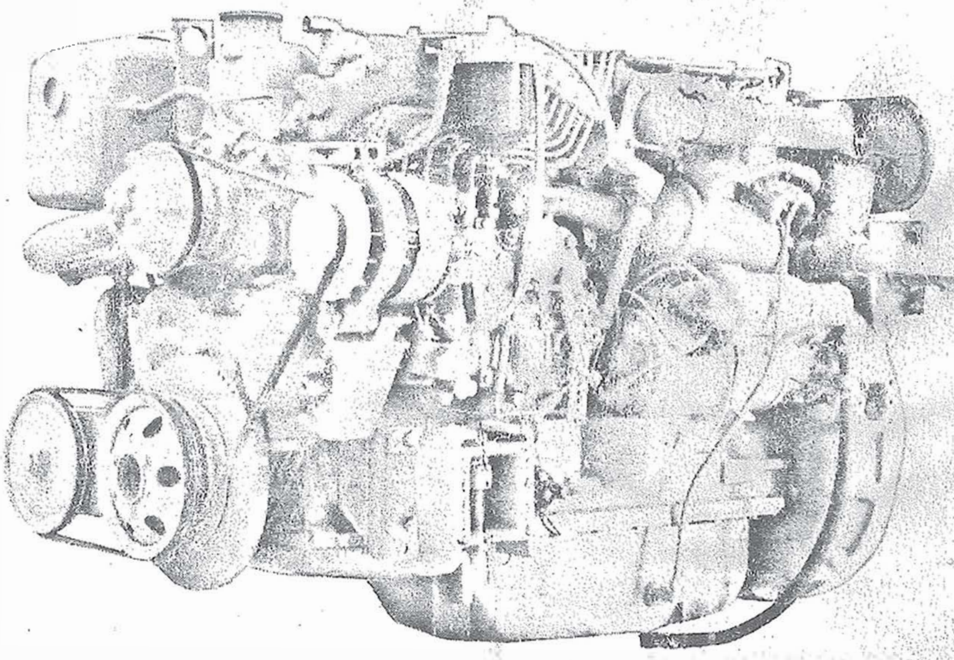
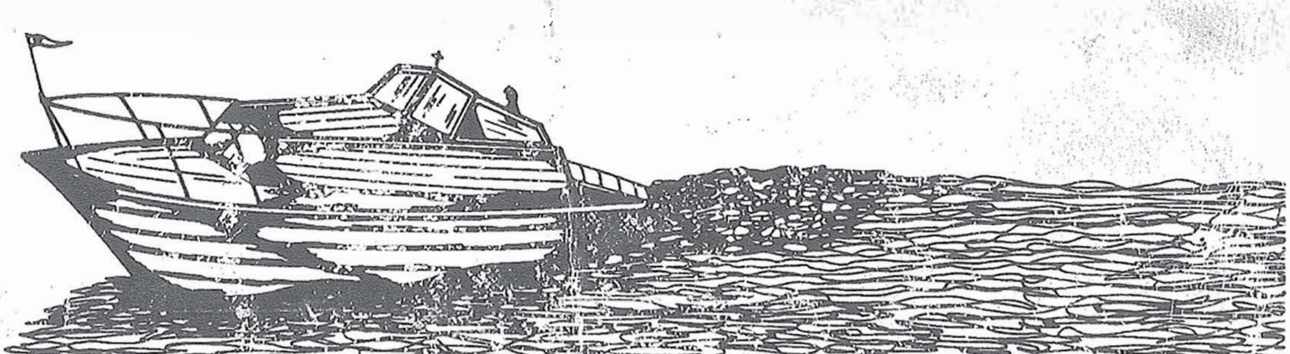
Chrysler Marine
CM655 Naturally Aspirated

CM655 Turbocharged

Diesel Service Manual





CM655 N.A., T.I.

MAR 119

Notes:
Upper Engine Gasket and Seal Set
Part # 4142149

Lower Engine Gasket and Seal Set
Part # 4142150

Section 1

INTRODUCTION

CONTENTS

email: partsdz@gmail.com
Phone: 269 673 2128 (leave message)

Section 1

INTRODUCTION

GENERAL

This manual provides the technician with information and instructions for operating and maintaining the Chrysler CM655 Naturally Aspirated (NA) and the CM655 Turbocharged (TI) Diesel Engines. In addition to this manual the boat manufacturers manual should be followed closely for modifications that may be made for this application. Whenever a question arises regarding this engine or this publication, write to:

Marine Division, Chrysler Corporation
Publication Manager
105 N. Marine Drive
Hartford, Wisconsin 53027

The information, specifications and illustrations in this publication are based on information in effect at the time this manual was printed. Continued improvement and advancement of product design may cause changes which may not be included in this manual. Each publication is reviewed and revised, as required, in an effort to update and include these changes in other editions.

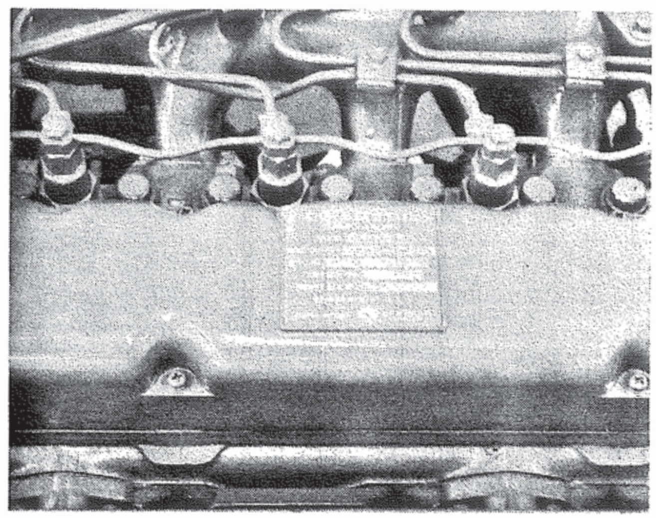


Figure 1. Nameplate.

The specification number, unit serial number and engine serial number must be used in any correspondence to correctly identify the unit. The engine serial number is also stamped on the left side of the engine block beneath the starter motor. Figure 2.

GENERAL INFORMATION

Engine Identification. Figure 1 shows the nameplate attached to the valve cover.

Chrysler Diesel Marine Engine Model CM655-TI III Max. Output, 200 H.P. @ 3150 RPM Spec. No. CM655DWLX-168 Unit Ser. No. E532125 Engine Ser. No. 6DS7-195106T Beaver Dam, WI

Nameplate Information

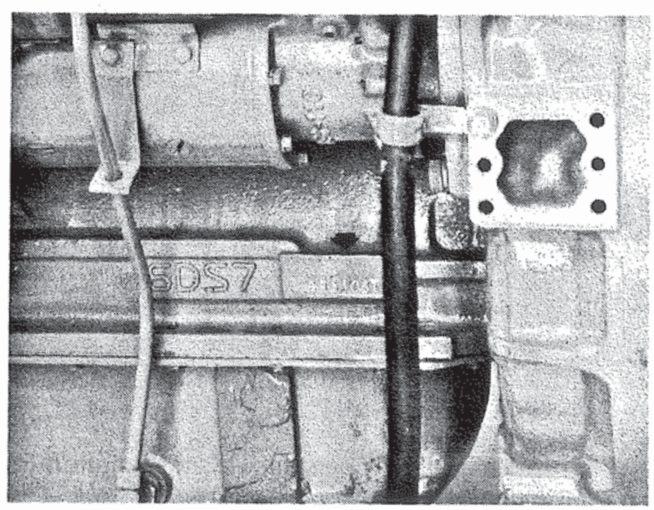


Figure 2. Engine Serial Number.

CHRYSLER MARINE DIESEL ENGINE SPECIFICATION SYSTEM

CM 6 55 B W L 10 103

- CM — CHRYSLER MARINE DIESEL
- 6 — NO. OF CYLINDERS
- 55 — DISPLACEMENT PER CYLINDERS
- 103 — ENGINEERING SPECIFICATION NUMBER

10 — REDUCTION: X-NO GEAR
10 - 1:1 DIRECT DRIVE
15 - 1.5:1 REDUCTION
19 - 1.9:1 REDUCTION*
20 - 2.0:1 REDUCTION
21 - 2.1:1 REDUCTION
25 - 2.5:1 REDUCTION
30 - 3.0:1 REDUCTION
37 - 3.7:1 REDUCTION
45 - 4.5:1 REDUCTION

INBOARD/OUTBOARD RATIOS

16 - 1.6:1 RATIO
18 - 1.89:1 RATIO
21 - 2.15:1 RATIO

L — PROPELLER SHAFT ROTATION: R - RIGHT HAND
L - LEFT HAND

W —
X - NOT APPLICABLE
W - WARNER DRIVE (HYDRAULIC)
N - PARAGON DRIVE (HYDRAULIC)
D - DANA DRIVE 90
V - VEE DRIVE
R - PARAGON MANUAL DRIVE
T - VOLVO OUTDRIVE
M - NISSAN HYD. LIGHT DUTY
P - NISSAN HYD. HEAVY DUTY (MVW & MVWR)
H - TWIN DISC
C - CHRYSLER STERN DRIVE

B — INJECTION PUMP: A-TYPE B PUMP-BOSCH TYPE
B-TYPE A PUMP-BOSCH TYPE
C-TYPE DPA PUMP-C.A.V.
D-TURBOCHARGED B PUMP-BOSCH TYPE

* (Warner Gear) 1.9:1 Gear has reverse rotation front input end to output end.

Section 2

ENGINE SPECIFICATIONS

CONTENTS

email: partsdz@gmail.com
Phone: 269 673 2128
(leave message)

Section 2

ENGINE SPECIFICATIONS

Engine Description. The Chrysler Marine CM655 Series Engine is available in naturally aspirated (NA) and turbocharged (TI) versions. Both are built around the same base engine of 331 cu. in. (5430 cc). Pre-combustion chamber design is used for fuel economy and quiet operation. Both engines are fresh water cooled.

The turbocharged version has intercooling between the turbocharger and intake manifold for increased engine life. A new wet turbocharger (TW) is also in use.

Chrysler Marine Diesel Model CM655-TI

Type — 6 cylinder, 4 cycle diesel turbocharged-intercooled. Indirect injection, pre-combustion chambers with glow plugs.

Horsepower Gross Rating	200 @ 3150 RPM (60° F, 29.92" Hg.)
Maximum High Idle (no load)	3400 RPM
Cruising RPM	2700-2800 RPM
Bore	3.858 in. (98mm)
Stroke	4.724 in. (120mm)
Displacement	331 cu. in. (5430cc)
Compression Ratio	19:1
Firing Order	1-5-3-6-2-4
Turbo Boost Pressure	8-13 PSI (0.55 - 0.91 kg/cm²) @ 3150 — Full load
Weight	1695 lbs. (770 kg.) w/Warner 72, 1.1 Drive

CAPACITIES

Lubricating Oil	
Level Installation	9 qts.* (8.53 L.)
15° Installation	8 qts.* (7.58 L.)
	* Add 1 qt. (1 liter) for filter change.
Coolant	
Fresh water	5 gal. (19 L.) (closed system)

ELECTRICAL SYSTEM

12 volt negative ground
12 volt 55 amp alternator
Glow plugs — 60 amp
Shut down — 30 amp

MARINE TRAMSMISSIONS	**RATIOS**
Warner Velvet Drive Model 10-18 & Model 72C	
Left Hand Rotation	1.0:1, 1.52:1, 2.10:1
Right Hand Rotation	1.91:1
Model 10-14	
Right & Left Hand	1.58:1, 2.03:1
Model 10-05 V-Drive	1.01:1, 1.5:1
Twin Disc Model MG502	
Right & Left Hand	1.54:1, 2.0:1

Chrysler Marine Diesel Model CM655-NA

Type — 6 cylinder, 4 cycle diesel, indirect injection, pre-combustion chambers with glow plugs

Horsepower Gross Rating	130 @ 3150 RPM
Maximum High Idle No Load	3400 RPM
Cruising RPM	2700-2800 RPM
Bore	3.858 in. (98mm)
Stroke	4.724 in. (120mm)
Displacement	331 cu. in. (5430cc)
Compression Ratio	19.0:1
Firing Order	1-5-3-6-2-4

CAPACITIES

Lubricating Oil		
Level Installation	9 qts.* (8.53 L.)
15° Installation	8 qts.* (7.58 L.)
	* Add 1 qt. (1 liter) for filter change.
Coolant		
Fresh Water	5 gal. (19 L.) (closed system)

ELECTRICAL SYSTEM

12 volt, negative ground
Alternator — 12 volt 55 amp
Glow Plugs — 60 amp
Shut down — 30 amp

MARINE TRAMSMISSIONS	RATIOS
Warner Velvet Drive Model 71C & 72C (10-17 & 10-18)	
Left Hand Rotation	1.0:1, 1.52:1, 2.10:1, 2.57:1, 2.91:1
Right Hand Rotation	1.91:1
Model 10-13	
Right & Left Hand	1.58:1, 2.03:1, 2.47:1, 2.93:1
"V" Drive 10-05	
Right & Left Hand	1:1, 1.5:1, 1.2:1, 2.5:1
Twin Disc Model MG502	
Right & Left Hand	1.54:1, 2.0:1, 2.47:1
Model PV-400 Left Hand	
Rotation Only	1.0:1, 1.5:1, 2.0:1, 2.5:1

FUEL & LUBRICANTS

Fuel Selection. Clean fresh fuel should be used at all times. Poor quality fuel reduces engine output and contaminates engine oil.

CAUTION

Fuel system and/or engine failure due to dirt or water in fuel is not covered under warranty.

No. 2 diesel fuel with a minimum cetane rating of 45 is recommended. If No. 2 diesel fuel is not available, No. 1 is acceptable

Engine Oil. Engine oil must conform to API (American Petroleum Institute) classification **"Service CD" for naturally aspirated engine; "Service CD" for turbocharged engine.** Correct engine oil viscosity (grade) is important, refer to Table 1.

Ambient Temp.	32°-50° F (0°-10°C)	50°F & Up (10°C & Up)
SAE Grade	SAE 30	SAE 40

Table 1.

Cooling System. Fresh water cooling (closed system) is protected by a 50/50 mix of permanent antifreeze and clean soft water providing protection to -20° F (-29° C). Permanent antifreeze with rust inhibitors must be used, **alcohol based antifreeze is not acceptable.**

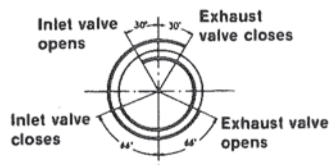
ENGINE DESIGN SPECIFICATIONS

1. Engine proper	Valve location		Overhead
	Cylinder liner		Wet type
	No. of piston ring	Compression ring	2
		Oil ring	1 (with expander)
	Valve timing	Intake valve opens	30° B.T.D.C.
		Intake valve closes	66° A.B.D.C.
		Exhaust valve opens	66° B.B.D.C.
		Exhaust valve closes	30° A.T.D.C.
2. Oil system	Lubrication method		Forced lubrication, gear pump
	Oil capacity		See pages 9 & 10
	Engine oil pressure	At speed	3 to 5 kg/cm² (43-71 p.s.i.)
		Idling	1.5 to 3.0 kg/cm² (21-42 p.s.i.)
	Oil pump	Type	Gear pump
		Ratio	1/2 (Rotation ratio against crankshaft)
		Volume	32 lit./min./1,000 RPM or more. [Pump oil temperature 50° C and oil pressure 3 kg/cm² (42 p.s.i.)]
	Oil filter		Full flow type, filter paper element used
	Relief valve	Type	Piston valve type
		Valve opening pressure	4.0 kg/cm² (57 p.s.i.)
	Oil bypass alarm	Type	Piston valve type with built-in contact
		Valve opening pressure	2.0 to 2.3 kg/cm² (28-33 p.s.i.)
	Oil cooler		Water cooled type

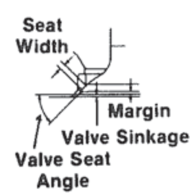
Continued.

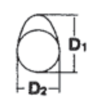
ENGINE DESIGN SPECIFICATIONS (CONT.)

3. Fuel system	Feed pump	Model	Bosch model ND-EP/KS22AC
		Manufactuer	Nippondenso Co., Ltd.
		Cam lift	6 mm. (.23 in.)
	Injection pump	Model	Bosch model ND-PES6A80B
		Manufacturer	Nippondenso Co., Ltd.
		Plunger diameter	8.0 mm. (.31 in.)
		Cam lift	8.0 mm. (.31 in.)
	Fuel injection timing		17° B.T.D.C. (without delivery valve) 15° B.T.D.C. (with delivery valve)
	Governor	Speed adjusting system	Minimum and maximum speeds All speed
		Manufacturer	Nippondenso Co., Ltd.
	Automatic timer	Model	ND-EP/SCZ
		Manufacturer	Nippondenso Co., Ltd.
		Type	Mechanical type
		Advance characteristics	Mechanical governor: Advance angle 7.5°/500 to 1,600 RPM Pneumatic governor: Advance angle 7°/500 to 1,550 RPM
	Injection nozzle	Manufacturer	Nippondenso Co., Ltd.
		Holder type	Bosch type ND-KD58SD
		Tip type	Throttle type ND-DN4SD
		Nozzle diameter	Single 0.8 mm. (.31 in.)
		Spray angle	4°
		Injection pressure	120 + 10 kg/cm² (1700 p.s.i. + 140 p.s.i.)
	Fuel filter		Filter paper element used
4. Cooling system	Water volume	Engine water jacket etc.	
		Total	20 lit. (5 gal.)
	Water pump	Type	Centrifugal type
		Ratio	1.25/1 (Rotation ratio against crankshaft)
		Capacity	100 lit. (26.4 gal.)/min. at 3,000 RPM (Pump)

Item				Nominal value	Assembly Standard	Limit of repair	Limit of use	Remedy	Remarks
Performance	No-load maximum speed			3,350 to 3,400 RPM (RSV governor)				Inspect and adjust governor	
Performance	Miniumum speed			580 to 620 RPM					
Performance	Compression pressure			26 kg/cm^2 (369.81 p.s.i.) or more (at 200 RPM)		Not sufficient if 20 kg/cm^2 (284.47 p.s.i.) or less		Refer to "Trouble shooting"	Both oil and water temperature at 20 to 30° C (68-86° F) Difference in pressure between cylinders must be less than 4 kg/cm^2 (56.89 p.s.i.)
Performance	Engine oil pressure			3 to 4 kg/cm^2 (42.67 to 56.89 p.s.i.) or more at 1,200 RPM. 1.5 kg/cm^2 (21.33 p.s.i.) or more at idling speed		Not sufficient if 2 kg/cm^2 (28.45 p.s.i.) or less Not sufficient if 0.5 kg/cm^2 (7.11 p.s.i.)or less			Oil temperature at 70° C (158° F)
Performance	Valve timing			See illus. at right	± 1° (Crankshaft angle)				
Performance	Fuel injection timing			17° B.T.D.C.	± 1° (Crankshaft angle)				Without delivery valve
Main moving parts	Cylinder liner	I.D.	Size mark A	98ϕ (3.8583"ϕ)	0 to +0.011 (0 to +.0004")	+0.30 (+.0118")	+1.20 (+.0473")	Rebore and hone cylinder to +0.50, +0.75, +1.00. (+.0197", +.0296", +.0394")	Liner and piston should be selected to fit with each other. Use same oversize parts for all 6 cylinders. Measure liner I.D. at position 90 mm. (3.5433") below top
Main moving parts	Cylinder liner	I.D.	Size mark B		+0.011 to +0.023 (+.0004 to +.0008")				
Main moving parts	Cylinder liner	I.D.	Size mark C		+0.023 to +0.035 (+.0008 to +.0014")				
Main moving parts	Cylinder liner	Roundness			0.02 or less (.0008")				
Main moving parts	Cylinder liner	Cylindricity			0.02 or less (.0008")				
Main moving parts	Cylinder liner	Projection above block top surface			0.11 to 0.20 (.0043 to .0079")				
Main moving parts	Piston	O.D.	Size mark A	98ϕ (3.8583"ϕ)	-0.126 to -0.135 (-.0049 to -.0051")				Measure across piston pin axis at position 77.3 mm. (3.0433") below top of piston.
Main moving parts	Piston	O.D.	Size mark B		-0.115 to -0.125 (-.0045 to -.0049")				
Main moving parts	Piston	O.D.	Size mark C		-0.105 to -0.114 (-.0039 to -.0045")				
Main moving parts	Clearance between piston ring and groove	Top ring		3 (.1181")	0.04 to 0.08 (.0157 to .0315")		0.20 (.0079")	Replace piston rings.	
Main moving parts	Clearance between piston ring and groove	2nd ring		2 (.0787")	0.025 to 0.065 (.0098 to .0295")		0.15 (.0059")		
Main moving parts	Clearance between piston ring and groove	Oil ring		5 (.1968")	0.025 to 0.065 (.0098 to .0295")		0.15 (.0059")		
Main moving parts	Piston ring side clearance	Top ring		3 (.1181")	0.3 to 0.5 (.0118 to .0197")		1.5 (.0591")	Replace only rings up to limit of use and thereafter replace piston if wear limit is exceeded.	Replace oil ring together with expander spring set.
Main moving parts	Piston ring side clearance	2nd ring		2 (.0787")	0.3 to 0.5 (.0118 to .0197")		1.5 (.0591")		
Main moving parts	Piston ring side clearance	Oil ring		5 (.1968")	0.3 to 0.5 (.0118 to .0197")		1.5 (.0591")		
Main moving parts	Piston ring side clearance	When free	Top ring		Approx. 12.5 (.4921")				
Main moving parts	Piston ring side clearance	When free	2nd ring						

Item				Nominal value	Assembly Standard	Limit of repair	Limit of use	Remedy	Remarks
Main moving parts	Ring end gap	When placed in 98+0ϕ (3.8583") gauge	Top ring		0.3 to 0.5 (.0118 to .0197")		1.5 (.0591")		If gauge is not available, gap can be measured by inserting ring in new cylinder liner.
			2nd ring						
			Oil ring						
	Piston Pin	Clearance between piston pin bore and piston pin		32ϕ (1.2598"ϕ)	0 to 0.017 (0 to .0005")	0.05 (.0020")	-0.03" (-.762mm) piston pin O.D.	Replace piston pin up to limit of repair. Replace piston if limit is exceeded.	
		Clearance between piston pin and connecting rod small end bushing		32ϕ (1.2598"ϕ)	0.020 to 0.052 (.0008 to .0020")	0.10 (.0039")	-0.03" (-.762mm) piston pin O.D.	Replace piston pin or bushing (Ream bushing if necessary).	
	Weight of piston		Weight difference per set		± 10 gr (± .353 oz)				
	Weight of connecting rod		Weight difference per set		± 10 gr (± .353 oz)				
	Connecting rod	Connecting rod bearing to crank-pin clearance		60ϕ (2.3622"ϕ)	0.035 to 0.100 (.0014 to .0039")	0.20 (.0079")	-1/16" (1.588mm) crankpin O.D.	Replace bearing up to limit of repair, and thereafter, grind crankpin and use undersize bearing if limit of repair is exceeded.	1. The connecting rod and the bearing cap should be used as a pair. 2. When assembling the connecting rod and the bearing cap, the match marks should be on same side.
	Connecting Rod	Connecting rod width and crank-pin width		41.0 (1.6142")	0.15 to 0.45 (.0059 to .0177")	0.60 (.0236")		Replace connecting rod.	
		Parallelism be-tween large end bearing and small end bushing			0.05/100 or less (.0020/3.9370")				
	Crankshaft	Distance between journal and pin centers		60 (2.3622")	± 0.3 (± .0118")				
		Parallelism be-tween pin and journal			Deflection should be 0.01 (.0004") or less in pin length.	0.03 (.0012")			
		Roundness of pin and journal			0.01 (.0004")or less in diameter difference				
		Cylindricity of pin and journal			0.01 (.0004") or less in diameter difference				
		Pin to journal fillet radius R		4 (.1575")	± 0.2 (± .0079")				
		Angle error between pins			+20' (.7874")				
		Bend of crankshaft			0.05 or less (.0020")	0.07 (.0028")		Repair or replace	

Item				Nominal value	Assembly Standard	Limit of repair	Limit of use	Remedy	Remarks
Main moving parts	Main bearing	Clearance between crankshaft journal and main bearing (when assembled)			0.036 to 0.098 (.0014 to .0039")	0.15 (.0059")	Up to limit of repair of lowest undersize	Replace bearing up to limit of repair. After the limit is exceeded, regrind journal and use undersize bearing of -0.25, -0.50, -0.75, -1.00. (-.0114", -.0197", -.0394")	Crankcase and the bearing cap should be used as a pair.
Main moving parts	Main bearing	Thrust plate to crank web clearance (Thrust gap)			0.100 to 0.198 (.0039 to .0078")	0.40 (.0157")	0.85 (.0335")	Replace thrust plate until limit of repair is reached. After the limit is exceeded, replace with oversize plate of +0.15, +0.30, +0.45 (+.0059", +.0118", +.0177")	
Main moving parts	Flywheel	Deflection of rear surface in axial direction			0.1 (.0039")	0.2 (.0079")			With flywheel installed on crankshaft
Main moving parts	Torsional damper	Runout			0.5 or less (.0197")				
Main moving parts	Crankcase	Out-of-flatness			0.5 or less (.0197")	0.2 or more (.0079")		Regrind.	
Main moving parts	Crankcase	Projection of cylinder liner flange from top surface of crankcase.			0.11 to 0.20 (.0043 to .0079")				
Crankcase	Pre-combustion chamber	Protrusion from cyl. head bottom surface.		9 (.3543")	-0.1 to -0.5 (-.0039 to -.0197")				
Crankcase	Cylinder head	Out-of-flatness			0.05 or less (.0020")	0.2 (.0079")		Regrind.	After removing precombustion chamber.
Crankcase	Cylinder head	Valve margin		1.5 (.0591")	± 0.15 (± .0059")		1.2 (.0473")	Replace valve seat insert.	
Crankcase	Cylinder head	Valve seat angle		45°					
Crankcase	Cylinder head	Valve sinkage		1.1 (.0433")	± 0.2 (± .0079")		1.6 (.0630")		
Crankcase	Cylinder head	Valve seat width	Inlet	1.4 (.0551")	± 0.14 (± .0016")		1.6 (.0630")		
Crankcase	Cylinder head	Valve seat width	Exhaust	2.8 (.1102")			3.2 (.1260")		
Crankcase	Valve guide	Depth of insertion (Protrusion above cylinder head)		22.5 (.8858")	0 -0.5 (.0197")				
Crankcase	Valve seat insert	I.D. of valve seat insert hole to the valve seat insert O.D.	Inlet	48ϕ (1.8898"ϕ)	-0.080 to -0.050 (-.0031 to -.0020")				-0.080, -0.050 (-.0031 to -.0020") indicates tightening allowance
Crankcase	Valve seat insert	I.D. of valve seat insert hole to the valve seat insert O.D.	Exhaust	39ϕ (1.4961"ϕ)					

Item				Nominal value	Assembly Standard	Limit of repair	Limit of use	Remedy	Remarks
Valve Mechanism	Valve	Valve stem to valve guide clearance	Inlet	9ϕ (.3543"ϕ)	0.055 to 0.085 (.0022 to .0033")	0.15 (.0059")		Replace valve guide if limit of repair is exceeded.	Both inlet and exhaust valve guides are identical.
			Ex-haust		0.070 to 0.100 (.0028 to .0039")	0.20 (.0079")			
		Margin		1.5 (.0591")	± 0.15 (± .0059")		Up to 1.2 (.0473") after refacing		
		Stem to valve face offset			0.03 or less (.0118") (Right angle to valve face)				
	Valve spring	Free length	Outer	55.4 (2.1653")			52.4 (2.0629")		
			Inner	51.2 (2.0158")			48.2 (1.8977")		
		Load (kg) /installed length	Outer		22.9 ± 1.3/47 (50.48 ± 2.86 lbs./1.8504")		19.4/47 (42.77 lbs./1.8504")		
			Inner		9.0 ± 0.6/42.3 (19.84 ± 1.32 lbs./1.6653")		7.6/42.3 (16.75 lbs./1.6653")		
	Valve clearance			0.3 (.0118") (when engine is cold)		0.18 to 0.40 (.0070 to .0157")		Adjust	
	Tappet	Tappet to crank-case tappet hole clearance.		22ϕ (.8661"ϕ)	0.015 to 0.066 (.0006 to .0025")	0.12 (.0047")	+0.10 (.0039") at tappet hole I.D.	Replace tappet	
	Push rod	Bend			0.4 or less (.0157")			Replace	
	Rocker	Rocker bushing to rocker shaft clearance.		23ϕ (.9055"ϕ)	0.020 to 0.051 (.0008 to .0020")	0.07 (.0028")		Replace bushing.	
	Camshaft	Cam shaft journal to cam shaft bushing clearance (Mounted on crank-case)	No. 1	54.5ϕ (2.1457"ϕ)	0.040 to 0.090 (.0016 to .0035")	0.15 (.0059")		Replace bushing	
			No. 2						
			No.3	54ϕ (2.1457"ϕ)					
			No. 4	53ϕ (2.0866"ϕ)					
		Camshaft end play		6.0 (.2362")	0.10 to 0.25 (.0039 to .0099")	0.3 (.0118")		Replace thrust plate	
		Cam profile		46.615 (1.8352")	+0.1 to -1.0 (+.0039 to -.0394") (At D1) (D1 - D2 = 7.189) (.2828")		(D1 - D2 = 6.69) (.2633")		
		Bend of camshaf			0.02 (.0008")	0.05 (.0020")		Replace or correct bend.	Measure at the No. 2 and No. 3 journals.
Gear train	Idler	Idler bushing to shaft clearance		40ϕ (1.5748"ϕ)	0.025 to 0.075 (.0010 to .0029")	0.1 (.0039")		Replace bushing.	
		Idler end play		30 (1.1811")	0.05 to 0.15 (.0020 to .0059")	0.35 (.0038")		Replace thrust plate.	
	Gear Backlash	Crankshaft gear to idler			0.09 to 0.19 (.0035 to .0112")	0.26 (.0103")		Replace gear.	Gear backlash in pitch circle (Right angle to the shaft)
		Idler to camshaft gear			0.1 to 0.2 (.0039 to .0079")	0.28 (.0110")			
		Idler to injec-tion pump gear							

Item				Nominal value	Assembly Standard	Limit of repair	Limit of use	Remedy	Remarks
Lubricating system	Oil pump gear	Oil pump gear to case clearance		51.965ø (2.0459"ø)	0.11 to 0.18 (.0043 to .0070")	0.2 (.0079")			
		Oil pump gear height to case depth clearance			0.20 to 0.04 (.0079 to .0016")	0.15 (.0059")			
		Backlash			0.08 to 0.20 (.0031 to .0079")		0.4 (.0157")		
	Drive gear shaft to bushing entrance			20ø (.7874"ø)	0.040 to 0.074 (.0016 to .0029")	0.15 (.0059")		Replace bushing.	
	Oil pump drive gear		Backlash		0.13 to 0.28 (.0051 to .0110")		0.6 (.0236")		
	Oil pressure adjusting valve		Valve opening pressure	4.0 kg/cm^2 (56.89 p.s.i.)	± 0.3 kg/cm^2 (4.27 p.s.i.)			Adjust by shims.	Changes 0.15 kg/cm^2 (2.13 p.s.i.) with 1 mm. (.0394") shim
	Oil filter bypass valve		Oil filter	2.0 kg/cm^2 (28.45 p.s.i.)	± 0.3 kg/cm^2 (± 4.27 p.s.i.)				
Cooling system	Water Pump Bearing	Case bearing fitting part to bearing outer race clearance		52ø (2.0472"ø)	-0.012 to 0.031 (-.0004 to .0012")		0.05 (.0020")	Replace case or water pump assembly.	
				42ø (1.6535"ø)	-0.011 to 0.023 (-.0004 to .0008")				
		Inner race to pump shaft clearance		20ø (.7874"ø)	-0.021 to 0.002 (-0010 to .00008")				Front
				20ø (.7874"ø)	-0.025 to 0.002 (-.0010 to .00008")				Rear
		Blade front end play			0.5 to 1 (.0197 to .0394")			Replace bearing and impeller when they touch each other.	
		Blade rear end play			0.5 to 1 (.0197 to .0394")				

TORQUE FOR GENERAL BOLTS AND NUTS

kg/m

Thread / Material								
	Diameter mm.	5	6	8	10	10	12	14
	Pitch mm.	0.8	1.0	1.25	1.25	1.5	1.25	1.5
4T (head mark: 4 or o)	Plated	0.28	0.4	1.0	2.0	2.0	3.7	6.0
	Not plated	0.34	0.5	1.2	2.5	2.4	4.5	7.3
7T (head mark: 7 or o)	Plated	0.5	0.7	1.7	3.4	3.3	6.1	9.9
	Not plated	0.6	0.9	2.1	4.1	4.0	7.5	12.2

ft/lbs

Thread / Material								
	Diameter mm.	5	6	8	10	10	12	14
	Pitch mm.	0.8	1.0	1.25	1.25	1.5	1.25	1.5
4T (head mark: 4 or o)	Plated	2.0	2.9	7.25	14.50	14.50	26.8	43.5
	Not plated	2.4	3.6	8.7	18.0	17.4	32.6	52.9
7T (head mark: 7 or o)	Plated	3.6	5.0	12.3	24.6	23.9	44.2	71.7
	Not plated	4.3	6.5	15.2	29.7	29.0	54.3	88.4

TORQUE CHART

Part to be tightened		O.D. mm.	Pitch mm.	Torque kg/m
Rocker shaft bracket bolt		10	1.5	4.2 (30.45 ft/lbs)
Rocker cover nut		8	1.25	2.0 (wet) (14.5 ft/lbs)
Cylinder head bolt		14	2.0	18 + 1.8/-0 (130.5 ±0 13 ft/lbs) NA 19.8 (143 ft/lbs) TI
Connecting rod cap nut		12	1.25	9.5 (69 ft/lbs)
Main bearing cap bolt		14	2.0	14 flange head bolt (wet) (102 ft/lbs) 16 flange head bolt (wet) (116 ft/lbs)
Flywheel lock bolt		12	1.25	9.0 F-marked bolt (wet) (65 ft/lbs) 11.0 H-marked bolt (wet) (80 ft/lbs)
Crankshaft pulley lock nut		24	1.5	40.0 (290 ft/lbs)
Idler shaft bolt		10	1.25	3.5 (25.4 ft/lbs)
Flywheel housing bolt		10	1.5	5.5 (40 ft/lbs)
Camshaft gear lock bolt		10	1.25	3.5 (25.4 ft/lbs)
Camshaft thrust plate				2.1 (15 ft/lbs)
Timing idle gear lock bolt		10	1.25	3.5 (25.4 ft/lbs)
Exhaust manifold mounting bolt and nut	Nut	10	1.25	3.5 (25.4 ft/lbs) 4.2 with self lock
	Bolt	10	1.5	3.5 (30.4 ft/lbs) 4.2 Washer-assembled
Glow plug case		14	1.5	8.3 (60 ft/lbs)
Pre-chamber fixing screw		45	1.5	40.0 (290 ft/lbs)
Fan bolt		10	1.5	3.5 (25.4 ft/lbs)
Nozzle assembly		28	2.0	8.0 to 10 (58 - 72.5 ft/lbs)
Injection pump delivery valve holder				2.5 to 3.5 (18 - 25.4 ft/lbs)
Injection pump flyweight				6.0 (43.5 ft/lbs)
Automatic timer round nut				6.0 to 7.0 (43.5 - 50.75 ft/lbs)
Injection nozzle body retaining nut				6.0 to 8.0 (43.5 - 58 ft/lbs)
Injection pump screw plug				5.5 to 7.0 (39.8 - 50.75 ft/lbs)
Injection pump delivery lock plate screw				0.8 to 1.1 (5.8 - 7.9 ft/lbs)
Injection pump governor shaft lock nut				1.8 to 2.6 (13 - 18.8 ft/lbs)
Injection pump camshaft rear end round nut				2.0 to 3.0 (14.5 - 21.75 ft/lbs)

Section 3

OPERATION

CONTENTS

Section 3

OPERATION

Pre-Starting Inspection. The life of a power train (engine and transmission) depends upon the care and attention it receives. Use of correct type and quantity of lubricants in the engine and transmission is an important factor in lengthening their life. Inspections should be made daily, prior to initial start up and at each refueling.

1. **Engine Oil Level.** Inspect engine oil for proper level. Add oil as required, but do not overfill. Engine oil level indicator (dipstick) is located on either side of the engine. Figure 3. Oil level should be maintained between the marks on the dipstick. Figure 4. Engine must not be operated with oil level below the lower mark on the dipstick. For continuous operating conditions, the engine oil level should be checked every 8 hours.

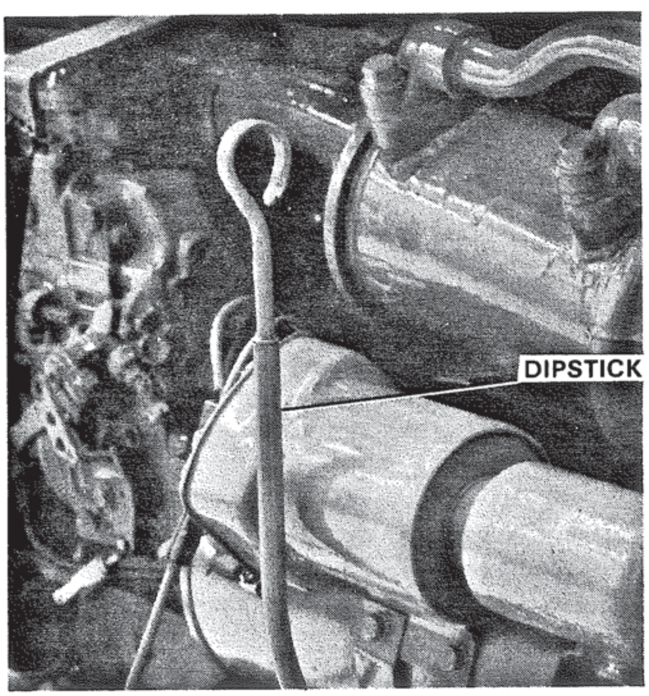


Figure 3. Engine Oil Dipstick.

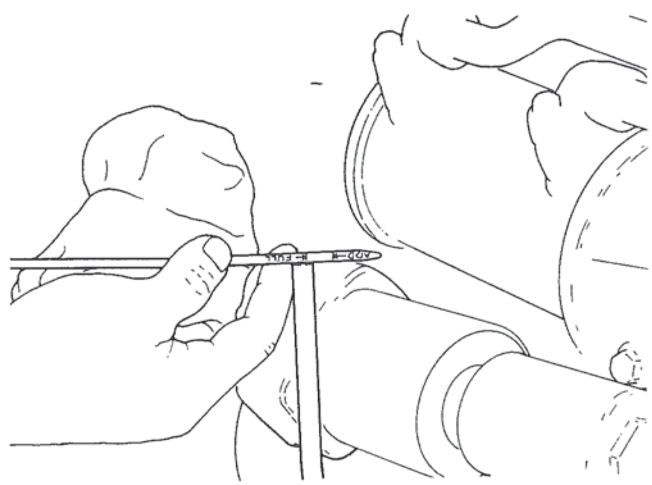


Figure 4. Engine Oil Level.

2. **Transmission.** Warner Velvet Drive: Check oil level before starting engine. Oil level should be maintained at full mark on the dipstick. The recommended fluid is "Dexron" or Automatic Transmission Fluid, Type "A", and is added as necessary through the dipstick opening. Figure 5.

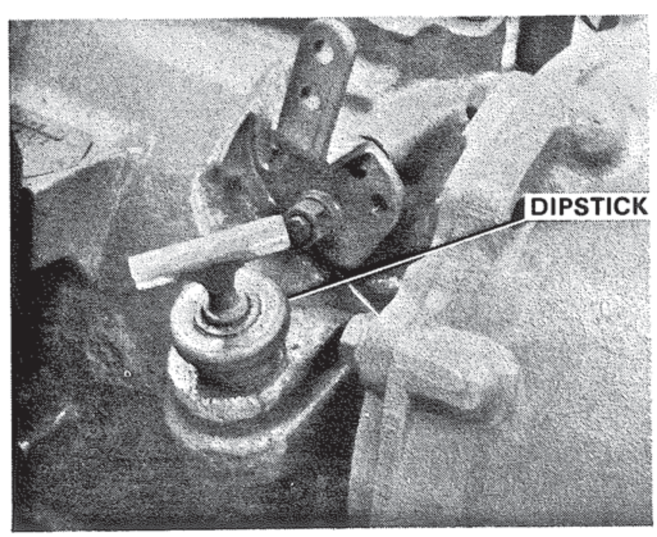


Figure 5. Warner Velvet Drive Dipstick.

Twin Disc Marine Gear: Check oil level with engine running at low idle and transmission in neutral. Oil level should be maintained at full mark on the dipstick. Figure 6. To add oil, remove transmission breather and bushing and fill through opening. Figure 7. **Use same type and grade oil as recommended for engine.**

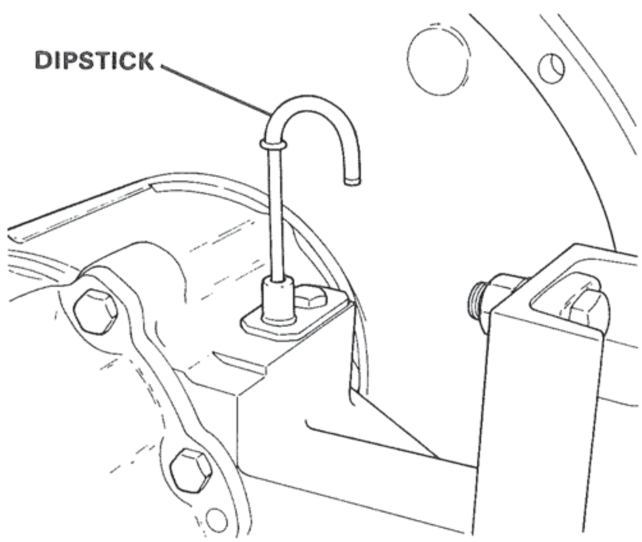


Figure 6. Twin Disc Dipstick.

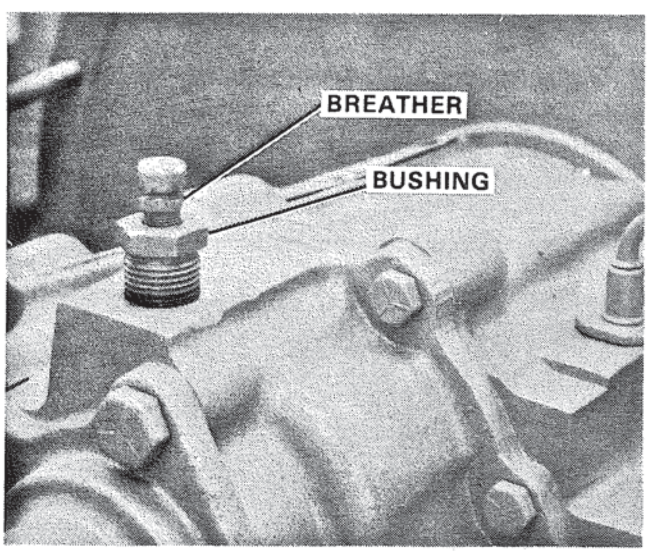


Figure 7. Twin Disc. Adding Oil.

3. **Coolant.** Coolant level should be checked daily with the engine cold and maintained between fluid level lines when the overflow bottle is used. Figure 8.

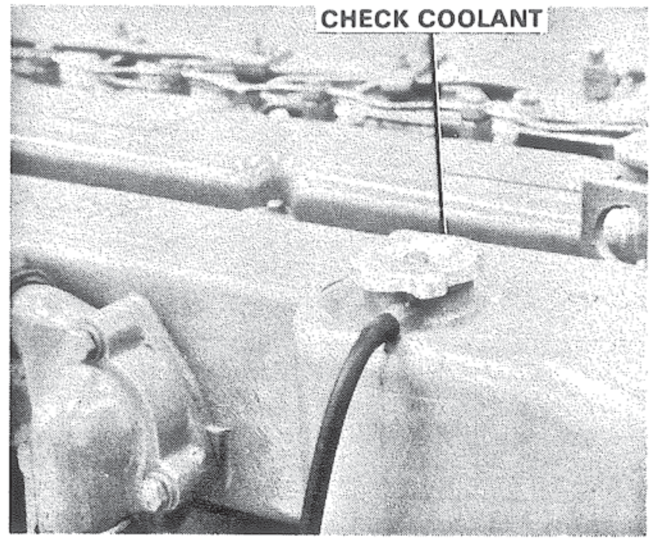


Figure 8. Fresh Water Cooling.

WARNING

Closed cooling system is equipped with a 14 PSI (0.9 kg/cm^2) pressure cap. If pressure cap must be removed when engine is at operating temperature, turn cap counterclockwise to stop, permitting built up pressure to escape through overflow tube.

Recommended coolant is a 50/50 solution of permanent type anti-freeze and clean soft water, providing engine protection for temperatures to -20° F (-29° C); when used year round, this mixture will provide anti-corrosion protection for the cooling system. Check that all seacocks and water supply valves are open. Check condition of water pump drive belts.

4. **Fuel.** Check fuel tank level, check that fuel valves are open. Always use a good grade No. 2 or No. 1 diesel fuel. Poor quality fuel reduces engine output and contaminates engine oil.

Dirt and water cause diesel engine problems. Filter all fuel added to storage tanks. If fuel is taken from drums use only pure fuel from the top, water and dirt settles to the bottom.

To avoid condensation when boat is not in use, fuel tanks should be kept filled.

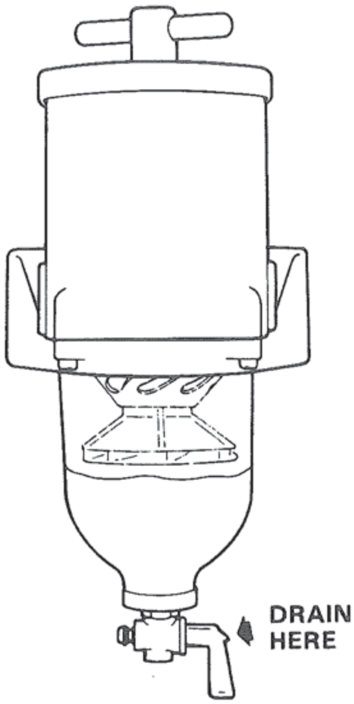


Figure 9. Primary Fuel Filter.

5. **Fuel Filter.** Drain primary fuel filter daily to remove all water and other contaminates. Open petcock at the bottom of the filter and drain into a cup until only clean fuel comes out. Figure 9. Tighten petcock securely to prevent accidental loosening.

CAUTION

All water must be removed daily. Water allowed to remain in the system can result in permanent damage to the fuel injection pump. Fuel system failure, or engine failure, attributable to dirt or water in fuel is NOT eligible for warranty consideration.

6. **Belts.** Check tension of accessory drive belts and examine for any signs of fraying or cracking. Proper belt tension is important to good belt life as well as proper operation of the driven equipment. See instructions pages 30 and 31 for tension checking.

Wear is one problem with loose belts but more important, a properly tightened belt will stay on the pulleys. If a belt does come off, the engine will overheat quickly.

7. **General.** Visually inspect engine, transmission and engine compartment for any signs of fuel, oil, coolant, or exhaust leaks. See that all electrical connections are clean and tight. Check to insure the shut down system operates correctly.

Starting Engine

1. Turn electrical system master switch on (if so equipped).

2. Set gear control lever in neutral position.

3. Set throttle control lever to 1/4 throttle.

CAUTION

When engine has not been operated for a considerable period of time, crank the engine over with the starter for 15 seconds with stop lever (or switch) in the stop position before going to step 4.

4. Move stop lever to start, or run, position.

5. Push glow plug button for 15 seconds but not more than 30 seconds to allow glow plugs to heat. Turn starter key switch to start position while holding glow plug button in ON position. Release both when engine starts.

CAUTION

Continuous operation of starter motor for more than 15 seconds and glow plugs for more than 30 seconds may damage starter motor, battery and glow plugs.

NOTE

When engine has been stopped for a short period of time only, engine can be started without using glow plugs.

6. If engine does not start at first attempt, wait 10 to 15 seconds and repeat Steps 1 through 5 above.

7. When engine starts release starter key and glow plug switch, set throttle control to idling position. Starter key must return to running position when released.

8. Set throttle control at 750 to 800 RPM idle, and check the following items to insure that all engine systems are operating correctly.

A. Oil pressure. Minimum allowable oil pressure at idling speed is 22 lbs. If engine oil pressure gauge does not register within 10 seconds, stop engine and investigate the cause.

B. Check raw water cooling circulation. Water circulation can be determined by observing discharge of water though exhaust outlets.

If a keel cooling system is used, engine temperature gauge should be monitored for gradual rise to normal operating temperature.

OPERATING PRECAUTIONS

Engine Compartment Ventilation. Engine air supply is as important as fuel. Air supply ducts and vents must be unobstructed.

ENGINE OPERATION

Do not cast off until engine is running smoothly.

Engine Oil Pressure should remain between 40-60 PSI.

A. TRANSMISSION (Warner Velvet Drive) oil temperature should not exceed 190° F (88° C). Discontinue operation if temperature exceeds 230° F (110° C). Extended periods of FREE WHEELING will cause transmission oil to overheat.

CAUTION

Do not shift drive into gear if engine speed is above 800 RPM. Shifting should be done between 550-800 RPM.

While under way . . .
Fresh Water Coolant Temperature should remain between 180° - 190° F (82° - 88° C).

Raw Water Cooling System should be monitored, check occasionally for water flow out the exhaust.

Unusual Noise should be diagnosed. Listen closely to engine sound.

Exhaust Color is very important. (Refer to Engine Troubleshooting.)

RUNNING UNDER EXTREME CONDITIONS

Hot Weather. In hot weather, high ambient temperature and moisture may lead to overheating. Observe the following:

1. **Coolant.** Make sure coolant is clean, level is between lines of overflow bottle and cap is tight. Cooling efficiency is lost if coolant is low or contaminated or water pump drive belt tension is incorrect.

2. **Engine Oil.** Viscosity of oil changes with temperature. Refer to Lubrication Section for proper viscosity and oil grade.

3. **Battery Electrolyte.** Batteries are subject to damage if electrolyte is low. Add distilled water to correct level — approximately 1/2 in. above plates. For other information pertaining to the battery, refer to Electrical System.

Cold Weather. Cold weather operation places extreme demands on engines and electrical systems.

Cooling System. Check the fresh water cooling system anti-freeze mix. The factory fill 50-50 anti-freeze/water mix provides protection to -20° F (-29° C).

Electrical System. Battery power, matched to engine cranking requirements is based on tests made at 80° F (20° C). At 32° F (0° C), battery capacity is reduced 35% while engine cranking demands increase by 65%.

A discharged or defective battery will not start the engine under cold conditions. Removing and storing the battery in a warm location may be necessary.

Battery cables must be of adequate size or voltage drop may cause slow cranking.

Engine Lubrication. Use correct engine oil specified for expected temperature. High viscosity oil adds to engine cranking requirements; however, too low a viscosity will not allow sufficient compression pressure for proper combustion and will not offer proper protection at operating temperatures.

Fuel System. When operating in cold weather fuel tanks should be kept at or near full to prevent condensation.

Check fuel filters daily and drain any accumulated water when taking engine out of service to prevent ice accumulation.

MAXIMUM RPM

Wide open throttle should allow the engine to operate at 3150 RPM for the turbocharged engine. The NA version may be operated at 2600 RPM to 3150 RPM wide open throttle.

ENGINE SHUT DOWN

A. Return throttle lever to idling position.

B. Return fuel stop lever to STOP position; push stop button.

C. After engine stops, turn key switch to OFF position.

D. Set electrical system master switch to OFF position (if so equipped).

E. Carefully inspect engine for any signs of oil, fuel, water or exhaust leakage.

F. Take appropriate corrective action for any indicated leakage, and for any trouble noted during operation of the unit.

MAINTENANCE

The following maintenance schedule is a guide that must closely be followed. Times shown are maximums; extreme operating conditions may demand more frequent servicing.

MAINTENANCE	Page	Check Fluid Level	Inspect Clean Adjust	Replace	Lube	Service
Daily						
Engine Oil	21	x				
Fuel Filter, Primary	23		x			
Fuel Tank	23	x				
Fuel Lines			x			
Coolant		x	x			
Drive Belts	23		x			
First 25 Hours (Break-in)						
Engine Oil and Filter	33			x		
Torque Cylinder Head Bolts			x			
Valve Clearance	26		x			
All External Fasteners			x			
Fuel Feed Pump Strainer, Fuel Filters	26-29		x			
Drive Belts	30,31		x			
Every 25 Hours						
Air Cleaner	33		x		x	
Battery	36	x				
Drive Belts	30,31		x			
Secondary Fuel Filter	28		x			
Every 100 Hours						
Engine Oil & Filter	33			x		
Intercooler } Spray fuel in	34		x			
Turbocharger } air inlet			x			
Primary Fuel Filter	27			x		
Secondary Fuel Filter	28			x		
Every 250 Hours						
Valve Clearance	26		x			
Air Cleaner	33			x	x	
Battery Cables	36		x			
Every 500 Hours						
Injection Nozzles			x			
Fuel Tank			x			
Fuel Feed Pump Strainer	29		x			
Every 1000 Hours (or annually, which ever occurs first)						
Engine Compression			x			
Injection Pump			x			
Cooling System	29		x			
Starter	36		x		x	
Battery	36		x			
Every 2500 Hours (or annually, which ever occurs first)						
Coolant	29			x		

INSPECTION AND MAINTENANCE

Long engine life and optimum performance are obtained through careful handling, daily inspection and proper maintenance.

This section covers important inspection points and maintenance.

Valve Clearance. Valve clearance is checked at the first 25 hours (break-in) and every 250 hours thereafter. Check with the engine cold, .012 in. (.305 mm) intake, .015 in. (.381 mm) exhaust, on TI; .0124 (.305 mm) intake, .012 (305 mm) exhaust, NA.

1. **Checking and adjusting valve clearance.** Set No. 1 piston at top dead center (TDC) on compression stroke. Align TDC mark on crankshaft dampener with timing pointer on timing gear case. Figure 10.

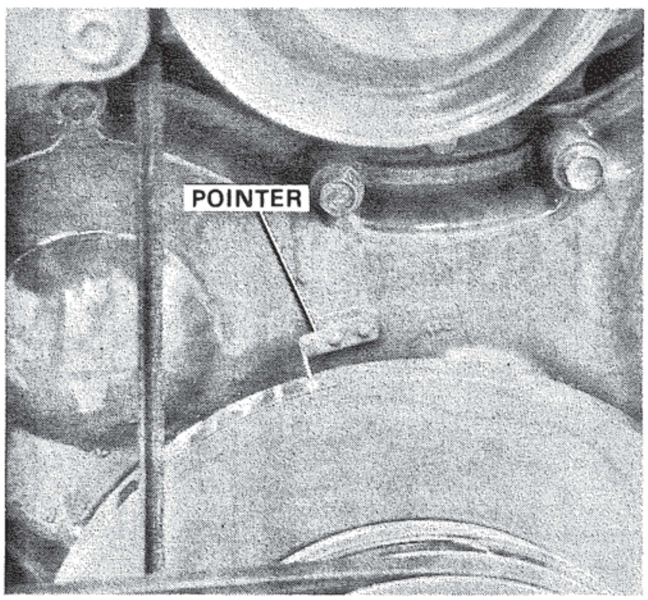


Figure 10. Establishing T.D.C.

NOTE

No. 1 piston is at TDC on compression stroke when there is play at both No. 1 piston intake and exhaust push rods.

Check and adjust valves as indicated in Table 2.

Measure valve clearance using feeler gauge. Figure 11. Adjust by loosening lock nut and turning adjusting screw. Recheck clearance after tightening lock nut.

2. Set No. 6 piston at TDC on compression stroke. Check and adjust valves indicated in Table 2.

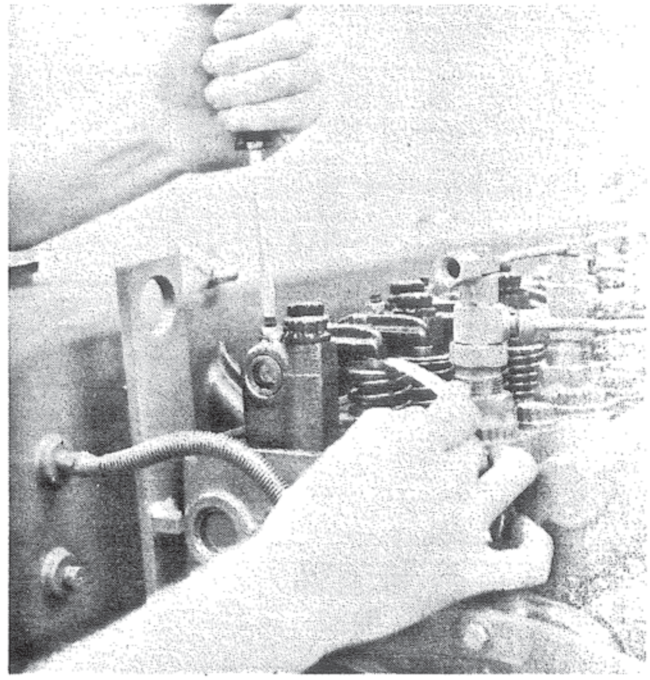


Figure 11. Adjusting Valve Clearance.

	Cylinder Number											
*	1		2		3		4		5		6	
	I	E	I	E	I	E	I	E	I	E	I	E
No 1 TDC	x	x	x			x	x			x		
No 6 TDC				x	x			x	x		x	x

*Note: No. 1 cylinder is at front end.

Table 2. Valve Adjusting Sequence.

Fuel System. Fuel system maintenance varies from **DAILY** to 1000 hour intervals. Water and poor quality fuel cause engine problems and contaminate engine oil.

CAUTION

Fuel system and/or engine failure due to dirt or water in fuel line is **not** covered under warranty.

Notations in the operating log of what is found in daily fuel inspections are important. Small amounts of water may be found during daily inspection due to condensation in the fuel tank, this is normal. If more than half a cup is found repeatedly, drain fuel tank and flush. Change all filter elements immediately and check fuel source to determine cause of contamination.

Fuel Filter - Primary. Drain contaminants from filter **daily** by opening petcock at bottom of bowl. Figure 12.

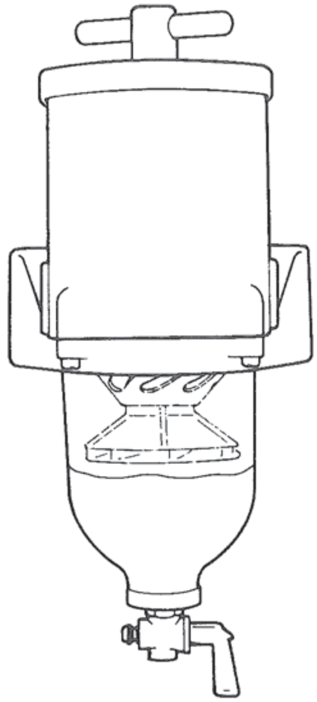


Figure 12. Primary Fuel Filter.

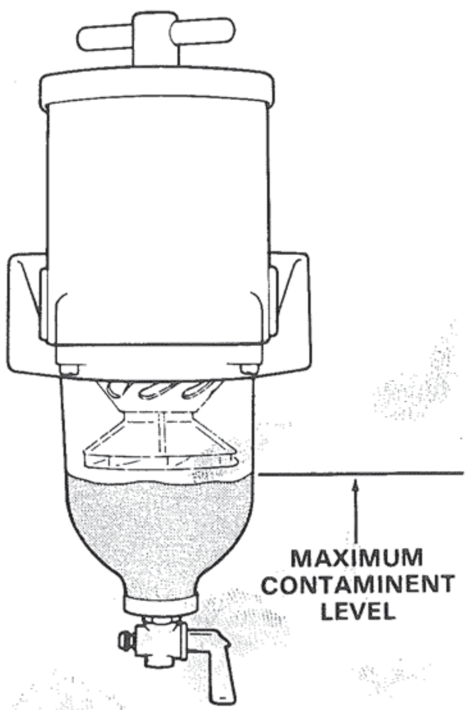


Figure 13. Maximum Water/Contaminant Level.

NOTE

Drain fuel into a clear container for visual checking. Dispose of fuel properly. Every 100 hours or 3 months (whichever occurs first) replace filter element.

CAUTION

Do not allow water or contaminants to reach bottom of centrifuge prior to draining, Figure 13.

Primary Fuel Filter.

1. Remove cover. Figure 14.

Figure 14. Removing Cover.

2. Grip element back and remove element. Figure 15.

3. Insert new element with a turning motion.

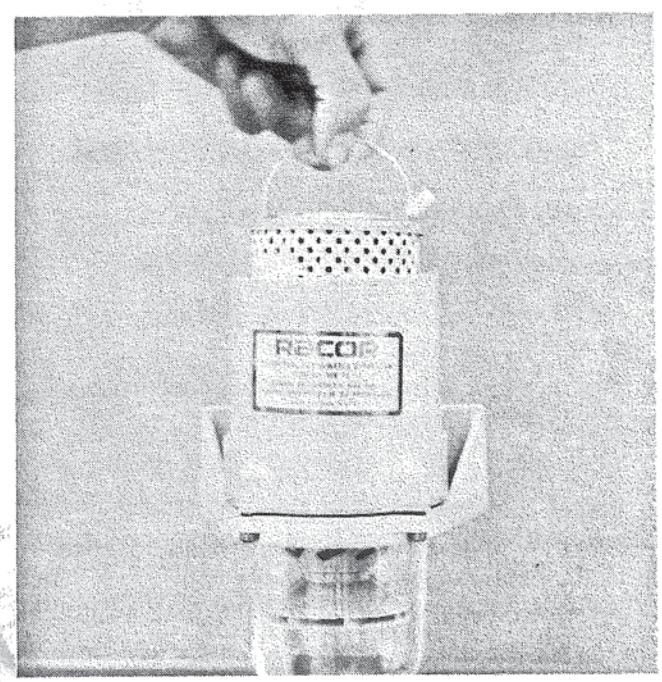


Figure 15. Removing Element.

CAUTION

Use only 30 micron elements (2 micron elements may clog prematurely).

4. Inspect gaskets in lid, replace if necessary.
5. Pour fresh clean fuel into filter until full.
6. Replace cover and tighten.

CAUTION

Use of methanol or alcohol based additives may damage clear bowl and centrifuge.

Fuel Filter — Secondary. Drain contaminants from filter every 100 hours by removing plug located at bottom of filter case. Figure 16.

NOTE

Drain fuel into a clear container for visual checking. Dispose of fuel properly.

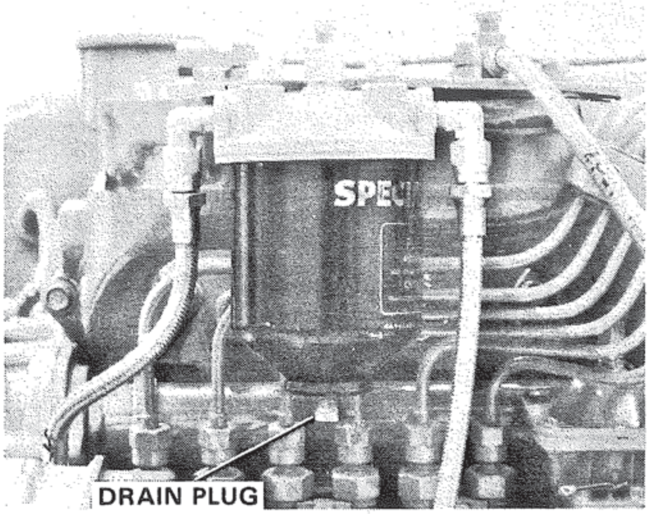


Figure 16. Draining Secondary Fuel Filter.

Every 100 hours replace filter element.

Replacing Secondary Fuel Filter Element.

1. Remove plug from bottom of case and drain fuel from filter.

2. Remove center bolt and separate case from head, discard element, gaskets and copper washer.

3. Clean filter case and center bolt in fresh fuel.

4. Install new gaskets in filter head. Place new element in filter case. Carefully position case in groove of filter head and secure with center bolt using new copper washer. Torque to 12-14 ft. lbs. (1.7 - 2.0 kg/cm).

5. Bleed air from filter.

A. Loosen bleed plug at top of center bolt. Figure 18.

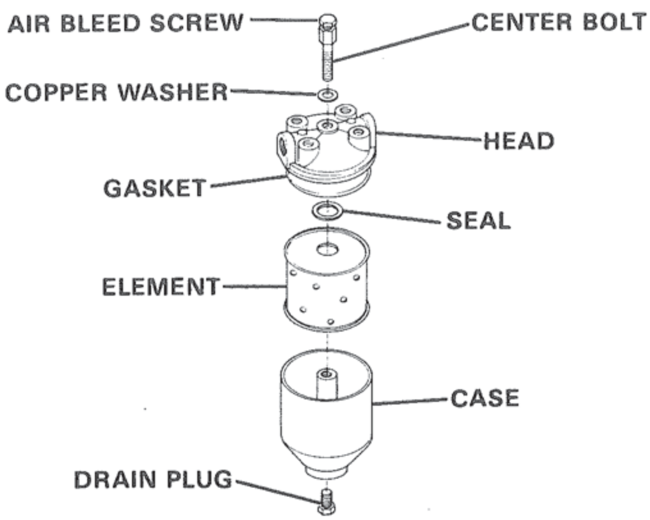


Figure 17. Secondary Fuel Filter.

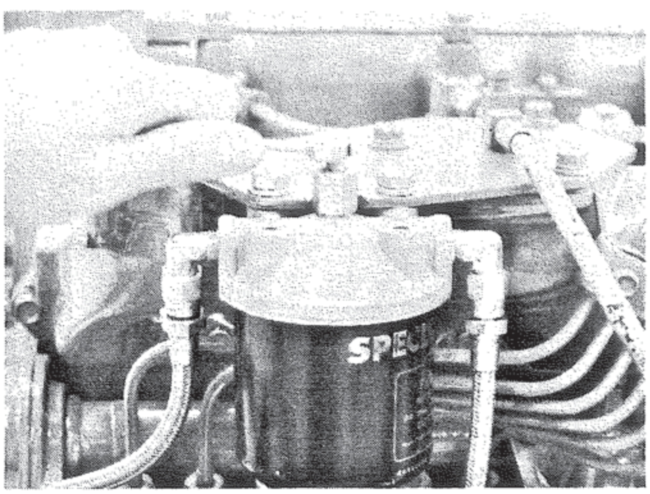


Figure 18. Loosening Bleed Screw.

B. Operate priming pump at side of injection pump until fuel (without air bubbles) flows from bleed hole. Figure 19. Tighten plug.

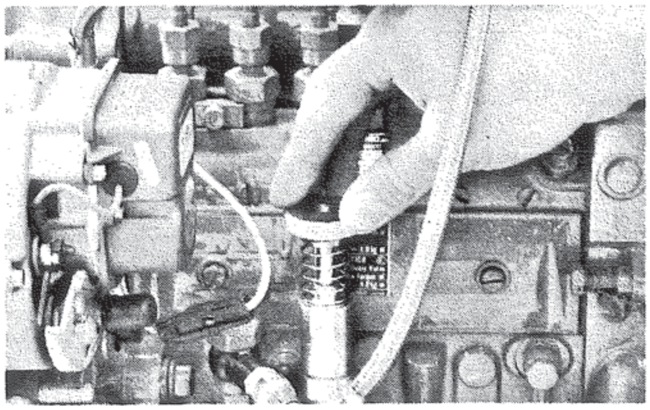


Figure 19. Bleeding Air from Filter.

FUEL FEED PUMP STRAINER

A strainer located at the inlet of the fuel feed pump is removed and cleaned every 500 hours.

Remove and Clean Strainer

1. Remove inlet screw from bottom of feed pump, Figure 20.

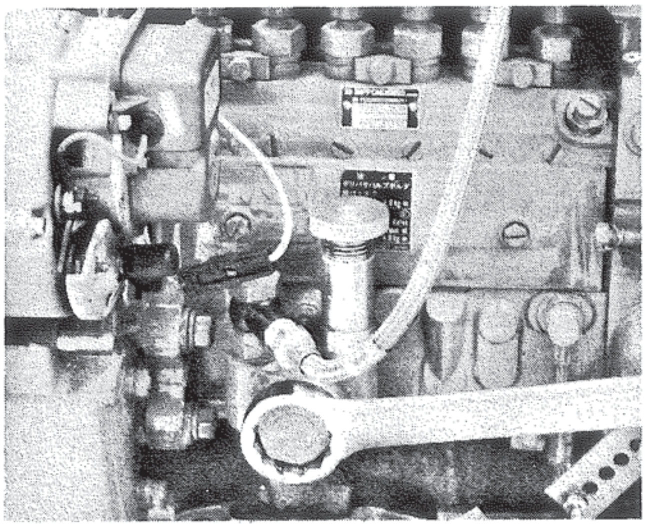


Figure 20. Removing Inlet Screw.

2. Pull screw from nipple, discard rubber gaskets.

3. Use a broad blade screwdriver (1/2 in. minimum) to remove strainer from screw.

4. Clean screw and strainer in fresh fuel and reassemble.

5. Replace rubber gaskets and reassemble to feed pump, tighten securely.

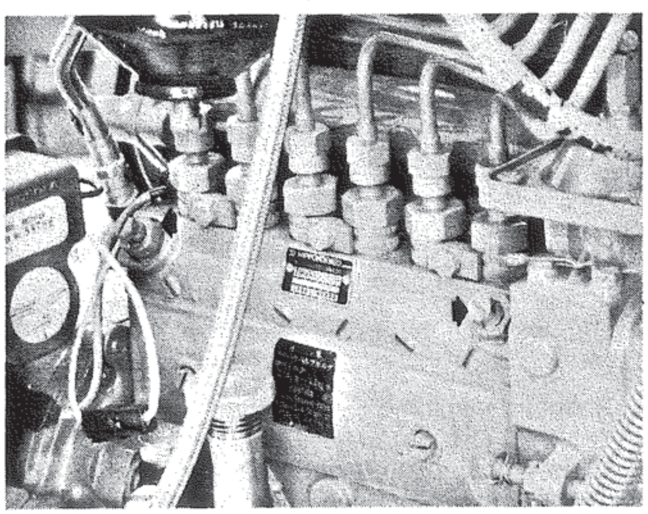


Figure 21. Fuel Injection Pump Air Bleed Screws.

6. Bleeding air from fuel injection pump.

A. Loosen bleed screw at rear of pump. Figure 21.

B. Operate priming pump at side of injection pump until fuel (without air bubbles) flows from bleed hole, tighten screw.

C. Loosen bleed screw at front of pump. Figure 21.

D. Repeat step "B".

BLEEDING AIR FROM FUEL SYSTEM

Air in a diesel fuel system will cause hard starting. Excessive air may prevent engine from running at all. Air must be bled from fuel system any time fuel filters are changed, a fuel line disconnected or running out of fuel. Follow procedures in "Replacing Secondary Fuel Filter" and "Fuel Feed Pump Strainer". Always begin at a point farthest from engine ending at fuel injection pump.

COOLING SYSTEM
(Closed, Fresh Water System)

Engine coolant level and coolant pump dive belts are checked **daily.** Coolant level in the closed (fresh water) system must be between lines on the overflow bottle.

WARNING

Closed cooling system is equipped with a 14 PSI pressure cap. If pressure cap must be removed when engine is at operating temperature, turn cap counterclockwise to stop, permitting built up pressure to escape through overflow tube.

Coolant must be clean and contain no engine oil. Dirty coolant should be drained, system flushed and refilled with a 50/50 mix of permanent antifreeze and clean soft water. When coolant must be added to bring system to proper level, clean soft water alone may be used, however 50/50 permanent antifreeze and clean soft water provides corrosion protection and consistent operating temperature.

When engine oil is found in cooling system, determine why and repair immediately.

All hose connections anf fittings, are inspected for tightness every 100 hours. Drive belt tension is checked at 25 hours. Every 2500 hours or yearly the system should be drained, cleaned and refilled.

Special cap with gasket is used with recovery bottle — inspect gasket — any leak to atmosphere will prevent water from returning to engine during cooling cycle (engine stopped).

Check and Adjust Fresh Water Pump Drive Belt. Check daily. Inspect and adjust every 25 hours. Loose belts may cause the engine to overheat.

Check Drive Belt Tension.

1. Place a straight edge on top of belt between alternator and water pump. Figure 22.

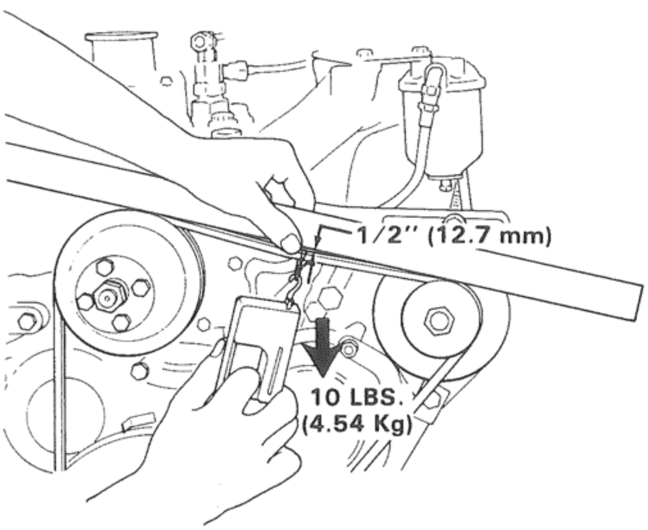


Figure 22. Checking Fresh Water Drive Belt Tension.

2. Apply 10 Lbs. (4.54 kg) down pressure on belt midway between pulleys, belt deflection should be 1/2 in. (12.7 mm).

NOTE

Belts too tight will cause short belt life and may damage alternator and/or water pump bearings. Belts too loose may jump out of pulley grooves or slip and cause short belt life.

Adjust Drive Belt.

1. Loosen alternator and mounting screws. Figure 23.

2. Pull alternator out to tighten belt. Tighten mounting screws and recheck belt tension.

Drain and Clean Cooling System.
(2500 hours or yearly)

1. Drain overflow bottle.

2. Remove expansion tank cap.

3. Remove drain plug from block allowing all coolant to drain out. Drain plug is located behind starter motor.

4. Remove thermostat.

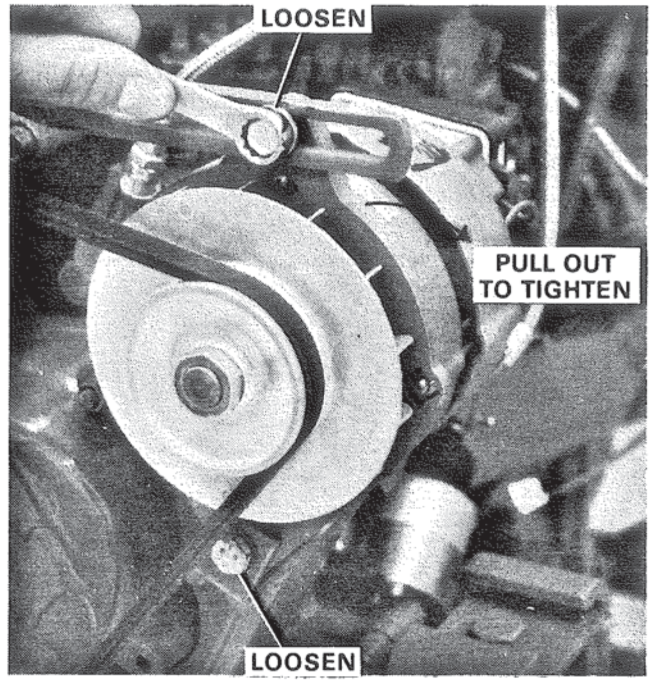


Figure 23. Adjusting Belt Tension.

5. Replace block drain plug and fill system with clean soft water and a reliable brand of cooling system cleaner. Follow cleaner manufacturer's instructions.

6. After cleaning, drain system and flush with water until water runs clear.

7. Replace thermostat.

8. Fill cooling system with new 50/50 antifreeze and water mix.

COOLING SYSTEM (Raw Water)

Raw water cooling pump drive belt is checked daily. Inspect and adjust drive belt every 25 hours. Heat exchanger, transmission oil coolers and intercooler (TI only) are checked and cleaned every 100 hours. Inspect and clean raw water pump every 1000 hours or yearly.

CAUTION

Chrysler Marine recommends use of a properly installed sea strainer to provide engine with an unrestricted flow of filtered water.

Regular inspection and cleaning are still required. Continuous operation in areas where seaweed, sea grass, etc. or other conditions which increase intake of foreign matter in engine cooling water supply requires more frequent maintenance.

Responsibility for maintaining unrestricted flow of clean water to engine is the owner's. Damages occurring from water restriction are not covered under warranty.

Check and Adjust Raw Water Pump Drive Belt. (25 hours) Loose belts may cause engine to overheat.

Check Drive Belt Tension.

1. Place a straight edge on top of belt between water pump and crankshaft pulley. Figure 24.

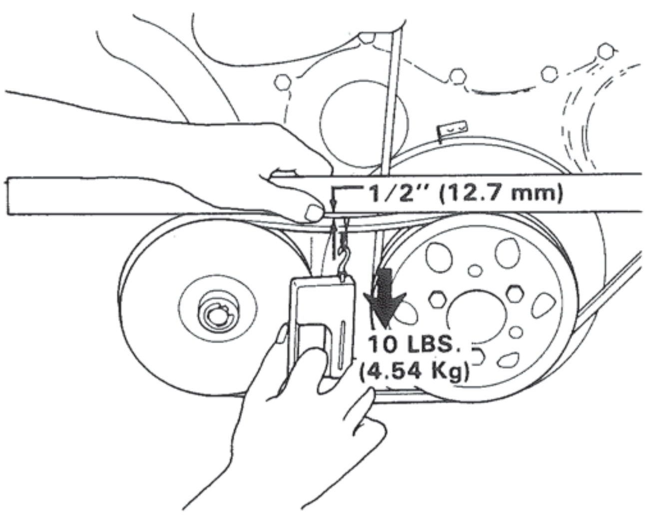


Figure 24. Checking Raw Water Drive Belt Tension.

2. Apply 10 lbs. (4.54 kg) down pressure on belt, midway between pulleys, belt deflection should be no more than 1/2 in. (12.7 mm).

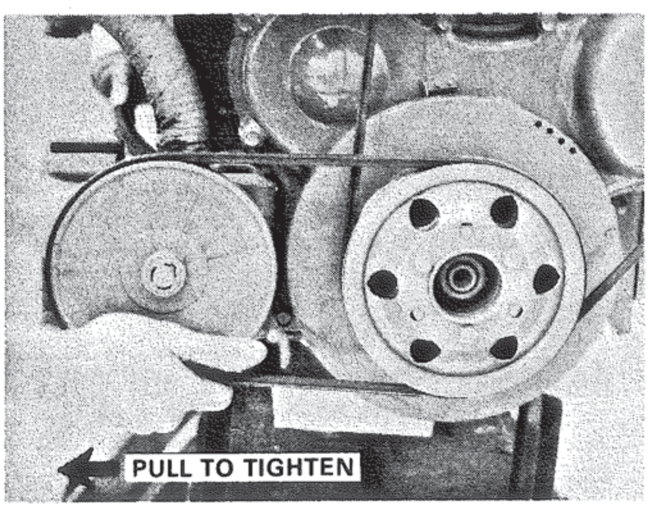


Figure 25. Adjusting Drive Belt.

NOTE

Belts too tight will cause short belt life and may cause water pump bearing damage. Belts too loose may jump out of groove or slip and cause short belt life and engine overheating.

Adjust Drive Belt.

1. Loosen raw water pump mounting screws, Figure 25.

2. Push pump out to tighten belt. Secure mounting screws and check belt tension.

Inspect and Clean Heat Exchanger Every Season.

1. Remove end caps from heat exchanger and inspect for debris. Figure 26.

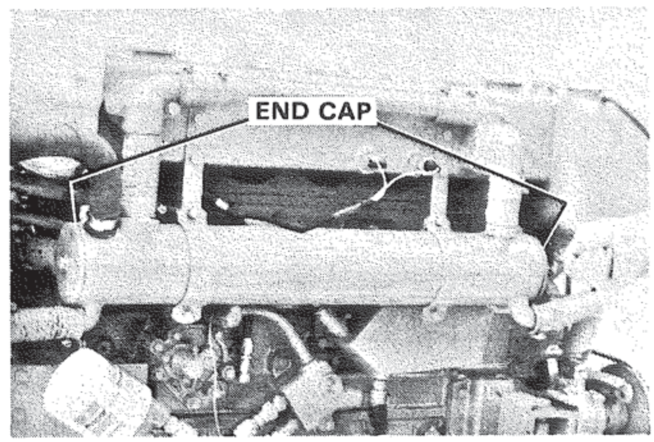


Figure 26. Cleaning Heat Exchanger.

2. Reverse flush with clean water.

3. Inspect sacrificial anode. Figure 27. Tap with hammer to break loose corrosion. Replace if eroded.

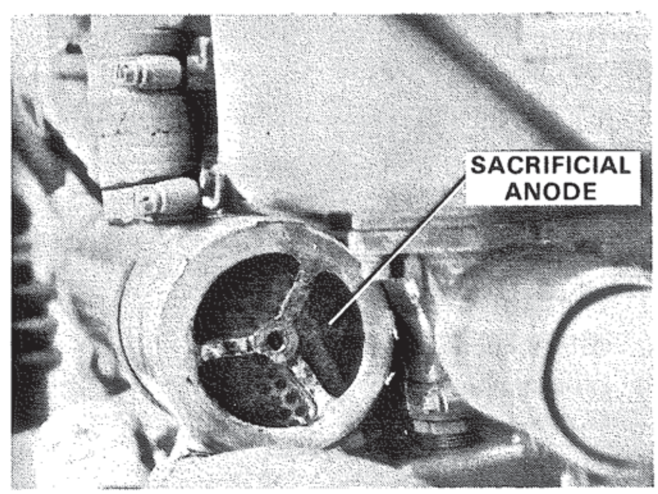


Figure 27. Inspecting Sacrificial Anode.

4. Use new gaskets and O-rings when reassembling.

NOTE

Failed raw water pump impellers will plug tubes and must be cleaned out.

Inspect and Clean Reverse Gear Oil Cooler (100 hours).

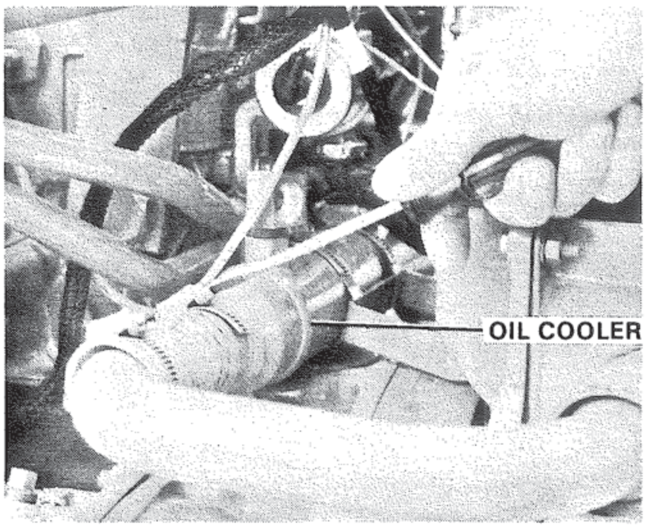


Figure 28. Cleaning Reverse Gear Oil Cooler.

1. Remove hoses from both ends and inspect for debris. Figure 28.
2. Reverse flush with clean water.
3. Inspect sacrificial anode, replace if eroded. Figure 29.

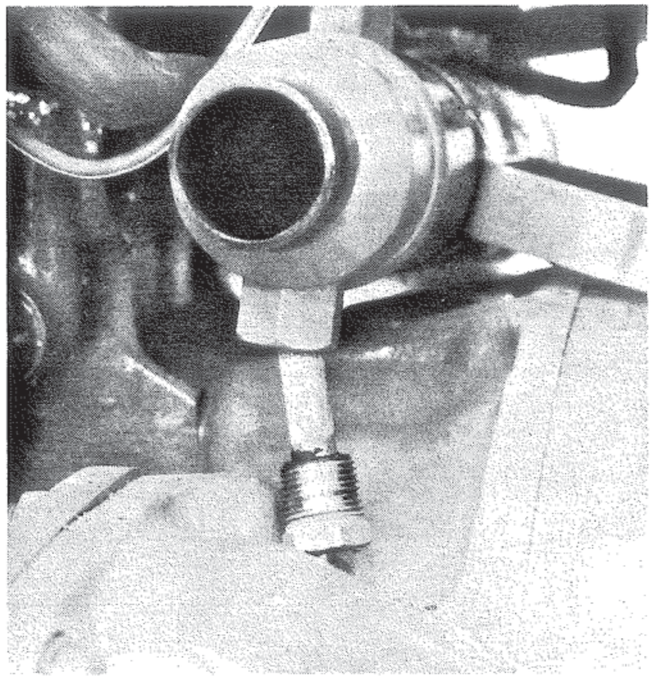


Figure 29. Inspecting Sacrificial Anode.

Inspect and Clean Intercooler (TI & TW only, 100 hours). Clearance between cooling fins is very fine and can become plugged.

1. Remove water hoses from intercooler. Figure 30.
2. Reverse flush with clean water.

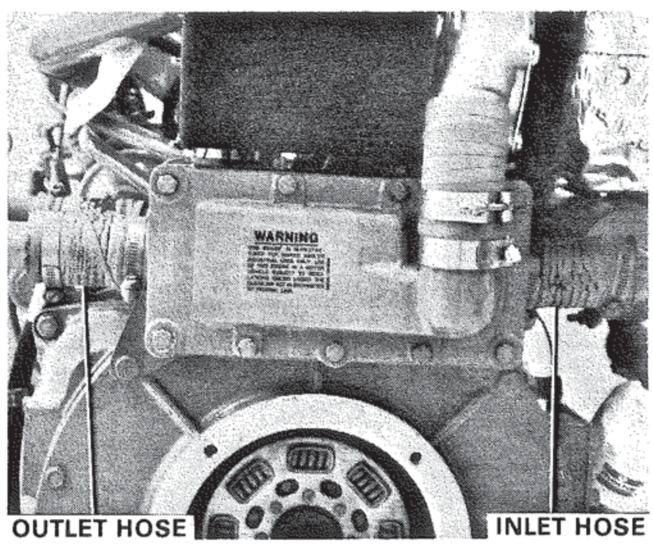


Figure 30. Intercooler.

Inspect and Clean Raw Water Pump (1000 hours or annually).

1. Remove pump from engine.
2. Disassemble pump, inspect rubber impeller for wear, cuts or set to vanes. Inspect pump housing for wear, pitting and cracks.
3. Inspect cam for wear, replace if worn.
4. Check pump bearings for wear.

NOTE

If inspection is taking place at time of laying up — leave pump apart. Allowing pump to remain assembled for extended periods without use causes impeller vanes to take a set.

4. Use new gaskets when reassembling pump.

LUBRICATING SYSTEM

Engine lubricating oil and engine oil filter are always changed together. The first change is at 25 hours (break-in) and every 100 hours thereafter. Extreme operating conditions (hot or cold), short runs or poor quality fuel may require more frequent changes.

Changing Engine Oil. Follow recommended oil grade and vicosity found in Fuel and Lubricants Section.

1. Bring engine to operating temperature.

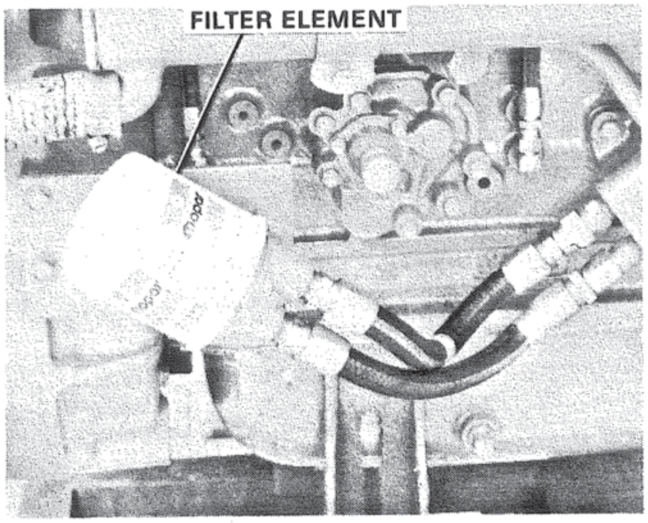


Figure 31. Oil Filter.

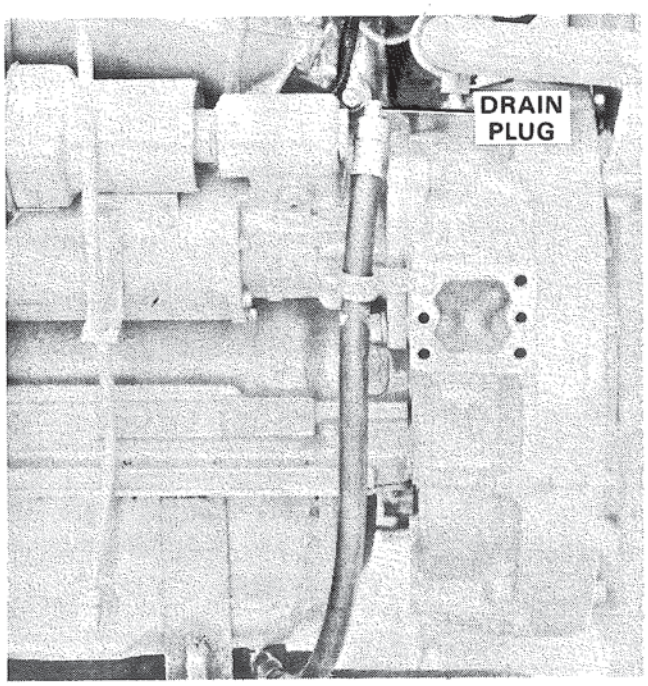


Figure 32. Changing Engine Oil.

2. Remove oil filter. Figure 31.

3. Remove plug from drain hose. Figure 32.

Allow oil to drain completely. Replace plug. Most applications may require use of a suction pump for oil removal.

4. Clean filter mounting surface, lubricate new filter gasket with clean engine oil and install new filter.

NOTE

Tighten new oil filter per filter manufacturer's instructions.

5. Install new oil. Figure 33. Fill to full level approximately 9 qts. (8.53 L) for level installation, 8 qts. (7.58 L) for 15° installation. Filter requires about one qt.

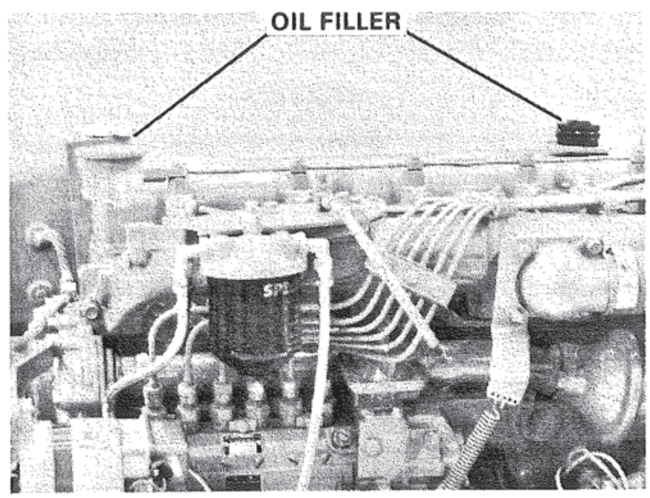


Figure 33. Installing Oil.

6. Start engine and allow to idle until oil pressure registers normal, check filter for leaks.

7. Stop engine and check oil level. Add oil as required.

AIR INTAKE AND EXHAUST SYSTEM

The air cleaner requires maintenance every 25 hours or as service requires and replacement every 250 hours. The turbocharger and intercooler require maintenance each 100 hours and 1000 hours or yearly.

Air Cleaner Inspection and Cleaning (25 hours).

1. Remove air cleaner element from engine. If excessive dirt has accumulated, schedule next inspection sooner or increase schedule if filter is clean; 100 hrs. maximum between cleanings.

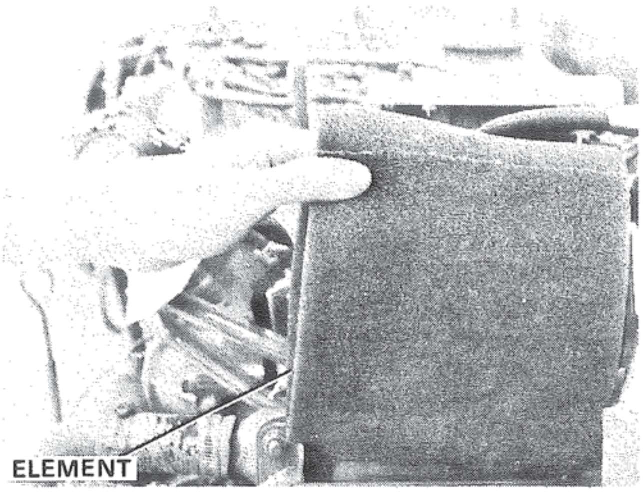


Figure 34. Air Cleaner.

2. Wash element in water containing a strong detergent, rinse and blow dry with compressed air.

NOTE

Do not wring or twist to remove water, damage to element will result.

3. Soak element in clean engine oil. Gently squeeze excess oil from element and place on air cleaner. Element must fit snuggly on air cleaner body, replace if loose.

Replace Air Cleaner Element (250 hours).

1. Soak new element in clean engine oil. Gently squeeze excess oil from element and place on air cleaner.

Turbocharger and Intercooler Cleaning. (100 hours)

1. Bring engine to normal operating temperature, 180° - 190° F (82°-88° C). Operate engine at 2700-2800 RPM with craft underway.

2. Spray 2 ozs. (56.7 G) (1 oz. (28.4 G) per minute) of clean diesel fuel into the air intake. A pump type oil can or hand pump atomizer should be used. Figure 35.

WARNING

Remove air cleaner while engine is running. Do not remove screen. Do not place hands or fingers near turbocharger inlet while engine is running. Vacuum at this point can draw fingers into compressor resulting in serious injury.

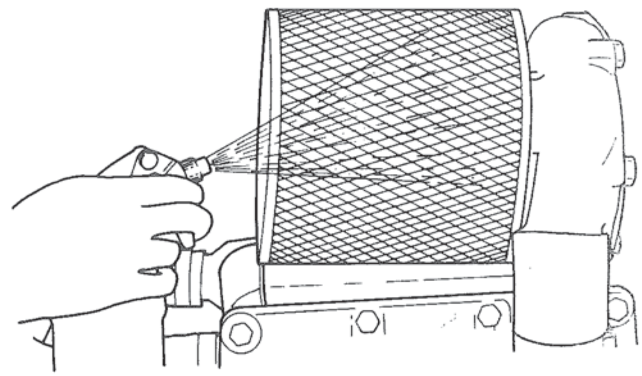


Figure 35. Cleaning Turbocharger.

Turbocharger Cleaning (1000 hours, yearly or lay up).

1. Remove turbocharger from engine. Figure 36.

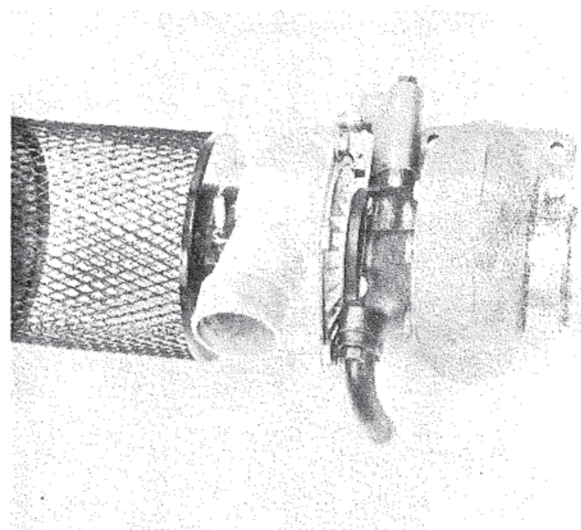


Figure 36. Turbocharger.

2. Separate compressor and turbine housings from center housing. Figure 37. Remove clean and replace one housing at a time to protect impeller.

CAUTION

Do not damage impeller blades during disassembly. If impellers are damaged, nicked, bent or cracked, replace them. Do not attempt to repair.

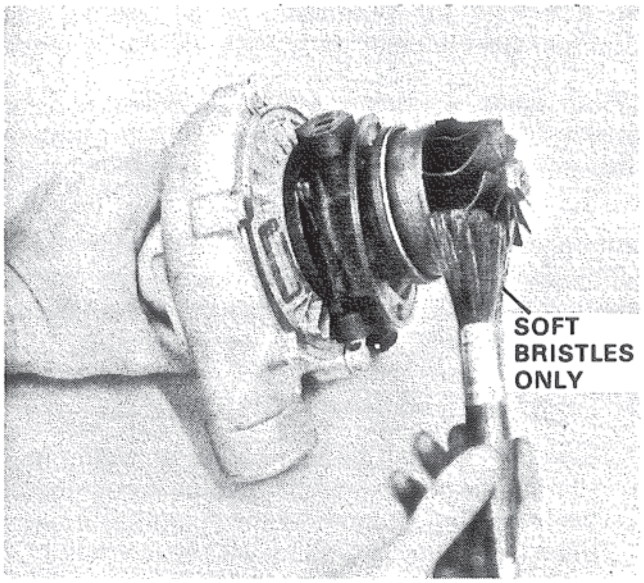


Figure 37. Cleaning Turbocharger.

CAUTION

Clean turbocharger parts with extreme care: use soft brush with nylon type bristles or small wooden device only. Rough cleaning will cause damage.

3. Clean dirt and carbon from turbocharger components — dirt will unbalance turbocharger.

4. Assemble turbocharger, torque cap screws 100-130 in. lbs. (1.2-1.5 kg/m).

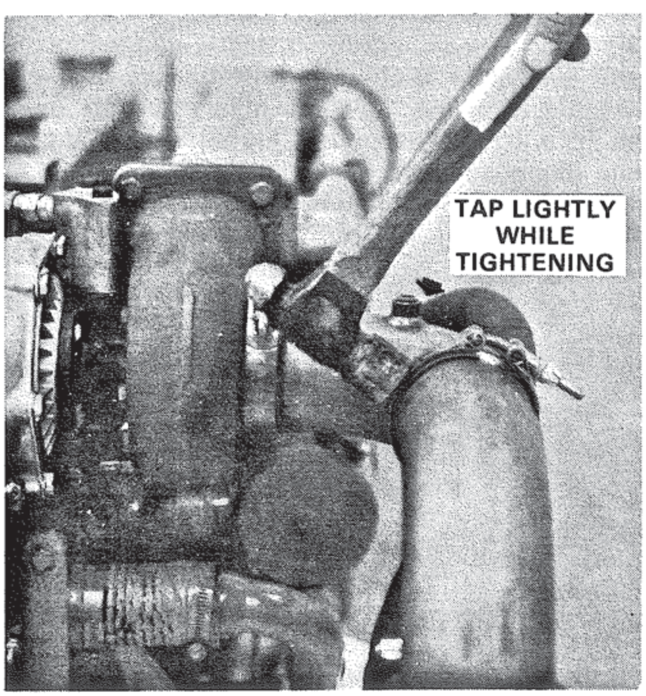


Figure 38. Tightening Clamps.

5. Mount turbocharger on engine. Use new gaskets.

6. Seat "V" band clamp on exhaust elbow by tapping lightly with a small hammer while tightening. Figure 38.

Exhaust System (100 hours). Inspect entire exhaust system for leaks. Any carbon deposit on system must be investigated and repaired.

NOTE

A spot of carbon 1/8 in. x 1/4 in. (3.18 x 6.35 mm) can indicate a large leak. Carbon particles will enter the air inlet and adhere to turbocharger and intercooler surfaces restricting air flow.

ELECTRICAL SYSTEM

The electrical system is 12 volt negative ground and includes a belt-driven 55 ampere alternator, solid state voltage regulator, starter motor, starter solenoid switch, sending units, switches and shut down solenoid.

The electrical system also includes a low oil pressure switch and a water temperature switch complete with wiring for easy installation of an optional alarm system.

CAUTION

Sending units and switches are for use with single station instrumentation only.

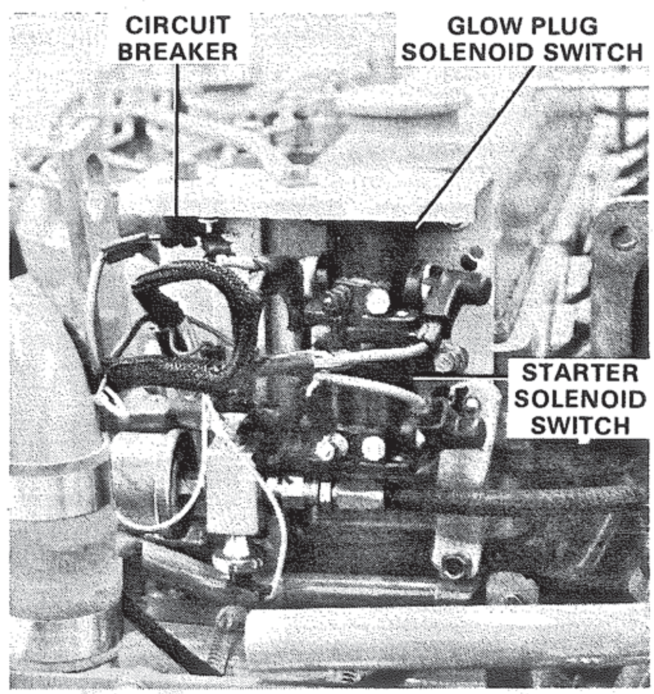


Figure 39. Electrical Components Panel.

The oil pressure sending unit and the low oil pressure switch are mounted on a panel at the rear of the engine. Other electrical components mounted on this panel include an oil pressure actuated switch which controls field current feed to the voltage regulator; glow plug solenoid switch; starter solenoid relay switch and a 50 ampere circuit breaker. Figure 39.

Battery. The battery will be maintained in top operating condition by regular routine inspection and maintenance. When not in use, the battery will discharge slowly.

1. **Electrolyte:** Electrolyte is checked every 25 hours or weekly. The correct level is approximately 1/2 in. (12.7 mm) above battery plates. Add distilled water to bring to proper level, do not overfill. After adding water, battery should be charged for at least 30 minutes to ensure proper mixing of added water and electrolyte.

2. **Specific Gravity:** The electrical charge of a battery is directly proportional to the specific gravity of the electrolyte and is checked with a hydrometer. A fully charged battery has a specific gravity reading of 1.260 plus .015 or minus .005 at 80° F. As specific gravity of electrolyte varies with temperature, the temperature must be checked and specific gravity reading corrected with the hydrometer temperature correction chart.

3. Battery should be kept clean and dry, battery connections clean and tight. A light film of grease applied to the connections will help miminize corrosion.

4. **Cold Weather:** During cold weather, battery must be charged immediately after adding distilled water. Water floating on top of battery electrolyte will freeze, damaging the battery — see (1) above. Battery capacity is considerable reduced at low temperatures. When engine is stored outside in very cold climates, it may be necessary to provide means of keeping battery warm. If necessary, remove battery and store indoors.

CAUTION

Extreme caution must be exercised when installing a battery, attaching a battery charger, or using a booster battery. Extensive damage to electrical circuits and components can result from reverse polarity, or from excessive voltage.

When using "Fast Charge" battery charger, both battery cables must be disconnected from the battery. Failure to observe the precaution can result in a burned out alternator. Never use a "Fast Charger" as a booster to provide starting voltage.

When using a booster battery, connect booster positive lead to the positive terminal of the battery; negative lead of booster battery to a good ground.

Alternator and Voltage Regulator. The alternator is equipped with sealed ball bearings and requires no lubrication. Alternator output is controlled by the solid state regulator which is **not** adjustable.

CAUTION

Never disconnect battery cables or wiring in charging system when the engine is running. Disconnecting any part of the charging circuit when the engine is running will result in failure of the voltage regulator and serious damage to the alternator.

Master Switch (if so equipped) must never be switched off until engine has completely stopped.

To ensure maximum output, the alternator terminals should be kept clean and tight, and drive belt tension checked ever 25 hours. Instructions for belt tension inspection and adjustment are found in Fresh Water Cooling System Maintenance.

NOTE

The most accurate belt tension can be obtained if belt is adjusted while warm and flexible after engine has been run.

Starter. 12-volt starter: positive lubrication is provided to the bearings by wick type oil reservoirs which may be filled by removing the two pipe plugs on the outside of the motor. Figure 40. To add oil to the pinion housing reservoir, the starter must be removed from the engine.

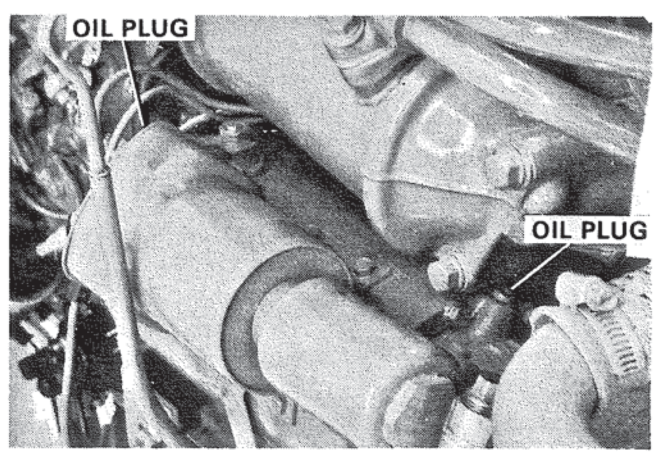


Figure 40. Starter Motor.

TROUBLESHOOTING

Problem	Possible Cause	Test Procedure/Remedy
Engine Does Not Start		
1. Engine turns over.		
A. Little smoke in exhaust gas (Fuel not being injected: loosen air bleeding screw of injection pump and operate priming pump to see if fuel is reaching injection pump).		
a. Fuel not reaching injection pump.	1. Fuel system contains air.	1. Bleed air from fuel filter and injection pump.
	2. Fuel line sucking air.	2. Repair cracked fuel line or adjust loose joint.
	3. Fuel tank empty.	3. Replenish fuel.
	4. Fuel feed pump inlet strainer clogged.	4. Remove strainer and clean.
	5. Fuel line clogged.	5. Clean fuel line using compressed air.
	6. Fuel filter clogged.	6. Disassemble, clean or replace filter.
	7. Fuel feed pump does not discharge any fuel. Valve not operating or plunger seized.	7. Disassemble and repair fuel feed pump.
	NOTE In this case, priming pump will feel light.	
b. Fuel is fed to fuel injection pump.	1. Injection pump inoperative. (Injection pump drive mechanism broken).	1. Repair defective parts.
	2. Injection line connection loose.	2. Fasten tightly.
	3. Injection pump control rack not moving.	3. Disassemble and repair.
	Plunger stuck in barrel.	Disassemble and repair or replace as necessary.
	Control sleeve stuck.	Disassemble and repair.
	4. Injection pump outlet valve stuck or spring broken.	4. Repair or replace.
B. A little smoke in exhaust gas. (Fuel injection insufficient).	1. Fuel system contains air.	1. Bleed filter and injection pump.
	2. Feed pump inlet strainer clogged.	2. Clean strainer.
	3. Fuel line clogged.	3. Clean line using compressed air.
	4. Fuel filter clogged.	4. Clean or replace filter.
	5. Fuel pump not discharging enough fuel.	5. Repair fuel pump.
	6. Pump control rack not in full open position.	6. Repair so it can travel over its full stroke.

Problem	Possible Cause	Test Procedure/Remedy
	7. Injection line connection loose.	7. Fasten tightly.
	8. Injection pump tappet catching.	8. Disassemble and repair.
	9. Injection pump tappet rollers or cams worn excessively.	9. Disassemble and replace worn parts.
	10. Sticky injection pump plunger or return spring broken.	10. Disassemble and repair or replace if required.
	11. Injection pump plungers worn excessively.	11. Replace.
	12. Injection pump control pinion set screw loose.	12. Tighten set screw firmly with setting marks on control sleeve and pinion in alignment.
	13. Injection pump delivery valves damaged or spring broken.	13. Repair or replace.
	14. Restricted fuel flow due to high viscosity.	14. Heat fuel if problem due to low air temperature or replace with better quality fuel.
	15. Nozzles are leaking excessively, so fuel injection insufficient.	15. Replace nozzles.
C. Much Smoke in Exhaust Gas. (Fuel injection sufficient, but combustion poor).		
a. Improper timing adjustment.	1. Improper mounting of injection pump.	1. Reinstall injection pump correctly.
	2. Injection pump tappets or cams badly worn.	2. Replace worn parts. Wear is caused by lack of lubricant, keep well lubricated.
	3. Adjusting screws on injection pump tappets loose.	3. Readjust timing and tighten adjusting screw firmly.
b. Fuel spray from nozzle poor.	1. Needle valve stuck to nozzle bodies, so nozzles remain open.	1. Disassemble nozzles and replace if necessary.
	2. Nozzles not seating properly on valve seats, leaking excessively.	2. Check nozzles, replace if necessary.
	3. Fuel injection pressure too low.	3. Test nozzle, adjust adjusting screw so pressure is 120 kg/cm^2 (1707 p.s.i.).
	4. Nozzle holder spring broken.	4. Replace spring and adjust injection pressure.
	5. Nozzle packings clogged.	5. Remove packings and remove carbon.

Problem	Possible Cause	Test Procedure/Remedy
c. Glow plugs do not become hot. (Usually, the glow plugs become red-hot in approx. 25 seconds. Pilot lamp (option, industrial) shows whether glow plugs have become red hot).	1. Starting switch out of order.	1. Check inner contacting points for poor contact or damage and make necessary repair.
	2. Glow plugs burned out.	2. If one or two plugs burned, usually the pilot lamp dims. To find which plugs are burned, short circuit their conductor plates one after another.
	3. Pilot lamp broken.	3. Replace lamp.
	4. Improper wiring.	4. Check and correct improper wiring or poor contact due to loose part.
d. Engine compression not sufficient to ignite fuel.	1. Engine rotating speed low. (It is difficult to start engine unless engine speed is 100 rpm or more).	1. If batteries discharged, charge or replace them. If engine oil solidified, heat it.
	2. Valve stems stuck to valve guides, valve remaining open.	2. Disassemble and repair.
	3. Valve seats not air-tight.	3. Disassemble and fit tightly.
	4. Valve spring broken.	4. Replace valve spring.
	5. Rocker arm keeping valves open.	5. Adjust valve clearance to specs.
	6. Excessive compression pressure leak due to worn cylinder or stuck piston rings.	6. Disassemble and repair.
	7. Excessive combustion gas leaking from between cylinder and cylinder head.	7. Inspect head gasket and replace with new one if necessary.
e. Improper fuel.	1. Fuel contaminated by water.	1. Replace with good fuel.
	2. Fuel quality poor.	2. Replace with good quality fuel.
2. Engine does not Rotate.		
A. Engine can be cranked by hand.		
a. Starter does not crank engine.	1. Battery switch not engaged.	1. Engage switch.
	2. Starting switch out of order.	2. Disassemble and check contact points and repair.
	3. Wrong wiring.	3. Check connection to switch, battery, starter, etc., and repair loose connections or short-circuits.
	4. Starter relay or blocking relay malfunctioning.	4. Inspect and repair.
	5. Starter or batteries malfunctioning.	5. Check and repair or replace.
	6. Battery capacity insufficient.	6. If battery discharged, charge or replace.

Problem	Possible Cause	Test Procedure/Remedy
		If capacity dropped due to low temperature, heat gradually, charge or replace.
	7. Poor contact due to starter brush seizure, wear or breakage.	7. Disassemble and check, replace damaged parts.
b. Starter rotates but does not mesh with ring gear.	1. Starter switch not adjusted properly.	1. Check and repair.
	2. Pinion gear or ring gear broken.	2. Check and repair or replace if necessary.
c. Starter pinion meshes with ring gear but does not crank engine.	1. Battery capacity insufficient.	1. Charge, warm or replace battery.
	2. Brush pressure on starter commutator low.	2. Check and repair brush and spring. Replace if worn or damaged.
B. Engine cannot be cranked by hand.		
a. Can be cranked with clutch disengaged.	1. Transmission trouble, bearing seizure or something caught between gears. (Industrial only)	1. Disassemble and repair.
b. Cannot be cranked by hand even with clutch disengaged.	1. Engine moving parts are seized.	1. Check pistons, connecting rod bearings, main bearings, camshaft bearings, timing gear and valves one after another, and repair if necessary.
	2. Engine assembled improperly (valves hitting pistons because of bad timing).	2. In this case, the engine can be rotated until valve comes into contact with piston. Disassemble and repair.
	3. Engine oil solidified.	3. Heat engine oil.
Engine Output Poor		
1. A Little Smoke in Exhaust Gas.		
A. Moving parts near seized.	1. Engine main parts near seized.	1. Check main parts one after another and make necessary repairs.
B. Fuel feed not sufficient.	1. Strainer in feed pump inlet clogged.	1. Clean strainer.
	2. Fuel line clogged.	2. Clean line, using compressed air.
	3. Filter element clogged.	3. Clean or replace filter.
	4. Fuel feed pump does not discharge enough fuel.	4. Repair pump.
	5. Injection pipe connection loose, fuel leaking.	5. Fasten tightly.

Problem	Possible Cause	Test Procedure/Remedy
	6. Injection pump tappets binding.	6. Disassemble and repair.
	7. Injection pump tappet rollers or cams are worn excessively.	7. Replace worn parts.
	8. Injection pump plungers stuck or return springs broken.	8. Repair or replace parts.
	9. Injection pump plungers badly worn.	9. Replace.
	10.Set screws on injection pump control pinion loose.	10.Tighten set screw with marks on control sleeve and pinion aligned.
	11.Injection pump delivery valves are damaged or springs broken.	11.Repair or replace.
	12.Nozzles leaking (In this case, return fuel increases and injection rate decreases).	12.Replace nozzles.
	13.Fuel not flowing well due to high viscosity.	13.Heat or replace.
2. Much White Smoke In Exhaust Gas.		
A. Timing extremely retarded.	1. Injection pump improperly assembled.	1. Reinstall injection pump.
	2. Injection pump tappet rollers or cams badly worn.	2. Replace worn parts. Wear caused by lack of lubrication. Ensure good lubrication.
	3. Adjusting screws on injection pump tappets loose.	3. Readjust timing, tighten screws firmly.
B. Poor combustion due to insufficient compression pressure. In ths case, there is white smoke after starting, black smoke as engine becomes warm.	1. Rocker arms keeping valves open.	1. Adjust valves to specs.
	2. Valve clearance too large.	2. Adjust to 0.03 mm (.0012 in.), when engine is cold.
	3. Valve stems sticking to guides or valves not seating properly.	3. Disassemble and repair.
	4. Valves not seating properly on seat, not air-tight.	4. Reassemble tightly.
	5. Valve springs broken.	5. Replace valve spring.
	6. Combustion leaks due to wear of cylinder or sticky piston ring.	6. Disassemble and repair.
C. Improper fuel.	1. Fuel contaminated by water.	1. Replace with good fuel.

Problem	Possible Cause	Test Procedure/Remedy
3. Much Black Smoke in Exhaust Gas.		
A. Timing extremely advanced. In this case, engine knocks loudly.	1. Injection pump assembled wrong.	1. Reinstall pump.
B. Fuel injection rate to each cylinder not uniform.	1. Tappet rollers or cams badly worn.	1. Replace worn parts. Wear due to lack of lubrication. Ensure good lubrication.
	2. Adjusting screws on tappet(s) loose.	2. Readjust timing, tighten screw.
	3. Tappet(s) sticking.	3. Repair.
	4. Plunger(s) worn excessively.	4. Replace.
	5. Plunger(s) stuck or springs broken.	5. Repair or replace if needed.
	6. Set screws on control pinion(s) loosened.	6. Tighten set screw, with marks on control sleeve and pinion aligned.
	7. Delivery valve seats damaged or valve springs broken.	7. Repair or replace.
C. Fuel spray from nozzle poor.	1. Needle valves stuck to nozzle bodies, keeping nozzles open.	1. Disassemble nozzles, replace if necessary.
	2. Nozzles not lapped properly on valve seats, leaking badly.	2. Disassemble nozzles, replace if necessary.
	3. Low fuel injection pressure due to loose adjusting screw(s).	3. Test nozzle, adjust screw so pressure is 120 kg/cm^2 (1707 p.s.i.).
	4. Nozzle holder spring broken.	4. Replace spring, adjust injection pressure.
	5. Nozzle packing badly stained.	5. Remove packing, remove carbon.
D. Poor combustion due to insufficient air intake. (Black smoke or white smoke when starting, black smoke when warm).	1. Rocker arm keeping valves open.	1. Adjust valve clearances to specs.
	2. Valve stems stuck to valve guides and valve remaining open.	2. Disassemble, repair.
	3. Valve seats not properly lapped to valves, not air-tight.	3. Refit tightly.
	4. Valve springs broken.	4. Replace valve spring.
	5. Gas leaking from cylinder head.	5. Tighten firmly, or replace if necessary.
	6. Air cleaner clogged.	6. Disassemble and clean.

Problem	Possible Cause	Test Procedure/Remedy
Engine Knocks		
A. Injection timing not proper.	1. Injection timing excessively advanced. In this case, engine knocks and emits black smoke.	1. Reinstall. (Pump installed wrong).
	2. Injection timing excessively retarded. In this case, engine knocks and emits white smoke.	2. Reinstall. (Pump installed wrong).
B. Fuel injection rate to each cylinder not uniform.	1. Knocking loud only in cylinders where fuel is injected at excessively high rate.	1. Adjust, repair or replace worn parts of injection pump.
	2. Knocking is loud in cylinders where fuel is injected at very advanced timing.	2. Adjust tappet screws or replace worn tappet rollers or cams.
C. Fuel spray from nozzle poor.	1. Ignition lag, simultaneous ignition of excess fuel.	1. Adjust or replace nozzles.
D. Engine compression poor.	1. Poor compression causes ignition delay.	1. Check rocker arm and valve assemblies, cylinder head, air cleaner.
E. Oil passing rings.	1. Oil pan overfilled with oil.	1. Drain oil to proper level.
(In this case, oil burns with fuel oil, causes knocking and dark gray smoke. Normally, knocking sound is weak and exhaust smoke will be pale blue).	2. Improper oil scraping due to worn or stuck rings.	2. Disassemble and repair, or replace rings if necessary. Also clean oil holes in piston.
	3. Cylinders worn excessively.	3. Disassemble and rebore cylinder or replace with new cylinder.
	4. Both viscosity and quality of engine oil inferior.	4. Replace with suitable oil.
F. Engine malfunction.	1. Connecting rod bolts loose.	1. Disassemble and repair.
(Unusual noise when engine rotates after fuel cut off).	2. Excessive clearance between cylinder and piston.	2. Disassemble and replace with suitable oversize parts to provide specified clearance.
	3. Foreign matter in cylinders being hit by pistons.	3. Disassemble and repair.
G. Engine cold.	1. In this case, the engine knocks loudly because of ignition lag caused by low compression temperature. This often happens just after starting.	1. Warm up engine well before running it full throttle.

Problem	Possible Cause	Test Procedure/Remedy
Heavy Smoke During Operation A. Heavy white smoke.	1. Timing excessively retarded.	1. Check injection pump installation, tappet adjustment or tappet roller, cam wear.
	2. Engine compression pressure insufficient.	2. Check valve clearance, operation; cylinder, or piston ring wear.
	3. Fuel contaminated by water.	3. Replace with good fuel.
	4. Oil goes above piston. Results in dark gray exhaust smoke.	4. Check for excess oil, bad oil ring, cylinder wear, inferior or wrong oil.
	5. Poor combustion due to cold engine operating temperature.	5. Check thermostat.
	6. Oil accumulated in exhaust pipe due to long idling of engine without loads.	6. Run engine under load. Oil in exhaust remains excessive. Check oil (see step 4).
B. Heavy black smoke.	1. Timing excessively advanced.	1. Reinstall injection pump.
	2. Fuel injection rate from pump too high.	2. Retighten control rack.
	3. Fuel injection rate to cylinder not uniform.	3. Check for misadjustment, wear of injection pump.
	4. Poor nozzle spraying.	4. Check adjustment, wear of nozzles.
	5. Poor engine compression.	5. Check rocker arm, valve assemblies, cylinder head and air cleaner.
	6. Excessive oil above piston.	6. Check for excess oil, bad oil rings, cylinder wear or inferior or wrong oil.
Engine Rotates at High Speed and does not Stop	1. Connecting link between throttle and injection pump control binding.	1. Check and repair.
	2. Governor internal sliding functions or linkages poor.	2. Disassemble and recondition so they will slide smoothly.
	3. Injection pump control rack binding, does not return to its no fuel position.	3. Disassemble and recondition so that it will travel smoothly over its whole stroke.
	4. Set screws on injection pump control pinions are loose.	4. Tighten set screw, with marks on control sleeve and pinion aligned.

Problem	Possible Cause	Test Procedure/Remedy
Trouble in Lubrication System		
A. Warning lamp comes on during operation at low speed.	1. Engine oil level too low.	1. Add oil to specified level.
	2. Oil pump cannot operate properly due to high oil viscosity. (This happens particularly in cold weather).	2. Heat oil or replace with good oil of suitable viscosity.
	3. Oil pressure switch malfunctioning.	3. Replace oil pressure switch.
	4. Line or strainer for oil pump suction side clogged.	4. Repair broken line or clean strainer.
	5. Line to oil pressure gauge clogged.	5. Remove and clean line.
	6. Oil pressure regulating valve (relief valve) malfunctioning.	6. Disassemble and check for broken spring or foreign matter in valve, sticky valve. Repair as necessary.
B. Warning lamp comes on during operation at high speed. (Oil thin, due to high temperature).	1. Unsuitable viscosity or quality of engine oil.	1. Replace with suitable oil.
	2. Continuous operation of engine at full throttle.	2. Discontinue operation of engine until lubricating oil temperature falls.
	3. Bearings, other parts seizing. (Metal particles may be found in oil).	3. Disassemble and check.
	4. Clogged oil filter element.	4. Replace element.
C. Warning lamp comes on during operation.	1. Oil pump strainer sucking air due to low oil level.	1. Add oil to specified level.
	2. Oil by-pass alarm out of order.	2. Disassemble and check.

LAYING UP AND FITTING OUT

Laying Up. During the running season, many owners make use of an engine room log. The engine room log can be used to determine what maintenance schedule change may be necessary to adapt the schedule to suit a local condition, one particular vessel, or a certain operating situation.

Prior to lay-up, some owners have a thorough inspection made at their Chrysler Marine distributor or dealer. Such an inspection will determine the amount of maintenance which should be completed before going into commission again.

A compression test, fuel injection system test and an over-all check-up will usually disclose the normal requirements. You can then tailor and schedule all items to arrive at a reasonable comissioning date.

Chrysler Engine Oil Supplement when used in the engine oil for a short time before lay-up, neutralizes acid conditions, breaks up gum and sludge formations as it cleans the engine interior. The foreign matter is then removed when the oil is changed on the day the vessel is removed from the water.

Engine Protection

1. It is advisable to lay-up the engine in the cleanest possible condition.

2. Change the oil and the oil filter. It is recommended that oil be drained while engine is at normal operating temperature, as the warm oil will drain more readily and completely, carrying with it foreign matter which might otherwise cling to the sides of the crankcase and internal parts of the engine. Fill crankcase with recommended type of oil of appropriate grade for the anticipated outside temperature. Refer to Operation Section for recommendations. To obtain the best corrosion protection add 1 pt. (.47 L) of crankcase Detergent and Rust Inhibitor, Chrysler Part No. 3419130, to the initial oil fill.

3. Remove glow plugs and using an oil squirt can spray approximately 1 oz. (28.35 G) of crankcase Detergent and Rust Inhibitor, Chrysler Part No. 3419130, cut 8 to 1 with engine oil, into each cylinder.

CAUTION

Do not put more than the specified amount of detergent into each cylinder, otherwise a hydraulic lock may occur resulting in serious engine damage.

Rotate the engine several revolutions while holding stop switch in off position with the starter to distribute the oil on the cylinder walls. Replace the glow plugs.

COOLING SYSTEM PROTECTION

Raw Water Cooling System

1. Flush the cooling system with fresh water. Flushing the cooling system prior to draining is desirable particularly on engines in boats operating in sea water in order to flush out sediment before it dries.

