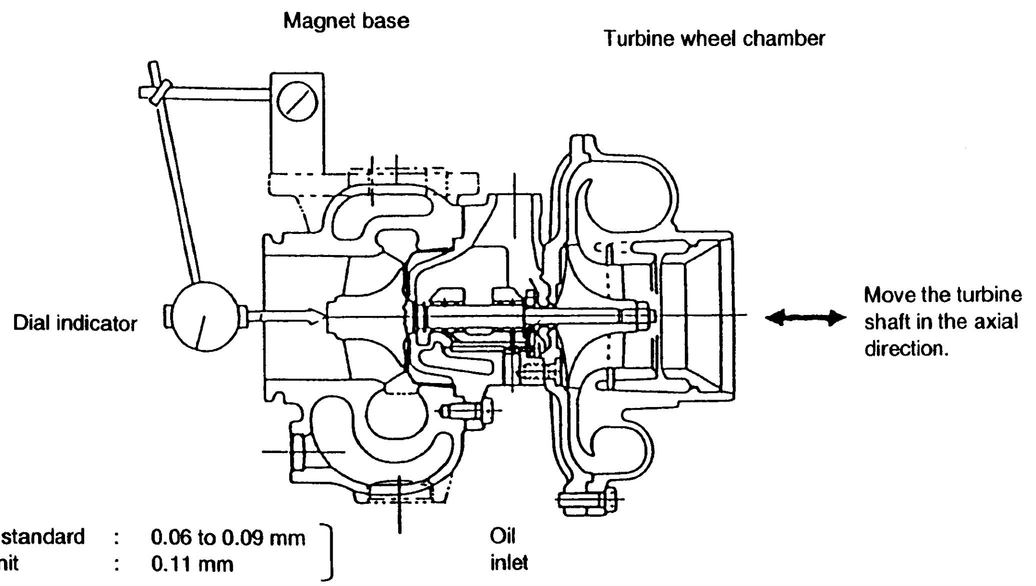
(1) Rotation of turbine shaft

Inspect the turbine shaft operation by listening to any abnormal sounds during running. For inspection using a listening bar, bring the tip end of the bar into strong contact with the turbocharger case and raise the engine speed gradually. If any high pitch sounds are generated at intervals of 2 to 3 seconds, the rotation is abnormal. Since the bearing or rotor may be defective in this case, either replace or overhaul the turbocharger.

(2) Inspection of turbine shaft play

Remove the turbocharger from the engine and inspect the turbine shaft play in the axial and radial directions according to the procedures below.
After removing the turbocharger from the engine, always blind the oil inlet and outlet ports with gummed tape.

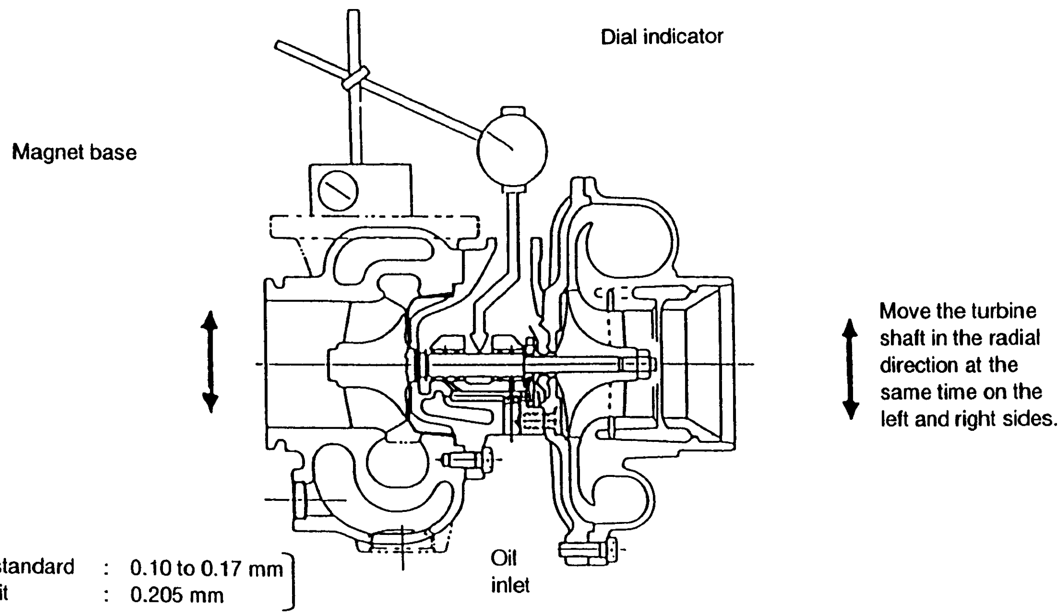
1) Turbine shaft play in axial direction



Service standard : 0.06 to 0.09 mm
Wear limit : 0.11 mm

(Play in axial direction)

2) Turbine shaft play in radial direction



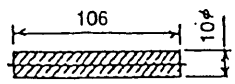
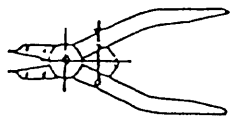
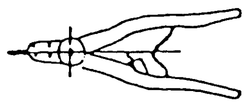
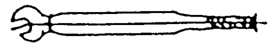
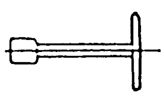
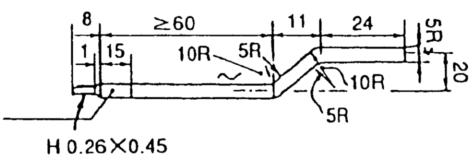
Service standard : 0.10 to 0.17 mm
Wear limit : 0.205 mm

(Play in radial direction)

4 - 5 Disassembly Procedure

4 - 5 - 1 Preparation for disassembly

In addition to the general tools, the following special tools are required for disassembling and reassembling the turbocharger.

Tool name	Use	Illustration
Bar	For removing thrust bearing and thrust bushing	 Material: Copper or brass
Pliers	For removing and installing floating bearing retaining ring	
Pliers	For removing and installing seal ring	
Torque screwdriver for TORX bolt (Universal type) 5 to 50kgf·cm (0.49 to 4.90 N·m)	For installing thrust bearing, for M4 [1.27±0.1N·m(13kgf·cm)]	Available in the market  (Type: TORX TT20 or equivalent)
Torque wrench for TORX bolt (Universal type)	For installing turbine housing, for M8 [28±1N·m(285kgf·cm)] For installing compressor housing, for M8 [23±1N·m(230kgf·cm)] For installing seal plate, for M8 [23±1N·m(230kgf·cm)]	Available in the market (Type: TORX TT40 or equivalent)
Torque wrench (single purpose type)	For tightening shaft end nut, for M7 [7.84N·m(80kgf·cm)]	
Box spanner	For fixing turbine shaft (14mm x 12 pointed head)	 Box part alone may be used.
Probe	For measuring play in axial and radial directions To be knurled here (rolette)	To be attached to a dial indicator 

4 - 5 - 2 Inspection before disassembly

(1) Check the turbine wheel and compressor impellers for interference with their housings. Also, check that the turbine shaft rotates smoothly.

(2) Measure the turbine shaft play
(See 3.8.4.2.2 Inspection of turbine shaft play)

1) Turbine shaft axial play
Wear limit: 0.110 mm
2) Turbine shaft radial play
Wear limit: 0.205 mm

4 - 5 - 3 Disassembly

[NOTICE]
As mounting angles of the turbine housing, bearing housing and compressor housing of the turbocharger are determined according to their mounting status on the engine, put match marks before beginning disassembly.

(1) Remove the boost hose

1) Move the hose clip 64 to the center of boost hose 63.
2) Disconnect boost hose 63 from compressor housing 31 and waste gate actuator 61.

(2) Remove the compressor housing

1) Remove the M8 TORX T screw bolt 33 using the torque wrench (TT40).
2) Remove compressor housing 31.
Note 1: The liquid gasket is applied to the compressor housing 31 and seal plate 11 mounting surfaces.
Note 2: Pay attention 50 as not to damage the compressor impellers when disassembling the compressor housing.

(3) Remove the compressor impeller

1) Attach the box spanner (14 mm) to the shaft end of turbine shaft 1 on the turbine side and remove the shaft end nut 7.

[NOTICE]
Pay attention to the loosening direction as the shaft end nut has left-handed thread.

2) Remove compressor impeller 8.

(4) Remove the seal plate

1) Loosen M8 TORX T screw bolt ⑭ securing the seal plate, using the torque wrench (TT40).
2) Remove seal plate ⑪.
   Note: Lightly tap the bearing housing side of the seal plate by a wooden hammer.
   Note: The liquid gasket is applied to the seal plate and bearing wheel mounting surfaces.
3) Remove oil thrower ③ from the seal plate.

(5) Remove the turbine housing

1) Remove M8 TORX T screw bolt ㊹ using the torque wrench (TT40).
2) Remove turbine housing ㊶.

(6) Pull off the turbine shaft

1) Lightly and manually secure heat insulation plate ㊷ and pull off turbine shaft ①.
   Note: If the turbine shaft is too tight, lightly tap the shaft end on the blower side by a wooden hammer.
2) Remove heat insulation plate ㊷.

(7) Remove the thrust bearing and thrust bushing

1) Loosen M4 TORX T screw bolt ㊾ securing the thrust bearing, using the screwdriver (TT20).
2) Remove thrust bearing ㉒ and thrust bushing ② using a bar (copper).

(8) Remove the floating bearing

1) Remove floating bearing ㉑ on the compressor side from bearing housing ㊿.
2) Remove retaining ring ㊾ on the turbine side from bearing housing ㊿, using the retaining ring pliers.
3) Remove floating bearing ㉑ on the turbine side from bearing housing ㊿.
4) Remove far-side retaining rings ㊾ of turbine and compressor sides from bearing housing ㊿, using the retaining ring pliers.

(9) Remove the seal ring

1) Remove seal ring ⑥ on the turbine side from turbine shaft ①.
2) Remove seal ring ④ on the compressor side from oil thrower ③.

4 - 6 Cleaning and Checking Procedures

4 - 6 - 1 Cleaning

(1) Checking before cleaning

Before cleaning, visually check each part for any trace of seizure, wear, foreign matter or carbon deposits. When parts are disassembled because of any trouble, carefully check for identifying the cause of trouble at this stage.

<Major checking items>

Check item	Position to be checked
Carbon deposits	1) Turbine side seal ring of turbine shaft ① and turbine wheel backside 2) Mounting portions for bearing housing ㊶ and thermal insulation plate ㊷ and inner wall of bearing housing
Lubrication status (wear, seizure, discoloration, etc.)	1) Journal of turbine shaft ① thrust bushing ② and oil thrower ③ 2) Floating bearing ㉑ and thrust bearing ㉒ 3) Internal circumference of bearing case of bearing housing (51)
Oil leakage	1) Inner wall of turbine housing ㊶ 2) Outer surface of bearing housing (51) and thermal insulation plate ㊷ mounting area 3) Turbine side seal ring ⑥ of turbine shaft ① and turbine wheel backside 4) Inner wall of compressor housing ㉛ 5) Backside of compressor impeller ⑧ 6) Surface of seal plate ⑪ and seal ring ④ inserting area

(2) Cleaning procedure

Part	Tools and detergent	Cleaning procedure
(1) Turbine shaft	1. Tools 1) Washing bucket (500 × 500) 2) Heat source: Steam or gas burner 3) Brush 2. Detergent General carbon removing agent available in the market	1) Immerse the turbine shaft in the washing bucket filled with detergent and warm up. Do not strike the blade to remove the carbon. 2) Immerse in the detergent until the carbon and other deposits are softened. 3) Use a plastic scraper or hard hair brush to remove the softened deposits. 4) Pay full attention so as not to damage the bearing surface and seal ring groove of the turbine shaft. 5) Any deposit remaining on the turbine shaft due to improper washing may cause unbalancing. Be sure to remove thoroughly. Never use a wire brush.
(2) Turbine housing	1. Tools Same as those for turbine shaft 2. Detergent Same as that for turbine shaft	1) Immerse the turbine shaft in the washing bucket filled with detergent and warm up. Do not strike the blade to remove the carbon. 2) immerse in the detergent until the carbon and other deposits are softened. 3) Use a plastic scraper or hard hair brush to remove the softened deposits.
(3) Blower impeller and housing	1. Tools 1) Washing bucket (500 × 500) 2) Brush 2. Detergent	1) Immerse in the detergent filled in the washing bucket until the deposit is softened. 2) Use a plastic scraper or hard hair brush to remove the softened deposits. Never use a wire brush.
(4) Others	(1) Wash all other parts with diesel oil. (2) Clean all lubricating oil paths by blowing with compressed air. (3) Be especially careful so as not to damage and get them rusted.	

4 - 6 - 2 Inspection procedure

(1) Compressor housing㉛

Check the compressor housing for any contact traces with the compressor impeller and defect, dent or cracks at joint surfaces, and replace if it is defective.

(2) Turbine housing㊶

Check for any contact traces with the turbine wheel, separation due to degradation by oxidation of the case surface, thermal deformation or cracks. Replace with a new one if defective.

(3) Compressor impeller ⑧

Check for any contact traces, chipping, corrosion or deformation. Replace with a new one if defective.

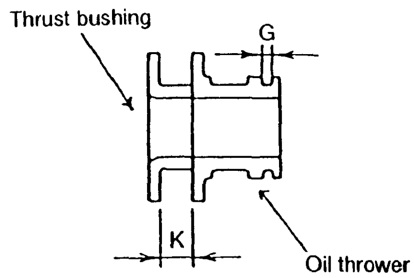
(4) Turbine shaft ①

1) Check for any contact traces, chipping, thermal discoloration or deformation at the turbine wheel. Check the shaft portion for bend, the journal portion for thermal discoloration or abnormal wear, and the seal ring groove for surface defect or wear. Replace with a new one if defective.
2) Measure the outside diameter (A) and seal ring groove width (E) of the turbine shaft journal. Replace with a new turbine shaft if beyond the wear limit.
   Wear limit of journal outside diameter (A):
   11.38 mm
   Wear limit of seal ring groove width (E):
   1.33 mm
3) Measure runout of the turbine shaft. Replace with a new one if measured runout exceeds 0.011 mm.

(5) Thermal insulation plate㊷

Check the thermal insulation plate for any contact traces, thermal deformation or corrosion. Replace with a new one if defective.

(6) Thrust bushing ②, oil thrower ③ and thrust bearing㉒



(Measuring dimensions of thrust bushing)

Check each part for wear, surface defect and discoloration. Replace with a new one if defective even if dimensions G and K are within the wear limit.

1) **Thrust bushing ②**
   Measure the seal ring groove width (K) of the thrust busing. Replace with a new one if the measured value exceeds the wear limit.

   Wear limit: 4.48 mm

2) **Oil thrower ③**
   Measure the seal ring groove width (G). Replace with a new one if the measured value exceeds the wear limit.

   Wear limit: 1.52 mm

3) **Thrust bearing㉒**
   Measure the thrust bearing width (J). Replace with a new one if the measured value exceeds the wear limit.

   Wear limit: 4.28 mm

(7) Floating bearing㉑

1) Check the floating bearing for abnormal wear, discoloration or surface defect. Replace with a new one if defective.

2) Measure inside diameter (C) and outside diameter (D) of the bearing.
   If it exceeds the wear limit, replace.
   Wear limit
   Outside diameter: 15.98 mm
   Inside diameter: 11.46 mm

(8) Bearing housing ⑤①

1) Check the castings surface for separation, dents and cracks caused by oxidation degradation. Replace faulty parts with new ones.

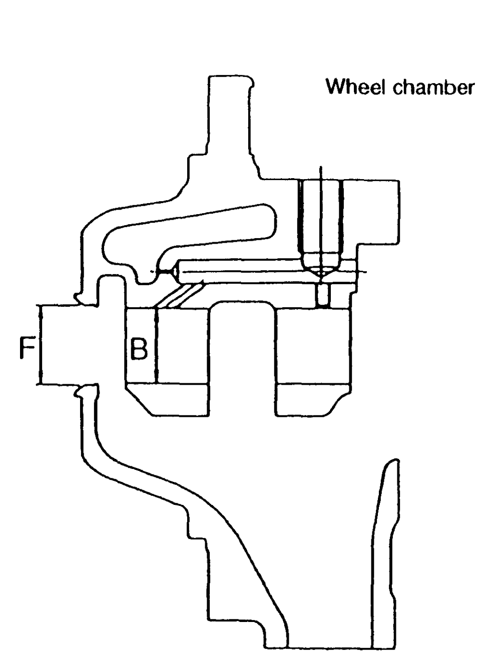
2) Check the retaining ring ⑤② for breakage and cracks. Replace with a new one if defective.

3) Measure dimensions (B) and (F) of the bearing housing shown in the illustration. Replace if either measured value exceeds the wear limit.

   Bearing housing inside diameter (B)
   Wear limit: 16.11 mm

   Seal ring insertion hole on turbine side (F)
   Wear limit: 17.03 mm

(Measuring dimensions of bearing housing)

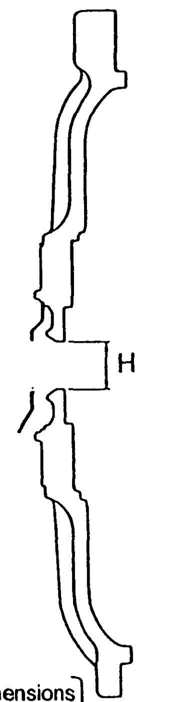


(9) Seal plate ⑪

1) Check the seal plate for any contact traces and defect, dent or cracks of the joint surfaces. Replace with a new one if defective.

2) Measure the seal ring insertion hole (H) on the compressor side.
   Replace the seal ring with a new one if the measured value exceeds the wear limit.

   Wear limit: 14.05 mm



[Measuring dimensions of seal plate]

(10) Seal rings ④ and ⑥

Replace seal rings with new ones.

(11) Check bolts, etc. for deformation.

Replace with new ones if defective. Also, replace the M4 and M8 TORX T screw bolt ⑤④ and ⑤③ with new ones.

4 - 7 Reassembly Procedure

4 - 7 - 1 Preparation for reassembly

(1) Prepare tools

Prepare general tools, special tools, liquid gasket (Three Bond No.1207) and LOCTITE No.242 before reassembling the turbocharger.

(2) Replace the parts

Always replace the following parts with new ones:

Turbine side seal ring ⑥	(1 pc.)
Compressor side seal ring ④	(1 pc.)
M4 pan head small screw 53	(3 pcs.)
M8 pan head small screw 54	(4 pcs.)

4 - 7 - 2 Reassembly

(1) Installation of floating bearing

1) Install retaining rings 52 to bearing housing 51 using the retaining ring pliers.
2) Install the turbine side floating bearing 21 to bearing housing 51.
3) Install the turbine side retaining ring 52 to bearing housing 51 using the retaining ring pliers.
4) Install the compressor side floating bearing 21 to bearing housing 51.

[NOTICE]
- ***The rounded surface of retaining ring faces to the bearing.***
- ***Apply engine oil to the floating bearing before reassembly.***

(2) Installation of turbine shaft

1) Fit seal ring ⑥ onto turbine shaft ①.
2) Install thermal insulation plate 42 to bearing housing 51 on the turbine side.
3) Apply engine oil to the journal portion of the turbine shaft and insert the shaft from the turbine side of bearing housing 51.

[NOTICE]
Pay sufficient attention so as not to damage the floating bearing by the turbine shaft. Position the seal ring end on the lube oil inlet side after centering with the turbine shaft.

(3) Installation of thrust bearing

1) Fit thrust bushing ② on turbine shaft ①.
2) Apply engine oil to the bearing portion of thrust bearing ㉒ and install it in bearing housing 51.
3) Apply Locktite on the threaded portion of M4 TORX T screw bolt 53 used for mounting thrust bearing and install it to the specified torque using the TORX torque screwdriver.
   Tightening torque:
   3.73±0.3N·m(38±3kgf·cm)

(4) Installation of turbine housing

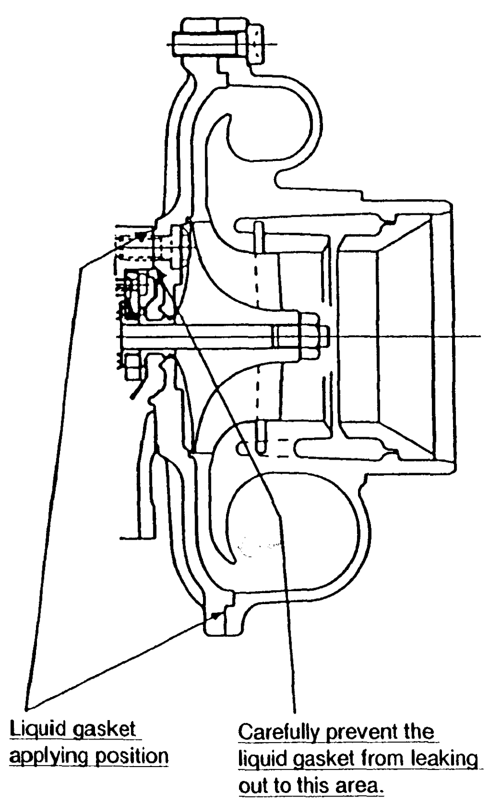
1) Install bearing housing 51 to turbine housing 41, aligning match marks marked before disassembly.

[NOTICE]
If the parts are replaced, install while confirming the oil inlet and outlet positions and the exhaust gas inlet position.

Tighten M8 TORX bolt 44 using the TORX torque wrench.
Tightening torque:
27.95±1N·m(285±10kgf·cm)

(5) Installation of seal plate

1) Fit seal ring ④ to oil thrower ③.
2) Insert oil thrower ③ into seal plate ⑪.
   Note: Position the seal ring end on the oil inlet side.
3) Apply the liquid gasket (Three Bond No.1207) on the flange surface of seal plate ⑪ on the turbine side.
   Note: See the figure on the right for the applying position.
   Liquid gasket thickness: 0.1 to 0.2 mm
4) Install seal plate ⑪ to bearing housing 51.
5) Apply Locktite on the threaded portion of M8 TORX bolt 54 for seal plate mounting, and tighten it with the torque wrench.
   Tightening torque:
   22.56±1N·m(230±10kgf·cm)



[Applying liquid gasket to seal plate and compressor housing]

(6) Installation of compressor impeller

1) Fit compressor impeller onto turbine shaft ①.
2) Set a box spanner (14 mm) on the turbine side end of turbine shaft ① and tighten shaft end nut ⑦.

[NOTICE]
Since the shaft end nut has the left-handed thread, pay attention to the tightening direction.

Tightening torque:
7.84±0.5N·m(80±5kgf·cm)

(7) Installation of compressor housing

1) Apply the liquid gasket (Three Bond No.1207) to the compressor side flange surface of seal plate ⑪.

   Note: For the applying position, see 3.8.7.2.5.
   Liquid gasket thickness: 0.1 to 0.2 mm

2) Assemble compressor housing ㉛ to bearing housing ㉛, aligning match marks marked before disassembly.

[NOTICE]
If the parts are replaced, install while confirming the oil inlet and outlet positions and the exhaust gas inlet position.

3) Tighten M8 TORX bolt ㉝ using the TORX torque wrench.
   Tightening torque:
   22.56±1N·m(230±10kgf·cm)

(8) Installation of boost hose

1) Place hose clip 64 on the center of boost hose 63.
2) Fit boost hose 63 to compressor housing ㉛ and waste gate actuator 61.
3) Move hose clip 64 to the nipple portion of compressor housing ㉛ and waste gate actuator 61, to prevent boost hose 63 from disconnection.

(9) Measurement of turbine shaft play

See the inspection procedure in section 3.8.4.2.2 for the measurement method.
If the turbine shaft play does not satisfy the standard, reassembly is necessary since poor assembly or use of a wrong part is conceivable.

1) Turbine shaft play in axial direction
   Service standard: 0.06 to 0.09 mm
2) Turbine shaft play in radial direction
   Service standard: 0.10 to 0.17 mm

4 - 8 Handling after Disassembly and Reassembly

When installing the turbocharger on the engine or handling the turbocharger after installation, strictly observe the instructions given below.
Especially pay full attention for preventing foreign matter entrance into the turbocharger.

4 - 8 - 1 Instructions for turbocharger installation

(1) Lubrication path

1) Add new engine oil through the oil inlet port before installation on the engine, and manually turn the turbine shaft to lubricate the floating and thrust bearings.
2) Flush the oil inlet pipe from the engine and outlet pipe, and check for crushed pipe and dirt or foreign matter remaining in the pipes.
3) Connect the pipes securely so as to ensure no oil leak from joints.

(2) Intake path

1) Check the intake line for foreign matter or dirt.
2) Connect securely to prevent any air leak from joints with the intake duct and air cleaner.

(3) Exhaust path

1) Check the exhaust system for dirt and foreign matter.
2) Since heat resistant steel nuts and bolts are used for the installation, do not use ordinary nuts and bolts for other use. Always apply anti-seizure agent on set nuts and bolts at tightening. (Use heat resistant bolts for the turbine housing.)
3) Connect exhaust pipes securely to prevent gas leak from each pipe joint.

4 - 9 Troubleshooting

Sufficient turbocharger performance and required engine output cannot be obtained if there is any fault. In such a case, first check each engine part to see if there is any fault. Then, inspect the turbocharger for troubleshooting according to the procedure shown below.

4 - 9 - 1 Excessively dense exhaust smoke

<Insufficient intake air amount>

Possible cause	Corrective action
1) Clogged air cleaner element	Replace or wash the element.
2) Blocked air intake port	Remove obstruction.
3) Leak from a joint in intake line	Inspect and repair.

<Turbocharger operation failure>

Possible cause	Corrective action
1) Deposit of impurities in oil sticking on the turbine side seal portion to hamper smooth turbine shaft rotation	• Turbocharger overhaul (disassembly and washing) and engine oil replacement
2) Bearing seizure • Insufficient lubrication or clogged lubrication piping • Excessively high oil temperature • Unbalanced rotating part • Insufficient warming up or sudden stop from loaded operation (no-load operation)	• Turbocharger overhaul (disassembly and repair) Inspect the oil system of the engine and repair faulty parts and replace the engine oil. • Replace or wash the faulty rotating part. • Strictly observe instructions in the operation manual.
3) Contact or breakdown of turbine wheel or compressor impeller • Over speed • Excessive exhaust temperature rise • Foreign matter invasion • Worn bearing • Faulty assembly	• Inspect and repair faulty engine parts. • Completely remove foreign matter after disassembling. Inspect the air cleaner and engine parts and repair as needed. • Disassemble turbocharger for repair. • Reassemble.

<Influence of exhaust resistance >

Possible cause	Corrective action
1) Exhaust gas leak before the turbocharger to decrease its speed	• Check the mounting portions and repair as needed.
2) Since exhaust piping is deformed or clogged, turbocharger speed does not increase.	• Repair the pipe to the normal operating condition.

4 - 9 - 2 White exhaust gas color

Possible cause	Corrective action
1) Oil flows to the compressor or turbine side due to clogged oil return pipe.	• Repair or replace the piping.
2) Abnormal wear or breakage of seal ring by excessive wear of bearing	• Disassemble and repair the turbocharger.

4 - 9 - 3 Excessive engine oil consumption

Possible cause	Corrective action
1) Abnormal wear or breakage of seal ring by excessive wear of bearing	• Disassemble and repair the turbocharger.

4 - 9 - 4 Engine output drop

Possible cause	Corrective action
1) Gas leak at exhaust system	• Check for faulty part and repair.
2) Air leak from discharge side of compressor	
3) Clogged air cleaner element	• Wash or replace the element.
4) Dirty or damaged turbocharger	• Disassemble and repair or replace the turbocharger.

4 - 9 - 5 Poor (slow) response (starting) of turbocharger

Possible cause	Corrective action
1) Hard carbon deposit on the turbine side (wheel sealing) to hamper turbine shaft smooth rotation	• Replace engine oil and wash the turbocharger after disassembly.
2) Incomplete combustion	• Check the engine combustion system and take corrective action to obtain good combustion.

4 - 9 - 6 Abnormal sound or vibration

<Abnormal sound>

Possible cause	Corrective action
1) Excessively narrowed gas path due to clogged nozzle in turbine housing or reverse flow of blower discharge during acceleration (generally called surging)	• Disassemble and wash the turbocharger.
2) Contacting rotating parts	• Disassemble and repair or replace the turbocharger.

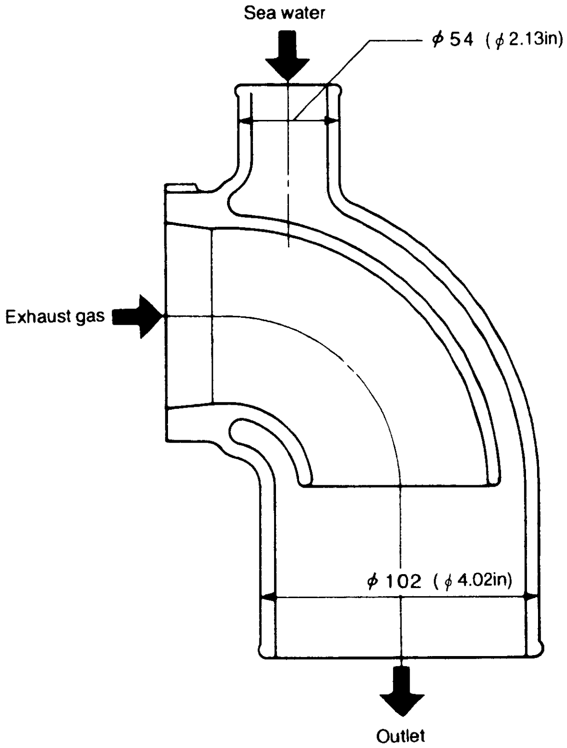
<Abnormal vibration>

Possible cause	Corrective action
1) Loose intake, exhaust or oil pipe connection with the turbocharger	• Check pipe connections of the turbocharger and repair as needed.
2) Chipping of turbine wheel or compressor impeller caused by contacting between rotating part and adjacent parts due to damaged bearing, or invasion by foreign matter	• Disassemble and repair or replace the turbocharger. If foreign matter has invaded, completely remove it.
3) Unbalanced rotating part	• Repair or replace the rotating part.

5. Mixing Elbow

5-1 Mixing elbow inspection

(1) Clean dirt and scale out of the air and cooling water lines.
(2) Repair cracks or damage to welds, or replace.
(3) Inspect the gasket packing and replace as necessary.



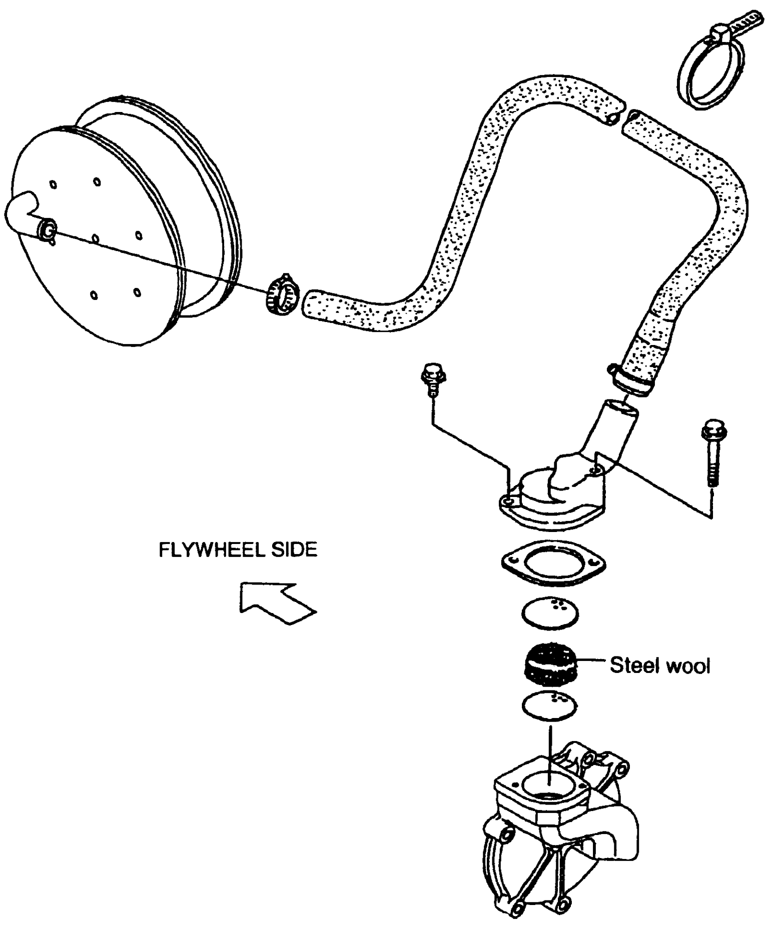
6. Breather

6-1 Construction

The mist in the crank chamber goes past the tappets in the cylinder block to the valve arm chamber, through the breather hose on the bonnet (head) cover, and to the outside.

6-2 Breather inspection

(1) Check to see whether the breather pipe is clogged up, and clean if necessary. Replace the pipe if damaged or cracked.



CHAPTER 5

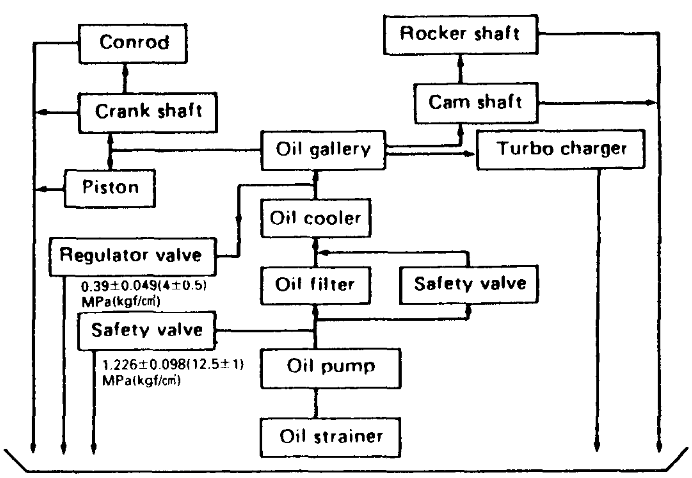
LUBRICATION SYSTEM

1. Lubrication System 5-1
2. Lube Oil Pump 5-3
3. Lube Oil Filter 5-6
4. Oil Pressure Control Valve 5-8
5. Lube Oil Cooler 5-9
6. Piston Cooling Nozzle 5-10
7. Rotary Waste Oil Pump (Optional) 5-11

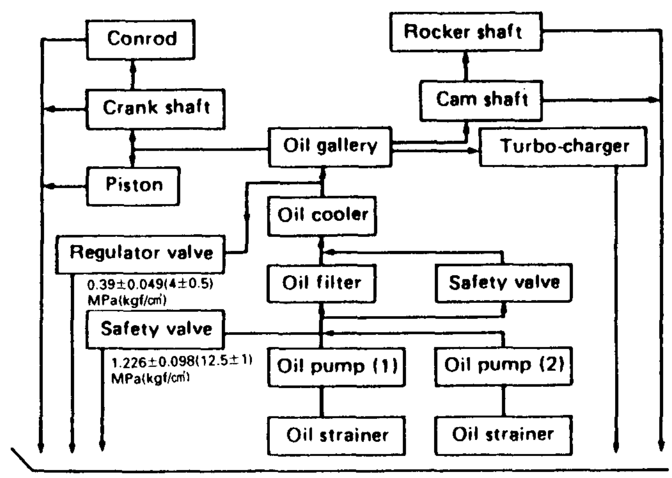
1. Lubrication System

The lube oil in the oil pan is pumped up through the intake filter and intake piping by the lube oil pump, through the holes in the cylinder body and on to the discharge filter.
The lube oil which flows from the holes in the cylinder body through the bracket to the oil element is filtered and sent to the oil cooler. It returns from the oil cooler to the bracket, the pressure is regulated, and it is fed back to the main gallery in the cylinder body.
The lube oil which flows in the main gallery goes to the crankshaft journal, lubricates the crank pin from there and a portion of the oil is fed to the camshaft bearings.
Oil is sent from the gear case camshaft bearing through the holes in the cylinder body and cylinder head to the valve arm shaft to lubricate the valve arm and valves.
Oil is also sent from the main gallery to the piston cooling nozzle to cool the piston surface, and is sent through the intermediate gear bearing (oil) holes to lubricate the intermediate gear bearings and respective gears.
Part of the lube oil is sent from the oil cooler discharge to the supercharger in engines fitted with one, and is then piped back from the supercharger to the oil pan.

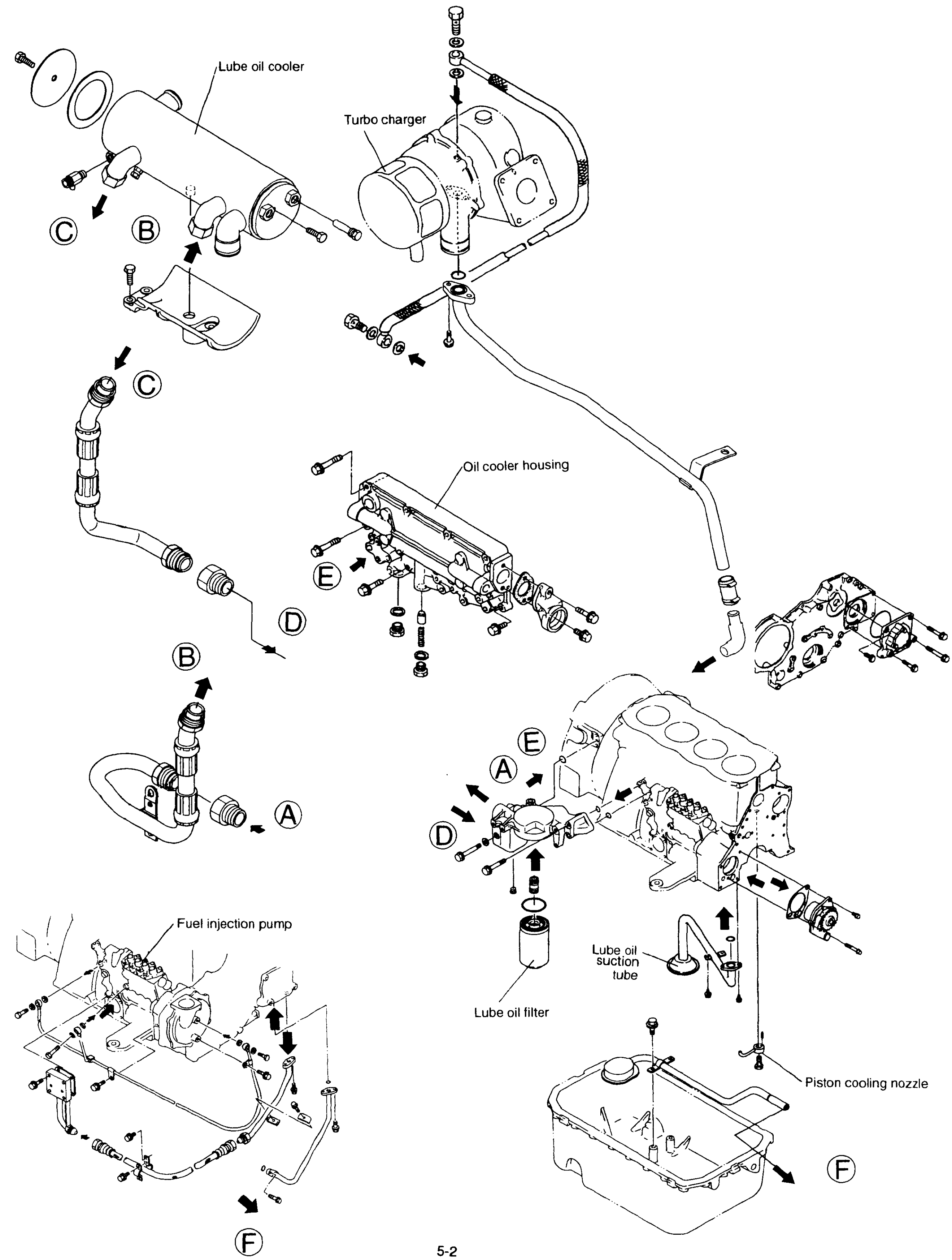
4LHA-HTE/HTZE/HTP/HTZP



4LHA-DTE/DTZE/DTP/DTZP
4LHA-STE/STZE/STP/STZP



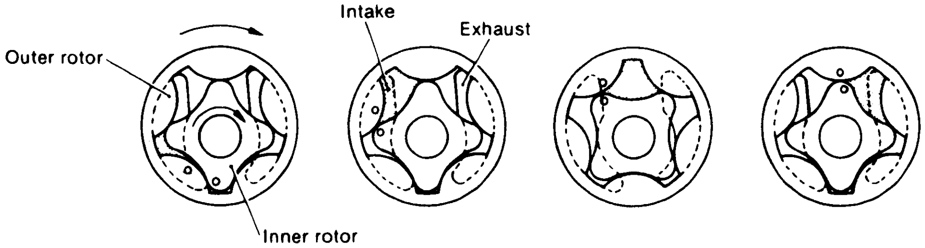
1-1 Construction

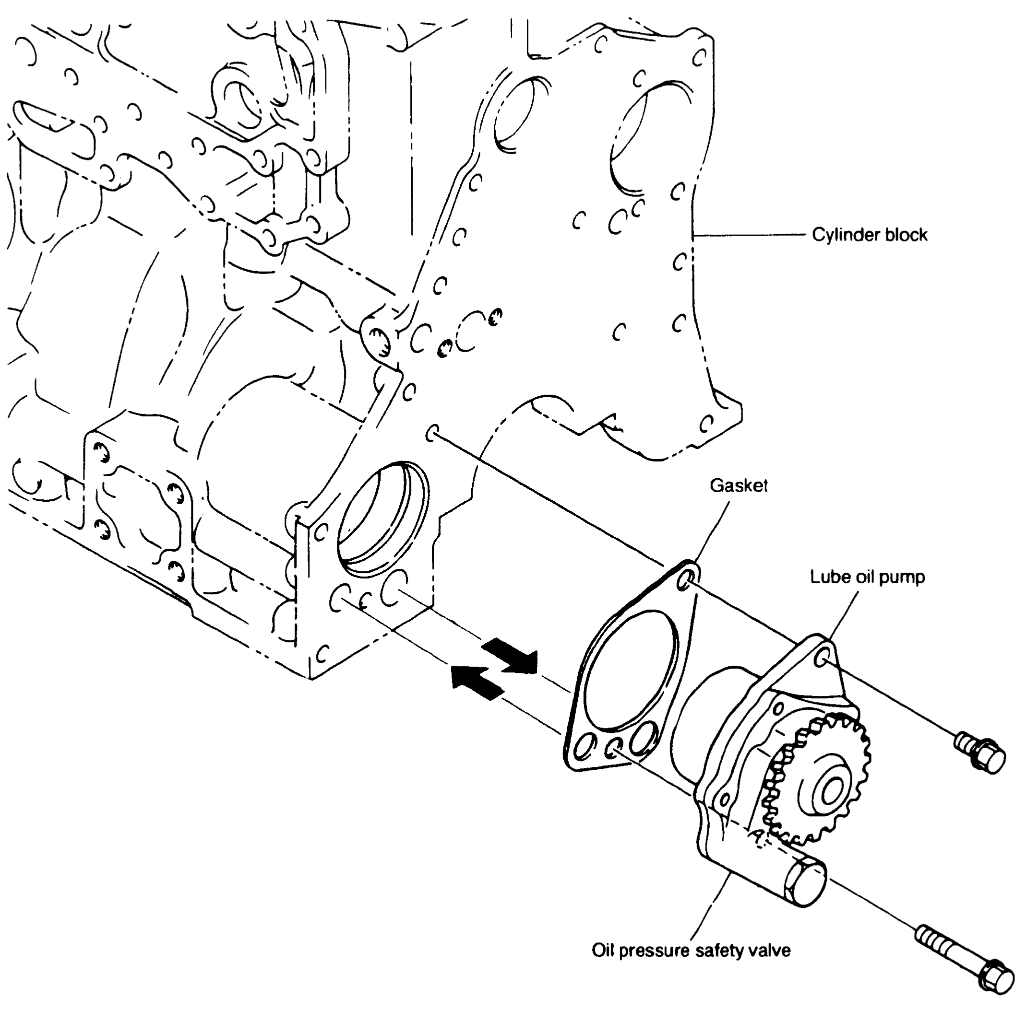


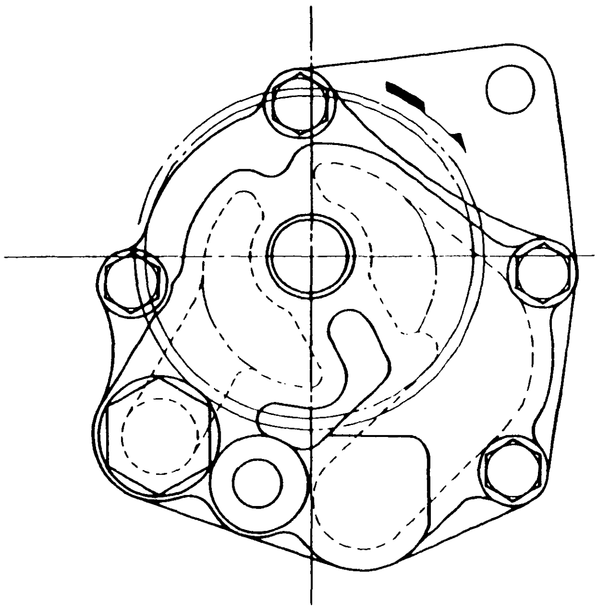
2. Lube Oil Pump

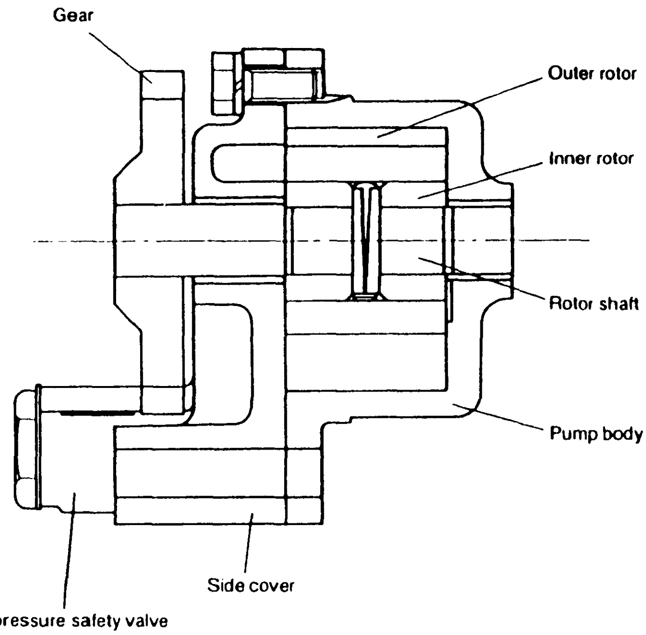
2-1 Lube oil pump construction

The trochoid type lube oil pump is mounted on the gear case side cylinder block and the rotor shaft gear is driven by the crankshaft gear through the idle gear.
The lube oil flows from the intake filter mounted on the bottom of the cylinder block through the holes in the cylinder block and gear housing, and out from the holes in the gear housing and cylinder block to the discharge filter. The lube oil pump is fitted with a pressure safety valve which maintains the discharge pressure at 0.39(4)MPa (kgf/cm²)









2-2 Specifications of lube oil pump

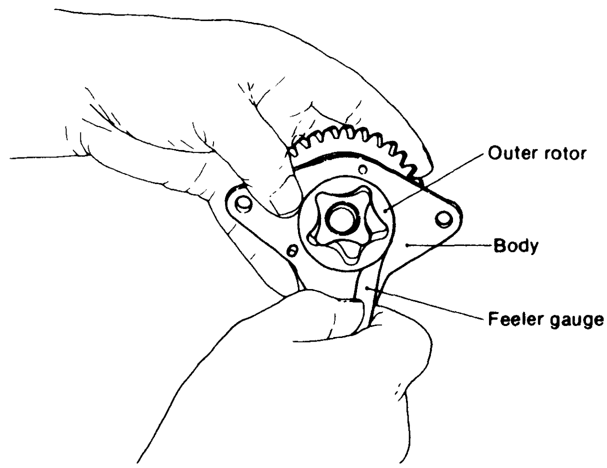
	4LHA-HTE	4LHA-DTE
Engine speed	3400 rpm	3400 rpm
Gear ratio (crank gear/pump gear)	24/22=1.02	24/22=1.02 24/27=0.89
Pump speed at 3300 rpm (Engine)	3468 rpm	3468/3026 rpm
Discharge volume	2600 ℓ/H	Total 3700 ℓ/H
Discharge pressure	0.39(4) MPa(kgf/cm²)	0.39(4) MPa(kgf/cm²)
Safety valve openning pressure	1.18(12) MPa(kgf/cm²)	1.18(12) MPa(kgf/cm²)

2-3 Lube oil pump disassembly

(1) Remove the lube oil pump assembly from the engine plate.
(2) The lube oil pump cover may be disassembled, but do not disassemble the rotor, rotor shaft or drive gear. The oil pressure regulating valve plug is coated with adhesive and screwed in, so it cannot be disassembled. These parts cannot be reused after disassembly. Replace if necessary as an assembly.

2-4 Lube oil pump inspection

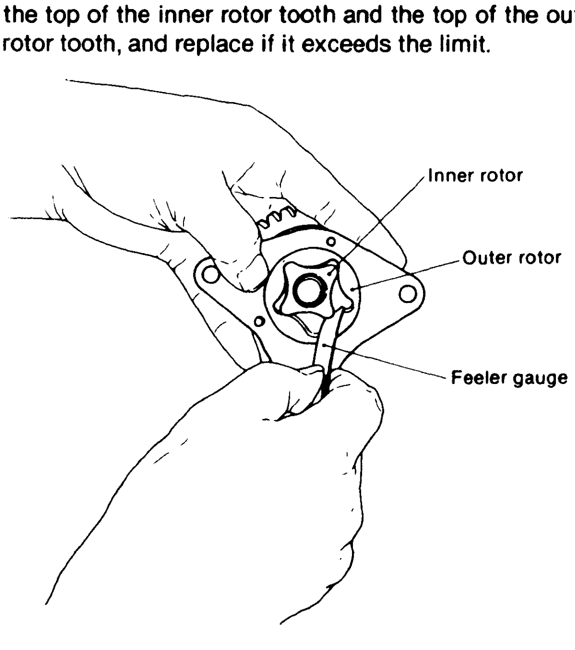
(1) Clearance between outer rotor and pump body
Insert a feeler gauge between the outer rotor and pump body to measure the clearance, and replace if it exceeds the limit.

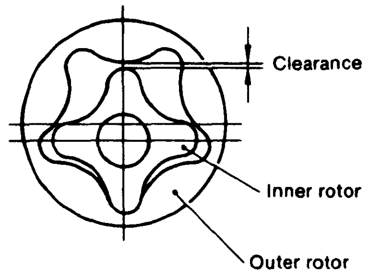


mm (in.)

	Standard	Wear limit
Outer rotor and pump body clearance	0.100 ~ 0.155 (0.0039 ~ 0.0061)	0.20 (0.0098)

(2) Clearance between outer rotor and inner rotor
To measure clearance, insert a feeler gauge between the top of the inner rotor tooth and the top of the outer rotor tooth, and replace if it exceeds the limit.

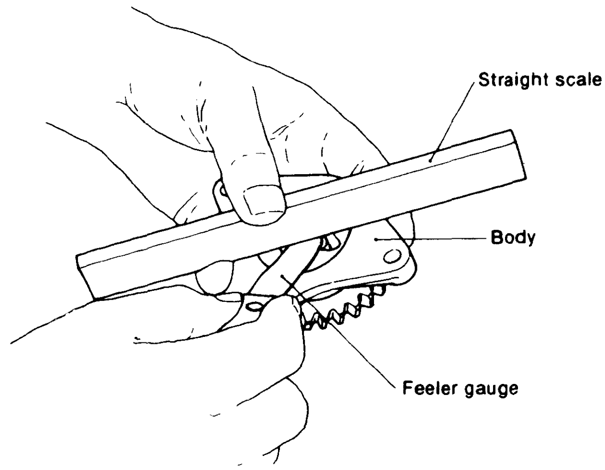




mm (in.)

	Standard	Wear limit
Outer rotor and inner rotor clearance	0.050 ~ 0.105 (0.0019 ~ 0.0041)	0.15 (0.0059)

(3) Clearance between pump body and inner rotor side of outer rotor
Place a straight-edge against the end of the pump body and insert a feeler gauge between the straight-edge and the rotor to measure side clearance. Replace the assembly if the clearance exceeds the limit.



mm (in.)

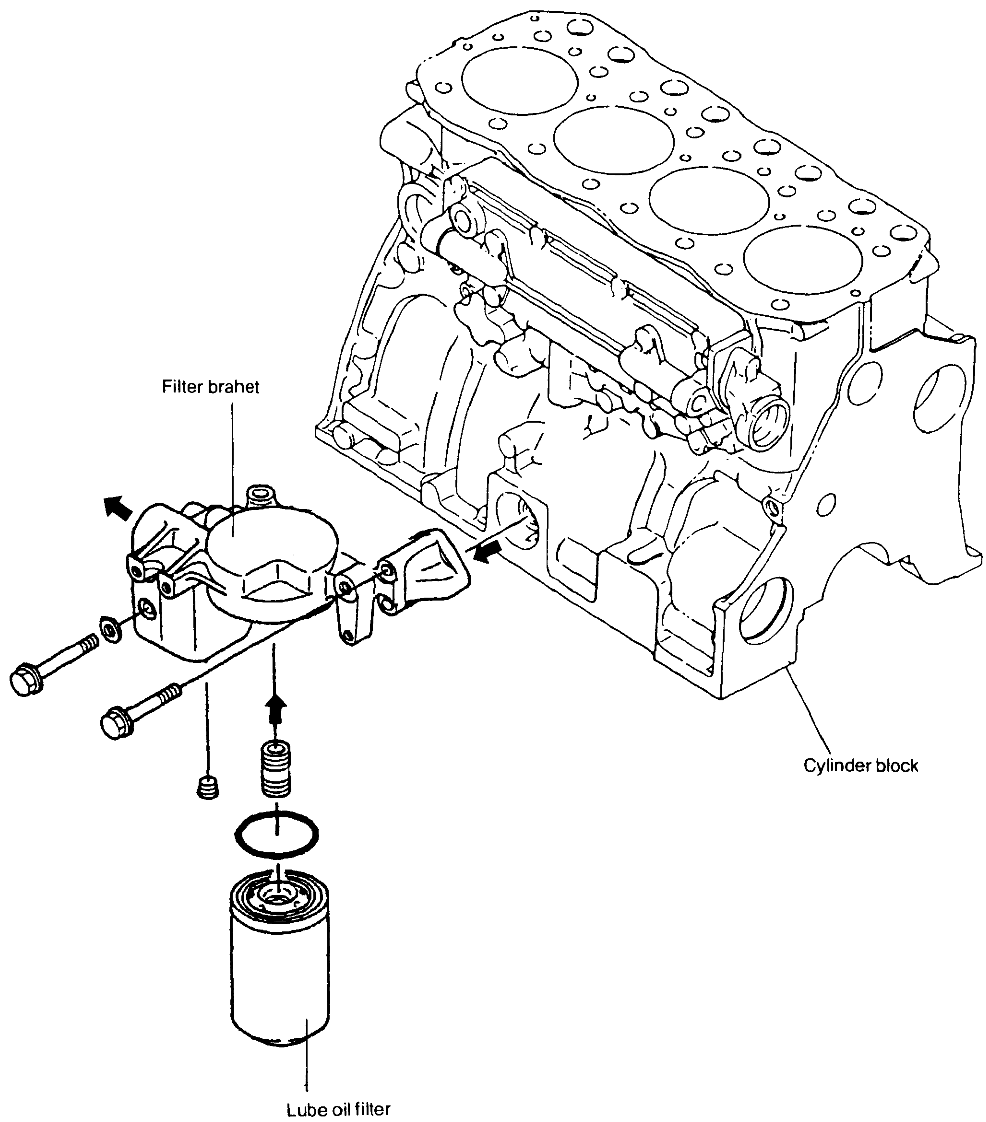
	Standard	Wear limit
Pump body and inner rotor, outer rotor clearance	0.05 ~ 0.10 (0.0020 ~ 0.0039)	0.13 (0.0051)

(4) Check for looseness of driver gear/rotor shaft fitting, and replace the entire assembly if loose or wobbly.
(5) Push the oil pressure regulating valve piston from the oil hole side, and replace the assembly if the piston does not return due to spring breakage, etc.
(6) Make sure that the rotor shaft rotates smoothly and easily when the drive gear is rotated.

3. Lube Oil Filter

3-1 Lube oil filter construction

The lube oil filter is a full-flow paper element type, mounted to the side of the cylinder block. It is an easy to remove cartridge type filter. To prevent seizure in the event of the filter clogging up, a bypass circuit is provided in the oil filter. The bypass valve in the filter element opens when the difference in pressure in front and behind the paper element reaches 0.078~0.118 (0.8~1.2)MPa(kgf/cm²).



3-2 Lube oil filter replacement

(1) Period

The paper element will get clogged up with dirt after long hours of usage, and eventually unfiltered oil will be fed to the engine through the bypass circuit. Replace the filter according to the following standard, as the dirt in unfiltered oil will of course have a detrimental affect on the engine.

Oil filter replacement period	Every 300 hours of engine operation

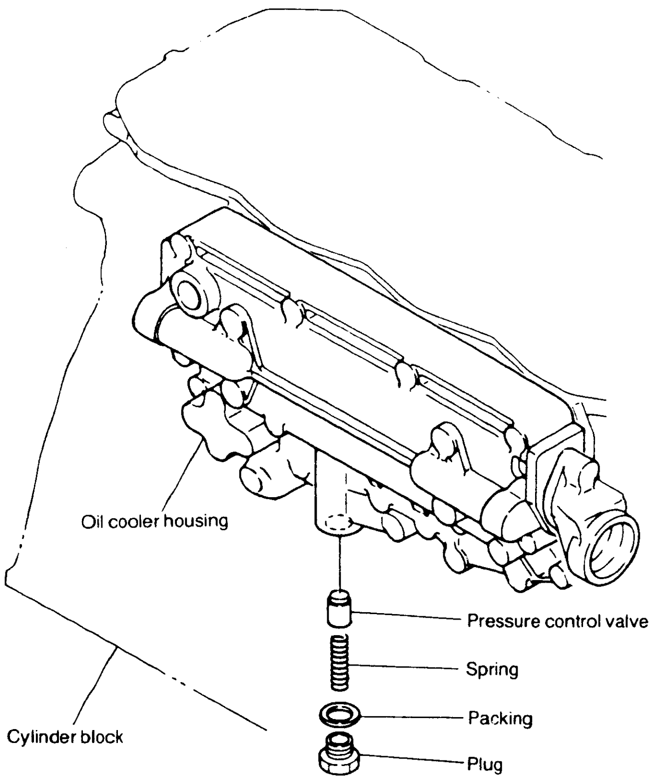
(2) Replacement

1) Remove the lube oil filter with the special tool.
2) Clean the filter mounting surface on the cylinder block and mounting screws.
3) Coat the filter rubber packing with lube oil.
4) Screw in the filter until the rubber packing comes in contact with the mounting surface, and then 2 ~ 3 turns more.
5) Run the engine after mounting the filter, and make sure that there is no oil leakage.

4. Oil Pressure Control Valve

4-1 Oil pressure control valve construction

The oil pressure control valve built into the oil cooler housing controls the oil pressure when the lube oil passes through the oil cooler housing. When the pressure of lube oil exceeds the setting, the control valve piston opens the bypass hole and lube oil flows back into the oil pan.

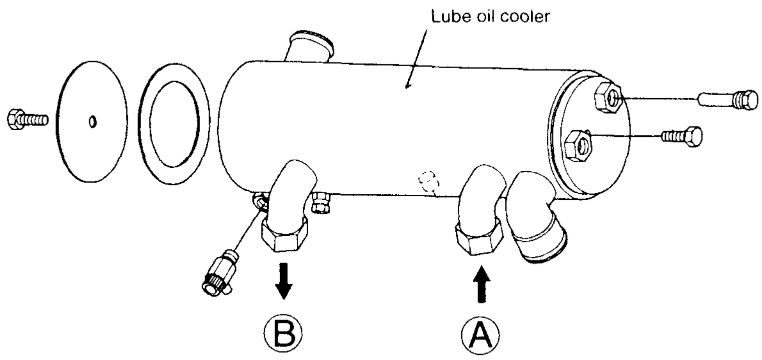


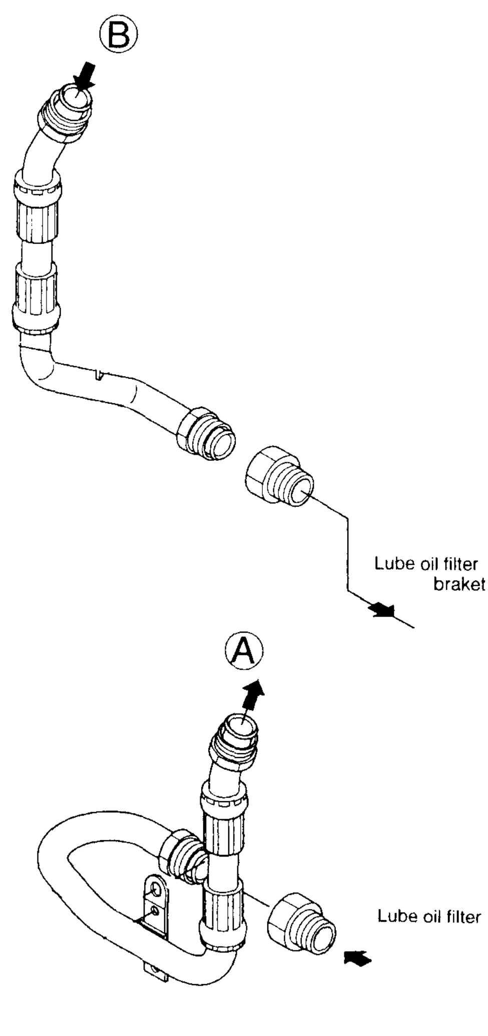
Regulating pressure	0.34 ~ 0.44(3.5~4.5) MPa(kgf/cm²)	at 3,400 rpm

4-2 Oil pressure control valve replacement

The control valve has been adjusted and assembled at the factory, so it should not be disassembled without good reason.

5. Lube Oil Cooler





	4LHA-HTE/-HTZE -HTP/-HTZP	4LHA-STE/STZE -STP/STZP 4LHA-DTE/DTZE -DTP/DTZP
Cooling area	$0.442m^2$	$0.739m^2$
Cooling water discharge volume	6000 ℓ/h	
Lubrication oil discharge volume (3300rpm)	2600 ℓ/h	3700 ℓ/h

5-2 Inspecting the lube oil cooler

(1) Clean the inside of the sea water pipes with a wire brush to prevent the build-up of scale.
(2) If the rubber hose connection or welds are corroded, repairor replace the cooler.
(3) Apply the following water pressures to the sea water and lube oil lines to check for any leakage. Repair or replace the cooler if there are any leaks.

	Test pressure
Lubricating oil circuit	1.47MPa(15kgf/cm²)
Sea water circuit	0.39MPa (4kgf/cm²)

6. Piston Cooling Nozzle

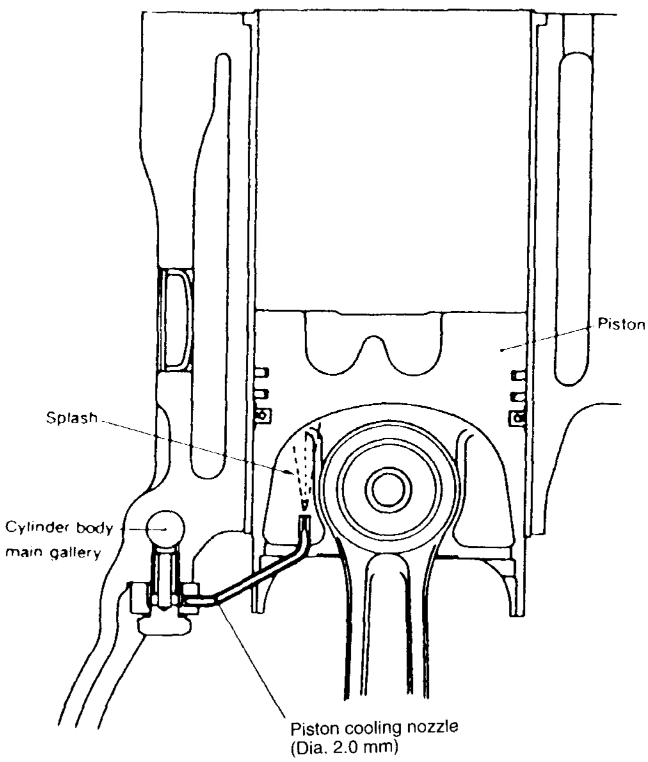
6-1 Piston cooling nozzle construction

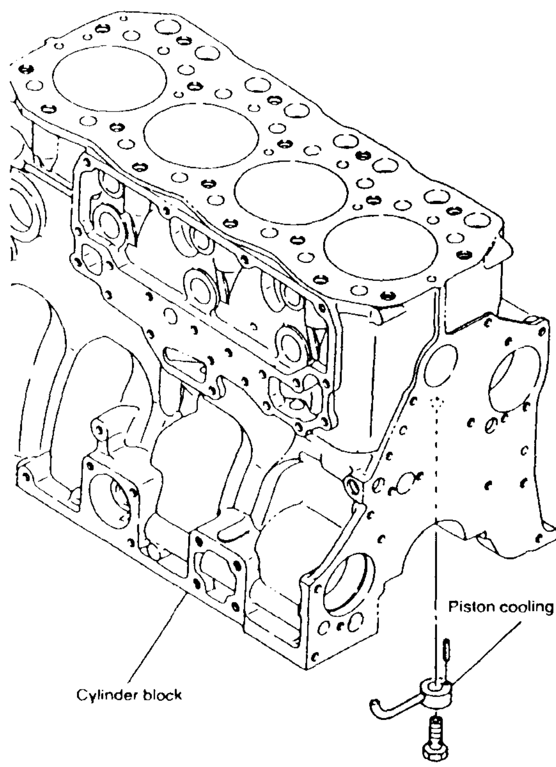
A nozzle made from steel pipe mounted on the lower part of cylinder body main gallery.Lube oil from the main gallery is sprayed out in a jet from the steel tip of this pipe.
This jet spray cools the piston surface when the piston goes down

6-2 Inspection of piston cooling nozzle

(1) Check the nozzle tip hole to see if it is clogged up with dirt or other foreign matter, and clean.
(2) Inspect the pipe mounting to see if it is or may become loose or come off due to vibration, etc., and replace if necessary.

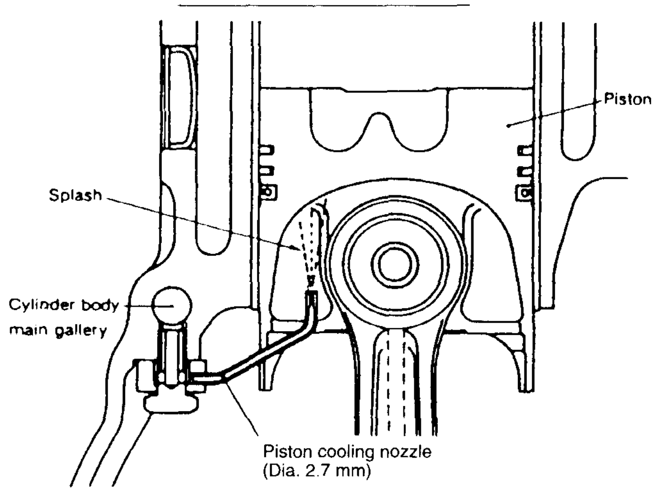
4LHA-HTE/HTZE/HTP/HTZP



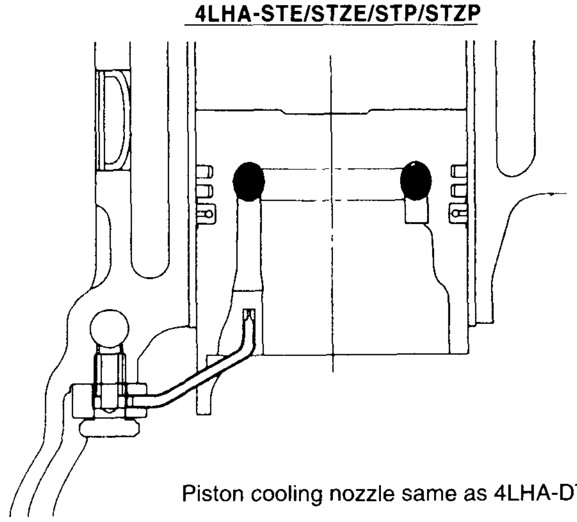


Oil injection volume	2.5 ℓ /min.
Oil injection pressure	0.39MPa(4.0kgf/cm²)

4LHA-DTE/DTZE/DTP/DTZP



4LHA-STE/STZE/STP/STZP

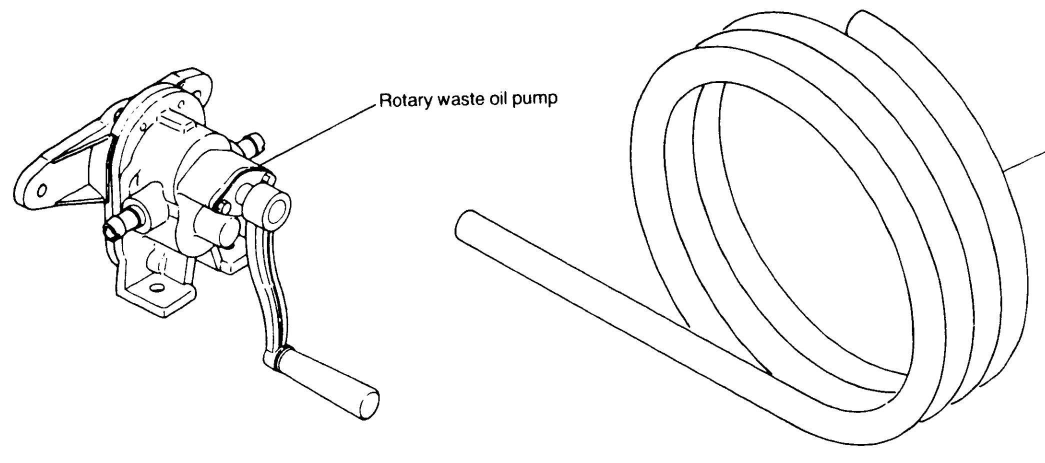


Piston cooling nozzle same as 4LHA-DTE one.

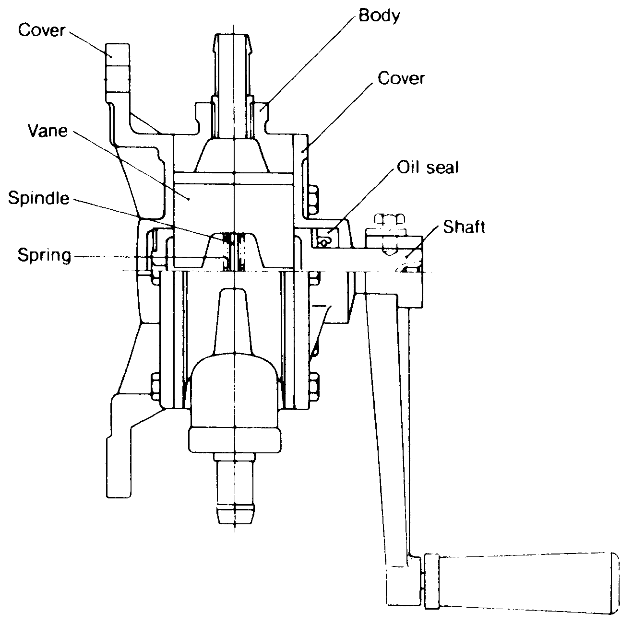
Oil injection volume	3.5~4.0 ℓ /min.
Oil injection pressure	0.39MPa(4.0kgf/cm²)

7. Rotary Waste Oil Pump (Optional)

A rotary waste oil pump to pump out waste oil during oil changing is available as an option.
This is a vane type pump. Turning the handle rotates the vanes and pumps out lube oil.



7-1 Construction



Rotary waste oil pump

Delivery capacity of one stroke	0.13ℓ (7.93 in.^{3})
Delivery pressure	0.147(1.5) MPa(kgf/cm^2) or below
Suction head	less than 1m (39.37 in.)
Part No.	124413-39100

Rubber hose

Inner dia. × length	ø12 × 1000mm (0.4724 × 39.37 in.)
Part No. of rubber hose	43720-001220

7-2 Inspecting the waste oil pump

(1) Disassemble the waste oil pump and check for spring breakage or vane damage when there is an extreme drop in discharge volume, and replace if necessary.
(2) Replace the oil seal if there is excessive oil leakage from the handle shaft.
(3) Replace the impeller if there is an excessive gap between the impeller and the covers on both sides of casing. This will cause a drop in discharge volume.
(4) The hose coupling is coated with adhesive and screwed in. It therefore cannot be disassembled.

CHAPTER 6

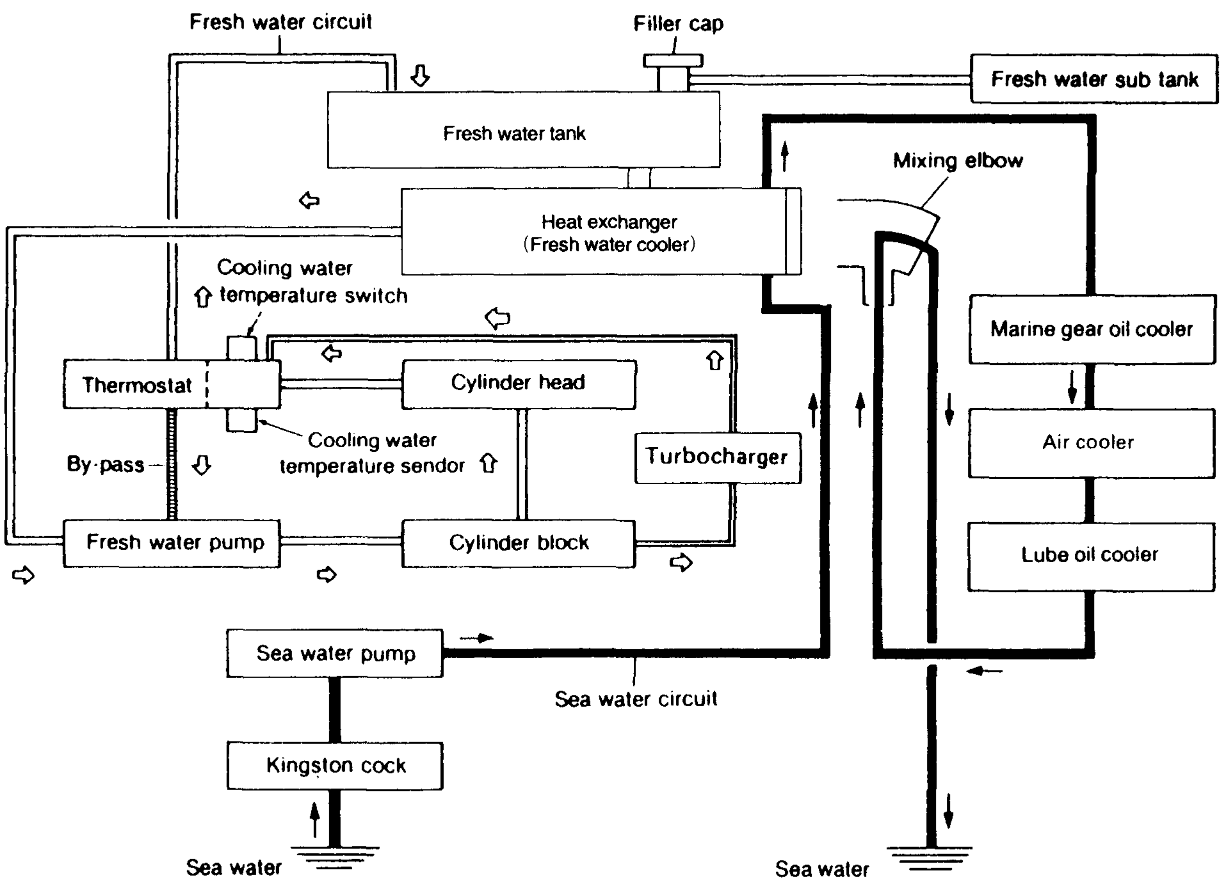
COOLING WATER SYSTEM

1. Cooling Water System 6-1
2. Sea Water Pump 6-4
3. Fresh Water Pump... 6-7
4. Heat Exchanger 6-10
5. Pressure Cap and Sub Tank 6-12
6. Thermostat 6-14
7. Kingston Cock (Optional) 6-16
8. Sea Water Filter (Optional) 6-17
9. Bilge Pump and Bilge Strainer (Optional) 6-18

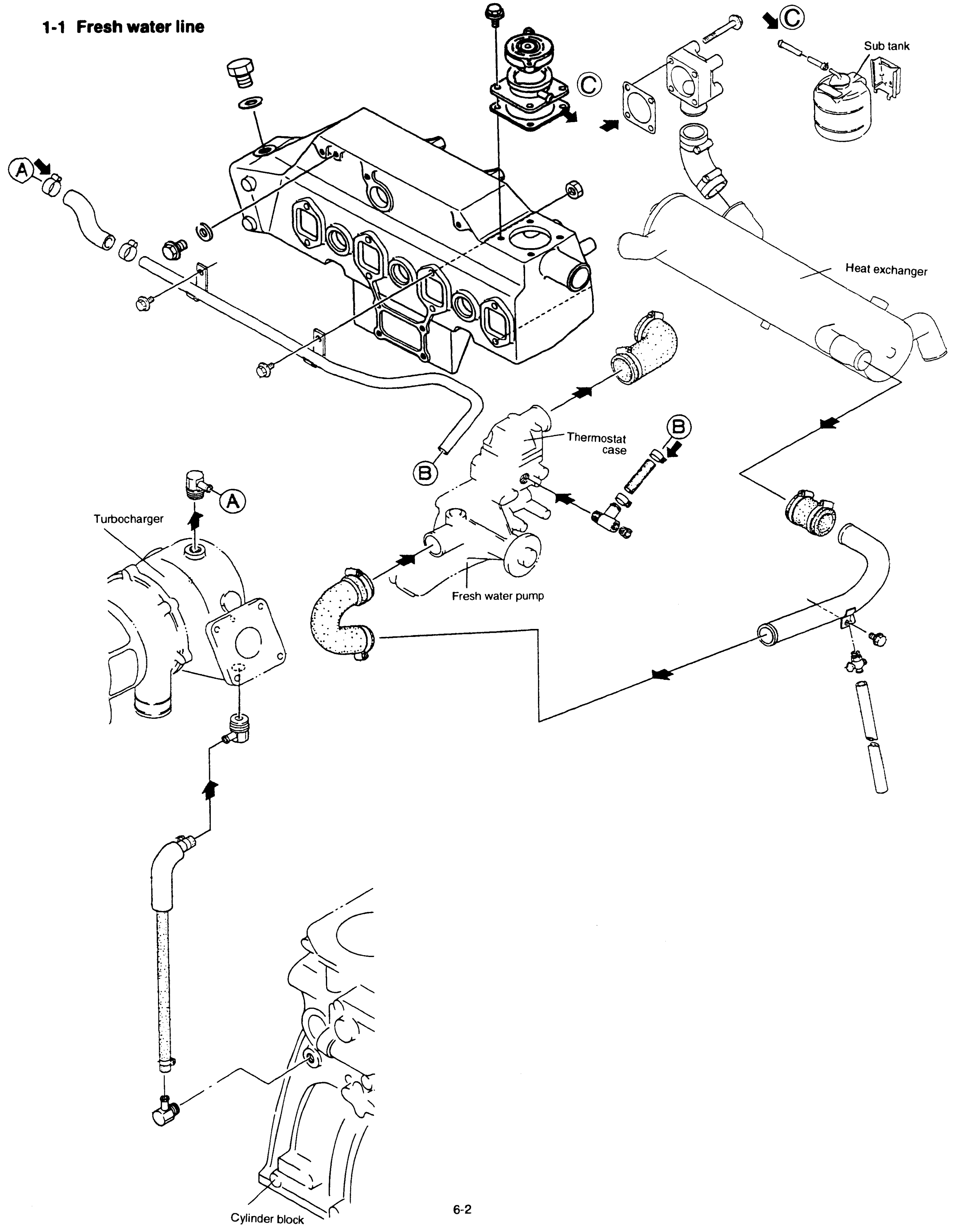
1. Cooling Water System

The cooling water system is of the indirect sea water coded, fresh water circulation type. The cylinders, cylinder heads, turbocharger and exhaust manifold are cooled with fresh water, and the lube oil cooler, air cooler and fresh water cooler (heat exchanger) use sea water.
Sea water pumped in from the sea by the sea water pump cools the lube oil in the lube oil cooler and then goes to the heat exchanger, where it cools the fresh water. Then it is sent to the mixing elbow and is discharged from the ship with the exhaust gas.
Fresh water is pumped by the fresh water pump from the fresh water tank to the cylinder jacket to cool the cylinders, turbocharger and then the cylinder head. The fresh water pump body also serves as a discharge passageway (line) at the cylinder head outlet, and is fitted with a thermostat.

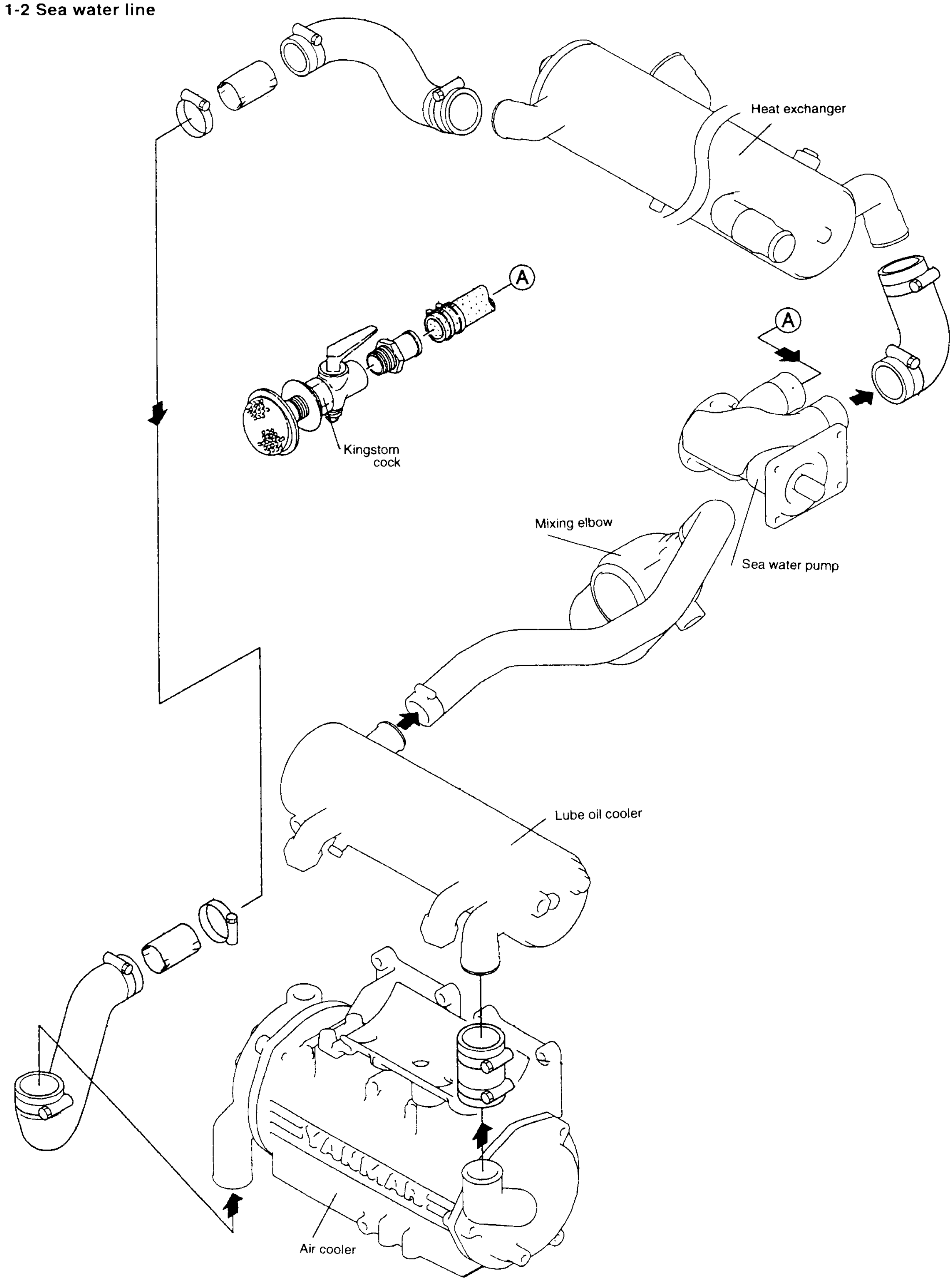
The thermostat is closed when the fresh water temperature is low, immediately after the engine is started and during low load operation, etc. Then the fresh water flows to the fresh water pump inlet, and is circulated inside the engine without passing through the heat exchanger.
When the temperature of the fresh water rises, the thermostat opens, fresh water flows to the head exchanger, and it is then cooled by the sea water in the tubes as it flows through the cooling pipe. The temperature of the fresh water is thus kept within a constant range by the thermostat.