2. Drain the impeller type water pump, by loosening the end cover.

3. Remove the impellers from the water pump.

NOTE

If the rubber impellers are allowed to stay in the pump during the lay-up period they will become set and will not function properly in further use. it is recommended that the impellers be removed from the pump.

4. Remove drain plugs from engine oil cooler, transmission oil cooler, and heat exchanger. The heat exchanger includes a sacrificial anode which should be checked and replaced as necessary. Remove hoses to and from intercooler.

5. Exhaust risers where used must also be drained by removing the lower drain plug or hose. This can be improved on by using suction side of pump.

"Wet storage" protection of the raw water cooling system is preferred, all drain plugs should be re-installed and a thoroughly mixed solution of 50% water and 50% high quality permanent type antifreeze is used to completely fill the raw water system. This may be done by removing the hose from the outlet of the raw water pump and using a hand pump to pump solution into the system through this hose. When system is filled antifreeze solution will be discharged from the exhaust elbow. Exhaust hose should be removed for this operation. Do not use oil base or other doubtful antifreeze compounds that could cause deterioration of the rubber hoses.

NOTE

In both "wet" and "dry" type of storage the raw water pump impellers should then be removed.

6. Loosen the tension on all belts.

Fresh Water Cooling System. Each fall, to assure maximum efficiency of the fresh water cooling system, the following procedures should be observed:

Drain, flush and refill cooling system. System is drained by opening cylinder block drain cock and removing drain plugs from lower rear of exhaust manifold and from the fresh water section of the heat exchanger. If coolant appears contaminated the system should be cleaned.

Fuel System Protection. Shut off fuel supply valves and clean all fuel filters and install new filter elements. Turn on fuel supply valves and operate hand priming pump until all air is removed and system is completely filled with fuel.

All water and sediment should be drained from the fuel tanks, after which the fuel tanks should be completely filled to minimize condensation during the storage period.

Remove air cleaner element and seal air inlet to protect the induction system.

Exhaust outlets should also be sealed.

Electrical System Protection. Remove battery for storage ashore where it will receive attention at frequent intervals.

When units such as alternator, or starter are removed for storage ashore, mounting openings should be sealed against the entrance of air, dust and moisture.

Electrical wiring, switches, fuse block and the grounding device should be examined.

All engine control linkages should be inspected for wear, proper adjustment and protection from rust and corrosion.

Reverse Gear and V-Drive Protection. Drain oil and refill with oil of the correct type for the particular type of transmission.

NOTE

Be sure that water is drained from the water jacket of the V-Drive.

Fitting Out. In the foregoing lay-up procedure, the engine was equipped with fresh engine oil and a new filter cartridge and sealed against the entrance of dust and other foreign matter. A visual inspection will determine the effectiveness of the seals as they are removed for installation of the various units. Mounting surfaces for the alternator and starter should be flat, smooth and clean.

Battery posts and cable connectors should be clean and bright. After tightening connections, a light film of grease will delay corrosion.

Cooling System drain plugs and the water pump cover and impeller should be installed and tightened.

Inspect fuel tank and fuel lines. Inspect, clean and install air cleaner element. Remove closures from exhaust outlets.

Start engine, observe all engine gauges for normal readings. See Engine Starting and Operation Procedures. While engine is warming up, check fuel and cooling system for leaks.

Engine to propeller shaft alignment should be checked after the boat has been in the water for several days. Clean mating surfaces of both flanges. Hold a .002 in. (.051 mm) feeler gauge against the reverse gear flange, in a perpendicular position corresponding to the hand on a clock at 12 o'clock. Pull the propeller shaft assembly into contact with the gauge sufficiently to produce a slight drag when withdrawing the gauge. Hold the shaft in this position and try the gauge at the three, six and nine o'clock positions. When the drag is equal at all four positions, the alignment is proper. A difference in feel at the six and twelve o'clock positions indicates that the fore and aft height of the engine needs readjustment. A difference in feel at the three and nine o'clock positions indicates that the engine should be shifted to the right or left. This shaft alignment should be checked periodically.

Notes:

email: partsdz@gmail.com
Phone: 269 673 2128 (leave message)

Notes:
Upper Engine Gasket and Seal Set Part # 4142149
Lower Engine Gasket and Seal Set Part # 4142150

Section 4

INSTALLATION

CONTENTS

Section 4

INSTALLATION

SPECIFICATIONS FOR MARINE APPLICATION

Intermittent (Pleasure Craft)

Maximum Installation Angle	15°
Suggested Engine Room Vent Area, Minimum	50 square in.
Air Consumption	425 cubic feet/min.

Cooling System

Heat Rejection to Coolant	10,600 BTU/mm.
Fresh Water Capacity	5 gal.
Raw Water Flow	35 gal. per min.
Maximum Inlet Restriction at Raw Water Pump	5 in. Hg. @ 3150 RPM
Maximum Raw Water Pump Pressure	10 p.s.i. @ 3150 RPM
Suggested Raw Water Pipe Size	1-1/4 in.
Suggested Sea Strainer Size	
Simplex	1-1/2 in.
Duplex	2 in.

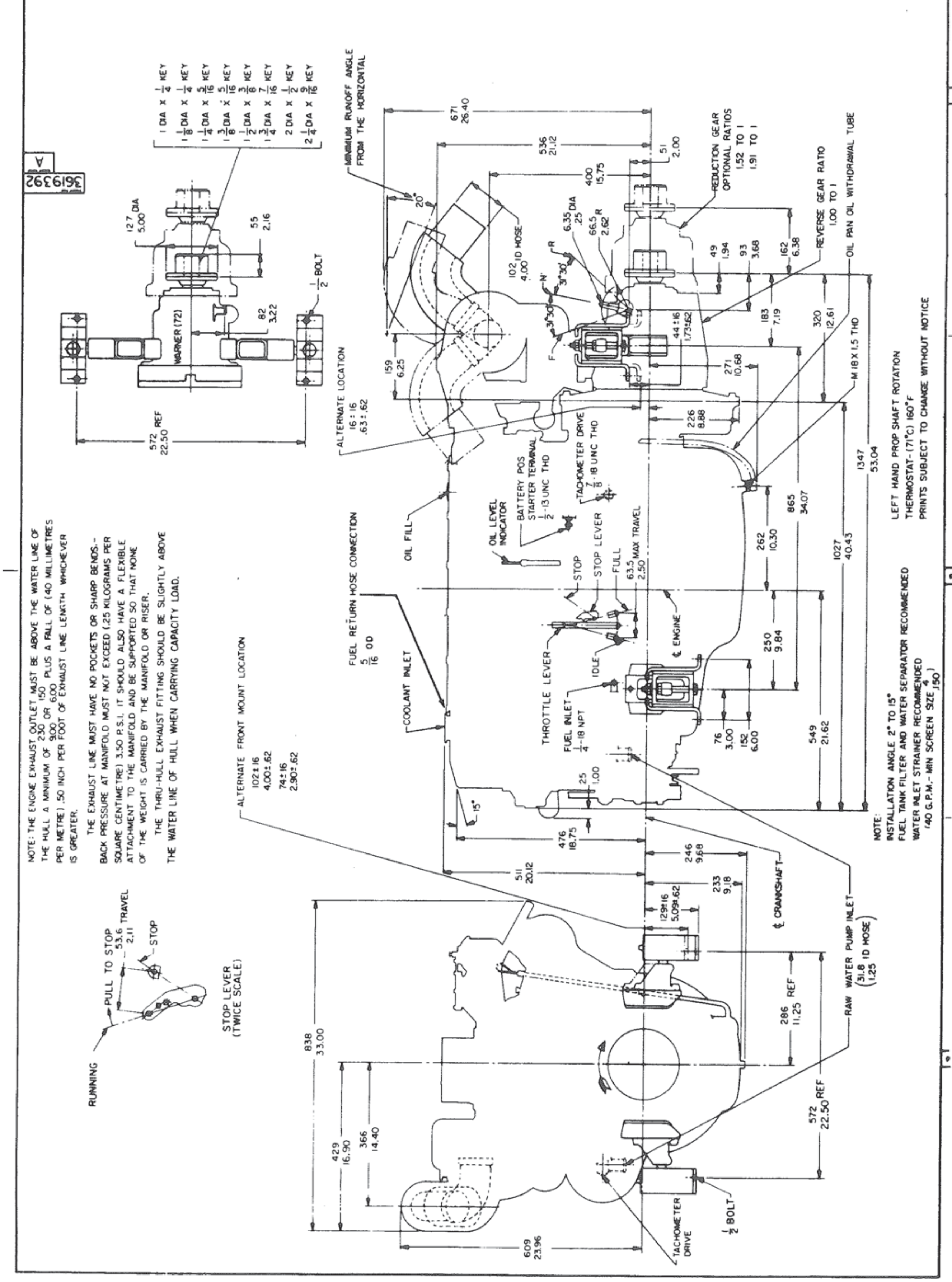
Fuel System

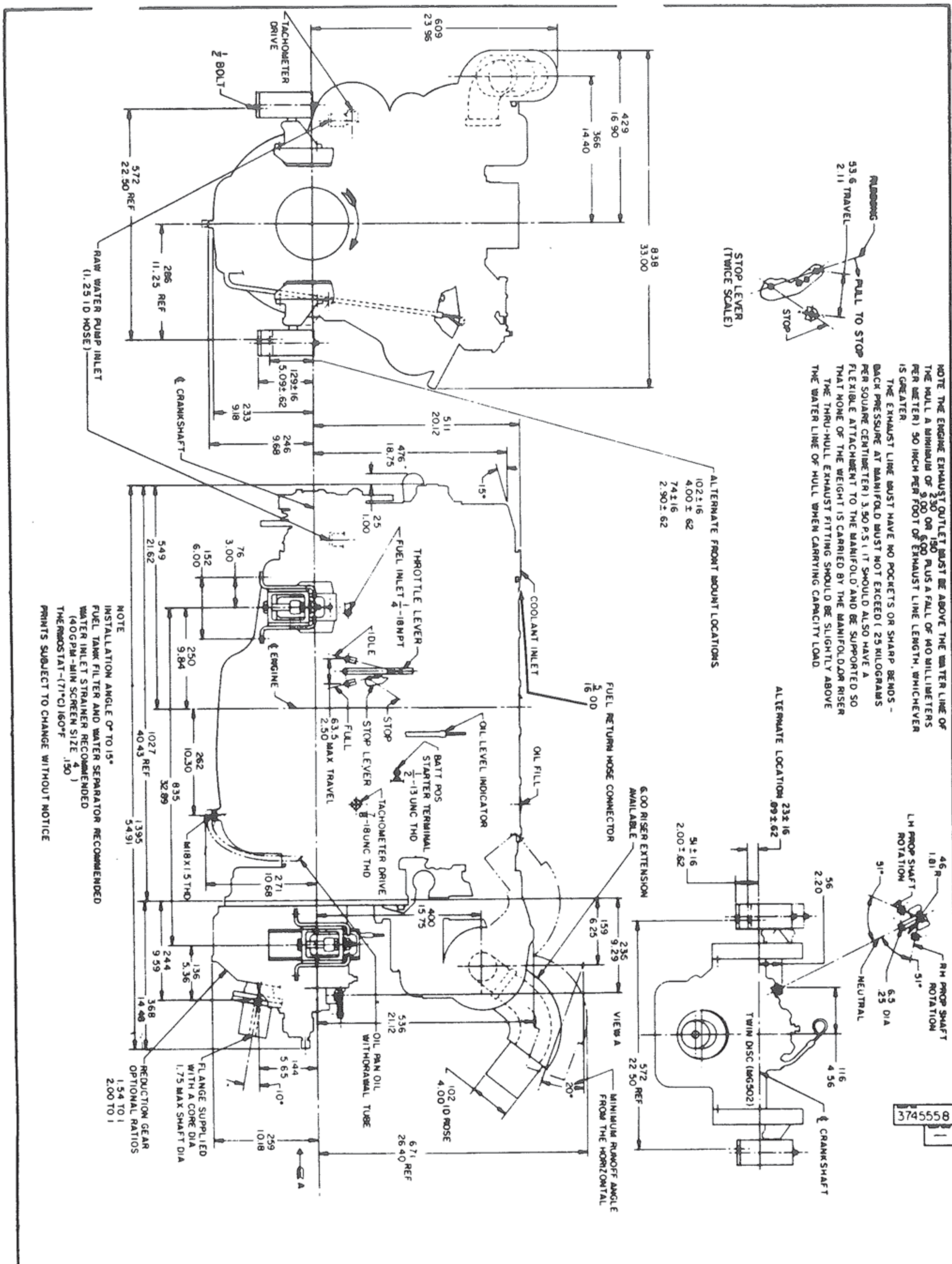
Maximum Fuel Consumption	13.5 gal. per hour
Fuel Line Size	5/16 in. ID (min.) up to 20 ft. 3/8 in. ID (min.) 20 ft. and longer
Maximum Fuel Lift	3 ft.

Exhaust System

Temperature (WOT)	1200° before turbo
Maximum Exhaust	1000° after turbo
Maximum Back Pressure At Turbo Outlet (Full Load)	3.5 in. Hg. @ 3150 RPM
Suggested Pipe Size	5 in.
Suggested Silencer Size	5 in.

Installation Diagram.





Installation Diagram.

CM655 (TURBOCHARGED - INTERCOOLED)

Rating and Propeller Selection.

		Fuel Consumption
Rated HP (Gross SAE)	200 @ 3150 RPM	13.5 GPH
Shaft HP	190 @ 3150 RPM	13.5 GPH
Recommended Cruising Speed Range	2600 to 2850 RPM	9.0 GPH 10.5 GPH

The CM655-TI engine is offered for Pleasure Craft operation and is to be operated where intermittent high speed is required. The turbocharger is matched to the engine for high speed operation, 3150 RPM **Full Load**. It is important to avoid overwheeling and full throttle operations at RPM's below 3000 RPM. Oversized propellers cause lengthy acceleration periods and increase the possibility of excessive smoke, because the effectiveness of the turbocharger is limited at low RPM.

In the selection of a propeller, Chrysler acts in an advisory capacity, since most of the factors concerned with the selection are variables controlled by others. The final selection is to be made in accordance with the principle that the engine is expected to be able to operate at/or near its rated power and speed for the application when the boat is carrying its rated load. If there is a large difference in displacement of the boat fully loaded and empty, the governor should keep the engine from overspeeding when the boat is empty.

The engine should be wheeled for 3150 RPM when the boat is **fully loaded** — full fuel and water, all boat equipment, boat supplies, and normal passenger load and passenger supplies on board.

When a boat is **lightly loaded**, such as a new boat without all passenger equipment load, the engine should be able to run 3200-3250 RPM (50-100 RPM reserve to allow for passenger and owner's equipment). When checking for this condition of prop. limiting RPM, it will be necessary to override the governor. Back out the high speed limit screw and run "Full Rack" as verification. Do not under any circumstances exceed 3400 RPM during this verification. By wheeling the boat in this manner, the final package will be assured to run at the rated speed of 3150 RPM under most all boat loading and weather conditions. Reset the high speed limit screw to 3150 RPM while under way at full helm throttle control travel (WOT). Make a final recheck that high idle (no load) does **not exceed** 3400 RPM. This data should be recorded as a part of the original boat data log.

To establish the cruising speed for a particular day's operating conditions (load, weather, etc.), check WOT RPM and back off 10% (300 RPM).

Before making a propeller selection, the following information is required:

1. Shaft horsepower or horsepower available at the propeller.
2. Hull type. (Generally speaking, this will be planing, semi-displacement or displacement.)
3. Engine rated power and speed.
4. Reduction ratio.
5. Space available for the propeller, including tip clearance and, if available, clearance forward to the strut or deadwood and aft to the rudder.
6. Displacement, both net (no fuel or water or disposable load) and gross (full fuel and water tanks and maximum disposable load).
7. Water line length with boat at rest and length overall.
8. Propeller shaft diameter.
9. Propeller shaft rotation for forward.

In addition to this information, several other items are very helpful.

1. The speed of which the boat is capable, using any other engine, and the engine speed, power, weight, reduction ratio, boat displacement, propeller diameter, pitch and type when the speed was measured.
2. Type of superstructure, as a means of determining the "sail effect". For example, a conventional houseboat has a very high sail effect, and a conventional runabout has a very low sail effect. This is not very important for propeller calculations unless speeds are over 20 knots.

Charts on next two (2) pages may be used to estimate the potential boat speed where the shaft horsepower, gross displacement and water line length are known. To use these charts, locate the shaft horsepower on the upper left hand side, as (1) on the examples shown. From the shaft horsepower go to the right to the displacement, as at (2) on the examples. From the displacement come straight down to the water line length, as at (3) on the examples. From the water line length, go to the left to knots, as at (4) on the examples.

Shaft horsepower is the rated power of the engine, less the power loss that results from its application. For example, there is approximately a 2% loss per helical gear tooth contact, a 3% loss per bevel gear tooth contact and other similar small losses for the hydraulic pump and parasitic drag in the transmission, a loss due to exhaust back pressure, and a possible loss due to the engine being run under atmospheric conditions other than standard, etc.

As an estimate of propeller diameter, the following formula may be of value:

$$\text{MIN. DIA. (Inches)} = \frac{\text{1/2 BOAT LENGTH (FT.)}}{2} \times 1.10$$

This is for typical cruiser type boats. Heavier boats will require larger diameters.

The boat speed may also be calculated if there is known performance of known power in the same or similar hull available. This is done by using Keith's Formula:

$$\text{KNOTS} = \sqrt{L} \times C \sqrt[3]{\frac{\text{HP} \times 1000}{\text{DISP.}}} \quad \&$$

$$C = \frac{\text{KNOTS}}{\sqrt{L}} \times \frac{1}{\sqrt[3]{\frac{\text{HP} \times 1000}{\text{DISP.}}}} \quad \&$$

$$\text{HP} = \text{DISP.} \left\{\frac{\text{KNOTS}}{10\,C\sqrt{L}}\right\}^3$$

in which L = designed water length at rest in feet

DISP. = Gross weight in pounds

C = A constant or number which varies for size and type of boat. This will usually be between 1.3 and 1.5.

This constant must be determined with care for reasonable accuracy. For exact predictions, have it tank tested. A rule of thumb for minimum propeller diameter in pleasure boats is:

$$\frac{\text{Load Water Line in Ft.}}{2} = \text{DIA in inches} + 10\%$$

Therefore a 30 ft. water line hull should use a 16 in. or 17 in. diameter propeller.

$$\frac{30}{2} = 15 + 1.5 — 16.5 \text{ in.}$$

SUGGESTED PROPELLER SELECTION FOR CM655-TI
(3 Blade Propellers)

Est. Speed	**Ratio**		
MPH	**1:1**	**1.5:1**	**2:1**
20	17 x 11	19 x 14	23 x 19
25	16 x 12	19 x 17	22 x 22
30	15 x 14	18 x 20	21 x 25
35	15 x 15	17 x 22	

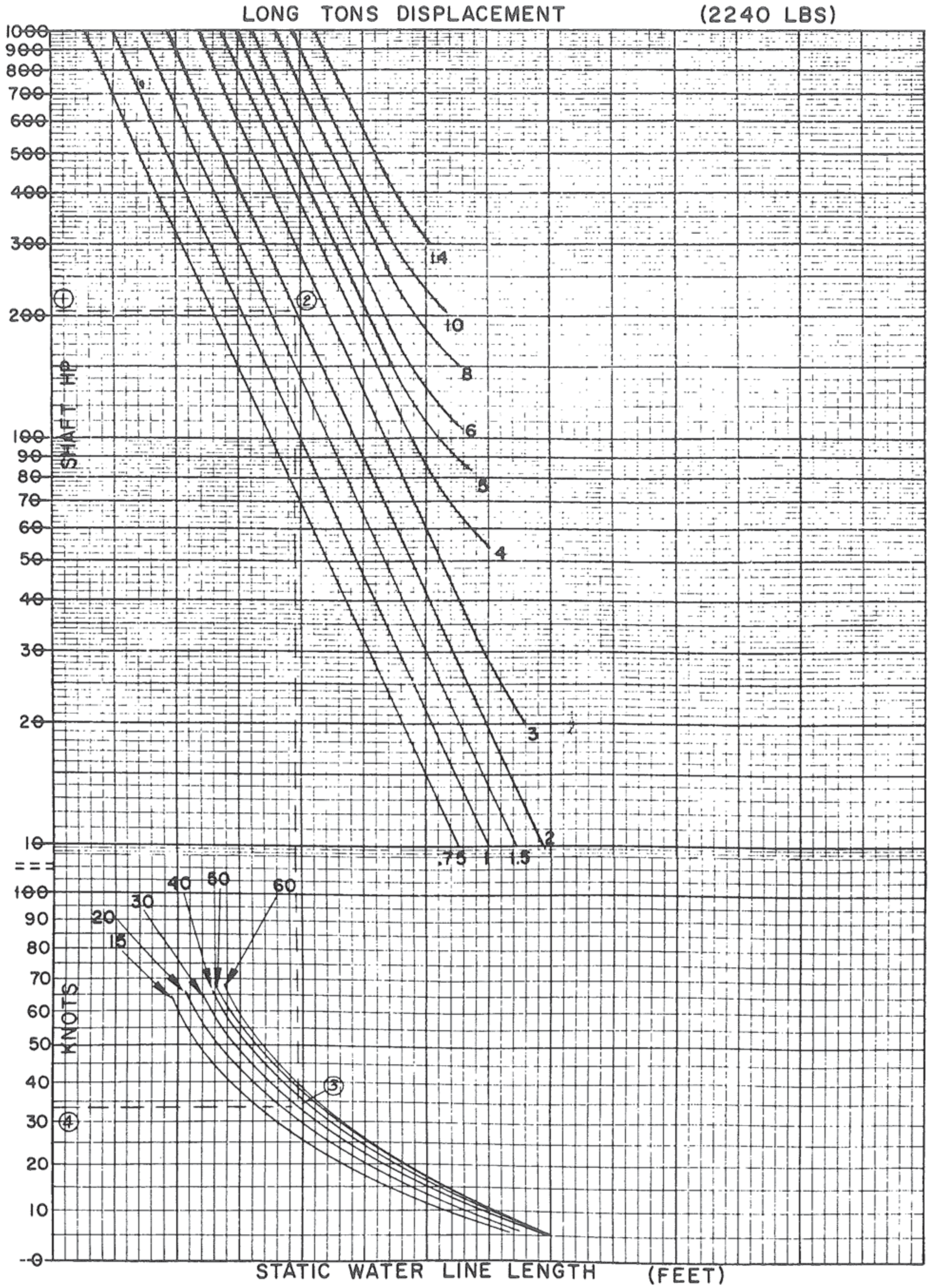


CHART: POTENTIAL SPEED ESTIMATOR FOR NON-STEPPED HARD CHINE PLANING HULLS

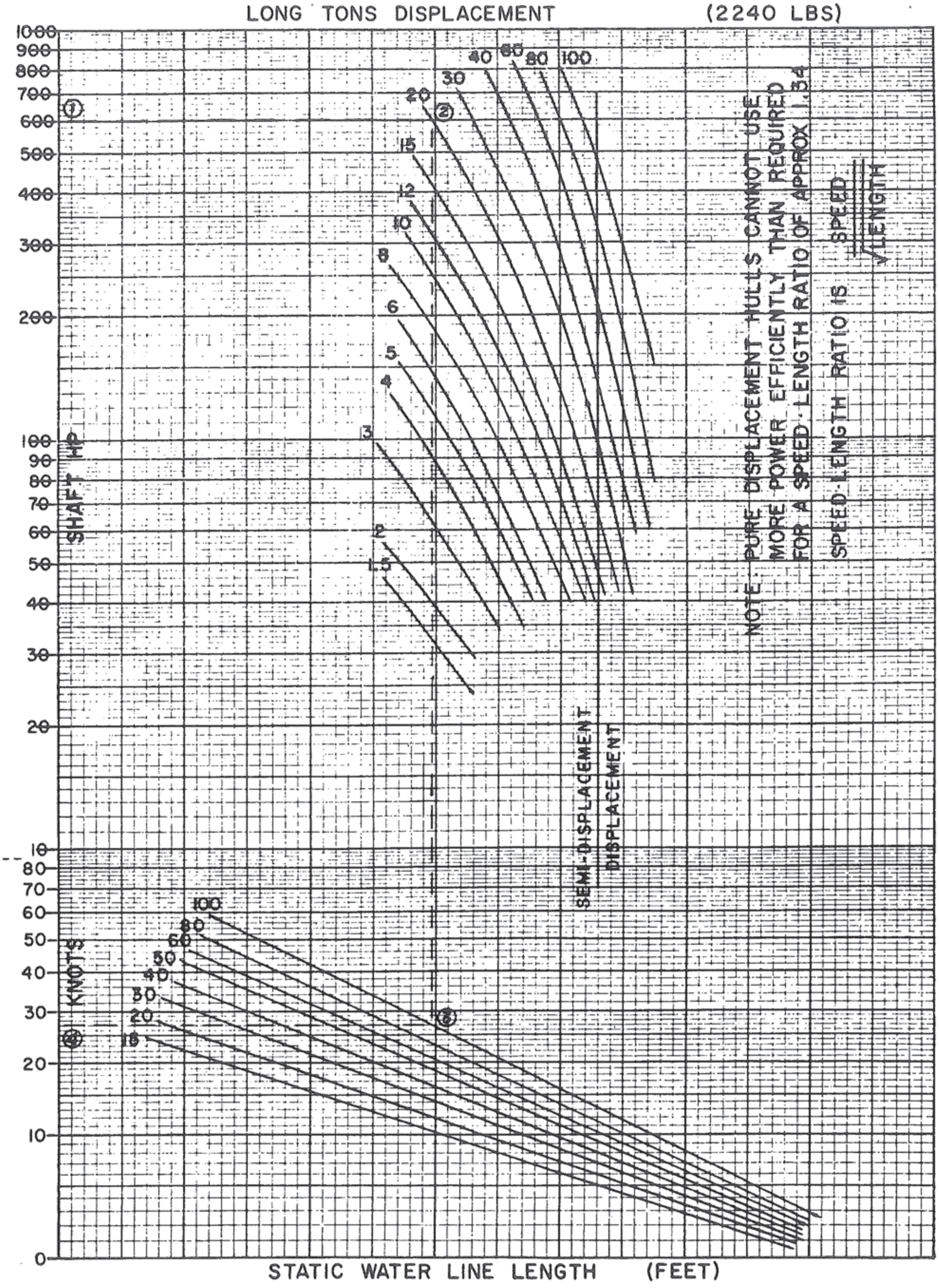


CHART: POTENTIAL SPEED ESTIMATOR FOR DISPLACEMENT AND SEMI-DISPLACEMENT HULLS

MOUNTING STRUCTURE, INSTALLATION AND ALIGNMENT OF THE ENGINE AND DRIVELINE HARDWARE

Shaft and Bearings. The propeller shaft angle is determined by a layout or loft. In making the layout, the starting point is the rudder. To determine the size of a conventional rudder, multiply the water line length in feet by the depth of the keel below the water line in feet, and multiply the result by .04. This will be the rudder area. It should not be deeper than the propeller because it depends upon the wash from the propeller to steer effectively. The trailing edge should be either ahead of the transom, or substantially below the bottom of the boat to prevent loss of effectiveness due to rudder cavitation in sharp or fast turns.

The propeller tip to boat clearance should be 10% or more of the propeller diameter. This is to keep it working efficiently in relatively undisturbed water and to prevent a drumming noise.

The propeller should be far enough ahead of the rudder so that the propeller can be removed without removing the rudder first. It is also good practice to offset the rudder and propeller shaft so that the shaft can be removed without first removing the rudder.

Locating the propeller as indicated from the rudder and the bottom of the boat locates one point on the shaft. The location of the forward end is established by clearance of the engine and/or transmision to the bottom of the boat, and by the general attempt to keep the shaft angle as shallow as practical. 10° to 15° is a good target angle for a planing boat and 0° to 15° for a displacement or semi-displacement boat. Higher angles are possible but require special consideration.

The strut is established by the propeller shaft diameter and angle, the shape of the bottom of the boat, and the diameter of the propeller. If the propeller is over 20 in. in diameter, or if a rough duty is anticipated, a "V" style strut should be considered. Whichever type of strut is used, the propeller should be no further away from the strut than one propeller shaft diameter.

Intermediate struts or stern bearings should be used where the distance between shaft supports is over 50 times the shaft diameter for bronze or mild steel and 80 times shaft diamter for K Monel and 17-4 Ph. stainless steel.

A conventional or offset shaft log can be used, depending upon the distance from the propeller shaft coupling to the packing nut. If the distance, using a conventional shaft log is less than 2 in. plus the length of the packing nut, an offset shaft log should be used in order to be able to renew the packing.

If the shaft length is more than 50 times its diameter, and the shaft log is near the mid point of the shaft, a stern bearing and shaft log may be combined.

It is always necessary to have a supply of water at the shaft log packing and all external shaft bearings for lubrication. In some applications, it is necessary to provide water from a bleed from the engine's raw water pump to make sure that there is a flow of water to the bearing. The combined shaft log and stern bearing, and a stern bearing mounted in deadwood are examples that may require means other than being submerged in water to have a flow of water at the bearing.

Engine Bed. The engine bed should be approximately twice the length of the engine or three times the distance between engine mounts and proportioned to fit the boat and engine. The engine beds should be made of a minimum 2 x 6 hardwood timber or equivalent. If hardwood is not used, steel plates thick enough and long enough to prevent the engine mounts from sinking into the wood should be used. Plates 1/4 in. thick, as wide as the engine bed stringers and twice as long as the engine mount, usually are satisfactory. The plates should be fastened at both ends as well as by the engine mounts.

Through bolts with nuts are recommended as best means to fasten engine mounts to engine bed. If engine bed stringers are built with integral metal tapping plates, bolting into these tapping plates is also satisfactory. Lag bolts are generally not recommended, however if used, extreme care should be taken to drill a straight and correct size hole, on stringer center.

There should be room for approximately 1/2 in. of shim under the engine mount when the engine and propeller shaft are aligned in order to be able to re-align the engine in the event that the hull shape changes due to strain or water absorption.

The engine beds should be bolted firmly to spread the load over as great a portion of the boat as possible, through stringers and chocks to the floor timbers, frames, keelsons and keel. Bolts should be spaced 18 in. or closer together. Although this description fits a wooden boat, the structure of fiberglass, steel, aluminum and ferro cement boats should provide equivalent strength and stiffness.

There are several alternate satisfactory methods of providing an engine bed. In general, the engine bed used should prevent relative motion between the engine and boat due to engine and propeller torque, propeller thrust, pitch and roll of the boat, flexure of the boat, and weight of the engine. It is desireable to fabricate an engine bed that not only provides the required structure but also provides accessibility to the lower part of the engine for servicing.

Driveline Hardware. The first item to consider in the driveline is the propeller, since this is involved in the selection of reduction ratio and all other driveline items. The correct propeller is essential for a satisfactory application.

In order to select the proper propeller, the speed that the boat will go when driven by the proposed engine is required. This can be calculated if the type of hull, length and weight are known. The maximum propeller diameter and the shaft angle should also be included if these are already established. See propeller selection data, above.

The second item to consider in the driveline is the propeller shaft. Its diameter depends upon its material, length between supports, speed, and power transmitted. The following chart is offered as a guide. The selected size should be increased, if the supports are spaced farther apart than 50 times the shaft diameter, to prevent whip.

There are various types of propeller shaft couplings as follows: tapered coupling with retaining nut, split clamp type, cross pin type, and set screw type. If the set screw type is used, the procedure must be as follows:

A. After correct shaft alignment has been established, run down the coupling set screw to make a mark on the shaft.

B. Remove or slide coupling out of the way and spot drill a recess in the shaft for the set screw.

C. Reassemble, tighten, and wire the set screw.

MINIMUM SHAFT SIZE FOR REDUCTION SHOWN

RATIO	1:1	1-1/2:1	2:1
Tobin Bronze	1-1/4	1-1/2	1-3/4
* Stainless or K Monel	1-1/8	1-1/4	1-1/2

* Stainless Steel, as referred to here is Chrysler Spec. MS3007, Commercial Spec. 17-4Ph. Minimum tensil strength is 135,000 p.s.i., 2% yield strength 105,000 p.s.i.

Driveline Alignment. As in any system of shaft and bearings, alignment is extremely important, especially when intermediate bearings are used. The location of the engine, strut and shaft log will be determined by the design of the boat and hardware. The preliminary alignment may be made by stretching a line along the center line that the shaft is to follow. It can be located at the rear of the strut by a cone shaped object with a hole in the center, and at the forward end by a fixture simulating the shaft coupling. This can be as simple as a piece of wood fastened to the engine bed with a small hole located where the center line of the shaft will be.

With the line stretched in place, a disc the same diameter as the propeller shaft, and with a slot going to the center, may be used as a gauge to locate all the hardware along the shaft. The final check is to try the propeller shaft, or any straight shaft or tube of the same diameter, in the holes. It should be free, with no evidence of binding or corner loading.

Although it is possible to check propeller shaft coupling face run out in the boat, it is good practice to check it on the shaft to be used before the shaft is put in the boat. Where there are twin installations, the coupling shaft ends should be marked so they won't be mixed.

Propeller Installation. After the fixed hardware is aligned and fastened firmly in place (using sealant where there are holes through the hull), the propeller should be installed. A block of wood should be put between the propeller tip and the bottom of the boat to keep the shaft from turning, and the nut tightened by pushing up on the wrench handle. To remove the propeller, the wood block and wrench should be so placed that the force on the wrench handle is also up. This reduces the bending force on the shaft. An impact wrench and hammer can also be used.

The front of the propeller hub should usually be located a distance from the rear face of the strut equal to between 1/2 and 1 times the shaft diameter.

Engine Alignment. When the propeller and propeller shaft coupling are installed and the shaft located fore and aft by locating the propeller relative to the strut, the shaft should be blocked or shimmed in the center of the shaft log. Next, the engine is located visually so that the engine half of the propeller shaft coupling is coaxial with and its face parallel to the shaft of the coupling. At this point, the engine should be firmly on all of its mounts, and provisions should be made for fine adjustment, using built in screw jacks, wedges or shims. If jacks are used, they should bear against steel plates to prevent damage to the engine bed.

At this point, one of the engine mounts closest to the coupling can be fastened to the engine bed. Engage the coupling pilot diameters fully and check the faces for parallelism with a feeler. If there is a gap allowing more than .0005 in. feeler per in. of face diameter (.002 in for 4 in. coupling, .003 in. for 6 in. coupling, etc.) to enter between the faces at any point, shift the opposite end of the engine in the direction needed to close the gap, pivoting on the fastened engine mount.

To check the squareness of the coupling face to the shaft center line, first align the engine with the shaft, Next, keep the engine coupling stationary and turn the propeller shaft 90°, 180° and 270° and recheck that faces are parallel. If they still are parallel, the face is square with the shaft. If they are not, but the gap is increased 50% or less, re-align the engine to split the difference and recheck the alignment with the shaft in four positions, 90° apart, relative to the engine. If the gap is now less than .003 in. for a 4 in. coupling, .0045 in. for a 6 in. coupling, .006 in. for an 8 in. coupling, etc., it is safe to securely fasten all engine mounts, recheck the alignment, and if it has not changed, fasten the coupling halves together.

Since a boat may not be perfectly rigid, the alignment should always be given its final check and the coupling bolted together in the water. When a boat is to be hauled out of the water, its coupling should be unbolted to prevent bending of the shaft.

If a boat is quite flexible, allowing about a .002 to .005 gap at the bottom of the flange, when held in a cradle will often make the alignment while in the water easier.

When a flexible coupling is used, it is good practice to align without the flexible coupling. Precise alignment using most flexible coupling is impossible. Be sure the shaft and engine are in alignment before installing the flexible coupling.

Engine alignment should be checked periodically, since the action of the sea may change the shape of a boat enough to disturb the engine alignment. The use of a flexible coupling with an engine that is properly aligned to begin with greatly extends the periods between alignment checks.

After the first time, engine alignment should be checked at the first oil change and after the first rough water experience. If the alignment has not changed, then checking once a season will probably be enough. If the alignment has changed, the frequency of re-alignment may be determined by the amount of the change and the amount of use the boat gets.

COMBUSTION AND VENTILATION AIR SUPPLY

Combustion Air. In order to avoid power loss due to inadequate air supply, it is necessary to have a minimum of .25 sq. in. combustion air access area per total horsepower in the engine compartment. (Propulsion and auxiliary engines must be considered.) In calculating the area, the restrictive effect of any screens, louvers, etc., must be taken into consideration.

It is required that the combustion air access be permanently open, rather than using hatches, etc. Provisions should be made to exclude rain, sea spray, and other foreign matter. If combustion air is piped or ducted to the engine room, the additional restricting losses of bends and long runs must be calculated and the air inlet area enlarged accordingly. In cases of this nature, it is not unusual to increase the minimum calculated area by 50%.

Ventilation Air. Proper engine compartment ventilation from the standpoint of natural ventilation (air entry at forward portion of compartment and exhaust at rear for best compartment cooling), as well as power ventilator requirements, specific location of ventilators, size of ventilators versus engine compartment net volume, and duct size data are documented in the above reference standard and must be complied with.

COOLING SYSTEM

The engine is cooled by fresh water which in turn transfers its heat to raw (sea) water by means of a heat exchanger. Each system has its own pump. The fresh water system is a closed system and is factory filled with 50/50 water and permanent anti-freeze with rust inhibitor for year round use. Subsequent refilling should be done using same 50/50 mixture. Re-check the coolant level after running about five (5) minutes to be sure all air is removed from the system.

Components. An expansion tank at the front of the engine has a pressure cap of 14 lbs. and must always be in place and tight when running. The cap is removed to fill and check the water level and must be **accessible.**

The raw water side consists of a factory installed raw water pump, and a boatbuilder installed water inlet and outlet. The raw water system uses sea water for cooling and returns the water overboard through the exhaust system. The raw water pump is a positive displacement type with a single rubber impeller and is designed to pump clean water.

The water inlet must be unrestricted and should include a sea cock and must have a sea strainer. The through hull fitting should be fitted with a scoop, positioned to take advantage of the ram effect of forward motion. The sea cock should be fastened directly to the through hull fitting, and should be a gate valve or other type providing a full, unrestricted opening. Glove valves should never be used.

An internal clear plastic type sea strainer or an external tapered self-cleaning sea strainer type are recommended. A high speed scoop is **not** a strainer capable of removing all debris. The supply line from the through hull fitting to the pump must be for 1-1/4 in. I.D. hose. All hoses must be wire reinforced or have a gap between solid sections no greater than 1-1/4 in. Suction/supply lines of greater length than 4 feet should be 1-1/2 in. I.D. hose.

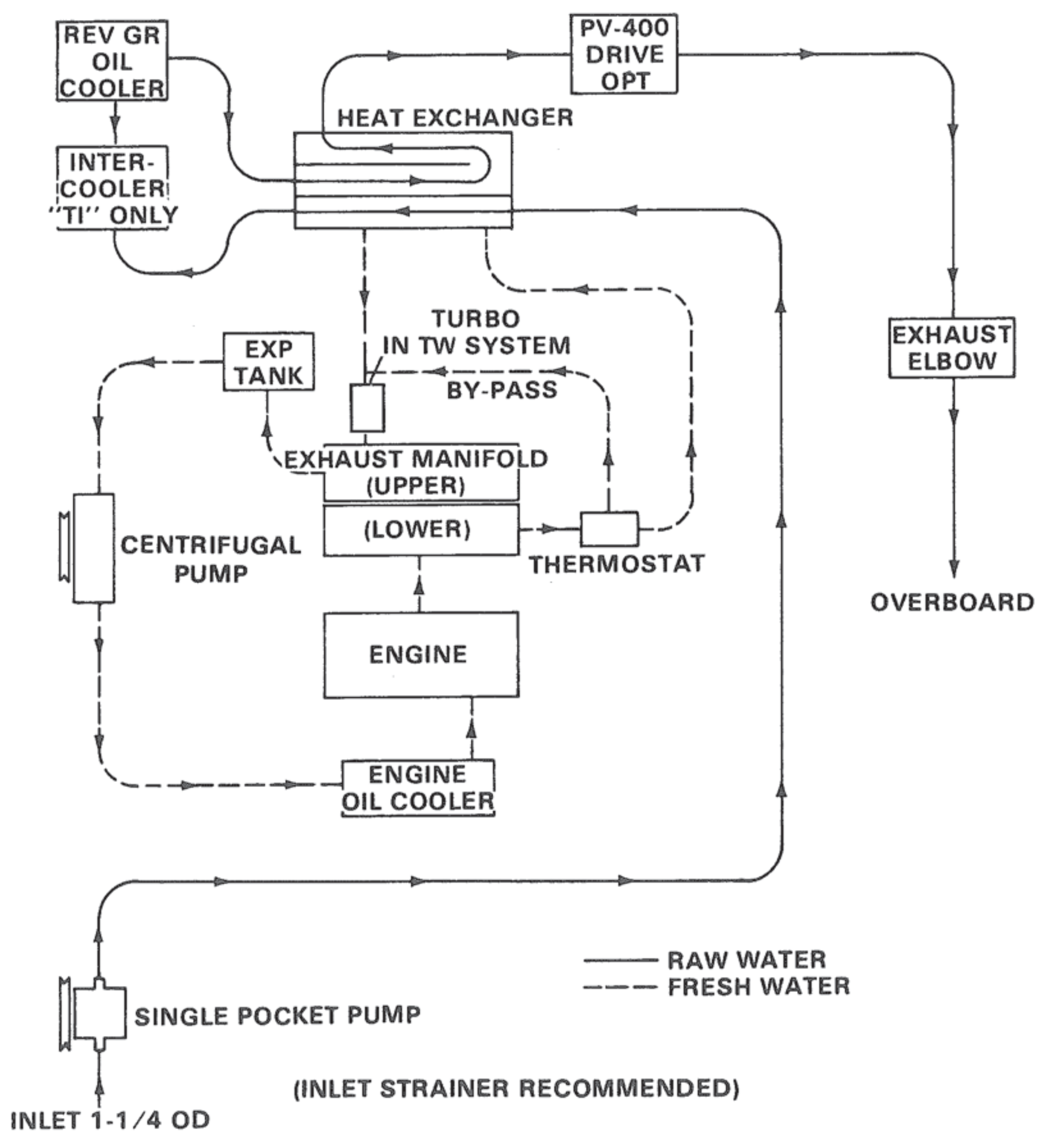
The intercooler is located at the rear of the engine and has a large number of small diameter cooling tubes (these can plug relatively easily if a sea strainer is not used).

A 1/8 in. pipe fittng should be provided by the boatbuilder at the inlet to the raw water pump to measure the inlet restriction with a vacuum gage or mercury manometer. The maximum reading should be **five (5) in. of mercury** with boat at top speed.

The water outlet from the heat exchanger is directed through the exhaust.

As a protection against electrolysis, all adjacent metals in the cooling system should be similar. Dissimilar materials should be connected by rubber hose.

FRESH WATER COOLING SYSTEM



CONTROLS

1. **Engine Start.** Controls for starting the engine are in the Electrical Section.

2. **Engine Stop.** The stop, or fuel cut-off lever has two positions — Stop and Run. The control must not hold lever in some mid point between Stop and Run, speed and power loss will result. Controls, at the helm, cables, etc., are provided by the boatbuilder. Engine shut-down control is actuated by energizing the shut-down solenoid.

3. **Speed Control.** Engine speed is controlled by an all-speed governor which controls engine speed according to control lever position. The control cable casing anchor bracket and swivel are made for cables conforming to SAE spec. for "push/pull" control cables. Cables made by Morse, Teleflex, Marmac and others whose product conforms to the SAE spec. are acceptable. Cables must be assembled according to the maker's "pull to open" instructions, and should have control end swivels that provide sufficient travel to move speed and shift control levers to their extreme positions, approximately 2-7/8 in. Control cables should follow a direct path with as few curves as possible. **In no case should a control cable radius be less than 8 in.** An assist spring is installed on the control lever to reduce operating loads. A series of holes at the upper end allow for adjustment. Select hole that gives lowest load but will allow governor lever to return to idle if control cable is not hooked up.

4. **Shift Controls.** The shift control lever on the reverse gear has three (3) positions, neutral, forward and reverse with detents in each position. Cable casing anchor bracket and swivel as supplied by Chrysler, are made for cables conforming to SAE's specs. The control and swivels must be adjusted so that neutral, forward and reverse detent positions in reverse gear coincide with the corresponding detents in the helm control. In addition to "push/pull" cable control method, cable and pulley, pneumatic, and hydraulic controls are sometimes used. They should be installed according to their maker's instructions. A safety switch can be installed in the system to prevent accidental starting in gear. This switch is referred to as a neutral start safety switch and is strongly recommended. The switch is installed in the starting circuit so that when the shift lever is in neutral, current will flow to the starter solenoid.

EXHAUST SYSTEM

General. For satisfactory operation, exhaust installation should meet requirements outlined in ABYC Standard P-1. Chrysler has additional requirements as follows:

1. Maximum exhaust back pressure at full load and RPM - 3.5 in. Hg. or 1.8 p.s.i.

2. Preferred exhaust size I.D. - 5 in.

3. Maximum external load applied to turbocharger and exhaust manifold - 150 in. lbs.(1.72 kg/m).

Effect of Exhaust Back Pressure. Optimum engine performance may be achieved by keeping exhaust back pressure as low as possible. However, the engine will operate with only a slight loss of horsepower up to a maximum of 3.5 Hg; measured at the turbo or within 6 in. of the turbo outlet flange.

Exhaust Insulation and Clearance. A space age lagging or insulation blanket is supplied to cover the turbocharger of the TI, its adapter, and the dry portion of exhaust outlet. The blanket insulates well enough so that outside surface of the lagging can be touched without burning the skin, even though the gas temperature within the turbo can reach 1200° F and the exhaust after the turbo can reach 1000° F. However, if the engine compartment is not properly ventilated or if exhaust components are installed too close to the boat, temperature may rise beyond a desirable level. The turbo, its attaching parts, and the dry portion of the exhaust outlet should not be closer than two inches to combustable material without protection — 1-1/2 in. with protection. The combustable portion should be protected with a layer of insulation of fiberglass or other insulating material covered with a heat shield. The shield may be a flat plate of steel or aluminum with a shiny surface to reflect heat.

Water injection in the exhaust allows use of a flexible section of hose to isolate engine movement, vibrations, and noise without burning the hose. After water injection, the exhaust is usually less than 200° F.

NOTE

The TW has water cooled turbo and other exhaust components.

Exhaust Plumbing after Engine Exhaust Elbow. The exhaust elbow supplied with the engine has provisions for 4 in. I.D. exhaust hose. Some installations may be able to stay within the back pressure limit of 3.5 Hg. with a 4 in. exhaust if there is a short exhaust run (e.g.: 6 ft. or less) and no muffler is used (because of the turbo, noise level may be acceptable without muffler). However, longer runs with several elbows will require at least a 5 in. I.D. exhaust line.

NOTE

A bellows hose section increasing the exhaust size from 4 in. to 5 in. I.D. is supplied with the engine.

A 5 in. muffler may be satisfactory if the exhaust is not too long or does not have too many 90° bends. Some mufflers have baffles that cause greater back pressure than desirable. It is best to have experience with the chosen brand. With the best planned system, experience is still the best guide. The amount of water injected into the exhaust may sometimes be reduced which will also reduce the back pressure, however, adequate cooling water at all RPMS is vital, especially at idle, therefore, any water reduction must be done with special care.

Supporting Exhaust Plumbing. The exhaust line should be supported so the weight of the line and muffler will not be transferred to the turbo under any conditions. Unsupported load can be estimated by determining external loading. The load should not exceed 150 in. lbs. (1.72 kg/m). In practice, this means the center of gravity of the outlet elbows can be 10 inches from the turbo and the elbow weigh 15 lbs. Chrysler supplies an outlet system that is lighter and closer to the turbo. Since the outlet consists of more than one swivel piece and can have a number of combinations, it is the boatbuilder's responsibility to keep the load on the turbo and exhaust manifold within the limits. Failure to do so may result in failure of the exhaust gaskets and bolts and may distort the turbo housing, causing a turbo impeller failure.

Chrysler Exhaust Components. The standard parts supplied:

1. 90° elbow, flanged at both ends for "V" band clamp, includes boss for pressure check.

2. 90° elbow, flanged on one end and with water injection nozzle on the other end for 4 in. I.D. hose.

3. Two (2) "V" band clamps.

4. Two (2) gaskets.

5. One (1) pc. 1-1/4 in. I.D. flex hose from heat exchanger to exhaust elbow.

6. Bellows — Turbo exhaust elbow (neoprene) 4 in. to 5 in. diameter.

Optional: 6 in. straight extension, Part No. 3619351, flanged on both ends for "V" band clamps.

One assembly method is shown on the installation drawings. There must be a minimum 20° downward slope to the outlet elbow or water may back up into the turbo. Chrysler requirement for run-off of exhaust water is 6 in. plus 1/2 in. per foot of exhaust length to prevent water from entering the exhaust and reaching the engine. Run-off height is determined by the highest point of the bottom of the exhaust line to the water line or bottom of the transom outlet, whichever is higher. In the event that supplied elbows do not give adequate run-off, the 6 in. extension may be installed between the elbows with gasket and V-Band clamp to obtain more run-off.

NOTE

The V-Band clamp uses a stainless steel T-bolt and self-locking nut (1/4 - 28). To avoid any leak at the swivel joint, this nut should be torqued to 10 ft. lbs.(1.38 kg/m). Tapping the clamp lightly while tightening the T-bolt and nut will help to seal the joint.

Use of the 6 in. extension horizontally between **turbo** and water injection elbow is difficult to do properly in relation to the run-off of the exhaust and to keep water out of the engine with the boat rolling in a beam sea. It is also more difficult to keep the turbo loading within specific limits due to increased moment arm. Because of these added difficulties, use of this combination should be avoided if possible.

The water injection elbow can be attached directly to the turbo when a riser is not required and height is a problem. The elbow can aim aft for conventional installation, or toward the front of the engine for a V-drive.

Flexibility in the exhaust system must always be considered due to movement between engine and hull. The hull can twist, the engine can move sideways and up and down. The exhaust line and muffler full of water in a pounding sea can move about. Allowing the engine to move freely while supporting the exhaust system is a mandatory requirement. Consider the movement of the engine in all planes remembering that exhaust hose is stiff. A hose should have a length between solid ends of about two (2) times the diameter or more, i.e.: a 4 in. hose should have a gap of 8 in. plus 2 in. at each end for clamps, or a total length of 12 in. Hangers and supports for the exhaust line, hoses, and muffler must allow engine movement, but maintain a total system flexibility. A neoprene bellows, supplied, allows flexibility in all planes and expands 4 in. I.D. to 5 in. I.D.

Exhaust Outlet Positioning at Transom. Correct positioning of the exhaust outlets at the transom and/or use of louvers will reduce odor/exhaust gas feedback.

1. A deflector or directional louvers at the transom end of the pipe direct the exhaust gas out of the transom suction and away from the cockpit area. The deflector should act as a nozzle or jet using the maximum back pressure allowable to give the gas some velocity to carry it away from the hull. The above method will be about 95% effective at cruising speeds and above. Idling with a stern wind offers more difficulties and can best be accomplished by a nozzle that carries the gas to the side of the hull so wind will carry the exhaust gas down the side of the hull rather than over the top of the transom. On some boats, deflectors may aim slightly up from the horizontal to enable the gas to clear the side of the trough caused by planing type hulls.

2. The transom exhaust outlets should be located as close to the side of the hull as possible to give the deflectors a chance to push the exhaust gas out of the area of suction caused by the transom.

Deviations. Deviations from any of the above recommendations should be reviewed in detail with a Chrysler applications engineering representative for installation approval.

ELECTRICAL

The CM655 uses a 12V Prestolite starting system and Motorola charging system. The engine is supplied with an engine wiring harness (with provisions for two (2) point alarm system) 50 amp. circuit breaker, oil pressure and water temperature senders and alarm switches, and a shut-down solenoid.

NOTE

Boat wiring must **not** be routed through the engine circuit breaker. A separate boat wiring circuit breaker must be used.

Tachometer and instruments are available as sales options. Instruments and senders are for single station operation and are manufactured by Stewart Warner. If different instruments are used, compatible sending units must be obtained from the instrument supplier.

A momentary contact switch is required to operate glow plugs. A relay is installed on the engine to carry the heavy amperage load. A toggle switch for glow plug use is supplied with the optional instrument cluster. It has been found beneficial to put a label close to the glow plug switch: "Hold 15 seconds before engaging starter".

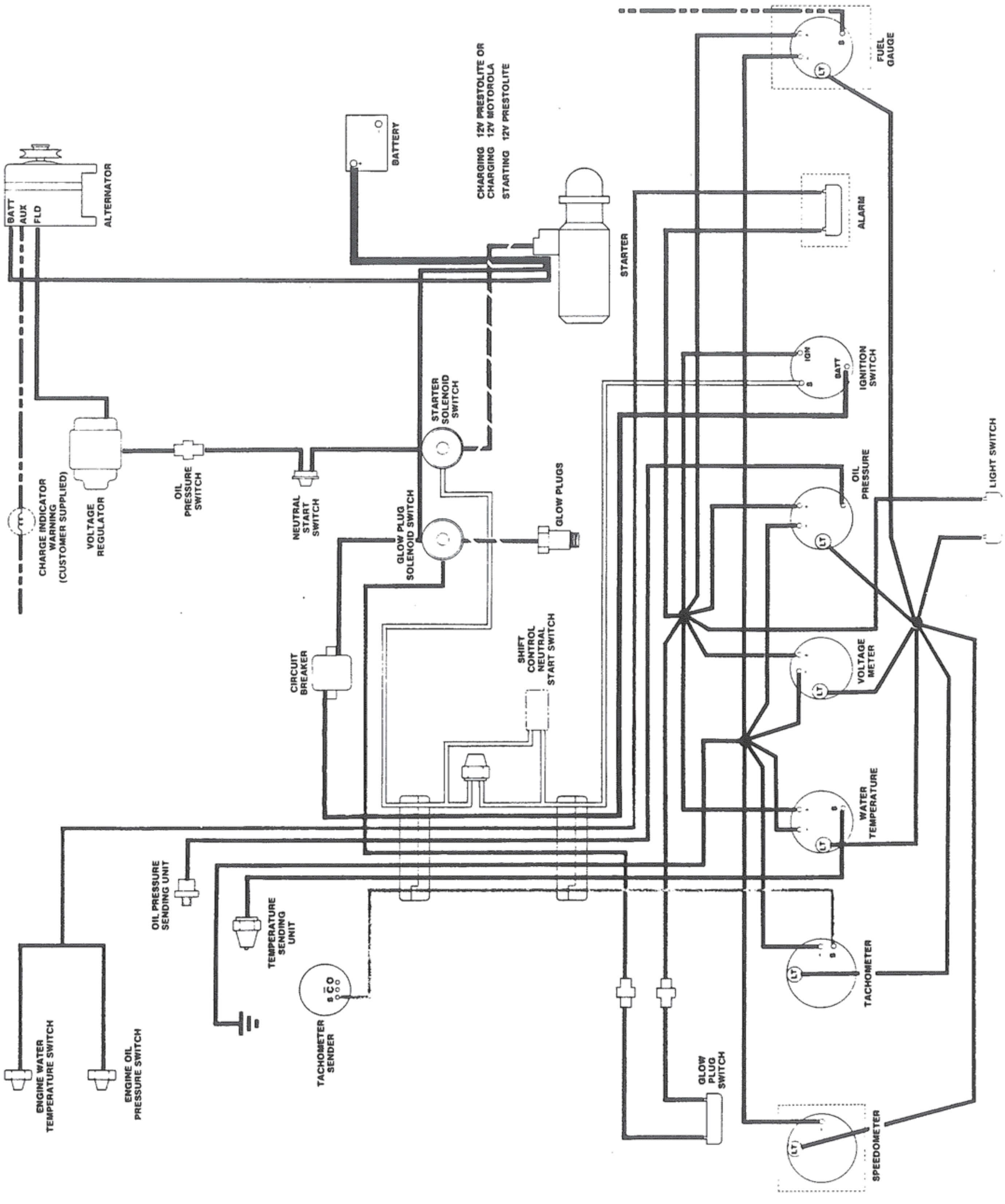
The starter circuit has a relay installed to carry heavy amperage permitting use of a key switch.

The alternator circuit has an engine oil pressure actuated switch which energizes the field circuit while running.

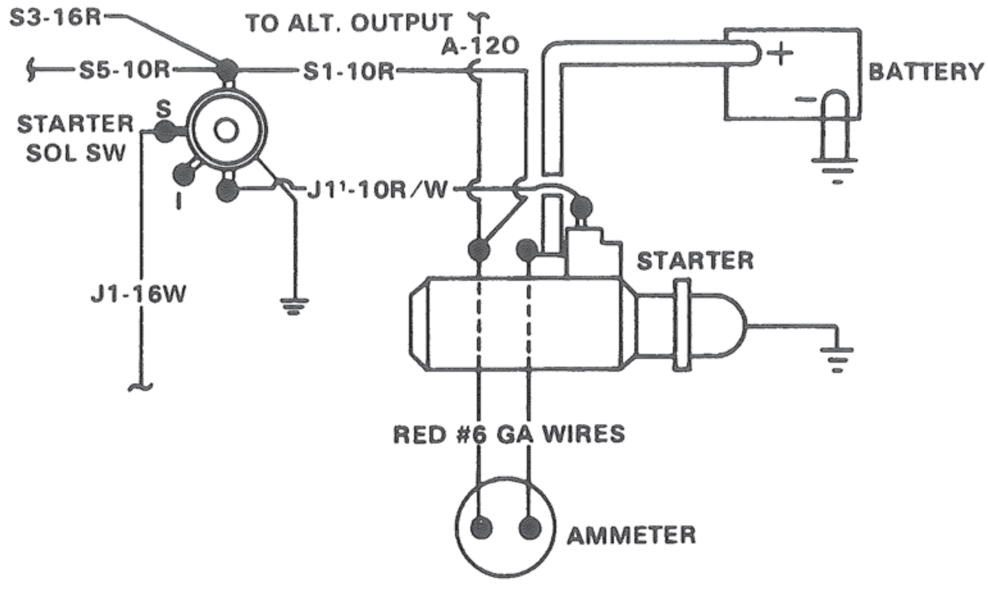
A shut-down solenoid is supplied with the engine and is connected to the fuel pump shut-down lever. (See drawing of solenoid ground wire tag.) A relay is installed in the circuit to reduce actuating amperage through the switch.

Battery and battery wiring size/length recommendations are indicated on the specifications listing. (Remember to add both cable lengths together to get total cable length.)

If a boatbuilder uses an ammeter instead of the voltmeter (as provided for in the Chrysler harness), separate wires (#8 typical or #6 for longer boats), will have to be run from the engine at the starter solenoid to the instrument panel. See wiring diagram instructions.



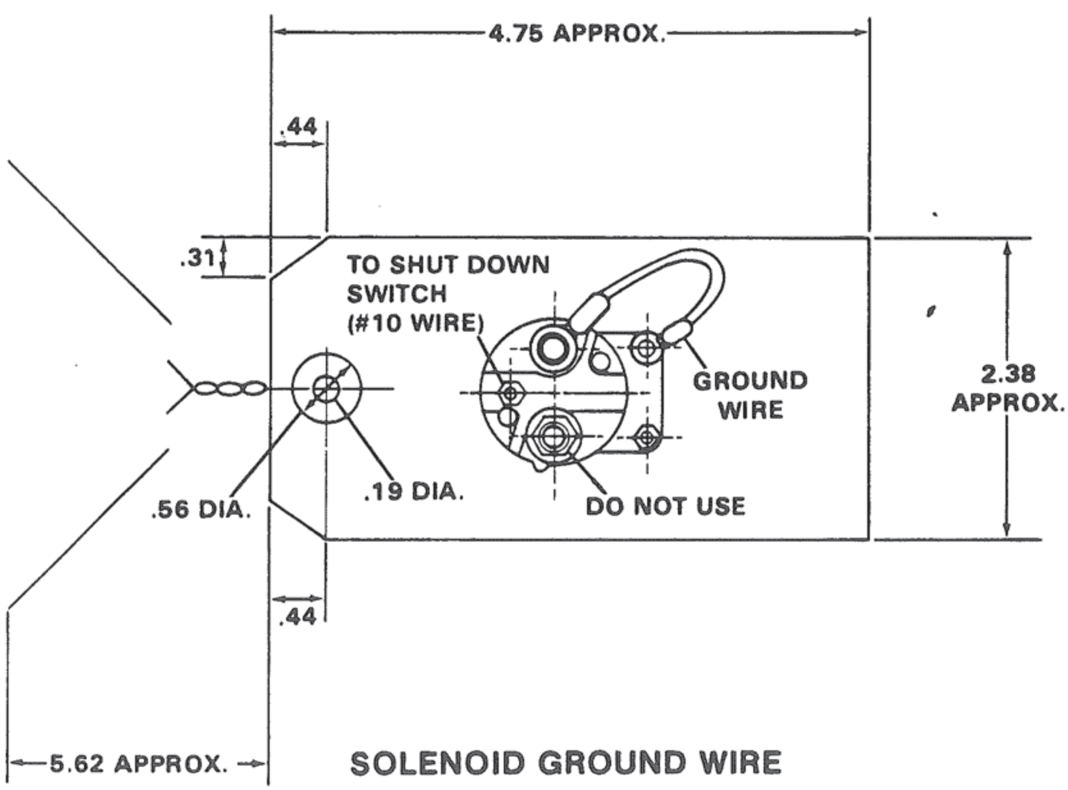
Electrical Wiring Diagram.



AMMETER INSTALLATION

Remove battery positive (+) cable at battery post.

Leave red battery cable in place at starter motor and remove orange alternator output wire and red (10 GA) supply wire from starter motor battery terminal. Connect orange and red wires removed above to a PED #6 GA wire (customer supplied) which leads to the ammeter. This connection must be fully insulated and held securely to prevent shorting or sparking. The other #6 GA ammeter wire is connected at the starter motor battery terminal with red battery cable. Restore battery post connection. This will place the ammeter in series with all current flow except starter cranking current.



SOLENOID GROUND WIRE

FUEL SYSTEM AND LUBRICATION

Engine Fuel Connection. The CM655 is supplied with a 1/4 in. female NPT fitting for fuel line connections. Full throttle fuel flow is 13.5 GPH; return line flow is approximately 1/4 GPH. The I.D. of the fuel feed line is to be at least 5/16 in. for lines up to 20 feet long, and 3/8 in. for longer lines. Return line size may be 3/16 in. I.D. Fuel lift to feed pump must be no more than three (3) feet from fuel tank pickup without the use of an auxiliary feed pump.

Shut-off valves should be installed in fuel line. When fuel tank(s) are installed with fuel level above the engine system, a shut-off must be supplied to close when engines are stopped. An electric solenoid valve may be necessary if manual valves are hard to reach or can be forgotten. Fuel levels higher than the engine may cause siphoning into the engine and fill a cylinder with fuel. This condition could cause a hydrostatic lock causing engine damage.

All fuel line fittings must be absolutely air tight to avoid engine performance problems.

Good Fuel Filtration is Extremely Important. Water or abrasive solids will severely shorten the life of the injection pump and injectors.

The engine is supplied with a primary and secondary fuel filter. The primary filter has great capacity for foreign material and is shipped loose to be mounted at a convenient position near the engine. This filter removes large material 30 microns and can remove a quantity of water. There is a drain on the bottom which should be opened to remove water collected. Easy access is required for draining the filter. The secondary filter is mounted on the engine and filters out fine materials (2-3 microns). Experience indicates the primary filter does the most work and must be serviced more often if fuel quality is poor.

Tanks and Lines Materials. Black iron, sheet steel, monel, some molded plastics and fiberglass reinforced with certain resins are acceptable tank materials. In the case of plastic and glass reinforced resin, consult with the supplier and the Coast Guard for recommendations. Coast Guard requirements prohibit the use of galvanized fuel tanks or lines on diesel-powered craft carrying passengers for hire because the zinc coating combines with the sulphur in the fuel to form zinc sulphate which will plug filter and destroy pumps and injectors. **Copper tanks and lines are not recommended,** although copper lines are often used in spite of warnings against them. Acceptable materials for lines are black iron, steel and certain rubber products, as recommended by the supplier. Rubber lines need an asbestos sheath to pass fire tests. All lines must be supported adequately in as protected a position as practical, and **the portion connected to the engine must be flexible and not subject to failure due to vibration.**

Configuration. The tank should be large enough to operate at least a day or as long as is required without refilling, and should be so located that any condition, from full to empty, will not seriously affect the trim of the boat. The fill pipe should not allow water to enter the tank when the cap is in place. The vent should have an air trap to prevent water from entering the tank.

The fill and vent pipes should extend far enough into the tank to assure a 2% air space for expansion. The fuel pick up should be high enough to allow 5% of the tank for settling debris and water, and there should be a drain valve on the bottom and clean out port on the top. The fuel return should not be adjacent to the fuel pickup because hot fuel is returned, and it should be allowed to cool before it is picked up again. Auxiliary engines must have their own supply and return lines.

The fuel tank must be electrically grounded to complete the installation.

Lubrication.

1. Lubricant recommendations have been revised since their original publication in operators manual. Current recommendations are as follows:

A. SAE 40W oil is to be used for ambient air temperatures above 50° F.

B. SAE 30W oil is to be used for ambient air temperatures from 32° F to 50° F.

C. Oil meeting API service "CD" is approved for use in the CM655TI.

2. Oil filtration with a full flow spin-on oil filter is adequate for pleasure boat applications. However, the boatbuilder has the option of remote mounting the oil filter by simply removing the hoses from the engine adapter and replacing them with hoses one size larger and long enough to reach the filter. The spin-on filter may be replaced by a larger capacity remote mounted filter, but the substitute must be approved by Chrysler.

SEA TRIALS

Procedure. The boat should be fully loaded. If not, then enough ballast should be added in the same location as additional weight would normally be carried to compensate for this. Trim tabs are becoming more common and can improve performance when weight distribution is too far aft or the hull is considered over-loaded. Tabs aft of the hull add planing surface to the hull and if adjustable can add lift as required by deflecting the flowing water downward.

In order to accurately determine the speed of the boat and evaluate its performance, sea trials should be conducted on a course between two (2) markers where the distance is accurately known. The time should be measured while on a straight course between the markers. Time should be recorded with a stop watch and speed calculated for each run. The speed and not the times should be averaged. The first series of three (3) runs should be made at 800 RPM under the rated speed for the application and 200 RPM should be added for each series of runs up to full throttle. On each run the following data is observed and recorded:

1. Air temperature.

A. Ambient air temperature outside the boat.

B. Air temperature at the engine air intake. This temperature should be as close as possible to ambient air temperature outside the boat, air intake system may have to be modified to insure this. Excessively high air intake temperature will restrict engine performance.

2. Sea water temperature should be recorded. Engine water temperature should remain under 210° F. Failure to do so is indicative of malfunction or incorrect arrangements of the cooling system. Operation of the raw water pump, position of sea cocks, hull scoops, and the raw water strainer, circulating water pump and thermostat should be checked if cooling problems are encountered.

3. Exhaust back pressure at any and all conditions of load must not exceed 3.5 in. of Mercury. It must be checked and if found excessive, the exhaust system must be modified to correct this condition.

4. Engine RPM should be noted both at the pilot house and in the engine room. Engine room RPM should be measured with a hand tachometer. Control movements and linkages should be adjusted to insure full throttle motion is possible and that engine comes up to rated speed (high idle) with gear disengaged.

5. With a properly sized propeller, full load engine RPM for all installations should be at the rated speed with a fully loaded, clean bottom vessel. To establish the cruising speed, check WOT RPM and back off 10%.

NOTE

WOT RPM may vary depending on boat loading, boat hull and propeller condition.

6. If WOT RPM is within 10% of high idle, the governor rather than the propeller may be controlling the engine speed. If you suspect that this is the case, try more pitch or override the governor by backing off the high speed limit screw. Do not exceed rating RPM for more than 5-10 seconds while overriding the governor (full rack) — do not exceed 3400 RPM under any circumstances. On twin screw vessels operate both engines simultaneously. For fuller explanation, see discussion on ratings and propeller.

Re-evaluation. If the results of the sea trials are not up to the expected performance; it may be necessary to re-evaluate:

A. Is the boat bottom clean?

B. Is the propeller damaged?

C. Does propeller slip calculation fall into an acceptable range?

D. Is boat trim angle acceptable for type of boat? Trim tabs may be necessary.

E. Does final boat weight balance allow proper running trim?

F. Does final boat weight correspond to design weight?

G. Has the fuel system been purged of air?

H. Are fuel filter and fuel lines free of water?

I. Are all the fuel fittings air tight?

J. Is the fuel pump shut-off lever in full run position?

K. Are all connections between turbo and intake manifold leak free?

Section 5

ELECTRICAL SYSTEM AND COMPONENTS

CONTENTS

Subsection

5A ELECTRICAL

GENERAL

The electrical system of this marine diesel is composed of three (3) major systems; starting system, generating system and warning system.

Starting System. When the STOP-START (or run) lever is in the START (or run) position allows fuel to enter the injectors.

The glow plug switch activates the glow plug relay, which, in turn, sends current to the glow plugs. The air in the combustion chamber is preheated by the glow plugs.

When the ignition switch is turned to "START" position, the starter relay is activated completing the circuit between starter motor and battery engaging the starter pinion with the flywheel ring gear and turning the engine over.

When the engine fires and speeds up, the starter armature is overrun causing the pinion to disengage. When the ignition switch is released (to "run" position), the circuit between the ignition switch and starter relay is opened.

Generating System. A 12 volt battery is used to provide starting and accessory operation. In order to maintain a charge, direct current (D.C.) must be put back into the battery.

A rotor turns inside the alternator creating a magnetic field. This field cuts through the windings of the stator and becomes 12 volts of alternating current (A.C.). This current is fed to the rectifier diodes and converted to 12 volts D.C., then fed to the battery.

Warning System. Sending units are provided for low engine oil pressure, high fresh water temperature, and fresh water temperature buzzer. Gauges must be observed carefully to prevent engine damage due to high water temperature and low or high oil pressure.

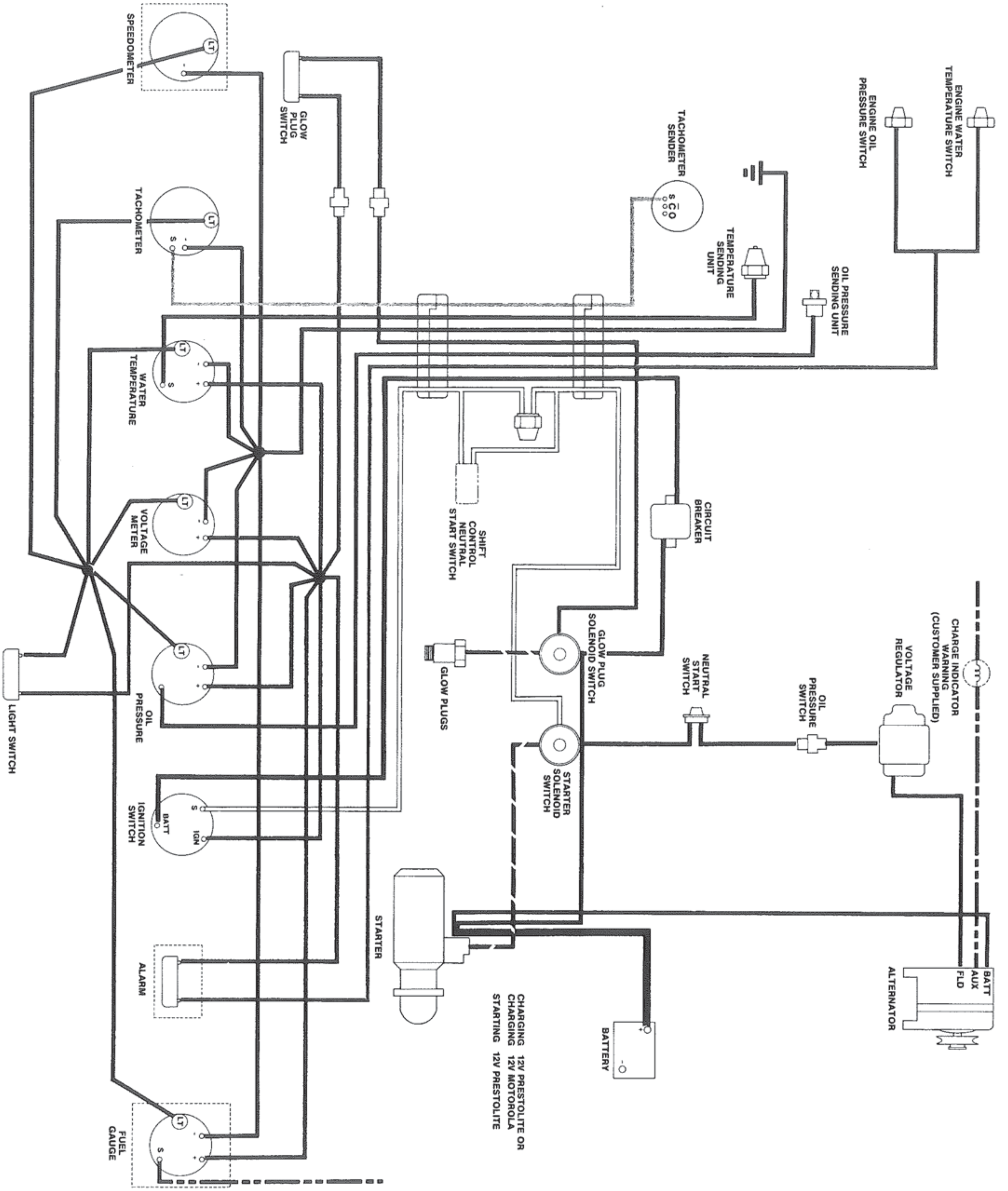


Figure 1. Electrical System, Wiring Diagram.

Subsection 5B

GENERATING SYSTEM

GENERAL

The information in this subsection explains how to troubleshoot and replace parts of the alternator generating system.

DESCRIPTION

The alternator charging circuit contains a battery, voltmeter or ammeter, regulator and alternator. Figure 1.

The alternator supplies the battery and accessory circuits with their electrical needs at a wide range of engine speeds.

1. **Drive End Head** houses a prelubed ball bearing. The drive end of the rotor shaft rotates in this bearing.

2. **Stator** contains three (3) phase windings, 120° apart, and three (3) lead wires.

3. **Rectifiers** convert AC to DC, pressed into heat sink and connected to stator lead wires, act as one-way current valves.

4. **Rotor,** "rotates" inside the stator inducing AC current into stator windings.

5. **Slip Ring End Head** contains rectifiers, heat sink plate along with field, output and auxiliary terminals.

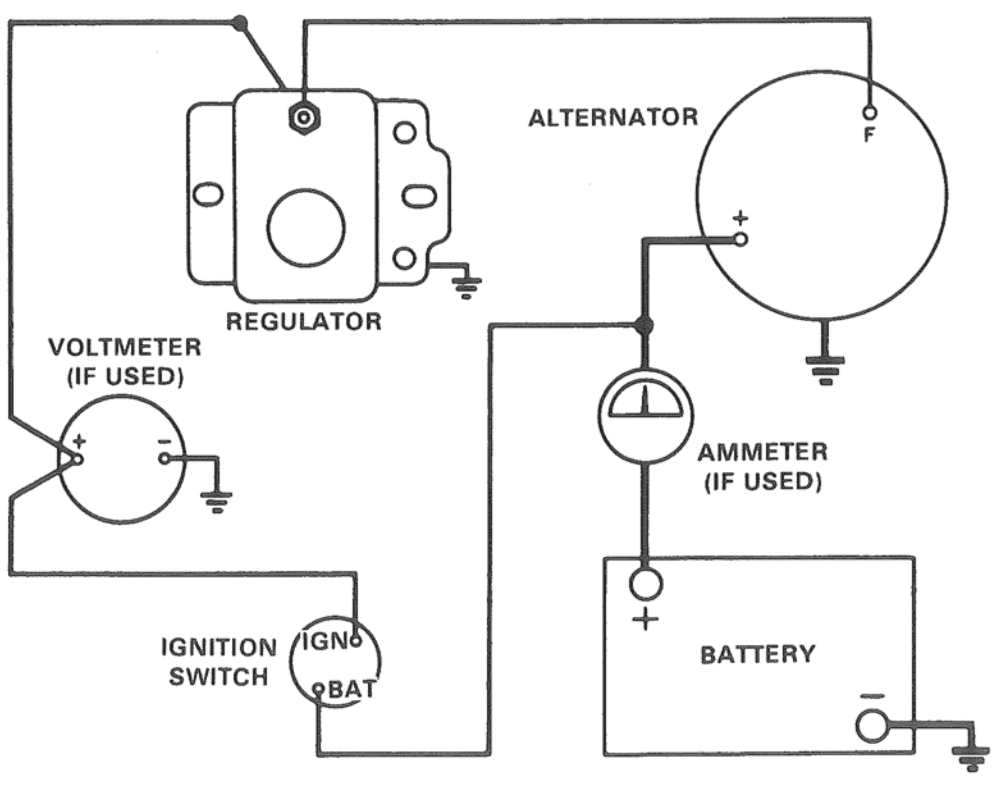


Figure 1. Alternator Charging Circuit.

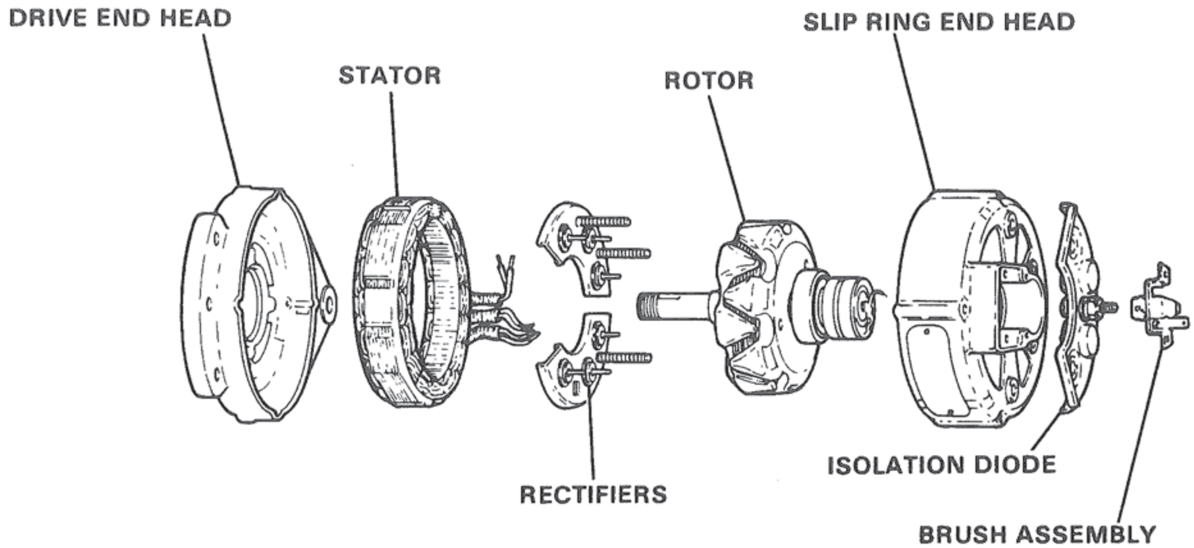


Figure 2. Main Alternator Components.

6. **Isolation Diode** connected by a stud of the left rectifier heat sink. The union between the stud and isolation diode provides auxiliary or regulator terminal.

7. **Brush Assembly** made of carbon and conducts current between rotor and regulator.

CAUTION

THE ALTERNATOR MUST NOT BE OPERATED ON OPEN CIRCUIT WITH THE ROTOR WINDING ENERGIZED.

IF AN ALTERNATOR MUST BE OPERATED WITH AN OPEN CIRCUIT THE FIELD CIRCUIT MUST BE DISCONNECTED.

DO NOT ATTEMPT TO POLARIZE THE ALTERNATOR. No polarization is required. Any attempt to do so will result in damage to alternator, regulator, or circuits.

GROUNDING OF THE ALTERNATOR OUTPUT TERMINAL MAY DAMAGE THE ALTERNATOR AND/OR CIRCUIT AND COMPONENTS.

REVERSED BATTERY CONNECTIONS MAY DAMAGE THE RECTIFIERS, VEHICLE WIRING OR OTHER COMPONENTS OF THE CHARGING SYSTEM.

IF A BOOSTER BATTERY OR FAST CHARGER IS USED, ITS POLARITY MUST BE CONNECTED CORRECTLY TO PREVENT DAMAGE TO THE ELECTRICAL SYSTEM COMPONENTS.

Troubleshooting. When diagnosing a failure in the generating system, care must be taken to think of the system as a whole. Poor electrical connections in boat wiring, worn or cracked insulation of wires, corroded battery terminals, system overloading or an improperly maintained battery often creates false impressions that a problem exists within the alternator. A careful visual inspection of wiring should be made before resorting to meter testing. A simple continuity test of wires in the system, to detect broken wires, can save valuable time.

Problem	Possible Cause	Test Procedure
Alternator fails to charge (No output)	A. Blown fusible wire in voltage regulator.	A. Locate and correct cause of fuse blowing. Install new fuse wire. Solder both ends of new fusible wire securely.
	B. Alternator or drive belt loose.	B. Tighten drive belt to specifications.
	C. Worn brushes and/or slip rings.	C. Install new brushes and/or slip rings.
	D. Sticking brushes.	D. Clean slip rings and brush holders.
	E. Open field circuit.	E. Test all the field circuit connections, and correct as required.
	F. Open charging circuit.	F. Inspect all connections in charging circuit, and correct as required.
	G. Open circuit in stator windings.	G. Remove alternator and disassemble. Test stator windings. Install new stator if necessary.
	H. Open rectifiers.	H. Remove alternator and disassemble. Test the rectifiers. Install new rectifiers if necessary.

CAUTION

DISCONNECT THE BATTERY, before connecting or disconnecting test instruments (except voltmeter) or before removing or replacing any unit or wiring.

Accidental grounding or shorting at regulator, alternator, ammeter or accessories will cause severe damage to units and/or wiring.

TO AVOID DAMAGE TO THE REGULATOR, DO NOT, AT ANY TIME, CONNECT BATTERY TO REGULATOR FIELD TERMINAL.

FIELD CIRCUIT MUST NEVER BE GROUNDED BETWEEN ALTERNATOR AND REGULATOR. Grounding of field terminal either at alternator or regulator will damage the rectifier.

IF IT IS NECCESSARY TO SOLDER ANY LEAD TO A RECTIFIER LEAD, use pliers as a heat dam between the solder joint and rectifier.

IN-BOAT TESTS

Open Diode - Trio Test - Engine Off.

1. Remove regulator from alternator housing, leaving leads connected.

2. Install jumper (A) between output and regulator terminals. Connect voltmeter leads as shown. Figure 3.

3. Start engine. If voltmeter reading is 13.75 volts - 14.75 volts, the positive (+) diode trio assembly is open and must be replaced. If reading is not in this range, remove jumper (A) and go to regulator test.

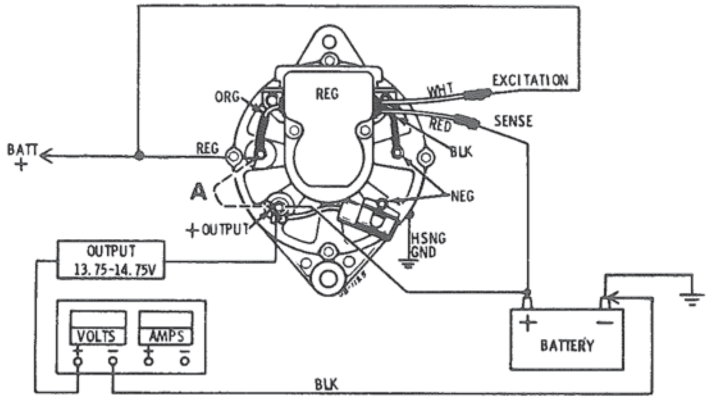


Figure 3. Open Diode-Trio Test

Regulator Test - Engine Off.

1. After hook-up is made and test leads connected, add an insulated jumper (A) from alternator regulator terminal to field terminal. Figure 4. Remove regulator screws to add jumper. Mount regulator to alternator with two (2) screws for test.

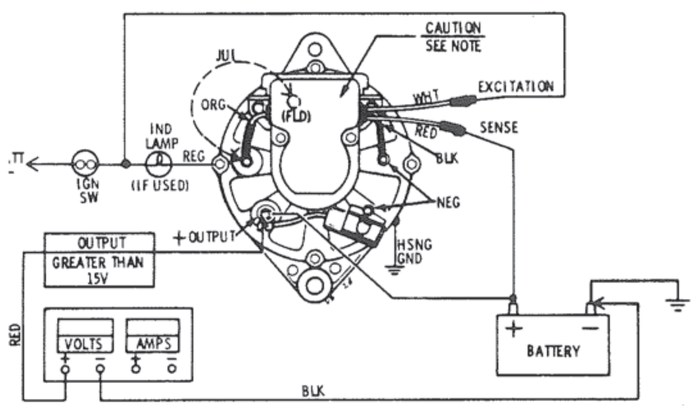


Figure 4. Regulator Test.

2. With key on and engine stopped, the indicator lamp should now be on, indicating an open regulator. If lamp is not on, check lamp and harness. If lamp is still not on, an open field circuit exists (brushes, slip rings, etc.). Alternator must be removed for repair.

3. If lamp is now on, with key on and engine stopped, run engine at fast idle (1,000 RPM) with no loads. If voltmeter reads 15.0 volts, the alternator is defective. Remove for repair.

Alternator Output Test - Engine Running (after hookup and test leads are connected).

1. Connect voltmeter. Figure 5. Start engine and set throttle to fast idle (1500 RPM). Turn on running lights. Check for reading of 14.2 - 14.7 volts. If battery voltage is less than 12.6 volts, remove alternator for repair.

2. Output voltage should increase about one (1) volt when red lead is disconnected and increase the same when connected. If red lead and connector are ok, remove alternator for repair.

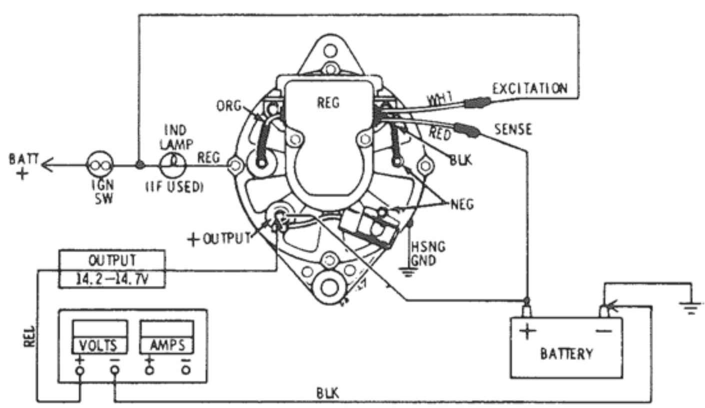


Figure 5. Alternator Output Test.

Testing Alternator Components. Clean all parts and visually inspect for cracks, wear, distortion and any signs of discoloration due to overheating or mechanical interference (grooving, seizing, etc.).

1. **Rotor.**

The rotor test for grounded or open windings is shown in Figure 6.

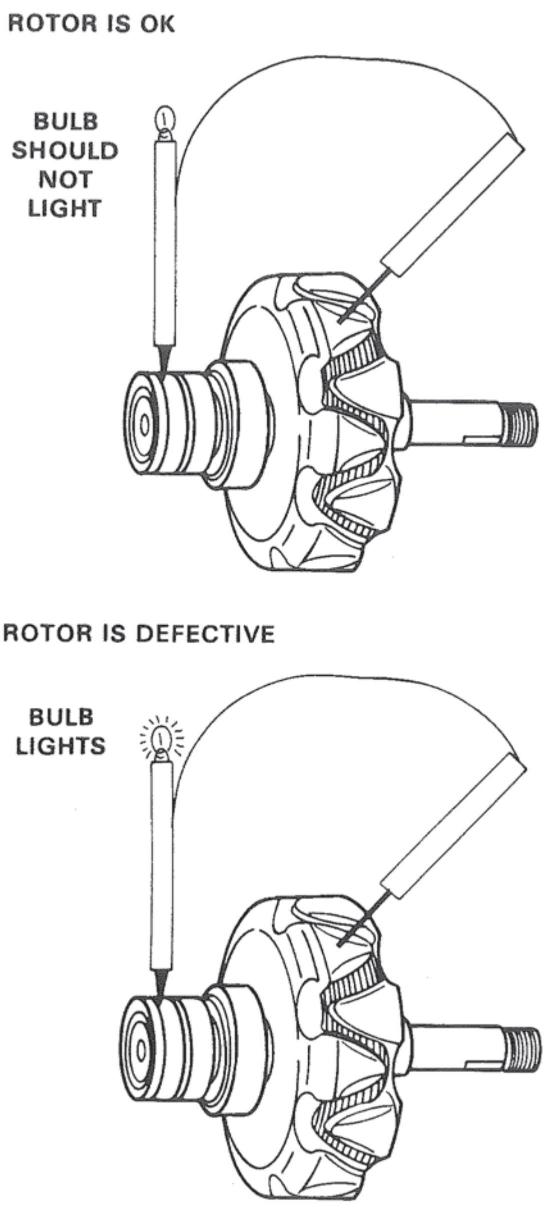


Figure 6. Rotor Test for Grounded or Open Windings.

2. **Rectifiers.**

A. It is necessary to unsolder stator leads from rectifier terminals to properly test each rectifier. In order to protect rectifier from damage, use a pliers as a heat dam. Figure 7. When resoldering lead, allow solder joint to cool for a few seconds before removing pliers. Twisting or bending terminal can damage rectifier.

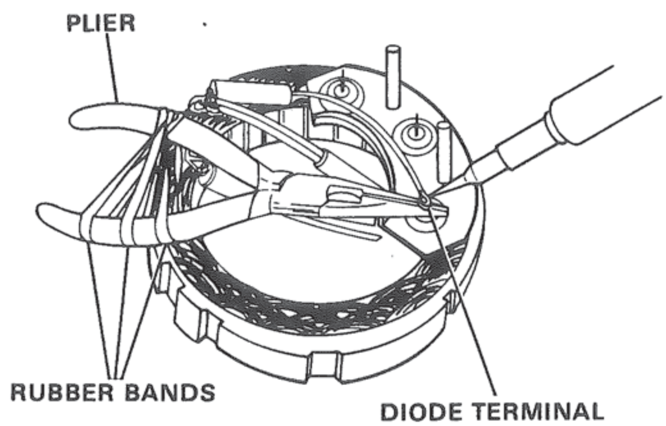


Figure 7. Unsoldering Rectifier Leads.

B. If available, use a commercial rectifier tester. Test points are shown in Figure 8. Continuity or ohmmeter test points are the same. Rectifiers in a given heat sink are all either positive (+) or negative (-).

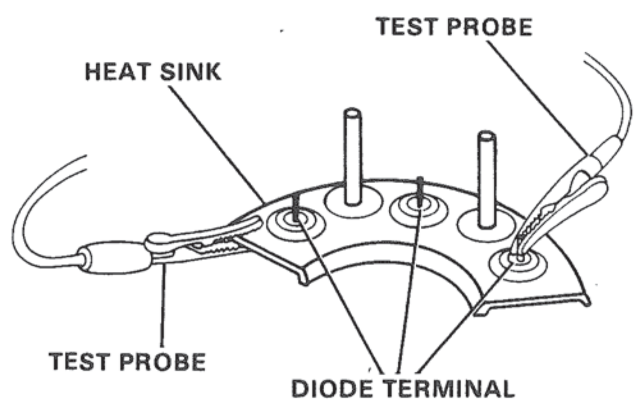


Figure 8. Rectifier Test Points.

C. Test light should not light and/or ohmmeter should register infinite ohms. All rectifiers in a given heat sink should operate the same. If test bulb lights with probes are positioned one way it should not light when test probes are reversed.

3. **Stator.**

A. Stator can be tested for grounded or open winding with aid of an ohmmeter or continuity tester.

B. Rectifiers must be disconnected from stator leads and stator should be removed from slip ring end head for access to leads.

C. Position continuity tester or ohmmeter test probes. Figure 9.

Bulb should light when probes touch leads.

A & B
A & C
B & C

Ohmmeter reading should be "0".

If bulb does not light or ohmmeter reading is "infinite ", an open winding is present. Replace stator.

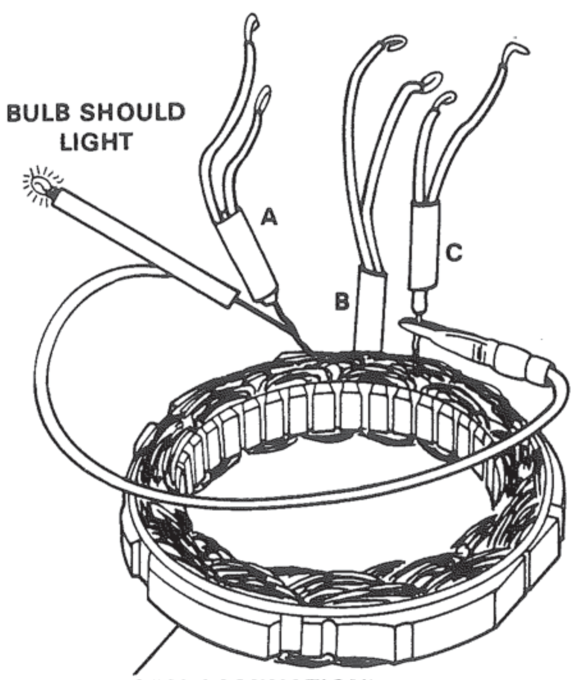


Figure 9. Stator Grounded or Open Winding Test.

D. Touch test probes between leads A, B, or C and stator body (lamination) bulb should not light and ohmmeter reading should be infinite. Figure 9. If bulb lights or ohmmeter shows "0" ohms, stator is grounded and must be replaced.

4. **Isolation Diode.**

A. Test for determining if diode will pass DC voltage in only one direction is shown in Figure 10. Diode should be isolated from alternator.

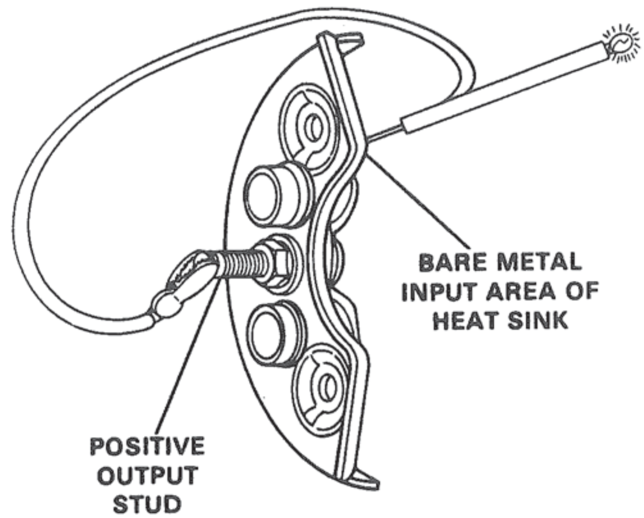


Figure 10. Isolation Diode Continuity Test.

B. Diode has two (2) rectifiers connected in parallel and is the voltage sensing diode operating throughout the output stud. The purpose of isolation diode is to provide a charge indicator lamp without using mechanical relay.

C. If alternator is producing sufficient voltage and charge indicator lamp is still on, a different lamp may be needed.

D. To determine which lamp will be needed, insert a variable resistant lamp and field rheostat into lamp circuit. Figure 11.

E. Start the engine and apply accessory load which made lamp glow. Gradually increase resistance with field rheostat until lamp glow is eliminated. Stop engine. Measure resistance of field rheostat with an ohmmeter. Select a fixed resistor of equal value and install it into charging lamp circuit. Wattage of lamp should be equal to that of the lamp.

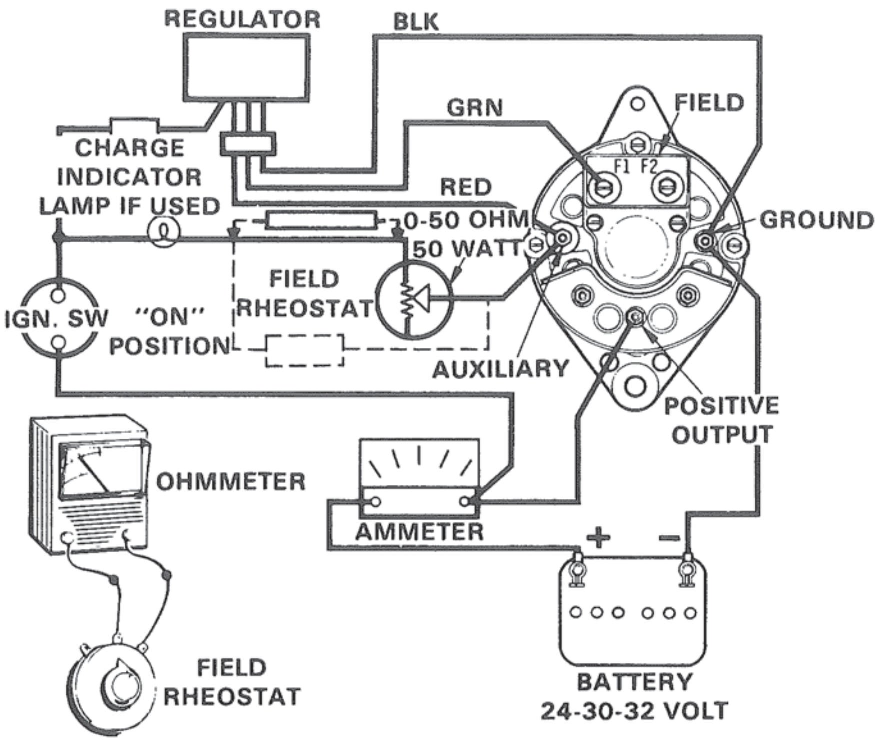


Figure 11. Eliminating Charge Lamp Glow.

5. **Brush Assembly.**

Brushes should be replaced if cracked, broken or worn to less than 3/16 in.

OVERHAUL

General. When repairing an alternator, complete disassembly may not be required.

This section covers steps for complete overhaul for use as needed.

Disassembly.

1. Remove regulator by detaching leads from auxiliary and ground terminals and removing two (2) screws.

2. Remove brush mounting screws and lift brush assembly from housing.

3. Remove isolation diode by removing hex nuts and insulators holding diode to terminal studs. Insulating washers and sleeve may be reused.

4. Separate housings as follows;

A. Place alternator in vise with protective jaws and remove four (4) thru-bolts.

CAUTION

Do not allow screwdriver to touch stator when separating housings. Stator could be damaged.

Clearance between stator and stator lamination is slightly more than 1/16 in.

B. Carefully insert two (2) screwdriver blades no more than 1/16" between housings and pry apart. Figure 12.

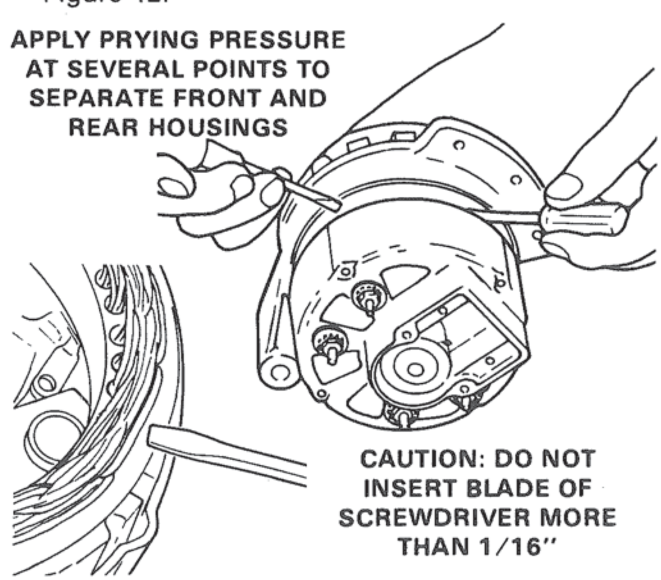


Figure 12. Separating Housings.

NOTE

At this point rear housing and stator are an assembly (front housing and rotor another).

5. Continue disassembly of stator and rear housing by removing all hex nuts and insulators from terminal studs.

6. Carefully tap diode terminal studs out of rear housing using a rubber mallet. Remove any insulating sleeves remaining in terminal stud holes.

CAUTION

Vise should have protective jaws.

7. To remove slip-fit pulley, clamp in a vise. Remove nut and lockwasher. Pull alternator from pulley.

8. Slide fan and pulley spacer off over key, remove key.

9. Use needle-nosed pliers to compress ears of front bearing retainer and lift it free of housing.

10. Tap shaft on a wooden block to remove rotor.

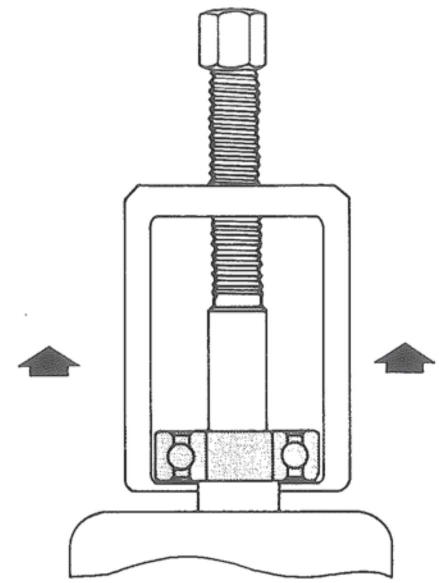


Figure 14. Removing Front Bearing.

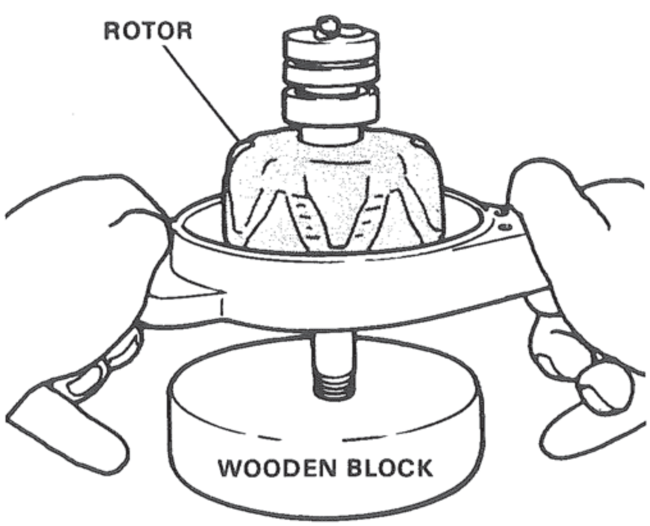


Figure 13. Separate Front Housing from Rotor.

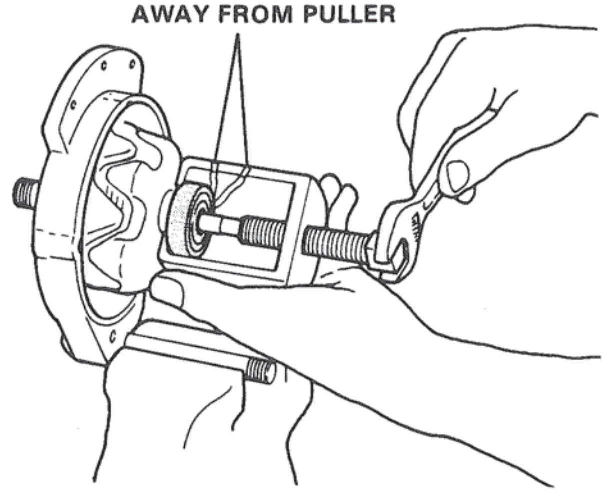


Figure 15. Removing Rear Bearing.

11. Remove front bearing from rotor shaft using a bearing puller. Figure 14.

12. Remove 1/4 - 28 socket head screw from rotor shaft to free slip rings from shaft.

13. Install puller and remove rear bearing from rotor shaft. Figure 15.

INSPECTION AND REPAIR

1. Inspect brushes. Do not reuse if cracked, broken or worn to less than 3/16 in. Figure 16.

2. **Clean Isolation Diode.**

CAUTION

Do not soak isolation diode in solvent or remove the protective, corrosion resistant paint.

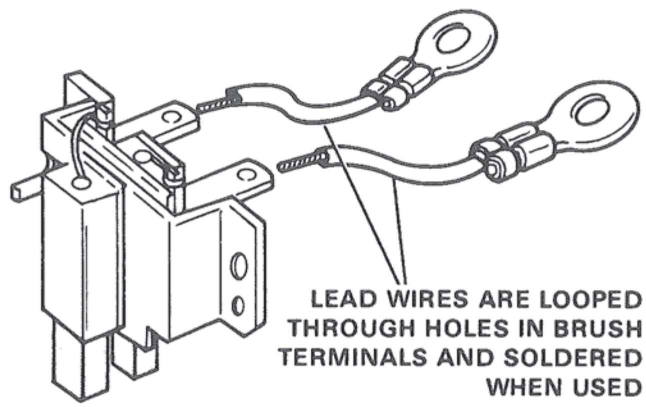


Figure 16. Inspecting Brushes.

3. Inspect rear housing as follows.

A. Check for cracked or broken webs, stripped threads and worn bearing bore.

B. Clean in solvent, dry.

C. Install new rear bearing retainer.

4. Inspect pulley for defects. Figure 17.

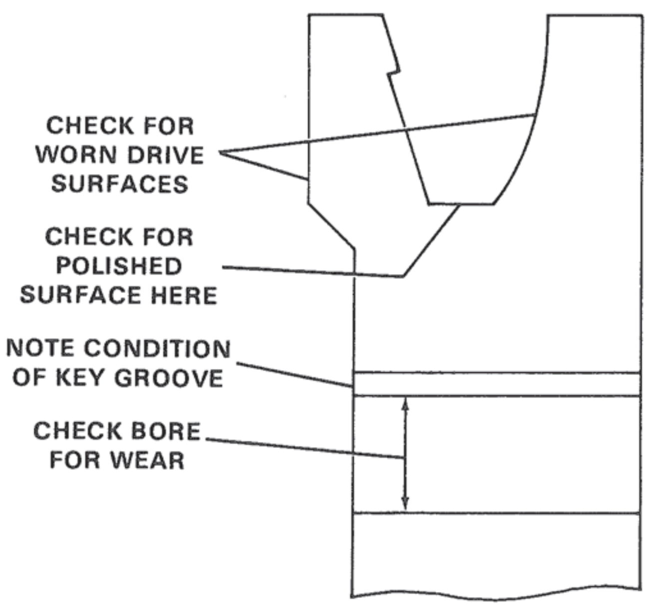


Figure 17. Inspecting Pulley.

5. Inspect fan or fin and bore cracks or defects.

6. Inspect front housing for cracks and wear. Clean with solvent and dry.

7. Replace any defective slip ring leads by unsoldering.

Reassembly.

1. Place rotor in an arbor press, pulley end down. Position rotor leads away from work area. Use a bearing installer that contacts only the inner race, press rear bearing on shaft until inner race contacts shoulder of shaft.

2. Guide rotor winding leads through square passage in slip ring hub. Install slip rings onto shaft (by hand), install socket head screw and lockwasher. Torque to 45 in. lbs. (51.7 kg/cm).

3. Install rotor leads as follows:

A. Place fiber washer on slip ring as shown. Washer prevents short circuits. Figure 18.

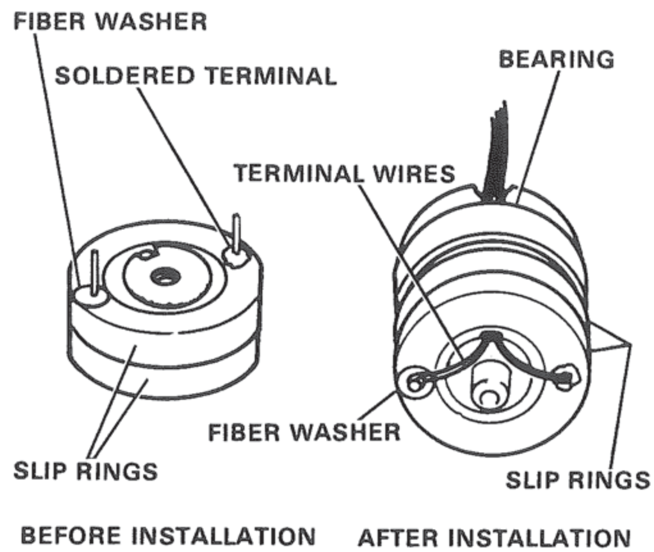


Figure 18. Attaching Rotor Leads to Slip Rings.

B. Wrap leads around slip ring terminals and solder using resin core solder. Be careful not to overheat and damage rings.

C. Secure wires to end of rotor with silicone rubber sealer.

D. Recheck leads for grounded or short circuit.

4. Support rotor with steel blocks in an arbor press. Place front housing over shaft. Use a bearing sleeve that contacts only the inner race and press until inner race contacts shoulder of shaft. Figure 19.

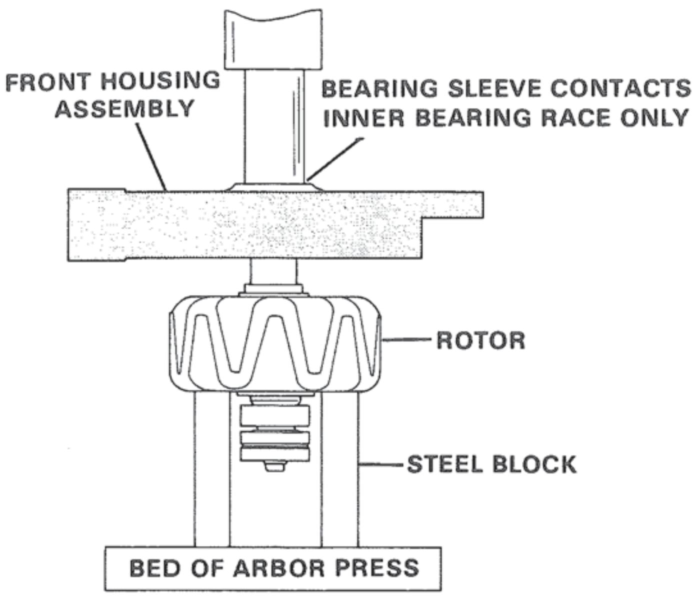


Figure 19. Assembling Front Housing to Rotor.

5. Install pulley spacer, key, fan, pulley lockwasher, nut and mount pulley in vise with protective jaws. Figure 20. Torque nut to 35-50 ft. lbs. (4.8-6.9 kg/m). Spin rotor by hand to make sure it spins freely.

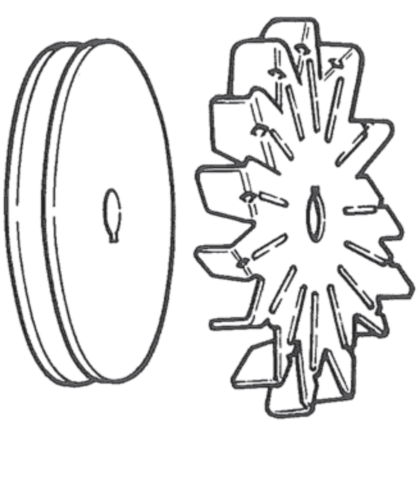


Figure 20. Installing Fan and Pulley

6. Place internal insulating washers and sleeves as shown in Figure 21. Stud A is the Auxiliary Terminal.

NOTE

Figure 22 shows cross-section of a rectifier diode heat sink designed to accept insulators that will "float" Stud A, from the sink. A short lead is soldered to the top left rectifier diode terminal, in addition to the lead from the stator winding. This second lead will conduct alternating current and voltage from diode terminal to insulated AC Terminal Stud.

Diode will continue to act as a rectifier, passing its share of energy through the diode to the heat sink as before.

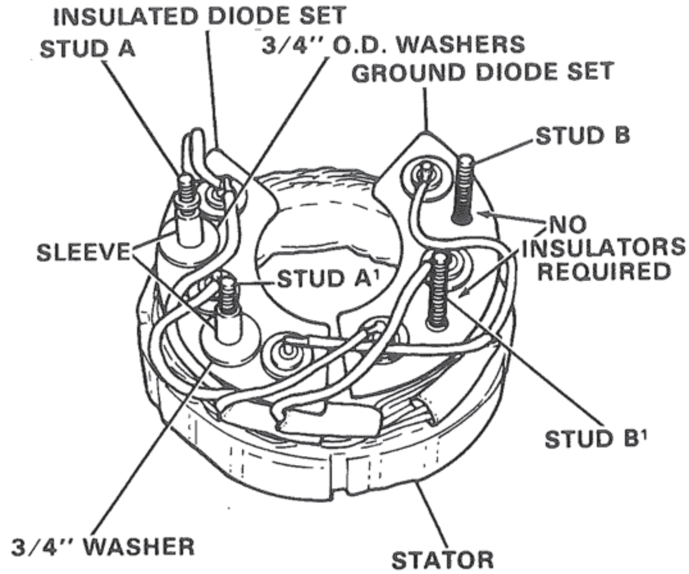


Figure 21. Placement of Internal Insulators.

7. Carefully insert rectifier diode terminal studs through rear housing.

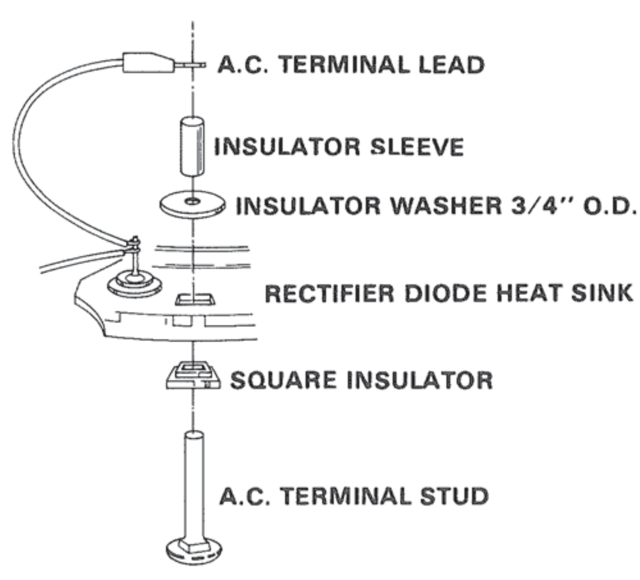


Figure 22. Insulators for AC Terminal Stud.

8. Install external insulating washers and locknuts over each stud.

9. Install brush assembly and tighten mounting screws to 16-20 in. lbs. (18.4-23 kg/cm).

10. Install isolation diode, torque nuts to 20-30 in. lbs. (23-34.5 kg/cm).

11. Connect brush lead to brush terminal and install felt seal between regulator and rear housing. Figure 23.

12. Tighten regulator cover screws to 20-30 in. lbs.

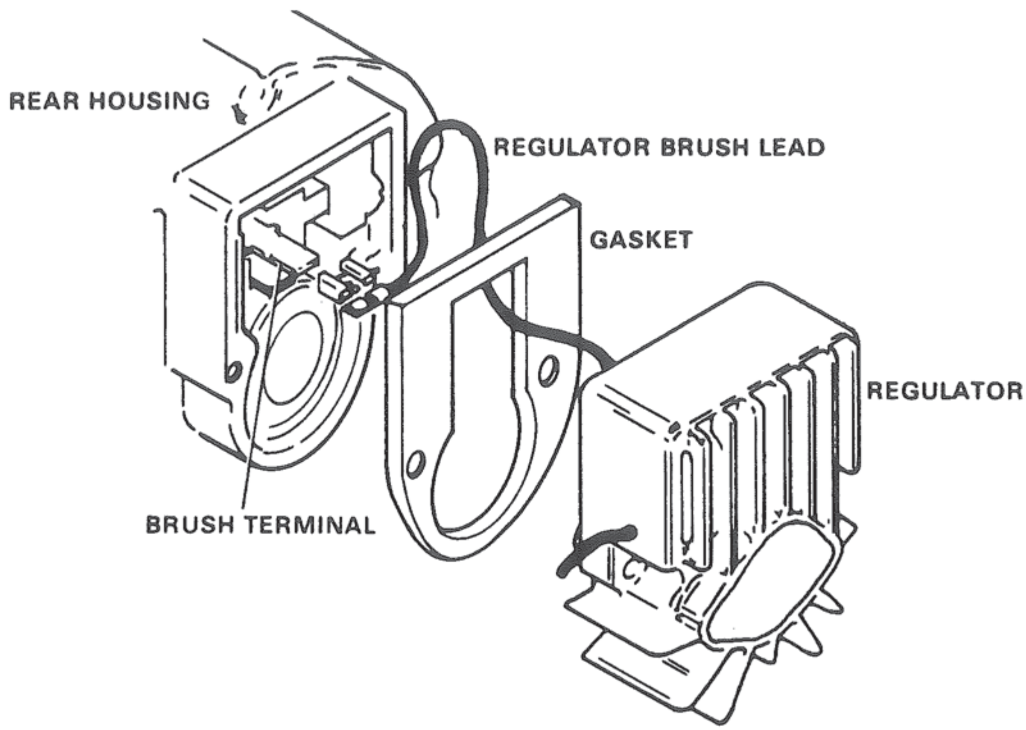


Figure 23. Installing Voltage Regulator.

PRESTOLITE

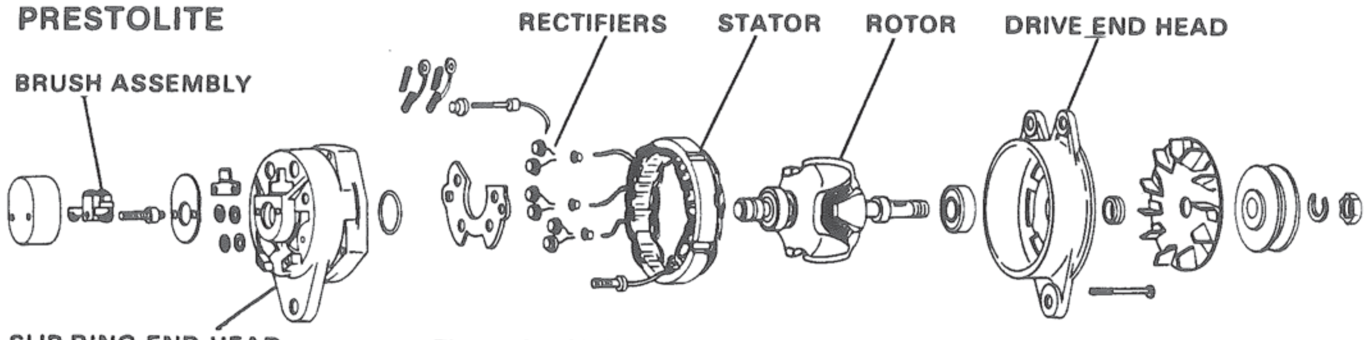


Figure 24. Main Alternator Components.

1. **Slip Ring End Head** which contains the rectifiers heat sink plate along with the field, output and auxiliary terminals and a prelubed ball bearing.

2. **Rectifiers,** which convert AC to DC, pressed into heat sink and connected to stator lead wires, besides acting as one-way current values.

3. **Stator** contains three (3) phase windings, 120° apart, and four (4) lead wires.

4. **Rotor** which "rotates" inside the stator inducing AC current into stator windings.

5. **Drive End Head,** houses a prelubed ball bearing. The drive end of the rotorshaft rotates in this bearing.

6. **Brush Assembly** made of carbon and conducts current between the rotor and the regulator.

TROUBLESHOOTING

General.

Problem	Possible Cause	Test Procedure
Alternator fails to charge. (No output)	A. Blown fusible wire in voltage regulator.	A. Locate and correct cause of the fuse blowing. Install new fuse wire. Solder both ends of new fusible wire securely.
	B. Alternator drive belt loose.	B. Adjust drive belt to specifications.
	C. Worn brushes and/or slip rings.	C. Install new brushes and/or slip rings.
	D. Sticking brushes.	D. Clean slip rings and brush holders.
	E. Open field circuit.	E. Test all the field circuit connections, and correct as required.
	F. Open charging circuit.	F. Inspect all connections in charging circuit, and correct as required.
	G. Open circuit in stator windings.	G. Remove alternator and disassemble. Test stator windings. Install new stator if necessary.
	H. Open rectifiers.	H. Remove alternator and disassemble. Test the rectifiers. Install new rectifiers if necessary.

CAUTION

DISCONNECT BATTERY before connecting or disconnecting test instruments (except voltmeters) or before removing or replacing any unit or wiring.

Accidental grounding or shorting at regulator, alternator, ammeter or accessories will cause severe damage to units and/or wiring. TO AVOID DAMAGE TO REGULATOR, DO NOT, AT ANY TIME, CONNECT BATTERY TO THE REGULATOR FIELD TERMINAL.

FIELD CIRCUIT MUST NEVER BE GROUNDED BETWEEN ALTERNATOR AND REGULATOR. Grounding of field terminal either at alternator or regulator will damage the rectifier.

IF IT IS NECESSARY TO SOLDER ANY LEAD TO A RECTIFIER LEAD, use pliers as a heat dam between solder joint and rectifier.

THE ALTERNATOR MUST NOT BE OPERATED ON OPEN CIRCUIT WITH THE ROTOR WINDING ENERGIZED.

DO NOT ATTEMPT TO POLARIZE ALTERNATOR. No polarization is required. Any attempt to do so may result in damage to alternator, regulator, or wiring. GROUNDING OF ALTERNATOR OUTPUT TERMINAL MAY DAMAGE ALTERNATOR AND/OR WIRING COMPONENTS.

REVERSED BATTERY CONNECTIONS MAY DAMAGE RECTIFIERS, WIRING OR OTHER COMPONENTS OF CHARGING SYSTEM.

IF A BOOSTER BATTERY OR FAST CHARGER IS USED, POLARITY MUST BE PARALLEL TO PREVENT DAMAGE TO ELECTRICAL SYSTEM COMPONENTS.

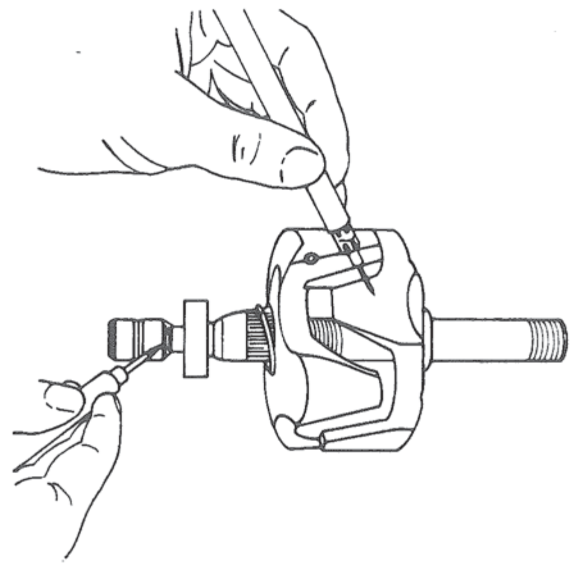


Figure 25. Rotor Ground Test.

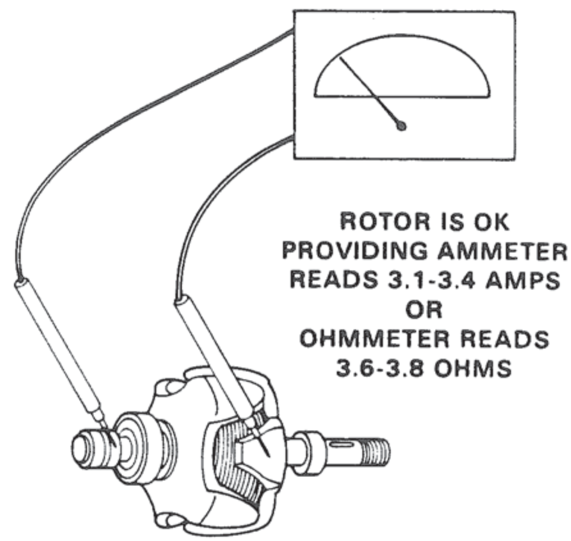


Figure 26. Test for Grounded or Open Windings.

Testing Alternator Components. Clean all parts and visually inspect for cracks, wear, distortion and any signs of discoloration due to overheating or mechanical interference (grooving, seizing, etc.).

1. **Rotor.**

Rotor is tested for grounded or shorted windings. Use either a battery powered continuity tester or electrical tester with an ohmmeter scale. Figure 25.

A. Place one test probe on a slip ring and the other on the rotor shaft. There should not be any continuity between the slip ring and the rotor shaft. Continuity tester should not light and ohmmeter should read infinite.

B. Test for shorted windings is shown in Figure 26.

C. Either an ammeter or ohmmeter can be used to detect shorted windings. Rotor current draw and resistance limits are as follows:

Current draw at 77° F - 3.1-3.4 AMPS at 12V.

Resistance at 77° F - 3.6-3.8 OHMS.

D. Current draw greater than 3.4 amps or an ohmmeter reading less than 3.6 ohms indicates the windings are shorted. Figure 27. No current draw or an infinite ohmmeter reading indicates an open winding. In either case rotor must be replaced.

2. **Rectifiers.**

A diode rectifier tester can detect shorted or open rectifiers without disconnecting rectifier leads. A continuity tester can determine if a set of rectifiers is defective in one test and which one is defective in a second test.

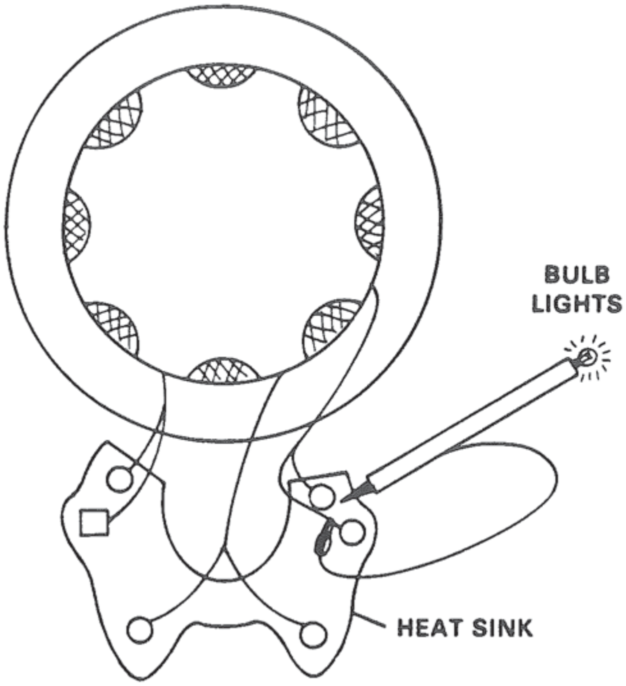


Figure 27. Rectifier Test.

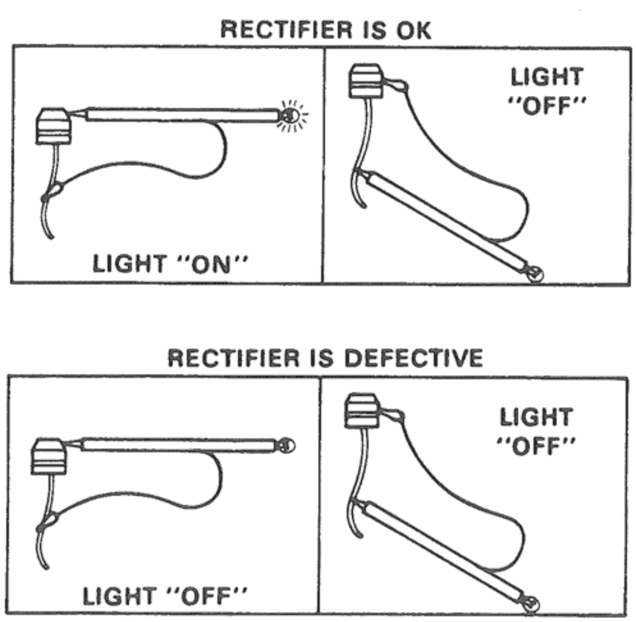


Figure 28. Individual Rectifier Tests.

A. Connect clip to stator lead. Figure 27. Touch test probe to heat sink. Probe bulb should light either in this position or by reversing the clip and probe. If the probe bulb lights in BOTH directions, one or both of the rectifiers in that heat sink is shorted.

B. To determine which rectifier is bad, disconnect stator test on each rectifier. Figure 28. The bulb will NOT light in either direction if the rectifier is defective (open). Replace rectifier if bulb does not light.

3. **Stator.**

Stator can be tested for open or grounded windings using a continuity tester or ohmmeter.

A. First separate stator from slip ring end head far enough to place a rag between stator and end head providing insulation between them.

B. Connect continuity clip to stator lead and test probe to stator frame or one ohmmeter test probe to stator frame and other to auxiliary terminal lead. Figure 29.

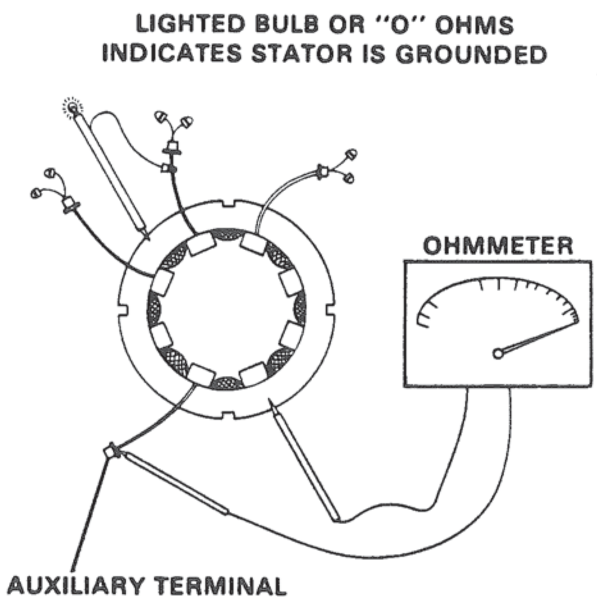


Figure 29. Stator Ground Tests.

If bulb lights, stator is grounded and must be replaced. A "0" ohm reading means the same.

NOTE

Shorted windings are almost impossible to detect because of low resistance in windings. Shorted stator windings will usually cause alternator to "growl" and be noisy in addition to overheating.

If all other electrical checks are normal and the alternator fails to supply its rated output, the stator should be replaced to determine whether or not it is defective.

4. Replace brushes if cracked or worn to less that 3/16 of an in.

OVERHAUL

General. When repairing alternator, complete disassembly may not be required. In most cases, it will be necessary only to perform those operations which are required to repair or replace defective part.

However, in this section, complete overhaul is covered step by step to provide detailed information on each operation. In actual service practice, these operations are used as required.

Disassembly.

NOTE

Special tools used in alternator repair can be obtained from a Prestolite distributor.

1. Before disassembling, mark slip ring end head, stator core and drive end head to be sure they are reassembled in the proper position. Figure 30.

2. Hold pulley in a vise with protective jaws. Remove retaining nut and lockwasher. Now pulley, fan, key and spacer can be removed from the shaft.

3. Remove four (4) through bolts. Tap drive end head lightly to separate drive end head and rotor, as an assembly, from stator and slip ring end head.

Alternator is now separated into two (2) major sub-assemblies. All components can be inspected and tested at this point. Avoid unnecessary removal of diodes, operations involved can ruin a good diode.

If it is necessary to separate stator and diodes from the end head, remove nuts, lockwashers, flat washers, and insulating washers from output and auxiliary terminal studs. Use special tools shown in Figure 31 , to carefully press three (3) negative diodes out of heat sink. End head can now be separated from stator and diode assembly. Figure 31.

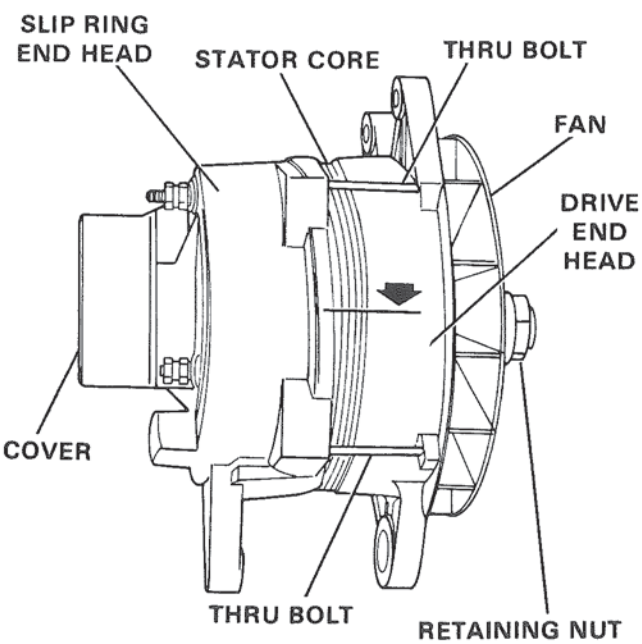


Figure 30. Marking for Reassembly.

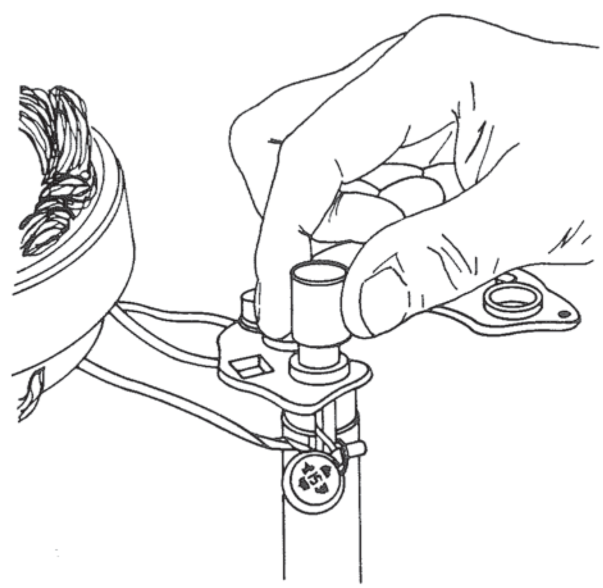


Figure 31. Diode Removal.

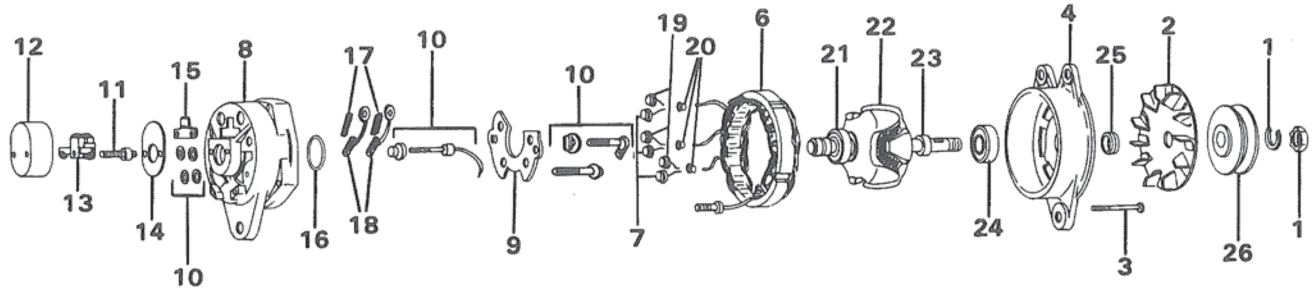


Figure 32. Alternator Components.

4. To remove drive end head from rotor, use a puller that grips the bearing retaining plate. Figure 32.

Do not attempt to remove rotor by supporting end head and pressing on rotor shaft as this may result in a broken or distorted end head.

5. Bearing can be removed from end head by removing retainer plate and screws, then pressing bearing out. Figure 33.

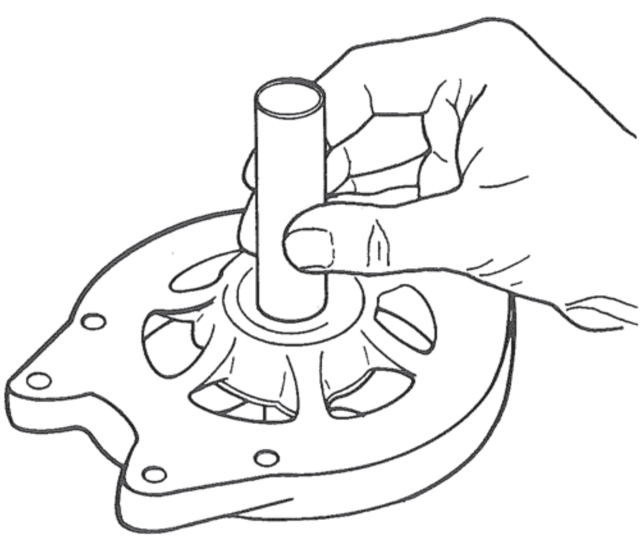


Figure 33. Bearing Removal.

6. Slip ring end bearing can be replaced by using a Prestolite slip ring and bearing package, part number P90-851, and following instructions contained in package.

ALTERNATOR COMPONENTS

Item No.	Description
1.	Nut and Washer Package, Rotor Shaft
2.	Fan, Ventilating
3.	Bolt Package, thru
4.	Head, Drive End
5.	Regulator, Voltage
6.	Stator
7.	Rectifier, Negative
8.	Head, Slip Ring End
9.	Plate, Rectifier
10.	Stud, Insulator and Bushing Package
11.	Nut and Stud Package, Cover Mounting
12.	Cover, Slip Ring
13.	Holder, Brush
14.	Plate, Back-up Brush Holder
15.	Insulator, Slip Ring End
16.	Seal, O-ring
17.	Spring Set
18.	Brush Set
19.	Rectifier, Positive
20.	Eyelet Package
21.	Slip Ring and Bearing Package
22.	Rotor, w/Bearing
23.	Retainer, Flat Washer
24.	Bearing
25.	Spacer, Rotor Shaft
26.	Pulley, Drive

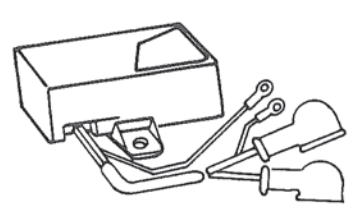


Figure 34. Voltage Regulator.

Assembly.

1. Place drive end head on arbor press and install bearing into bore.

2. Install snap ring and retainer cup onto rotor shaft. Use a tool that fits over the shaft against the inner bearing race and press until race seats against retaining cup. Figure 35.

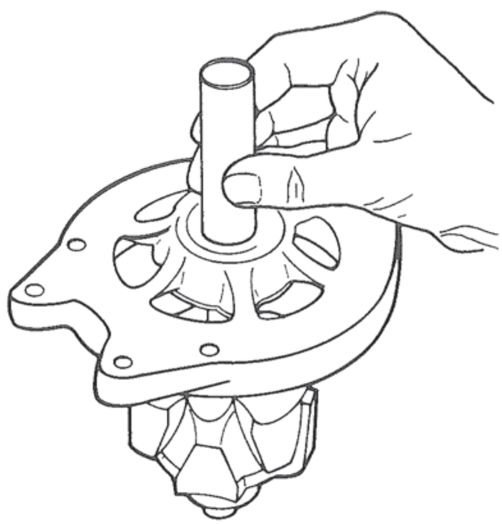


Figure 35. Bearing Installation.

3. Install rectifiers into head sink using special tools. Figure 36. Reconnect stator leads to rectifiers by using arbor press. DO NOT HAMMER!

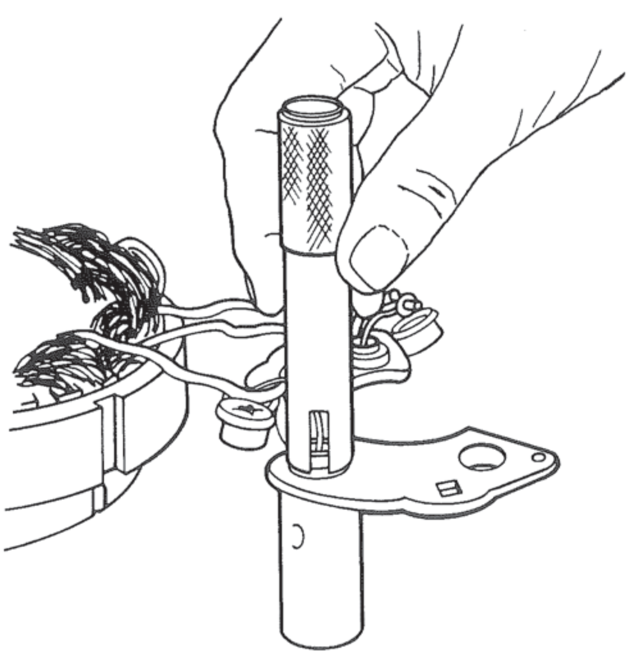


Figure 36. Diode Installation.

NOTE

When soldering leads to rectifiers use pliers as a heat dam on lead between solder joint and rectifier. Excessive heat will damage rectifiers. Figure 37.

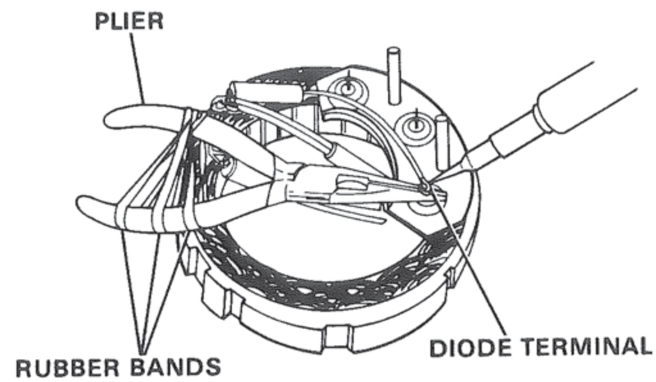


Figure 37. Soldering Leads to Rectifiers.

4. Reassemble rectifiers mounting plate (heat sink) studs and insulators. Figure 38.

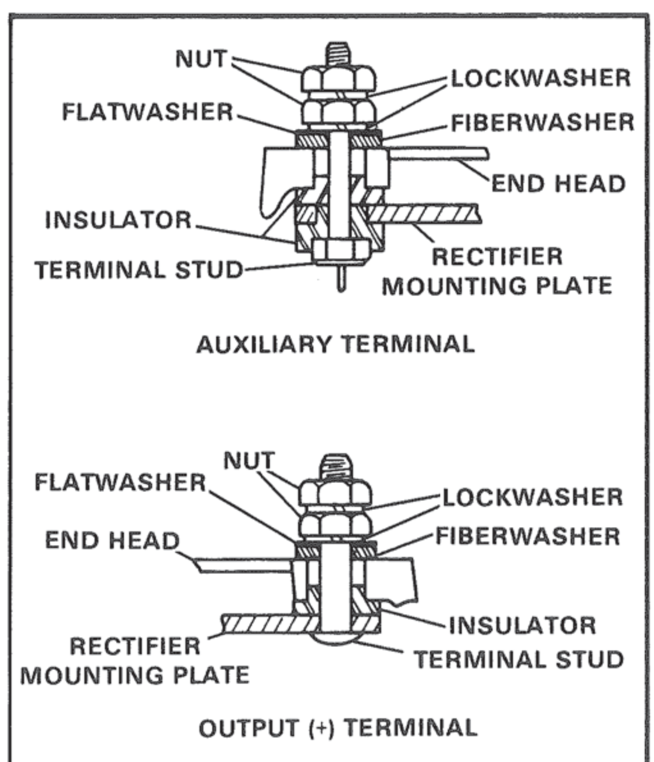


Figure 38. Correct Assembly of Insulators.

5. Assemble end head and stator. Position stator leads so they can't come in contact with the rotor.

6. Install springs and brushes into brush holder, lubricate O-ring. Hold brushes in holder and install drive end head, with rotor, into slip ring end head, with stator.

7. Install four (4) thru-bolts and tighten securely.

8. Install spacer, key, fan, pulley, lockwasher and retaining nut. Secure pulley in a vise with protective jaws and torque 35 ft. lbs. (4.8 kg/m).

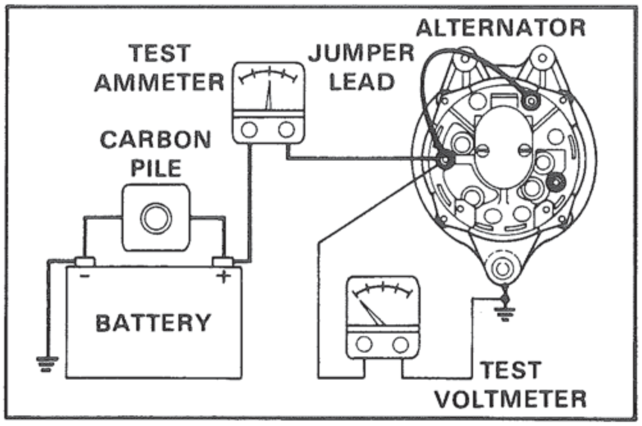


Figure 39. Connections for Bench Testing.

9. Install end cover over brushes and slip rings making certain leads don't contact cover.

10. To check alternator output, run test. Figure 39.

TEST SPECIFICATIONS
ANE Type Alternator

Voltage:	12
Output:	45 Amperes
Ground Polarity	Negative

Rotor Tests.

Resistance at 77° F - 3.6 to 3.8 ohms.

Current draw at 77° F - 3.1 to 3.4 amperes at 12.0 volts.

Full Field Output Tests. The following specifications are obtained by operating alternator with a jumper lead connected from output terminal to field terminal. Regulator must not be connected to alternator.

Volts	Amperes Output	Alternator RPM
14.0	10 Min.	1500 Min.
14.0	40 Min.	4000 Min.

Subsection 5C

STARTING SYSTEM

GENERAL

The information in this subsection is concerned with troubleshooting the starting system and replacement of electrical components.

Description. The electrical starting system consists of six (6) major components: starter motor, starter relay, glow plug relay, fuel shutoff solenoid, battery and ignition switch.

NOTE

The battery and ignition switch are not covered in this manual. All test information pertaining to these components should be obtained from battery manufacturer and boat maker.

CAUTION

All tests must be made with drive in neutral.

TROUBLESHOOTING

Starting Circuit. Troubleshooting the starting circuit is a systematic check starting with the battery. The following checks are made assuming battery and ignition switch are operating properly (see Manufacturers Service Instructions).

Voltage Drop Test. This test is made to locate any high resistance connections which would impede starter motor efficiency.

1. Using a voltmeter capable of low readings, test for voltage drops at three (3) locations while cranking engine. Figure 3. Voltage drop specifications are:

Point A	0.3 volt maximum
Point B	0.1 volt maximum
Point C	0.2 volt maximum

A small change in voltage will occur after each portion of the circuit is eliminated.

2. A definite change in the voltmeter reading indicates last part eliminated in test is at fault.

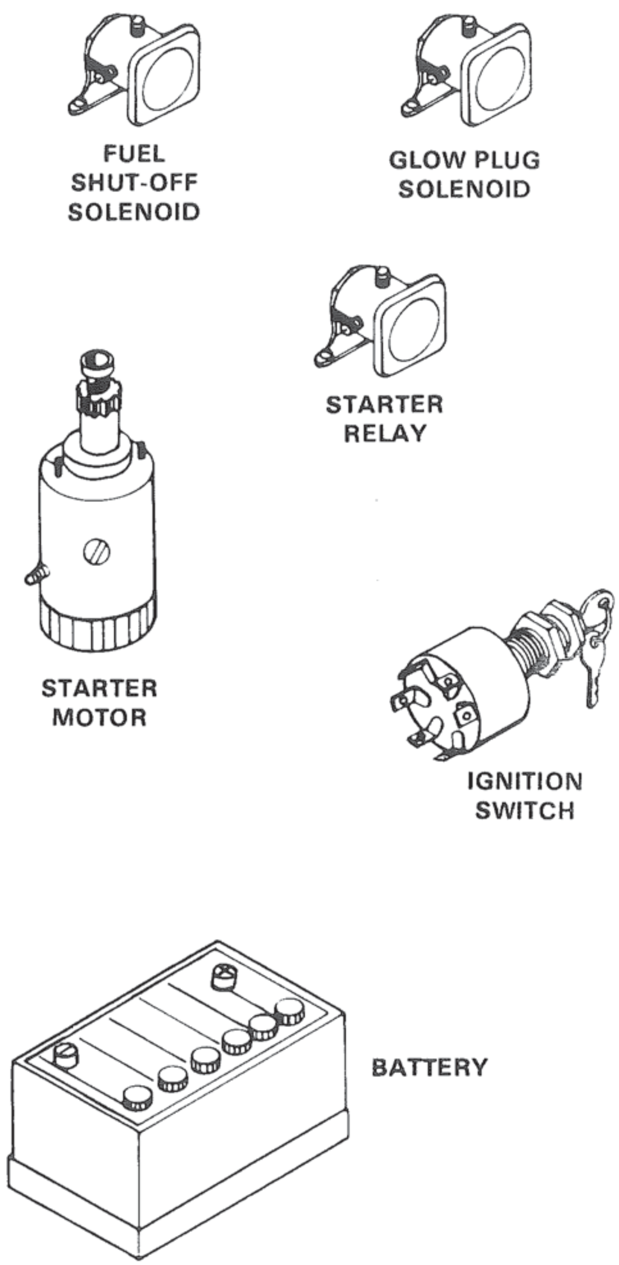


Figure 1. Starting System.

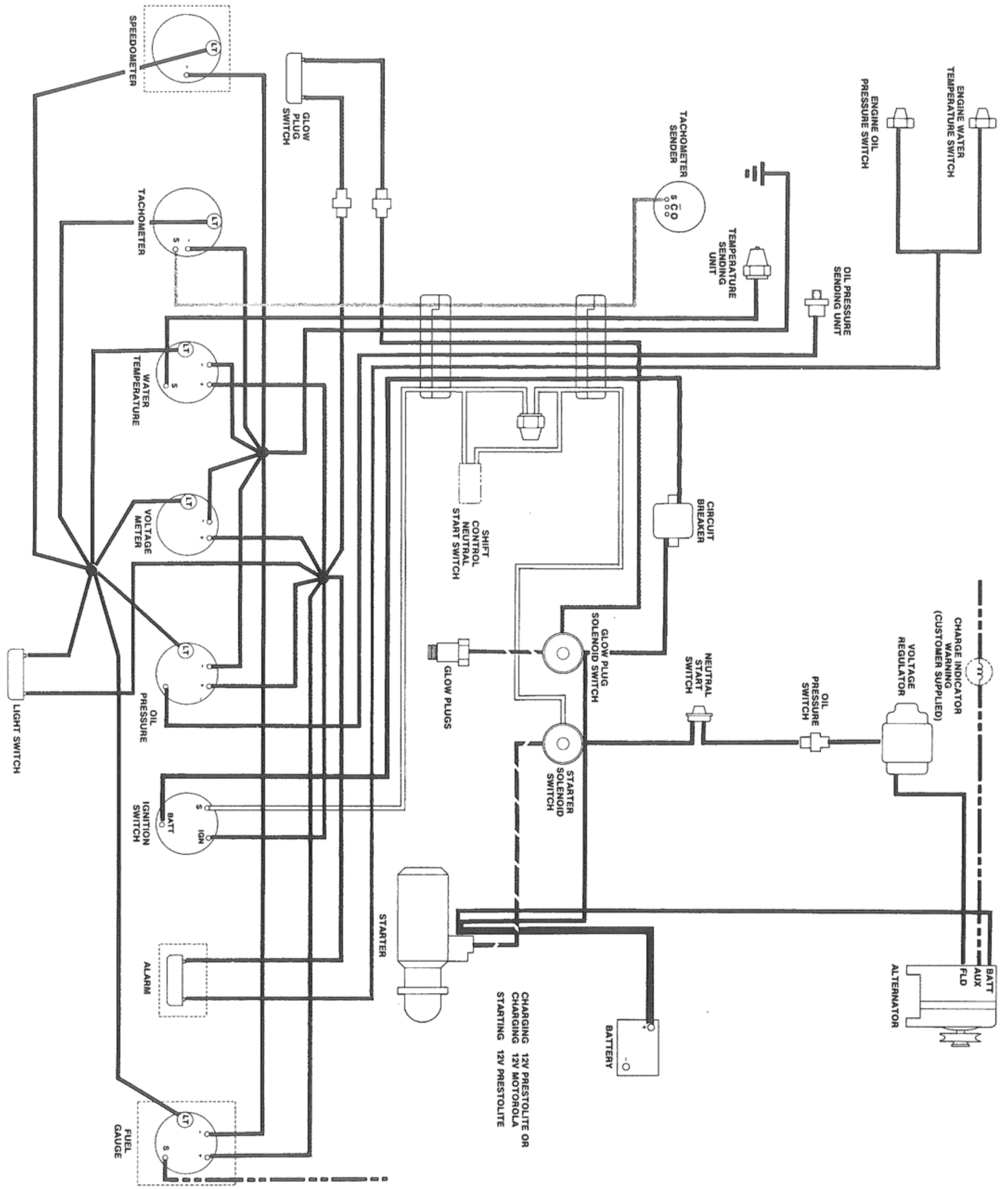


Figure 2. Wiring Diagram.

Problem	Possible Cause	Test Procedure
Starter fails to operate.	A. Faulty battery.	A. Check specific gravity. Recharge or replace.
	B. Ignition switch.	B. Test and replace if necessary.
	C. Grounded or open windings.	C. Test and replace if neccessary.
	D. Starter relay faulty.	D. Test and replace if necessary.
	E. Starter solenoid faulty.	E. Test and replace if neccessary.
	F. Broken wire(s) in system.	F. Run continuity tests and replace if necessary.
	G. Corrosion on battery, relay or solenoid contacts.	G. Test and clean contacts.

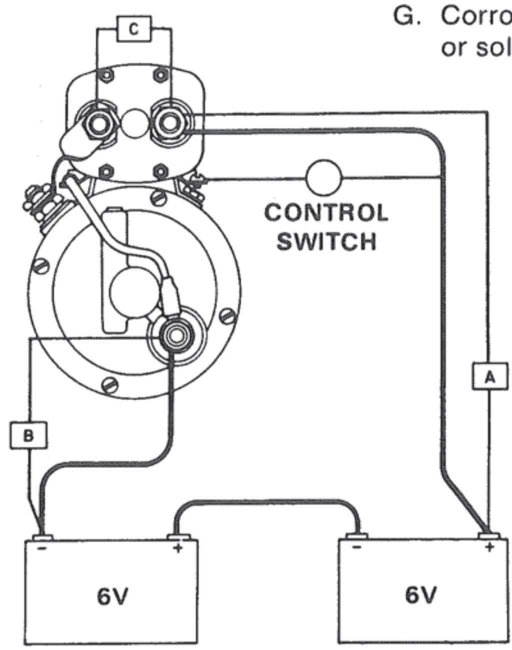


Figure 3. Voltage Drop Test.

STARTER MOTOR

General. This starter has a piggyback mounted solenoid with plunger and pinion mechanism totally enclosed. The motor itself is throughly sealed with gaskets, O-rings and an oil seal.

Seven (7) major components of the starter are as follows. Figure 4.

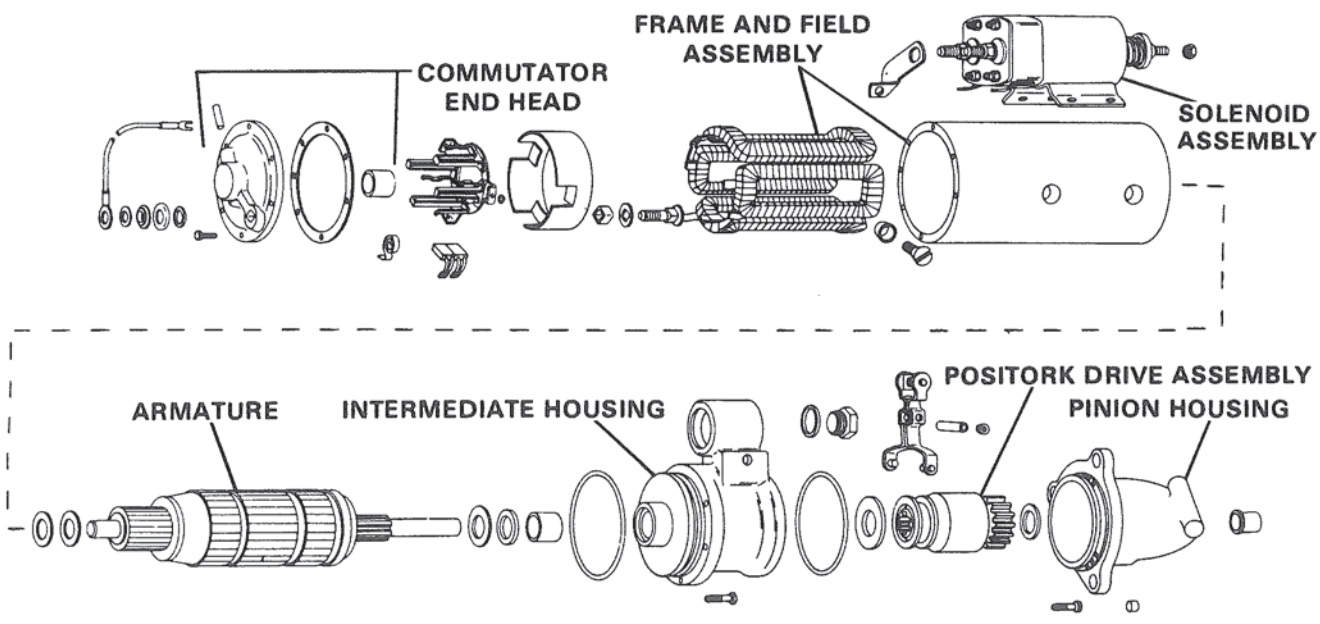


Figure 4. Major Starter Components.

1. **Commutator End Head** contains a bearing, which supports commutator end of armature shaft, a felt wick, which is saturated with oil to lubricate bearing, and a mounting hole for the ground terminal stud.

2. **Frame and Field Assembly** includes a frame which physically supports other components of the motor, field coils, brush holder, brushes and pole shoes.

3. **Solenoid Assembly** contains a removable battery terminal stud plate; contact disc, which makes contact with the motor and battery terminal studs when solenoid is energized; solenoid base and moving core, which pushes contact disc forward and pulls shift lever, which controls drive assembly movement. A boot type seal is used around moving core assembly providing a seal for the moving core and also seals the intermediate housing opening.

4. **Armature** is made of laminated iron core assembled to the armature shaft; a commutator, made up of a number of copper segments insulated from each other and from the shaft; and armature windings wound in the slots of the core and connected to the commutator segments.

5. **Intermediate Housing Assembly** contains a bearing which supports center of armature shaft; an oil reservoir which provides lubrication for the bearing and an oil seal which is mounted on motor side of center bearing to prevent any water, dirt or oil from entering motor. An O-ring seal is used around housing where it is fastened to frame. This, along with gaskets used on commutator end, provides complete sealing, of motor portion, of unit.

The intermediate housing also contains a solenoid access hole, providing a means for solenoid and drive timing adjustment and solenoid removal for servicing; and a steel pin, which provides the mounting and pivot point for the drive shift lever. The access hole is sealed with a plug and gasket while the steel pin is held in position and sealed between two (2) pipe plugs.

6. **Positork Drive Assembly** provides engagement with flywheel ring gear. The solenoid switch is adjusted so that the motor can't be energized until pinion gear is engaged in ring gear. This greatly reduces pinion and ring gear wear.

7. **Pinion Housing** contains a bearing, which supports drive end of armature shaft, felt oil wick to lubricate bearing, an O-ring, sealing intermediate and pinion housings and plugs, filling unused pinion housing positioning holes.

Electrical Bench Testing. All tests are made at 77° F/25° C. Check all parts for signs of excessive wear, seizing and overheating.

Testing Armature. If inspection does not reveal cause of failure, test armature for shorts, grounds and balance. Follow test equipment manufacturer's procedure or use the following:

1. Armature short test.

A. Place armature in growler jaws and turn power switch to GROWLER position. Figure 5.

B. Hold a steel band parallel with and touching armature core. Turn armature slowly in growler jaws. If steel blade vibrates at any area of the core, area is shorted and armature must be replaced.

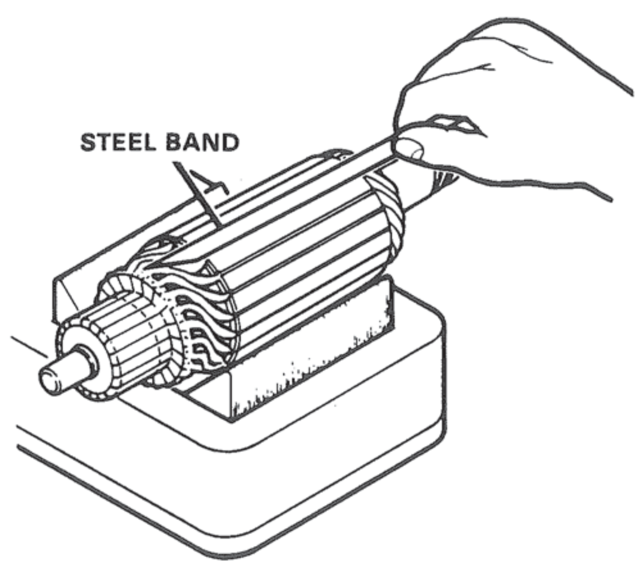


Figure 5. Armature Short Test.

2. Armature ground test.

A. Place armature in growler jaws and turn power switch to TEST position. Figure 6.

B. Touch one test lead to armature core, touch other lead to each commutator bar one at a time. If test light glows on any bar, armature is grounded and must be replaced.

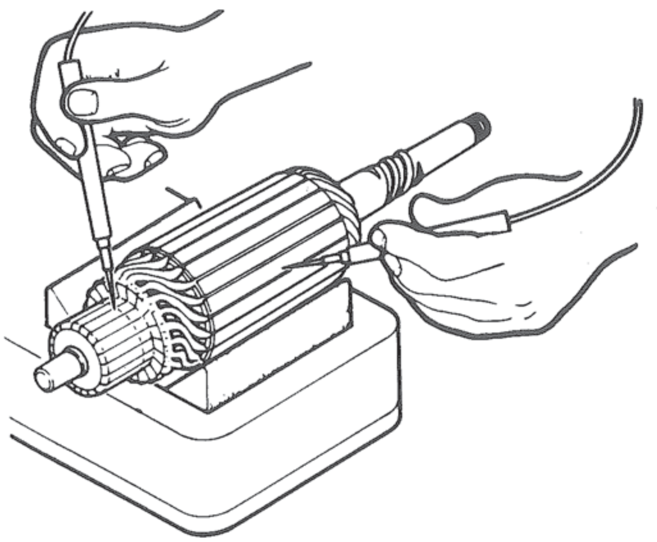


Figure 6. Armature Ground Test.

NOTE

Ground test can also be done with an ohmmeter. Attach one lead to commutator sections. Meter should show infinity or very high resistance.

3. Armature balance test.

A. Place armature in growler jaws and turn power switch to GROWLER position. Figure 7.

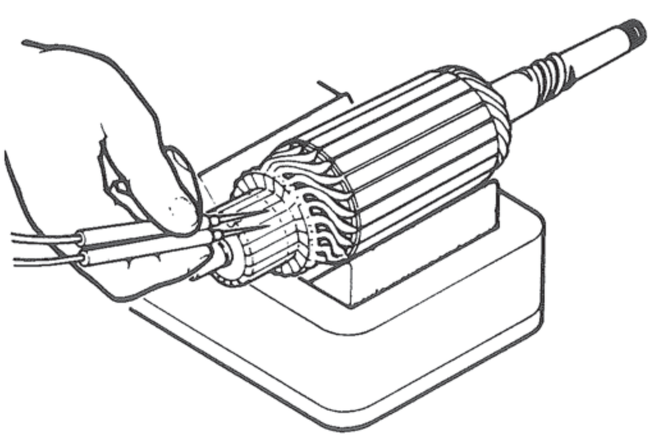


Figure 7. Armature Balance Test.

B. Place contact fingers of meter test cable across any two (2) commutator bars at side of commutator.

C. Adjust voltage control until needle hits highest reading.

D. Test each commutator bar with the bar next to it until all bars are checked. A zero reading indicates an open circuit between a pair of bars.

Testing Frame Field Coils. Check grounds by placing one test probe of the 110 volt test light on the frame and the other test probe on the field coil terminals. Figures 8 and 9 tester lights, fields are grounded.

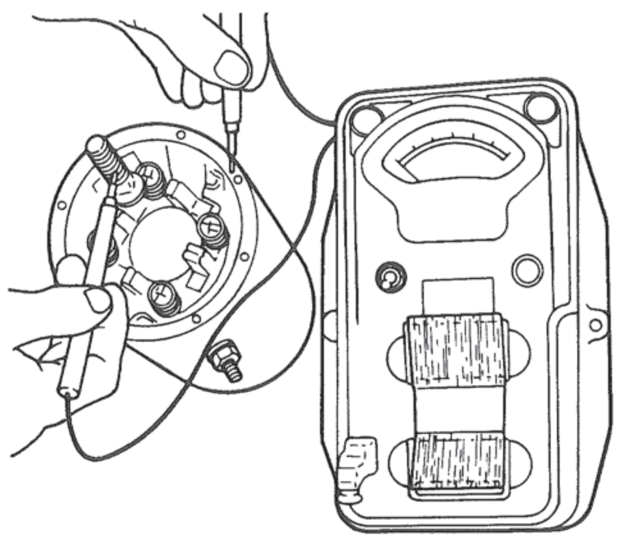


Figure 8. Field Coil Test.

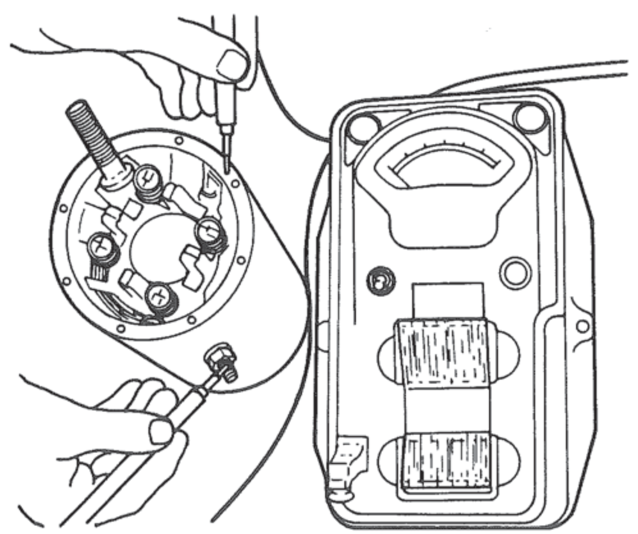


Figure 9. Field Coil Test.

Testing Brush Holder. To test brush holder assembly for grounds, touch one probe of the test light to the frame and other probe to brush holder. If bulb lights, replace the brush holder assembly. Figure 10. Brushes should be replaced if damaged, cracked or worn to 3/8 in. or less. Brush spring tension, with new brushes should be 70-90 oz. Test with spring scale hooked under brush spring at brush.

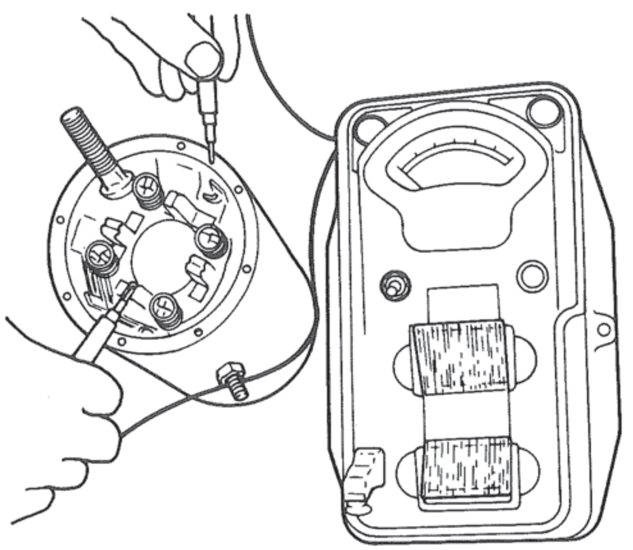


Figure 10. Brush Holder Test.

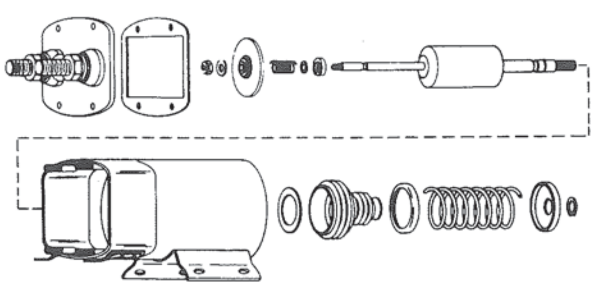


Figure 11. Solenoid Assembly.

Solenoid Assembly.

1. Remove four (4) cover retaining nuts and pull cover away far enough to expose the series winding connection on the motor terminal stud.

2. Remove connecting screw and separate cover from solenoid. If contact assembly or terminal studs are burned, eroded or pitted, replace before testing. See Figure 11 for proper parts stack-up.

3. Check current draw of solenoid windings. Figure 12. The series winding is connected from small terminal on right side of solenoid to motor terminal stud connector.

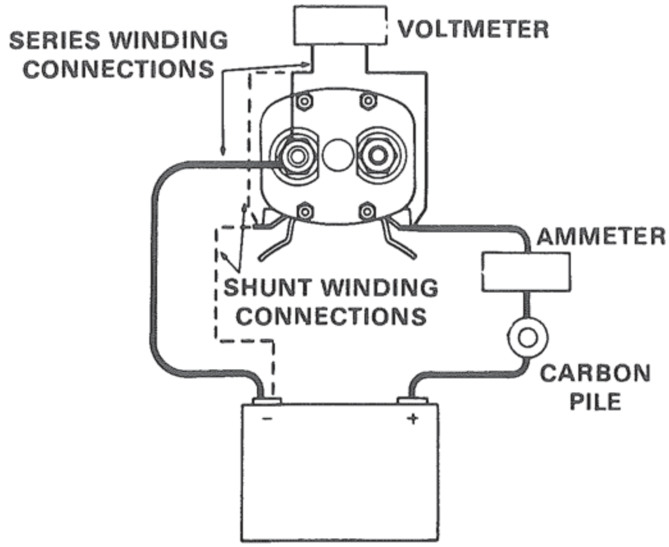


Figure 12. Solenoid Test.

Current draw at 77° F/25° C should be as follows:

12 volt solenoids — test at 6.0 volts
Series winding — 34 to 40 amperes
Shunt winding - 6 to 7 amperes

4. Inspect moving core and boot. Replace if damaged.

5. If terminal studs have been loosened in cover plate, reseal insulators with a coat of glyptal. Keep glyptal from contact surfaces of nut and terminal studs. Apply a film of light grease to large section of boot so it can be installed. Install solenoid on motor. Make sure shift mechanism is properly assembled.

Adjustments. There are two (2) adjustments that can be made on this type of motor — Armature-end-play and Pinion position.

Armature end play adjustment is made by adding or removing thrust washers on commutator end of armature shaft. A tolerance of .005-.030 is acceptable.

Pinion position assures correct relation between solenoid and Positork drive. Pinion and ring gear damage may result if adjustment is not correct. Pinion position is accomplished in two (2) steps. Refer to Figure 13 for necessary tools.

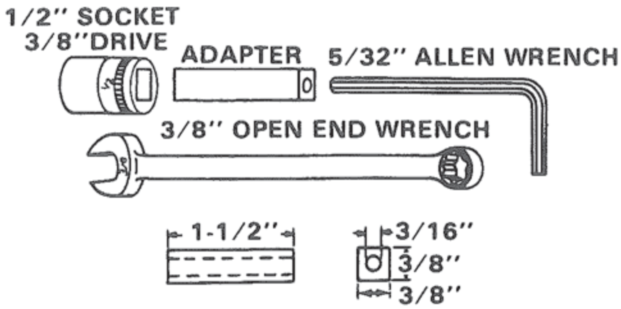


Figure 13. Pinion Position Tools.

1. Connect a 6 volt battery to starter and solenoid. Figure 14.

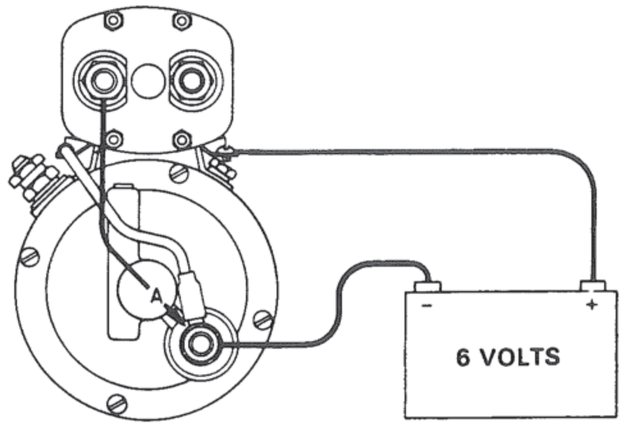


Figure 14. Pinion Position Test.

Momentarily connect jumper "A" from motor terminal stud (of solenoid) to terminal stud on commutator end head. This will shift the solenoid and drive into the cranking position. Remove jumper lead. Drive will remain in cranking position until battery is disconnected. Push drive toward commutator end to remove slack in linkage.

2. Measure distance between outside edge of drive sleeve and thrust washer. Figure 15.

Adjust to .020 in. - .050 in. by turning adjusting nut in or out as required.

3. To make this test, it will be necessry to have an interference block cut to the dimensions shown. Figure 16.

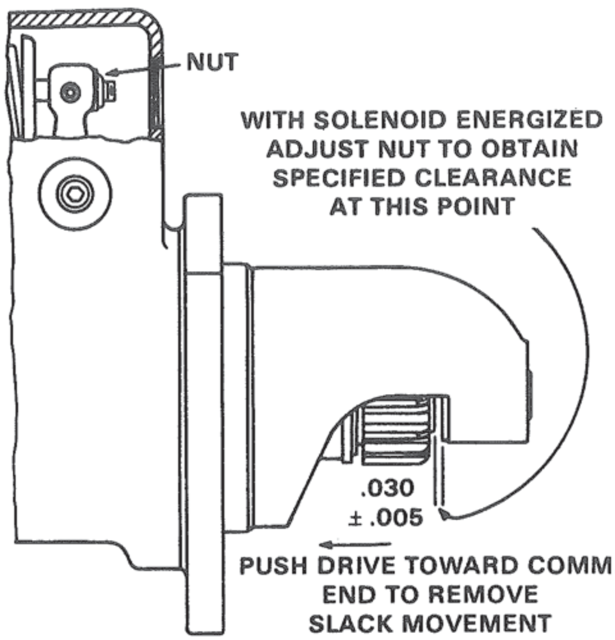


Figure 15. Pinion Adjustment.

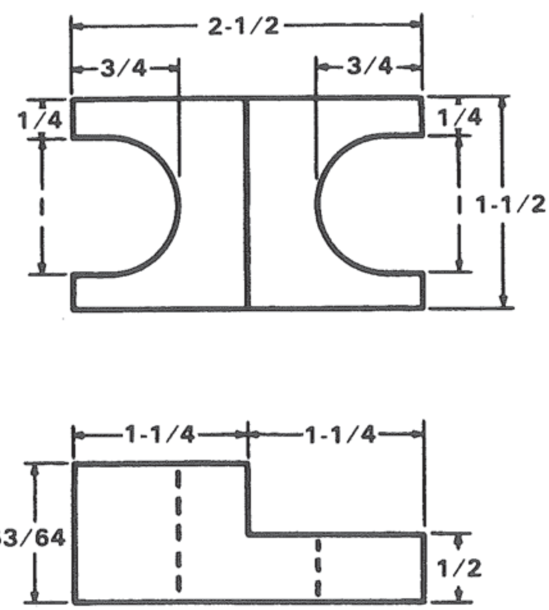


Figure 16. Interference Block.

4. Connect solenoid to 12 volt power supply. Figure 17.

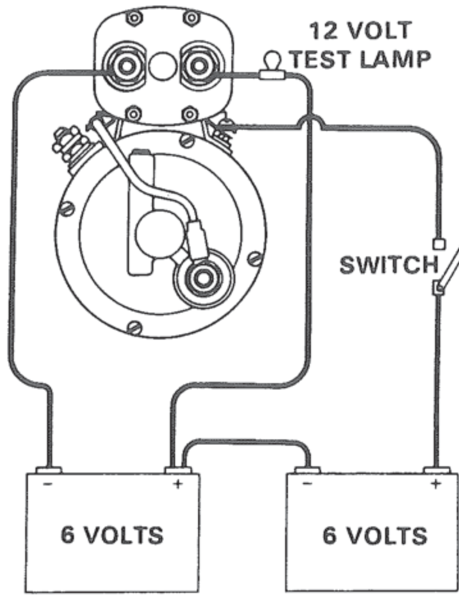


Figure 17. Solenoid Ground Test.

5. Place block against drive gear and close switch. Figure 18. Test light should not light.

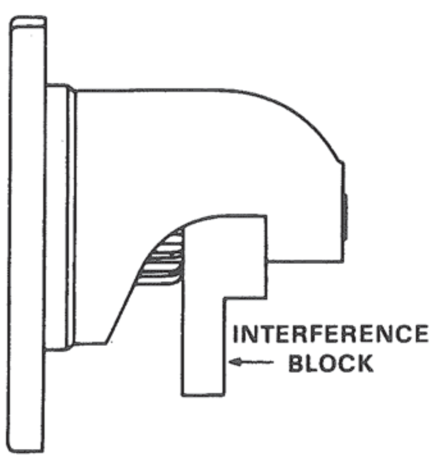


Figure 18. Positioning Interference Block.

CAUTION

Due to the amount of current being passed through the solenoid series winding, these tests should be made as brief as possible.

6. If test bulb lights, solenoid has been assembled wrong. Remove cover from solenoid and check contact component assembly. Figure 11. If test light does not light, connect a carbon pile and volt meter to circuit. Figure 19.

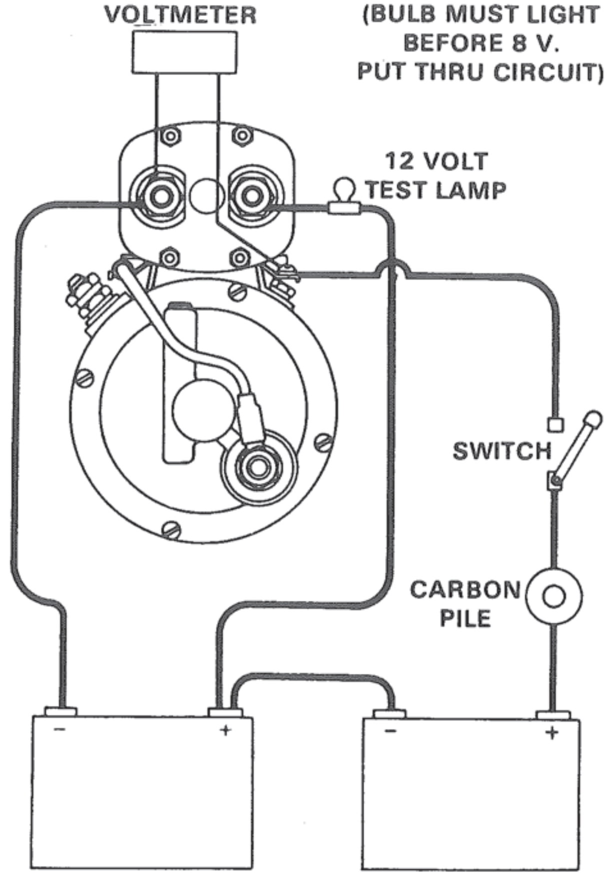


Figure 19. Voltage Adjustment.

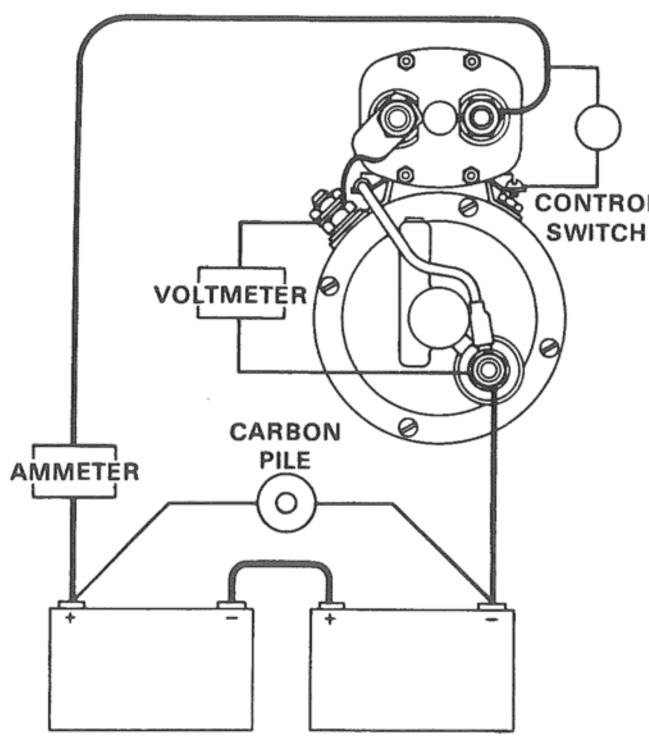


Figure 20. Current Draw Test.

7. Position the .500 side of the interference block against drive gear and adjust voltage with carbon pile. Test light must light before 8 volts on 12 volt motors. If test light does not light, turn adjusting nut out until light comes on. After all adjustments have ben made, replace plug and washer in the shift linkage cover.

8. Test motor for free running current draw. Connect as shown. Figure 20.

9. If current draw is excessive, check bearing alignment and end play. Two (2) or three (3) raps with a rawhide hammer will often help bearing alignment.

DISASSEMBLY

Solenoid.

1. Remove plug and gasket from immediate housing using tools from Figure 21.

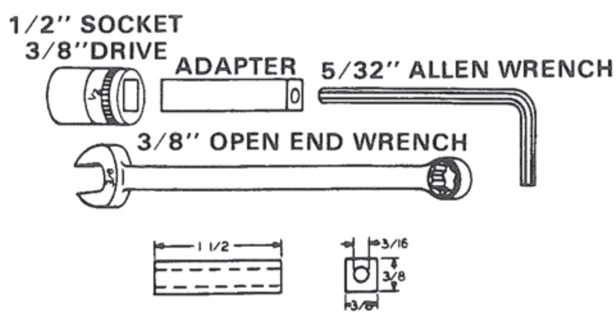


Figure 21. Tools.

2. Remove nut from end of moving core shaft.

NOTE

An adapter should be made to facilitate adjusting nut removal, replacement and adjustment. Drill a 3/16 in. hole through the center of a piece of 3/8 in. square stock 1-1/2 in, 3/8 in. long adapter is used with a 1/2" socket, 3/8" drive, a 5/32 in. Allen wrench and a 3/8 in. open end wrench.

3. Install adapter and socket.

4. Insert Allen wrench through adapter to hold moving core shaft. Hold Allen wrench stationary and turn adapter with open end wrench.

5. Disconnect solenoid lead from front motor terminal. Remove nut and lockwasher from motor terminal. Remove nut and lockwasher from motor terminal stud.

6. Remove four (4) cap screws that hold solenoid to motor frame and separate solenoid assembly from motor.

Commutator End Head.

6. Remove nut, lockwasher, flat and insulating washers from terminal stud. Remove retaining bolts or screws and separate end head from motor.

Frame Coil and Field Assembly.

8. Remove retaining bolts that connect intermediate housing to frame assembly from intermediate housing.

Shift Lever Pin.

9. Remove two (2) pipe plugs to expose shift lever pin. Use a small drift punch or screwdriver to push pin out of intermediate housing.

NOTE

Before separating intermediate housing and pinion housing, scribe or center punch locating marks so pinion housing can be reassembled in original position.

Housings.

10. After marking housing, remove socket head retaining bolts and separate two (2) housings.

11. Slide intermediate housing and drive assembly from armature shaft.

INSPECTION AND REPAIR

1. After motor is disassembled, each part should be cleaned and inspected for wear or damage.

2. Inspect each bearing for roughness, seizing or wear. Clean and check condition of all insulation.

ASSEMBLY

General. Saturate bearings and wicks in SAE 20 oil. Apply a light coat of grease to armature shaft and splines before assembling.

When installing bearings they must be positioned as follows:

Commutator end bearing — flush with bearing bore.
Pinion housing bearing — flush with inside of housing bore.
Intermediate bearing — flush with armature side of bearing bore.

1. Install drive assembly and intermediate housing, assemble pinion and intermediate housings and secure with socket key mounting bolts.

2. Install shift lever pin and two (2) pipe plugs into intermediate housing.

3. Assemble frame and field assembly and install retaining bolts which connect intermediate housing to frame and field assembly.

4. Assemble end head to main assembly, install insulating washers, flat washer, lockwasher and nut to terminal stud.

5. Install solenoid and mounting bolts to starter motor.

6. Install nut and washer to terminal stud and solenoid lead to front motor terminal.

7. Install nut to end of moving core shaft using tools shown in Figure 18.

8. Install new gasket and plug into intermediate housing.

TEST SPECIFICATIONS

	Terminal Voltage	Maximum Amperes	RPM	Torque Ft. Lbs.
No Load Test (Bench)	10.0	110	7,500	0
Stall Torque Test	2.0	690	0	16.0

Test Temperature 77° F/25° C

Section 6

ENGINE

CONTENTS

Subsection 6A

GENERAL

1. Definition of terms and units used in this section is as follows:

A. Front and rear.

Water pump or crankshaft pulley end of the engine is front, flywheel end is rear.

B. Right and left sides of the engine are determined by viewing from flywheel end of engine.

C. Upper and Lower.

Cylinder head of engine is upper, oil pan is lower.

D. Units.

Length, surface area, and quantities are expressed in the metric system. Temperatures are presented in centigrade. Inch dimensions and fahrenheit temperatures are in parentheses when applicable.

2. Direction of Engine Rotation.

The direction the propeller turns, viewed from the propeller coupling flange end. Rotation is stamped in the model number.

NOTE

Direction of rotation of auxiliary equipment such as injection pump, alternator, etc. is determined by viewing it from the drive side.

3. Terms Used in Servicing Standard.

Definition of terms used in the text or in the tables of Servicing Standard is as follows:

Nominal value: Nominal dimensions used in designing.

Assembly standard: Standard clearance between assembled parts, or standard performance of assembly.

Limit of repair: Limit of clearance between parts or limit of dimension of a part at which the part requires repair.

Limit of use: Limit dimension and value of a part at which the part is not servicable in either performance or strength and requires replacement.

GENERAL SERVICING PROCEDURES

Thorough cleaning of an engine prior to disassembly is recommended. If a steam cleaner is used, remove electrical components and drive belts first.

NOTE

Prior to cleaning carefully check the engine for evidence of problems i.e. leaks, cracks, worn components.

During disassembly, check each part removed for mating or alignment marks for use during reassembly. If none are found, scribe or stamp one to assure correct assembly.

Use correct tools for all operations to prevent unnecessary damage. A list of special tools designed for work on this engine appears on each Section Index page.

During reassembly clean each part thoroughly and place in clean engine oil (*) prior to installing it on the engine. Follow torque chart on page 18, Section 2.

* (unless instructed not to)

CAUTION

Engine and fuel system (except filters) are metric designs. All specifications and inspection dimensions must be made using metric measuring instruments. Inch dimensions enclosed in parentheses are for reference only.

Notes:

Notes:
Upper Engine Gasket and Seal Set Part # 4142149
Lower Engine Gasket and Seal Set Part # 4142150

Subsection 6B

CYLINDER HEAD AND VALVE TRAIN

General Information. The cylinder head is cast iron. Independent intake and exhaust ports arranged alternately provide uniform temperature distribution. Water passages at the bottom of the head contain flow-directors aiming coolant around exhaust ports and the bridge between valves. Replaceable valve seats and valve guides (intake and exhaust) provide long term durability. Removeable precombustion chambers for each cylinder are used providing high combustion efficiency. A bonded steel-asbestos head gasket with stainless steel fire rings is used. The gasket is designed to help maintain cylinder head bolt torque and provide excellent sealing. The cylinder head is secured to the block with 25 special steel, 14 mm. bolts.

Intake and exhaust valves are made of high alloy heat resistant steel, valve stems receive the Tuffride process for better wear. Valve guides, made from special cast iron have oil grooves for valve stem lubrication.

Rocker arms have replaceable bushings and induction hardened wear surfaces. Tappets are cylindrical and are removable without removing the camshaft.

ROCKER ARMS AND SHAFT ASSEMBLY

Removal.

NOTE

If engine is still in boat, disconnect battery leads and shut off fuel supply.

1. Remove rocker cover.

2. Determine which rocker arms are holding valves open and back off rocker arm adjusting screws. Figure 1.

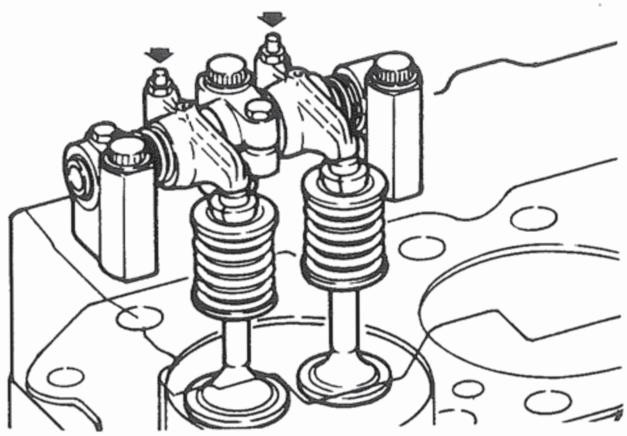


Figure 1. Loosening Rocker Arms.

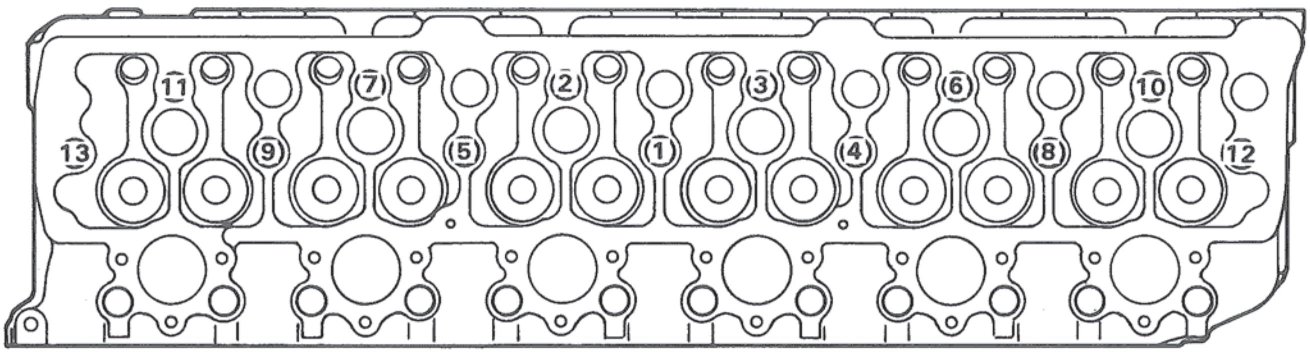


Figure 2. For Rocker Arm Removal Only.

CAUTION

Drain water from engine before removing rocker bolts (head bolts in phase II) as water may leak into cylinder.

3. Loosen bolts securing rocker shaft brackets to head. Follow sequence shown. Figure 2.

4. Remove rocker arm assembly from head.

Disassembly.

1. Remove bolts securing rocker shaft supports to rocker shaft. Figure 3.

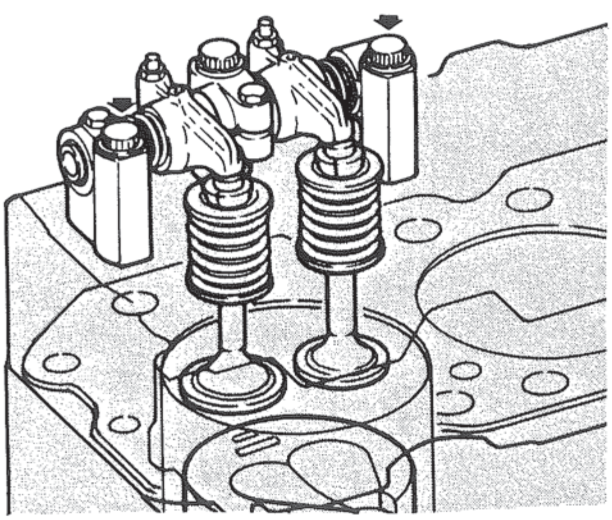


Figure 3. Disassembly of Rockershaft.

2. Slide components from shaft and place in order of removal for ease in assembly.

INSPECTION AND REPAIR

Rocker Arm.

1. Check valve cap contact surface for wear. Figure 4. If wear is noted, replace rocker arm.

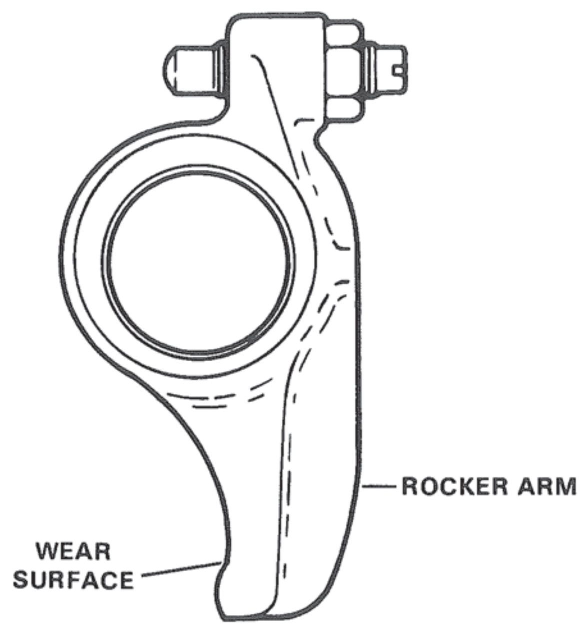


Figure 4. Checking Rocker Arm.

2. Check rocker arm oil hole for blockage.

3. Measure rocker arm bushing I.D., the nominal dimension is 23 mm. Measure O.D. of rocker shaft where this rocker works, the nominal dimension is 23 mm. If the difference between the two exceeds 0.12 mm. replace the rocker arm bushing.

4. Repeat step 3 for balance of rocker arms.

5. Replace rocker arm bushing.

A. Use Special Tool No. MH 061286 to remove old bushing.

B. Place new bushing on rocker arm, bushing seam toward adjusting screw, oil hole in bushing lined up with oil hole in rocker arm. Figure 5.

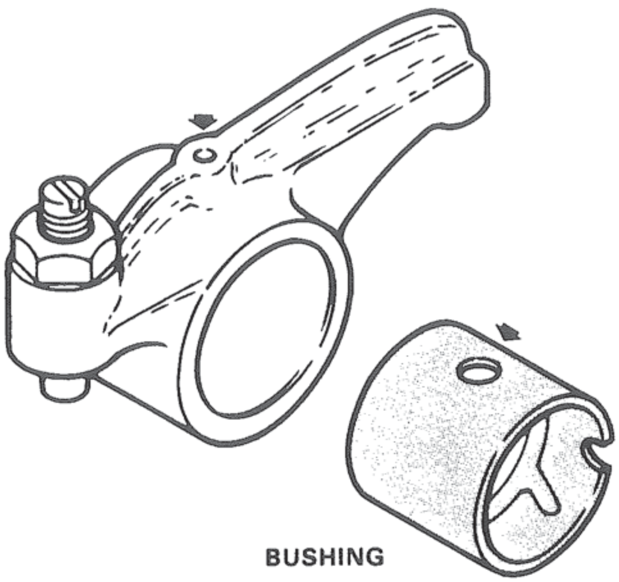


Figure 5. Installing Bushing.

C. Press new bushing in place, check oil hole line-up.

Valve Clearance Adjusting Screw.

1. Inspect adjusting screw for wear or damage. Figure 6. Replace if defective.

Push Rod.

1. Inspect both ends of push rod for wear or damage. Replace if defective.

2. Place push rod on a flat surface (ends of rod must not touch inspection plate). Figure 7.

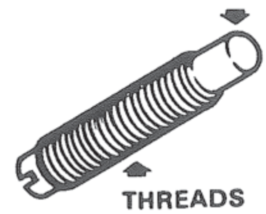


Figure 6. Adjusting Screw Inspection Points.

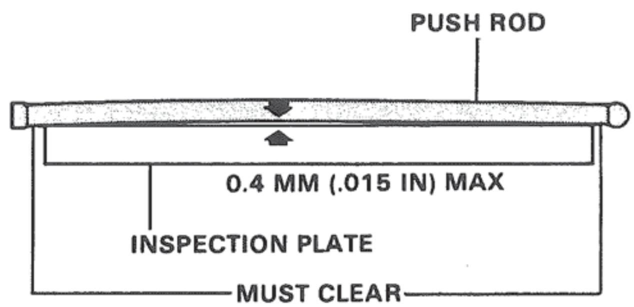


Figure 7. Checking Push Rod.

3. Use a 0.4 mm. feeler gauge and check for straightness. Roll push rod on plate checking as it rolls. If 0.4 mm. feeler gauge goes between push rod and plate at any point, replace push rod.

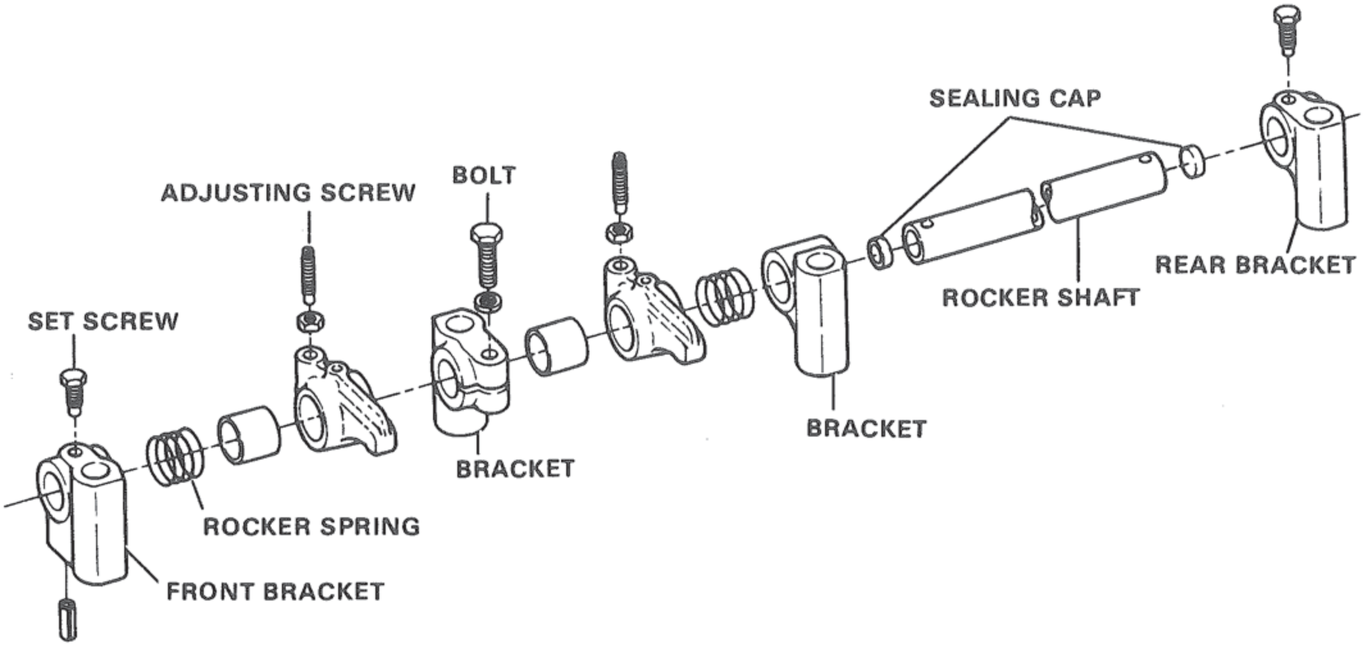


Figure 8. Rocker Assembly.

Assembly.

1. Follow sequence of disassembly. Figure 8.

2. Insert both push rods, replace valve caps.

3. Place rocker assembly on head, place head bolts in oil then in mounting holes.

4. Tighten head bolts, follow tightening sequence. On NA models, torque to 18 + 1.8/- 0 kg/m (130.5 + 13/- 0 ft lbs); on Turbo engines 20 + .7/-0 (145 ft lbs + 5/-0).

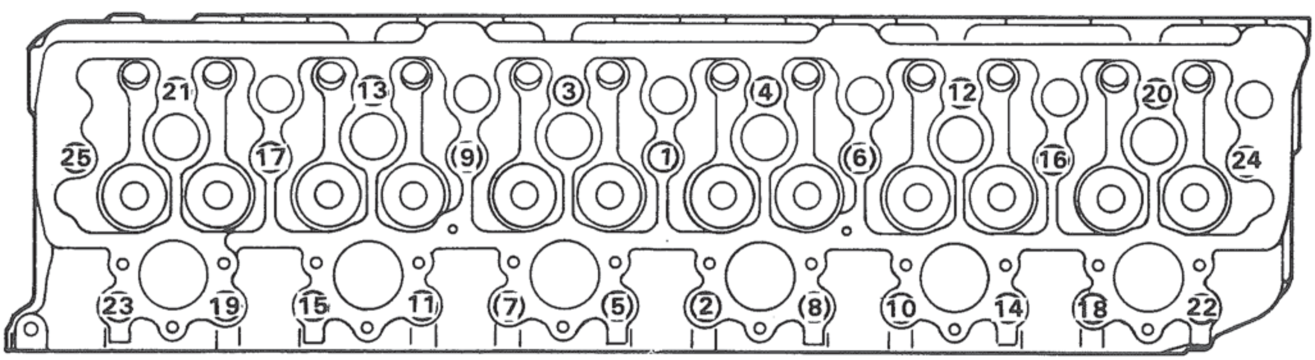


Figure 9. Head Bolt Tightening Sequence.

Notes:
Upper Engine Gasket and Seal Set
Part # 4142149

Lower Engine Gasket and Seal Set
Part # 4142150

Phone 269 673 2128 (leave message)

NOTE

Tighten **all** bolts as shown. Not just those removed.

5. Adjust valves. Set intake valves at .3 mm (.012 in.), exhaust valves at .38 mm (.015 in.), TI; .3 mm (.012 in.) intake and .3 mm (.012 in.) exhaust, NA.

A. Set No. 1 piston at top dead center (TDC) on compression stroke. Align TDC mark on crankshaft dampener with timing pointer on timing gear case. Figure 10.

NOTE

TDC mark is between one and six.

Piston is at the TDC on compression stroke when there is play at both intake and exhaust push rods.

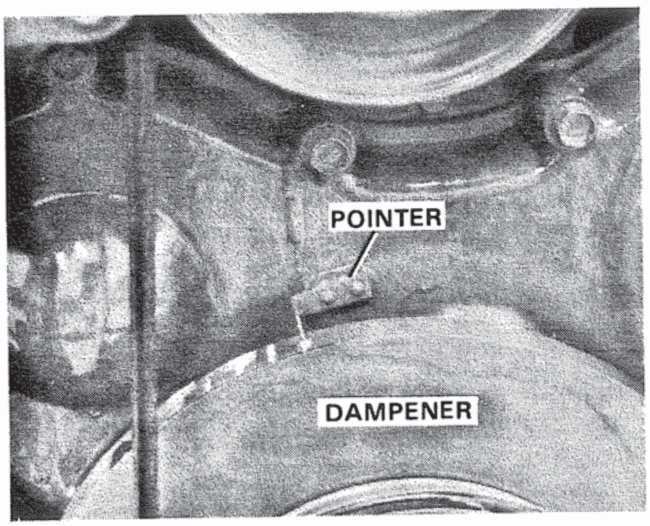


Figure 10. Setting Timing.

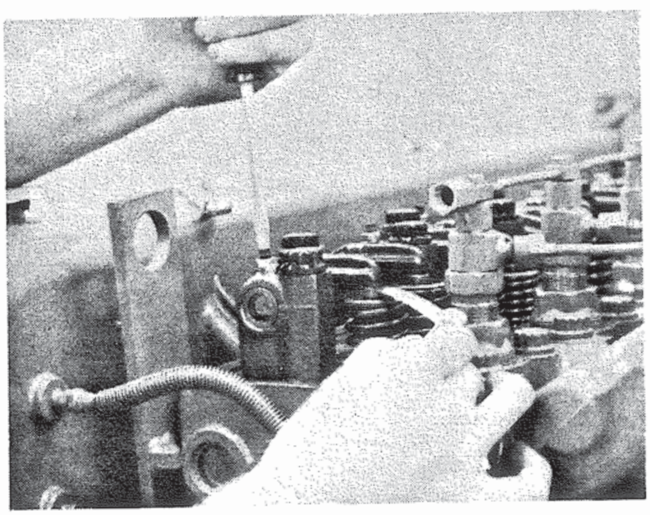


Figure 11. Checking Valve Clearance.

6. Check and adjust valves indicated in Table 4.

A. Measure valve clearance using feeler gauge. Figure 11. Adjust by loosening lock nut and turning adjusting screw. Recheck clearance after tightening lock nut.

B. Set No. 6 piston at TDC on compression stroke. Check and adjust valves indicated in Table 4.

7. Install rocker cover using a new gasket.

*	Cylinder Number											
	1		2		3		4		5		6	
	I	E	I	E	I	E	I	E	I	E	I	E
No 1 TDC	X	X	X			X	X			X		
No 6 TDC				X	X			X	X		X	X

Table 4. Valve Adjustment.

*Note: No. 1 cylinder is at front end.

CYLINDER HEAD ASSEMBLY

Removal.

1. Drain fresh water cooling system and disconnect all electrical hookups to manifolds.

2. Disconnect cooling system bypass. Figure 12. Remove heat exchanger.

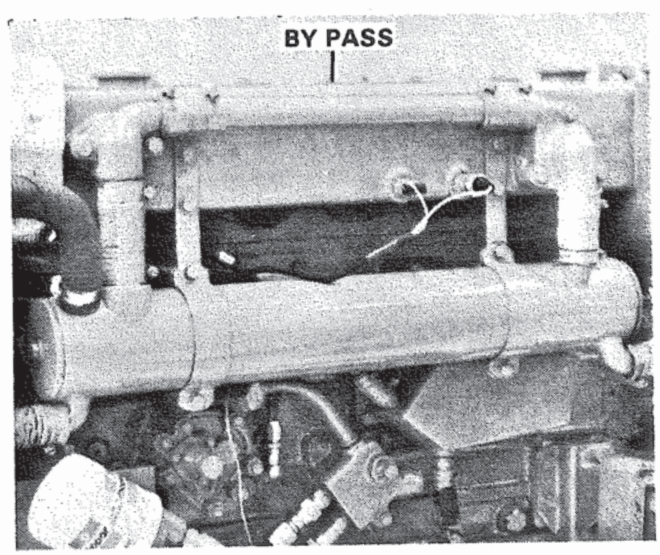


Figure 12. Disconnecting Cooling System Bypass.

3. Remove turbocharger and intercooler hoses, (T.I. only). Figure 13.

4. Remove fuel filter from intake manifold. Disconnect aneroid hose from intake manifold, (T.I. & T.W. only). Figure 14.

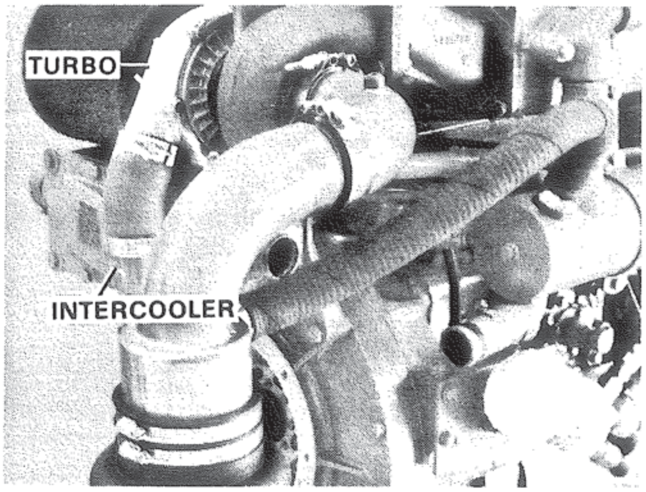


Figure 13. Removing Turbocharger and Intercooler Hoses (T.I. & T.W. Only).

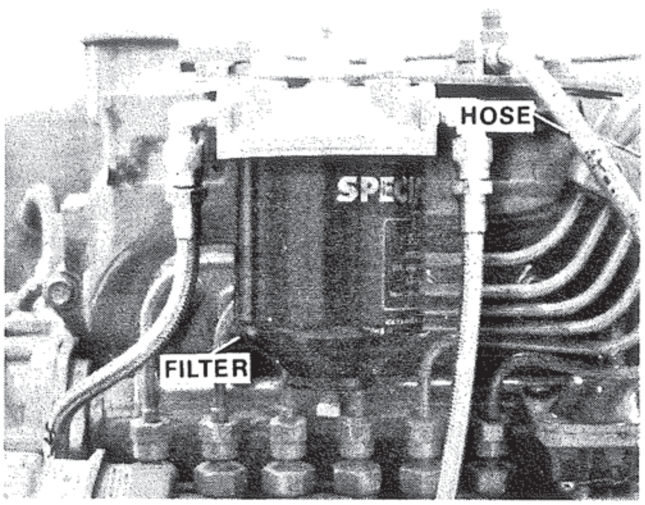


Figure 14. Removing Fuel Filter.

5. Remove fuel injection lines and disconnect fuel injection pump spring. Plug all injection lines.

6. Remove two (2) screws securing electrical panel to rear of engine and lay down on bell housing.

7. Remove intake manifold.

8. Remove rocker cover and rocker arm assembly.

NOTE

Remove all head bolts while removing rocker arm assembly. Loosen bolts in same sequence as tightening.

9. Remove push rods and place in order of removal for ease in assembly.

10. Remove valve caps.

11. Remove cylinder head.

12. Remove cylinder head gasket.

Disassembly.

1. Remove nozzle holders. Figure 15. Use Special Tool No. MH060011 nozzle holder wrench.

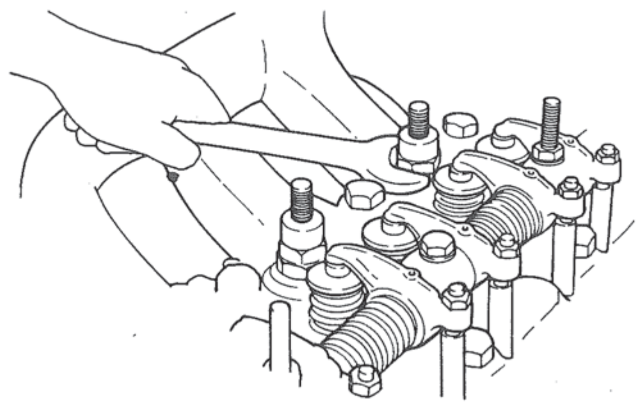


Figure 15. Removing Nozzle Holders.

2. Remove pre combustion chambers.

A. Remove glow plug connection plates.

B. Remove glow plugs, glow plug cases, o-rings and gaskets. Figure 16.

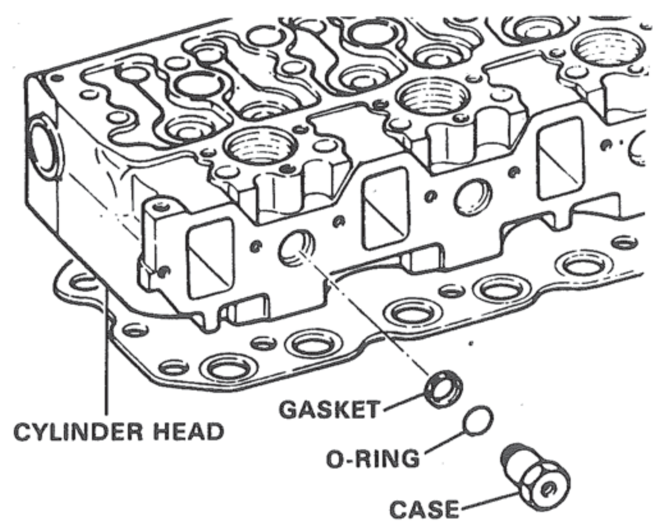


Figure 16. Removing Glow Plugs.

C. Remove combustion chamber retainers.

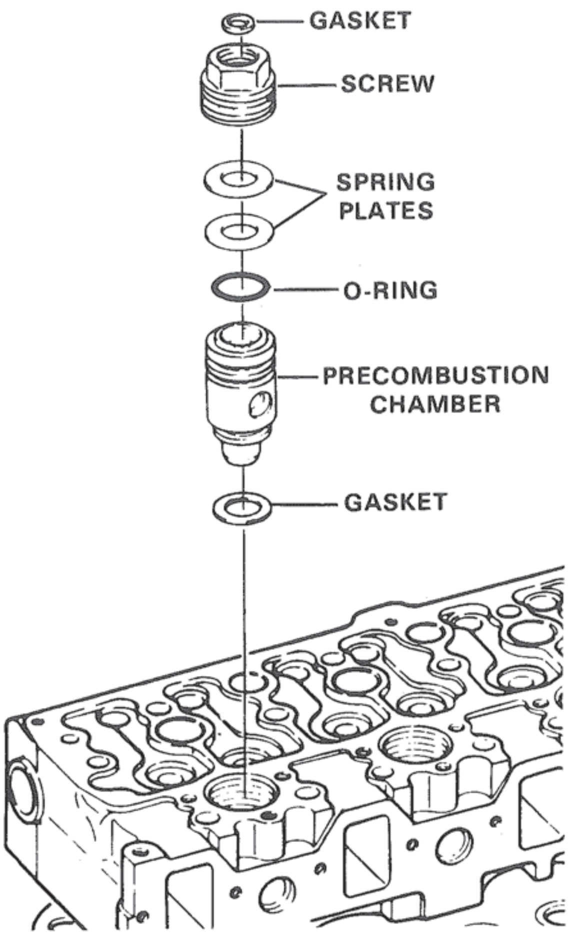


Figure 17. Combustion Chamber Assembly.

D. Remove spacers from inside combustion chamber.

E. Use puller, Special Tool No. 30091-60700, to remove combustion chamber.

F. Use gasket puller, Special Tool No. 30091-60700, to remove combustion chamber gasket and nozzle tip gasket.

3. Remove valves.

A. Compress valve spring with Special Tool No. 30091-08500, remove valve cotters.

B. Release spring compressor and remove upper spring retainer, valve springs and lower retainer, remove valve.

INSPECTION AND REPAIR

Cylinder Head. Inspect cylinder head for cracks and damage prior to cleaning and further disassembly.

1. Clean cylinder head thoroughly.

2. Check flatness of cylinder head by placing a straight edge on gasket surface. Use a 0.05 mm. feeler gauge and check flatness. Change position of straight edge frequently, vary position from end to end, corner to corner. Figure 18.

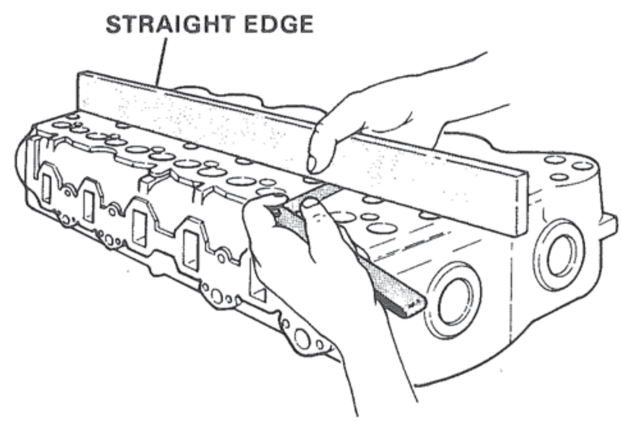


Figure 18. Checking Flatness of Cylinder Head.

A. If flatness varies by 0.05 mm. (0.002 in.) or less head is good.

B. If variance exceeds 0.05 mm. (0.002 in.) resurface head by surface grinding.

NOTE

If resurfacing requires removal of material in excess of 0.2 mm. (0.008 in.) head must be replaced.

3. Inspect water directors. Replace if director is corroded or shows any indication of wear.

4. Replace water director.

A. Remove old water director.

B. Place new part in head position water hole in director to aim at bridge between intake and exhaust valves. Figure 19.

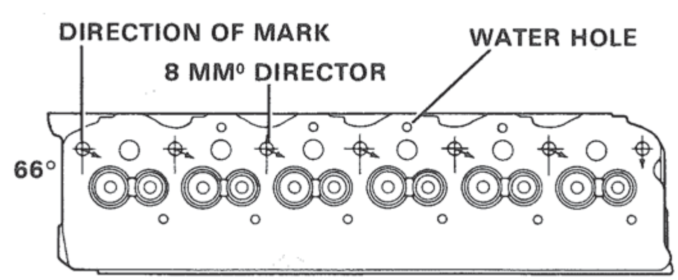


Figure 19. Direction of Installation of Water Director.

C. Tap new director in with a soft hammer.

5. Check valve guides.

A. Check valve guide for uneven wear at top and bottom. Figure 20.

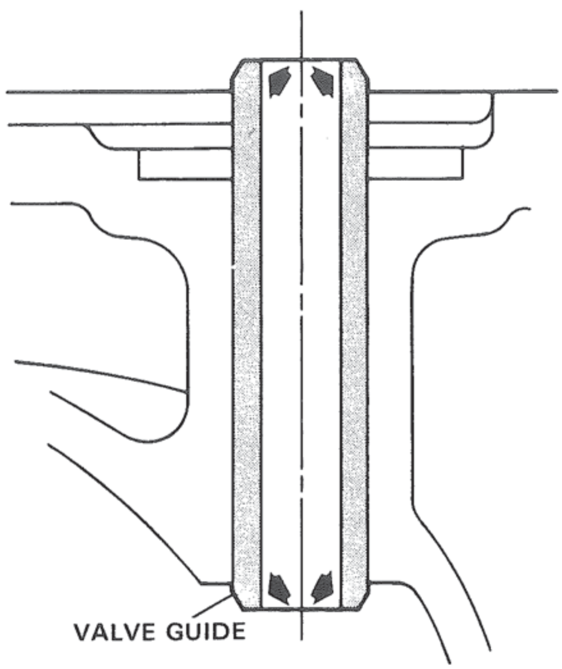


Figure 20. Checking Wear of Valve Guide.

Measure I.D. twice each end, at right angles, compare dimensions. If wear is excessive replace guide.

B. Use a new intake valve and check intake valve guides by measuring valve stem O.D. and guide I.D. The difference should be 0.055 mm. to 0.085 mm. If clearance exceeds 0.085 mm. replace guide.

C. Use a new exhaust valve and check exhaust valve guides.

6. Replace valve guides.

A. Press old guides out from gasket side, use Special Tool No. MH061066. Figure 21.

B. Press new guide in from top (rocker arm side) using Special Tool No. MH061224. Figure 22.

When guide is installed, check height. Dimension should be 22.5 mm. Figure 22.

7. Inspect valve seat. Seating area must be even and smooth. Figure 23.

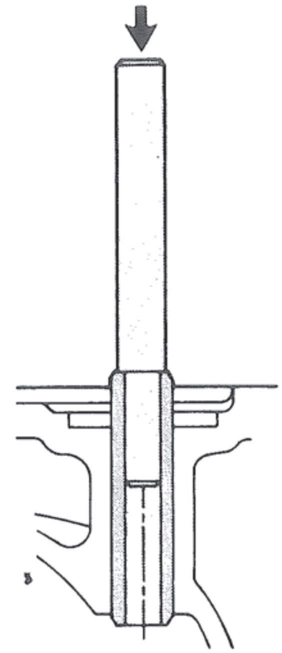


Figure 21. Removing Valve Guide.

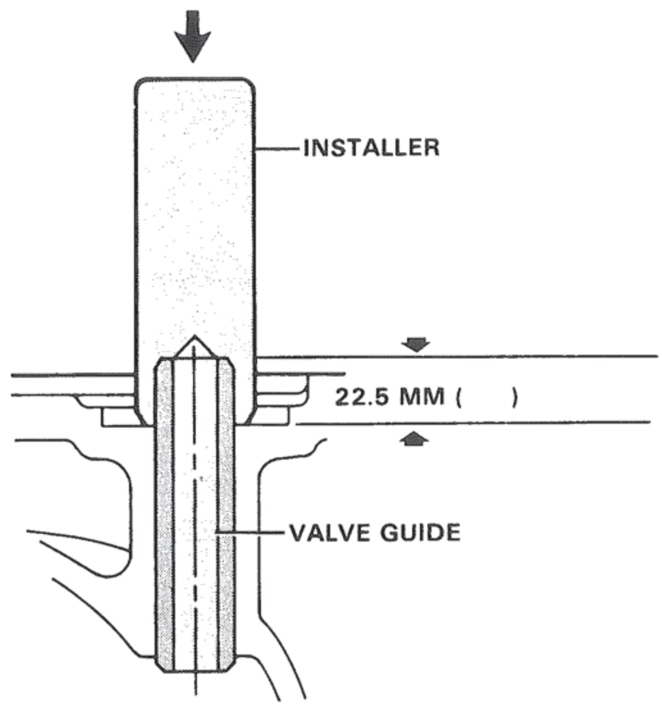


Figure 22. Installing Valve Guide.

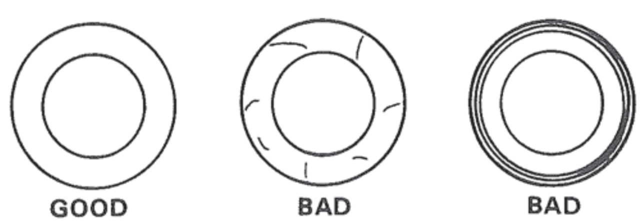


Figure 23. Valve Seat Conditions.

Check seat angle (45°), width (2.1 ± 0.5 mm.) and seat depth. If valve seat requires resurfacing check seat depth first to determine if sufficient stock exists.

8. Reface Valve Seats.

A. Use a 45° stone or cutter to reface seat. Remove as little material as possible.

B. Measure seat width, seat should be 2.1 ± 0.15 mm. If width exceeds 2.25 mm., it must be corrected.

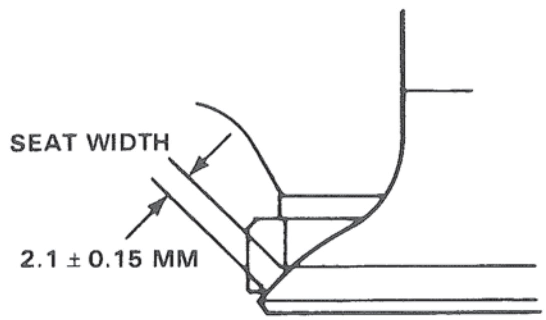


Figure 24. Valve and Seat Regrinding Dimensions.

C. Check seat depth.

9. Correcting and/or checking valve seat width and depth.

A. Check seat depth by placing a **new** valve in head. Clean surfaces thoroughly. Measure the distance between head surface and valve face. Dimension must be 1.0 ± 0.35 mm. Figure 25. If dimension excees 1.35 mm., valve seat must be replaced.

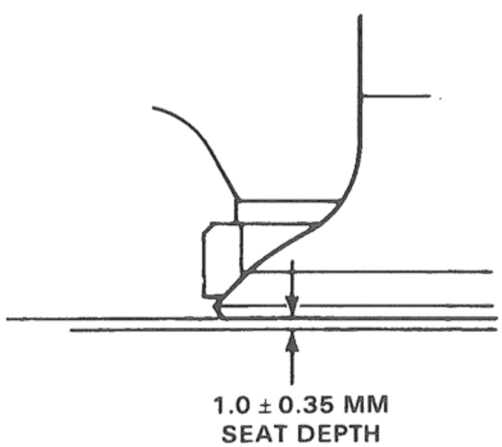


Figure 25. Checking Valve Seat Depth.

B. Place new part in head, position water hole in director to aim at bridge between intake and exhaust valves. Figure 19.

10. Replace valve seats.

A. Reduce thickness of valve seat to 0.5 to 1.0 mm. using an end mill or valve seat cutter.

CAUTION

Do not allow cutter to come in contact with cylinder head.

B. Pry remaining part of seat from head.

CAUTION

Protect head surface from scratching.

C. Measure I.D. of valve seat cavity. Figure 26.

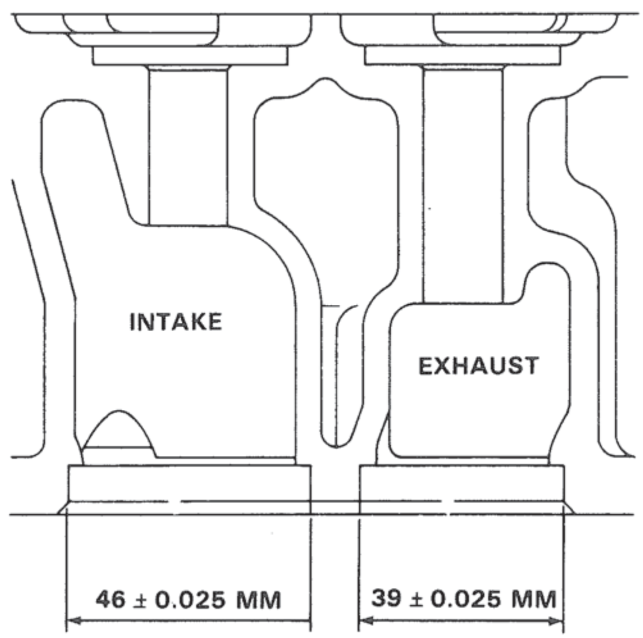


Figure 26. Valve Seat Cavity Dimensions.

If I.D. exceeds dimensions use oversize seats.

NOTE

Seat to head is an interference fit, seat diameter hole diameter by 0.50 to 0.80 mm.

D. Place a new seat in dry ice while heating cylinder head to 80° to 100° C (176° to 212° F).

E. Insert cooled seat in heated cylinder head cavity, drive in using Special Tool. Figure 27.

WARNING

Do not handle cold valve seat with bare hands. Allow seat and head to normalize to room temperature.

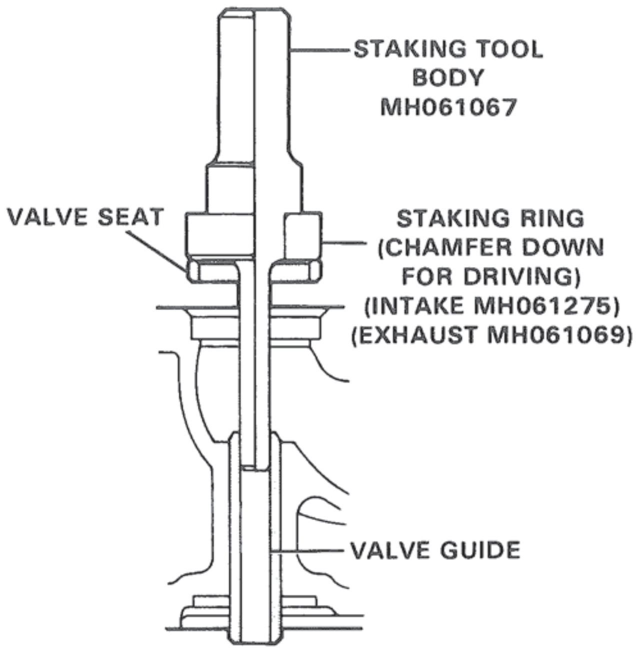


Figure 27. Drive in Valve Seat.

F. Stake valve seat in place, use Special Tool. Figure 28.

G. Lap valve and valve seat, check for proper contact.

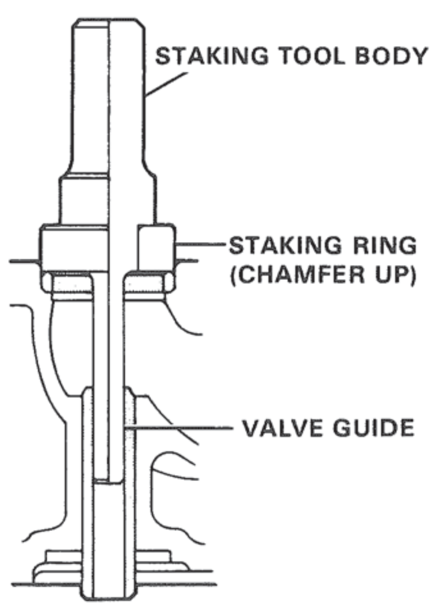


Figure 28. Staking Valve Seat.

11. Inspect valves. Thoroughly clean valves, remove all carbon from face and stem. Measure O.D. of valve stem and valve margin. Inspect valve face.

A. Measure stem O.D. at various places along length of valve. Figure 29.

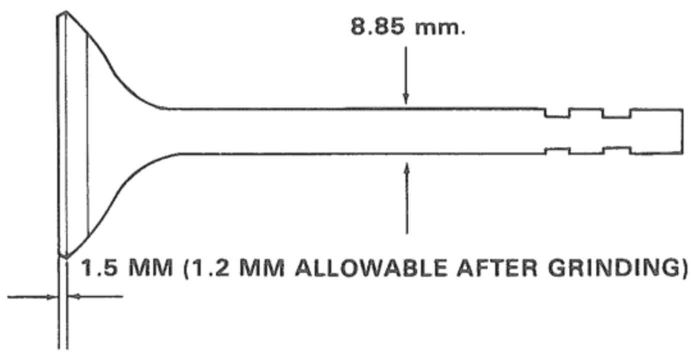


Figure 29. Valve Dimensions.

If valve stem diameter is 8.85 mm or less, replace valve.

B. Measure valve margin. If measurement is less than 1.2 mm. (after grinding) replace valve.

12. Reface valves. Valve face must be ground at 45°. After grinding, check margin, if measurement is less than 1.2 mm. replace valve.

13. Check valve seat to valve face contact.

A. Apply red lead to valve seat and set valve in place.

B. Rotate valve exerting light pressure against valve.

C. Remove valve and inspect seat and valve face for contact. If perfect contact is not made lap valves.

14. Lapping valves. Lapping valves is very important and needed to assure proper sealing and avoid premature valve and/or seat failure. Valves require metal to metal contact for heat conduction away from the valve area.

A. Apply a thin coat of medium grit (120-150) lapping compound and engine oil evenly around valve face.

CAUTION

Do not allow lapping compound to get on valve stem or into valve guide.

B. Gently tap valve against seat, then turn back and forth briskly.

C. Turn valve 1/4 turn increments, and repeat B.

D. Repeat steps A, B, and C using fine (200 grit) lapping compound.

E. Clean area thoroughly with clean diesel fuel and re-check with red lead (step 13). Repeat lapping if required.

15. Inspect valve springs. Check for breakage, squareness, free length and compression.

A. Check squareness by standing spring on a flat surface, place a square next to spring. Figure 30.

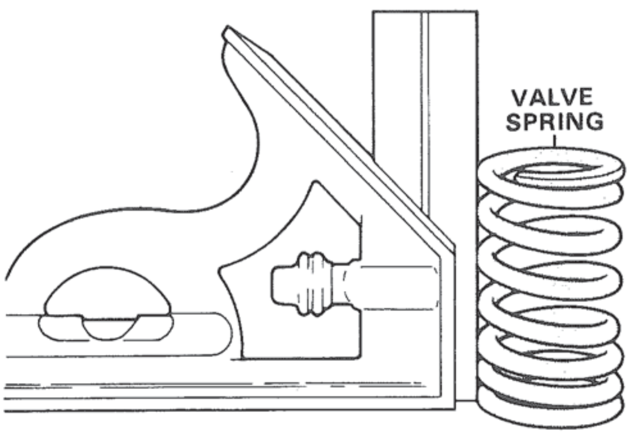


Figure 30. Checking Spring Squareness.

Check spring from both ends. Replace springs more than 1.58 mm. (1/16 in.) out of square.

B. Measure free length using same set up.

	Free Length	Load Test
Inner	51.2-48.2 mm.	10.1-8.1 kg @ 41.8 mm. (22.3 - 17.8 lbs.)
Outer	55.4-52.4 mm.	25.7-20.6 kg @ 46.5 mm. (56.6 - 45.4 lbs.)

Table 5. Valve Spring Dimensions.

C. Check compression using a valve spring tester. Figure 31.

16. Inspect precombustion chamber. Check jet for cracks or enlargement of outlet holes. Figure 32.

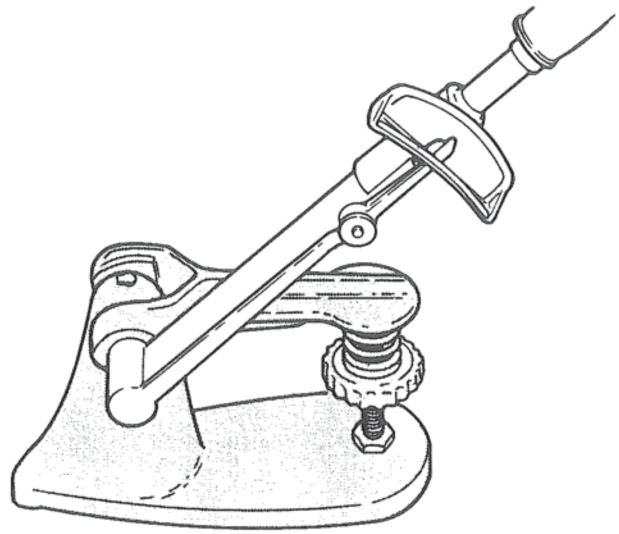


Figure 31. Testing Valve Spring Compression.

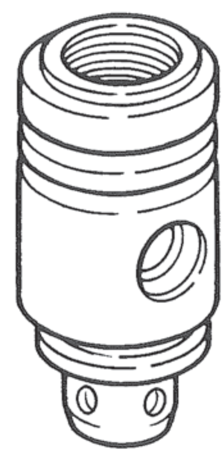


Figure 32. Inspecting Precombustion Chamber.

Replace if cracked. Remove and discard o-ring and gasket.

Assemble Cylinder Head Assembly. Clean each part prior to assembly. Do not reuse gaskets, packings or o-rings. Refer to pages 17, 18 and to relevant sections for tightening torque and recommended sealant when not mentioned in text.

1. Place lower spring retainers over valve guides.
2. Install valve stem seals. Figure 33.

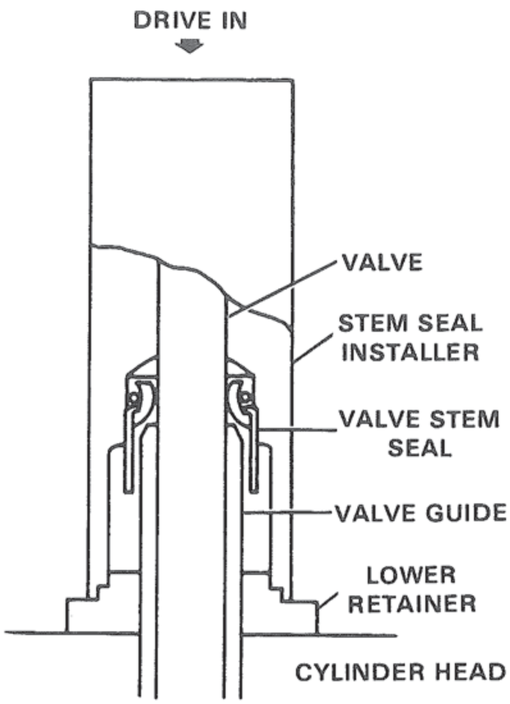


Figure 33. Installing Valve Stem Seal.

A. Place lower spring retainer over valve guide.

B. Place new valve stem seal on guide, dip end of seal installer, Special Tool No. MH060028, in engine oil and push through seal into guide.

C. Press installer down until it comes in contact with spring retainer. Figure 33.

3. Dip valve stems in clean engine oil and insert in head.

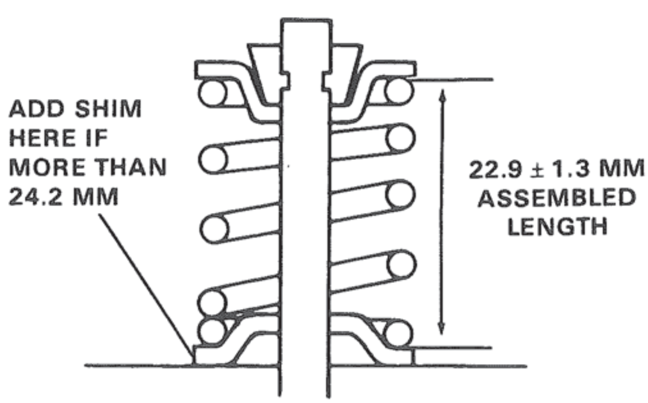


Figure 34. Checking Assembled Spring Height.

4. Install inner valve springs, outer valve springs and upper retainer over valve. Compress springs and install valve cotters.

5. Check spring height. Figure 34.

If any springs exceed 24.2 mm. when assembled, add shim to assembly beneath lower spring retainer.

6. Install precombustion chambers.

A. Place gaskets on seat in cylinder head. Figure 35.

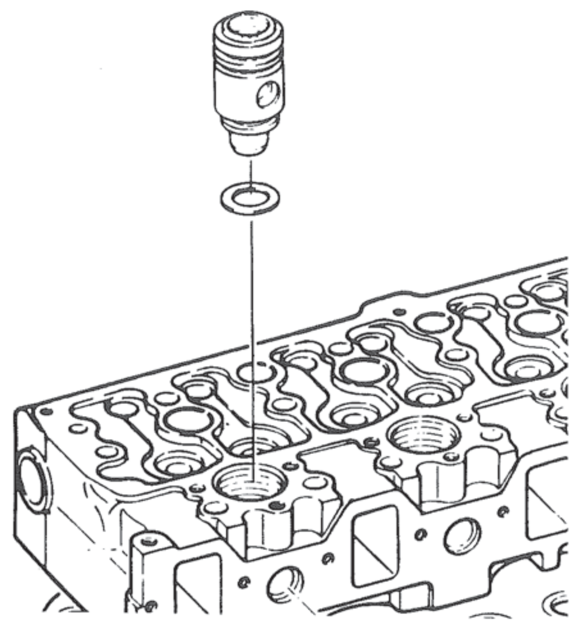


Figure 35. Precombustion Chamber Assembly.

B. Place o-rings in groove of precombustion chamber.

C. Insert precombustion chamber in head cavity (line up glow plug hole in chamber with hole in head) and press in.

D. Position spring plates and loosely secure with a retainer.

E. Align glow plug holes in chamber and head, do not damage threads.

F. Assemble o-ring and copper washer to glow plug holder and thread into precombustion chamber. Tighten to 8.3 kg/m (60 ft. lbs.).

G. Tighten retainer, torque 40.0 kg/m (290 ft.lbs.).

7. Reassemble rocker arm assembly.

8. Install a new head gasket on cylinder block, apply gasket sealant to both sides of gasket.

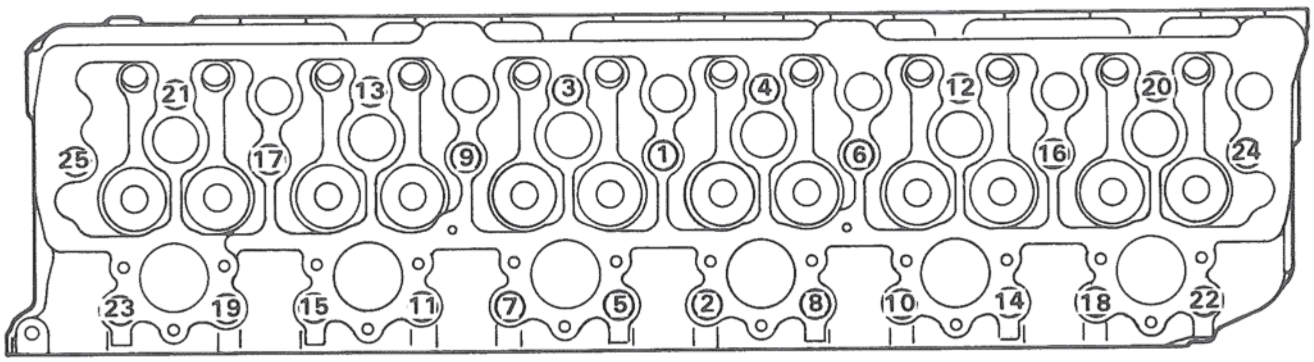


Figure 36. Cylinder Head Bolt Tightening Sequence.

9. Lower cylinder head on block, line up with locating pins.

10. Place push rods in position, replace valve stem caps. Set rocker arm assembly in place.

11. Oil threads of cylinder head bolts and tighten, follow sequence. Figure 36.
Torque cylinder head bolts to 18 + 1.8/- 0 kg/m (130.5. + 13/-0 ft. lbs.) N.A., and to 20 kg/m (145 ft. lbs.) for T.I. and T.W.

12. Install glow plugs and connectors.

13. Install exhaust manifold, torque fasteners to 3.5 kg/m.

14. Install intake manifold, apply gasket sealant (Mopar sealing compound 3419115) to both sides of gasket.

15. Install turbocharger.

16. Install electrical panel to rear of head.

17. Adjust valves and replace valve cover.

18. Install injectors and fuel lines, bleed air from system.

19. Change engine oil and filter.

20. Fill closed cooling system.

Notes:
Upper Engine Gasket and Seal Set Part # 4142149
Lower Engine Gasket and Seal Set Part # 4142150

Phone: 269 673 2128 (leave message)

Notes: Undersize bearings call 269 673 6933 email; PartsAndGaskets@gmail.com

Subsection 6C

CRANKCASE AND MAIN MOVING PARTS

General Information. The crankcase is a lightweight iron casting. Seven (7) main bearings support the forged steel crankshaft. Crankshaft thrust bearings are located at the rear main. Wet slip fit cylinder liners are used for ease in rebuilding although oversize pistons are available if reboring is performed. Three (3) rings are used on aluminum pistons and free floating piston pins are secured by retaining rings at each end. The camshaft is forged steel and runs in four (4) replaceable bushings. Helical cut gears located at the front of the engine are driven by the crankshaft gear.

Disassembly.

1. Disconnect electrical hookups and battery leads.

2. Shut off fuel supply at fuel tank and disconnect fuel lines at engine.

3. Disconnect raw water hose connection at strainer and exhaust connection.

4. Loosen engine mounts and disconnect transmission. Lift engine with transmission from boat.

5. Place engine on a suitable stand. Figure 1.

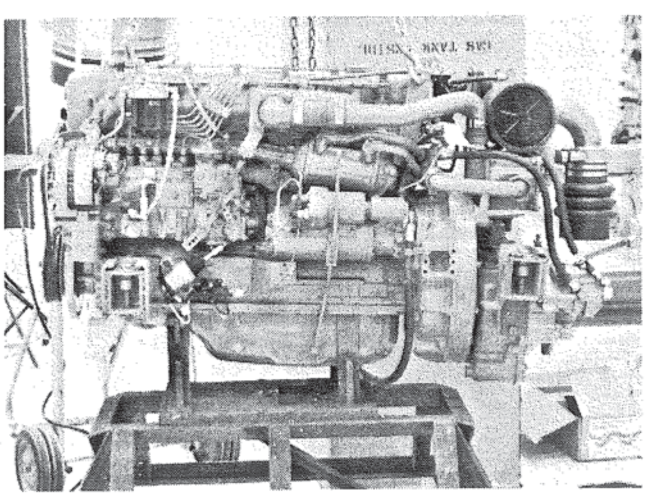


Figure 1. Engine Removed.

CAUTION

Engine and transmission weigh 1250 pounds. Use a stand rated for this weight.

6. Remove transmission; drain water from engine.

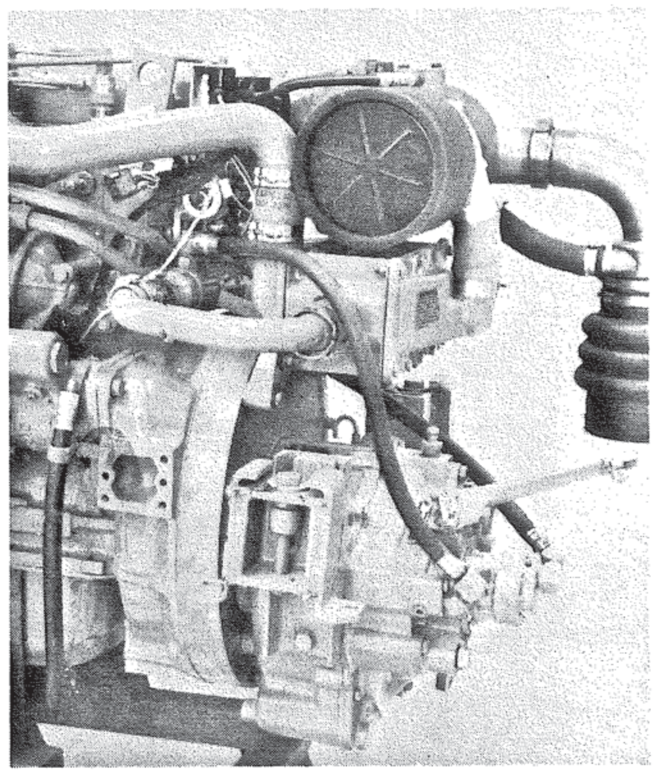


Figure 2. Transmission.

7. Drain oil and remove oil filter.

8. Remove turbocharger (TI & TW only) and air cleaner.

9. Remove starter and alternator.

10. Remove raw water cooling system:

A. Heat exchanger.

B. Intercooler (TI & TW only).

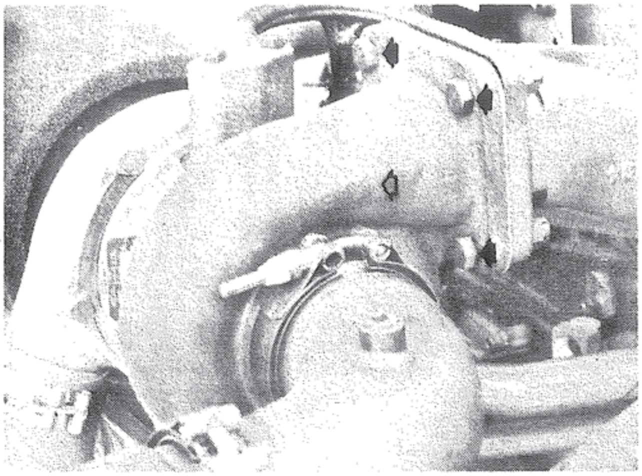


Figure 3. Removing Turbocharger.

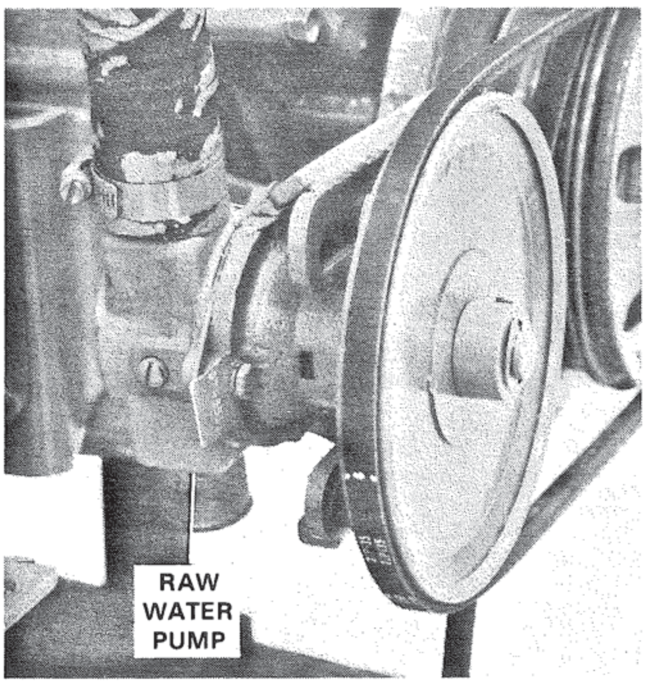


Figure 4. Removing Raw Water Cooling System.

C. Transmission cooler.

D. Raw water pump.

11. Remove oil pump and oil cooler.

12. Remove rocker arm assembly.

13. Remove fuel filter and aneroid hose (TI & TW only) from intake manifold.

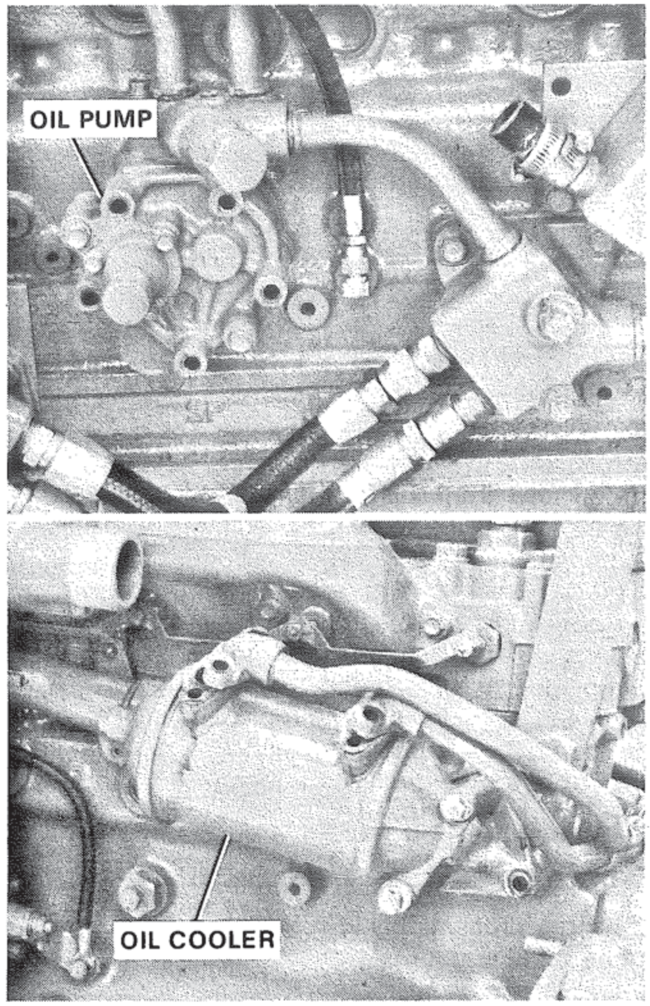


Figure 5. Removing Oil System.