1-1 Fresh water line



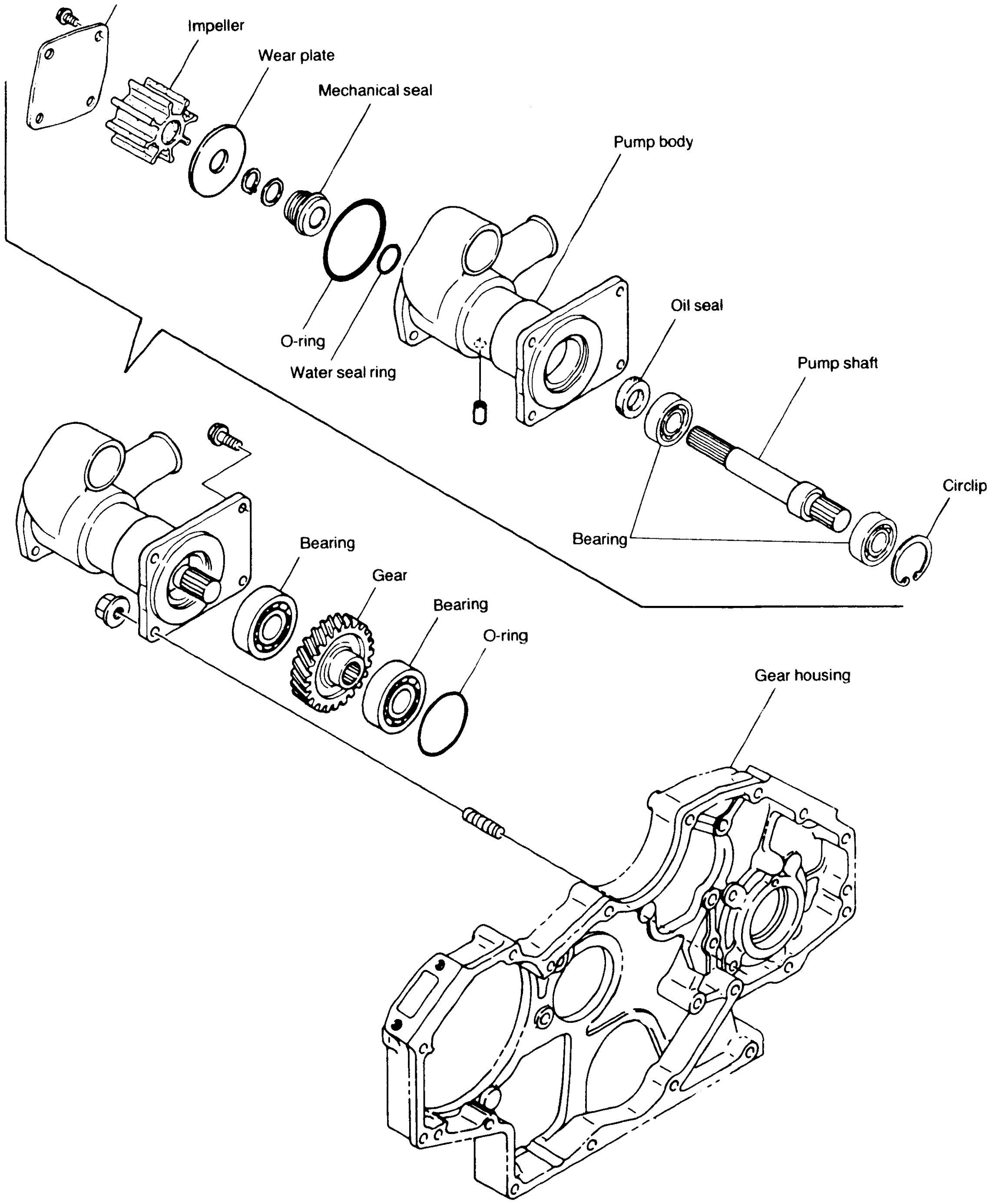
1-2 Sea water line

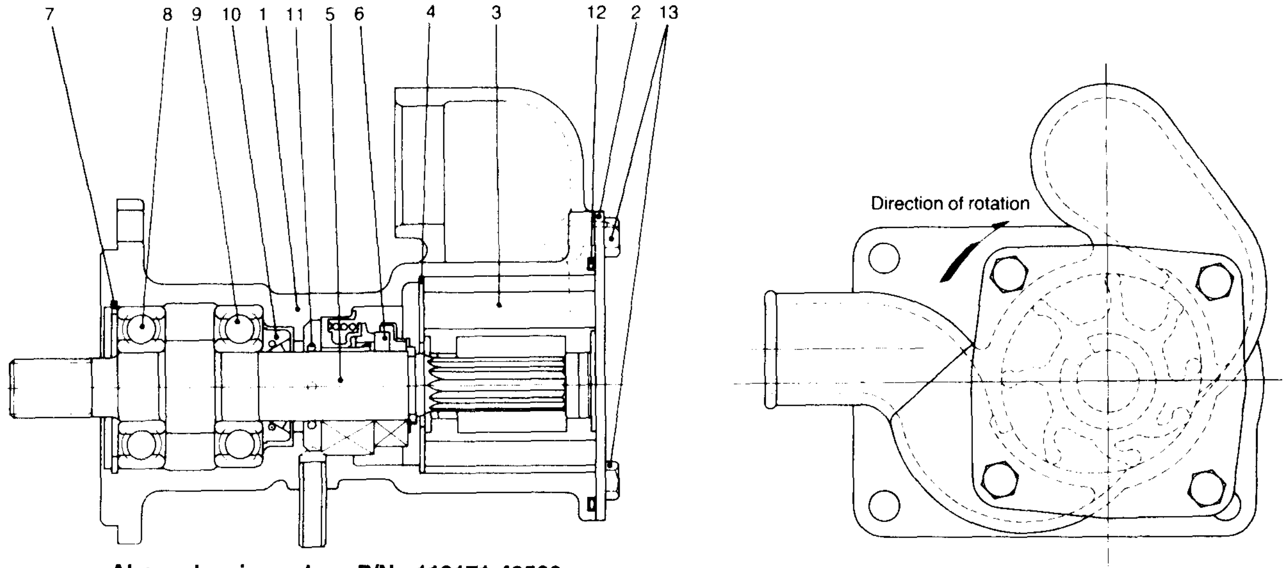


2. Sea Water Pump

2-1 Sea water pump construction

The sea water pump has a rubber impeller. The sea water pump is mounted to the gear case, and the drive gear on the end of the sea water pump shaft meshes with the camshaft gear to drive the pump.





Above drawings show P/No.119171-42500

1. Sea water pump body
2. Side cover
3. Impeller (C-type)
4. Wear plate
5. Pump shaft
6. Mechanical seal
7. Circlip
8. Bearing
9. Bearing
10. Oil seal
11. Water seal ring
12. O-ring
13. Hexagonal bolt

For 4LHA-HTE/HTZE/HTP/HTZP
: P/No. 119171-42500

For 4LHA-DTE/DTZE/DTP/DTZP
-STE/STZE/STP/STZP
: P/No. 119175-42500

2-2 Specifications of sea water pump (4LHA-HTE/HTZE/HTP/HTZP)

Gear ratio (crank gear/pump gear)	24/27
Pump speed	3000 rpm
Suction head	0.5m (1.66 ft)
Total head	9.5m (31.16 ft)
Delivery capacity	6000ℓ/h (198315 in.^{3}/h)

2-3 Sea water pump disassembly

(1) Remove the rubber hose from the sea water pump outlet and then the sea water pump assembly from the gear case.
(2) Remove the sea water pump cover and take out the O-ring, impeller and wear plate.
(3) Remove the mechanical seal side stop ring.
(4) Insert pliers from the drive gear long hole and remove the stop ring that holds the bearings.
(5) Lightly tap the pump shaft from the impeller side and remove the pump shaft, bearings, and drive gear as a set.
(6) Remove the oil seal and mechanical seal if necessary.

2-4 Sea water pump inspection

(1) Inspect the rubber impeller, checking for splitting around the outside, damage or cracks, and replace if necessary.

mm (in.)

	Standard	Clearance at assembly	Maximum allowable clearance	Wear limit
Impeller width	31.6 ~ 31.8 (1.2440 ~ 1.2519)	0 ~ 0.3 (0 ~ 0.0118)	0.8 (0.0314)	31.3 (1.2322)
Wear plate thickness	2 (0.0787)			1.8 (0.0708)
Housing width	33.8 ~ 33.9 (1.3307 ~ 1.3346)			—
Side plate thickness	2 (0.0787)			1.8 (0.0708)

(3) Inspect the mechanical seal and replace if the spring is damaged, or the seal is corroded. Also replace the mechanical seal if there is considerable water leakage during operation.

Ccoling water leakage	less than 3 cc/h (0.18 in.³/h)

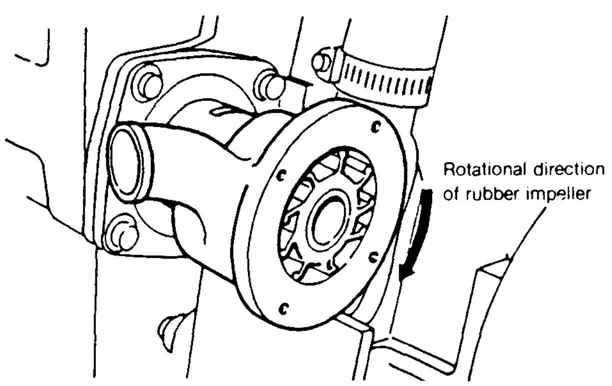
Parts No.of mechanical seal	123472-42060 for 4LHA-HTE/HTZE/HTP/HTZP
	129670-42560 for 4LHA-DTE/DTZE/DTP/DTZP -STE/STZE-STP/STZP

2-5 Sea water pump reassembly

(1) When replacing the mechanical seal, coat the No.1101 oil seal and pressure fit. Coat the sliding surface with a good quality silicon oil, taking sufficient care not to cause any scratches.
(2) When replacing the oil seal, coat with grease and insert.
(3) Mount the pump shaft, ball bearing and gear assembly to the pump unit and fit the bearing stop ring. Be sure not to forget the water O-ring when doing this.

NOTE: Coat the shaft with grease.

(4) After inserting the mechanical seal stop ring, mount the wear plate and impeller.



NOTE: 1. When inserting the impeller in the pump, make sure that the impeller lies in the proper direction.
2. Coat the inside of pump body impeller housing with grease.

(5) Mount the O-ring between the pump body and side cover.

NOTE: Replace the O-ring.

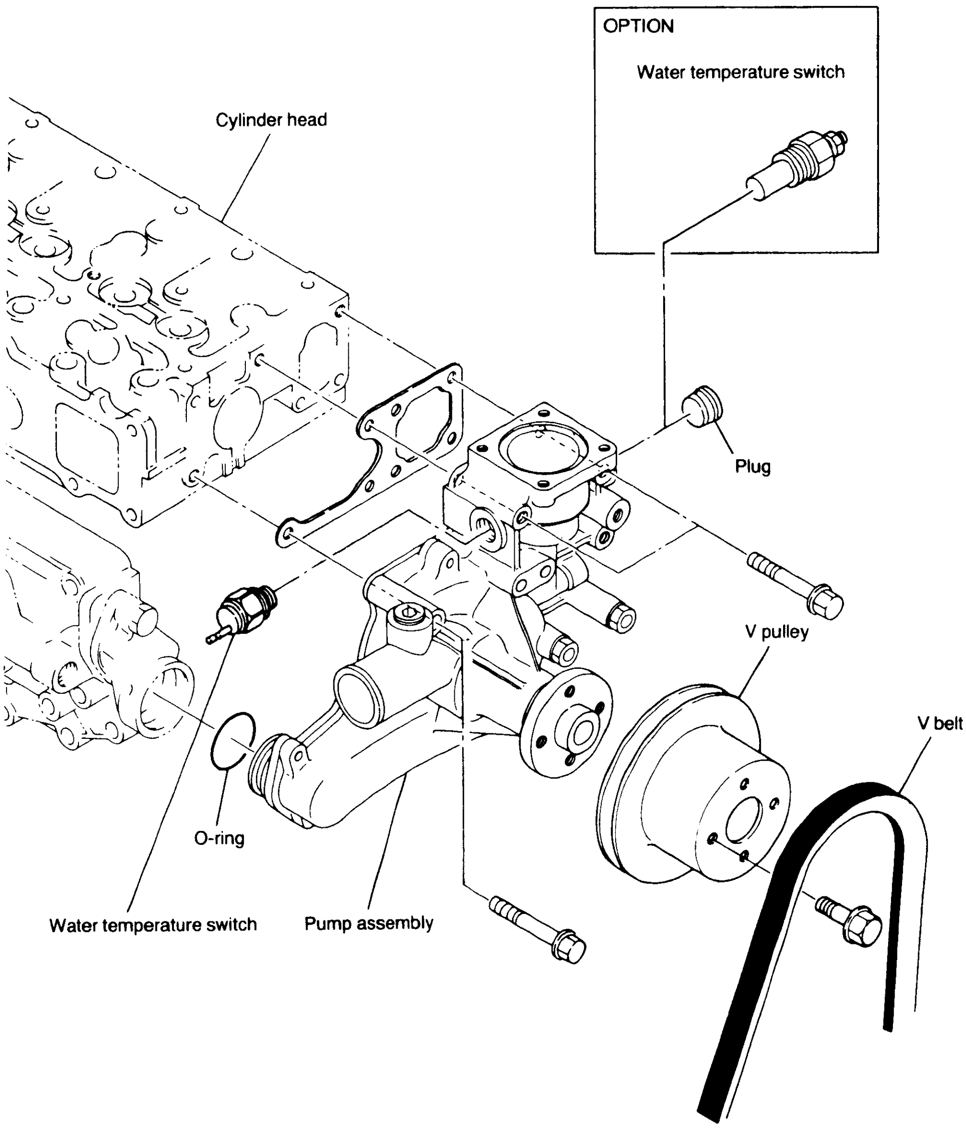
O-ring P/No. : 24321-000700
(For 4LHA-HTE/HTZE/HTP/HTZP)
P/No. : 119175-42570
(For 4LHA-DTE/DTZE/DTP/DTZP -STE/STZE/STP/STZP)

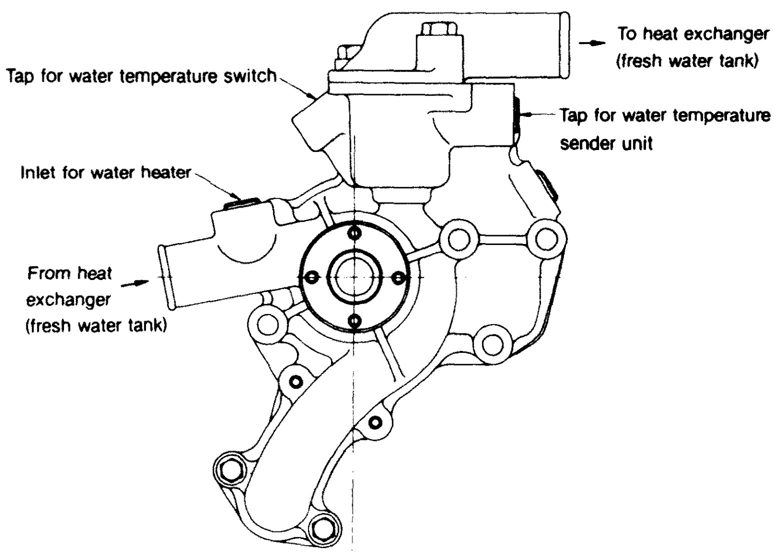
Impeller P/No. : 123325-42020
(For 4LHA-HTE/HTZE/HTP/HTZP)
P/No. : 127610-42200
(For 4LHA-DTE/DTZE/DTP/DTZP -STE/STZE/STP/STZP)

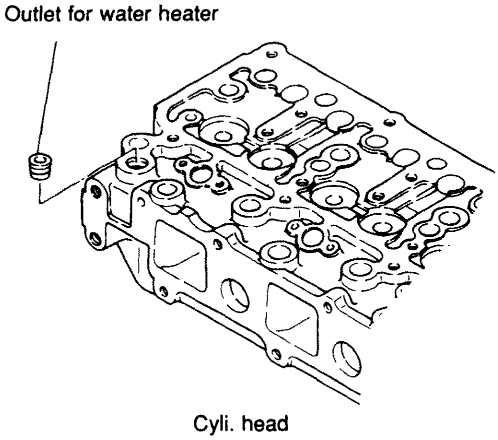
3. Fresh Water Pump

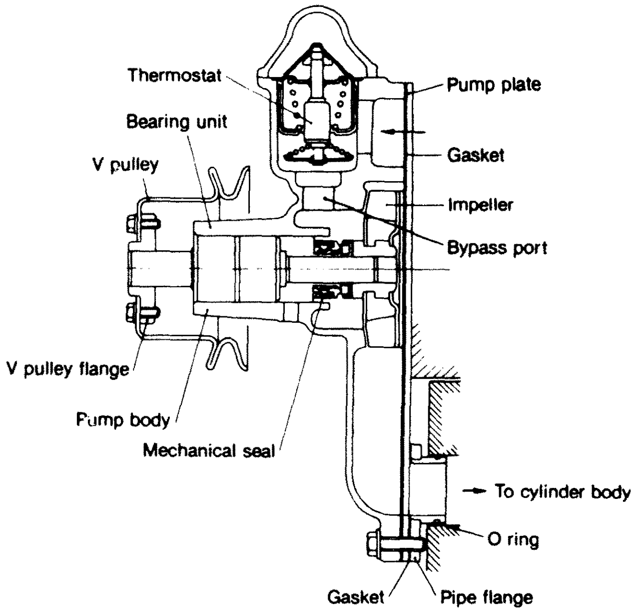
3-1 Fresh water pump construction

The fresh water pump is of the centrifugal (volute) type, and circulates water from the fresh water tank to the cylinders and cylinder head.
The fresh water pump consists of the pump body, impeller, pump shaft, bearing unit and mechanical seal. The V pulley on the end of the pump shaft is driven by a V belt from the crankshaft.
The bearing unit assembled in the pump shaft uses grease lubricated ball bearings and cannot be disassembled.
The totally enclosed mechanical seal spring presses the impeller seal mounted on the impeller side away from the pump body side. This prevents water from leaking along the pump shaft.
As the impeller and pulley flanges are press fit assembled, they cannot be disassembled.









3-2 Specifications of fresh water pump

Crank shaft speed (max.)	3600 rpm
Pulley ratio (crank shaft/pump shaft)	Ø134/Ø120 ϕ134/ϕ120 = 1.083
Pump shaft speed	2970-3030 rpm
Delivery capacity	150 ℓ/min (5284 in.^{3}/min)
Total head	5m (16.4 ft)

3-3 Fresh water pump disassembly

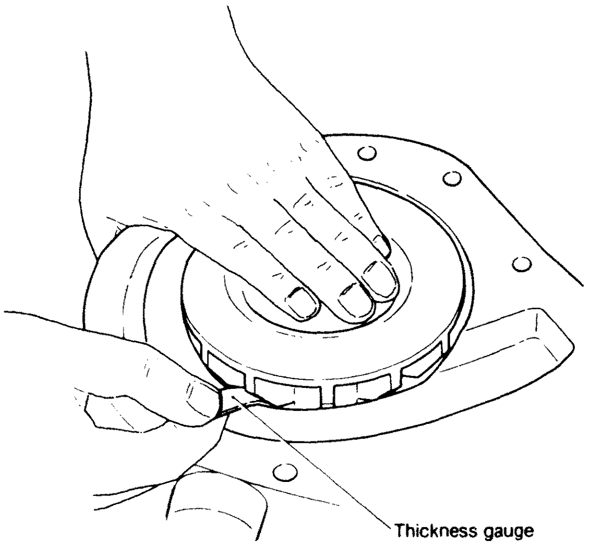
(1) Do not disassemble the fresh water pump. It is difficult to disassemble and, once disassembled, even more difficult to reassemble. Replace the pump as an assembly in the event of trouble.
(2) When removing the fresh water pipe as an assembly from the cylinder and cylinder head, replace the cylinder intake pipe O-ring.
(3) When the fresh water pump body and cylinder intake flange and/or fresh water pump and pump plate are disassembled, retighten to the specified torque.

Tightening torque for pump setting bolts	686~1079(70~110) N(kgf)·cm

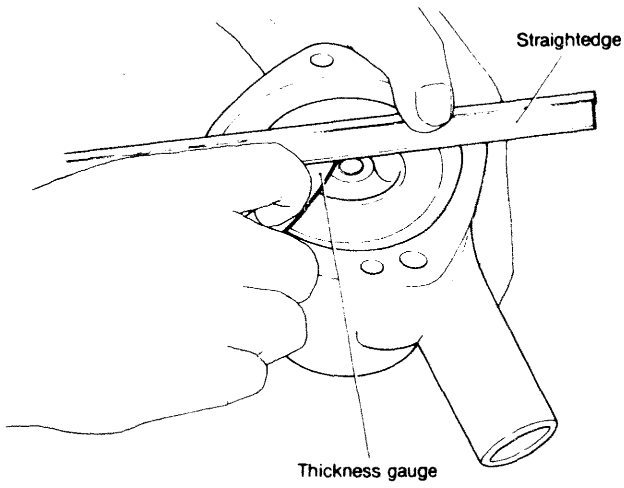
3-4 Fresh water pump inspection

(1) Bearing unit inspection
Rotate the impeller smoothly. If the rotation is not smooth or abnormal noise is heard due to excessive bearing play or contact with other parts, replace the pump as an assembly.
(2) Impeller inspection
Check the impeller blade, and replace if damaged or corroded, or if the impeller blade is worn due to contact with pump body.
(3) Check the holes in the cooling water and bypass lines, clean out any dirt or other foreign matter and repair as necessary.
(4) Replace the pump as an assembly if there is excessive water leakage due to mechanical seal or impeller seal wear or damage.
(5) Inspect the fresh water pump body and flange, clean off scale and rust, and replace if corroded.
(6) Measure the clearance between the impeller and the pump body, and the impeller and the plate.
Measure the clearance between the impeller and the pump body by pushing the impeller all the way towards the body, and inserting a thickness gauge diagonally between the impeller and the body.
Measure the clearance between the impeller and the plate (pump body bracket) by placing a straight-edge against the end of the pump body and inserting a thickness gauge between the impeller and the straight-edge.

Measuring clearance between impeller and pump body.



Measuring clearance between impeller and pump body bracket.



mm (in.)

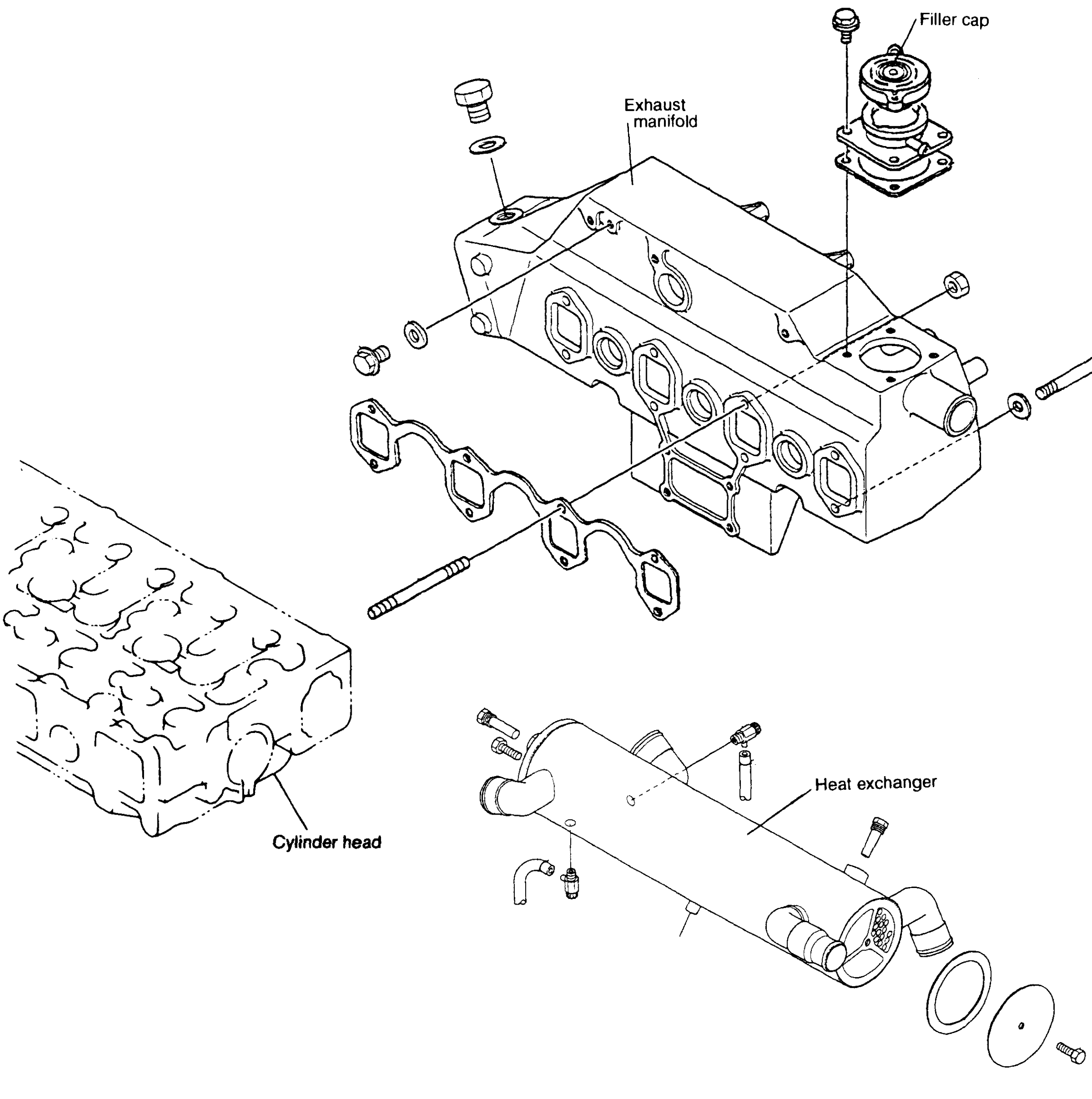
	Standard	Wear limit
Clearance between impeller and body	0.3 ~ 1.1 (0.0118 ~ 0.0433)	1.5 (0.0590)
Clearance between impeller and plate	1.5 (0.0590)	—

4. Heat Exchanger

4-1 Heat exchanger construction

The heat exchanger cools the hot fresh water that has cooled the inside of the engine with sea water.
The inside of the heat exchanger cooling pipe consists of 36 small dia. tubes and baffle plates.
The sea water flows through the small dia. tubes and the fresh water flows through the maze formed by the baffle plates.

There is a reservoir at the bottom of the cooling pipe which serves as the fresh water tank. There is an exhaust water passageway (line) in the reservoir which forms a water cooled exhaust gas manifold.
The filler cap on top of the heat exchanger has a pressure valve, which lets off steam through the overflow pipe when pressure in the fresh water system exceeds the specified value. It also takes in air from the overflow pipe when pressure in the fresh water system drops below the normal value.



4-2 Specifications of heat exchanger

Radiation area	m^2 (in.^{2})	0.593 (919)
Fresh water discharged volume	ℓ/hr (in.^{3}/hr)	8.000 (488.160)
Sea water discharged volume	ℓ/hr (in.^{3}/hr)	6.000 (366.119)
Fresh water flow speed in cooling pipe	m/s (ft/s)	1.5 (4.9)
Sea water flow speed in cooling tube	m/s (ft/s)	2.17 (7.12)

4-3 Disassembly and reassembly of the heat exchanger

(1) Remove the covers on both sides and take out the cooling pipe and O-ring(s).

NOTE: Replace the O-ring(s) when you have removed the cooling pipe.

(2) Remove the filler assembly.

4-4 Heat exchanger inspection

(1) Cooling pipe inspection

1) Inspect the inside of the tubes for rust or scale build-up from sea water, and clean with a wire brush if necessary.

NOTE: Disassemble and wash when the cooling water temperature reaches 85°C.

2) Check the joints at both ends of the tubes for looseness or damage, and repair if loose. Replace if damaged or corroded.
3) Check tubes and replace if leaking.
4) Clean any scale or rust off the outside of the tubes.

(2) Heat exchanger body inspection

1) Check heat exchanger body and side cover for dirt and corrosion. Replace if excessively corroded, or cracked.
2) Inspect sea water and fresh water inlets and outlets, retighten any joints as necessary and clean the insides of the pipes.
3) Check the exchaust gas intake flange and line, and replace if corroded or cracked.

5. Pressure Cap and Sub Tank

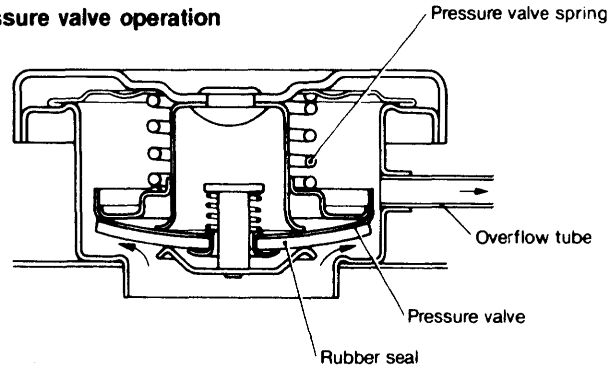
5-1 Pressure cap construction

The pressure cap mounted on the fresh water filler neck incorporates a pressure control valve. The cap is mounted on the filler neck cam by placing it on the rocking tab and rotating. The top seal of the cap seals the top of the filler neck, and the pressure valve seals the lock seat.

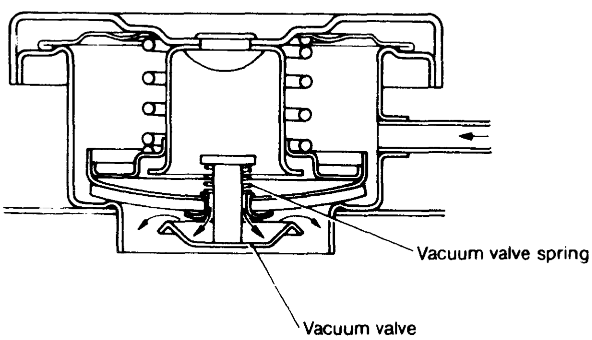
5-2 Pressure cap pressure control

The pressure valve and vacuum seal both seal the valve seat when the pressure in the fresh water system is within the specified value of 0.088(0.9)MPa(kgf/cm²). This seals the fresh water system.
When the pressure within the fresh water system exceeds the specified value, the pressure valve opens, and steam is discharged through the overflow pipe. When the fresh water is cooled and the pressure within the fresh water system drops below the normal value, atmospheric pressure opens the vacuum valve, and air is drawn in through the overflow pipe.

Pressure valve operation



Vacuum valve operation



The sub tank, (which will be described later), keeps the water level from dropping due to discharge of steam when the pressure valve opens.

Action of pressure control valve

Pressure valve	Open at 0.088(0.9)MPa(kgf/cm²)
Vacuum valve	Open at 0.0049(0.05)MPa(kgf/cm²) or below

5-3 Pressure cap inspection

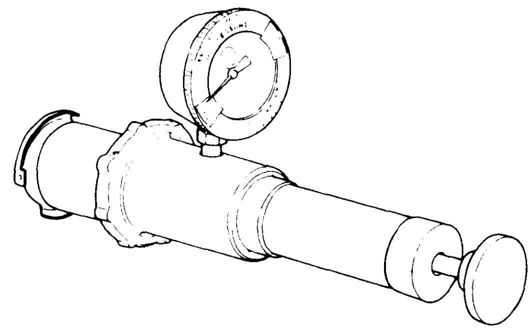
Precautions

Do not open the pressure cap while the engine is running or right after stopping because high temperature steam will be blown out. Remove the cap only after the water has had a chance to cool down.

(1) Remove scale and rust, check the seat and seat valve, etc. for scratches or wear, and the spring for corrosion or settling. Replace if necessary.

NOTE: Clean the pressure cap with fresh water as it will not close completely if it is dirty.

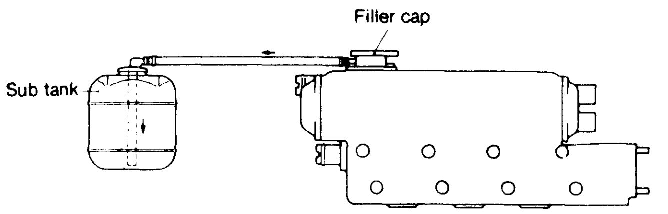
(2) Fit the adapter on the tester to the pressure cap. Pump until the pressure gauge is within the specified pressure range〔0.0735~0.103(0.75~1.05) MPa(kgf/cm²)〕 and note the gauge reading. The cap is normal if the pressure holds for six seconds. If the pressure does not rise, or drops immediately, inspect the cap and repair or replace as necessary.

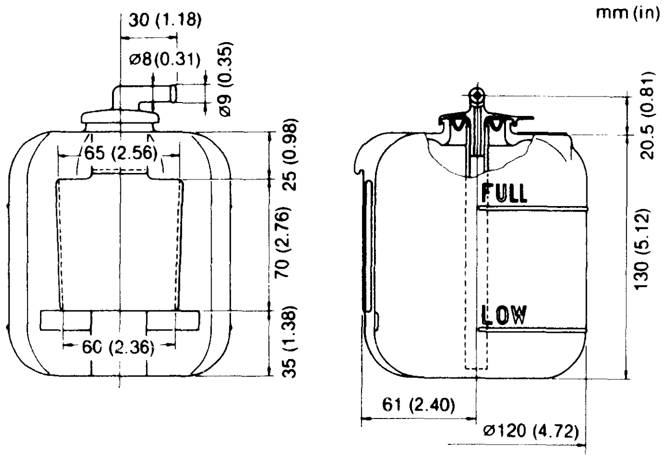


Parts No. of cap tester	120445-44600

5-4 Function of the sub tank

The pressure valve opens to discharge steam when the steam pressure in the fresh water tank exceeds 0.088(0.9) MPa(kgf/cm²).
This consumes water. The sub tank maintains the water level by preventing this discharge of water.
The steam discharged into the sub tank condenses into water, and the water level in the sub tank rises.
When the pressure in the fresh water system drops below the normal value, the water in the sub tank is sucked back into the fresh water tank to raise the water back to its original level.
The sub tank facilitates long hours of operation without water replacement and eliminates the possibility of burns when the steam is ejected from the filler neck becase the pressure cap does not need to be removed.





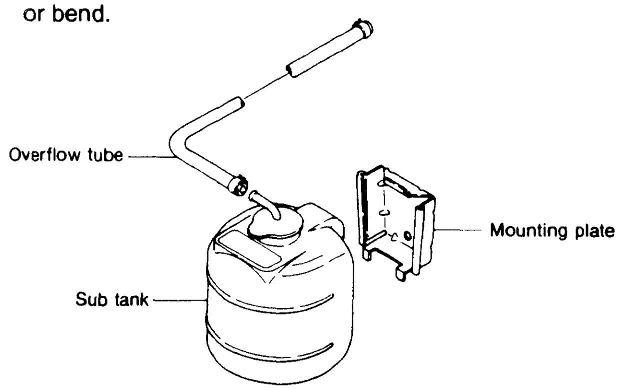
5-5 Specifications of sub tank

Subtank capacity	Overall capacity	1.25ℓ (76.27 in.³)
	Full-scale position	0.8ℓ (48.81 in.³)
	Low-scale position	0.2ℓ (12.20 in.³)
Part No. of subtank		120445-44530

5-6 Mounting the sub tank

(1) The sub tank is mounted at approximately the same height as the heat exchanger (fresh water tank). (allowable difference in height: 300mm (11.8110in.) or less)

(2) The overflow pipe should be less than 1000mm (39.3701in.) long, and mounted so that it does not sag or bend.



NOTE: Make sure that the overflow pipe of the sub tank is not submerged in bilge. If the overflow pipe is submerged in bilge, water in the bilge will be siphoned into the fresh water tank when the water is being cooled.

5-7 Precautions on usage of the sub tank

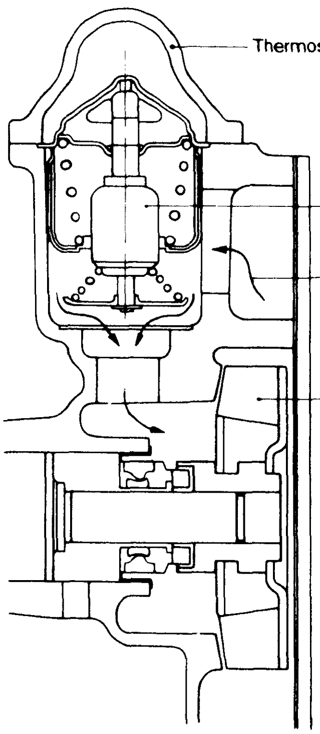
(1) Check the sub tank when the engine is cool and refill with fresh water as necessary to bring the water level between the low and full marks.

(2) Check the overflow pipe and replace if bent or cracked. Clean out the pipe if it is clogged up.

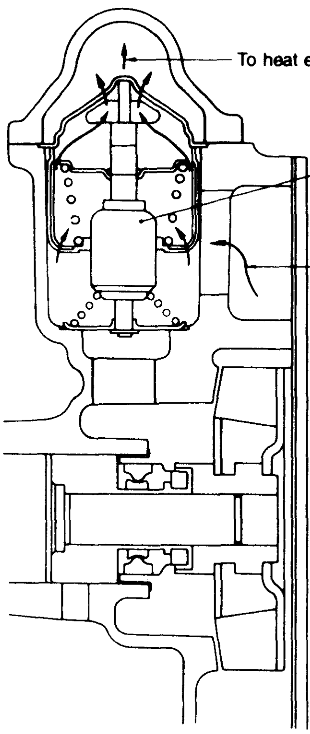
6. Thermostat

6-1 Functioning of thermostat

The thermostat opens and closes a valve according to changes in the temperature of the fresh water inside the engine, controlling the volume of water flowing to the heat exchanger from the cylinder head, and in turn maintaining the temperature of the fresh water in the engine at a constant level.
The thermostat is bottom bypass type. It is located in a position connected with the cylinder head outlet line at the top of the top of fresh water pump unit.
When the fresh water temperature is low (75.0 ~ 78.0°C or less), the thermostat is closed, and fresh water goes from the bypass line to the fresh water pump intake and circulates in the engine.
When the fresh water temperature exceeds the above temperature, the thermostat opens, and a portion of the water is sent to the heat exchanger and cooled by sea water, the other portion going from the bypass line to the fresh water pump intake.
The bypass line is closed off as the thermostat valve opens, and is completely closed when the fresh water temperature reaches 81.5°C (valve lifts 4mm (0.1575in.)), sending all of the water to the heat exchanger.



When valve is closed (by-pass passage is opened)



When valve is opened (by-pass passage is closed)

6-2 Thermostat construction

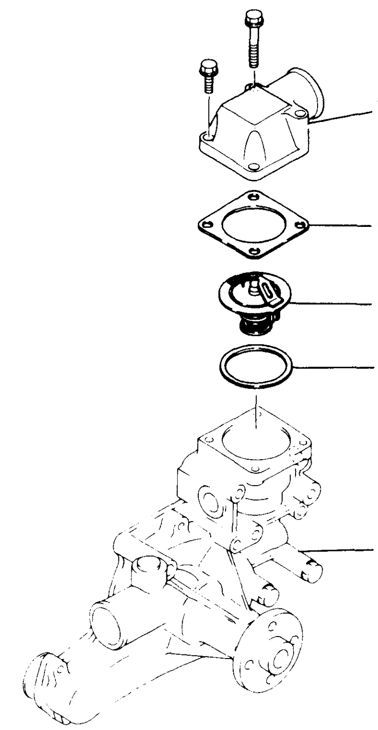
The thermostat used in this engine is of the wax pellet type, with a solid wax pellet located in a small chamber. When the temperature of the cooling water rises, the wax melts and increases in volume. This expansion and construction is used to open and close the valve.

6-3 Characteristics of thermostat

Opening temperature	71°C
Full open temperature	85°C
Valve lift at full open	8 mm (0.31 in)

6-4 Thermostat inspection

Remove the thermostat cover on top of the fresh water pump and take out the thermostat. Clean off scale and rust and inspect, and replace if the characteristics (performance) have changed, or if the spring is broken, deformed or corroded.



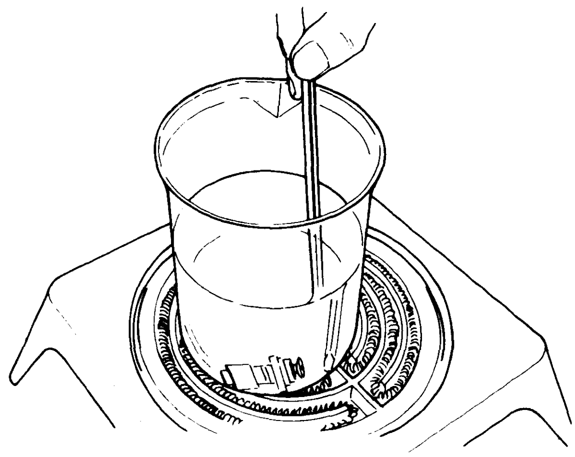
Part No. of thermostat	121850-49810

6-5 Testing the thermostat

(1) Put the thermostat in a beaker with fresh water, and heat it on an electric stove. The thermostat is functioning normally if it starts to open between 75 ~ 78°C, and opens 8mm (0.3150in.) or more at 90°C. Replace the thermostat if it is not functioning normally.

(2) Normally, the thermostat should be inspected every 500 hours of operation, but, it should be inspected before this if the cooling temperature rises abnormally or white smoke is emitted for a long time after engine starting.

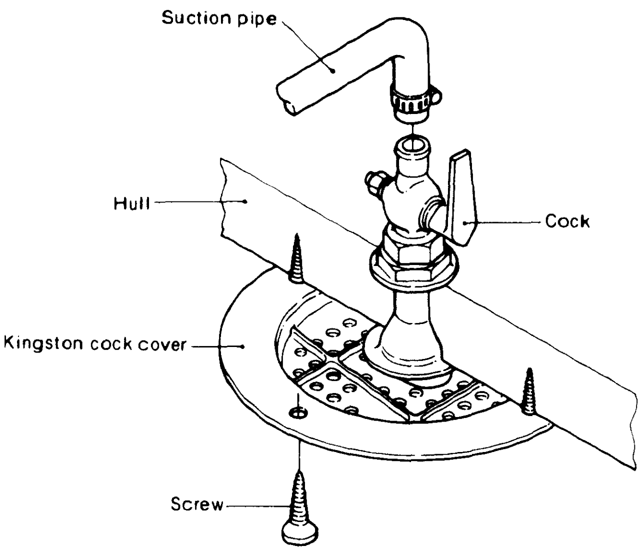
(3) Replace the thermostat every year or 2000 hours of operation (whichever comes first).

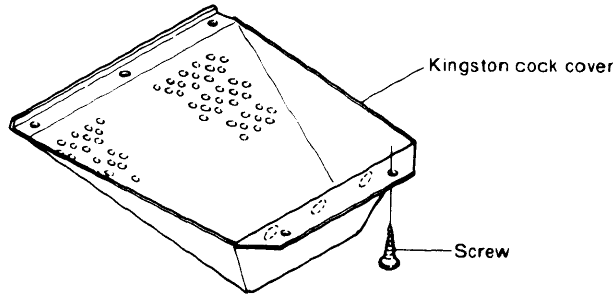


7. Kingston Cock (Optional)

7-1 Construction

The Kingston cock, installed on the bottom of the hull, controls the intake of cooling water into the boat. The Kingston cock serves to filter the water so that mud, sand, and other foreign matter in the water does not enter the water pump.
Numerous holes are drilled in the water side of the Kingston cock, and a scoop strainer is installed to prevent the sucking in of vinyl, etc.





7-2 Handling precautions

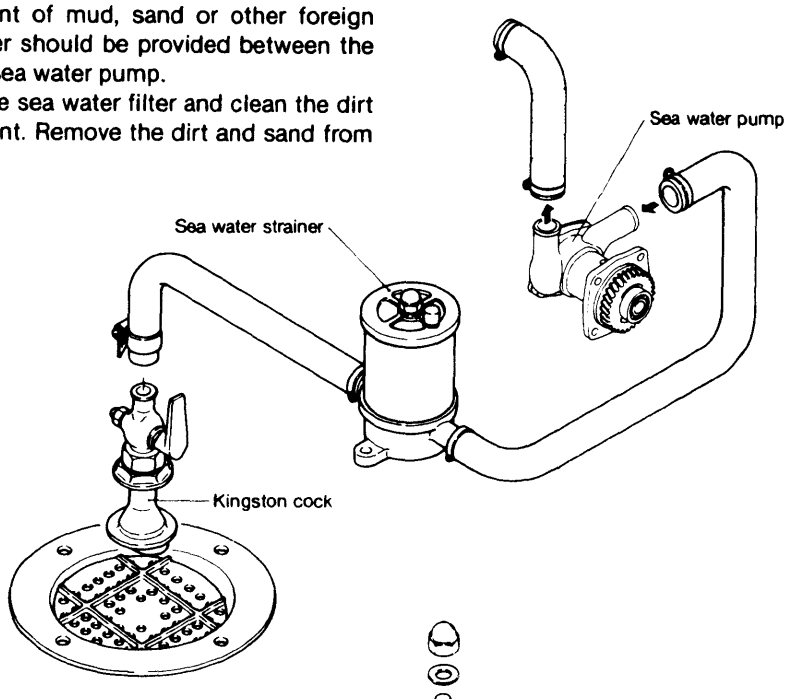
Caution the user to always close the Kingston cock after each day of use and to confirm that it is open before beginning operation.
If the Kingston cock is left open, water will flow in reverse and the vessel will sink if trouble occurs with the water pump.
On the other hand, if the engine is operated with the Kingston cock closed, cooling water will not be able to get in, resulting in engine and pump trouble.

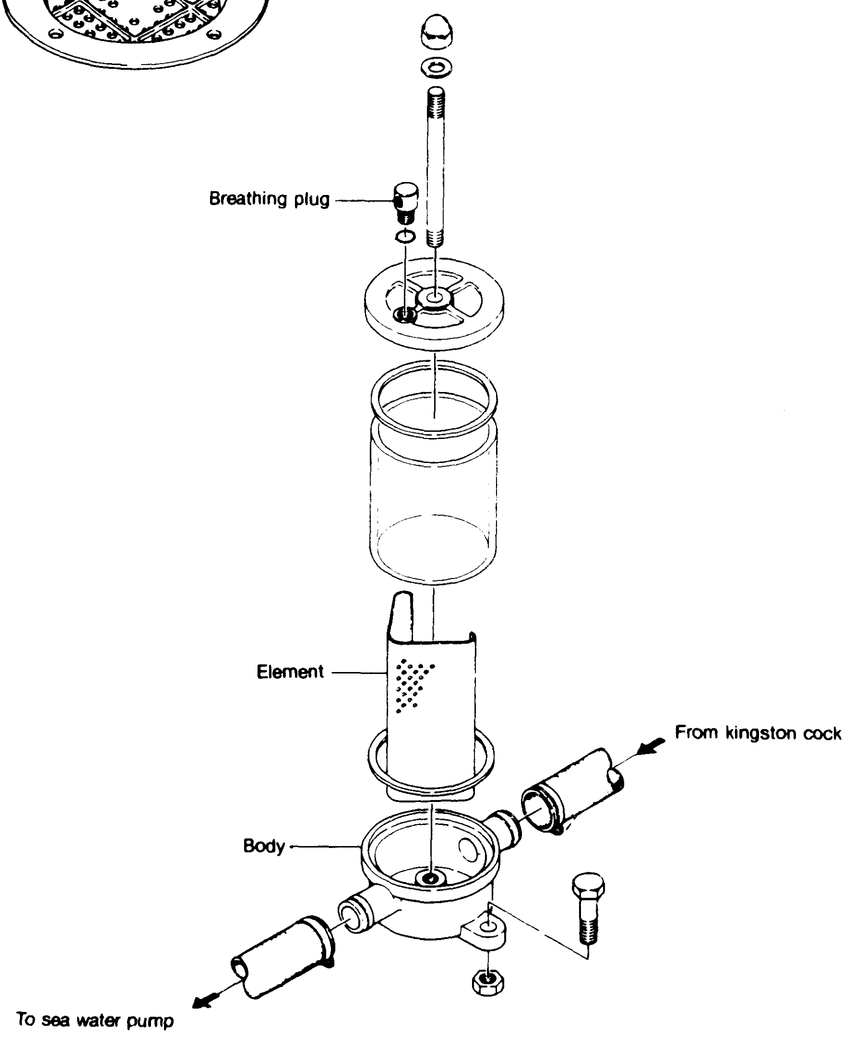
7-3 Inspection

When the cooling water volume has dropped and the pump is normal, remove the vessel from the water and check for clogging of the Kingston cock.
If water leaks from the cock, disassemble the cock and inspect if for wear, and repair or replace it.

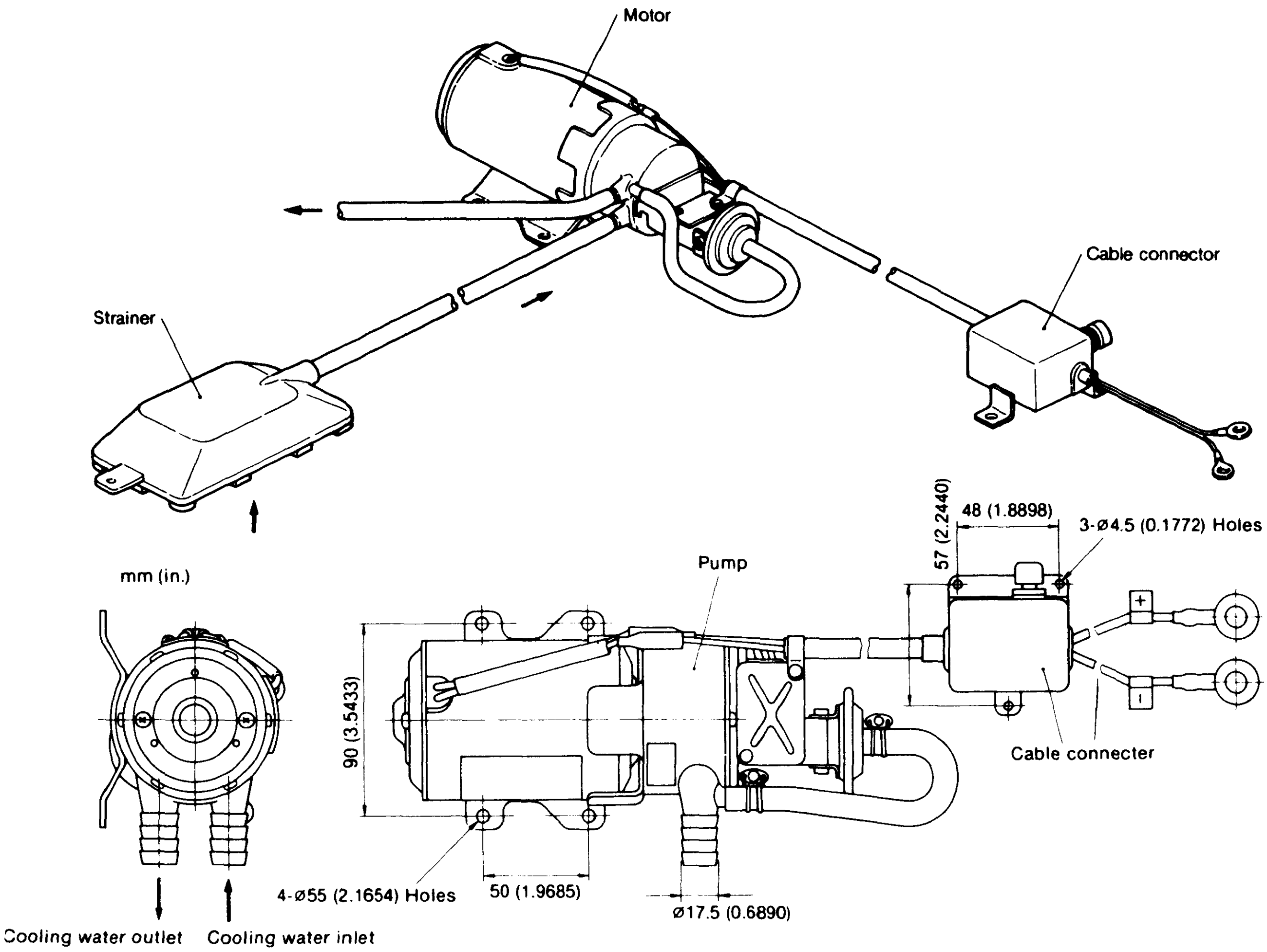
8. Sea Water Filter (Optional)

When operating the engine in areas where the sea water contains a large amount of mud, sand or other foreign matter, a sea water filter should be provided between the kingston cock and the sea water pump.
Occasionally inspect the sea water filter and clean the dirt and scale off the element. Remove the dirt and sand from the bottom of the filter.





9. Bilge Pump and Bilge Strainer (Optional)



9-1 Bilge pump

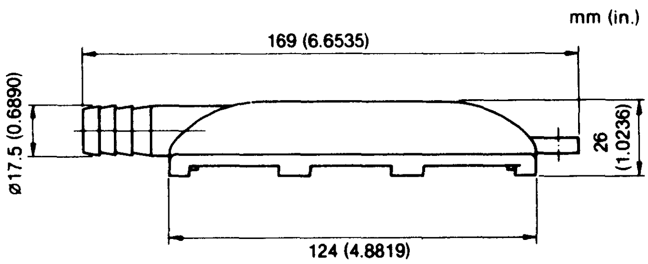
9-1.1 Specifications

Code No.	120345-46010 (with strainer)
Model No.	BP190-10
Rating	60 min.
Voltage	12V
Output	90W
Mass	3.0kg

9-1.2 Performance of pump (in pure water)

Suction performance	Voltage	11.5V
	Max. suction lift	1.2m (3.94 ft)
	Suction time	4 sec.
Pumping lift performance	Voltage	11.5V
	Current	8A
	Total lift	1m (3.28 ft)
	Lifting volume of water	17 ℓ/min

9-2 Bilge strainer



CHAPTER 7

REDUCTION AND REVERSING GEAR

7-1. Marine gear model KW5A

1. Construction 7-1-1
2. Shifting Device 7-1-5
3. Inspection and Servicing 7-1-10
4. Special Tools 7-1-20
5. Disassembly 7-1-21
6. Reassembly 7-1-29

Marine Gear Model

KM5A

1. Construction

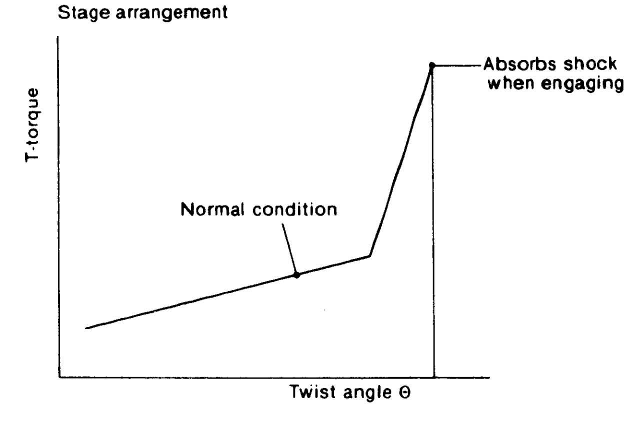
1-1 Construction

The clutch is a cone-type, mechanically operated clutch. When the drive cone (which is connected to the clutch shaft by the lead spline) is moved forward or backward, its taper contacts with the clutch gear and transfers power to the output shaft.

The construction is simple when compared with other types of clutch and it serves to reduces the number of components, making for a lighter, more compact unit which can be operated smoothly. Although it is small, the power transmission efficiency is high even under a heavy load. It is also durable and reliable because high grade materials are used for the shaft and gear, and a taper roller bearing is incorporated. Power transmission is smooth because connection with the engine is made through the damper disc.

- The drive cone is made from special aluminum bronze which has high wear-resistance and durability. The drive cone is connected with the clutch shaft. The taper angle, diameter of the drive cone, twist angle, and diameter of the involute spline, are designed to give the greatest efficiency, thus ensuring that the drive cone can be readily engaged or disengaged.
- Helical gears are used for greater strength. The intermediate shaft is supported at 2 points to reduce deflection and gear noise.
- The clutch case and mounting flange are made from an aluminum alloy of special composition to reduce weight. This is non-corrosive in seawater.
- The damper disc is fitted to the input shaft, so power can be transmitted smoothly. Springs of different strengths are used for the damper disc so that two stages of torque and twist angle are applied. That is, in the first stage, only the weak spring is used, and the strong spring comes into action for a torque higher than a predetermined value.

This prevents gear noise due to torsional vibration, as well as absorbing shock when engaging.



There is a small clearance between the dipstick and the inside of the dipstick tube. A small hole in the dipstick works as a breather.

- When the load on the propeller is removed, the engagement of the drive cone and the clutch gear is maintained by the shifter and V-groove of the drive cone. Even when the drive cone's tapered area and V-groove are worn, this engagement is maintained by the shift lever device. Accordingly no adjustment of the remote control cable is required.
- The cup spring on the rear of the clutch gear absorbs rotational fluctuations and stabilizes the engagement of the drive cone and the clutch gear. Thus, the durability of the cone against wear is enhanced.

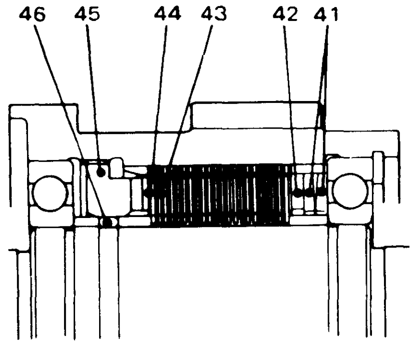
- A torque limiter is built into the input shaft gear to prevent damage caused by excessive torque.
- The lube oil temperature can be controlled because in addition to the input shaft gear which functions as a centrifugal pump, an oil cooler is also equipped.
- The oil cooler is equipped with a cooling water drain cock to prevent cracks caused by freezing in cold weather. It is therefore easy to drain the water.
- The propeller shaft can rotate in both counter clockwise (C.C.W.) and clockwise (C.W.) directions.

NOTE: Since the difference in reduction gear ratio between C.C.W. and C.W. rotations is within 0.13%, no problem occurs in operation.

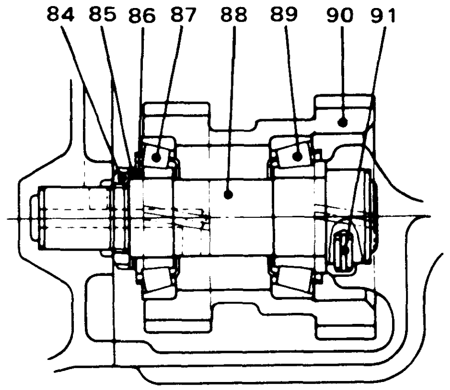
1-2 Specifications of Angle Drive Marine Gear

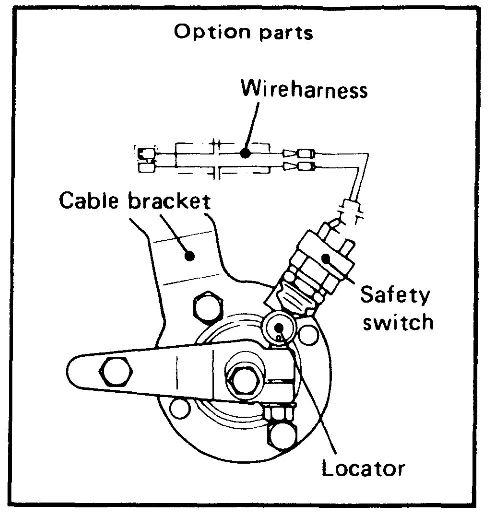
Model		KM5A		
For engine models		4LHA-HTE		
Down angle		7 degree		
Clutch		Constant mesh gear with servo cone clutch (wet type)		
Direction of rotation	Input shaft	Counter-clockwise, viewed from stern.		
	Output shaft	Bi-rotation		
Reduction ratio		2.57	2.07	1.46
Propeller shaft rpm at cont. rating		1245	1546	2187
Remote control	Control head	Single lever control		
	Cable	Morse, 33-C (Cable travel 76.2mm or 3 in.)		
	Clamp	YANMAR Made, standard accessory		
	Cable connector	YANMAR Made, standard accessory		
Output shaft coupling	Outer diameter	ϕ130mm (5.18")		
	Pitch circle diameter	ϕ108mm (4.25")		
	Connecting bolt holes	4–ϕ12.3mm (4–ϕ0.48")		
Position of shift lever		Right side, viewed from stern		
Lubricating oil		Same as Engine lube oil		
Lubricating oil capacity		2.6ℓ		
Lube oil cooler		Sea-water cooling		

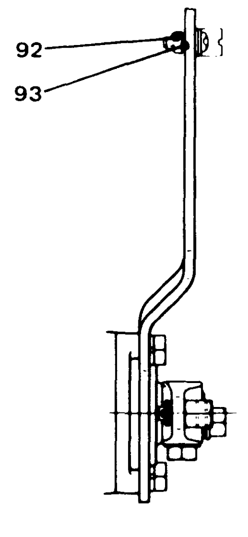
1-3 KM5A Sectional View

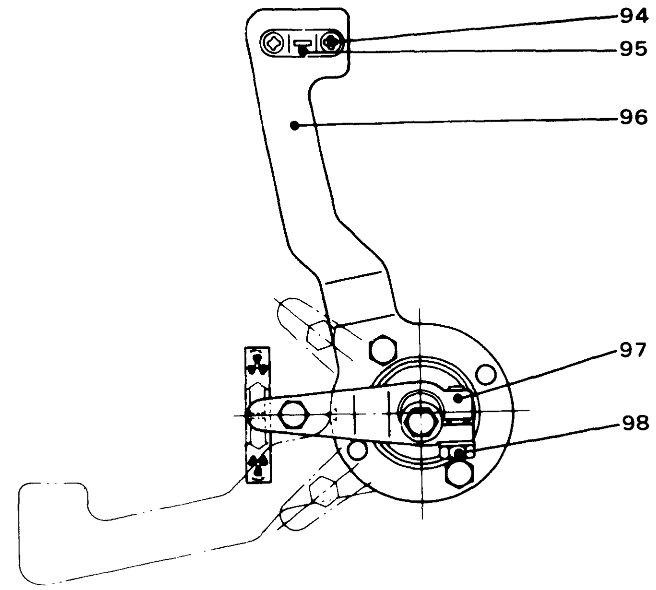


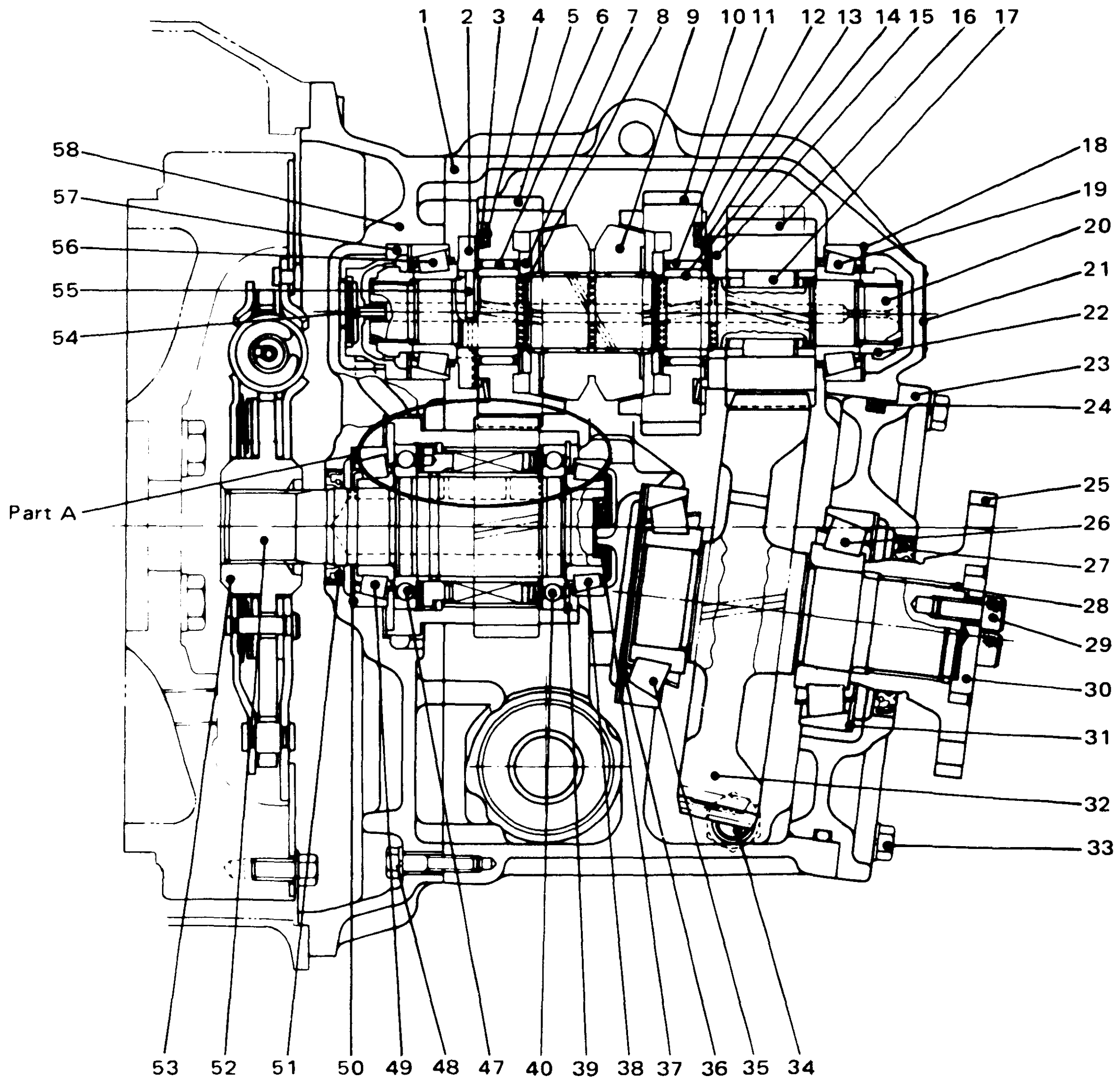
Detail of part A

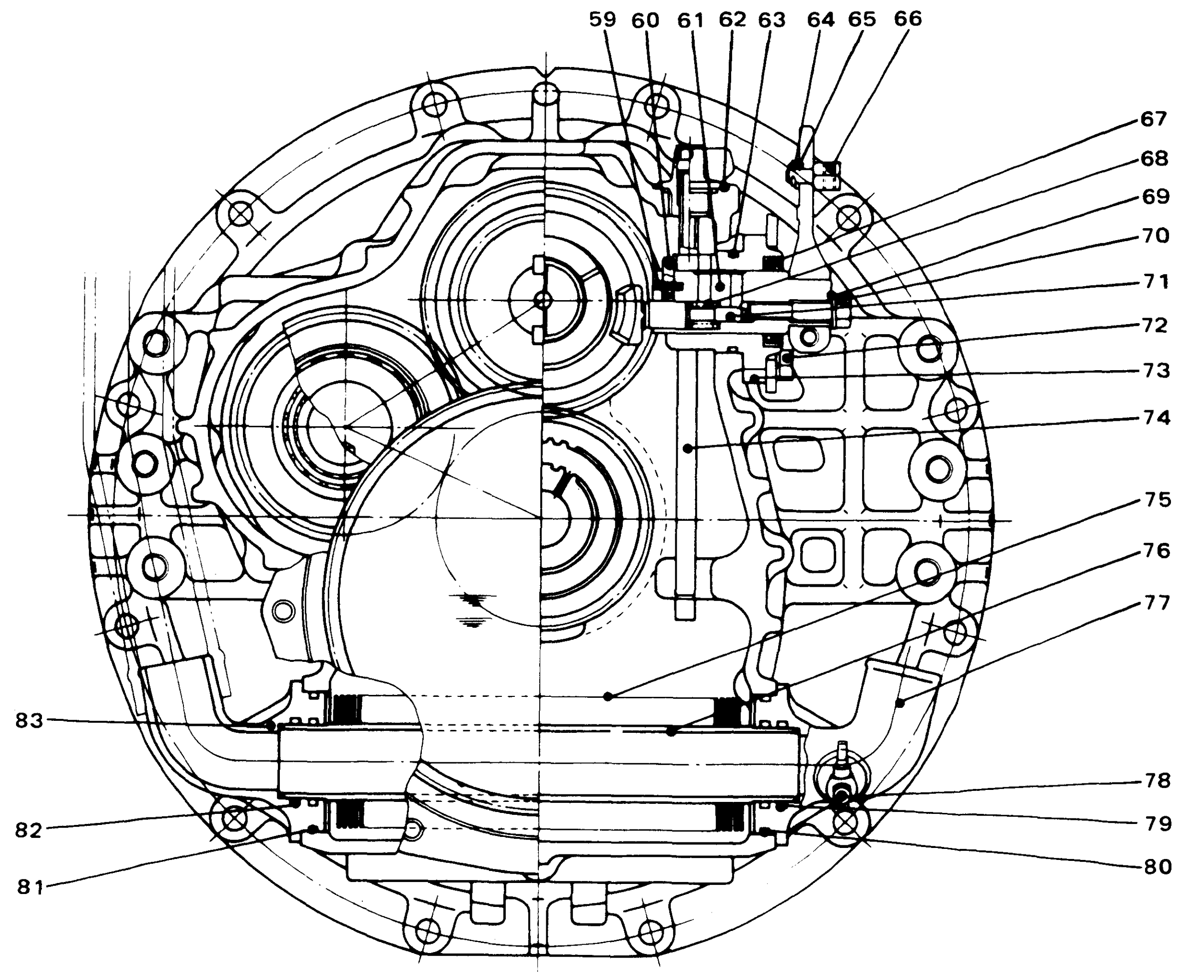










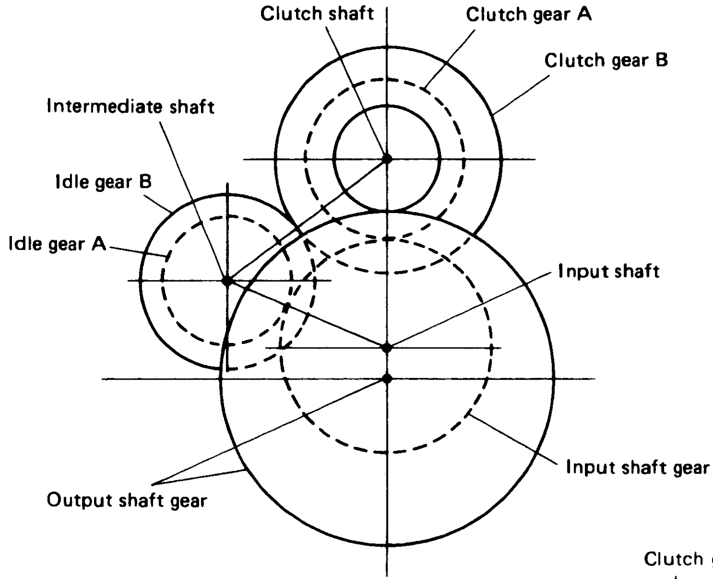


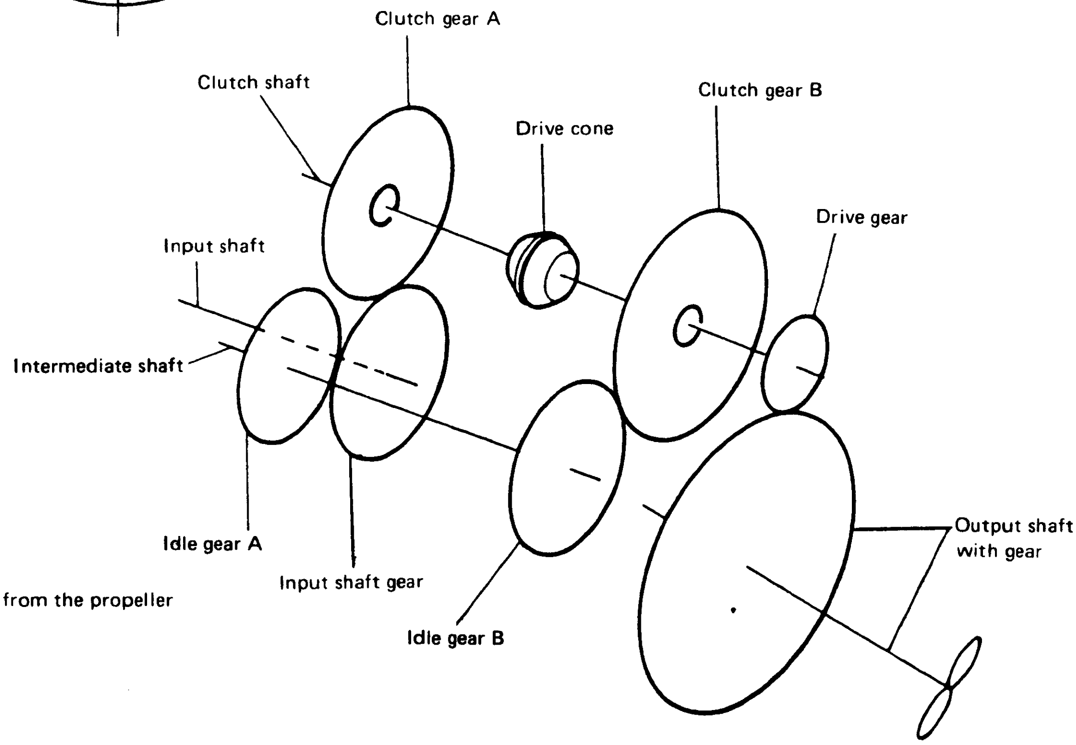
1 Clutch case
2 Thrust collar (A)
3 Spring retainer
4 Cup spring
5 Clutch gear (A)
6 Needle bearing
7 Thrust collar (B)
8 Snap ring
9 Drive cone
10 Clutch gear (B)
11 Needle bearing
12 Cup spring
13 Spring retainer
14 Inner race
15 Thrust collar (A)
16 Driving gear
17 Key
18 Shim
19 Bearing
20 Clutch shaft
21 Name plate
22 End nut
23 Output shaft cover
24 O-ring
25 Output shaft coupling
26 Bearing
27 Oil seal
28 O-ring
29 Bolt
30 Coupling retainer
31 Shim
32 Output shaft
33 Bolt
34 Drain plug
35 Bearing
36 Shim
37 Oil seal
38 Bearing
39 Snap ring
40 Bearing
41 Cup spring
42 Spacer
43 Plate (A)
44 Plate (B)
45 Lock nut
46 O-ring
47 Bearing
48 Bolt
49 Bearing
50 Shim
51 Oil seal
52 Input shaft
53 Dumper disk
54 Filter
55 Pin
56 Bearing
57 Filter case
58 Mounting flange
59 Spring pin
60 Location pin
61 Shift lever shaft
62 O-ring
63 O-ring
64 Washer
65 Split space pin
66 Pivot
67 Oil seal
68 Spring
69 Shim
70 Stopper bolt
71 Shifter
72 Bolt
73 Side cover
74 Dipstick
75 Oil-cooler body
76 Pipe
77 Cooler
78 Cock
79 O-ring
80 O-ring
81 O-ring
82 O-ring
83 Cover
84 End nut
85 Washer
86 Shim
87 Bearing
88 Intermediate shaft
89 Bearing
90 Intermediate shaft gear
91 Spring pin
92 Lock nut
93 Washer
94 Bolt
95 Washer
96 Cable bracket
97 Shift lever
98 Bolt

1-4 Power Transmission System

1-4-1 Arrangement of shafts and gear

KM5A





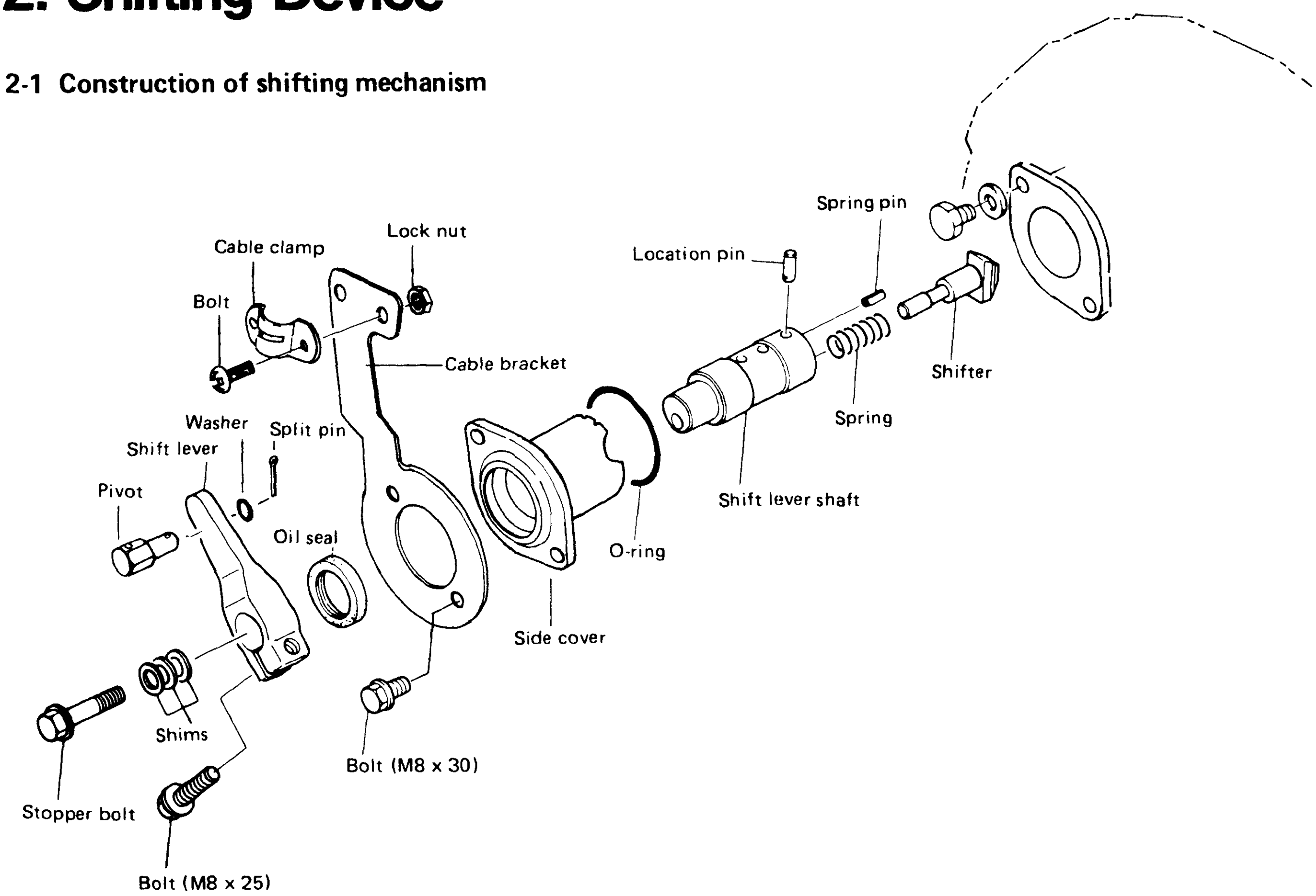
Shaft arrangement viewed from the propeller

1-4-2 Reduction ratio

Input shaft gear	Clutch gear		Intermediate shaft		Drive gear	Output shaft with gear	Reduction ratio
	A	B	Idle gear A	Idle gear B			
37	39	41	38	40	36	50	1.46
					29	57	2.07
					25	61	2.57

2. Shifting Device

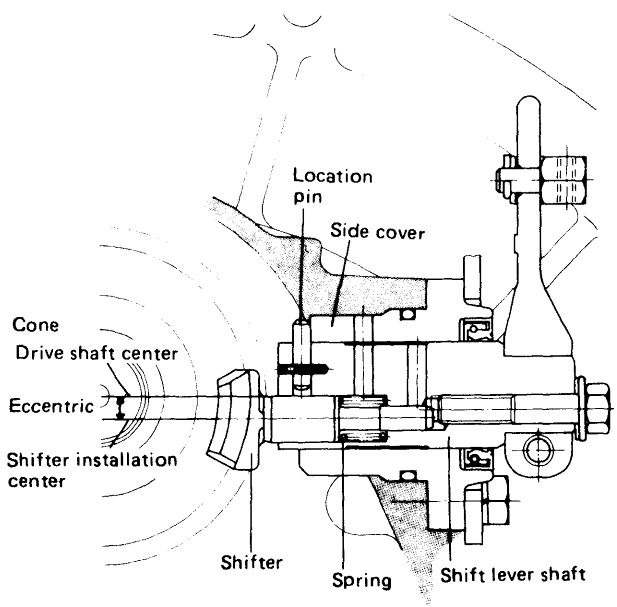
2-1 Construction of shifting mechanism



The shift lever shaft is installed on the side cover with neutral, clutch gear (A) and clutch gear (B) positions provided on the cover. The neutral, clutchgear (A) and clutch gear (B) location pins of the shift lever shaft are constantly inserted into their respective grooves on the shift lever by the tension of the shifter spring. The shifter is set on the eccentric hole of the shift lever shaft and moves the drive cone in the neutral position either to the clutch gear (A) or clutch gear (B) positions, and then back to the neutral position. (The shift lever shaft moves slightly to the shift lever (or drive cone) side when the shift lever is placed in the clutch gear (A) or clutch gear (B) positions.)

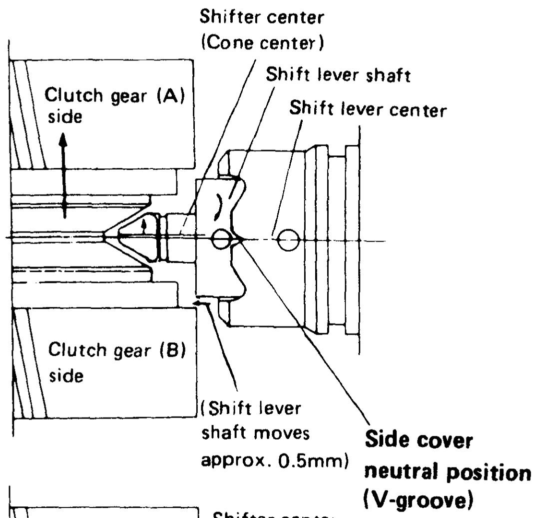
NOTE:1 Clutch gear (A) position: clockwise propeller rotation viewed from propeller side (C.C.W.)

NOTE:2 Clutch gear (B) position: Counterclockwise propeller rotation viewed from propeller side (C.W.)

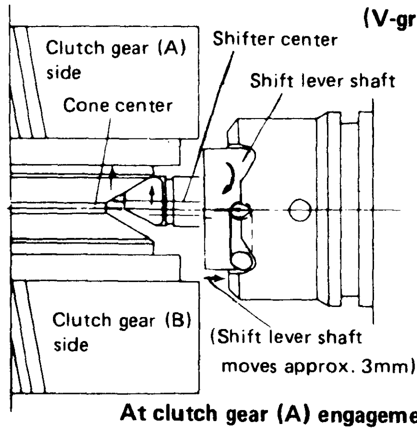


2-2 Clutch gear (A) and clutch gear (B) operation (Neutral ⇒ clutch gear (A), Neutral ⇒ clutch gear (B))

When the shift lever is moved to the clutch gear (A) position from the neutral position, the shift lever shaft starts to revolve, and the location pin disengages from the neutral V-groove position of the side cover. (Shift lever moves approx. 0.5mm to the drive cone side.) At this time the shifter, which is set on the eccentric hole of the shift lever shaft, moves the drive cone's V-groove to the clutch gear (A).



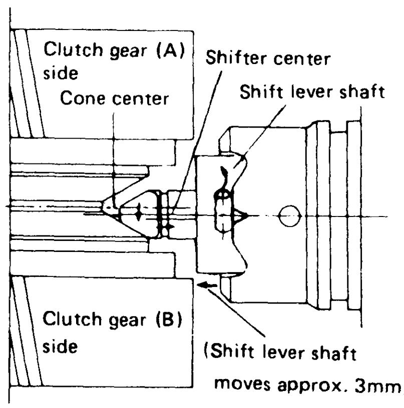
When the location pin of the shift lever shaft falls into the clutch gear (A) position groove on the side cover, the shift lever shaft moves approx. 3mm to the shift lever side, and the shifter starts to press the drive cone V-groove to the clutch gear (A) side by spring force.



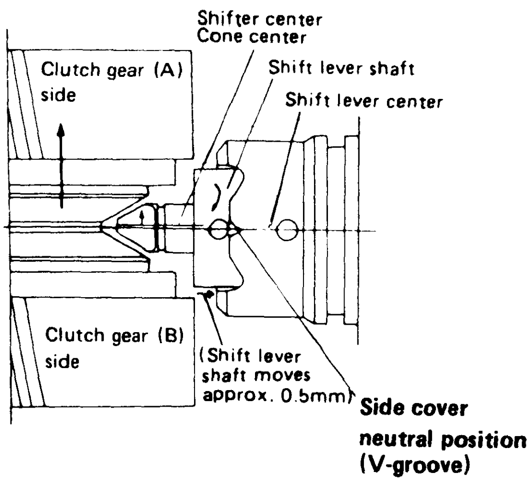
At clutch gear (A) engagement position

2-3 Engagement and disengagement of clutch (Clutch gear (A) ⇒ Neutral, Clutch gear (B) ⇒ Neutral)

When the shift lever is moved to the clutch gear (A) position from the neutral position, the shift lever shaft starts to revolve, and the location pin disengages from the clutch gear (A) position groove on the side cover. (The shift lever shaft moves approx. 3mm to the drive cone side.) At this time, the shifter which is set on the eccentric hole of the shift lever shaft, is moved to the neutral side (clutch gear (B) side). The drive cone, however, is engaged with the clutch gear (A) as the torque force produced by the revolving centrifugal force.