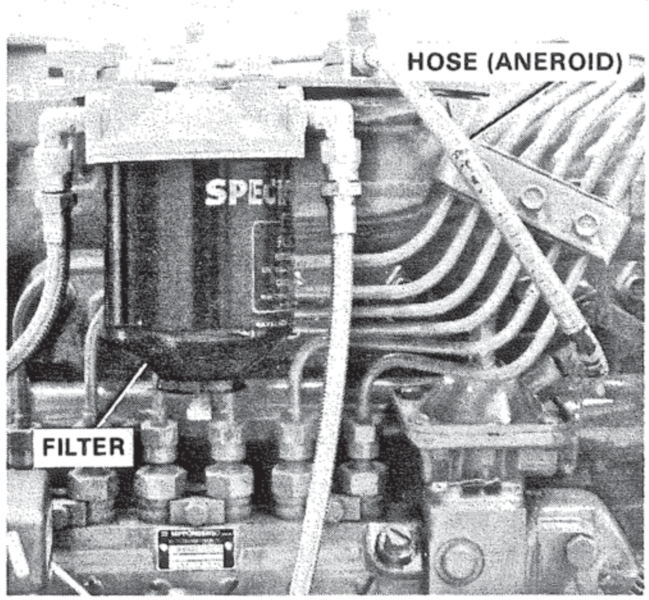


Figure 6. Removing Fuel Filter, Aneroid Hose.

14. Remove cylinder head (with intake and exhaust manifolds).

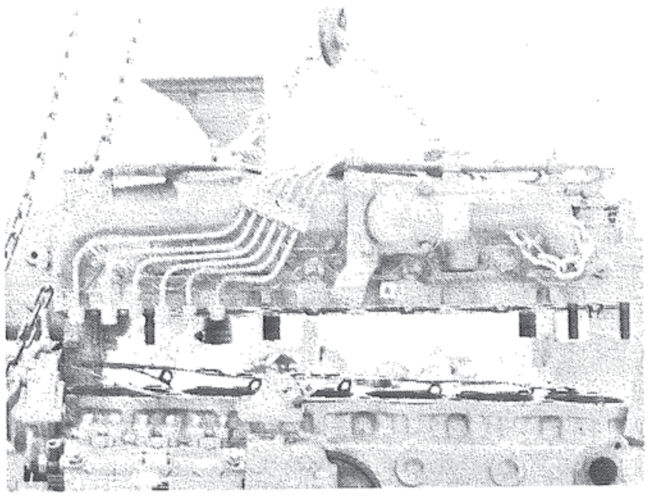


Figure 7. Removing Cylinder Head.

15. Remove freshwater water pump.

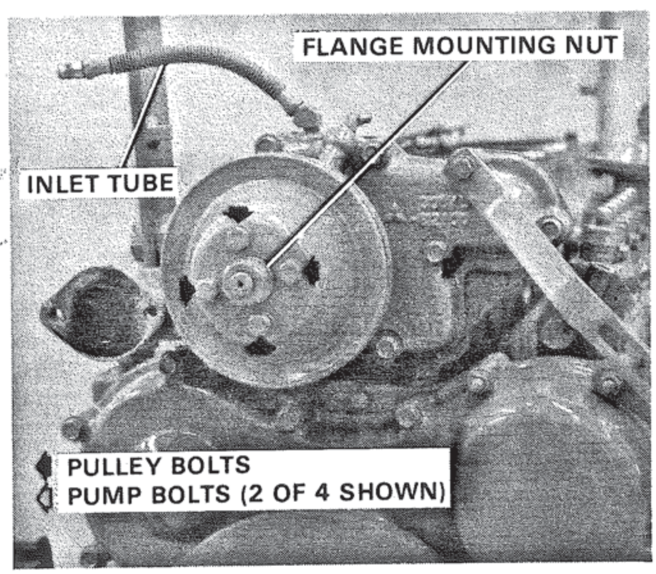


Figure 8. Removing Fresh Water Pump.

16. Remove crankshaft pulley.

NOTE

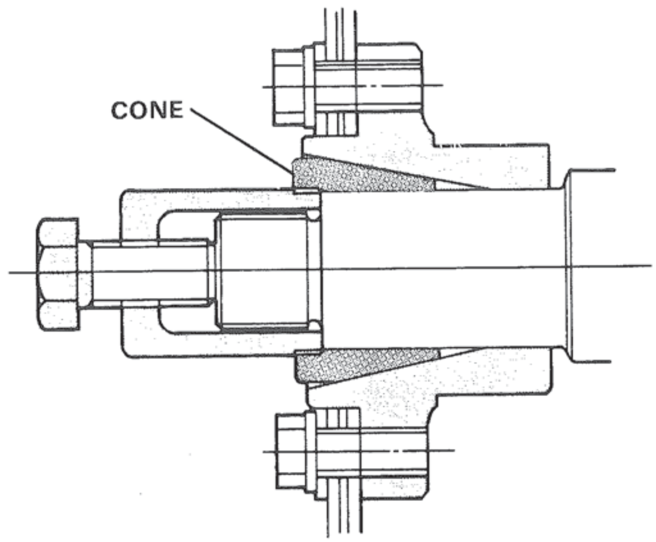
A special puller is usually needed to pull the cone.

A. Thread crankshaft pulley puller Special Tool No. MH061101 into pulley cone. Figure 9.

B. Remove cone and slide pulley from crankshaft.

17. Remove torsional dampener from driveshaft.

18. Remove capscrews securing timing gear cover. Figure 10. Remove cover from engine.



MH061101 PULLER

Figure 9. Remove Crankshaft Pulley Cone.

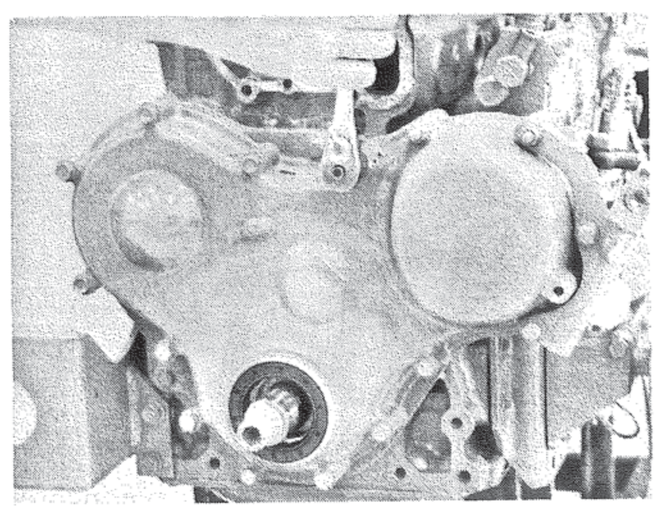


Figure 10. Removing Timing Gear Cover.

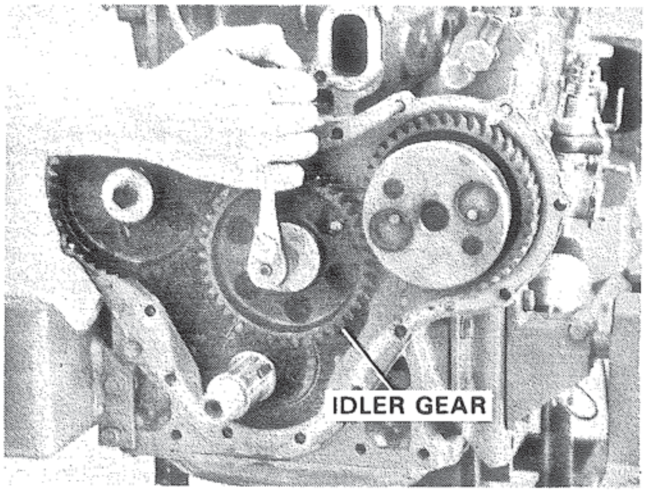


Figure 11. Remove Idler Gear.

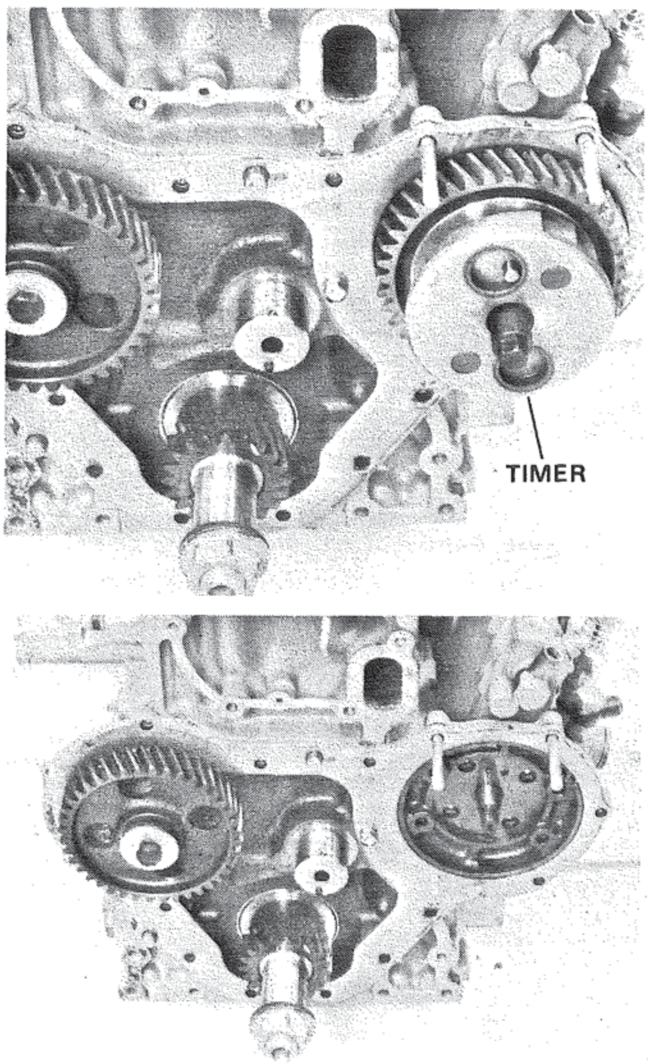


Figure 12. Remove Automatic Timer.

19. Remove thrust plate bolt, remove idler gear. Figure 11.

20. Remove automatic timer.

A. Remove round nuts. Figure 12, top.

B. Use Special Tool No. MH061097 to remove automatic timer and injection pump gear.

21. Remove camshaft with gear attached.

22. Remove flywheel.

A. Remove flywheel housing adapter plate.

B. Remove flex plate.

C. Remove bolts securing flywheel.

D. Thread flywheel bolts into blind flywheel holes until bolts bottom against crankshaft flange. Figure 13.

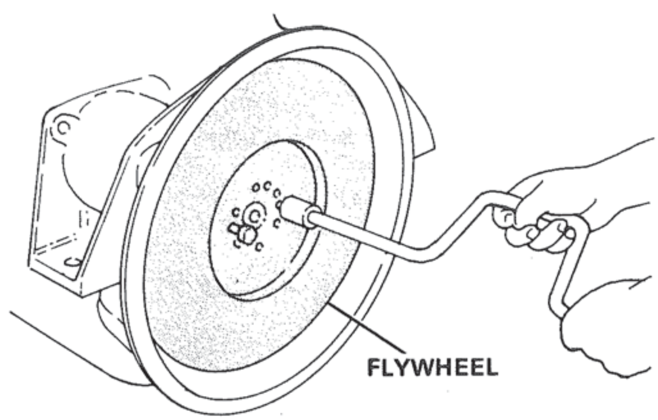


Figure 13. Remove Flywheel.

Tighten alternately until flywheel comes off.

23. Turn engine up side down on stand or lay on its left side on bench.

24. Remove oil pan. Figure 14.

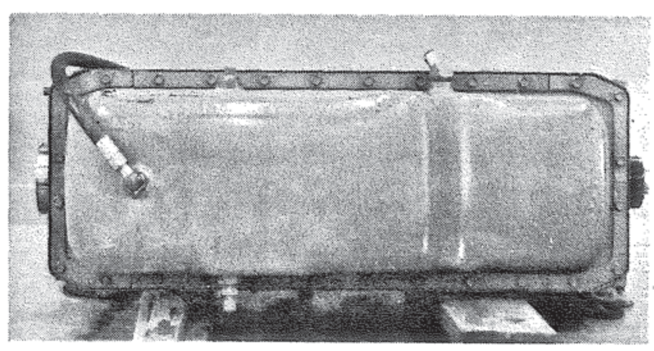


Figure 14. Remove Oil Pan.

25. Remove oil strainer.

26. Remove pistons and rods.

A. Inspect top of liner for carbon build up or ridge. Figure 15.

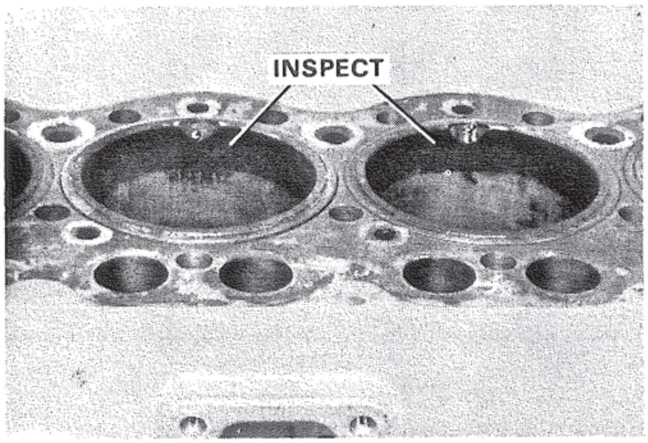


Figure 15. Inspect for Carbon Buildup or Ridge.

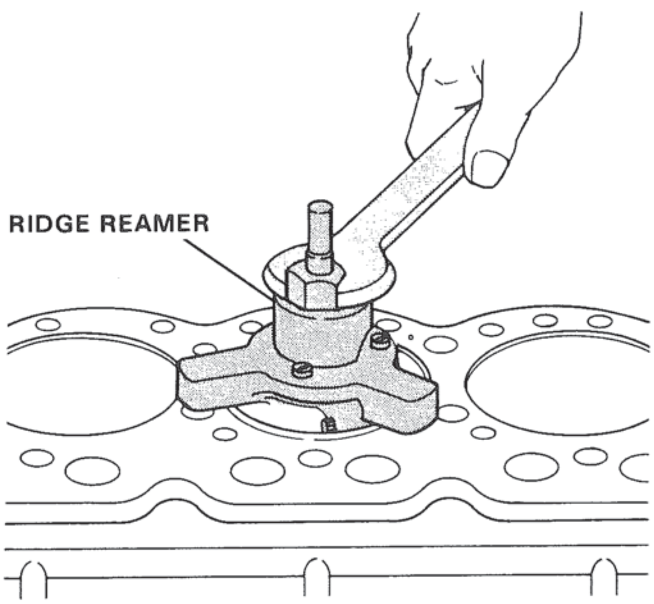


Figure 16. Removing Ridge.

Remove carbon, use ridge reamer to remove ridge if necessary. Figure 16.

NOTE

If carbon or ridge are not removed, damage to the piston will occur during removal.

B. Remove nuts securing bearing cap, push piston and rod assembly from engine.

C. Replace rod cap and nuts on rod and tag with cylinder number.

27. Disassemble piston.

A. Remove piston rings, use ring remover (Special Tool No. MH060014). Figure 17.

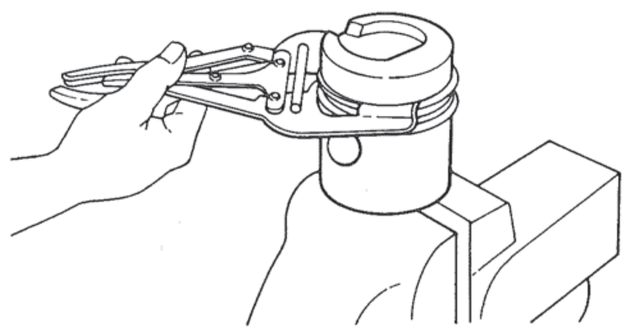
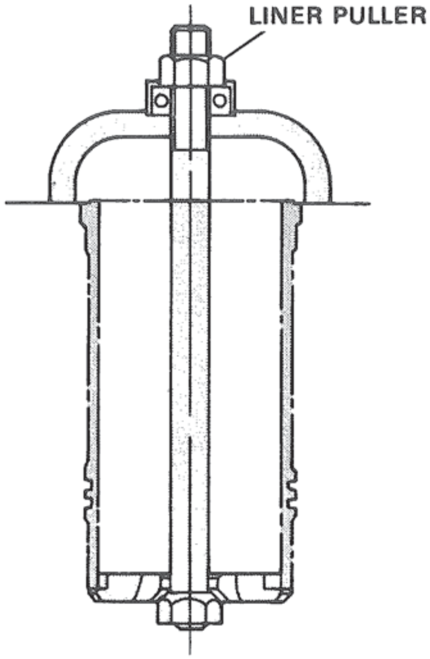


Figure 17. Removing Piston Rings.

B. Remove retaining rings securing piston pin.

C. Push pin out. Do not force. If pin is tight, heat piston in hot water, then remove pin.

28. Assemble liner puller Special Tool No. MH061088 and tighten top nut. Liner will slide free from block.



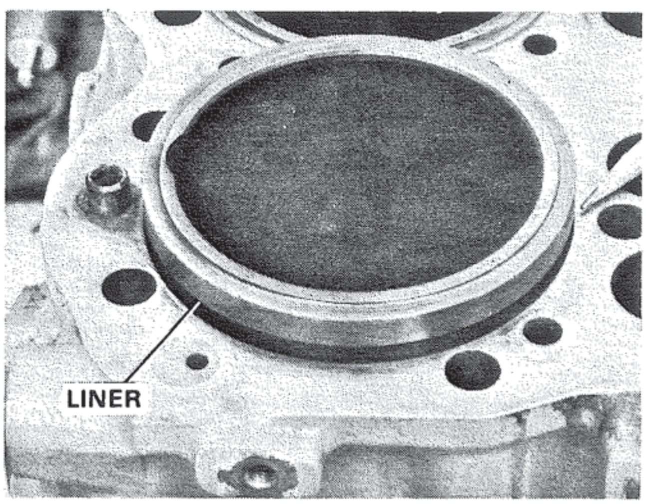


Figure 18. Removing Liner.

29. Remove front plate with injection pump. Figure 19.

30. Place engine block on its top and remove crankshaft.

A. Remove front and rear bearing caps. Use cap puller Special Tool No. MH061083. Figure 20.

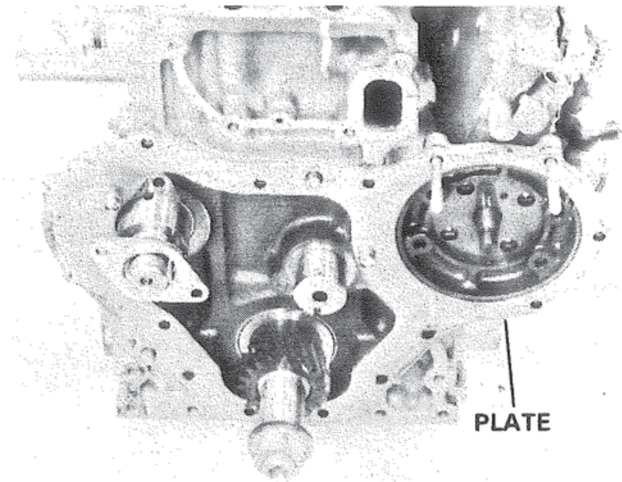


Figure 19. Removing Front Plate.

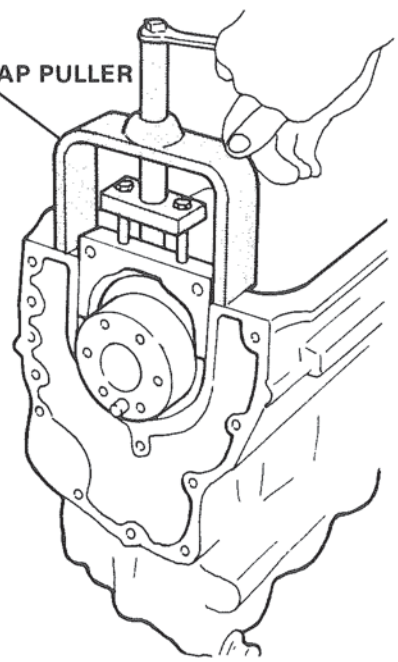


Figure 20. Removing Front Bearing Cap.

B. Remove remaining caps using Special Tool No. MH061071.

C. Remove crankshaft by lifting straight up. Figure 21.

CAUTION

Do not allow crankshaft to swing free, damage to crankshaft and/or block may occur.

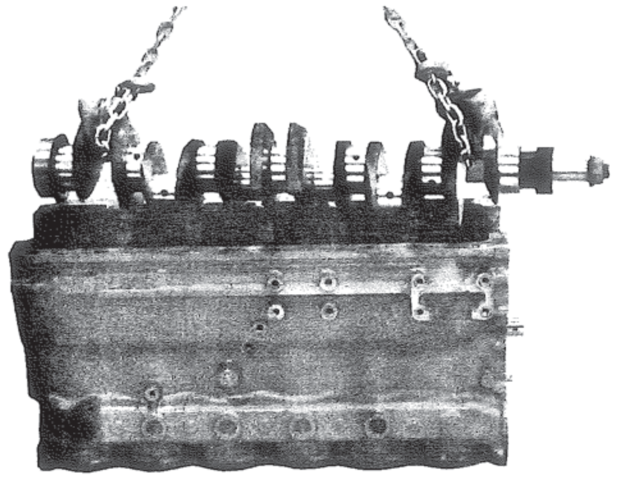


Figure 21. Removing Crankshaft.

INSPECTION AND REPAIR

Thoroughly clean all engine components. Visually inspect for obvious wear or damage. Each part must be checked dimensionally prior to reuse. Discard all old gaskets and seals after they have been inspected for signs of leaks or wear. If a problem is found, inspect mating parts for problems.

CYLINER LINERS

General. Cylinder liners in this engine are replaceable or may be rebored to three (3) different oversize dimensions matching three (3) oversize pistons, +0.50 mm., +0.75 mm. and +1.00 mm. Replacement liners are machined to the original bore diameter of 98 mm. Standard bore cylinder liners and pistons used in this engine are select fit. That is, a liner and piston are selected to work together based on a preferred clearance. New standard bore liners and pistons are classified as "A", "B" or "C", only like classifications may be used together.

To determine what class a standard bore liner is, measure its diameter 90 mm. down from the top of the liner. Figure 22.

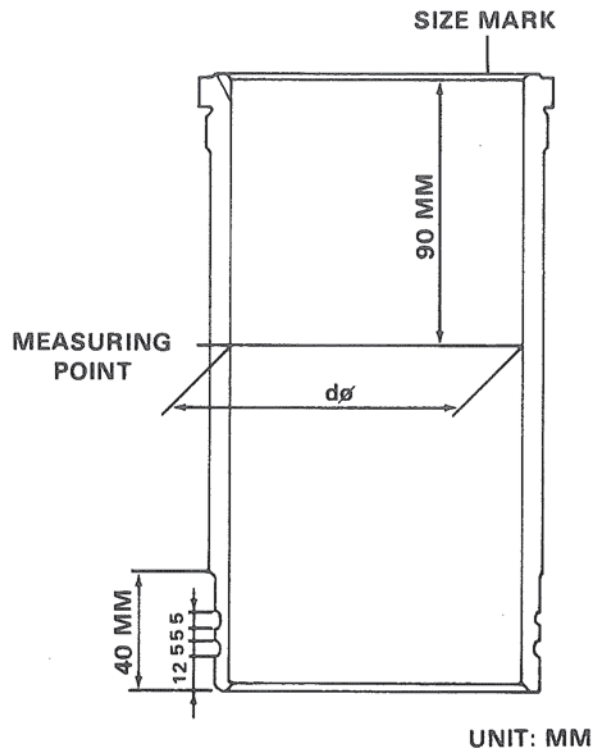


Figure 22. Cylinder Liner.

Find the dimension in the following table, determine the classification and stamp the appropriate letter on top liner edge.

Determining if a liner may be reused as is, rebored to the next oversize diameter or replaced is determined by careful inspection and dimensional checking. Inspect liners for scratches or uneven wear. If a ridge reamer was used prior to piston removal, check liner for step at point ridge was removed.

Size Classification	Liner Bore Diameter	Piston Diameter
A	98.000-98.011 mm.	97.865-97.874 mm.
B	98.012-98.023 mm.	97.875-97.885 mm.
C	98.024-98.035 mm.	97.886-97.895 mm.

Table 1. Liner Bore Classifications.

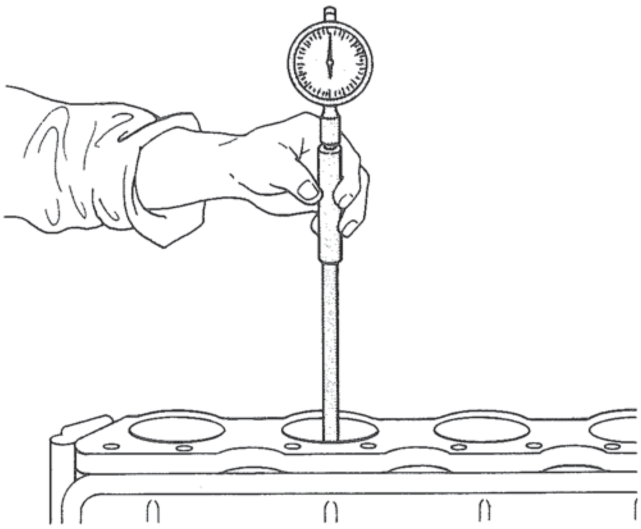


Figure 23. Measuring I.D. of Liner.

Checking Liner Dimensions.

1. Measure liner I.D. using a dial readout micrometer or inside micrometer. Figure 23.

2. Measure I.D. and write down readings. Measurements are made at four (4) points. Figure 24.

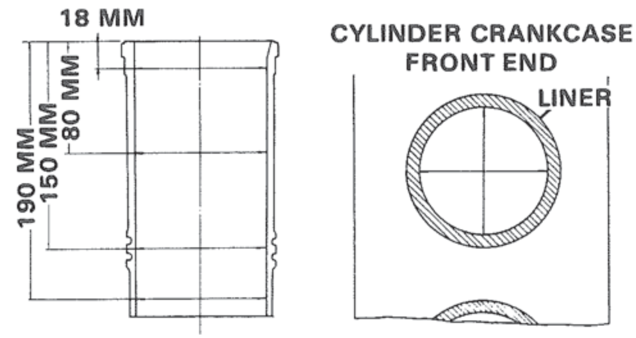


Figure 24. Where to Measure Liner.

Measured Diameter	Measurement Finding	Action to be Taken
98.000-98.035	Within assembly standard	Re-use
98.036-98.300	Within limit of repair	May be re-used
98.301-99.050	Outside wear limits	Rebore to nearest oversize
99.051 and up	Limit of use exceeded	Replace liner

Table 2. Liner Wear Limits.

Oversize bores for which pistons are available are 98.500 mm., 98.750 mm. and 99.000 mm. If a liner diameter approaches 99.000 prior to boring, though it is within the limit of use, it is doubtful a reliable engine will result from reusing this liner. When reboring, refer to dimensions written down while checking. If wear to liner is uneven, the largest diameter is used to determine which oversize dimension will be used. If one liner is bored oversize, all liners must be bored to same size.

PISTONS

General Information. Pistons are available in standard size and three (3) oversize-dimensions, +0.50, +0.75 and +1.0 mm. Standard bore pistons and liners are select fit, that is a piston and liner are selected to work together based on a preferred clearance. Table 1.

To determine what class a standard size piston is measure its diameter 77.3 mm. down from the top at right angles to the piston pin bore. Figure 25.

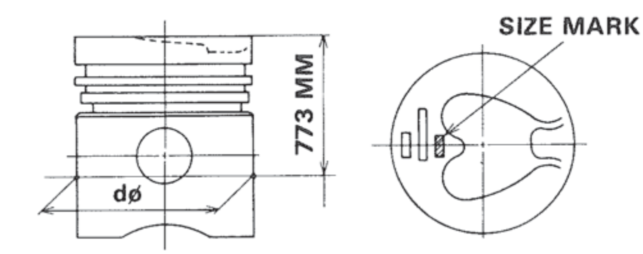


Figure 25. Measuring Piston.

Find the dimension in the following table, determine the classification and stamp the appropriate letter on top of piston.

Size Classification	**Piston Diameter**
A	97.865-97.874
B	97.875-97.885
C	97.886-97.895

In addition, pistons must match each other in weight. The difference between the lightest and heaviest must be ± 5 gr. (± 0.18 oz.). The weight is stamped on the top of each piston. Figure 26.

Inspect piston for cracks, scoring or uneven wear. Ring grooves must be free of carbon buildup and scratches.

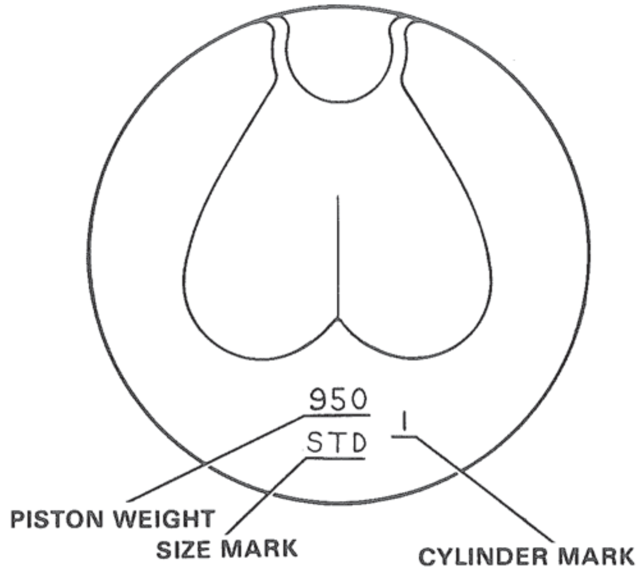


Figure 26. Piston.

Checking Piston Dimensions. Piston is measured using a micrometer.

1. Measure on piston pin center line and a right angles to it. Figure 27.

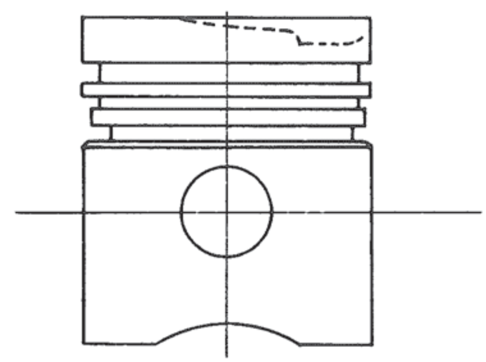


Figure 27. Piston Measurement.

2. Measure piston pin bore. Figure 28. Bore diameter should be 32.00-32.05 mm. Replace piston if 32.05 mm. is exceeded.

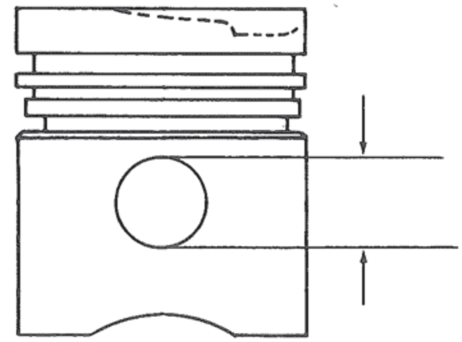


Figure 28. Piston Pin Measurement.

Piston Rings. Piston rings are checked dimensionally when reusing old rings or installing new rings. Check end clearance and groove clearance.

1. Check end clearance by placing ring in a new liner, push in with a piston to assure it is at right angle with liner. Measure end clearance with a feeler gauge. Figure 29.

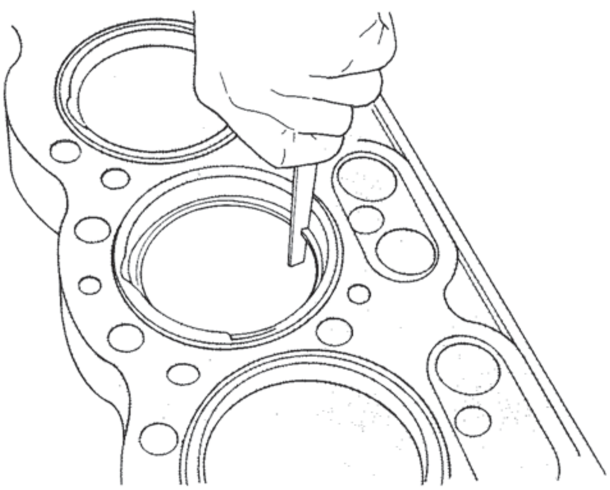


Figure 29. Measuring Piston Ring End Gap.

2. End gap should be 0.3 - 1.5 mm.

3. Remove ring from liner and measure end gap when free. Dimension should be 12.5 mm. (approx.).

NOTE

Free end gap of less than 12.5 mm. may indicate ring has lost tension or has taken a set. Replace ring.

Second and Third Ring Side Clearance.

4. Place second and third rings in grooves of piston. Measure ring to groove clearance with a feeler gauge. Clearance must be 0.025 - 0.065 mm. If clearance exceeds 0.15 mm. place ring on new piston, check clearance again. If clearance is not within tolerance replace piston.

Top Ring Side Clearance.

5. Place top ring in top groove of piston. Hold ring in groove with a straight edge. Figure 30.

Use a feeler gauge to check side clearance. Clearance must be 0.04 - 0.08 mm. If side clearance exceeds 0.20 mm. place ring on a new piston, check clearance again. If clearance still exceeds 0.20 mm. replace ring, if clearance is not within tolerance, replace piston.

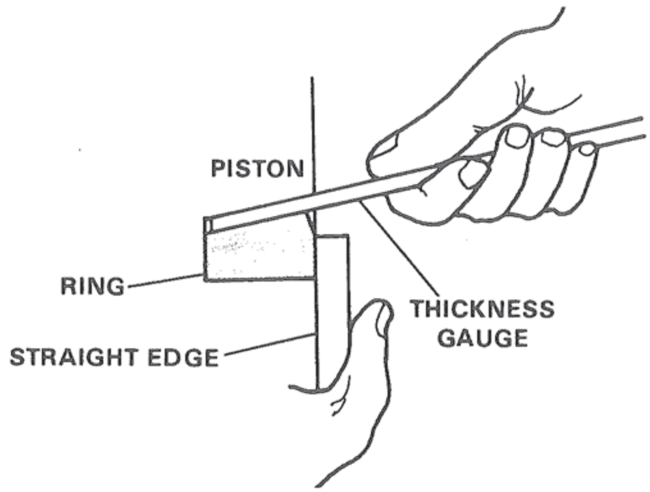


Figure 30. Checking Top Ring Side Clearance.

Piston Weight. Weigh each piston. Find the lightest piston, each piston must weigh no more than +20 gr. (.706 oz.).

CRANKSHAFT

Inspection of crankshaft is primarily dimensional checking of crank journals and checking for straightness. Obvious wear or damage should be checked first to see if crankshaft is repairable.

Measure Crankshaft Journal. Place crankshaft on a clean surface, measure main bearing and rod journals.

1. Use a micrometer and take readings around circumference of journal. Write readings down.

2. If readings indicate journal is out of round or is tapered 0.03 mm. or more, grind journal to next undersize.

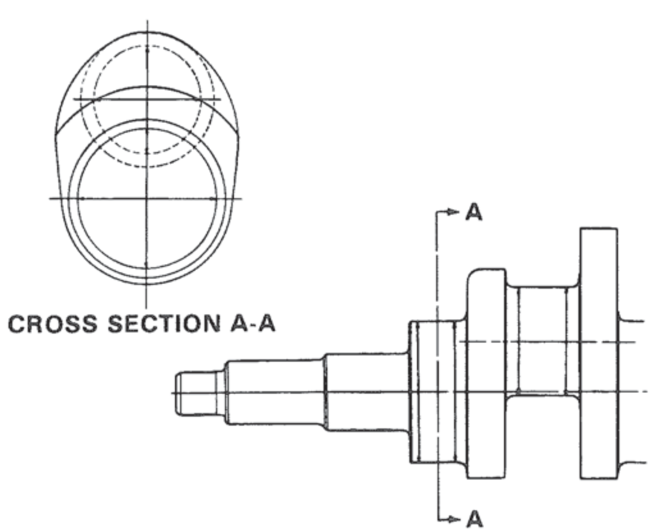


Figure 31. Measuring Outer Diameter of Crankshaft Journal and Pin.

CRANKSHAFT DIMENSIONS. (mm.)

Journal	STD	Regrind At	0.25 U.S.	Regrind At
Rod	59.965/59.945	59.850	59.715/59.695	59.600
Main	77.950/77.930	77.878	77.700/77.685	77.628

0.50 U.S.	Regrind At	0.75 U.S.	Regrind At	IOUS	Replace Crank At
59.465/59.445	59.350	59.215/59.195	59.100	58.965/58.945	58.850
77.450/77.430	77.378	77.200/77.180	77.180	76.950/76.930	76.878

Table 3. Crankshaft Dimensions.

3. If readings exceed regrind limit, grind to the next undersize. Do not change fillet radius or journal width.

Grinding Crankshaft. When grinding the crankshaft, grind it 0.035 to 0.055 mm. (crankpin) or 0.050 to 0.070 mm. (crank journal) smaller than the main bearing undersizes, this will eliminate fitting of bearings.

Example. When using a 0.50 mm. undersize bearing, grind-finish journal to:

78.0-0.5-(0.050 to 0.070) = 77.45 to 77.43.

Grind-finish crankpin to:

60.0-0.5-(0.035 to 0.055) = 59.465 to 59.445 and it will have a standard clearance with the bearing of 0.5 U.S.

NOTE

In grinding, be careful not to change the fillet radius and width.

CAUTION

The distance between centers of journal and pin must be kept within the range of 60 ± 0.05 mm.

NOTE

If crankshaft is reground, check hardness. Hardness must be 75 shore.

CAUTION

If crankshaft is rehardened, it must be magnafluxed prior to reuse.

Check Crankshaft for Straightness.

1. Support crankshaft at front and main bearing journals on V-blocks.

2. Measure at center main using a dial indicator. Figure 32.

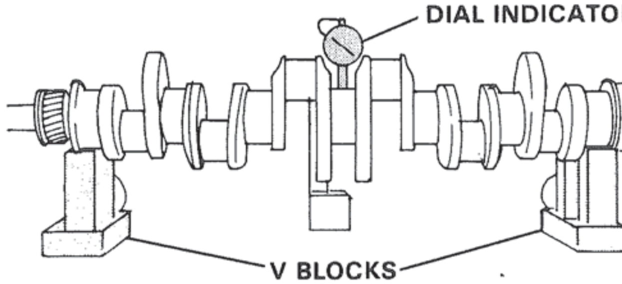


Figure 32. Checking Crankshaft Straightness.

3. Reading of 0.00 - 0.05 mm. run out is acceptable, 0.05 - 0.07 mm. is repairable. A reading in excess of 0.07 is not repairable, crankshaft must be replaced.

Item	S.T.D.	0.25 U.S.	0.50 U.S.	0.75 U.S.	0.10 U.S.	Toler-ance	Fillet radius
Crankpin	60 mm.	59.750 mm.	59.500 mm.	59.250 mm.	59.0 mm.	-0.035 mm. -0.055 mm.	4.0 ± 0.2 mm.
Crank journal	78 mm.	77.750 mm.	77.500 mm.	77.250 mm.	77.0 mm.	-0.050 mm. -0.070 mm.	4.0 ± 0.2 mm.

Table 4. Crankshaft Journal and Pin Undersize, and Fillet Radius.

Main Bearings. If crankshaft has been checked and is being re-used without regrinding, main bearings may be checked for possible re-use.

1. Inspect bearing for scoring, wear or obvious damage.

2. Assemble bearing cap with bearings to block. Torque to 16 kg/m (wet), 18 kg/m (dry).

3. Measure I.D. of bearing. Figure 33.

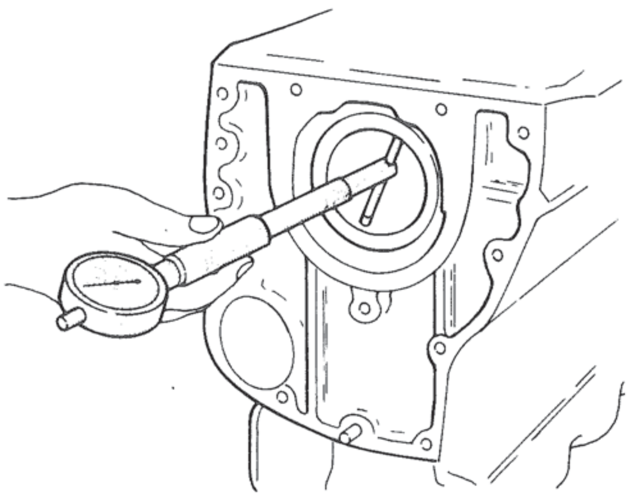


Figure 33. Measuring Inner Diameter of Main Bearing.

Make measurements just inside edge at both ends of bearing, three points around circumference. Figure 34.

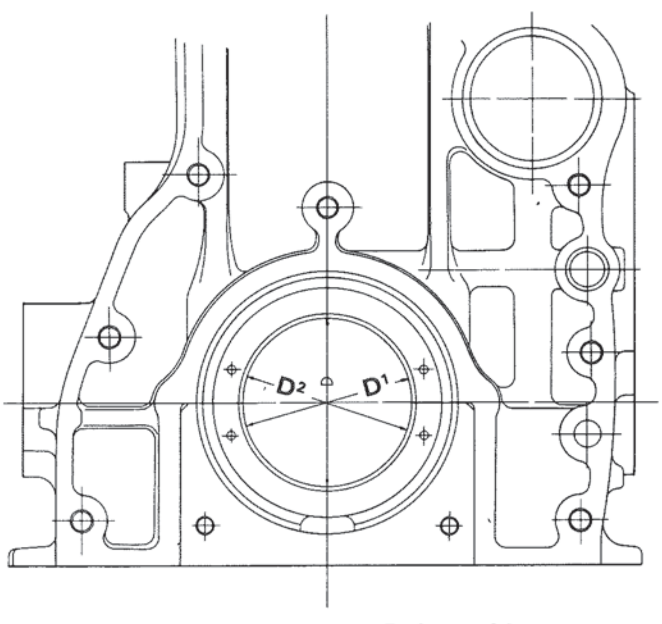


Figure 34. Measuring Points of Inner Diameter of Main Bearing.

4. Write down measurements:

D = Vertical diameter.

D1 = Horizontal diameter, first reading.

D2 = Horizontal diameter, second reading.

$$D3 = \frac{D1 + D2}{2}$$

Compare, D ≥ D3, if difference exceeds 0.01 mm. replace bearings. Compare inside bearing diameter to crankshaft journal diameter. If difference exceeds 0.15 mm. replace bearing.

REPLACING MAIN BEARINGS

If it is determined that main bearings are to be replaced, it is important they be fitted properly. Uneven contact with crankcase or bearing cap may cause seizure. To eliminate this, bearings are designed to extend beyond crankshaft centerline when relaxed. When a bearing cap is properly torqued end pressure forces the bearing to completely fill the available space. However, too much end pressure will cause the bearing to buckle. Therefore, bearings must be fitted using the following procedure.

1. Clean bearing backs and bore surfaces in crankcase and bearing cap, insert bearings.

2. Hold bearing even with crankshaft centerline at one end, place a 500 kg. (1100 lbs.) load on the other.

3. Maintain load and check bearing projection above centerline. Bearing must be flush to 0.04 mm. above centerline. Figure 35.

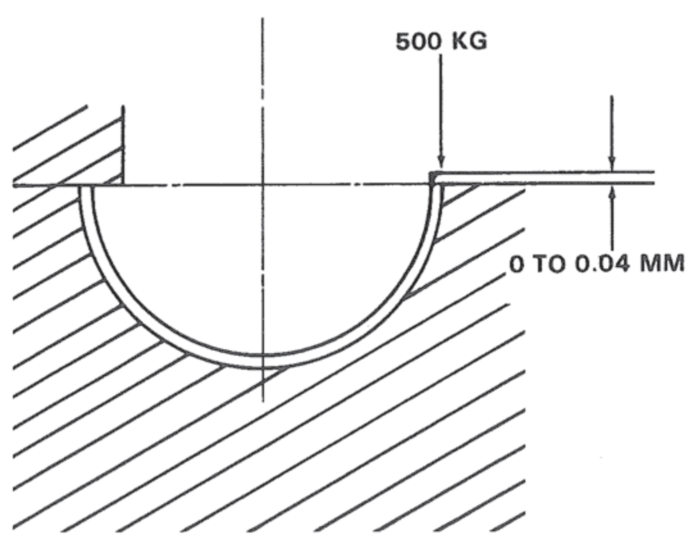


Figure 35. Main Bearing Fitting.

4. If bearing is flush prior to reaching 500 kg. (1100 lbs.) or projects more than 0.04 mm. (.0016 in.) reject bearing.

CAUTION

Do not grind bearing cap face to make bearing fit.

Connecting Rods. Connecting rods are checked visually for cracks. Inspect areas at point curved portion meets straight. Figure 36.

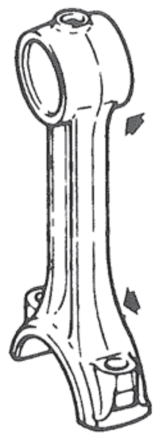


Figure 36. Inspecting Connecting Rod for Cracks.

Inspect oil hole at small end for obstruction or dirt. Clean with small drill or rod.

CAUTION

Do not use a large drill or rod. Remove any burr or material raised in the bushing I.D.

Measure top bushing I.D. Check rod for bend or twist measure side clearance on crankshaft and weigh rods.

Measure Rod, Piston Pin Bushing.

1. Use an inside micrometer to measure bushing I.D. Dimension should be 32.020 - 32.052 mm. If reading exceeds 32.052, replace bushing.

Inspect Rod for Bend or Twist.

1. Place rod in a connecting rod aligner. Bend or twist must not exceed 0.05 mm. when measured over 100 mm. length.

2. If rod aligner is not available, use a bar the same diameter as crank pin in large end and piston pin in other.

Checking for Bend.

A. Place large bar in "V" blocks on a surface plate.

B. Support rod in a vertical position.

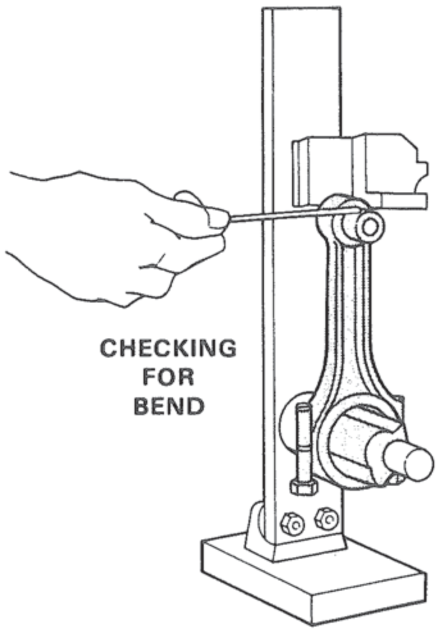


Figure 37. Inspection of Connecting Rod.

C. Center piston pin in small rod end and measure bend with a surface gauge.

Checking for Twist.

D. Leave large end in "V" blocks and lay rod down, piston pin resting in another set of "V" blocks.

E. Repeat measurement.

Measure Piston Pin to Crankshaft Journal Centerline Distance.

1. Use same set up and measure distance. Dimension must be 60 ± 0.3 mm.

Measure Side Clearance.

1. Place connecting rod with bearings on crankshaft. Torque rod cap nuts to 8.5 to 10.5 kg/m.

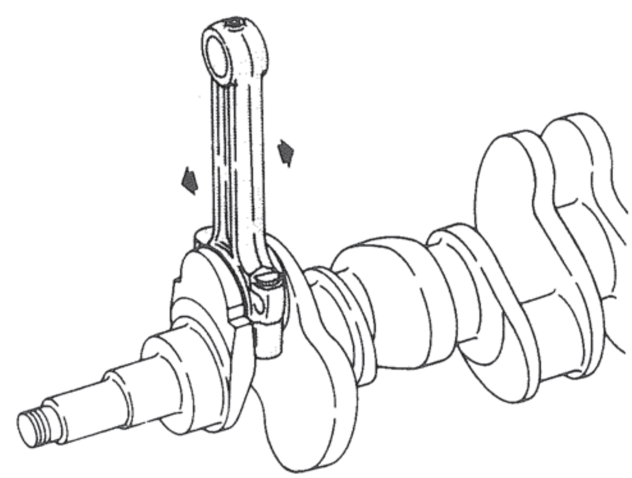


Figure 38. Checking Rod Side Clearance.

Mark	Range of Weight	Mark	Range of Weight
W	1833 to 1852 g.	A	1753 to 1772 g.
X	1813 to 1832 g.	B	1733 to 1752 g.
Y	1793 to 1812 g.	C	1713 to 1732 g.
Z	1773 to 1792 g.		

Table 4. Connecting Rod Weights.

2. Check rod for freedom of movement.

3. Slide rod against one side, measure clearance with a feeler gauge. Figure 38. Normal clearance is 0.15 - 0.45 mm., if clearance exceeds 0.60 mm. replace rod.

Check Connecting Rod Weight. Rod weights must be checked. When replacing a connecting rod, use a new rod that matches the remaining rods in weight. Table 4.

Check Rod Bearing. If crankshaft has been checked and is being re-used without regrinding, bearings may be checked for possible re-use.

1. Inspect bearing for scoring, wear or other obvious damage.

2. Place rod cap with bearing on rod. Torque rod cap nuts to 8.5 to 10.5 kg/m.

3. Measure I.D. of bearing. Figure 39.

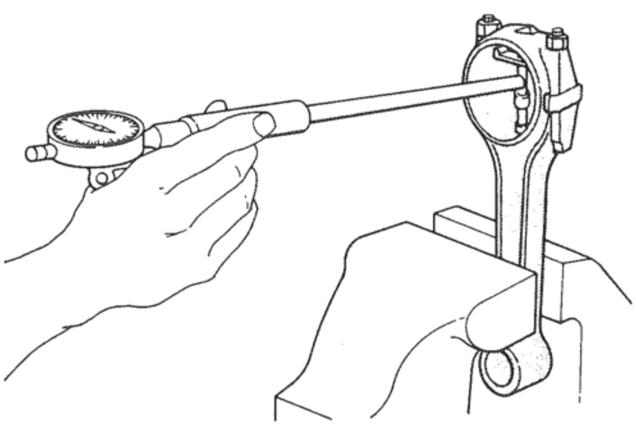


Figure 39. Measuring Inner Diameter of Connecting Rod Bearing.

Make measurements just inside edge at both ends of bearing. Figure 40.

NOTE

Measure at three (3) points around the circumference. Figure 40.

4. Write down measurements:

D = Vertical diameter.

D1 = Horizontal diameter, first reading.

D2 = Horizontal diameter, second reading.

$$D3 = \frac{D1 + D2}{2}$$

Compare, D ≥ D3, if difference exceeds 0.01 mm. replace bearing. Compare inside bearing diameter to crankshaft journal diameter, if difference exceeds 0.20 mm., replace bearings.

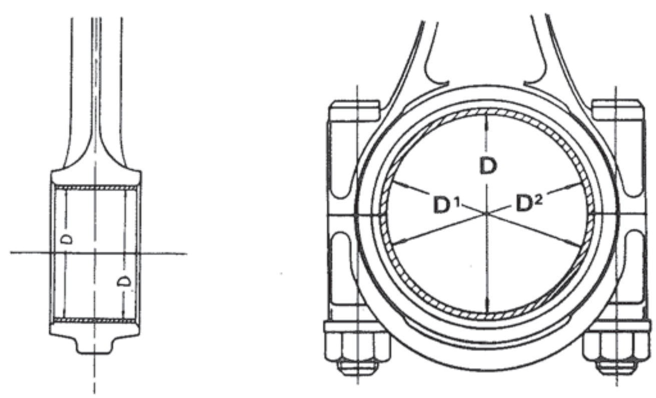


Figure 40. Measuring Points of Inner Diameter of Connecting Rod Bearing.

REPLACING CONNECTING ROD BEARINGS

If it is determined that rod bearings are to be replaced, it is important they be fitted properly. Uneven contact with crankcase or bearing cap may cause seizure. To eliminate this, bearings are designed to extend beyond crankshaft throw centerline when relaxed. When a bearing cap is properly torqued end pressure forces the bearing to completely fill the available space. However, too much end pressure will cause the bearing to buckle. Therefore, bearing must be fitted using the following procedure.

1. Clean bearing backs and bore surfaces in connecting rod and rod cap, insert bearings.

2. Hold bearing even with crankshaft throw centerline at one end, place a 500 kg. (1100 lbs.) load on the other.

3. Maintain load and check bearing projection above centerline. Bearing must be flush to 0.04 mm. above centerline. Figure 41.

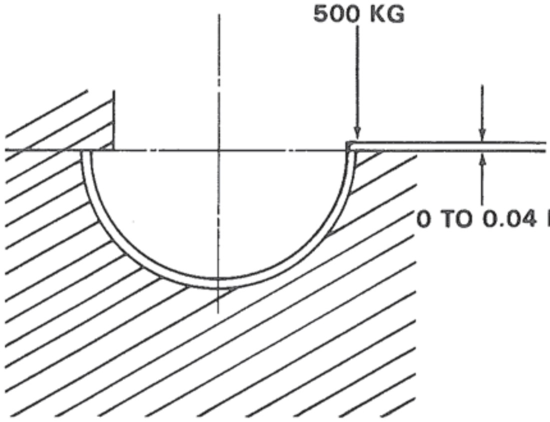


Figure 41. Main Bearing Fitting.

4. If bearing is flush prior to reaching 500 kg (1100 lbs.) or projects more than 0.04 mm (.0016 in.) reject bearing.

CAUTION

Do not grind bearing cap face to make bearing fit.

CAMSHAFT

Check cam lobes oil pump drivegear and bearing surfaces for scratches, uneven wear or damage. Surface scratches may be burnished.

NOTE

Do not grind or alter cam lobes. Check camshaft dimensionally, also check straightness.

Checking Cam Height.

1. Measure height and width of each cam lobe. Figure 42.

2. Subtract D2 from D1, difference must be 7.189 - 6.69 mm. If remainder is less than 6.69 mm., replace camshaft.

Checking Camshaft Straightness.

1. Support camshaft and rear bearing journals on V blocks resting on an inspection surface plate.

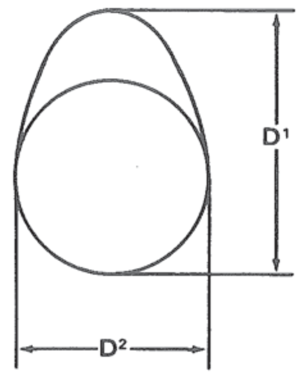


Figure 42. Measuring Camshaft Lobe.

2. Check at both remaining bearing journals by slowly revolving camshaft in V blocks.

Dial indicator reading must fall between 0.00 - 0.50 mm. at both journals.

3. If reading exceeds 0.05 mm., straighten using a press.

Camshaft Bearing and Journal Wear.

1. Measure camshaft bearings, take two (2) readings at 90° to each other. Figure 43. Compare readings, if difference exceeds 0.01 mm., replace bearing. Write down average of readings.

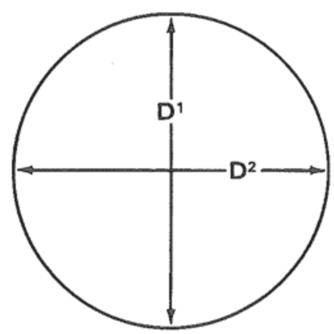


Figure 43. Measuring Camshaft and Bearings.

2. Measure camshaft bearing journals, take two (2) readings at 90°. Compare readings, if journal is out of round, replace camshaft.

3. Subtract camshaft bearing journal O.D. dimension from bearing I.D. Difference should be 0.04 - 0.15 mm. If difference exceeds 0.15 replace bearing.

Replacing Camshaft Bearing.

4. Remove bearing using Special Tool No. MH061070, pull bearing out. Figure 44.

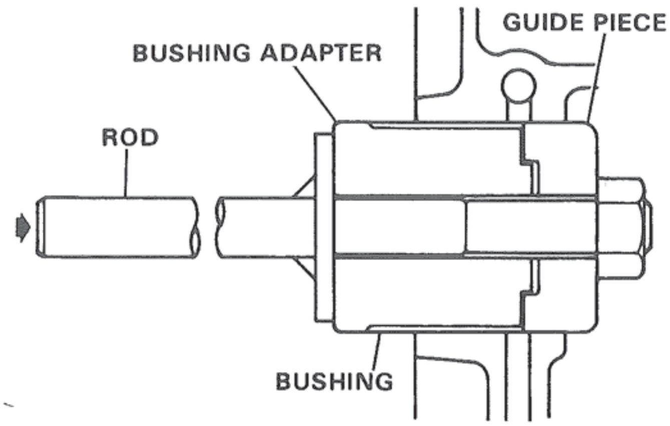


Figure 44. Removing Camshaft Bearing.

5. Place new bearing on tool, assemble guide to end and secure with nut.

6. Place guide end into bore, align oil hole in bearing with oil hole in bore and press bearing in. Figure 45.

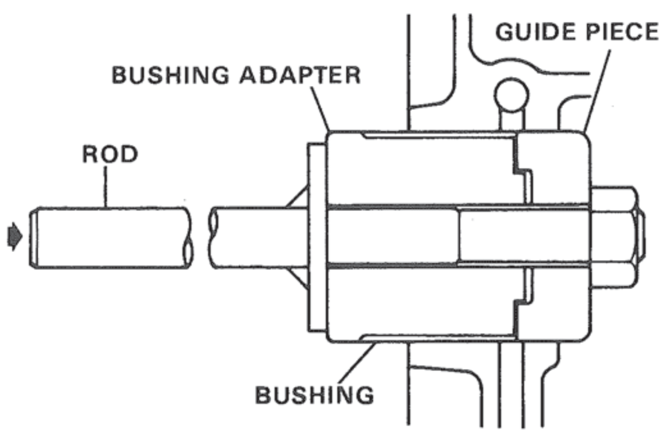


Figure 45. Installing Camshaft Bearing.

7. Repeat steps in 2 and 3.

Gear Train Backlash. Check backlash of timing gears. Replace all parts found to exceed maximum limits.

1. Place all gears on front of engine.

2. Place injection pump in position and secure to block using mounting bracket at governor end of pump.

Measure Backlash Idler Gear and Crankshaft Gear.

3. Mount a dial indicator on front of engine and position gauge at right angles to idler gear tooth. Figure 46.

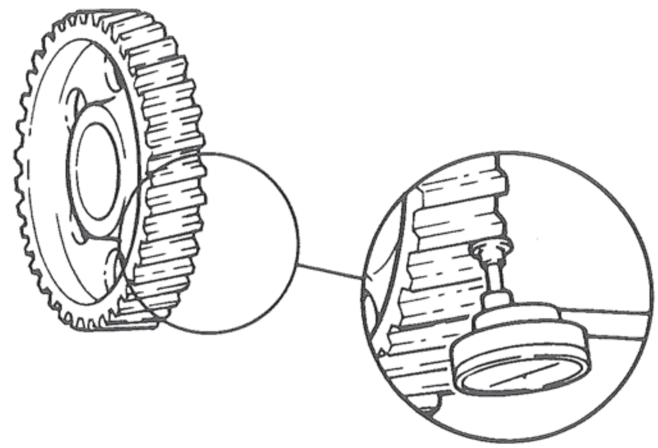


Figure 46. Measuring Gear Backlash.

4. Turn idler gear to right, hold gear in place and zero dial indicator.

5. Turn idler gear to left and take reading. Repeat two (2) times, average readings.

Measure Backlash Idler Gear and Camshaft Gear.

6. Repeat procedures 3-5 on camshaft gear.

Measure Backlash Idler Gear and Fuel Injection Pump Gear.

7. Repeat procedures 3-5 on fuel injection pump.

8. Compare readings taken with Table 5. If backlash exceeds maximum, replace gear.

Gears	Backlash Limits
Crankshaft gear and Idler Gear	0.09 - 0.26 mm.
Idler Gear and Camshaft Gear	0.1 - 0.28 mm.
Idler Gear and Injection Pump Gear	0.1 - 0.28 mm.

Table 5. Timing Gear Backlash Limits.

GEAR TRAIN INSPECTION AND REPAIR

Idler Gear.

1. Inspect idler gear for wear or broken teeth.
2. Measure idler gear bushing for wear.

A. Measure I.D. of bushing.

B. Measure O.D. of idler shaft.

C. Subtract shaft diameter from bushing diameter.

D. Difference must be 0.025 - 0.100 mm. If difference exceeds 0.100 mm., replace bushing.

3. Assemble idler gear to idler shaft.
4. Check end play of gear.

A. Push gear back, measure end play with a feeler gauge.

B. Clearance must be 0.05 - 0.35 mm. If end play exceeds 0.35 mm., replace thrust plate.

Idler Shaft. If inspection shows idler shaft is worn or damaged, shaft may be replaced.

Replacing Idler Shaft.

1. Remove idler shaft using Special Tool No. MH061077, idler shaft puller.
2. Press new idler shaft in using press.

Camshaft Gear and Thrust Plate.

1. Inspect camshaft gear for wear or broken teeth.
2. Measure camshaft end play.

A. Insert camshaft with gear in engine and securely tighten thrust plate.

B. Use same set up as used to measure gear train backlash except position dial indicator on face of camshaft gear.

C. Push in on camshaft and hold it there while zeroing dial indicator.

D. Pull back sharply on camshaft and note reading.

E. Repeat step "D" two (2) times, average reading. End play must be 0.05 - 0.35 mm. If end play exceeds 0.35 mm. replace thrust plate.

NOTE

Thrust plate may be reused by reversing it.

FLYWHEEL

1. Inspect flywheel for cracks for other damage. Replace if cracked.
2. Inspect ring gear for worn or broken teeth.

REASSEMBLY

Prior to reassembly, make certain all components are clean. Fill a container with fresh, clean engine oil for use in coating parts during reassembly.

1. Install all plugs in cylinder block.
2. Place cylinder block on its top. Figure 47.

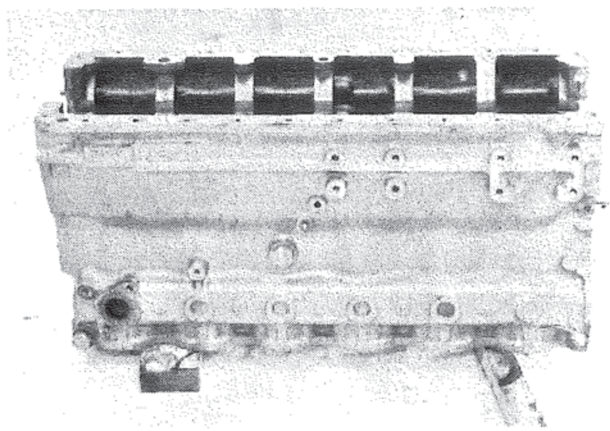


Figure 47. Preparing for Reassembly.

3. Install upper main bearings. Install upper thrust bearings with pins to rear (flywheel end) of No. 7 bearing. Figure 48.

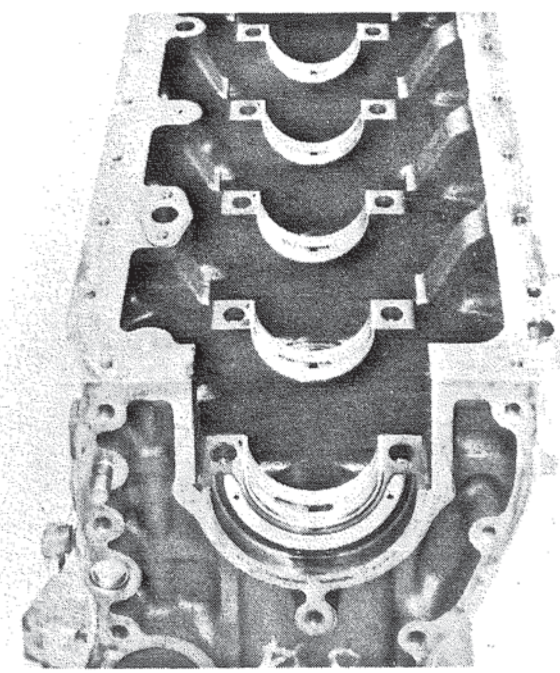


Figure 48. Installing Upper Main Bearings.

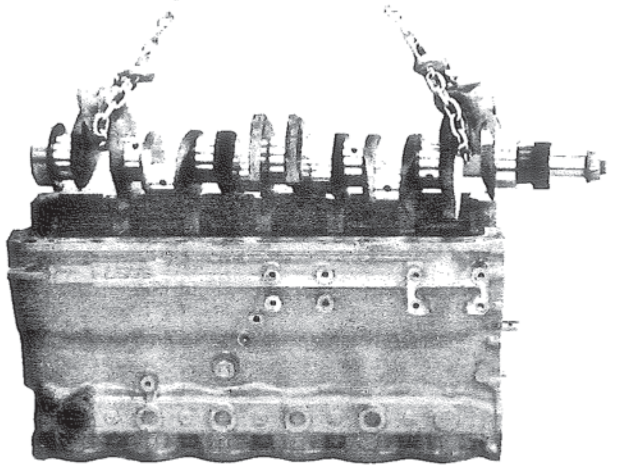


Figure 49. Lowering Crankshaft in Position.

4. Coat bearing surfaces with clean engine oil.
5. Lower crankshaft into place. Figure 49.

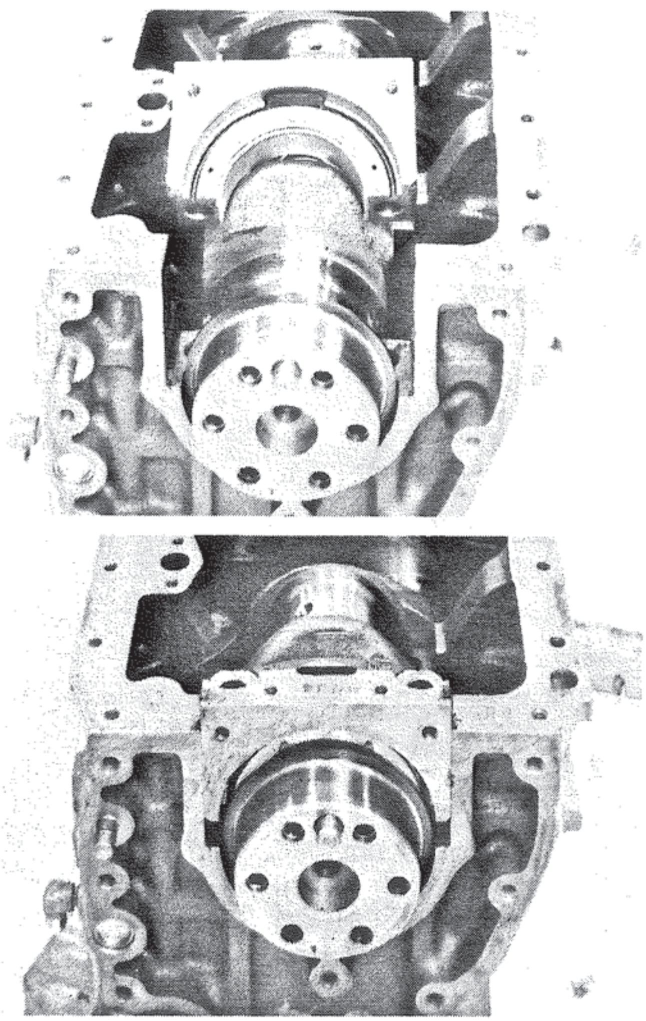


Figure 50. Installing Thrust Bearings.

6. Place bearings in No. 1 and No. 7 main bearing caps. Install thrust bearings to No. 7 bearing cap. Figure 50.

7. Coat bearing surfaces with oil and place bearing caps over crankshaft.

8. Apply RTV Sealant (Special Tool No. 8983) to flange of main bearing bolts and tighten. Torque to 18 kg/m (130.5 ft. lbs.).

9. Check crankshaft end thrust.

A. Measure clearance with a feeler gauge. Figure 51.

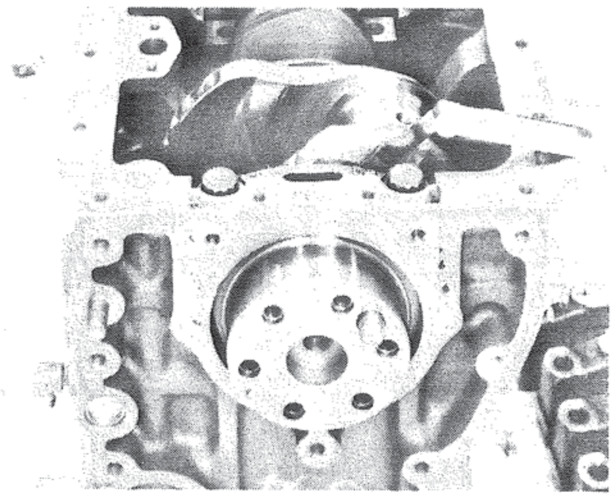


Figure 51. Measuring End Thrust.

B. Clearance should be 0.100 - 0.198 mm., clearance of 0.400 mm. is acceptable. Over 0.400 mm. clearance requires replacement of thrust bearings. Oversize thrust bearings are available in + 0.15, 0.30 and 0.45 mm.

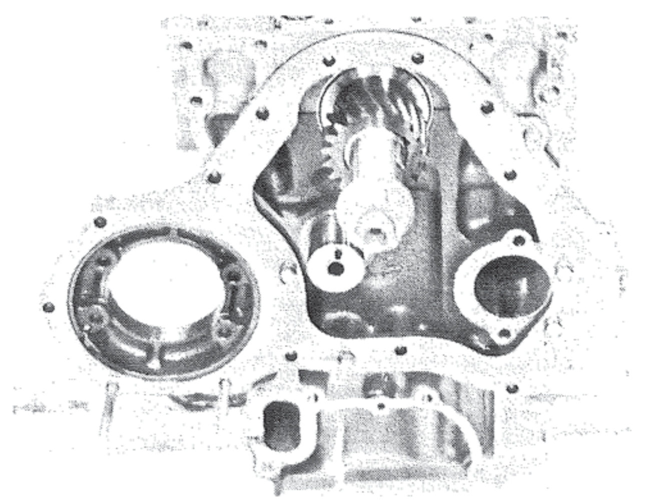


Figure 52. Installing Front Plate.

NOTE

Wear is normally greater at the rear. Replace both top and bottom rear thrust bearings first.

10. Press side seals into front and rear bearing caps.

11. Install remaining bearing caps. Turn crankshaft frequently while torquing to assure free movement. Torque main bearing bolts to 18 kg/m (130.5 ft. lbs.).

12. Install front plate using a new gasket and sealing compound. Figure 52.

13. Install fuel injection pump.

14. Liberally oil camshaft bearings, slowly guide camshaft into place. Secure camshaft thrust plate. Figure 53.

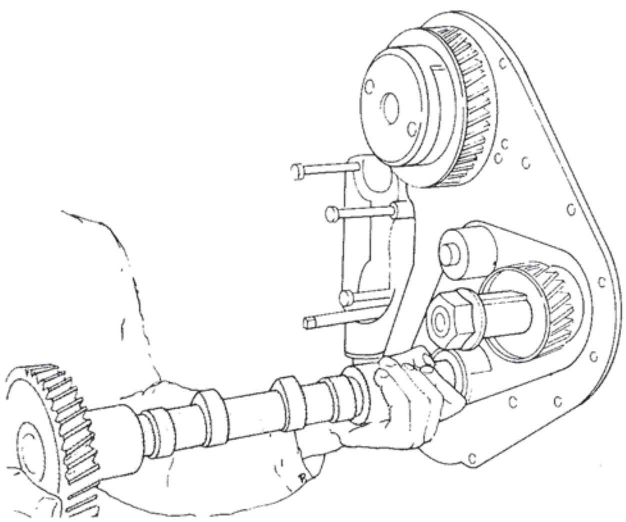


Figure 53. Installing Camshaft.

15. Dip tappets in oil and install.

16. Install flywheel housing using a new O-ring and rear oil seal. Figure 54.

NOTE

Check alignment of dowel pins carefully. Rear main oil leaks will occur if alignment is poor.

17. Measure run-out of flywheel housing.

A. Mount dial indicator on crankshaft. Figure 55.

B. Turn crankshaft, run-out must be less than 0.2 mm. (.008 in.).

C. If run-out exceeds 0.2 mm., loosen capscrews retaining housing, tap housing gently and retighten capscrews.

Repeat until run-out is within 0.2 mm. (.008 in.).

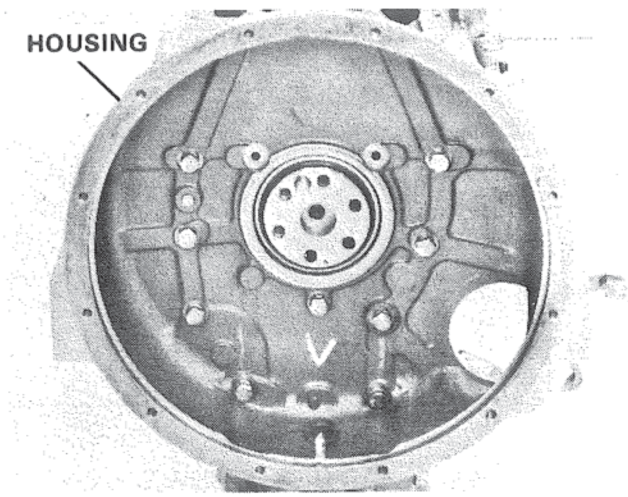


Figure 54. Installing Flywheel Housing.

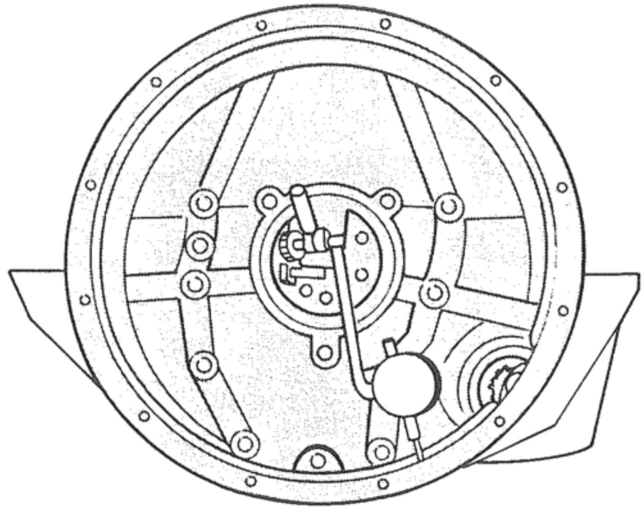


Figure 55. Measuring Flywheel Housing Run-out.

D. Torque capscrews to 5.5 kg/m (39.4 ft. lbs.).

18. Install flywheel, use new lockwashers and bend to lock after torquing capscrews, 9.0 kg/m (65.2 ft. lbs.) with "F" mark, 11.0 kg/m (79.7 ft. lbs.) with "H" mark.

19. Install cylinder liners.

A. Clean bore in block.

B. Lubricate new O-rings in a soapy liquid and place them in grooves of liner.

C. Line up notch in top of liner with left side of block, mark on opposite side with matching mark in top of block. Figure 56.

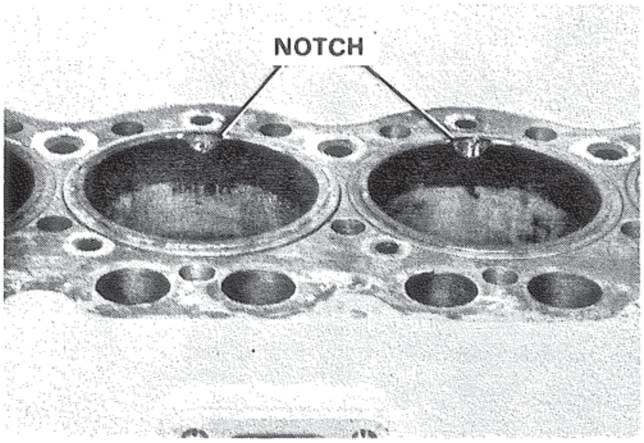


Figure 56. Liner Installation Marks.

D. Grasp liner with both hands and gently push into block. Figure 57.

CAUTION

Do not turn or twist liner. Damage to O-ring seals will occur.

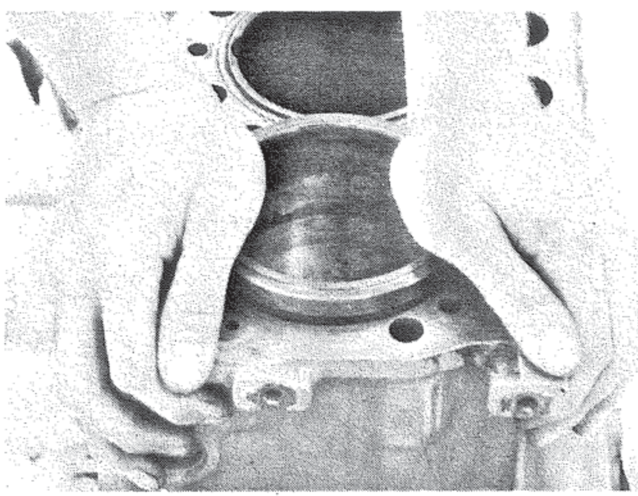


Figure 57. Inserting Liner.

E. Tap gently around top of liner to assure proper seating.

NOTE

Do not hit hard, liner may bounce off its seat.

20. Measure liner projection above crankcase.

A. Mount a dial indicator on crankcase. Figure 58.

B. Liner should extend above face 0.11 to 0.20 mm (0.0043 to 0.0079 in.).

21. Assemble pistons and connecting rods.

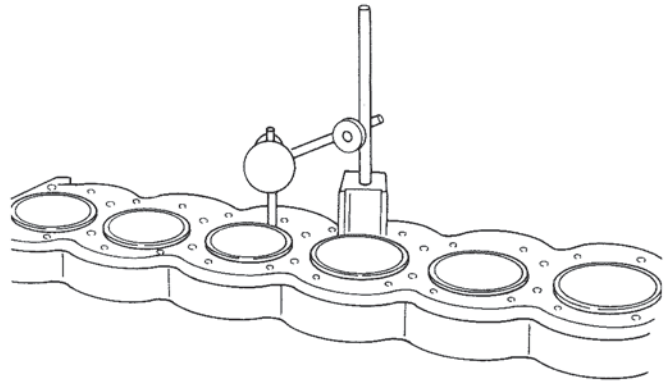


Figure 58. Measuring Liner Projection.

A. Warm piston to 100° C to 120° C (212° F to 248° F).

B. Check parts for correct position. Figure 59.

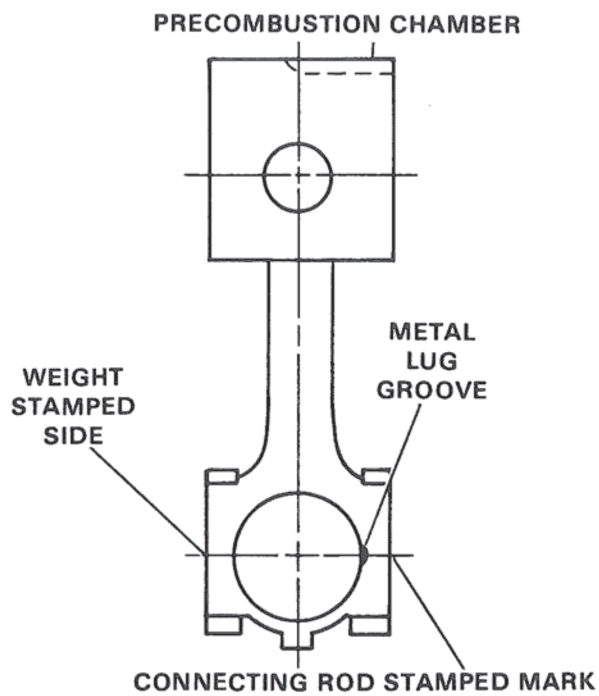


Figure 59. Proper Positions of Piston and Rod.

C. Press piston pin in slowly, insert retaining rings at each end of piston pin.

D. Install piston rings on piston using a piston ring tool. Follow Figure 60, for correct ring sequence.

E. Position rings with openings 90° from one another. Figure 61.

22. Install piston in engine.

A. Dip piston in oil.

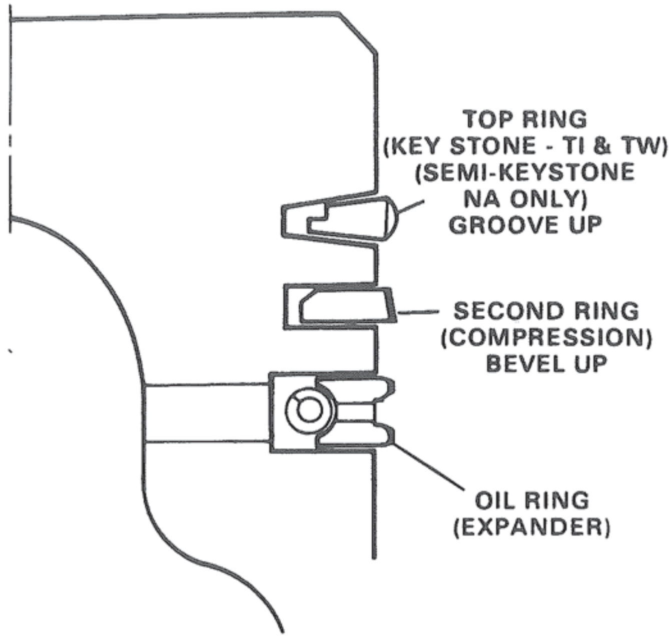


Figure 60. Ring Sequence.

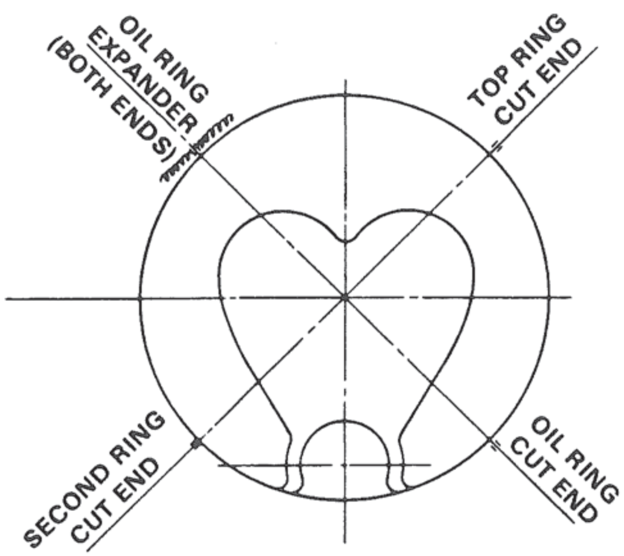


Figure 61. Piston Ring Positions.

B. Remove rod cap.

C. Place piston assembly in piston installer Special Tool No. MH061095.

D. Place in piston bore and turn until precombustion depression is opposite camshaft. Figure 62.

E. Press piston into liner with thumbs. Figure 63.

F. Guide rod over crankshaft, coat area with oil.

G. Assemble rod cap to rod and torque to 9.5 kg/m (68.9 ft. lbs.).

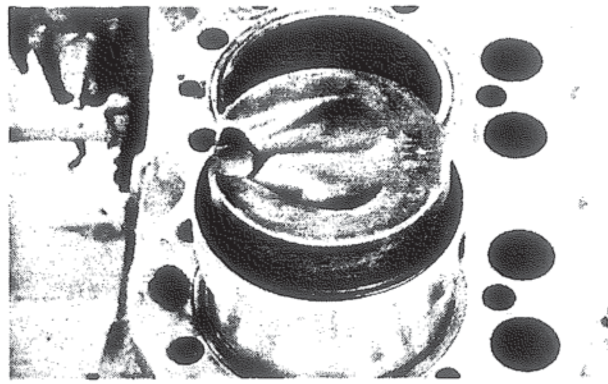


Figure 62. Correct Piston Assembly Sequence.

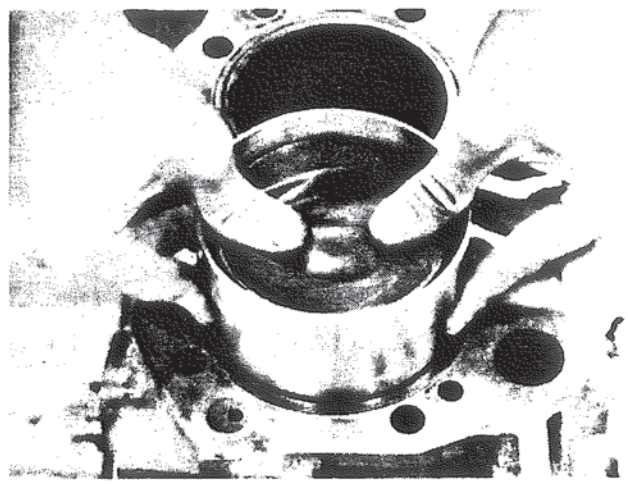


Figure 63. Installing Piston.

NOTE

Check alignment closely. Turn crankshaft frequently to assure freedom of movement.

23. Check piston projection.

A. Mount dial indicator on crankcase.

B. Measure piston projection with piston at TDC.

C. Piston should extend above crankcase 0.5 to 0.7 mm. (0.019 to 0.027 in.).

NOTE

If projection exceeds 0.7 mm. (0.0276 in.), check connecting rod bearings for proper clearance.

NOTE

Keep piston projection measurements written down for future use when checking piston face to cylinder head clearance.

24. Install timing gears.

A. Place woodruff key in camshaft.

B. Slide camshaft gear in place and secure with capscrew, torque capscrew to 2.1 kg/m (15 ft. lbs.). Figure 64.

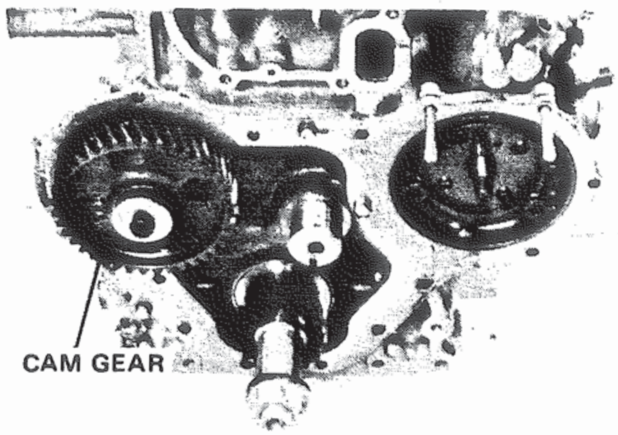


Figure 64. Installing Cam Gear.

C. Install crankshaft gear.

D. Place injection pump drive gear on back of automatic timer and secure with six (6) capscrews. Figure 65.

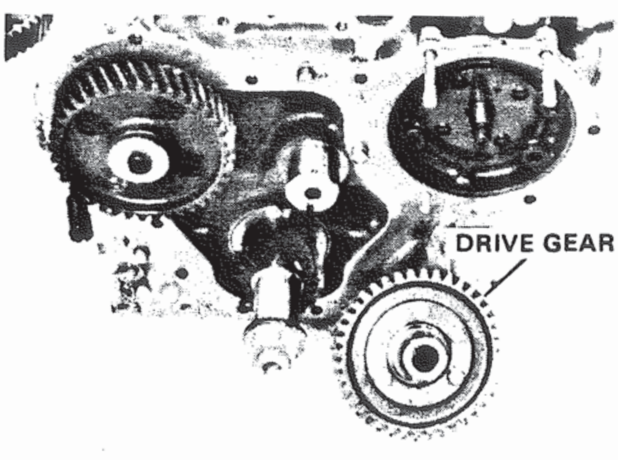


Figure 65. Assembling Drive Gear to Automatic Timer.

E. Place automatic timer on injection pump driveshaft and secure with round nut. Torque to 6-7 kg/m (43.5 to 50.7 ft. lbs.). Figure 66.

F. Refer to Figure 67 and install idler gear. Secure with thrust plate.

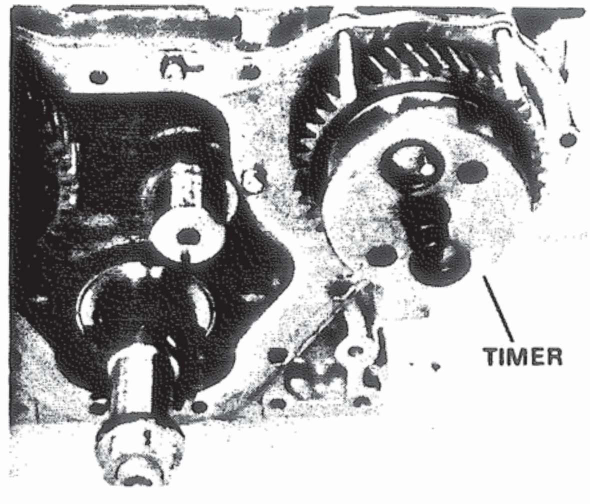


Figure 66. Installing Automatic Timer.

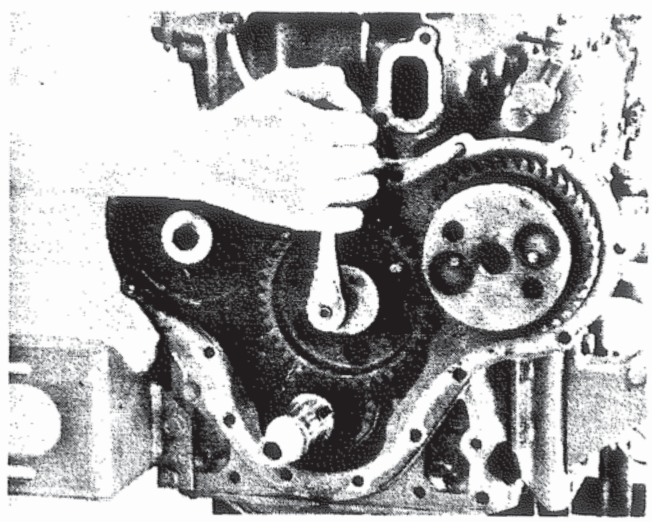


Figure 67. Installing Timing Gears.

25. Install front cover.

A. Apply gasket sealant to both sides of gasket.

B. Coat front seal with oil.

C. Install front cover using Timing Gear Cover Aligning tool MH061074 to align front seal with crankshaft. Figure 68.

D. Secure front cover.

26. Install crankshaft pulley with torsional dampener assembled to it. Insert cone and secure with nut. Torque to 40 kg/m (290 ft. lbs.).

27. Install water pump (see Cooling System).

28. Install alternator (see Electrical System).

29. Install side cover.

30. Install cylinder head (see Cylinder Head Section). Check piston to head clearance.

31. Install starter (see Starter Section).

32. Install lubrication system (see Lubrication Section).

33. Fill with oil to proper level.

34. Adjust valves.

35. Inspect injection timing (see Fuel Section).

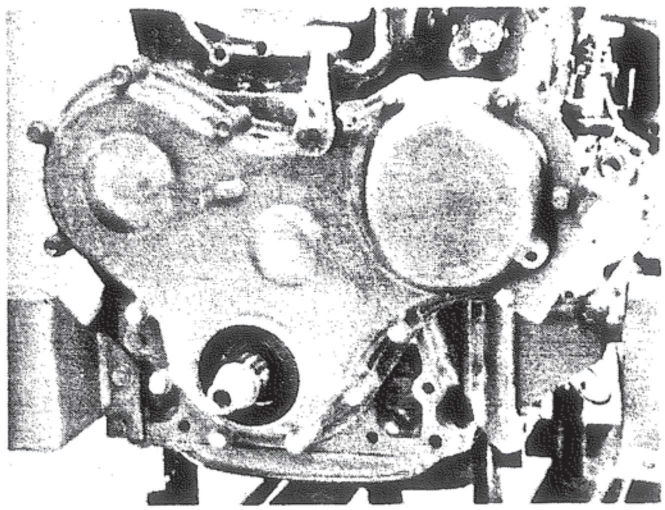


Figure 68. Installing Front Cover.

Notes: Undersize bearings call 269 673 6933 email; PartsAndGaskets@gmail.com

Section 7

COOLING SYSTEM

CONTENTS

Subsection 7A

COOLING SYSTEM

GENERAL

The engine is cooled by fresh water which then transfers its heat to raw (sea) water by means of a heat exchanger. Each system has its own pump.

The fresh water system is a closed system, factory filled with 50/50 water and permanent anti-freeze with rust inhibitor for year round use.

An expansion tank at the front of the engine has a pressure cap of 14 lbs. that must always be in place and tight when running. The cap is removed to fill and check the water level and must be **accessible.** When refilling, use a 50/50 mixture. Run engine for about five (5) minutes to be sure all air is removed from the system and re-check the coolant level.

The engine is supplied with a recovery system whereby the overflow, or expansion is collected in a container and drawn back in the engine when cool.

The raw water system consists of a factory installed raw water pump, and a boatbuilder installed water inlet and outlet. The raw water system uses sea water for cooling and returns the water overboard through the exhaust system. The raw water pump is a positive displacement type with a single rubber impeller and is designed to pump clean water. The water inlet must be unrestricted and should include a sea cock and must have a sea strainer. The through hull fitting should be fitted with a scoop, positioned to take advantage of the ram effect of forward motion. The sea cock should be fastened directly to the through hull fitting, and should be a gate valve or other type providing a full, unrestricted opening. Globe valves should never be used.

An internal clear plastic type sea strainer or an external tapered self-cleaning sea strainer is recommended. A high speed scoop is **not** a strainer capable of removing all debris. The supply line from the through hull fitting to the pump must be for 1-1/4 in. I.D. hose. All hoses must be wire reinforced or have a gap between solid sections no greater than 1-1/4 in. Suction/supply lines over 4 feet long should be 1-1/2 in. I.D. hose.

The intercooler, located at the rear of the engine, has a large number of small diameter cooling tubes (these can plug relatively easily if a sea strainer is not used).

A 1/8 in. pipe fittng should be provided by the boatbuilder at the inlet to the raw water pump to measure the inlet restriction with a vacuum gage or mercury manometer. The maximum reading should be **five (5) in. of mercury** with boat at top speed.

The water outlet from the heat exchanger is directed through the exhaust.

As a protection against electrolysis, all adjacent metals in the cooling system should be similar. Dissimilar materials should be connected by rubber hose.

OPERATION

Fresh Water. Figure 1.

The fresh water cooling system starts at the tank, which holds the fresh water-coolant mixture. Coolant is piped from the reservoir to the suction side of the water pump.

Cooling begins as the pump pushes water through the oil cooler and into the engine block. Once inside the engine coolant is pumped into water jackets to cool cylinders, combustion chambers and the cylinder head before reaching water jackets in the lower section of the exhaust manifold. The exhaust manifold is divided into two (2) sections — lower and upper. From this point the coolant travels to the thermostat which directs the coolant in one of two directions.

Down — through the heat exchanger where is is cooled by the raw water system, then to the upper exhaust manifold and back into the coolant tank.

Up — through the by-pass tube into the upper exhaust manifold and back into the coolant tank. Coolant expands into a recovery bottle mounted on the bulk head.

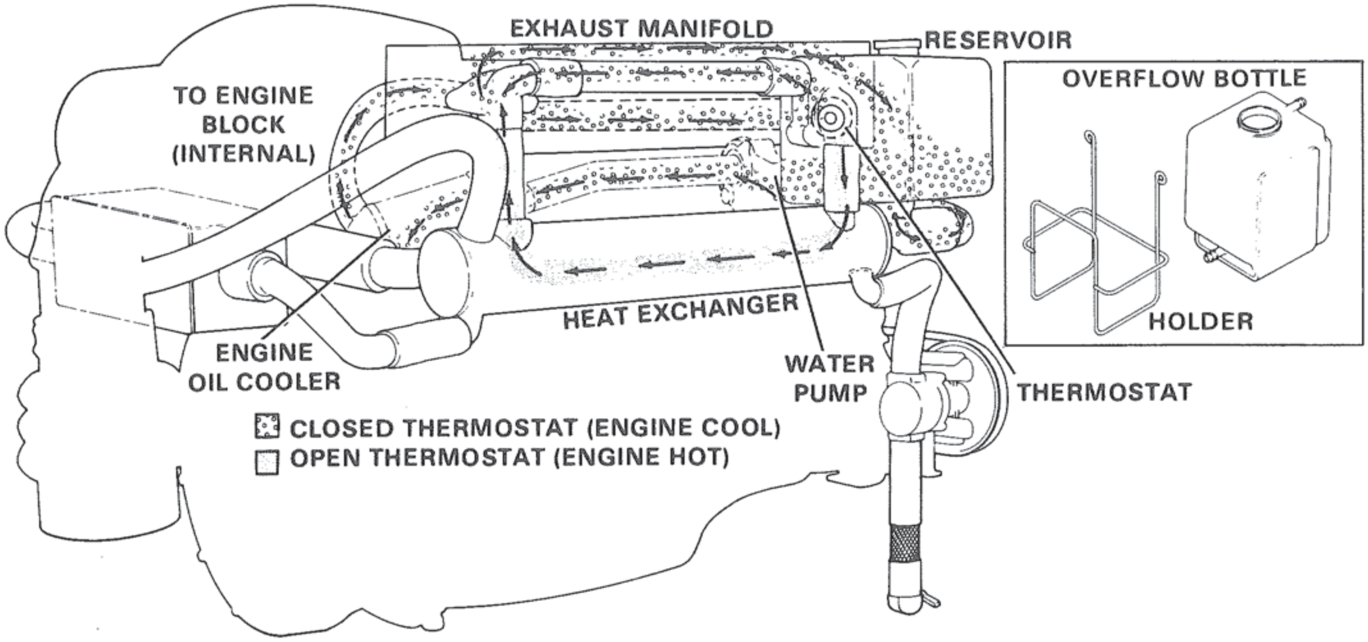


Figure 1. Fresh Water System.

Raw Water. Figure 2.

Raw or sea water is taken in from the suction side of the raw water pump and directed through the bottom section of the heat exchanger. From there water flows through the intercooler and transmission oil cooler into the middle section of the heat exchanger to the upper section and finally overboard through the exhaust port.

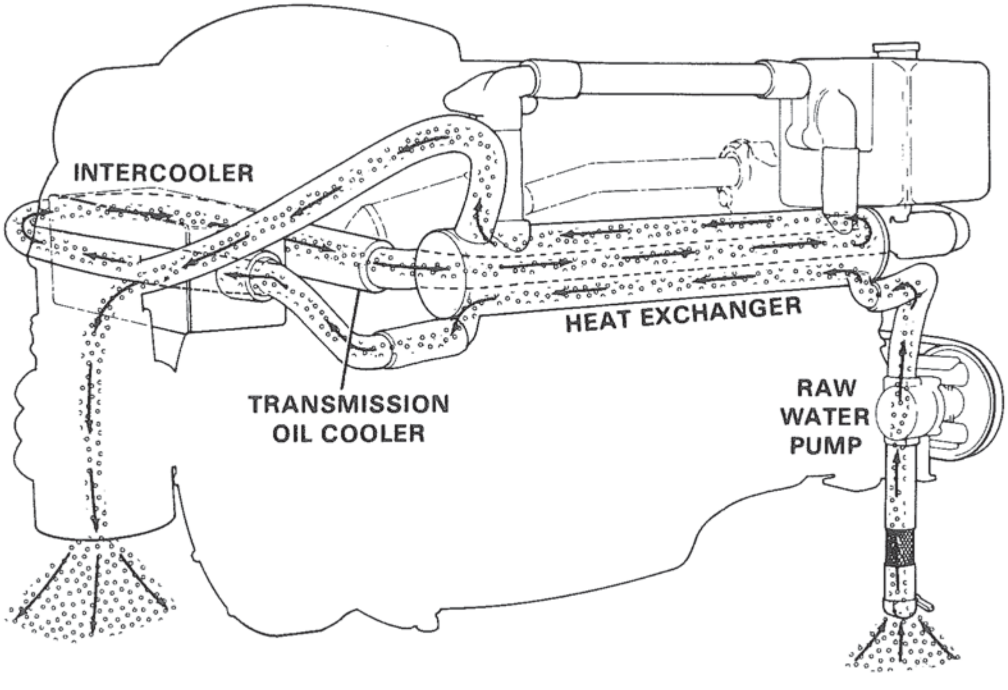


Figure 2. Raw Water System.

SPECIFICATIONS

Fresh Water Capacity	5 gal. (closed system)
Anti-Freeze	Permanent type w/rust inhibitors (alcohol based not acceptable) Mixture 50/50 w/soft water (Provides protection to -20° F)
Fresh Water Coolant Temperature	Between 180° - 190° F
Fresh Water Drive Belt Tension	10 lbs. down - pressure between pulleys (1/2 in. deflection)
Raw Water Drive Belt Tension	Same as fresh water belt
Raw Water Pump	Positive Displacement Type
Fresh Water Pump	Centrifugal (Impeller) Type
Raw Water Pump	Inlet vacuum of 5 in. Hg. (127 mm.) (May be exceeded upon acceleration)
Fresh Water Pressure Cap	14 lbs. (With gasket for recovery system)

Notes:

Subsection 7B

RAW WATER PUMP

SERVICING

NOTE

The raw water pump is located at the lower left hand corner of the engine (when facing front of engine). Figure 1.

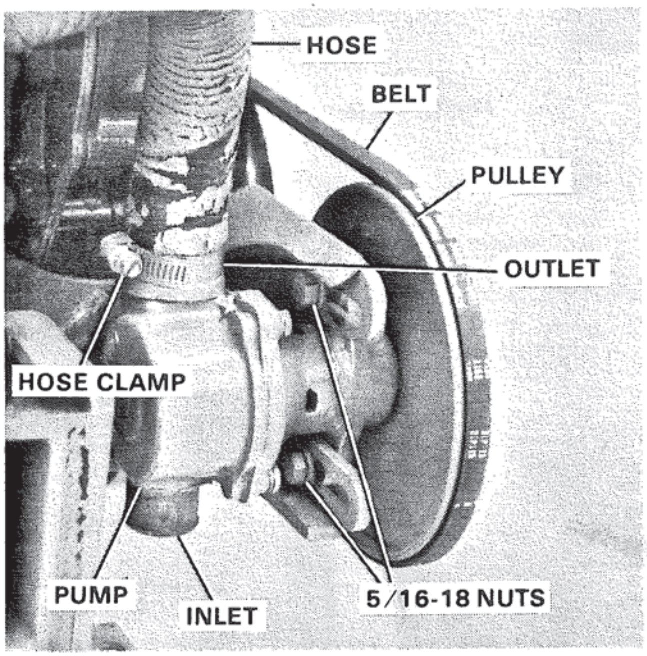


Figure 1. Raw Water Pump.

Removal.

1. Remove pump as follows:

A. Remove two (2) 5/16-18 nuts that secure water pump to mounting bracket. Figure 1.

B. Remove drive belt, hose clamp and hose from outlet (top) side of pump.

Disassembly.

1. Remove pulley by removing retaining ring, and loosening set screw. Figure 2.

2. Remove key and pulley spacer.

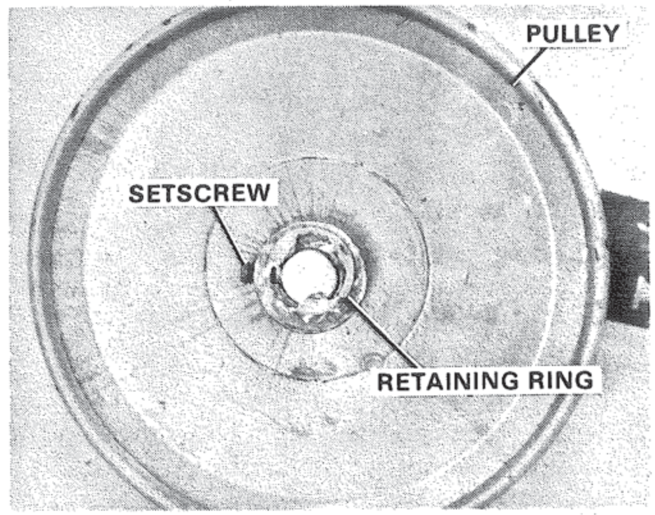


Figure 2. Removing Pulley.

3. Separate housing from body after removing three (3) 1/4-20 hex head bolts. Figure 3.

4. Disassemble body as follows:

A. Remove impeller and end plate. Figure 3.

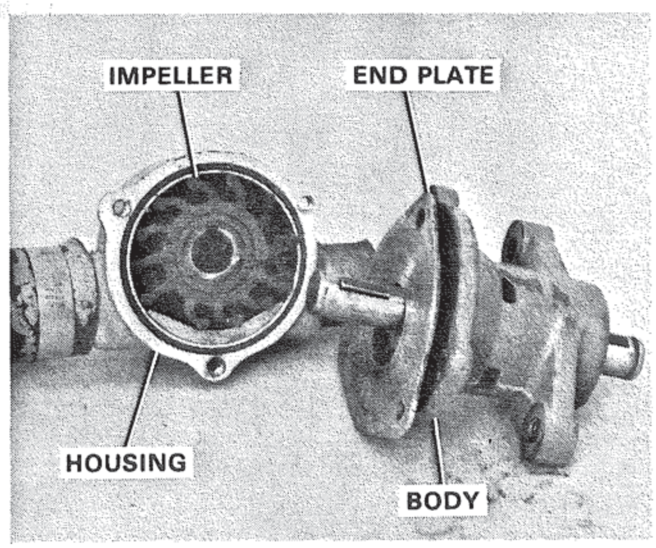


Figure 3. Separating Pump.

B. Remove key from key way and retaining ring from inside end of shaft.

C. Remove thrust washer seal seat. Figure 4.

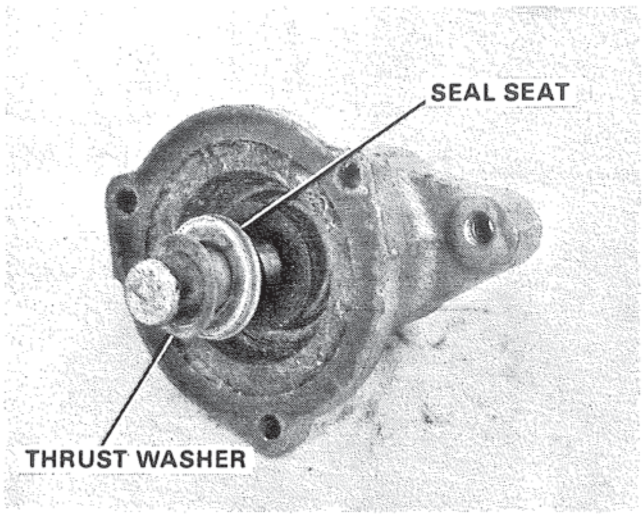


Figure 4. Removing Seal Seat.

D. Remove retaining ring and key from drive end of body.

E. Place body in arbor press and press shaft w/bearings from body. Figure 5.

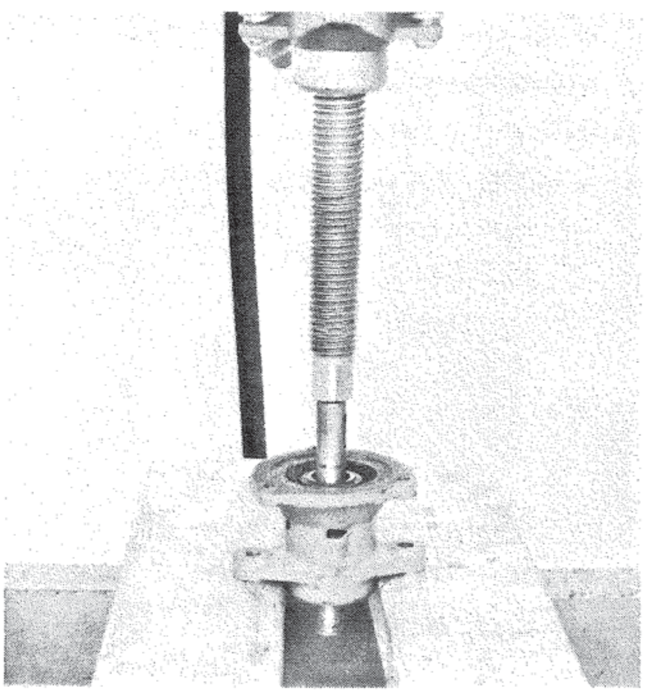


Figure 5. Pressing Shaft from Body.

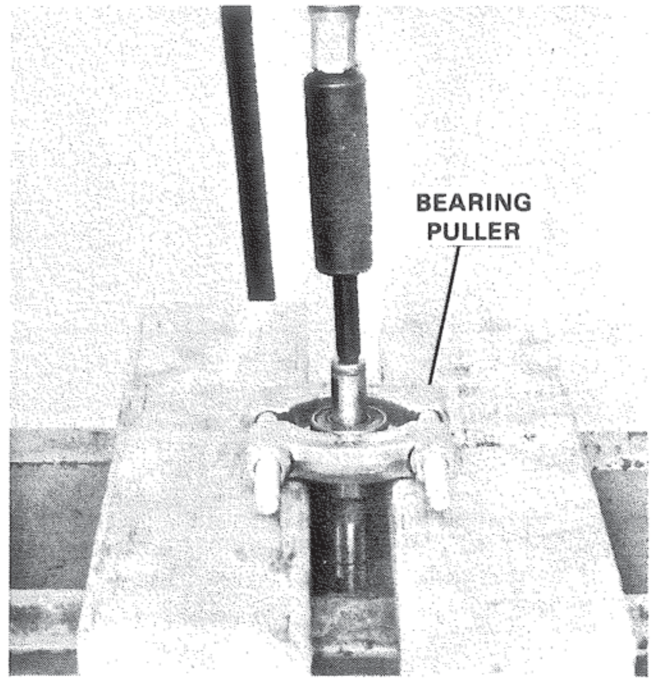


Figure 6. Removing Bearings.

F. Remove retaining ring and press bearings and spacer one at a time, from shaft, using a suitable tool. Figure 6.

G. Remove large internal retaining ring from bore of body, then press mechanical seal from body. Figure 7.

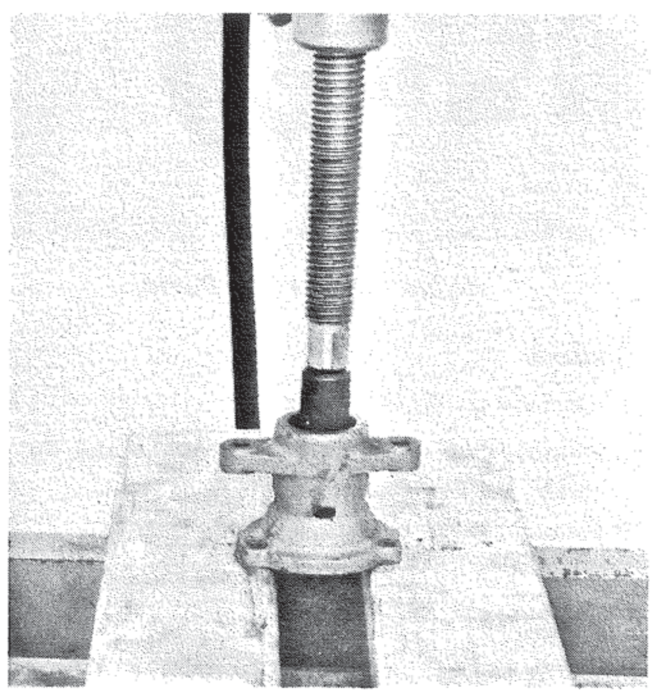


Figure 7. Removing Mechanical Seal.

H. Remove cam by loosening small screw on outside of housing.

Inspection and Repair.

1. Inspect all parts for signs of wear or obvious damage. Replace all damaged or worn parts.
2. Check impeller for brittleness and other damage.
3. Inspect mechanical seal and seal seat for smoothness. If seal or seat is not smooth, replace both.
4. Check inlets and outlets for obstructions.
5. Inspect keyways for distortion.

Assembly.

1. Assemble body as follows:

A. Install cam.

B. Install mechanical seal into bore of body until it bottoms out in bore. Figure 8.

C. Install large internal retaining ring behind seal in bore.

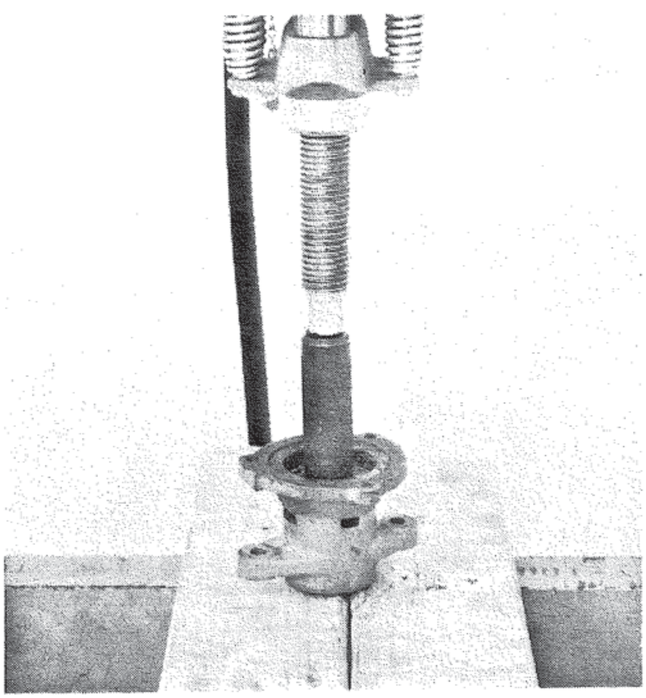


Figure 8. Installing Mechanical Seal.

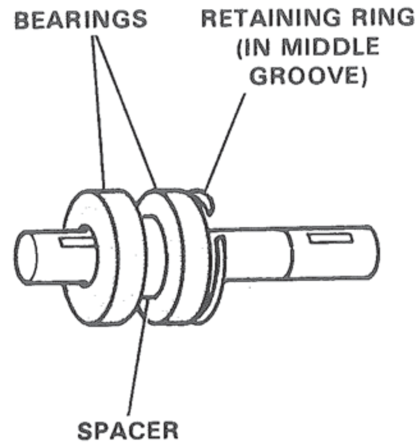


Figure 9. Installing Bearings.

D. Install retaining ring into middle groove of shaft and press one bearing flush against it. Install a spacer against the first bearing, second bearing against the spacer. Figure 9.

E. Install shaft assembly into body and secure with large internal retaining ring. Figure 10.

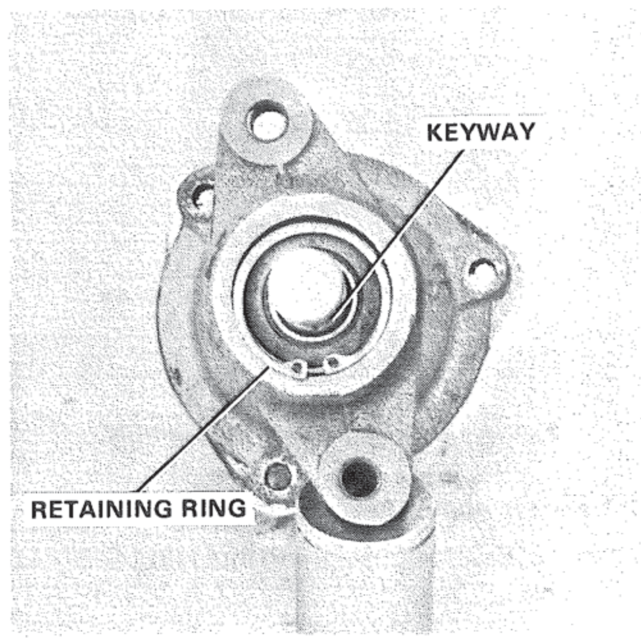


Figure 10. Securing Shaft Assembly Drive End.

F. Install seal seat and thrust washer onto shaft. Figure 11. Secure with retaining ring, then install with key. Figure 12.

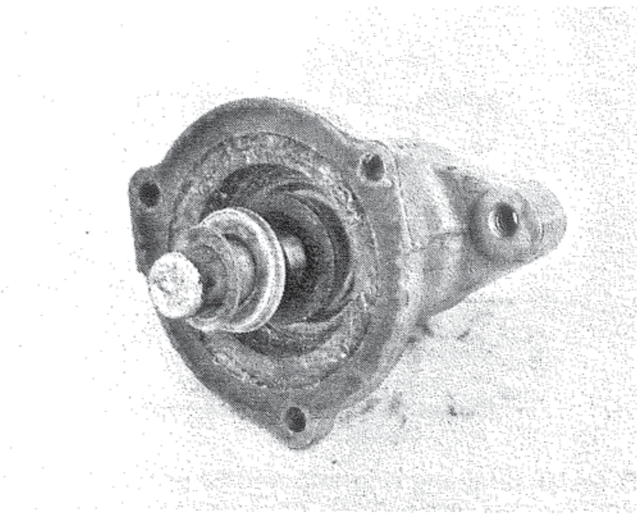


Figure 11. Installing Seal, Seat and Thrust Washer

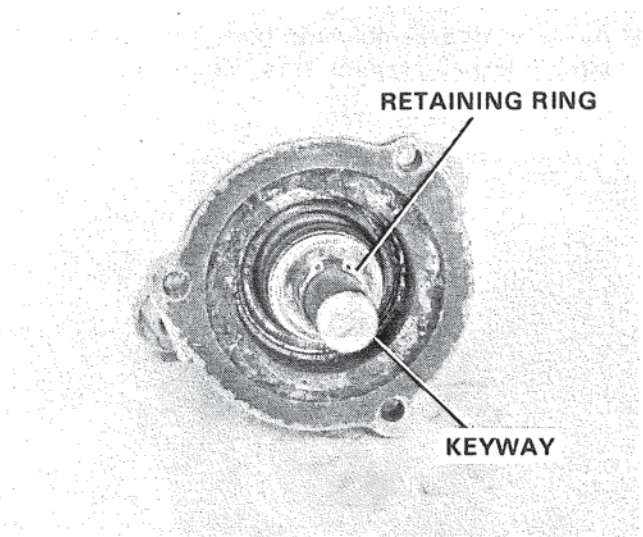


Figure 12. Securing Shaft Assembly.

G. Assemble end plate and impeller.

2. Secure body to housing with three (3) 1/4-20 hex head bolts.

3. Install key into key way.

Installation.

1. Install pump to mountng bracket; and spacer, pulley and retaining ring to shaft. Tighten set screw. Figure 13.

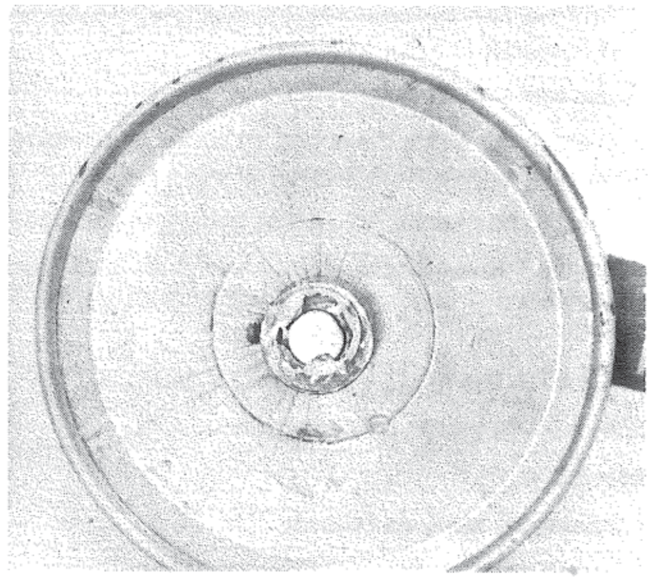


Figure 13. Securing Pulley.

2. Install belt over pulley and tighten mounting nuts securely when proper belt tension has been reached. Figure 14. Reinstall inlet and outlet hoses and clamps.

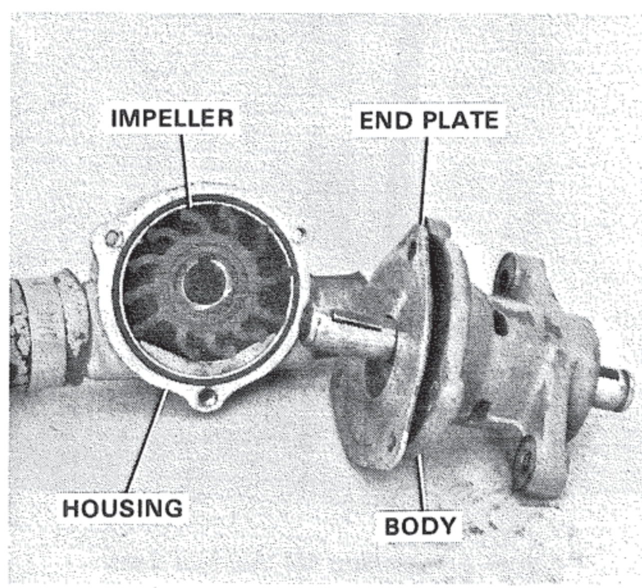


Figure 14. Installing Pump.

1 - SCREW
2 - HOUSING
3 - O-RING GASKET
4 - CAM
5 - IMPELLER
6 - END PLATE
7 - DRIVE KEY
8 - RETAINING RING
9 - SHAFT
10 - THRUST WASHER
11 - SEAL SEAT
12 - MECHANICAL SEAL
13 - BODY
14 - RETAINING RING
15 - BALL BEARING
16 - BEARING SPACER
17 - SPACER
18 - KEY
19 - PULLEY
20 - BELT
21 - RETAINING RING

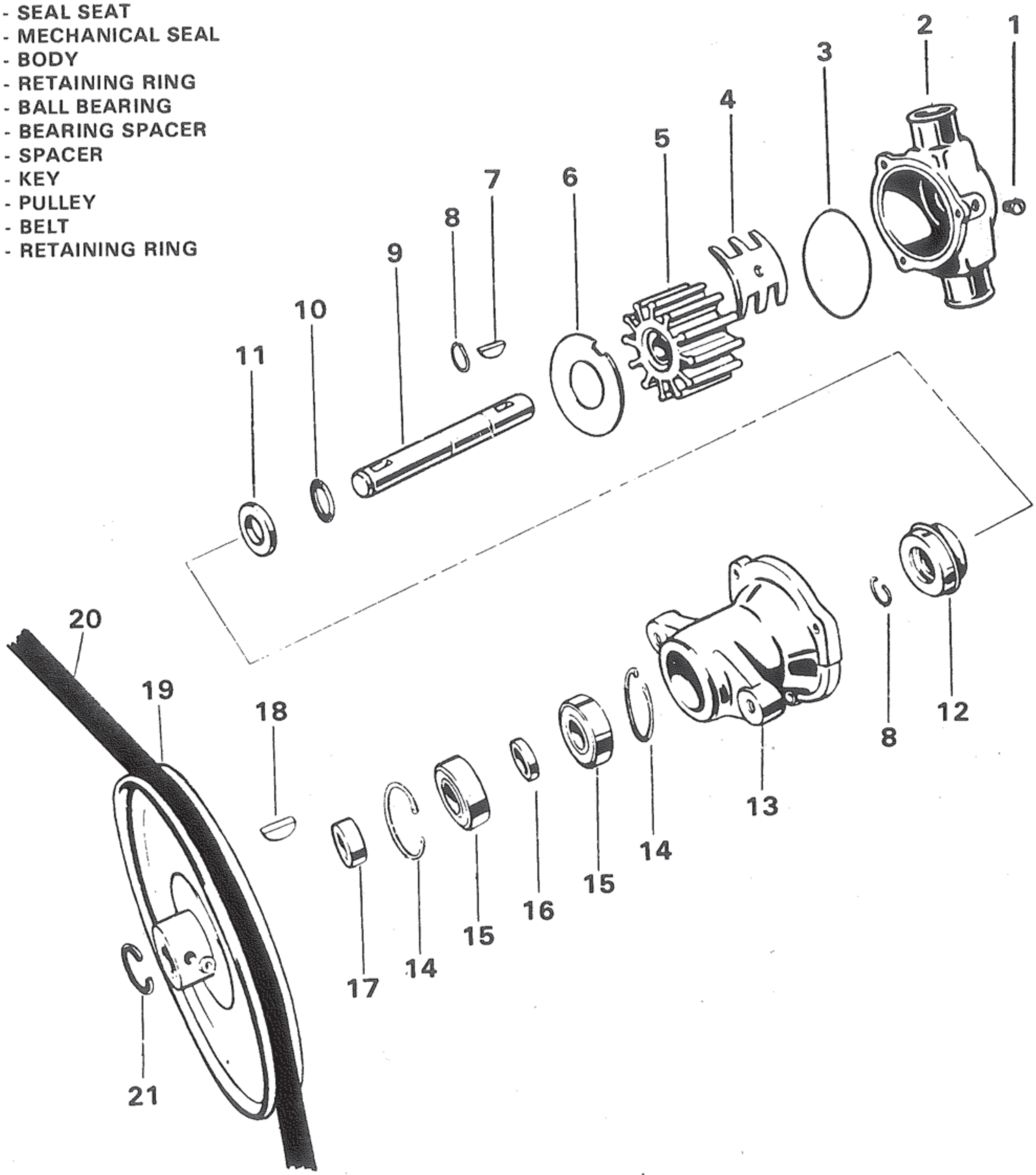


Figure 15. Raw Water Pump. Exploded View.