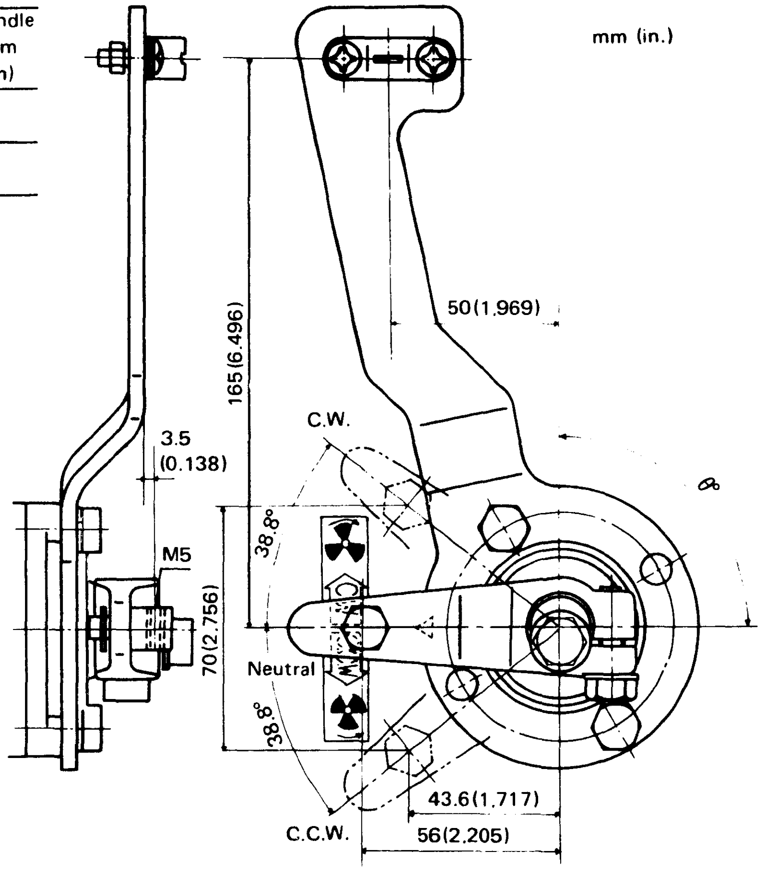


Further, when the shift lever shaft starts to revolve, and the positioning pin falls into the neutral V-groove position of the side cover (the shift lever shaft travels approx. 5mm to the shift lever side), the shifter moves to the shift lever side (to the spring side) while moving the V-groove of the drive cone to the clutch gear (B) side. The movement of the shifter to the shift lever side, however, is stopped when the shifter end contacts the stopper bolt. The shifter only works to press the V-groove of the drive cone to the clutch gear (B) side. Thus, the drive cone is disengaged from the clutch gear (A). After this disengagement, the transmission torque of the drive cone is decreased to zero and the shift lever is returned to the neutral position by spring force.



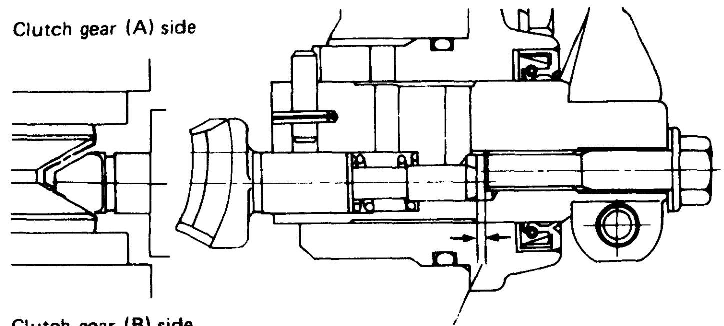
2-4 Clutch shifting force

Shifting position / Shifting direction	Shift lever position at 56mm	Remote control handle position at 170mm (Cable length, 4m)
Engaging force at 1000 rpm	29~39N (3~4kgf)	39~49N (4~5kgf)
Disengaging force at 1000 rpm	59~78N (6~8kgf)	69~93N (7~9.5kgf)



2-5 Adjustment of shifting device

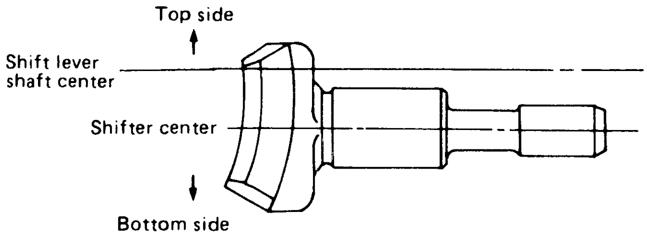
Whenever the side cover, shift lever shaft, shifter, stopper bolt or drive cone is replaced, be sure to adjust the clearance between the shifter end and the stopper bolt with shims. If the adjustment of this clearance is inadequate, the drive cone may not connect properly when the shift lever is moved to the neutral position, either from the clutch gear (A) or clutch gear (B) position.

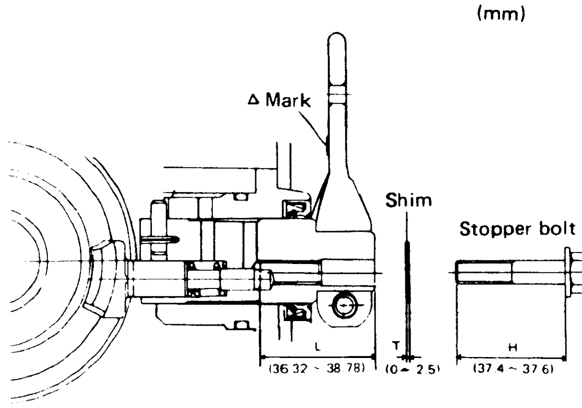


2-5-1 Measurement and adjustment of clearance

(1)Assemble the shifting mechanism (without installing the stopper bolt of the shifter) to the marine gear case.

NOTE: Ensure the correct alignment of the shifter before assembly.





(2)Turn the shift lever 10 ~ 15 degrees either to the clutch gear (A) or clutch gear (B) position from the neutral position.

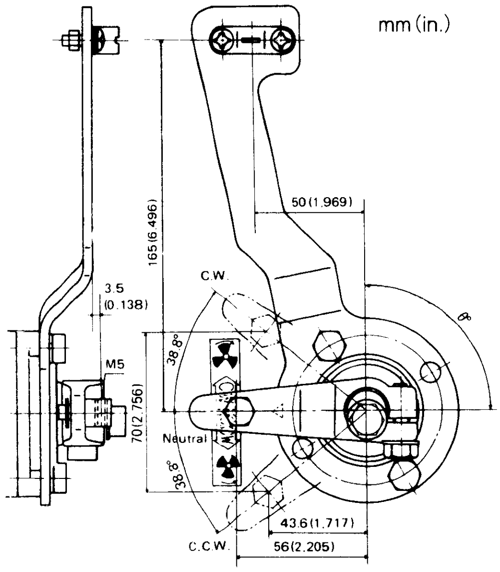
(3)Measure the L-distance between the shift lever shaft end surface and the shifter end.

(4)Measure the H-distance (the distance from the neck of the stopper bolt to its end).

(5)Obtain the shim thickness "T" by the following formula.

$$\boxed{T = (H - L + 1.25) \pm 0.1\text{mm } (0.0039\text{in.})}$$

NOTE: Shim set includes one each of 1mm, 0.4mm, 0.3mm, 0.25mm shims.
(YANMAR Part No. 177088-06380)

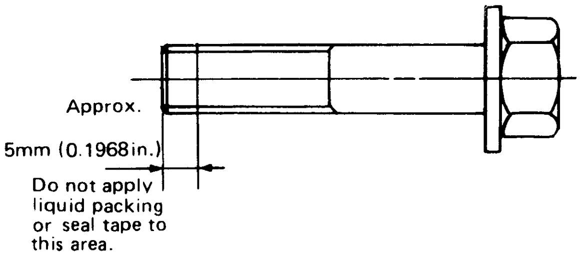


(6)Insert shim (s) of proper thickness to the stopper bolt side and tighten to the shift lever shaft.

NOTE: When tightening the stopper bolt, apply either a non-drying type liquid packing (THREE BOND No.1215), or a seal tape around the bolt threads.

NOTE. Shift lever must be installed in the direction of the Δ-mark ensuring the specified installation angle (θ).

$\theta = 90°$



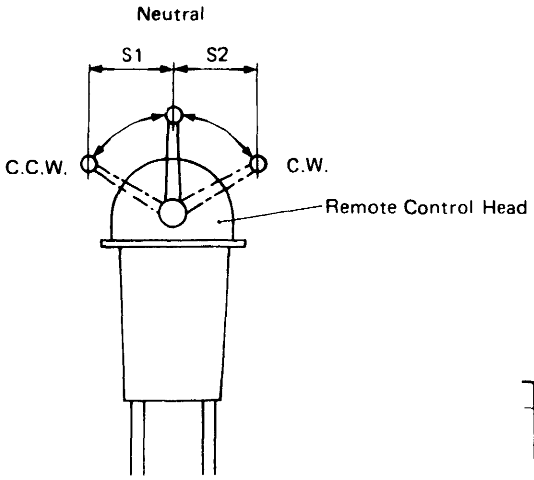
2-5-2 Inspect for the following points (to be inspected every 2-3 months)

(1)Looseness at the connection of the cable connector and the remote control cable.

(2)Looseness of the attaching nut of the cable connector and the shift lever.

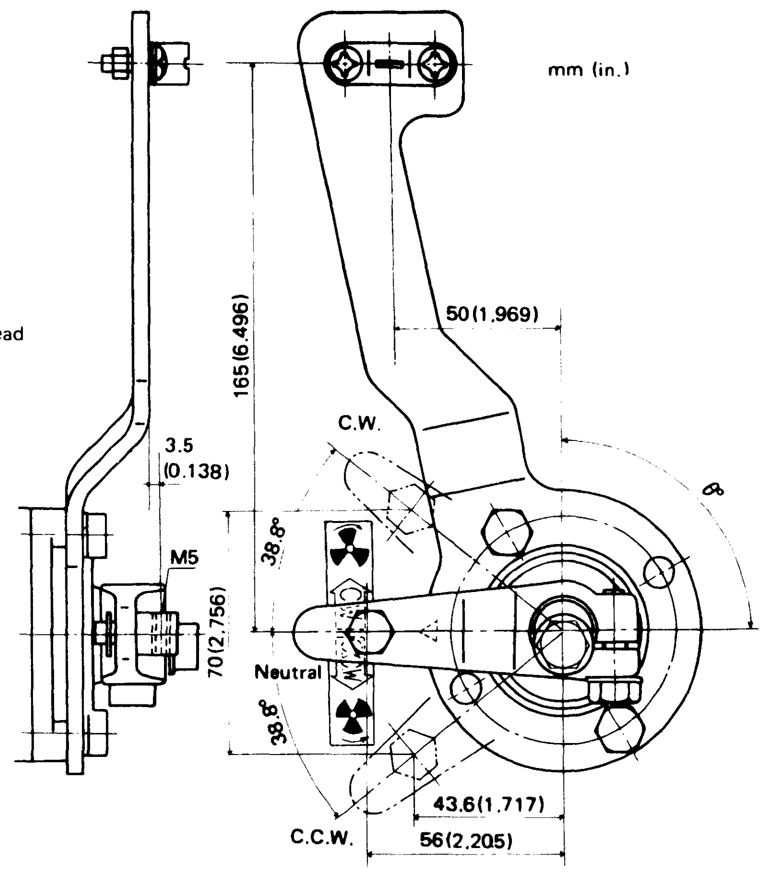
2-6 Adjustment of the remote control head Marine gearbox control side

(1)Equal distribution of the control lever stroke.



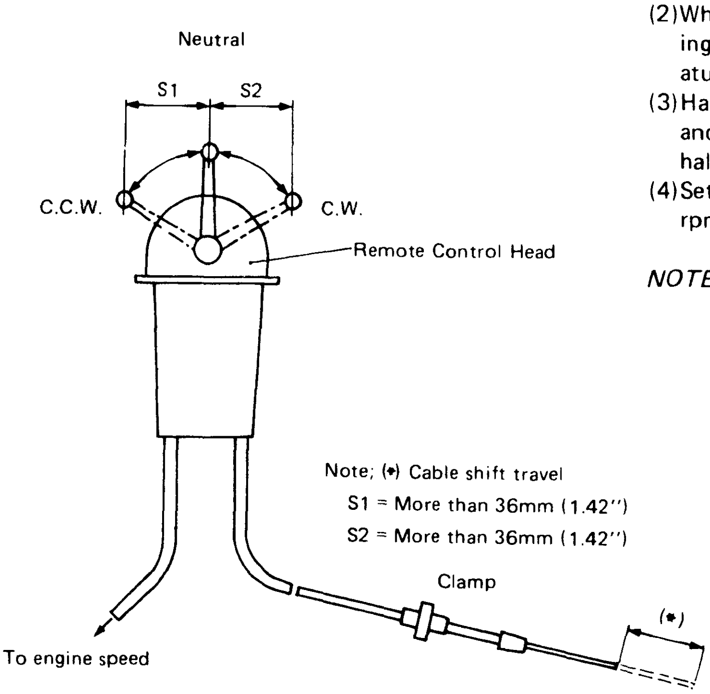
The stroke between the neutral position → C.W. position (S2), and the neutral position → C.C.W. position (S1) must be equalized.

When either stroke is too short, clutch engagement becomes faulty.



(2)Equalizing the travel distance of the control cable.

After ensuring the equal distribution of the stroke described in (1), connect the cable to the control head. Adjust so that the cable shift travel of the S_1 and S_2 control lever strokes becomes identical.



2-7 Cautions

(1)Always stop the engine when attaching, adjusting, and inspecting.

(2)When conducting inspection immediately after stopping the engine, do not touch the clutch. The oil temperature is often raised to around 90°C (194°F).

(3)Half-clutch operation is not possible with this design and construction. Do not use with the shift lever halfway to the engaged position.

(4)Set the idling engine speed at between 800 and 850 rpm.

NOTE: The dual(Two) lever remote control device cannot be used.

3. Inspection and Servicing

3-1 Clutch case and cover

(1)Check the clutch case and cover for cracking with a test hammer.
Perform a color check when required.
If the case and cover are cracked, replace those together.

(2)Check for staining on the inside surface of the bearing section.
Also, measure the inside diameter of the case and cover.
Replace the case and cover if these are worn beyond the wear limit.

3-2 Bearing

(1) Rusting and damage.
If the bearing is rusted or the taper roller retainer is damaged, replace the bearing.

(2) Make sure that the bearings rotate smoothly.
If rotation is not smooth, if there is any binding, or if any abnormal sound is evident, replace the bearing.

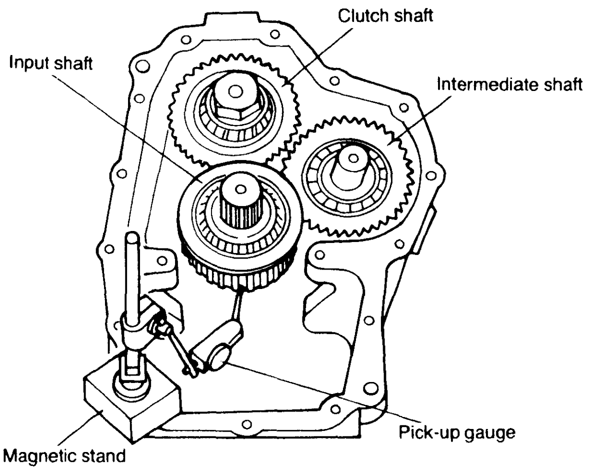
3-3 Gear

Check the surface, tooth face conditions and backlash of each gear. Replace any defective part.

(1)Tooth surface wear.
Check the tooth surface for pitting, abnormal wear, dents, and cracks. Repair the lightly damaged gears and replace heavily damaged gears.

(2)Tooth surface contact.
Check the tooth surface contact. The amount of tooth surface contact between the tooth crest and tooth flank must be at least 70% of the tooth width.

(3)Backlash.
Measure the backlash of each gear, and replace the gear when it is worn beyond the wear limit.

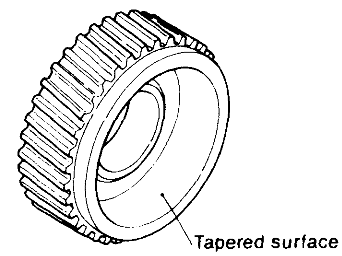


mm (in.)

	Maintenance Standard	Wear limit
Input shaft gear Clutch gear Idle gear	0.08 ~ 0.16 (0.0031 ~ 0.0063)	0.3 (0.0118)
Drive gear Output shaft gear	0.12 ~ 0.20 (0.0047 ~ 0.0079)	0.3 (0.0118)

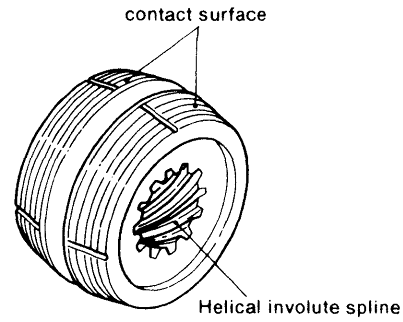
3-4 Clutch gear (A) and (B)

(1)Contact surface with drive cone.
Visually inspect the tapered surface of the clutch gears (A) and (B) where they make contact with the drive cone to check if there is any abnormal condition or sign of overheating.
If any defect is found,
replace the gear.



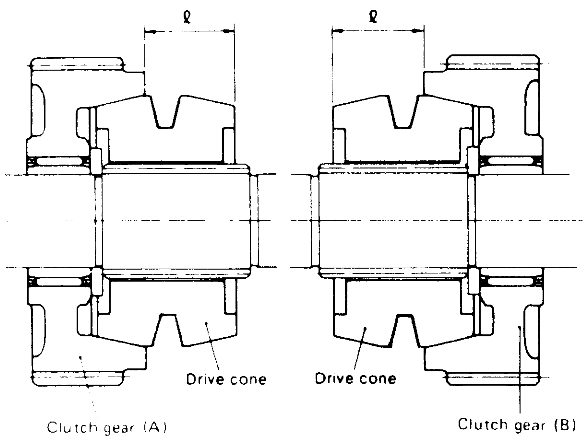
3-5 Drive cone

(1)Visually inspect that part of the surface that comes into contact with the circumferential triangular slot to check for signs of scoring, overheating or wear. If deep scoring or signs of overheating are found, replace the cone.



(2)Check the helical involute spline for any abnormal condition on the tooth surface, and repair or replace the part should any defect be found.

(3)Measure the amount of wear on the tapered contact surface of the drive cone, and replace the cone when the wear exceeds the specified limit.

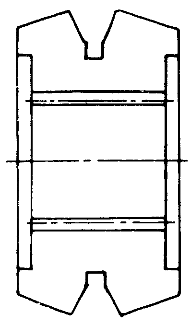


mm (in.)

	Standard dimension	Limited dimension
Dimensions ℓ	32.7 ~ 33.3 (1.2874 ~ 1.3110)	31.6 (1.2441)

***NOTE:** When dismantled, the forward or reverse direction of the drive cone must be clearly identified.*

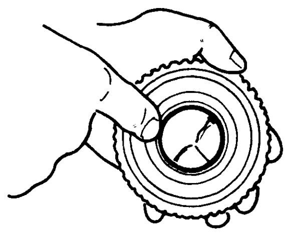
(4)If the wear of the V-groove of the drive cone is excessive, replace the part.



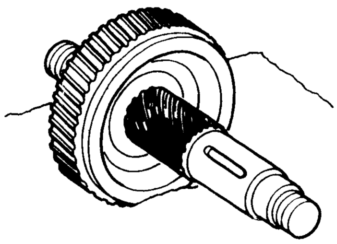
***NOTE:** When replacing the drive cone, the drive cone and clutch gears (A) and (B) must be lapped prior to assembly.*
The lapping procedure is described below.

3-5-1 Lapping Procedure for Drive Cone

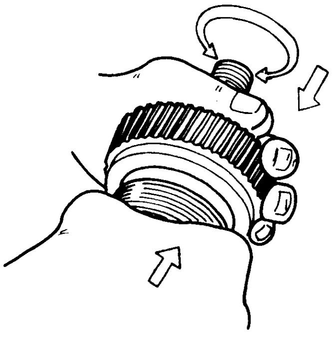
(1) Coat the lapping powder onto the cave of the clutch gear (Lapping powder: 67 micron silicon carbide #280).



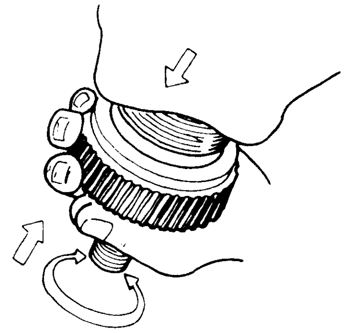
(2)Set the clutch gear on the clutch shaft with a needle bearing and then set the drive cone on the clutch shaft.



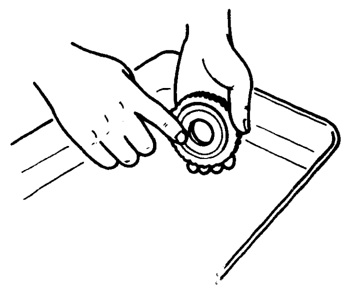
(3)Lap the clutch gear's cave and drive cone, pushing them together by hand.

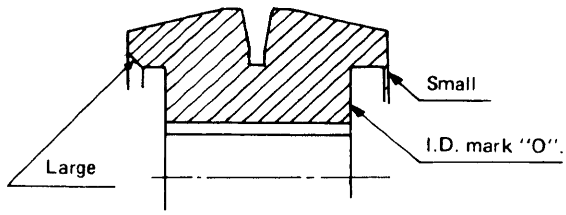


(4)Push and turn the clutch gear about 5 times both clockwise and counter-clockwise.



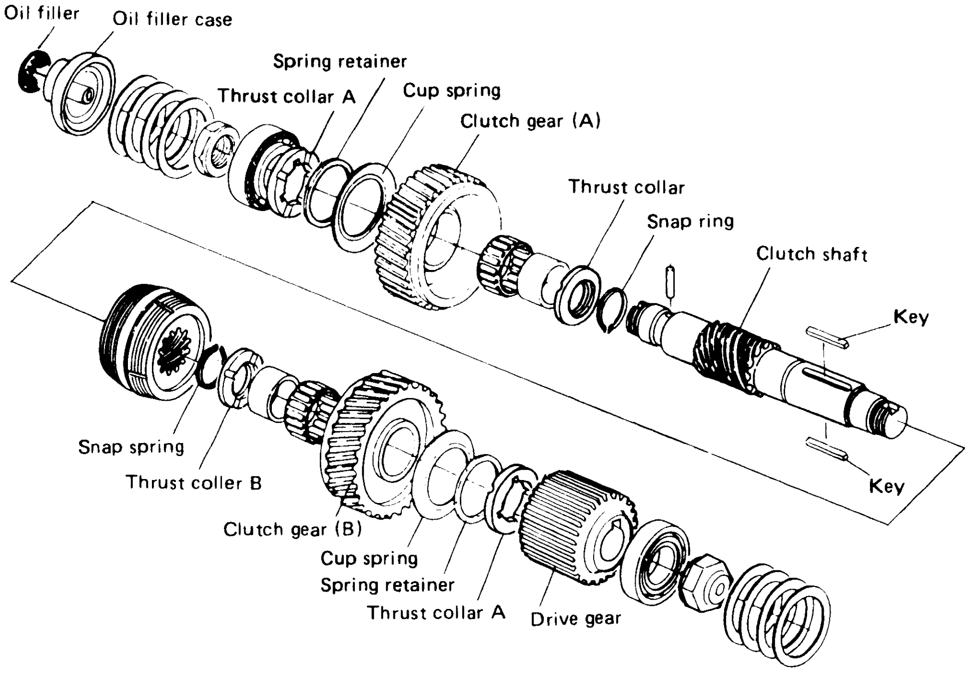
(5)After lapping them, wash them with washing oil. The lapped parts should be cleaned completely.





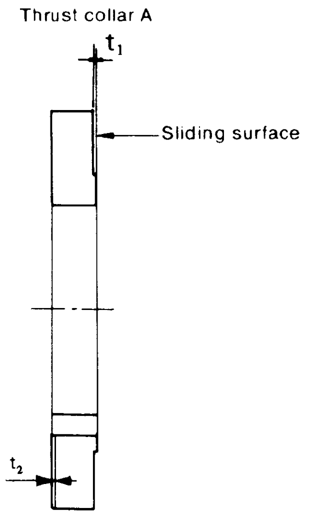
NOTE: Do not mix the combination of the lapped parts. The washing oil should be changed frequently in order to prevent residual powder being left on the parts. When assembling the drive cone, be sure to check its alignment. The larger chamferring face should be on the clutch gear (A) side.

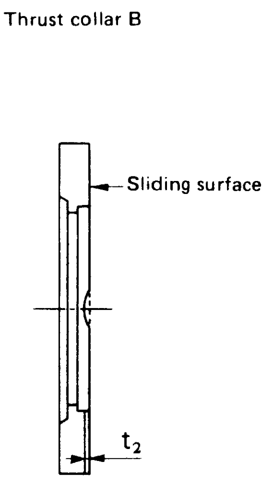
3-6 Thrust coller A and B for clutch shaft



(1) Visually inspect the sliding surface of thrust collar A or B to check for signs of overheating, scoring, or cracks. Replace the collar if any abnormal condition is found.

(2) Measure the thickness of thrust collar A or B, and replace it when the dimension exceeds the specified limit.





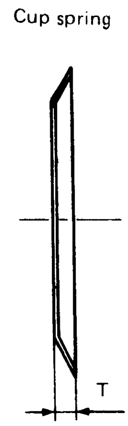
mm (in.)

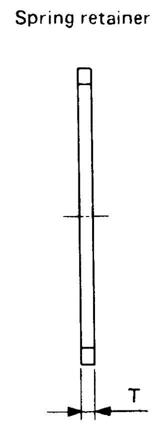
Stepped wear	Standard	Limit
Thrust collar A, t_1	t_1 0.1 (0.0039)	0.05 (0.0020)
Thrust collar A, t_2 B, t_2	t_2 1.0 (0.0394)	0.7 (0.0276)

3-7 Cup spring and spring retainer

(1) Check for cracks and damage to the cup spring and spring retainer. Replace the part if defective.

(2) Measure the free length of the cup spring and the thickness of the spring retainer. If the length or the thickness deviates from the standard size, replace the part.

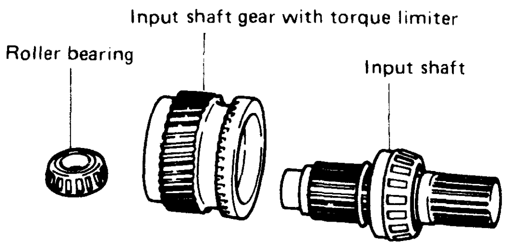




mm (in.)

	Standard	Limit
Cup spring, T	2.86 ~ 3.06 (0.1126 ~ 0.1205)	2.66 (0.1047)
Spring retainer, T	2.92 ~ 3.08 (0.1150 ~ 0.1213)	2.8 (0.1102)

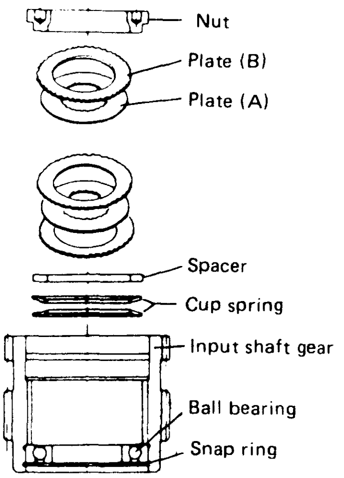
3-8 Input shaft



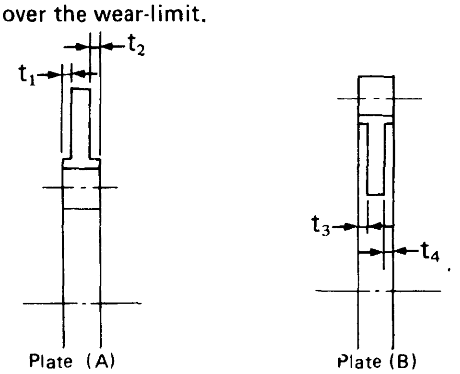
(1) Spline part.
Whenever uneven wear and/or scratches are found, replace with a new part.

(2) Surface of oil seal.
If the sealing surface of the oil seal is worn or scratched, replace.

(3)Torque limiter parts.
If the torque limiter has slipped due to excessive torque, measure the size of the inner parts listed top right. If the parts are excessively damaged replace.



(4)Plates (A) & (B)
Plates (A) & (B) will be worn in stepped configuration as shown below. Replace if the measurement is found to be over the wear-limit.



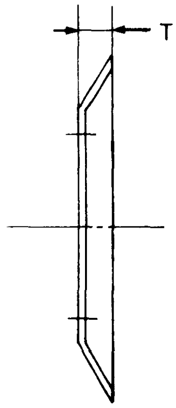
mm (in.)

Stepped wear	Limit	Q'ty/unit
Plate (A) $(t_1 + t_2)$	0.03 (0.0012)	22
Plate (B) $(t_3 + t_4)$	0.03 (0.0012)	23

(5)Cap spring

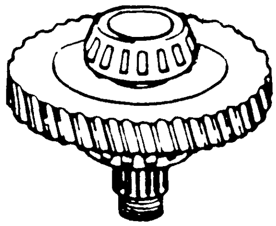
mm (in.)

	Standard	Limit
Cup spring, T	3.5 ~ 3.8 (0.1378 ~ 0.1496)	3.35 (0.1319)



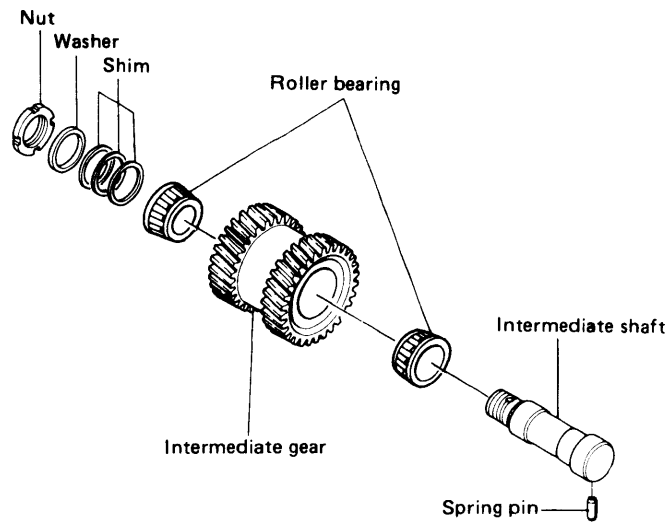
Cup spring

3-9 Output shaft

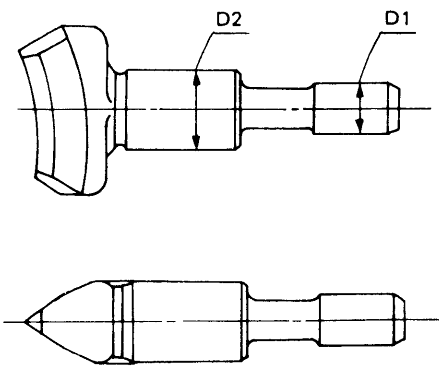


(1)Visually inspect the spline, oil seal and O-ring, and repair or replace a part when any abnormal condition is found on its surface.

3-10 Intermediate shaft



(1)Visually inspect the shaft and repair or replace a part when any abnormal condition is found on its surface.

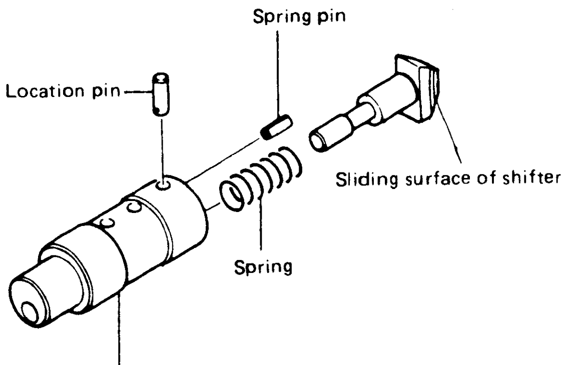


mm (in.)

	Standard	Limit
D1	6.69 ~ 6.70 (0.2634 ~ 0.2638)	6.50 (0.2559)
D2	11.966 ~ 11.984 (0.4711 ~ 0.4718)	11.95 (0.4705)
Shift lever shaft, Shifter insertion hole	12.0 ~ 12.018 (0.4724 ~ 0.4731)	12.05 (0.4744)

3-11 Shifting device

3-11-1 Shifter



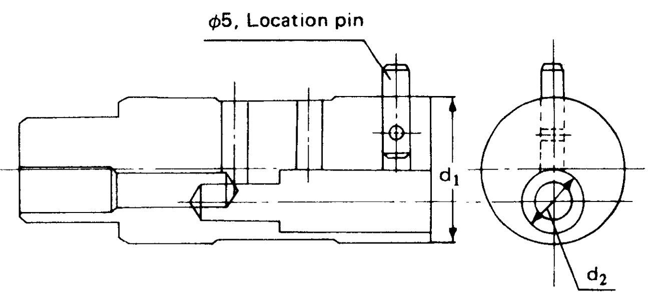
(1)Visually inspect the surface which contacts with the drive cone, and replace the shifter when signs of over-heating, damage or wear are found.

(2)Measure the shaft diameter of the shifter. Replace the shaft if the size deviates from the standard.

3-11-2 Shift lever shaft and location pin

(1)Check the shift lever shaft and location pin for damage or distortion, and replace defective parts. If the location pin must be replaced, replace it together with the shift lever shaft.

(2)Measure the diameter of the shift lever shaft and the shifter insertion hole. Replace the part if the size deviates from the standard value.



mm (in.)

	Standard	Limit
d_1	27.959 ~ 27.98 (1.1001 ~ 1.1016)	27.90 (1.0984)
d_2	12.0 ~ 12.018 (0.4724 ~ 0.4731)	12.05 (0.4744)
Side cover, Shift insertion hole	28.0 ~ 28.021 (1.1024 ~ 1.1032)	28.08 (1.1055)

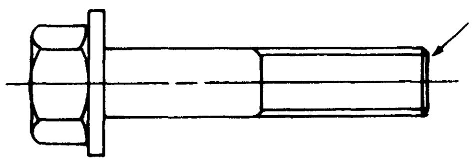
3-11-3 Shifter spring

(1)Check the spring for scratches or corrosion.
(2)Measure the free length of the spring.

Shifter spring	Standard	Limit
Free length	22.6 mm (0.890in.)	19.8 mm (0.780in.)
Spring constant	8.375N/mm (0.854 kgf/mm)	—
Length when attached	14.35 mm (0.5650 in.)	—
Load when attached	69.10N (7.046 kgf)	59.6N (6.08 kgf)

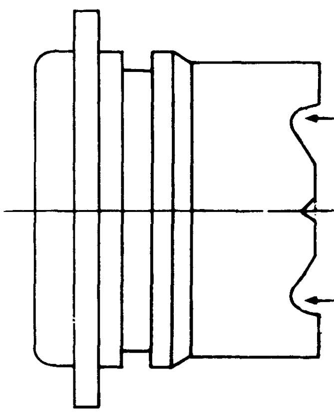
3-11-4 Stopper bolt

Check the stopper bolt. If it is worn or stepped, replace.

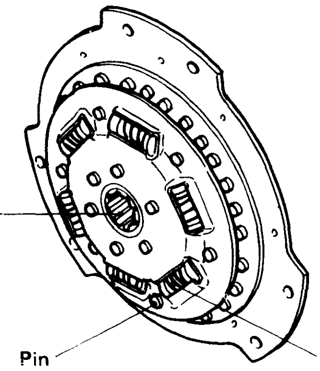


3-11-5 Side cover and oil seal

(1)Check the neutral, clutch gear (A) and clutch gear (B) position grooves. Replace if the grooves are worn.
(2)Measure the insertion hole of the shift lever shaft. Replace if the size deviates from the standard value.
(3)Check the oil seal and the O-ring for damage. Replace if the part is defective.



3-12 Damper disc



(1) Spline part.
Whenever uneven wear and/or scratches are found, replace with a new part.
(2) Spring.
Whenever uneven wear and/or scratches are found, replace with a new part.
(3) Pin wear.
Whenever uneven wear and/or scratches are found, replace with a new part.
(4) Whenever a crack or damage to the spring slot is found replace the defective part with a new one.

3-13 Shim adjustment for output and input shafts

Check the thickness of the shims for the intermediate, clutch, input and output shafts. When the component parts are not replaced after dismantling, the same shims can be reused. When the clutch case, mounting flange and clutch case cover or any one of the following parts is replaced the shim thickness must be determined in the following manner.

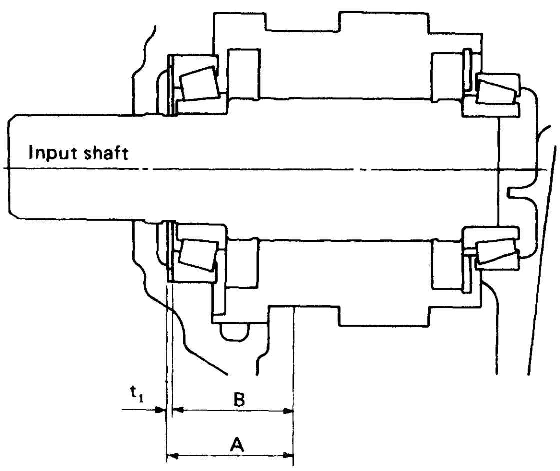
For input shaft parts :	input shaft, bearing.
For output shaft parts:	output shaft, bearing.
For intermediate shaft parts :	intermediate shaft, spacer, gear bearing.
For clutch shaft parts :	clutch shaft, thrust collar (A), (B), gear, bearing.

(1) Input Shaft

Measure the distance A and B.

Thickness of Shim t_1

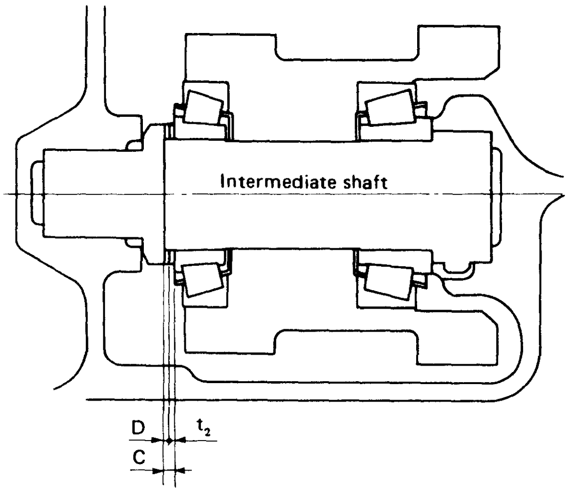
$$t_1 = (A - B)^{\pm 0.05}\,\mathrm{mm}$$



(2) Intermediate Shaft

Measure the distance C and thickness D

$$t_2 = (C - D)^{\,0}_{-0.1}\,\mathrm{mm}$$



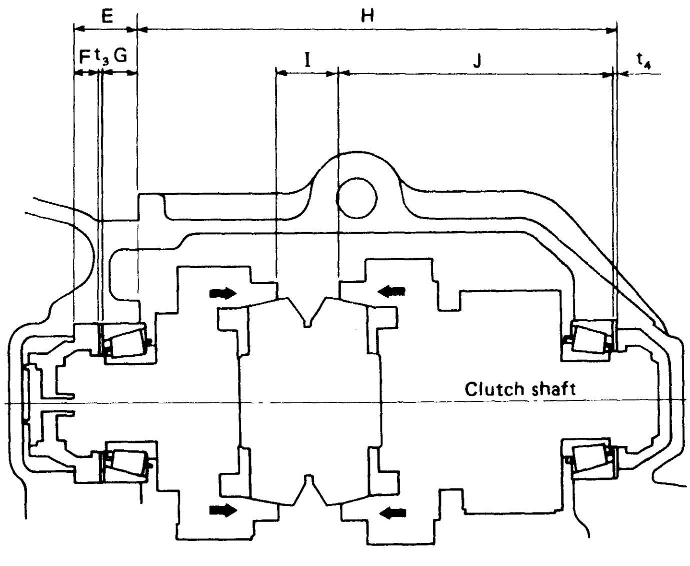
(3) Clutch Shaft

Measure the distance H, I and J.

$$t_4 = \left(H - 66 - \frac{I}{2} - J\right)^{\pm 0.05}\mathrm{mm}$$

Then measure distance E, F and G.

$$t_3 = (E - F - G)^{\pm 0.05}\,\mathrm{mm}$$

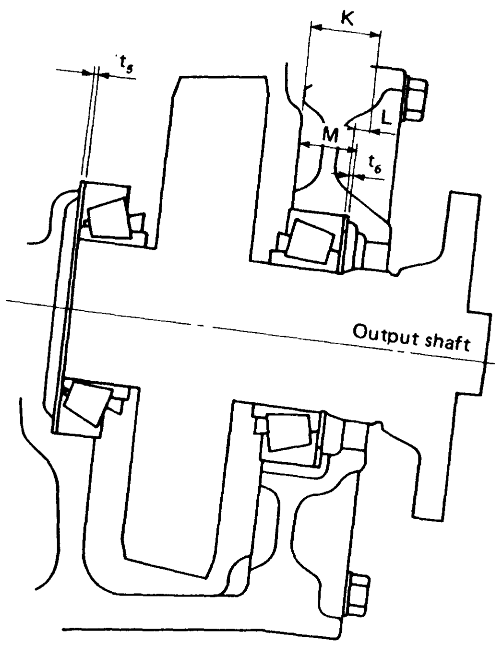


NOTE: When measuring the distances I and J, the clutch gears must be pushed in the direction of the drive cone.

(4)Output Shaft

Adjust the thickness of Shim t_5 to make the backlash of gear at 0.12 ~ 0.20 mm (0.0047 ~ 0.0079 in.)
Then measure the distances K, L and M.

$t_6 = (M + L - K)^{+0.1}_{+0}$ mm



(5)Standard size of parts

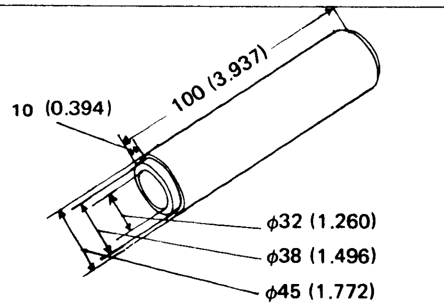
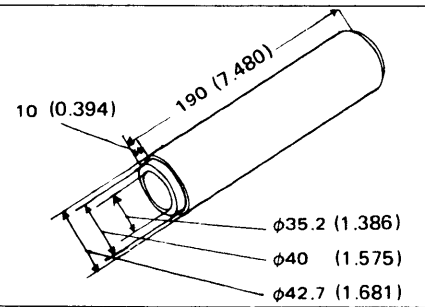
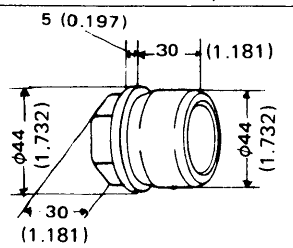
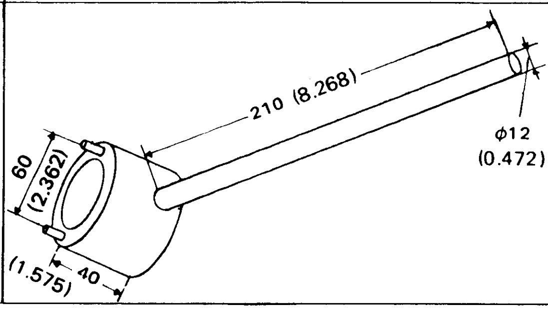
mm (in.)

A	B	C	D	E	F	G	H	I	J	K	L	M	Drive cone neutral center position
41.0~ 41.2 (1.614~ 1.622)	39.4~ 40.9 (1.551~ 1.610)	2.1~ 3.3 (0.0827~ 0.1299)	1.9~ 2.1 (0.075~ 0.0827)	26.0~ 26.2 (1.0236~ 1.0315)	9.0~ 10.0 (0.3543~ 0.3937)	14.6~ 15.6 (0.5748~ 0.6142)	188.0~ 188.2 (7.4016~ 7.4094)	23.3~ 24.2 (0.9173~ 0.9528)	108.6~ 109.7 (4.2756~ 4.3189)	23.9~ 24.1 (0.9409~ 0.9488)	104.8~ 106.1 (4.1260~ 4.1772)	22.7~ 22.8 (0.8937~ 0.8976)	66 (2.5984)

NOTE: Compare your measurements with the above standard size. If your measurements differ greatly from the standard sizes, the measurements may not be correct. Check and measure again.

Adjusting point	Part No.	Thickness. mm (in.)	No. of shims
t1	177095-02150	0.1 (0.0039)	2
		0.3 (0.0118)	1
		0.5 (0.0197)	2
		1.0 (0.0394)	1
t2	177074-03410	0.1 (0.0039)	2
		0.3 (0.0118)	1
		0.5 (0.0197)	1
		1.0 (0.0394)	1
t3 & t4	177075-02150	0.3 (0.0118)	4
		0.4 (0.0157)	4
		0.5 (0.0197)	4
t5 & t6	177074-02350	0.1 (0.0039)	6
		0.3 (0.0118)	2
		0.5 (0.0197)	2
		1.0 (0.0394)	2

4.Special Tools

Name of tool	Shape and size mm(in.)	Application
Inserting tool Part No. 177099-09040		For installing clutch shaft bearings (Common use marine gear model, KBW10)
Inserting tool Part No. 177075-09030		For installing input and intermediate shaft bearings (Common use for marine gear model, KBW20, 21 & KM4A)
Spline socket Part No. 177073-09020		For checking limiter torque of the torque limiter (Common use marine gear model, KM4A)
Ring nut wrench Part No. 177074-09010		For removing and tightening the torque limiter

5.Disassembly

5-1 Disassembling the clutch and accessories.

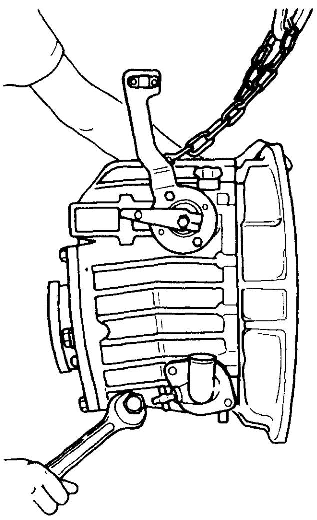
(1) Remove the remote-control cable and the C.W. hose of L.O. cooler.

(2) Dismount the clutch main body from the mounting flange.

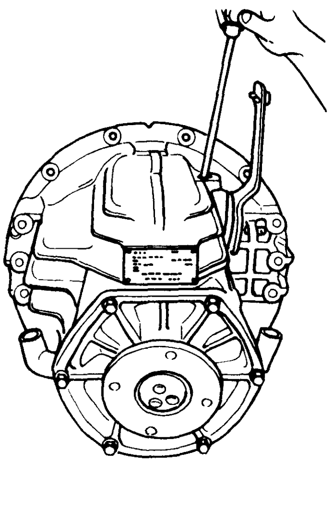
(3) Drain the lubricating oil

Drain the lubricating oil by loosening the plug at the bottom of the clutch case. Also remove the dipstick from the clutch case at the same time.

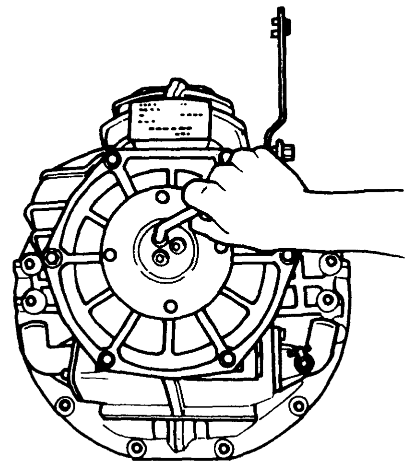
(4) Remove the drain plug and pull out the L.O.



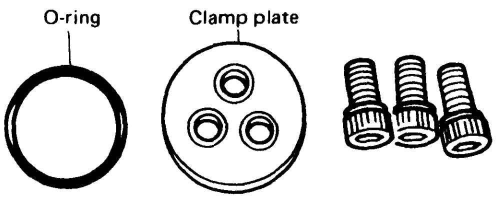
(5) Remove the dipstick.



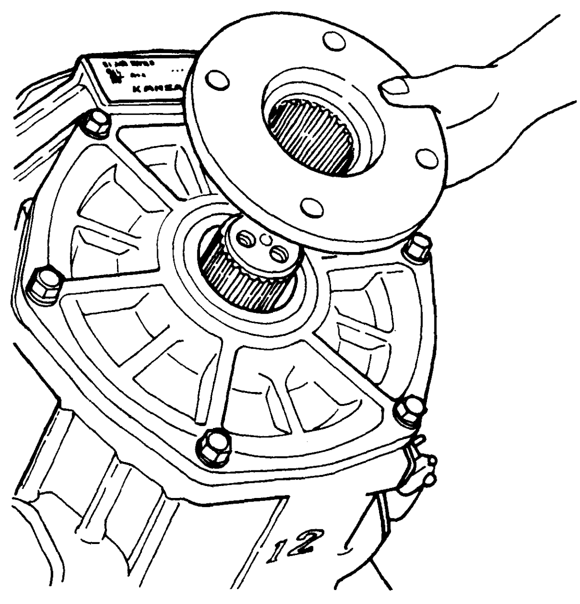
(6) Remove the fastening bolts of the output shaft coupling.



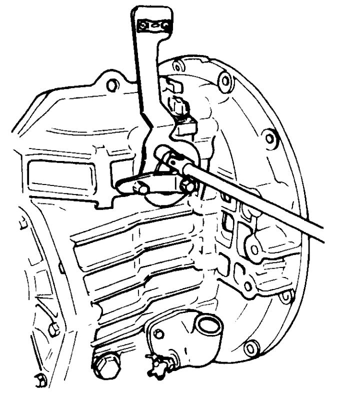
Remove the clamp plate and O-ring.



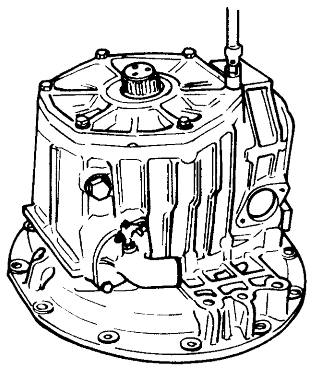
Remove the output shaft coupling.



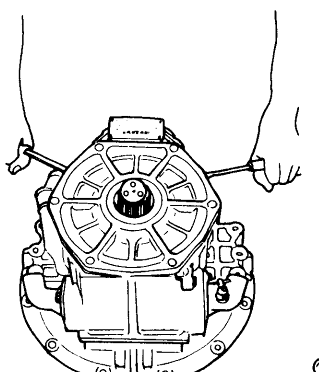
(7) Remove the fixing bolts on the side cover of clutch case, and also remove the shift lever shaft assembly.

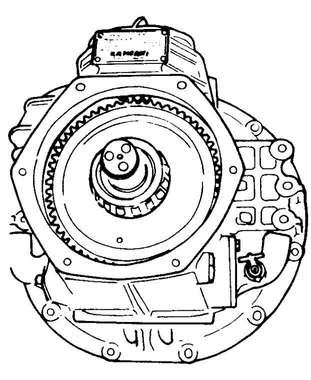


(8) Remove the fastening bolts of the rear cover.

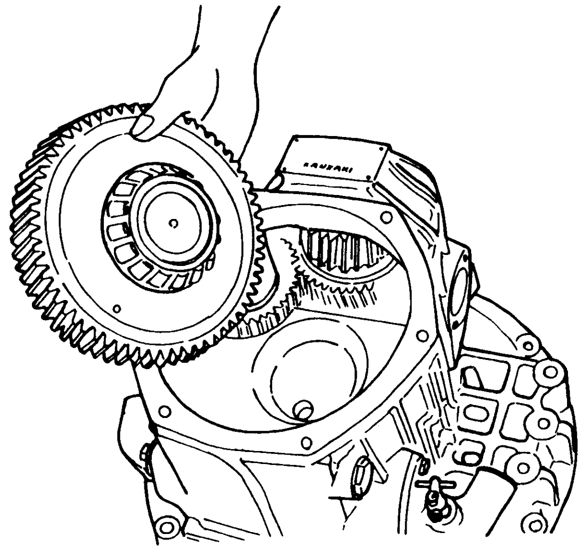


Remove the rear cover from the clutch case.



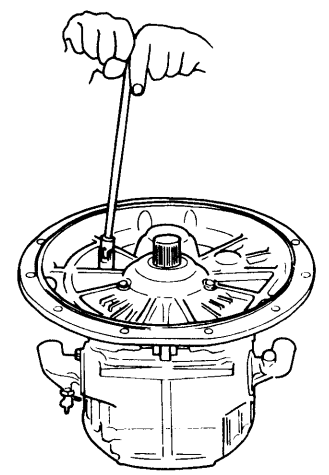


(9) Remove the output shaft.

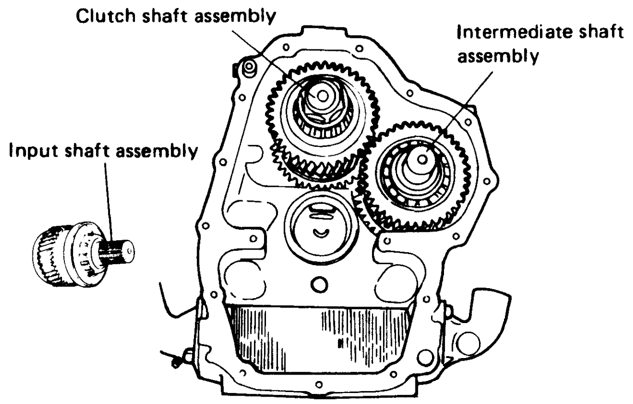


(10) Removing the mounting flange

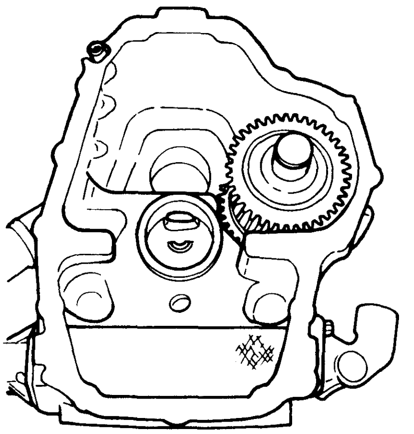
Remove the fastening bolt of the mounting flange and then remove the mounting flange.

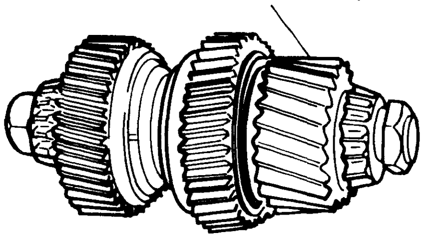


(11) Removing the input shaft assembly.
Draw out from the mounting flange side of the case.

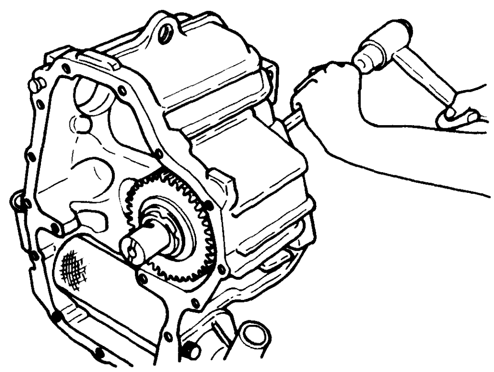


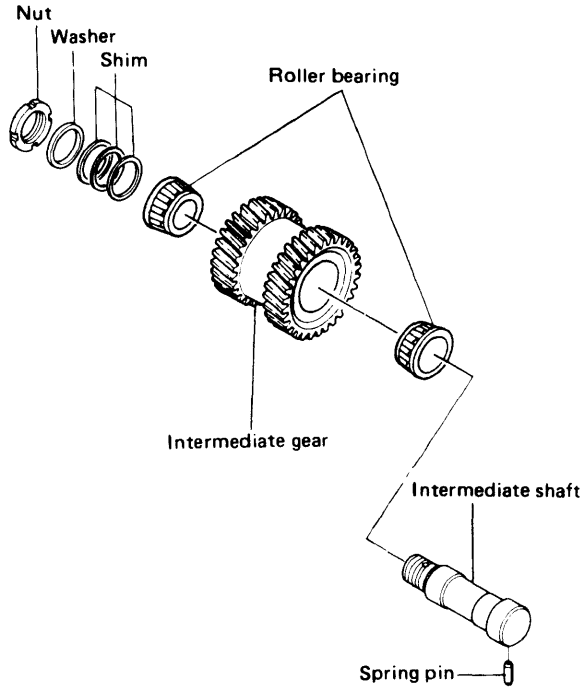
(12) Remove the clutch shaft assembly.



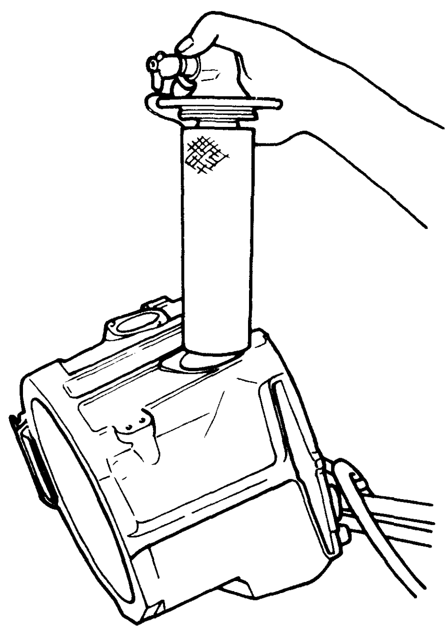


(13) Draw out the intermediate shaft tapping to the mounting flange side with a aluminum bar.





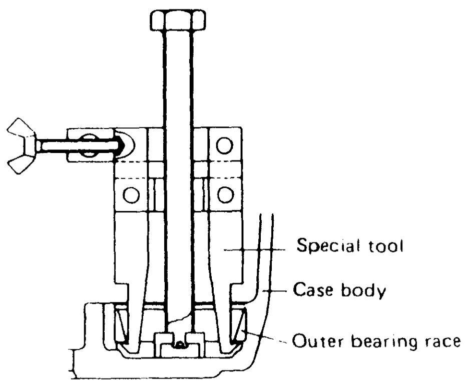
(14) Remove the oil cooler.

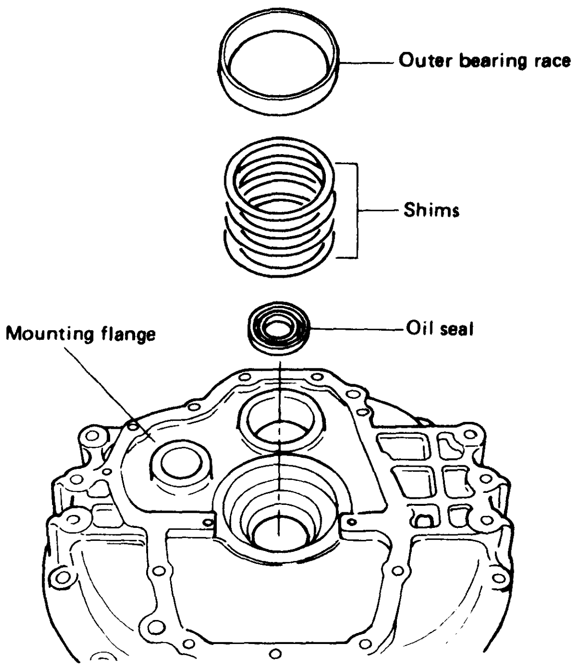


(15)Draw out the outer bearing reces.

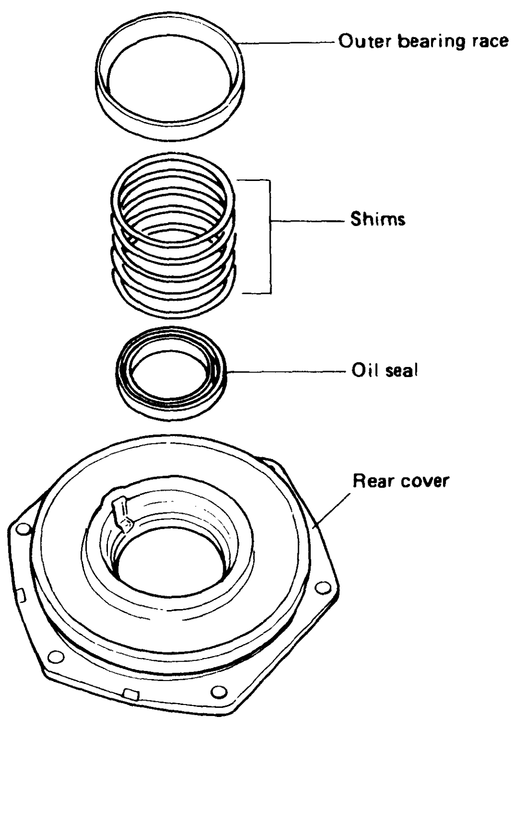
1) Remove the outer bearing races of the mounting flange, the case cover and the case.

NOTE: Remove the outer bearing races with a special tool.





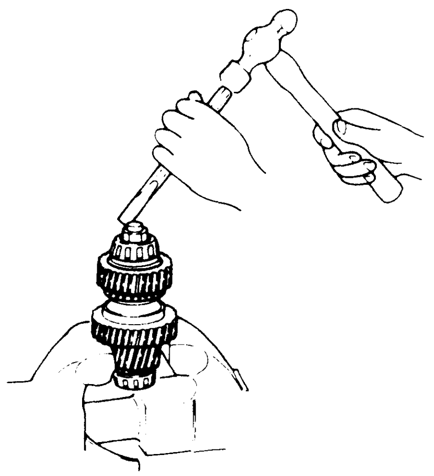
(16) Remove the oil seals of the mounting flange and the case cover.

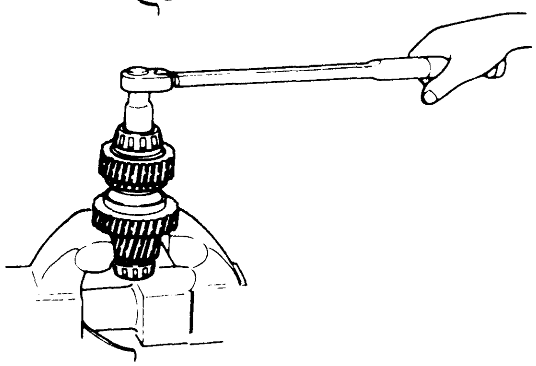


5-2 Disassembling the clutch shaft

5-2-1 Clutch gear (A) side

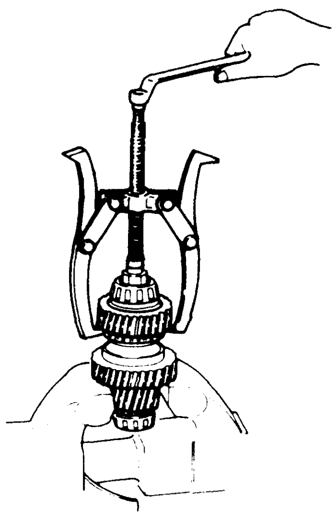
(1) Loosen the calking of the end nut and remove the nut. Remove the nut by a torque wrench, fixing the clutch shaft in a vice.



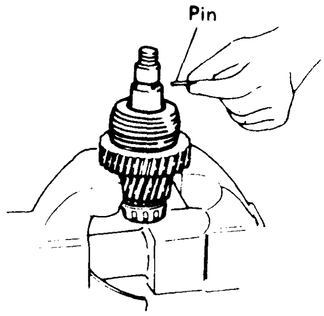


NOTE: Remember that the nut has a counterclockwise thread.

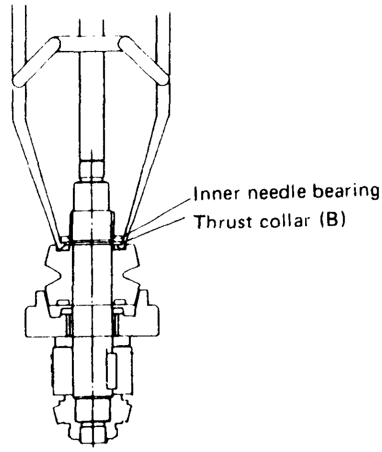
(2)Take out the clutch gear (A), Thrust collar (A), cup spring, spring retainer and inner bearing trace. The clutch gear (A) must be withdrawn using a pulley extracter, with the clutch shaft fixed in a vice.



(3)Remove the pin.

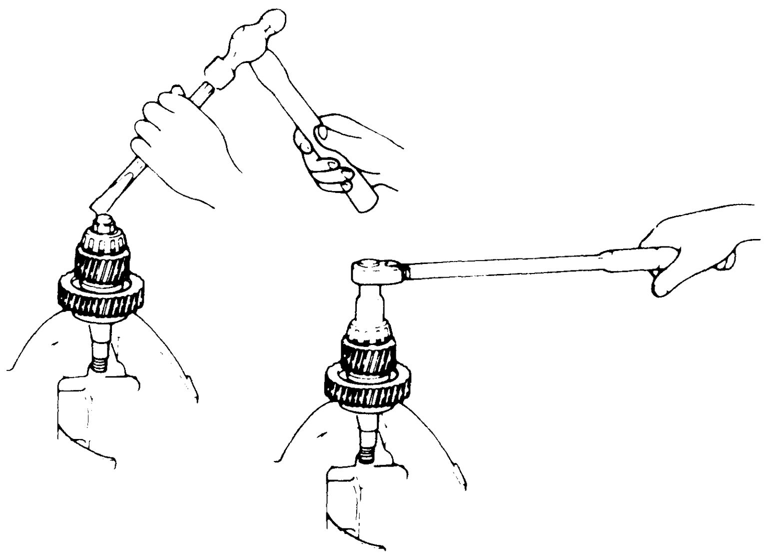


(4)Withdraw the thrust collar (B), inner needle bearing by pulley extractor.



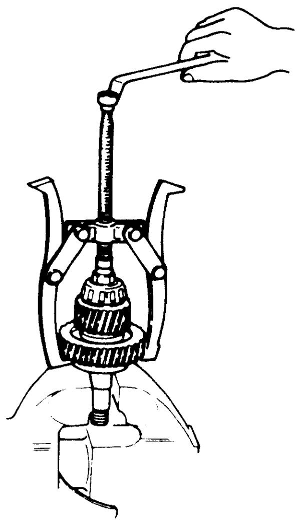
5-2-2 Clutch gear (B) side

(1)Loosen the calking of the end nut and remove the nut. Remove the nut by a torque wrench, with the clutch shaft fixed in a vice.

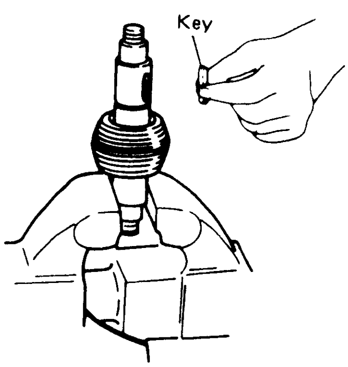


NOTE: Remember that the nut has a left-handed thread.

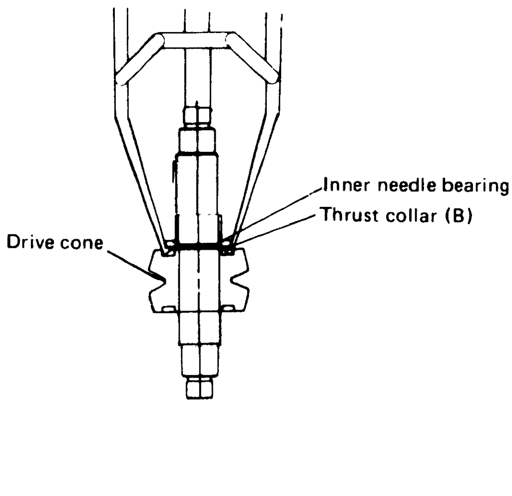
(2)Withdraw the large gear (B), thrust collar (A), cup-spring, spring retainer, drive gear and inner bearing race.
Use a pulley extracter, with the clutch shaft fixed in a vice.



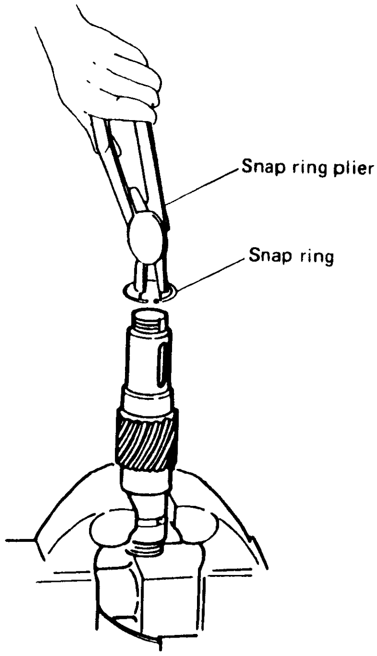
(3)Remove the key.



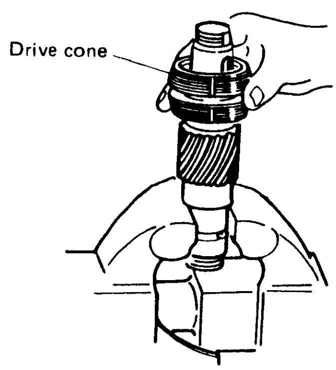
(4)Withdraw the thrust collar (B) and inner needle bearing race with the pulley extractor.



(5)Remove the snap rings.

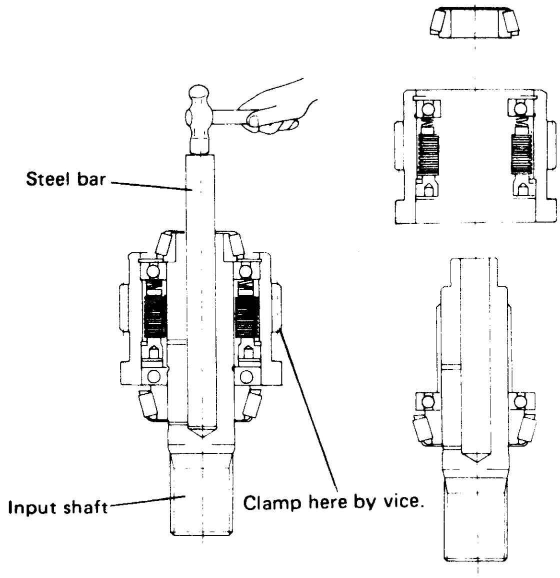


(6)Draw out the drive cone.

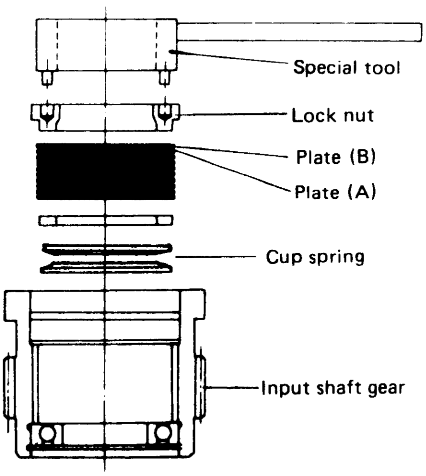


5-3 Disassembling the input shaft

(1)Draw out the input shaft tapping to the small roller bearing side with a steel bar.

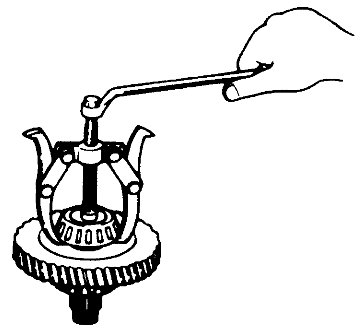


(2)Fix the input shaft gear in a vice, and remove the lock nut with a special tool.



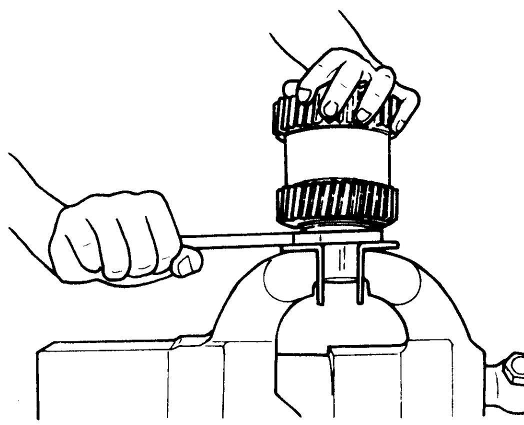
5-4 Disassembling the output shaft

(1)Remove the bearing inner race from the output shaft. Use a pulley extracter, fixing the output shaft in a vice.

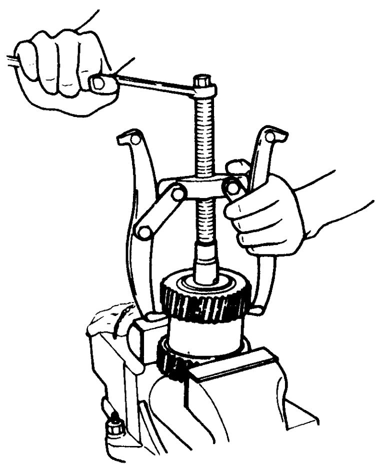


5-5 Disassembling the intermediate shaft

(1)Remove the lock nut with the intermediate shaft fixed in a vice.

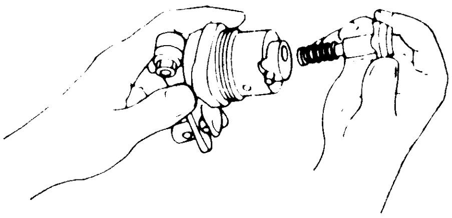


(2)Withdraw the gear and bearing by pulley extractor, with the gear fixed in a vice.

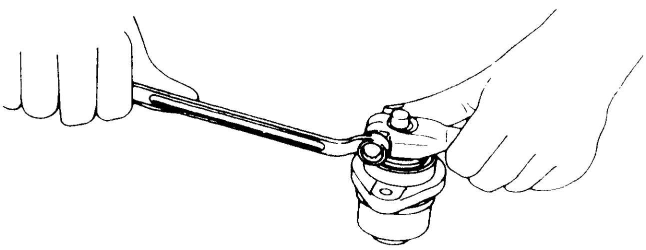


5-6 Disassembling the shifting device

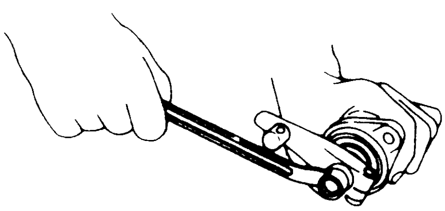
(1)Take out the shifter and shifter spring.



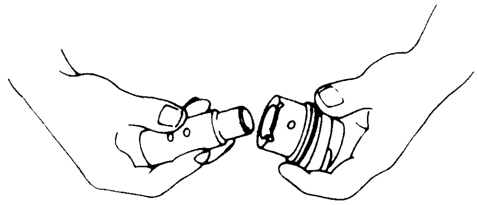
(2)Remove the stopper bolt of the shifter and shim.



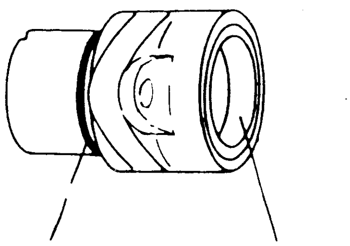
(3)Loosen the belt of the shift lever and remove the shift lever and cable bracket.



(4)Remove the shift lever to the anti-shift lever side.



(5)Remove the oil-seal and O-ring.

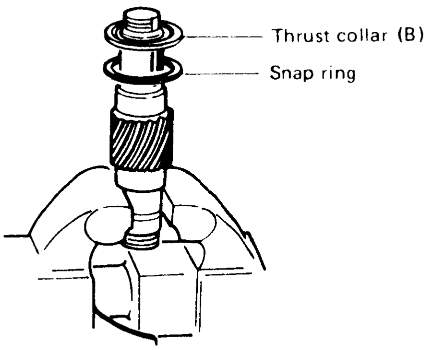


6.Reassembly

6-1 Reassembly of clutch shaft

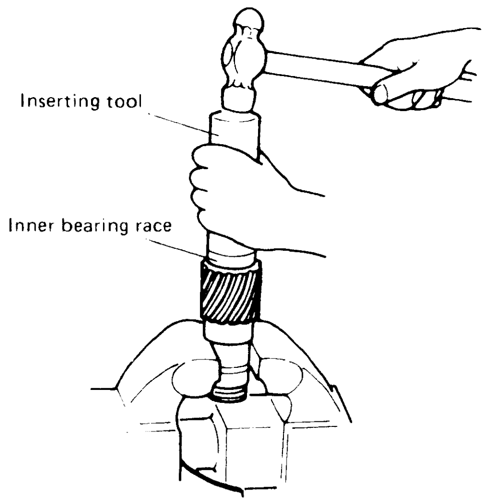
6-1-1 Clutch gear (B) side

(1)Fit the clutch gear (B) side snap ring and thrust collar (B) onto the shaft.

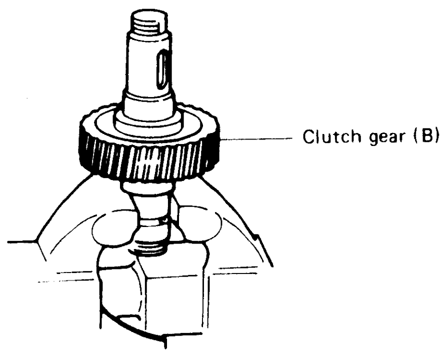


NOTE: 1) Insure that slots in thrust washer face gear side.
2) Position slots in thrust washer on the oil holes of the shaft.

(2)Drive in the inner needle bearing race using the inserting tool.

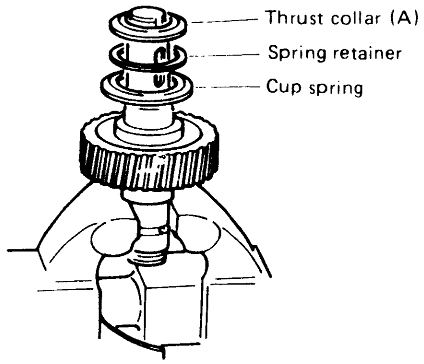


(3)Assemble the needle bearing and clutch gear (B).



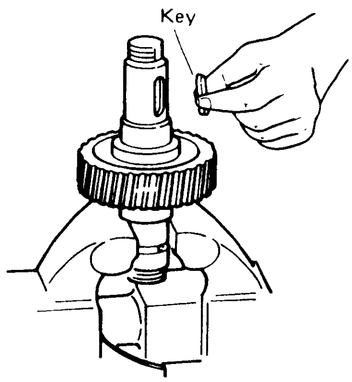
NOTE: Check that the clutch gear (B) rotates smoothly.

(4)Fit the cup spring, spring retainer, thrust collar (A).

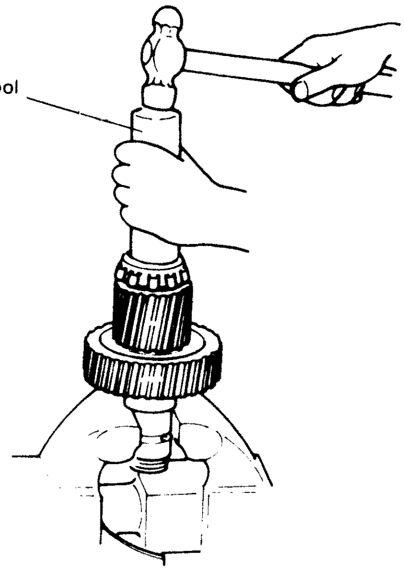


NOTE: 1) Drive in with a plastic headed hammer Do not hit hard.
2) When fitting the thrust collar (A), note the fitting direction. Fit it keeping the stepped surface toward the drive gear side.
3) Check that the clutch gear (B) rotates smoothly.
4) Cup spring is installed with slope facing in toward spring retainer.

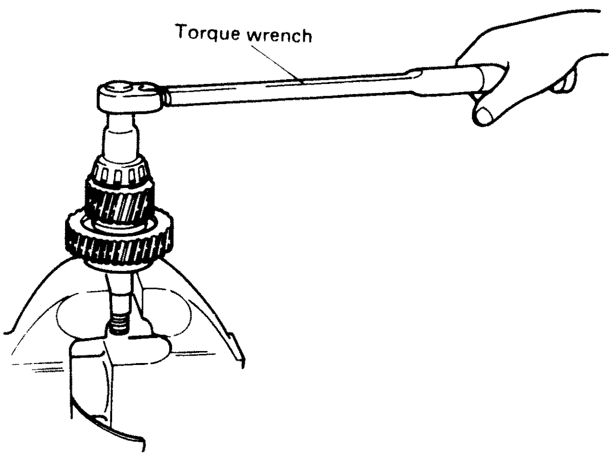
(5)Fit the keys.



(6)Drive in the driving gear and inner bearing race using the inserting tool.



(7)Set and tighten the clutch gear (B) end nut.
Fit the clutch shaft in a vice, and tighten the nut with a torque wrench.

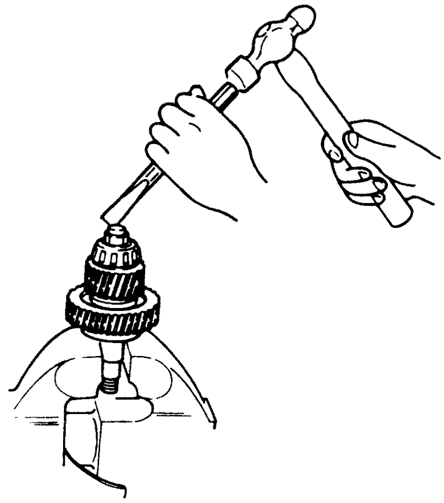


Tightening torque	392N·m (40kgf-m)

NOTE: 1) Remember it is a left-handed thread.

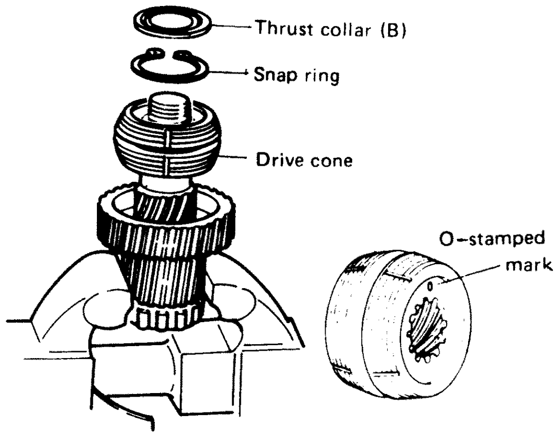
2) Use the clutch gear (A) side nut which is used before dismantling for the clutch gear (B) end nut. This is not to make the calked portion to the same point.

(8)Calking the end nut and clutch shaft.



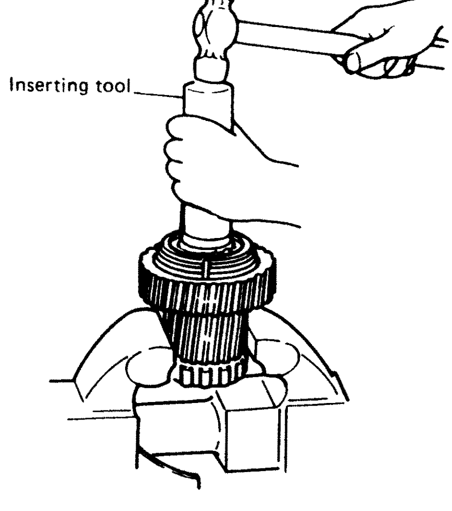
6-1-2 Clutch gear (A) side

(1)Insert the drive cone, snap ring and thrust collar (B).

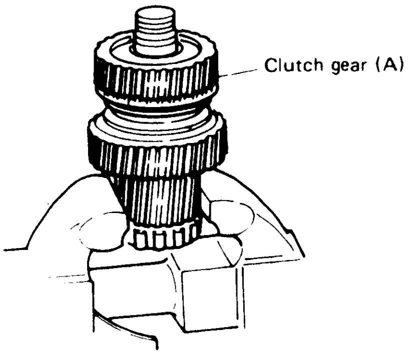


NOTE: Insert it keeping the O-stamped make surface toward the clutch gear (B) side.

(2)Drive in the inner needle bearing race, using an inserting tool.

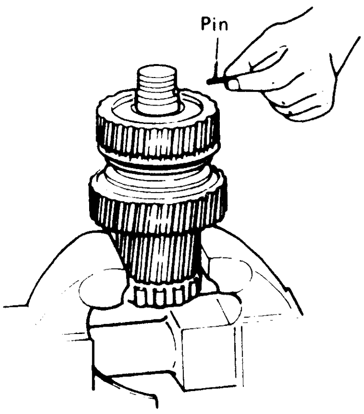


(3)Assemble the needle bearing and clutch gear (A).

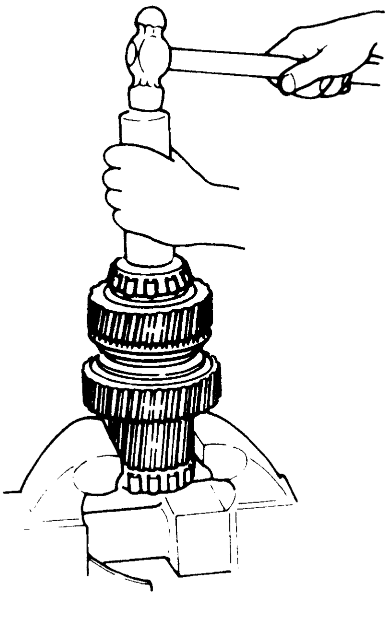


NOTE: Check that the clutch gear (A) rotates smoothly.

(4)Insert the pin.

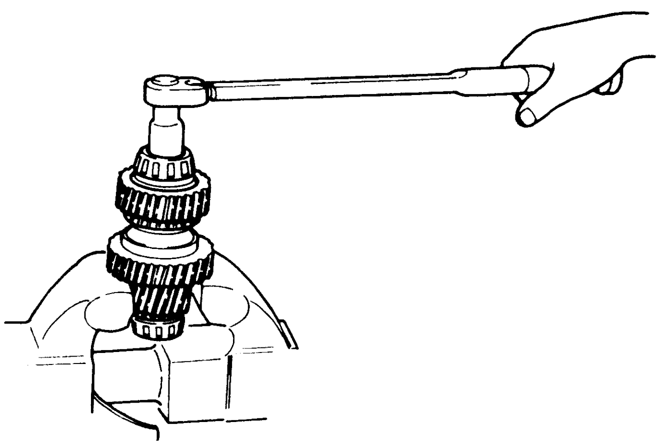


(5)Fit the cup spring, spring retainer and thrust collar (A) and drive in the inner bearing race using the inserting tool.



NOTE: 1) When fitting the thrust collar (A), note the fitting direction. Fit it keeping the stepped surface toward the roller bearing side.
2) The pin cannot be fitted after the inner bearing race has been driven in.
3) Check that the large gear (B) rotates smoothly.

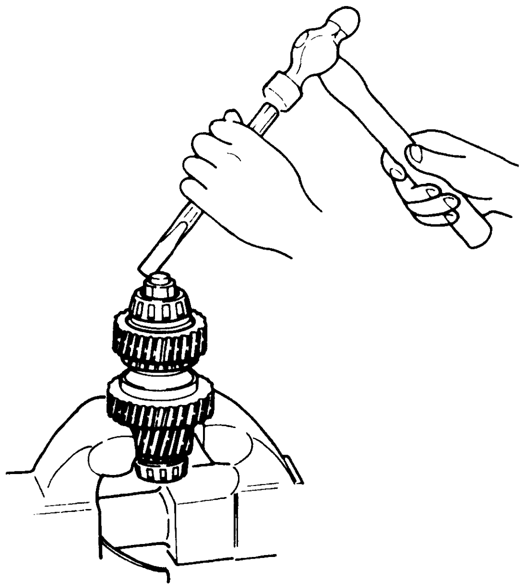
(6)Set and tighten the clutch gear (A) end nut. Fix the clutch shaft in a vice and tighten the nut with a torque wrench.



Tightening torque	392N·m (40kgf-m)

NOTE: 1) Remember it is a left-handed thread.

(7)Calk the end nut and clutch shaft.

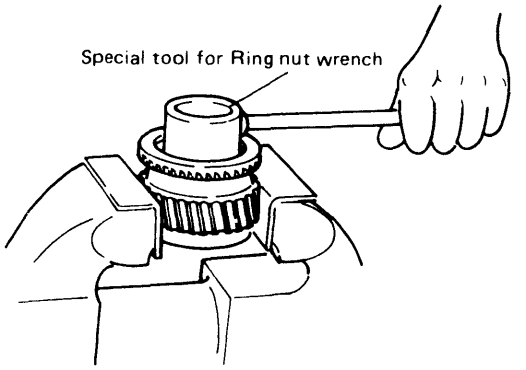


NOTE: Use the clutch gear (A) side nut which is used before dismounting for the clutch gear (B) end nut.
This not to make the calked portion to the same point.

6-2 Reassembly of input shaft

(1)Drive in the ball bearing and fit the snap ring into the input shaft gear.

(2)Insert the cup springs, spacer, plates (A) and plates (B) and temporarily lock the lock nut.

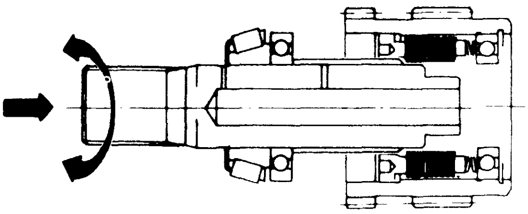


NOTE: Apply lube oil to each insert part.

(3)Fit the O-ring onto the input shaft.

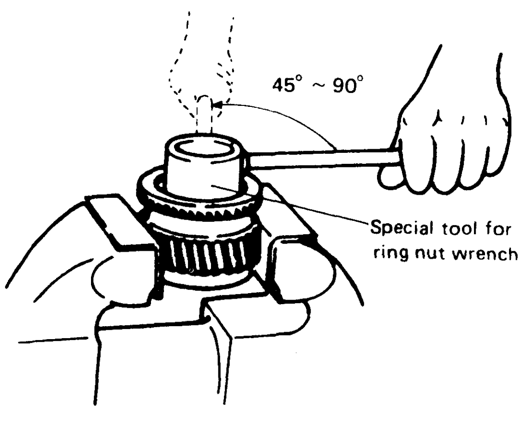
(4)Drive the ball bearing and the inner bearing race using a inserting tool.

(5)Insert the input shaft into the plate (A).

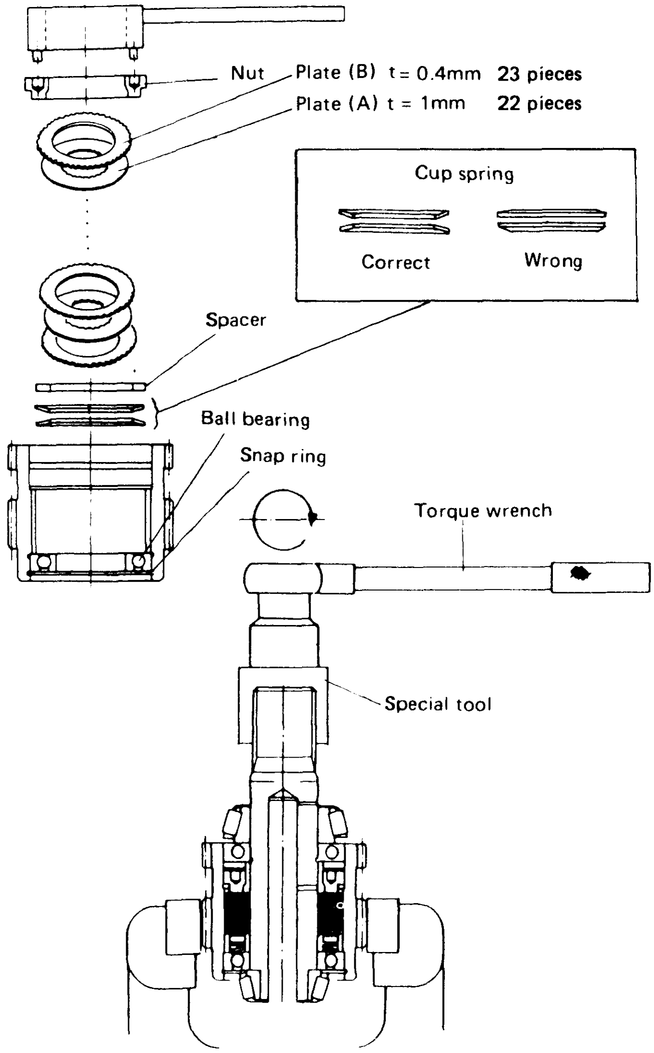


(6)Take out the input shaft again.

(7)Tighten the nut firmly by using a special tool, then return the nut to 45 – 90 degrees.



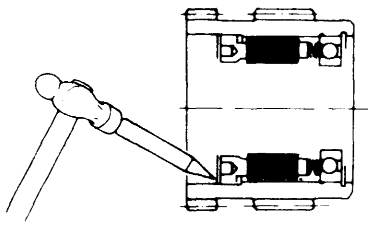
(8)Insert the input shaft, then measure the torque of the input shaft using a torque wrench.



Torque:	785-883N·m (80-90kgf-m)

NOTE: Match up the teeth of plate (A).

(9)Take out the input shaft and calking the lock nut end of the thread.



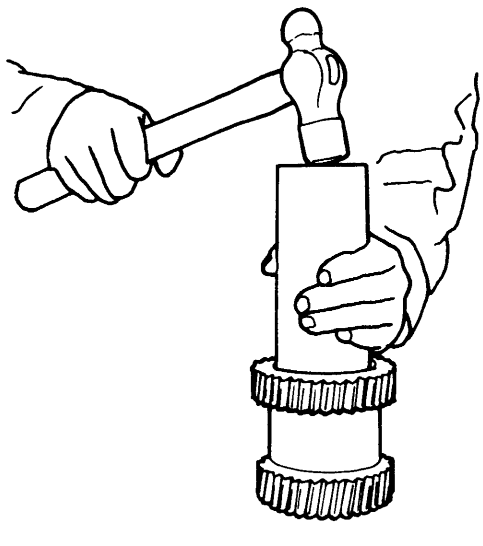
(10)Insert the input shaft into the input gear assembly.

(11)Drive in the inner bearing race onto the input shaft end.

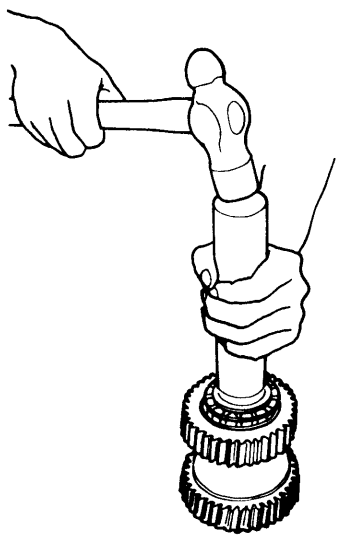
6-3 Reassembly of the clutch case

6-3-1 Reassembly of the intermediate shaft

(1)Drive in the outer bearing race using the inserting tool.

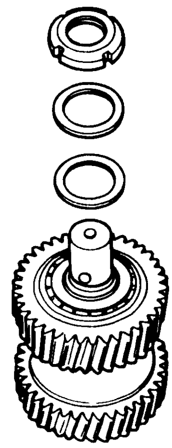


(2)Drive in the bearing, inserting the gear and drive in the bearing for opposite side.

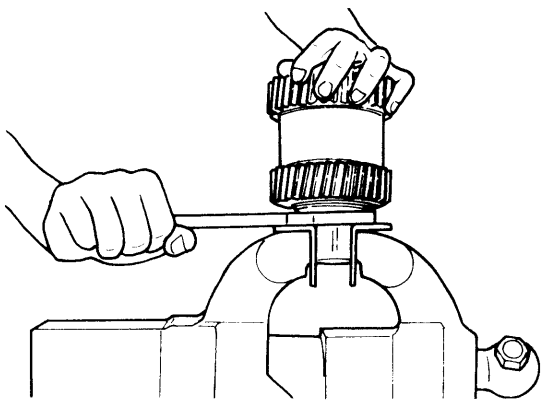


NOTE: Check that the gear rotates smoothly.

(3)Insert the shim and collar.

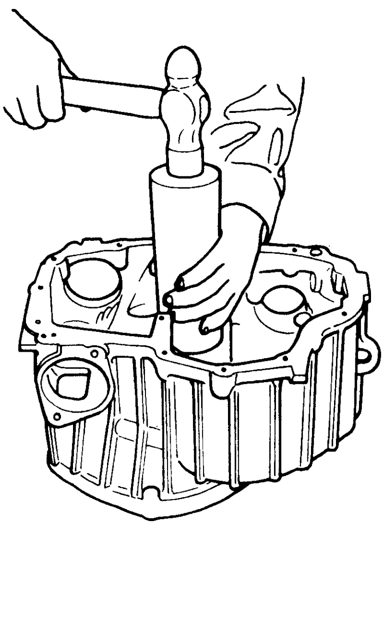


Tighten the lock nut.

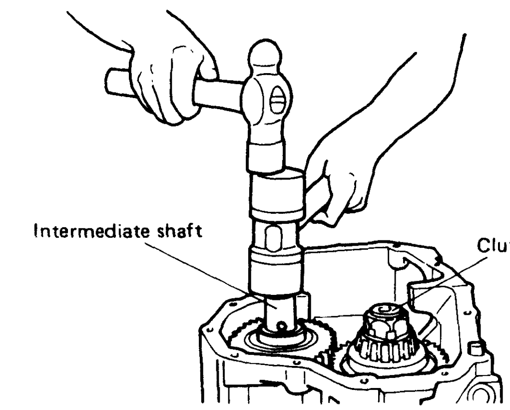


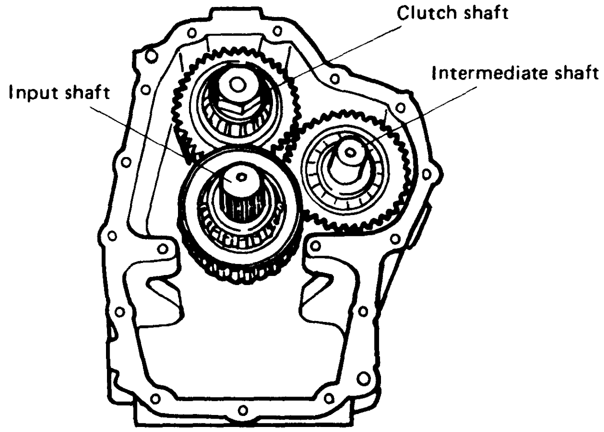
6-3-2 Reassembly of the bearing outer races and shims in the clutch case

(1)Drive the input shaft outer bearing race and clutch shaft outer bearing race into the clutch case.



6-3-3 Reassembly of the clutch shaft assembly, intermediate shaft assembly and input shaft assembly into the clutch case

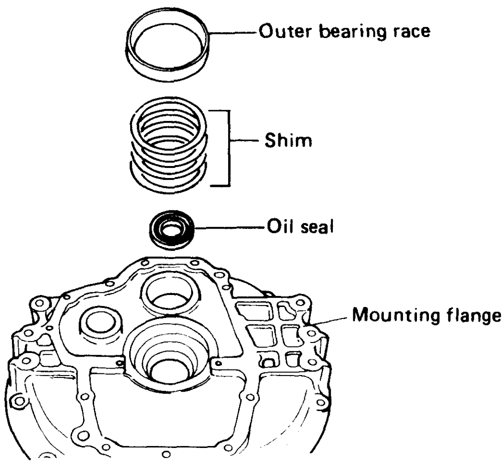




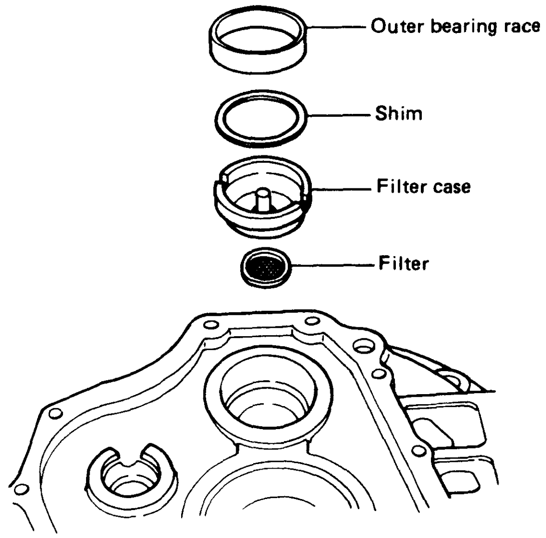
6-3-4 Reassembly of the mounting flange

(1)Insert the oil seal and the shim into the mounting flange.

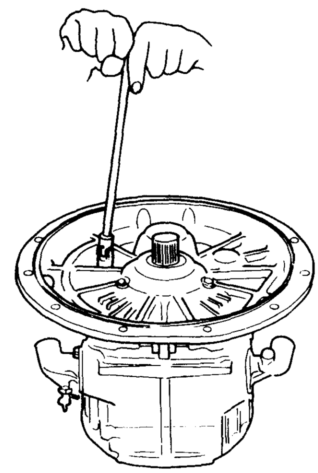
(2)Drive the outer bearing race into the mounting flange.



(3)Insert the clutch shaft shim, lube oil filter case and filter into the mounting flange.

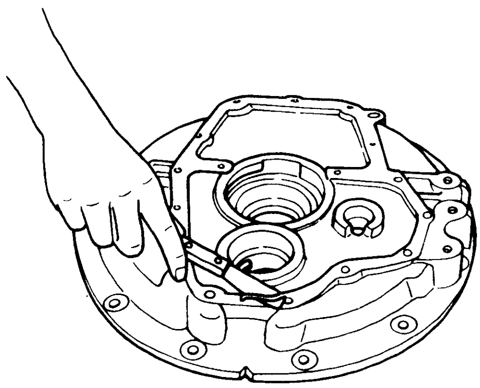


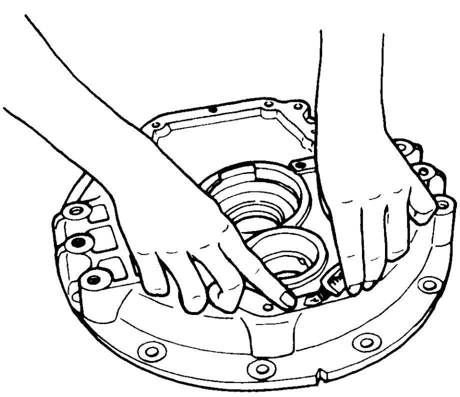
(4)Fit the mounting flange onto the clutch case, and tighten the bolt.



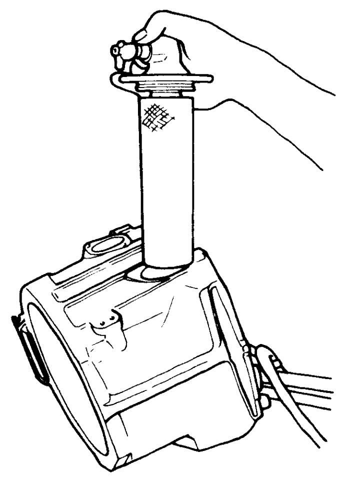
Tightening torque	22.6-27.5N·m (2.3-2.8kgf-m)

NOTE: Apply non-drying liquid packing to the matching surface of the mounting flange and the clutch case.



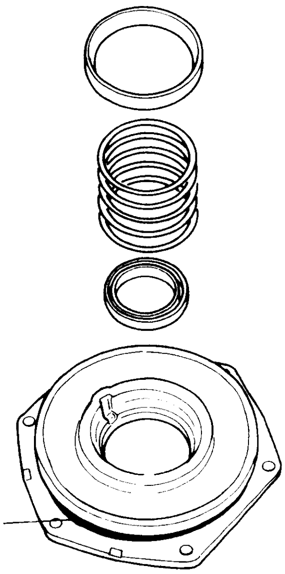


6-3-5 Reassembly of the oil cooler

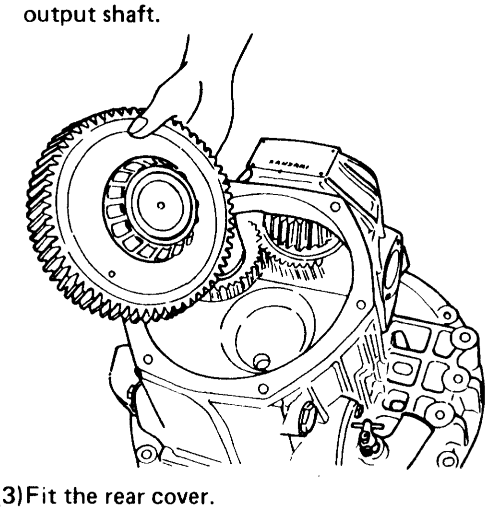


6-3-6 Reassembly of the rear case

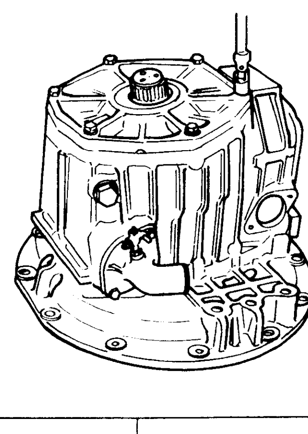
(1) Insert the oil seal, shims and outer bearing race into the rear cover.



(2) Insert the outer bearing race into the clutch case and output shaft.

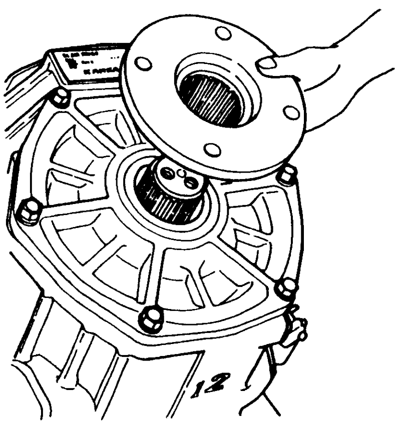


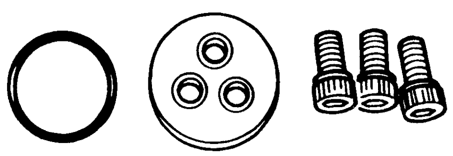
(3) Fit the rear cover.



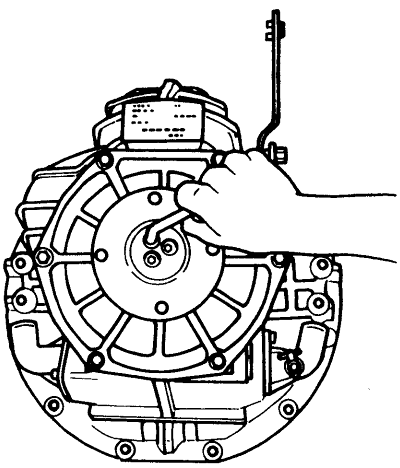
Tightening torque	49-59N·m (5-6kgf-m)

(4)Insert the output coupling, O-ring and clamp plate into the output shaft.



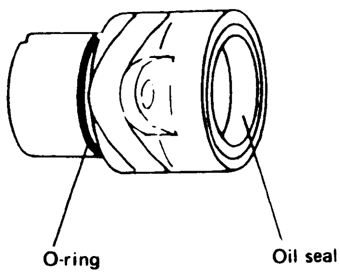


Tighten the bolts.

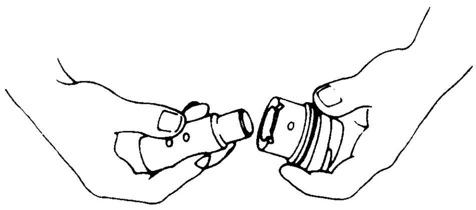


6-3-7 Reassembly of the shifting device

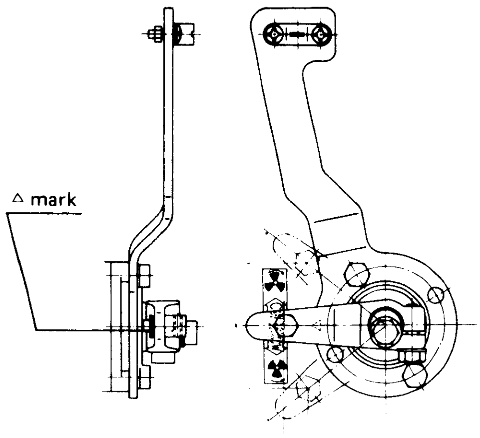
(1)Fit the oil seal and O-ring to the side cover.



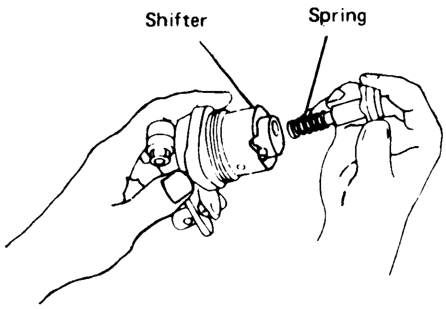
(2)Insert the shift lever shaft to the side cover.



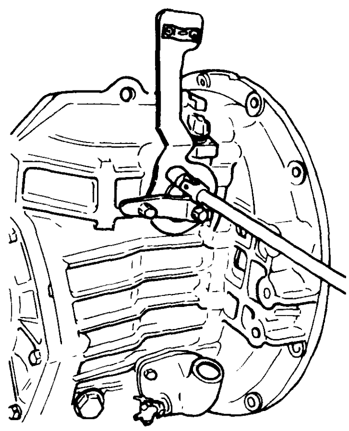
(3)Fit the shift lever to the shift lever shaft.
NOTE: Check the direction of the shift lever △ mark.



(4)Insert the shifter spring and shifter to the shift lever shaft.



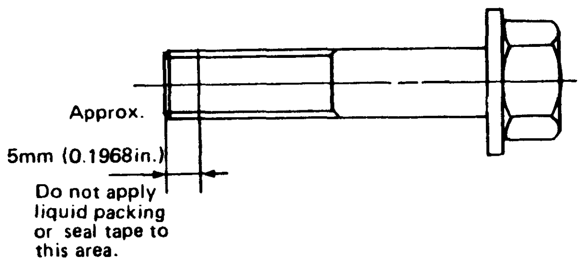
(5)Fit the side cover assembly and the remote control bracket to the clutch case.



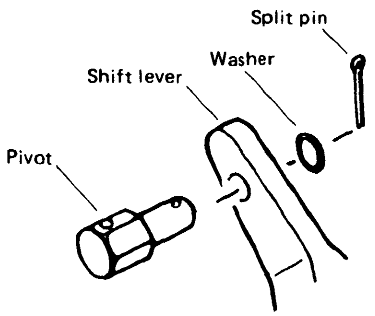
NOTE: 1) Check the direction of the shifter (Top and bottom side).
2) The shift lever may not turn smoothly if the clutch case is not filled with lubricating oil.

(6)Fit the shim and stopper bolt to the shift lever shaft.

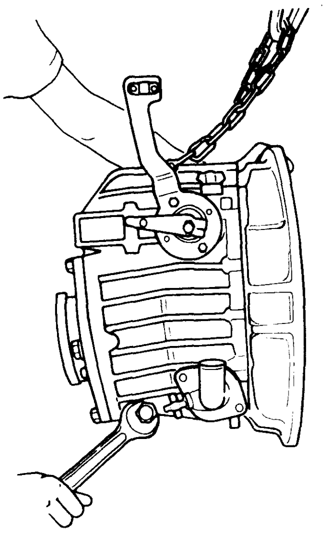
NOTE: Apply non-drying liquid packing or seal tape to the thread of the stopper bolt.

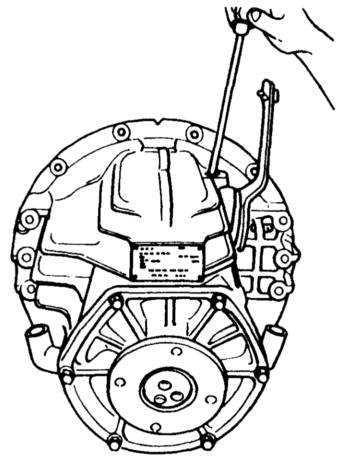


(7)Fit the pivot to the shift lever.



6-3-8 Reassembly of the lube oil drain plug and the dipstick





7-2. Marine gear model HSW630A1

1. Construction 7-2-1
2. Shifting Device 7-2-2
3. Inspection and Servicing 7-2-6
4. Disassembly 7-2-9
5. Reassembly 7-2-23

1. Construction

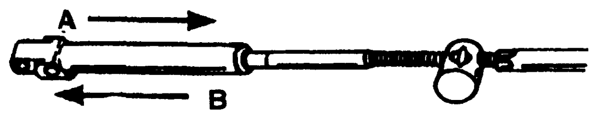
The Hurth transmission is a "full power reversing" transmission, allowing a standard (LH rotation) engine to be used for both rotations. Propeller rotation is determined by shift cable attachment at the remote controll.

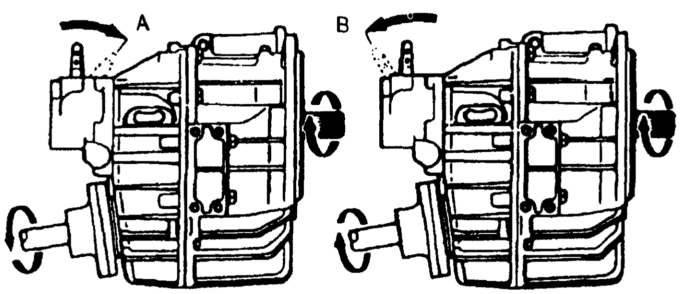
NOTE: All engines are LH rotation as viewed from flywheel end of engine.

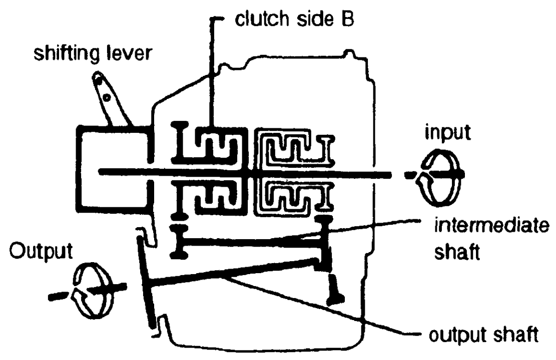
IMPORTANT: Transmission propeller rotation is determined by the shift cable installation in the remote control.

- RIGHT HAND ROTATION - Control cable will have to be installed in remote control so that cable end will move in direction "A" when shift handle is placed in the forward position.

- LEFT HAND ROTATION - Control cable will have to be installed in remote control so that cable end will move in direction "B" when shift handle is placed in the forward position.



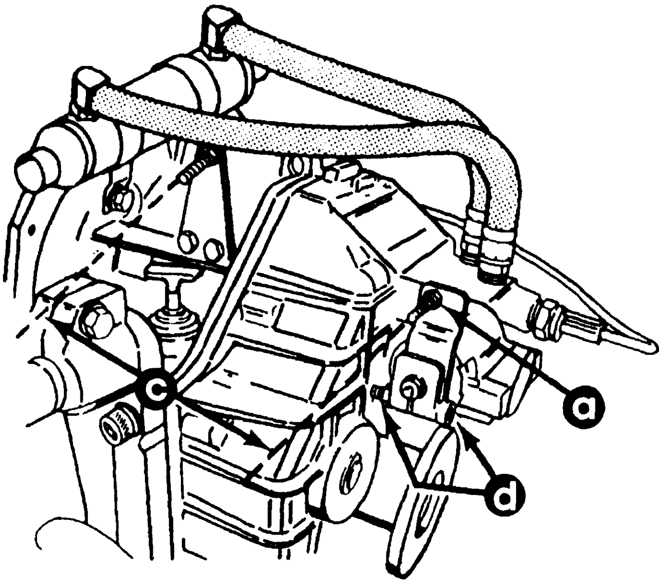


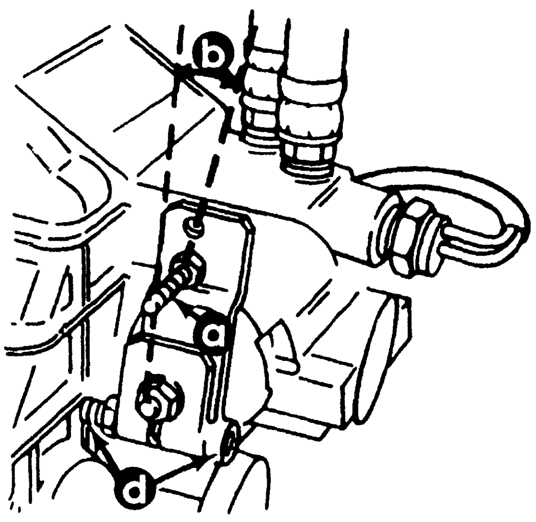


"B" is Forward Gear for LH Rotation Propeller

2. Shifting Device

IMPORTANT: Check that shift lever is positioned approximately 10° aft as shown when in the neutral detent position and that the distance between studs in the following is set at 7-1/8 in. (317.5 mm). If necessary, loosen "c" is as shown when in the neutral detent position, and retighten clamping bolt.





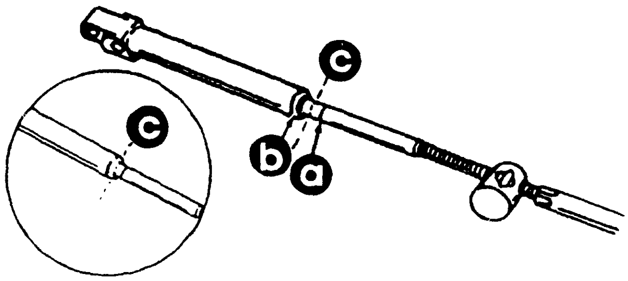
a - Shift lever
b - Lever, in Neutral Detent, Must Be Approximately 10° Aft of Vertical
c - Dimension between Studs -7-1/8 in.(317.5 mm)
d - Clamping Bolt

Typical Hurth Transmission Shown

1. Place remote control shift lever and transmission shift lever, in neutral position.

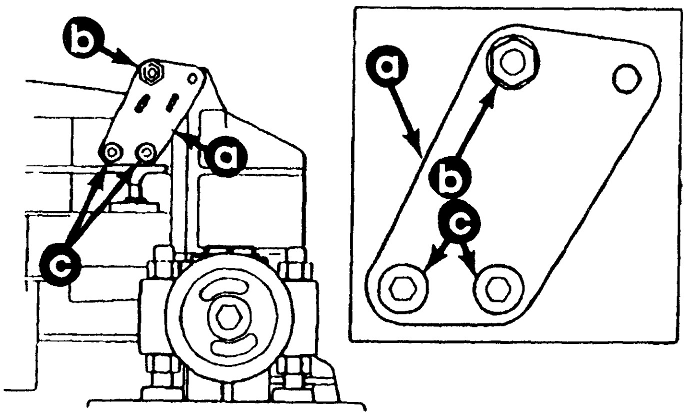
2. Locate center of remote control and control shift cable play (backlash) as follows:

   a. Check that remote control is in neutral position.
   b. Push in on control cable end with enough pressure to remove play, and mark position "a" on tube.
   c. Pull out on control cable end with enough effort to remove play, and mark position "b" on tube.
   d. Measure distance between marks "a" and "b" and mark position "c" half-way between marks "a" and "b".



⚠ WARNING
Avoid serious personal injury or property damage caused by improper shifting. Anchor stud for shift cable must be installed in the correct hole when using "late style" bracket.

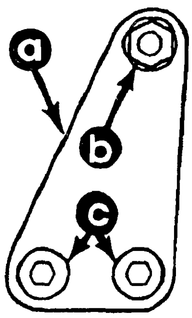
3. The shift cable anchor stud bracket should be installed. On late style bracket with two anchor stud location holes, the hole marked "630" as shown is to be used on the 630A transmission. (Refer to Transmission Identification Plate for specific transmission model designation.)



a - Bracket, Shift Cable
b - Shift Cable Anchor Stud
c - Bracket-to-Transmission Fasteners

Late Style Shift Cable Bracket Shown

NOTE: Anchor stud for shift cable on early style bracket with only one locating hole should be installed as shown.



a - Bracket, Shift Cable
b - Shift Cable Anchor Stud
c - Bracket-to-Transmission Fasteners

Early Style Shift Cable Bracket Shown

4. Center cable end-play, then adjust cable barrel to align holes in barrel and cable end guide, with attaching points on transmission.

5. Temporarily install shift cable. Do not secure at this time.

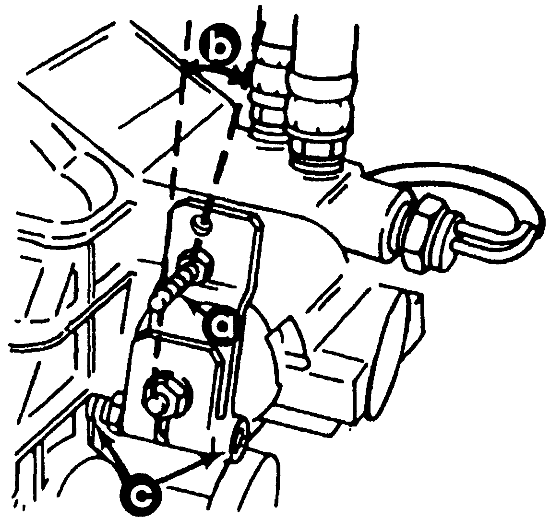
IMPORTANT: Transmission is "fully" in gear when shift lever comes to a stop, in either direction.

6. Place remote control shift lever in the forward gear position. Check to ensure transmission is fully in gear, as follows:

   a. Hold shift lever in position.
   b. Carefully slide shift cable off of anchor points.
   c. Attempt to move transmission shift lever further.

7. Temporarily install shift cable onto anchor points again. Do not secure at this time. Place remote control shift lever in the reverse gear position. Check that transmission is fully in gear, following the same procedure as outlined above.

8. If transmission shift lever will position properly in one gear, but not in the other, recheck shift cable adjustment. If transmission shift lever will not position properly in both gears, move transmission shift lever stud (a), from top hole in shift lever, to bottom hole, and recheck for proper positioning. If proper positioning is still not obtained, remote control does not provide sufficient shift cable travel and must be replaced.

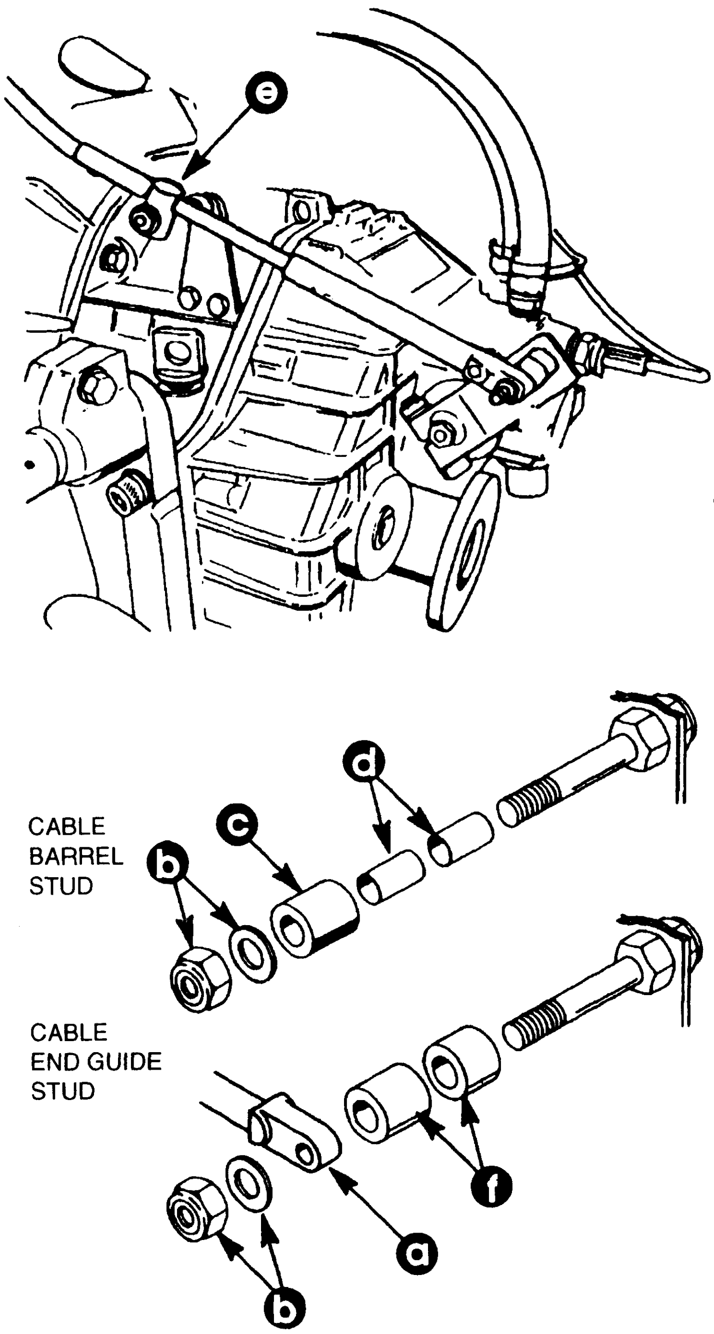


a - Shift Lever Stud
b - Lever in Neutral Detent, Must Be Approximately 10° Aft of Vertical
c - Clamping Bolt

9. Once shift cable adjustment is correct, secure shift cable(s) with hardware as shown, referring to appropriate configuration following:

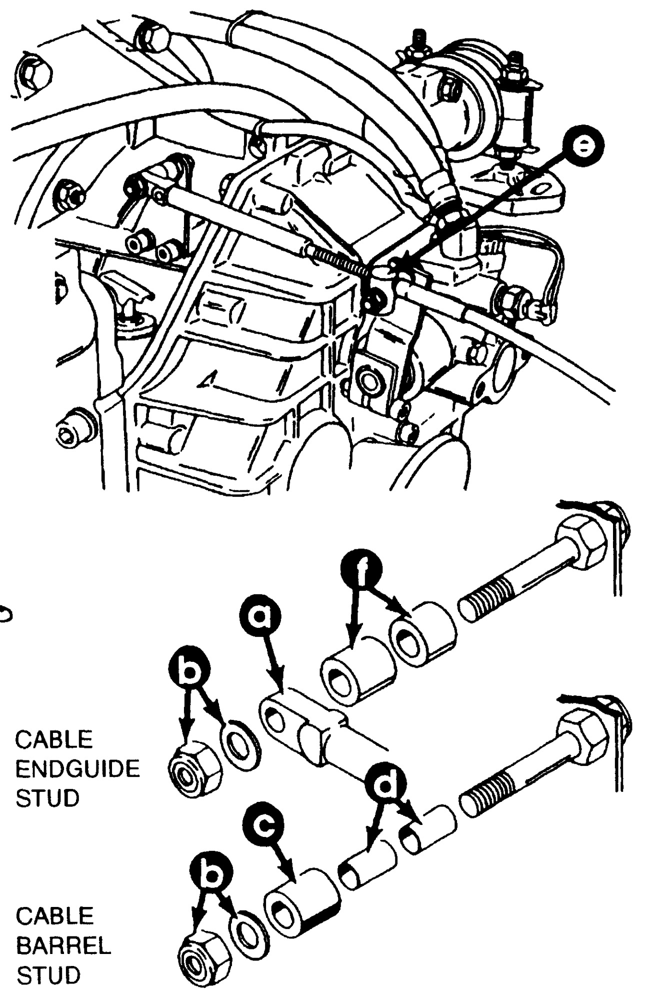
NOTE: To change cable approach direction on single or dual station installations, only the spacer/bushings have to be switched to the opposite stud (the studs are identical).

SINGLE CABLE - FORWARD ENTRY



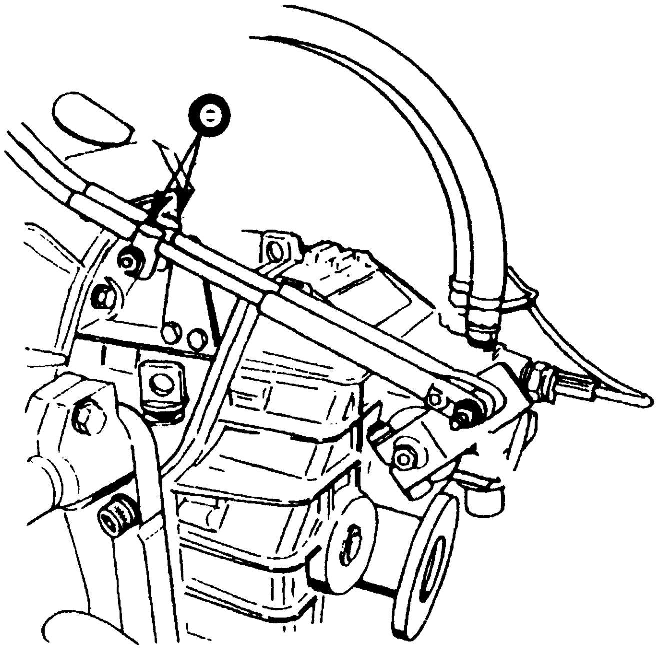
a - Cable End Guide
b - Locknut and Washer (Tighten Until Bottomed, Then Back Off 1 Full Turn)
c - Spacer (Fits Over Bushings)
d - Bushings
e - Cable Barrel
f - Spacers (Fit Over Stud)

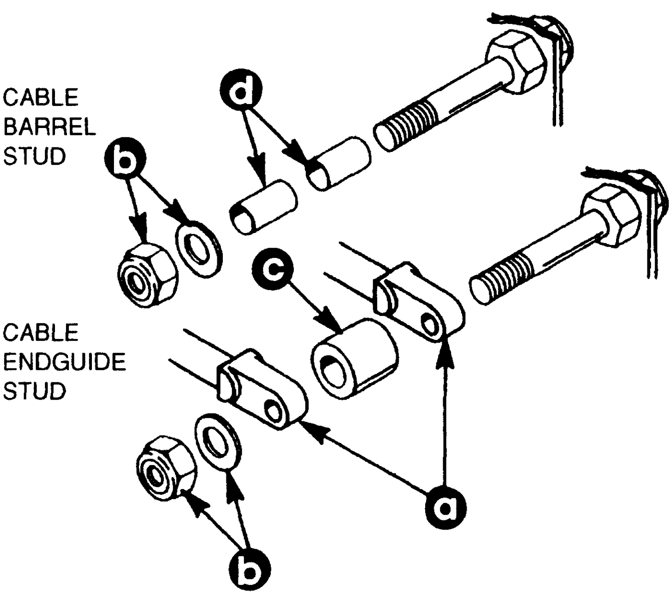
SINGLE CABLE - REAR ENTRY



a - Cable End Guide
b - Locknut and Washer (Tighten Until Bottomed, Then Back Off 1 Full Turn)
c - Spacer (Fits Over Bushings)
d - Bushings
e - Cable Barrel
f - Spacer (Fits Over Stud)

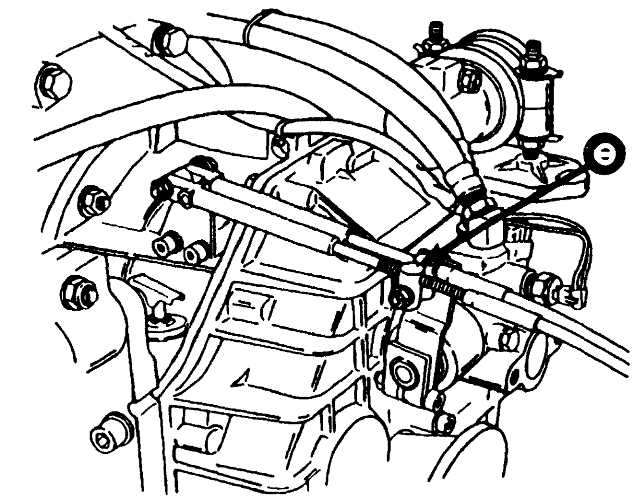
DUAL CABLE - FORWARD ENTRY

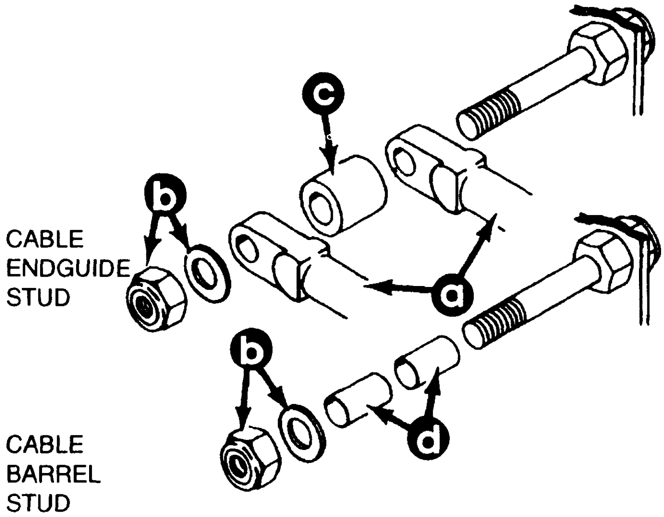




a - Cable End Guides
b - Locknut and Washer (Tighten Until Bottomed, Then Back Off 1 Full Turn)
c - Spacer (Fits Over Stud)
d - Bushings
e - Cable Barrels

DUAL CABLE - REAR ENTRY



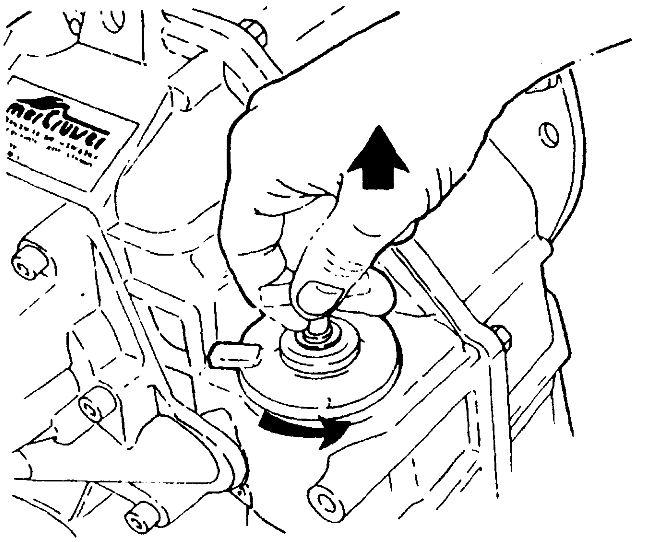


a - Cable End Guides
b - Locknut and Washer (Tighten Until Bottomed, Then Back Off 1 Full Turn)
c - Spacer (Fits Over Stud)
d - Bushings
e - Cable Barrels

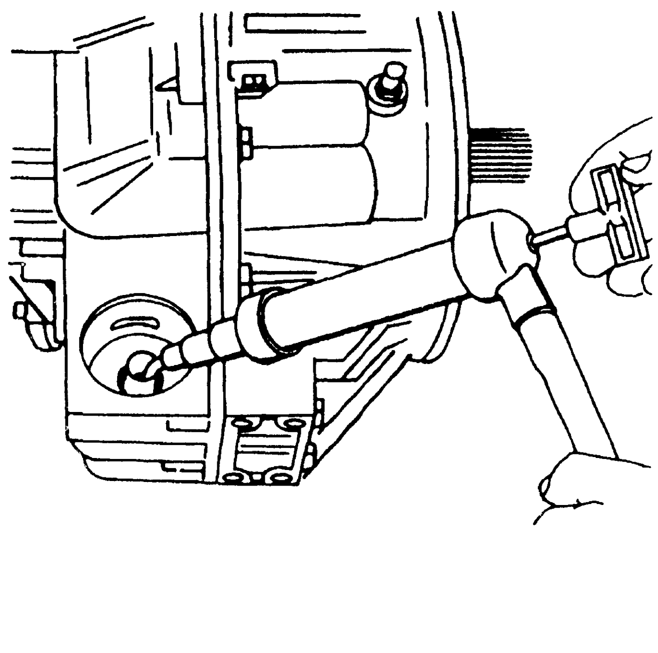
3. Inspection and Servicing

(1) Draining Transmission

1. Clean the exterior of transmission before disassembly.
2. Remove oil filter from housing by turning (counter-clockwise) and pulling at the same time.



3. Push hose of suction pump through suction pipe and down to the bottom of the housing.

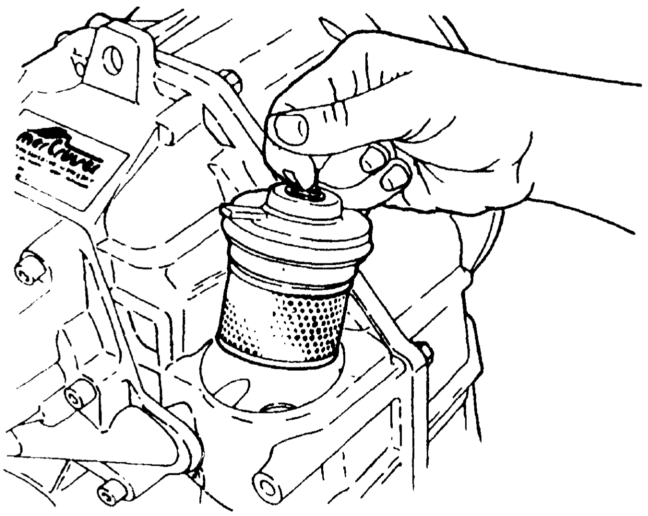


(2) Filling Transmission

IMPORTANT: Use only Automatic Transmission Fluid (ATF) as recommended in "Specifications".

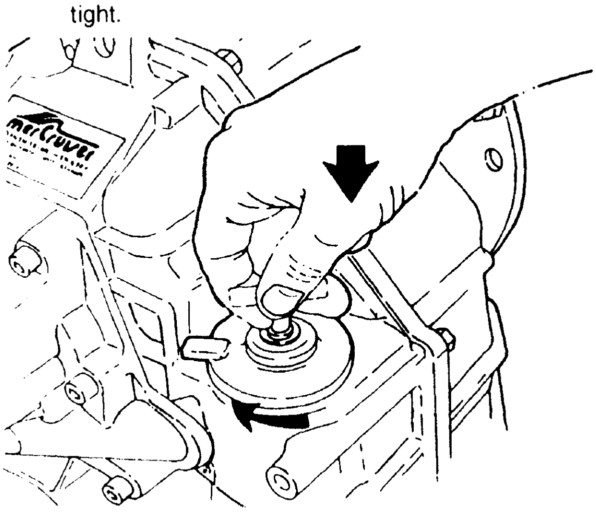
1. Fill transmission to proper level, thru oil filter cavity. (Refer to specifications for capacity.)
2. Install filter as follows:

   a. Coat O-ring on filter cover with transmission fluid.

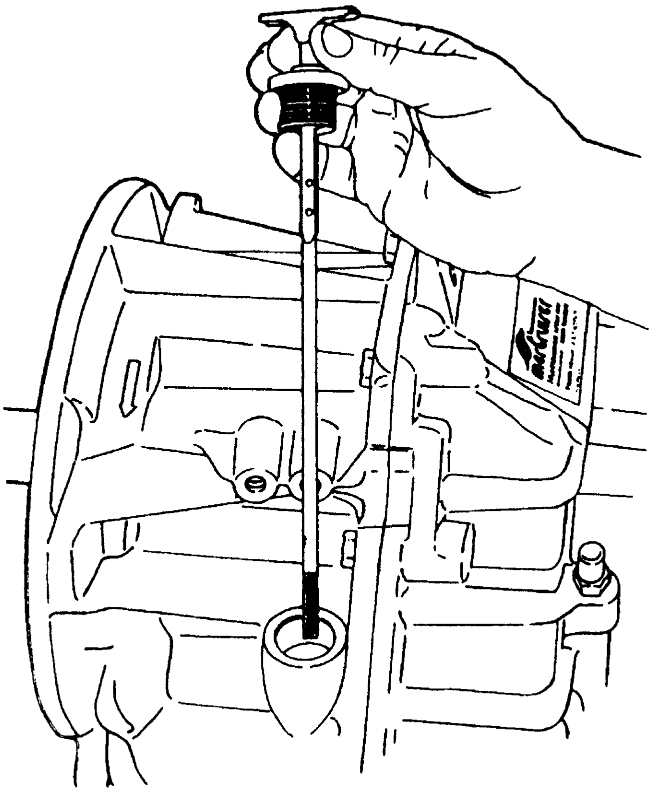


⚠ CAUTION
Transmission fluid filter and cover must be properly seated to avoid fluid to avoid fluid foaming and/or loss of fluid, thus resulting in decreased efficiency and/or damage to transmission.

   b. Push down until cover is fully seated (top of cover flush with housing), then, turn "T"-handle clockwise until tight.



3. Start engine and run for two minutes to fill system with fluid.
4. Stop engine and check fluid level. Fluid should be between "Min" and "Max" lines on dipstick.

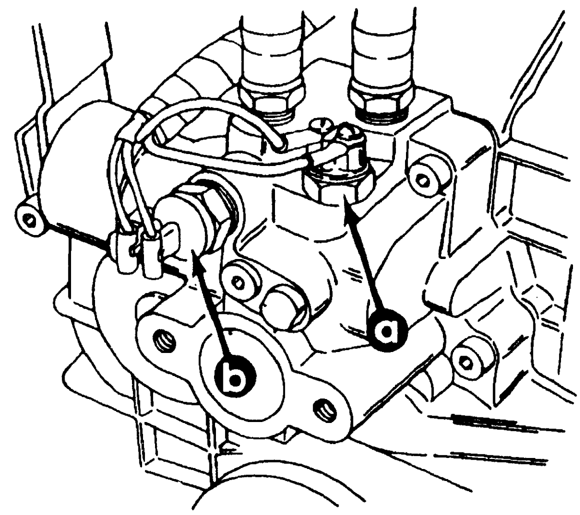


Typical Hurth Transmission Shown

(3) Transmission Removal

1. Refer to Removal and Installation, Section 2B-"MIE Inboard) Models" and remove engine and transmission as instructed.

2. Disconnect wires from neutral safety switch and audio warning temperature switch.

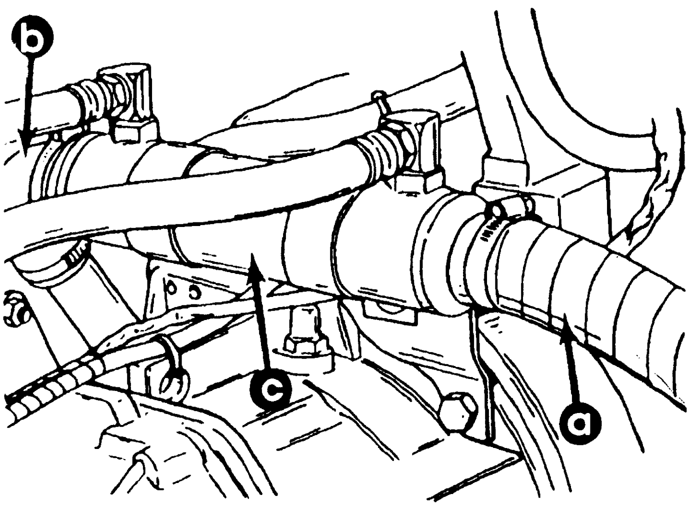


a - Neutral Safety Switch
b - Audio Warning Temperature Switch

Typical Hurth Transmission Shown

3. Follow instructions "a" or "b":

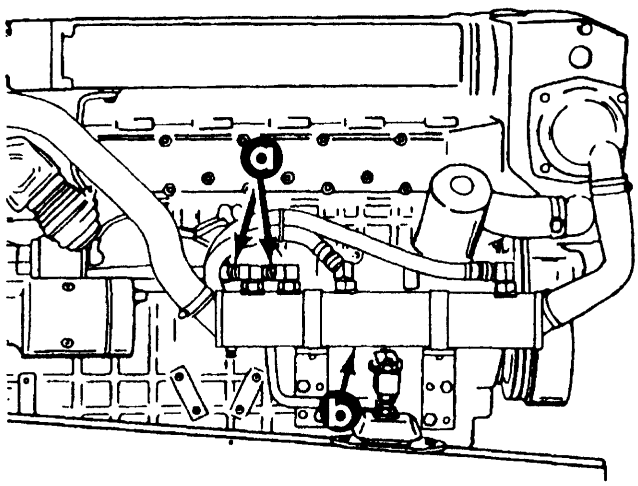
   a. **On 530D-TA, 636D-TA, D183 and D219 Engines:** Disconnect seawater hoses from transmission fluid cooler.



a - Seawater Inlet Hose
b - Seawater Outlet Hose
c - Transmission Fluid Cooler

530D-TA, 636D-TA, D183 and D219 Shown

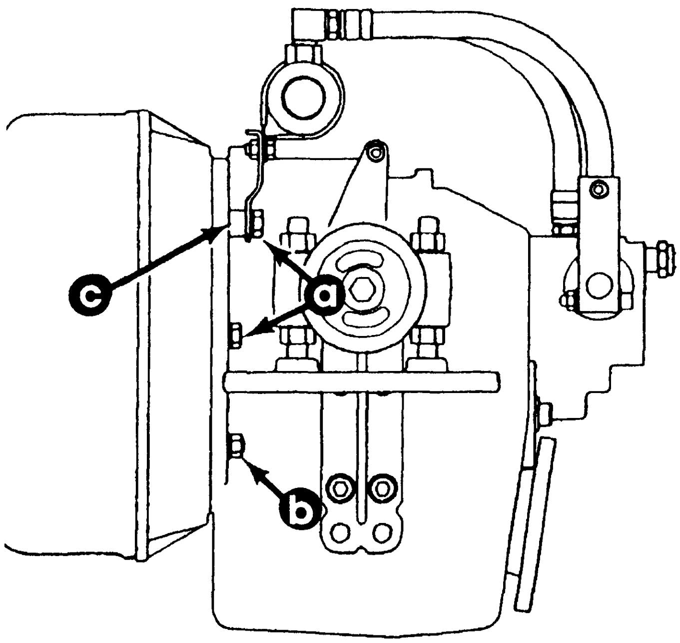
b. **On D254 Engines:** Disconnect transmission fluid cooler hoses from tandem engine oil/transmission fluid cooler. Note position of hoses to aid in proper reassembly.



a - Transmission Fluid Cooler Hoses
b - Tandem Engine Oil/Transmission fluid Cooler

D254 Shown

4. Remove four bolts with locknuts (2 with spacers on engines with cooler bracket as shown) and two nuts with lockwashers. Retain hardware and remove transmission.



a - Bolts With Lockwashers [4 - Two On Each Side (Two With Spacers If Cooler Bracket)]
b - Nuts With Lockwashers (One On Each Side)
c - Spacer

Typical Down Angle Transmission

4. Disassembly

IMPORTANT: Ensure work area is clean before disassembly is started. Be sure to use lint free cloths when clearing and/or handling parts.

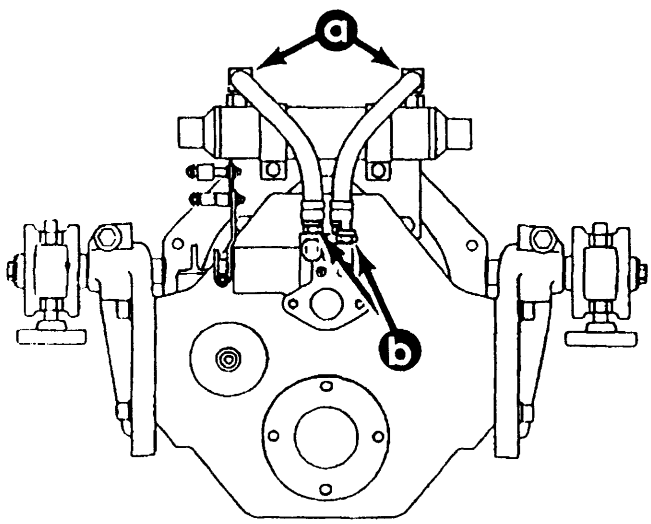
TRANSMISSION FLUID COOLER/HOSES

IMPORTANT: Do not attempt to remove transmission fluid cooler lines from transmission until removed from cooler or damage by twisting could result.

1. Follow instructions "a" or "b":
   a. **On 530D-TA, 636D-TA, D183 and D219 Engines:**

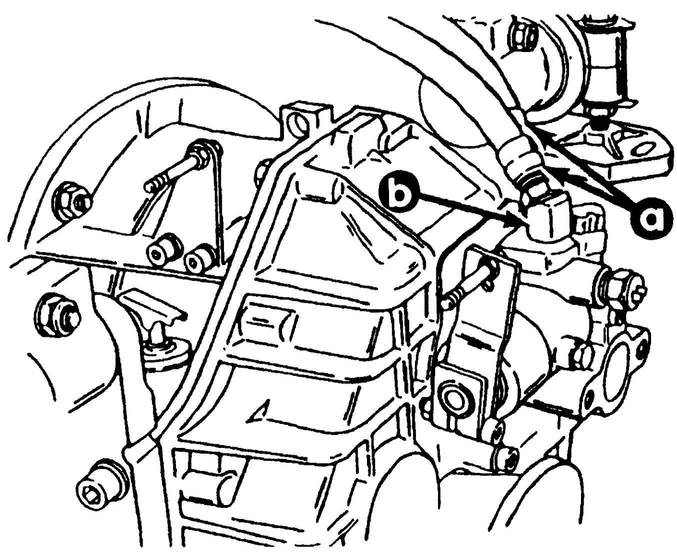
      (1) Disconnect transmission fluid hoses from cooler.

      (2) Then, disconnect hoses from transmission.



a - Transmission Fluid Hoses (At Cooler)
b - Transmission Fluid Hoses (At Transmission)

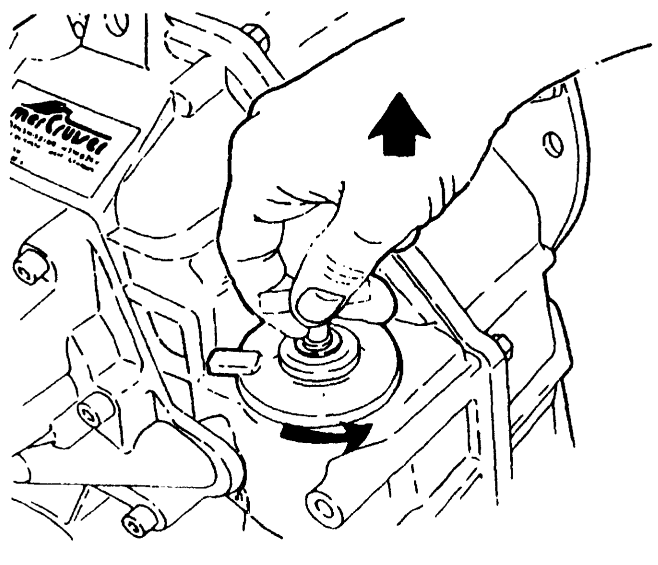
   b. **On D254 Engines:** Remove transmission fluid hoses from 45° elbow connectors on transmission. (Previously disconnected from cooler.)



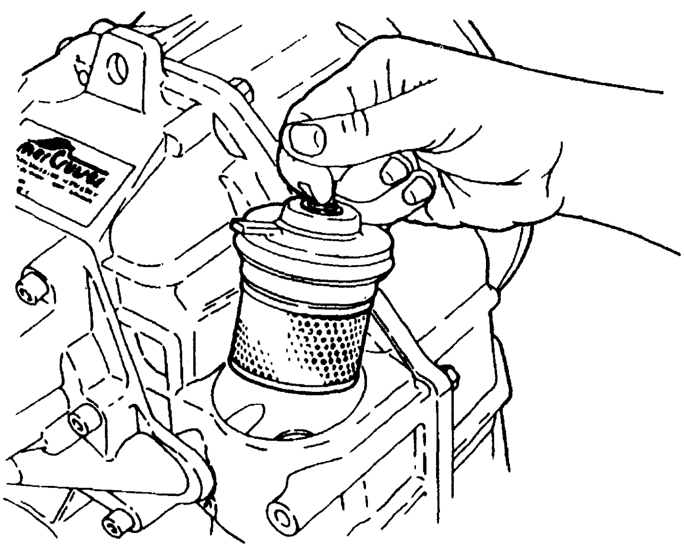
a - Transmission Fluid Hoses
b - 45° Elbow Connector (2 - One Hidden In This View)

OIL FILTER and DIPSTICK

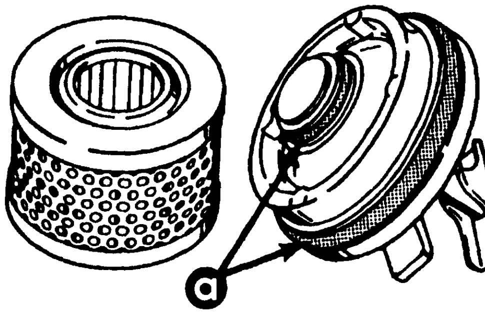
2. Remove oil filter from housing by turning "T"-handle counterclockwise and pulling up on cover.



3. Remove filter element from cover.

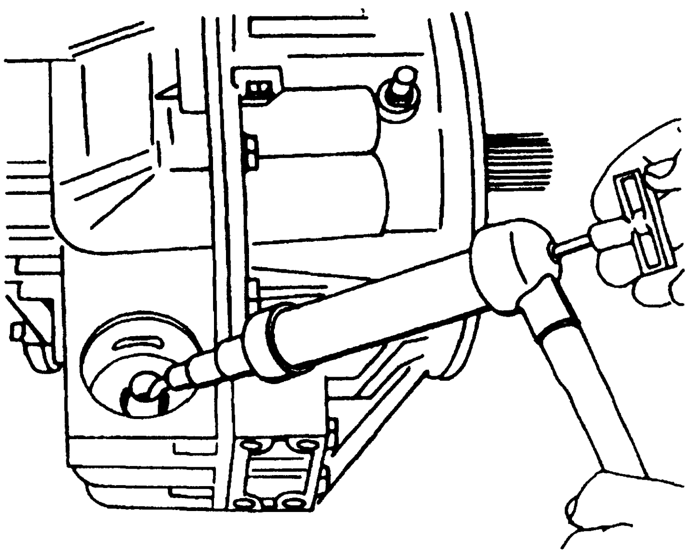


4. Inspect O-rings for wear and replace if necessary.

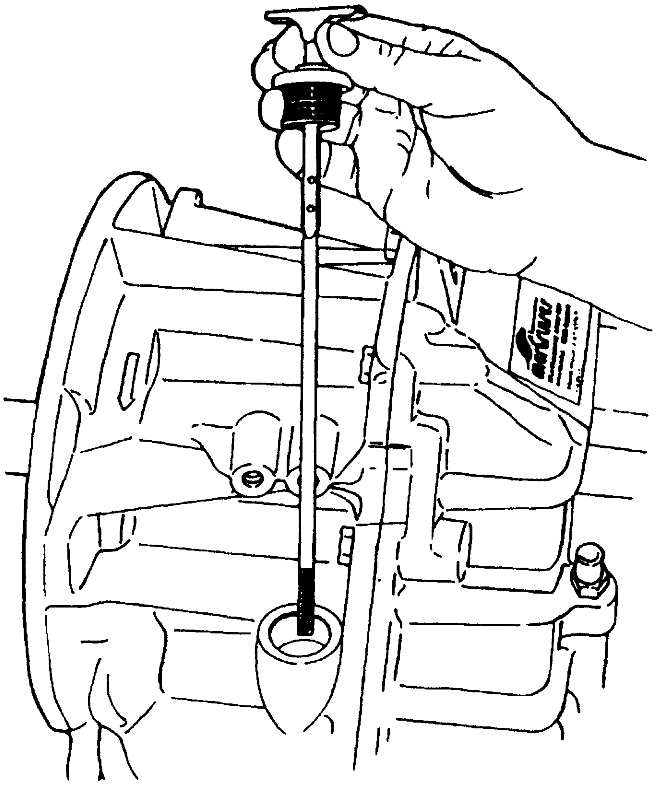


a - O-rings

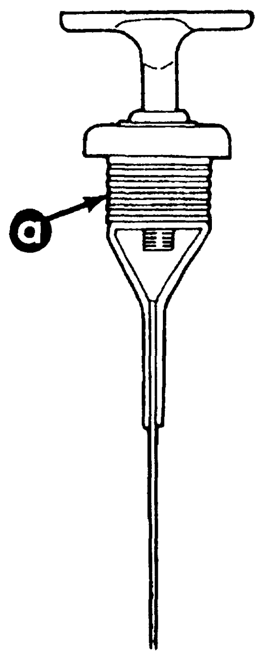
5. Push hose of suction pump through suction pipe and down to the bottom of the housing. Pump fluid from housing.



6. Remove dipstick by turning (counterclockwise) and pulling at the same time.



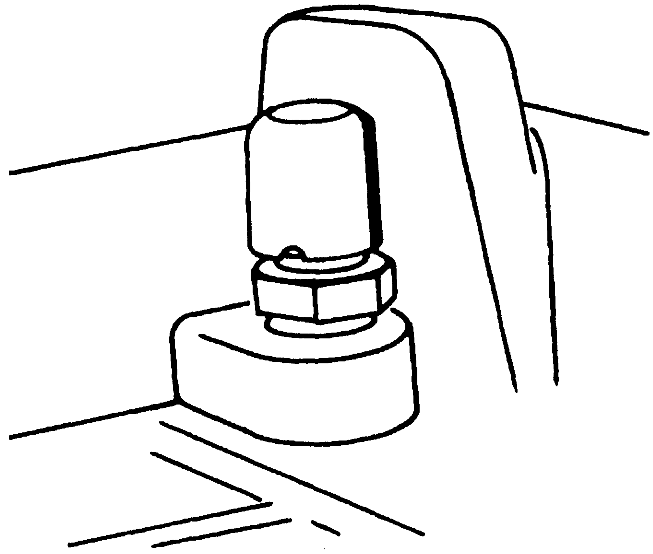
7. Inspect seal for wear and replace if necessary.



a - Seal

BREATHER VALVE

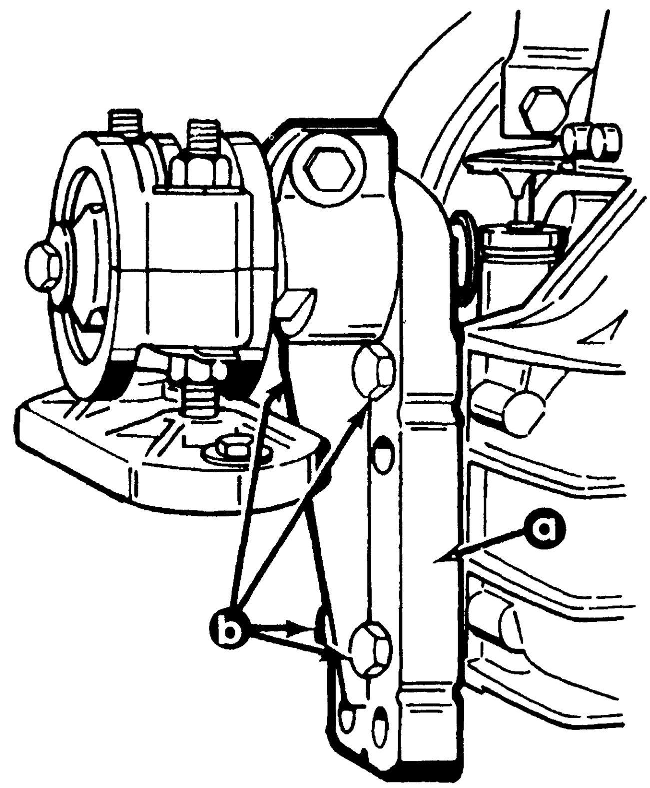
8. Remove breather valve. Clean with suitable cleaner, allow to dry and coat with oil.



a - Breather Valve

MOUNTS

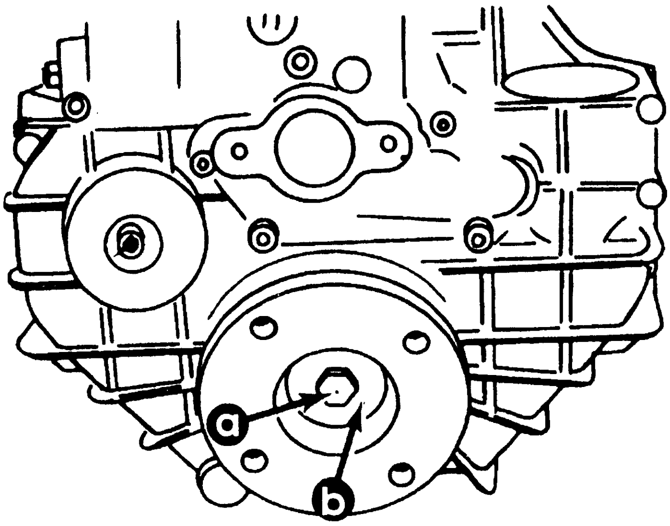
9. Remove mounts from transmission housing. Inspect mounts for damage and replace if necessary.

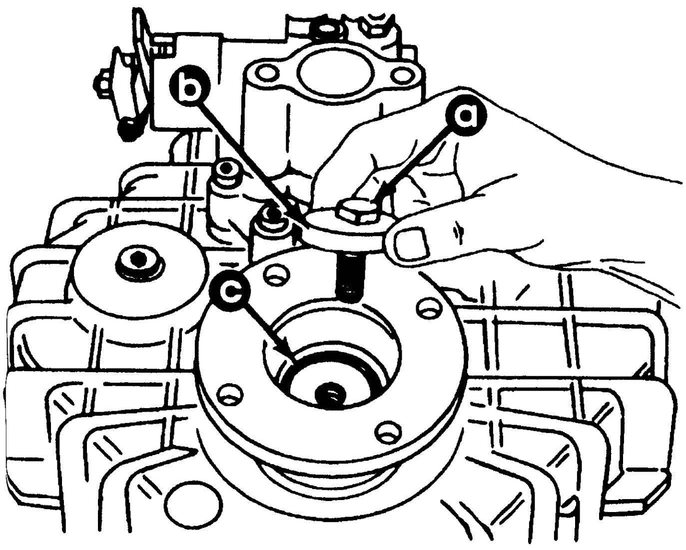


a - Transmission Mount
b - Retaining Screws (4 Total on Each Mount - One Hidden In This View)

OUTPUT FLANGE

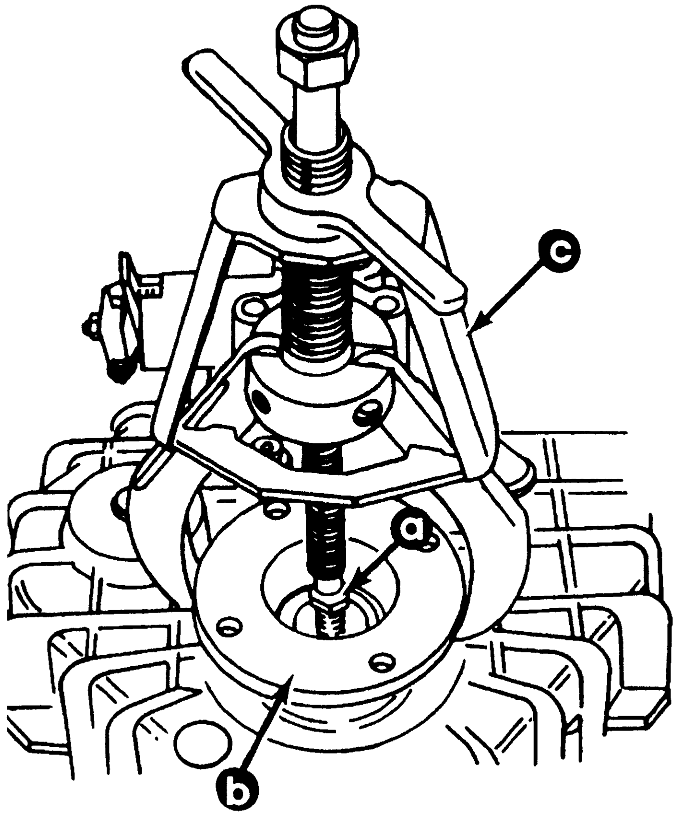
10. Remove bolt, washer and O-ring.

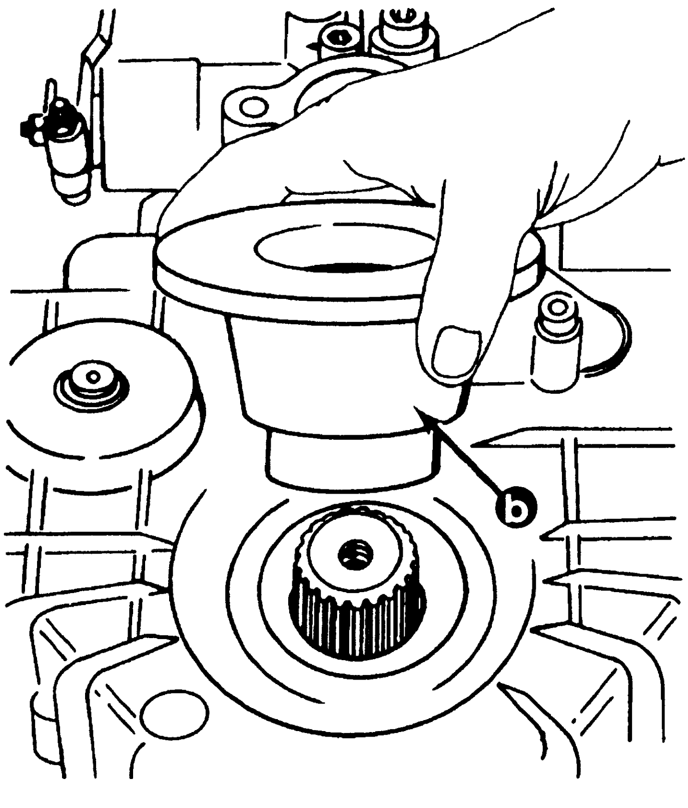




a - Bolt
b - Washer
c - O-ring

11. Reinstall bolt andd remove flange using appropriate puller.

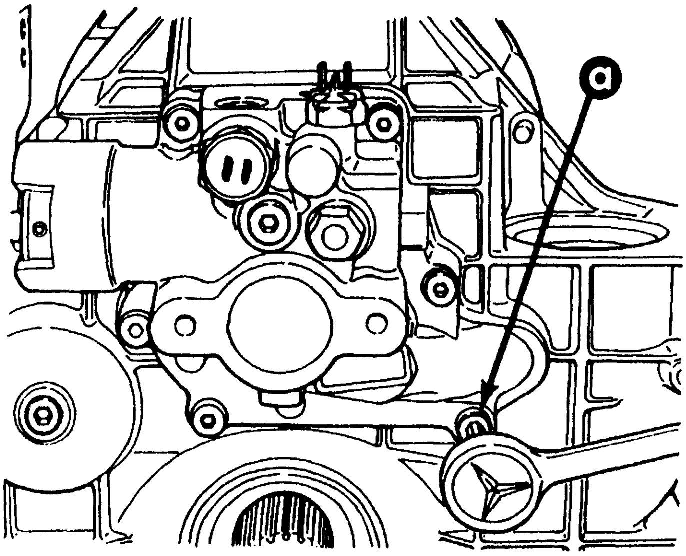




a - Bolt
b - Flange
c - Puller

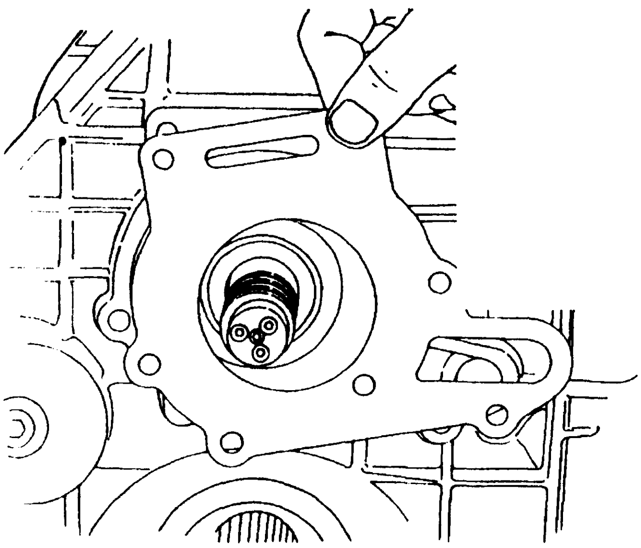
CONTROL BLOCK

12. Remove hex head bolts (6).



a - Hex Head Bolts (6)

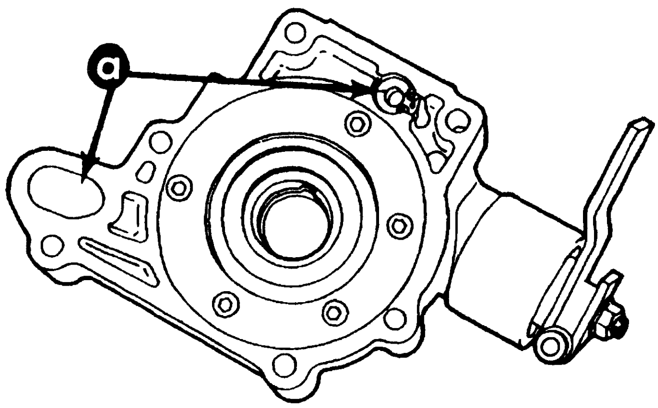
13. Remove control block and gasket from housing.



⚠ CAUTION

Be careful not to allow dirt to enter control block from front side.