Notes:

Subsection 7C

FRESH WATER PUMP

SERVICING

NOTE

The fresh water pump is located at the upper front of the engine. Figure 1.

Removal.

1. Drain coolant by disconnecting inlet tube.

2. Remove pulley as follows:

A. Loosen flange mounting nut using a 15/16 in wrench. Figure 1.

B. Remove four (4) pulley mounting bolts using a 1/2 in. wrench. Figure 1.

C. Remove pulley.

3. Remove pump from engine by removing four (4) pump mounting bolts. Figure 1.

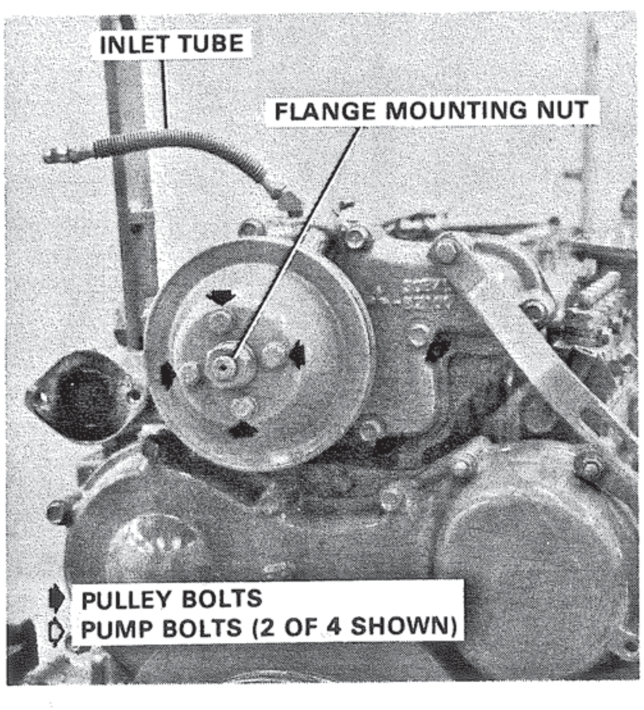


Figure 1. Removing Fresh Water Pump.

Disassembly.

1. Remove cover by removing five (5) cover mounting bolts using a 1/2 in wrench. Figure 2.

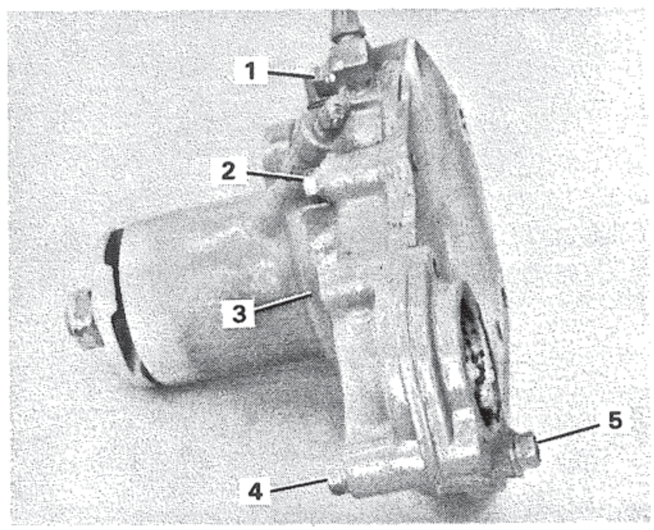


Figure 2. Removing Cover.

2. Remove flange nut and flange. Figure 3.

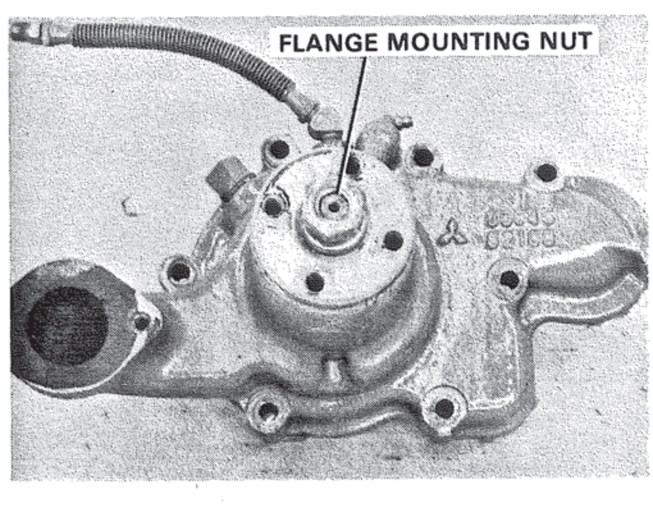


Figure 3. Removing Nut and Flange.

3. Remove internal retaining ring from the drive end of pump shaft using pliers.

4. Unthread impeller from drive shaft. Figure 4.

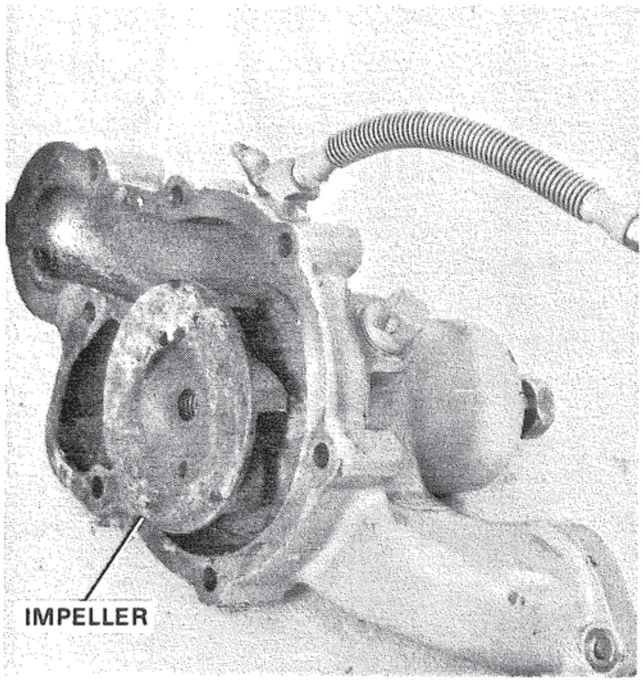


Figure 4. Removing Impeller.

5. Press shaft from body. Figure 5.

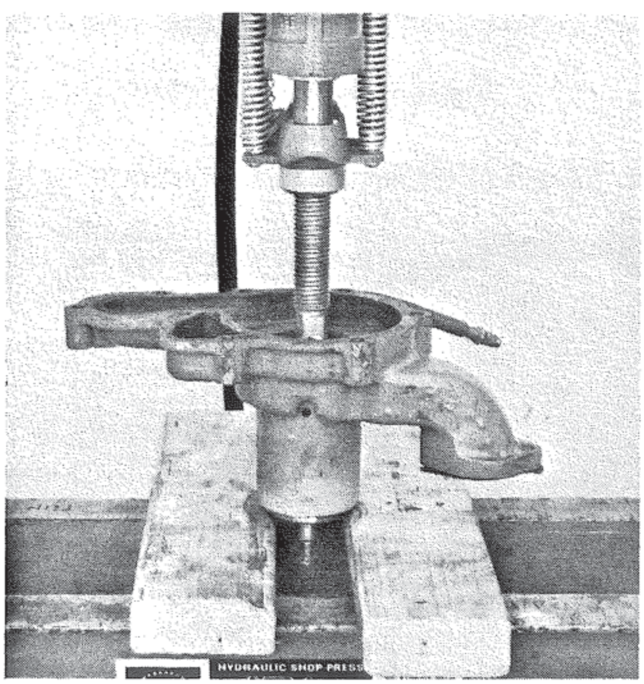


Figure 5. Pressing Shaft from Body.

6. Remove retaining ring from shaft.

7. Remove bearings from shaft using a suitable bearing puller. Figure 6.

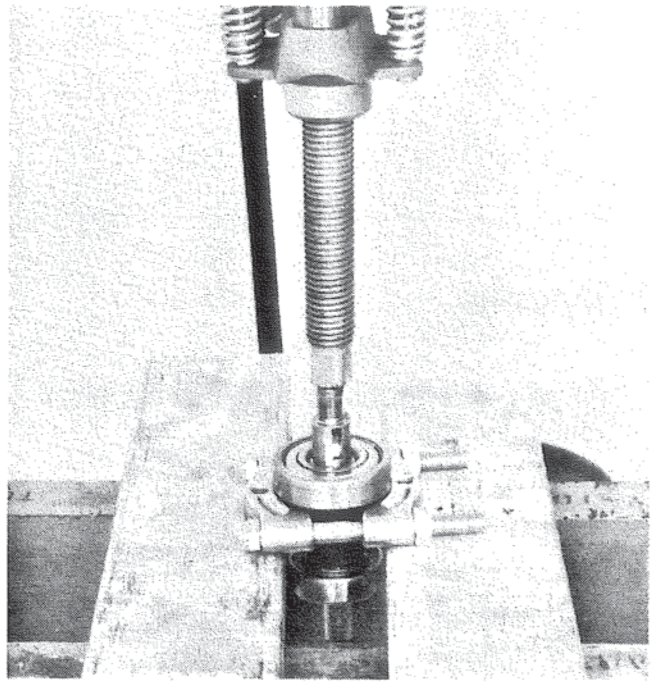


Figure 6. Removing Bearings.

8. Press mechanical seal from body using proper tool. Figure 7.

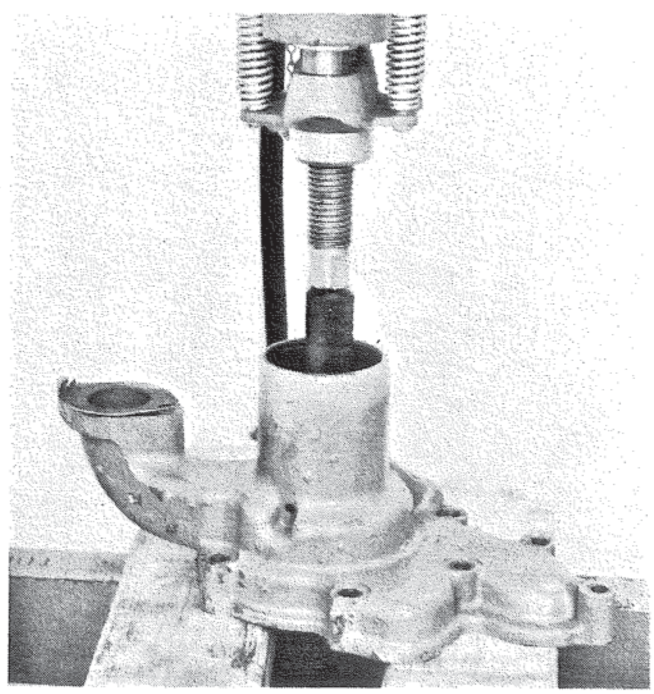


Figure 7. Removing Mechanical Seal.

9. For lubrication or replacement, grease fitting location is shown in Figure 8.

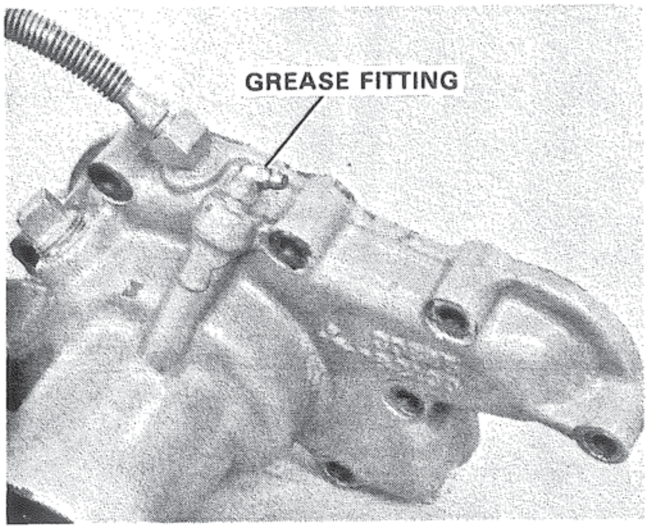


Figure 8. Grease Fitting Location.

Inspection and Repair.

1. Inspect all parts for wear and/or corrosion. Replace all worn parts.
2. Inspect impeller for broken or cracked blades. Replace impeller if cracked.
3. Replace gasket if cover has been removed.

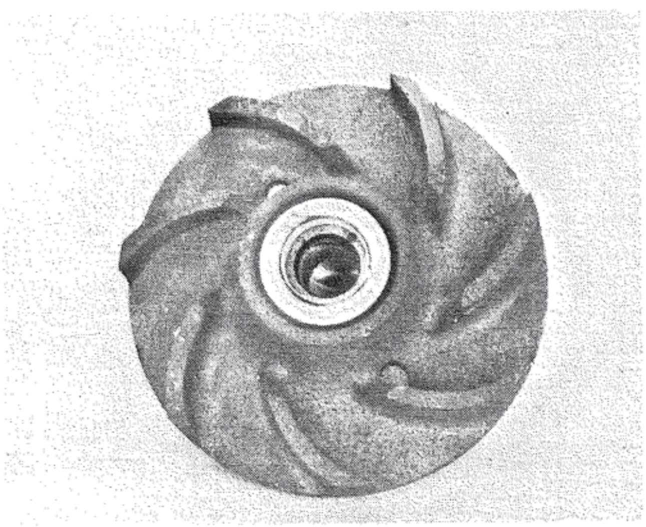


Figure 9. Inspecting Impeller Bore.

4. Inspect inlet and outlet parts for foreign particles or obstructions.
5. Mechanical seal must have smooth sealing surfaces. If surfaces are not smooth, replace seal.
6. The mating part to the mechanical seal is located in the impeller bore. Figure 9. Inspect it. Pry it from bore, if needed, and carefully press a new seal in so it is flush with the impeller bore.
7. Check key way for distortion.
8. Check bearings for wear and play.

Reassembly.

1. Press mechanical seal into housing bore until it "bottoms out" in bore.

NOTE

Do not press on sealing surface as damage may occur. Figure 10.

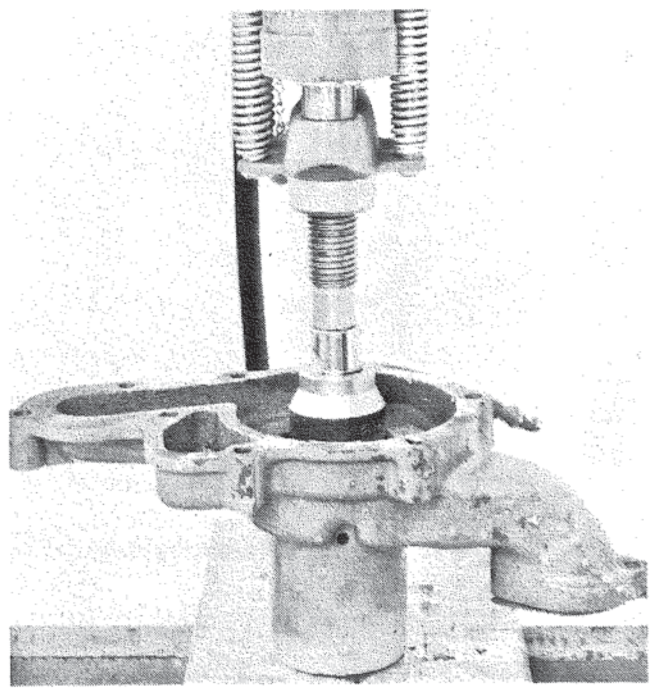


Figure 10. Installing Mechanical Seal.

2. Press small bearing onto shaft. Figure 11. Install retaining ring into groove on shaft. Figure 12.

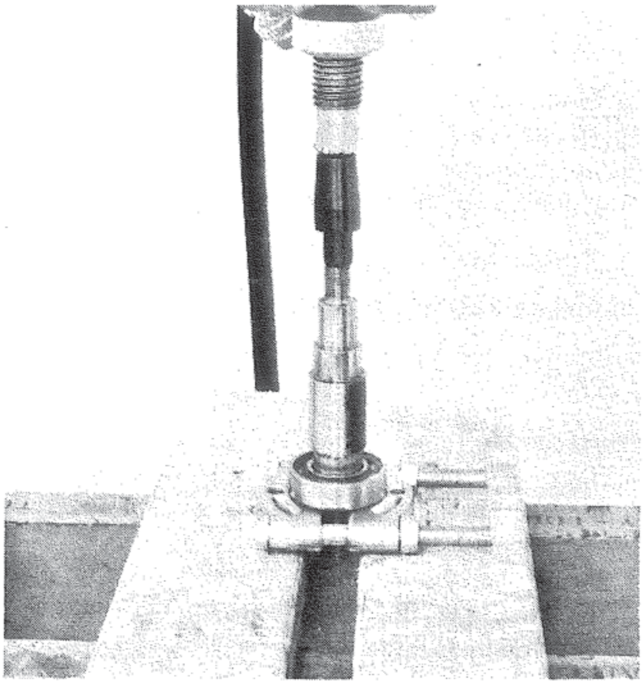


Figure 11. Installing Small Bearing.

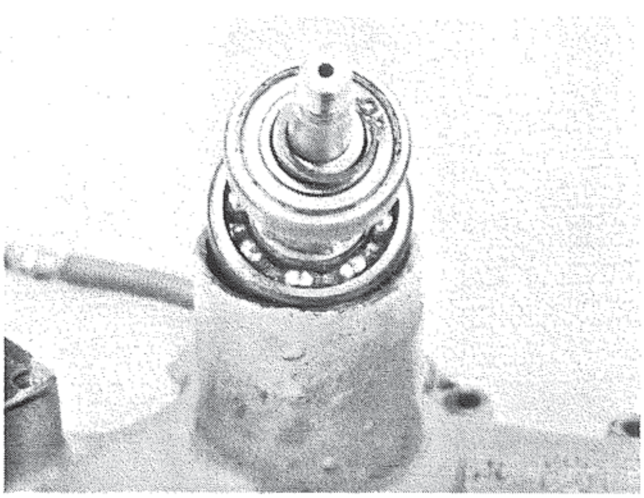


Figure 12. Installing Retaining Ring.

3. Press large bearing onto shaft. Figure 13.

4. Press shaft assembly into bore of pump body and install impeller. Figure 14.

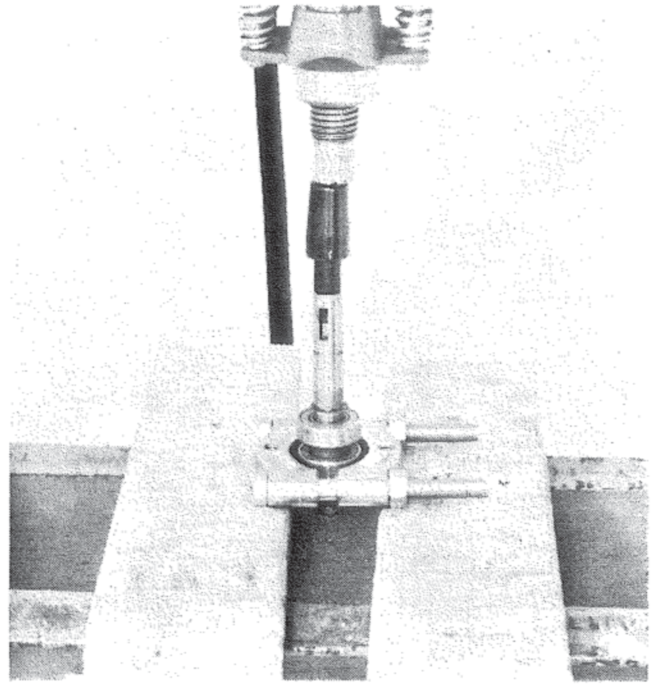


Figure 13. Installing Large Bearing.

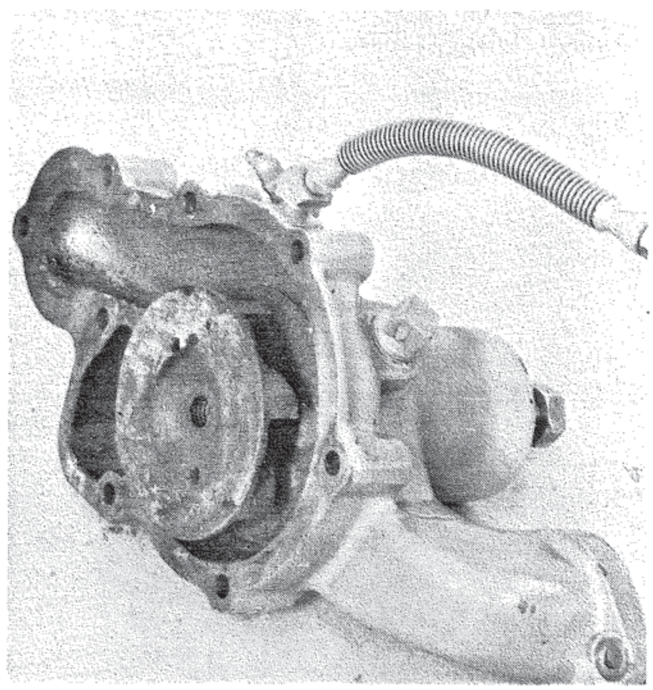


Figure 14. Installing Impeller.

5. Install retaining ring into groove. Figure 15.

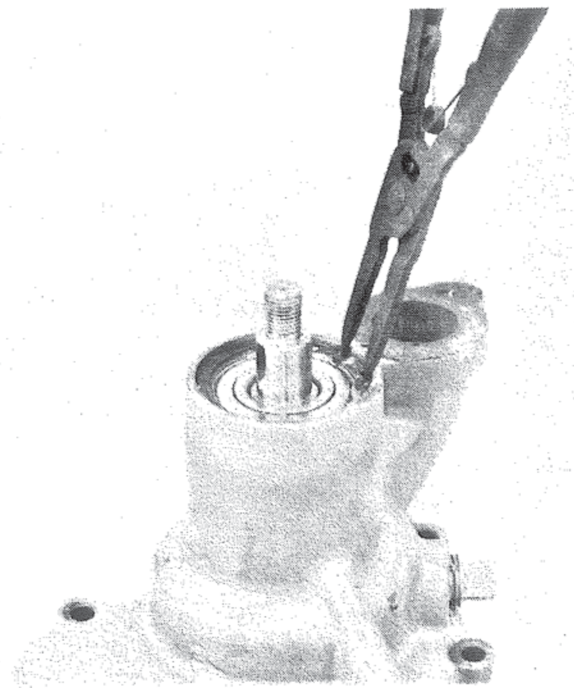


Figure 15. Installing Retaining Ring.

6. Install flange and flange nut. Figure 16.

7. Install new cover gasket, cover and cover mounting bolts securely. Figure 17.

Installation.

1. Mount pump to engine. Figure 18.

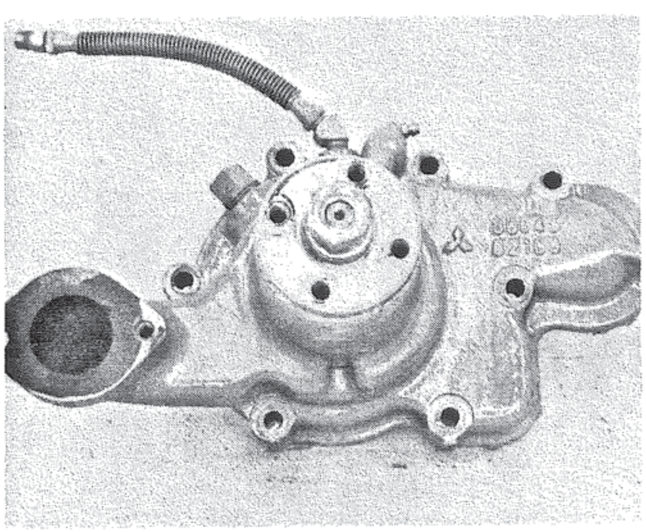


Figure 16. Installing Flange.

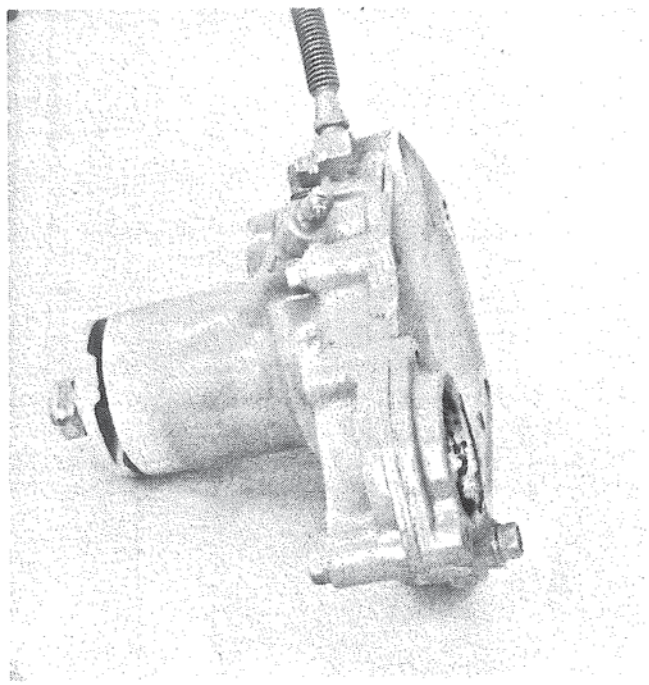


Figure 17. Installing Cover.

2. Install pulley securely.
3. Install drive belt.
4. Connect inlet tube.

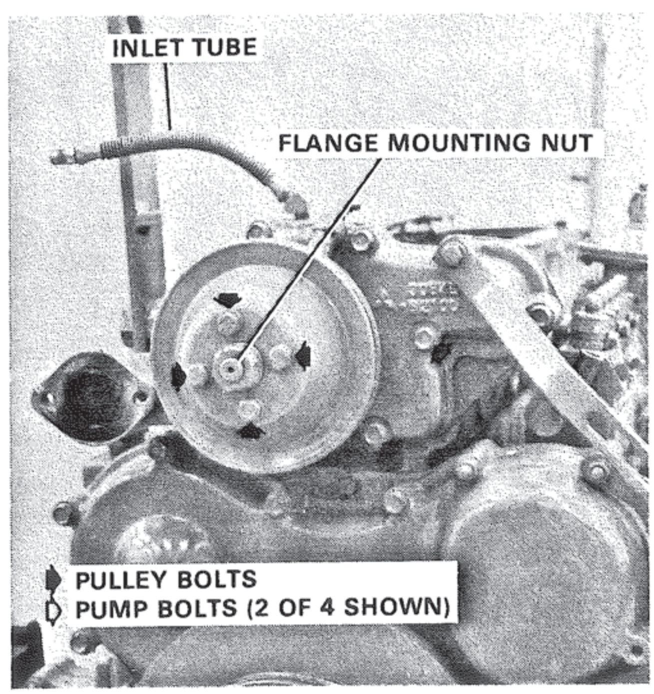


Figure 18. Installing Pump.

1 - WATER PUMP ASSEMBLY
2 - GASKET
3 - GREASE FITTING
4 - SEAL
5 - IMPELLER
6 - WATER PUMP COVER
7 - GASKET
8 - BOLT - 8x50
9 - BOLT - 8x45
10 - BOLT W/WASHER 8x70
11 - BOLT W/WASHER 8x50
12 - SNAP RING
13 - BALL BEARING
14 - WATER PUMP SHAFT
15 - BALL BEARING
16 - SNAP RING
17 - WOODRUFF KEY
18 - NUT
19 - WASHER
20 - FLANGE
21 - BOLT W/WASHER 8x55
22 - BOLT 8x38
23 - BY-PASS PIPE
24 - GASKET
25 - FLANGE
26 - O-RING
27 - WATER PIPE
28 - STRAP
29 - BOLT W/WASHER 8x14
30 - BOLT 8x25

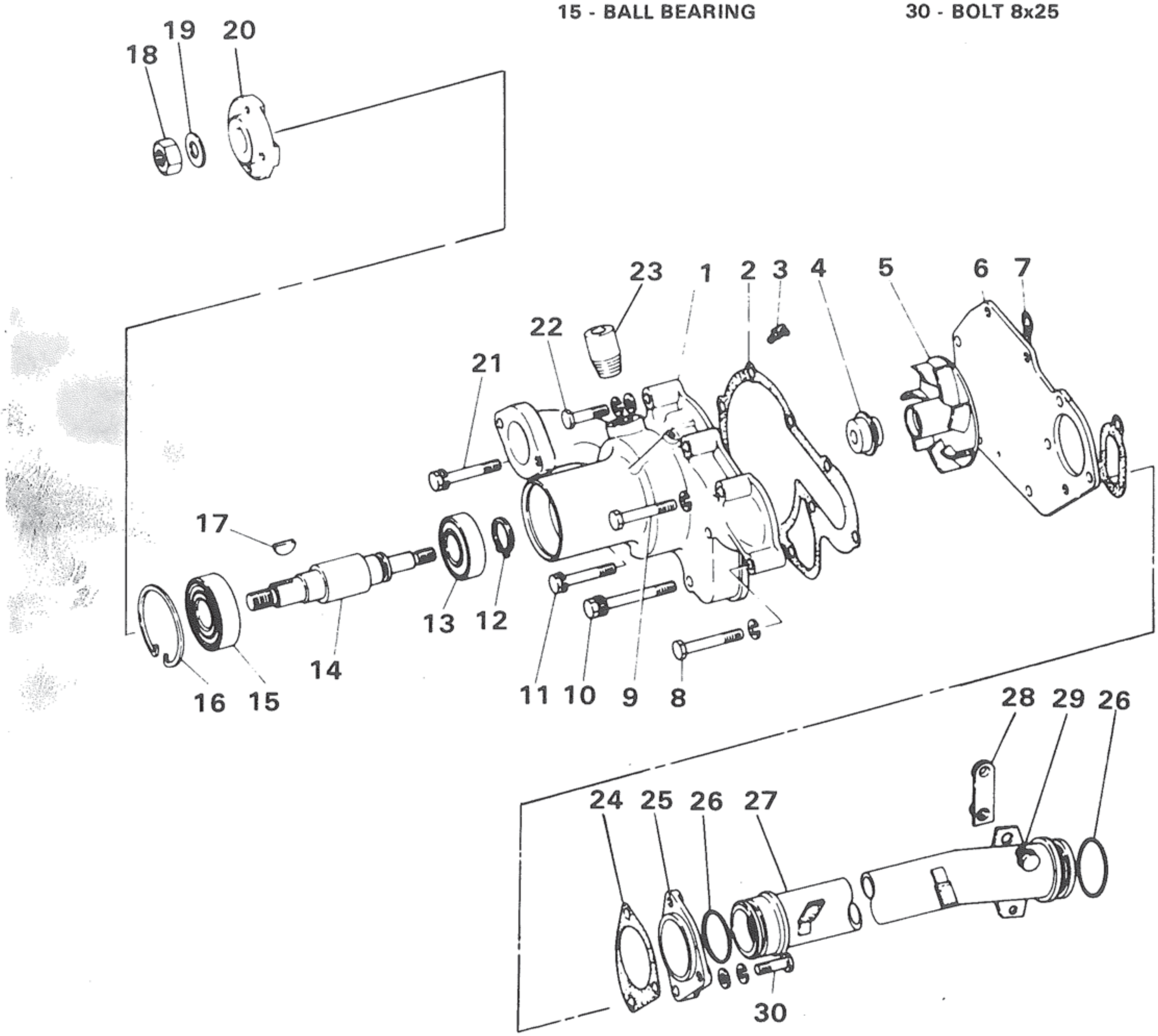


Figure 19. Fresh Water Pump Exploded View.

Section 8

ENGINE LUBRICATION SYSTEM

CONTENTS

Section 8

ENGINE LUBRICATION SYSTEM

GENERAL

A pressurized lubrication system with an externally mounted oil pump, driven by the camshaft, draws oil from the oil pan. A screen on the bottom of the pick-up tube in the oil pan strains the oil prior to entering the pump. Oil under pressure is conducted through external tubes to an oil cooler. A pressure sensing by pass valve in the oil pump stops the flow of oil to the oil cooler when a pressure differential of 2.0 kg/cm² is exceeded and directs the flow of oil to the filter.

A relief valve located downstream of the oil filter maintains engine oil pressure at no more than 4 kg/cm² by bypassing excess oil to the oil pan.

Internally, holes off the main oil gallery lead to the top of the main bearings and the bottom of the camshaft bearings. The crankshaft is drilled allowing oil to pass from main bearings to rod bearings.

The upper engine and timing gears receive oil through the front camshaft bearing. An oil jet located at the idler gear provides lubrication for the gear train. Oil is routed up through the block, head and up the front rocker shaft support to the rocker shaft. Holes at each rocker arm location supply oil to rocker arm bushings. A hole drilled in the top of the rocker arm sprays oil over the push rod end. Oil returns to the pan from the head through the pushrod holes lubricating tappets and cam lobes.

OIL PUMP

Description. The externally mounted oil pump is a positive displacement gear pump. Driven by the

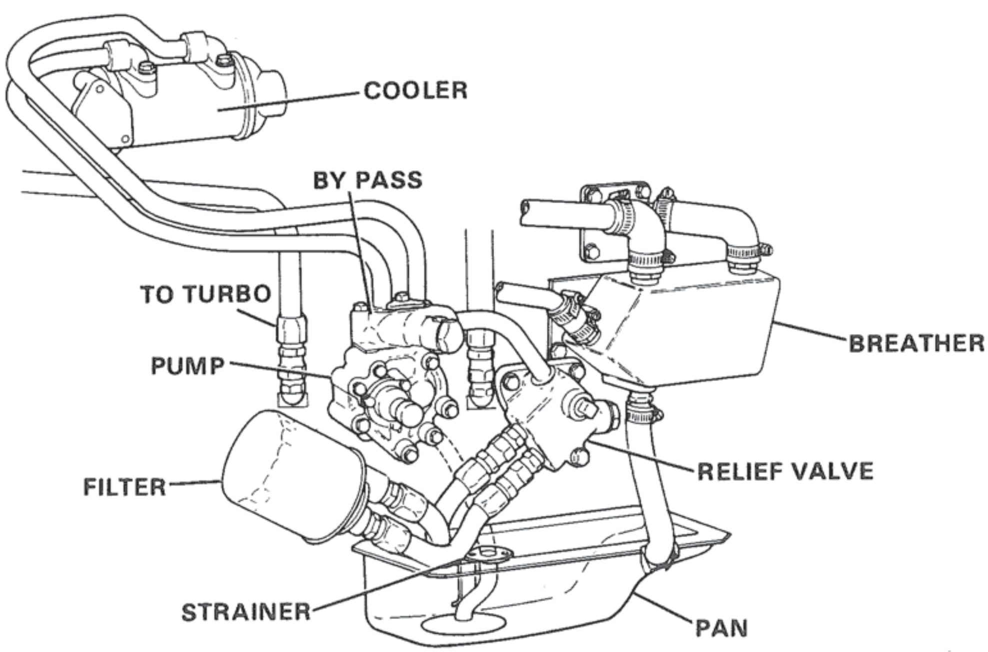


Figure 1. Lubricating System.

camshaft, it turns 1/2 crankshaft speed. At engine speeds above 1000 RPM, oil temperature 50° C (122° F) and oil pressure of 3 kg/cm^2 (42.7 p.s.i.), the pump supplies 32 lit./min. (8.4 gal./min.).

Removal.

1. Remove capscrew and retainer plate securing oil cooler lines to top of pump. Figure 2.

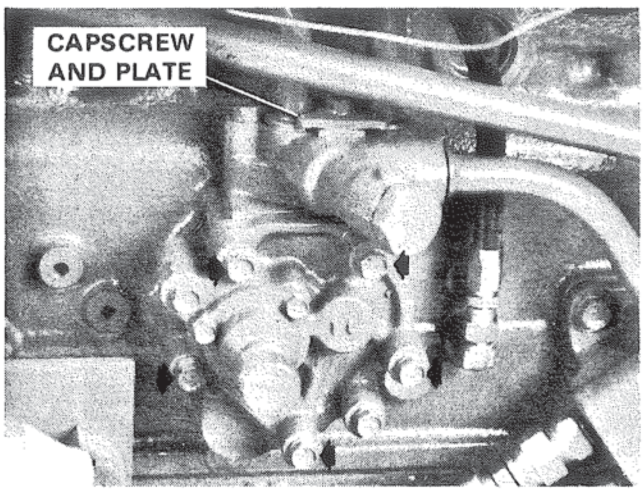


Figure 2. Removing Oil Pump.

2. Remove five (5) capscrews securing pump to crankcase. Figure 2.

3. Lift two (2) oil lines from top of pump and separate pump from crankcase. Turn pump to left enough to remove line leading to relief valve, pull pump from engine.

Disassembly.

1. Remove two (2) remaining capscrews holding pump cover to body, remove cover.

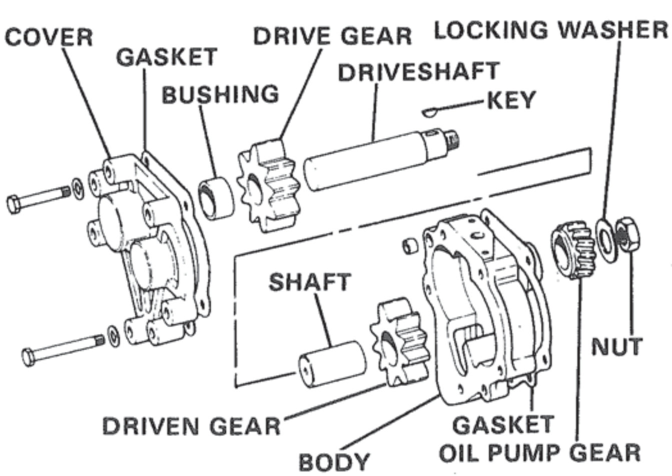


Figure 3. Oil Pump Assembly.

2. Remove nut, locking washer and oil pump drive gear from driveshaft.

3. Remove driven gear and drive gear with driveshaft.

Inspection and Repair. Inspect parts for visual defect and obvious wear. Put gears back in body.

1. Measure clearance between gears and body. Figure 4.

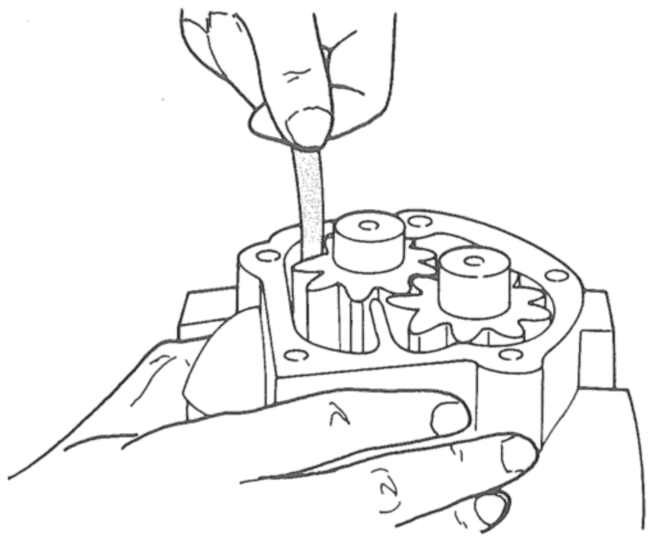


Figure 4. Measuring Gear to Body Clearance.

Clearance should be 0.11 to 0.20 mm. (.0043 to .0079 in.). If clearance exceeds 0.20 mm. (.0079 in.) replace body or gears.

2. Measure clearance between gear face and body face. Figure 5.

NOTE

Remove gasket and clean body face.

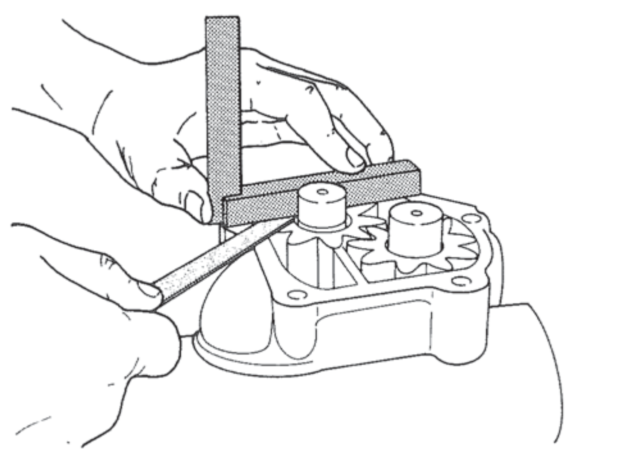


Figure 5. Measuring Gear Face to Body Face Clearance.

Clearance should be 0.02 to 0.15 mm. (.0008 to .0059 in.). If clearance exceeds 0.15 mm. (.0059 in.) measure gear height. Figure 6.

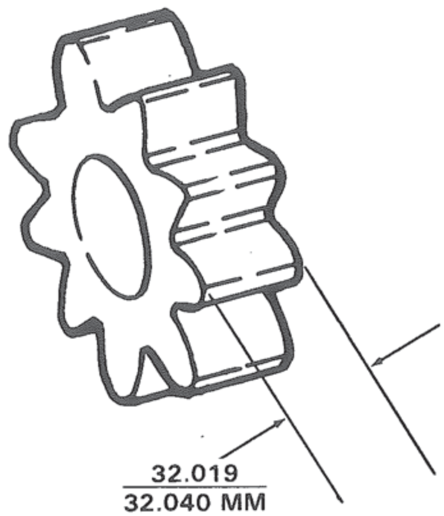


Figure 6. Measuring Gear Height.

Gear should measure 32.019 - 32.040 mm (1.888 - 1.889 in.). If gear is within tolerance, remove body.

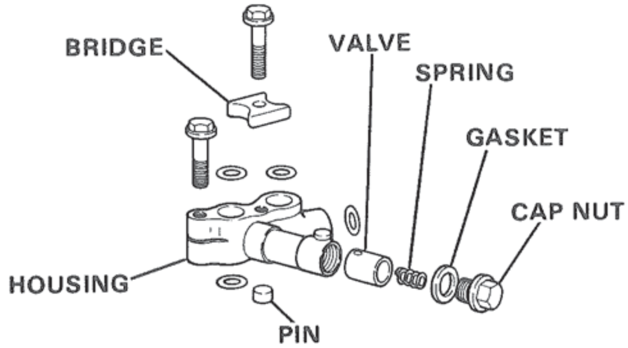
3. Measure driveshaft where it rides in cover bushing. Dimension should be 20.00 m. - 19.90 mm. If shaft is worn below 19.90 mm. replace shaft.

4. Measure I.D. of bushing in cover. Subtract driveshaft diameter from bushing I.D. Clearance should be 0.040 - -.15 mm. Replace bushing when clearance exceeds 0.15 mm.

5. Inspect gear backlash. Assemble gears to pump. Insert pump and engage with camshaft. Secure pump. Using a dial indicator measure backlash of oil pump gear with camshaft. Backlash should measure 0.08 to 0.40 mm. If 0.40 mm. is exceeded replace gear. Move dial indicator to driven (idler) gear. Measure backlash between drive gear and driven gear. Backlash should measure 0.13 to 0.60 mm. (0051 to 0236 in.). If 0.60 is exceeded replace gears.

6. Check oil cooler bypass valve opening pressure. Valve should open at 2 ± 0.3 kg/cm^2 (28.4 ± 4.27 in. lbs.). Pressure is adjusted by adding or removing shims. A 1 mm. (.0394 in.) shim added, increases or removed, decreases opening pressure by 0.177 kg/cm^2 (2.5 in. lbs.).

Reassembly. Thoroughly clean all parts and place in clean engine oil.



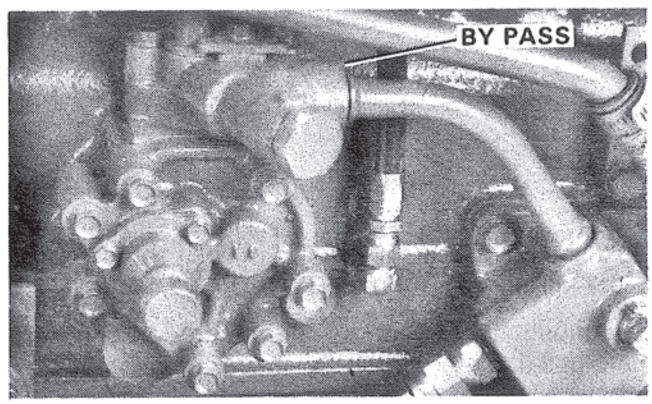


Figure 7. Checking Oil Cooler Bypass Valve.

1. Place driveshaft (with gear) in body.

2. Assemble gear and woodruff key to driveshaft. Place locking washer and nut on end of shaft, tighten nut and bend edge of washer up to secure nut.

3. Apply gasket sealant to both sides of body to cover gasket.

4. Place gasket and cover on body and secure with capscrews.

5. Place bypass valve on pump and secure.

RELIEF VALVE

Removal.

1. Remove three (3) bolts.

Disassembly.

1. Remove cap nut, then relief valve components.

Inspection and Repair.

1. Clean metal parts in solvent.

2. Discard gasket unless it is in near new condition.

3. Check spring for breaks, lack of tension.

1 - RELIEF VALVE HOUSING
2 - VALVE, RELIEF
3 - SPRING, RELIEF VALVE
4 - GASKET
5 - NUT, CAP
6 - GASKET
7 - BOLT 10 x 75
8 - BOLT W/WASHER 10 x 30

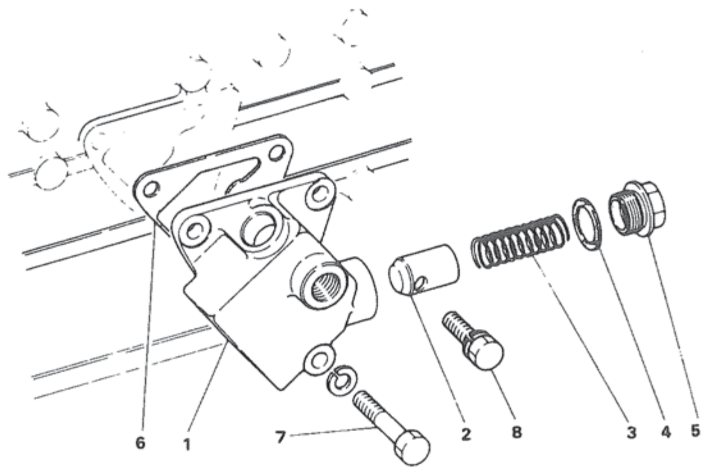


Figure 8. Relief Valve.

4. Check opening pressure of valve: it should be 4.0 $\pm$ 0.3 kg/cm^2 (57 $\pm$ 4 p.s.i.).

5. Adjust, if needed, by shimming; oil pressure changes 0.18 kg/cm^2 (2.5 p.s.i.) with each shim.

Reassembly.

1. Assemble valve, spring, gasket and secure with cap nut.

Installation.

1. Secure relief valve housing to block with three (3) screws and washers.

OIL PICKUP

The oil pickup tube is located inside the oil pan and is assembled to the bottom of the crankcase. The pickup is equipped with a replaceable wire mesh strainer which removes larger contaminants from the oil.

Removal.

1. Drain engine oil and remove oil pan.

2. Remove two (2) capscrews securing pickup tube to crankcase.

Disassembly.

1. Remove retaining ring securing screen, remove screen.

Inspection and Repair.

1. Clean parts in solvent.

2. Inspect screen and tube for damage. Replace if damage is found.

Reassembly.

1. Place screen in bottom of pickup and secure with retaining ring.

OIL COOLER

Correct oil temperature is maintained by the oil cooler. Oil leaves the oil pump and is piped directly to and through the oil cooler. The cooler, mounted at the left rear of the engine is connected directly to the water pump via a pipe.

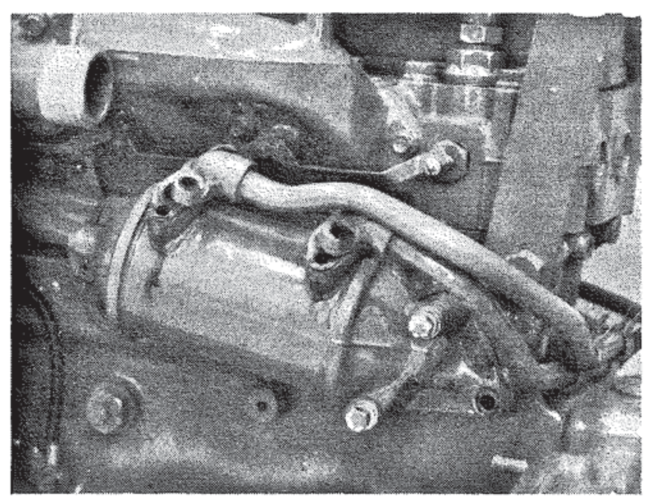


Figure 9. Removing Oil Cooler.

Maintenance of the oil cooler includes cleaning and pressure testing.

Removal.

1. Remove capscrews securing oil lines to cooler and three (3) capscrews securing cooler to engine. Figure 9.

Disassembly.

1. Scribe lines from end covers to body for aid in reassembly.

2. Remove center bolt and pull end covers from body.

Inspection and Repair.

1. Clean in solvent. Scale or rust present can be removed using a commercial cooling system cleaner. (Follow manufacturer's instructions.)

2. Pressure test cooling tubes. Replace end caps using new O-rings at each end.

CAUTION

In the following tests, do not exceed air pressures given, damage to cooler may result.

A. Plug one water inlet and apply 3.0 kg/cm² (42 p.s.i.) air pressure to the other end. Submerge cooler in water and observe oil openings for air bubbles.

B. Remove cooler from water, drain all water from cooler.

C. Plug one oil inlet and apply 15 kg/cm² (213 p.s.i.) to the other Submerge in water and observe water openings for air bubbles.

D. If air bubbles are observed in either test replace cooler.

Reassembly.

1. Loosely assemble cooler.

2. Remove **all** water from oil chamber.

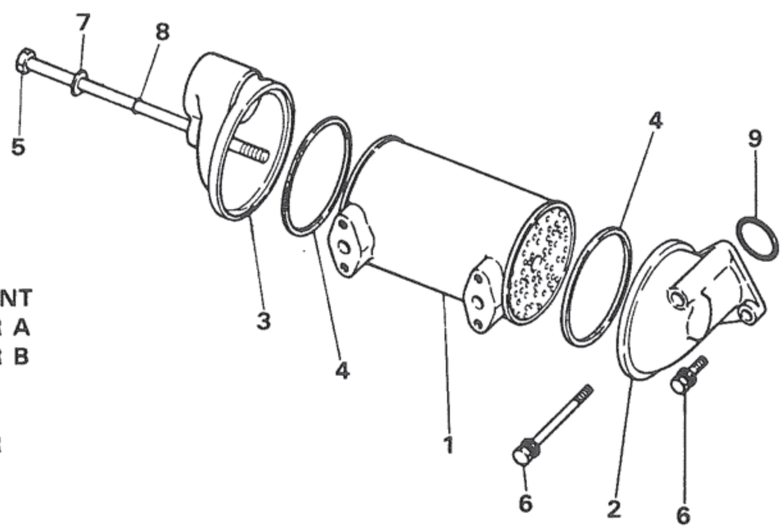
3. Insert a new O-ring in mounting flange groove of rear cover.

4. Slide fresh water tube into front cover and position cooler on engine. Secure with capscrews.

5. Tighten center bolt.

6. Start engine. Allow engine to run at low idle and check cooler for leaks.

7. Check oil level and closed coolant system level. Add as required.



1 - OIL COOLER ELEMENT
2 - OIL COOLER COVER A
3 - OIL COOLER COVER B
4 - PACKING
5 - CENTER BOLT
6 - BOLT AND WASHER
7 - PLAIN WASHER
8 - O-RING
9 - O-RING

Figure 10. Oil Cooler Assembly.

Notes:

Section 9

AIR INTAKE AND EXHAUST SYSTEM

CONTENTS

Section 9

AIR INTAKE AND EXHAUST SYSTEM

NATURALLY ASPIRATED

General. The naturally aspirated air intake and exhaust system consists of three (3) major components; air cleaner, intake manifold and water jacketed exhaust manifold.

TURBOCHARGED

General. The turbocharged intake and exhaust system consists of five (5) major components; air cleaner, turbocharger, intercooler, intake manifold and water jacketed exhaust manifold.

Air Cleaner. Both engine versions use the same air cleaner assembly. An expanded metal frame provides support for a foam element.

Maintenance and service instructions for the air cleaner are found in Section III - Operation.

TURBOCHARGER

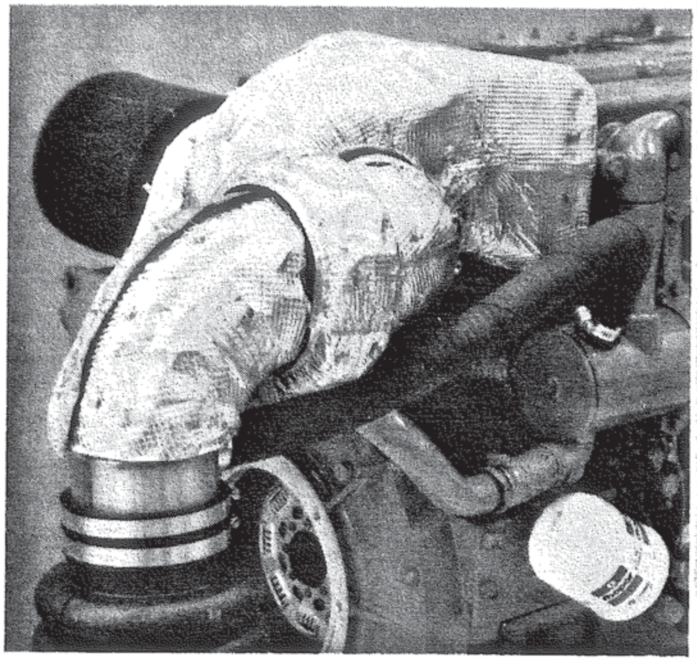
General. The turbocharger located at the rear of the engine is mounted to a cast iron duct attached to the outlet of the exhaust manifold. The main center housing supports a shaft with a turbine wheel on the exhaust side and compressor wheel on the intake side. The shaft runs in pressure lubricated bearings. Removable compressor and turbine housings are attached to either side.

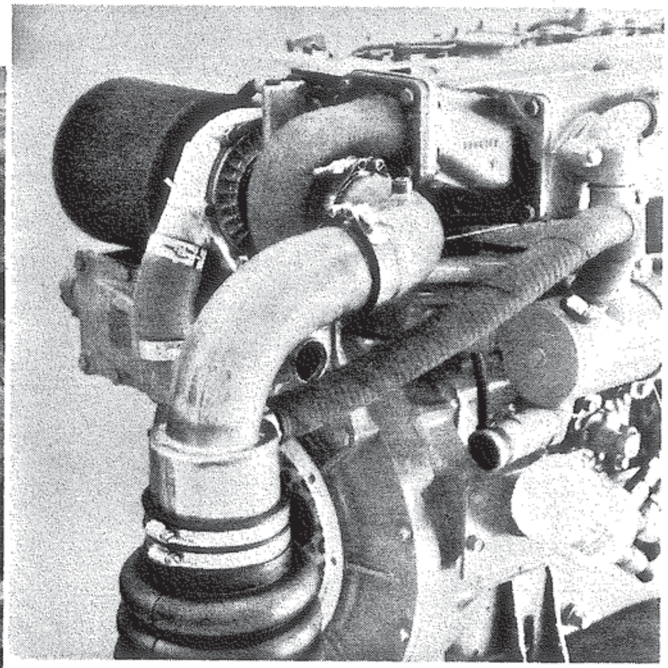
Principles of Operation. Exhaust gas flows into the turbine side of the turbocharger. Exhaust gas pressure and heat energy extracted from the gas rotates the turbine wheel and shaft, causing the compressor wheel attached to the opposite end to rotate. Cooled and expanded exhaust gas leaves the turbocharger through the turbine housing and enters the exhaust system. Rotation of the compressor wheel draws air through the air cleaner into the compressor housing where the air is compressed and delivered under pressure (8-15 p.s.i.) to the intake manifold.

Intake manifold pressure (boost pressure) varies with compressor speed which varies with engine speed.

Higher engine speed = higher compression speed = higher boost pressure.

Higher boost pressure means a greater volume of air being delivered to the engine which allows delivery of more fuel resulting in more power.





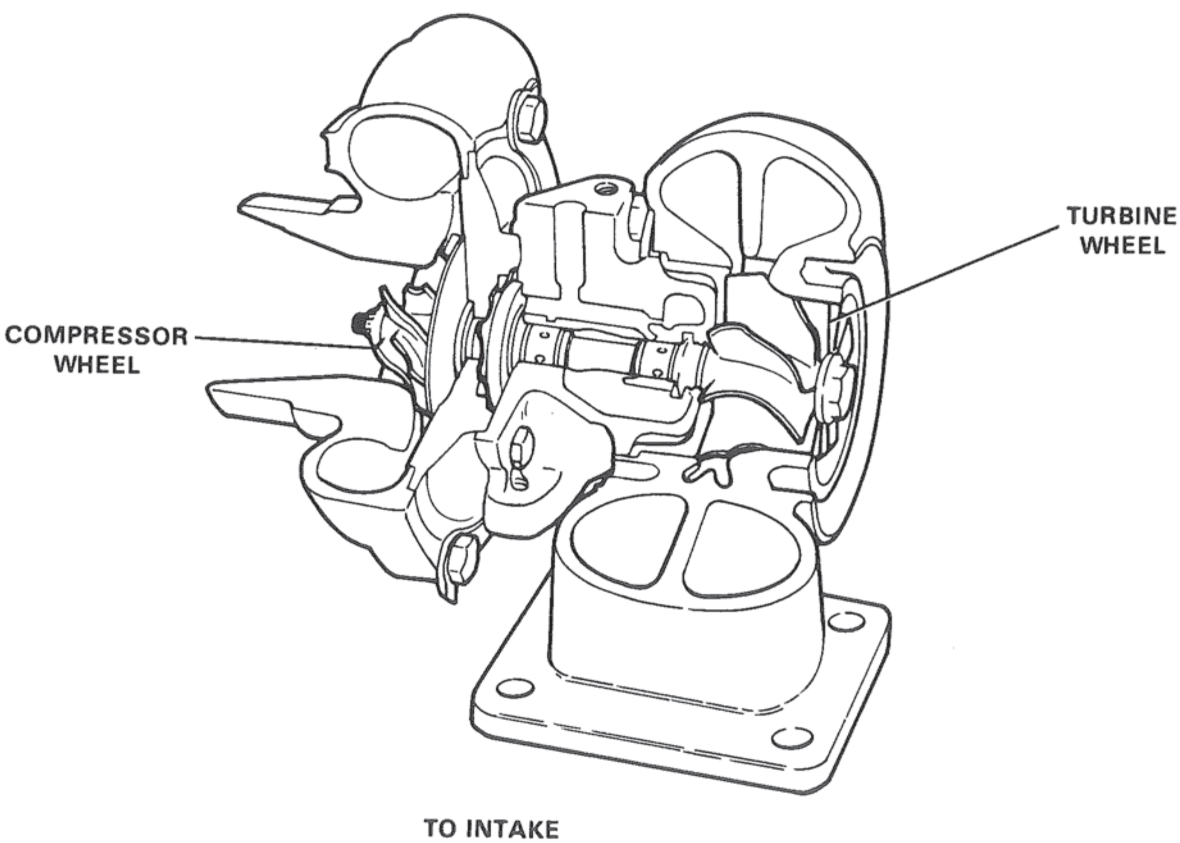


Figure 1. Turbocharger (TI).

Turbocharger Failure.

It is extremely important to find the exact cause of turbocharger failure as soon as it happens; and in all cases before installing a replacement.

CAUTION

If cause of failure is not found, failure often reoccurs and may result in costly engine damage.

Major Causes of Turbocharger Failure.

1. Foreign material in either the exhaust or air induction systems.
2. Lack of lubrication and/or oil lag.
3. Foreign material or dirt in lubrication system.
4. Oil oxidation or oil breakdown.

Foreign Material in Exhaust or Air Induction Systems.

1. Foreign material causes damage because of the extremely high speed of turbine and compressor wheels. Small particles (such as sand) erode the leading edges of the blades. Large hard particles tend to rip or tear the blades. Soft material, such as shop towels or rubber, roll the blades back.

Thorough cleaning of the exhaust manifold is essential.

NOTE

Small spots of carbon can indicate large leaks. All exhaust connections must be tight.

2. It is extremely important to service the turbocharger air inlet system carefully. Be sure that no foreign objects are in the piping and that all air connections are in place and secure.

NOTE

Carbon particles will deposit on oily surfaces of turbo and intercooler. A clogged intercooler will eventually cause a loss of RPM and black smoke.

Compressor wheel damage can throw and imbed pieces of metal in the air filter element. If air filter element is not changed, metal pieces can shake out and fail another turbocharger.

Lack of lubrication and oil lag.

1. This type of failure occurs when the oil pressure and flow is not sufficient to:

A. Lubricate the journal and thrust bearings.

B. Stabilize the shaft and journal bearings.

C. Reach bearings before unit is accelerated to high speeds.

2. Turbocharger bearings need for oil increases with turbocharger speed and engine load. Insufficient oil to the turbocharger bearings for periods as short as a few seconds during heavy load cycle when shaft speed is high will cause bearing failures.

Foreign Material or Dirt in Lubrication System.

1. Operating an engine with contaminated or dirty oil is costly to both turbocharger and engine. *The engine does operate with unfiltered oil:*

A. In cold weather when engine oil is congealed — filter bypass can be open.

B. When oil filter is clogged — bypass can be open.

C. Filter bypass valve can stick in open or partly open position.

D. Filter element can be ruptured.

E. Filter element improperly installed.

2. Contaminated or dirty oil fails turbocharger bearings sooner than engine bearings because the turbocharger shaft rotates at a much higher speed. When this happens, the cause should be found and corrected before installing a replacement turbocharger. If not, a second turbocharger failure and extensive engine damage are likely.

Check oil samples at oil filter change periods to help prevent this type failure.

Oxidation or Oil Breakdown. Oxidation and/or breakdown of engine oil creates sludge. Primary causes are engine overheating, excessive piston blowby, mixing non-compatible oils, engine coolant leaking into oil, wrong grade or quality of oil and ignoring proper oil and filter change intervals.

Sludge affects turbocharger performance, life, and engine life.

Centrifugal action of the turbocharger shaft throws oil against internal walls of the center housing where sludge particles accumulate. Sludge restricts oil drainage from turbine end journal bearing causing turbine seal leakage. Deposited sludge at the turbine end becomes coked (baked) and very hard from high temperatures in this area. This hard coke can flake off and begin wearing the turbine end journal bearing and bearing bore, but usually turbine seal leakage occurs first. Shaft rotation may or may not be affected.

Inspect center housing by looking through the oil drain opening. Sludge will appear on the shaft between the bearing journals and in the center housing from oil drain opening back to the turbine end. In these cases, turbocharger can often be repaired by disassembling, cleaning and installing a repair kit.

NOTE

When oil leakage is noted at turbine end of the turbocharger, always check turbocharger oil drain tube and engine breather for restriction. Correct before working on the turbocharger.

When sludged engine oil is found, engine oil and oil filter must be changed.

Troubleshooting a Turbocharged Engine System. A turbocharger does not change operating characteristics of an engine. The turbocharger's only function is to supply a greater volume of air to the engine so that more fuel can be burned to produce more power. A turbocharger is not a power source within itself. It functions only as dictated by flow, pressure and temperature of engine exhaust gas.

A turbocharger will not overcome malfunctions or deficiencies in the engine fuel system, timing, plugged air cleaners, loose intake or exhaust connections, valve problems, scored pistons and liners, etc. If a turbocharged engine has malfunctioned and the turbocharger is operational troubleshoot as though the engine were non-turbocharged.

Noise. Each turbocharged engine system has its own distinctive sound or noise level. In many cases, malfunctions can be detected when this noise level changes. If noise level changes to a higher pitch it can indicate an air leak between air cleaner and engine or a gas leak in the exhaust system between turbocharger and engine. Noise level cycling can indicate plugged air cleaner or restriction in front of the turbochager air inlet or heavy dirt build up in the compressor housing and on compressor wheel. Sudden reduction in noise level with black or blue smoke, and oil leakage indicates complete failure.

Noise Check. With engine running, check turbocharger for uneven noise and vibration. If found shut down engine and proceed to "Inspection" below. If there is no abnormal noise and vibration, check further under troubleshooting guide in this section.

If no oil, dirt or sludging is appears proceed to troubleshooting air system in this section.

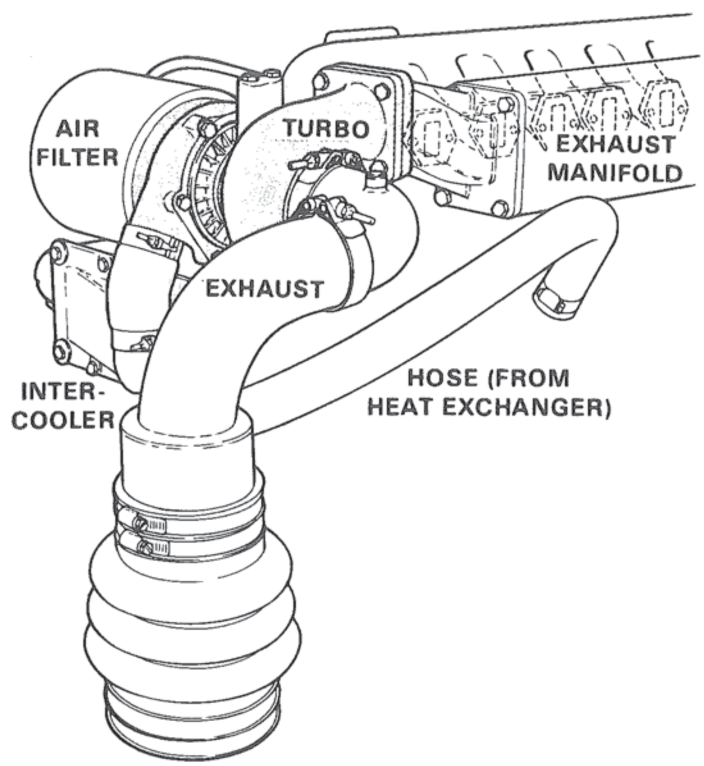


Figure 2. Air Intake and Exhaust System.

Inspection.

1. Remove inlet and exhaust tubing from turbocharger.

2. Inspect both wheels for blade damage caused by foreign material. The compressor wheel is easily inspected by looking through the compressor housing air inlet opening. A light is necessary when examining the turbine wheel blade tips, they are inside the turbine housing and you have to look between the turbine wheel blades from the exhaust outlet end of the turbine housing.

3. Examine outer blade tip edges (both wheels) adjacent to housing bores and check for wheel rub.

4. Rotate shaft wheel assembly by hand, check for drag or binding conditions. Push shaft side to side, rotate to feel for rub.

5. Lift up both ends of the shaft at the same time, feel for excessive journal bearing clearance. If clearance is normal, very little shaft movement will be detected. If shaft is rocked up and down from one end only, normal bearing clearances (.003-.006) could incorrectly be indicated at .015-.020. Shaft end play is measured without removing the turbocharger from the engine.

6. If the shaft assembly rotates freely, no wheel damage, binding or rubs have been noted, the turbocharger is serviceable.

DISASSEMBLY

NOTE

Serviceable turbochargers are often removed from engines before cause of malfunction has been determined. Inspect before removing.

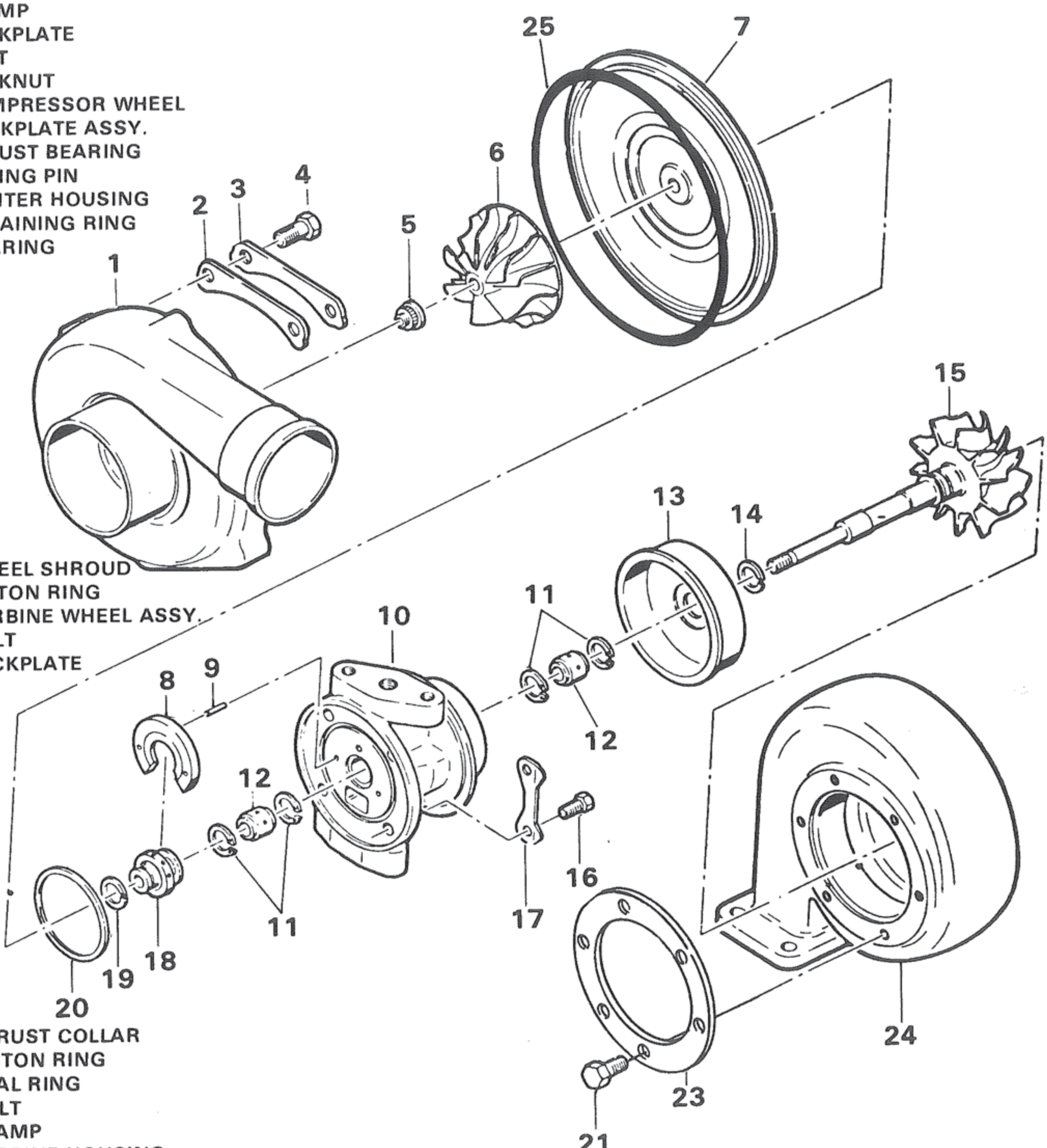
Disassemble turbocharger following sequence of index numbers. Figure 3.

A. Clean exterior of turbocharger with cleaning solvent before disassembly.

B. Match-mark compressor housing (1), turbine housing (24), and center housing (10) with a punch or scribe to assure correct reassembly.

C. Bend down tabs of lockplates (3 and 17), remove bolts (4 and 16), lockplates (3 and 17), clamp (2), and housings (1 and 24).

1 - COMPRESSOR HOUSING
2 - CLAMP
3 - LOCKPLATE
4 - BOLT
5 - LOCKNUT
6 - COMPRESSOR WHEEL
7 - BACKPLATE ASSY.
8 - THRUST BEARING
9 - SPRING PIN
10 - CENTER HOUSING
11 - RETAINING RING
12 - BEARING



13 - WHEEL SHROUD
14 - PISTON RING
15 - TURBINE WHEEL ASSY.
16 - BOLT
17 - LOCKPLATE

18 - THRUST COLLAR
19 - PISTON RING
20 - SEAL RING
21 - BOLT
23 - CLAMP
24 - TURBINE HOUSING
25 - O-RING

Figure 3. Turbocharger.

TROUBLESHOOTING

Problem	Possible Cause	Test Procedure/Remedy
1. Oil on Housing or on Wheel	1. Excessive engine idling	1. Avoid excessive idling
A. Compressor End	2. Seal leak	
	A. Air lack (Restriction, air cleaner to compressor; duct loose, compressor to intake manifold; leak or crack, intake manifold)	A. Clean, tighten or repair
	B. Oil block (Turbo drain line or crankcase breather)	B. Remove restrictions
	C. Wear (Compressor wheel, housing or bearings)	C. Disassemble, repair
	3. Air cleaner restriction	3. Clean or replace air filter
	4. Oil viscosity wrong	4. Replace oil
	5. Excessive blow by (oil carry over)	5. Replace ring, valve guides.
B. Turbine End	1. Excessive engine idling	1. Avoid excessive idling
	2. Seal leak	
	A. Oil excess or block (Pre oiling excess; turbo drain line or crankcase breather block)	A. Restore oil to proper level, remove restrictions
	B. Exhaust system block	B. Remove blocks
	C. Dirt (Center housing, coked or sludged; carbon behind turbine wheel)	C. Disassemble, clean and repair
	D. Turbo bearings worn (Oil supply poor)	D. Replace worn bearings, ensure oil quality, viscosity and supply
2. Turbocharger Noisy	1. Air intake and exhaust system blockage	1. Clean system, make sure all fittings are tight
	2. Turbo binding	
	A. Dirty or damaged turbo parts	A. Clean and repair
	B. Oil quality poor or oil blocked	B. Check for cause or contamination, replace oil

Problem	Possible Cause	Test Procedure/Remedy
3. Parts Damaged or Worn		**NOTE** Replace damaged parts.
A. Bearings	1. Oil supply or quality poor	1. Replace bearings, find cause of problem, change oil
B. Compressor Wheel	1. Air intake contaminated	1. Clean, tighten air intake system
	2. Turbo mounting loose	2. Tighten mounting
	3. Dirt on compressor housing	3. Repair housing
	4. Bearings worn	4. See problem 3A above.
C. Turbine wheel	1. Exhaust system, foreign object.	1. Clean system
	2. Turbo mounting loose	2. Tighten
	3. Dirt, damage (Carbon behind turbine wheel; center housing, coked, sludged; turbine housing damaged)	3. Clean and repair
	4. Exhaust temperature high, engine overfueled	4. Correct overfueling condition
	5. Bearings worn	5. See problem 3A above.
4. Center Housing Coked, Sludged	1. Oil quality poor or turbo drain line, crankcase breather blocked	1. Remove blocks, replace oil
	2. Coolant leak into crankcase	2. Repair
	3. Exhaust temperature high, engine overfueled	3. Correct overfueling condition
5. Dirt Deposition on Compressor Wheel	1. Exhaust leak due to leaky gasket	1. Clean system, replace with new gaskets
	2. Exhaust leak from turbine joint between center housing and turbine housing.	2. Tighten bolts

CAUTION

Use care when removing compressor housing to avoid damaging compressor wheel blades.

D. Clamp a 3/4 in. socket or box wrench in a vise and place the hex end of the turbine wheel assembly (15) in the socket or wrench.

NOTE

A turbine wheel assembly holding fixture can be fabricated and used during removal of locknut (5).

E. Hold center housing and rotating assembly in the vertical position, use a double universal socket wrench to avoid placing bending loads on turbine wheel shaft, remove locknut (5).

F. Lift compressor wheel (6) from shaft of turbine wheel assembly (15). Remove turbine wheel assembly with piston ring (14) from center housing (10). Remove piston ring from turbine wheel assembly.

G. Straighten tabs of lockplates (17) and remove bolts (16), lockplates (17), and backplate assembly (7).

NOTE

If necessary, lightly tap backplate assembly with a lead or brass hammer to remove it from center housing.

H. Do not disassemble backplate assembly (i.e., remove the spring pressed into the backplate counterbore).

I. Do not remove pins (9) from center housing (10) unless replacement of pins is required.

Cleaning.

NOTE

Before cleaning parts, inspect for burning, rubbing, or other damage that might not be evident after cleaning. Refer to Troubleshooting if evidence of such damage is found.

Clean all parts in a non-caustic cleaning solution. Use a soft bristle brush, a plastic blade scraper, and dry compressed air to completely remove accumulated surface matter.

CAUTION

Do not use abrasive cleaning methods which might damage or destroy machined surfaces.

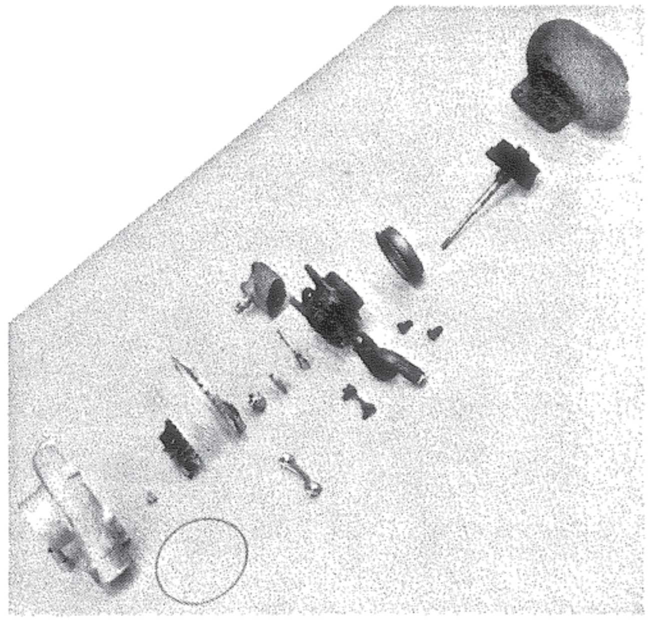


Figure 4. Turbocharger.

Carefully check turbine-end oil cavity of center housing and remove all carbonized oil. Figure 5. If center housing includes an oil squirt hole, Figure 6, make sure that the hole is free of carbonized oil or other foreign material. If hole is blocked, clear by running a wire through it, which is of the same diameter as the hole.

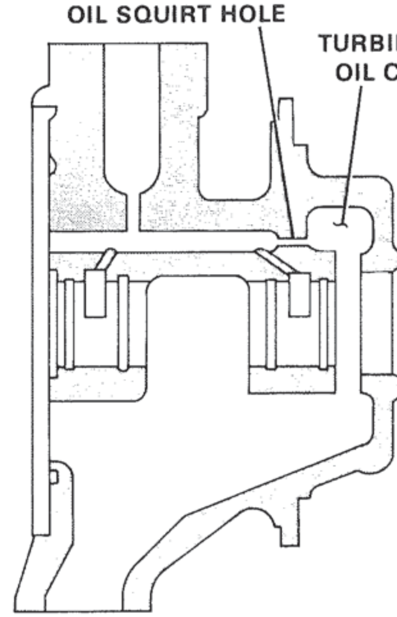


Figure 5. Sectional View of T04/T04B Center Housing.

Inspection.

1. Inspect all bolts for worn, stripped, or crossed threads and corrosion. Threads must be free of corrosion.

2. Inspect compressor housing for damage caused by rubbing of the compressor wheel. Check compressor housing mounting flange for nicks, dents, or warping that could prevent proper sealing with the backplate assembly. Check all tapped holes for worn, stripped, or crossed threads and corrosion. Check counterbore that mates with backplate assembly for nicks, dents, or warping that could prevent proper sealing with the backplate assembly.

3. Check compressor wheel nut for cracks, and nicked, worn, stripped, or crossed threads.

4. Check compressor wheel for blade damage due to rubbing on compressor housing, erosion of blade tips due to ingestion of dirt and sand into the compressor, and for foreign object impact.

5. Check turbine wheel assembly for the following:

A. Blade damage due to rubbing on the turbine housing.

B. Blade damage due to impact with foreign objects expelled from the engine and ingested by turbine.

C. Blade tip erosion. Blade tip thickness must not be less than 0.025 in.

D. Excessive wear of piston ring groove. The ring groove must be free of step wear, and width of the groove must not exceed 0.0735 in.

E. Excessive wear of wheel hub adjacent to the piston ring groove. Hub diameter must not be less than 0.681 in.

F. Excessive wear of bearing journals. The diameter of the journals must not be less than 0.3994 inch, and the maximum out-of-roundness must not exceed 0.0001 inch.

G. Nicked, worn, stripped, or crossed threads.

6. Check wheel shroud for damage due to rubbing of the turbine wheel, for erosion, and for warping.

7. Inspect the backplate assembly for the following:

A. Worn or damaged backplate bore. The diameter of the bore between the piston ring operating area (smaller diameter) and the compressor wheel must not exceed 0.5010 in., entire bore must be free of scratches and scores.

B. Loose or damaged thrust spring. Spring must be securely pressed into the backplate counterbore, and be free of cracks, corrosion, or surface damage from contact with thrust bearing.

C. Cracked or warped backplate. The backplate-to-center housing mounting surface must be flat within 0.0005 in. total indicator reading.

8. Inspect thrust bearing for scratching, scoring, galling or excessive wear of bearing surfaces. Bearing face that mates with center housing and bearing surfaces that mate with the thrust collar must be flat within 0.003 total indicator reading. Inspect bearing bore for wear or damage caused by contact with bottom of bearing groove in thrust collar as a secondary result of extreme journal bearing wear and radial shaft motion. The diameter of the bore must not exceed 0.430 in. Check oil passages in thrust bearing for clogging with dirt or other foreign material. Oil passages must be clean and free of all obstructions.

9. Inspect thrust collar for the following defects.

A. Scratching, scoring, galling, or excessive wear of the sides and bottom of thrust bearing groove. Sides of groove must be free of surface defects, must have a surface finish of 16 microinches AA or better, and must be parallel to the collar face that is installed toward center housing. Width of groove must not exceed 0.1752 in. Diameter of bottom of groove must not be less than 0.370 in.

B. Step wear of the piston ring groove. The width of the groove must not exceed 0.066 in.

C. Scratching, scoring, galling or excessive wear of the thrust collar end surfaces. End surfaces must be free of surface defects, and must be parallel within 0.0001 in. total indicator reading.

10. Inspect center housing bores for wear or damage. All bore surfaces must be free of scratches and scores. Diameter of journal bearing bores must not exceed 0.6228 in. Diameter of standard turbine-end seal bore must not exceed 0.703, and diameter of stepped turbine-end seal bore must not exceed 0.713 in.

Repair and Replacement. One hundred percent replacement of parts listed in Table 1 at each overhaul is recommended, or whenever these parts are removed.

Repair or replace all other parts and assemblies as follows:

A. Clean wheel rub from compressor housing, using silicon carbide abrasive cloth. If more than light clean-up of damaged area is required, replace the housing.

B. Replace all parts that do not meet inspection requirements.

Part Nomenclature	Index Numbers
Bolt	4, 16
Lockplate	3, 17
Seal ring	20
Piston ring	14, 19
Retaining ring	11
Bearing	12

Table 1. Parts to be Replaced 100 Percent At Overhaul or Disassembly.

Reassembly. Reassemble turbocharger in reverse sequence of disassembly, observing the following:

A. Fill the piston ring groove in turbine wheel assembly (15) with high vacuum silicon grease (manufactured by the Dow Corning Corporation, Midland, Michigan); then install piston ring (14) on turbine wheel assembly.

CAUTION

Do not force the piston ring into the center housing bore, this part is easily broken.

B. With piston ring and shroud (13) installed on turbine wheel assembly, carefully guide wheel assembly shaft through bearings (12) to avoid damaging bearing bores. Start the piston ring into bore of center housing by gently rocking turbine wheel; then slide shaft into center housing as far as it will go.

C. Engage serrated end of the turbine wheel assembly in a 3/4 in. socket or box end wrench clamped in a vise, or install turbine wheel assembly in a holding fixture.

D. Start thrust collar (18) on shaft of turbine wheel assembly; then install thrust bearing (19) in groove of collar, slide the assembled parts down against center housing so pins (9) engage holes provided in thrust bearing.

E. Install backplate assembly (7) over shaft of turbine wheel assembly and carefully guide piston ring (14) into backplate bore. This can be accomplished easily if the ring gap is started into the bore first.

CAUTION

Do not force the piston ring into the backplate bore, this part is easily broken.

F. Align bolt holes in backplate assembly with bolt holes in center housing, and install bolts (16) with lockplates. Tighten bolts to 75-90 in. lbs.; bend tabs of lockplates up against the bolts.

G. Install compressor wheel (10) on shaft of turbine wheel assembly.

CAUTION

Tighten the locknut using a socket wrench with a double universal joint to avoid imposing bending loads on turbine wheel assembly shaft.

H. Make sure that front face of compressor wheel and washer face of locknut (5) are clean and smooth. Apply a light coat of oil to threads and washer face of locknut; then install locknut on shaft and tighten to 18-20 in. lbs. above drag torque required to bottom locknut.

NOTE

Bottoming of locknut will be indicated by a sharp increase above drag torque observed while running nut down.

I. After nut has been torqued to 18-20 in. lbs., it must be tightened an additional 90°. This stretches the shaft 0.0055-0.0065 in. for proper installation of compressor wheel.

J. Apply a coat of Fel-Pro (manufactured by Fel-Pro Incorporated, Skokie, Illinois) or equivalent high temperature compound to the threads of bolts (21) before installation.

CAUTION

Looseness of turbine housing can result in damage to the turbine wheel sufficient to require replacement of the turbine wheel assembly.

K. After attaching turbine housing (24) to center housing and rotating assembly, tighten bolts (21) just enough to prevent turbine wheel from contacting housing, but loose enough to permit the turbine housing to rotate. Do not bend up tabs of lockplates at this time.

CAUTION

Looseness of compressor housing can result in damage to the compressor wheel sufficient to require replacement of the wheel.

L. Orient assembled parts so compressor wheel is facing up, and install compressor housing (1) on backplate assembly. Install clamps (2), lockplates (3), and bolts (4). Tighten bolts just enough to prevent the housing from contacting compressor wheel, but loose enough to permit compressor housing to rotate.

M. Align turbine and compressor housing and center housing match marks. Tighten bolts to 100-130 in. lbs. Bend tabs or lockplates up against bolt head.

Prelubrication.

CAUTION

Turbochargers must be prelubricated after overhaul or failure may occur.

Lubricate turbocharger that will not be used immediately, as follows:

A. Pour 4-5 ounces of clean lubricating oil into oil inlet port of center housing.

B. Turn compressor wheel and turbine wheel assembly by hand a minimum of ten (10) revolutions to coat all bearing and journal surfaces with oil.

C. Rotate complete turbocharger about its vertical and longitudinal center lines as required to coat all interior surfaces of the unit with oil.

D. Drain excess oil from turbocharger through both oil inlet and outlet ports of center housing.

Prelubricate turbocharger as follows:

A. Check that oil inlet and oil drain lines are clean; hoses are not hardened and that inner lining has not deteriorated or started to flake off (if metal tubing is used, check that it is not restricted or collapsed).

B. Make certain that engine oil is clean and at operating level.

C. Pour 3-4 ounces of clean lubricating oil into oil inlet port.

D. Disconnect air inlet duct from compressor housing, and turn compressor wheel by hand a minimum of ten (10) revolutions to coat all bearing and journal surfaces with oil.

E. Position a container under disconnected oil supply line and purge air by cranking engine until there is a steady flow from the oil supply line.

F. Reconnect oil supply line to oil inlet port of center housing.

G. Add an equivalent amount of clean lubricating oil to the crankcase and discard oil caught in the container.

H. Reconnect air inlet ducting to the compressor housing.

I. Start the engine and operate at low idle speed for 3-4 minutes to allow engine oil pressure and flow to stabilize.

J. Check all oil connections for leakage.

Initial Run-in Procedures. If engine is broken in, no initial run-in procedures are required. However, if engine is new or newly overhauled, a screen of 100 mesh or finer must be installed in the oil supply line to turbocharger during engine run-in period. This must be done to ensure that no metal particles from the engine are introduced into turbocharger lubrication system.

CAUTION

Do not leave screen in place following initial run-in period, cleaning of screen is not provided for in normal periodic maintenance procedures for the engine. Operation of turbocharger with a clogged filter screen would result in failure of the turbocharger due to lack of lubrication.

CAUTION

Follow precautions below when oil and filters are changed:

1. Crank engine without starting until filter and oil system is filled and a steady oil pressure is shown on the gauge, or start and run engine at low idle long enough to obtain a steady oil pressure reading, otherwise, a bearing failure may result due to lack of lubrication. Priming oil filters with clean oil will reduce engine cranking time.

2. After long periods of engine inoperation and after engine oil and filter changes, follow prelubrication procedures.

3. Operating engine on an incline with low oil level or any other condition that will cause the oil pump to pick up air, or cause a severe drop in oil pressure for a few seconds can cause turbocharger failure.

AIR SYSTEM CHECKS

Engine Not Running.

1. Check air cleaner for restricted condition.

2. Check all hose clamps for tightness. (Exhaust, gasket and ring clamps.)

3. Check intake manifold gaskets.

4. Check hoses for cracks or deterioration.

WARNING

Do not place hands or fingers near the turbocharger air inlet bore while engine is running. Air pressure drop at this location can draw fingers into the compressor wheel blades and cause injury.

1. Check air tube and connections between air cleaner and turbocharger by lightly spraying connections with starting fluid. Leaks are indicated by increase in engine speed.

2. Check air leaks between turbocharger and engine by feel and application of a light weight oil or soap suds on intercooler crossover tube, connections and hoses.

Exhaust gas leakage between engine block and inlet to turbocharger will also create a noise level change and reduce turbocharger performance. Check exhaust system as follows:

1. Check manifold gaskets for leakage.

2. Check manifold retaining bolts for tightness.

3. Check manifold for cracks or porosity.

4. Check turbocharger inlet gasket for leaks.

5. Check turbocharger inlet flange bolts for tightness.

Exhaust gas leakage is detected by heat discoloration in the area of the leak and soot at exhaust elbow clamps.

INTERCOOLER

General. The intercooler located at the rear of the engine is connected by air hoses between the turbocharger compressor outlet and intake manifold and water hoses between the heat exchanger and transmission cooler.

Principle of Operation. Raw water enters the intercooler core after leaving the heat exchanger. While passing through the intercooler it removes heat from the compressed (turbocharged) air passing around the core.

Troubleshooting. Intercooler troubleshooting is best accomplished during regular maintenance. Troubleshooting procedures for complete engine contain check points for the intercooler, refer to Troubleshooting Guide, Section 3.

Removal. Disconnect hoses and remove two (2) capscrews securing intercooler to flywheel housing. Figure 6.

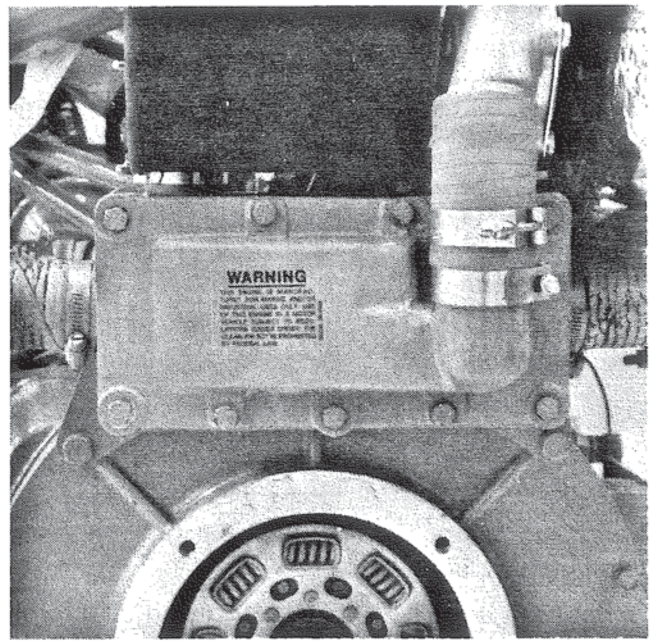


Figure 6. Removing Intercooler.

Disassembly.

1. Remove capscrews holding front and back covers to body.

2. Carefully pry covers from body.

3. Remove gaskets.

Inspection and Repair.

1. Clean all surfaces, remove all gasket material and sealing compound on sealing surfaces.

2. Backwash cooling core by flushing with clean water (water side).

3. Remove any soot or dirt from exterior of cooling core (air side).

CAUTION

Do not use sharp instruments. Damage to core may result.

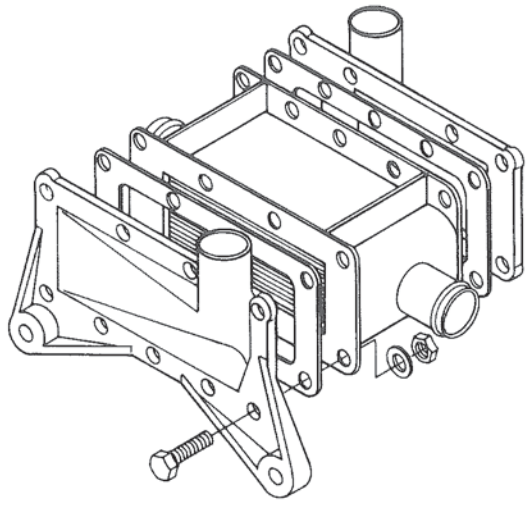


Figure 7. Intercooler.

4. Pressure test core.

A. Plug one water opening and apply 15 p.s.i. air pressure to the other.

B. Submerge intercooler body in water and check for air bubbles.

Reassemble.

1. Use new gaskets. Apply sealant, Special Tool No. T8983 to both sides of gaskets.

2. Replace covers and tighten securely.

3. Pressure test assembled unit.

A. Plug one air opening and apply 15 p.s.i. air pressure to the other.

B. Submerge in water and check for air bubbles at, 1, front and rear cover gasket joints, 2, water openings.

CAUTION

Remove all water from air chamber prior to installation on engine.

Installation.

1. Mount intercooler on flywheel housing, tighten mounting screws securely.

2. Connect hoses.

3. Start engine and observe for water leaks.

Notes:

Section 10

FUEL SYSTEM

CONTENTS

Section 10

FUEL SYSTEM

GENERAL

The fuel system consists of a fuel tank, primary fuel filter, fuel (feed) pump, secondary fuel filter, injection pump, governor, automatic timer, fuel feed lines, injection nozzles and a leak-off line. Figure 1.

The primary fuel filter (30 micron) separates water from fuel and filters dirt. The fuel (feed) pump, driven by the eccentric cam of the injection pump camshaft, delivers fuel through the secondary filter (1-2 micron) to the injection pump. (A priming pump built into the fuel pump can be used to send fuel to the injection pump by hand.)

A mechanical governor, linked to the throttle, and responsive to intake manifold pressure through an aneroid (TI & TW only), limits engine speed and controls fuel injection rate by mechanical connection to the control rack of the injection pump.

The injection pump injects fuel through injection lines and nozzles into precombustion chambers.

Excess fuel returns through a leak off line to the fuel tank.

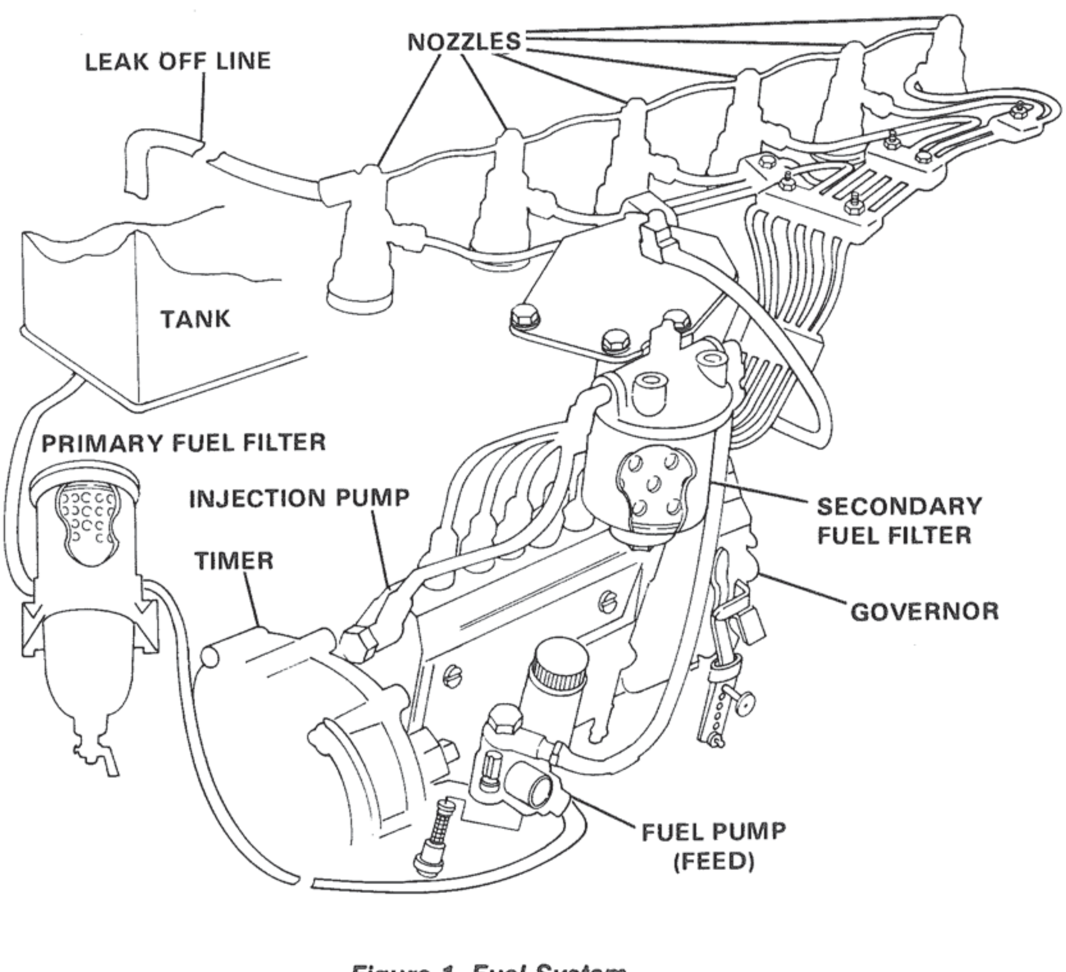


Figure 1. Fuel System.

TOOLS NEEDED

Section	Special Tool	Description	Use
		Ruler	
		End Wrenches	
		Socket Wrenches & Extensions	
		Torque Wrench	
		Screwdrivers	
		Plastic Hammer (or equivalent)	
		Solvent	
		Lubricant	
		Clean Fuel Oil	
		Denso Bond	
Nozzles		Dial Indicator	
		Micrometer, Outside	
		Micrometer, Inside	
		Spring Scale	
		Feeler Gauge	
		Magnifying Glass	Inspecting nozzle body
	MH060011	Nozzle Holder Wrench	Removing, installing nozzles
		Nozzle Tester	Testing nozzle popping pressure
Fuel Pump		Pressure Gauge	Testing fuel pump pressure
Fuel Injection Pump	MH061097	Extractor	Removing timer
	95905-01100 95905-03101	Supports	(Dis)Assembling injection pump
	95904-03413 95906-01020	Coupling & Round Nut Spanner	Turning camshaft
	95905-01008	Tappet Insert	Removing, installing camshaft
	95905-03004	Screw Plug Wrench	Removing installing screw plugs
	95905-05030	Power Clamp	Removing, installing tappets
	95905-02030	Tappet Clamp	Removing, installing tappets
	95905-01030	Plunger Clamp	Removing, installing plunger
	95905-01002	Eye Wrench	Removing delivery valve holders
	95905-05050	Delivery Valve Extractor	Removing delivery valve
	95905-01006	Delivery Valve and Gasket Adapter	Installing Delivery Valve
	95905-01080	Camshaft Clearance Tool	Checking camshaft end play

CAUTION

Engine and fuel system (except filters) are metric designs. All specifications and inspection dimensions must be made using metric measuring instruments. Inch dimensions enclosed in parentheses are for reference only.

SPECIFICATIONS

INJECTION PUMP

Injection Pump 190000-2820 (TI)
090000-8853 (NA)

Manufacturer Nippondenso

Pump Type ND-PES6A80D320RND282 (TI)
ND-PES6A80B320RND885 (NA)

Rotation of Pump Clockwise (viewed from drive side)

Injection Order 1-5-3-6-2-4

Injection Interval 60° ± 30′

Plunger 8 mm. (0.314 in.) dia., 15 mm. (0.591 in.) Right Lead

Delivery Valve 6 mm. (0.236 in.) dia., 35 mm^3 (0.0021 $in.^3$) Retraction Volume

Cam Lift 8 mm. (0.315 in.)

Fuel Injection Timing 15° B.T.D.C. (with delivery valve)
17° B.T.D.C. (without delivery valve)

Pre Stroke 2.15-2.25 mm. (0.0846-0.0885 in.) (TI)
(2.2 ± 0.05 mm. (0.086 ± 0.019 in.) (NA)

Tappet Clearance More than 0.2 mm. (0.0079 in.)

CALIBRATION OF PUMP

Pump Speed (RPM)	Rack Travel mm. (in.)	Counting Stroke	Delivery Quantity cm^3 (cu. in.)	Max. Spread In Delivery cm^3 (cu. in.)
1550	12.8 (.50)	200	17.2-18.0 (1.05-1.09)	0.6 (.017)
1000	12.8 (.50)	200	16.6-17.4 (1.01-1.06)	0.4 (.011)
250	6.1 (.24)	500	2.7-5.3 (.46-.32)	1.0 (.028)

GOVERNOR

	TI	NA
Governor	(090800-5450) (ND-EP/RSV250-1600A2/302ND545)	(090800-3662) (ND-EP/RSV200-1600A2/302ND366)

Governor Type RSV, All Speed Control

GOVERNOR ADJUSTMENT SPECIFICATIONS (TI)

	Lever Position (Degrees)	Pump Speed (RPM)	Rack Travel MM (IN.)	NOTES
MAXIMUM SPEED CONTROL	45 ± 5	1550 1600 (by the lever) 1700	12.7-12.9 (500-.507) 11.7-11.9 (.460-.468) 3.0-5.0 (.118-.196)	1. Zero Degree Setting of Adjusting Lever is 40° From Vertical 2. Shaded Area Shows Initial Rack Setting
IDLING SPEED CONTROL	5 ± 5	350 (by the lever) 350 (by idle spring)	4.9-5.1 (.19-.20) 5.8-6.0 (.22-.23)	
ADAPTER SPRING	45 ± 5	300	13.3-13.5 (.52-.53)	
				Pressure kg/cm^2 (PSI)
ANEROID	45 ± 5	550	10.5-10.7 (.41-.42)	0
			Rack Starts Moving	0.16-0.19 (2.3-2.7 PSI)
			12.8-13.2 (.503-.519)	0.46-0.52 (6.6-7.4 PSI)
Speed Drop: 6% Adjusting Screw: 4 turns				

GOVERNOR ADJUSTMENT SPECIFICATIONS (NA)

	Lever Position (Degrees)	Pump Speed (RPM)	Rack Travel MM (IN.)	
MAXIMUM SPEED CONTROL	52 ± 5	1550 1600 (by the lever) 1670	10 ± 0.1 (.3937 ± .0039) 9.5 ± 0.1 (.374 ± .0039) 2.9-4.9 (.1141-.1929)	**NOTES** 1. Zero Degree Setting of Adjusting Lever is 40° From Vertical
IDLING SPEED CONTROL	10 ± 5	250 (by the lever) 250 (by idle spring)	5.5 ± 0.1 (.2165 ± .0039) 6.0 ± 0.1 (.2362 ± .0039)	
TORQUE CONTROL	52 ± 5	240	10.7 ± 0.1 (.4213 ± .0039)	

INJECTION PUMP AND GOVERNOR ADJUSTMENT (TI)

DELIVERY SPECIFICATIONS

	Lever Position (Degrees)	Pump Speed (RPM)	Counting Stroke	Delivery Quantity: cm³/6 Cyl. (cu. in./6 Cyl.)
FULL LOAD	Push Starting Fuel Control Shaft In. 45 ± 5	1550	500	259.5-268.5 (15.8-16.4)
ANEROID	Set Aneroid Pressure to Zero kg/cm² 45 ± 5	550	500	174-183 (10.6-11.2)

INJECTION PUMP AND GOVERNOR ADJUSTMENT (NA)

DELIVERY SPECIFICATIONS

	Lever Position (Degrees)	Pump Speed (RPM)	Delivery Quantity: cm³/6 Cyl. (cu. in./6 Cyl.)
FULL LOAD	52 ± 5	1550	183 ± 3 (7.2 ± .1181)

NOTE

When stop lever is pulled out all the way, adjusting lever is at full load position, and pump is driven at 1575 RPM, rack travel should be 0.

TIMER

Timer SCZ type (Gear type)

Identification Code ND-EP/SCZ500-1550A7ND87

TIMER ADVANCE CHARACTERISTICS

Pump RPM	500	800	1100	1600	1800
Advance Angle	Advance begins less than 0.5°	2° ± 0.5°	4° ±0.5°	7° ± 5°	7° ± 5°

NOZZLE

Nozzle & Nozzle Holder Assembly Type (093500-0551)

Nozzle Holder Identification Code ND-KD58SD55-N

This nozzle holder is a KD type and mounted by cylinder screw to the engine. Nozzle opening pressure is adjusted by screw.

Opening Pressure 120-130 kg/cm² (170.6-184.9 p.s.i.)

Nozzle Retaining Nut 6-8 kg/m torque (43-58 ft. lbs.)

Nozzle Identification Code ND-DN4SD24

Spray Angle 4° Throttling Type Nozzle

NOZZLE TEST CONDITIONS

Calibration Nozzle	093400-0540 (ND-DN12SD12A)
Nozzle Opening Pressure	175 kg/cm² (2490 p.s.i.)
High Pressure Pipe	2 φ x 6 φ x 600 mm. (0.08 x 0.24 x 28.6 in.)
Feed Pressure	2 kg/cm² (28.4 p.s.i.)
Fuel Temperature	40-45° C (104-113° F)

FUEL PUMP

Feed Pump Type Bosch plunger type w/ priming pump

I.D. No. ND—FP/KS22AC6ND56

Cam Lift 6 mm. (0.236 in.)

Feed Pump Pressure 1.8-2.2 kg/cm² (25.6-31.3 p.s.i.) at 600 RPM

Feed Pump Quantity more than 900 cc/min. (54.9 cu. in.) at 1000 RPM

FUEL FILTER, PRIMARY

Manufacturer Racor

Model 500 FG.

Maximum Rated Flow 4 lpm (1.05 gpm)

Port Size 9/16 in. x 18 UNF STR THD with O-ring

Micron Size Filtration 30

FUEL FILTER, SECONDARY

Manufacturer Fram

Model FBM 1110-PBM

Maximum Rated Flow 92 GPH @ 5 p.s.i.

Micron Size Filtration 1-2

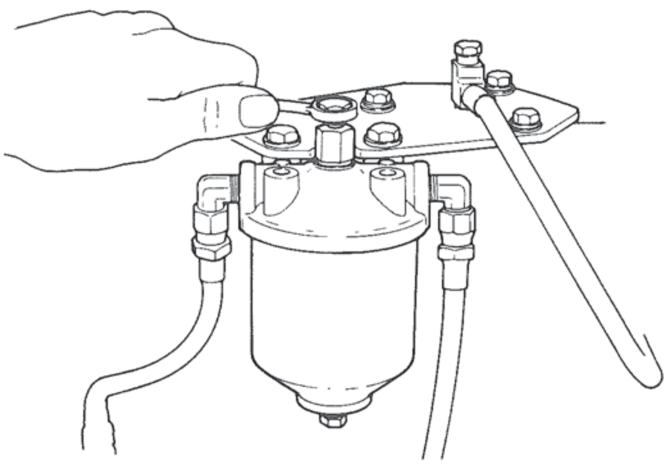
ADJUSTMENTS

Bleeding Fuel Filter (Secondary). Figure 2.

1. (Back out) priming pump handle, pump handle up and down to bring fuel up to the fuel pump.

2. Loosen fuel filter bleeder screw and pump handle until fuel flows with no air bubbles.

3. Tighten screw.



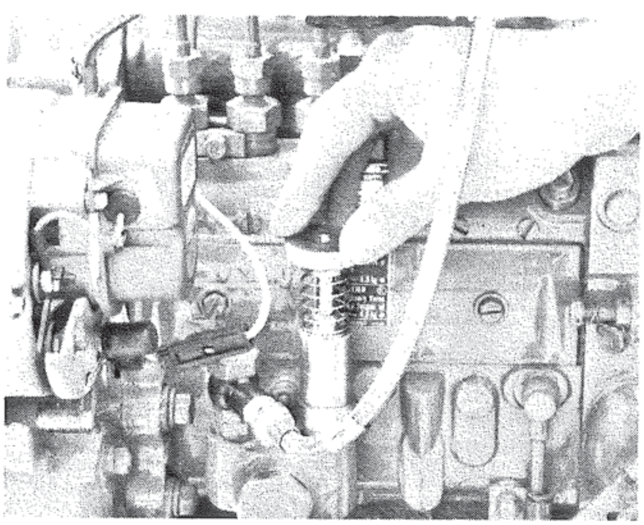


Figure 2. Bleeding Secondary Fuel Filter.

Bleeding Injection Pump. Figure 3.

1. Loosen bleeder screw (1) Figure 3, and pump priming pump until fuel flows without any air bubbles.

2. Loosen other bleeder screw (2) and bleed.

3. Finish bleeding air by setting throttle full open and turning starter for about ten (10) seconds.

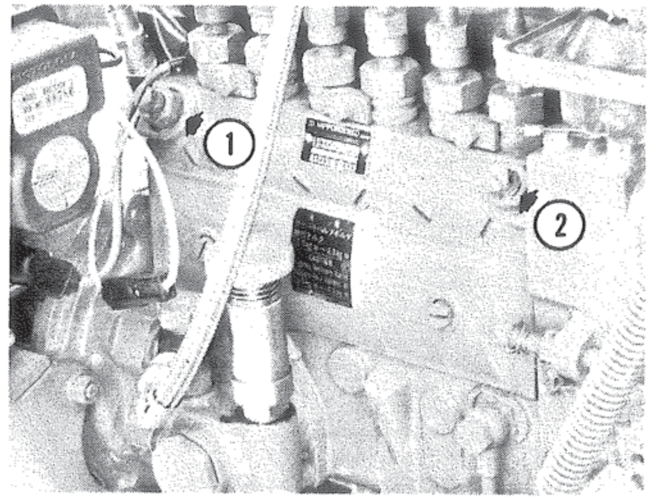


Figure 3. Bleeding Injection Pump.

ADJUSTMENTS

Governor.

1. Make initial control rack setting as follows:

A. Place lever at full open position 45° ±5° (TI); (52° ± 5° (NA).

B. Run pump at 1500 RPM (TI), 1550 (NA).

C. Rack travel should be 12.7-12.9 mm. (.50-.51 in.) TI; 10 ± 0.1 mm. (.3937 ± .0039 in.) NA.

2. On TI, adjust adapter spring as follows:

A. Push starting fuel control shaft in.

B. Set lever to 45° ± 5°

C. Run pump at 300 RPM.

D. Rack travel should be 13.3-13.5 mm. (.52-.53 in.).

3. On TI, adjust aneroid as follows:

A. Set adjusting lever to full load position, run pump at 555 RPM with zero aneroid pressure, adjust screw so rack travel is 10.5-10.7 mm. (.41-.67 in.).

NOTE

Turning in screw increases travel; turning out screw decreases travel.

B. Direct pressure slowly to fitting on top of aneroid; rack should start to move at .16-.19 kg/cm^2 (2.3-2.7 p.s.i.).

NOTE

Adjust by removing plug and adjusting bushing.

C. Increase pressure to .46-.52 kg/cm² (6.6-7.4 p.s.i.): rack travel should be 12.8-13.2 mm. (.50-.52 in.).

4. Adjust idling speed as follows:

A. Push starting fuel control shaft in.

B. Set lever to 5° ± 5° (TI); 10° ± 5° (NA).

C. Run pump at 350 RPM (TI); 250 (NA).

D. Rack travel should be 4.9-5.1 mm. (.19-.20 in.), TI; 5.5 ± 0.1 (2165 ± .0039 in.), NA.

5. Adjust maximum speed as follows:

A. Push starting fuel control shaft in.

B. Set lever to 45° ± 5° (TI); 52° ± 5° (NA).

C. Run pump at 1600 RPM.

D. Rack travel should be 11.7-11.9 mm. (.460-.468 in.), TI: 9.5 ± 0.1 mm (.3740 ± .0039 in.) NA.

Timing.

1. Set up to check timimg by disconnecting No. 1 injection line at delivery valve.

2. Turn crankshaft slowly until fuel just begins to move out of delivery valve holder.

3. The pointer should be lined up with the 15° BTDC mark on the torsional dampener. Figure 4.

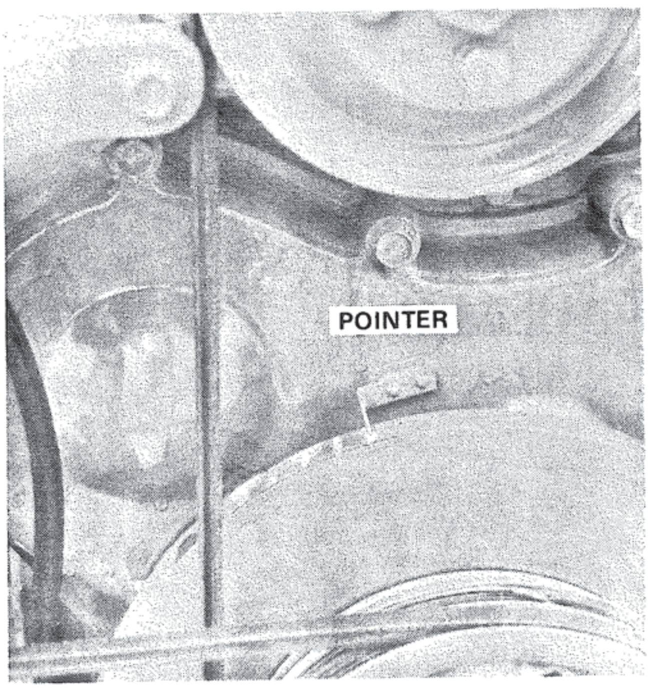


Figure 4. Checking Timing.

A. If timing is way off, (as much as 20°) the pump is probably not installed right: Reinstall pump, following steps in Fuel Injection Pump part of this section.

B. If timing is off, follow steps below.

4. Adjust timing by moving pump, as follows:

NOTE

There are small marks on the edge of the injection pump flange and one mark on the timing gear case. The distance between marks on the flange equals 6°. Figure 5.

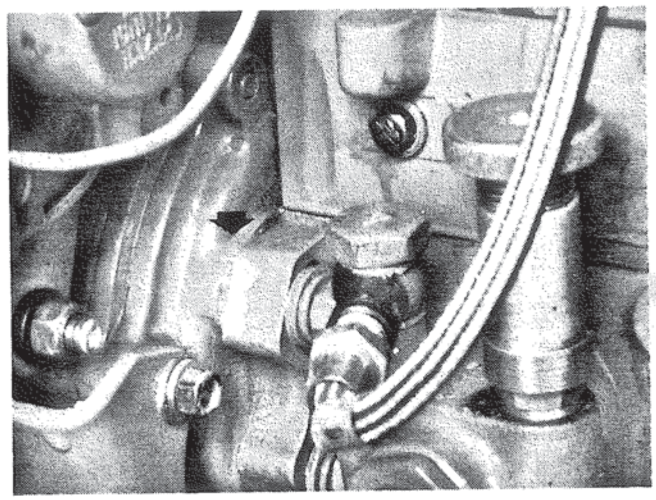


Figure 5. Adjusting Timing.

A. If timing is early move pump up away from crankcase.

B. If timing is late move pump down toward crankcase.

PRIMARY FUEL FILTER

General. A Racor filter is used. It contains an element to filter fuel and a centrifuge device that separates water from fuel.

CAUTION

Never use alcohol based additives: clear bowl and centrifuge could be damaged.

SERVICE NOTES

The element should be changed every 100 hours.

CAUTION

Water should be drawn off daily. DO NOT allow water or contaminents to reach bottom of centrifuge. If more than two (2) cups a day is present, fuel quality or storage conditions are not adequate. Figure 6.

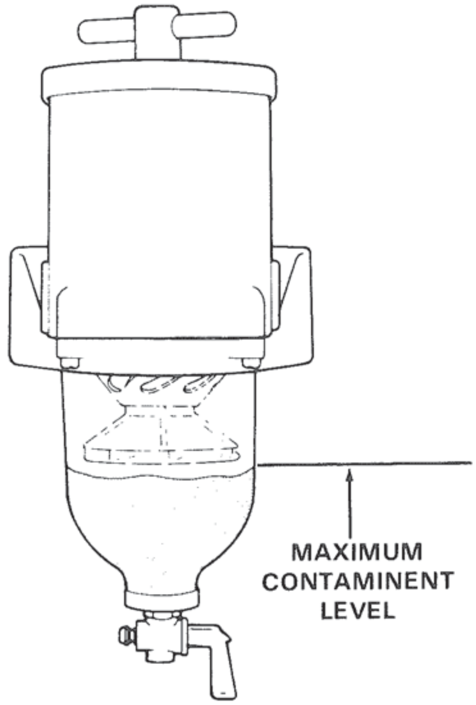


Figure 6. Maximum Water Contaminent Level.

Replacing Filter Element.

1. Remove cover.
2. Grip bale on element and remove element. Figure 7.
3. Insert new element with a turning motion.
4. Inspect small O-ring between handle and cover and large gasket between cover and body. Replace if necessary.
5. Pour fresh clean fuel into filter until full.
6. Replace cover and tighten.

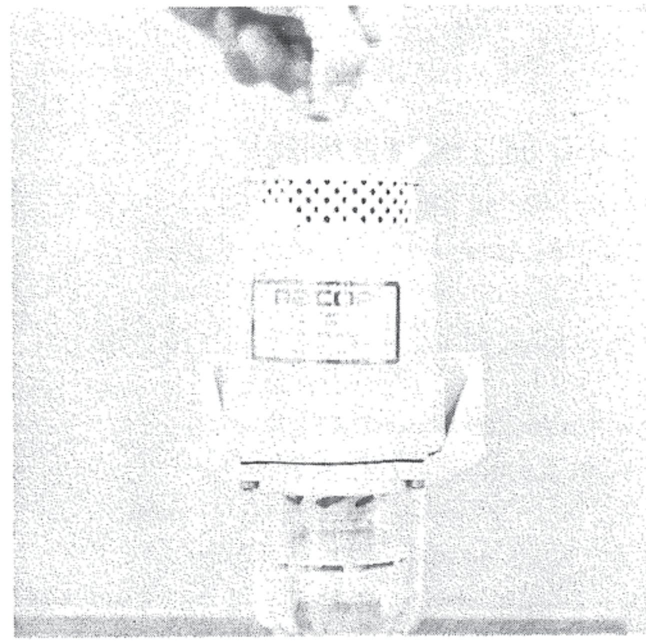


Figure 7. Replacing Element.

NOTE

If changing the element fails to restore primary filter to good working order, follow troubleshooting steps on next page.

Removal.

1. Disconnect fittings at inlet and outlet.
2. Remove primary filter.

Disassembly.

1. Turn T-handle off and remove handle and cover.
2. Remove O-ring from handle, gasket from cover.
3. Grip bale on element and remove element.
4. Remove drain valve and bowl plug gasket.
5. Remove bracket from body by removing four (4) screws.
6. Remove centrifuge and baffle.
7. Remove gasket and ball from centrifuge.

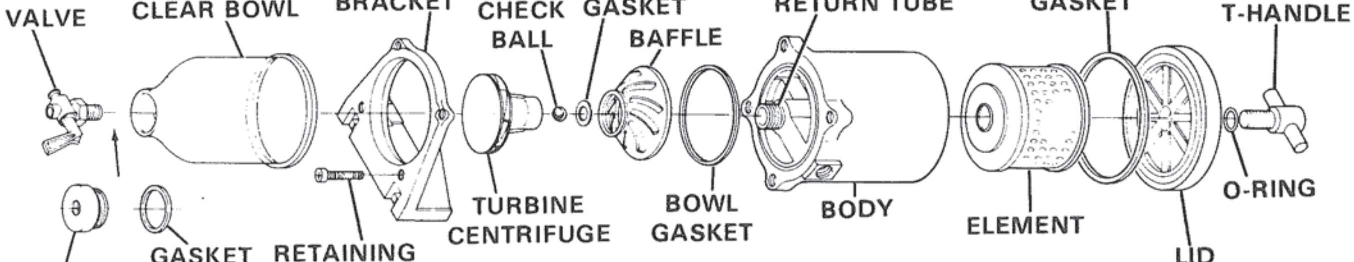


Figure 8. Primary Fuel Filter.

Problem		Possible Cause		Test Procedure/Remedy
1. Poor vacuum, poor flow to primary filter.	1.	Fuel (partly) shut off.	1.	Turn on fuel.
	2.	Fuel line plugged or collapsed	2.	Clean or replace line.
	3.	Inlet to primary filter plugged.	3.	Disconnect line.
			3A.	Open drain hole.
			3B.	Blow out with compressed air.
2. Poor flow through filter.	1.	Severe plugs.	1.	Remove bowl, centrifuge.
			1A.	Clean.
3. Air suction leak. (Air bubbles rise from centrifuge action in bowl.)	1.	Leak between inlet and tank.		
	2.	Low fuel.	2.	Add fuel.
		Leak between inlet and tank.		
	3.	Loose fittings.	3.	Tighten fittings.
	4.	Pin holes in lines.	4.	Replace lines.
	5.	O-ring not seating.	5.	Reinstall or replace O-ring.
4. Air suction leak. (No bubbles in bowl.)		Leak between outlet and fuel pump.		
	1.	Loose fittings.	1.	Tighten fittings.
	2.	Pin holes in lines.	2.	Replace lines.
	3.	O-ring not sealing.	3.	Reinstall or replace O-ring.
	4.	Mismatched hose fittings.	4.	Replace fittings.
		NOTE 37° to 45° will sometimes cause hairline cracks.		
	5.	Cover gasket faulty.	5.	Replace gasket.
	6.	Fuel pump fittings.	6.	Replace fittings.
5. Air suction at top or bottom of filter.	1.	Gasket at drain bowl, poor seal.	1.	Wet with fuel.
			1A.	Hand tighten only.
	2.	Gasket at drain bowl	2.	Replace gasket.
6. Fuel bleed back (to tank).	1.	Air leak or check valve problem.	1.	Remove inspect and clean valve and seat.

Inspection and Repair.

1. Clean non-metal parts in mild detergent and rinse thoroughly.
2. Clean check ball and body in solvent.
3. Inspect all parts for wear, cracks.
4. Replace gaskets if cracked, brittle, worn or damaged in any way.

Reassembly.

1. Place check ball, then gasket in centrifuge.
2. Place baffle over centrifuge and screw centrifuge onto body.
3. Place gasket in seat on body, place glass bowl in bracket and install bracket to body with four (4) screws.