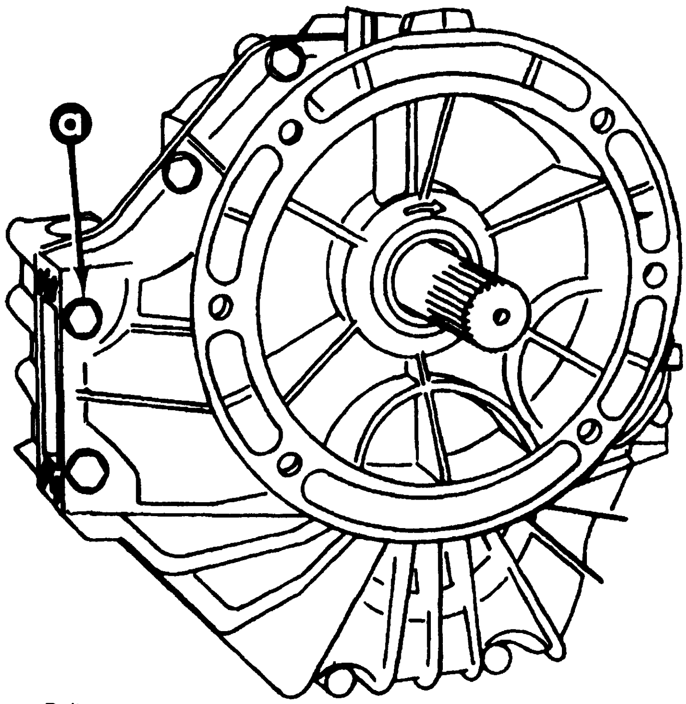
14. Cover openings in control block with a protective cloth.



a - Openings

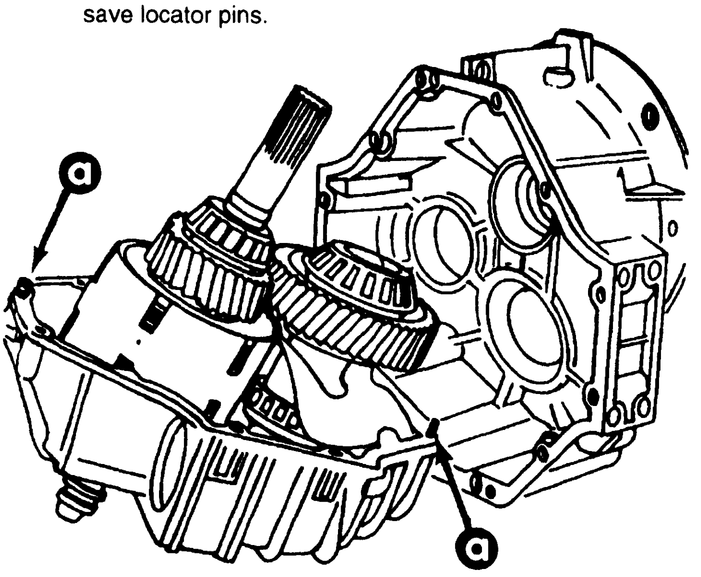
HOUSING

15. Remove hex head bolts (12) from input side of housing.



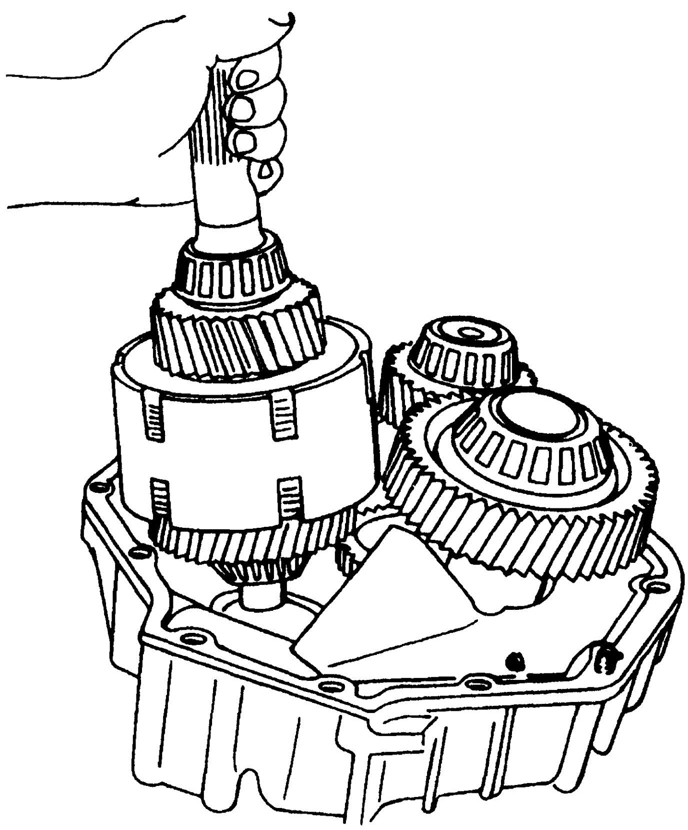
a - Bolts

16. Remove input side of housing. Be sure to locate and save locator pins.

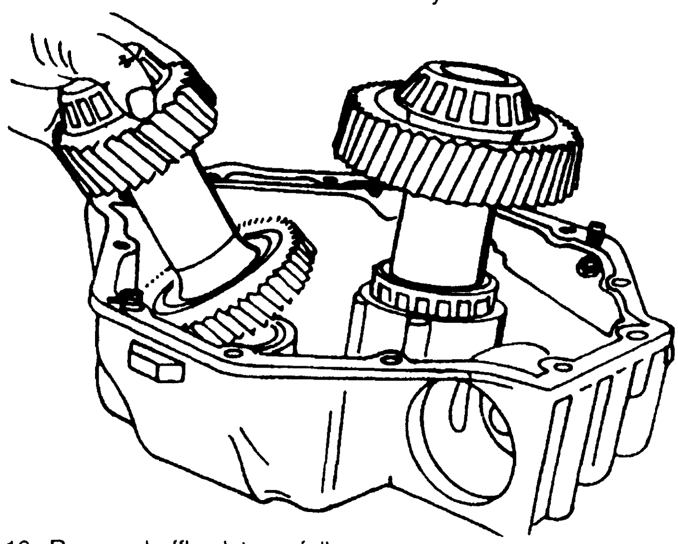


a - Locator Pins

17. Remove input shaft assembly.



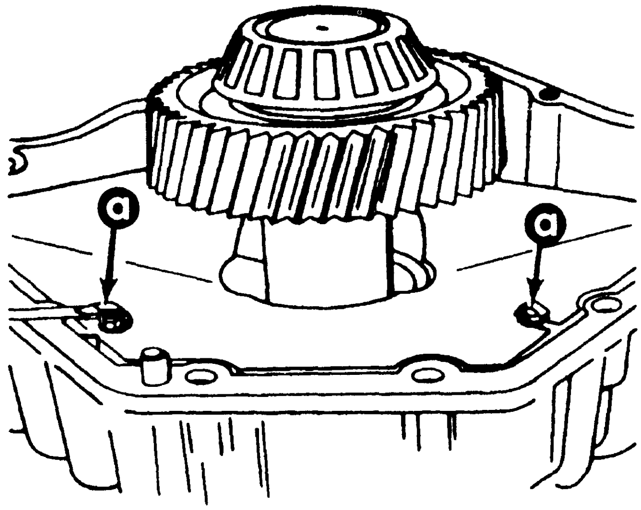
18. Remove intermediate shaft assembly.

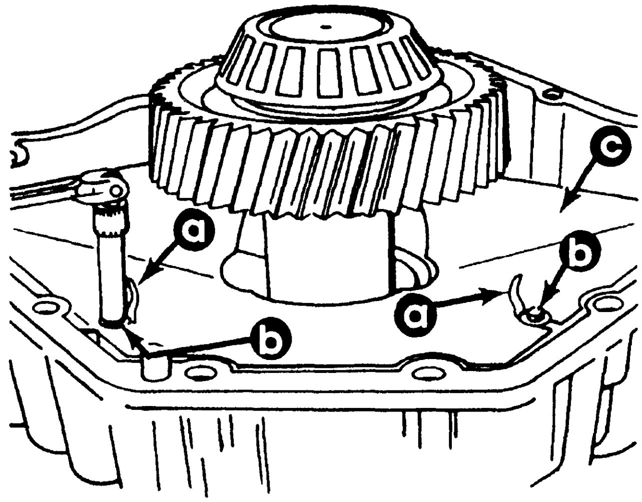


19. Remove baffle plate as follows:

   a. Bend tabs up away from screws.

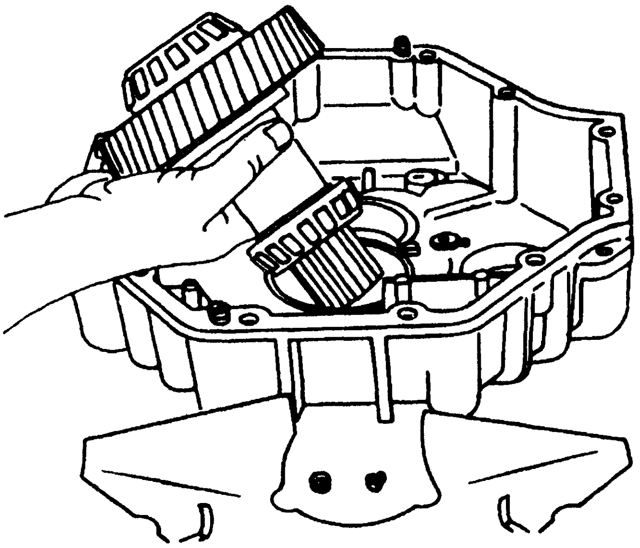
   b. Remove screws, then; remove baffle plate.





a - Tabs
b - Screws
c - Baffle Plate

20. Remove output shaft assembly.



BEARING, GEAR and SEAL INSPECTION

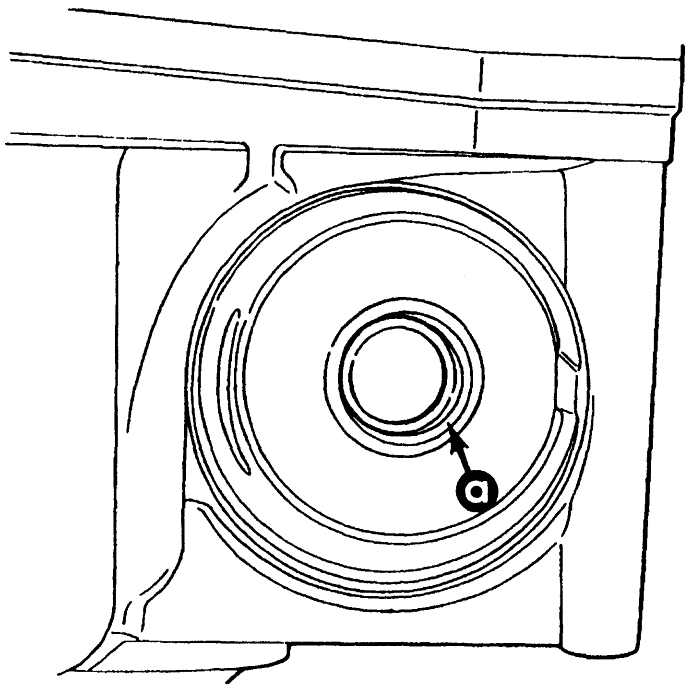
21. Inspect all tapered roller bearings, the piston rings on the input shaft and all gears for wear. If damage has been found on the gearing of the intermediate or output shaft, it is ALWAYS necessary to replace the complete shaft.

    When gears on the input shaft have to be replaced, the tapered roller bearings and needle bearings MUST BE replaced as well.

22. Turn gears of input shaft to check correct operation of the reversing clutch. If it is hard to turn the gears, the clutch is probably damaged.

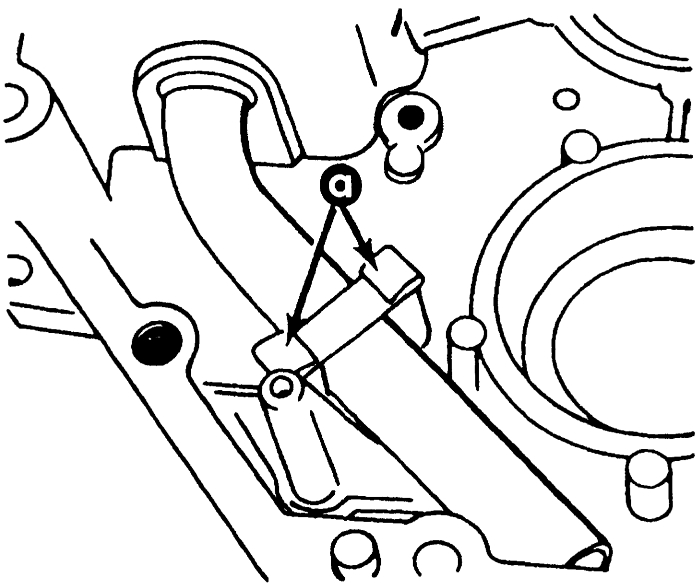
SEALS

23. Remove suction pipe seal as follows:



a - Seal

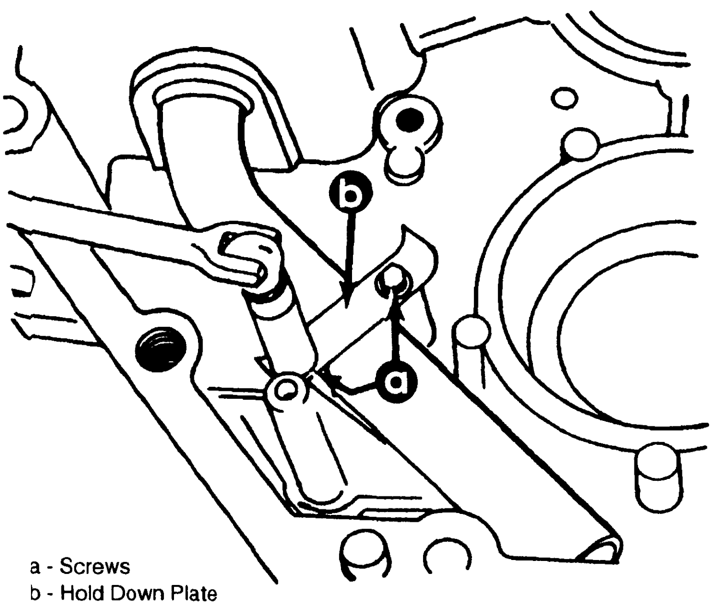
a. Bend tabs up away from screws.



a - Tabs

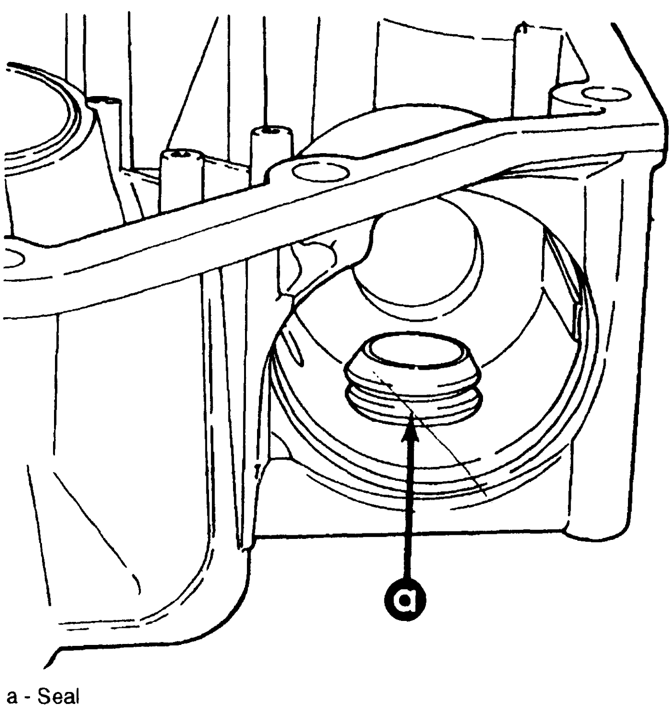
b. Remove screws and hold down plate.

c. Remove suction pipe by pulling downward out of seal.



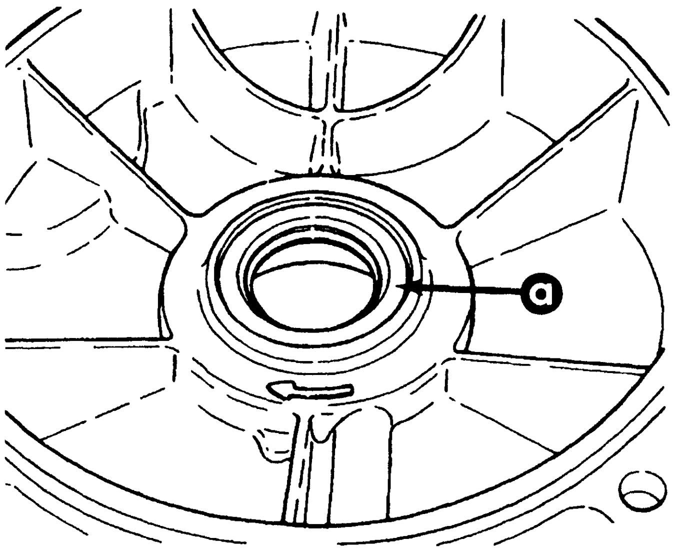
a - Screws
b - Hold Down Plate

d. Remove seal from top side.



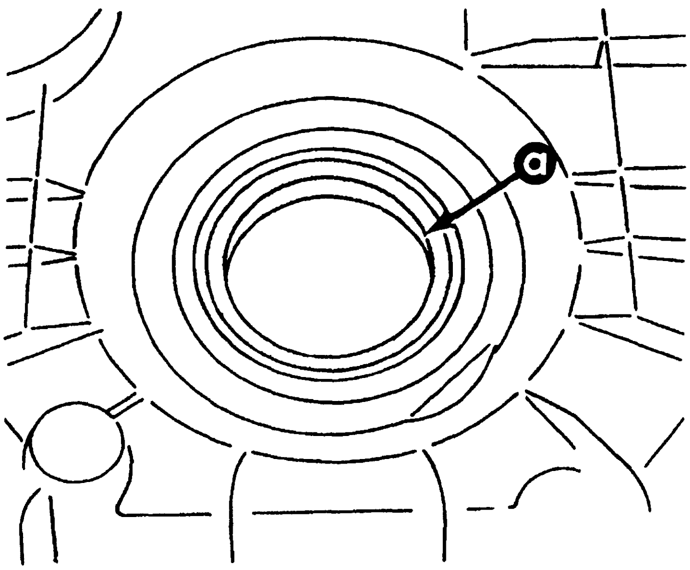
a - Seal

24. Remove input shaft seal using appropriate mandrel.



a - Seal

25. Remove output shaft seals using appropriate mandrel.



a - Seal

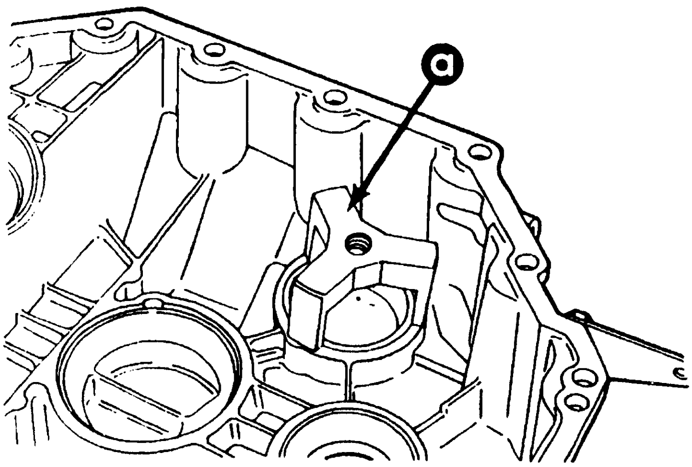
TAPERED ROLLER BEARING CUPS

IMPORTANT: Do not remove tapered roller bearing cups unless replacing tapered roller bearings. Bearing and cup must be replaced as a set.

IMPORTANT: Do not mix up shims under cups on the input housing side. Shims are required to adjusting the bearing preload.

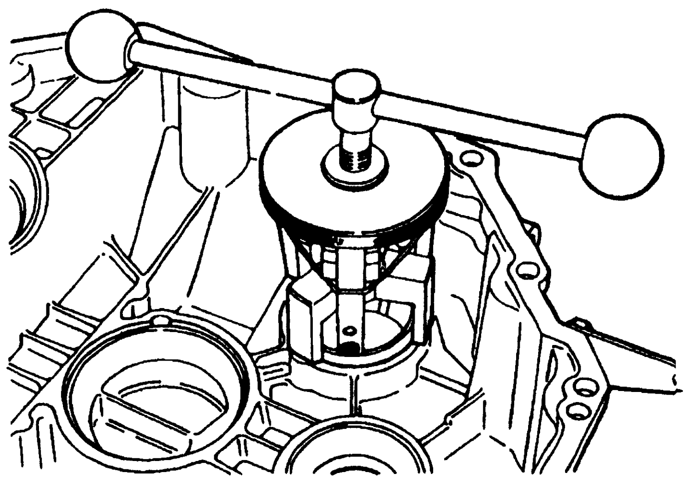
26. Pull tapered roller bearing cups from housing use special puller as follows:

    a. Position appropriate puller guide (large diameter or small diameter) over cup as shown.

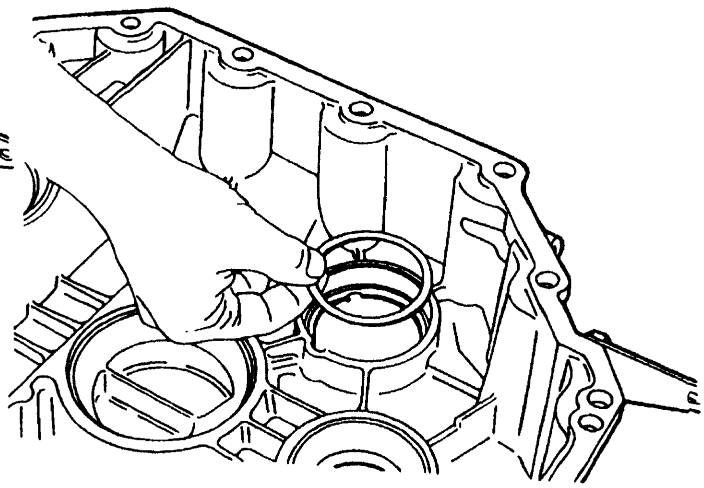


a - Small Diameter Puller Guide

    b. Pull bearing cup from housing tool as shown.



    c. **Input Housing Side:** Remove and retain shims. DO NOT MIX UP.

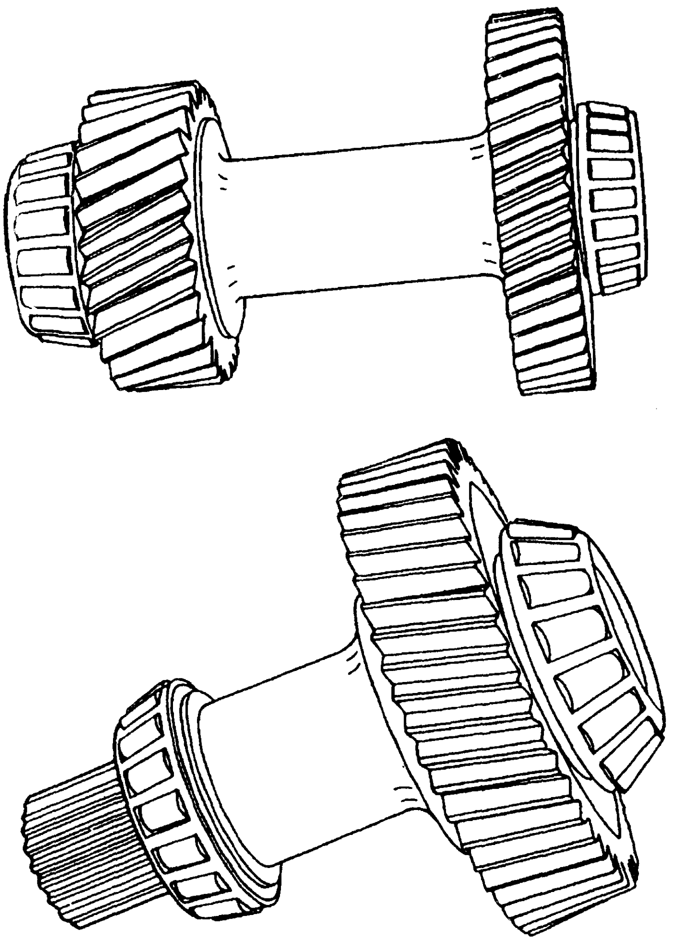


TAPERED ROLLER BEARINGS

CAUTION

Gears should never be removed from intermediate shaft or output shaft, as this will affect proper gear allignment.

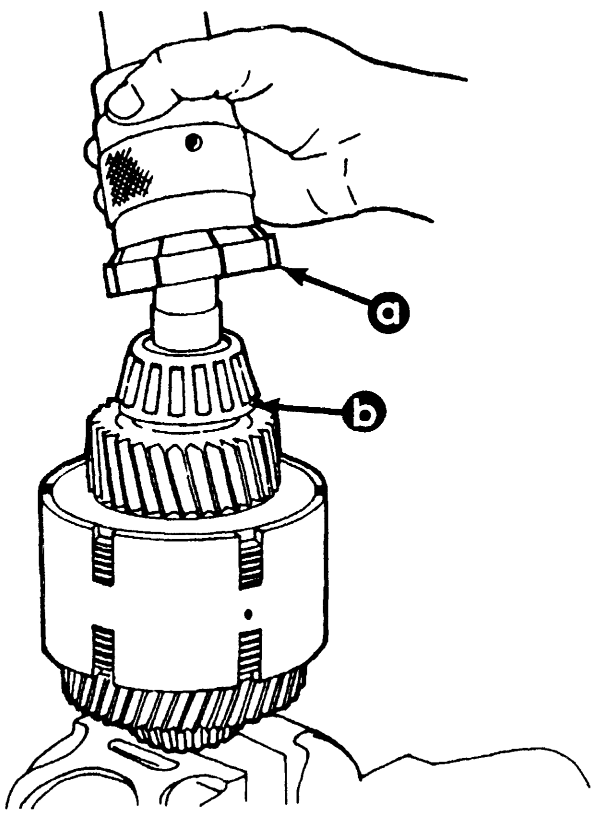
27. Remove tapered roller bearings from intermediate shaft and output shaft by using a universal puller plate and pressing bearings off.



REVERSING CLUTCH, GEARS and TAPERED ROLLER BEARINGS

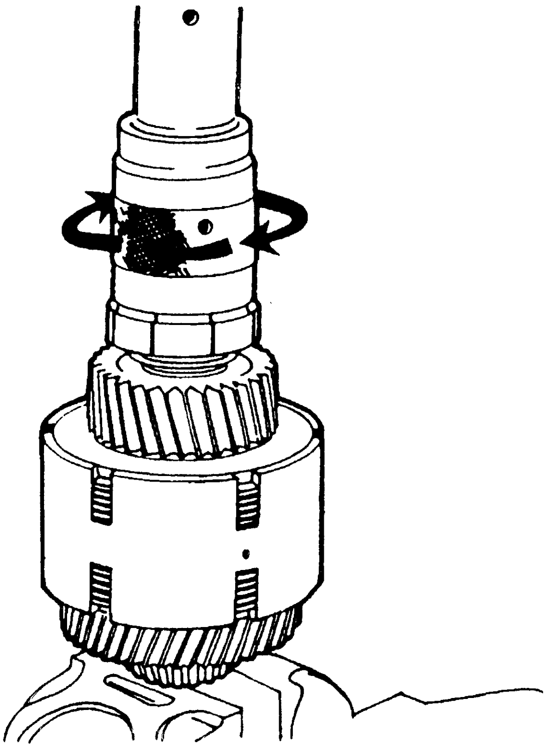
28. Remove tapered roller bearing from splined end of input shaft using special tool as follows:

    a. Place tool over tapered roller bearing. Ensure jaws of tool will be pulling on bottom edge of rollers and NOT on the cage.

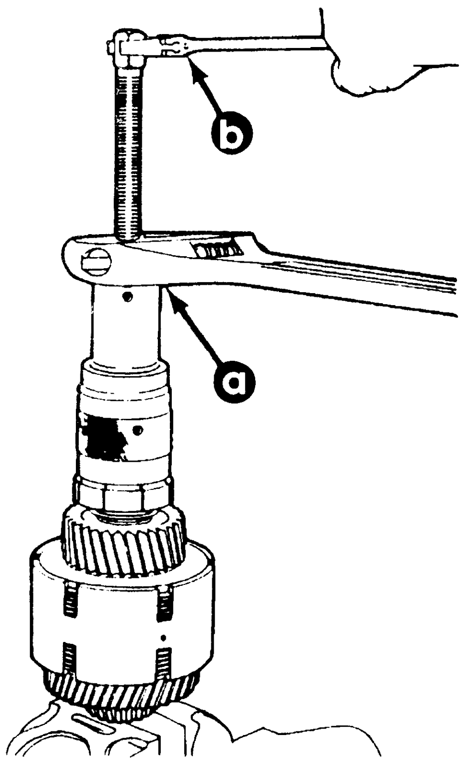


a - Jaws
b - Bottom Edge of Rollers

b. Tighten jaws onto bearing by turning on knurled part of tool. Tighten assembly.

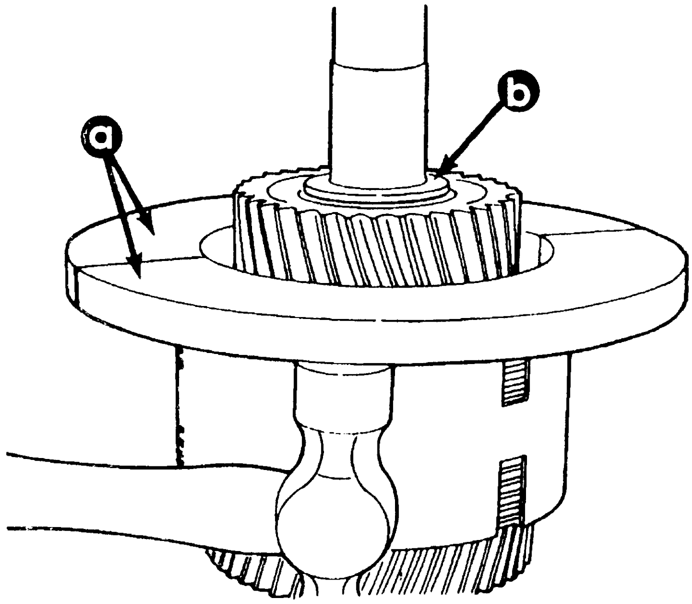


c. Pull tapered roller bearing from shaft using tool as shown.



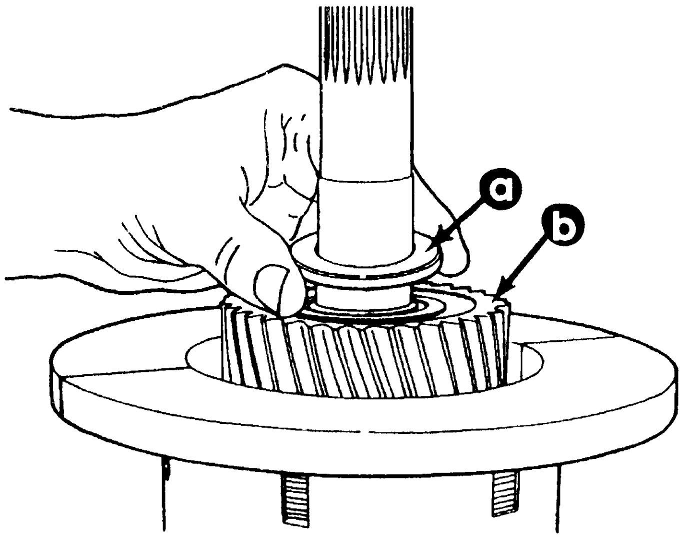
a - Hold Tool Stationary
b - Turn Top Nut

29. Remove butting ring from splined end of input shaft by installing special tool as shown and lightly tapping upward on tool.



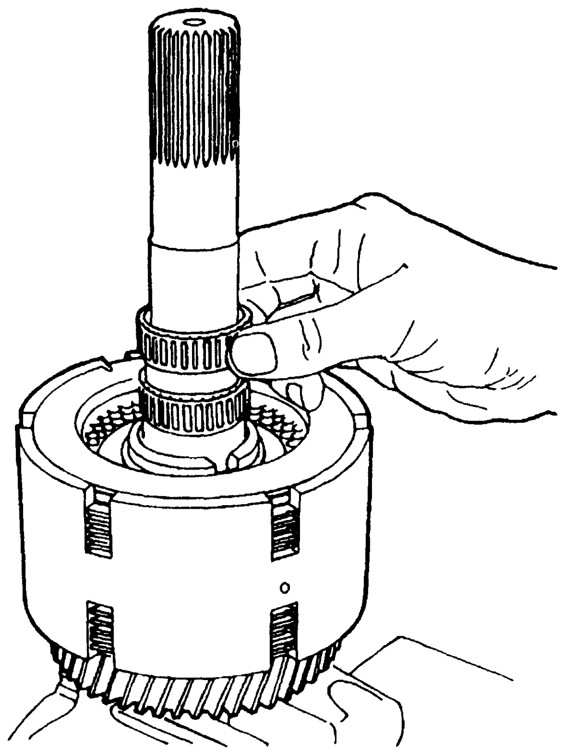
a - Special Tool
b - Butting Ring

30. Remove butting ring and gear assembly.

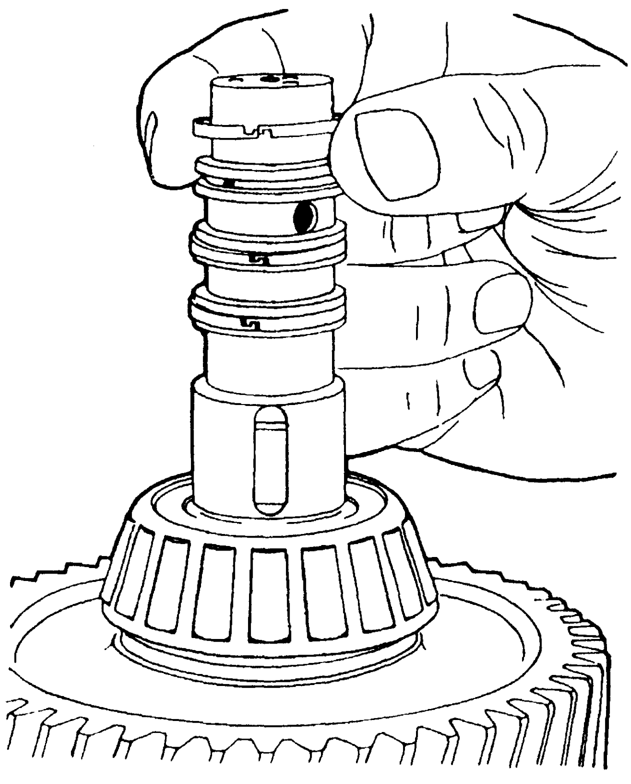


a - Butting Ring
b - Gear Assembly

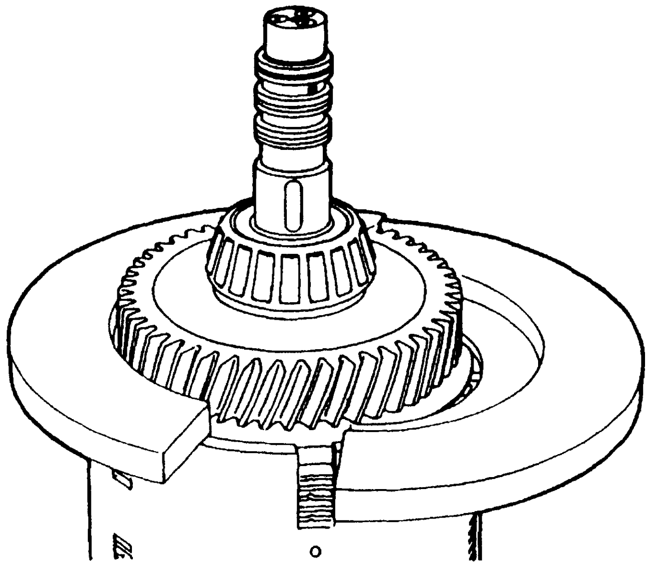
31. Remove needle bearings.



32. Remove piston rings from shaft.



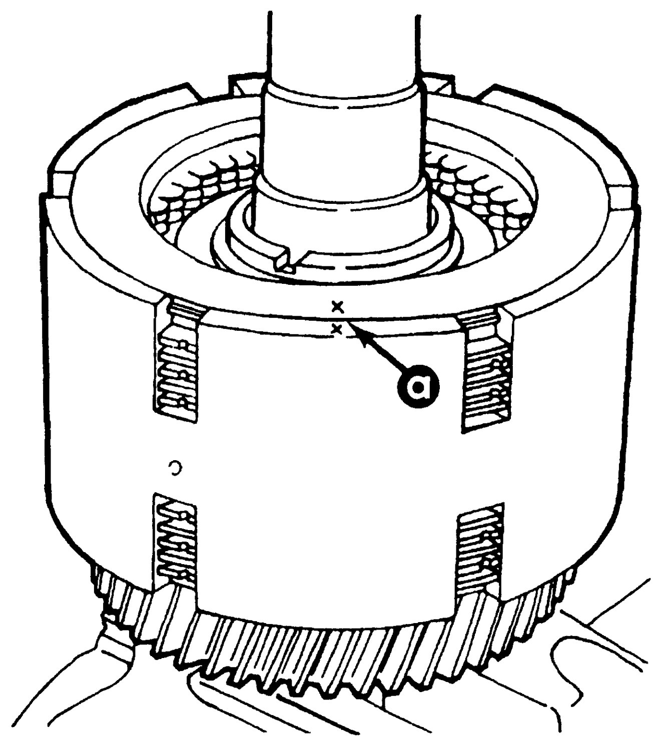
33. Remove tapered roller bearing, butting ring and gear from piston end of shaft using special tool as shown. Press all components off at the same time. Then, remove needle bearings.



CLUTCH DISCS

NOTE: Discs on both sides of clutch are removed in the same manner.

IMPORTANT: Reference marks are placed on the clutch housing and end disc to aid in locating the snap ring opening.



a - Reference Marks

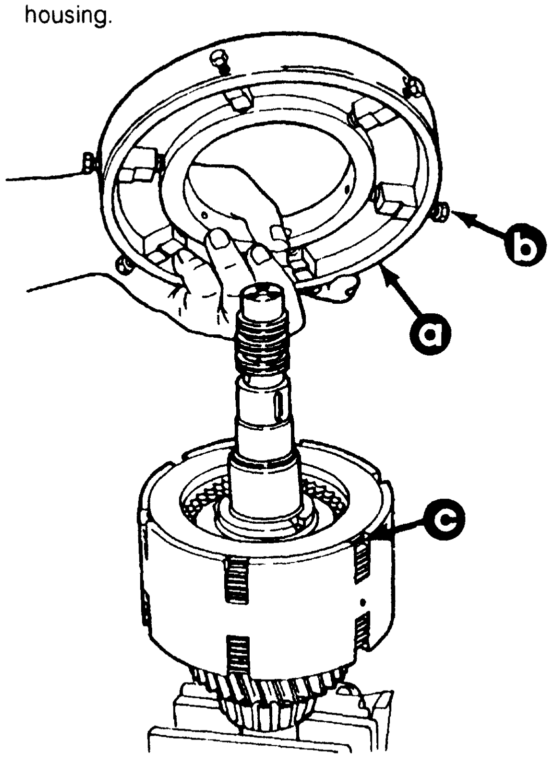
34. Position snap ring compression tool on clutch assembly so that compression screws are centered over slots in clutch housing.

35. Remove end disc and snap ring as follows:

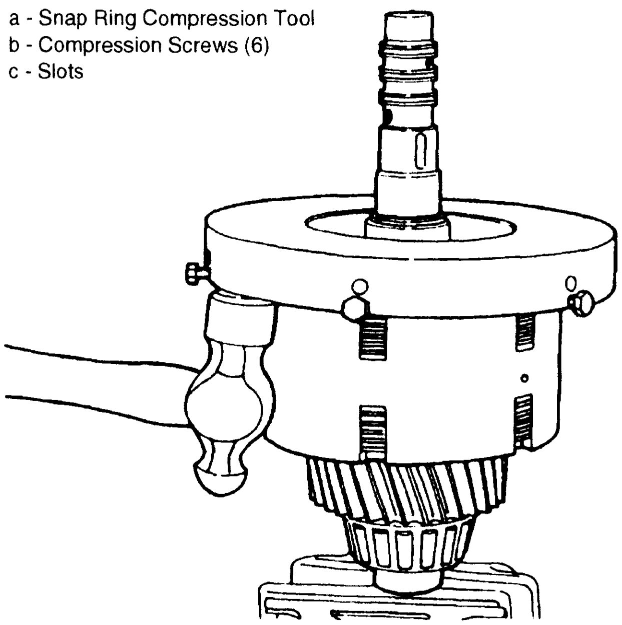
    a. Tighten all compression screws until a slight resistance is felt.

    b. Tighten compression screws evenly (approximately 1/2 turn at a time).

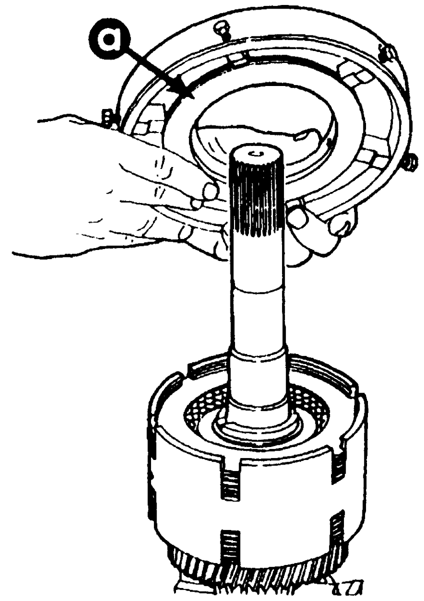
    c. Tap up rightly on bottom edge of compression tool unitil snap ring pops up and out of groove in clutch housing.



a - Snap Ring Compression Tool
b - Compression Screws (6)
c - Slots

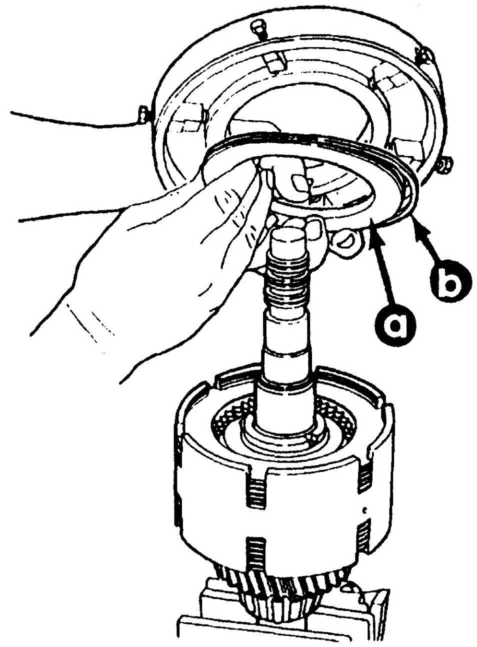


NOTE: For ease of reassembly, end disc and snap ring should not be removed from tool unless their condition is questionable.



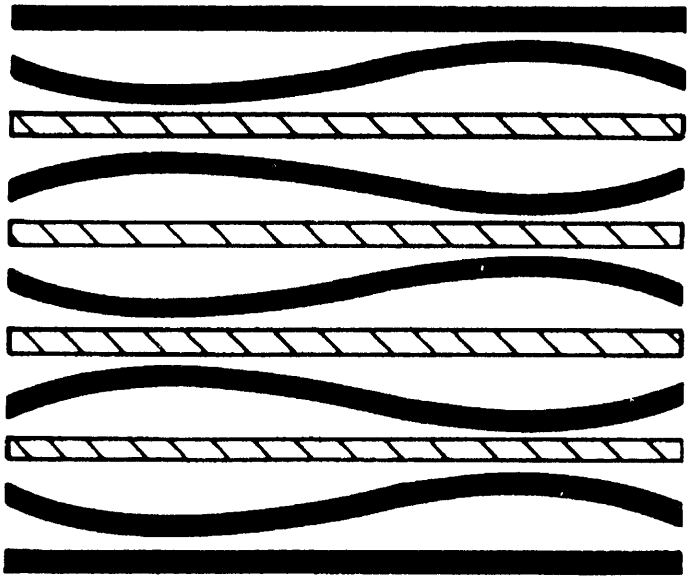
a - End Disc (Snap Ring Compressed)

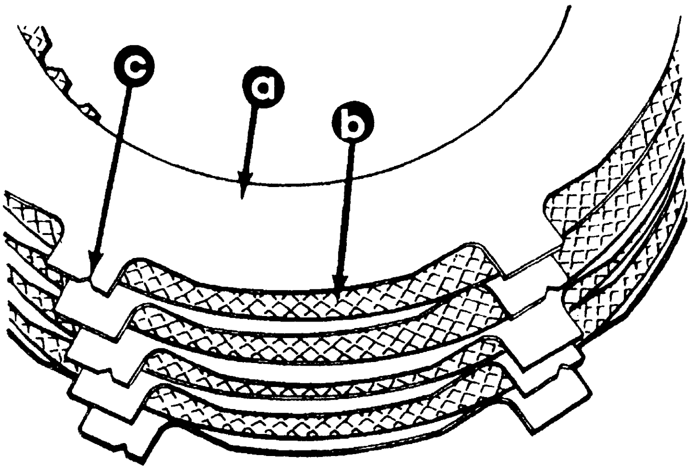
    d. If necessary, remove end disc and snap ring from tool.



a - End Disc
b - Snap Ring

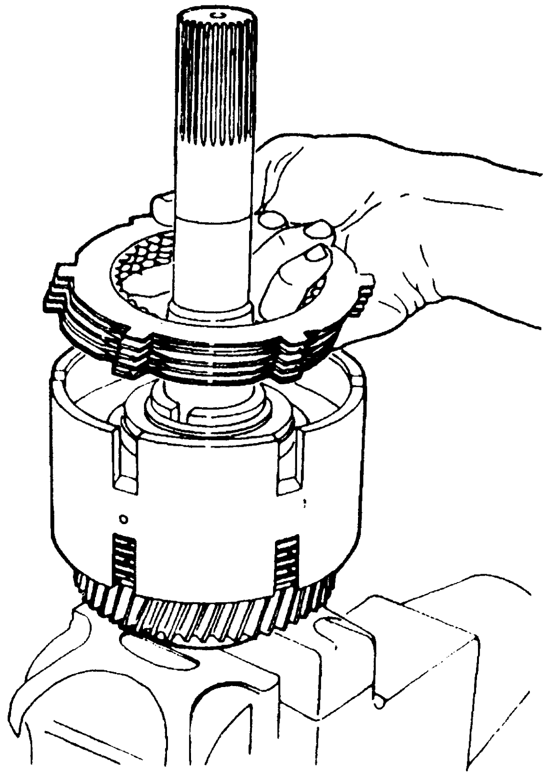
IMPORTANT: Thrust discs have a wave pattern. These discs must be reinstalled in a specific pattern, when reassembled. Make note of notches in thrust disc tabs, and how they are arranged.





a - Thrust Discs (5)
b - Inner Discs (4)
c - Notches

36. Remove discs.

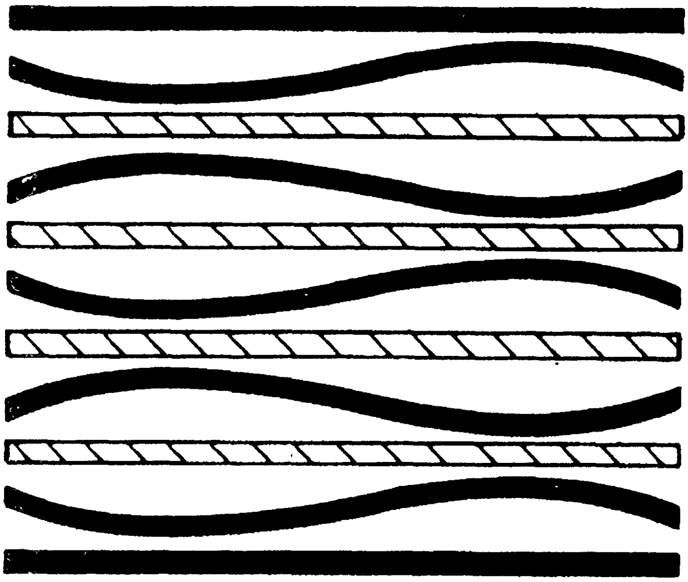


37. Inspect thrust discs and inner discs for wear. Replace if there is any questionable wear.
38. Remove and inspect disc on opposite side of clutch in same manner.

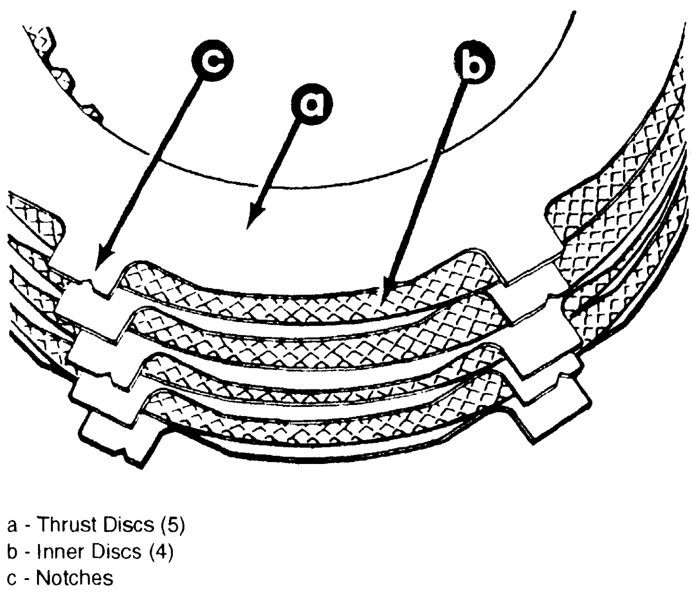
5. Reassembly

CLUTCH DISCS

IMPORTANT: Thrust discs have a wave pattern. These discs must be reinstalled in a specific manner as explained following.

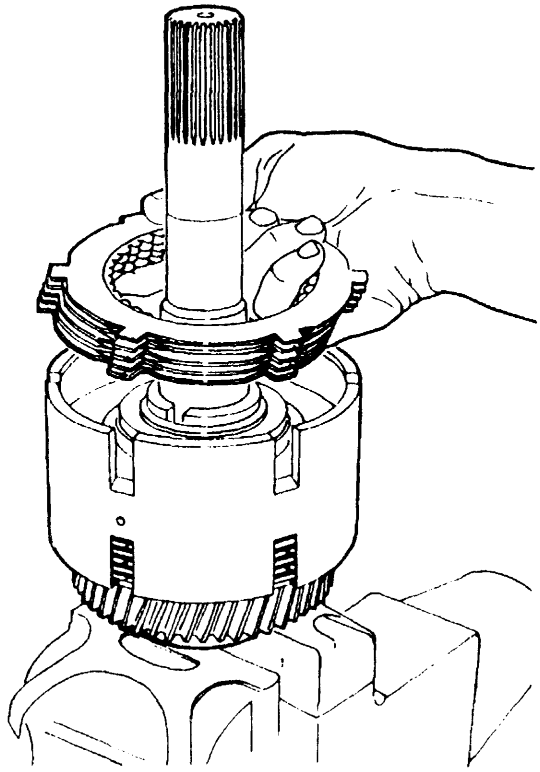


1. Arrange thrust discs and inner discs as shown. Ensure notches on thrust disc tabs are aligned as shown.

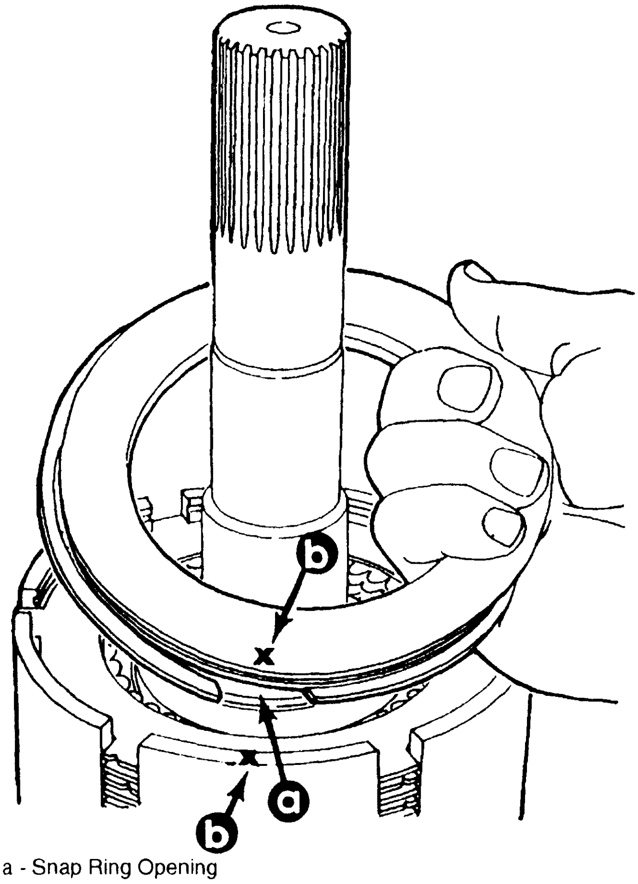


a - Thrust Discs (5)
b - Inner Discs (4)
c - Notches

2. Install discs in clutch housing.



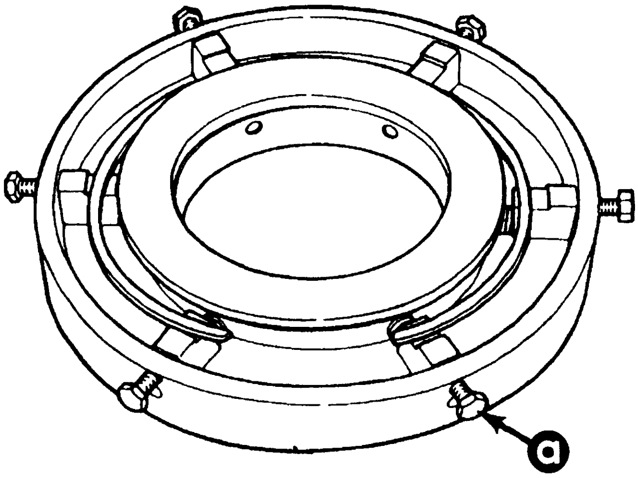
3. Align snap ring opening with reference marks on end disc and clutch housing.



a - Snap Ring Opening
b - Reference Marks

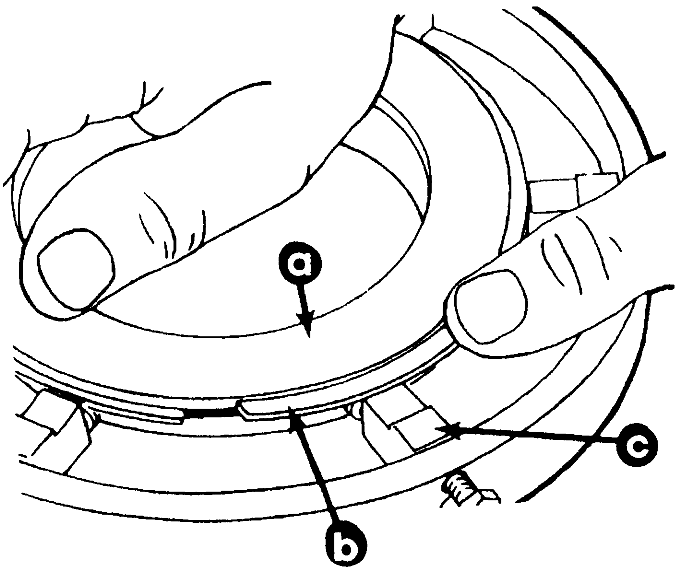
4. If end disc and snap ring were removed from tool, reinstall as follows:

   a. Loosen all compression screws on tool.



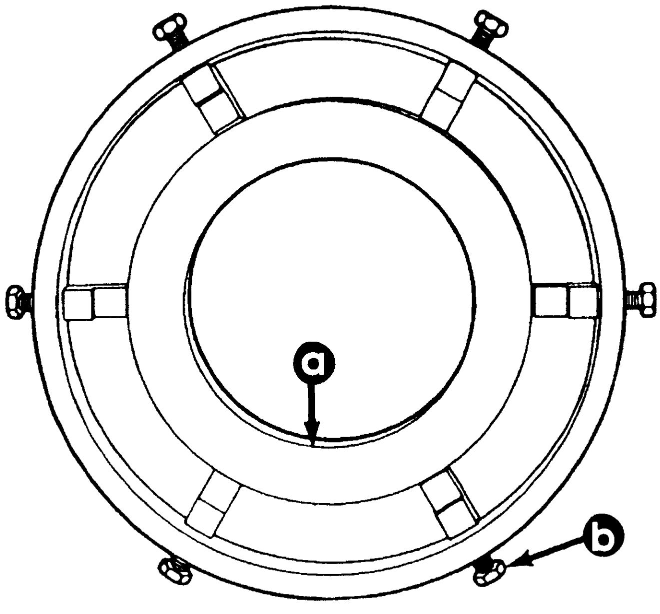
a - Compression Screws

   b. Place snap ring into groove in end disc and compress by hand so that compression dogs will hold in on snap ring.



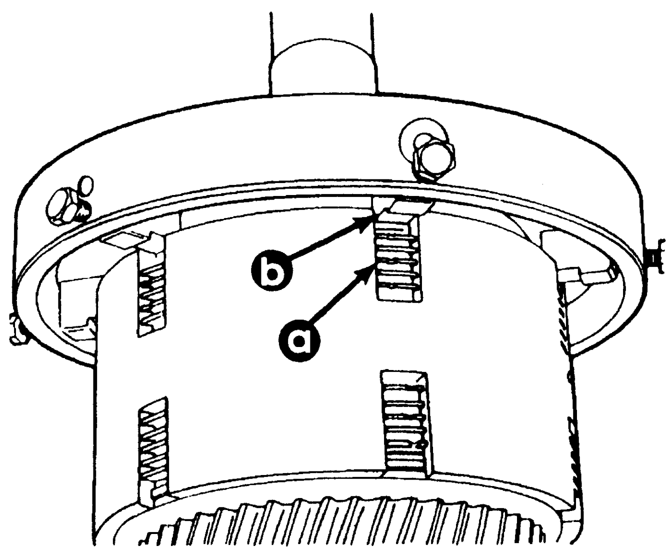
a - End Disc
b - Snap Ring
c - Compression Dogs

   c. Tighten compression screws evenly to completely compress snap ring into end disc.



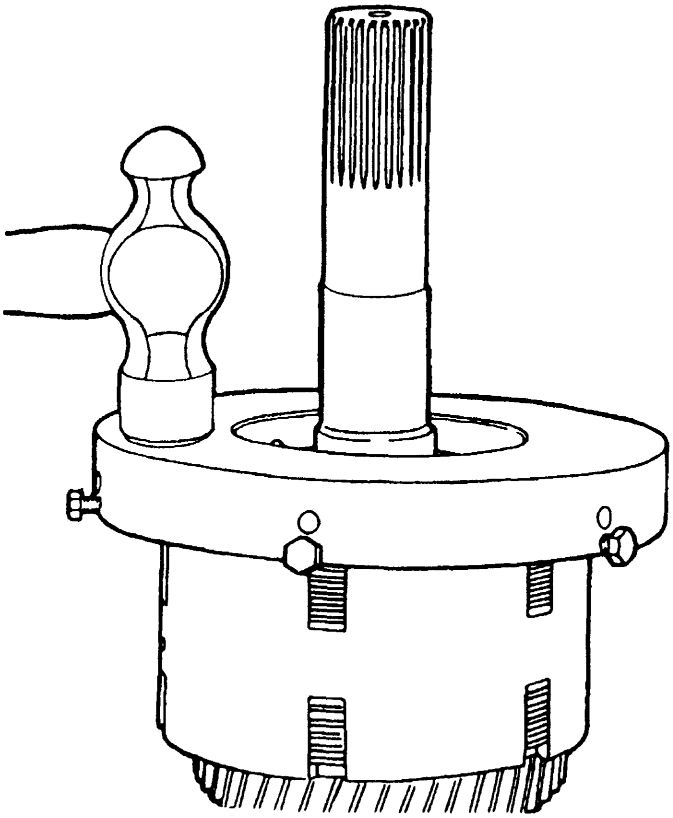
a - End Disc
b - Compression Screws

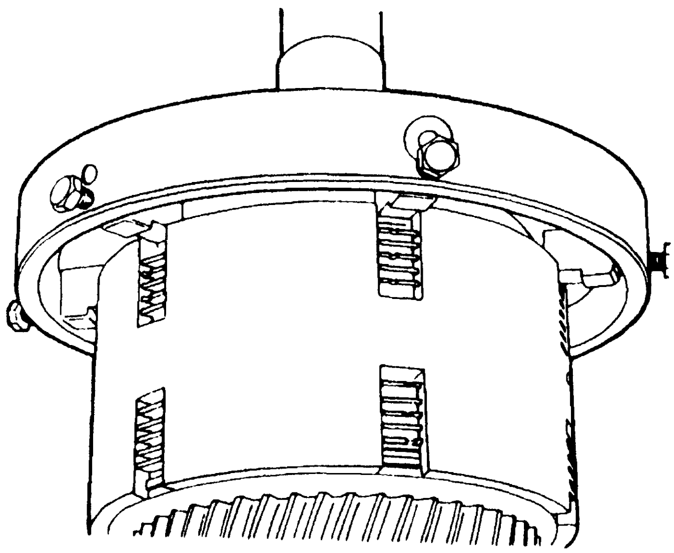
   d. Carefully lower end disc and special tool onto clutch housing and align compression dogs with slots in housing.



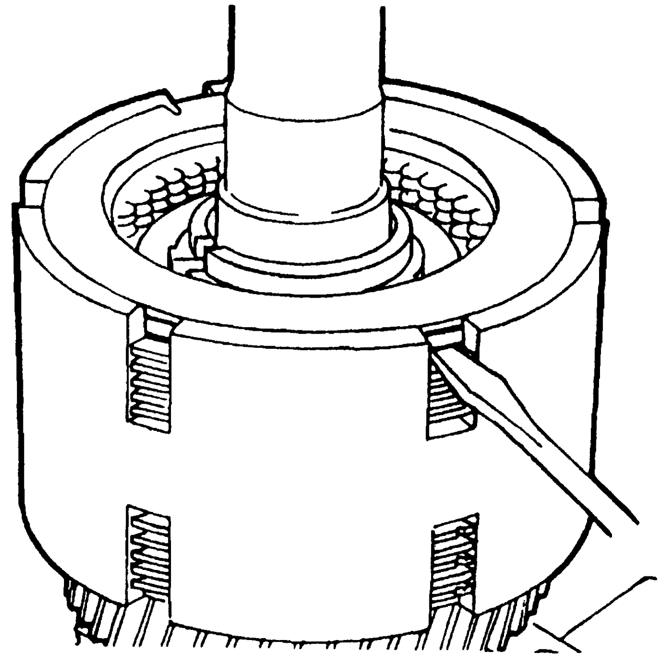
a - Slots
b - Compression Dogs

5. Tap lightly around top of tool until end disc bottoms. Loosen compression screws and remove tool.





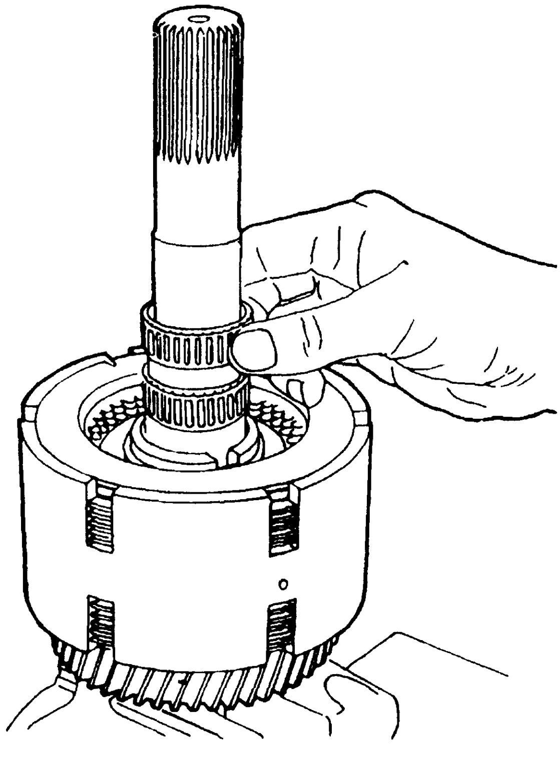
6. Double check that snap ring has been properly seated by prying up lightly on end disc.



7. Reinstall discs on opposite side of clutch in same manner.

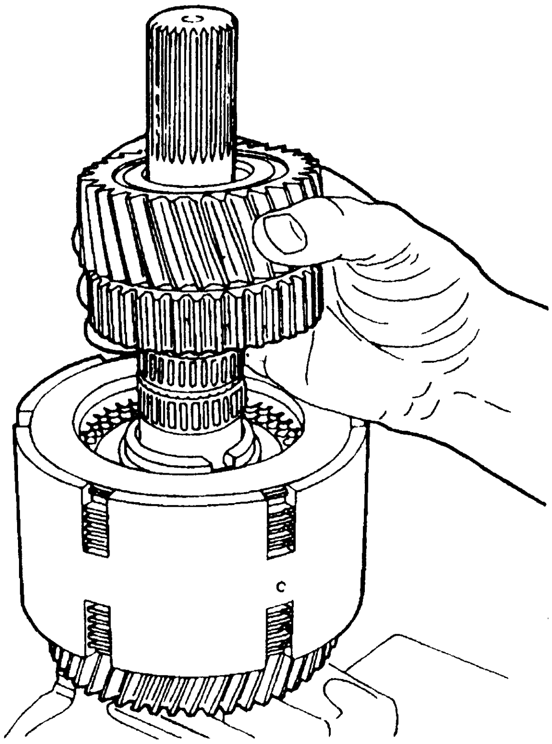
NEEDLE BEARINGS

8. Reinstall needle bearings.

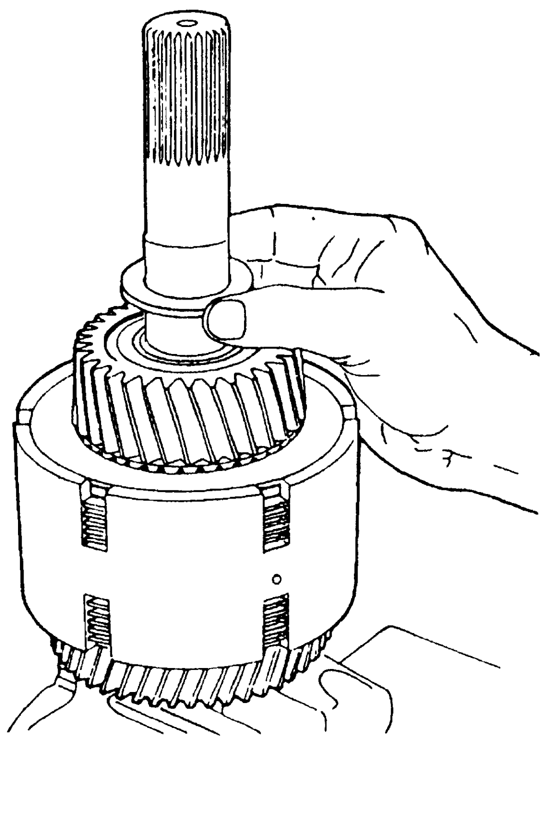


GEAR ASSEMBLY

9. Reinstall gear assembly. Twist gear assembly from side to side to allow splines to engage with inner discs. Ensure all inner discs are engaged with splines by observing through slots in clutch housing.



10. Reinstall butting ring.

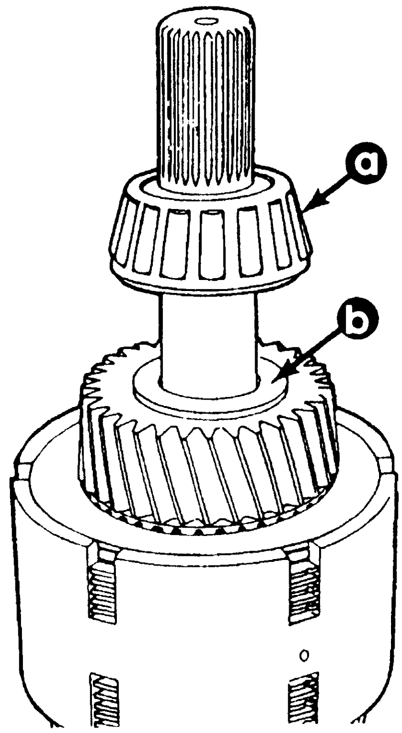


TAPERED ROLLER BEARING

⚠ CAUTION

Do not touch bearing once it has been heated. Severe burns could result. Use special protective gloves to handle bearing.

11. Heat inner race of tapered roller bearing using a torch lamp and press bearing onto shaft. When beaing has cooled down (Do Not cool with water), tap bearing **carefully** down to ensure proper seating against butting ring, using a soft (copper) punch **tap on inner race only**.

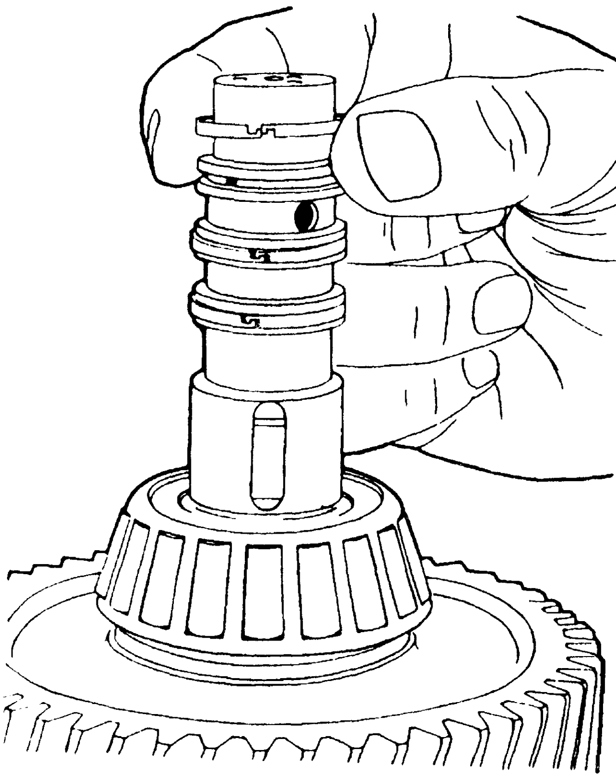


a - Tapered Roller Bearing
b - Butting Ring

12. Install components on opposite side of clutch assembly in same manner.

⚠ CAUTION
Use care in reinstalling piston rings on input shaft. Piston rings are brittle and may snap if spread too far open.

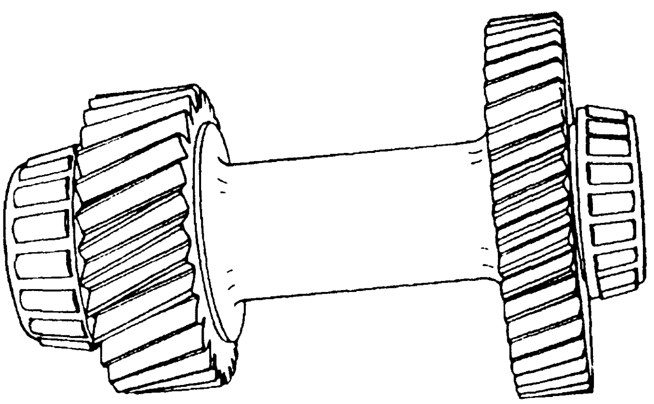
13. Reinstall piston rings on input shaft. Ensure ends of rings are coupled as shown. Then, position rings so that ends are staggered so no two are aligned.



INTERMEDIATE SHAFT

⚠ WARNING
Do not touch bearing once it has been heated. Severe burns could result. Use special protective gloves to handle bearing.

14. Heat inner race of tapered roller bearing using a torch lamp and press bearing onto shaft. When bearing has cooled down.(Do Not cool with water), tap bearing carefully down to ensure proper seating against gear, using a soft (copper) punch. Tap on inner race only.

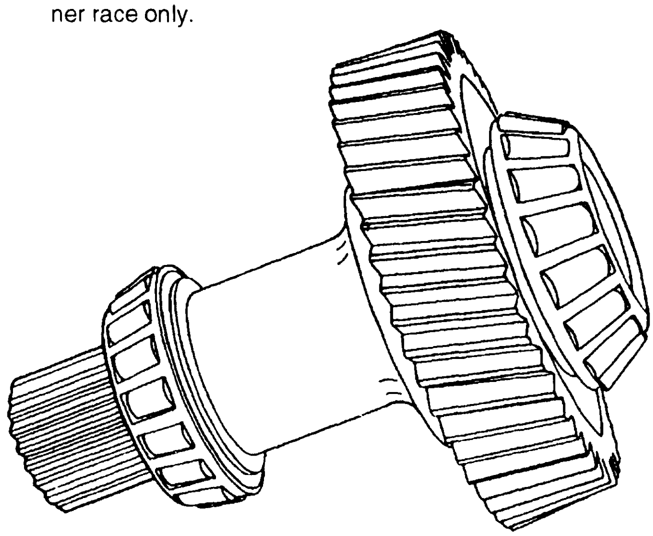


15. Install tapered roller bearing on opposite end of shaft in the same manner.

OUTPUT SHAFT

Do not touch bearing once it has been heated. Severe burns could result. Use special protective gloves to handle bearing.

16. Heat inner race of tapered roller bearing using a torch lamp and press bearing onto shaft. When bearing has cooled (Do Not cool with water), drive bearing down against gear using a soft (copper) Punch, tapping on inner race only.



17. Install tapered roller bearing on opposite end of shaft in the same manner.

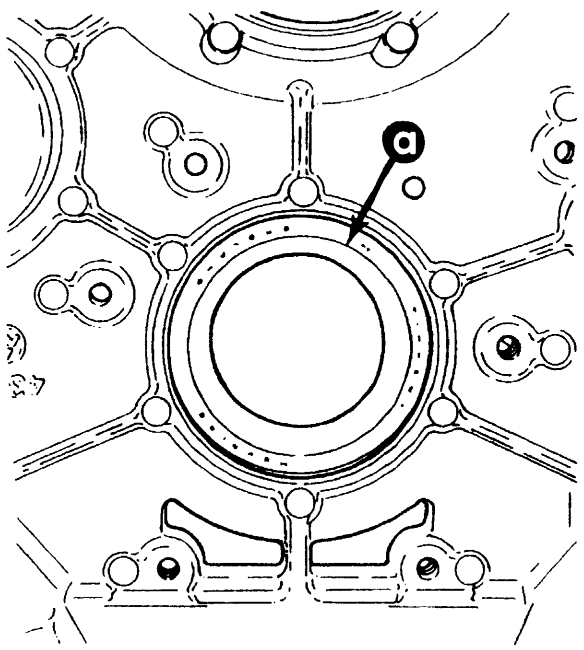
NOTE: Bearing on splined end of shaft is tapped until seated against shoulder on shaft.

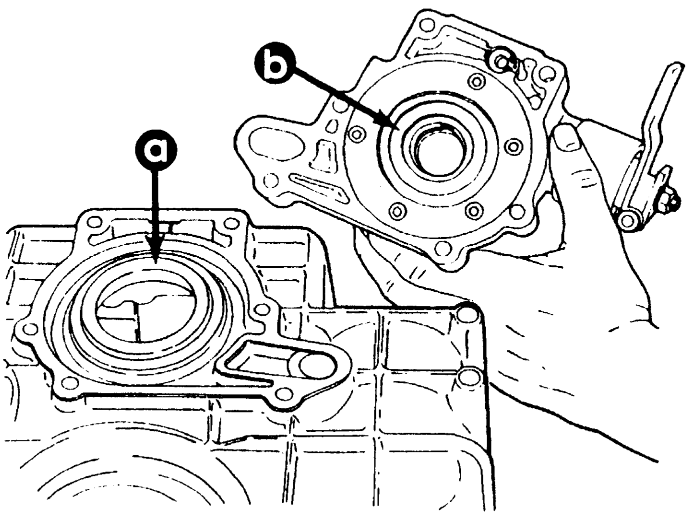
Preassembly of Output Half of Housing

IMPORTANT: If tapered roller bearing cups were removed, ensure output shaft seal IS NOT in place, as it will be necessary to heat housing prior to installing bearing cups.

IMPORTANT: The tapered roller bearing cup on the input shaft (control block end) is properly positioned by bottoming out on the face of the control block assembly. It will be necessary to temporarily install control block to install this tapered roller bearing cup.

18. Temporarily install control block on outer housing. Tighten bolts securely.



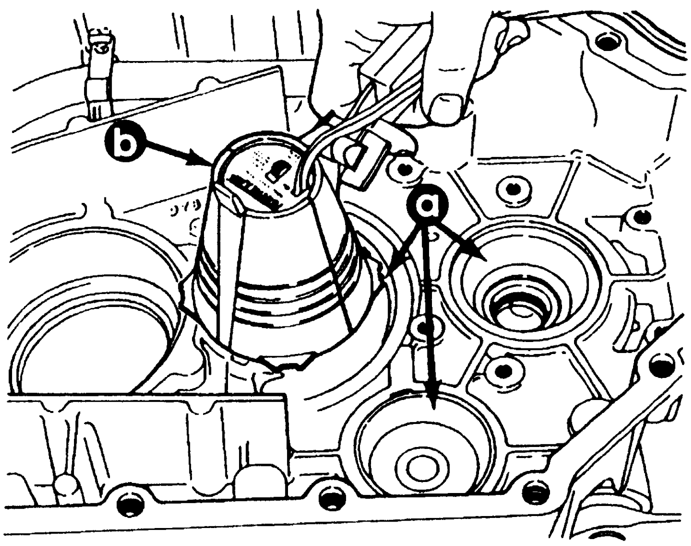


a - Input Shaft Bearing Cup
b - Control Block Face

⚠ WARNING

Use care in handling housing, once it is heated with torch lamp. Severe burns could result. Use special protective gloves when handling housing.

19. Heat bearing bores of housing using a torch lamp and install bearing cups using a suitable mandrel.



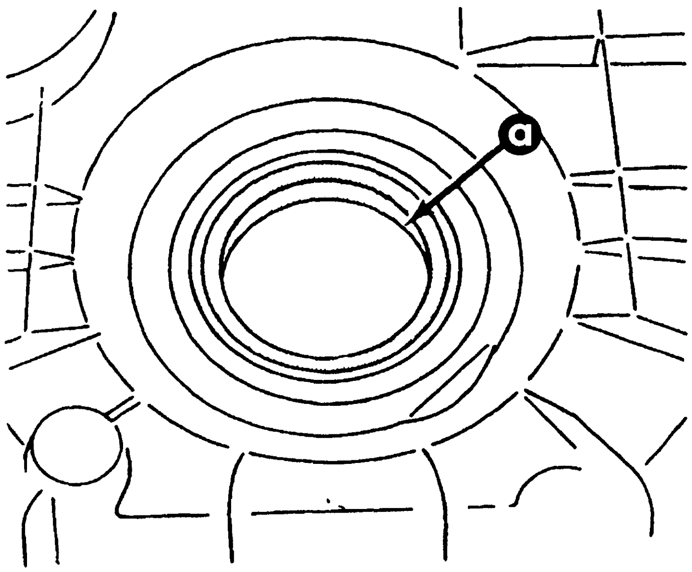
a - Bearing Cups
b - Torch Lamp

20. Allow housing to cool (Do Not cool with water) and then tap bearing cup with suitable mandrel to ensure it is properly seated.

21. Remove control block assembly.

OUTPUT SHAFT SEAL

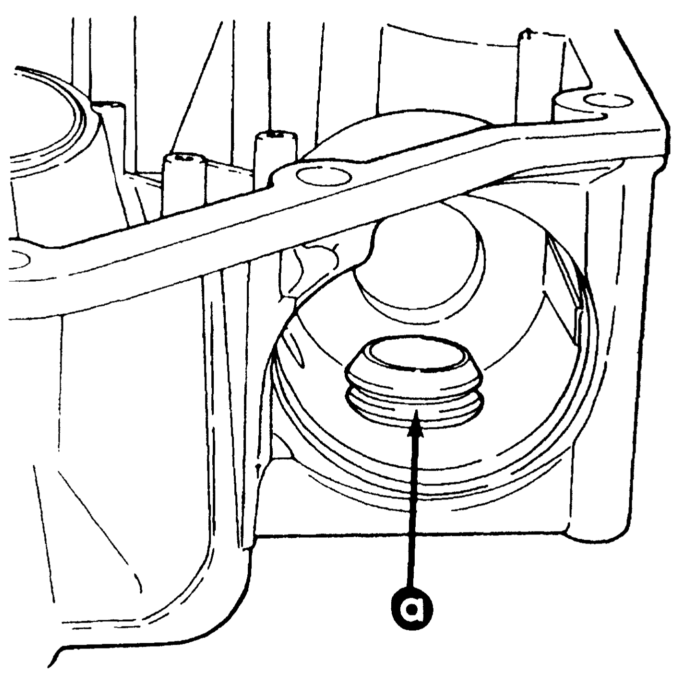
22. **If bearing were not replaced and no shimming is required,** push new seal onto special mandrel. Ensure seal will be positioned with lip of seal facing inward. Drive seal uniformly into bore of housing to the point that it is countersunk 0.040 in. (1 mm) with reference to housing surface.



a - Seal

SUCTION PIPE

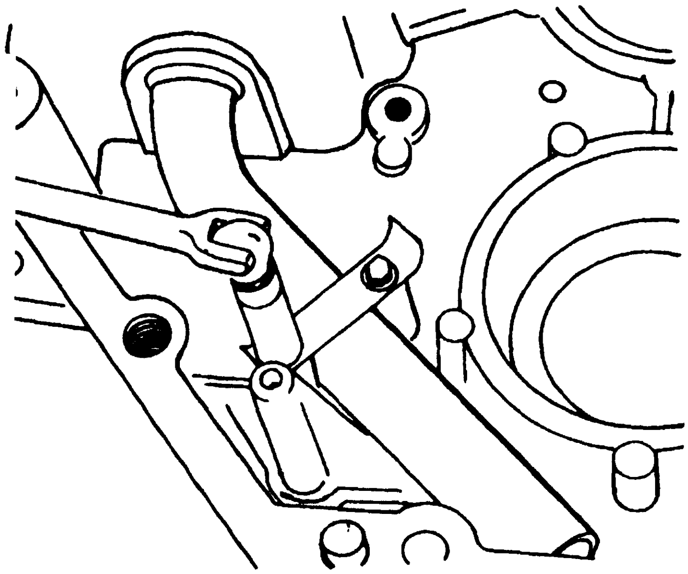
23. Reinstall suction pipe seal in bottom of oil filter bore. Coat seal with ATF.



a - Seal

24. Reinstall suction pipe. Place one drop of Loctite Type "A" on screw threads. Then, secure suction pipe down with retainer plate. Tighten screws securely.

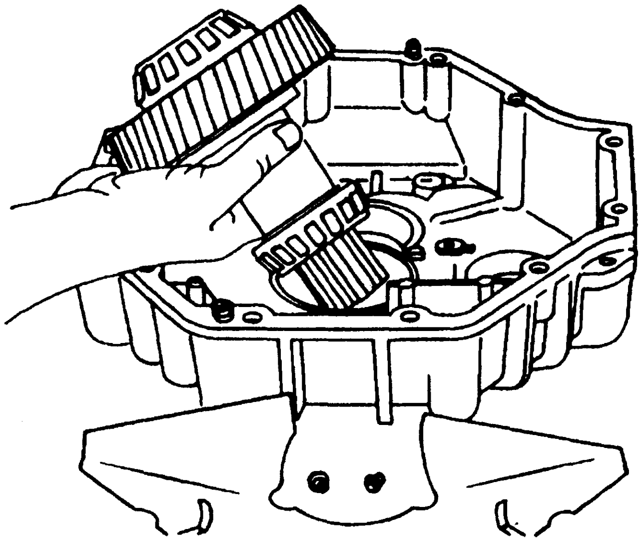
25. Bend tabs down over screws.



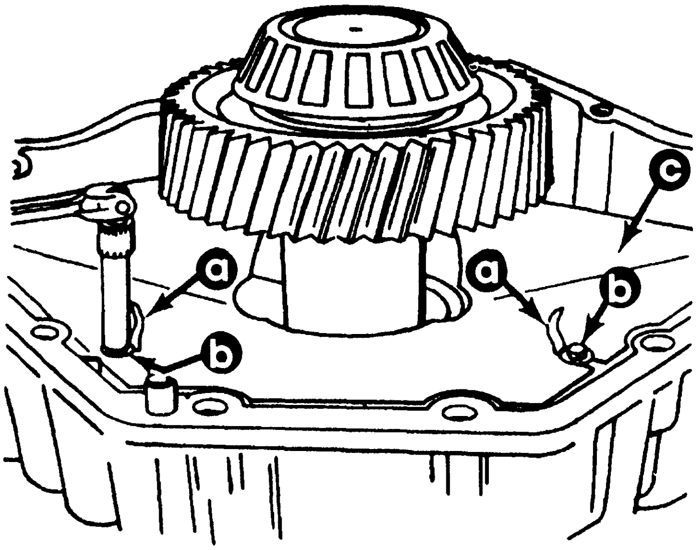
SHAFTS and BAFFLE PLATE

26. Coat tapered roller bearings with ATF.

27. Install output shaft.

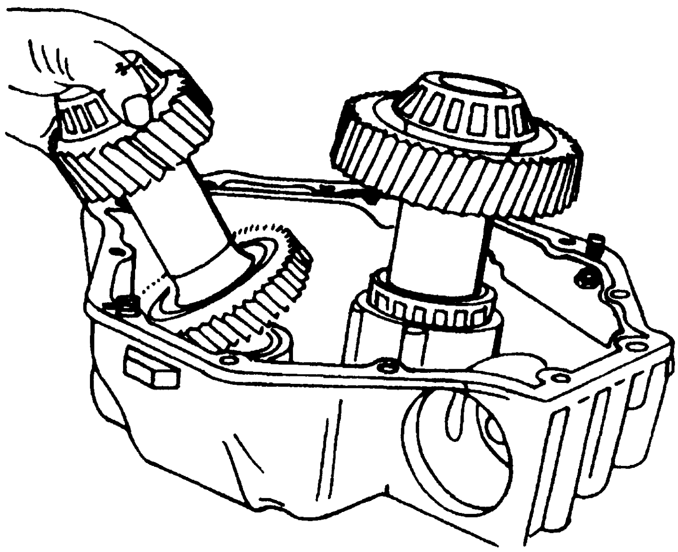


28. Install baffle plate. Apply one drop of Loctite Type "A" to screws. Tighten screws securely and bend tabs down over screws.

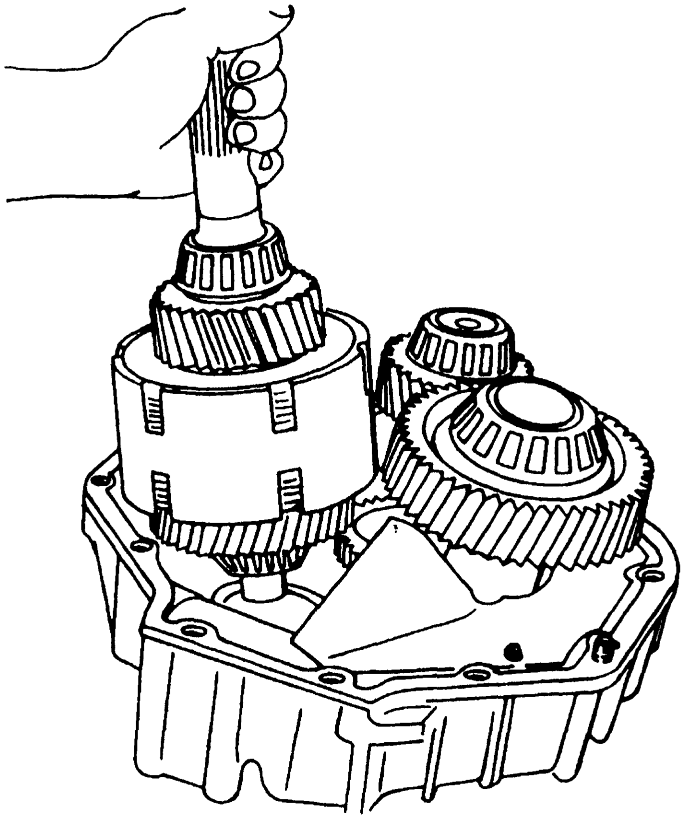


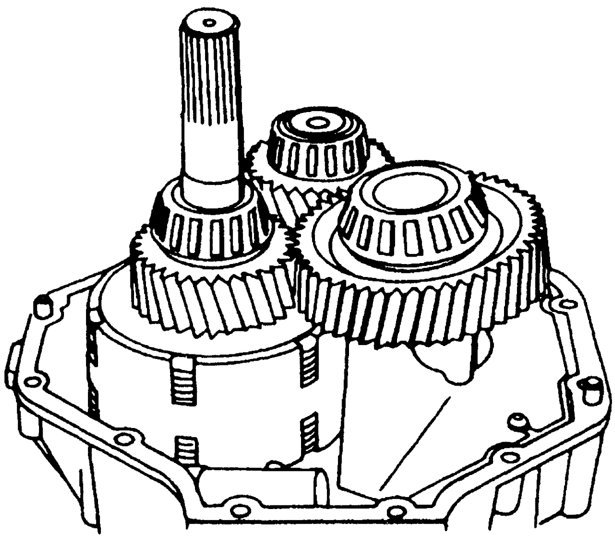
a - Tabs
b - Screws
c - Baffle Plate

29. Install intermediate shaft.



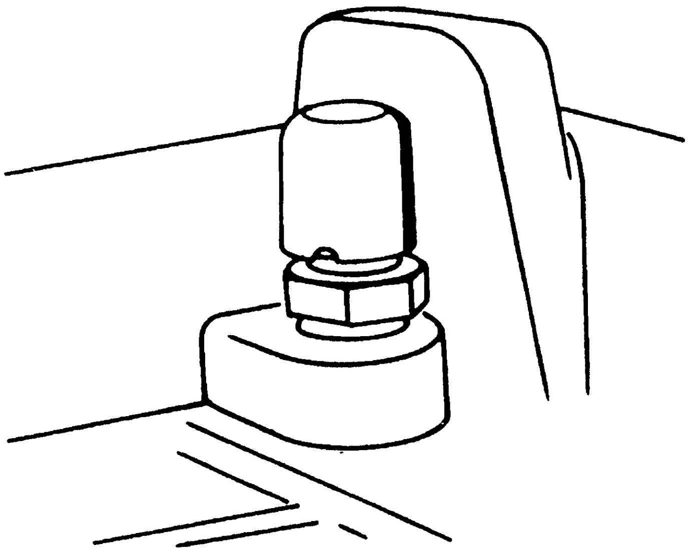
30. Install input shaft. Ensure all gears mesh as shown.





Preassembly of Input Half of Housing

31. Install breather valve (do not overtighten).



BEARING PRELOAD ADJUSTMENT

IMPORTANT: If new tapered roller bearings have been installed, the preload must be readjusted. If bearing were not replaced, proceed to the final reassembly section.

NOTE: The required preload of bearings of the individual shafts is obtained by using shims beneath the tapered roller bearing cups in the input half of the housing.

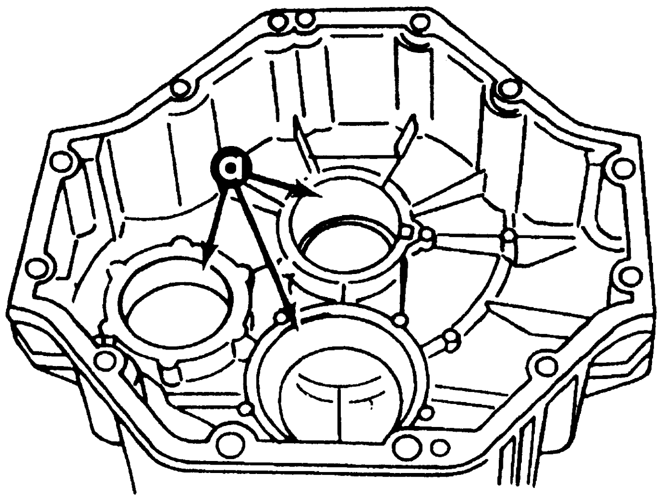
NOTE: Shims which have been removed during disassembly may be reused.

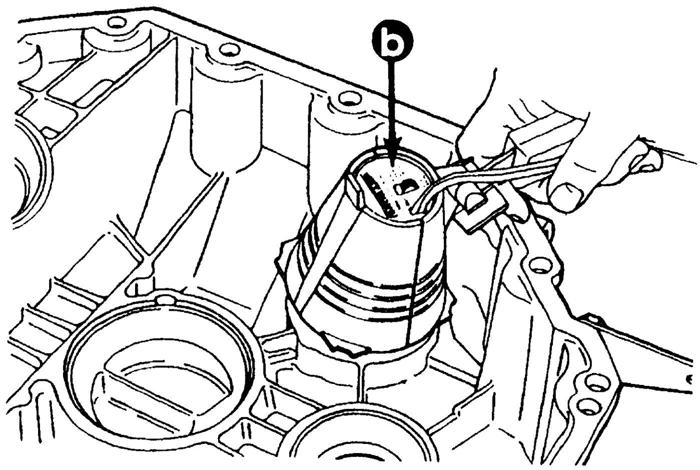
32. Subtract approximately 0.008 in (0.2mm) of shims from each bearing cup bore. Remove and set aside, but do not mix up.

⚠ WARNING

Use care in handling housing once it has been heated with a torch lamp. Severe burns could result. Use special protective gloves when handling housing.

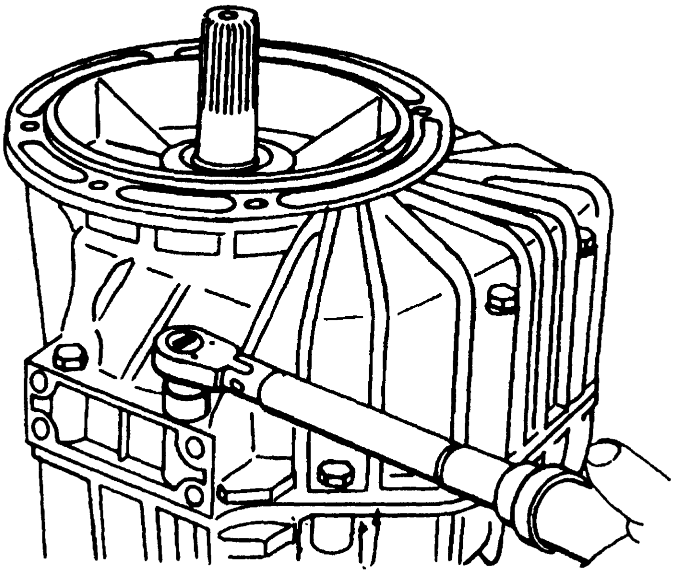
33. Heat each tapered roller bearing cup bore with a torch lamp. Insert shims (less those removed) and bearing cups into appropriate bearing bores. When housing has cooled (Do Not cool with water), tap bearing cups with a suitable mandrel to ensure that cups are fully seated.





a - Bearing Cups
b - Torch Lamp

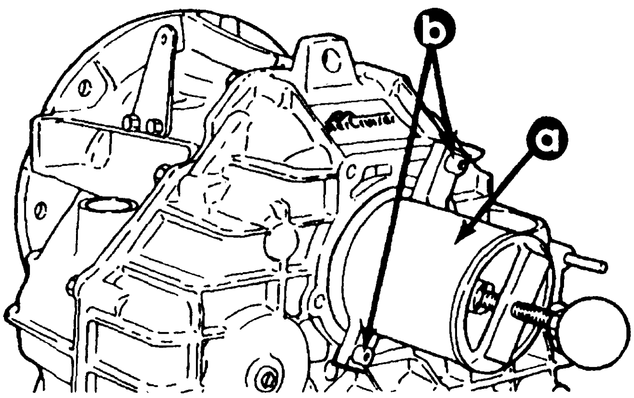
34. Install input half of housing onto output half. Ensure locator pins are in place. Install bolts and lockwashers and torque to 36 lb. ft. (49 N.m).



INPUT SHAFT PRELOAD

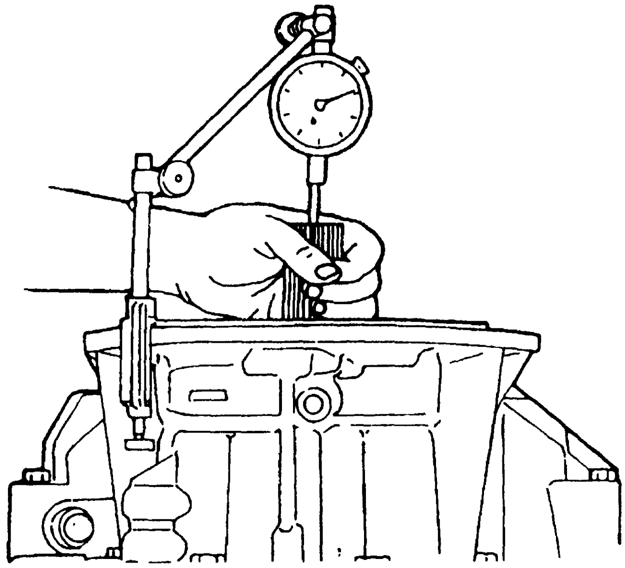
35. Measure bearing clearance as follows:

    a. Install special tool as shown. Tighten hold down bolts securely.

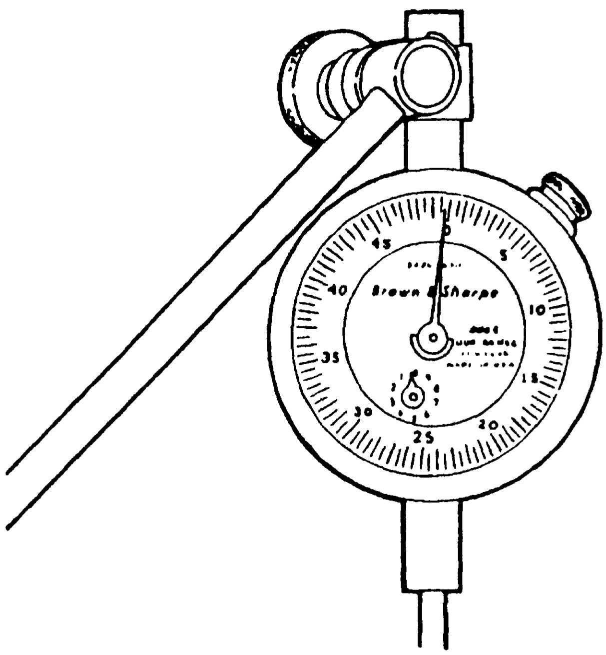


a - Special Tool
b - Hold Down Bolts

    b. Mount dial indicator on input shaft. Turn input shaft several times to seat bearing.

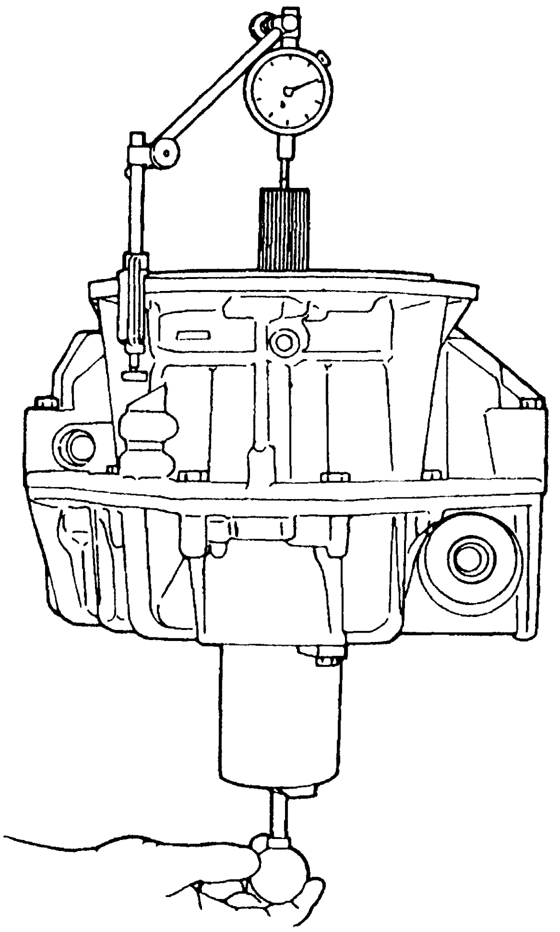


    c. Zero the dial indicator.

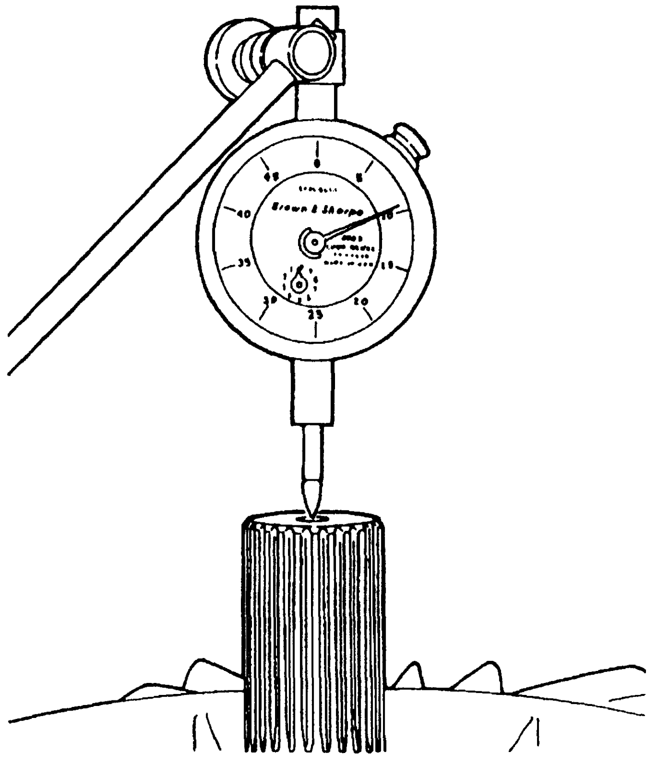


IMPORTANT: The following step should be done very carefully to obtain the actual bearing clearance. Avoid bumping the input shaft and turn very slowly on the special tool knob. (Shaft will only be moving a very small amoun.)

d. Slowly turn the special tool knob clockwise to push the shaft upward. (Perform the above sequence several times to ensure on accurate reading.)



e. Make note of reading. The bearing clearance measured **PLUS** the preload required is equal to the amount of shim thickness to be **ADDED.**



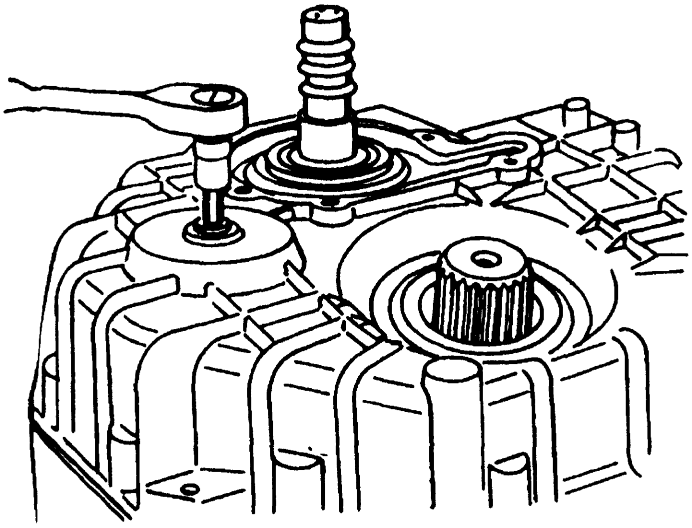
Example:

Bearing Clearances Measured	0.009 in.
+ Bearing Preload Required	0.004 in.
= Shims to Be Added	0.013 in.

INTERMEDIATE SHAFT PRELOAD

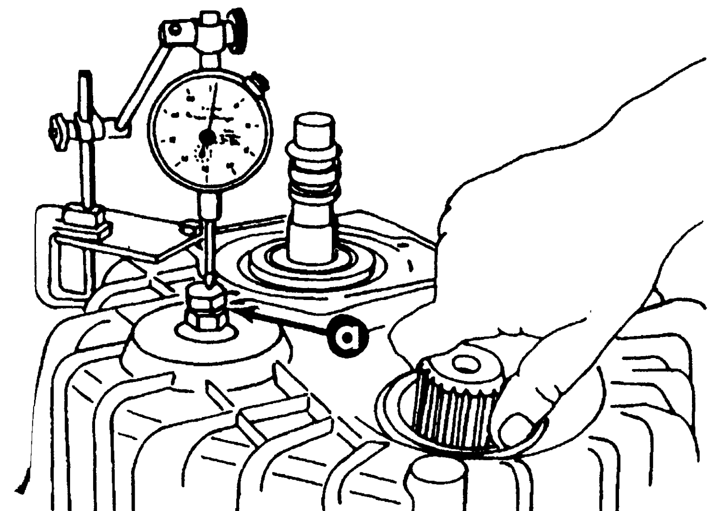
36. Measure bearing clearance as follows:

   a. Remove hex plug from housing.



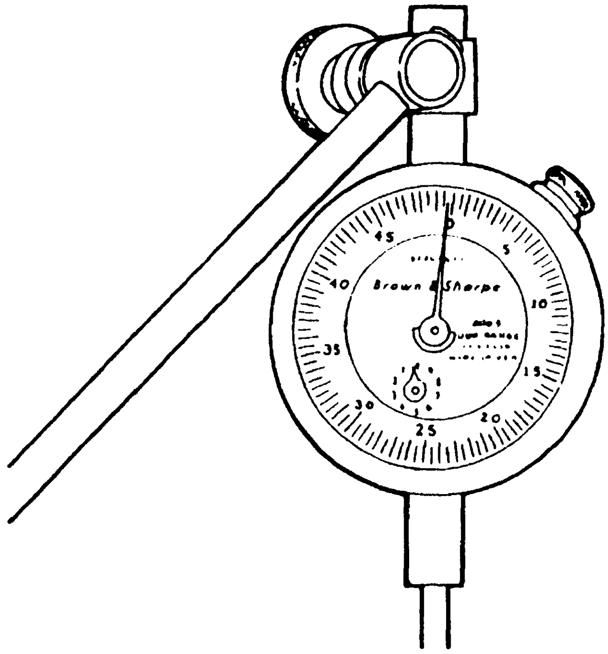
   b. Screw special bolt with nut into intermediate shaft and tighten snuggly. Turn nut up until it touches bolt head.

   c. Mount dial indicator on bolt head. Turn output shaft several times to ensure bearing is seated.



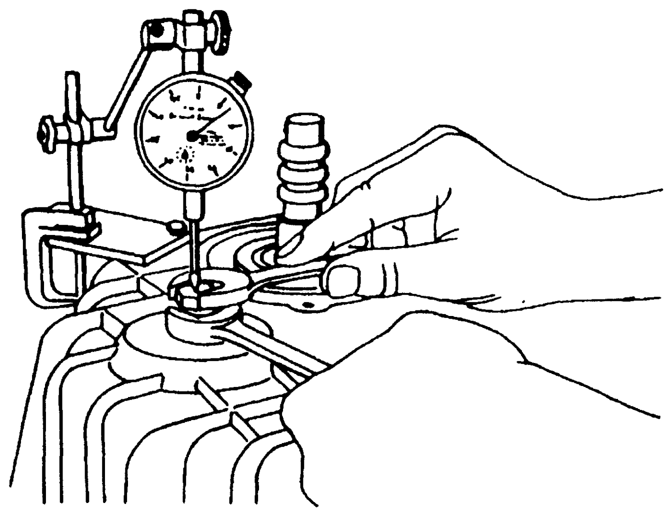
a - Special Bolt with Nut

   d. Zero dial indicator.



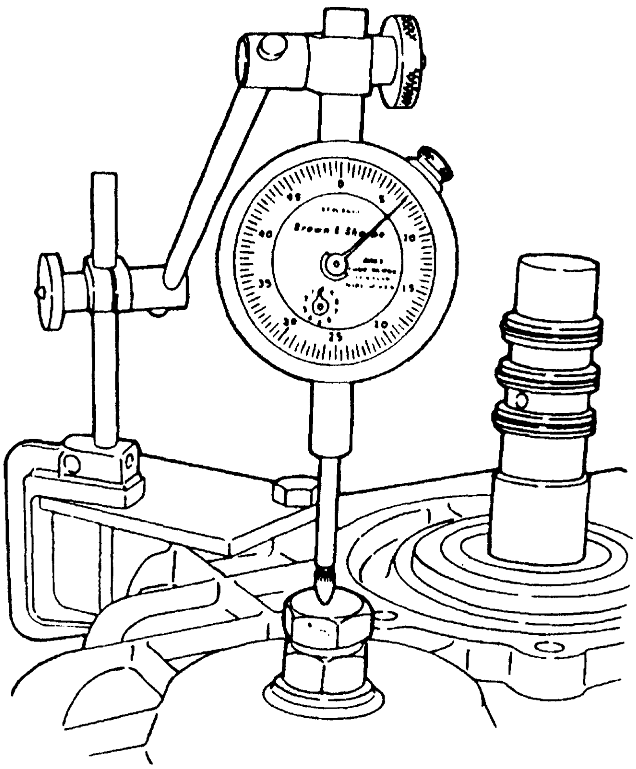
IMPORTANT: The following step should be done very carefully, to obtain the actual bearing clearance. Turn nut very slowly as shaft will only be moving a small amount.

   e. Hold bolt with one wrench and slowly turn down nut to pull shaft upward. (Perform the above sequence several times to ensure accurate reading.)



a - Bolt-Hold Stationary
b - Nut-Turn to Move Shaft

f. Make note of the reading. The bearing clearance measured **PLUS** the preload required is equal to the amount of shim thickness to be **ADDED.**



Example:

Bearing Clearances Measured	0.007 in.
+ Bearing Preload Required	0.004 in.
= Shims to Be Added	0.011 in.

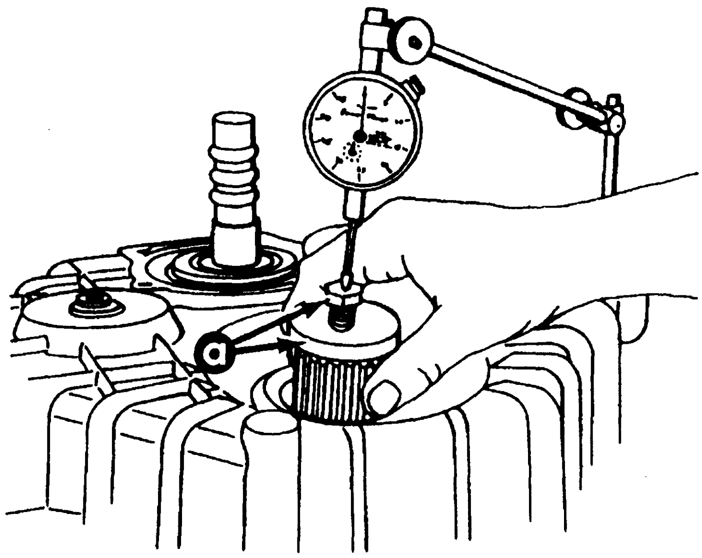
g. Remove dial indicator, special bolt and nut, and reinstall hex plug. Tighten securely.

OUTPUT SHAFT PRELOAD

37. Measure the bearing clearance as follows:

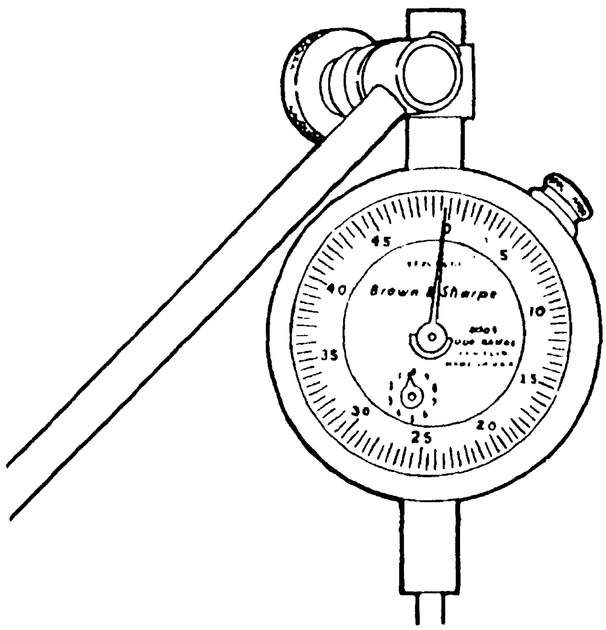
a. Install flange washer and bolt. Tighten snuggly.

b. Mount dial indicator on bolt head. Turn output shaft several times to ensure bearing is seated.



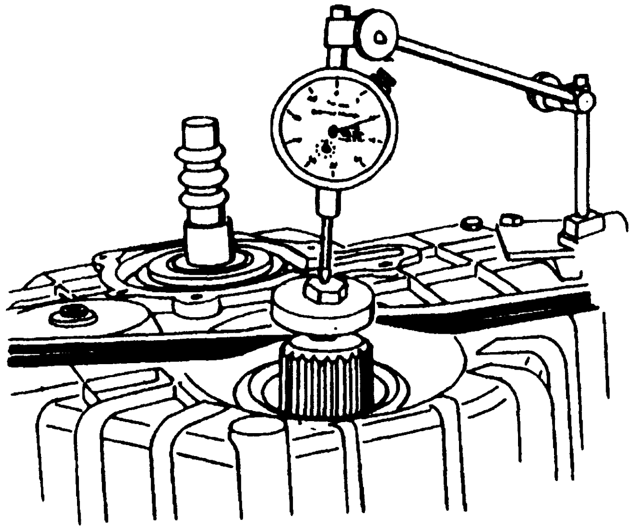
a - Flange Washer and Bolt

c. Zero dial indicator.

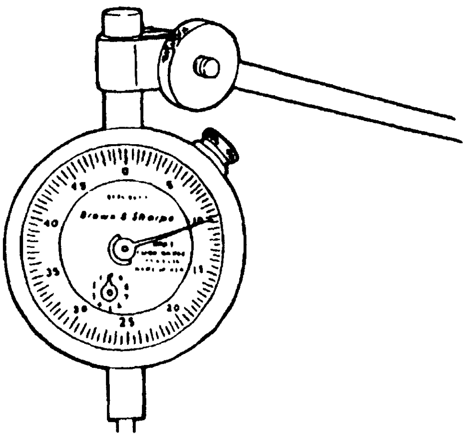


IMPORTANT: The following step should be done very carefully to obtain the actual bearing clearance. Pry up gently and evenly to lift shaft. Shaft will only move a small amount.

d. Pry up on washer to lift output shaft.



e. Make note of the reading. The bearing clearance measured **PLUS** the preload required is equal to the amount of shim thickness to be **ADDED.**

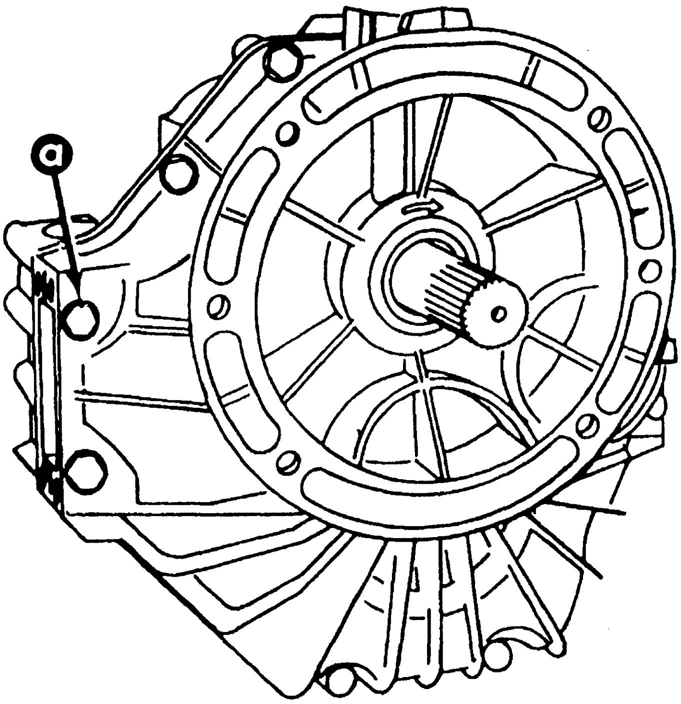


Example:

Bearing Clearances Measured	0.010 in.
+ Bearing Preload Required	0.004 in.
= Shims to Be Added	0.014 in.

f. Remove dial indicator. Remove bolt and flange washer.

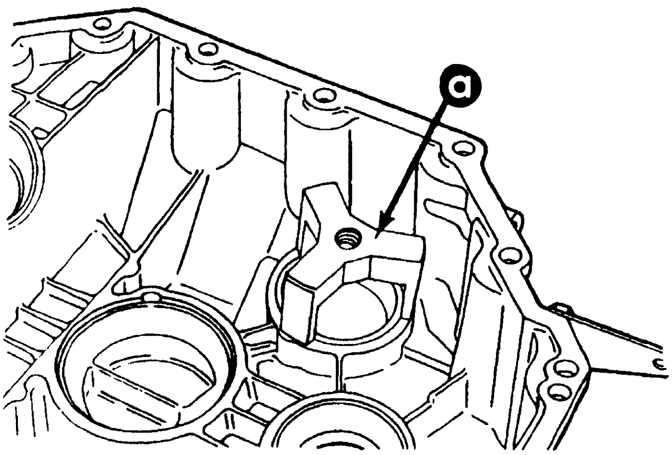
38. When thickness of shims to be ADDED has been determined, the input half of housing must again be removed. Remove bolts and lockwashers, then lift off input half of housing.



a-Bolts

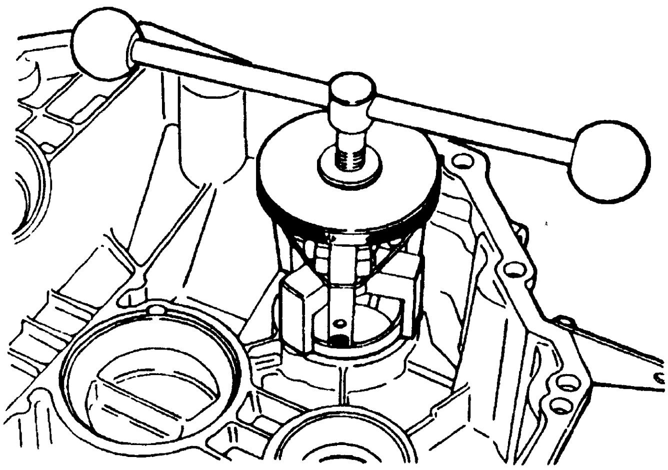
39. Remove tapered roller bearing cups from housing using special puller as follows:

    a. Position appropriate puller guide (large or small diameter) over cup as shown.

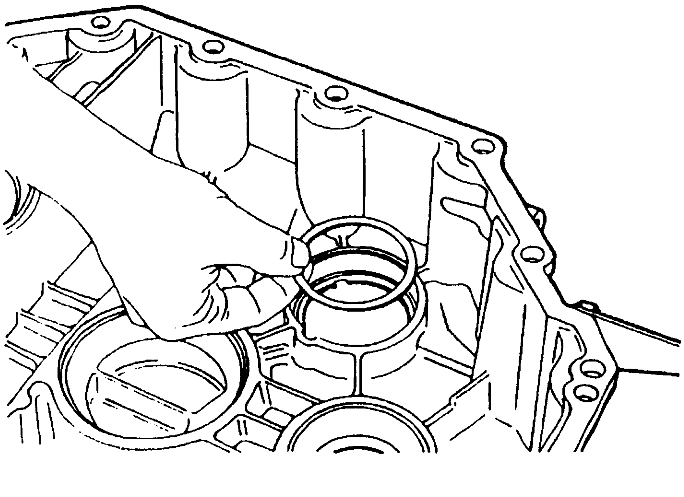


a - Small Diameter Puller Guide

    b. Pull bearing cup from housing as shown.



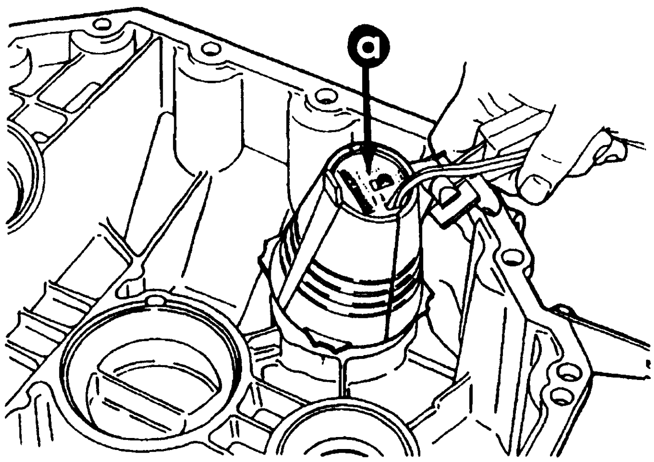
40. Add the necessary amount of shims as determined previously to the appropriate bearing bores.

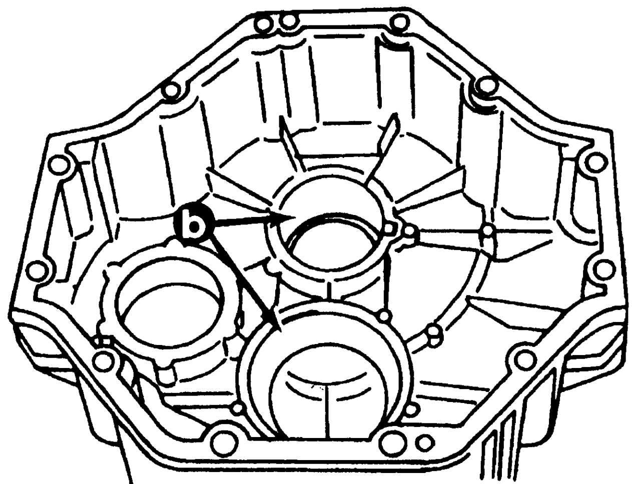


⚠ WARNING

Use care in handling housing once it has been heated with a torch lamp. Severe burns could result. Use special protective gloves when handling housing.

41. Heat each tapered roller bearing cup bore with a torch lamp. Install bearing cups into appropriate bore and tap into place using a suitable mandrel. When housing has cooled (Do Not cool with water), tap bearing cups to ensure they are fully seated.





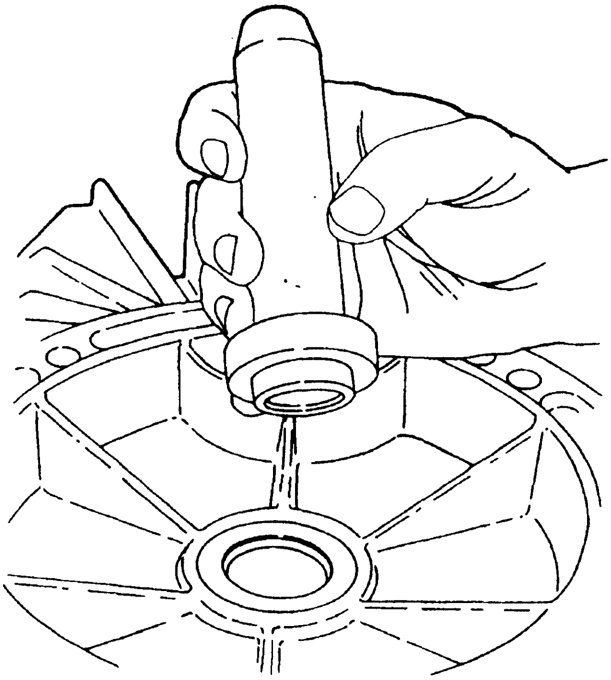
a - Torch Lamp
b - Bearing Cups

Final Assembly

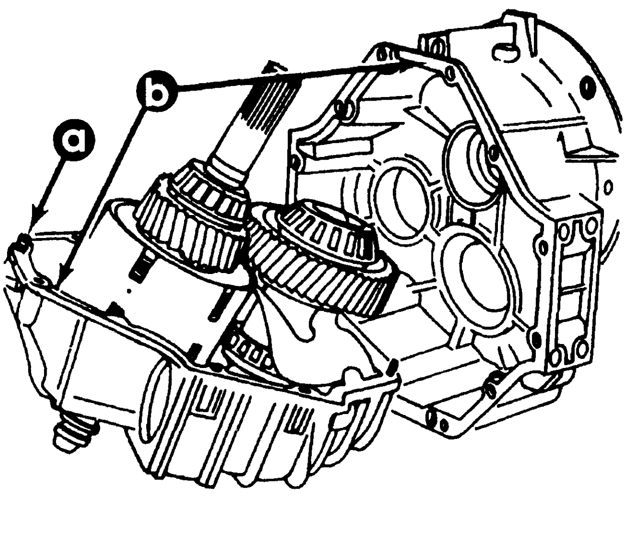
INPUT SHAFT SEAL

1. Push new seal onto special mandrel. Ensure seal will be positioned with lip of seal facing inward.

   Drive seal uniformly into bore of housing to the point that it is countersunk 0.040 in. (1 mm) with reference to housing surface.

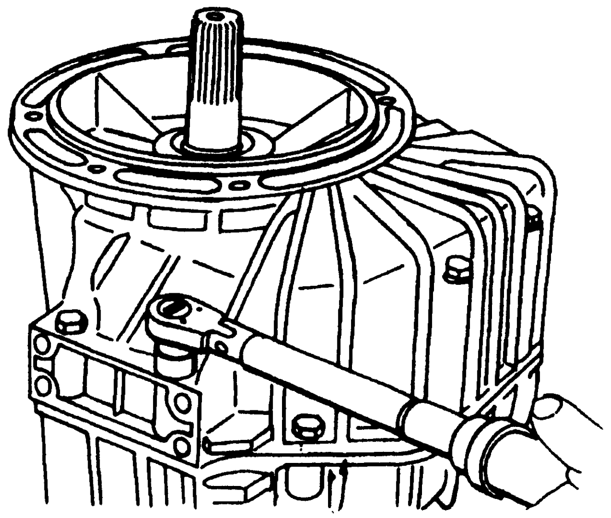


2. Coat lips of seals on input and output shafts with ATF.
3. Apply a thin layer of Loctite 515 Sealer to machined surfaces on housing halves. Reinstall input half of housing. Ensure locator pins are properly positioned.

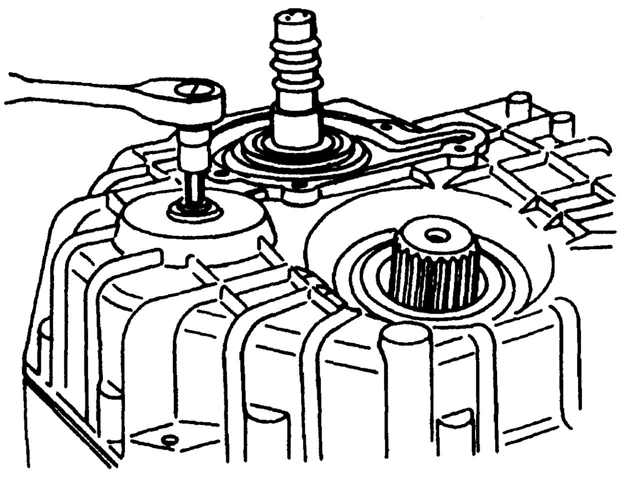


a - Locator Pins
b - Machined Surface

4. Install bolts and lockwashers and torque to 49N·m(5kgf·m)



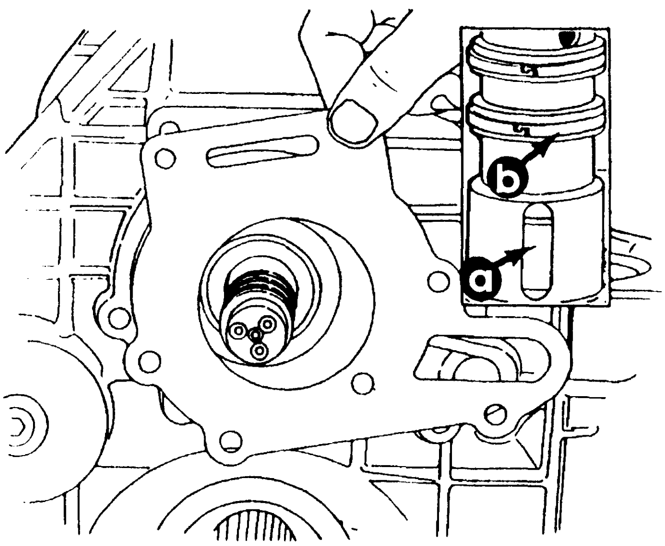
5. Double check to ensure that there is no shaft clearance on all three shafts. Refer back to previous steps if necessary, and use dial indicator.
6. Remove intermediate shaft hex plugs. Apply a drop of Loctite Type "A" to threads and reinstall in housing. Tighten securely.



CONTROL BLOCK

7. Ensure piston rings are in place and the key is in keyway. Align key on shaft with keyway in control block.

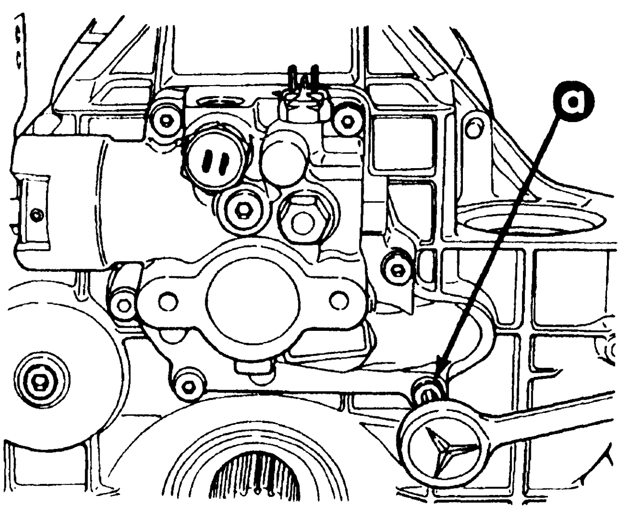
8. New gasket between control block and housing.



a - Key
b - Piston Rings

9. Carefully push control block onto input shaft.

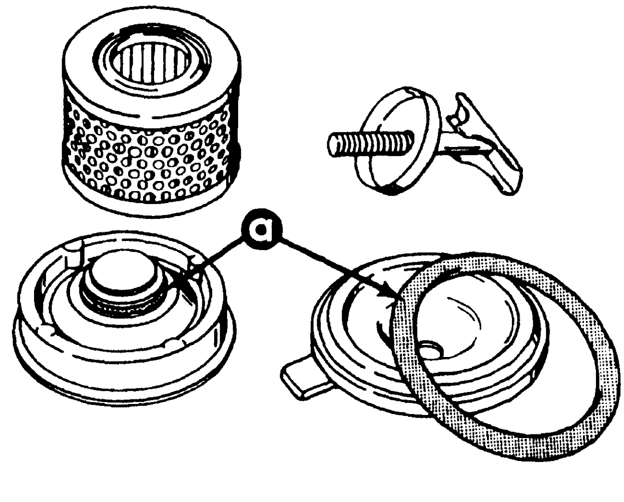
10. Coat each hex socket head bolt with a drop of Loctite Type "A". Secure control block to housing with bolts and lockwashers. Torque to 25N·m(2.5kgf·m).



a - Hex Socket Head Bolts (6)

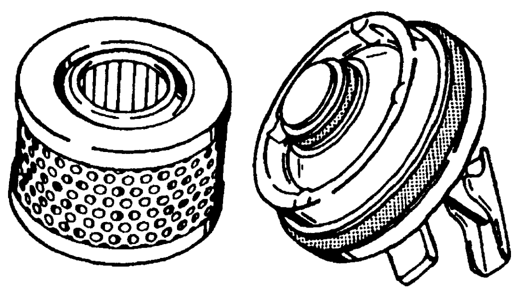
FLUID FILTER

11. Coat new O-rings with ATF.



a - O-rings

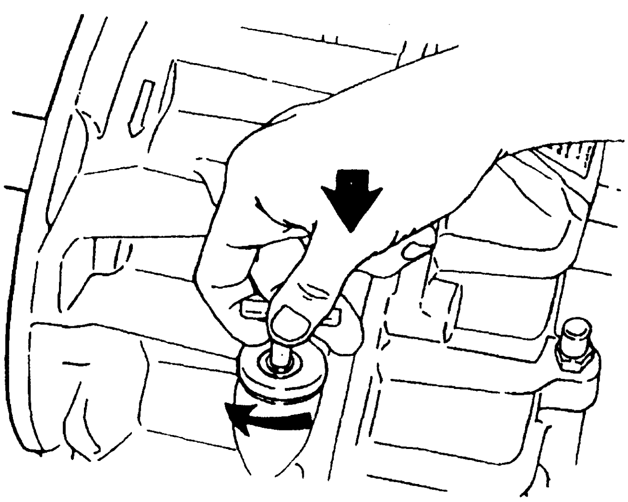
12. Reassemble filter assembly as shown. DO NOT tighten and compress upper O-ring.



DIPSTICK

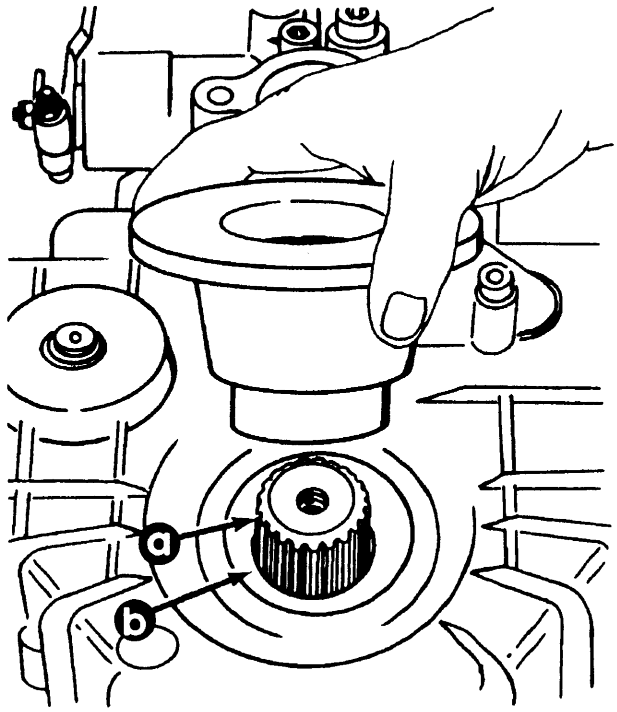
13. Coat sealing ring on dipstick with ATF.

14. Install dipstick into transmission and tighten by pressing down and turning clockwise at the same time.



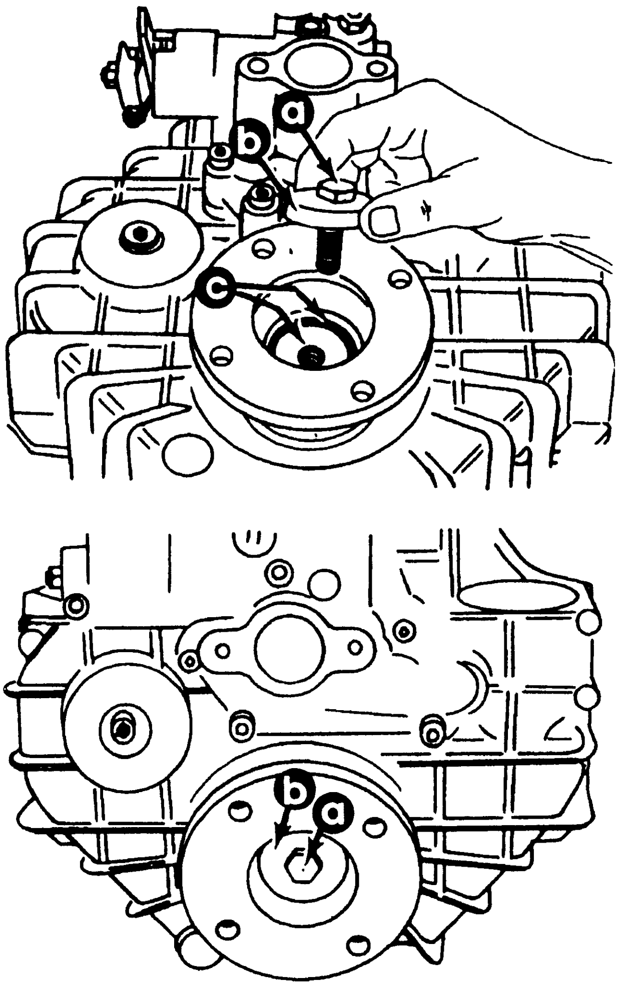
OUTPUT FLANGE

15. Coat output shaft splines with a thin coat of Loctite type "A".
16. Coat lip of output shaft seal with ATF.
17. Install output shaft flange. Be careful not to damage output shaft seal.



a - Splines
b - Output Shaft Seal

18. Install O-ring into flange and coat with ATF.
19. Install washer and bolt. Torque to 85N·m(8.7kgf·m)

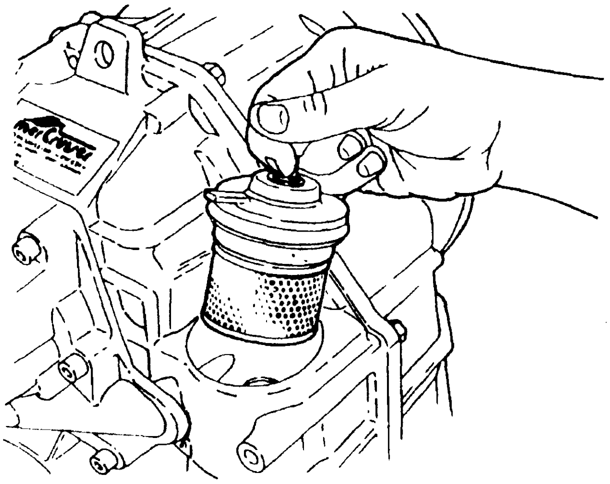


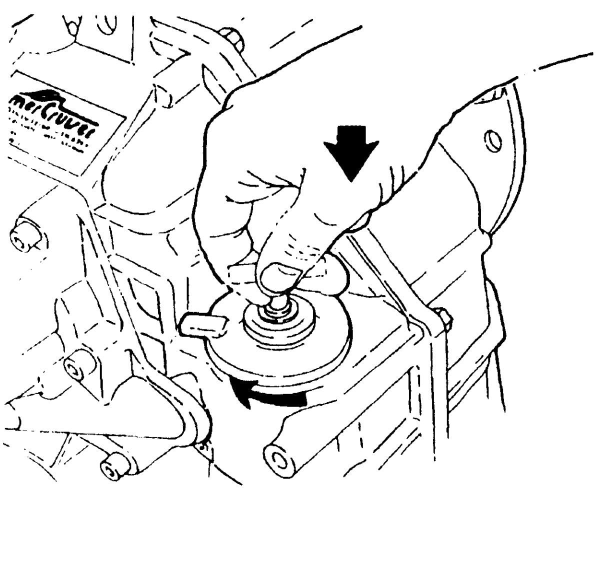
a - Bolt
b - Washer
c - O-ring

FILLING WITH TRANSMISSION FLUID

IMPORTANT: Use only ATF (Automatic Transmission Fluid), such as, Dexron II-D.

20. Fill transmission to proper level, thru oil filter cavity. (Refer to specifications for capacity.)
21. Install filter as follows:
    a. Install filter and push down so that cover is flush with housing.
    b. Turn T-handle clockwise until O-ring compresses and cover is snug. Do not overtighten or the O-ring in the cover could be damaged.



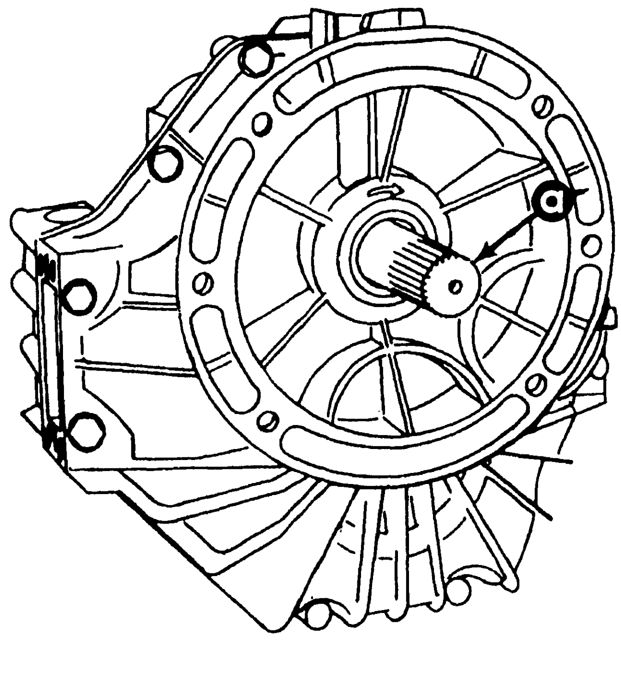


a - Cover
b - T-Handle
c - O-ring

22. Check fluid level. Fluid should be between "MIN" and "MAX" marks on dipstick.

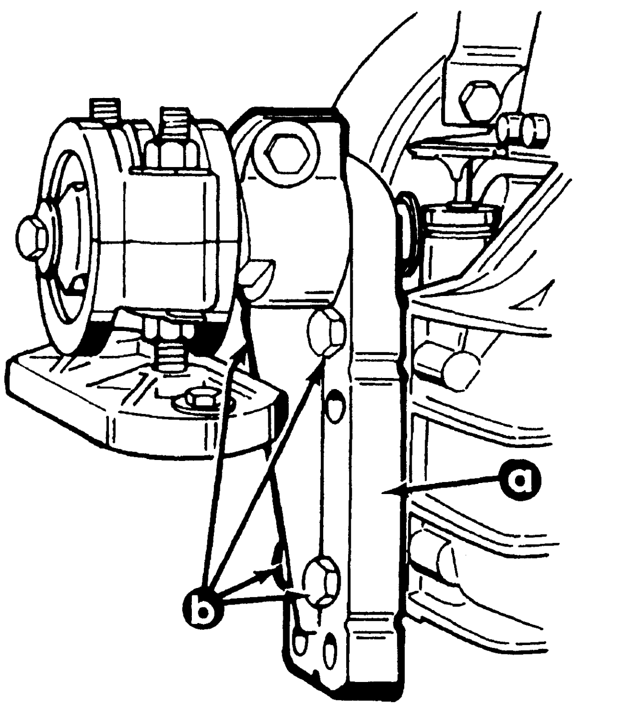
Transmission Installation

1. Coat splines on input shaft with 2-4-C Marine Lubricant.



a - Input Shaft

2. Instali mounts on transmission housing having previously inspected for damage and replaced if needed. Torque screws to 68N·m(6.9kgf·m).



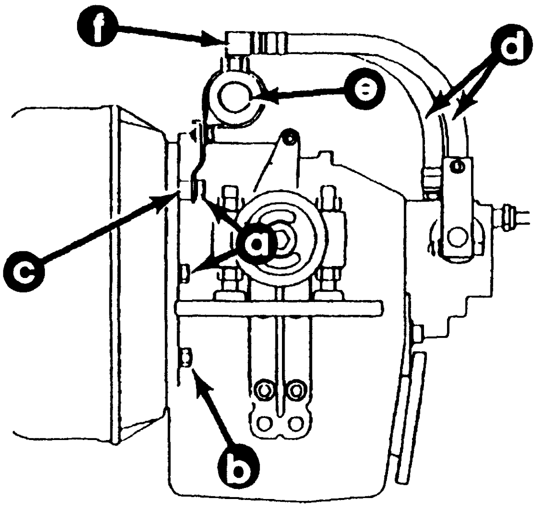
a - Transmission Mounts
b - Screws [4 Each Side (One Partially Hidden In This View)]

3. Follow instructions "a" or "b":

a. **On 530D-TA, 636D-TA, D183 and D219 Engines:**

(1) Install transmission on flywheel housing with transmission cooler and bracket in position using hardware and fasteners as shown. Torque fasteners to 68N·m(6.9kgf·m).

(2) Install transmission fluid hoses at transmission and then attach to cooler 90° elbow connectors where noted upon disassembly. Tighten all hose fittings securely.

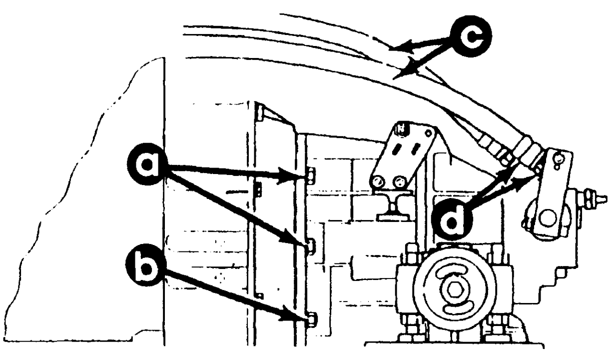


a - Bolts With Lockwashers [4 - Two On Each Side (Two With Spacers If Cooler Bracket)]
b - Nuts With Lockwashers (One On Each Side)
c - Spacer
d - Transmission Fluid Hoses
e - Cooler
f - 90° Elbow Connector (2 - One Hidden In This View)

b. **On D254 Engines:**

(1) Install transmission on flywheel housing and secure with hardware shown. Torque fasteners to 68N·m (6.9kgf·m).

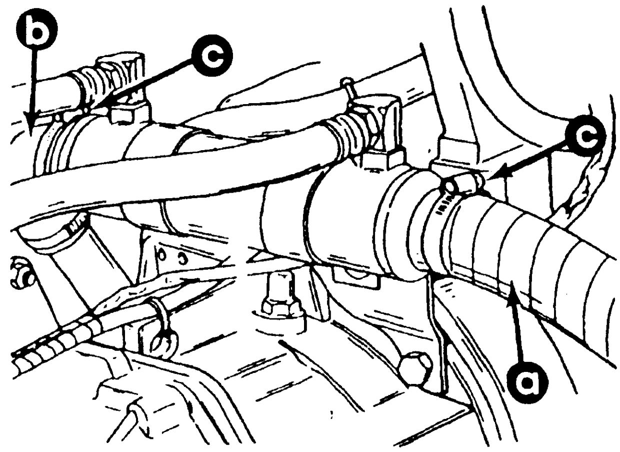
(2) Install transmission fluid hoses to transmission 45fl elbow connectors. Tighten securely.



a - Bolts With Lockwashers (4 - Two On Each Side)
b - Nuts With Lockwashers (One On Each Side)
c - Transmission Fluid Hoses
d - Transmission Fluid Hose 45fl Elbow Connector (2 - One Hidden In This View)

4. Follow instructions "a" or "b":

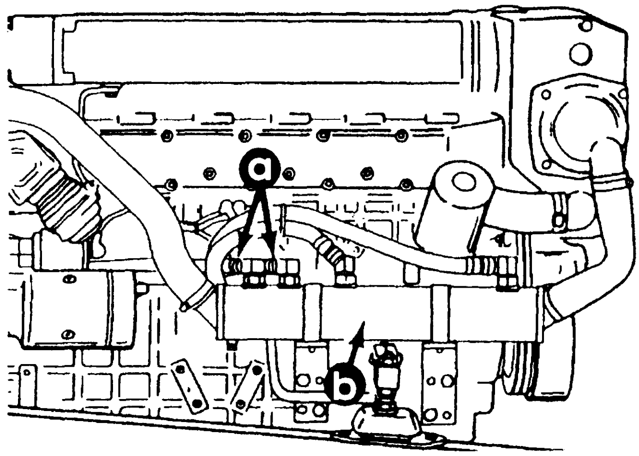
a. **On 530D-TA, 636D-TA, D183 and D219 Engines:** Connect seawater hoses to transmission cooler. Tighten hose clamps securely.



a - Seawater Inlet Hose
b - Seawater Outlet Hose
c - Hose Clamp

530D-TA, 636D-TA, D183 and D219 Shown

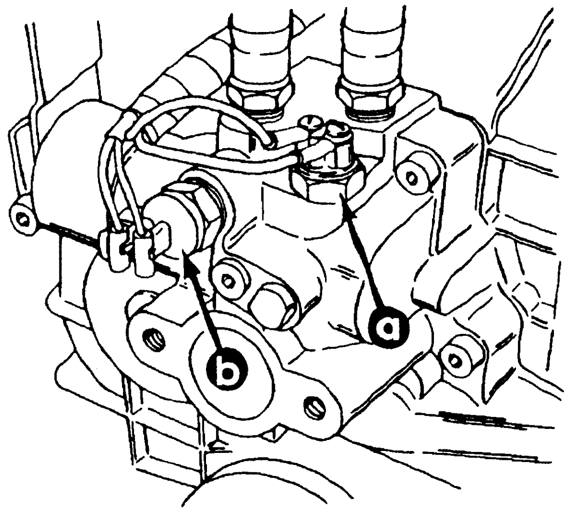
b. **On D254 Engines:** Connect transmission fluid cooler hoses as noted on disasse mbly to tandem engine oil/ transmission fluid cooler.



a - Transmission Fluid Cooler Hoses
b - Tandem Engine Oil/Transmission Fluid Cooler

D254 Shown

5. Connect wires to neutral safety switch and to audio warning temperature switch. Coat connections on neutral safety switch with Liquid Neoprene.

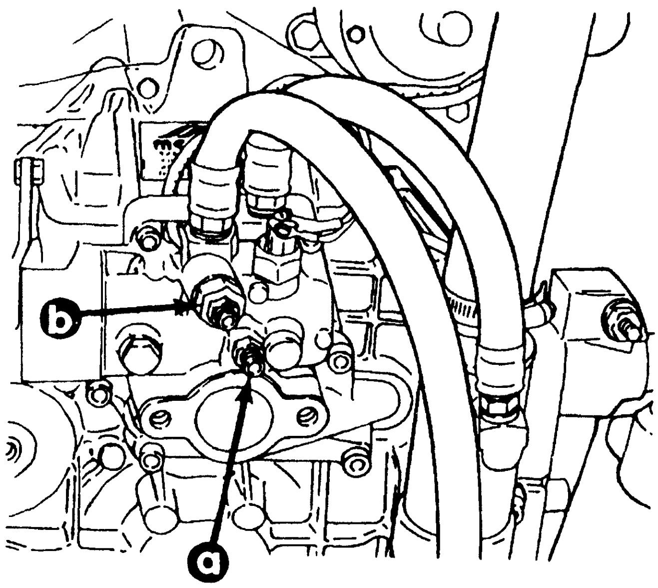


a - Neutral Safely Switch
b - Audio Warning Temperature Switch

6. Refer to Removal and Installation, Section 2B-"MIE (Inboard) Models" and install engine with transmission as instructed.

Functional Test

1. Connect a pressure gauge and thermometer to fluid pump at locations shown.



a - Pressure Gauge (M10x1 Thread) - Remove Plug
b - Thermometer (3/8 in. Thread) - Remove Temperature Sender

Typical Hurth Transmission Shown

2. Perform functional tests as shown in chart following. Refer to "Operating Specifications" for correct readings.

Tests to be carried out:

1. Leakages
2. Noise emission
3. Direction of rotation, LH/RH
4. Lube oil temperature
5. Shifting pressure

The function test should be carried out as follows:

Motor speed rpm	Shift lever position	Duration minutes	Test		
800-1000	neutral	5	1	2	5**
600-800 (idling speed)	A ↔ B position repeatedly	—	1	2	3
1500-2500	B position	*	1	2	4
600-800 (idling speed)	A ↔ B position repeatedly	—	1	2	3
Idling-max. speed	A position	—	1	2	5**
600-800	from A → B position	—	1	2	
Idling-max. speed	B position	—	1	2	5**

* Until an oil temperature of 75-80flC (167-176flF) has been reached ** at different speeds

CHAPTER 8

REMOTE CONTROL (OPTIONAL)

1. Remote Control System 8-1
2. Remote Control Installation..8-2
3. Remote Control Inspection...8-5
4. Remote Control Adjustment.......................................8-6

1. Remote Control System

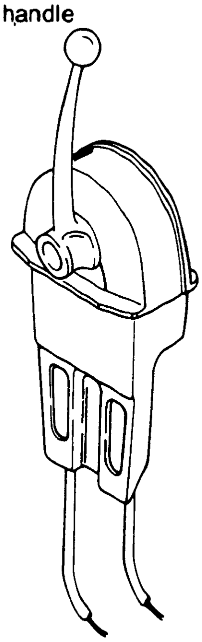
1-1 Construction of remote control system

The remote control permits one handed control of the engine speed, changing from forward to reverse, and stopping.
Fittings which allow for easy connection of the remote control cables with the fuel injection pump and transmission are provided with the remote control set.
The use of Morse remote control cables, clamps and a remote control head, are also provided for. The device to stop the engine is electric and will be explained under the section on electrical equipment.

1-2 Remote control device components

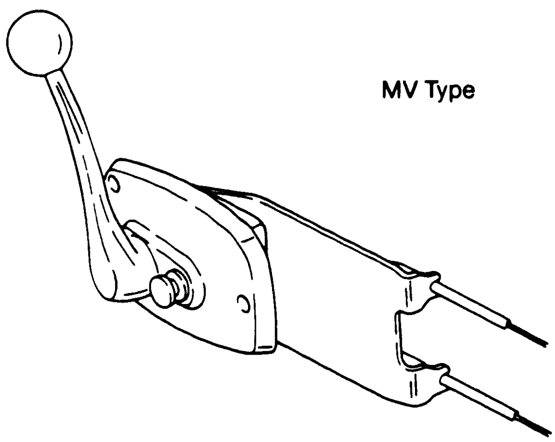
	Morse description	Yanmar Part No.
Remote control head	Morse MT2 top mounting single lever	41730-000680
	Morse MV side mounting single lever	128170-86500
Remote control cable	Morse 33C x 4m (13.12ft.)	41710-000360
	Morse 33C x 7m (23.00ft.)	129470-86500
Engine stop cable	Yanmar 4m (13.12ft)	129470-67550
	Yanmar 7m (22.96ft)	129470-67560

(1) Remote control handle



MT-2 Type

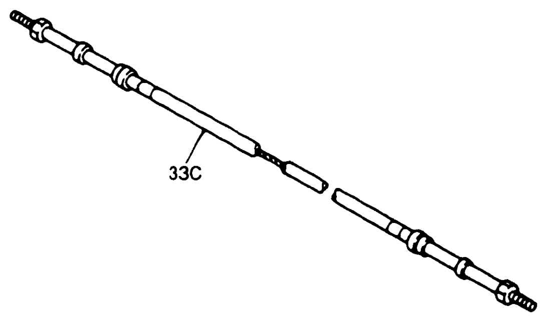
The model MT-2 remote control has been designed so that operation of the clutch (shift) and governor (throttle) can be effected with one lever.
Two cables are required for the MT-2 single, one for the clutch and the other for the governor.
When warming up the engine, to freely control the governor separately from the clutch, put the lever in-neutral, the central position, and pull the knob in the center of the control lever. When the lever is returned to the neutral position, the knob automatically returns to its original position, and the clutch is free. The governor can then be operated freely.



MV Type

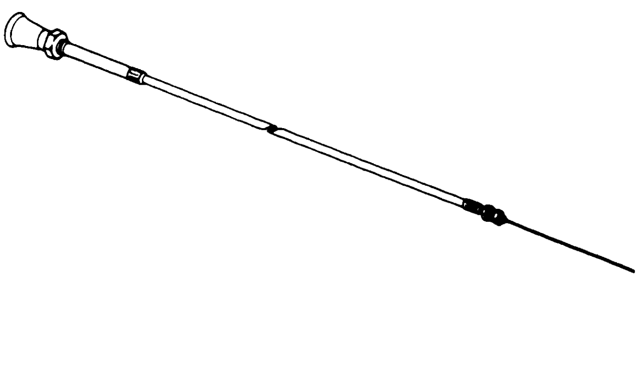
The MV type controller has been designed so that operation of the clutch and throttle can be effected with one lever. When the button next to the control lever is pulled out with the lever in the central position, it holds the clutch in the neutral position so that the throttle can be opened all the way and warm up the engine.
When the engine is warmed up, return the handle to the central position and push the button back in. Control of the clutch and throttle is thus effected with one handle.

(2) Remote control cable



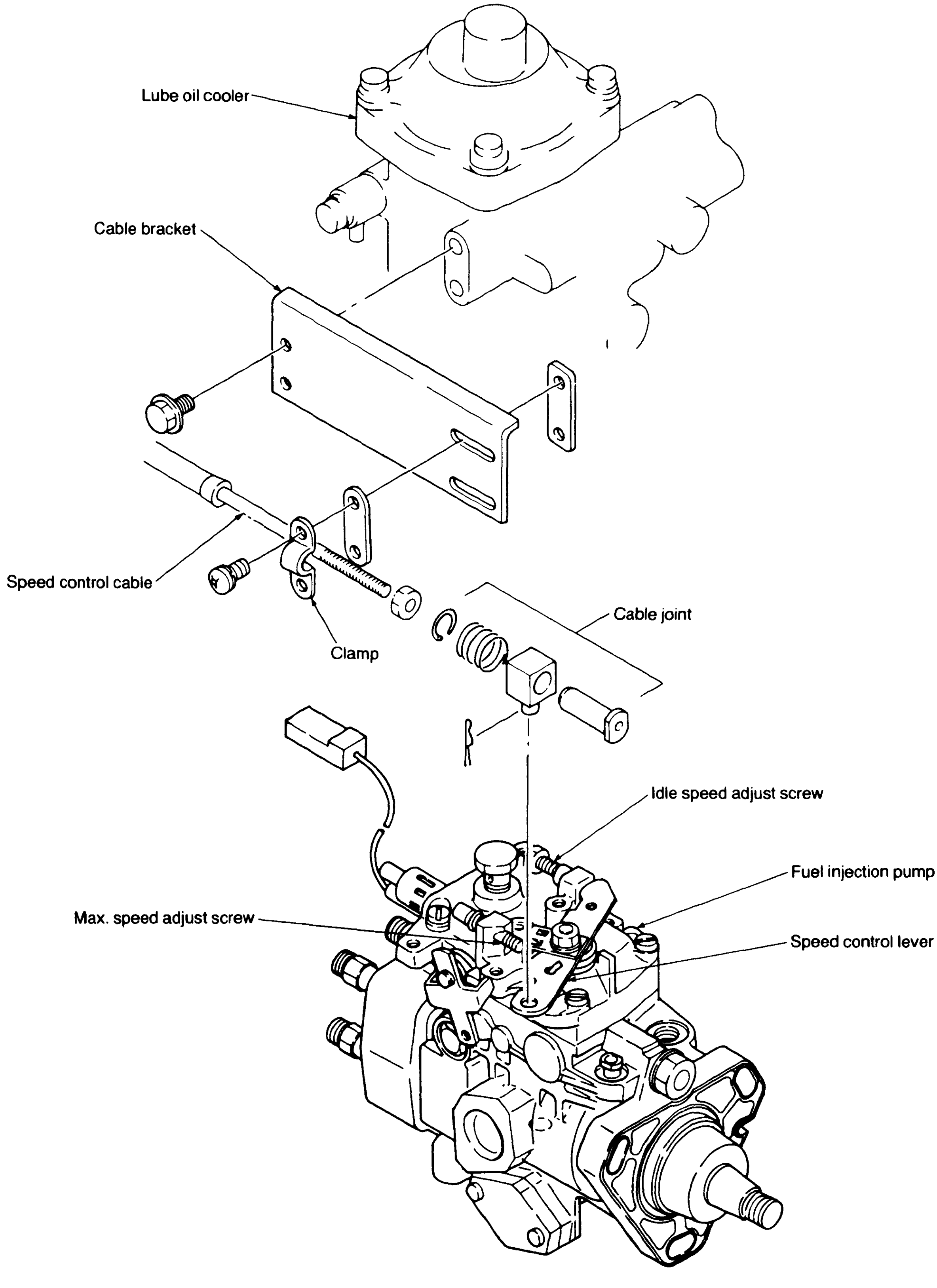
Use only Super-Responsive Morse Control Cables.
These are designed specifically for use with Morse control heads. This engineered system of Morse cables, control head and engine connection kits ensures dependable, smooth operation with an absolute minimum of backlash.

(3) Engine stop cable

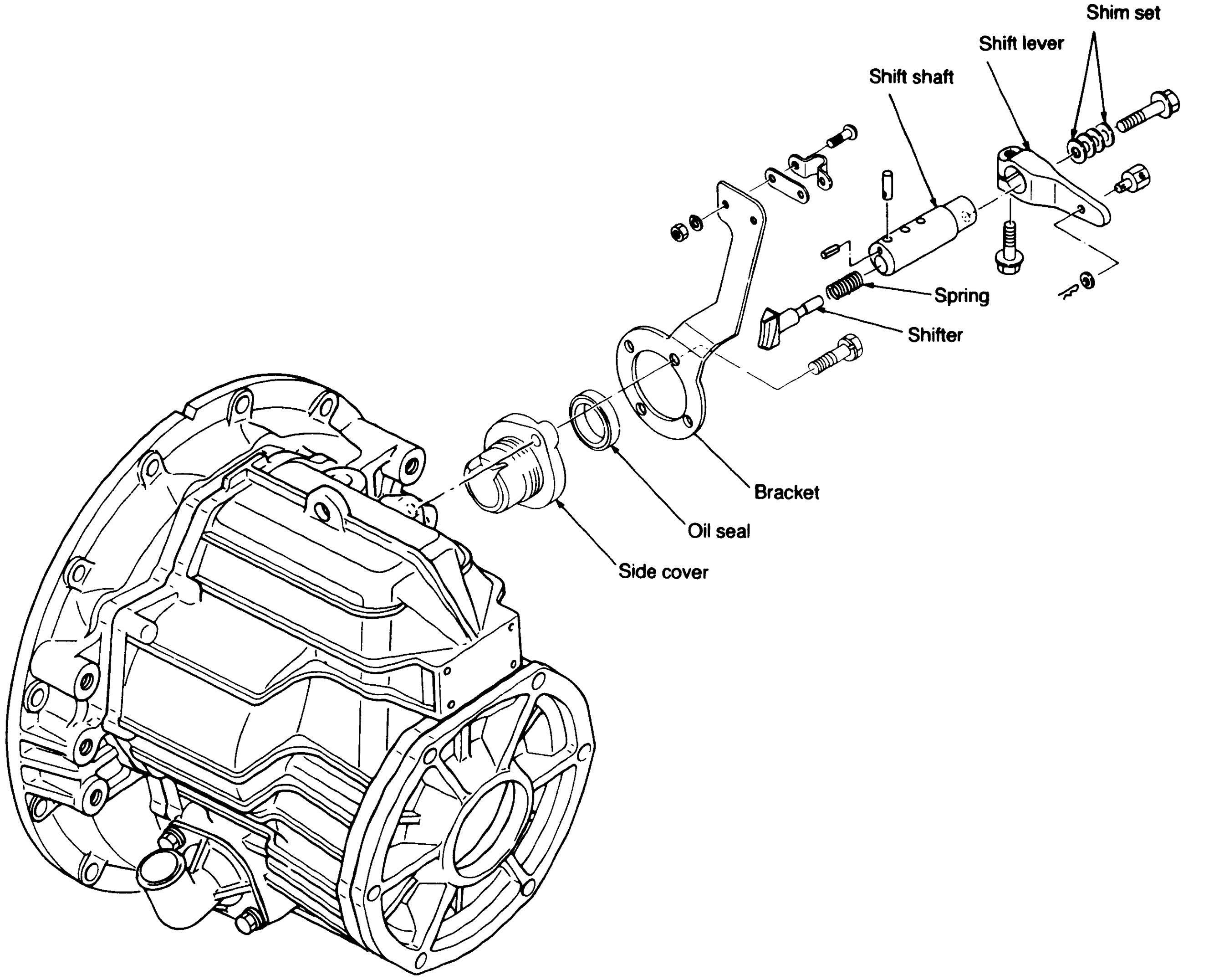


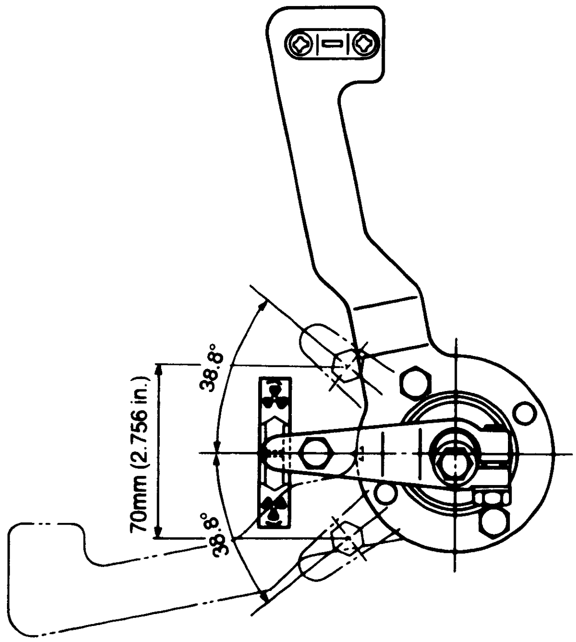
2. Remote Control Installation

2-1 Speed control

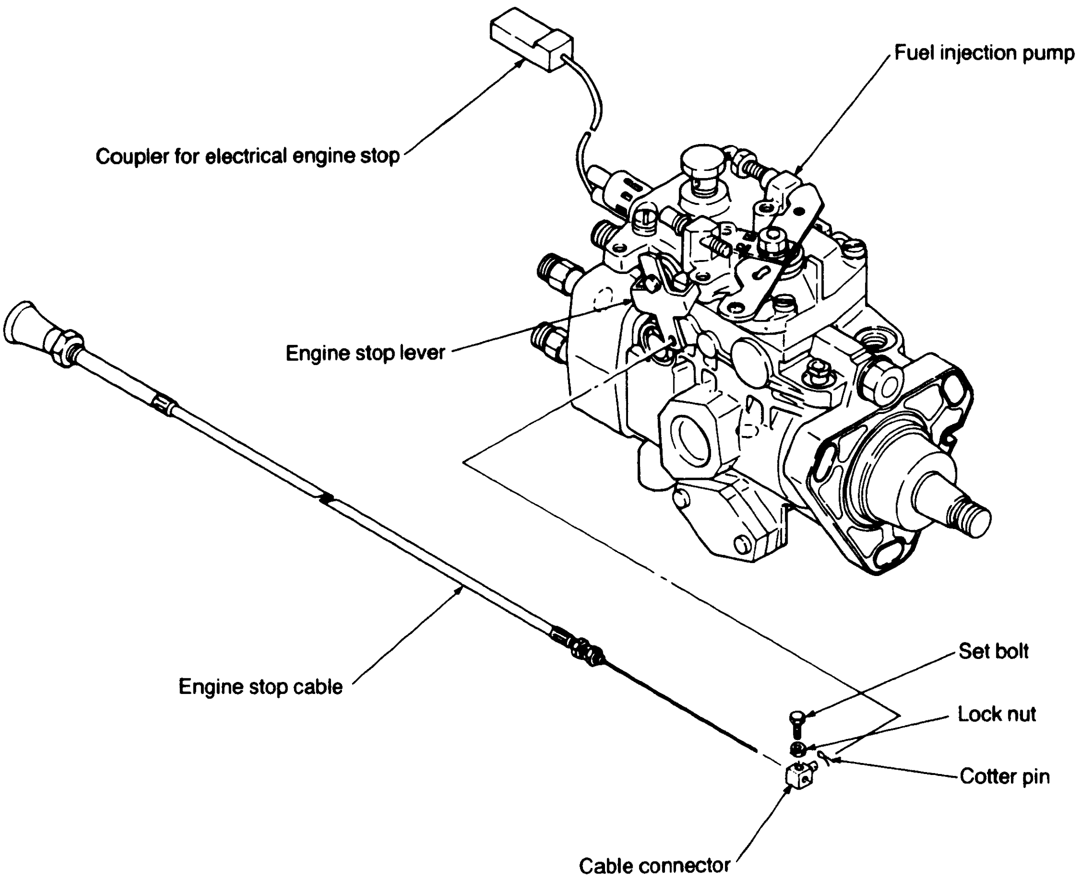


2-2 Clutch control



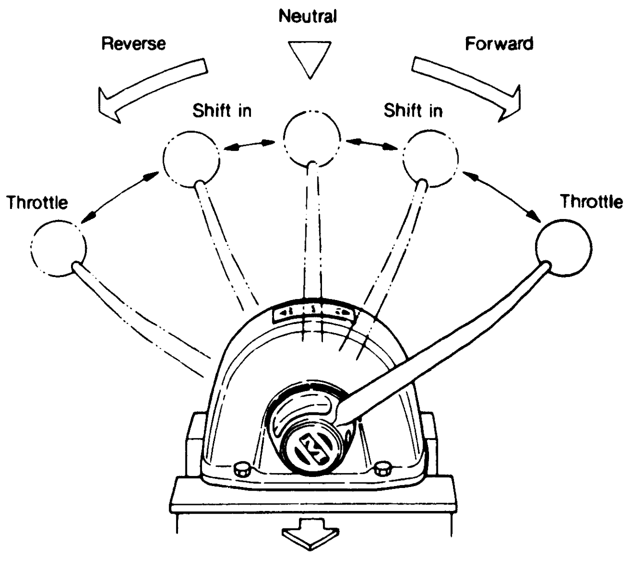


2-3 Engine stop



3. Remote Control Inspection

(1) When the control lever movement does not coincide with operation of the engine, check the cable end stop nut to see whether or not it is loose, and readjust/retighten when necessary.

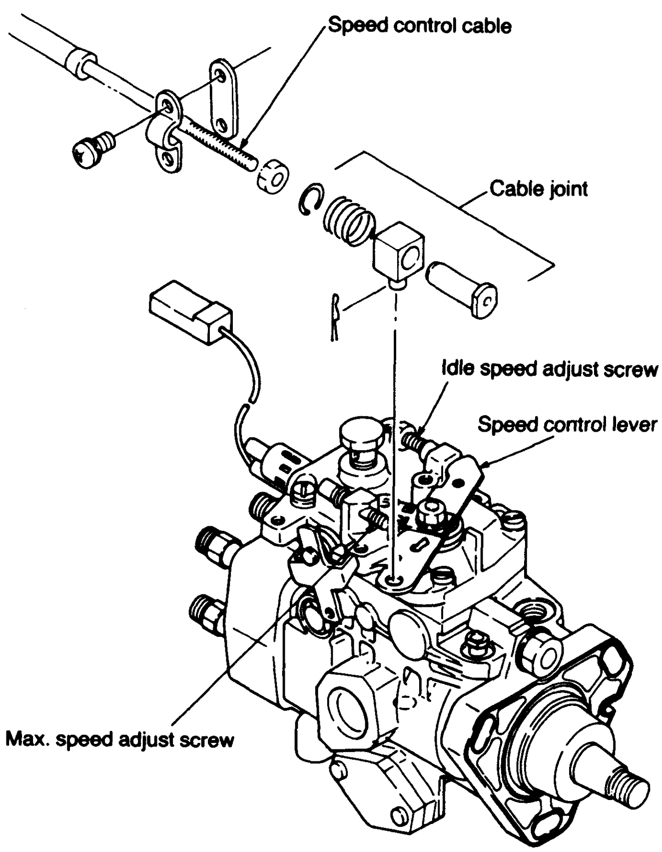


(2) Too many bends (turns) in the cable or bends at too extreme an angle will make it difficult to turn the handle. Reroute the cable to reduce the number of bends or enlarge the bending radius as much as possible (to 200mm or more).
(3) Check for loose cable bracket/clamp bolts or nuts and retighten as necessary.
(4) Check cable connection screwheads, cable sleeves and other metal parts for rust or corrosion. Clean off minor rust and wax or grease the parts. Replace if the parts are heavily rusted or corroded.

4. Remote Control Adjustment

(1) Shift lever adjustment
Move the lever several times—the movement of the clutch lever on the engine from forward, neutral and reverse must coincide with the forward, neutral and reverse on the control lever. If they do not coincide, adjust the fittings as necessary (first engine side, then controller side).

(2) Throttle lever adjustment
Move the control lever all the way to full throttle several times, and then return The throttle lever on the engine must lightly push against the idle switch when it is returned. If it is properly adjusted, the knob can be easily pulled out when the lever is in the neutral position, and will automatically return when the control lever is brought back to the neutral position. If the control lever presses too hard against the knob, it may not return automatically, in which case the cable end must be adjusted as explained for the clutch. The knob cannot be pulled out when the lever is not in the neutral (central) position.