4. Install bowl plug gasket and drain valve.

5. Turn element onto tube in body.

6. Assemble gasket in groove of cover and O-ring under T handle.

7. Install T handle and cover onto body.

FUEL FILTER, SECONDARY

Removal.

1. Disconnect fuel lines.

2. Remove filter assembly by removing two (2) lockwashers and bolts holding filter to bracket.

Replacing Element.

1. Remove plug from bottom of case and drain fuel.

2. Remove center bolt.

3. Separate case from head, discard element, gaskets and copper washer.

4. Clean filter case and center bolt in fresh fuel.

5. Install new gaskets in head, new element in case.

6. Position case in groove of head and secure with new copper washer and center bolt. Torque to 1.6-1.9 kg/m (12-14 ft. lbs.).

7. Install filter to bracket with two (2) lockwashers and bolts and connect fuel lines.

8. Bleed as follows:

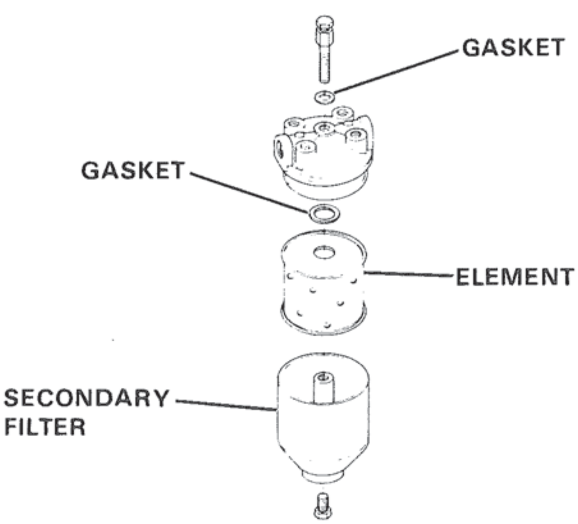


Figure 9. Secondary Fuel Filter.

A. Loosen bleed plug at top of center bolt using 6 point socket to avoid stripping head. Figure 10.

B. Pump priming pump until solid fuel, without air bubbles, flows from bleed hole.

C. Tighten plug.

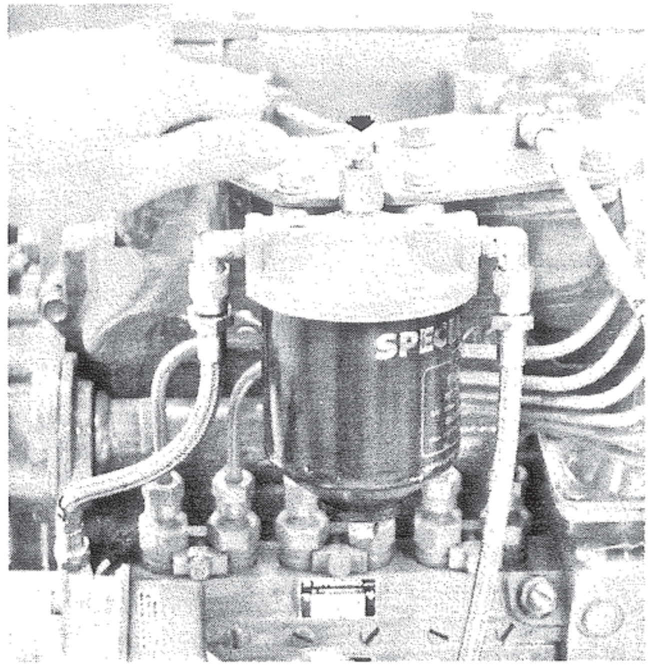


Figure 10. Bleeding Secondary Fuel Filter.

NOZZLES

General. A throttle type nozzle is used. When fuel pressure reaches 120 kg/cm^2 (1706 p.s.i.) (the popping pressure) it overcomes spring pressure, pushes the nozzle tip up and allows fuel to be injected into a precombustion chamber.

Removal.

1. Disconnect fuel injection lines at nozzles.

2. Disconnect leak off fittings and remove leak off line.

3. Unthread nozzles out of precombustion chambers using nozzle holder wrench, Special Tool MH060011. Figure 11.

4. Pry gasket off precombustion chamber.

CAUTION

Cover all openings exposed by removal steps to avoid contamination of fuel delivery system.

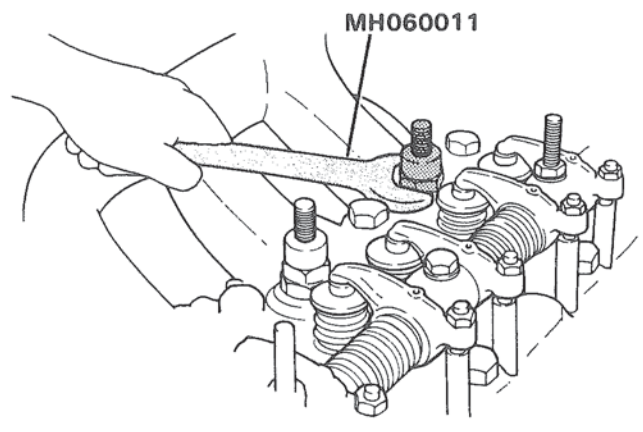


Figure 11. Removing Nozzles.

Testing and Adjustment.

Starting (Popping) Pressure.

1. Set nozzle on nozzle tester and pump handle several times to bleed air from system.

2. Pump handle at a rate of more than 60 times a minute and note starting pressure on gauge. Figure 12.

NOTE

Gauge will rise gradually, then drop suddenly when starting pressure is reached. (Gauge pressure will usually also begin to vibrate slightly during injection.)

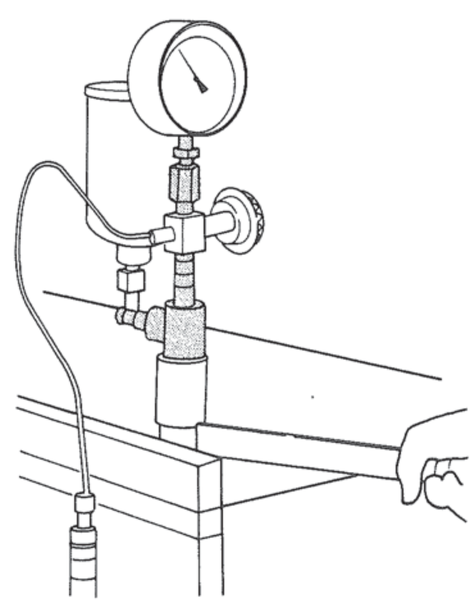


Figure 12. Testing Nozzle.

3. If pressure is not right adjust with adjusting screw. Table 1.

	Assembly Standard	Repair Limit
Nozzle Injection Starting Pressure	120 ± 10 kg/cm²	110 kg/cm²
	1706 ± 142 PSI	(1564 PSI)

Table 1. Nozzle Injection Spring Pressure.

Spray Pattern.

DESIGN NOTE

The type of nozzle used produces two (2) kinds of spray: "throttle injection" and "main injection." Throttle injection is first, smaller in volume and is made up of narrow streams of large particles of fuel. Main injection follows with a sudden increase in volume and wider streams of fine particles of fuel.

TESTING NOTE

Both kinds of spray pattern should be tested. A tester with a stroroscope is ideal, although a hand tester can be used.

Throttle Injection.

1. Pump tester handle at a speed of one (1) stroke per second.

2. Check spray pattern as follows:

A. Fuel should come out in steady smooth pulses making a hissing sound.

NOTE

Vibration during injection should be felt at handle of pump.

NOTE

Fuel spray does not have to break off cleanly during throttle injection phase.

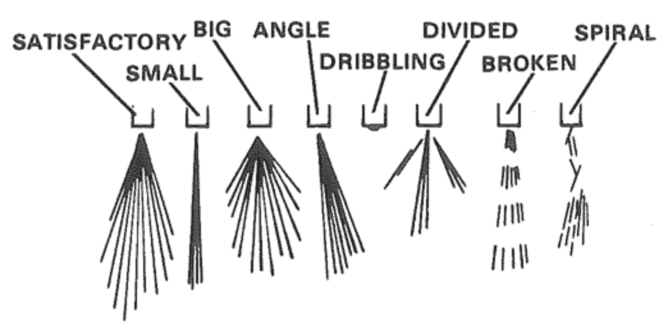


Figure 13. Nozzle Spray Pattern (Throttle Injection).

B. Spray direction: spray should flow straight out in line with nozzle.

C. Spray pattern: check pattern with patterns shown in Figure 13.

Main Injection.

1. Pump tester handle at 4-6 strokes per second.

2. Check spray as follows:

A. Width: spray should be 4° wide.

B. Direction: spray should flow in line with nozzle.

C. Spray quality: spray should consist of very fine particles.

D. Spray (integrity): injection must break off clean. Move handle a few times. If nozzle is wet between spray, adjust or replace.

Oil Tightness.

1. Adjust nozzle so injection starts at 120 kg/cm² (1706 p.s.i.).

2. Raise pressure slowly to about 105 kg/cm² (1493 p.s.i.).

3. Check for leaks at bottom of nozzle.

Disassembly.

1. Place body in vice.

2. Loosen retaining nut.

CAUTION

Be careful not to damage valve while disassembling nozzle during next step.

3. Remove nozzle tip with needle valve.

4. Remove cylinder screw.

5. Remove cap nut and adjusting screw.

6. Take body out of vice and carefully remove pressure spring, pin and washer.

Inspection and Repair.

1. Remove carbon from parts with soft material such as wood.

2. Soak all metal parts, including body in solvent.

3. Check nozzle assembly as follows:

A. Check that needle valve will slide smoothly in and out of nozzle tip and that it fits well.

B. Inspect body with magnifying glass for wear.

C. Check pin for wear.

D. Check pressure spring for cracks, damage or sagging.

E. Inspect contact surfaces of pressure pin and needle valve for wear.

F. Check for wear between nozzle holder body and nozzle tip by using a compound such as red lead.

CAUTION

When in doubt, replace parts since poor contact will cause leaks preventing delivery of fuel.

4. Check leak off line for defects.

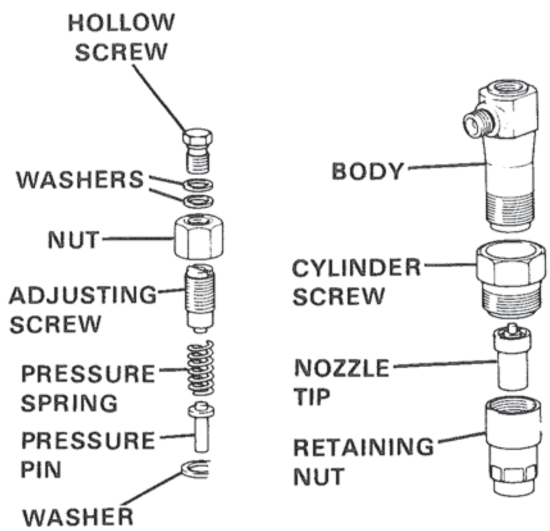


Figure 14. Nozzle.

Reassembly.

1. Place body in vice and install washer, pressure pin and pressure spring.

2. Install adjusting screw finger tight and install cap nut.

3. Turn assembly upside down in vice and place cylinder screw on body.

4. Install nozzle tip assembly as follows.

NOTE

If using a new nozzle tip assembly that comes coated with plastic and anti corrosive grease, be sure to clean assembly in solvent and check that valve moves smoothly in nozzle tip.

A. Coat assembly in clean lubricant.

B. Assemble valve into tip, place them in retaining nut.

C. Install assembly on holder body.

D. Install retaining nut, and torque to 6-8 kg/m (43-58 ft. lbs.) while making sure assembly is centered.

Installation.

1. Test nozzle as outlined above.

2. Install new copper washer so that groove fits to end of retaining nut.

3. Install nozzles and torque to 8-10 kg/m (58-73 ft. lbs.), using nozzle holder wrench, Special Tool MH060011.

4. Install washer.

5. Install leak off line.

6. Connect injection lines.

FUEL (FEED) PUMP

TESTING.

Performance Testing.

1. Run injection pump at 150 RPM. Pump should deliver fuel within forty five (45) seconds.

Discharge Pressure Test.

1. Run injection pump at 600 RPM with discharge side of fuel pump fully open. Discharge pressure should be 1.8-2.2 kg/cm^2 (25.6-31.3 p.s.i.).

Discharge Rate Test.

1. Adjust oil pressure to 1.5 kg/cm^2 (21.3 p.s.i.) using pressure gauge.

2. Run injection pump at 600 RPM with discharge side of fuel pump fully open.

3. Measure how much fuel comes out in one minute. Table 2.

(Injection Pump) Speed	Assembly Standard	Repair Unit
1000 RPM	900 cc/min. (54.9 cu. in.)	600 cc/min. (36.6 cu. in.)

Table 2. Fuel Pump Discharge Rate Standards.

Removal.

1. Disconnect line from fuel tank and line to injection pump.

2. Remove fuel pump by removing three (3) nuts that hold fuel pump to injection pump.

Disassembly.

1. Remove piston assembly as follows:

A. Remove plug and washer. Figure 15.

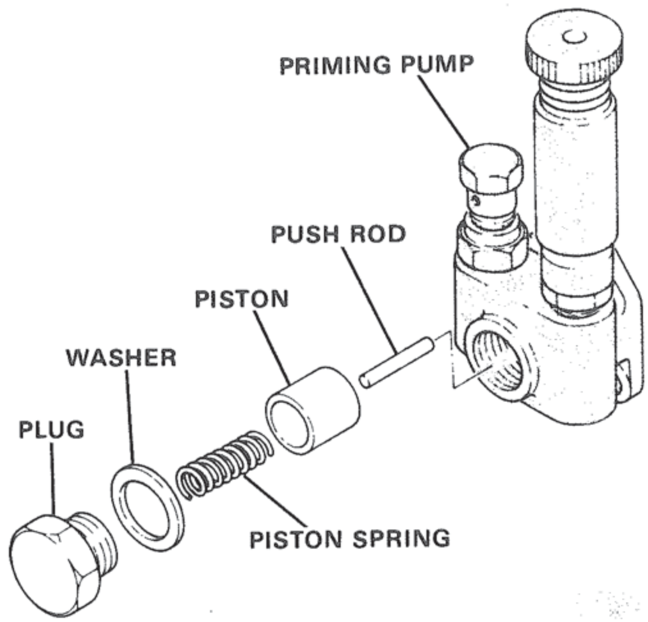


Figure 15. Removing Piston Plug.

B. Remove piston spring and piston.

C. Remove push rod and tappet spring by removing snap ring in back of housing.

D. Remove tappet roller pin by tapping it out gently with a pin of the same size.

2. Remove one check valve assembly by unthreading priming pump; remove other assembly by removing screw and valve support.

3. Remove filter by unthreading screw.

Inspection and Repair.

1. Clean all parts in solvent.

Check Valves.

1. Check seats of both valves for wear and replace if necessary.

Tappet Assembly.

1. Measure inside and outside diameter of tappet and replace if needed. Table 3.

2. Measure outside diameter of roller and replace if needed. Table 4.

1 - COVER
2 - PRIMING PUMP
3 - RING
4 - CHECK VALVE SPRING
5 - CHECK VALVE
6 - TAPPET ROLLER
7 - SNAP RING
8 - TAPPET
9 - SLIDING BLOCK
10 - ROLLER PIN
11 - NIPPLE
12 - FILTER
13 - SCREW
14 - PLUG
15 - WASHER
16 - PISTON SPRING
17 - PISTON
18 - SEAL WASHER
19 - PUSH ROD
20 - HOUSING ASSEMBLY
21 - VALVE SUPPORT
22 - SCREW

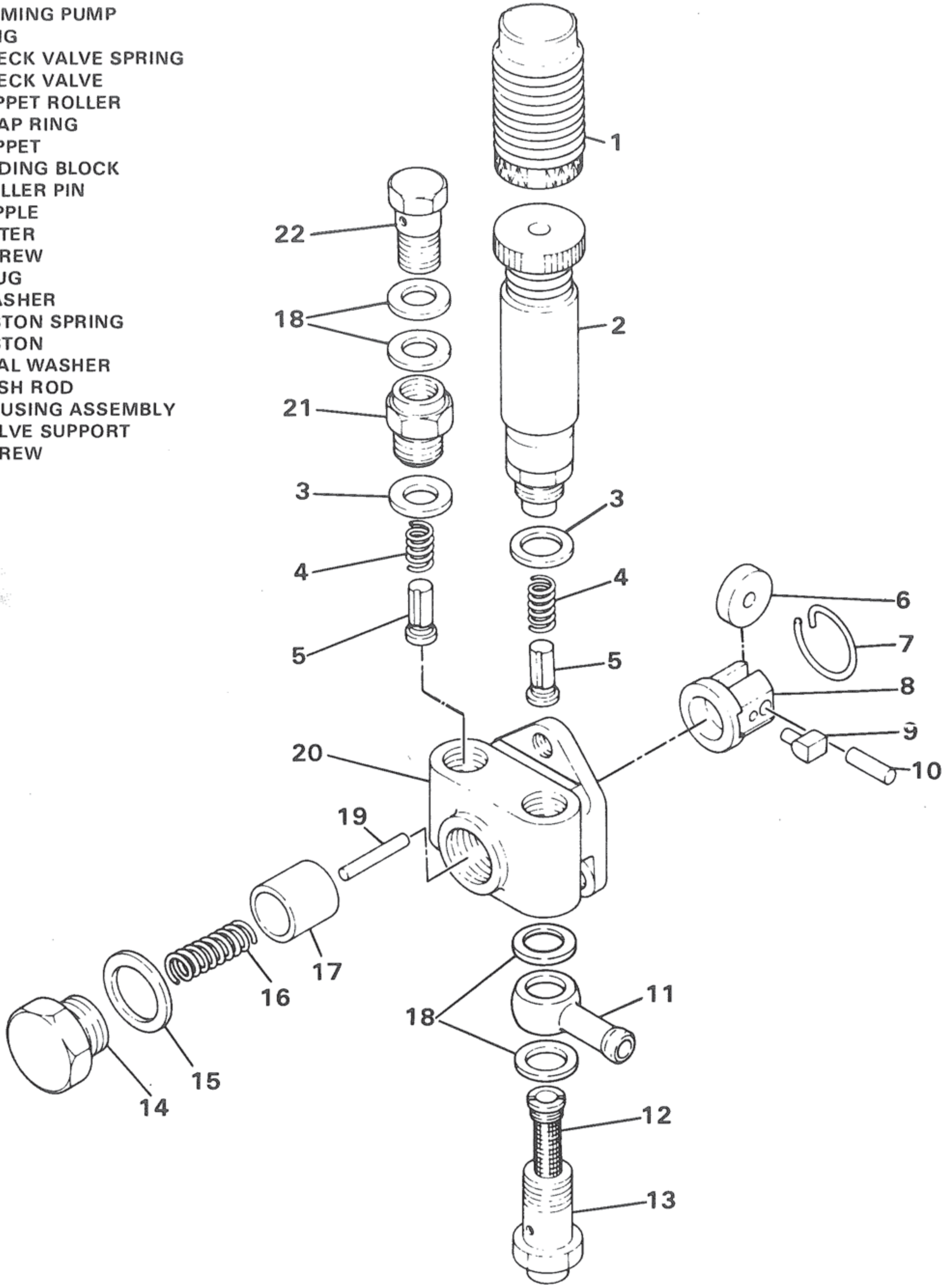


Figure 16. Fuel Pump.

Tappet	Use Limit
Outer diameter	20 mm - 0.1 or less (.78 in. - .0004 in.)
Inner diameter	20 mm. + 0.1 mm. or more (.78 in. + .0004 in.)

Table 3. Tappet Wear Specifications.

Tappet Roller	Use Limit
Outer diameter	15-0.075 mm. (.59-.0029 in.)

Table 4. Tappet Roller Wear Specifications.

3. Assemble tappet roller and roller pin to tappet and check overall play. If play is more than 0.3 mm. (.01 in.), replace assembly.

Housing.

1. Inspect fuel pump housing for damage, cracks or broken threads.

Priming Pump.

1. Check priming pump piston and cylinder for rust.

Filter.

1. Make sure filter is clean and undamaged.

Reassembly.

1. Install piston assembly as follows:

A. Insert roller pin into tappet and tappet roller.

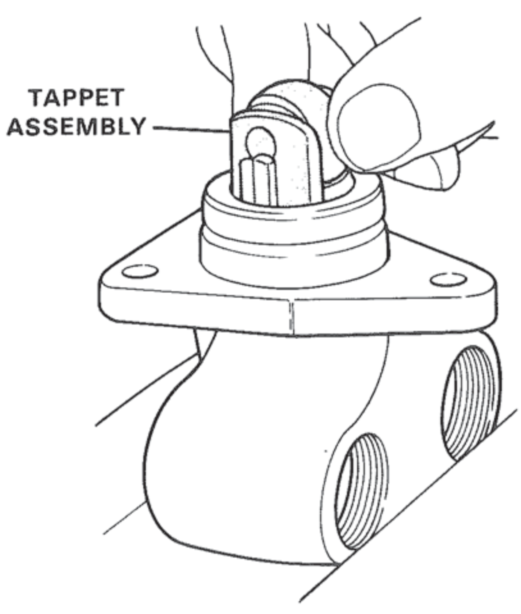


Figure 17. Inserting Tappet.

B. Place sliding block into tappet so that block lines up with slot in housing. Figure 17.

C. Insert push rod, then piston and piston spring into housing. Figure 18.

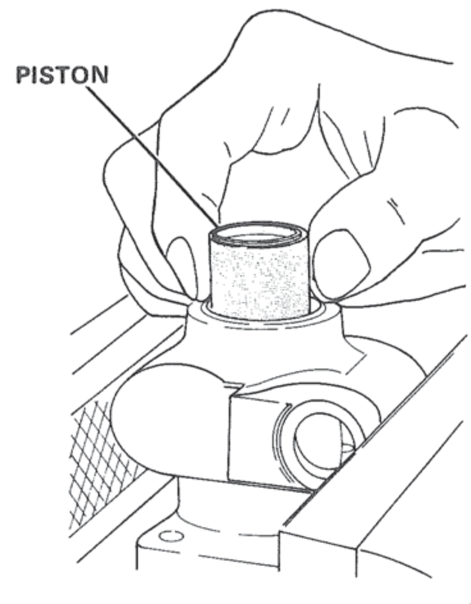


Figure 18. Installing Piston.

D. Install washer, plug on outside end of pump; secure inside end to assembly with snap ring.

2. Install check valves as follows:

A. Install check valve and spring, ring, priming pump, priming pump spring and cover. Figure 19.

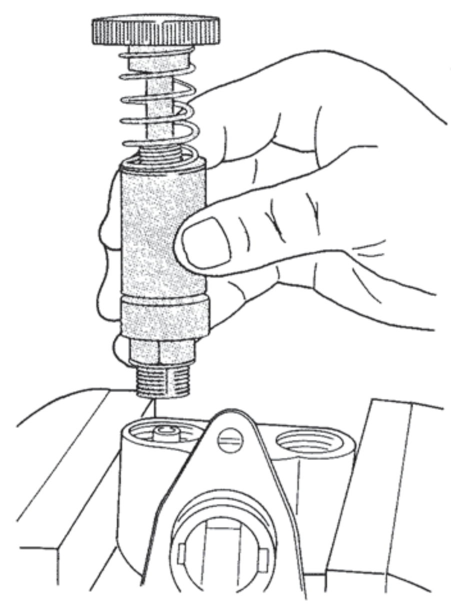


Figure 19. Installing Priming Pump.

B. On left side install check valve and spring, ring; thread in the valve support; and secure with two (2) seal washers and screw.

3. Install filter assembly as follows:

A. Install seal ring, nipple, seal ring, filter and screw.

Installation.

1. Install fuel pump to injection pump with three (3) screws.

2. Connect fuel lines.

3. Test pump as outlined in this section.

FUEL INJECTION PUMP

NOTE

Timing is covered under Timing in this section.

NOTE

If governor won't adjust, fuel pump won't put out fuel or if unit is noisy, tear down is probably necessary.

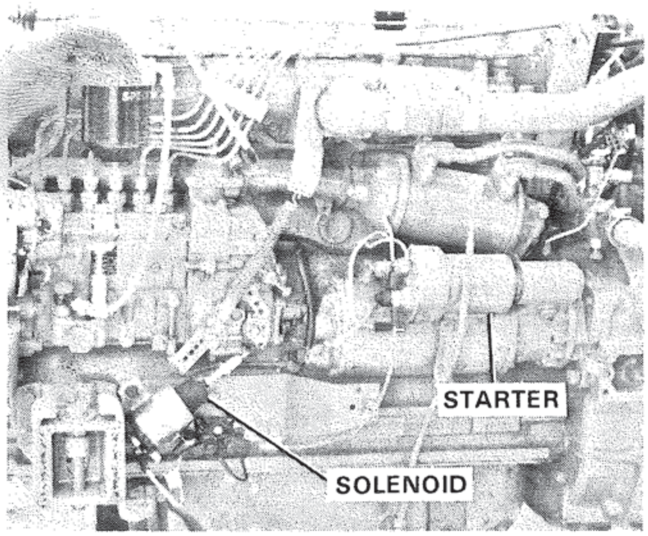


Figure 20. Disconnecting Injection Pump.

Removal. Figure 20.

NOTE

Starter must be removed to remove injection pump.

1. Remove starter.

2. Disconnect fuel feed lines from fuel pump and injection pump; disconnect oil line.

3. Disconnect throttle cable.

4. Disconnect engine stop wire.

5. Disconnect solenoid at clip on stop lever.

6. Disconnect injection lines.

7. Disconnect aneroid hose at intake manifold.

8. Remove injection pump rear end stay.

9. Remove upper nuts from timing gear case.

10. Loosen injection pump flange bolts.

11. Remove governor injection pump and timer as an assembly. Figure 21.

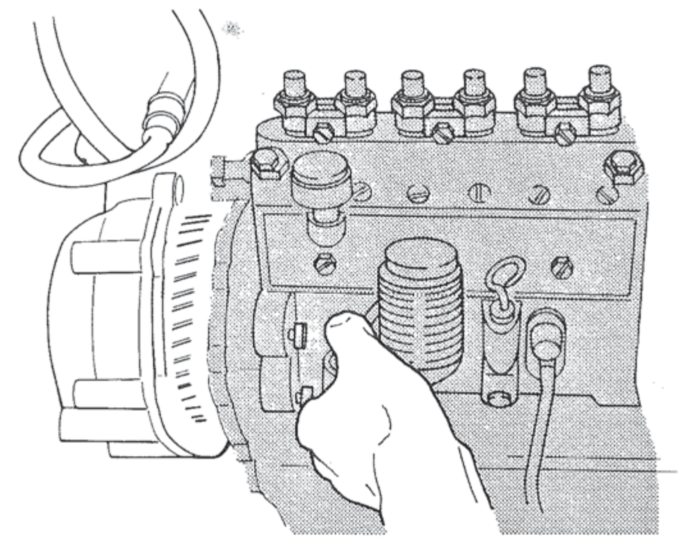


Figure 21. Removing Injection Pump.

CAUTION

1. Make sure work area is clean; keep delivery valves and plunger assemblies in clean fuel oil during repair work.

2. Keep parts together as sets.

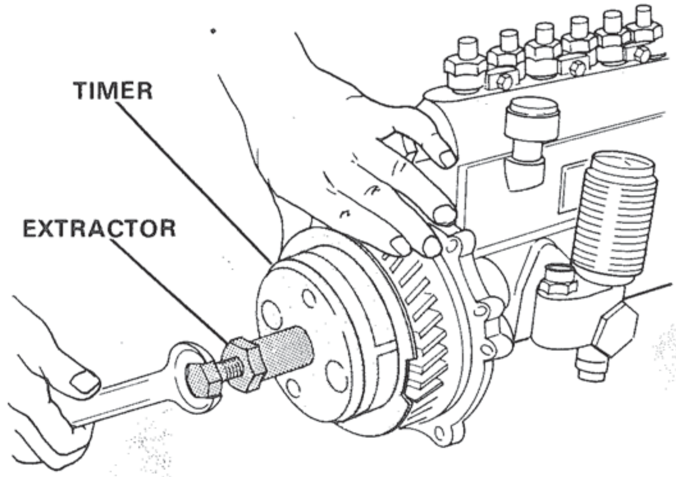


Figure 22. Removing Timer.

12. Drain engine oil.

13. Remove timer as follows:

A. Loosen (remove) "round nut" of automatic timer.

B. Remove timer assembly using extractor, Special Tool No. MH061097. Figure 22.

14. Remove flange plate from injection pump.

15. Install injection pump on supports, Special Tool Nos. 95905-01100 and 95905-03101. (Remove housing, gears, etc.).

16. Remove fuel pump by removing three (3) nuts that hold pump to injection pump.

17. Remove governor as outlined under governor in this section.

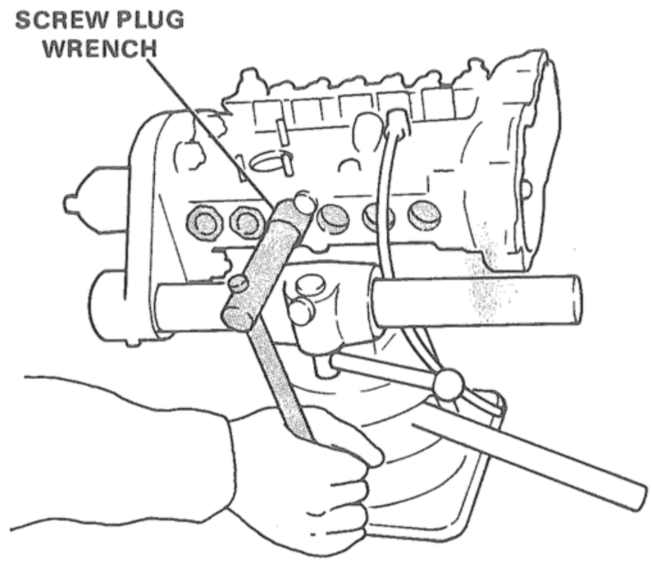


Figure 24. Removing Screw Plugs.

Disassembly.

1. Remove cover plate.

2. Prepare for disassembly as follows:

A. Assemble coupling and round nut, Special Tool No. 95904-03413, and holding spanner, Special Tool No. 95906-01020 to camshaft.

B. Turn camshaft so tappets move up. Insert tappet insert, Special Tool No. 95905-01008 into tappet service holes. Figure 23.

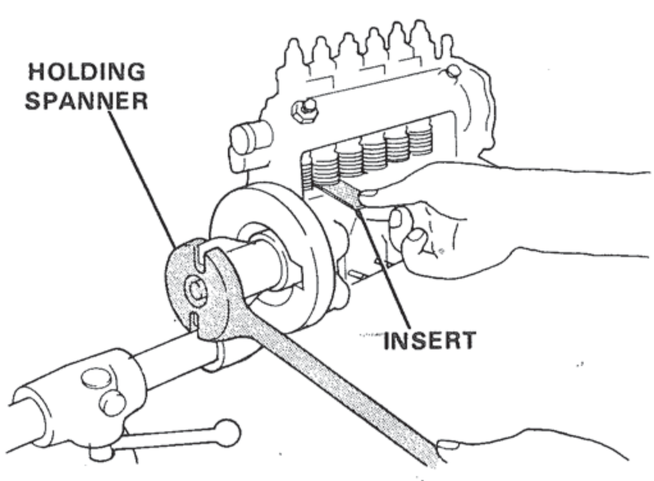


Figure 23. Installing Tappet Inserts.

3. Remove camshaft as follows:

A. Place injection pump on its side.

B. Remove screw plug, using screw plug wrench, Special Tool No. 95905-03004. Figure 24.

C. Remove bearing cover and gasket by removing four (4) screws. Figure 25.

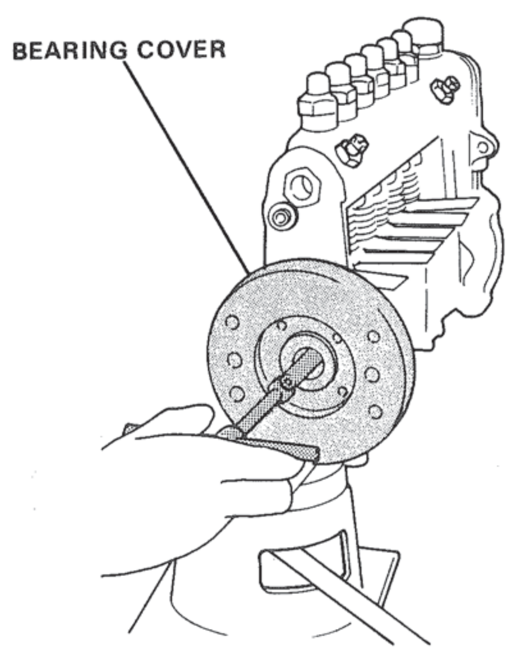


Figure 25. Removing Bearing Cover.

D. Remove center bearing set screw. Figure 26.

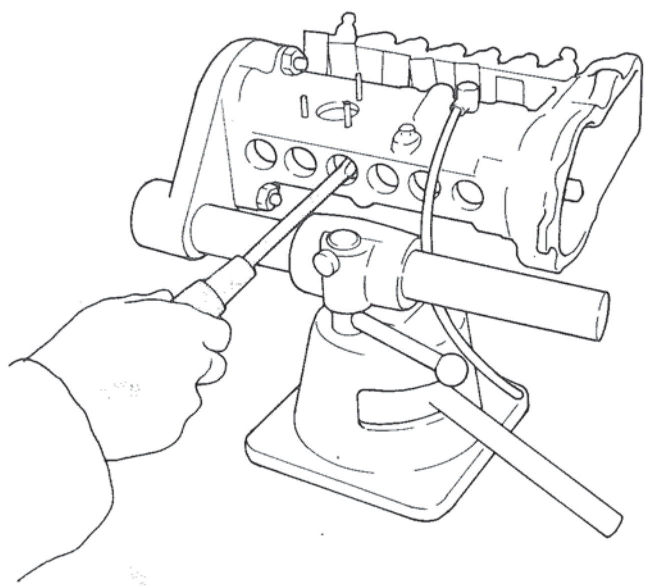


Figure 26. Removing Center Bearing Set Screw.

NOTE

Center bearing is installed on camshaft and pressed into pump housing.

E. Remove center bearing and camshaft by tapping camshaft out, little by little using plastic hammer from governor side.

4. Check control rack as follows:

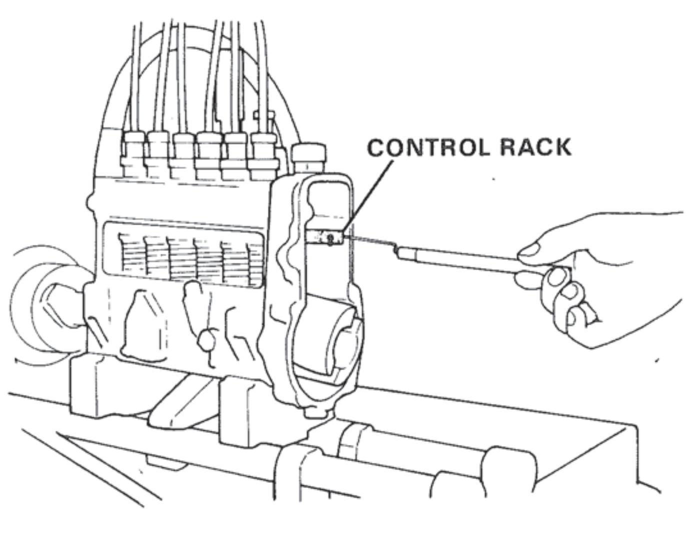


Figure 27. Checking Control Rack Resistance.

A. Check control rack resistance: standard is 150 g (5.29 oz.) or less at 0 RPM. Figure 27.

B. Check smoothness of rack travel; if rack does not slide smoothly, check each part carefully during disassembly.

C. Note positions of pinions when rack is at both ends of its travel so that reassembly can be done right.

5. Remove tappets as follows:

A. Push up tappets and remove inserts using roller clamp, Special Tool No. 95905-05030.

B. Hold tappet inside camshaft chamber with roller clamp, Special Tool No. 95905-05030, and remove tappets through camshaft bearing hole, using tappet clamp, Special Tool No. 95905-02030. Figure 28.

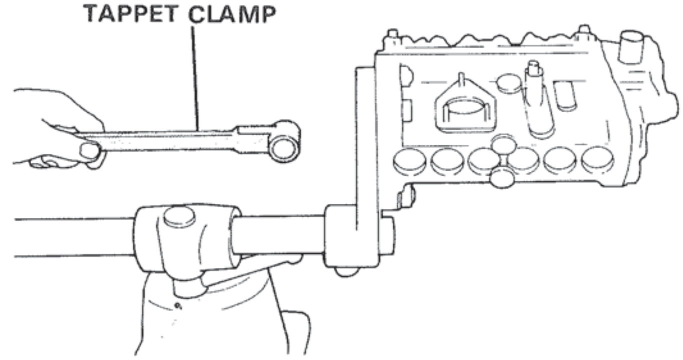


Figure 28. Removing Tappets.

6. Remove plunger assembly as follows:

A. Hold lower seat of plunger spring with plunger clamp, Special Tool No. 95905-01030, and remove plungers and lower seats through screw plug holes. Figure 29.

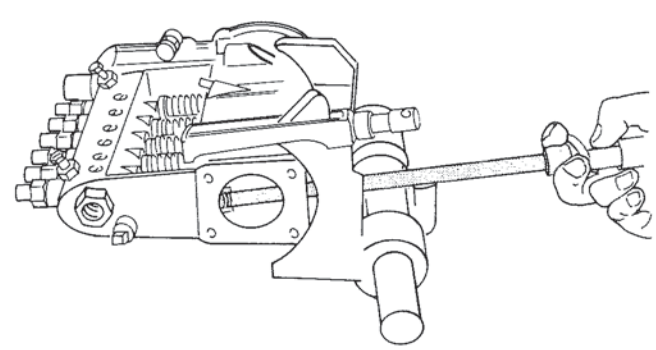


Figure 29. Removing Plunger.

B. Remove plunger springs, upper seats and control sleeves with pinions.

7. Remove control rack by loosening guide screw and pulling rack out. Figure 30.

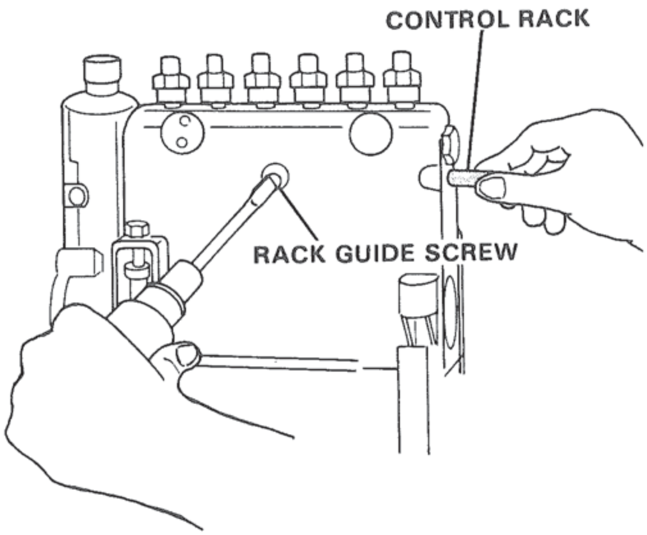


Figure 30. Removing Control Rack.

8. Remove delivery valve assembly as follows:

A. Remove delivery valve holder lock plates.

B. Remove holders, using eye wrench, Special Tool No. 95905-01002. Figure 31.

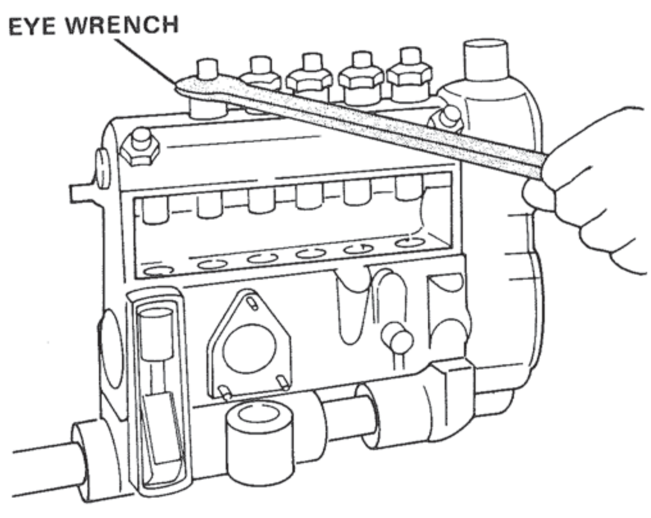


Figure 31. Removing Delivery Valve Holders.

C. Remove springs.

CAUTION

In next step, do not force extractor into hole.

D. Insert delivery valve extractor, Special Tool No. 95905-05050 carefully into valve seat hole. Figure 32.

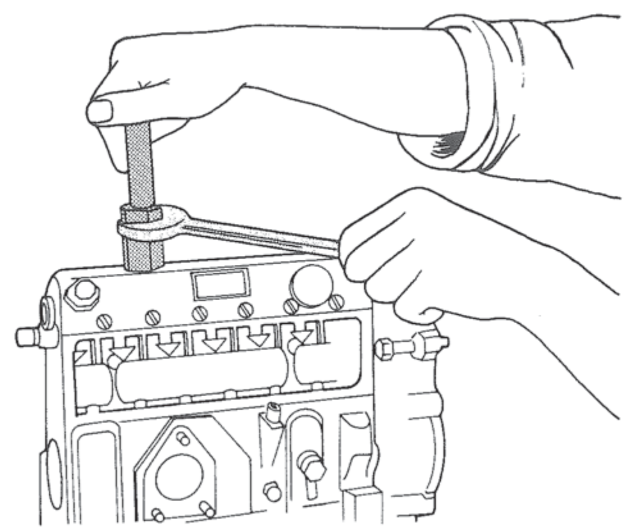


Figure 32. Removing Delivery Valves.

E. Remove seat and gasket using tool as lever.

F. Remove valve seat from extractor.

NOTE

Keep valves and seats together as sets.

G. Remove plunger barrel. Figure 33.

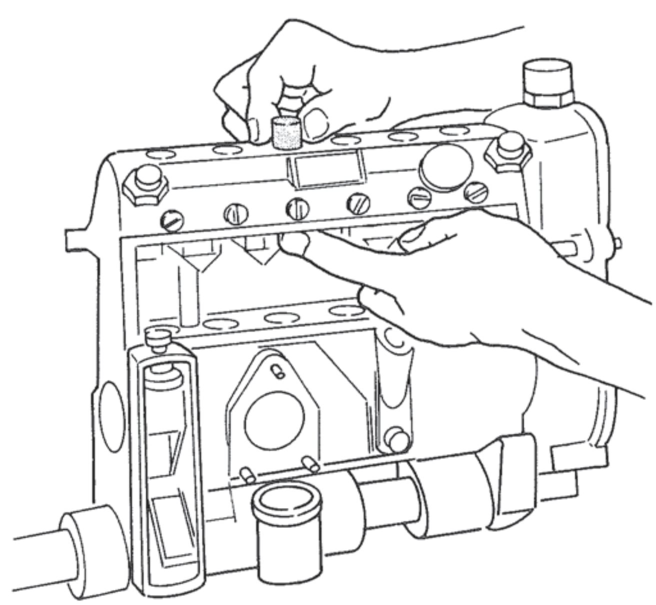


Figure 33. Removing Plunger Barrel.

Inspection and Repair.

CAUTION

Clean all parts in clean fuel oil.

Plunger.

1. Check sliding surface of plunger for damage; replace entire delivery valve assembly if damaged. Figure 34.

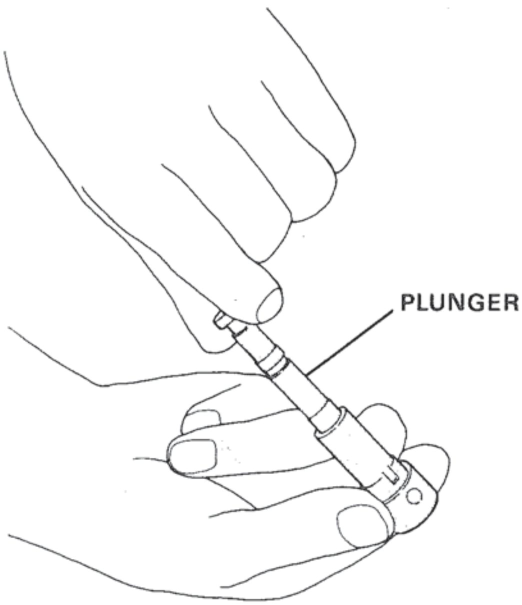


Figure 34. Checking Plunger.

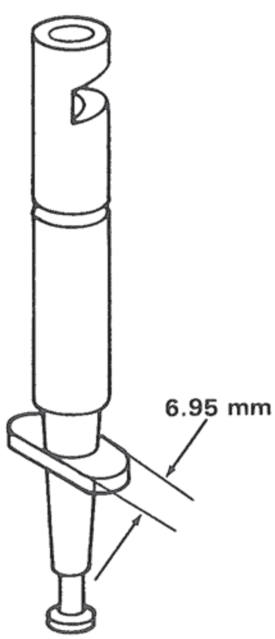


Figure 35. Checking Plunger Tab.

2. Test plunger for sinkage as follows:

A. Tilt pump 60°.

B. Place plunger in hole about two thirds (2/3) of the way out on it's stroke.

C. Let go of plunger and see if plunger sinks smoothly into cylinder of its own weight.

D. Turn plunger and repeat test.

E. Replace delivery valve as an assembly if plunger fails test.

3. Measure width of tab on plunger. Replace if less than 6.95 mm. (.273 in.). Figure 35.

4. Measure width of slot in control sleeve. Replace if more than 7.12 mm. (.280 in.). Figure 36.

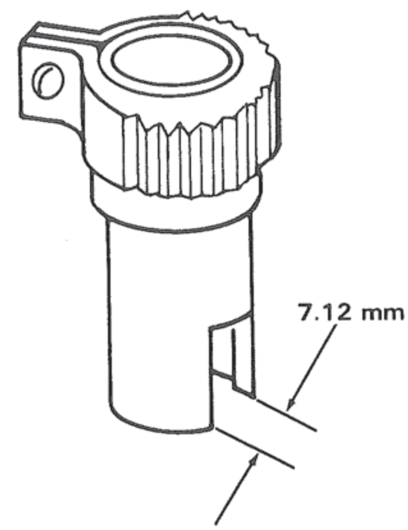


Figure 36. Checking Control Sleeve.

5. Check surfaces of plunger for scratches, signs of sticking or signs of wear such as glossy areas.

6. Check plunger for oil tightness as follows:

NOTE

If testing new plunger, make sure anti rust compound is removed.

A. Assemble plunger and an inspected delivery valve into pump housing.

B. Attach a pressure gauge that can measure up to 400 kg/cm^2 (about 5700 p.s.i.) to delivery valve holder.

C. Set control rack to no load position, run pump at 200 RPM, check pressure. Table 5.

Plunger Oil Tightness at 200 RPM	Assembly Standard	Limit of Repair
	150-200 kg (2133-2844 PSI)	150 kg/cm^2 (2133 PSI)

Table 5. Plunger Oil Tightness Specifications.

Delivery Valve.

1. Check valve and seat for wear, cracks. Replace both if either one is defective.

2. Pull valve up, close hole in bottom of seat with finger, let valve go and check that valve sinks smoothly and quietly until it covers hole in seat. Replace assembly if test failed.

3. Cover hole in bottom of seat with finger, insert valve into seat. Hold, then release valve to check that valve closes fully to its original position under its own weight. Replace assembly if test failed. Figure 37.

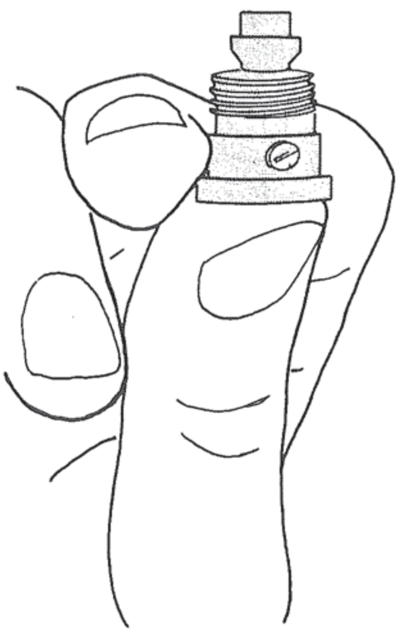


Figure 37. Checking Delivery Valve.

4. Check oil tightness of delivery valve as follows:

A. Place valve in pump and attach pressure gauge (capacity to 400 kg/cm^2 [5700 p.s.i.]) to holder.

B. Turn pump until pressure is 150 kg/cm^2 (2133 p.s.i.); stop pump and bring control rack to 0 mm.

C. Measure time it takes for pressure to go down to 10 kg/cm^2 (142 p.s.i.). If less than five (5) seconds, replace delivery valve.

Control Rack and Piston. Figure 38.

1. Check control rack for bends and wear.

2. Check backlash of rack to pinions. Table 6.

Backlash Control Rack to Pinions	Assembly Standard	Limit of Use
	.15 mm. (.0059 in.)	.25 mm. (.0099 in.)

Table 6. Control Rack Backlash, Specifications.

3. Check slide resistance of rack with spring scale. Replace rack if reading is over 150 g. (5.29 ou.).

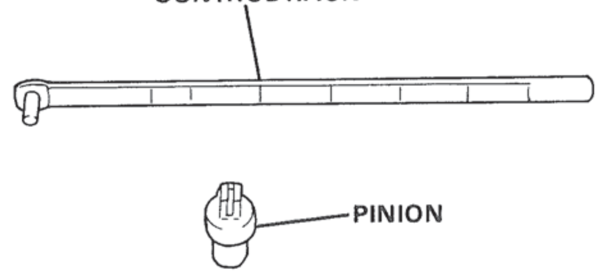


Figure 38. Control Rack and Pinion.

Tappet.

1. Check tappet roller, bushing and pin for damage, uneven wear.

2. Check tappet to roller clearance with dial indicator and replace if clearance is over .3 mm. (.0118 in.).

3. Measure O.D. of tappet roller. Replace if defective. Table 7.

	Assembly Standard	Limit of Use
Tappet Roller	17 ⊖0.027 mm (.699 o ± .0010 in)	- 0.075 mm (-.0030 in)

Table 7. Tappet Roller Specifications.

4. Check tappet to pump housing clearance. Replace if clearance is more than limit of use. Table 8.

	Assembly Standard	Limit of Use
Tappet to Pump Housing Clearance	.02-.062 mm. (.0008 - .0024)	.25 mm. (.009 in.)

Table 8.

Delivery Valve Spring, Plunger Spring.

1. Check for cracks, damage or rust.

2. Check spring free length, replace if defective. Table 9.

	Assembly Standard
Delivery Valve Spring	32.0 ± 0.5 mm. (1.259 ± .019 in.)
Plunger Spring	39.0 ± 1.0 mm. (1.535 ± .039 in.)

Table 9.

3. Check plunger spring seat for pitting and replace if pits are more than 0.1 mm. (.0039 in.) deep.

Camshaft and Tapered Roller Bearings.

1. Check camshaft, especially cam surfaces, keyway for wear or damage. Figure 39.

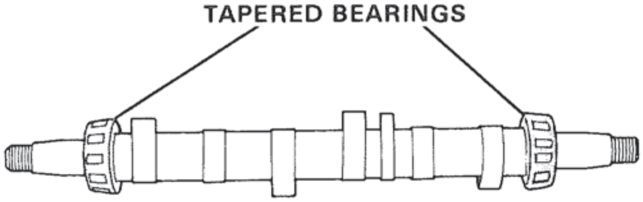


Figure 39. Camshaft.

2. Check cam long dimension and replace camshaft if wear is more than limit of use. Table 10.

	Assembly Standard	Limit of Use
Cam (long) Diameter	32 mm ± 0.1 mm (1.259 in ± .0039 in)	- 0.2 mm (.0079 in)

Table 10.

3. Check bearings for wear, damage.

4. Replace bearings, if necessary, as follows:

A. Remove bearing and shim(s) using gear puller. Figure 40.

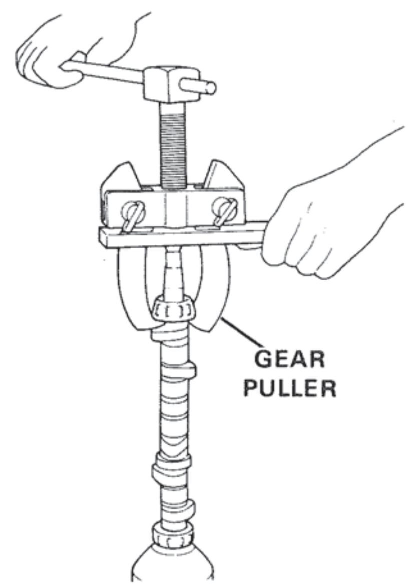


Figure 40. Pulling Bearings.

B. Remove outer race from bearing cover, using gear puller, Special Tool No. 95905-04050. Figure 41.

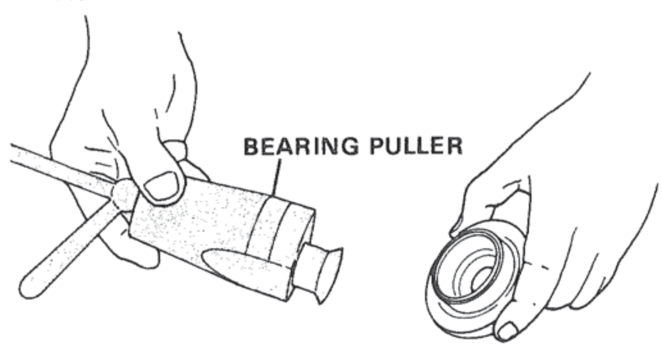


Figure 41. Removing Outer Race.

C. Press outer race into bearing cover using press.

D. Press shim and inner race onto camshaft using an adapter, such as a piece of pipe and press.

Pump Housing.

1. Check housing for cracks; threaded areas for damage.

2. Measure tappet hole I.D. Replace housing if wear is more than limit of use. Table 11.

	Limit of Use
Pump Housing Tappet Hole I.D.	24 + 0.15 mm. (.944 + .0059 in.)

Table 11.

Reassembly.

1. Install pump housing on pump support, Special Tool No. 95905-01100 and angle support, Special Tool No. 95905-03101; and install governor as outlined in this section.

2. Install plunger as follows:

A. Make sure valve seats in housing are clean.

B. Line up dowel pin of housing with locating slot in plunger (feed hole on cover plate side) and insert plunger by hand.

3. Install delivery valves as follows:

A. Place delivery valve with gasket in housing.

B. Attach delivery valve and gasket adapter, Special Tool No. 95905-01006.

C. Drive valves in by tapping lightly with wood or plastic hammer until bottoms of valves touch top of plunger. Figure 42.

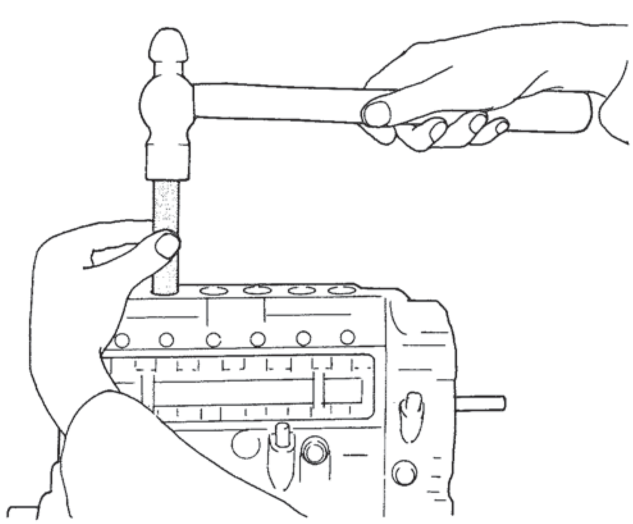


Figure 42. Installing Delivery Valves.

D. Place spring on valves.

E. Install delivery valve holders; tighten snug only.

4. Install control rack and pinions as follows:

A. Insert rack into housing, install guide screw and check that rack moves easily through its entire stroke.

B. Tilt housing until top is lower than bottom.

C. Place control rack in center of stroke.

NOTE

As each pinion and sleeve is installed:

1. Move control rack to center of its stroke.

2. Move rack to check sleeve-to-rack engagement.

3. Check that control sleeve slides smoothly without too much play. (Lack of smoothness causes hunting).

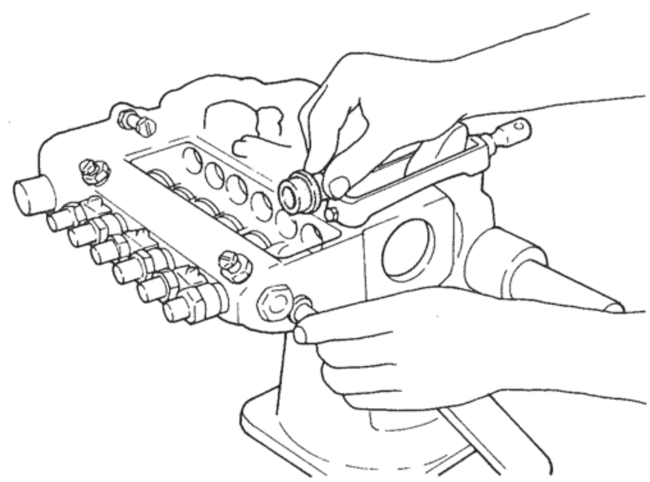


Figure 43. Assembling Control Rack to Sleeve.

D. Position pinions in control sleeve so that joint of pinion lines up with center of notch in lower sleeve and tighten clamp.

E. Insert pinions into plunger until it meshes with rack.

5. Install upper spring seats and plunger springs into control sleeves.

6. Install lower spring seats into plungers.

7. Install plungers into barrels, using plunger clamp, Special Tool No. 95905-01030, Figure 44, so mark on driving face is up toward side of cover (control groove side).

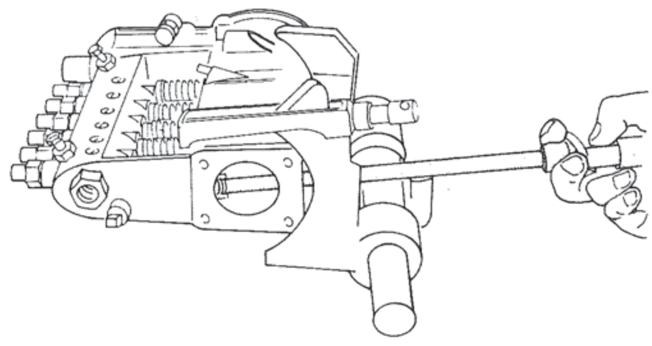


Figure 44. Installing Plungers.

8. Install tappet assembly as follows:

A. Insert tappets through camshaft bearing hole using tappet clamp, Special Tool No. 95905-02030. Figure 45.

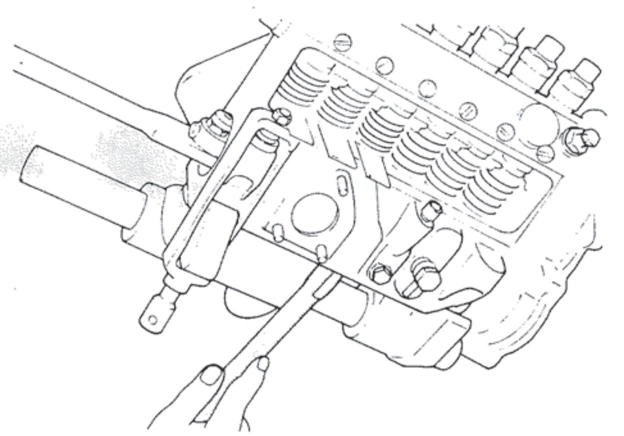


Figure 45. Inserting Tappets.

B. Push up tappets, using roller clamp, Special Tool No. 95905-05030; and push in tappets making sure driving face of plunger is lined up with groove in control sleeve.

C. Install insert, Special Tool No. 95905-01000 to hold tappets in place.

In next step, torquing holders, move rack right and left to check that rack moves easily.

9. Torque delivery valve holders to 2.5-3.5 kg/m (15-25 ft. lbs.)

10. Check that control rack resistance is 150 g. (5.3 ou.) or less.

11. Install camshaft as follows:

CAUTION

1. Be careful not to damage oil seal while installing camshaft.

2. Alignment mark on end of camshaft must face automatic timer.

A. Apply engine oil to camshaft bearings.

B. Install camshaft and center bearing so that set screw hole is lined up for bolt from bottom of housing. Figure 46.

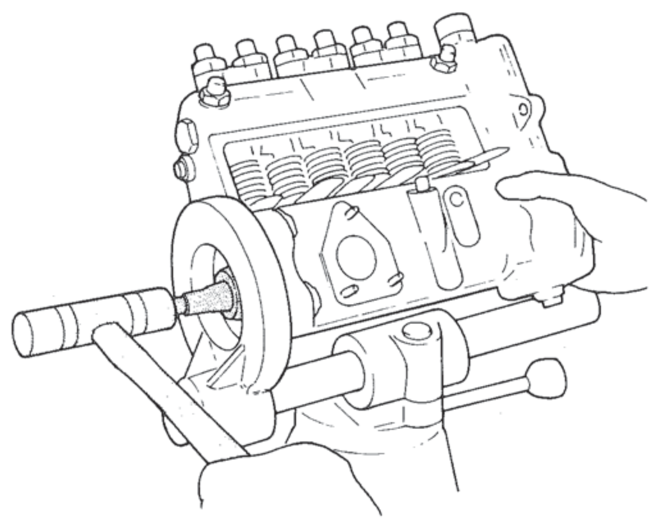


Figure 46. Installing Camshaft.

12. Check camshaft end play as follows:

A. Temporarily install bearing cover.

B. Install camshaft clearance tool, Special Tool No. 95905-01080.

C. Place a micrometer on camshaft.

D. Press shaft to pump side, turn in dial.

E. Lightly tap shaft to other side.

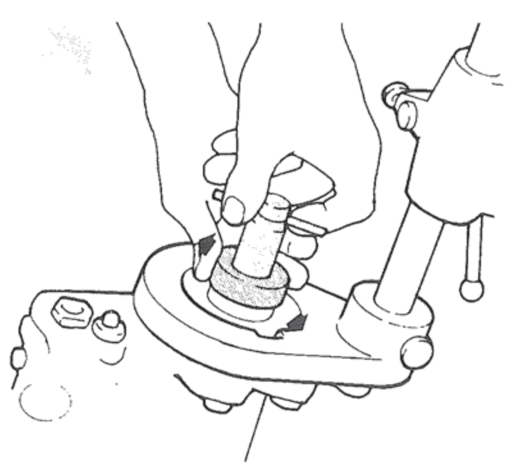


Figure 47. Checking Camshaft End Play.

F. Turn dial and check reading against specifications. Table 12.

	Assembly Standard	Limit of Repair
Camshaft End Play	0.03-0.05 mm. (.0012-.0020	0.1 mm. (.0039 in.)

Table 12. Camshaft End Play Specifications.

13. Shim camshaft, if needed, as follows:

A. Choose shim(s) listed in table that will bring end play within assembly standard.

	Shim Thicknesses (mm.)	
Camshaft Shims	0.10	0.16
	0.12	0.18
	0.14	0.50

Table 13. Camshaft Shims Available.

B. Install shims between bearing in governor housing and adjusting ring.

14. Install bearing cover as follows:

A. Remove cover, apply RTV Sealant (Special Tool No. 8983) to mounting surface of housing.

B. Install O-ring and cover.

15. Install flange to camshaft.

16. Turn camshaft and detach tappet insert.

17. Lay pump on side and install screw plugs, using screw plug wrench, Special Tool No. 95905-03004, torque to 5.5-7.0 kg/m (40-50 ft. lbs.).

18. Install new felt plate, apply grease to threads of screw plugs and tighten.

19. Install cover plate.

20. Install lock plates on delivery valve holders and torque to 0.8-1.1 kg/m (5.8-7.9 ft. lbs.)

Installation.

1. Install woodruff key to injection pump camshaft.

2. Install automatic timer, secure with round nut and torque to 6-7 kg/m (43.5-50.75 ft. lbs.).

SPECIAL NOTE

The following steps are critical to the timing of the engine.

3. Secure flange plate to injection pump so that mark on flange plate is on center mark on injection pump flange. Figure 48.

3A. Use long studs in front cover to guide pump at installation.

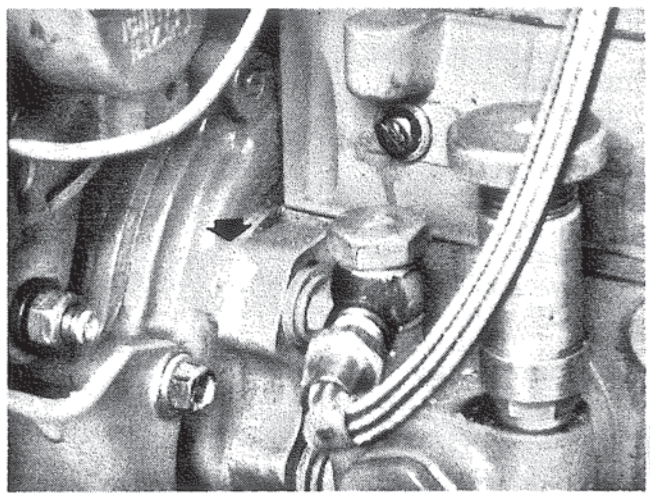


Figure 48. Installing Flange to Injection Pump.

4. Turn crankshaft until piston in No. 1 cylinder is at top dead center on compression stroke (rocker arms loose).

5. Install pump as follows:

A. Line up mark on tooth of gear with mark on pump.

B. Insert pump until pump gear meshes with idler gear and push pump into place.

NOTE

As pump is inserted gear will rotate and mark on gear will not be lined up with mark on pump as viewed with pump almost home.

6. Check timing as outlined in this section under Timing.

1 - HOUSING PUMP
2 - O-RING
3 - PUMP ELEMENT
4 - VALVE ASSEMBLY
5 - GASKET
6 - SPRING
7 - HOLDER
8 - LOCKPLATE SET
9 - GUIDE SCREW
10 - CONTROL RACK
11 - BREATHER ASSEMBLY
12 - WASHER
13 - NIPPLE
14 - SCREW
15 - WASHER
16 - O-RING
17 - ROLLER BEARING
18 - SHIM
19 - RING
20 - PLATE ASSEMBLY
21 - COVER PLATE
22 - PACKING
23 - SCREW
24 - SCREW
25 - WASHER
26 - DRAIN SCREW
27 - DRAIN SCREW WASHER
28 - CENTER BEARING
29 - WASHER
30 - SCREW
31 - O-RING
32 - TAPPET ASSEMBLY
33 - BOLT
34 - NUT
35 - BODY
36 - ROLLER PIN
37 - TAPPET ROLLER
38 - ROLLER BUSHING
39 - SCREW PLUG
40 - LOWER SPRING SEAT
41 - PLUNGER SPRING
42 - UPPER SPRING SEAT
43 - CONTROL SLEEVE
44 - CONTROL PINION
45 - CLAMP SCREW
46 - WOODRUFF KEY
47 - CAMSHAFT
48 - WASHER
49 - CONTROL RACK COVER
50 - SCREW
51 - RING
52 - SHIM
53 - ROLLER BEARING
54 - BEARING COVER GASKET
55 - COVER BEARING
56 - BOLT W/WASHER
57 - SPRING WASHER
58 - ROUND TIMER NUT

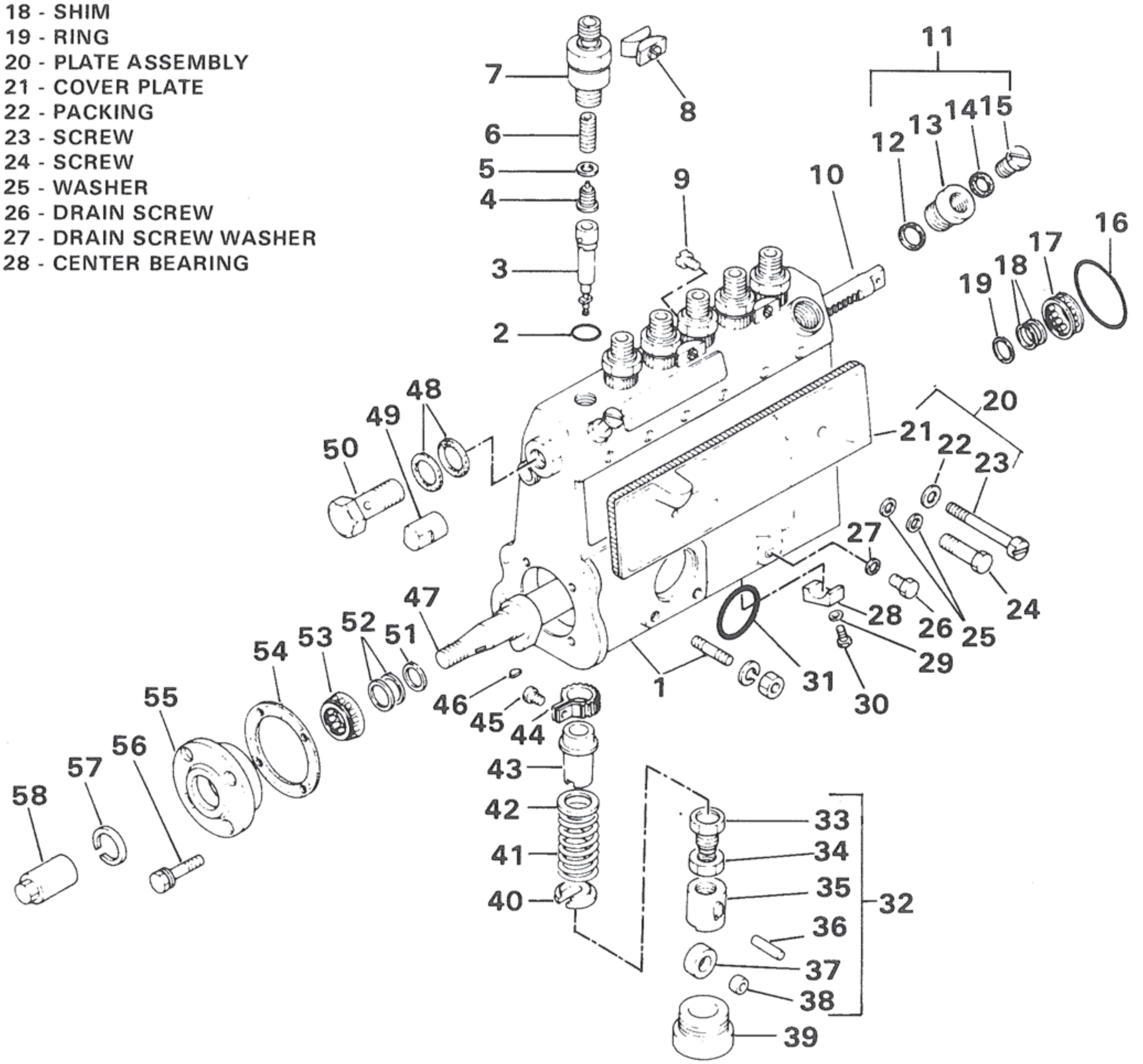


Figure 49. Injection Pump. Exploded View.

GOVERNOR

NOTE

Adjustment is covered under Adjustments in this section.

NOTE

If governor will not adjust, injection pump does not put out fuel or if unit is noisy, tear down is probably necessary.

Removal.

1. Remove governor, injection pump and automatic timer as an assembly, as outlined under Fuel Injection Pump in this section.

Removal Notes.

1. Nippondenso, the governor manufacturer, advises that the governor should not be taken apart unless absolutely necessary. If the governor is noisy or it will not work right after being adjusted, it probably needs cleaning or rebuilding.

The governor may be sent to a Nippondenso repair center.

Note torques during disassembly to aid in proper reassembly.

2. Clean outside of governor and make sure work area is clean.

3. Drain oil.

4. Remove cover (with lever assemblies) as follows:

A. Remove six (6) screws holding cover to housing.

NOTE

Screws are different lengths.

CAUTION

In next steps be careful not to let weight of cover assembly damage starting spring or shackle.

B. Disconnect starting spring from bracket in housing, using needle nose pliers.

C. Unfasten clip holding end of shackle to control rack.

5. Remove governor housing as follows:

A. Remove six (6) screws holding governor housing to injection pump, using a thin wall socket and flexible extension.

Cleaning and Inspection.

1. Clean both assemblies with clean diesel fuel.

2. Inspect all parts for wear, cracks or damage.

Disassembly.

1. Remove lever assemblies from cover as follows:

A. Remove lever support shaft at top of cover by removing screw plugs on each end of shaft.

B. Disengage support lever by removing pin.

C. Remove adjusting lever by removing bolt, spreading bracket, and pulling off lever.

D. Remove swivel lever from cover by pressing shaft first one way, then the other until it can be worked free.

E. Remove stop lever assembly.

2. Separate levers, if needed, by removing pins, control spring, cotter pin.

NOTE

Replace all seals and O-rings.

3. Disassemble housing assembly as follows:

A. Remove aneroid by removing four (4) screws.

B. Remove control shaft by removing bolt and E clips.

C. Remove flyweight by removing spring washers and pulling assembly off camshaft.

Reassembly.

1. Assemble housing as follows:

A. Press flyweight assembly onto camshaft and secure with spring washers.

B. Install control shaft and secure with bolt and E clips.

C. Install aneroid with four (4) screws.

2. Install lever assemblies to cover as follows:

A. Install swivel lever with lever bushings, new oil seals and O-rings.

B. Install lever support shaft at top of cover, secure with screw plugs.

C. Engage support lever by installing pin.

D. Install adjusting lever.

E. Install stop lever assembly, making sure end of return spring is hooked into spring cover.

3. Install governor housing to injection pump with six (6) screws.

4. Install cover assembly to housing as follows:

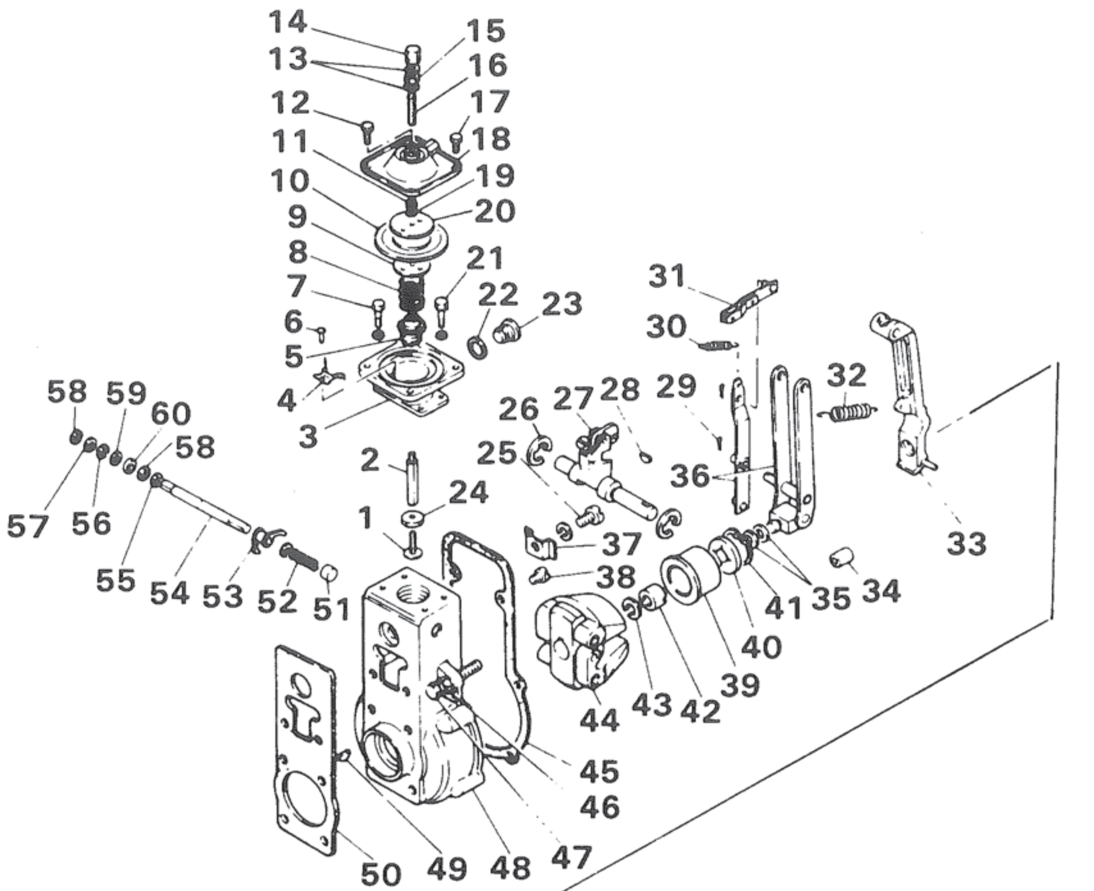
A. Connect starting spring to bracket in housing.

B. Fit sleeve into flyweights.

C. Fasten clip from shackle to control rack.

D. Secure cover to housing with six (6) screws and washers.

1 - SCREW
2 - SHAFT
3 - ANERIOD HOUSING
4 - SPRING CLIP
5 - BUSHING
6 - RIVET
7 - BOLT W/WASHER
8 - SPRING
9 - UPPER SPRING SEAT
10 - DIAPHRAGM
11 - NUT
12 - BOLT
13 - GASKET
14 - COVER 15 - NUT
16 - SCREW
17 - BOLT
18 - ANEROID COVER
19 - WASHER
20 - THRUST WASHER
21 - BOLT
22 - GASKET
23 - CLOSING PLUG
24 - STOP NUT
25 - BOLT W/WASHER
26 - E-RING
27 - LEVER ASSEMBLY
28 - WOODRUFF KEY
29 - PIN
30 - START SPRING
31 - SHACKLE ASSEMBLY
32 - CONTROL SPRING
33 - TENSION LEVER
34 - SLIDER
35 - SHIM PLATE
36 - LEVER ASSEMBLY
37 - PLATE
38 - BOLT W/WASHER
39 - SLEEVE ASSEMBLY
40 - THRUST BEARING
41 - SNAP RING
42 - ROUND NUT
43 - SPRING WASHER
44 - FLYWEIGHT ASSEMBLY
45 - GASKET
46 - LOCKNUT
47 - SCREW
48 - GOVERNOR HOUSING
49 - WOODRUFF KEY
50 - GASKET
51 - CAP
52 - SPRING
53 - LEVER ASSEMBLY
54 - LEVER SHAFT
55 - WASHER
56 - E-RING
57 - WASHER
58 - E-RING
59 - PLATE WASHER
60 - OIL SEAL
61 - SCREW PLUG
62 - LEVER SHAFT
63 - COVER ASSEMBLY
64 - BOLT
65 - WASHER
66 - SCREW PLUG
67 - IDLE SPRING
68 - ADAPTER SCREW
69 - WASHER
70 - CAP NUT
71 - LOCKNUT
72 - GASKET
73 - CAP NUT
74 - LOCKNUT
75 - O-RING
76 - BUSHING
77 - BOLT W/WASHER
78 - COVER PLATE
79 - SET SCREW
80 - O-RING
81 - SCREW
82 - O-RING
83 - COLLAR
84 - SCREW
85 - LEVER ASSEMBLY
86 - OIL SEAL
87 - BUSHING
88 - BOLT W/WASHER
89 - STOP LEVER
90 - SPRING COVER
91 - RETURN SPRING
92 - O-RING
93 - BUSHING
94 - LOCKNUT
95 - SCREW
96 - ADAPTER ASSEMBLY
97 - SCREW
98 - SHIM
99 - ADAPTER
100 - SPRING
101 - WASHER
102 - SNAP RING
103 - SUPPORT LEVER
104 - GOVERNOR SHAFT
105 - SPRING CUP
106 - OUTER SPRING
107 - MIDDLE SPRING
108 - INNER SPRING
109 - PLATE CAP
110 - SUPPORT PIN
111 - LEVER CAP



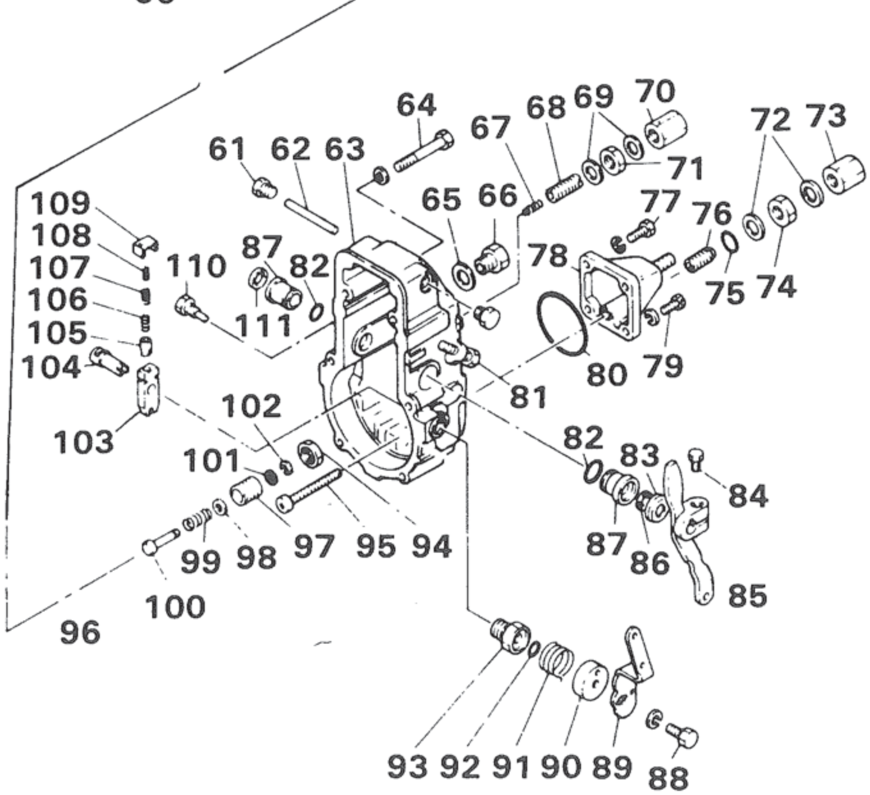


Figure 50. Governor (TI). Exploded View.

1 - HOUSING, GOVERNOR
2 - PLUG, SCREW
3 - GASKET
4 - PLUG, SCREW
5 - SCREW
6 - SCREW
7 - E-RING
8 - LEVER ASSEMBLY, SWIVELING
9 - KEY, WOODRUFF
10 - SHACKLE ASSEMBLY
11 - PIN
12 - SPRING, START
13 - SPRING, CONTROL
14 - SHAFT, GOVERNOR
15 - SPRING, INNER "A"
16 - SPRING, OUTER "B"
17 - SEAT SPRING
18 - RIVET
19 - LEVER, SUPPORT
20 - CUP, SPRING
21 - O-RING
22 - BUSHING, LEVER
23 - CAP, LEVER
24 - PLUG, SCREW
25 - SHAFT, SUPPORT, LEVER
26 - COVER, GOVERNOR
27 - SCREW, SET
28 - ADAPTER
29 - SPRING, IDLING
30 - SCREW, ADAPTER
31 - E-RING
32 - NUT, LOCK
33 - WASHER
34 - NUT, CAP
35 - NUT, CAP
36 - GASKET
37 - NUT, LOCK
38 - BOLT W/WASHER
39 - SCREW, SET
40 - PLATE, COVER
41 - GASKET, PLATE COVER
42 - LEVER, ADJUSTING
43 - SCREW
44 - OIL SEAL
45 - BUSHING, LEVER
46 - SCREW
47 - SCREW
48 - LEVER, STOP
49 - COVER, SPRING
50 - SPRING, RETURN
51 - O-RING
52 - BUSHING, BEARING
53 - PLUG, SCREW
54 - WASHER
55 - SCREW, STOP, FULL LOAD
56 - NUT, LOCK
57 - ADAPTER ASSEMBLY
58 - RING, SNAP
59 - WASHER
60 - SCREW, ADAPTER
61 - SHIM
62 - SPRING
63 - ADAPTER
64 - LEVER, TENSION
65 - LEVER ASSEMBLY, CONTROL
66 - SHIM, PLATE
67 - BEARING, BALL
68 - SLEEVE, GOVERNOR
69 - NUT, ROUND
70 - WASHER, SPRING
71 - FLYWEIGHT ASSEMBLY
72 - NUT, LOCK
73 - GASKET
74 - WASHER, PLATE
75 - KEY, WOODRUFF
76 - PIN

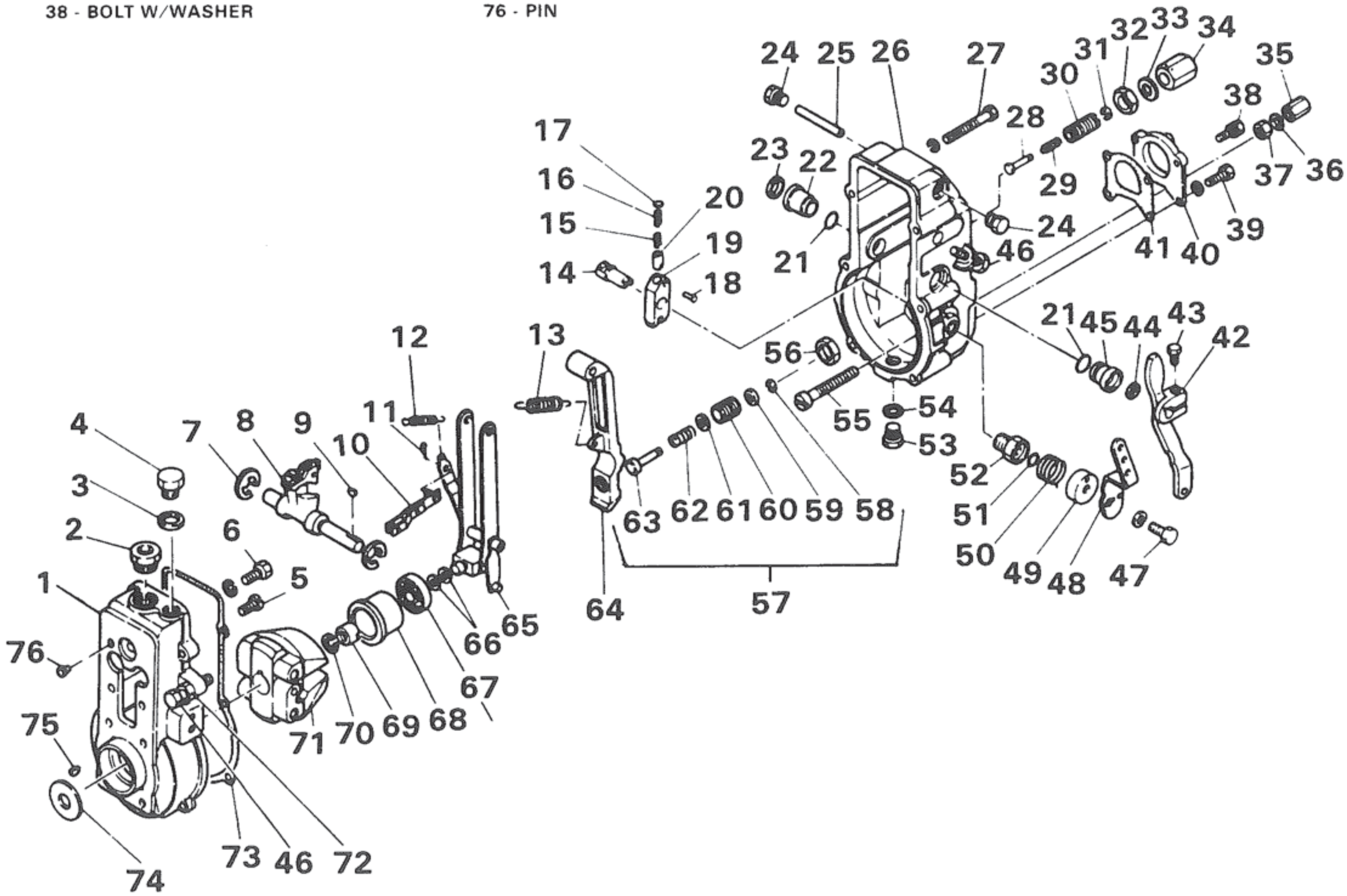


Figure 51. Governor (NA). Exploded View.

AUTOMATIC TIMER

Description. The automatic timer is a mechanical timer mounted to the injection pump camshaft. A set of gears controls fuel injection timing, based on engine speed.

Testing.

1. Set up to test timer as follows:

A. Attach timer to injection pump.

B. Connect assembly to driving coupling of bench tester.

C. Install strobo-switch on No. 1 tappet slider of pump. Figure 52.

D. Set indicator so that 0° angle and injection starting point of No. 1 cylinder fit together.

NOTE

Angle degrees are marked on edge of coupling.

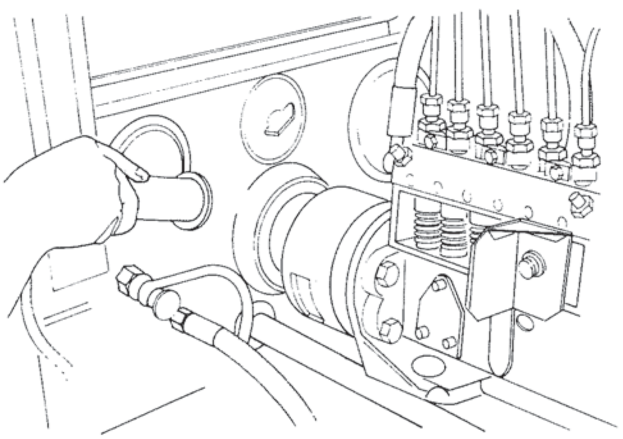


Figure 52. Testing Automatic Timer.

2. Test timer by measuring advance angle injection to pump speed. Table 14.

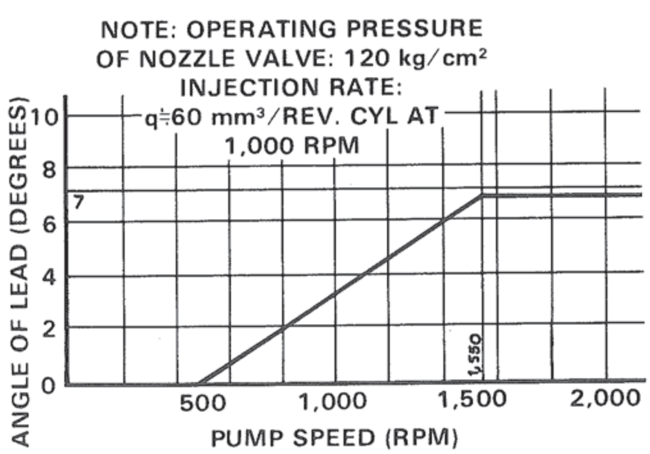


Table 14. Timer Specifications.

3. Adjust timer, if test results fall out of range shown in Table 14, by shimming with washers as outlined in Reassembly.

Removal.

1. Remove injection pump, automatic timer and governor as an assembly, as outlined in this section under Injection Pump.

2. Remove round nut.

3. Remove automatic timer with injection pump gear from injection pump. Figure 53.

4. Remove gear from timer.

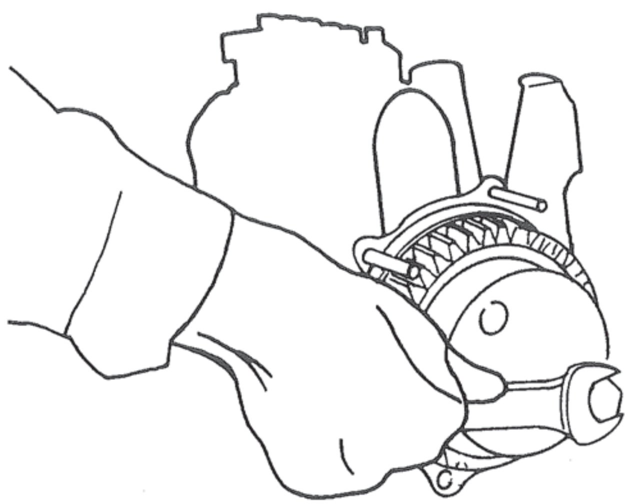


Figure 53. Removing Automatic Timer.

Disassembly.

1. Remove snap ring and plate washer/thrust washer. Figure 54.

2. Remove driving flange as follows:

WARNING

Timer spring may pop out during removal of flange.

A. Insert spanner in driving flange, turn slowly.

B. Remove driving flange, spring and spring seats.

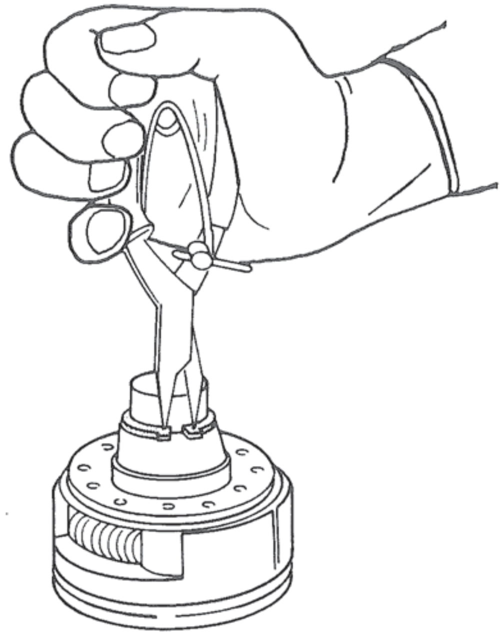


Figure 54. Removing Snap Ring.

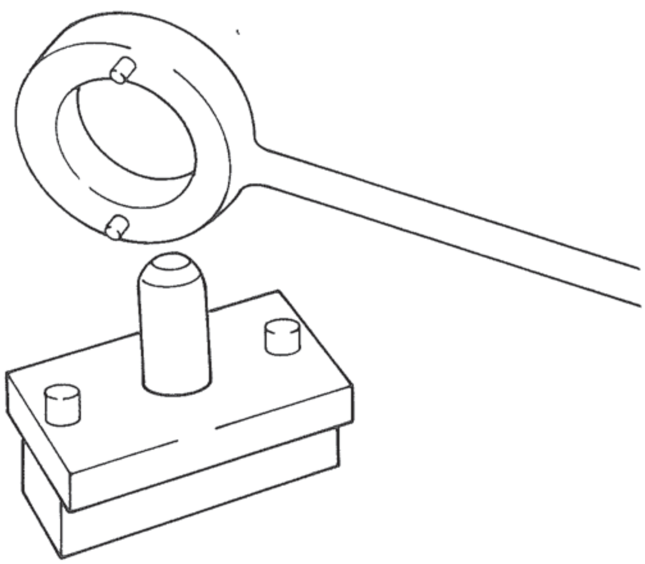


Figure 55. Automatic Timer Tools.

Inspection and Repair.

1. Clean parts in solvent.
2. Inspect all parts for unusual wear, damage.
3. Check weight holder pin for looseness.
4. Check springs for cracks.

Reassembly.

1. Install weight on hub bolt and driving flange on weight.
2. Fit springs with seats, washers between hub bolt and driving flange seat.
3. Secure assembly using spanner as follows: Figure 56.

A. Make sure driving flange bolts are on weight.

B. Make sure guide pins of spring seats stay inside springs.

C. Move spanner back and forth until journal of driving flange fits on sliding face of weight.

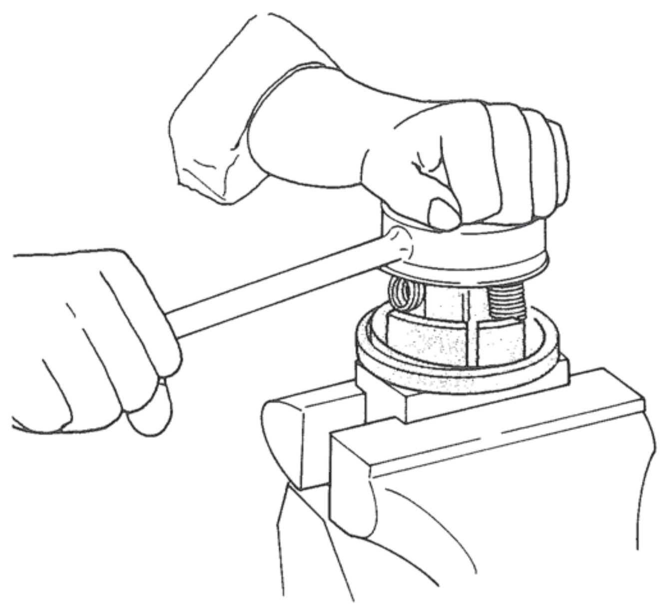


Figure 56. Installing Timer Spring Assembly.

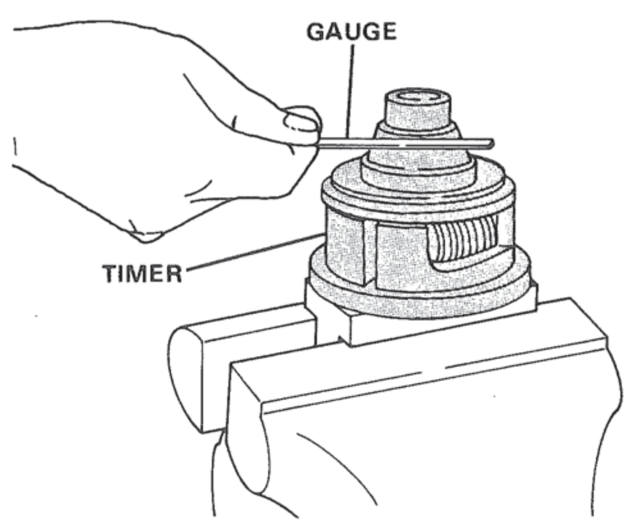


Figure 57. Checking Thrust Clearance.

4. Check that spring seats are in place.

5. Install washers and secure with snap ring.

6. Check and adjust washer clearance as follows:

A. Check clearance with feeler gauge. Figure 57.

B. If clearance is 1 mm. (.0039 in.) or more select from shim(s) available: 0.01 and .2 mm. to bring clearance down to a dimension less than .1 mm. (.0039 in.).

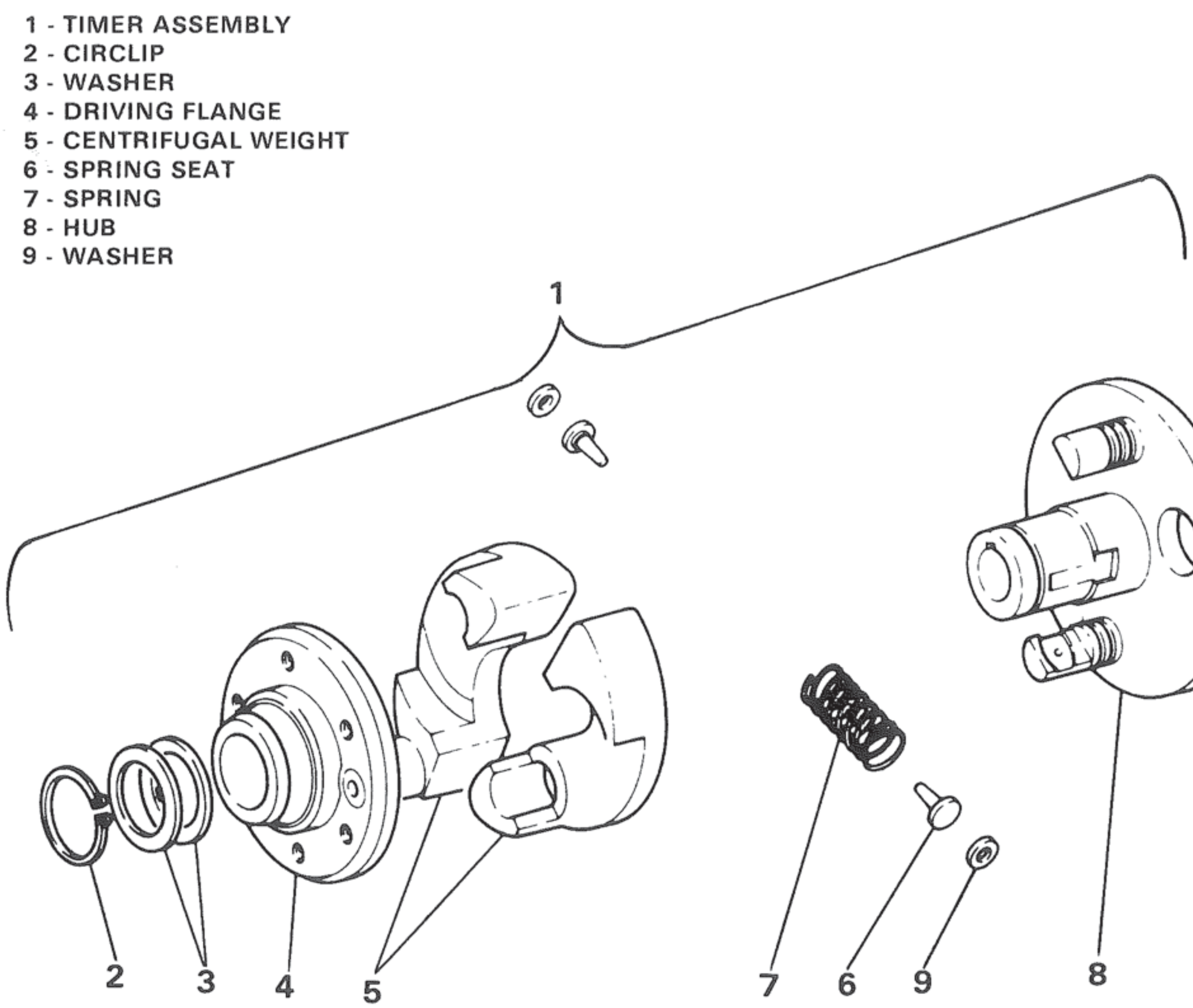


Figure 58. Automatic Timer. Exploded View.

Section 11

DRIVES

CONTENTS

WARNER DRIVE - MODELS 10-17, 10-18

GENERAL

This subsection deals with the operation, maintenance and repair of Warner Drives.

OPERATION

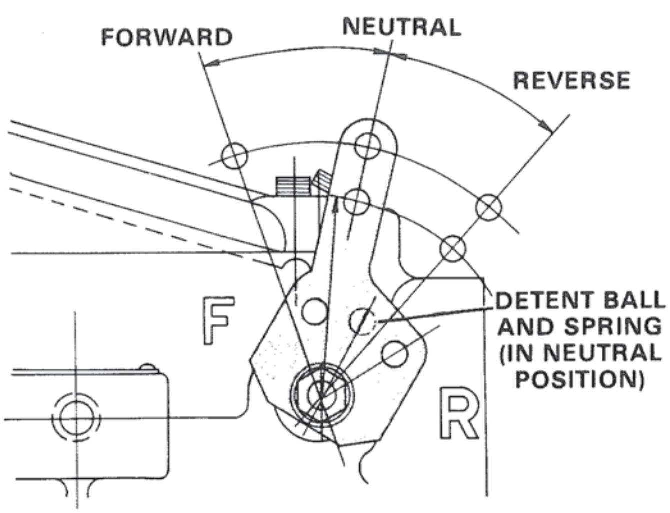


Figure 1. Shift Lever Positions.

A detent ball and spring assembly properly locates the shift lever in three (3) positions: forward, neutral and reverse. Figure 1.

Forward. Oil, at regulated pressure, flows from the control valve into the transmission case and into the cavity behind the piston of the forward clutch cylinder. The piston movement forces the clutch discs together with the clutch hub, in turn, connecting the input shaft, output shaft and ring gear. Therefore when the input shaft turns, the output shaft turns.

Neutral. The oil flow is blocked by and at the control valve, preventing the clutch from moving or engaging with other parts.

Reverse. Oil, at regulated pressure, flows through the transmission case into the reverse clutch cavity causing the clutch piston and pressure plate to lock the clutch plate to the case. Now the ring gear can't rotate. The sun gear spins at input speed and the planetary gearset pinions rotate on their own axes causing the output shaft to spin in reverse.

Shifting. Shift from forward to reverse below high idle engine speeds (approximately 1000 RPM). This will prevent damage of the marine gear.

Components. The transmission consists of a planetary gear set, a forward clutch, a reverse clutch, an oil pump, and a pressure regulator and rotary control valve. All of these are contained in a cast iron housing along with necessary shafts and connectors, to provide forward, reverse and neutral operation. A direct drive ratio is used for all forward operation. In reverse the speed of the output shaft is reduced by a 1.10 ratio from that of the input shaft speed, and is in the opposite direction. Helical gearing is used to provide quieter operation than can be obtained with spur gearing.

The transmission is fast shifting to give the boat operator complete control of the vessel. Shifting is accomplished by the fore and aft movement of the shift lever. Figure 1. This movement rotates the control valve and directs oil under controlled pressure to the required channels. Oil pressure is provided by the crescent type pump, the drive gear of which is keyed to the drive shaft and operates at transmission input speed to provide screened oil to the pressure regulator.

From the regulator valve the oil is directed through the proper circuits to the bushings and anti-friction bearings requiring lubrication. A flow of lubricant is present at the required parts whenever the front pump is turning and it should be noted that supply is positive in forward, neutral and reverse conditions.

The unit has seals to prevent escape of oil.

Both the input and output shafts are coaxial, with the input shaft splined for the installation of a drive damper, and the output shaft provided with a flange for connecting to the propeller shaft.

MAINTENANCE

Lubrication. THE PROPERTIES OF THE OIL USED IN THE TRANSMISSION ARE EXTREMELY IMPORTANT TO THE PROPER FUNCTION OF THE HYDRAULIC SYSTEM. THEREFORE, IT IS EXTREMELY IMPORTANT THAT THE RECOMMENDED OIL, AUTOMATIC TRANSMISSION FLUID (ATF), TYPE "A", SUFFIX "A", BE USED.

Filling Oil. When filling the transmission, oil should be added until it reaches the full mark on the dipstick. The quantity of oil depends upon the angle of the installation, but information to serve as a guide on possible amount needed may be found in chart below. The unit should be turned over at engine idle speed for a short time in order to fill all circuits, including the cooler and cooler piping.

NOTE

Be sure the cooler is properly installed and the transmission contains oil before cranking or starting engine.

Checking Oil. The oil level should be checked immediately after shutting off engine and sufficient oil added to again bring the transmission oil level to the full mark on the dipstick assembly. The dipstick assembly need not be threaded into the case to determine the oil level. It need only be inserted into the case until the cap or plug rests on the surface surrounding the oil filler hole.

The transmission should be checked periodically to maintain proper oil level, and oil should be added if necessary.

Oil Pressures. Transmission line pressures should be between 110 - 150 p.s.i. (7.73 - 10.54 kg/cm^2)at engine speeds between 450 and 2000 RPM at normal operating temperatures of 150 - 165° F (66 - 74° C). When operating the transmission at low temperatures or excessive speeds pressures of 200 - 250 p.s.i. (14.1 - 17.6 kg/cm^2) may be obtained.

A maximum transmission oil temperature of 190° F (88° C) is recommended.

Changing Oil. It is recommended that the transmission oil be changed once each season. After draining oil from the unit, the removable oil screen should be thoroughly cleaned before refilling the transmission with the recommended oil type labeled Dextron Automatic Transmission Fluid or Chrysler Automatic Transmission Fluid, AO-ATF-2848A. If the Dextron type fluids are not available, type "A", suffix "A" may be used. The reverse gear should be filled to the "Full" mark on the dipstick.

OIL CAPACITY

Transmission Model	Transmission Oil Capacity (Qts.) Level	15° Inclined
AS11-72C or CR	2.1	1.7

NOTE

Oil capacity does not include capacity needed for transmission cooler and oil lines which in many cases require an amount greater than in this chart.

Oil Draining.

1. Remove oil filler plug located below the shift lever on rear left side of transmission case.

2. If space permits, place container having approximately three (3) quart capacity under drain cap. Unscrew the drain plug and cooler return tube assembly. Allow oil to drain into pan.

TORQUE SPECIFICATIONS

Part Number	Description	Application	Torque Lbs.-Ft.
179822	5/16-18 x 1-1/2 Hex Head Bolt	Pump to Adapter	17-22 (2.34-3.03 kg/m)
4911	3/8-16 x 1-1/4 12 Point Capscrew	Adapter to Case	27-37 (3.72-5.10 kg/m)
179793	1/4-20 x 5/8 Hex Head Bolt	Valve Cover to Case	8-11 (1.10-1.52 kg/m)
115729	5/16-24 Nut	Shift Lever to Valve	8-11 (1.10-1.52 kg/m)
4737Q	7/16-14 x 1-1/8 Hex Head Bolt	Bearing Retainer to Case	27-32 (3.72-4.41 kg/m)
4775L	1-20 Nut	Output Shaft Nut	100-200 (13.79-23.59 kg/m)
4885B	3/4-14 Bushing	Cooler Return to Case	25-35 (3.45-4.83 kg/m)
444687	1/8-27 Dryseal Pipe Plug	Case	7-12 (.97-1.66 kg/m)
444858 } Opt. 444860 }	1/4-18 Dryseal Pipe Plug	Adapter	12-30 (1.66-2.76 kg/m)
444866	3/8-18 Dryseal Pipe Plug	Case	17-28 (2.34-3.72 kg/m)
71-A195	3/4-14 Pipe Plug	Dipstock Assy. into Case	10-15 (1.38-2.07 kg/m)

INSTALLATION PRECAUTIONS

Transmission Oil Cooler. The oil cooler must be properly connected to the transmission before the engine is cranked or started. Failure to properly connect the oil cooler will result in the blowing out of the forward clutch piston due to over pressurization.

A cooler of sufficient size should be used to assure that the maximum oil temperature of the transmission will not exceed 190° F (88° C). Failure to provide proper cooling may result in damage to the transmission from insufficient oil flows and pressures if the transmission is operated at temperatures above the maximum recommended.

The proper oil cooler inlet and outlet connections are covered in the text.

Although the type of cooler used is optional, a selection of three different sized coolers is manufactured for installation with these transmissions. Information regarding these coolers may be secured upon request from your local dealer.

Control Lever Position. The position of the control lever on transmission when in forward should be shifted to the point where it covers the letter "F" on the case casting, and is located in its proper position by the poppet ball. The Warranty is cancelled if the shift lever poppet spring and/or ball is permanently removed, or if the control lever is changed or repositioned in any manner, or if linkage between remote control and transmission shift lever does not have sufficient travel in both directions. This does not apply to tranmissions equipped with Warner Gear electrical shift control.

Front Pump Mounting. Before mounting the transmission on the engine be sure that the pump is correctly installed. Position the pump mounting bolt holes and arrows indicating direction of rotation to correspond with the direction of rotation required by the engine. If the pump is not installed for the proper rotation the pump will not produce oil pressure to operate the transmission when the engine is started.

KEY TO TROUBLESHOOTING CHART

1. Loose bolts — tighten.
2. Damaged gasket.
3. Damaged oil seal.
4. Oil line fittings loose — tighten.
5. Case leaks, porosity — replace.
6. Oil filler plug or cap leaks — replace or tighten.
7. Damaged control valve O-ring.
8. Foreign material on mating surfaces — clean.
9. Damaged oil cooler, water and oil mixing — replace.
10. No oil — check at once.
11. Pump improperly located for engine rotation — locate correctly.
12. Sheared drive key - replace.
13. Faulty oil gauge — clean or replace, bleed air from gauge line.
14. Dirty oil screen — clean or replace.
15. Low oil level — add oil to proper level.
16. Regulator valve stuck — clean surfaces of burrs, dirt, or scoring. Polish inner bore with crocus cloth until valve moves freely.
17. Worn oil pump — replace if necessary.
18. Regulator spring weight low — replace. 98-108 #@ 1-1/16 in. height.
19. High oil level — drain oil to proper level.
20. Low water level in cooling system.
21. Dirty oil cooler — clean or replace.
22. Cooler too small — replace with larger cooler.
23. Worn or misaligned bushings in transmission case — replace.
24. Worn or damaged clutch piston oil seals.
25. Worn or damaged clutch sealing rings.
26. Clutch improperly assembled.
27. Damaged or broken belleville spring.
28. Worn or damaged clutch plate(s) — replace.
29. Damaged or broken clutch springs.
30. Regulator valve not notched.
31. Inadequate torque on output shaft nut — tighten.
32. Nicks on gears — remove with stone.
33. Excessive runout between engine housing and crankshaft.
34. Wrong damper assembly.
35. Damaged damper assembly parts — replace.

36. Body-fit bolts not used in mounting holes.

37. Control linkage improperly adjusted.

38. Control lever and poppet ball corroded — clean and lubricate.

39. Control linkage interference — check.

40. Wrong oil used in transmission — change.

41. Cold oil.

42. Planetary gear failure — replace or repair if necessary.

43. Ring gear mounting plate not securely held (only reduction units AS4- , AS14- , AS5- , and AS15-).

TROUBLESHOOTING CHART

Complaints & Symptoms	Remedy: Transmission in Boat	Remedy: Transmission Removed
Internal & External Leaks		
1. Oil leaks at pump		1 2 3 8
2. Oil on exterior of transmission	1 4 6 7	2 5 8
3. Oil leaks at rear bearing retainer	1 2* 3* 8	
4. Water in transmission oil or oil in cooling water	9	
Transmission Malfunctions in All Ranges		
1. No oil pressure	10	11 12
2. Low oil pressure	13 14 15 16 18	17
3. High oil temperature	9 15 19 20 21 22	42
4. Failure of reduction gear		42 43
Transmission Malfunctions in Forward Range		
1. Low oil pressure	13 14 15 16 18	17
2. Forward clutch engages improperly	37	12 23 24 25 26 27 28
3. Forward clutch drags	37	26 27 28
4. Reduction unit failure		42 43
Transmission Malfunctions in Reverse Range		
1. Low oil pressure	13 14 15 16 18	17
2. Reverse clutch engages improperly	37	24 26 28 29
3. Reverse clutch drags	37	26 28 29
4. Reverse gear set failure		42
5. Reduction gear set failure		42 43
Transmission Malfunctions in Neutral		
1. Output shaft drags excessively in forward rotation	37	26 27 28
2. Output shaft drags excessively in reverse rotation	37	26 28 29 42
Miscellaneous Transmission Problems		
1. Regulator valve buzz	30	
2. Gear noise - forward	31	32 43
3. Gear noise - reverse	31	32 42 43
4. Pump noise	15	17 32
5. Damper noise or failure		33 34 35 36
6. Shifts hard	16 39	7 37 38
7. High oil pressures	16 40 41	

*If installation allows access, otherwise remove transmission.

DISASSEMBLY

Valve and Spring.

1. Remove three (3) hex head bolts, lockwashers, valve cover and valve cover gasket. Figure 2.

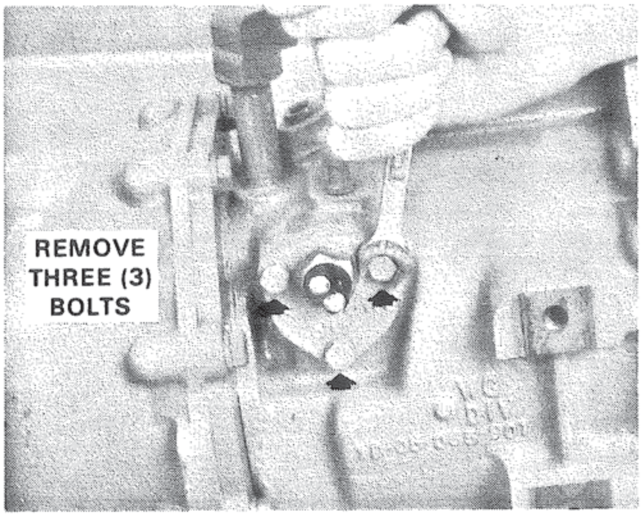


Figure 2. Removing Valve Cover.

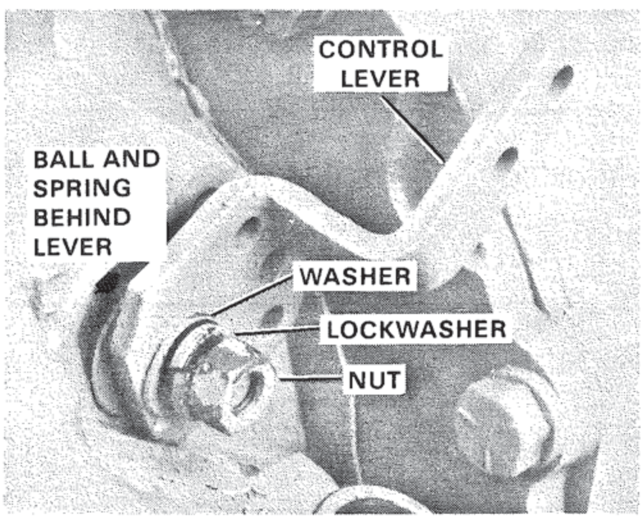


Figure 3. Shift Lever and Related Parts.

2. Remove shift lever and associated parts. Figure 3.

3. Tap with soft hammer on exposed threaded shaft upon which shift lever was mounted, and pull valve and spring assembly out of case from right side. Figure 4.

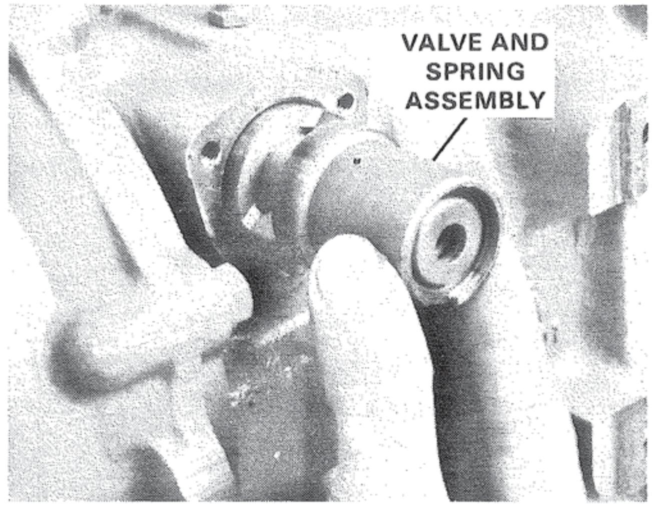


Figure 4. Removing Valve and Spring Assembly.

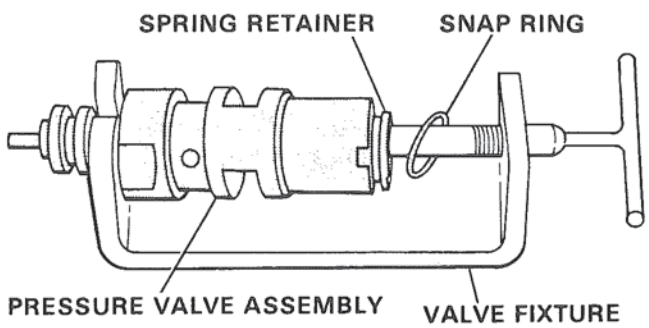


Figure 5. Control Valve Assembly in Fixture.

4. Place valve and spring assembly in a suitable holder. Figure 5. Depress the valve spring retainer and valve spring until the snap ring is free to be removed. The components of the valve and spring assembly can now be removed in the order shown in Figure 6.

NOTE

The control valve assembly can also be disassembled by using an arbor press with suitable tools. Figure 7.

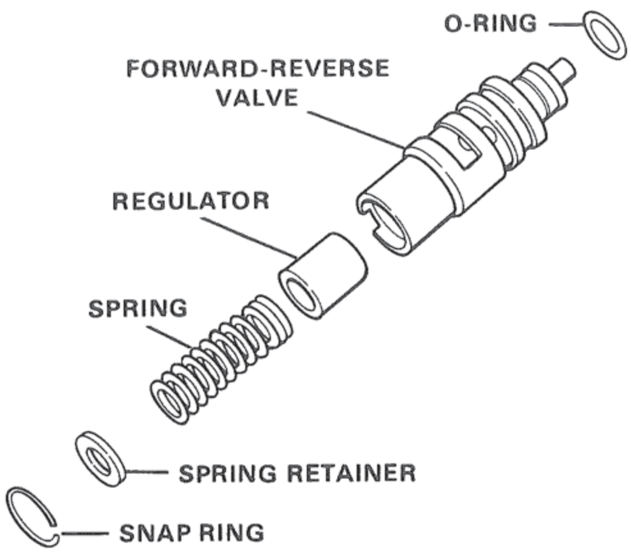


Figure 6. Exploded View of Valve and Spring Assembly.

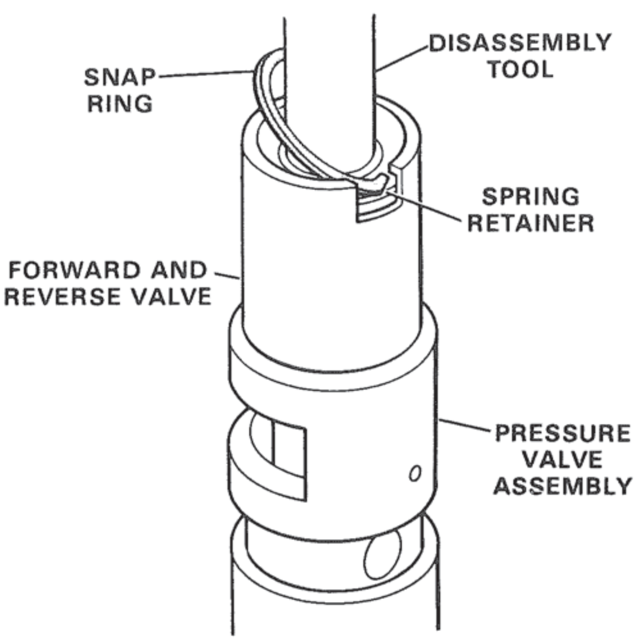


Figure 7. Removing Snap Ring.

Front Pump.

1. Remove the four (4) front pump attaching bolts. Figure 8. Place a protective covering over splines to prevent damage to seal lip, and lift pump assembly squarely up and over the protruding input shaft.

2. For the pump assembly with the backing plate, remove the one (1) flat head machine screw and lift backing plate to expose gears. Figure 9.

NOTE

Two different pump assemblies are used. One includes a backing plate which must be removed before the gears are exposed.

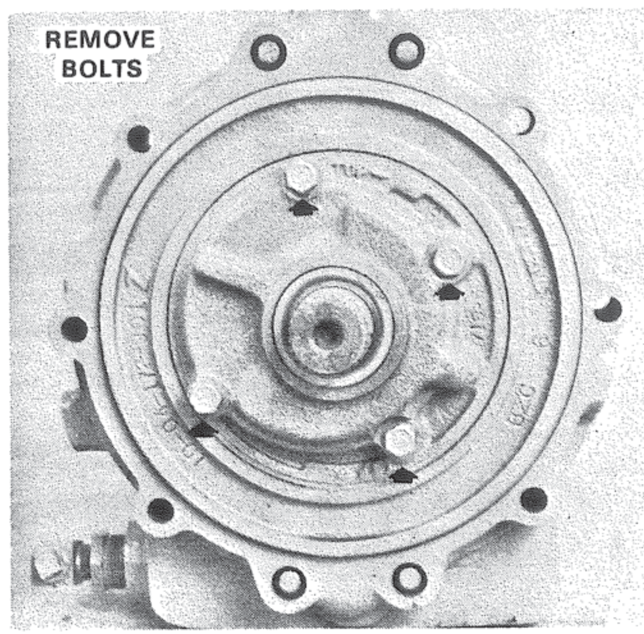


Figure 8. Removing Pump From Adapter.

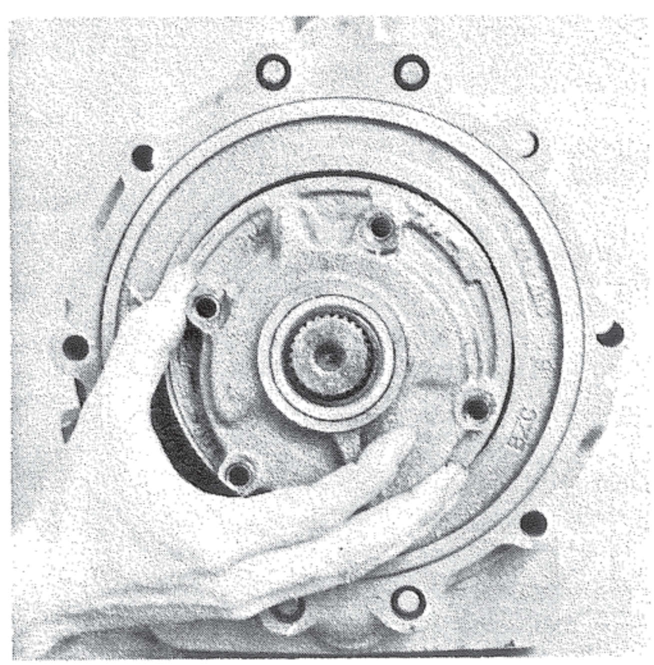


Figure 9. Removing Backing Plate.