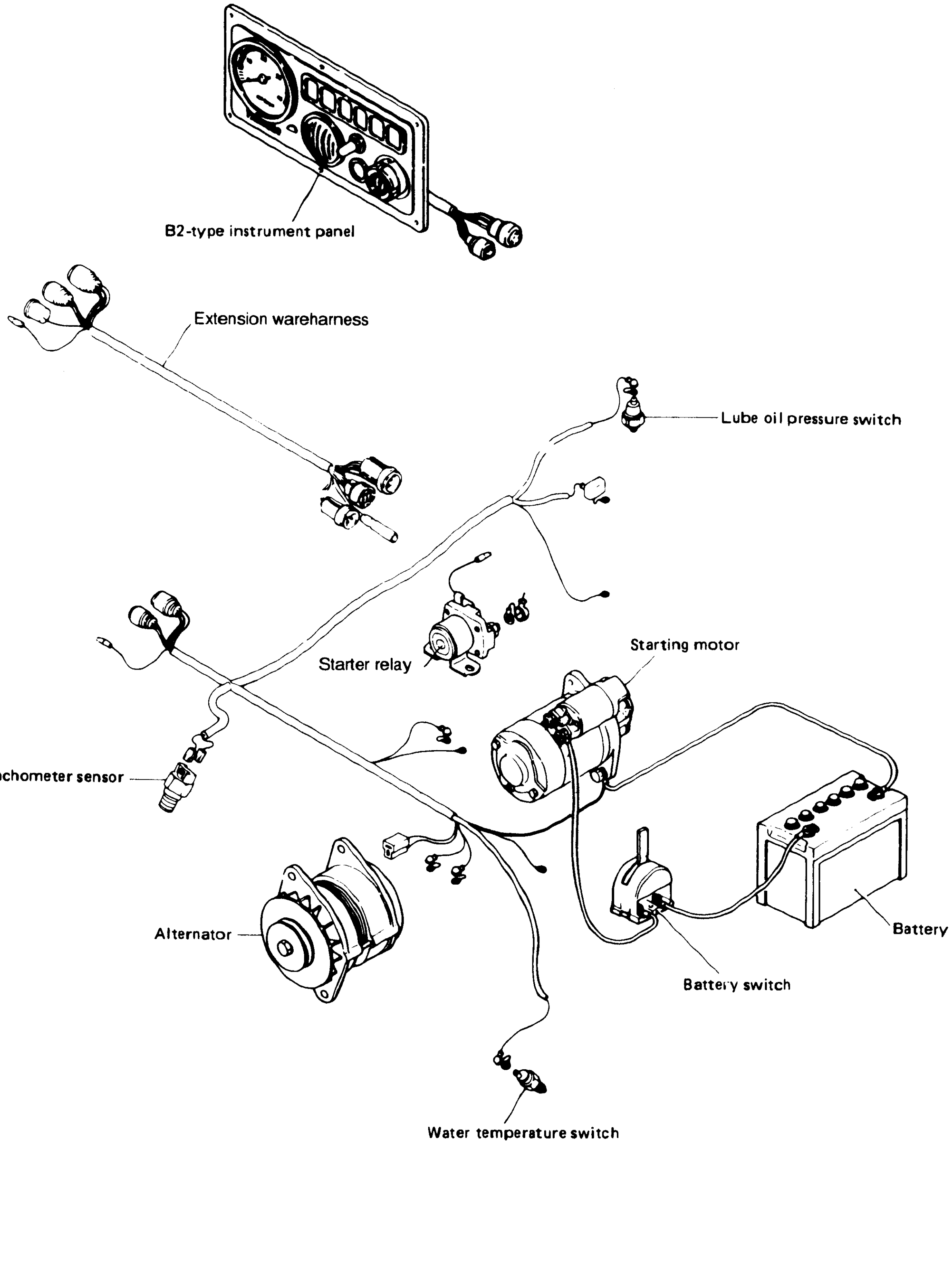
CHAPTER 9

ELECTRICAL SYSTEM

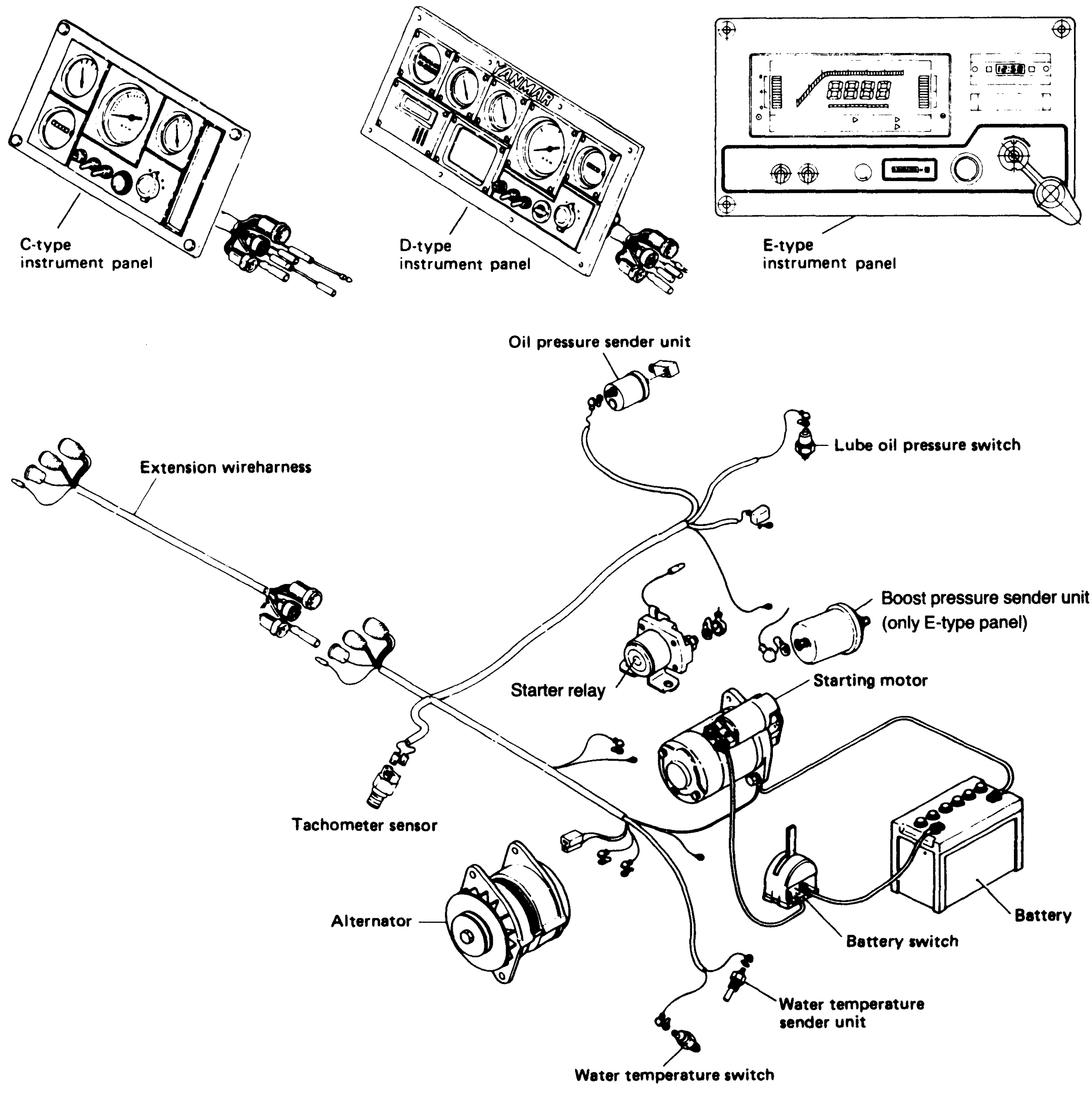
1. System Diagram 9-1
2. Battery 9-3
3. Starter Motor 9-7
4. Alternator 9-17
5. Instrument Panel 9-35
6. Warning Devices 9-37
7. Tachometer 9-40

1. System Diagram

1-1 System diagram of electric parts (B2-type)

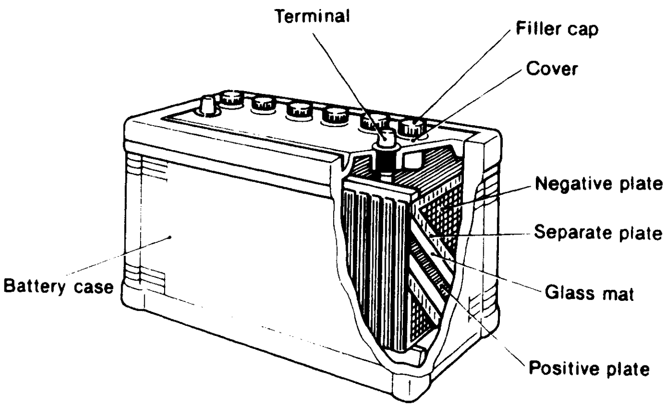


1-2 C-type, D-type and E-type



2. Battery

2-1 Construction



The battery utilizes chemical action to convert chemical energy to electrical energy. This engine uses a lead acid battery which stores a fixed amount of power that can be used when required. After use, the battery can be recharged and used again.
As shown in the figure, a nonconductive container is filled with dilute sulfuric acid electrolyte. Lead dioxide positive plates and lead dioxide negative plates separated by glass mats are stacked alternately in the electrolyte. The positive and negative plates are connected to their respective terminals.
Power is removed from the battery by connecting the load across these two terminals.
When the battery is discharging, an electric current flows from the positive plates to the negative plates. When the battery is being charged, electric current is passed through the battery in the opposite direction by an external power source.

2-2 Battery capacity and battery cables

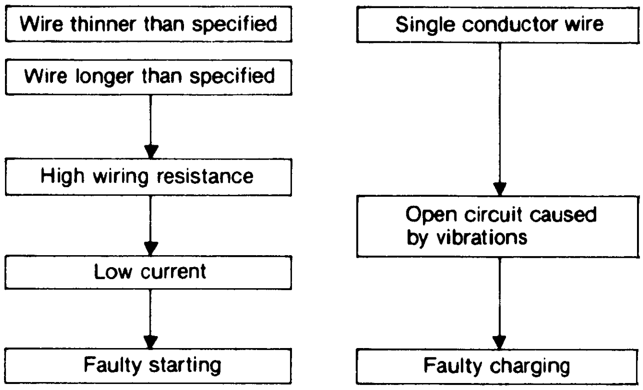
2-2.1 Battery capacity

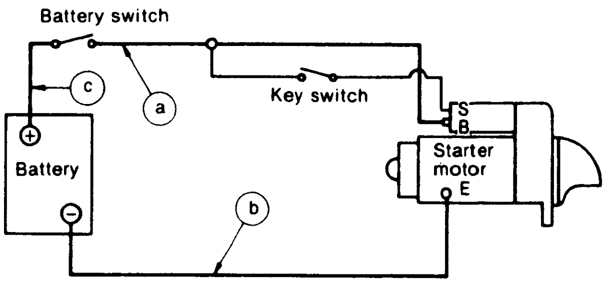
Since the battery has a minimum capacity of 12V, 70AH, it can be used for 100 ~ 150AH.

Battery capacity	minimum	12V — 100AH
	standard	12V — 120AH
	cold weather	12V — 150AH
Full charged specific gravity		1.26

2-2.2 Battery cable

Wiring must be performed with the specified electric wire. Thick, short wiring should be used to connect the battery to the starter, (soft automotive low-voltage wire [AV wire]).
Using wire other than that specified may cause the following troubles:





The overall lengths of the wire between the battery (+) terminal and the starter (B) terminal, and between the battery (−) terminal and the starter (E) terminal, should be determined according to the following table.

Voltage system	Allowable wiring voltage drop	Conductor cross-section area	a + b + c allowable length
12V	0.2V or less/100A	20mm² (0.0311 in.²)	Up to 2.5m (98.43 in.)
		40mm² (0.062 in.²)	Up to 5m (196.87 in.)

Note: Excessive resistance in the key switch circuit (between the battery and start [S] terminals) can cause improper pinion engagement. To prevent this, follow the wiring diagram carefully.

2-3 Inspection

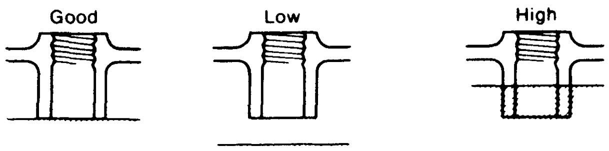
The quality of the battery governs the starting performance of the engine. Therefore the battery must be routinely inspected to ensure that it functions perfectly at all times.

2-3.1 Visual inspection

(1) Inspect the case for cracks, damage and electrolyte leakage.
(2) Inspect the battery holder for tightness, corrosion, and damage.
(3) Inspect the terminals for rusting and corrosion, and check the cables for damage.
(4) Inspect the caps for cracking, electrolyte leakage and clogged vent holes.
Correct any abnormal conditions found. Clean off rusted terminals with a wire brush before reconnecting the battery cable.

2-3.2 Checking the electrolyte

(1) Electrolyte level

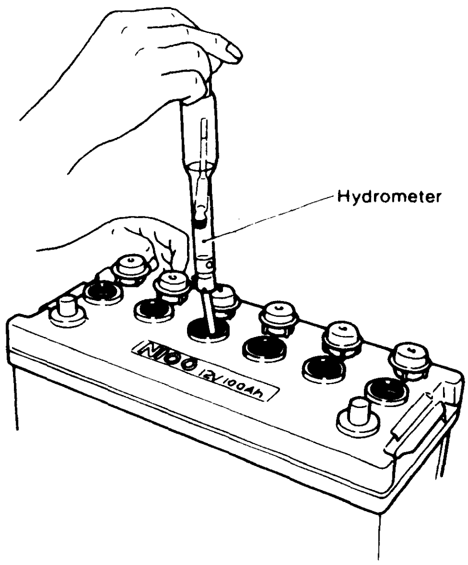


Check the electrolyte level every 7 to 10 days. The electrolyte must always be 10 ~ 20mm (0.3937 ~ 0.7874in.) over the top of the plates.

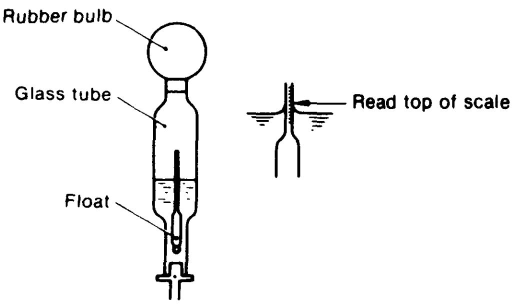
NOTES: 1. The "LEVEL" line on a transparent plastic battery case indicates the height of the electrolyte.
2. Always use distilled water to bring up the electrolyte level.
3. When the electrolyte has leaked out, add dilute sulfuric acid with the same specific gravity as the electrolyte.

(2) Measuring the specific gravity of the electrolyte

1) Draw some of the electrolyte up into a hydrometer.



2) Take the specific gravity reading at the top of the scale of the hydrometer.



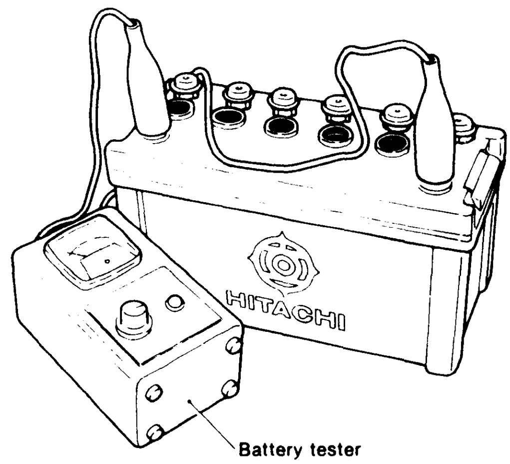
3) The battery is fully charged if the specific gravity is 1.260 at an electrolyte temperature of 20°C. The battery is discharged if the specific gravity is 1.200 (50%). If the specific gravity is below 1.200, recharge the battery.

4) If the difference in the specific gravity among the cells of the battery is ±0.01, the battery is OK.

5) Measure the temperature of the electrolyte.
Since the specific gravity changes with the temperature, 20°C is used as the reference temperature.
Reading the specific gravity at 20°C
$S_{20} = St + 0.0007 (t - 20)$
S_{20}: Specific gravity at the standard temperature of 20°C
St: Specific gravity of the electrolyte at t°C
0.0007: Specific gravity change per 1°C
t: Temperature of electrolyte

2-3.3 Voltage test

Using a battery tester, the amount of discharge can be determined by measuring the voltage drop which occurs while the battery is being discharged with a large current.



(1) Connect the tester to the battery.
12V battery tester
Adjust the current (A).

(2) Connect the (+) lead of the tester to the (+) battery terminal, and the (−) tester lead to the (−) battery terminal.

(3) Push the TEST button, wait 5 seconds, and then read the meter.
• Repeat the test twice to make sure that the meter indication remains the same.

2-3.4 Washing the battery

(1) Wash the outside of the battery with a brush while running cold or warm water over the battery. (Make sure that no water gets into the battery.)

(2) When the terminals or other metal parts are corroded due to exposure to electrolyte leakage, wash off all the acid.

(3) Check the vent holes of the caps and clean if clogged.

(4) After washing the battery, dry it with compressed air, connect the battery cable, and coat the terminals with grease. Since the grease acts as an insulator, do not coat the terminals before connecting the cables.

2-4 Charging

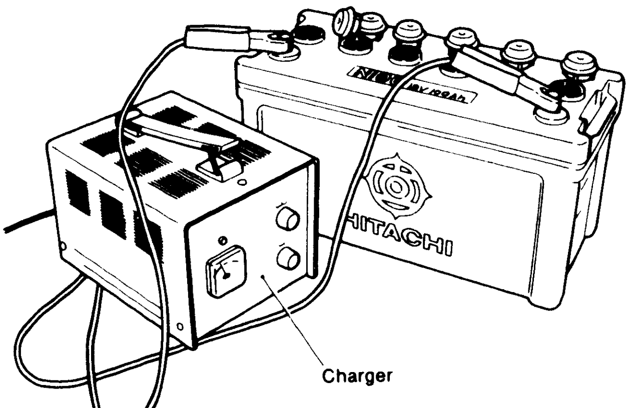
2-4.1 Charging methods

There are two methods of charging a battery: normal and rapid.
Rapid charging should only be used in emergencies.

- Normal charging...Should be conducted at a current of 1/10 or less of the indicated battery capacity (10A or less for a 100AH battery).
- Rapid charging...Rapid charging is done over a short period of time at a current of 1/5 ~ 1/2 the indicated battery capacity (20A ~ 50A for a 100AH battery). However, since rapid charging causes the electrolyte temperature to rise too high, special care must be exercised.

2-4.2 Charging procedure

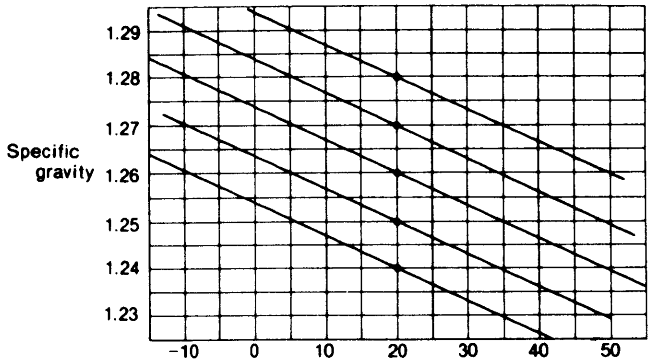
(1) Check the specific gravity and adjust the electrolyte level.
(2) Disconnect the battery cables.
(3) Connect the red clip of the charger to the (+) battery terminal and connect the black clip to the (−) terminal.



(4) Set the current to 1/10 ~ 1/5 of the capacity indicated on the outside of the battery.
(5) Periodically measure the specific gravity during charging to make sure that the specific gravity remains at a high fixed value. Also check whether gas is being generated.

2-4.3 Charging precautions

(1) Remove the battery caps to vent the gas during charging.
(2) While charging, ventilate the room and prohibit smoking, welding, etc.
(3) The electrolyte temperature should not exceed 45°C during charging.
(4) Since an alternator is used on this engine, when charging with a charger, always disconnect the battery (+) cable to prevent destruction of the diodes.
(Before disconnecting the (+) battery cable, disconnect the (−) battery cable [ground side].)

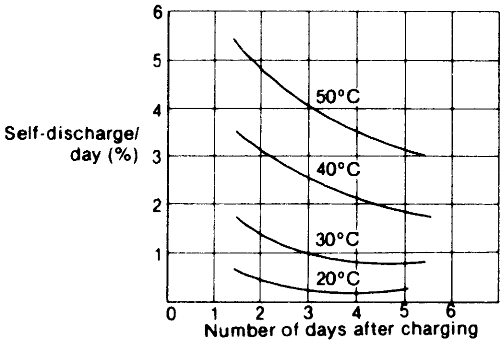


Electrolyte temperature and specific gravity

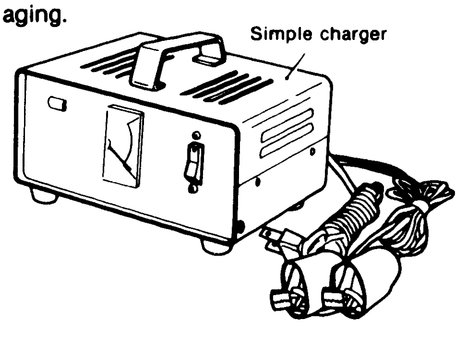
2-5 Battery storage precautions

The life of a battery depends considerably on how it is handled. Generally speaking, however, after about two years its performance will deteriorate, starting will become difficult, and the battery will not fully recover its original charge even after recharging. Then it must be replaced.

(1) Since the battery will self-discharge about 0.5%/day even when not in use, it must be charged 1 or 2 times a month when it is being stored.



(2) If charging by the engine alternator is insufficient because of frequent starts and stops, the battery will rapidly lose power.
Charge the battery as soon as possible after it is used under these conditions.
(3) An easy-to-use battery charger that permits home charging is available from Yanmar. Take proper care of the battery by using the charger as a set with a hydrometer.
When the specific gravity has dropped to about 1.16 and the engine will not start, charge the battery up to a specific gravity of 1.26 (24 hours).
(4) Before putting the battery in storage for long periods, charge it for about 8 hours to prevent rapid aging.

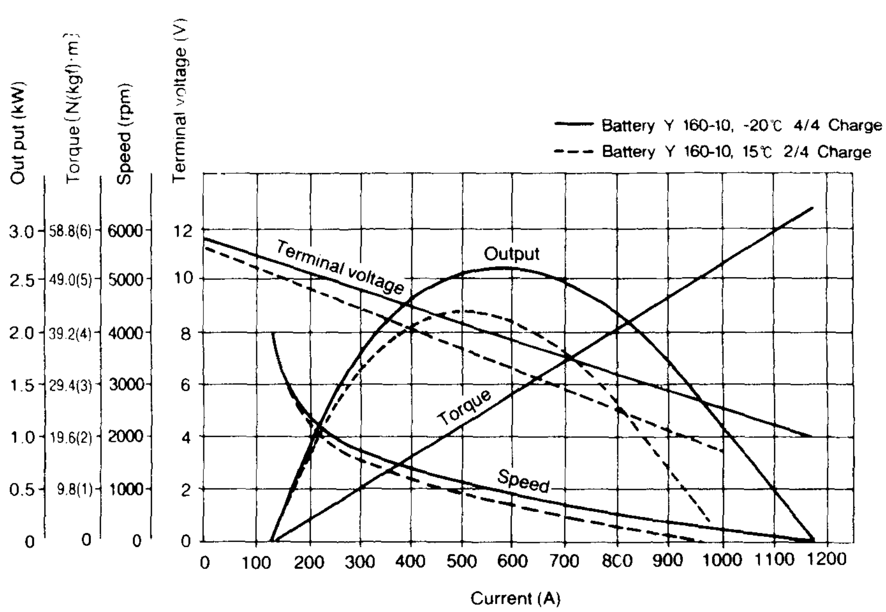


3. Starter Motor

The starter motor is installed on the flywheel housing. When the starting button is pushed, the starter motor pinion flies out and engages the ring gear of the flywheel. Then the main contact is closed, current flows, and the engine is started.
After the engine starts, the pinion automatically returns to its initial position when the starting button is released. Once the engine starts, the starting button should be released immediately. Otherwise, the starter motor may be damaged or burned out.

1 Specifications and Performance

Engine model		All
Model		S13-41A
Rating (sec.)		30
Output (kW)		2.5
Direction of rotation (viewed from pinion side)		Clockwise
Mass kg		7.3
Clutch system		Overrunning
Engagement system		Magnetic shift
No. of pinion teeth		15
Pinion flyout voltage (V)		8 or less
No-load	Terminal voltage (V)	12
	Current (A)	150 or less
	Speed (rpm)	3800 or greater
Loaded characteristics	Terminal voltage (V)	8.25
	Current (A)	500A
	Speed (rpm)	1000 or greater
	Torque N(kgf)·m	19.6 (2.0) or greater

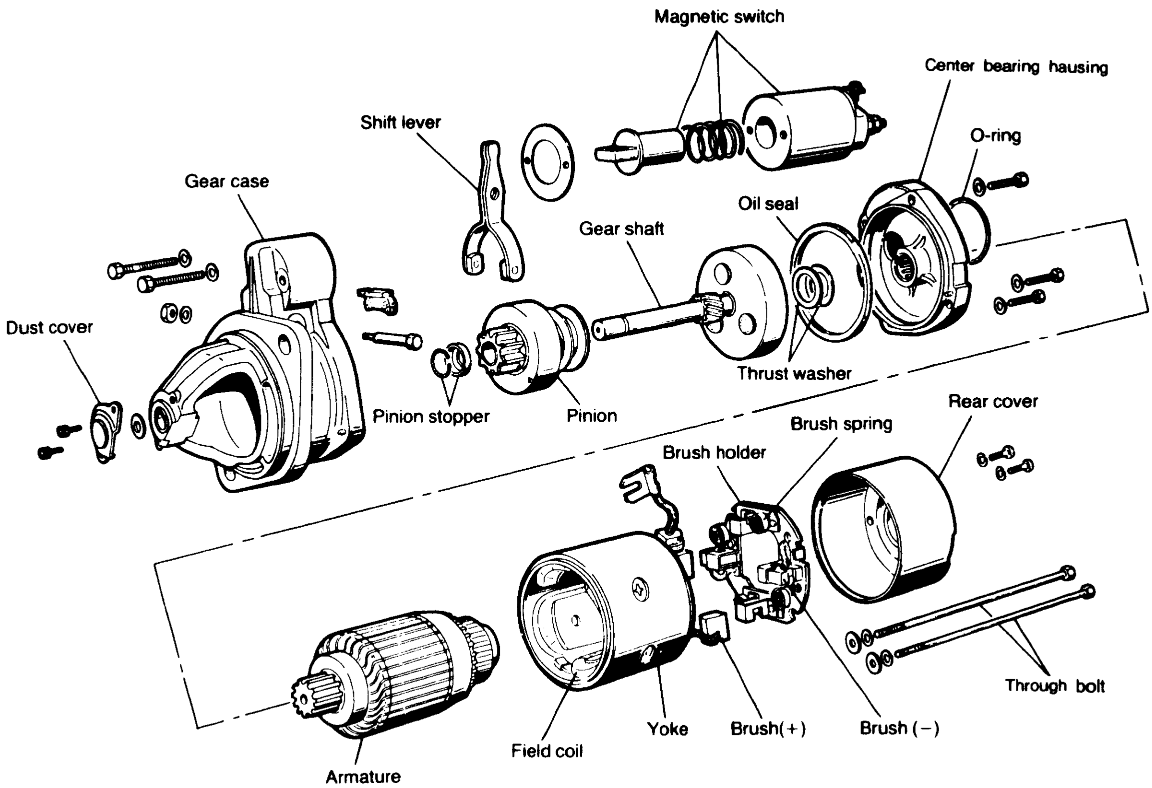


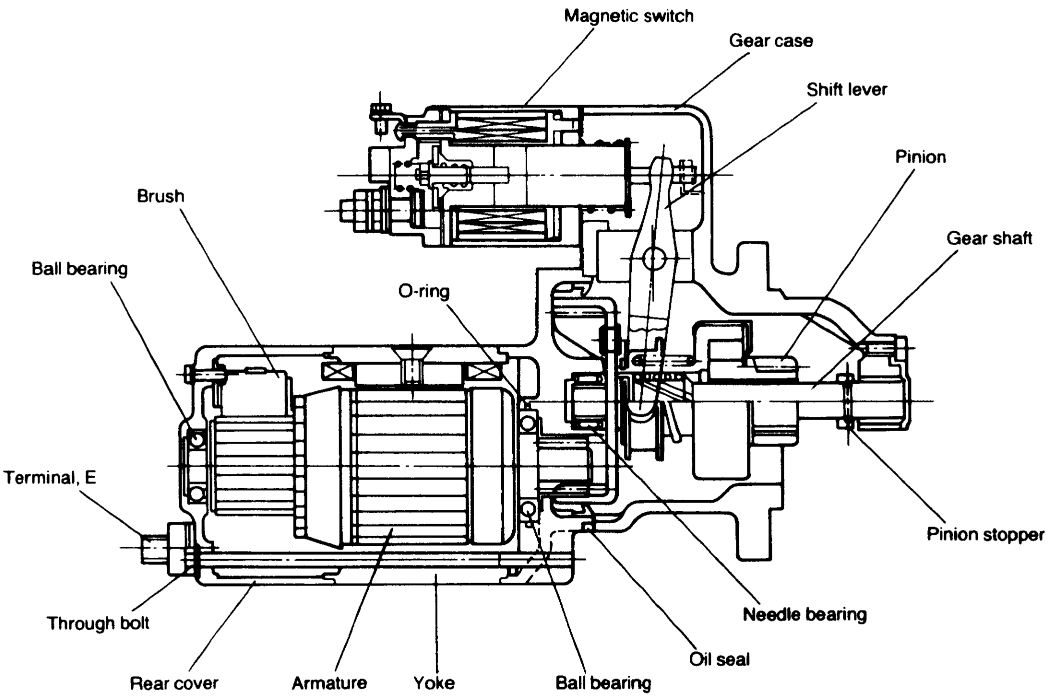
S13-41A Performance curves

2 Features

(1) The starter motor is compact and produces high output through high speed revolutions. It has increased torque with employing a reduction gear to reduce the speed between the armature and the pinion.
(2) The use of ball bearings at the armature shaft (front and rear sides) and the needle bearings for the gear shaft (rear side) has boosted the durability of the starter moto

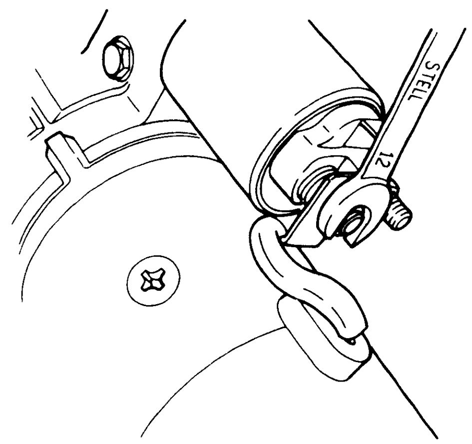
3 Construction



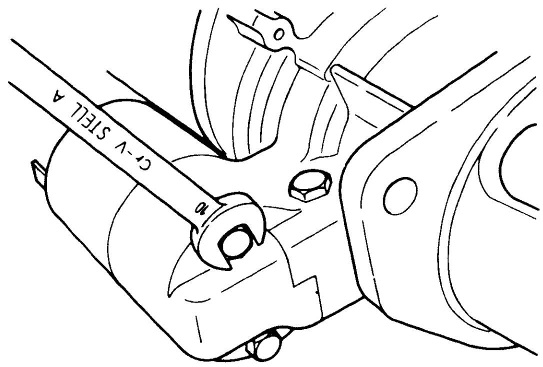


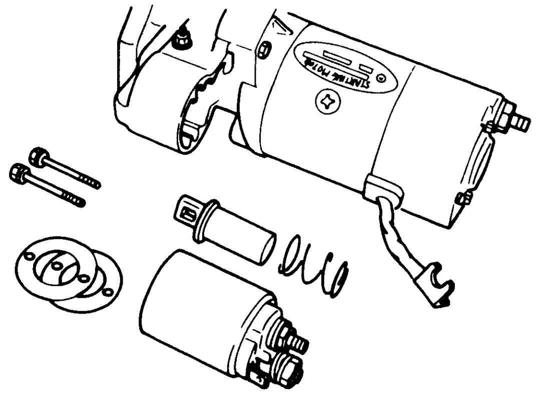
4 Disassembly

(1) Disconnect the magnetic switch wiring.
Loosen the M8, nut and disconnect the magnetic switch wiring.

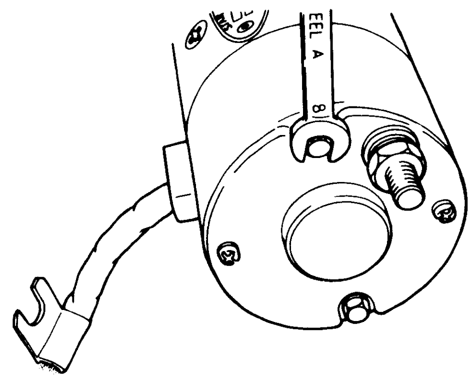


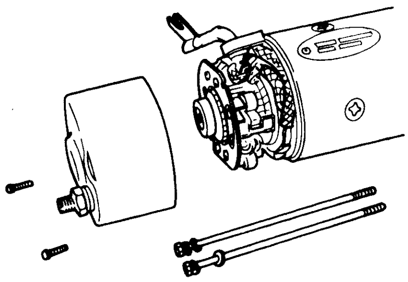
(2) Remove the magnetic swtich.
Remove the two M6 bolts.



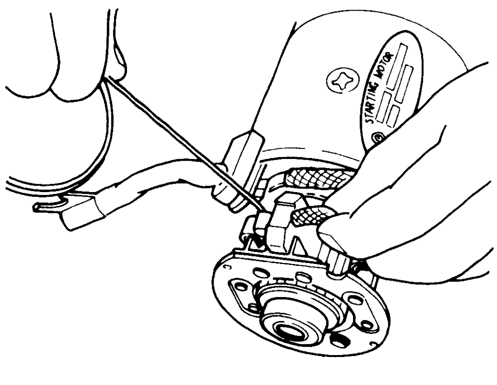


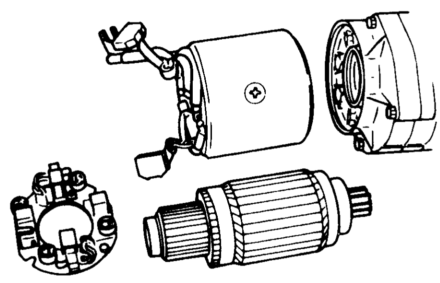
(3) Remove the rear cover.
1) Remove the two screws holding the brush holder.
2) Remove the two M5 through bolts.
3) Remove the rear cover, using the minus (−) driver.



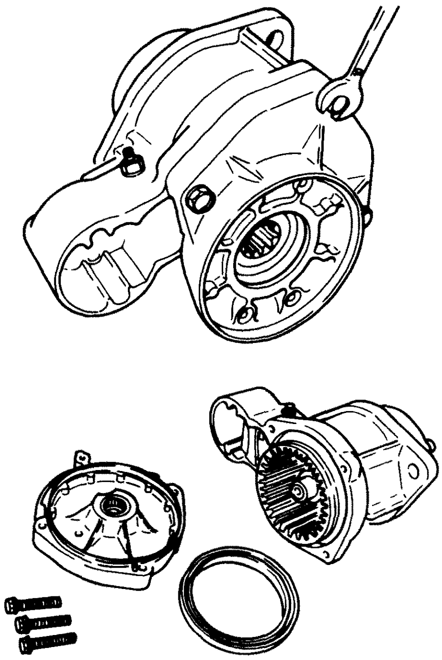


(4) Remove the brush holder.
1) Float the minus (−) brush from the commutator.
2) Remove the plus (+) brush from the brush holder.
3) Remove the armature form the yoke.

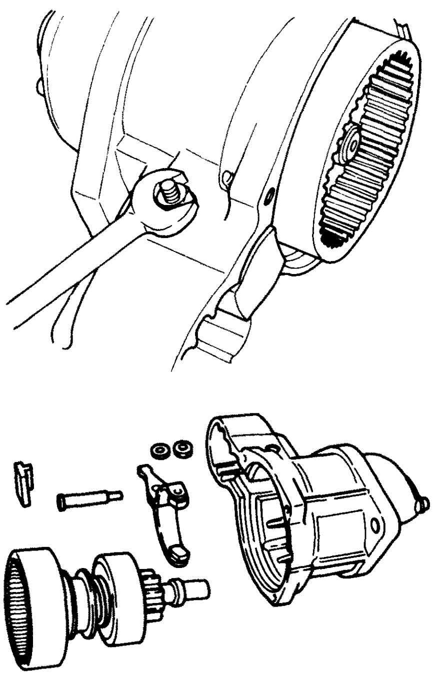




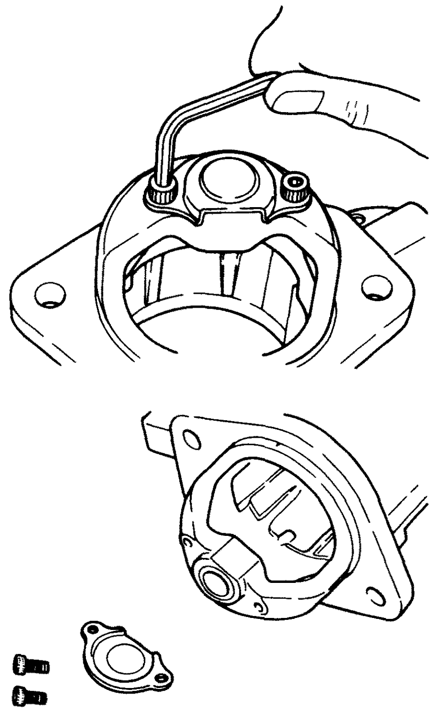
(5) Remove the center bearing housing.
1) Remove the three M6 bolts from the gear case.
2) Remove the center bearing housing and oil seal from the gear case.



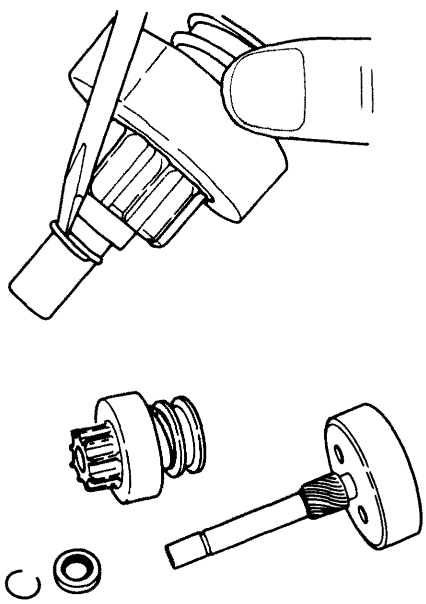
(6) Remove the shift lever pin.
1) Remove the M6 bolt from the gear case.
2) Remove the shift lever pin from gear case.



(7) Remove the dust cover.
1) Remove the two M5 bolts.
2) Remove the dust cover from the gear case.



(8) Remove the pinion.
1) Slide the pinion stopper to the pinion side.
2) Remove the pinion stopper clip, using the minus (−) driver.
3) Remove the pinion from the gear shaft.



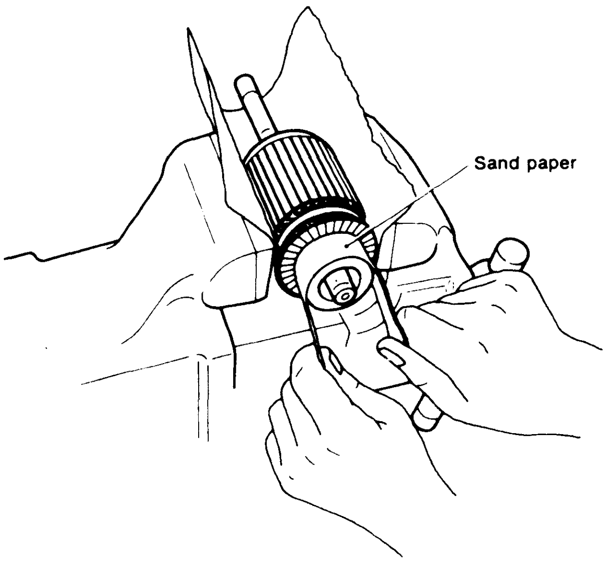
5 Maintenance standard

Model					S13-41A
Brush	Standard spring load			N (kgf)	31.4 (3.2)
	Standard height			mm (in.)	18 (0.7087)
	Wear limit			mm (in.)	7 (0.2756)
Magnetic switch	Series coil resistance			Ω	0.33 at 20°C (68°F)
	Shunt coil resistance			Ω	0.7 at 20°C (68°F)
Commutator	Outside diameter	Maintenance standard		mm (in.)	38 (1.4961)
		Wear limit		mm (in.)	36.6 (1.4409)
	Deflection	Repair limit		mm (in.)	0.1 (0.0039)
		Repair accuracy		mm (in.)	0.05 (0.0020)
	Mica undercut	Maintenance standard		mm (in.)	0.2 (0.0079)
		Repair limit		mm (in.)	0.5~0.8 (0.0197~0.0315)
Standard dimension	Armature shaft diameter	Front side		mm (in.)	25 (0.9843)
		Rear side		mm (in.)	12 (0.4724)
		Repair limit	Front side	mm (in.)	24.90 (0.9803)
			Rear side	mm (in.)	11.90 (0.4685)
		Deflection		mm (in.)	below 0.08 (0.0031)
	Pinion sliding section	Shaft diameter		mm (in.)	13.950~13.968 (0.5492~0.5499)
		Hole diameter		mm (in.)	14.03~14.05 (0.5524~0.5532)
	Gear case	Shaft diameter		mm (in.)	13.950~13.968 (0.5492~0.5499)
		Hole diameter		mm (in.)	14.0~14.018 (0.5512~0.5519)

6 Inspection

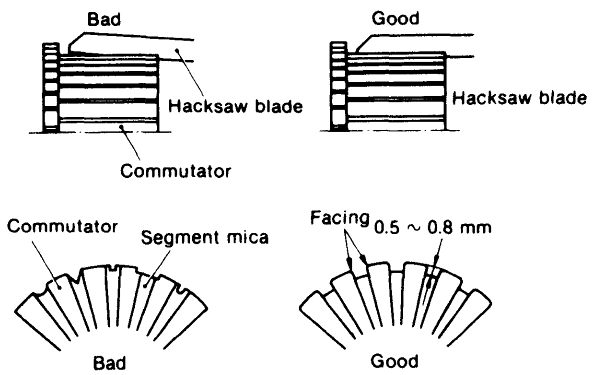
6.1 Armature

(1) Commutator
Inspect the surface of the commutator. If corroded or pitted, sand with #500 ~ #600 sandpaper. If the commutator is severely pitted, grind it to within a surface roughness of at least 0.1mm (0.0039 in) by turning it on a lathe. Replace the commutator if damage is irreparable.



Model	S13-41A	
	Maintenance standard	Wear limit
Commutator outside diameter	Ø38 (1.4961)	Ø36.6 (1.4409)
Deflection	Repair limit 0.1 (0.0039)	Repair accuracy 0.05 (0.002)

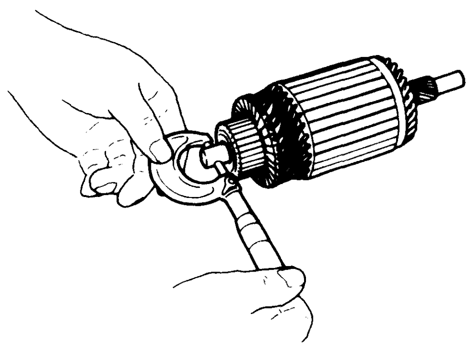
(2) Mica undercut
Check the mica undercut, correct with a hacksaw blade when the undercut is too shallow.



mm (in.)

	Maintenance standard	Repair limit
Mica undercut	0.2 (0.0079)	0.5 ~ 0.8 (0.0197 ~ 0.0315)

(3) Armature shaft outside diameter
Measure the outside diameter of the armature shaft at four locations: front, center, end, and pinion. Replace the armature if the shaft is excessively worn.
Check the bend of the shaft; replace the armature if the bend exceeds 0.08mm (0.0031 in)

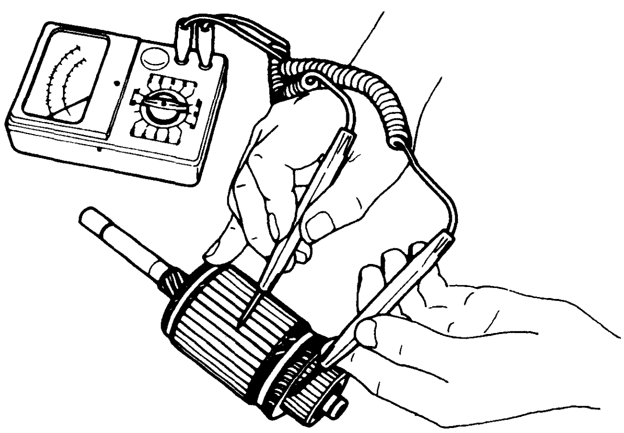


mm (in.)

		Maintenance standard	Repair limit
Armature shaft diameter	Front side	Ø25 (0.9843)	Ø24.90 (0.9803)
	Rear side	Ø12 (0.4724)	Ø11.90 (0.4685)

(4) Armature coil continuity and ground test
Using a tester, check for continuity between the commutator and the shaft (or armature core). Continuity indicates that these points are grounded and that the armature must be replaced.

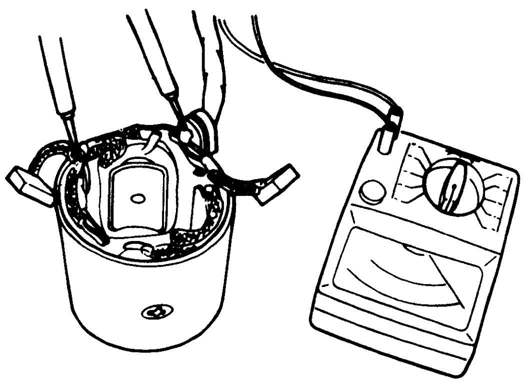
Checking commutator for insulation defects.



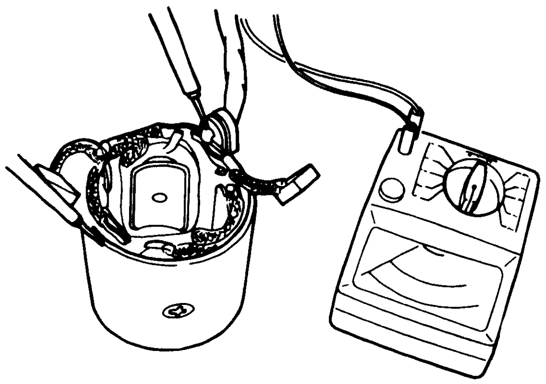
Kind of test	Check point	Normal	Abnormal
Continuity	Commutator between armature	YES	NO (Broken or disconnected coil)
Insulation	Commutator between armature or shaft	NO	YES (Short-circuit)

6.2 Field coil

(1) Field coil continuity and ground test.



Field coil continuity test

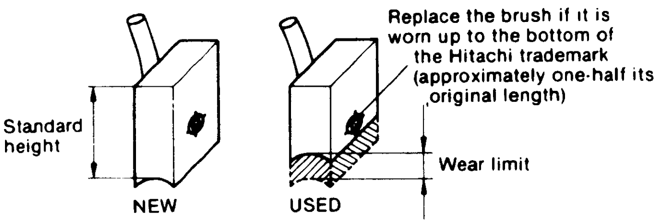


Field coil insulation test

Kind of test	Check point	Normal	Abnormal
Continuity	Terminal between field coil	YES	NO (Wiring broken)
Insulation	Field coil between yoke	NO	YES (Short-circuit)

6.3 Brush

(1) Brush dimensions
Replace brushes which have been worn beyond the specified wear limit.

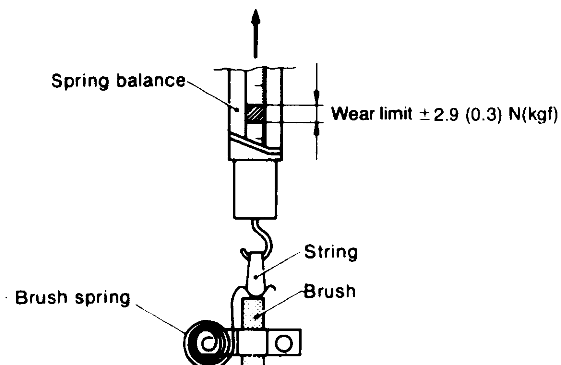


mm (in.)

	S13-41A
Brush standard height	18 (0.7087)
Wear limit	7 (0.2756)

(2) Brush appearance and movement in brush holder
If the outside of the brush is damaged, replace it. If the movement of the brushes in the brush holder is hampered because the holder is rusted, repair or replace the holder.

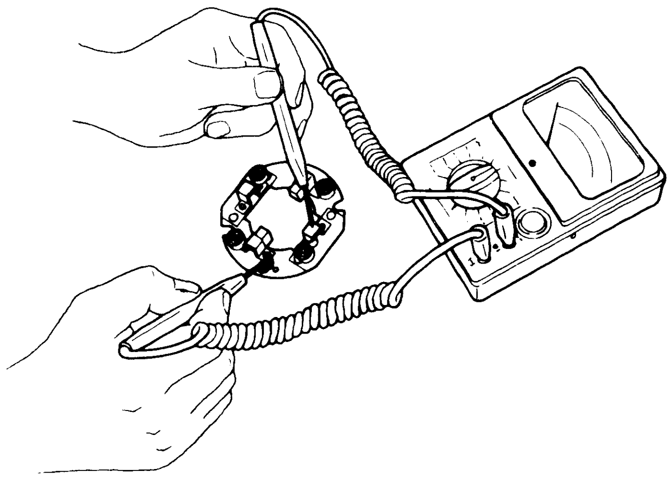
(3) Brush spring
Since the brush spring pushes the brush against the commutator while the motor is running, a weak or defective spring will cause excessive brush wear, resulting in sparking between the brush and the commutator during operation. Measure the spring force with a spring balance; replace the spring when the difference between the standard value and the measured value exceeds ±0.3kg (0.66 lb)



(Measuring brush spring force)

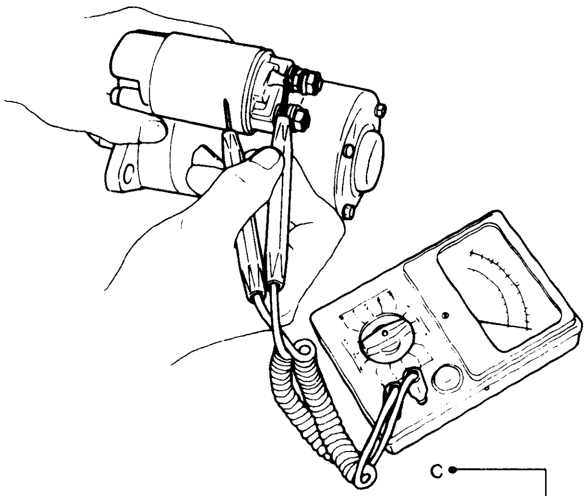
	S13-41A
Standard spring load	31.4 (3.2) N(kgf)

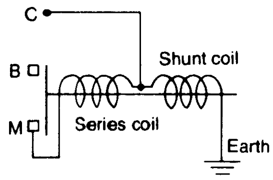
(4) Brush holder ground test
Check for continuity between the insulated brush holder and the base of the brush holder assembly. Continuity indicates that these two (− between +) points are grounded and that the holder must be replaced.



6.4 Magnetic switch

(1) Shunt coil continuity test
Check for continuity between the S terminal and the magnetic switch body (metal part). Continuity indicates that the coil is open and that the swtich must be replaced.

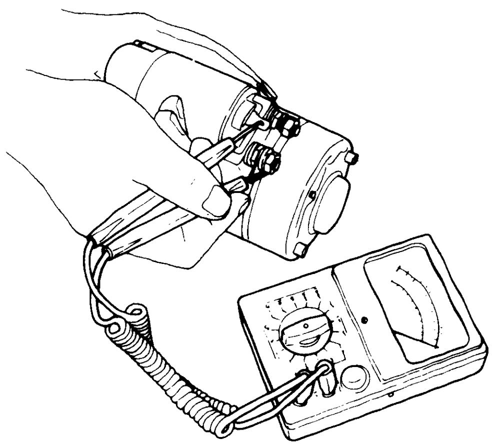




Magnetic switch wiring

	S13-41A
Coil resistance (at 20°C)	0.70Ω

(2) Series coil continuity test
Check for continuity between the S terminal and M terminal. Continuity indicates that the coil is open and that it must be replaced.



	S13-41A
Resistance value (at 20°C)	0.33Ω

6.5 Pinion

(1) Inspect the pinion teeth and replace the pinion if the teeth are excessively worn or damaged.
(2) Check if the pinion slides smoothly; replace the pinion if faulty.
(3) Inspect the springs and replace if faulty.

6.6 Ball bearing

(1) Check whether the ball bearing makes any abnormal sound and replace the ball bearing if necessary.

7 Reassembly precautions

Reassemble the starter motor in the reverse order of disassembly, paying particular attention to the following:

(1) Lubrication
Lubricate each bearing and spline (points indicated in the figure below) with high quality "Hitachi Electrical Equipment Grease A"
The following lubricants may be used in place of Hitachi Electrical Equipment Grease A.

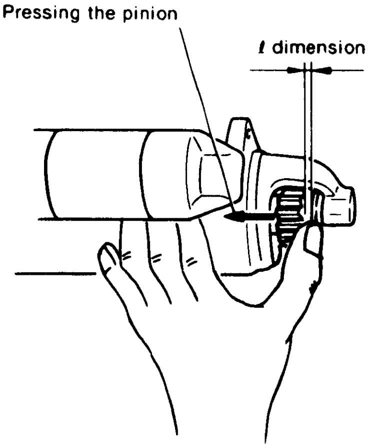
Magnetic switch plunger	Shell	Aeroshell No.7
Bearing and spline	Shell	Albania Grease No.2
Reduction gear	Shell	Aeroshell No.7
Sliding of shift lever	Shell	Aeroshell No.7

8 Adjustment and performance test

(1) L-size measurement (gap between pinion and pinion stopper)
When the pinion is at the projected position, measure the gap between the pinion and pinion stopper. This check should be made with the pinion pressed back lightly to take up any play in the engagement linkage.

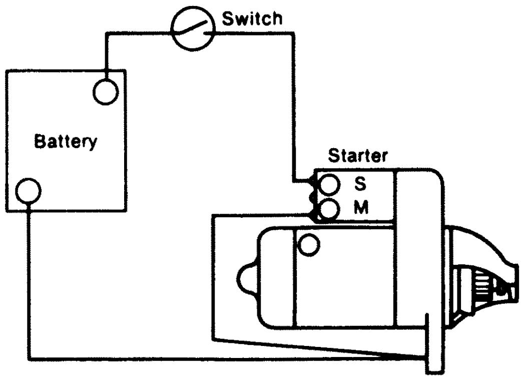
mm (in.)

	Starter motor	ℓ dimension
	S13-41A	0.3 ~ 1.5 (0.0118 ~ 0.0591)



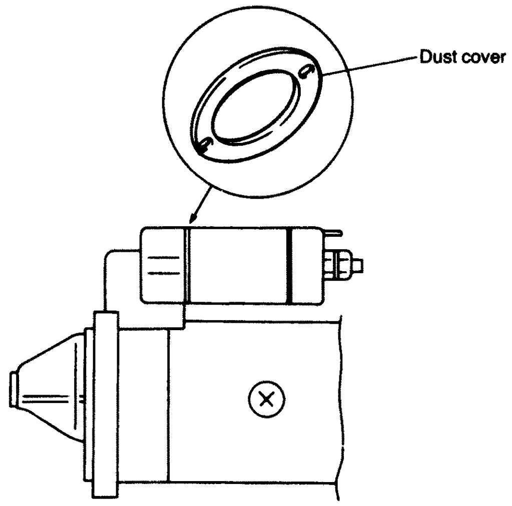
Measuring of ℓ dimension

(2) Pinion movement
After complete assembly of the starter motor, connect up the motor as in Fig.



(3) Plunger movement
Adjustment made by adjusting stroke of magnetic plunger to the prescribed value.

1) Shim adjusting.
Adjust the ℓ-dimension dust cover at the magnetic switch attach section.



(4) Thrust gap of armature
No adjustment type.

(5) Thrust gap of gear shaft

mm (in.)

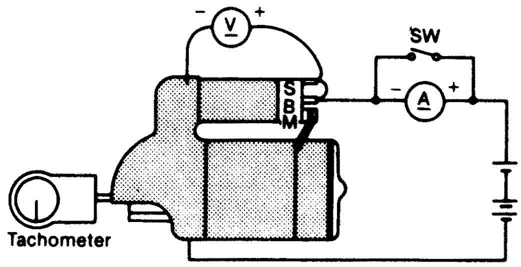
	Normal gap	Wear limit	Kind of thrust washer
Thrust gap of gear shaft	0.1 ~ 0.7 (0.0039~0.0275)	Over, 0.7 (Over, 0.0275)	Thickness, 0.15, 0.25 (0.0059, 0.0098)

9 Testing

9.1 No load test

Test procedure

(1) Connect the positive side of the ammeter (A) to the positive terminal of the battery, and connect the negative side of the ammeter to the B terminal of the starter.



(2) Connect the negative terminal of the battery to the body of the starter.
(3) Connect the positive side of the voltmeter (V) to the B terminal of the starter, and connect the negative side of the voltmeter to the body of the starter.
(4) Attach the tachometer.
(5) Connect the B terminal of the starter to the S terminal of the magnetic switch.

- The magnetic switch should begin operation, and the speed, current, and voltage should be at the prescribed values.
- A fully charged battery must be used.
- Since a large current flows when the starter is operated, close the protection circuit switch before initial operation, then open the switch and measure the current after the starter reaches a constant speed.

10 Troubleshooting

(1) Pinion fails to advance when the starting switch is closed

Problem	Cause	Corrective action
Wiring	Open or loose battery or switch terminal	Repair or retighten
Starting switch	Threaded part connected to pinion section of armature shaft is damaged, and the pinion does not move	Repair contacts, or replace switch
Starter motor	Threaded part connected to pinion section of armature shaft is damaged, and the pinion does not move	Replace
Magnetic switch	Plunger of magnetic switch malfunctioning or coil shorted	Repair or replace

(2) Pinion is engaged and motor rotates, but rotation is not transmitted to the engine

Problem	Cause	Corrective action
Starting motor	Overrunning clutch faulty	Replace

(3) Motor rotates at full power before pinion engages ring gear

Problem	Cause	Corrective action
Starter motor	Torsion spring permanently strained	Replace

(4) Pinion engages ring gear, but starter motor fails to rotate

Problem	Cause	Corrective action
Wiring	Wires connecting battery and magnetic switch open or wire connecting ground, magnetic switch and motor terminals loose	Repair, retighten, or replace wire
Starter motor	Pinion and ring gear engagement faulty Motor mounting faulty Brush worn or contacting brush spring faulty Commutator dirty Armature, field coil faulty Field coil and brush connection loose	Replace Remount Replace Repair Repair or replace Retighten
Magnetic switch	Contactor contact faulty Contactor contacts pitted	Replace Replace

(5) Motor fails to stop when starting switch is opened after engine starts

Problem	Cause	Corrective action
Starting switch	Switch faulty	Replace
Magnetic switch	Switch faulty	Replace

4. Alternator

The alternator serves to keep the battery constantly charged. It is installed on the cylinder block by a bracket, and is driven from the V-pulley at the end of the crankshaft by a V-belt.
The type of alternator used in this engine is ideal for high speed engines with a wide range of engine speeds. It contains diodes that convert AC to DC, and an IC regulator that keep the generated voltage constant even when the engine speed changes.

4-1 Features

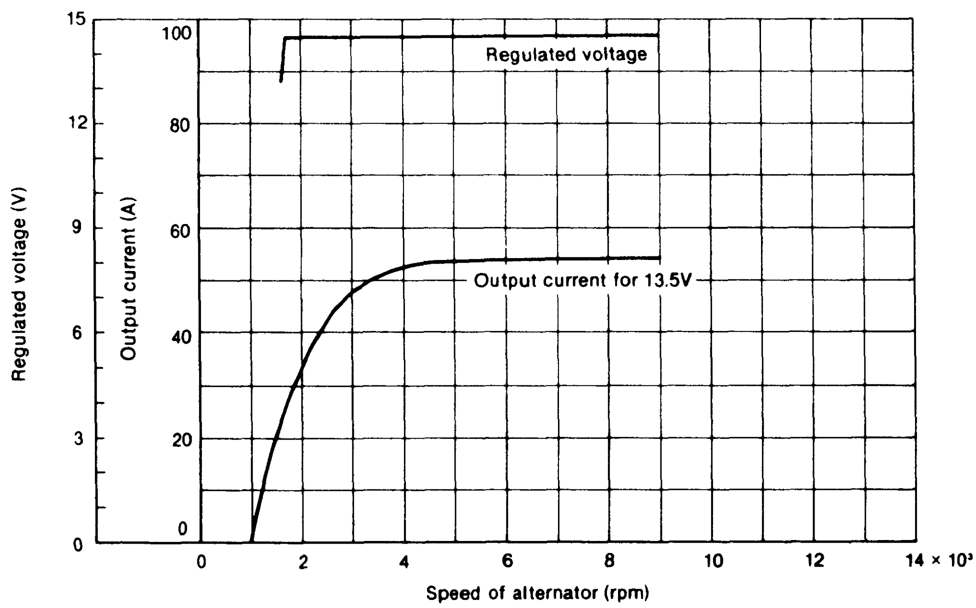
The alternator contains a regulator using an IC, and has the following features.

(1) The IC regulator is self-contained, and has no moving parts (mechanical contact points). It therefore has superior features such as freedom from vibration, no fluctuation of voltage during use, and no need for readjustment.
Also, it is of the over-heating compensation type and can automatically adjust the voltage to the most suitable level depending on the operating temperature.
(2) The regulator is integrated within the alternator to simplify external wiring.
(3) It is an alternator designed for compactness, lightness of weight, and high output.
(4) A newly developed U-shaped diode is used to provide increased reliability and easier checking and maintenance.
(5) As the alternator is to be installed on board, the following measures are taken to provide salt-proofing.
1) The front and rear covers are salt-proofed.
2) Salt-proof paint is applied to the diode.
3) The terminal, where the inboard harness is connected to the alternator, is nickel plated.

4-2 Specifications

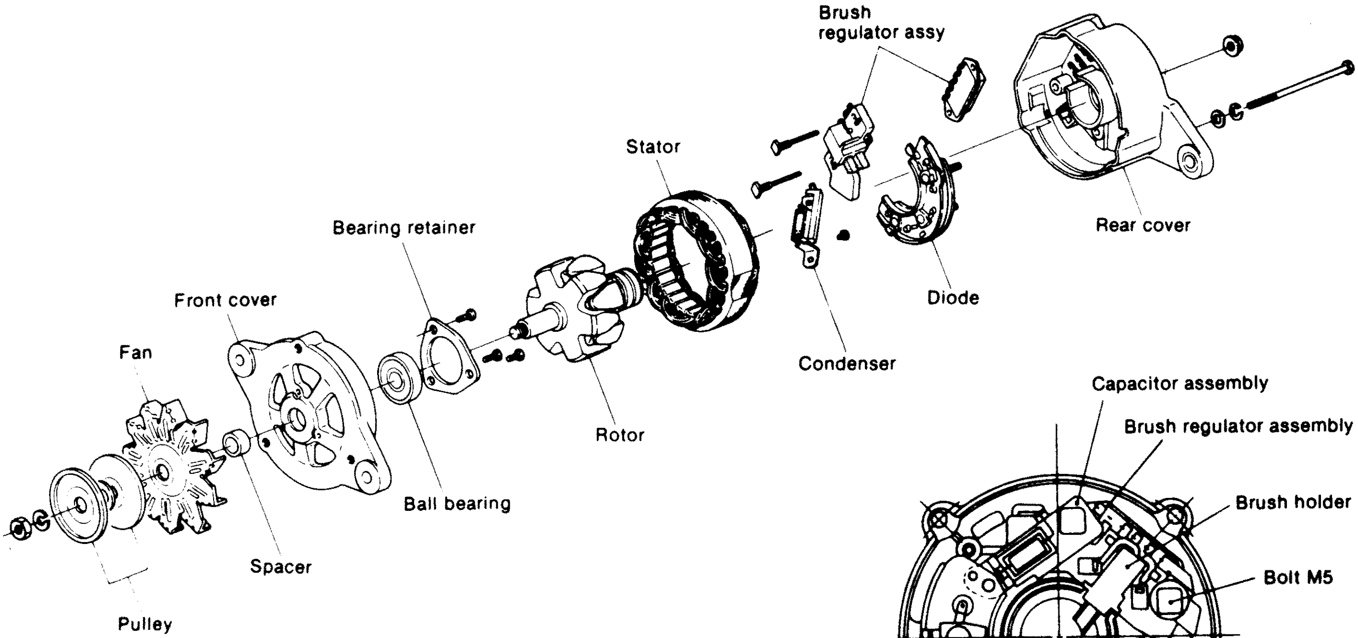
Model of alternator	LR155-20 (HITACHI)
Model of IC regulator	TRIZ-63 (HITACHI)
Battery voltage	12V
Nominal output	12V/55A
Earth polarity	Negative earth (⊖)
Direction of rotation (viewed from pulley end)	Clockwise
Mass	4.3kg
Rated speed	5000 rpm
Operating speed	1000 ~ 9000
Speed for 13.5V	1000 or less
Output current at 20°C	over 53A/5000 rpm
Regulated voltage	14.5 ±0.3V (Standard temperature voltage gradient, −0.01/°C)

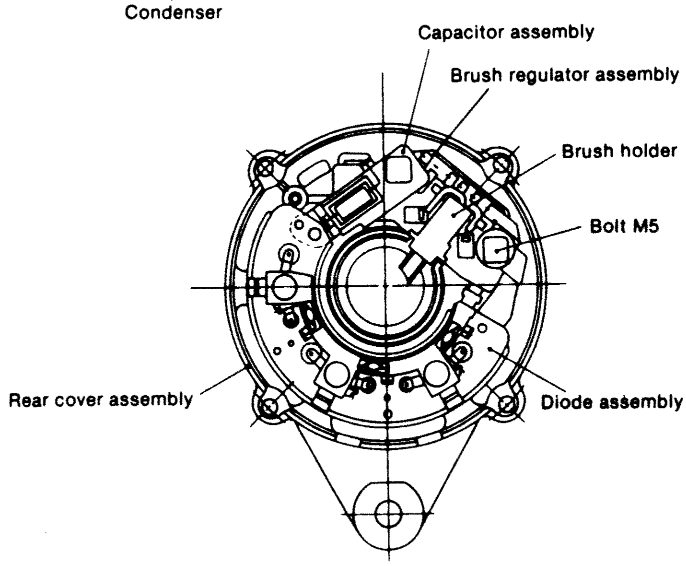
4-3 Characteristics

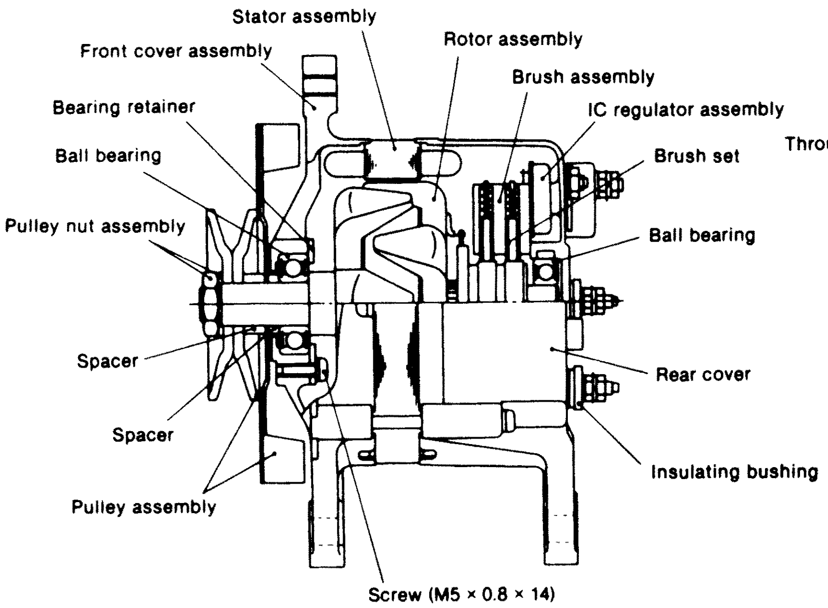


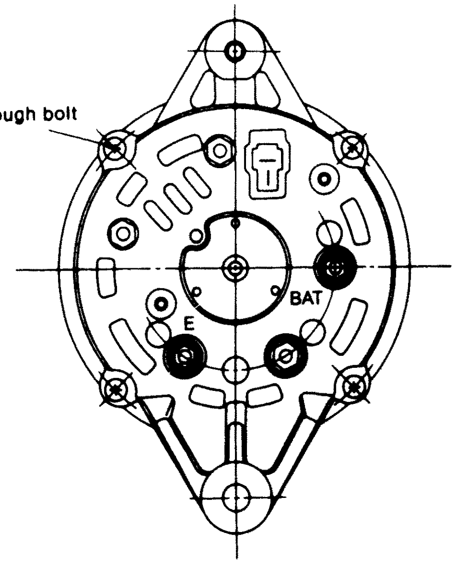
4-4 Construction

This is a standard rotating field type three-phase alternator. It consists of six major parts: the pulley, fan, front cover, rotor, stator and rear cover. The IC regulator is an integral part of the alternator.









4-5 Alternator functioning

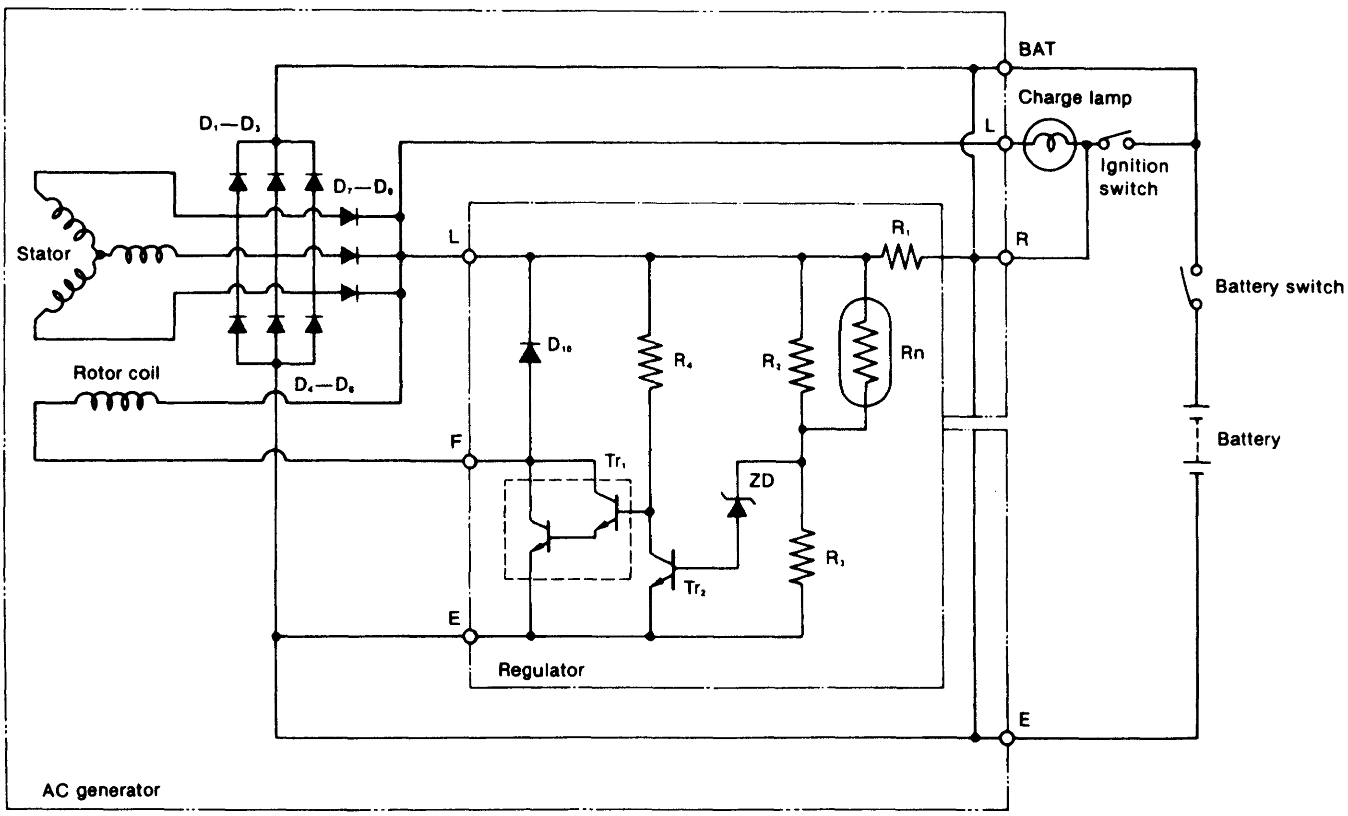
(1) IC regulator
The IC regulator is the transistor (Tr_1) which is series-connected with the rotor. The IC regulator controls the output voltage of the generator by breaking or conducting the rotor coil (exciting) current.
When the output voltage of the generator is within the standard value, the transistor (Tr_1) turns on. When the voltage exceeds the standard value, the Zener diode goes on and the transistor (Tr_1) turns off.
With the repeated turning on and off of the transistor, the output voltage is kept at the standard value. (Refer to the circuit diagram below.)

(2) Charge lamp
When the transistor (Tr_1) is on, the charge lamp key switch is turned to ON, and current flows to R_1, R_4 and to Tr_1 to light the lamp. When the engine starts to run and output voltage is generated in the stator coil, the current stops flowing to this circuit, turning off the charge lamp.

(3) Circuit diagram

4-6 Handling precautions

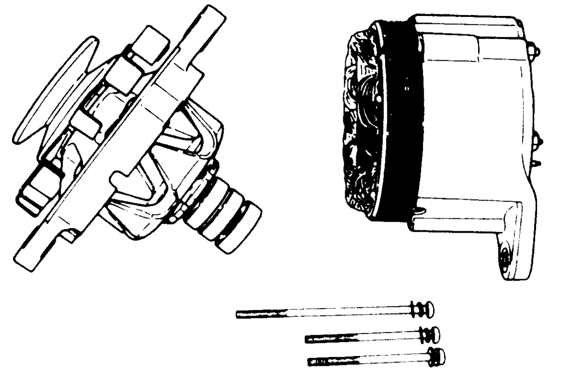
(1) Be careful of the battery's polarity (+, − terminals), and do not connect the wrong terminals to the wrong cables, or the battery will be short-circuited by the generator diode.
In this case too much current will flow, the IC regulator and diodes burn out, and the wire harness will burn.
(2) Make sure of the correct connection of each terminal.
(3) When quick-charging, etc., disconnect either the battery terminal on the AC generator or the terminal on the battery.
(4) Do not short-circuit the terminals.
(5) Do not conduct any tests using high tension insulation resistance. (The diodes and IC regulator will burn out.)



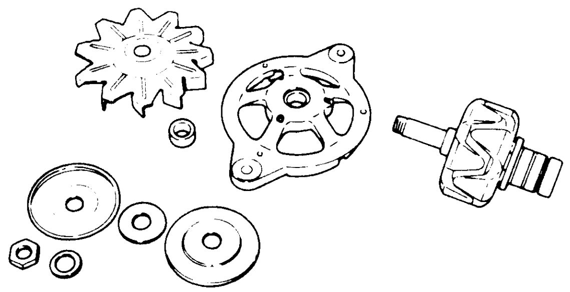
BAT:	Generator output terminal	D_1—D_6:	Output commutation diode
D_{10}:	IC protecting diode	R_1—R_4:	Resistor
L:	Charge lamp terminal	D_7—D_9:	Charging lamp switching diode
ZD:	Zener diode	F:	To supply current to rotor coil
E:	Earth	Rn:	Thermistor (Temperature gradient resistance)
Tr_1, Tr_2:	Transistor		

4-7 Disassembling the alternator

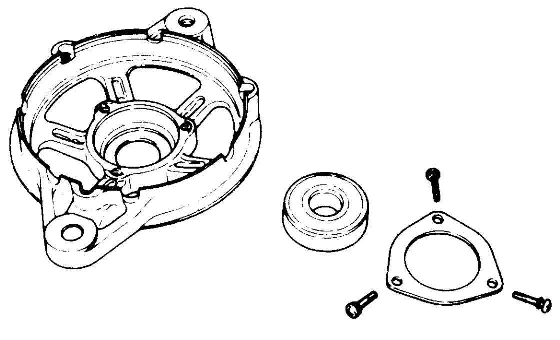
(1) Remove the through-bolt, and separate the front assembly from the rear assembly.



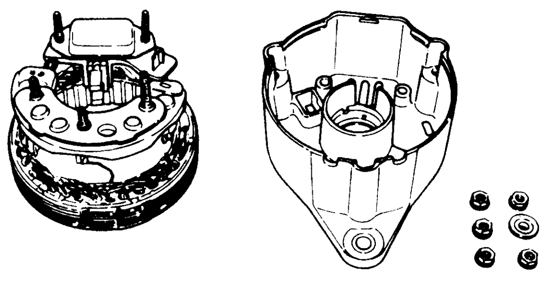
(2) Remove the pulley nut, and pull out the rotor from the front cover.



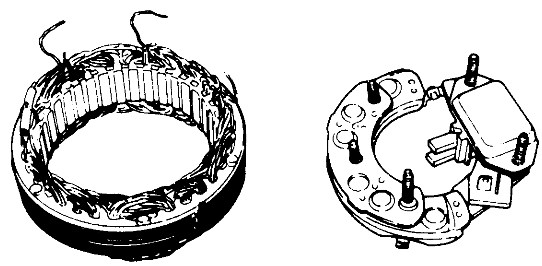
(3) Remove the ø5mm (ø0.1969in.) screw from the front cover, and then remove the ball bearing.



(4) Remove the nut, the brush-holder, and diode fixing nut at the BAT, and the terminal screws of the rear cover. Separate the rear cover from the stator (with the diode and brush holder).

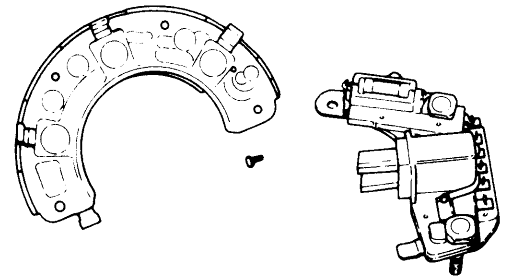


(5) Disconnect the soldered joint of the stator lead wire, and remove the diode and brush regulator assemblies from the stator at the same time.

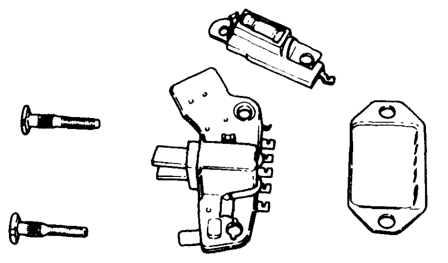


(6) Separating the regulator

1) To separate the regulator, remove the ø3mm (ø0.1181in.) rivet which keeps the diode assembly and the brushless regulator in place, and the soldered joint of the L-terminal.



2) To replace the IC regulator, disconnect the soldered joint of the IC regulator and pull out the two bolts. Do not remove these two bolts except when replacing the IC regulator.

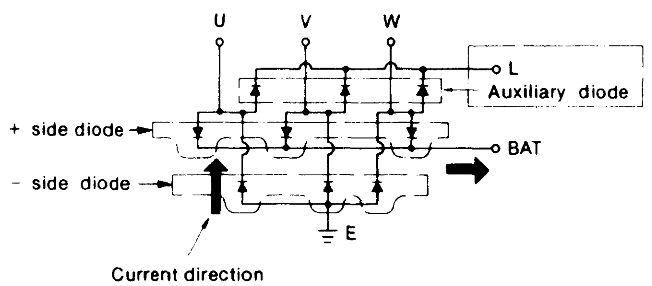


4-8 Inspection and adjustment

(1) Diode

Between terminals		BAT (+ side diode)	
	Tester wire	+ side	− side
U.V.W.	+ side		No continuity
	− side	Continuity	

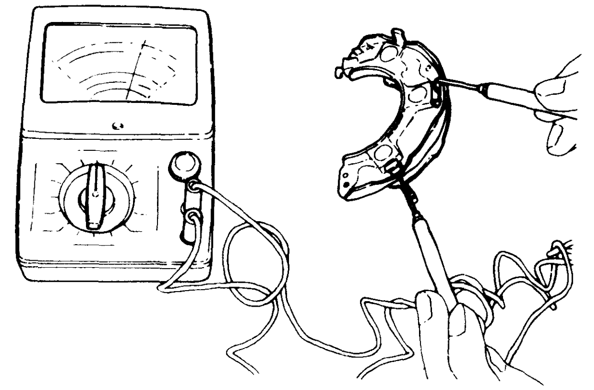
Between terminals		E (− side diode)	
	Tester wire	+ side	− side
U.V.W.	+ side		Continuity
	− side	No continuity	



U.V.W.: terminal from the stator coil

Current flows only in one direction in the diode as shown in Fig. 181. Accordingly, when there is continuity between each terminal (e.g. BAT and U), the diode is in normal condition (photo). When there is no continuity, the diode is defective.
When the tester is connected in the reverse of above, there should be no continuity. If there is, the diode is defective.

After repeating the above test, if any diode is found to be defective, replace the diode assembly. Since there is no terminal on the auxiliary diode, check the continuity between both ends of the diode.



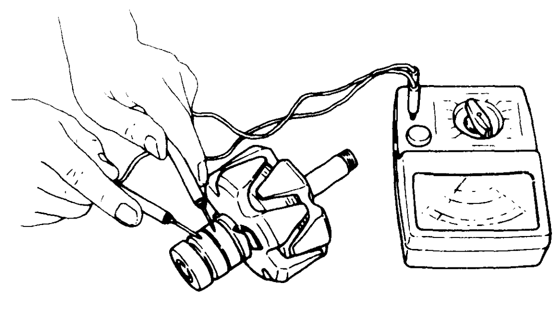
CAUTION: Do not use high tensile insulation resistance such as meggers, etc. for testing. The diode may burn out.

(2) Rotor
Inspect the slip ring surface, rotor coil continuity and insulation.

1) Inspecting the slip ring surface
Check if the surface of the slip ring is sufficiently smooth. If the surface is rough, grind the surface with No. 500—600 sand paper. If it is contaminated with oil, etc., wipe the surface clean with alcohol.

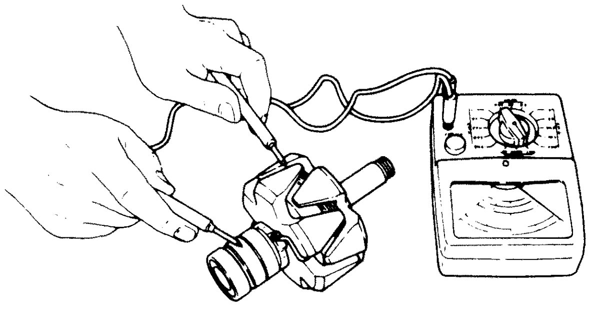
	Standard	Wear limit
Slip ring outer dia.	ø31.6mm (1.2441in.)	ø30.6mm (1.2049in.)

2) Rotor coil continuity test
Check the continuity in the slip ring with the tester. If there is no continuity, there is a wire break. Replace the rotor coil.

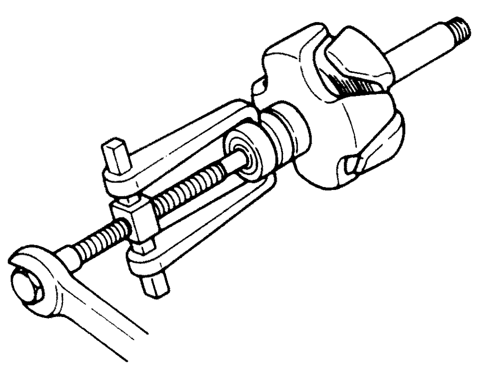


Resistance value	Approx. 3.34Ω at 20°C

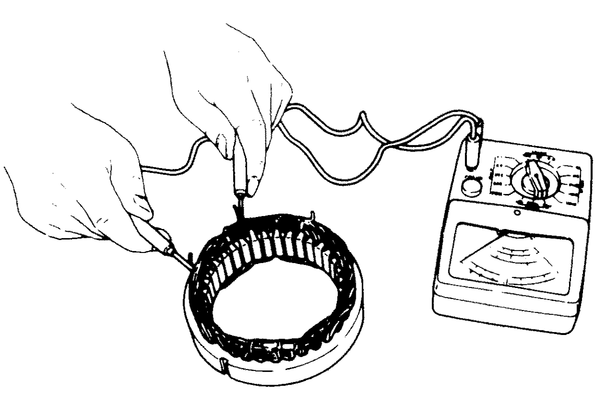
3) Rotor coil insulation test
Check the continuity between the slip ring and the rotor core, or the shaft. If there is continuity, insulation inside the rotor is defective, causing a short with the earth circuit. Replace the rotor coil.



4) Check the rear side ball bearing. If the rotation of the bearing is heavy, or produces abnormal sounds, replace the ball bearing.

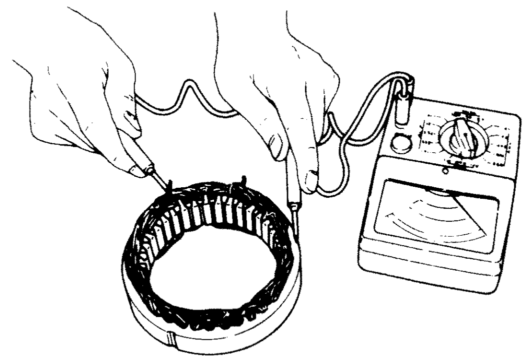


(3) Stator
1) Stator coil continuity test
Check the continuity between each terminal of the stator coil. If there is no continuity, there is a wire break in the stator coil. Replace the stator coil.

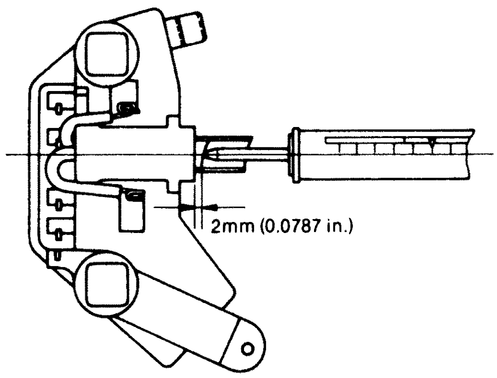


Resistance value	Approx. 0.077Ω at 20°C 1-phase resistance

2) Stator coil insulation test
Check the continuity between the terminals and the stator core. If there is continuity, insulation of the stator coil is defective. This will cause a short-circuit with the earth core. Replace the stator coil.