3. Remove pump drive gear, front pump gasket, and woodruff key. Figure 10.

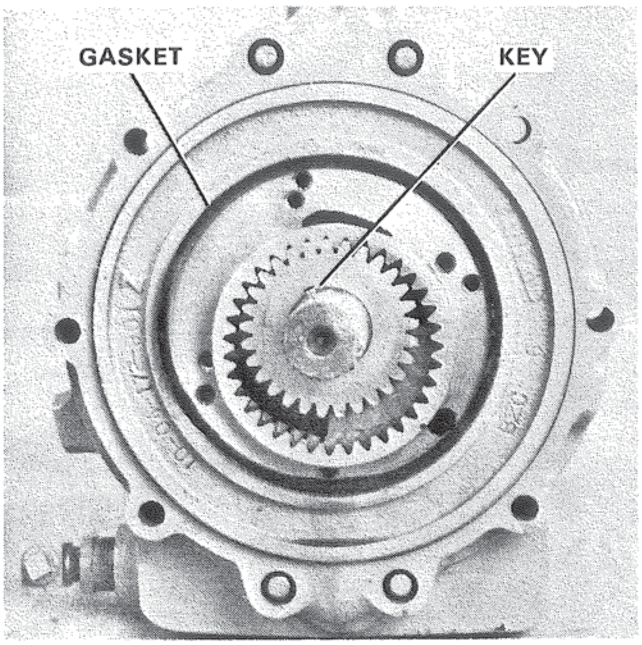


Figure 10. Removing Pump Drive Gear Key and Front Pump Gasket.

4. Mark gears to identify for proper relocation of gear faces during reassembly. Figure 11. Figure 12 shows views of the different front pump parts when completely disassembled.

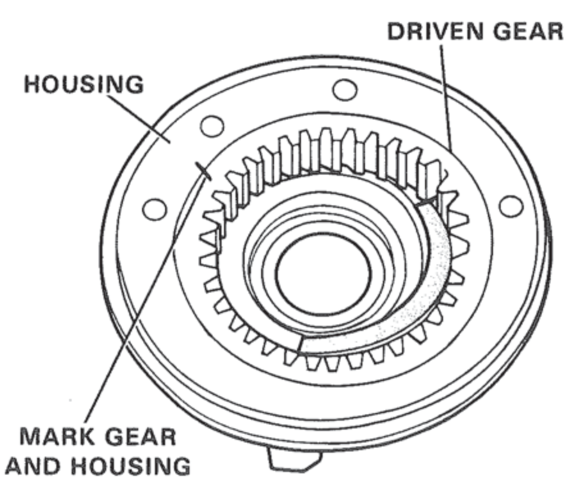


Figure 11. Marking Pump Gear Alignment.

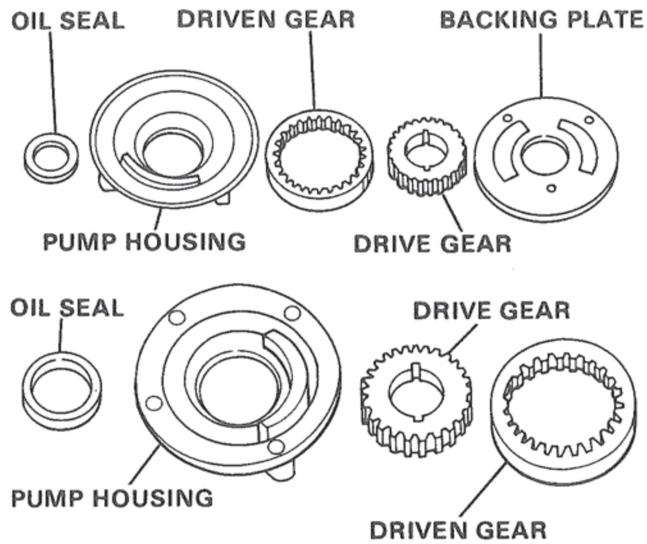


Figure 12. Front Pump Parts.

Adapter and Reverse Clutch Piston.

1. Remove the four (4) cap screws (12 point head). Figure 13. Lift off adapter and reverse clutch piston. Figure 14. If necessary, tap the adapter with a soft hammer to remove.

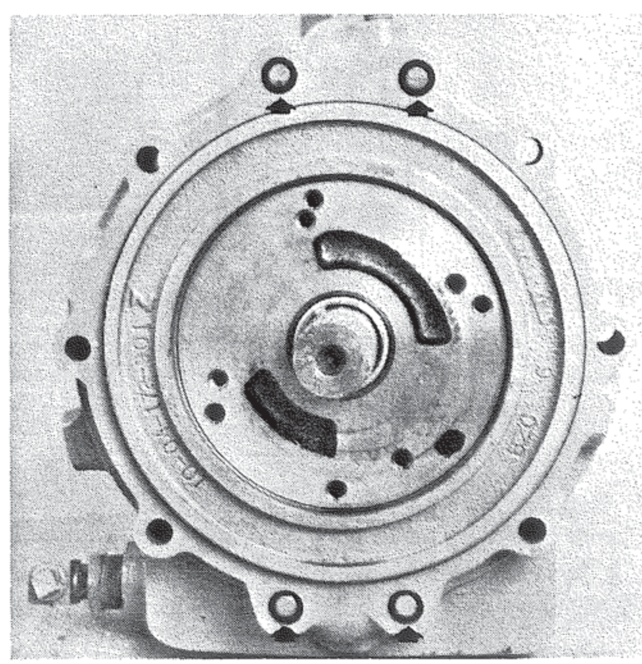


Figure 13. Removing Adapter from Case.

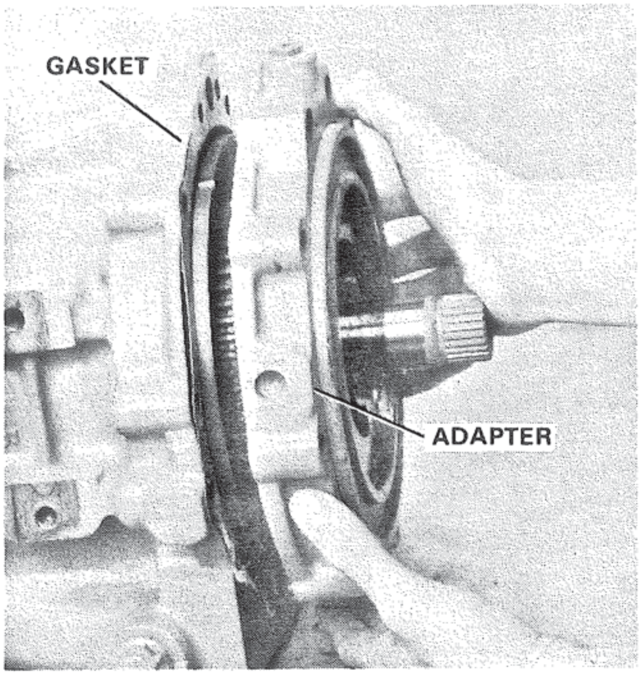


Figure 14. Removing Adapter and Reverse Clutch Assembly from Case.

CAUTION

The reverse clutch pressure plate may stick momentarily to the reverse clutch piston. To avoid damage, prevent pressure plate from dropping.

2. Force compressed air into reverse clutch cavity while holding piston and piston will pop out of reverse clutch cavity. Figure 15.

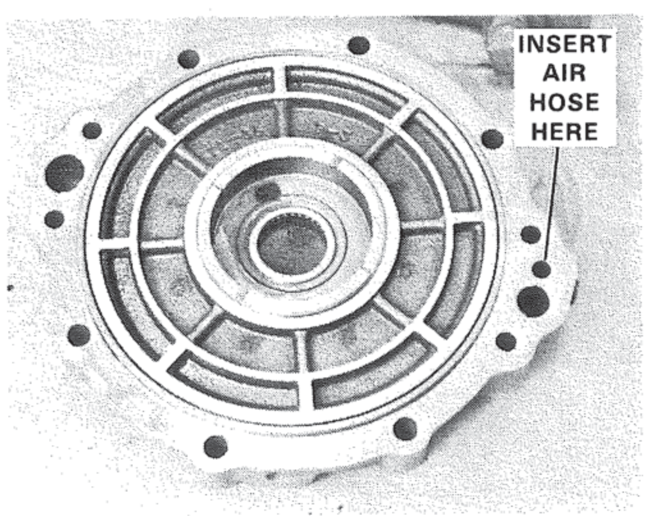


Figure 15. Disassembling Reverse Clutch Piston from Adapter.

3. Remove sealing rings. Figures 16 and 17.

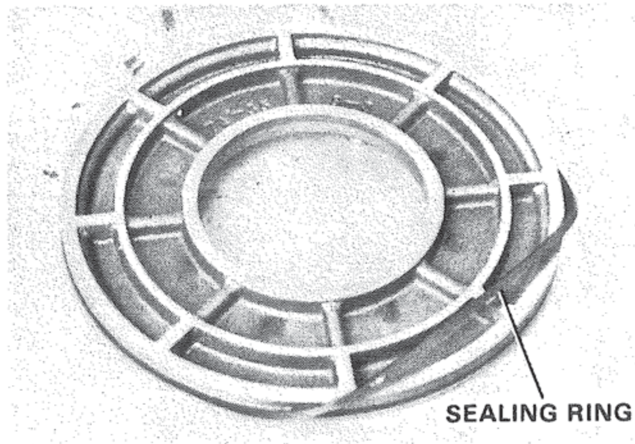


Figure 16. Removing Sealing Ring.

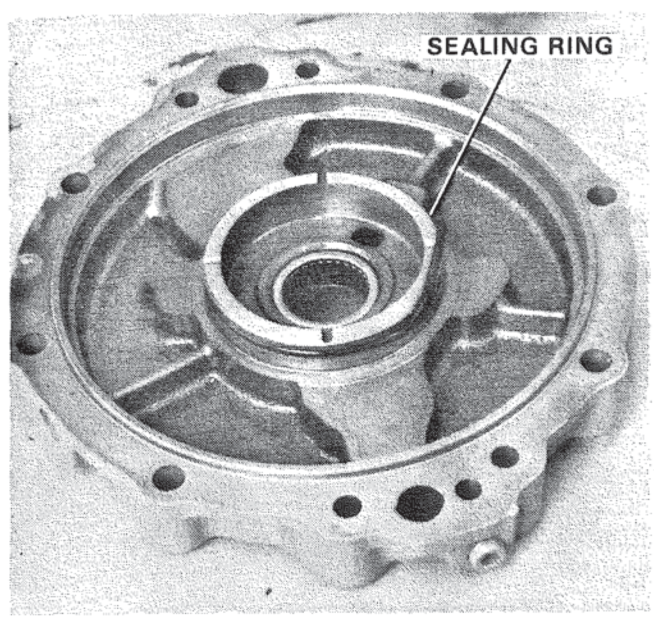


Figure 17. Removing Sealing Ring.

Pressure Plate and Hardware.

4. Thrust washer can now be lifted from position shown in Figure 18.

5. Remove clutch pressure plate, Figure 18, and then lift out the remaining clutch plates. Figure 19.

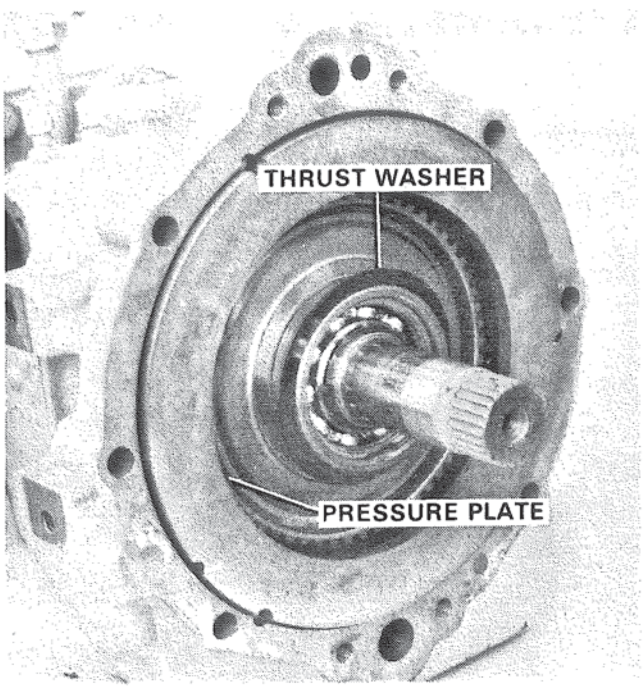


Figure 18. Removing Thrust Washer and Reverse Clutch Pressure Plate.

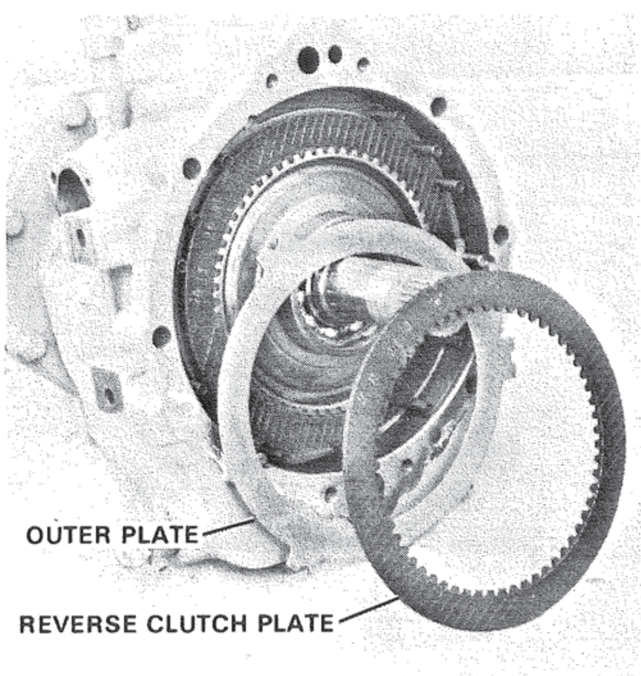


Figure 19. Removing Reverse Clutch Plates.

6. The twelve (12) pressure plate springs and the three (3) dowel pins can now be removed. Figure 20.

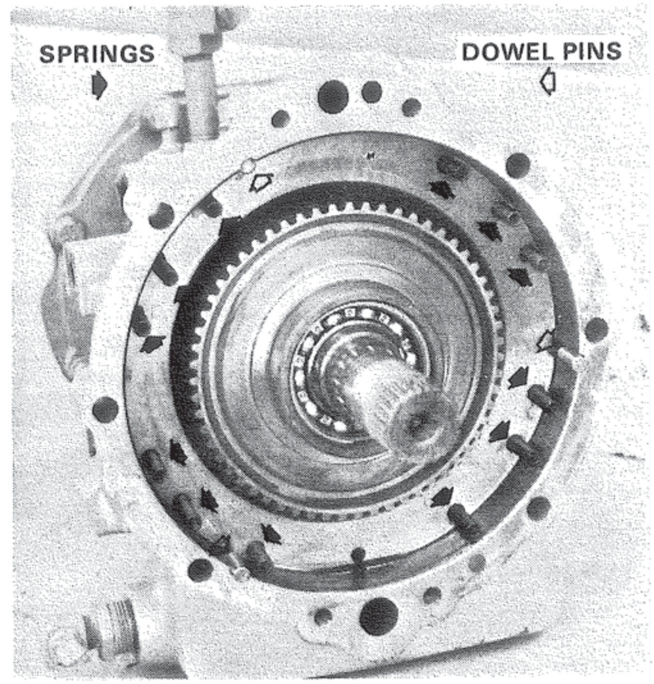


Figure 20. Removing Twelve (12) Pressure Plate Springs and Three (3) Dowel Pins.

Drive Gear and Clutch.

1. Grasp the exposed front end of the input gear and lift straight up; drive gear and clutch assembly parts lift easily out of opening in front. Figure 21.

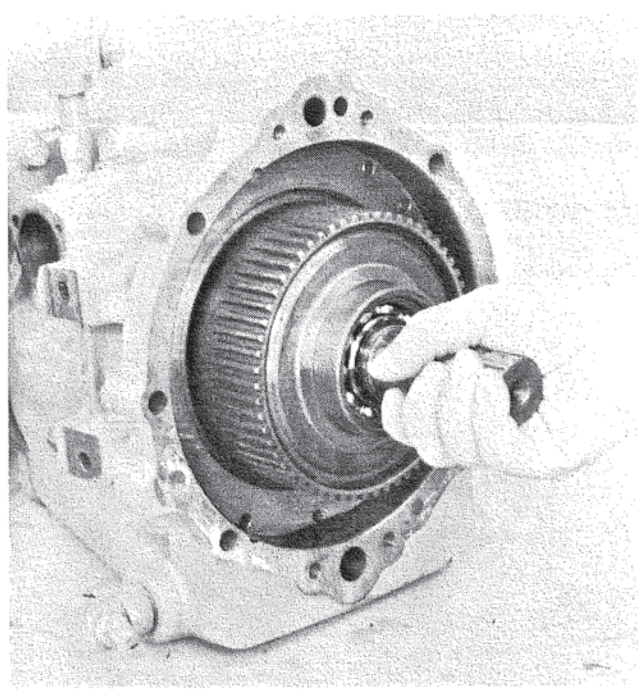


Figure 21. Removing Drive Gear and Clutch Assembly.

2. Remove thrust washer located between drive gear and planetary carrier. Figure 22.

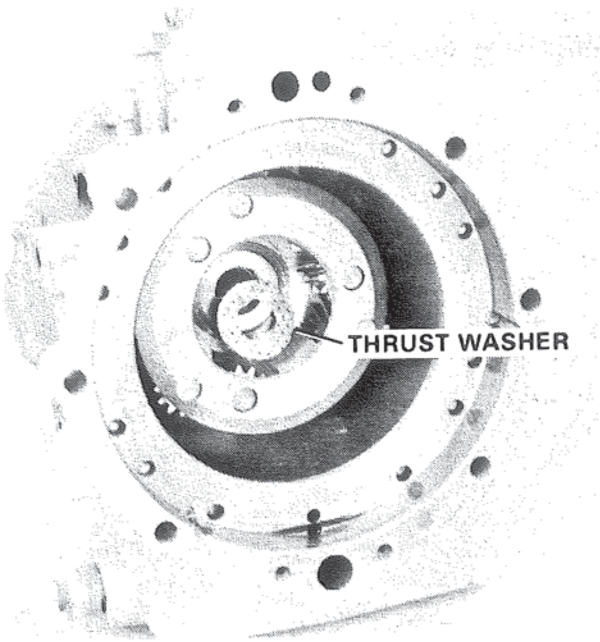


Figure 22. Removing Thrust Washer.

3. Stand drive gear and clutch assembly in suitable fixture and remove internal and external snap rings at ball bearing from the drive gear and clutch cylinder. Figures 23 and 24. Do not permit drive gear to move forward after the above snap rings are removed.

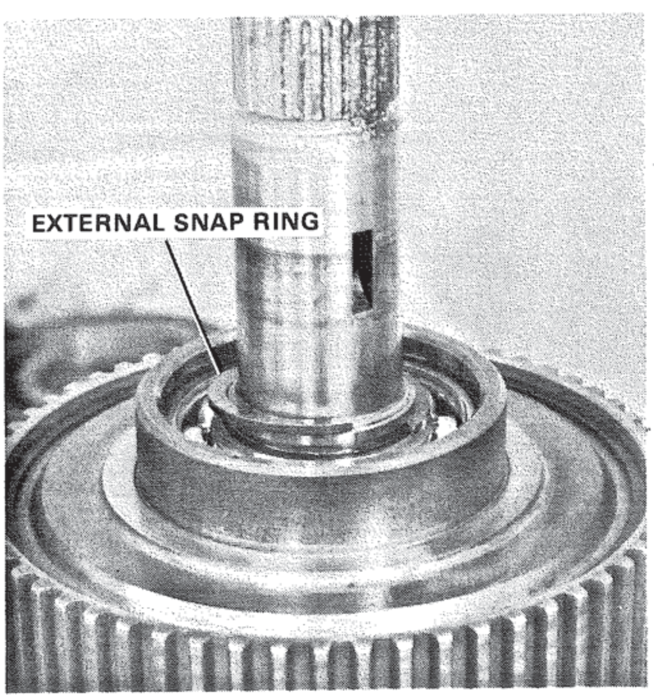


Figure 23. Removing External Snap Rings.

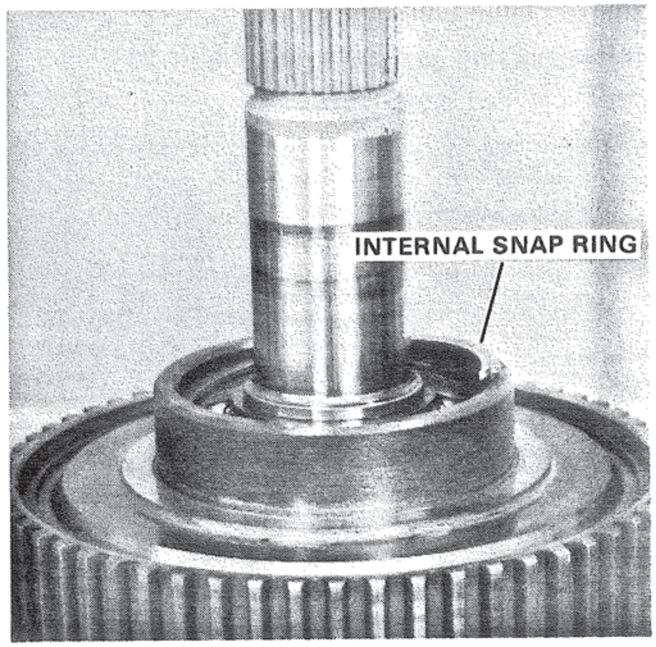


Figure 24. Removing Internal Snap Ring.

4. While holding the ring gear, tap the front end of the drive gear with soft hammer. The drive gear and forward clutch hub assembly will pass through the ring gear and forward clutch assembly to come out of the rear end of this ring gear.

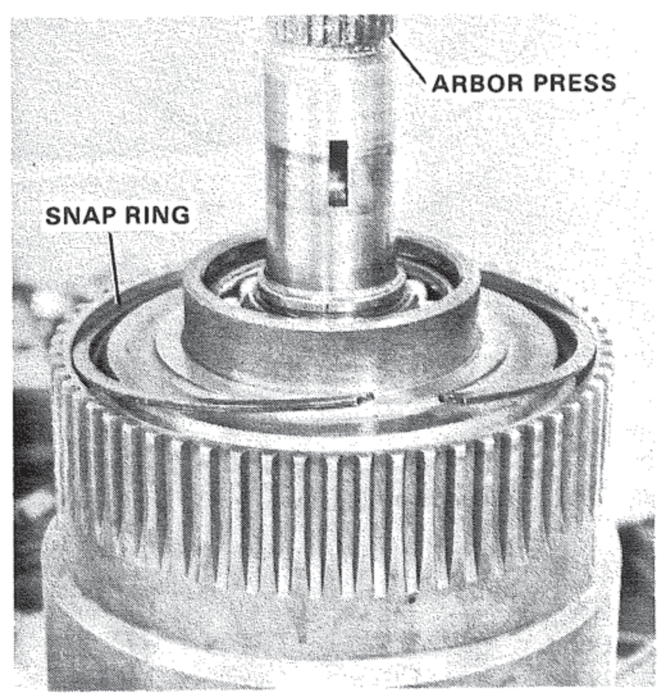


Figure 25. Removing Ring Gear Snap Ring.

Forward Clutch.

1. Remove bearing from clutch cylinder by tapping with soft blunt tool.

2. Remove ring gear snap ring, Figure 25.

3. While holding ring gear, tap with soft blunt tool on exposed face of forward clutch cylinder inside of ring gear. Forward clutch cylinder will move forward to disassemble out of front of ring gear. Figure 26. After removing the clutch spring and the clutch spring snap ring, all parts of the forward clutch can be disassembled. Figures 27, 28, 29, 30, and 31.

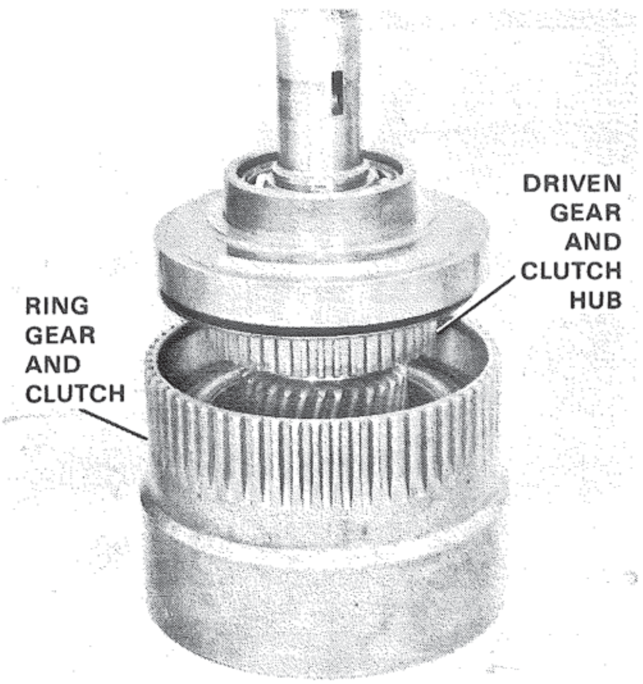


Figure 26. Removing Ring Gear and Clutch Assembly from Drive Gear.

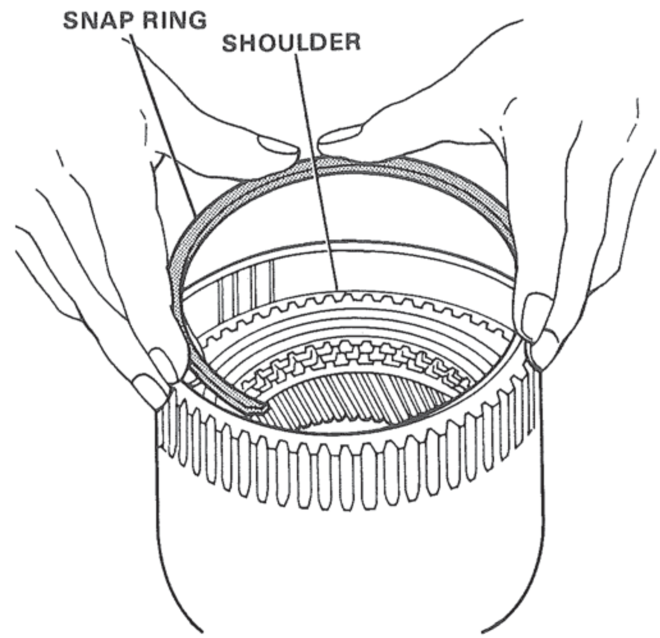


Figure 28. Removing Clutch Spring Snap Ring.

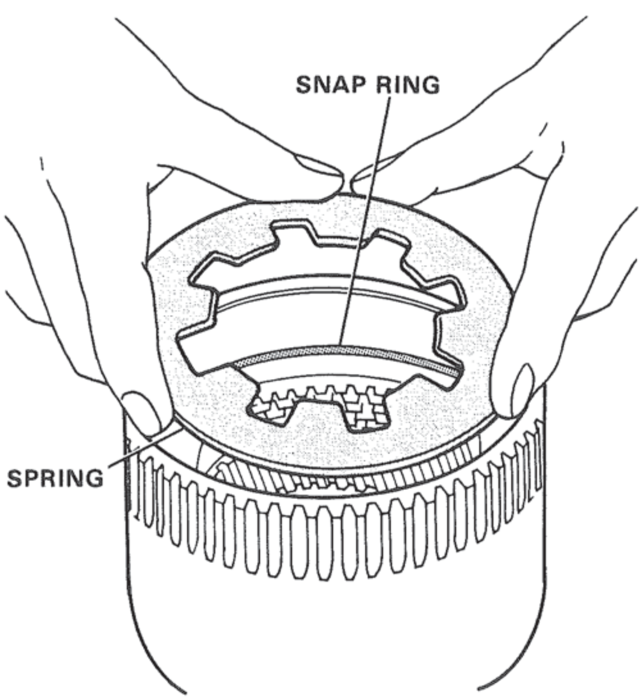


Figure 27. Removing Clutch Spring.

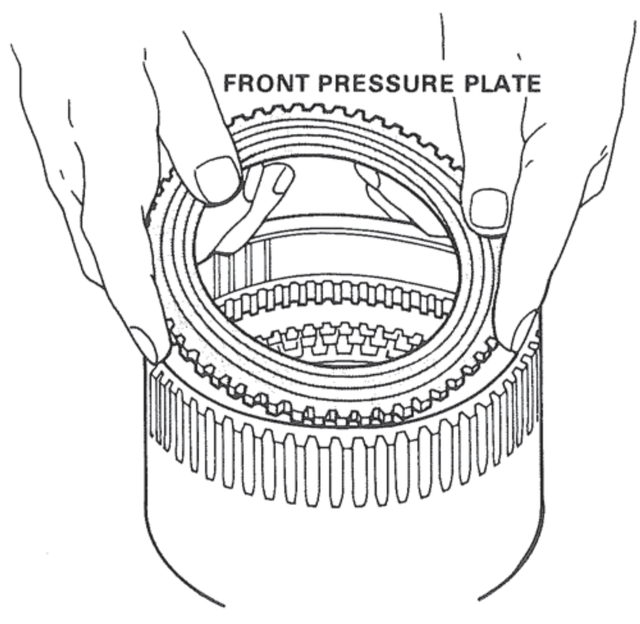


Figure 29. Removing Clutch Front Pressure Plate.

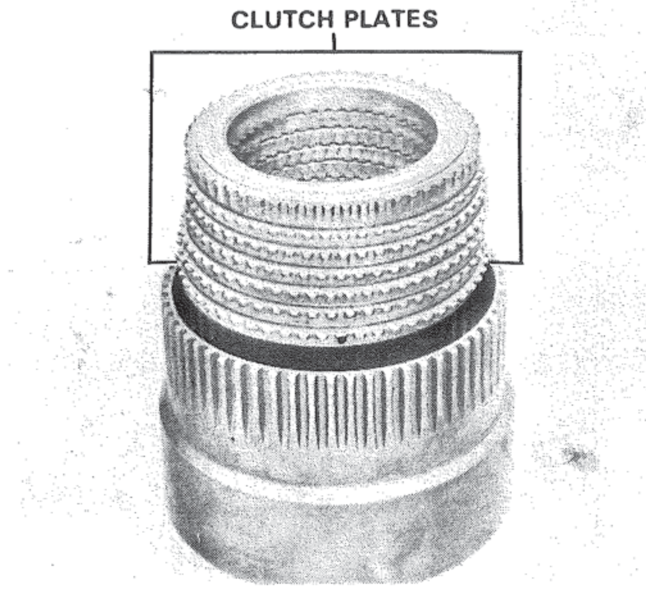


Figure 30. Removing Forward Clutch Plates.

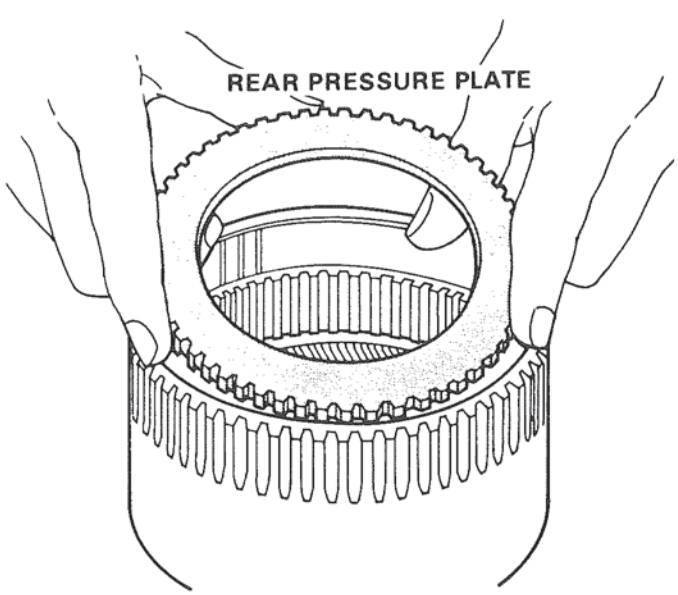


Figure 31. Removing Rear Clutch Pressure Plate.

4. Piston can be removed from forward clutch cylinder to position in Figure 32, by applying compressed air to clutch cavity through one of three (3) holes in inside of forward clutch cylinder, while other holes are blocked.

5. Remove forward clutch sealing rings. Figures 33 and 34.

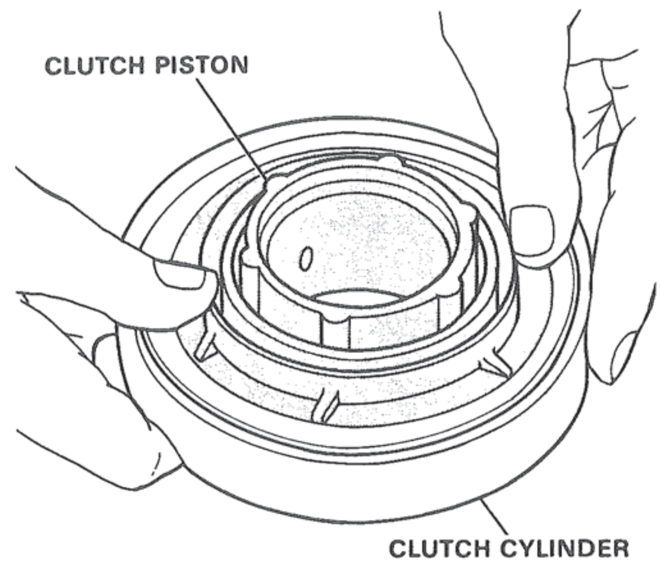


Figure 32. Removing Forward Clutch Piston.

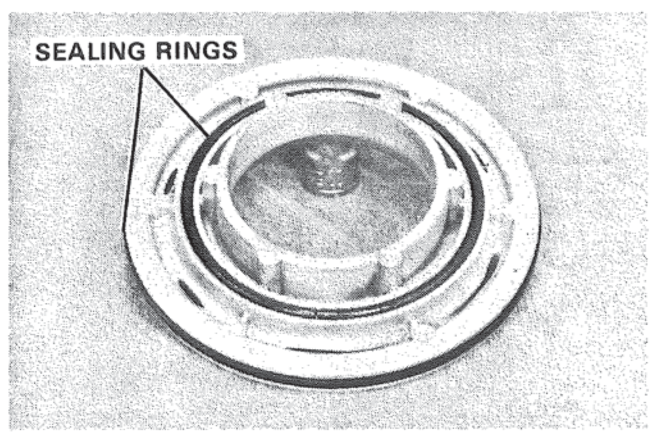


Figure 33. Removing Clutch Sealing Ring.

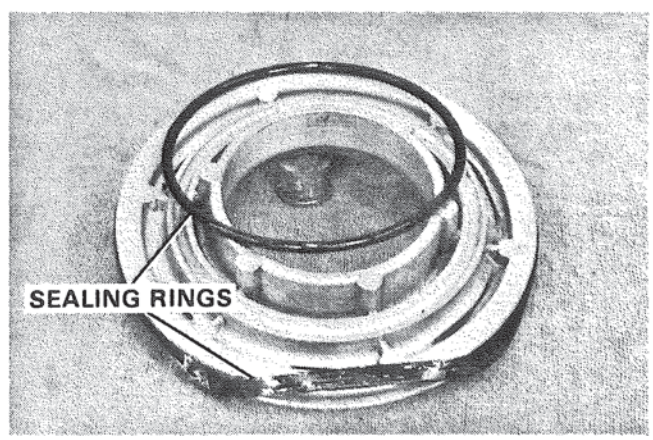


Figure 34. Removing Clutch Sealing Ring.

6. Remove main shaft nut shown in Figure 35.

7. Using bearing puller, pull coupling from output shaft.

8. Remove six (6) hex head bolts and lockwashers. Figure 36.

9. Remove bearing retainer and gasket.

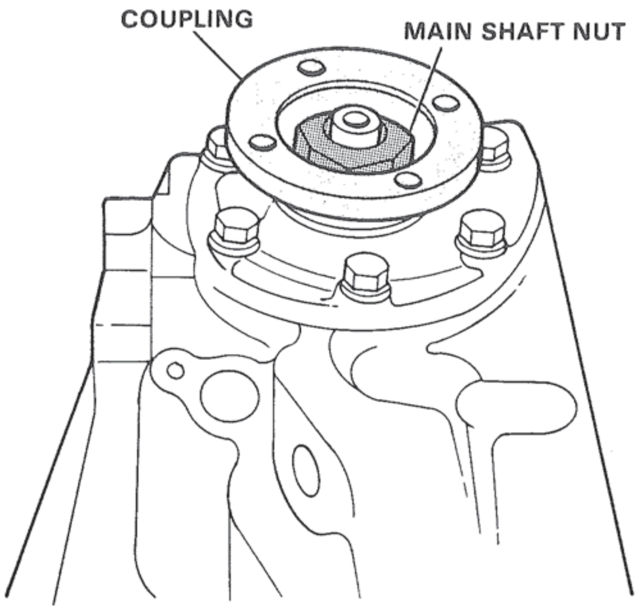


Figure 35. View of Complete Assembled Output Shaft.

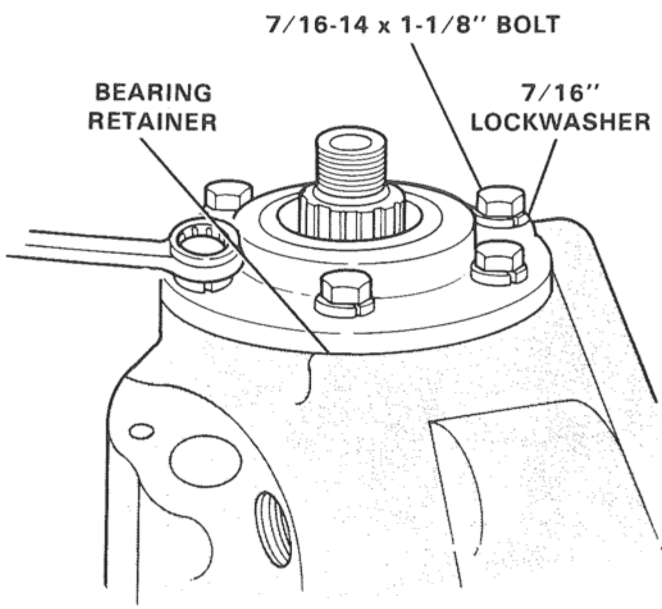


Figure 36. Disassembling Bearing Retainer on Rear of Case.

Removal of Rear Bearing.

NOTE

The following paragraphs describe alternate methods of removing the rear bearing. Either method is okay.

1. Using bearing puller, grasp bearing by exposed groove in outside diameter and gently pull bearing from case. Figure 37.

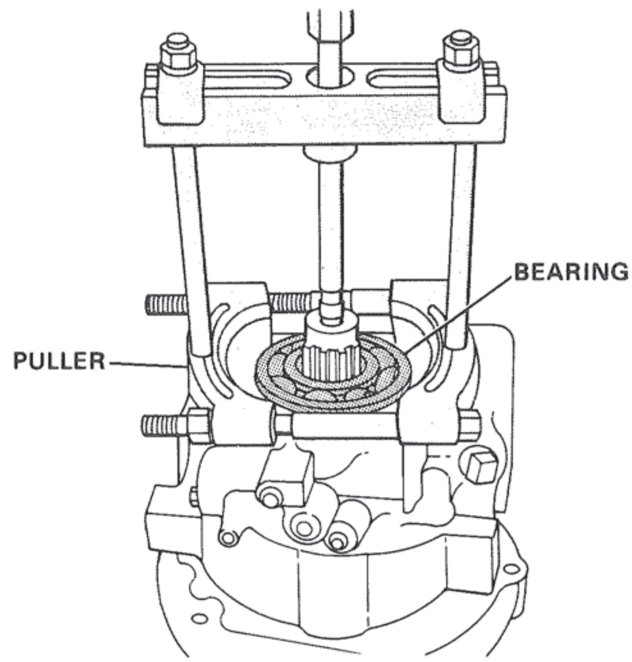


Figure 37. Removing Bearing from Case.

2. Place transmission, with front face down, on arbor press. Using suitable tool, press down on exposed end of output shaft until shaft is free of bearing inside diameter. Protect pinion cage and output shaft from damage from fall during this operation.

INSPECTION AND GENERAL INSTRUCTIONS.

1. Cleanliness is absolutely necessary during assembly to insure proper functioning of transmission. Transmission case passages should always have pipe plugs removed to allow for thorough cleaning. When available, use compressed air to dry parts before they are assembled. Do not wipe parts with rags to clean or dry them as lint from the cloth may cause erratic valve action.

2. Inspect all parts for damage or wear. Replace defective parts.

3. All gaskets, oil seals and rubber sealing rings should be replaced except in relatively new units. Replace parts as needed.

4. Oil seals and bearings are best installed by using an arbor press, suitable fixtures, and tools to properly align parts being assembled. Hammering seals and bearings into position can damage parts.

5. Automatic transmission fluid type "A" suffix "A" should be used to lubricate parts as they are assembled. Petroleum jelly may be used on gaskets or other parts that must be held in position during assembly. All rubber parts will slide freely if lubricated.

6. Tighten all bolts and screws to the recommended torque.

REASSEMBLY PRECAUTIONS

The following list contains a number of assembly problems which it is felt require special attention during the reassembly of the direct drive transmissions. The information below includes the locations in the manual where information and instructions are available on these important assembly features.

1. Installation of proper pinion cage and output shaft assembly in transmission cases without bushings, page 00.

2. Selection of the proper clutch spring snap ring, page 00.

3. Selection of the proper ring gear snap ring, page 00.

4. Installation of the proper selective snap ring, page 00.

5. Installation of adapter on transmission case should follow the procedures outlined, page 00, for tightening the capscrews. If bolts are not alternately tightened a small amount, damage can result to the needle bearing and its input shaft race.

6. Protection of pump seal during assembly of pump assembly over input drive gear, page 00.

7. Mounting pump to correspond to the engine rotation, page 00.

8. Check input shaft to insure that it rotates freely when turned by hand after transmission is assembled, page 00.

ASSEMBLY

Oil seal in Bearing Retainer.

1. Inspect rubber lip of seal for cracks, holes or brittle condition of rubber lip material.

2. Place front face of bearing retainer on arbor press table. Apply a suitable sealant to the outside diameter of seal before installing squarely into bore of housing with seal lip positioned as in Figure 38. Caution should be observed to insure that too much sealant is not used.

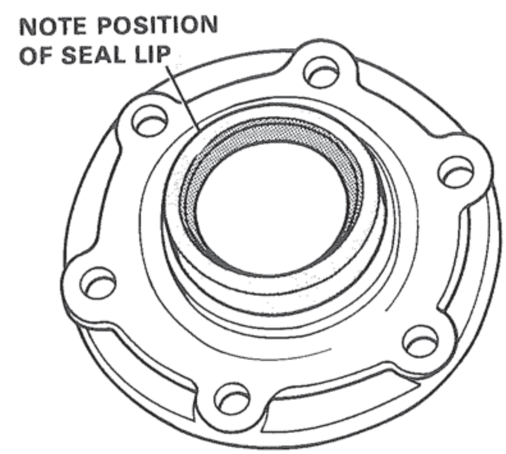


Figure 38. Installing Oil Seal.

3. Using arbor press and suitable tool, as shown in Figure 39, press the oil seal into the bearing retainer until the rear face of the oil seal is flush with the rear face of the bearing retainer.

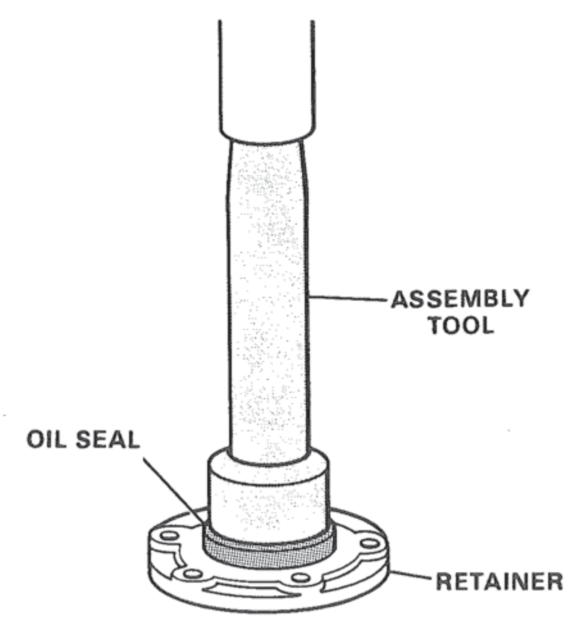


Figure 39. Pressing Oil Seal In Retainer.

Baffle in Transmission Case.

1. Place oil baffle inside transmission case with curved portion below bosses in case. Figure 40.

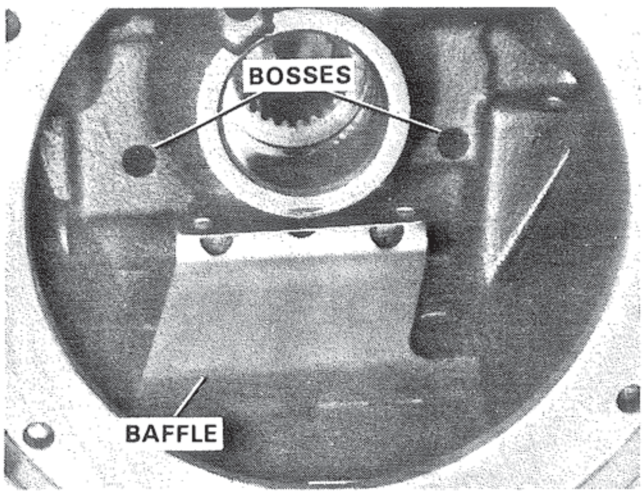


Figure 40. Installing Oil Baffle.

2. Position front end of baffle so that center of baffle rests on top of the boss at front center of transmission case and the turned down corners of the baffle are located below the cast spherical bosses at the front of transmission case. Snap baffle into position by lifting up on curved portion so that the two large holes are located firmly on the spherical bosses at rear of transmission case.

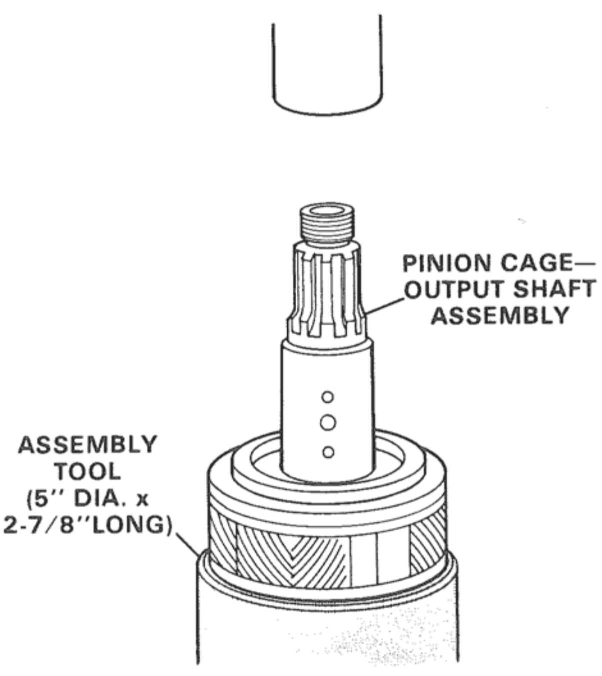


Figure 41. Pinion Cage and Output Shaft Assembly on Arbor Press.

Pinion Cage and Output Shaft Assembly in Transmission Case.

1. Place the pinion cage and output shaft assembly on a 5 in. diameter by 2-7/8 in. long assembly tool, which, in turn, is mounted on an arbor press, as indicated in Figure 41.

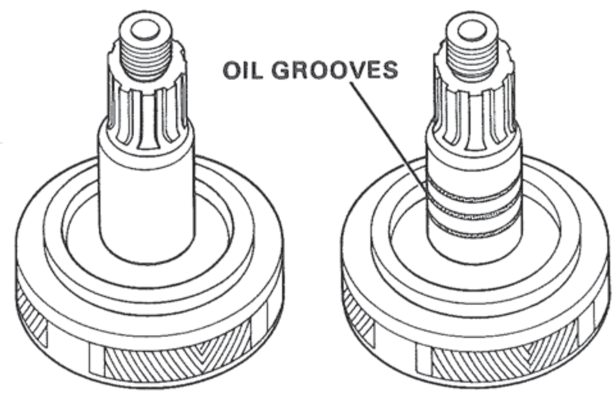


Figure 42. Late and Early Model Pinion Cage and Output Shaft.

NOTE

If the transmission case does not have bronze bushings for the output shaft journal, use only the output shafts with three oil grooves. Figure 42.

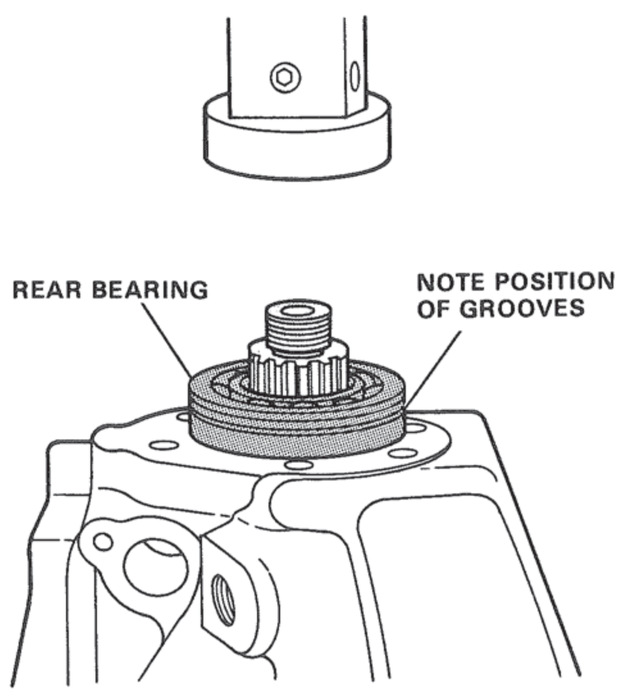


Figure 43. Shaft, Pinion and Bearing Assembly.

2. Place the transmission case over the pinion cage and output shaft assembly so transmission case rests squarely on arbor press table which is supporting assembly tool. Figure 43.

3. Inspect the bearing bore and remove dirt or burrs.

4. Inspect the rear bearings for scored or damaged balls and races and for loose or cracked ball retainer. Replace the bearing with a new part if damage is detected.

5. Inspect the bearing for presence of dirt. If dirt is present, wash bearing until clean then lubricate with automatic transmission fluid type "A" suffix "A", before assembly.

6. With the groove on the outside diameter of the bearing located toward the rear of the transmission, place the bearing over the projecting output shaft and squarely in the bearing bore.

7. Using an assembly tool designed to press evenly on the bearing outer and inner races, press bearing down until seated against shaft or case shoulder. Figure 44.

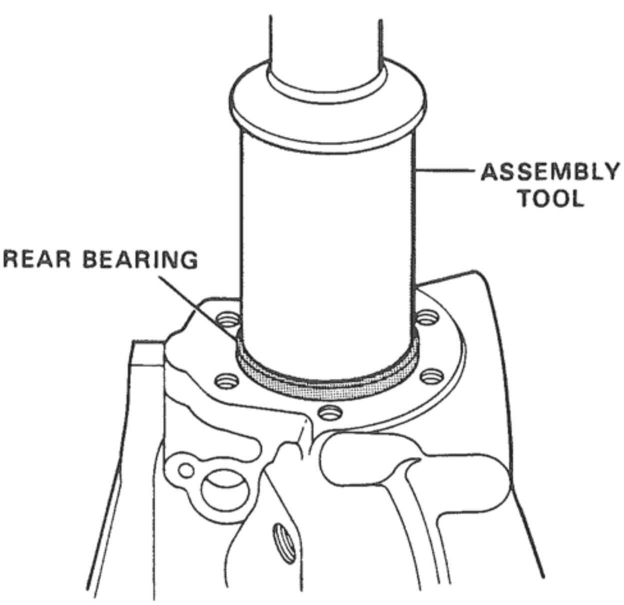


Figure 44. Rear Bearing Pressed In Place.

8. Place bearing retainer gasket on rear of transmission case. Gasket may be coated with petroleum jelly for easier assembly.

9. Place bearing retainer in place on rear of case. Figure 45. Install six (6) 7/16 lockwashers and six (6) 7/16-14 hex head bolts; tighten bolts to a torque of 42 - 50 ft. lbs. (5.79 - 6.90 kg/m)

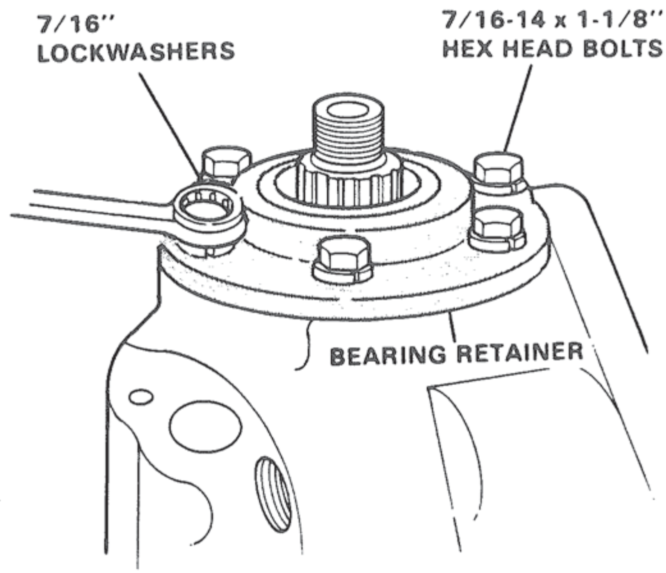


Figure 45. Installing Bearing Retainer onto Case.

10. Inspect and lubricate the hub diameter of rear coupling which runs in contact with the rubber lip of oil seal. If this surface is scratched or burred, replace the part with a new piece to prevent seal-lip damage and oil leakage.

11. After lubricating the splined portion of coupling, assemble the splined coupling onto the externally splined portion of the output shaft. When the coupling has been aligned squarely on the output shaft and hand assembly has proceeded as far as possible, place a suitable tool on the coupling, Figure 46, and gently press the coupling with arbor press until contact with the bearing inner race is made.

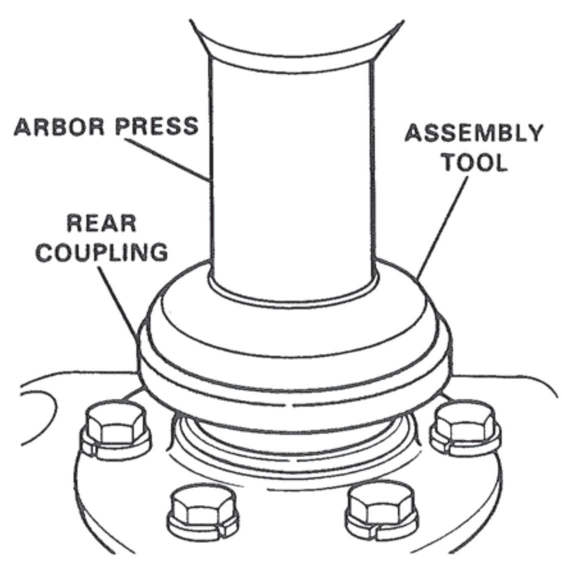


Figure 46. Installing Rear Coupling.

12. Assemble main shaft nut in place on output shaft and tighten to prescribed torque of 100 - 200 ft. lbs. (13.79 - 23.59 kg/m). This should bring inner race of bearing solidly in contact with the shoulder on output shaft and eliminate any detectable end play in the coupling and output shaft combination. Figure 47.

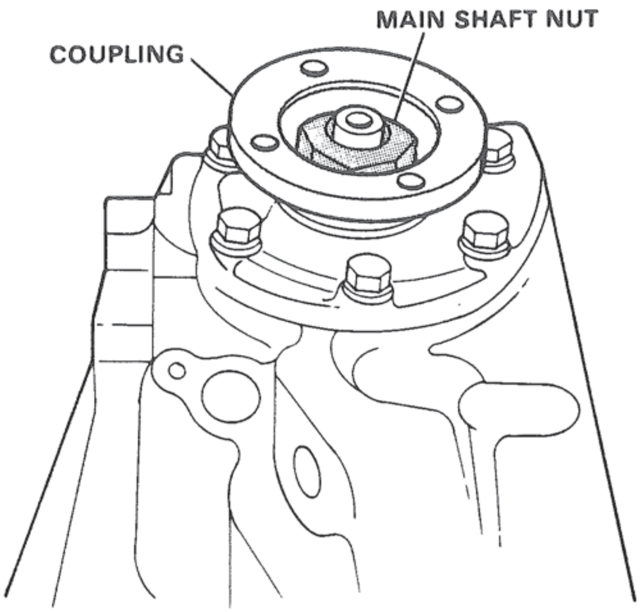


Figure 47. View of Completely Assembled Output Shaft.

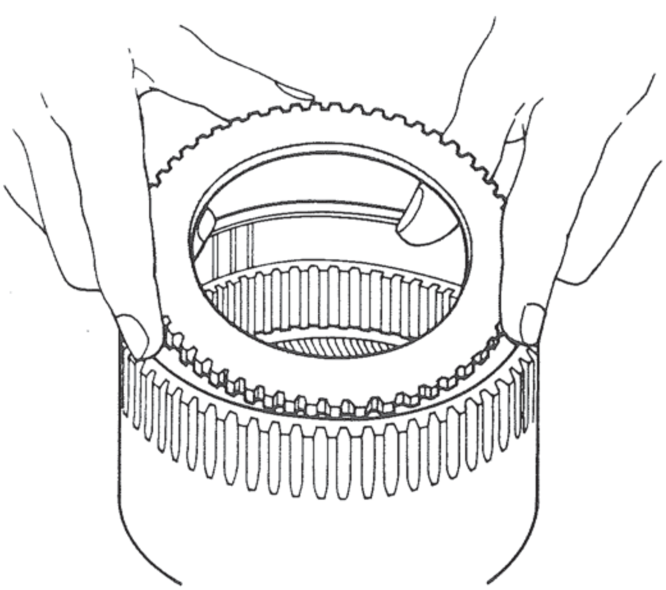


Figure 48. Installing Clutch Pressure Plate.

Forward Clutch into Ring Gear.

1. Place the ring gear on a clean surface with the external teeth up. Figure 48.

2. Remove all dirt and solid particles from the shoulder inside the gear formed by the top of the internal helical gear.

3. With the smoothly ground surface in the upward position, install the clutch pressure plate (rear) into the ring gear. Figure 48. Assembly is complete when the clutch pressure plate is firmly and squarely seated on the shoulder at the bottom of the internal splines.

4. Lubricate seven (7) clutch inner plates and six (6) outer clutch plates, arrange and assemble. Figure 49.

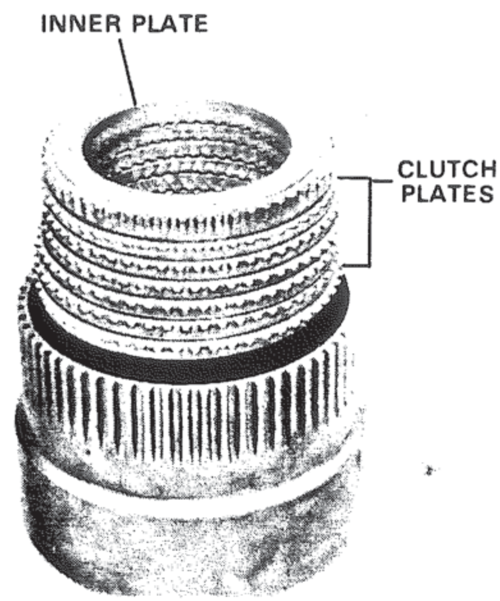


Figure 49. Installing Forward Clutch Plates.

5. Install clutch pressure plate (front) with flat face down in contact with clutch plate. Figure 50.

6. Install clutch spring snap ring. Figure 51. Assembly is complete when snap ring is squarely and firmly seated on the internal shoulder provided by the top of the internal splines.

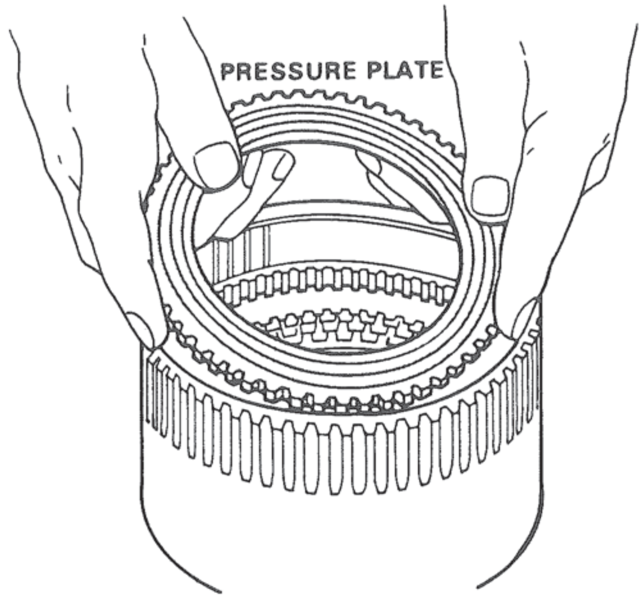


Figure 50. Installing Clutch Pressure Plate.

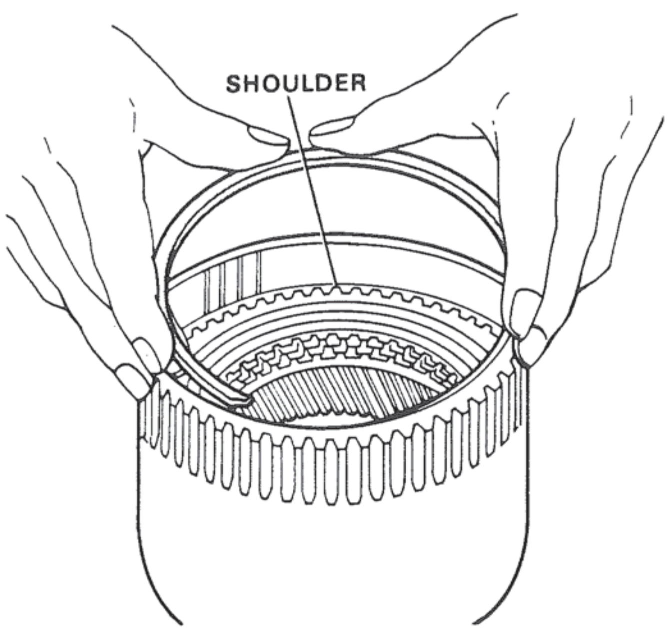


Figure 51. Installing Clutch Spring Snap Ring.

CAUTION

Be sure you have the proper snap ring. The clutch spring snap ring is .090 to .093 in. thick and has a free diameter of 5-19/32 in. + 1/16 in.

7. With the concave side of the clutch spring facing down, install in ring gear. Figure 52. Assembly is complete when the clutch spring is seated firmly and squarely on clutch snap ring.

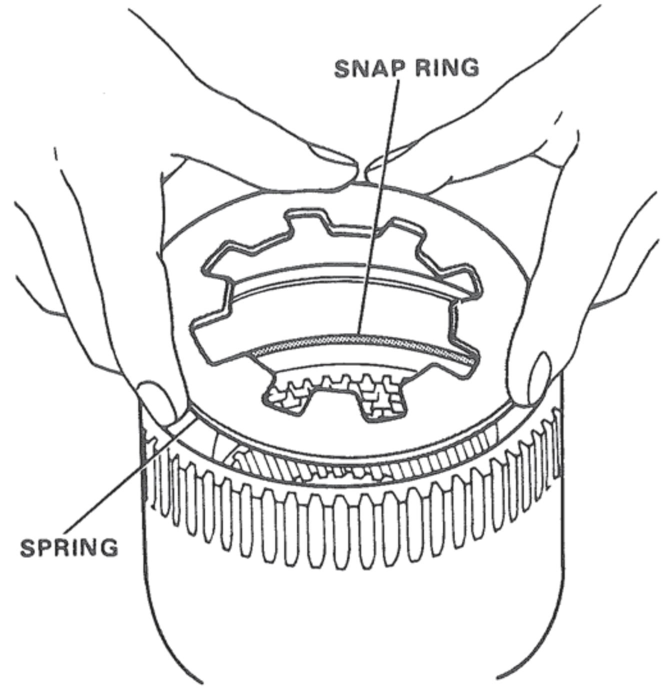


Figure 52. Installing Clutch Spring.

8. Assemble the clutch spring bearing ring and a lubricated clutch sealing ring on the forward clutch piston. Figure 53. Inspect the inside diameter of the forward clutch piston having contact with the sealing ring; remove all burrs or scratches and lubricate before assembly.

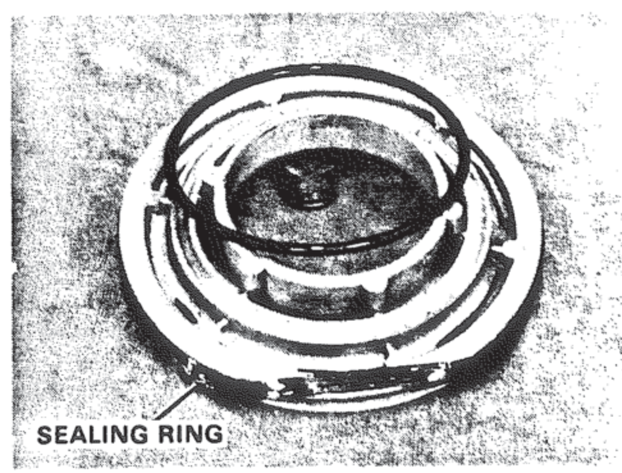


Figure 53. Installing Clutch Sealing Ring.

9. Install a well lubricated sealing ring in forward clutch cylinder. Figure 54. Lubricate entire forward clutch cylinder before continuing assembly.

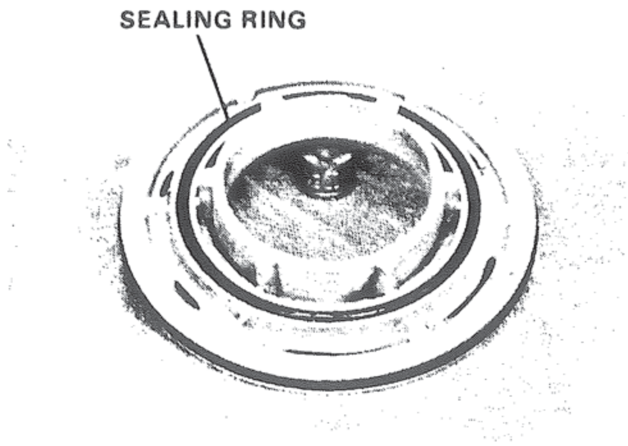


Figure 54. Installing Sealing Ring.

10. After aligning the assembled forward clutch piston squarely on the assembled forward clutch cylinder, press the clutch piston into the forward clutch cylinder. Figure 55. This is a hand assembly and should not require pounding by hammer or pressing on arbor press. Assembly is complete when piston "bottoms" in forward clutch cylinder.

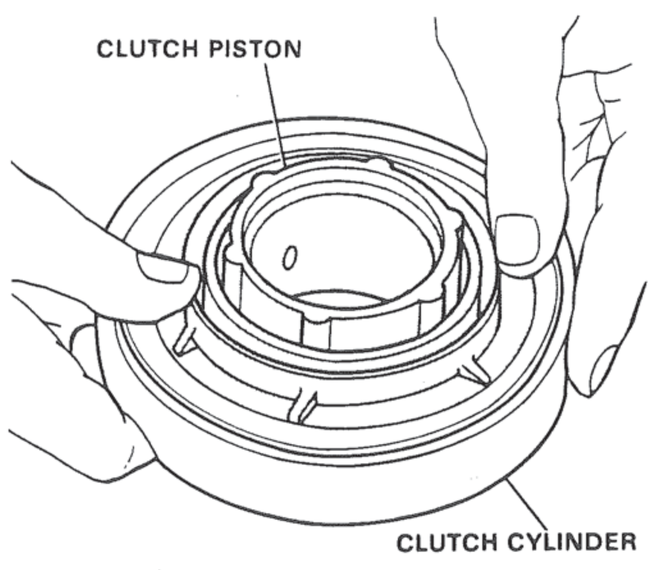


Figure 55. Installing Forward Clutch Piston.

11. Place the combined parts on a suitable support on an arbor press. Figure 56. Center the clutch spring in the ring gear.

12. Place clutch sealing ring assembly into the open top of the assembly described in step 11. Figure 56. Place a suitable assembly tool squarely on top of the forward clutch cylinder and press down with the arbor press until the forward clutch cylinder is firmly seated on the snap ring and the groove for the snap ring is fully exposed. Check, by looking into rear of ring gear, to see that the clutch spring bearing ring is properly assembled on the forward clutch piston.

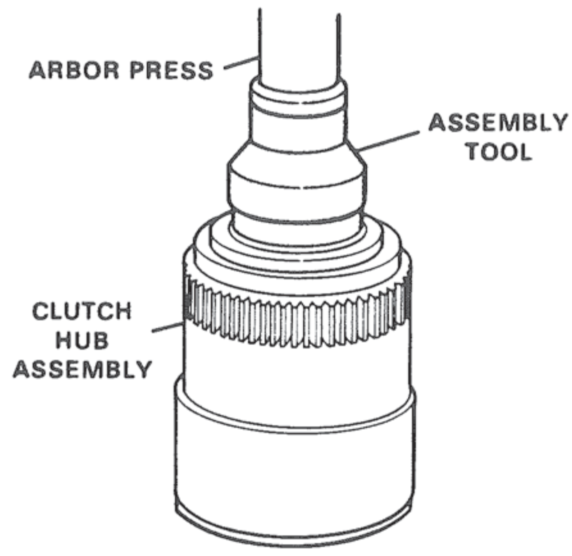


Figure 56. Pressing Forward Clutch Hub into Ring Gear.

13. While maintaining load from arbor press, assemble ring gear snap ring. Figure 57. Tap ring while in place to insure full seating of ring in groove.

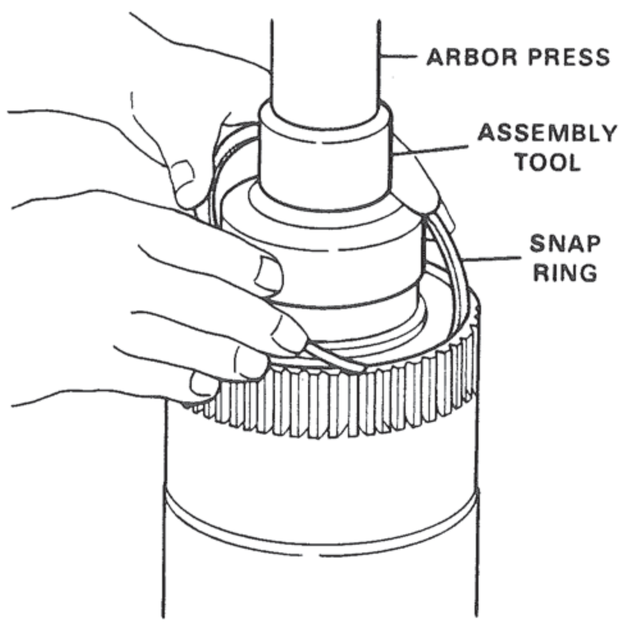


Figure 57. Installing Ring Gear Snap Ring.

CAUTION

Be sure you have the proper snap ring. The ring gear snap ring is .074 in. - .078 in. thick and has a free diameter of 5-7/8 in. + 1/16 in.

14. Place the forward clutch and ring gear assembly on an arbor press with the assembly supported on the face of the ring gear. Figure 58.

15. Place a suitable assembly tool in the arbor press to apply force on the clutch pressure plate compressing the clutch plates and clutch pressure plate against the clutch snap ring. The gap between the clutch pressure plate and the shoulder of the snap ring groove in the ring gear can then be measured with a feeler gauge. Figure 58.

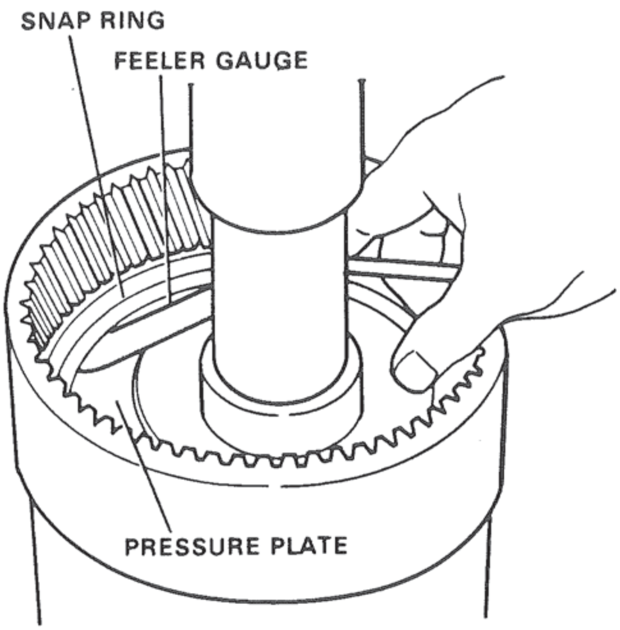


Figure 58. Measuring Gap for Selective Snap Ring.

16. Install one, or more when needed, of the selective snap rings, as shown in Figure 59, to obtain a proper clutch plate clearance of .040 in. - .065 in.

CAUTION

Be sure the proper snap ring is used. The "Selective Snap Ring" has a free diameter of 5-11/16 in. + 1/16 in. These rings are variable in thickness and are color coded as follows: green — .050 in. to .054 in. thick; orange — .074 in. - .078 in. thick; and white — .096 in. - 100 in. thick.

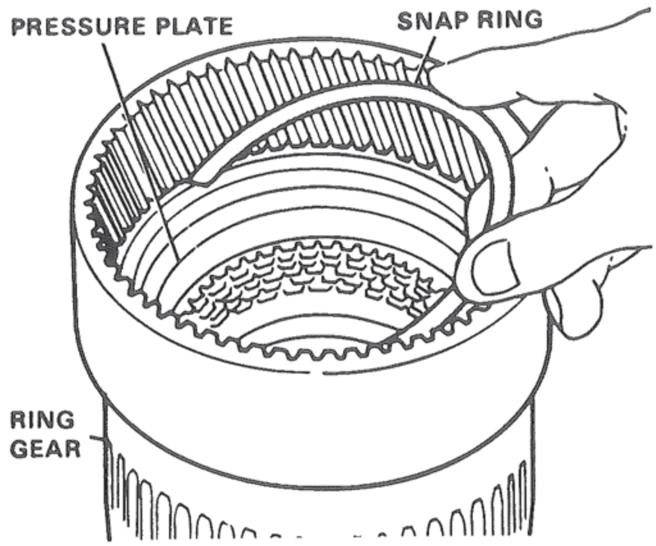


Figure 59. Installing Selective Snap Ring.

Assembly of Forward Clutch Hub and Sealing Rings on Drive Gear.

1. Place the forward clutch hub on a suitable support placed on an arbor press in the position shown in Figure 60.

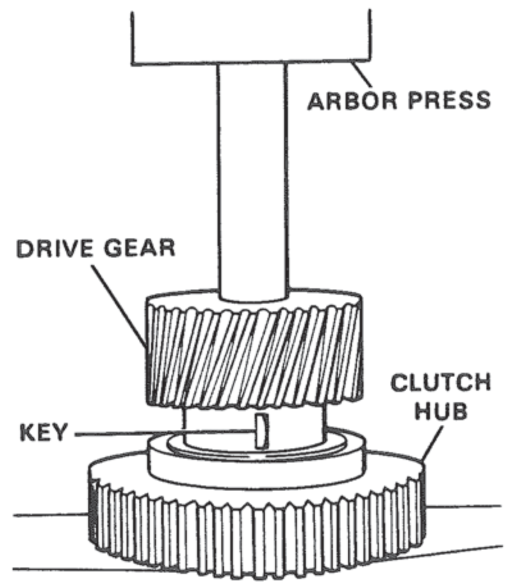


Figure 60. Pressing Drive Gear into Forward Clutch Hub.

2. Assemble woodruff key in the keyway provided on the drive gear.

3. Lubricate the outside diameter of the gear on that area which presses into the forward clutch hub.

4. Install the drive gear and woodruff key squarely into the forward clutch hub, being careful to align the woodruff key with the mating keyway in the forward clutch hub. Figure 60. Press the drive gear into the forward clutch hub until the gear "bottoms" on the face of the forward clutch hub and the groove for the snap ring is fully uncovered.

5. Invert the parts referred to in step 1 and install snap ring in the groove provided. Figure 61. Tap ring after assembly with suitable tool to insure full seating in groove.

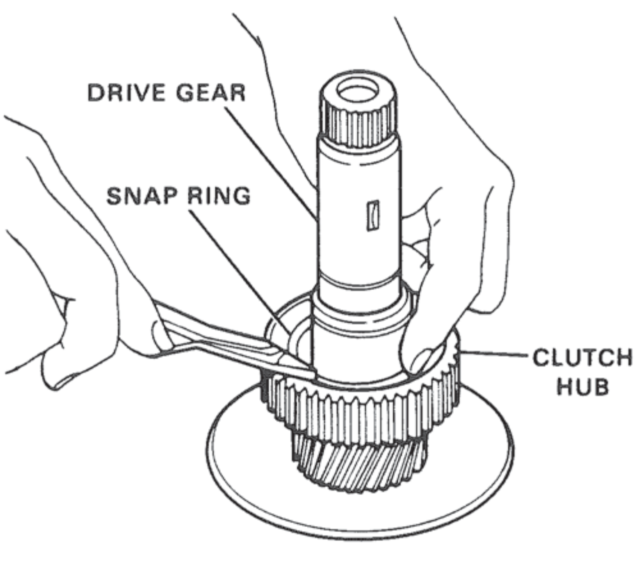


Figure 61. Installing Clutch Hub Snap Ring.

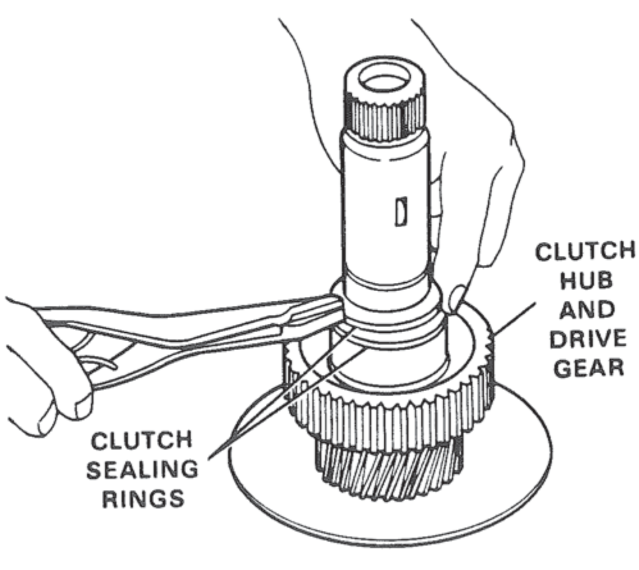


Figure 62. Installing Forward Clutch Sealing Rings onto Drive Gear.

6. Install two (2) forward clutch sealing rings in grooves provided on drive gear. Figure 62. After installing rings in groove, hook ends and turn rings to insure freedom of rotation.

Drive Gear and Clutch Assembly.

1. With drive gear and clutch hub in assembly tool, place ring gear and forward clutch assembly over drive gear as shown in Figure 63.

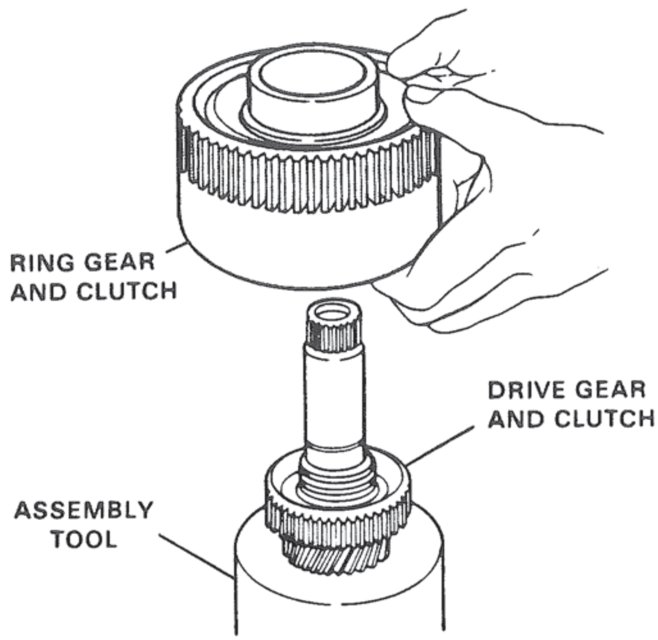


Figure 63. Assembling Ring Gear and Clutch Assembly Drive Gear.

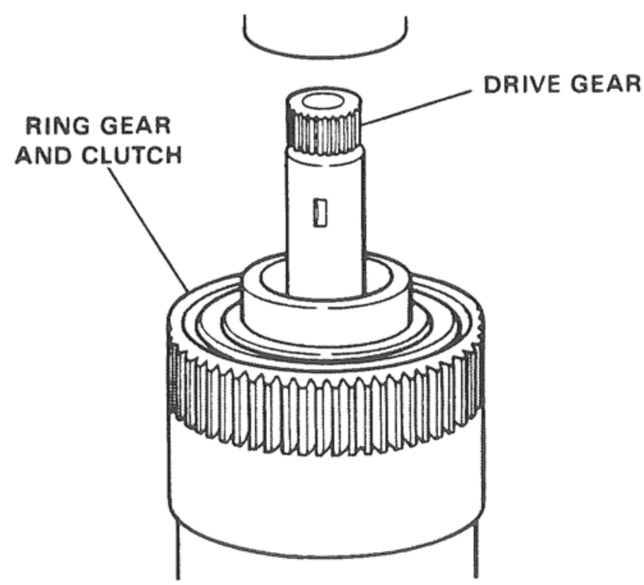


Figure 64. Assembling Ring Gear and Clutch Assembly onto Drive Gear.

2. Lower ring gear and clutch assembly until internal teeth of clutch plates begin to engage teeth on forward clutch hub. Rotate ring gear to align teeth of plates with teeth on clutch hub. Do not force ring gear, as damage to teeth on plates will result. When ring gear and clutch are in correct position, rear end of ring gear should be against the assembly tool or "flush" with the rear thrust face of drive gear. Figure 64. Do not remove drive gear and clutch assembly from assembly tool or move drive gear forward until this procedure is completed. Any movement of the drive gear forward will result in the clutch plates becoming disengaged with clutch hub and sealing rings moving out of position.

3. Place aligned parts and assembly tool in place on arbor press. Place bearing over protruding drive gear and squarely into bore at front of forward clutch cylinder; press bearing down with arbor press until bearing is fully seated on shoulder and snap ring grooves in front of bearing are exposed. Figure 65.

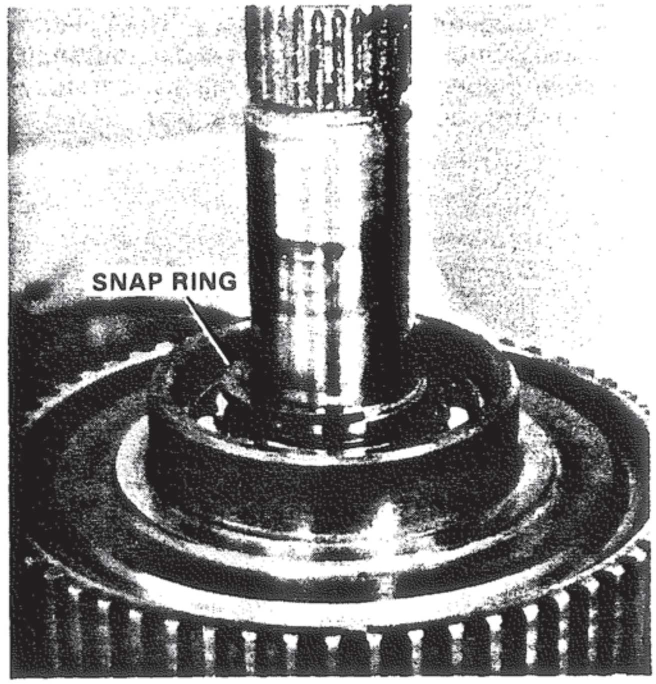


Figure 66. Installing External Snap Ring.

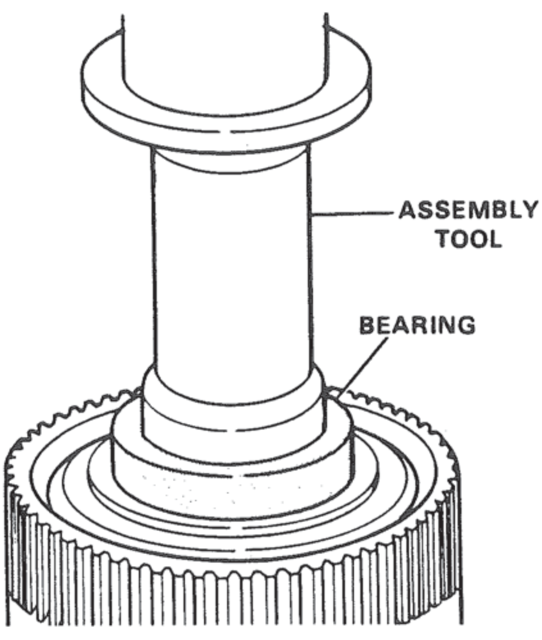


Figure 65. Installing Clutch Bearing.

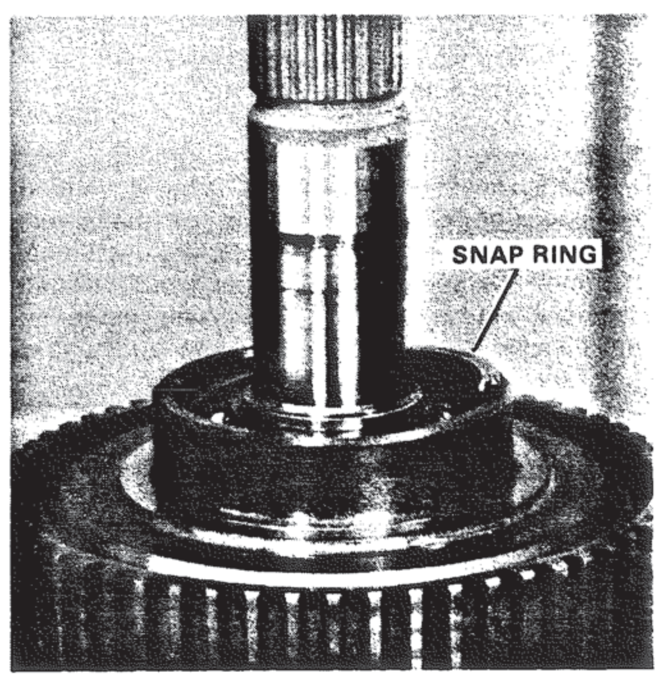


Figure 67. Installing Internal Snap Ring.

4. Install external snap ring onto drive gear. Figure 66.

5. Install internal snap ring in clutch cylinder. Figure 67.

Drive Gear, Clutch Assembly, Reverse Clutch Plate and Reverse Clutch Pressure Plate.

1. Place previously assembled parts on a smooth, clean surface. Figure 68.

2. Coat the drive gear thrust washer with petroleum jelly and assemble into pinion cage and output shaft assembly. Figure 68. Center the washer carefully over bore provided for rear of drive gear.

Figure 68. Installing Thrust Washer.

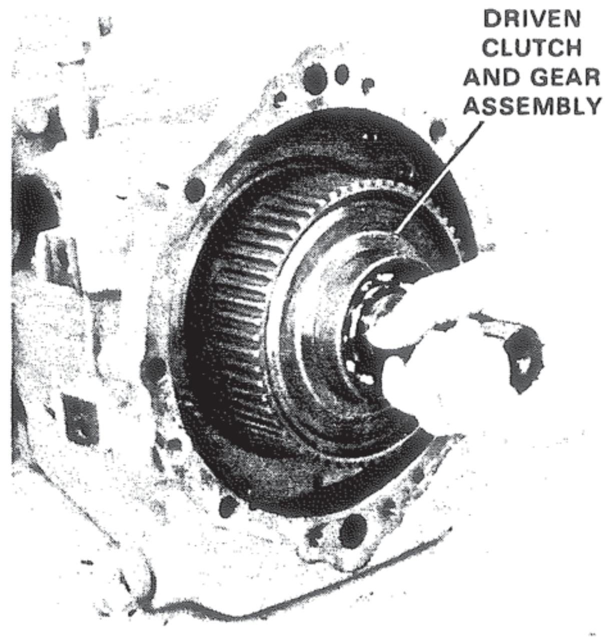


Figure 69. Installing Drive Gear and Clutch Assembly.

3. After lubricating the rear end of the drive gear and checking centered position of the thrust washer, install the drive gear and clutch assembly into the case and pinion cage and output shaft assembly. Figure 69. Care and proper centering must be exercised at this point to prevent damage to the bushings when the rear diameter of the drive gear enters the output shaft.

4. Install the twelve (12) pressure plate springs in the holes provided in the reverse clutch cavity. The holes should be free from dirt and all springs should be firmly seated.

5. Coat the three (3) dowel pins with petroleum jelly and assemble them in the three (3) grooves provided at the outside diameter of the reverse clutch cavity. Figure 70. Assembly is complete when the dowel pin is firmly seated on end and into the groove, as far as groove contour will permit.

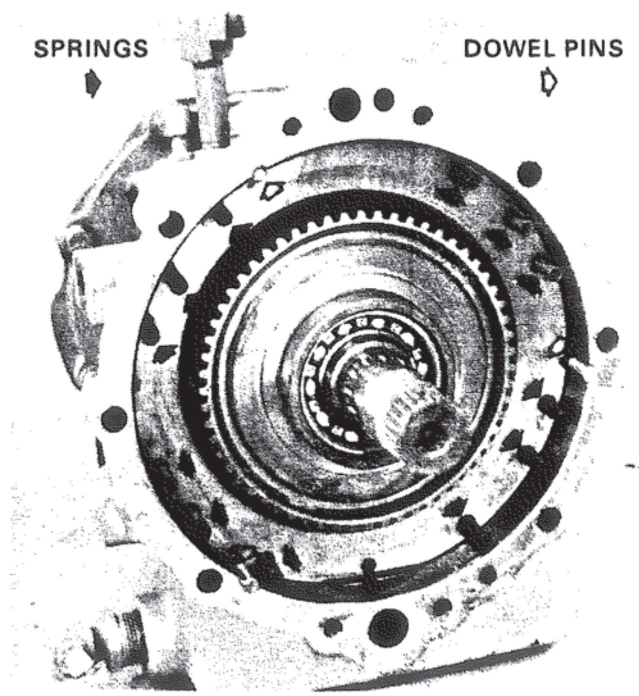


Figure 70. Installation of Twelve (12) Pressure Plate Springs and Three (3) Dowel Pins.

6. Install one of the reverse clutch plates over the exposed teeth of the ring gear. Install the outer clutch plate with the odd shaped lug located as shown in Figure 71, to obtain the proper spacing with reference to the springs. Install the second reverse clutch plate on top of the outer clutch plate and over the exposed splined teeth of the ring gear.

7. Install the reverse clutch pressure plate with the

twelve (12) holes in the downward position. Align the cast slot in the pressure plate with the large oil hole in the front face of the transmission case. Figure 72. Since the twelve (12) pressure plate springs are not evenly spaced, the slot and oil hole alignment are required to locate the pressure plate with relation to the pressure plate springs. Figure 71. A properly assembled reverse pressure plate will appear as shown in Figure 72. If pressure plate does not drop down to position, approximately flush with transmission case front face, check the three (3) dowel pins for possible misalignment.

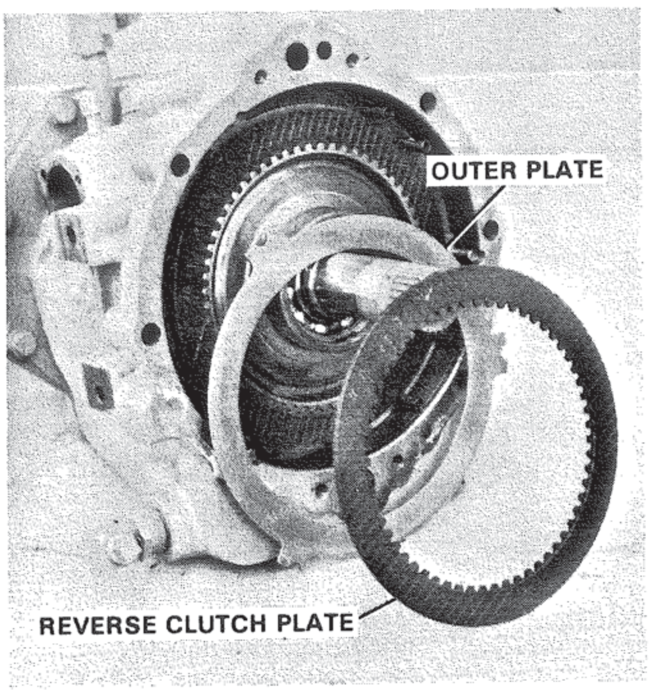


Figure 71. Installing Reverse Clutch Plates.

8. Coat thrust washer with petroleum jelly and assemble.

Reverse Clutch Piston into Adapter.

1. After checking adapter for the following, place it on a clean surface. Figure 73.

A. Clean needle bearing assembly, properly installed and free from damage.

B. Oil passages free from presence of dirt and obstruction.

C. Reverse clutch cavity outer wall, smooth clean surface free from scratches or burrs and coated generously with petroleum jelly.

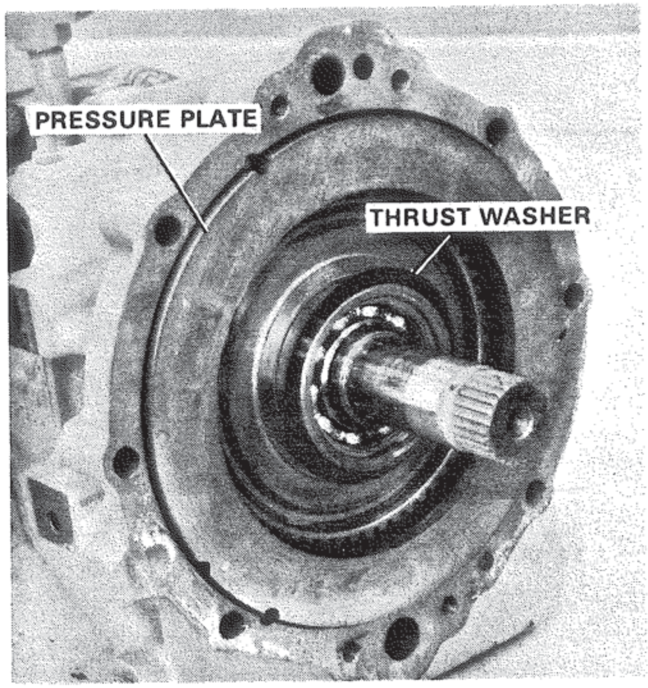


Figure 72. Installing Thrust Washer and Reverse Clutch Pressure Plate.

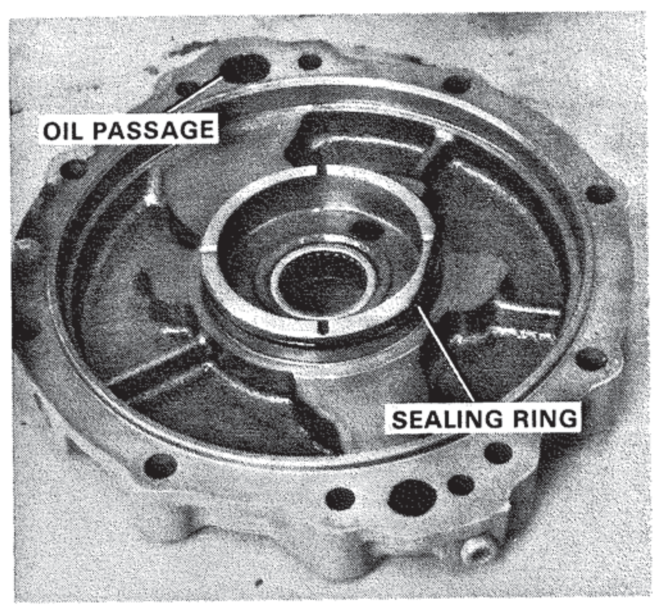


Figure 73. Assembling Sealing Ring.

D. Sealing ring coated with petroleum jelly and installed in groove of adapter hub.

2. After lubricating sealing ring with petroleum jelly, assemble in groove of reverse clutch piston. Figure 74.

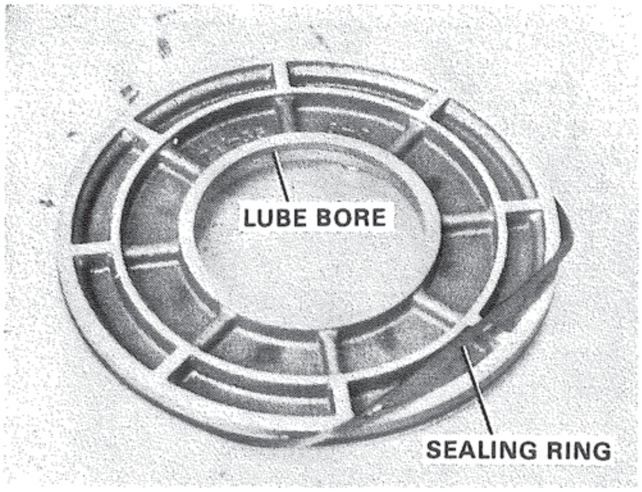


Figure 74. Assembling Sealing Ring.

3. Examine inside diameter of reverse clutch piston for smooth clean surface free from scratches or burrs and coat generously with petroleum jelly.

4. Place the reverse clutch piston, as assembled in step 2 on the adapter, as assembled in step 1. Figure 75. Press down on reverse clutch piston while pulling a smooth, clean screwdriver blade around the exposed portion of the sealing ring. This will aid the camfered bore in the adapter to compress the sealing ring into the groove in the outside diameter of the piston. Assembly can be completed by using hand pressure until piston has "bottomed" in reverse clutch cavity.

Exposed face of clutch piston should be flush with adjacent surrounding surface on adapter when assembly is completed.

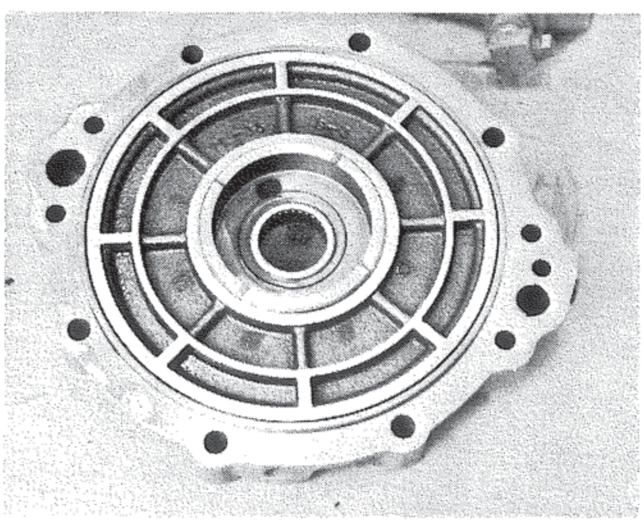


Figure 75. Installing Reverse Clutch Piston in Adapter.

Adapter and Reverse Clutch Piston onto Transmission Case.

1. With parts assembled resting on the rear face of coupling, coat the exposed front of the transmission case with petroleum jelly and assemble in place the case and adapter gasket. Figure 76.

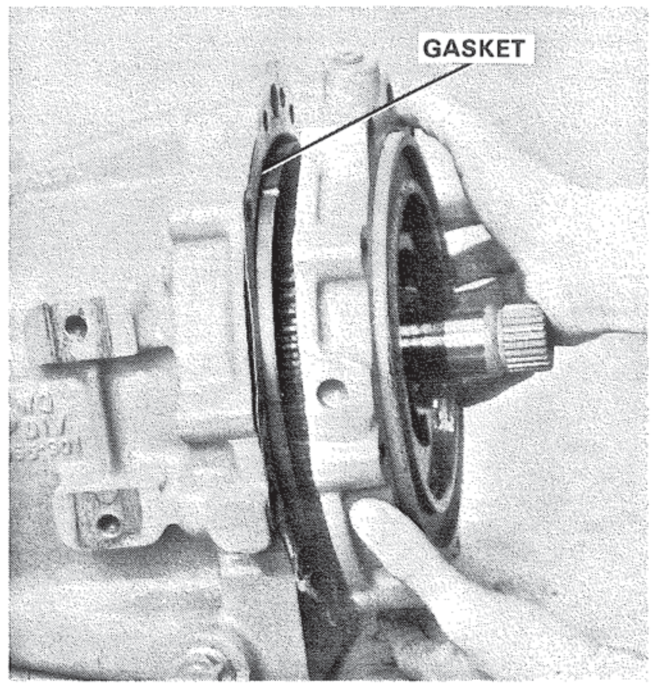


Figure 76. Installing Adapter and Reverse Clutch Assembly and Case.

2. Lift adapter assembly parts above transmission housing. Figure 76. Align the oil holes, then lower the reverse clutch piston and adapter assembly squarely into the input gear and transmission case.

3. When the shoulder on the rear of the adapter has entered the mating bore in the reverse clutch cavity, located in the front of the transmission case and a check of the gap between case and adapter indicates the adapter is squarely in place, install the four (4) cap screws. Figure 77. The adapter can now be pulled down squarely, until contact with the case is made, by alternately tightening the cap screws a small amount and checking frequently for binding. When adapter is pulled down as far as possible, tighten the four (4) cap screws to 27 - 37 ft. lbs. (3.72 - 5.10 kg/m).

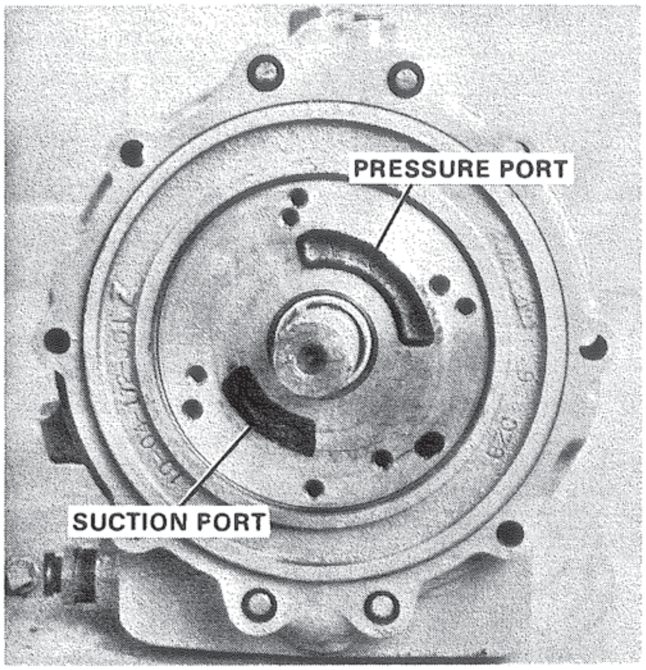


Figure 77. Mounting Adapter to Case.

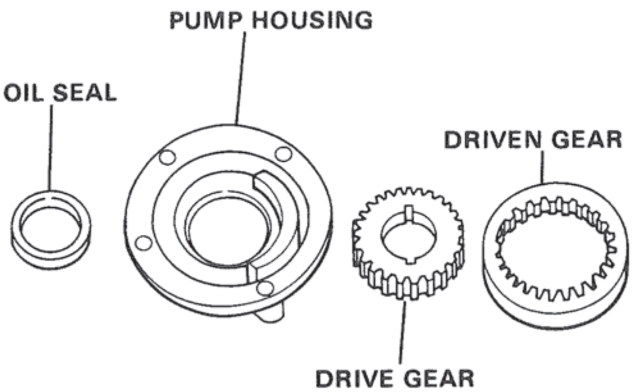


Figure 78. Front Pump Parts.

Front Pump.

1. Collect the parts shown in Figure 78 and check carefully for the following:

A. Scoring in gear pockets, crescent, and gear face.

B. Oil seal lip for brittle condition, cracks and cuts. Oil seal outside diameter for dents or scratches.

C. Gear teeth for burrs.

The front pump assembly without the backing plate can only be used with the new (71C-A8) adapter, Figure 77, the new key (4873), and the new version of the drive gear with the relocated pump keyway.

2. Place pump housing squarely on arbor press table. Apply a suitable sealant to the outside diameter of seal before installing squarely into bore of housing with seal lip positioned as in Figure 79. Caution should be observed to insure that too much sealant is not used, that any excess is wiped away after the seal is installed, and that the sealant does not get on the sealing element.

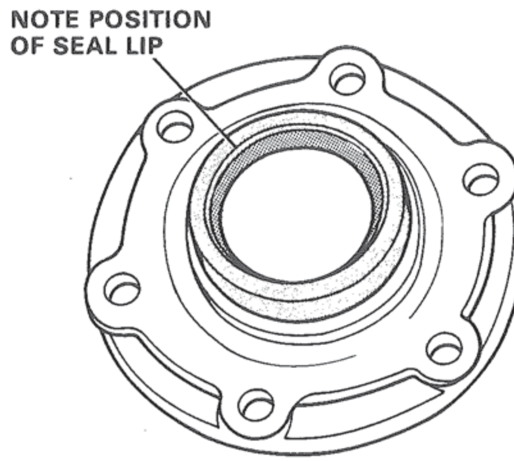


Figure 79. Installing Pump Oil Seal.

3. Using an arbor press and suitable tool, press seal into housing until front face of seal is flush with front face of pump housing. Figure 80.

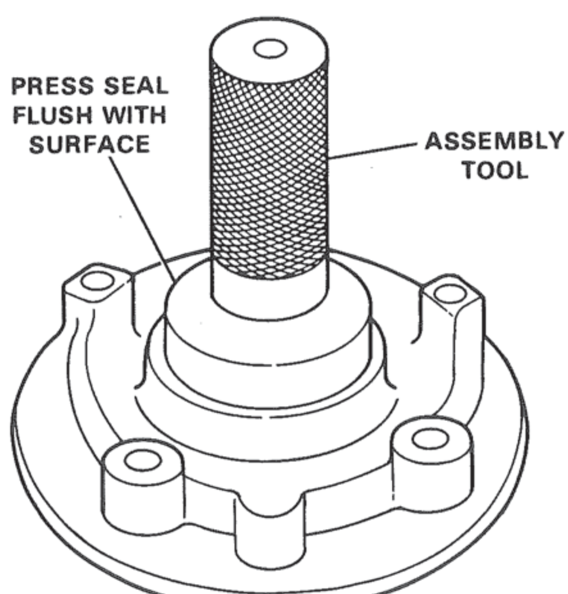


Figure 80. Pressing Pump Oil Seal Into Housing.

4. After seal is assembled, lubricate the pump housing with the proper transmission oil and place as shown in Figure 81. Install lubricated driven gear with identification mark.

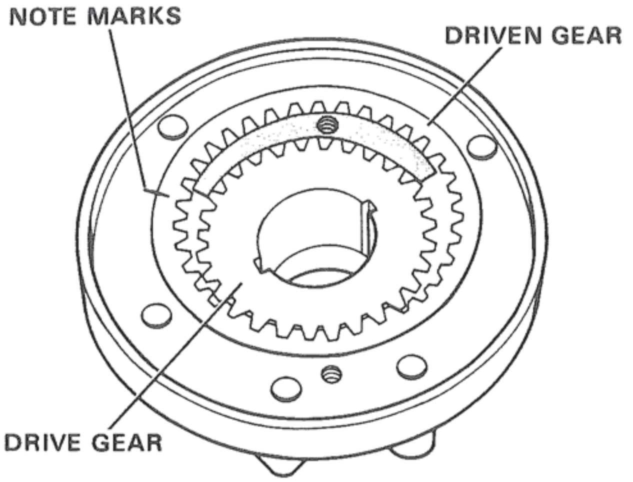


Figure 81. Installing Pump Driven Gear.

Mounting Front Pump.

1. Place previously assembled parts as shown in Figure 78, after inspecting the adapter face for dirt and obstructions.

2. Lubricate and install front pump gasket. Figure 82.

3. Install woodruff key. Figure 82.

NOTE

Check parts list to determine that proper key and shaft are used.

4. Install the pump drive gear on the input shaft, with one of the woodruff key slots in drive gear mating with the woodruff key on the input shaft.

NOTE

The two pump gears should be assembled so that the same gear faces are matched with the machined face of the pump housing as found at disassembly.

5. Cover the splined portion of the input drive gear with a suitable tool to protect the rubber lip on the seal during the assembly of the remaining front pump parts.

6. With the pump driven gear properly installed in the front pump housing, assemble the housing and pump driven gear squarely over the protruding input shaft and assembly tool. A slight rotation of the pump housing and pump driven gear will allow engagement of pump gear teeth. Figure 83.

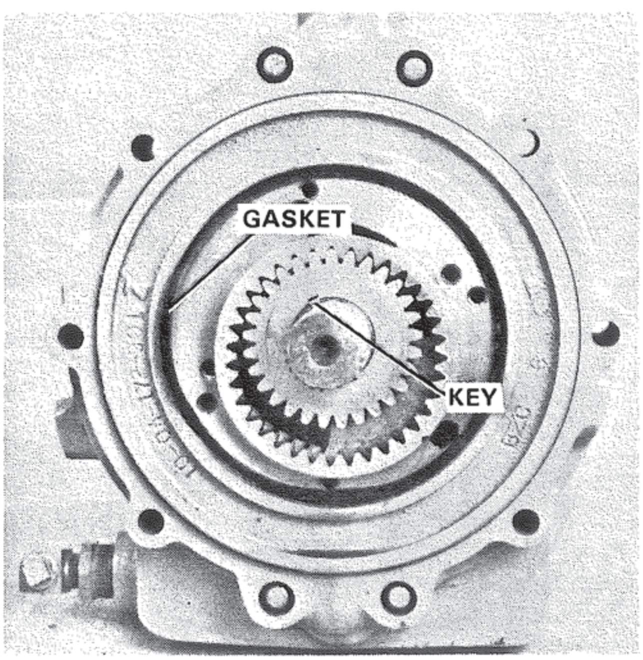


Figure 82. Installing Pump Drive Key and Gasket.

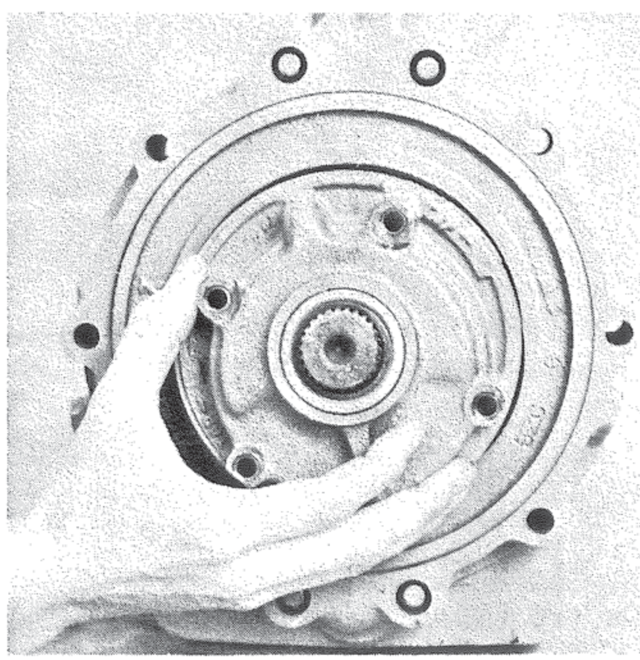


Figure 83. Installing Pump.

7. Orient the pump mounting bolt holes and arrow indicating direction of rotation to correspond with the direction of rotation required by the engine. Figure 84. If not installed for the proper rotation, the pump will not produce oil pressure to operate the transmission when engine is started.

NOTE

With the exception of the 2.10/1 reduction gear the orientation of the pump on the transmission may be changed for installation on engines with rotation opposite to that for which the transmission was originally assembled. The hand of rotation of the pump on a 2.10/1 transmission should always agree with original factory installation and must not be changed.

8. With the pump assembled squarely against the adapter and pump gasket, and the seal assembly tool removed, install four (4) 5/16-18 hex head bolts. Tighten hex head bolts evenly to torque of 17 - 22 ft. lbs. (2.34 - 3.03 kg/m)

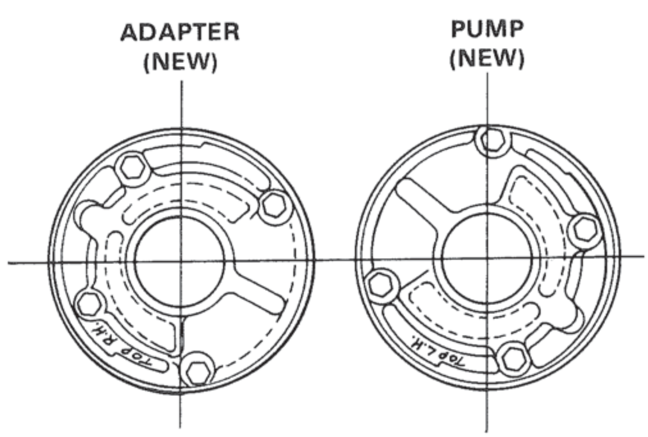


Figure 84. Orientation Markings.

9. Check freedom of rotation of pump gears in pump housing by rotating the input shaft. If the pump will not rotate freely, disassemble the pump and check for foreign material in the pump. Any dirt particles on the adapter face will also tend to cock the pump when mounted on the adapter and cause it to seize.

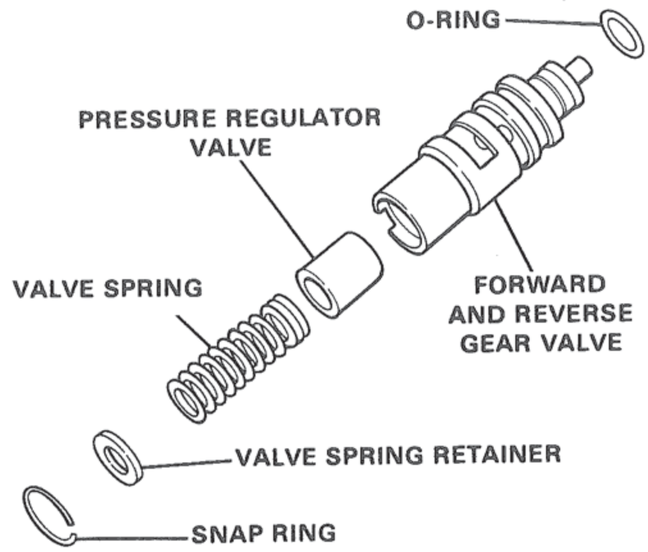


Figure 85. Valve and Spring Assembly.

Valve and Spring Assembly.

1. Collect the valve and spring assembly components, as shown in Figure 85, on a clean surface and note carefully the following:

A. The hollow portion of the pressure regulator valves face the valve spring.

B. The valve spring assembles into the pressure regulator valve.

C. The concave portion of the valve spring retainer assembles over the valve spring.

2. After carefully checking the pressure regulator valve and the bore in the forward and reverse gear transmission for dirt and burrs, assemble all valve and spring components. Figure 85.

3. Place the assembled parts in a suitable assembly fixture or arbor press. Figure 86. Turning handle of threaded plunger, compress the regulator valve spring groove for the snap ring in the pressure regulator valve is fully exposed.

4. Install snap ring shown in Figure 87. The O-ring shown in Figure 85 should be installed on end of valve.

Installation of Valve and Spring Assembly.

1. Place entire assembly on clean flat surface. Into the opening provided high on the right-rear side of the transmission case, place the valve and spring assembly, threaded end first. Figure 88. This is a hand assembly and is completed when the valve and spring assembly "bottom" against the shoulder in the case bore.

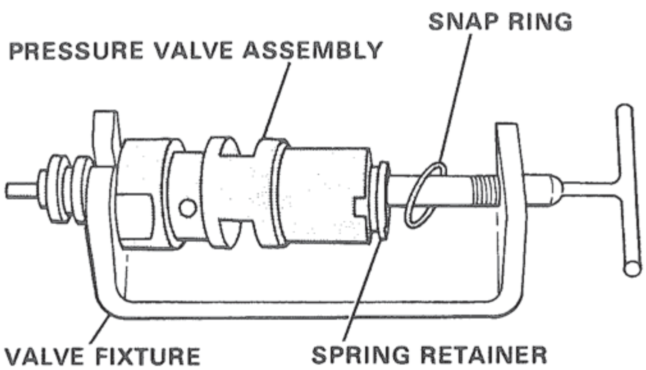


Figure 86. Control Valve Assembly in Fixture.

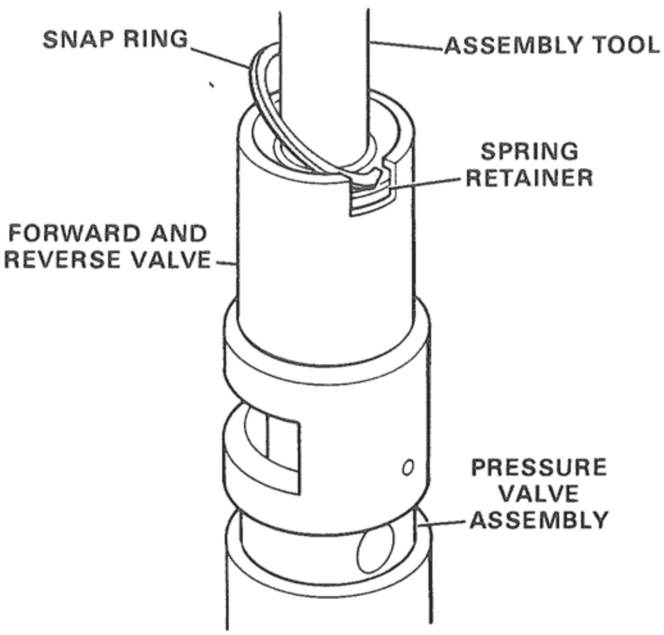


Figure 87. Installing Snap Ring.

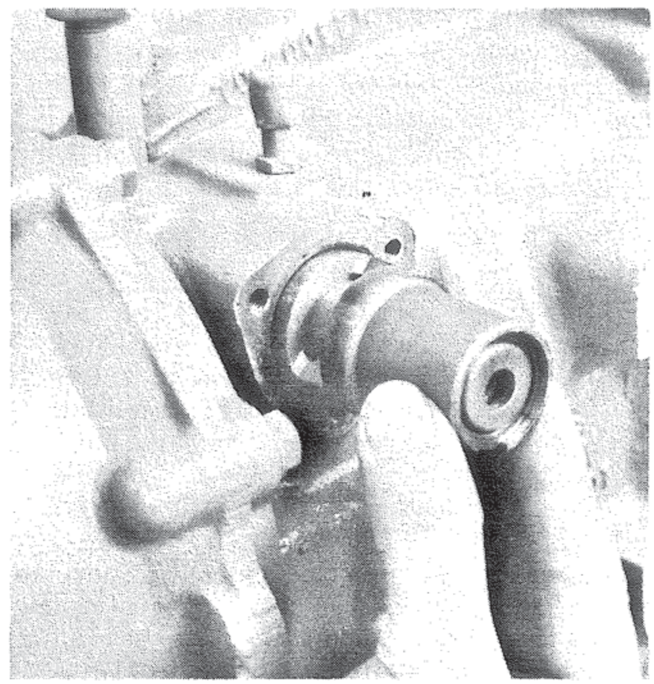


Figure 88. Installing Valve and Spring Assembly.

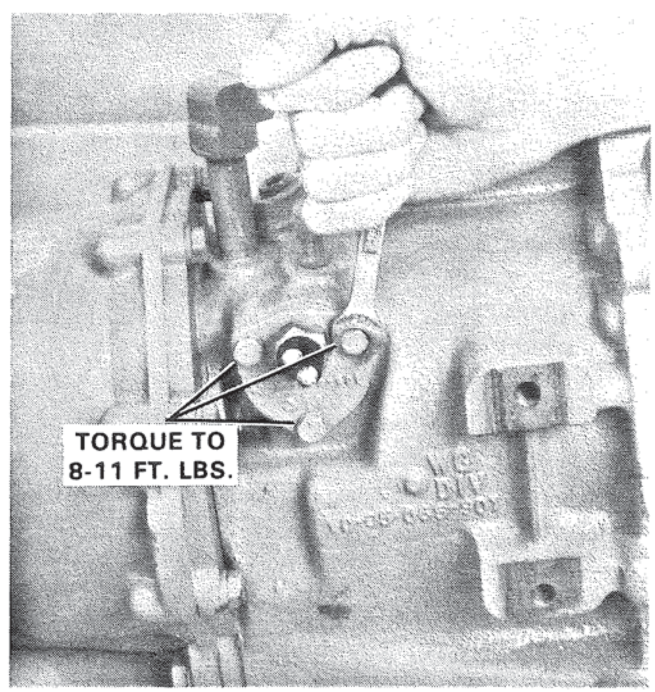


Figure 89. Securing Valve Cover Assembly.

2. To insure neutral position of valve and easier assembly of lever, align .369 - .376 in. width slot in valve with bottom 1/4-20 bolt hole in valve cover face of case.

3. Assemble the valve cover gasket, valve cover, lockwashers and hex head bolts. Torque hex head bolts to 8 - 11 ft. lbs. (1.10 - 1.52 kg/m). Figure 89.

Shift Lever Assembly.

1. Assemble shift lever and related parts in the order shown in Figure 90 and torque hex nut to 8 - 11 ft. lbs. (1.10 - 1.52 kg/m). Rotation of the valve and spring assembly through the forward, neutral and reverse positions should require no more than fingertip effort. If valve binds in rotation, remove and inspect.

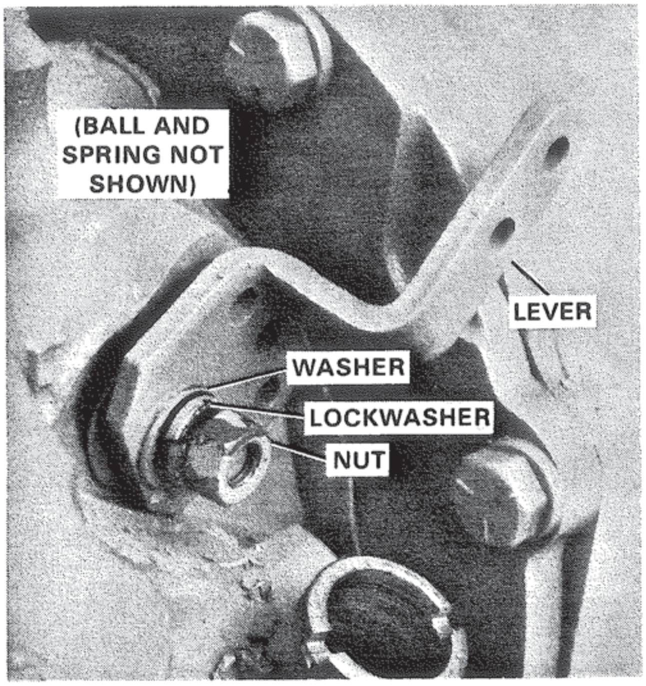


Figure 90. Assembling Shift Lever and Related Parts.

Oil Strainer Assembly and Oil Drain Plug into Transmission Case.

1. Assemble the oil strainer assembly, cooler line return bushing and cooler return tube assembly in the order shown in Figure 91. The screen end of the oil strainer assembly should be approximately 1/2 in. below the face of the case when the assembly is correctly installed.