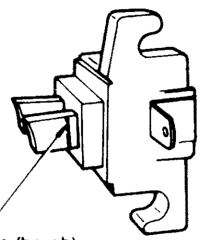


(4) Brush
The brush is hard and wears slowly, but when it is worn beyond the allowable limit, replace it. When replacing the brush, also check the strength of the brush spring. To check, push the spring down to 2mm (0.0787in.) from the end surface of the brush holder, and read the gauge.



Brush spring strength	2.50~3.38 (0.255~0.345) N(kgf)

(5) Brush wear
Check the brush length.
The brush wears very little, but replace the brush if worn over the wear limit line printed on the brush.



mm (in.)

	Maintenance standard	Wear limit
Brush length	16 (0.6299)	9 (0.3543)

(6) IC regulator

Connect the variable resistance, two 12V batteries, resistor, and voltmeter as shown in the diagram.

1) Use the following measuring devices.

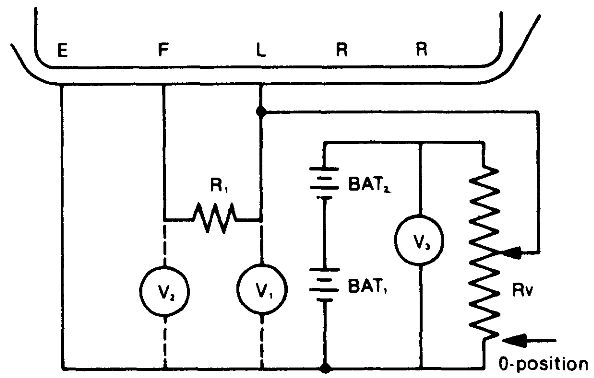
Resistor (R_1)	100Ω, 2W, 1pc.
Variable resistor (Rv)	0—300Ω, 12W, 1pc.
Battery (BAT_1, BAT_2)	12V, 2pcs.
DC voltmeter	0—30V, 0.5 class 1pc. (measure at 3 points)

2) Check the regulator in the following sequence, according to the diagram.

a) Check V_3 (BAT_1 + BAT_2 voltage). If the voltage is 20—26V, both BAT_1 and BAT_2 are normal.

b) While measuring V_2 (F-E terminal voltage), move Rv gradually from the 0-position. Check if there is a point where the V_2 voltage rises sharply from below 2.0V to over 2.0V. If there is no such point, the regulator is defective. Replace the regulator. If there is a sharp voltage rise when testing, return the Rv to the 0-position, and connect the voltmeter to the V_1 position.

c) While measuring V_1 (voltage between L-E terminals), move Rv gradually from the 0-position. There should be a point where the voltage of V_1 rises sharply by 2—6V. Measure the voltage of V_1 just before this sharp voltage rise. This is the regulating voltage of the regulator. If this voltage of V_1 is within the standard limit, the regulator is normal. If the voltage deviates from the limit, the regulator is defective. Replace the regulator.



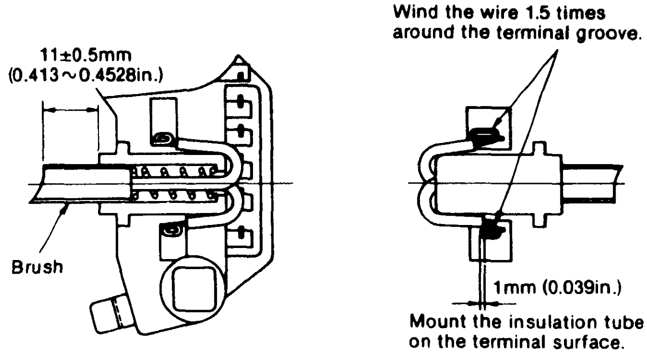
4-9 Reassembling the alternator

Reassembly is done in the reverse order of disassembly. For reassembly, be careful of the following points. (Refer to 4—7 disassembling alternator).

(1) Assembling the brush regulator

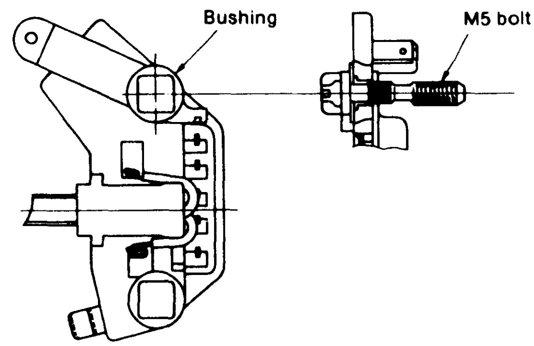
1) Solder the brush.

Position the brush as shown in the drawing and solder it. Be careful not to let the solder drip into the pig tail (lead wire).



NOTES: 1. Use non-acid type paste.
2. The soldering iron temperature is 300 ~ 350°C.

2) Mount the IC regulator on the brush holder as illustrated, and press in the M5 bolt. Do not forget to assemble the bushing and the connecting plate at the same time.
(If the bushing is left out, the output terminal will be earthed and the battery short-circuited).



NOTES: 1. Insertion pressure is 981 (100) N(kgf)
2. Insert vertically.

(2) Connecting the brush regulator assembly and diode

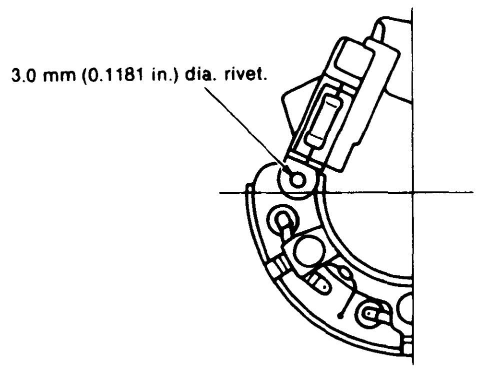
1) Check the rivets

Place the rivets as shown in the figure, and then calk them using the calking tool.

Calking force	4903 (500) N(kgf)

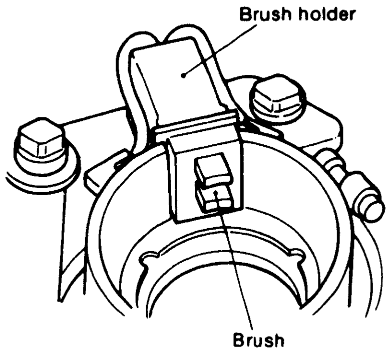
2) Connect the brush to the diode.

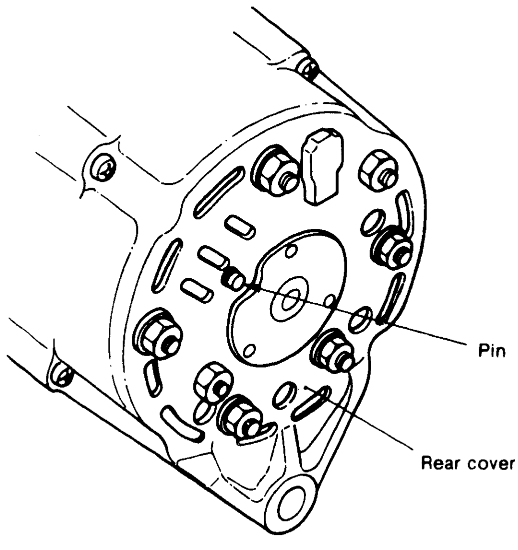
Insert the brush side terminal into the diode terminal, calk it, and then solder into place.



Rivetting pressure	4903 (500) N(kgf)

(3) Assembling the rear cover
Insert pins from the outside of the rear cover. Install the brush on the brush holder, then attach the rear cover. After assembly, pull out the pins.



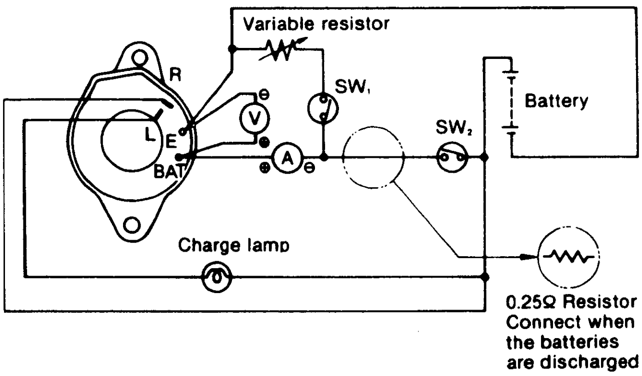


(4) Tightening torques

Positions	Tightening torque N(kgf)·cm
Brush holder fixing	314–392 (32 ~ 40)
Diode fixing	314–392 (32 ~ 40)
Bearing retainer fixing	314–392 (32 ~ 40)
Pulley nut tightening	3923–5884 (400 ~ 600)
Through-bolt tightening	314–392 (32 ~ 40)

4-10 Performance test

Conduct a performance test on the reassembled AC generator as follows. The following is the circuit for the performance test.



(1) Measuring devices

DC voltmeter	0—15V or 0—30V, 0.5 Class, 1pc.
DC ammeter	0—100A, 1.0 Class, 1pc.
Variable resistor	0—0.25Ω, 1kW, 1pc.
Lamp	12V, 3W
100Ω resistor	3W
0.25Ω resistor	25W

(2) Measuring the regulating voltage
1) When measuring devices are connected in the performance test circuit as shown above, the charge lamp lights.
2) Close SW_2 while keeping SW_1 open and run the AC generator. When the revolutions of the generator are gradually raised, the charge lamp goes off.
3) Raise the revolutions of the AC generator, and read the voltmeter gauge when the revolutions reach about 5,000 rpms.

NOTES: 1. Make sure that the ammeter indication at this time is less than 5A. If the indication is over 5A, connect the 0.25Ω resistor. The voltmeter indication at this time must be within the prescribed regulating voltage value.
2. Raise the AC generator revolutions high to make sure the regulating voltage does not fluctuate along with changes in the revolution speed.

(3) Precautions for measuring the regulating voltage
1) When measuring the voltage, measure the voltage between the AC generator BAT terminal, or Battery + terminal, and AC generator E-terminal.
2) Use a fully charged battery.
3) Measure the voltage quickly.
4) Keep SW_1 open for measurement.

4-11 Alternator 12V/80A (OPTIONAL)

The alternator serves to keep the battery constantly charged. It is installed on the cylinder block by a bracket, and is driven from the V-pulley at the end of the crankshaft by a V-belt.
The type of alternator used in this engine is ideal for high speed engines with a wide range of engine speeds. It contains diodes that convert AC to DC, and an IC regulator that keep the generated voltage constant even when the engine speed changes.

4-11.1 Features

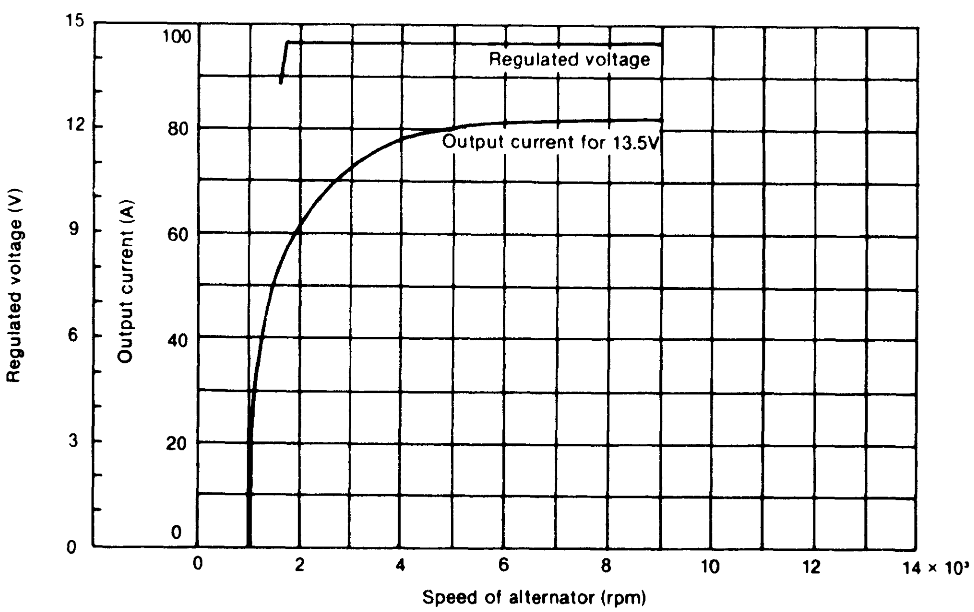
The alternator contains a regulator using an IC, and has the following features.

(1) The IC regulator is self-contained, and has no moving parts (mechanical contact points). It therefore has superior features such as freedom from vibration, no fluctuation of voltage during use, and no need for readjustment.
Also, it is of the over-heating compensation type and can automatically adjust the voltage to the most suitable level depending on the operating temperature.
(2) The regulator is integrated within the alternator to simplify external wiring.
(3) It is an alternator designed for compactness, lightness of weight, and high output.
(4) A newly developed U-shaped diode is used to provide increased reliability and easier checking and maintenance.
(5) As the alternator is to be installed on board, the following measures are taken to provide salt-proofing.
1) The front and rear covers are salt-proofed.
2) Salt-proof paint is applied to the diode.
3) The terminal, where the inboard harness is connected to the alternator, is nickel plated.

4-11.2 Specifications

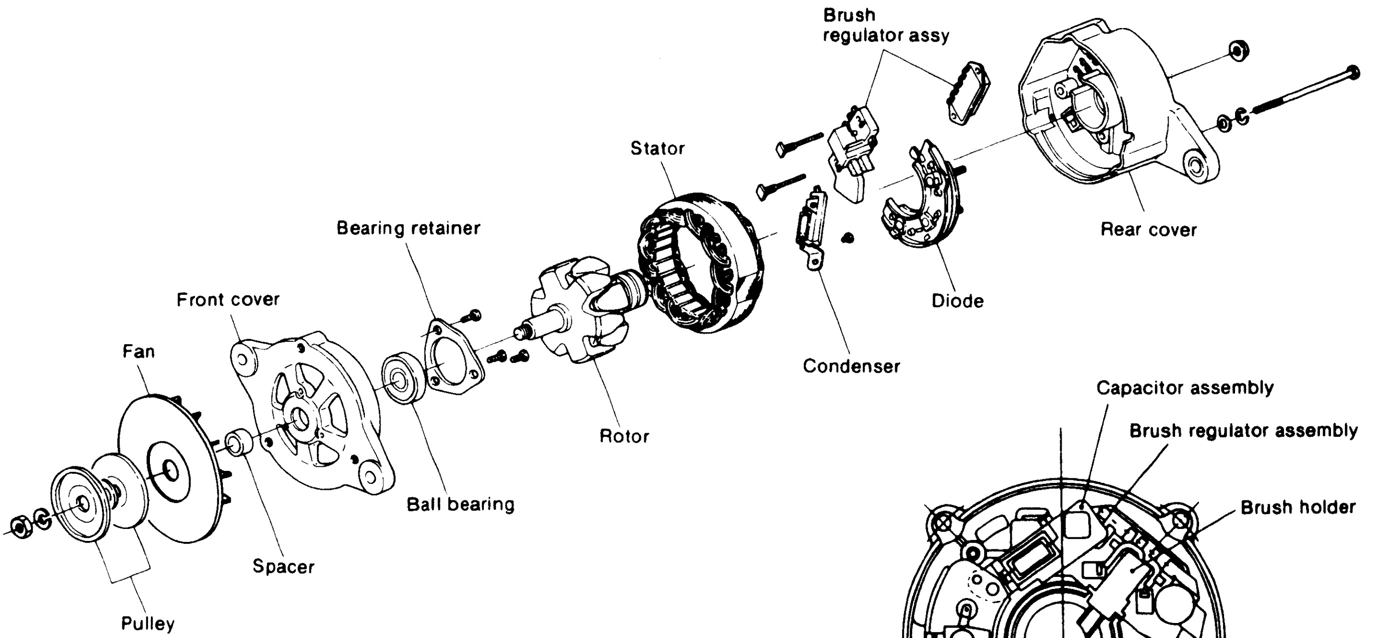
Model of alternator	LR180-03 (HITACHI)
Model of IC regulator	TRIZ-63 (HITACHI)
Battery voltage	12V
Nominal output	12V/80A
Earth polarity	Negative earth (⊖)
Direction of rotation (viewed from pulley end)	Clockwise
Mass	5.8kg
Rated speed	5000 rpm
Operating speed	1000 ∿ 9000
Speed for 13.5V	1000 or less
Output current at 20°C	over 78A/5000 rpm
Regulated voltage	14.5 ±0.3V (Standard temperature voltage gradient, −0.01/°C)

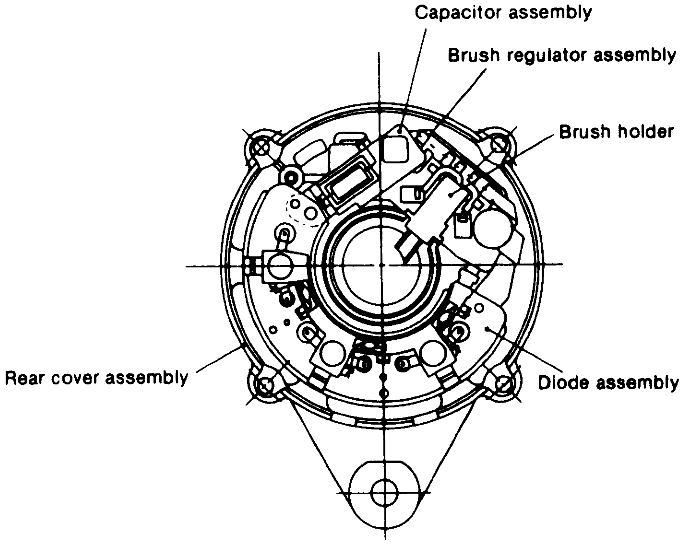
4-11.3 Characteristics

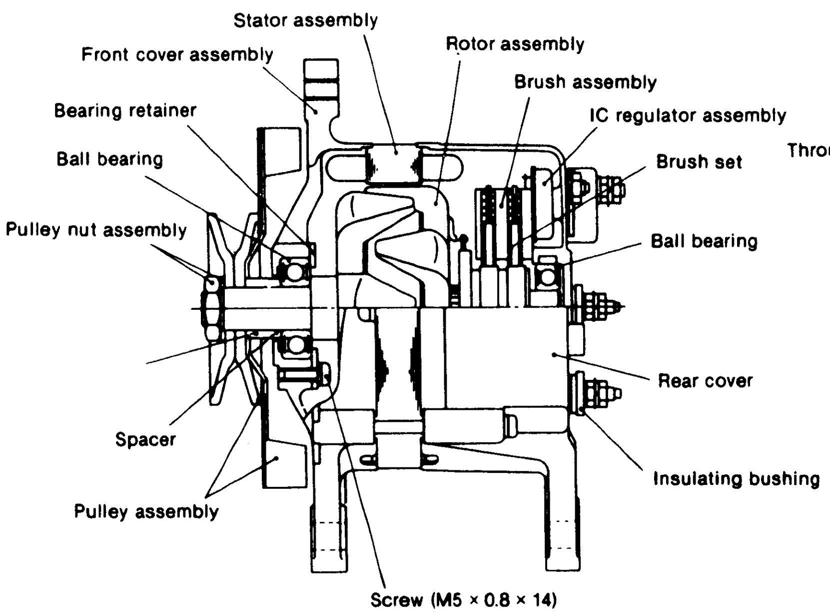


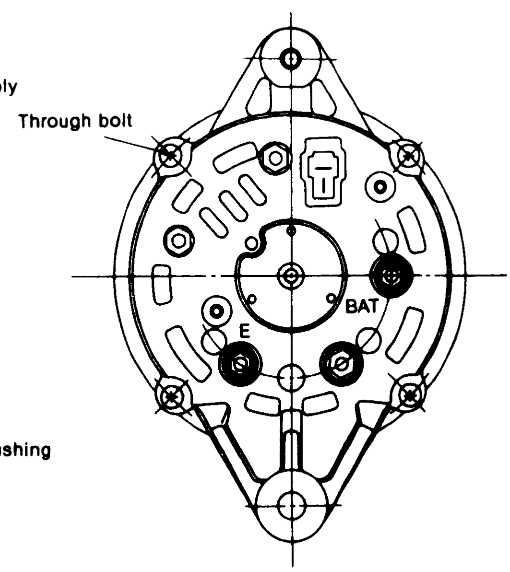
4-11.4 Construction

This is a standard rotating field type three-phase alternator. It consists of six major parts: the pulley, fan, front cover, rotor, stator and rear cover. The IC regulator is an integral part of the alternator.









4-11.5 Alternator functioning

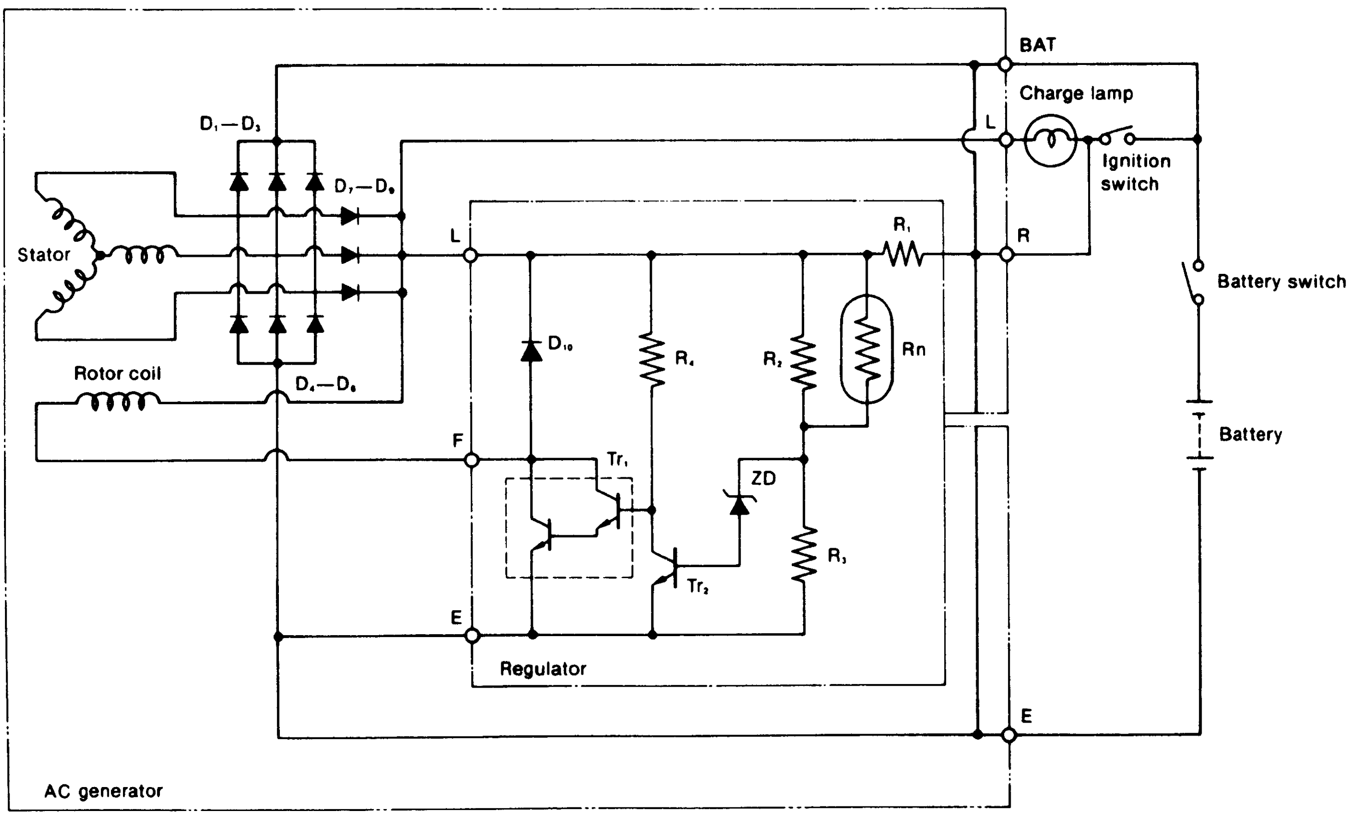
(1) IC regulator
The IC regulator is the transistor (Tr_1) which is series-connected with the rotor. The IC regulator controls the output voltage of the generator by breaking or conducting the rotor coil (exciting) current.
When the output voltage of the generator is within the standard value, the transistor (Tr_1) turns on. When the voltage exceeds the standard value, the Zener diode goes on and the transistor (Tr_1) turns off.
With the repeated turning on and off of the transistor, the output voltage is kept at the standard value. (Refer to the circuit diagram below.)

(2) Charge lamp
When the transistor (Tr_1) is on, the charge lamp key switch is turned to ON, and current flows to R_1, R_4 and to Tr_1 to light the lamp. When the engine starts to run and output voltage is generated in the stator coil, the current stops flowing to this circuit, turning off the charge lamp.

(3) Circuit diagram

4-11.6 Handling precautions

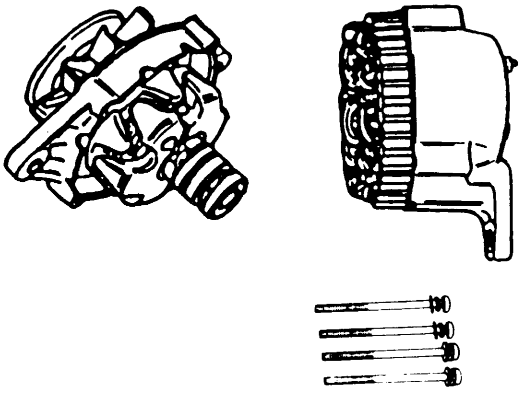
(1) Be careful of the battery's polarity (+, − terminals), and do not connect the wrong terminals to the wrong cables, or the battery will be short-circuited by the generator diode.
In this case too much current will flow, the IC regulator and diodes burn out, and the wire harness will burn.
(2) Make sure of the correct connection of each terminal.
(3) When quick-charging, etc., disconnect either the battery terminal on the AC generator or the terminal on the battery.
(4) Do not short-circuit the terminals.
(5) Do not conduct any tests using high tension insulation resistance. (The diodes and IC regulator will burn out.)



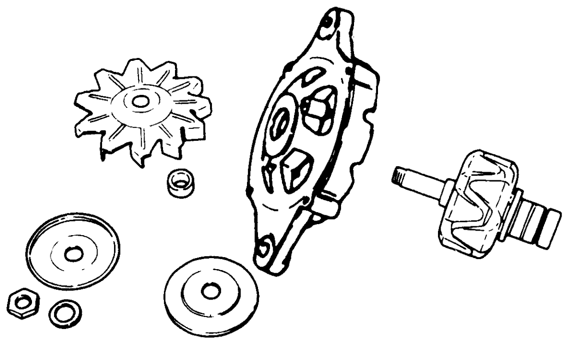
BAT:	Generator output terminal	D_1—D_6:	Output commutation diode
D_{10}:	IC protecting diode	R_1—R_4:	Resistor
L:	Charge lamp terminal	D_7—D_9:	Charging lamp switching diode
ZD:	Zener diode	F:	To supply current to rotor coil
E:	Earth	Rn:	Thermistor (Temperature gradient resistance)
Tr_1, Tr_2:	Transistor		

4-11.7 Disassembling the alternator

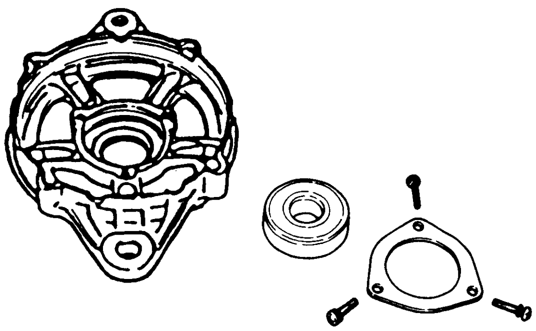
(1) Remove the through-bolt, and separate the front assembly from the rear assembly.



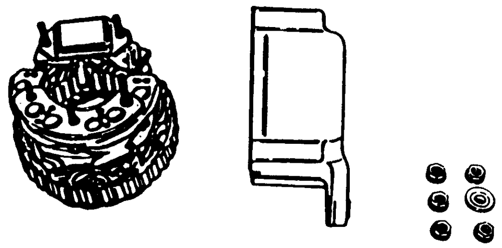
(2) Remove the pulley nut, and pull out the rotor from the front cover.



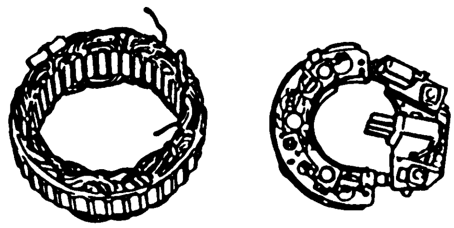
(3) Remove the ø5mm (ø0.1969in.) screw from the front cover, and then remove the ball bearing.



(4) Remove the nut, the brush-holder, and diode fixing nut at the BAT, and the terminal screws of the rear cover. Separate the rear cover from the stator (with the diode and brush holder).

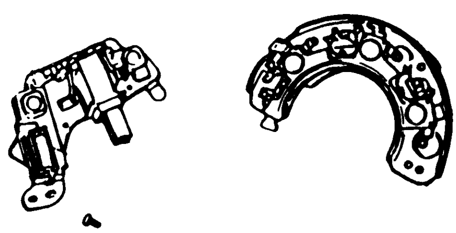


(5) Disconnect the soldered joint of the stator lead wire, and remove the diode and brush regulator assemblies from the stator at the same time.

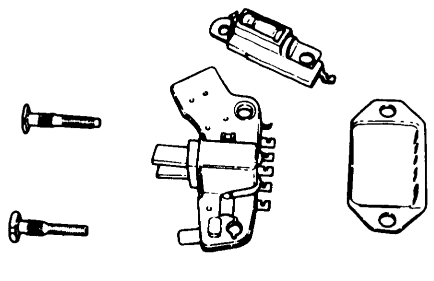


(6) Separating the regulator

1) To separate the regulator, remove the ø3mm (ø0.1181in.) rivet which keeps the diode assembly and the brushless regulator in place, and the soldered joint of the L-terminal.



2) To replace the IC regulator, disconnect the soldered joint of the IC regulator and pull out the two bolts. Do not remove these two bolts except when replacing the IC regulator.

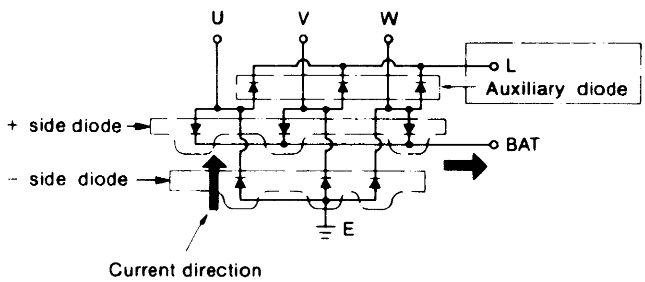


4-11.8 Inspection and adjustment

(1) Diode

Between terminals		BAT (+ side diode)	
	Tester wire	+ side	− side
U.V.W.	+ side		No continuity
	− side	Continuity	

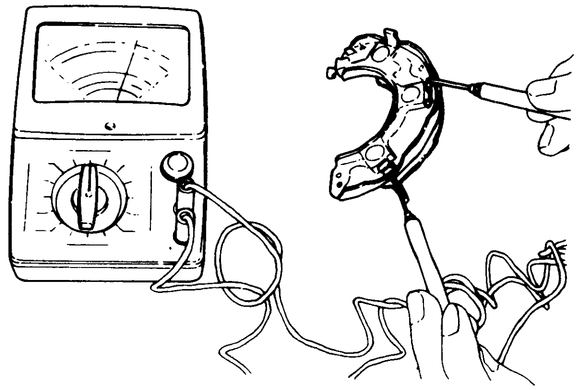
Between terminals		E (− side diode)	
	Tester wire	+ side	− side
U.V.W.	+ side		Continuity
	− side	No continuity	



U.V.W.: terminal from the stator coil

Current flows only in one direction in the diode as shown in Fig. 181. Accordingly, when there is continuity between each terminal (e.g. BAT and U), the diode is in normal condition. When there is no continuity, the diode is defective.
When the tester is connected in the reverse of above, there should be no continuity. If there is, the diode is defective.

After repeating the above test, if any diode is found to be defective, replace the diode assembly. Since there is no terminal on the auxiliary diode, check the continuity between both ends of the diode.



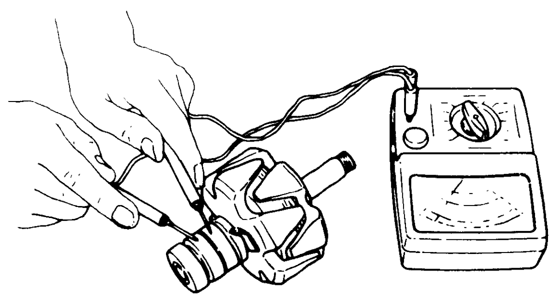
CAUTION: Do not use high tensile insulation resistance such as meggers, etc. for testing. The diode may burn out.

(2) Rotor
Inspect the slip ring surface, rotor coil continuity and insulation.

1) Inspecting the slip ring surface
Check if the surface of the slip ring is sufficiently smooth. If the surface is rough, grind the surface with No. 500—600 sand paper. If it is contaminated with oil, etc., wipe the surface clean with alcohol.

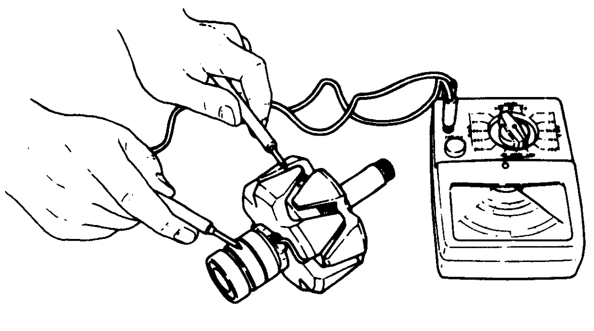
	Standard	Wear limit
Slip ring outer dia.	ø31.6mm (1.2441in.)	ø30.6mm (1.2049in.)

2) Rotor coil continuity test
Check the continuity in the slip ring with the tester. If there is no continuity, there is a wire break. Replace the rotor coil.

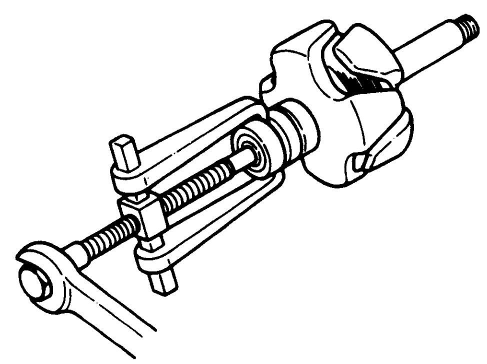


Resistance value	Approx. 2.58Ω at 20° C

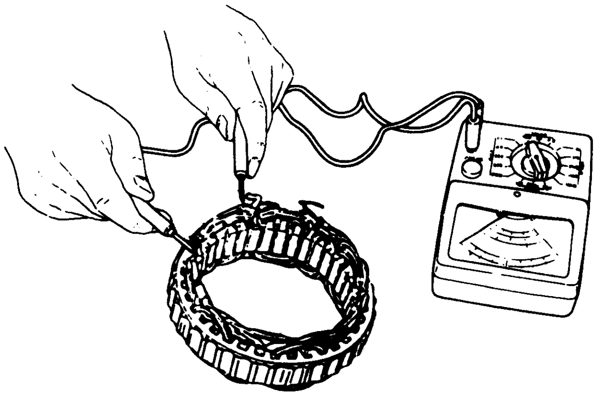
3) Rotor coil insulation test
Check the continuity between the slip ring and the rotor core, or the shaft. If there is continuity, insulation inside the rotor is defective, causing a short with the earth circuit. Replace the rotor coil.



4) Check the rear side ball bearing. If the rotation of the bearing is heavy, or produces abnormal sounds, replace the ball bearing.

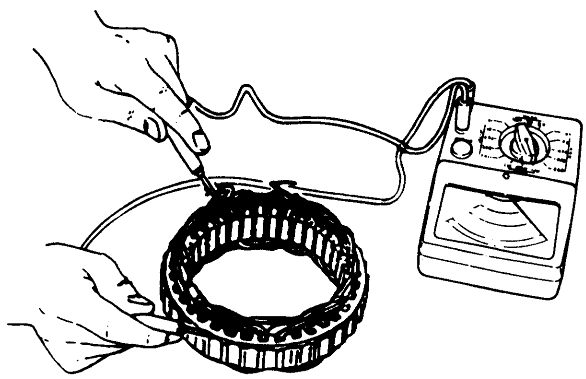


(3) Stator
1) Stator coil continuity test
Check the continuity between each terminal of the stator coil. If there is no continuity, there is a wire break in the stator coil. Replace the stator coil.

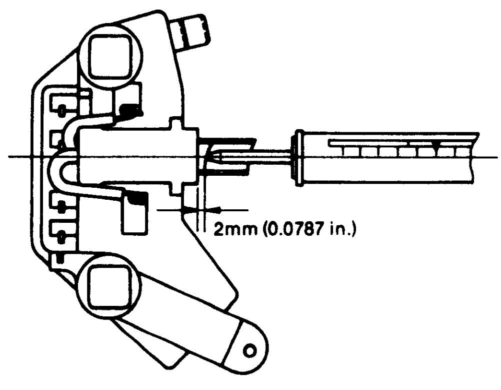


Resistance value	Approx. 0.041Ω at 20°C u, v-phase resistance
	Approx. 0.036Ω at 20°C w-phase resistance

2) Stator coil insulation test
Check the continuity between the terminals and the stator core. If there is continuity, insulation of the stator coil is defective. This will cause a short-circuit with the earth core. Replace the stator coil.

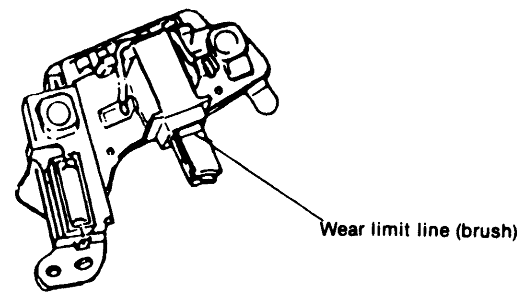


(4) Brush
The brush is hard and wears slowly, but when it is worn beyond the allowable limit, replace it. When replacing the brush, also check the strength of the brush spring. To check, push the spring down to 2mm (0.0787in.) from the end surface of the brush holder, and read the gauge.



Brush spring strength	2.50–3.38 (0.255 ~ 0.345)N(kgf)

(5) Brush wear
Check the brush length.
The brush wears very little, but replace the brush if worn over the wear limit line printed on the brush.



mm (in.)

	Maintenance standard	Wear limit
Brush length	16 (0.6299)	9 (0.3543)

(6) IC regulator

Connect the variable resistance, two 12V batteries, resistor, and voltmeter as shown in the diagram.

1) Use the following measuring devices.

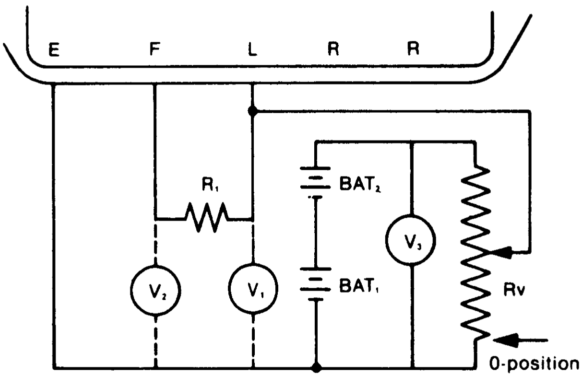
Resistor (R_1)	100Ω, 2W, 1pc.
Variable resistor (Rv)	0—300Ω, 12W, 1pc.
Battery (BAT_1, BAT_2)	12V, 2pcs.
DC voltmeter	0—30V, 0.5 class 1pc. (measure at 3 points)

2) Check the regulator in the following sequence, according to the diagram.

a) Check V_3 (BAT_1 + BAT_2 voltage). If the voltage is 20—26V, both BAT_1 and BAT_2 are normal.

b) While measuring V_2 (F-E terminal voltage), move Rv gradually from the 0-position. Check if there is a point where the V_2 voltage rises sharply from below 2.0V to over 2.0V. If there is no such point, the regulator is defective. Replace the regulator. If there is a sharp voltage rise when testing, return the Rv to the 0-position, and connect the voltmeter to the V_1 position.

c) While measuring V_1 (voltage between L-E terminals), move Rv gradually from the 0-position. There should be a point where the voltage of V_1 rises sharply by 2—6V. Measure the voltage of V_1 just before this sharp voltage rise. This is the regulating voltage of the regulator. If this voltage of V_1 is within the standard limit, the regulator is normal. If the voltage deviates from the limit, the regulator is defective. Replace the regulator.



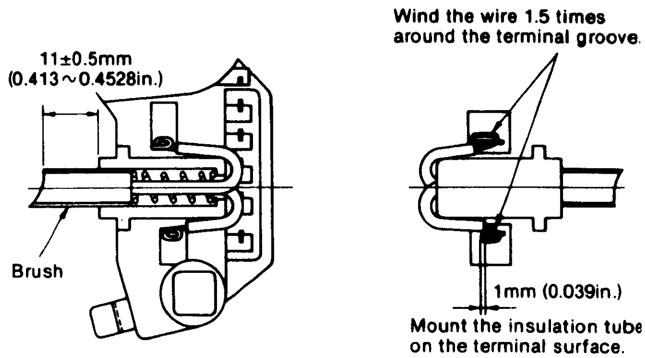
4-11.9 Reassembling the alternator

Reassembly is done in the reverse order of disassembly. For reassembly, be careful of the following points. (Refer to 4—7 disassembling alternator).

(1) Assembling the brush regulator

1) Solder the brush.

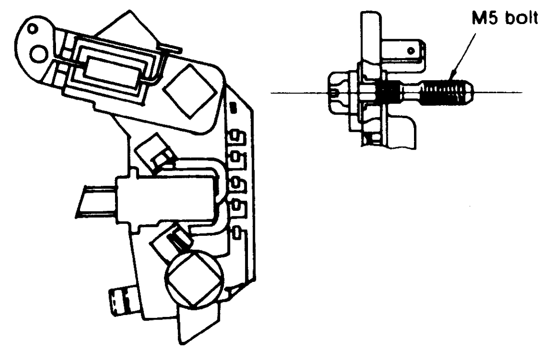
Position the brush as shown in the drawing and solder it. Be careful not to let the solder drip into the pig tail (lead wire).



NOTES: 1. Use non-acid type paste.
2. The soldering iron temperature is 300 ~ 350°C.

2) Mount the IC regulator on the brush holder as illustrated, and press in the M5 bolt. Do not forget to assemble the bushing and the connecting plate at the same time.

(If the bushing is left out, the output terminal will be earthed and the battery short-circuited).



NOTES: 1. Insertion pressure is 981 (100) N(kgf)
2. Insert vertically.

(2) Connecting the brush regulator assembly and diode

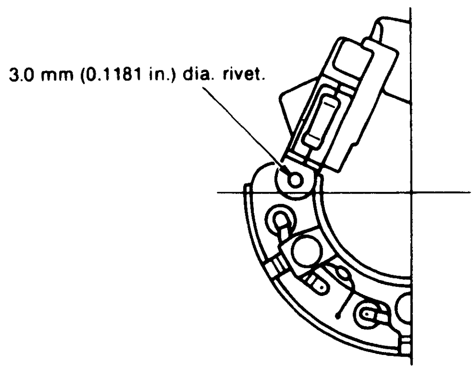
1) Check the rivets

Place the rivets as shown in the figure, and then calk them using the calking tool.

Calking force	4903 (500)N(kgf)

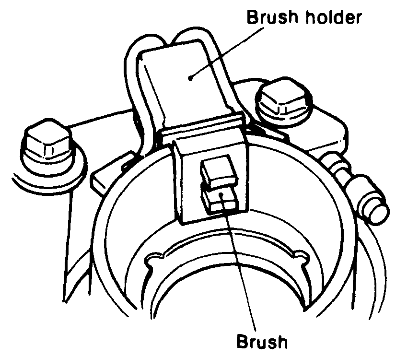
2) Connect the brush to the diode.

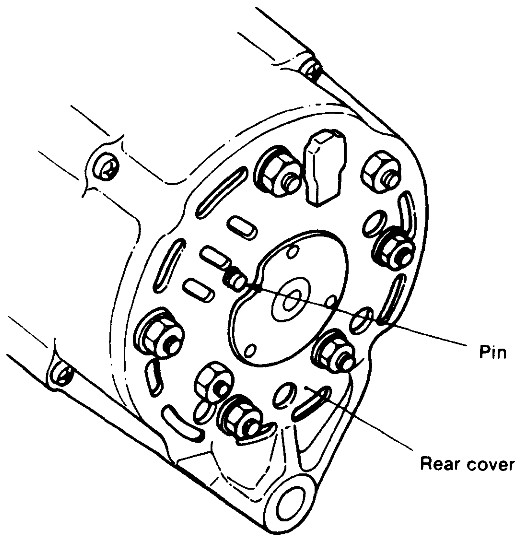
Insert the brush side terminal into the diode terminal, calk it, and then solder into place.



Rivetting pressure	4903(500)N(kgf)

(3) Assembling the rear cover
Insert pins from the outside of the rear cover. Install the brush on the brush holder, then attach the rear cover. After assembly, pull out the pins.

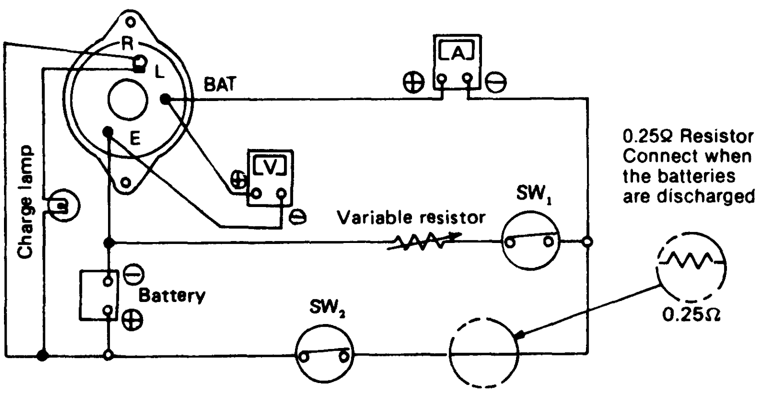




(4) Tightening torques

Positions	Tightening torque N(kgf)·cm
Brush holder fixing	314–392 (32 ~ 40)
Diode fixing	588–686 (60 ~ 70)
Bearing retainer fixing	314–392 (32 ~ 40)
Pulley nut tightening	3923–5884 (400 ~ 600)
Through-bolt tightening	314–392 (32 ~ 40)

4-11.10 Performance test
Conduct a performance test on the reassembled AC generator as follows. The following is the circuit for the performance test.



(1) Measuring devices

DC voltmeter	0—15V or 0—30V, 0.5 Class, 1pc.
DC ammeter	0—100A, 1.0 Class, 1pc.
Variable resistor	0—0.25Ω, 1kW, 1pc.
Lamp	12V, 3W
100Ω resistor	3W
0.25Ω resistor	25W

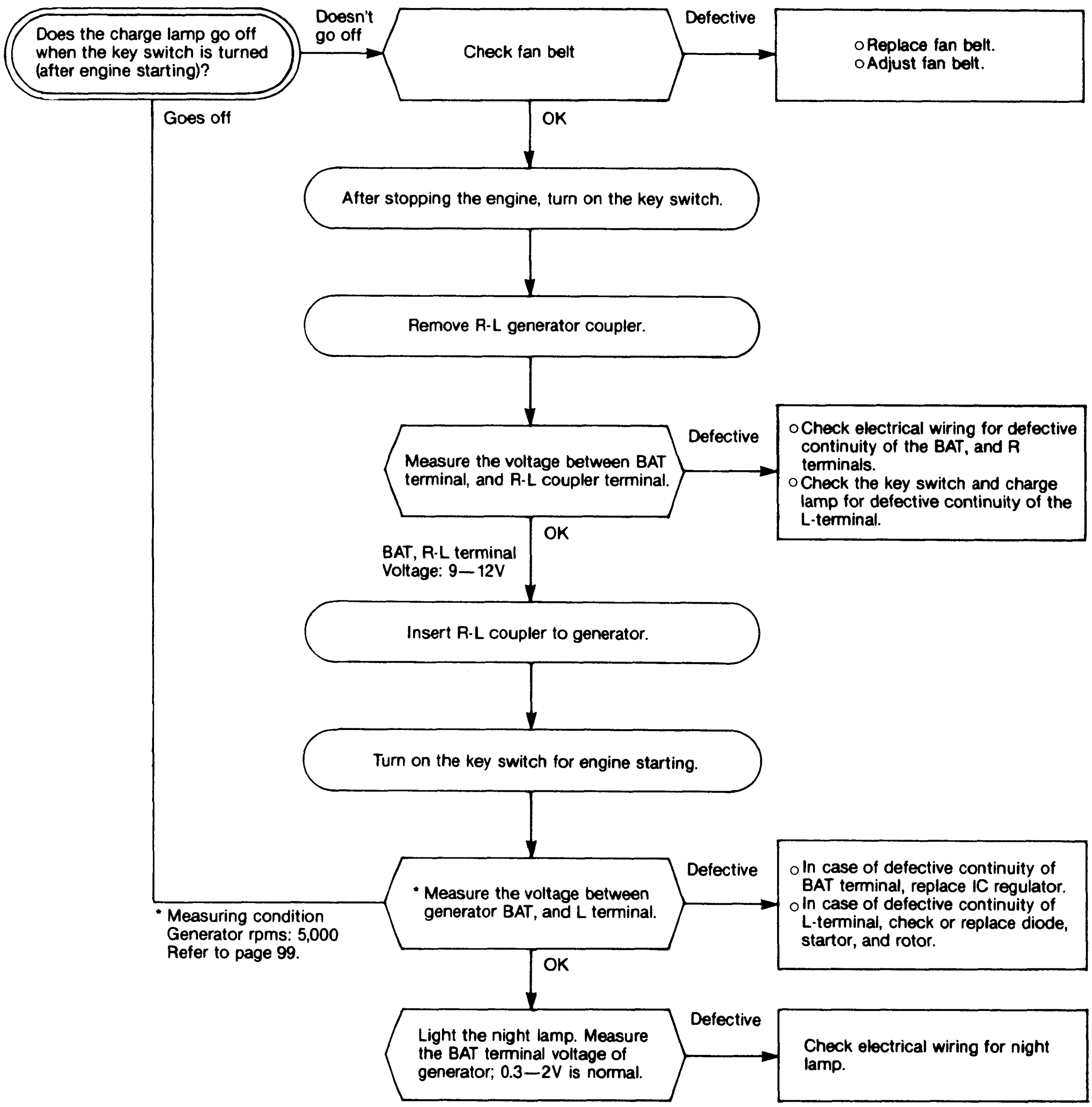
(2) Measuring the regulating voltage
1) When measuring devices are connected in the performance test circuit as shown above, the charge lamp lights.
2) Close SW_2 while keeping SW_1 open and run the AC generator. When the revolutions of the generator are gradually raised, the charge lamp goes off.
3) Raise the revolutions of the AC generator, and read the voltmeter gauge when the revolutions reach about 5,000 rpms.

NOTES: 1. Make sure that the ammeter indication at this time is less than 5A. If the indication is over 5A, connect the 0.25Ω resistor. The voltmeter indication at this time must be within the prescribed regulating voltage value.
2. Raise the AC generator revolutions high to make sure the regulating voltage does not fluctuate along with changes in the revolution speed.

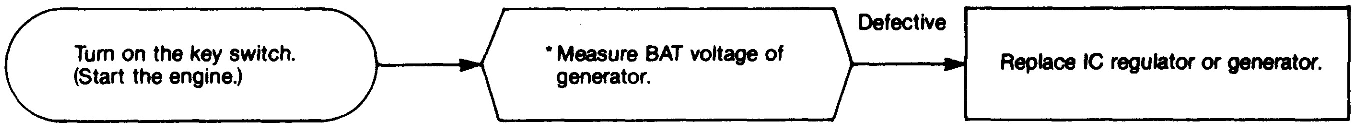
(3) Precautions for measuring the regulating voltage
1) When measuring the voltage, measure the voltage between the AC generator BAT terminal, or Battery + terminal, and AC generator E-terminal.
2) Use a fully charged battery.
3) Measure the voltage quickly.
4) Keep SW_1 open for measurement.

4-12 Troubleshooting

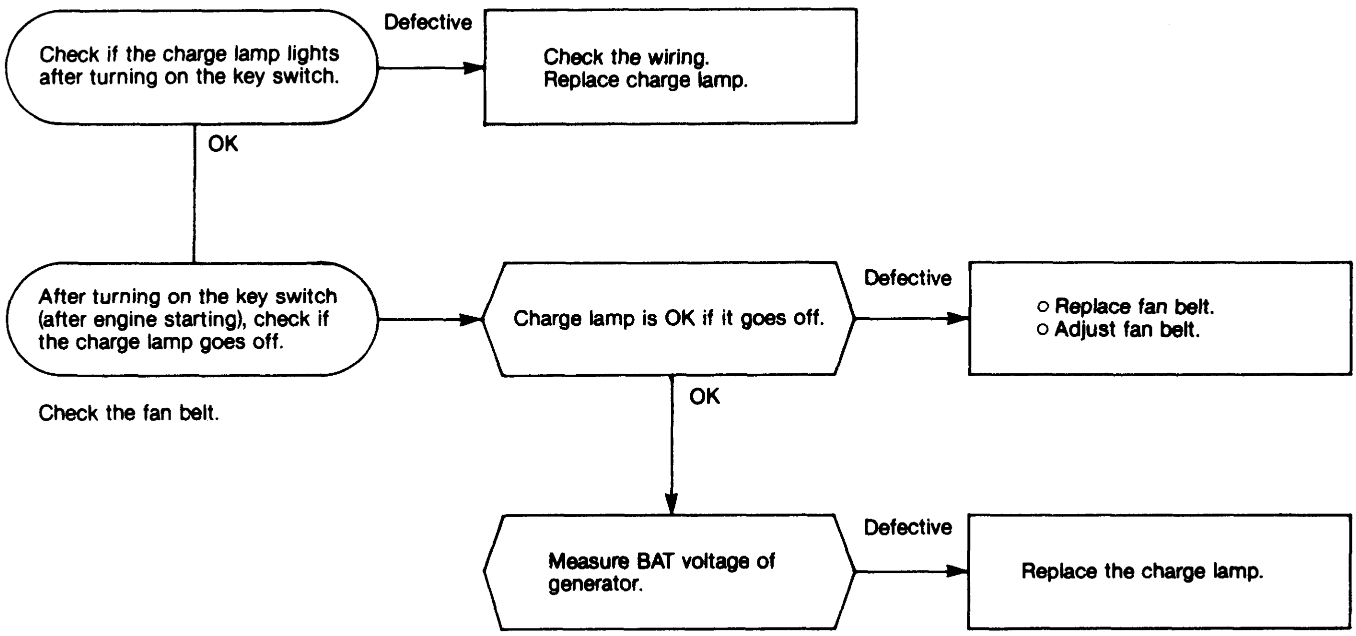
(1) Charging failure



(2) Overcharging

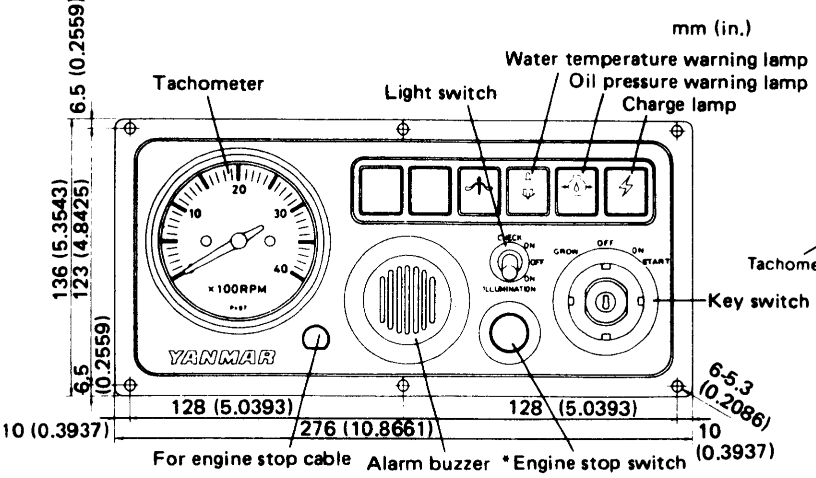


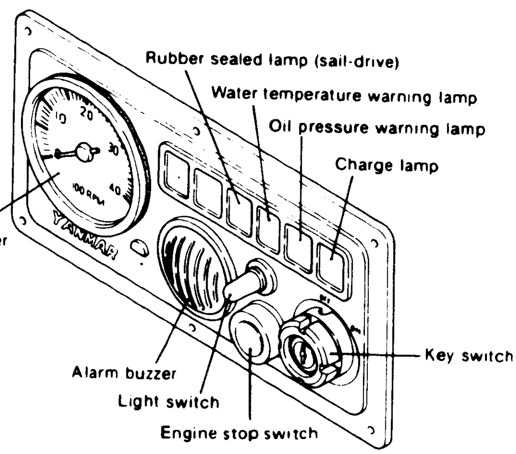
(3) Charge lamp failure



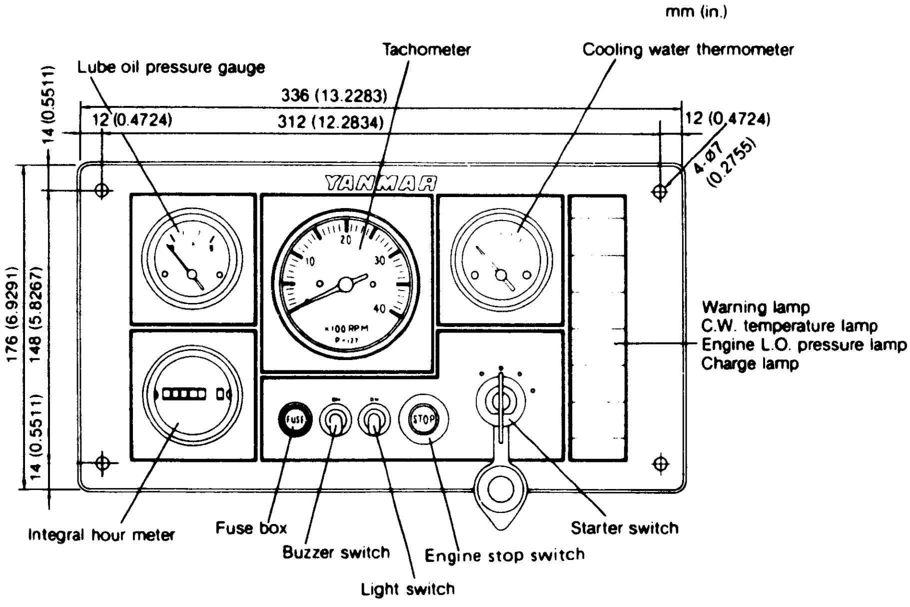
5. Instrument Panel

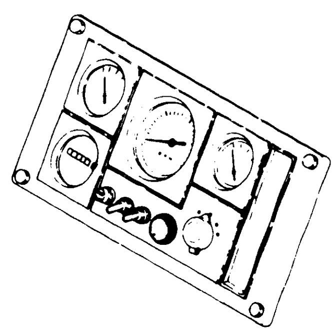
5-1 B2-type instrument panel with wiring



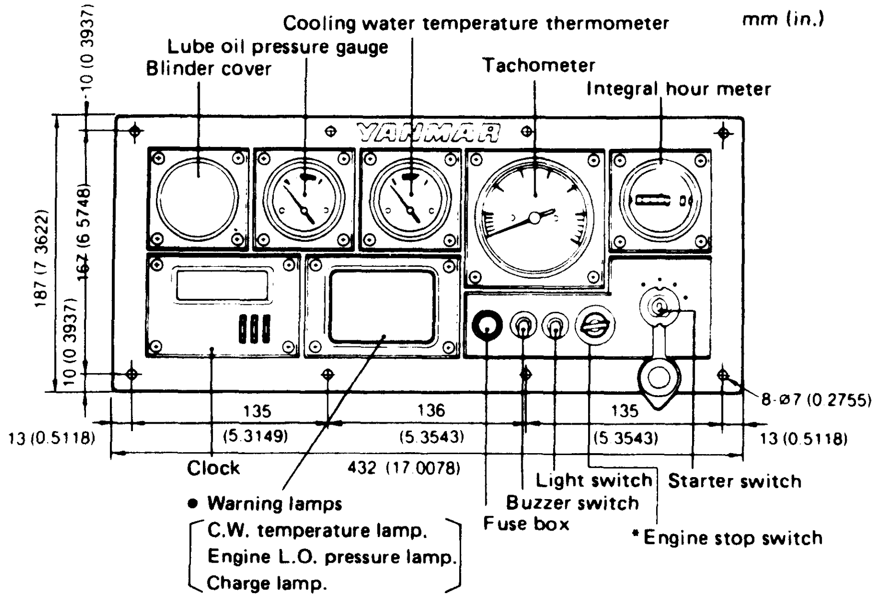


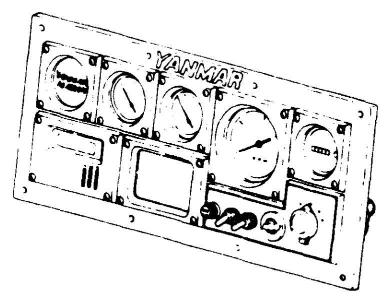
5-2 C-type instrument panel



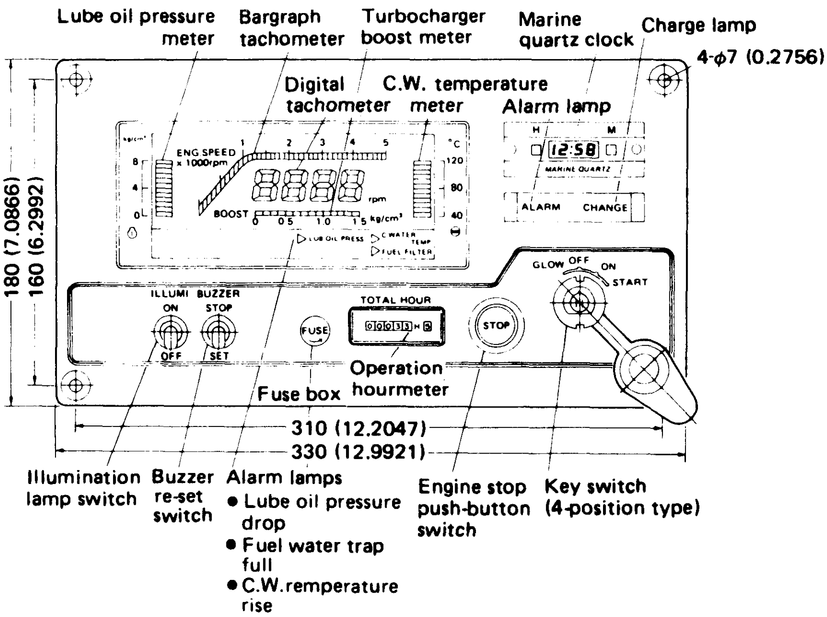


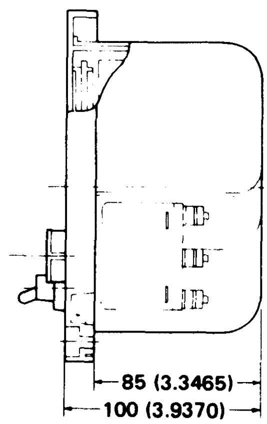
5-3 D-type instrument panel





5-4 E-type instrument panel

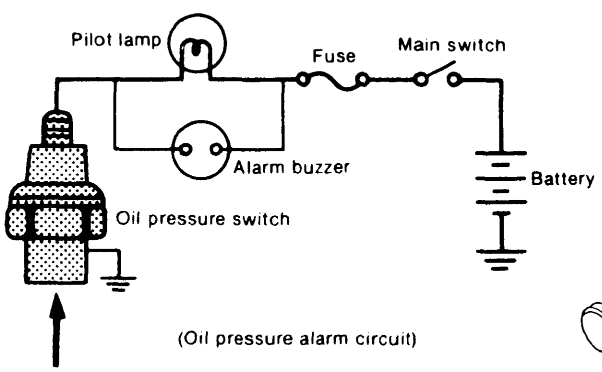




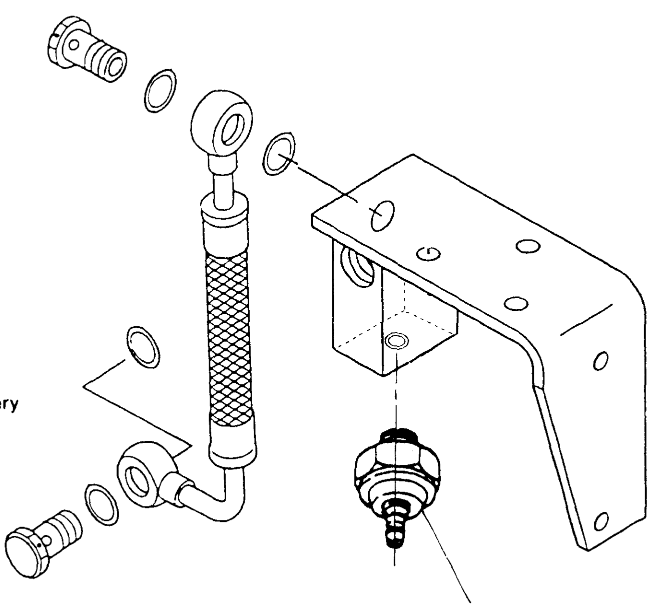
6. Warning Devices

6-1 Oil pressure alarm

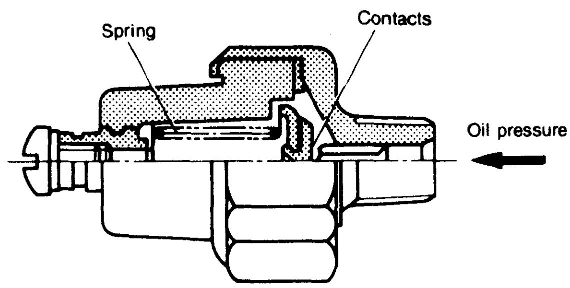
If the engine oil pressure is below 0.0098 ~ 0.0294 (0.1 ~ 0.3) MPa (kgf/cm²), with the main switch in the ON position, the contacts of the oil pressure switch are closed by a spring, and the lamp is illuminated through lamp → oil pressure switch → ground circuit system. If the oil pressure is normal, the switch contacts are opened by the lubricating oil pressure and the lamp remains off.



(Oil pressure alarm circuit)



Oil pressure switch



Part No.	124060-39451
Rated voltage	12V
Operation pressure	0.0098~0.0294(0.1~0.3)MPa(kgf/cm²)
Lamp capacity	5W

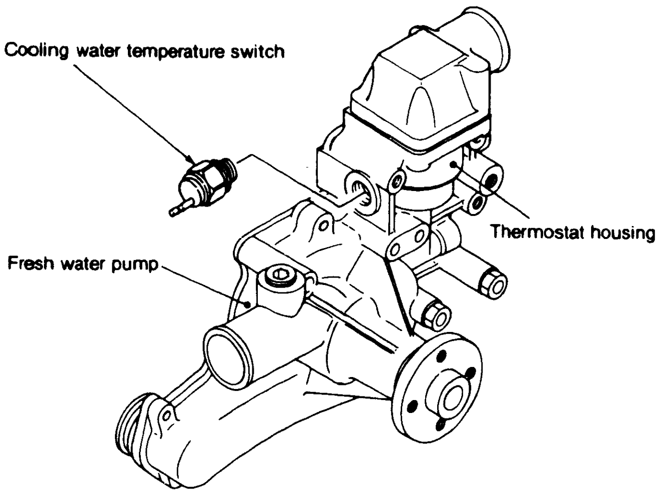
Inspection

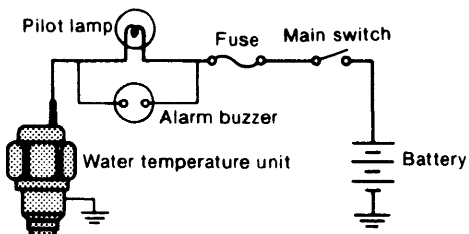
Problem	Inspection item	Inspection method	Corrective action
Lamp not illuminated when main switch set to ON	1. Oil pressure lamp blown out	(1) Visual inspection (2) Lamp not illuminated even when main switch set to ON position and terminals of oil pressure switch grounded	Replace lamp
	2. Operation of oil pressure switch	Lamp illuminated when checked as described in (2) above	Replace oil pressure switch
Lamp not extinguished while engine running	1. Oil level low	Stop engine and check oil level with dipstick	Add oil
	2. Oil pressure low	Measure oil pressure	Repair bearing wear and adjust regulator valve
	3. Oil pressure faulty	Switch faulty if abnormal at (1) and (2) above	Replace oil pressure switch
	4. Wiring between lamp and oil pressure switch faulty	Cut the wiring between the lamp and switch and wire with separate wire	Repair wiring harness

6-2 Cooling water temperature alarm

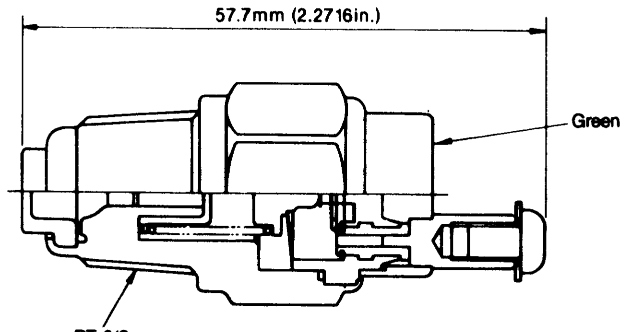
A water temperature lamp and water temperature gauge, backed up by an alarm in the instrument panel, are used to monitor the temperature of the engine cooling water. A high thermal expansion material is set on the end of the water temperature unit. When the cooling water temperature reaches a specified high temperature, the contacts are closed, and an alarm lamp and buzzer are activated at the instrument panel.

Operating temperature	ON	93 ~ 97°C (199 ~ 206°F)
	OFF	88°C (190°F) or high
Electric capacity		DC 12V, 1A
Response time		with in 60 sec.
Indication color		Green
Part code No.		127610-91350
Tightening torque		23.5~31.4(2.4~3.2)N(kgf)·m



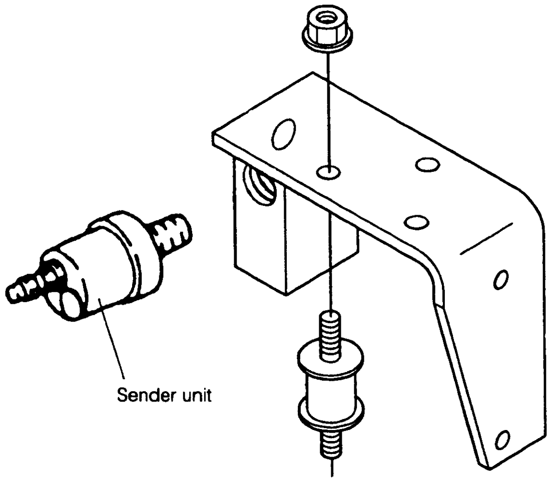


(Water temperature alarm circuit)

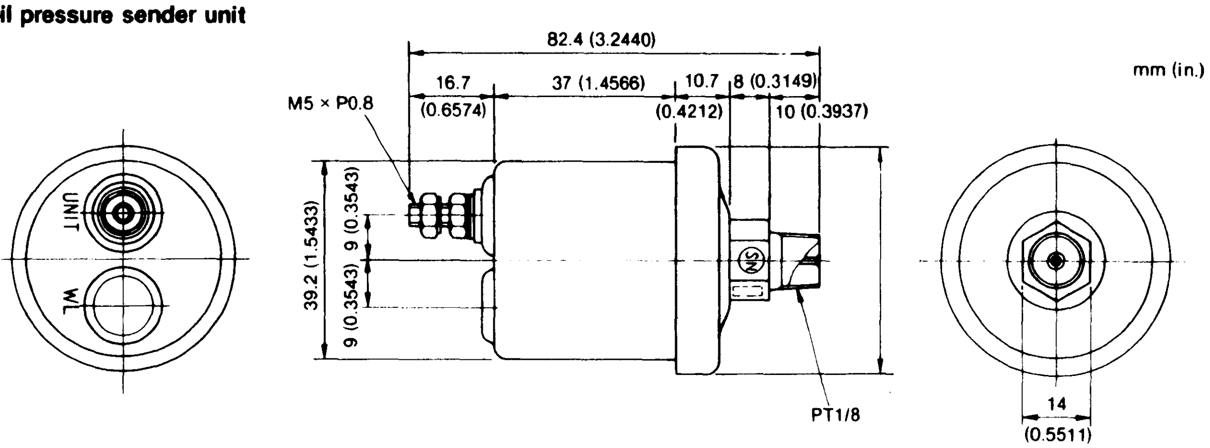


6-3 Sender unit for lube oil pressure gauge

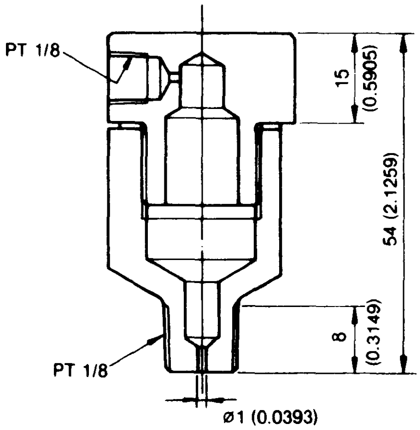
Oil pressure is measured when the oil enters into the main gallery after being fed from the lube oil cooler and passing through oil pressure control valve. Make sure to mount a vibration damper when mounting the oil pressure sender unit.



Lube oil pressure sender unit



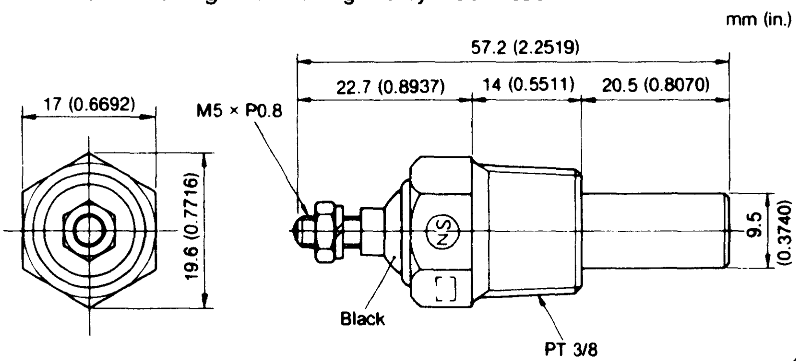
Damper

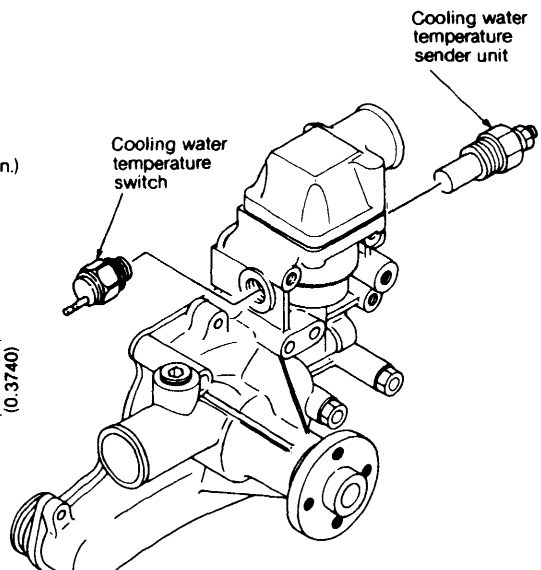


Type	Resistance switch
Rated voltage	DC 12/DC 24
Max. operating pressure	0.78 (8) MPa (kgf/cm²)
Part code No.	144626-91560

6-4 Sender unit for the cooling water temperature gauge

The water temperature sender unit has a mounting seat for mounting on the fresh water pump unit. Water temperature is measured when the cooling water flows into the thermostat housing after leaving the cylinder head.



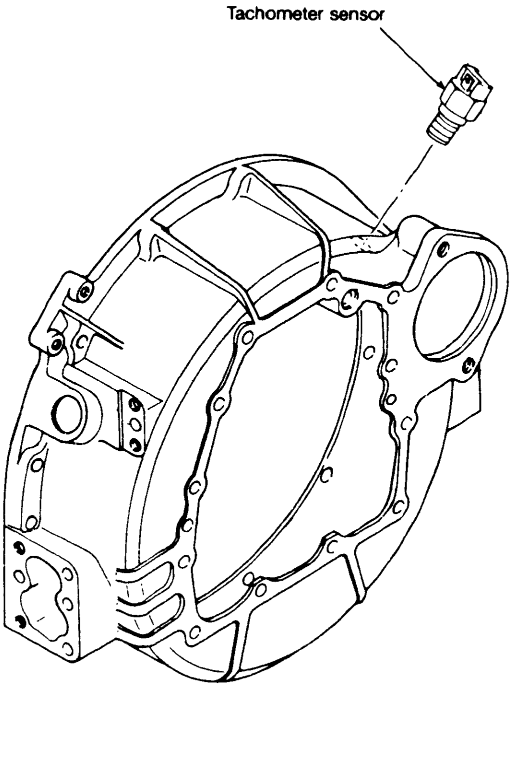


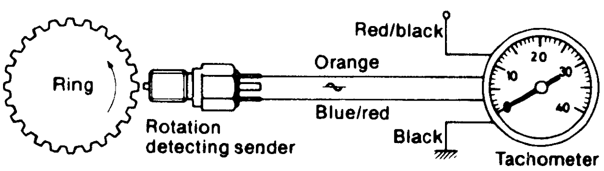
Type	Thermistor switch
Rated voltage	12V/24V
Part code No.	144626-91570

7. Tachometer

7-1 Construction of tachometer

The tachometer indicates the number of revolutions per minute by means of an electrical input signal which is generated as a pulse signal from the magnetic pickup sender (MPU sender).
The function of the sender is to convert the rotary motion into an electrical signal by means of counting the number of teeth of the ring gear connecting with the flywheel housing.



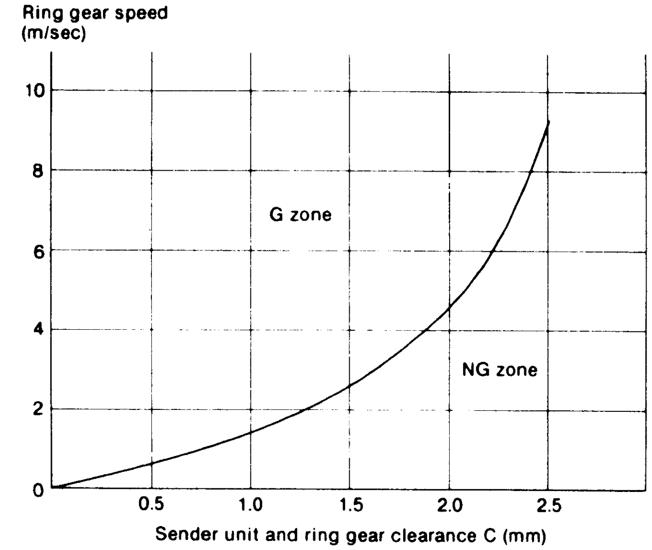


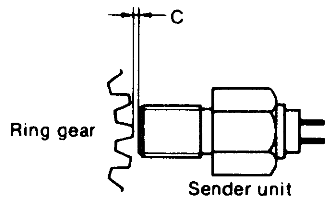
7-2 Specifications and dimensions of tachometer

(1) Specifications

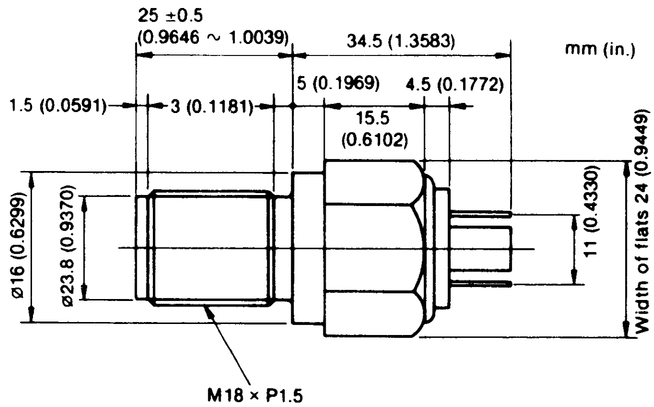
Rated voltage		DC 12V
Range of operating voltage		10 ~ 15V
Illumination		3.4W/12V
Ring gear	No. of teeth	127
	Module	2.54
Part No. of tachometer		120130-91200 (128696-91100)
Part No. of sender unit		128170-91160

(2) Sensitivity limit of sender unit

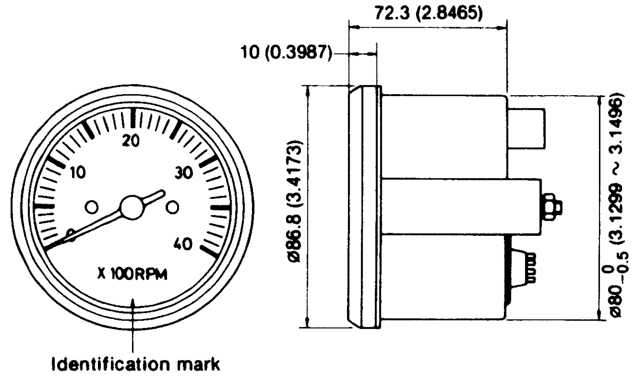




(3) Dimensions of sender unit



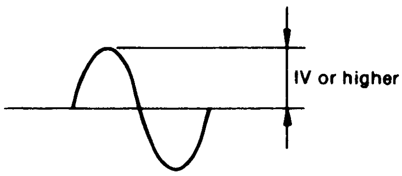
(4) Dimensions and shape of tachometer



7-3 Measurement of sensor unit characteristics

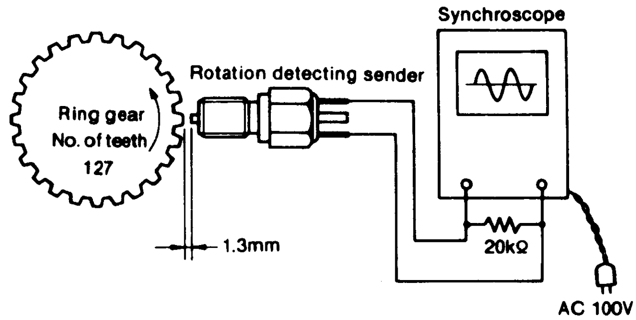
(1) Measurement of output voltage

Output voltage	1.0V or higher



Measuring conditions

Number of teeth of ring gear	127
Gap between the ring gear and sender	1.3mm (0.0511 in.)
Resistance	20kΩ
Speed of ring gear	500 rpm (approx. 800Hz)
Measuring temperature	20°C (68°F)
Measuring instrument	Synchroscope

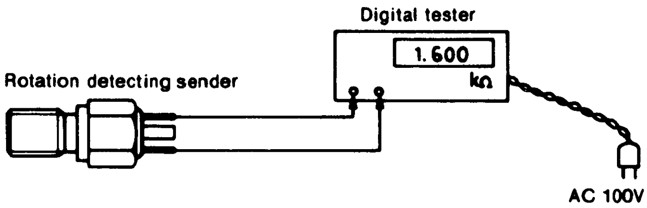


* Check the output wave pattern and number of pulses when carrying out the output voltage measurement.

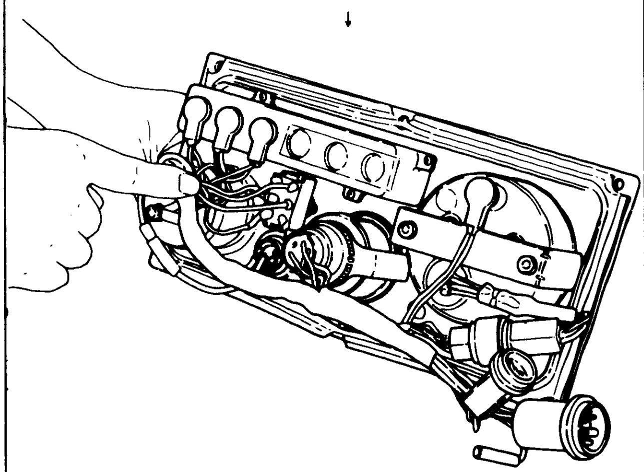
(2) Measurement of internal resistance

Measuring conditions

Measuring temperature	20°C (68°F)
Measuring instrument	Digital tester



7-4

Fault	Diagnosis	Remedy
Does not function well. 1) Pointer does not move. 2) Functions intermittently.	Check if there is an open-circuit cable connection at the rear of the meter, a loose or disconnected terminal, or bad continuity due to corrosion. ↓ 	Yes Make good the connection.
	Disconnect at the instrument terminals, and measure the voltage between the cable terminals. (To be 10 ~ 16V) ↓ Satisfactory	No If the input voltage is abnormal, check the cause. (e.g. short-circuit, disconnection, or blown fuse, etc.)

	Check if the sender is loosely fitted. ↓ No	Yes Fix the sender securely.
	Measure the internal resistance of the sender. (To be 1.6 ±0.1kΩ at 20°C) ↓	No Replace the sender.
	Measure the output voltage of the sender. (To be 1V or higher at 20°C)	No Replace the sender.

YANMAR INDUSTRIAL DIESEL ENGINE

MODEL 4LHA-STE/STZE/STP/STZP
4LHA-DTE/DTZE/DTP/DTZP
4LHA-HTE/HTZE/HTP/HTZP

SERVICE MANUAL

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