2. Tighten cooler line return and oil drain bushing to recommended torque of 25 - 35 ft. lbs. (3.45 - 4.83 kg/m).

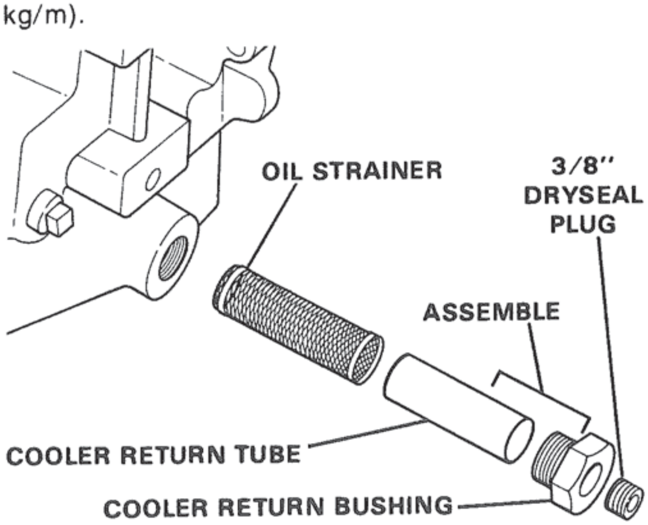


Figure 91. Installing Oil Strainer and Cooler Return Tube and Bushing Assembly.

Miscellaneous Parts.

1. Install the breather assembly. Figure 92. Do not hammer on the top of the breather assembly as this will damage the sealing element.

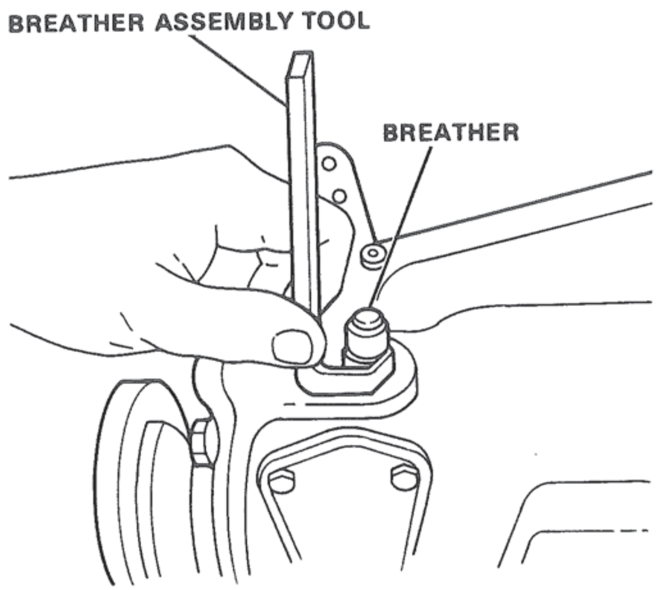


Figure 92. Installing Breather Assembly.

2. Install the dipstick assembly as shown in Figure 93, and tighten to a torque sufficient only to prevent oil leakage, approximately 10 - 15 ft. lbs. (1.38 - 2.07 kg/m).

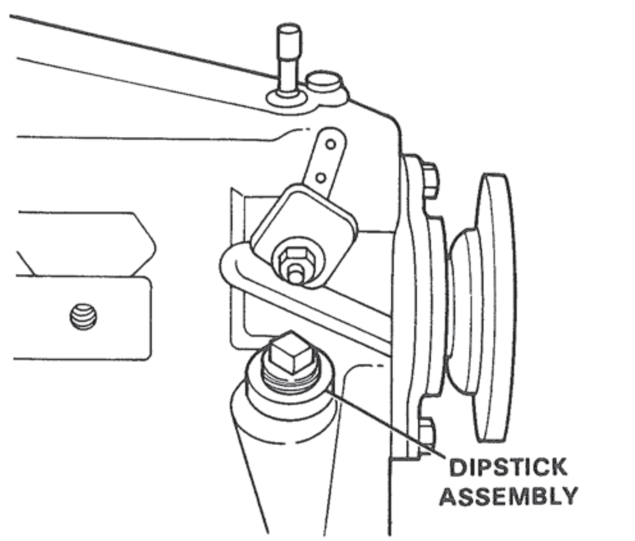


Figure 93. Installing Dipstick.

3. Install 3/8-18 and 1/8-27 dryseal plugs and tighten securely. Figure 94.

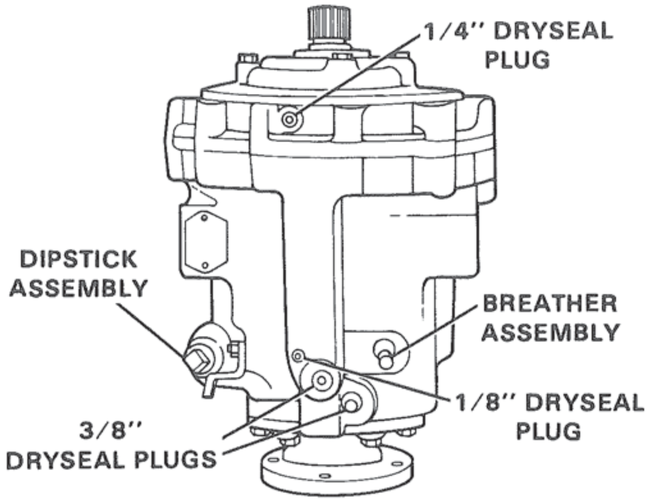


Figure 94. Placement of Miscellaneous Pipe Plugs.

Neutral Switch Assembly.

1. Unscrew three (3) hex head bolts, remove valve cover and gasket. Figure 89. Discard valve cover, gasket hex head bolts and lockwashers.

2. Shift control lever into neutral position. Assemble gasket provided in neutral switch kit. Figure 95. Assemble neutral switch cam, making sure to align tang "A" on cam with slot "B" in valve. Figure 96.

3. Neutral switch cam correctly assembled. Figure 97.

4. Assemble valve cover and neutral switch with neutral switch located between two (2) top 1/4-20 bolts. Figure 98. Use the three (3) 1/4 - 20-7/8 in. long hex head bolts provided in neutral switch kit. Tighten bolts to recommended torque of 8 - 11 ft. lbs. (1.10 - 1.52 kg/m) and assemble starter solenoid wires to switch.

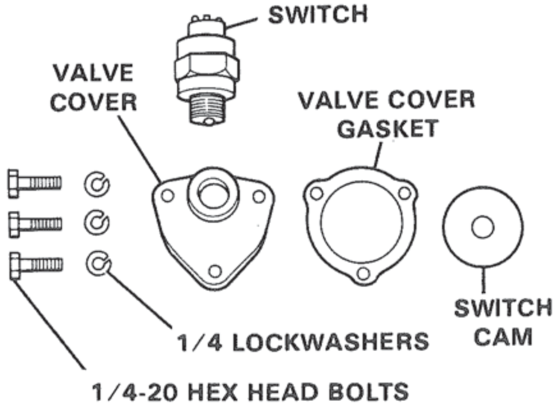


Figure 95. Neutral Switch Kit.

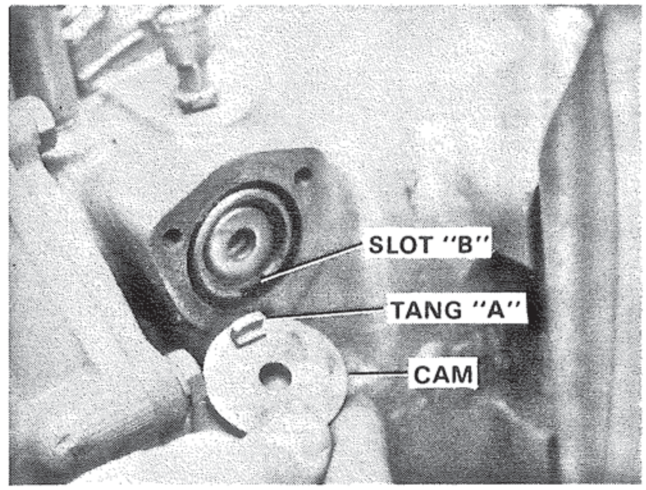


Figure 96. Neutral Switch Assembly.

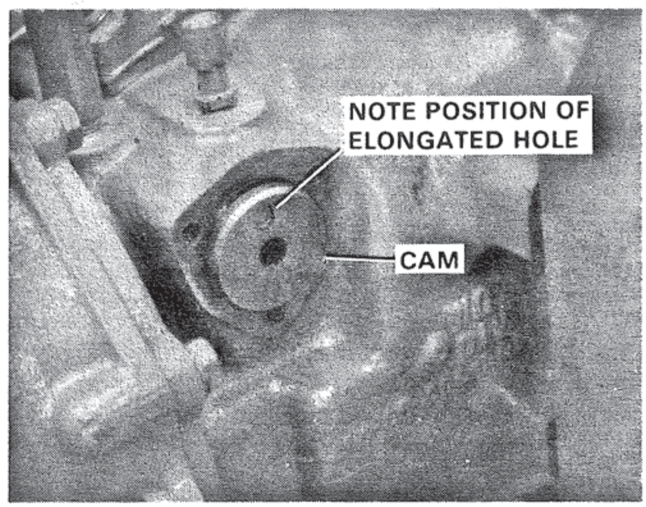


Figure 97. Neutral Switch Cam in Correct Position.

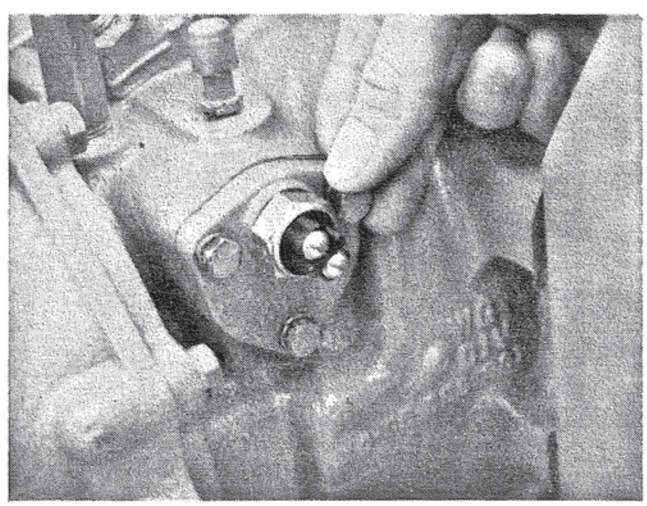


Figure 98. Neutral Switch Correctly Assembled.

SPECIAL INFORMATION AND INSTRUCTIONS MODEL 72C TRANSMISSIONS.

NOTE

It may be found that in a Model 72C transmission assembly a number of components may vary from the description and illustrations presented in the preceding portion of this manual. This results from changes which have been made since the first introduction of this model. In this section the information and description is presented for those features which are no longer incorporated in the current production models.

Oil Filler Cap and Dipstick Installation.

1. Place oil filler cap and dipstick assembly in the oil filler tube provided on rear left side of transmission case. Figure 99. Push down on filler cap and dipstick until assembly "bottoms" on tube, then turn cap to right as far as cap screw permits.

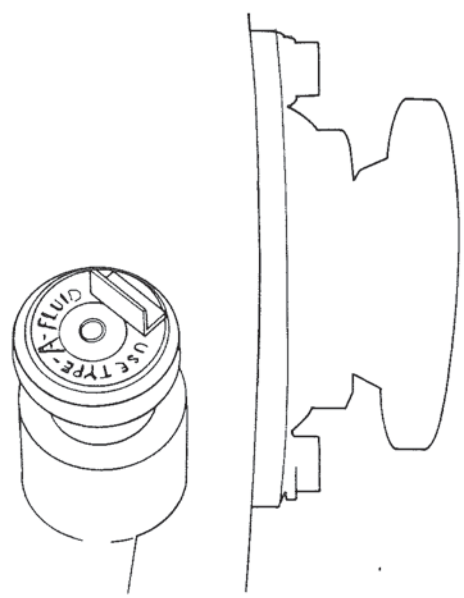


Figure 99. Oil Filler Cap and Dipstick Installation.

Installation of Oil Strainer Assembly and Oil Drain Plug into Transmission Case.

NOTE

The 72C transmissions formerly used a cooler return bushing with threads other than the tapered dryseal pipe threads now used. This installation with the (4885) cooler return bushings, Figure 100, required a copper annular gasket (120428) to prevent leakage. Oil strainer (71-A98C) was also formerly used in this assembly, but has now been replaced with oil strainer 71C-A98A, which is fully interchangeable. The two bushings are not interchangeable and the correct parts must be assembled as illustrated in Figures 91 or 100. Those installations requiring the use of the parts in Figure 100 can be easily identified by the machined face on the case boss as indicated.

2. Assemble the oil strainer assembly, annular gasket, and cooler return line bushing in the order shown in Figure 100. The end of the strainer will be approximately 7/16 in. (11.1 mm) below the outside machined surface of the case, when inserted in the case to its full depth. Mount the annular gasket on the cooler return bushing and tighten in the case.

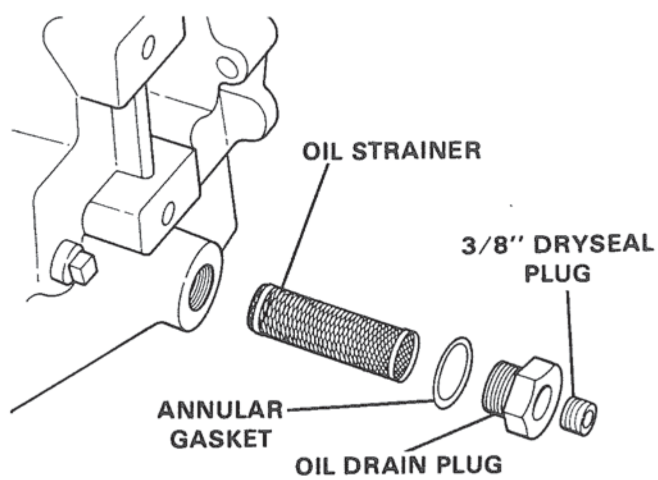


Figure 100. Oil Strainer and Return Bushing Installation.

Breather Installation.

1. In addition to the breather assembly shown in Figure 92, other breather assemblies will be found in use as illustrated in Figure 101 and Figure 102. These illustrations demonstrate the manner in which the breather assemblies are installed.

2. The breather in Figure 102 is supplied for those installations where a pressure type breather replaces the breather shown in Figure 101. This breather is used with an internally threaded bushing which presses into the case before the installation of the threaded breather assembly.

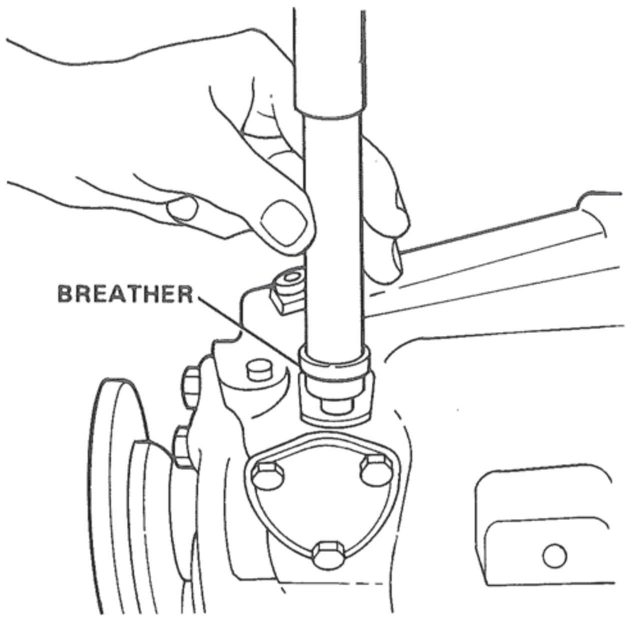


Figure 101. Breather Assembly.

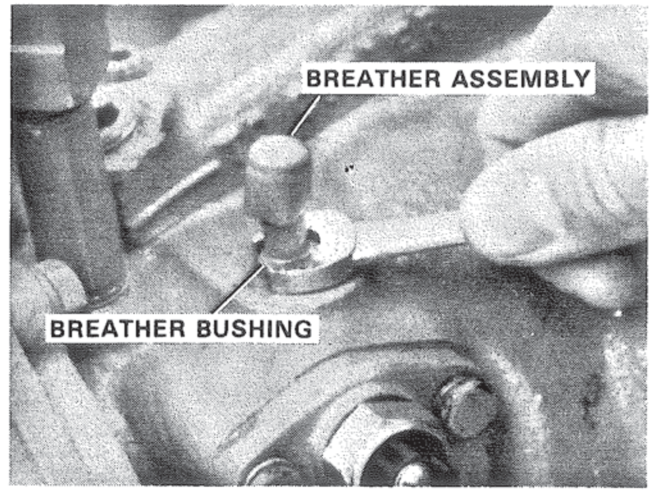


Figure 103. Pump Porting in 71B-8 Adapter.

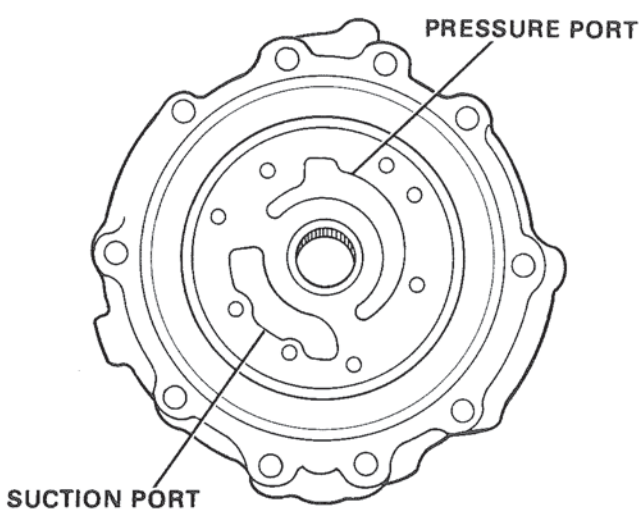


Figure 102. Adapting Breather Assemblies.

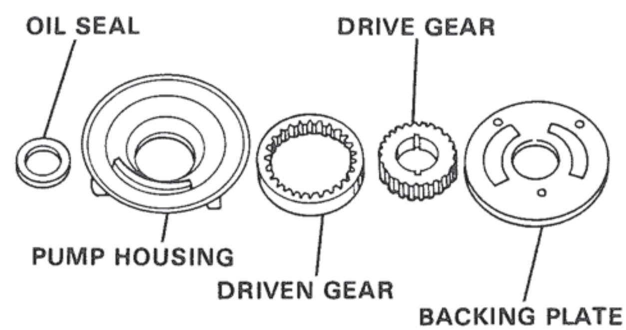


Figure 104. Front Pump Assembly 71-A60.

Front Pump Assembly.

NOTE

The following instructions are for the assembly of the front pump with a backing plate. Figure 104. This pump can be used with either of the two different adapter housings, but it should normally be found assembled on the one shown in Figure 103. Any of the various versions of the input shafts may be used with this pump, but the proper key must always be used with each shaft.

1. Collect the parts shown in Figure 104 and check carefully for the following:

A. Scoring in gear pockets, crescent, backing plate and gear faces.

B. Dents and burrs on both faces of backing plate.

C. Oil seal lip for brittle condition, cracks and cuts. Oil seal outside diameter for dents or scratches.

D. Gear teeth for burrs.

2. Place pump housing squarely on arbor press table. Apply a suitable sealant to the outside diameter of seal before installing squarely into bore of housing with seal lip positioned as shown in Figure 105. Caution should be observed to insure that too much sealant is not used, that any excess is wiped away after the seal is installed, and that the sealant does not get on the sealing element.

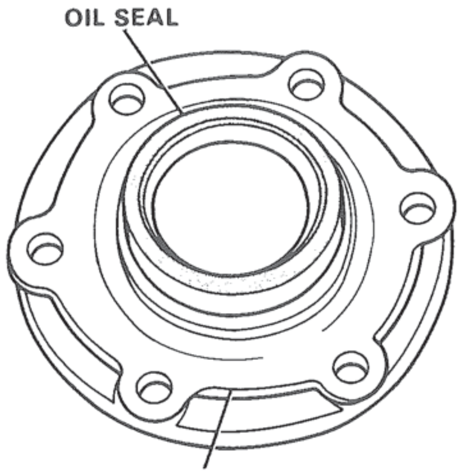


Figure 105. Installing Oil Seals.

3. Using an arbor pess and suitable tool, press seal into housing until front face of seal is flush with front face of pump housing. Figure 106.

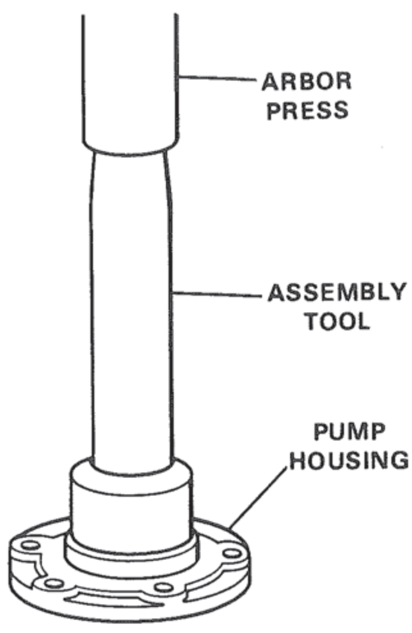


Figure 106. Installing Oil Seal.

4. Place housing, lubricated with automatic transmission fluid type "A" suffix "A", and complete with seal in position shown in Figure 107. Install lubricated gears as shown, with reassembly identification marks matched.

5. Inspect both faces of backing plate for dirt, lubricate and assemble. Figure 108.

6. Install the mounting screw and tighten to final torque of 25 - 35 in. lbs. (28.7 - 40.2 kg/cm) Figure 109. Check rotation of gears as assembled in pump housing; disassemble and inspect if gears do not turn freely.

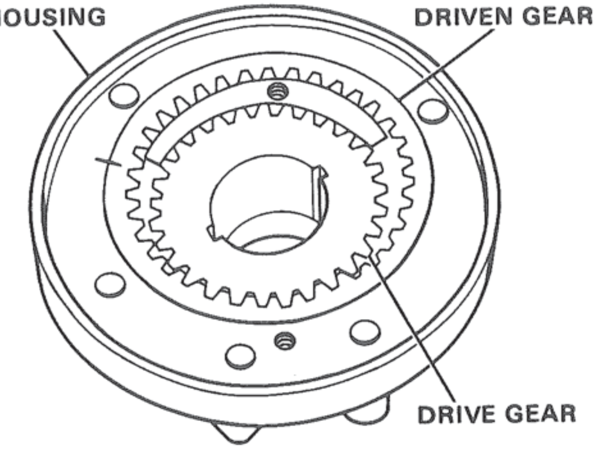


Figure 107. Installing Pump Gears.

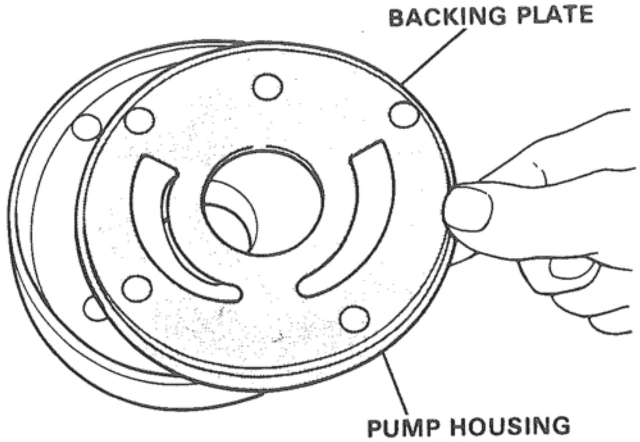


Figure 108. Assembling Backing Plate.

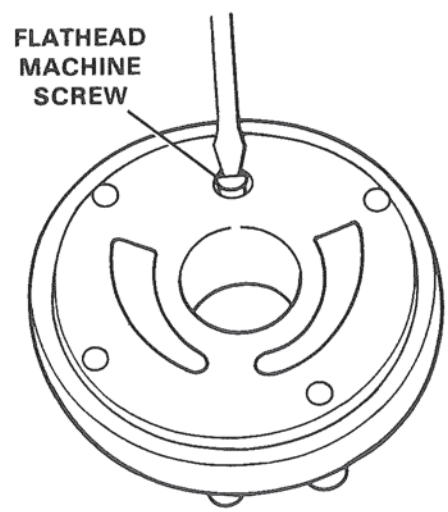


Figure 109. Installing Flat Head Machine Screw through Backing Plate.

Mounting Front Pump on Transmission.

1. Place assembled transmission on rear face of coupling in upright position. Figure 110. Inspect upper exposed adapter face for dirt and obstructions, then lubricate and install front pump gasket.

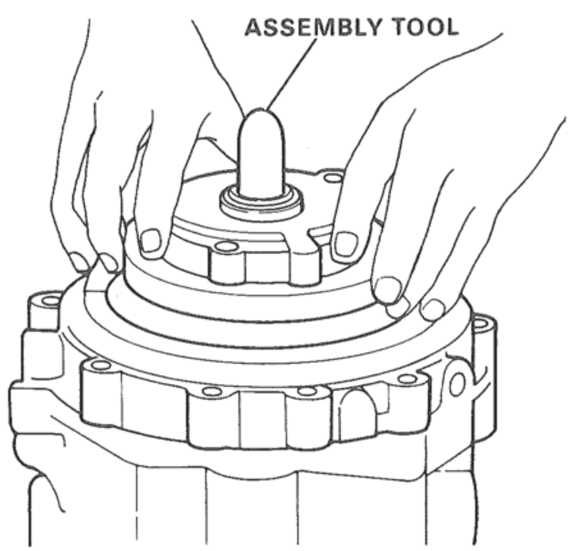


Figure 110. Mounting Front Pump.

2. Install woodruff key.

NOTE

Check to see that proper key and shaft are used.

3. Use a suitable tool to cover the splined portion of the input shaft and thereby protect the rubber lip on the oil seal during assembly of front pump.

4. After checking the following items, place the front pump assembly squarely down over the protruding input shaft and assembly tool.

A. Alignment of woodruff key slot in drive gear with mating woodruff key on the input shaft.

B. Orientation of pump mounting bolt holes and direction of rotation arrow, depending on desired direction of input rotation. Figure 111 or 112.

C. Freedom of rotation pump gears in housing.

NOTE

The location of the markings on the 71-60 pump housing identifying the orientation of the pump assembly on the adapter for right or left hand rotation will vary depending upon which pump assemblies and adapters are used.

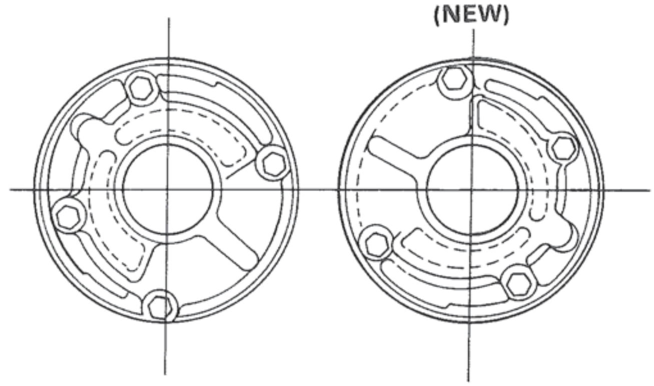


Figure 111. Orientation Markings for New 71-1A60 Pump Assembly on 71-8B Adapter.

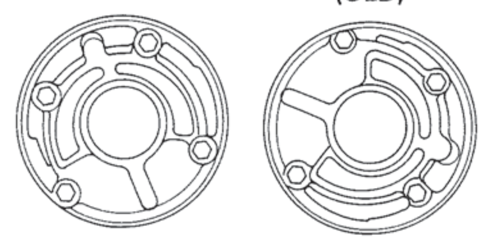


Figure 112. Orientation Markings for Old 71-1A60 Pump Assembly on 71-8B Adapter.

The newer pump assembly with backing plate, identified by the rib on the pump housing, will be properly mounted when the marking on the pump housing appears as shown in Figure 111, when mounted on the 71-8B adapter. If the same pump were mounted on the new adapter 71C-8, Figure 77, the pump markings would be identical to those illustrated for the new 71C-A60 pump in Figure 84.

The older pump assembly with backing plate identified by the absence of the rib on the 71-60 pump housing, would appear as illustrated in Figure 112, when mounted on the old 71-8B adapter. Figure 103. This older pump assembly with backing plate could also be mounted on the new 71C-8 adapter, Figure 77, but this has not been illustrated as no original factory installations were made in this manner.

5. With front pump assembly resting squarely on gasket and seal assembly tool removed, install four (4) 1-7/8 in. long hex head bolts. Figure 113. Tighten hex head bolts evenly to torque of 17 - 22 ft. lbs. (2.34 - 3.03 kg/m).

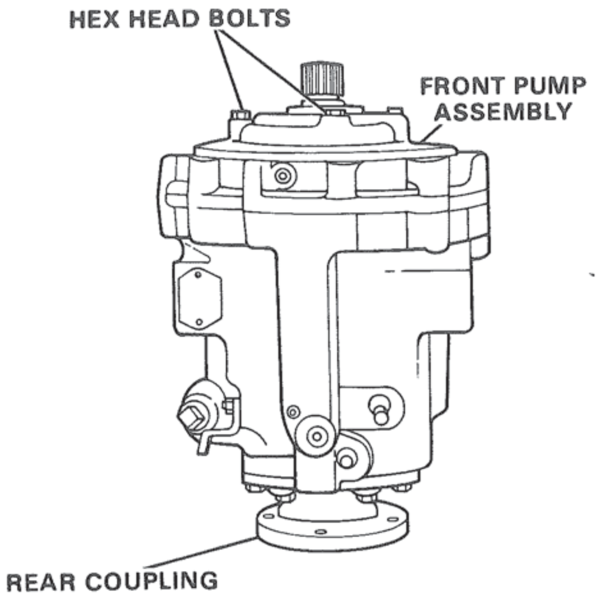


Figure 113. Mounting Front Pump Assembly.

Elimination of Regulator Valve Buzz. New pressure regulator valves (71-243) have a relief at the outer diameter at the closed end for the elimination of regulator valve buzz. Figure 114. If a transmission should have a valve buzz and contains a 71-243 pressure regulator valve which does not have the relief, the valve should be replaced, or reoperated as illustrated.

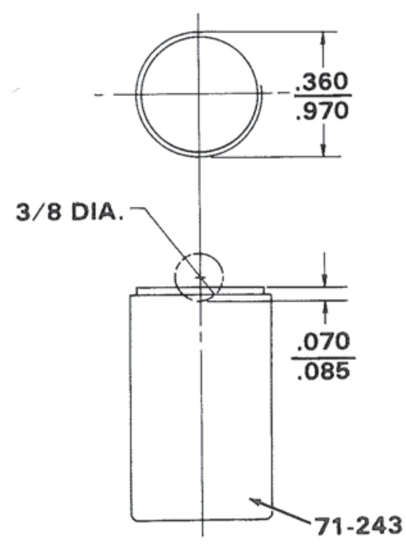


Figure 114. Reoperation to Eliminate Regulator Valve Buzz.

Drive Gear and Plug Assemblies. The two methods of sealing the end of the drive gear are illustrated in Figure 115. Sketch "B" illustrates the method now used and sketch "A" the method formerly used. The two drive gear assemblies, varying only in the method of sealing the end of the shaft are fully interchangeable.

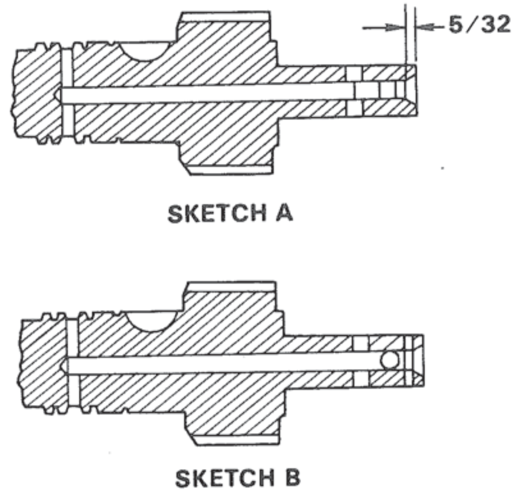


Figure 115. Versions of Drive Gear and Plug Assemblies.

Pinion Cage and Output Shaft Assembly. Pinion cage and output assembly has been supplied with three oil grooves around the shaft diameter. Figure 116. This shaft can be used to replace any shafts. However, shafts without the grooves must not be used with those forward and reverse transmission cases supplied without the 71-28B bushings.

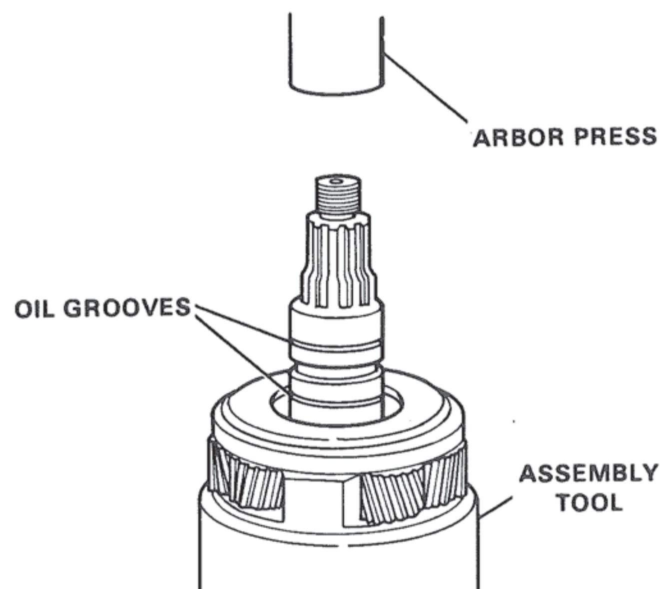


Figure 116. Pinion Cage and Output Shaft Assembly with Oil Grooves.

Forward and Reverse Gear and Bushing Assembly. Two versions of the transmission case have been supplied; one includes bronze bushings for the output shaft journal, the other is designed for use without the bushings. These two versions of the transmission case are completely interchangeable, except that the case without bushings cannot be used with the output shaft assemblies which do not have the oil groove. Figure 116. If it becomes necessary to replace a case of the design without bushings because of worn journals, it can be returned to your engine supplier. He can return the case to Warner Gear for reoperation and installation of bushings and can furnish information concerning the cost of this service.

Adapter Cap Screws. The 3/8-16 x 1-1/4 in. hex socket cap screws (138243) formerly used to fasten the adapter to the transmission case have now been replaced with a twelve (12) point cap screw (4911) which has better locking characteristics. The two types are completely interchangeable.

SPECIAL INFORMATION AND INSTRUCTIONS MODEL 72-TRANSMISSIONS

NOTE

Except for the discussions and illustrations on the features included in this section all other information concerning the Model 72-Transmissions may be found in preceding sections of the manual containing information for the assembly or disassembly of the Model 72C Transmission or in the special supplementary section for these transmissions.

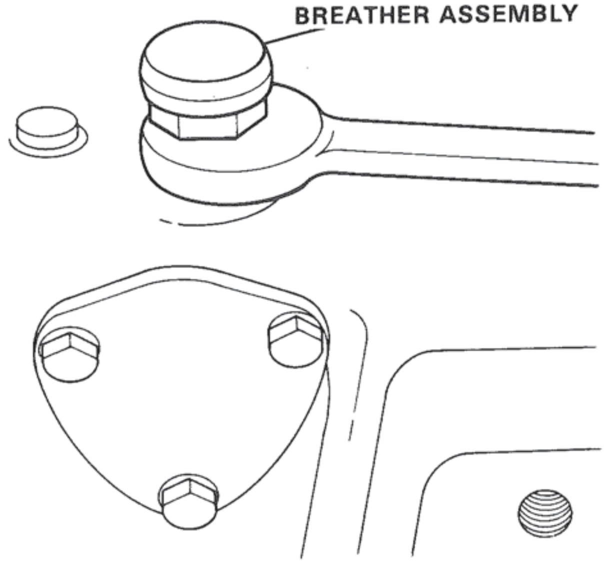


Figure 117. Breather Installation.

Installation of Breather Assembly. Assemble the screw-in type breather assembly as shown in Figure 117.

Assembly of Front Pump.

1. The pump assembly for the Model 72 transmission (71-A60) contains a different seal than the pump assembly with backing plate for the Model 72C (71-1A60). They are identical in all other respects, with the exception that the seal should be pressed into the pump housing until front face of seal is 1/8 in. (3.2 mm) above front face of pump housing. Figure 118.

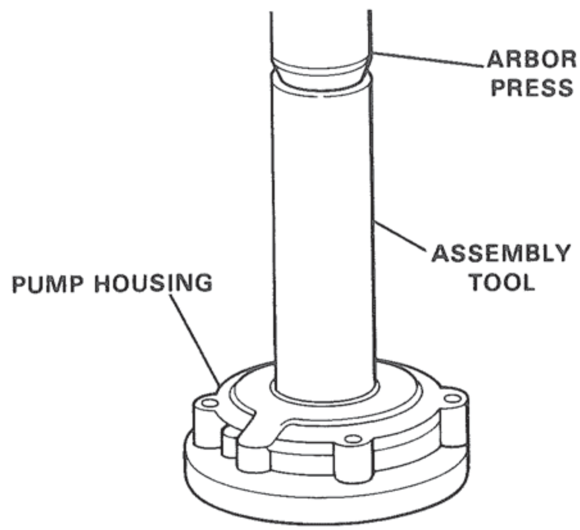


Figure 118. Installing Oil Seal.

2. On some early production Model 72 transmissions the overall height of the pump housing between faces measured 1-7/8 in. (4.76 m) instead of 1-5/8 in. (4.1 m) on all other later pump assemblies. For any pump housing having the 1-7/8 in. (4.76 m) dimension, assemble the seal 1/8 in. (3.2 mm) below pump face.

Reverse Clutch Plate Selection. On early Model 72 transmissions the case cavity depth for the reverse clutch parts measured only .780 - .784 in. (1.98 - 1.99 m). These units require placement clutch parts different from those specified for present production transmissions and should be ordered as specified below:

Index No.	Part No.	Part Name	No. Req'd
16	71-87	Dowel Pin	3
18	72-A66	Reverse Clutch Plate	2
98	72-176	Outer Reverse Clutch Plate	1

SPECIAL SERVICE KITS.

NOTE

Special service kits are available to the original equipment manufacturer for distribution to their various dealers. These kits offer convenience in repairing all Model 72 Forward and Reverse Gear Transmissions for which our standard marine warranty has expired. The chart in Figure 120 lists all service kits available and identifies the parts they contain. Only those dealers who are well qualified in the repair of the marine transmissions should be permitted to service planetary gear sets.

Planetary Service Kits. These repair kits make possible the replacement of individual pinions and related parts of the planetary gear sets and eliminate the necessity of replacing the entire planetary assembly. The kits available for all direct drive Model 72 Forward and Reverse Gear Transmissions are listed in Figure 120, with information identifying the parts in each kit. The Inner Pinion Kit (A4867JJ) and the Outer Pinion Kit (A4867HH) cannot be interchanged, but should only be used in the locations in the planetary as shown in Instruction Sheet. Figure 121.

NOTE

In disassembling the individual gear sets the pinion shaft pin retaining the pinion pin should be removed intact after the removal of the oil collector ring. The pinion shaft pin should not be removed by pounding on the end of the pinion pin to break the retaining pin, as this distorts the immediate area of the pinion carrier and will produce a damaged thrust surface and improper pinion clearance when the planetary is reassembled.

Oil Collector Ring Kit. After assembly of the individual pinions in the planetary, the oil collector ring must be assembled and securely fastened to the planetary carrier. The oil collector ring which was removed to repair the planetary assembly should always be discarded and replaced with a new part (A4867KK).

Transmission Case Service Bushing Kit. For those transmissions requiring the replacement of the bushing in the transmission case presized service bushings are available. This A4867-VV bushing service kit is listed in Figure 120 and additional installation information is illustrated in Figure 122. The kit may be used in all Model 72 direct drive transmissions which required the replacement of their bushings.

Output Shaft Service Bushing Kit. The installation of the output shaft bushing is illustrated on Pinion Cage Service Instruction Sheet Figure 121. Be sure to identify the different bushings in the kit (A4867DD) and install with the oil holes and grooves as illustrated in the instructions.

Clutch Pack Kits. Kit (A4867AB) is supplied for all Model Forward and Reverse Transmission clutch packs. See Figure 120 for information on these kits.

Small Parts Repair Kits. Two separate kits are supplied (A4867M) for Model 72 Forward and Reverse Gear Transmission and (A4867WW) for Model 72C Forward and Reverse Gear Transmission. Each of these kits contain the many small miscellaneous parts needed during the repair and rebuilding of a transmission. See chart, Figure 120, for additional information.

NOTE

Where needed, assembly instruction sheets are included in the service kits.

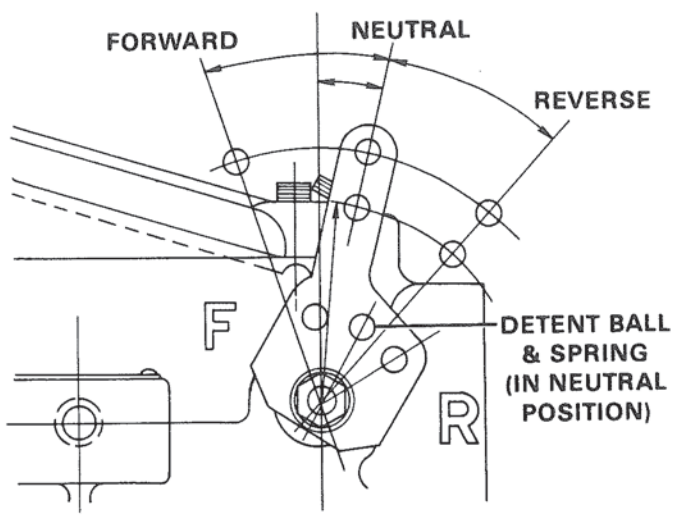


Figure 119. ASI-72 Shift Lever Positions.

Assembly of Shift Lever. The shift lever assembly procedure is the same for the Model 72 transmissions as that described and illustrated for the Model 72C. Although the present shift lever, 71-79B can be substituted for the lever shown in Figure 119, it would change the travel of the control linkage for shifts between "Neutral" and "Forward" positions.

Selection of Output Shaft Coupling. Early Model 72 transmissions used a smaller diameter coupling (4547BA) than the present coupling (4547AY). Order the correct part to replace the one used on your transmission. This will avoid any installation problem concerning the mating part (coupling-rear half) which would arise from their difference in size and bolts used for assembly. See parts list for additional information.

Cooler Return to Transmission. On the Model 72 transmissions it is now recommended that the cooler oil flow be returned to the transmission case. Transmissions with the cooler flow returning in a manner other than that now recommended need not be changed. However, the arrangement now recommended conforms to practices followed on other transmission installations and permits better control of the cooler return oil flow to the pump suction.

NOTE

If cooler return flow is changed to the new location, be sure that the oil strainer installed is similar to the one illustrated in Figure 100. The old strainer assembly with one end enclosed would block the flow of the cooler return oil.

Service Kit Number	Kit Name	Used With	Material List Quan.	Part No.	Description
A4867DD See Instruction Page 00	Output Shaft Bushing Kit	All Model 72 Forward & Reverse Gear Only	1	71-9B	Main Drive Gear Bushing
			1	71-9C	Main Drive Gear Bushing
A4867KK See Instruction Page 00	Oil Collector Ring Kit	All Model 72 Forward & Reverse Gear Only	1	72-135	Oil Collector Ring
A4867HH See Instruction Page 00	Outer Pinion Kit	All Model 72 Forward & Reverse Gear Only	1	L3-105	Pinion, Right Hand
			1	72-39	Pinion Shaft, Outer
			3	L3-41	Pinion Bearing Spacer
			2	72-43	Pinion Thrust Plater
			1	4717L	Pinion Shaft Pin
			48	4741A	Pinion Roller
A4867JJ See Instruction Page 00	Inner Pinion Kit	All Model 72 Forward & Reverse Gear Only	1	L3-5	Pinion, Left Hand
			1	L5-39	Pinion Shaft
			3	L3-41	Pinion Bearing Spacer
			2	72-43	Pinion Thrust Washer
			1	R4-40	Pinion Shaft Pin
			48	4741A	Pinion Roller
4867VV See Instruction Page 00	Transmission Case Service Bushing Kit	All Model 72 Forward & Reverse Gear	2	71-28C	Output Shaft Bushing
A4867AB	Clutch Pack Kit	All Model 72 Marine Trans.	7	5C-A66A	Inner Clutch Plate Assembly
			6	3-176	Outer Clutch Plate
			1	5L-67	Rear Clutch Pressure Plate
			1	5C-175C	Front Clutch Pressure Plate
A4867WW	Small Parts Repair Kit	Model 72C Marine Transmissions	Misc. Pieces		All Gaskets, Sealing Rings, Thrust Washers, Snap Rings Woodruff Keys, Dowel Pins, Seals and other Miscellaneous Parts.
A4867M	Small Parts Repair Kit	Model 72 Marine Transmissions	Misc. Pieces		All Gaskets, Sealing Rings, Thrust Washers, Snap Rings Woodruff Keys, Dowel Pins, Seals and other Miscellaneous Parts.

Figure 120. Service Kits.

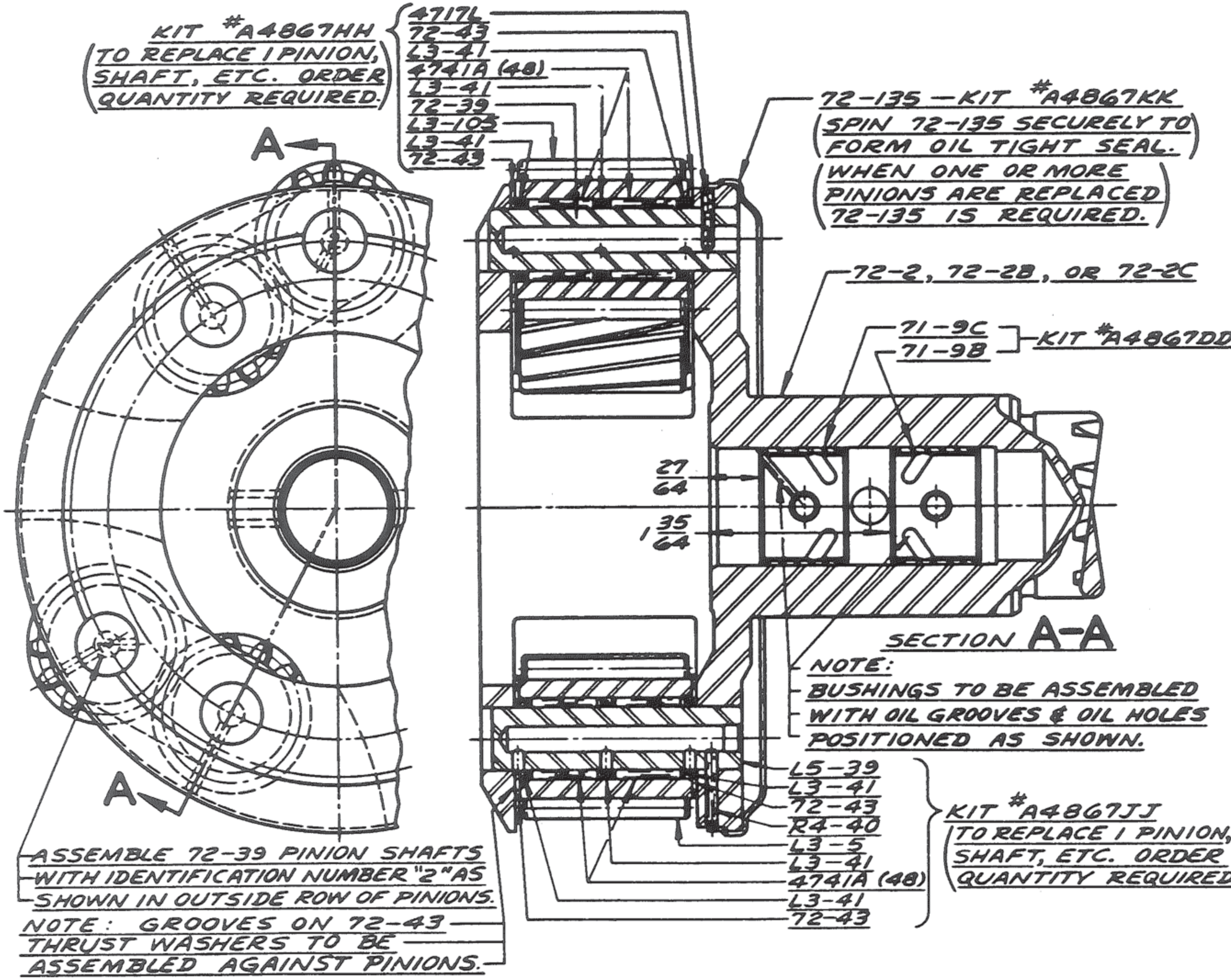
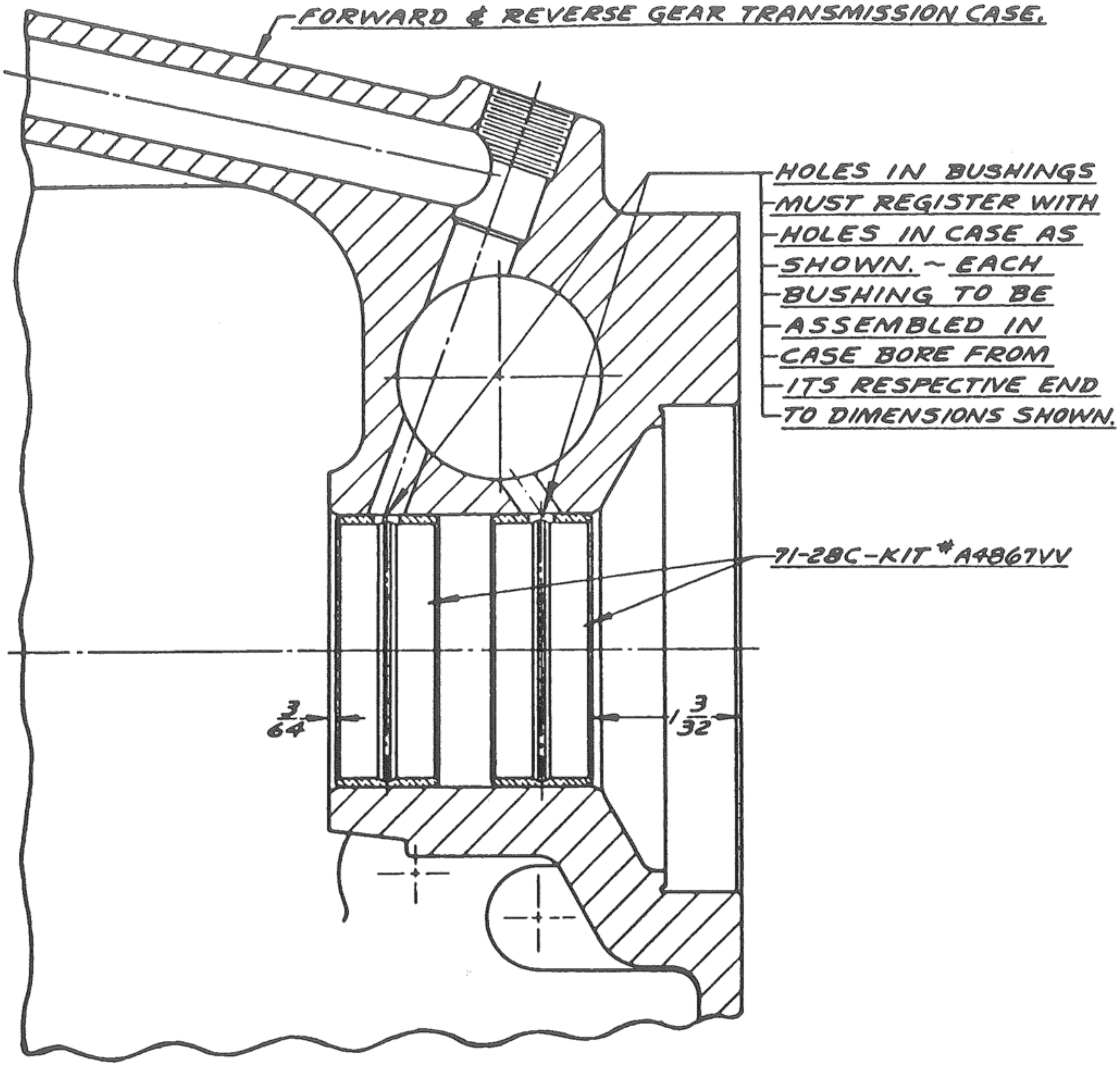


Figure 121. Inner and Outer Pinion Installations.



NOTE

The 71-28C bushing is the pre-sized bushing for field service of the original 71-28B bushing installed at factory.

Figure 122. Transmission Case and Service Bushings.

WARNER DRIVE-CR2 UNITS, 10-13, 10-14

GENERAL

CR2 units are available in 24 different assemblies. Twelve assemblies are available in each of two sizes. The smaller Model 10-13 units are similar in size to the 71C transmission. The larger Model 10-14 units are similar in size to the 72C transmissions. Four different ratios are available in each of three types in both sizes. One type has output shaft rotation the same as engine when forward is selected. One type has output shaft rotation opposite to engine when forward is selected. A chart shows the various CR2 assemblies currently available.

The Velvet Drive CR2 marine gear was designed especially for twin screw applications. Its counter rotating feature eliminates the need for opposite rotating engines.

CR2 assemblies consist of a forward and reverse portion built into the front case and a reduction portion built into the reduction housing.

FORWARD AND REVERSE PORTION

The forward and reverse portion consists of a planetary gear set, forward clutch, reverse clutch, oil pump, pressure regulator valve and rotary control valve assembled into a cast iron case. A direct drive ratio is provided for forward operation. All 10-13 models have a 1.00: 1.00 ratio in reverse. All 10-14 models have a 1.10: 1.00 ratio in reverse. Helical gearing is used to provide quieter operation than can be obtained with spur gearing.

The transmission is fast shifting to give the boat operator complete control of the vessel. Shifting is accomplished by fore and aft movement of the shift lever. This movement rotates the control valve to direct oil under pressure to the required channels.

Oil pressure is provided by a crescent type pump. The pump drive gear is keyed to the input shaft and operates at transmission input shaft speed. Pressure lubrication is provided at all times in forward, neutral and reverse.

REDUCTION PORTION

The reduction portion is housed in the rear or reduction housing. The reduction drive gear is splined to the output shaft of the forward and reverse transmission and it is meshed with the ring gear on units having the same input and output shaft rotation when operated in forward. The reduction drive gear drives an idler gear which drives the ring gear on units having the output shaft turning opposite to input shaft when operated in forward. The ring gear and output shaft are one piece construction and are held firmly in position by tapered bearings.

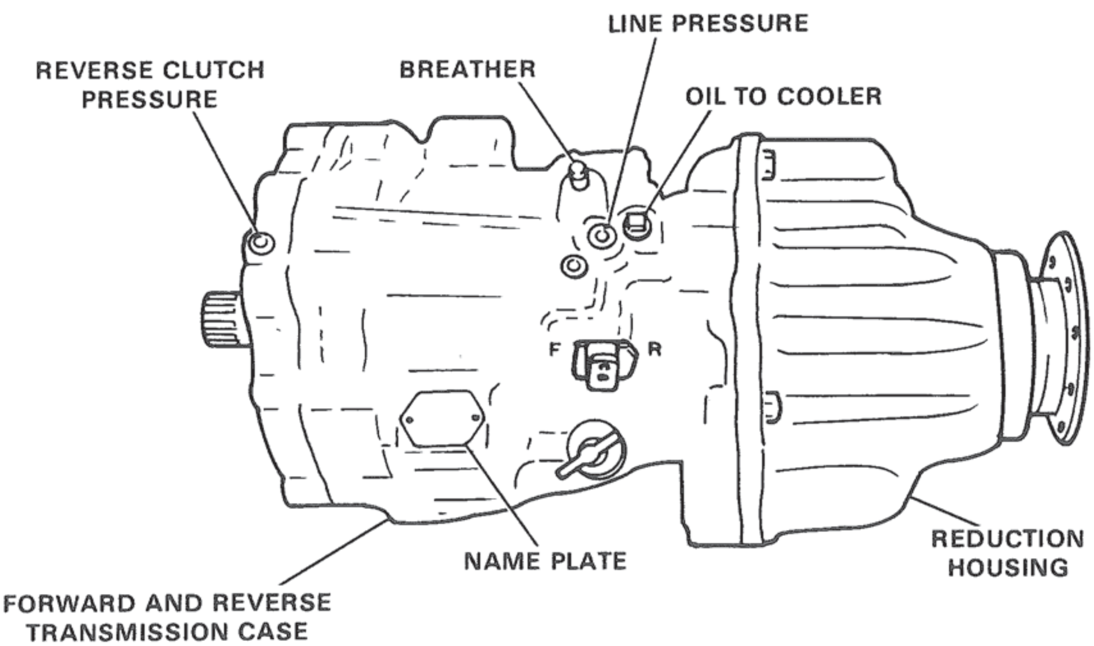


Figure 1. Transmission

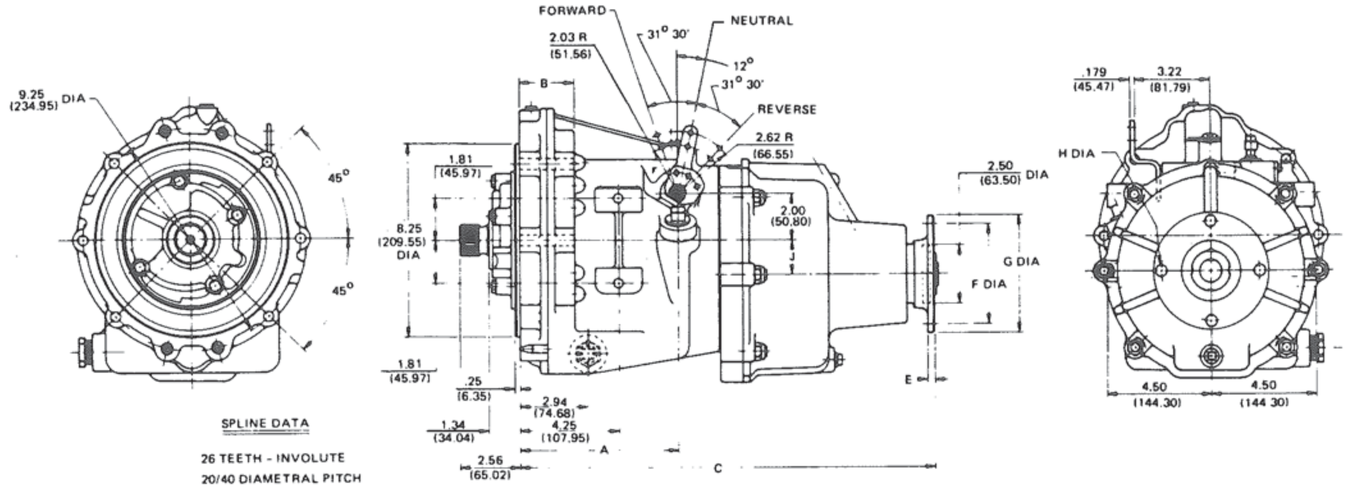
CR2
(DROP CENTER ASSEMBLIES)

NE=NON-AUTOMOTIVE ENGINE
E=AUTOMOTIVE ENGINE
O=AUTOMOTIVE OPPOSITE

ASSEMBLY NUMBER	REDUCTION RATIO		SHAFT ROTATION (1)			(2) PUMP SETTING	(3) PROPELLER REQUIRED	NAME PLATE STAMPED
				OUTPUT				
	FORWARD	REVERSE	INPUT	FORWARD	REVERSE			
10-13-000-001	1.58:1.	1.58:1	(4) L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-1.6
10-13-000-002	1.58:1	1.58:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	O-1.6
10-13-000-003	2.03:1	2.03:1	L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-2.0
10-13-000-004	2.03:1	2.03:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	O-2.0
10-13-000-005	2.47:1	2.47:1	L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-2.5
10-13-000-006	2.47:1	2.47:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	O-2.5
10-13-000-007	2.93:1	2.93:1	L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-3.0
10-13-000-008	2.93:1	2.93:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	O-3.0
10-13-000-009	1.58:1	1.58:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-1.6
10-13-000-010	2.03:1	2.03:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-2.0
10-13-000-011	2.47:1	2.47:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-2.5
10-13-000-012	2.93:1	2.93:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-3.0
10-14-000-001	1.58:1	1.74:1	L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-1.6
10-14-000-002	1.58:1	1.74:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	O-1.6
10-14-000-003	2.03:1	2.23:1	L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-2.0
10-14-000-004	2.03:1	2.23:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	E-2.0
10-14-000-005	2.47:1	2.72:1	L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-2.5
10-14-000-006	2.47:1	2.72:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	O-2.5
10-14-000-007	2.93:1	3.22:1	L.H.	ENGINE	OPPOSITE ENGINE	→	L.H.	E-3.0
10-14-000-008	2.93:1	3.22:1	L.H.	OPPOSITE ENGINE	ENGINE	→	R.H.	O-3.0
10-14-000-009	1.58:1	1.74:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-1.6
10-14-000-010	2.03:1	2.23:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-2.0
10-14-000-011	2.47:1	2.72:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-2.5
10-14-000-012	2.93:1	3.22:1	R.H.	ENGINE	OPPOSITE ENGINE	←	R.H.	NE-3.0

(1) VIEWED FROM BEHIND COUPLING FACING ENGINE
(2) VIEWED FROM IN FRONT OF TRANSMISSION INTO PUMP
(3) VIEWED FROM BEHIND BOAT
(4) L.H. – LEFT HAND OR COUNTERCLOCKWISE
R.H. – RIGHT HAND OR CLOCKWISE

CAUTION: Engine rotation must be the same as shown on the chart (input shaft rotation). Failure to comply can result in premature gear damage.



SPLINE DATA

26 TEETH - INVOLUTE
20/40 DIAMETRAL PITCH
30° PRESS. ANGLE
1.300 (33.02) PITCH DIA

NOTE: Parenthetical dimensions are in millimeters.

Figure 2. Installation Drawing for CR2 Transmissions.

MODEL	A	B	C	E	F DIA	G DIA	H DIA	REDUCTION	J OFFSET DIMS. OUTPUT ROTATION	
									ENGINE	OPPOSITE
71C SERIES										
10-13	6.82 (173.23)	2.39 (60.71)	18.42 (467.87)	.31 (7.87)	4.25 (107.95)	5.00 (127.00)	.45 (11.43)	1.58	1.23 (31.24)	1.06 (26.92)
								2.03	1.66 (42.16)	1.49 (37.85)
								2.47	1.95 (49.53)	1.77 (44.96)
								2.93	2.16 (54.86)	1.99 (50.55)
72C SERIES										
10-14	7.76 (197.10)	2.64 (67.06)	19.36 (491.74)	.31 (7.87)	4.25 (107.95)	5.00 (127.00)	.45 (11.43)	1.58	1.23 (31.24)	1.06 (26.92)
								2.03	1.66 (42.16)	1.49 (37.85)
								2.47	1.95 (49.53)	1.77 (44.96)
								2.93	2.16 (54.86)	1.99 (50.55)

GENERAL SPECIFICATIONS

MODEL	MAXIMUM SAE HP INPUT		AVAILABLE RATIOS	OUTPUT ROTATION	DRY WEIGHT
	GASOLINE	DIESEL			
10-13	255 @ 4200 rpm	145 @ 3200 rpm	1.58, 2.03, 2.47, 2.93 to 1.00	OPTIONAL	162 lb. (73.5 kg.)
10-14	380 @ 4200 rpm	185 @ 3200 rpm			175 lb. (79.4 kg.)

NOTE: The above transmission ratings are subject to change without notice and are intended only as a general guide. Specific applications should be referred to Warner Gear for engineering assistance.

INSTALLATION INSTRUCTIONS

An Installation Manual may be acquired from Warner Gear if you have a need for more complete instructions than those given in the following paragraphs.

Before mounting the transmission on the engine, be sure that the arrow located at the top front of the pump points in the direction the unit will be driven by the engine. The pump on CR2 units should not be changed from the original factory setting as shown in the chart on page 00.

An oil cooler must be properly connected to the transmission before the engine is cranked or started. Failure to properly connect the oil cooler results in overpressurization and possibly blowing out of the forward clutch piston. Warranty claims due to this type of failure will not be allowed.

An oil cooler of sufficient size should be used to assure that maximum oil temperature of transmission will not exceed 190° F (88° C). Failure to provide proper cooling may result in damage to the transmission from insufficient oil flow and pressures caused by high temperatures.

The Warner Gear 9 or 12 in. coolers or a cooler of equal capacity will usually give proper cooling. A final test of the completed installation should be made to determine that oil to cooler leaving the transmission does not exceed 190° F (88° C).

The cooler outlet on CR2 units is located just behind the selector valve at rear near top of forward and reverse transmission case. Oil from cooler should be returned to the sump fitting at the lower right side of the forward and reverse transmission case. Red plastic plugs are currently installed in the cooler openings to identify their location.

Water should be fed directly to the cooler. Water inlet temperatures above 110°F (43°C) are permissible only if larger sized coolers are used to maintain the recommended transmission temperature.

Cooler oil lines should have a .41 in. (1.04 cm) or larger inside diameter.

Air can be trapped above the oil in a cooler unless the cooler outfitting is located at the highest point on the cooler. Trapped air reduces cooling capacity, causes foaming, pump cavitation, and loss of oil through the breather.

Horizontal mounting is preferred because it prevents oil from draining from the cooler. Drain back from a cooler which is mounted higher than the transmission sump will give a misleadingly high reading of the sump oil level.

The transmission and engine should be installed so that the maximum angle relative to horizontal does not exceed 15° when the boat is at rest, and should not exceed 20° when operating at the worst bow high condition. A higher angle of installation along with low oil level can permit pump cavitation when operating in rough water where pitching and rolling tends to throw the oil away from the pump inlet.

The remote controls should position transmission selector lever exactly in the forward, neutral and reverse poppet positions. The control lever should always be located over the letter "F" on the case casting when the boat moves in a forward direction. Early failure can be expected when the transmission is operated in reverse when boat moves forward.

The Warranty is cancelled if the shift lever poppet spring and/or ball is permanently removed or if the control lever is changed or repositioned in any manner, or if linkage between remote control and transmission shift lever does not have sufficient travel in both directions.

PROPELLER SHAFT COUPLINGS

Coupling to Shaft Assembly. See form 1044 for specifications of couplings available from Warner Gear.

The propeller shaft coupling must be keyed to the propeller shaft. The key should be a close fit with keyway sides, but should not touch the top of the keyway in the coupling hub. The coupling should be a light press fit on the shaft, and may be warmed in hot oil to permit easier assembly.

NOTE

Propeller shaft coupling distortion may occur when the propeller shaft is a few thousandths under the size required for the particular coupling, thus permitting the coupling to cock and distort as the set screws are tightened. A blank coupling should be machined to fit an undersized shaft. Distorted coupling may be refaced in a lathe.

Two optional methods for fastening the coupling to the propeller shaft are used. Type 1 couplings are pilot drilled through one side only, and the shaft and opposite side of the coupling must be drilled with the coupling in position on the propeller shaft. A 1/4 in. (6.35 mm) stainless steel spring pin must then be driven into the coupling and shaft to retain these parts. The spring pin should be selected so that it will be the same length as the coupling hub diameter and should be approximately flush with the coupling when assembled.

Type 2 couplings are drilled and tapped for set screws which are used to retain these parts. Some propeller shaft couplings are drilled and tapped for set screws, and are also pilot drilled for spring pin installation.

Transmission Coupling to Propeller Shaft Coupling Alignment. Vibration, gear noise, loss of RPM and premature oil seal and bearing failure can be caused by misalignment of the transmission coupling and propeller shaft coupling. The propeller shaft is usually fixed in the boat structure, and alignment is achieved by adjusting the engine mounts or by changing engine mount shims.

Preliminary alignment of the coupling faces should be carefully made prior to installing the engine and transmission hold-down bolts. A final alignment check should be made after the boat has been placed in the water. The fuel tanks should be filled and a normal load should be in position when making the final shaft alignment check.

It is common for a boat to change with age or various loads. An alignment check should be made at the beginning of each boating season.

Check coupling alignment with all bolts removed from the couplings. Hand hold couplings together with the snap fit engaged and check to determine the maximum clearance between couplings. Rotate the propeller shaft and then rotate the transmission coupling through at least one complete turn, stopping at 90° intervals and using a feeler gauge to check the air gap between the two. Figure 3.

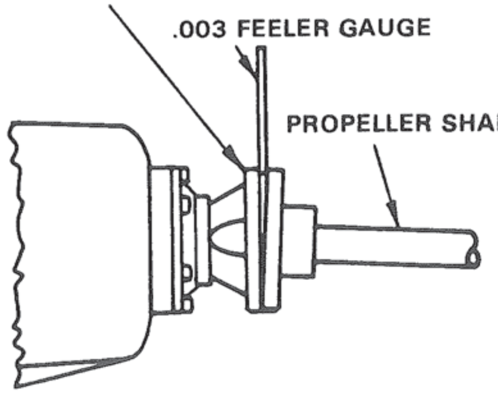


Figure 3. Checking Coupling Alignment.

TRANSMISSION OPERATION

Starting Engine. Place transmission selector in neutral before starting engine. Shifts from any selector position to any other selector position may be made at any time and in any order if the engine speed is below 1000 RPM; however, it is recommended that all shifts be made at the lowest feasible engine speed.

Neutral. Move the shift lever to the center position where the spring loaded ball enters the chamfered hole in the side of the shift lever and properly locates lever in neutral position. With shift lever so positioned, flow of oil to clutches is blocked at the control valve. The clutches are exhausted by a portion of the valve and complete interruption of power transmission is insured.

Forward. Move the shift lever to the extreme forward position where the spring loaded ball enters the chamfered hole in the side of the shift lever and properly locates lever in forward position.

Reverse. Move transmission shift lever to the extreme rearward position where the spring loaded ball enters the chamfered hole in the side of the shift lever and properly locates it in the reverse position.

Free Wheeling. Short periods of free wheeling are permissible. Extended periods of free wheeling at high speeds may cause the transmission to overheat; therefore, it is recommended that transmission sump temperature be monitored and free wheeling discontinued whenever 230°F (111°C) is reached. A temperature alarm kit, for installation in transmission sump, is available from your Velvet Drive dealer. The transmission may be cooled by operating the engine to circulate the transmission oil and cooler water. Free wheeling can be continued after the transmission has been cooled to a safe temperature. The transmission should be in good condition and full of fluid anytime free wheeling is permitted.

A suitable propeller shaft locking device may be found advantageous on installations requiring extended periods of free wheeling at high speeds.

Shifting. Except in an emergency, shift from forward to reverse below high idle engine speeds (approximately 1000 RPM). This will prevent damage or abuse of the marine gear which might necessitate its early repair.

TROUBLESHOOTING CHART

	Remedy	
Complaints & Symptoms	**Transmission in Boat**	**Transmission Removed**
Internal & External Leaks		
1. Oil leaks at pump		1 2 3 8
2. Oil on exterior of transmission	1 4 6 7	2 5 8
3. Oil leaks at rear seal	3*	
4. Water in transmission oil or oil in cooling water	9	
5. Oil leak from breather	9 15 19 43	
Transmission Malfunctions in All Ranges		
1. No oil pressure	10	11 12
2. Low oil pressure	13 14 15 16 18	17
3. High oil temperature	9 15 19 20 21 22 30	17 42
4. Failure of reduction gear		23
Transmission Malfunctions in Forward Range		
1. Low oil pressure	13 14 15 16 18	17
2. Forward clutch engages improperly	37	12 20 24 25 26 27 28
3. Forward clutch drags	37	26 27 28
4. Reduction unit failure		23
Transmission Malfunctions in Reverse Range		
1. Low oil pressure	13 14 15 16 18	17
2. Reverse clutch engages improperly	37	24 26 28 29
3. Reverse clutch drags	37	26 28 29
4. Reverse gear set failure		42
5. Reduction gear set failure		23
Transmission Malfunctions in Neutral		
1. Output shaft drags excessively in forward position	37	26 27 28
2. Output shaft drags excessively in reverse rotation	37	26 28 29 42
Miscellaneous Transmission Problems		
1. Regulator valve buzz	15 16	
2. Gear noise - forward	31	32
3. Gear noise - reverse	31	32 42
4. Pump noise	15	17 32
5. Damper noise or failure		33 34 35 36
6. Shifts hard	7 16 37 38 39	
7. High oil pressures	16 30 40 41	

*If installation allows access, otherwise remove transmission.

KEY TO TROUBLESHOOTING CHART

1. Loose bolts — tighten.
2. Damaged gasket — replace.
3. Damaged oil seal — replace.
4. Oil line fitting loosened — tighten.
5. Case leaks, porosity — replace.
6. Oil filler plug leaks — replace or tighten.
7. Damaged control valve O-ring — replace.
8. Foreign material on mating surfaces — clean.
9. Damaged oil cooler, water and oil mixing — replace.
10. No oil — find leak and fill.
11. Pump improperly located for engine rotation — locate correctly.
12. Sheared drive key — replace.
13. Faulty oil gauge — replace, bleed air from gauge line.
14. Dirty oil screen — clean or replace.
15. Low oil level — add oil to proper level.
16. Regulator valve stuck — polish with crocus cloth to remove burrs and clean.
17. Worn oil pump — replace.
18. Regulator valve spring weight low — replace.
19. High oil level — drain oil to proper level.
20. Low water level in cooling system — fill.
21. Dirty oil cooler — clean or replace.
22. Cooler too small — replace with larger cooler.
23. Inspect reduction unit — repair.
24. Worn or damaged clutch piston oil seals — replace.
25. Worn or damaged clutch sealing rings — replace.
26. Clutch improperly assembled — rebuild.
27. Damaged or broken Belleville springs — replace.
28. Worn or damaged clutch plate(s) — replace.
29. Damaged or broken clutch springs — replace.
30. Cooler lines damaged or too small — replace.
31. Inadequate torque on output shaft nut — tighten.
32. Nicks on gears — remove with stone.
33. Excessive runout between engine housing and crankshaft — align.
34. Wrong damper assembly — replace.
35. Damaged damper assembly — replace.
36. Body fit bolts not used in mounting holes — replace.
37. Control linkage improperly adjusted — adjust.
38. Control lever and poppet ball corroded — clean and lubricate.
39. Control linkage interference — check and adjust.
40. Wrong oil used in transmission — change.
41. Cold oil.
42. Planetary gear failure — replace or repair.
43. Damaged breather — replace.

HYDRAULIC FLUID RECOMMENDATIONS

Use automatic transmission fluid of the type used in passenger cars. SAE No. 30 diesel engine oil may be used if engine speed will not exceed 3000 RPM and oil is cooled with engine jacket water. The use of transmission oil additives is not recommended.

Filling Transmission.

CAUTION

Be sure the transmission is filled and a cooler is properly installed before cranking or starting engine.

The transmission, cooler, and cooler lines must be filled and the complete hydraulic system must be purged of air prior to making the final oil level check. A properly installed cooler will be self-purging. The oil cooler and cooler lines will be filled from the transmission and after a brief period of operation, it will be necessary to add oil to raise oil level to the full mark.

Oil Capacity. Approximately 2-1/2 quarts (2.36 liters) will fill most CR2 units to the oil level mark on dipstick. Many variables have a direct relationship to oil capacity. Additional oil will be required to fill oil cooler and cooler lines. The angle of installation will make a difference in the quantity of oil required to fill the transmission.

Checking Oil Level. The oil level should be maintained at the full mark on the dipstick. Check oil level prior to starting the engine.

Filling and Checking the Hydraulic System. The Velvet Drive hydraulic circuit includes the transmission, oil cooler, lines and any gauge lines connected into the circuit. The complete hydraulic circuit must be filled when filling the transmission and this requires purging the system of air before the oil level check can be made. The air will be purged from the system if the oil level is maintained above the pump suction opening while the engine is running at approximately 1500 RPM. The presence of air bubbles on the dipstick indicates that the system has not been purged of air.

New applications or a problem installation should be checked to insure that the oil does not drain back into the transmission from the cooler and cooler lines. Check the oil level for this drain only, immediately after the engine is shut off and again after the engine has been stopped for more than one hour (overnight is excellent). A noticeable increase in the oil level after this waiting period indicates that the oil is draining from cooler and cooler lines. The external plumbing should be changed to prevent any drain back.

Changing Oil. A seasonal oil change is recommended in pleasure boats. Work boats may require more frequent changes. Change oil anytime the oil becomes contaminated, changes color, or becomes rancid smelling.

Oil Temperature. A maximum sump oil temperature of 190°F (88°C) is recommended. Discontinue operation anytime sump oil temperature exceeds 230° F (110° C).

Operating Pressures.

At 600 engine RPM		
In neutral	117-130 PSI	9.14 kg/cm²
Forward clutch	85-105 PSI	5.98-7.38 kg/cm²
Reverse clutch	88-102 PSI	6.19-7.17 kg/cm²
At 2000 engine RPM		
Forward clutch	95-130 PSI	6.68-9.14 kg/cm²
Reverse clutch	95-130 PSI	6.68-9.14 kg/cm²

TRANSMISSION DISASSEMBLY

1. Loosen coupling nut.

2. Remove bolts which retain reduction housing to forward and reverse transmission.

3. Pull reduction housing and attached parts from forward and reverse transmission. Remove nut, coupling, ring gear, output shaft and bearing cones from reduction housing. Press rear bearing cup from reduction housing and pull front cup from housing only if these parts need to be replaced.

4. Remove nut and reduction drive gear.

5. Remove bearing cone and spacer from output shaft.

6. Remove six (6) cap screws and reduction adapter.

7. Press idler gear shaft if used, from reduction adapter. Remove idler gear and related parts from adapter.

8. Remove four (4) cap screws from pump. Note direction in which the arrow nearer top face of pump is pointed. The pump can only pump oil when the arrow at top face of pump points in direction pump is rotated by the engine.

NOTE

Pump should not be changed from original setting.

9. A plastic rubber mallet may be used to loosen pump as it is removed from transmission.

10. Remove pump drive key from input shaft.

11. Remove the four (4) adapter to case cap screws and pull adapter from transmission. Catch loose reverse clutch parts as adapter is removed.

12. Remove reverse clutch pressure plate, friction and steel plates, dowels and springs from unit.

13. Pull forward clutch and ring gear assembly from transmission.

14. Pull pinion cage and output shaft assembly from transmission.

15. Oil baffle may be removed by pressing down to snap baffle from the two spherical bosses at rear of case.

16. Needle bearing should only be removed when replacing these parts.

17. Disassemble ring gear and forward clutch as follows:

A. Remove the two snap rings from in front of annular bearings.

B. Tap front end of input shaft gently on wooden surface to cause ring gear and attached parts to slide from sun gear shaft.

C. Remove ring gear snap ring. Press clutch cylinder and piston from ring gear.

D. Remove remaining components from ring gear.

TRANSMISSION ASSEMBLY

Forward and Reverse Transmission.

1. Press a needle bearing into bearing bore at rear of case.

2. Press a needle bearing (.30 below front face) into bore of carrier assembly.

3. Position front center portion of baffle above and outer tabs below boss at front of case then lift curved portion at rear to snap the two large holes in baffle over the spherical bosses at rear of case.

4. Assemble a sealing ring into each of the three shaft grooves behind carrier. Lubricate sealing ring and locate ring ends up to insure that ends will be pulled down into groove by weight of ring.

5. Center shaft and sealing rings in bore of case to insure against breaking sealing rings as pinion cage and output shaft are assembled into forward and reverse transmission case.

6. An assembly fixture or suitable blocks positioned under rear face of case should be used to hold parts assembled, in steps 1 through 5, in an upright position while forward and reverse transmission assembly is completed.

Forward Clutch and Ring Gear.

1. Place ring gear on a bench with the external teeth located up. Be sure that all dirt has been cleaned from shoulder and splines of ring gear.

2. Install pressure plate with ground face located up in ring gear. Pressure plate should rest squarely on shoulder at bottom of internal splines.

3. Assemble a friction plate then alternating with steel and friction plates, assemble either seven (7) friction and six (6) steel or five (5) friction and four (4) steel plates depending upon the model being assembled.

4. Assemble the flat side of pressure plate against the top friction plate in ring gear.

5. Assemble the clutch spring snap ring against ends of internal splines. This snap ring does not assemble into a groove.

NOTE

The clutch spring snap ring should be from .090 in. - .093 in. (2.3 - 2.4 mm) thick and have a free diameter approximately 5-19/32 in. (14.21 cm).

6. Assemble clutch spring concave side down into ring gear. Center spring over snap ring.

7. Assemble sealing ring into clutch piston groove and sealing ring into clutch cylinder hub groove. Lubricate and assemble piston into cylinder bore. Assemble clutch spring bearing ring into groove on face of piston.

8. Center the ring gear and parts assembled into it under an arbor press and press clutch piston and cylinder assembly into ring gear. Assemble the snap ring into groove above clutch cylinder.

NOTE

The ring gear snap ring is from .074 in. - .078 in. (1.9 - 2.0 mm) thick and has a free diameter of approximately 5-7/8 in. (14.9 cm).

9. Clutch assemblies having seven (7) friction plates use a selective snap ring which must be selected and installed between the pressure plate and ring gear web. This snap ring is not used in assemblies having only five (5) friction plates. Position clutch and ring gear on a bench with external teeth of ring gear resting on bench. Press down lightly on clutch pack while a feeler gauge is used to determine the clearance between pressure plate and ring gear web. Figure 4. Select a snap ring

to reduce this dimension (clutch pack clearance) to .049 in. - .065 in. (1.0 - 1.7 mm). Two (2) of the thinnest rings may be required.

NOTE

Selective snap rings have a free diameter of approximately 5-11/16 in (14.55 cm). A color code has been used to help identify each ring as to thickness as charted below:

Color	Inch	MM
Green	.050 - .054	1.3 - 1.4
Orange	.074 - .078	1.7 - 1.9
White	.096 - .100	2.4 - 2.5

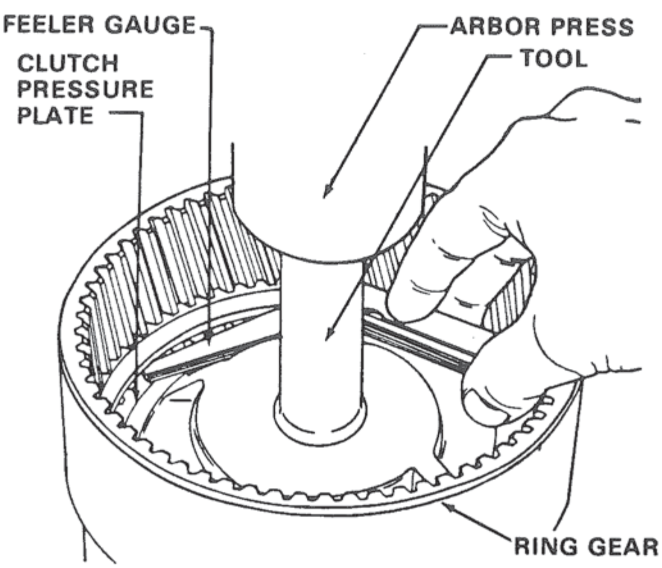


Figure 4. Measuring Gap for Selective Snap Ring.

Hub and Sealing Ring on Drive Gear.

1. Assemble the woodruff key into keyway provided in drive gear.
2. Assemble drive gear through clutch hub aligning keyway and key as parts are pressed together under an arbor press.
3. Assemble a snap ring in drive gear groove in front of hub.
4. Assemble two sealing rings in grooves of drive gear. Rings should be free in the grooves.

Drive Gear to Ring Gear and Clutch Assembly.

1. Align clutch hub teeth with clutch plate teeth as drive gear and hub are assembled into clutch and ring gear assembly; then position these parts under an arbor press with input shaft splines up and rear face of ring gear and sun gear resting on a flat surface and shaft extended down through a hole in the support plate.
2. Press the annular bearing over shaft and into clutch cylinder hub bore.
3. Install a snap ring in drive gear groove in front of bearing.
4. Install a snap ring in clutch cylinder hub in front of bearing.
5. Assemble a thrust washer against rear face of sun gear. Use petrolatum to hold washer in position during assembly.
6. Assemble the two sealing rings in grooves of drive gear shaft. Use petrolatum to hold rings in position. Do not use rings which have been cut or mutilated in any manner.
7. Rotate clutch and drive gear assembly to engage teeth as the assembly is lowered into position in transmission. Use care to prevent sealing ring damage.
8. Assemble the thrust washer on face of clutch cylinder.
9. Assemble twelve (12) pressure plate springs in the holes provided in reverse clutch cavity.
10. Coat three (3) dowel pins with petrolatum and assemble in grooves provided in outer diameter of the reverse clutch cavity.
11. Assemble a reverse clutch friction plate over exposed splines of ring gear.
12. Assemble a steel reverse clutch plate locating the odd shaped lug over the dowel which is nearest to one of the springs. Repeat steps 10 and 11 until either two (2) friction and one (1) steel or three (3) friction and two (2) steel plates have been assembled depending upon the model being assembled.
13. Locate the twelve (12) holes down and align the cast "V" slot of the reverse clutch pressure plate with the large oil hole at the top of front face of transmission case. Springs must engage holes in pressure plate which will be level when properly assembled.

Reverse Clutch Piston into Adapter.

1. Press the needle bearing into adapter.
2. Assemble a clutch sealing ring in adapter groove.
3. Assemble a clutch seal ring in reverse clutch piston groove.

4. Lubricate sealing rings and assemble piston into adapter. A smooth screwdriver may be used to help start sealing ring into cylinder bore.

5. Assemble gasket to adapter face and lower gasket and adapter straight down over input shaft and rest on front face of case. Twisting the adapter will unseat pressure plate from springs and should be avoided.

6. Assemble the four (4) cap screws and tighten evenly to the recommended torque. Should the adapter bottom against dowels, it would be necessary to loosen the cap screws and shift adapter into alignment with dowels.

7. Assemble the woodruff key into keyway in input shaft.

8. Assemble pump drive gear over input shaft and drive key.

9. Assemble pump gasket into pump bore on front face of adapter.

10. Coat pump seal outside diameter with a suitable gasket sealer and press in until flush with front face of pump housing.

11. Assemble driven gear into pump housing.

12. Assemble pump housing and driven gear to adapter. The arrow located nearer top of front face of pump should point in the direction indicated in the chart on page 00 for the model being assembled. The pump on CR2 units should not be indexed for opposite rotation. Models are available for both engine rotations.

13. Assemble four (4) cap screws and tighten evenly to the recommended torque.

Reduction Portion of Transmission.

1. Press the front bearing cone over forward and reverse transmission output shaft.

2. Assemble a gasket to rear face of case.

3. Press bearing cups into each bore of reduction unit adapter.

4. Assemble adapter to rear face of case. Torque the six (6) 7/16-14 hex socket head cap screws to the recommended torque.

5. Assemble a bearing spacer, bearing cone, gear and nut onto output shaft. The proper spacer must be determined by assembling these parts, torquing nut to the recommended 240 ft. lbs. (33.1 kg/m). Then, checking end play of shaft. Compressed air (approximately 90 p.s.i. [6.3 kg/cm^2]) may be fed into the line pressure tap and unit shifted into reverse to help hold output shaft while tightening output shaft nut. The output shaft should have from .0000 - .0018 in. (.0 - .5 mm) end play. With the correct spacer installed, no more than 45 in. lbs. (51.7 kg/cm) should be required to rotate the output shaft.

Idler Gear with Tapered Bearings (1.58 and 2.03:1 Units).

1. Press a bearing cup into each side of idler gear. Assemble a bearing cone in each bearing cup. Place gear and bearing components in approximate running position. Use a feeler gauge to determine clearance between end of bearing cones and adapter. Select a spacer which is from .001 in. - .002 in. (.02 - .05 mm) thicker than the measured clearance to give a preload to tapered bearings.

2. Place suitable blocks against rear gasket face of adapter and lay a bar with a 5/16 (7.9 m) drilled hole through it to bridge over the adapter. Locate blocks and bar so that a 1/4-20 bolt may be inserted through the 5/16 in hole and screwed into the 1/4-20 hole in adapter near idler shaft location. Tightening the bolt against the bar will lift the adapter boss to give clearance needed to assemble spacer and gear with bearings in a position not quite in mesh with reduction drive gear.

3. Loosen the 1/4-20 cap screw to permit adapter to close down to preload tapered bearings. Try turning the gear which should not spin but should not have a heavy drag. Correct bearing drag if necessary by changing the selective spacer.

4. Align gear and bearing components to permit assembling idler shaft. Shaft should be a drive fit for the last 1/4 in (.64 cm) of movement into adapter.

Idler Gear with Bearing Rollers (2.47 and 2.93:1 Units).

1. Assemble two rows of 17 or 26 rollers with a pinion bearing spacer between rows and at each end of rollers. Petrolatum should be used to hold rollers and spacers in position.

2. Assemble the gear with rollers and spacers into position with a tabbed thrust washer at each end into position in adapter. Thrust washer tabs should be located in adapter recess.

3. Assemble idler shaft through adapter boss and gear being careful not to damage or lose rollers. Locate the drill point recess on end of shaft a 3 o'clock position when viewed behind unit. Shaft

must be driven the last 1/4 in. (.64 cm) into adapter press fit.

Reduction Housing, Bearing and Output Shaft.

1. Press two bearing cups to bottom of bores in reduction housing.

2. Press the larger bearing cone over output shaft and against rear face of ring gear. Place a selective spacer over output shaft and locate against shoulder.

3. Assemble shaft and bearing into reduction housing. Assemble rear bearing, coupling and nut to output shaft. The oil seal should not be installed at this time. Tighten coupling nut to 240 ft. lbs. (33.1 kg/m). The correct selective spacer will cause bearings to be preloaded from .0002 - .002 in. (.0 - .1 mm) and a torque wrench used to rotate output shaft should read between 1.5 - 39.0 in. lbs. (1.72 - 44.8 kg/cm). Replace spacer with a thinner one if torque is less or with a thicker one if torque is greater than specified.

4. Remove nut and coupling after correct spacer has been selected and press an oil seal flush with rear face of reduction housing.

5. Replace coupling and nut. Apply Permatex or similar gasket cement to rear face of coupling under nut to prevent leakage through splines of shaft coupling.

6. Assemble a gasket and reduction housing with attached parts to rear face of forward and reverse transmission.

7. Assemble six (6) 7/16-14 x 1-3/8 hex head bolts to retain reduction housing to forward and reverse transmission.

BOLT TORQUE CHART FOR CR2 UNITS

Part Number	Part Description	Ft. Lbs.	kg/m
0000444687	1/8-27 Dryseal Plug	7- 12	.97- 1.66
0000444866	3/8-18 Dryseal Plug	16- 27	2.35- 3.73
4885B	Bushing	25- 35	3.46- 4.84
4911	3/8-16 x 1-1/4 Cap Screw	27- 37	3.73- 5.12
0000444858	1/4 Pipe Plug	12- 20	1.66- 2.77
10-00-183-021	5/16-18 x 1-3/8 Hex Head Bolt	17- 22	2.35- 3.05
0000115729	5/16-24 Hex Nut	8- 11	.41- 1.52
0000179793	1/4-20 x 5/8 Hex Head Bolt	8- 11	.41- 1.51
10-00-183-023	7/16-14 Hex Socket Head Cap Screw	73- 83	10.10-11.48
4775Q	1-20 Thin Hex Nut	220-260	29.43-35.96
0000138887	5/8-18 x 5/8 Socket Head Set Screw	10- 20	1.38- 2.77
0000444581	3/8-18 Square Head Pipe Plug	17- 27	2.35- 3.73
0000179861	7/16-14 x 1-38/ Hex Head Bolt	50- 60	6.92- 8.30

REDUCTION GEAR ASSEMBLY 1.91:1 RATIO

GENERAL

The 1.91 to 1 reduction gear box operates in conjunction with any of the following models: Model 70, 70R, 70C, 70CR, 71, 71R, 71C, 71CR, 72, 72R, 72C and 72CR. It consists of a planetary gear set which reduces the input revolutions by a fixed 1.91 to 1 ratio.

CAUTION

Do not use older oil strainer assembly, Figure 2, with closed end and wire ring in a reduction transmission with new oil circulation system. Figure 1. This would block the flow of the cooler return oil.

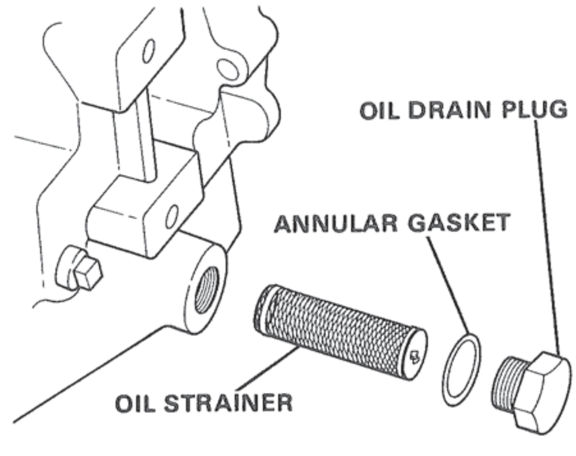


Figure 2. Older Oil Strainer System.

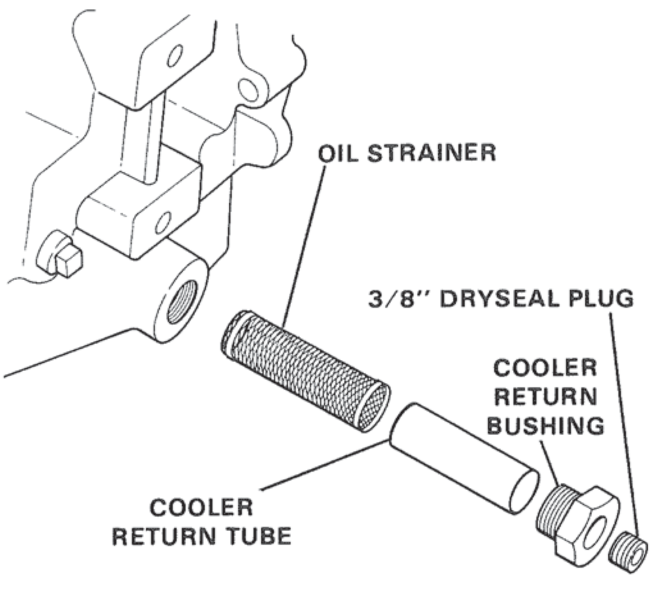


Figure 1. Newer Oil Strainer System.

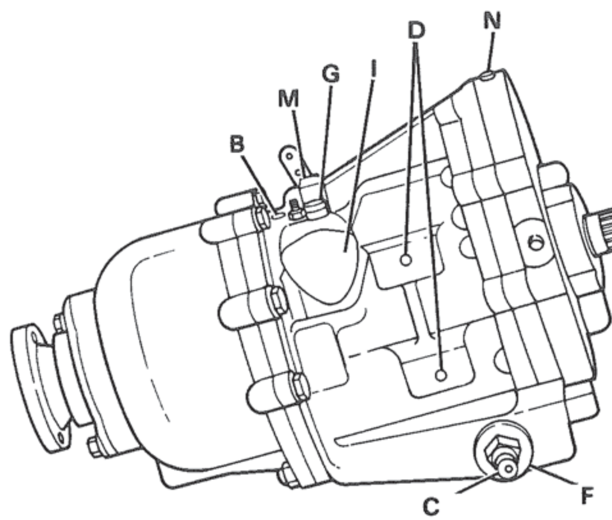


Figure 3. Transmission, Right Side View.

"A" MODEL	HAND OF ROTATION	"A" MODEL	HAND OF ROTATION	"B" RATIO	"C" COLOR	WEIGHT EMPTY
*AS17-72C	Counterclockwise	*AS17-72CR	Clockwise	1.91:1	Green	154
AS7-72	Counterclockwise	AS7-72R	Clockwise	1.91:1	Green	154
*AS7-71C	Counterclockwise	*AS7-71CR	Clockwise	1.91:1	Red	144
AS7-71	Counterclockwise	AS7-71R	Clockwise	1.91:1	Red	144
*AS7-70C	Counterclockwise	*AS7-70CR	Clockwise	1.91:1	Blue	143
AS7-70	Counterclockwise	AS7-70R	Clockwise	1.91:1	Blue	143

*Transmission Assemblies Presently in Production.

The hand of rotation referred to above is when viewed from stern of boat looking forward. The propeller rotation in forward drive for the above transmission is opposite to engine rotation.

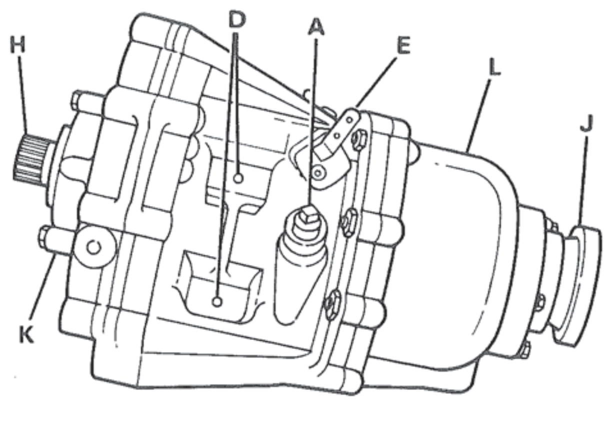


Figure 4. Transmission, Left Side View.

The following list identifies important features of transmissions in Figures 3 and 4.

A. Oil filler cap

B. Oil outlet opening to cooler

C. Oil inlet opening from cooler

D. Mounting pads and mounting bolt holes

E. Shift lever

F. Oil drain plug

G. Breather

H. Drive gear

I. Valve cover

J. Coupling

K. Oil pump

L. Reduction gear box

M. Main line pressure tap

N. Reverse clutch pressure tap

The direction of rotation of the splined output shaft of the reduction gear box is opposite to engine rotation, but is coaxial with the input shaft on the main unit. Lubrication pressure is supplied by the pump in the main transmission.

LUBRICATION RECOMMENDATIONS

THE PROPERTIES OF THE OIL USED IN THE TRANSMISSION ARE EXTREMELY IMPORTANT TO THE PROPER FUNCTION OF THE HYDRAULIC SYSTEM. THEREFORE, IT IS EXTREMELY IMPORTANT THAT THE RECOMMENDED OIL, AUTOMATIC TRANSMISSION FLUID (ATF), TYPE "A", SUFFIX "A" BE USED.

For other important information pertaining to filling of the transmission with oil, refer to section "Lubrication Recommendations" of the appropriate 71C or 72C direct drive manuals.

Transmission Model	Transmission Oil Capacity (Qts.) Level	15 Inclined
AS7-70C or CR	2.7	2.5
AS7-71C or CR	2.7	2.5
AS17-72C or CR	2.8	2.7

NOTE

Oil capacity does not include capacity needed for transmission cooler and oil lines, which may in many cases require an amount greater than in the above table.

Installation Precautions and Operation. It is recommended that all installations using a reduction gear have a suitable locking device or brake to prevent rotation of the propeller shaft when the boat is not under direct propulsion. If the marine gear is not in operation and the forward motion of the boat causes the propeller shaft to rotate, lubricating oil will not be circulated through the gear because the oil pump is not in operation. Overheating and damage to the marine gear unit may result unless rotation of the propeller shaft is prevented. Except in an emergency, shift from forward to reverse drive through neutral at engine speeds below 1000 rpm to prevent damage to the engine or marine gear.

For other important information refer to sections "Installation Precautions" and "Transmission Operation" of the appropriate 71C or 72C direct drive manuals.

DISASSEMBLY

Reduction Housing from Forward and Reverse Transmission.

1. Place transmission right side up on a clean bench and loosen the main shaft nut.

2. Place an inch thick block under the rear of the forward and reverse transmission just forward of reduction unit adapter so that reduction unit will clear bench.

3. Remove the two 7/16 bolts and lockwashers which fasten the reduction housing and the reduction adapter to the forward and reverse transmission case, and the 3/8 bolts, which fasten the reduction adapter to the reduction housing. Slide the reduction housing main shaft, and ring gear from the forward and reverse transmission.

Sun Gear, Pinion Cage Assembly and Lube Oil Strainer.

1. Remove snap ring, which retains sun gear to output shaft. Figure 5.

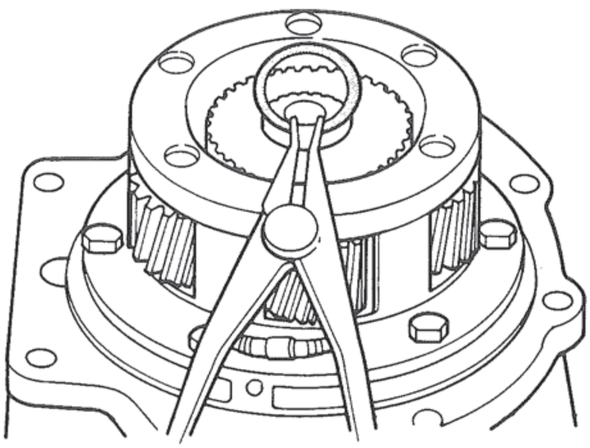


Figure 5. Removing Snap Ring.

2. Remove the six (6) 5/16 - 18 x 3/4 lock bolts and the 5/16 lockwashers which retain pinion cage assembly to reduction unit adapter. Figure 6.

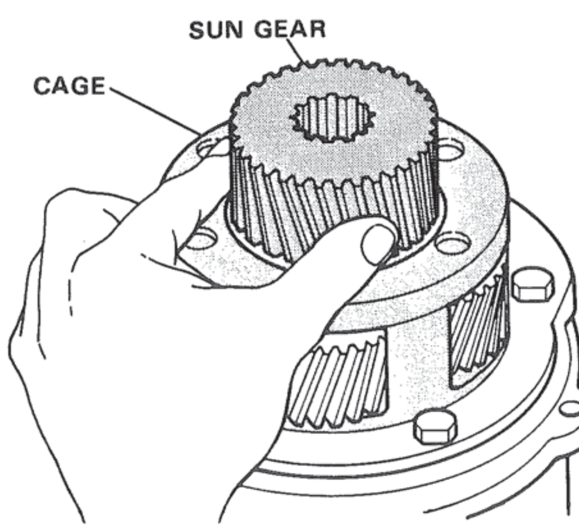


Figure 6. Removing Sun Gear.

3. Tap lightly on pinion cage while exerting a steady pull on the pinion cage assembly. When the pinion cage becomes free, the sun gear will also slide off the output shaft.

4. Lift the lube oil strainer from the reduction unit adapter. Figure 7.

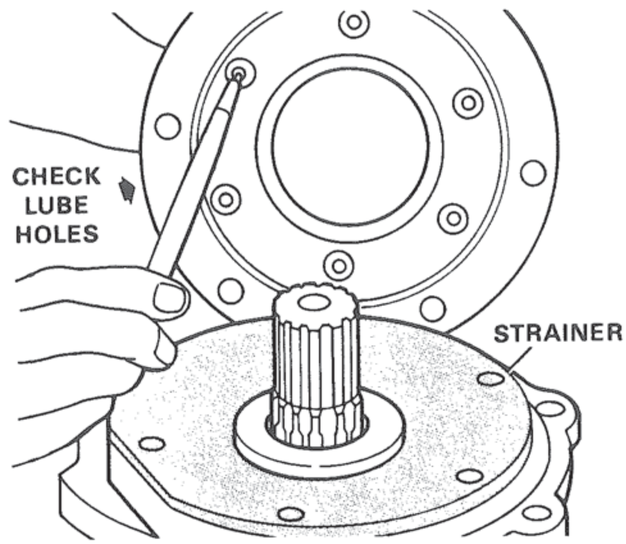


Figure 7. Removing Strainer.

5. Remove the six (6) 7/16 - 14 x 1 lock bolts and the six (6) 7/16 lockwashers. Figure 8.

6. Tap gently on the exposed edges of reduction unit adapter while exerting a pull until adapter is free of snap fit on bearing O.D.

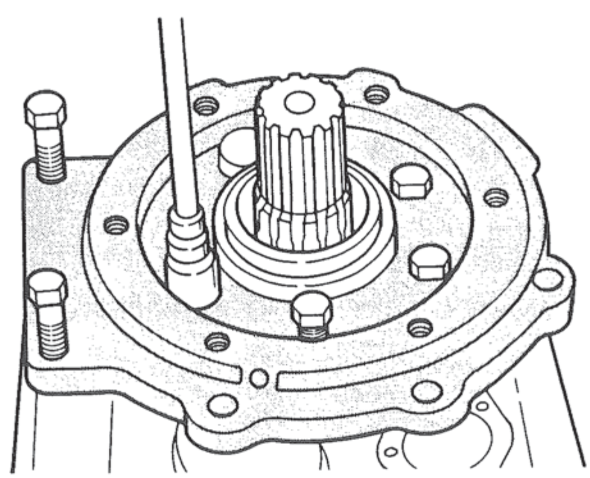


Figure 8. Removing Reduction Unit Adapter.

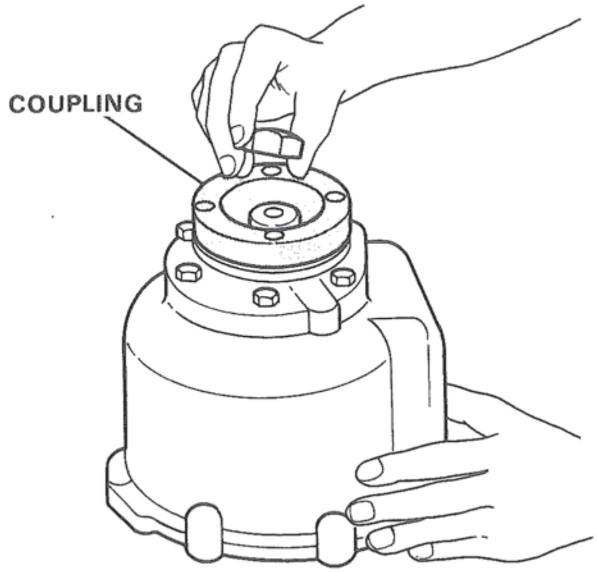


Figure 9. Removing Coupling and Nut.

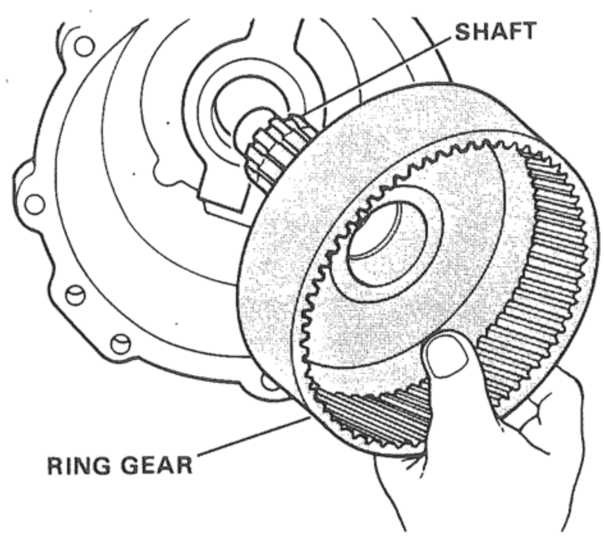


Figure 10. Removing Ring Gear and Main Shaft.

Main Shaft, Coupling, and Bearing.

7. Remove main shaft nut and coupling as shown in Figure 9.

8. Remove main shaft and ring gear assembly from reduction housing. Figure 10.

9. Remove six (6) hex head bolts and lockwashers, then remove bearing retainer. Figure 11.

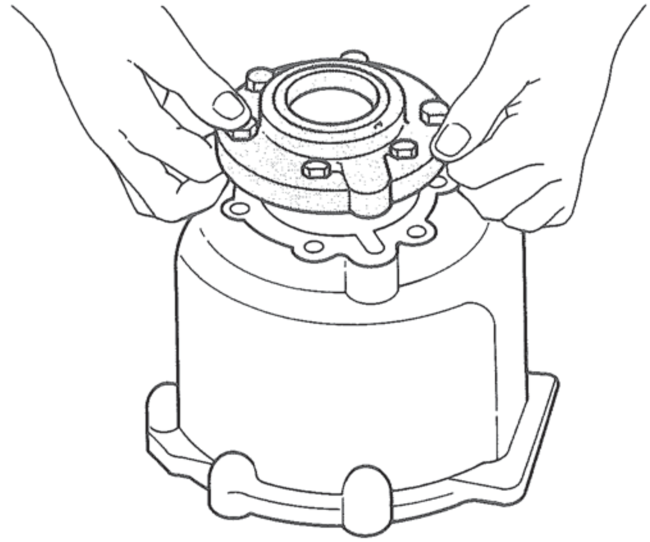


Figure 11. Removing Bearing Retainer.

10. Remove the rear tapered roller bearing cone from outer race.

11. Place the reduction housing, rear face down, on a clean flat surface in an arbor press. Place a suitable tool against the forward face of the forward tapered roller bearing cone and press remaining parts of the bearing out through the rear of the housing.

Forward and Reverse Transmission.

12. If necessary to disassemble forward and reverse section of transmission, remove the snap ring from output shaft assembly behind bearing. Figure 12.

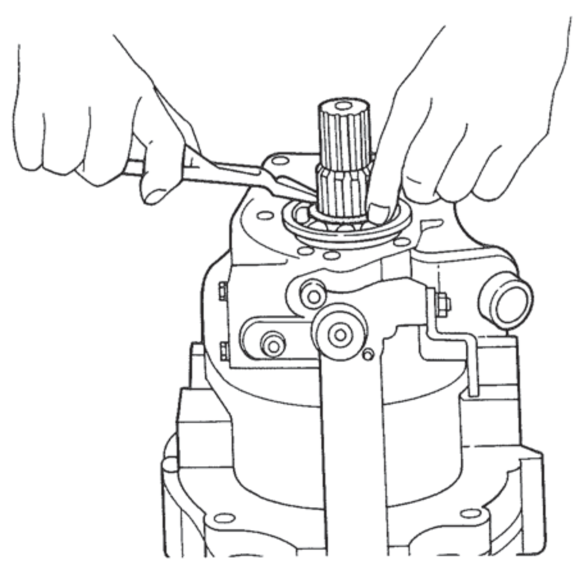


Figure 12. Removing Snap Ring.

13. Follow disassembly procedure given in Service Manual "Velvet Drive" Hydraulic Transmission either Model 70C and 71C, or 72C as required for disassembly of forward and reverse transmission.

INSPECTION AND GENERAL INSTRUCTIONS

1. Cleanliness is absolutely necessary during assembly to insure proper functioning of transmission. Transmission case passages should always have plugs removed to allow for thorough cleaning. When available, use compressed air to dry parts before they are assembled. Do not wipe parts with rags to clean or dry them as lint from the cloth may cause erratic valve action.

2. Inspect all parts for damage or wear. Replace defective parts.

3. All gaskets, oil seals and rubber sealing rings should be replaced except in relatively new units. Judgment should then be exercised as to the need for replacing these parts.

4. Oil seals and bearings are best installed by using an arbor press, suitable fixtures, and tools to properly align parts being assembled. Hammering seals and bearings into position can severely damage parts.

5. Automatic Transmission Fluid, type "A", suffix "A" should be used to lubricate parts as they are assembled. Petroleum jelly may be used on gaskets or other parts that must be held in position during assembly. All parts will assemble more freely if lubricated.

6. Tighten all bolts and screws evenly to the recommended torque.

7. Reduction pinion cage service instructions are covered under Planetary Service Kits in this manual.

ASSEMBLY

Pinion Cage and Output Shaft Assembly.

1. Mount the pinion cage and output shaft assembly and the same clutch and planetary assembly fixture as would be used for a direct drive transmission in an arbor press.

NOTE

Pinion cage and output shaft assemblies (71-1A2C) have been supplied with three oil grooves and without oil grooves. Figure 13. The groove shafts may be used in transmission cases having bronze bushings and in transmission cases without bronze bushings. The ungrooved shafts may be used only in transmission cases which have bushings installed.

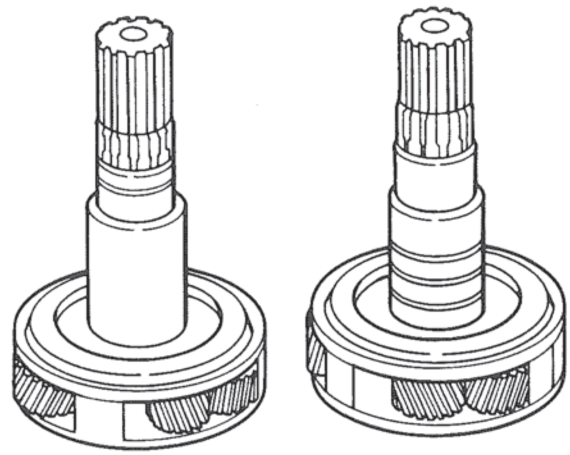


Figure 13. Grooved, Ungrooved Pinion Cage and Output Shafts.

2. Place the transmission case over the pinion cage and output shaft assembly so transmission case rests squarely on arbor press table which is supporting assembly tool. Figure 14.

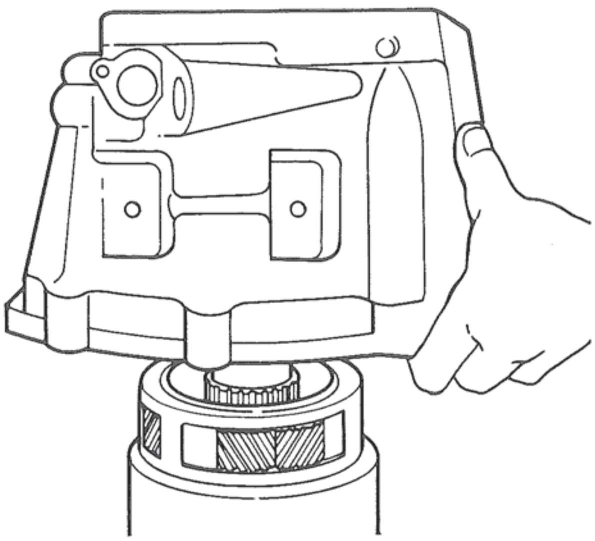


Figure 14. Assembling Case Over Output Shaft.

3. Inspect the bearing bore for possible dirt or burrs.

4. Inspect the rear bearing for scored or damaged ball and races and for loose or cracked ball retainer. Replace the bearing with a new part if damage is detected.

5. Inspect the bearing for presence of dirt. If dirt is present, wash bearing until clean and lubricate with automatic transmission fluid, type "A", suffix "A", before assembly.

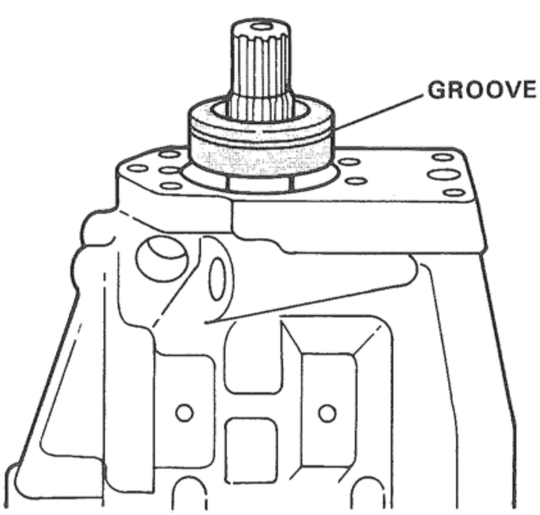


Figure 15. Output Shaft Bearing Properly Positioned for Assembly.

6. With the groove on the outside diameter of the bearing located toward the rear of the transmission, place the bearing over the projecting output shaft and squarely in the bearing bore. Figure 15.

7. Using an assembly tool designed to press evenly on the bearing outer and inner races, press bearing down until seated against shaft or case shoulder. Figure 16.

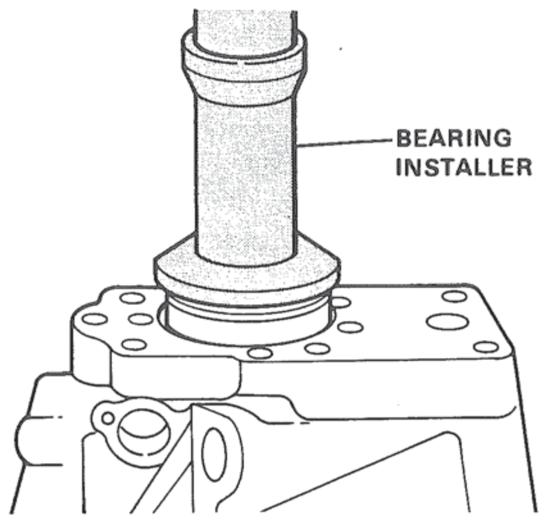


Figure 16. Installing Bearing.

8. Install the snap ring firmly into the exposed groove on output shaft. Figure 17.

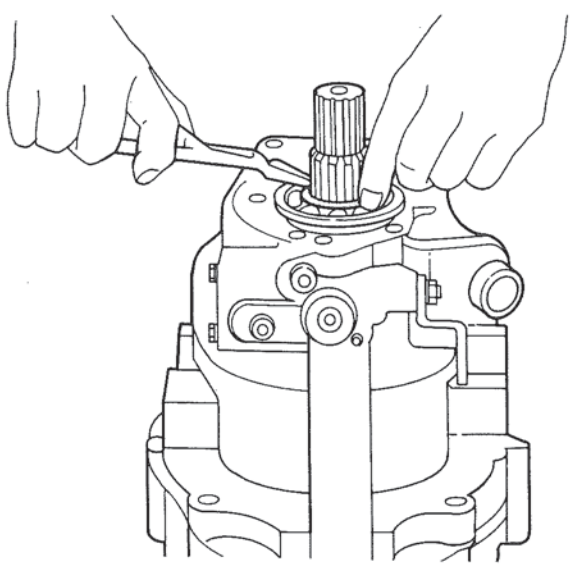


Figure 17. Installing Snap Ring onto Output Shaft.

9. Complete the forward and reverse transmission assembly by following instructions for Model 70C and 71C, or 72C "Velvet Drive" Hydraulic Transmission.

Reduction Unit Adapter.

1. Assemble the reduction unit adapter gasket, and align gasket holes with matching case holes. Figure 18.

CAUTION

Check carefully for presence of lubrication hole pointed out in Figure 19. This passage and the matching hole below the gasket in transmission case should be free from dirt or other obstructions.

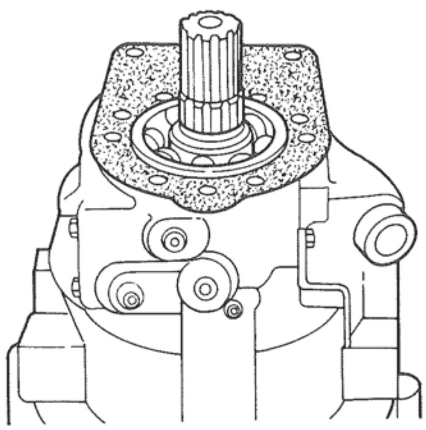


Figure 18. Assembling Gasket, Checking Oil Passage.

2. Check for obstructions and align oil hole with oil hole in gasket as the reduction unit adapter is placed squarely over the outside diameter of piloting bearing. Figure 20. Insure alignment of the bolt holes by assembling in place two (2) 7/16 - 14 x 1-3/4 hex head bolts. Install and tighten evenly to the specified torque the six (6) 7/16 - 14 x 1 lock bolts and lockwashers. Remove the two (2) 7/16 - 14 x 1-3/4 hex head bolts. Figure 20.

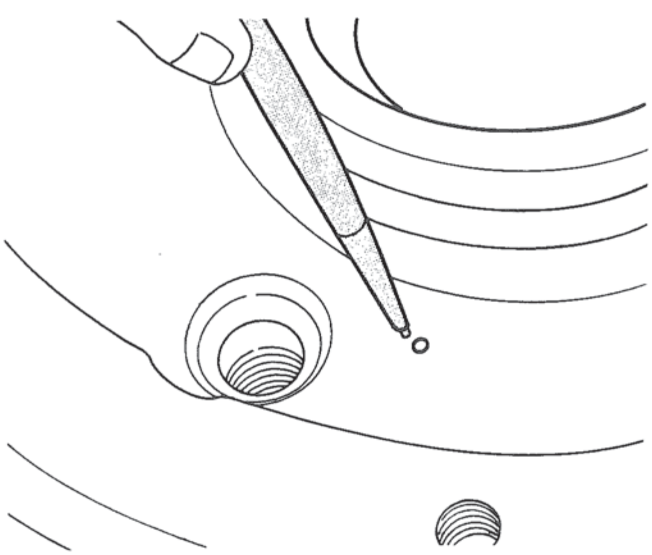


Figure 19. Inspecting Oil Hole in Adapter.

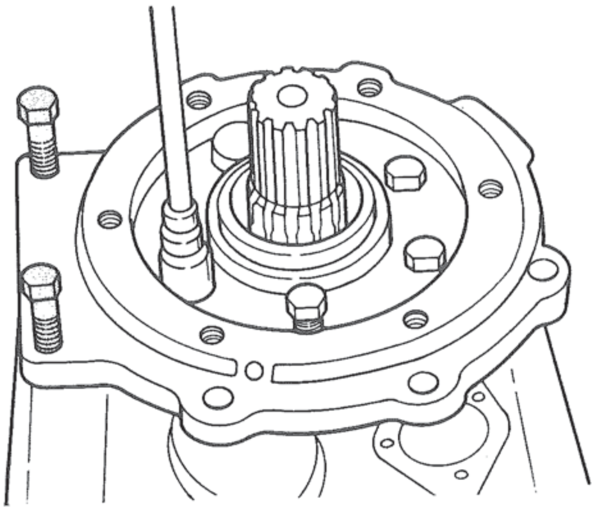


Figure 20. Installing Reduction Unit Adapter.

NOTE

On earlier models, which used the fill tube in the transmission case, it is necessary to install the 3/8 - 16 x 1-1/8 hex head adapter bolt located nearest to fill tube before the adapter is assembled. The bolt will not assemble after adapter is bolted into place.

Pinion Cage.

1. Inspect the lube oil strainer carefully. Remove all dirt or other contamination and replace screen if holes are detected. Assemble in place and align holes. Figure 21.

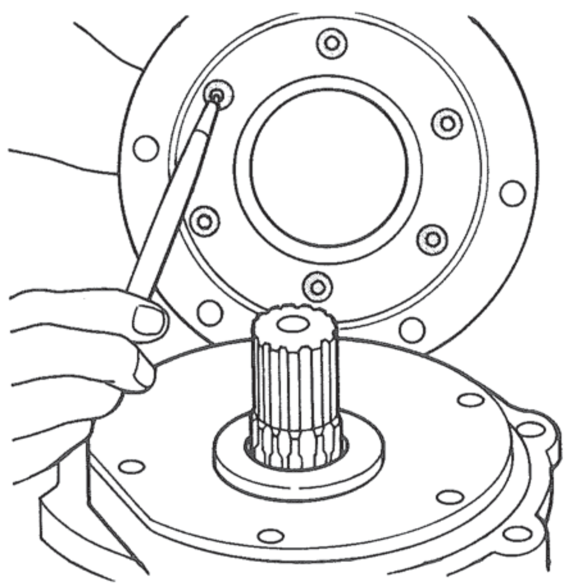


Figure 21. Inspecting and Assembling Pinion Cage Assembly.

2. The pinion cage assembly should be carefully inspected for the following before assembly: Figure 25.

A. Retaining ring should be firmly in place.

B. The front end of each pinion pin contains a pressure lubrication oil passage. Figure 21. These holes should be open and free from contamination.

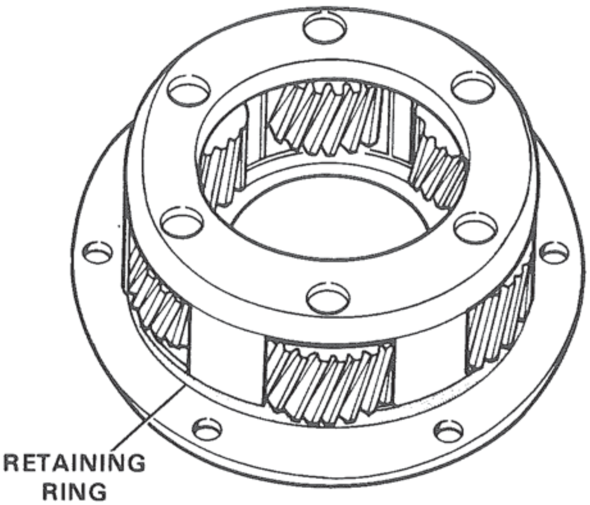


Figure 22. Assembling Pinion Cage.

3. To assemble the pinion cage assembly on the reduction unit adapter, proceed as follows:

A. Check pilot diameters shown in Figure 21 and remove all burrs.

B. Place the pinion cage assembly squarely over the projecting pilot diameter of the reduction unit adapter.

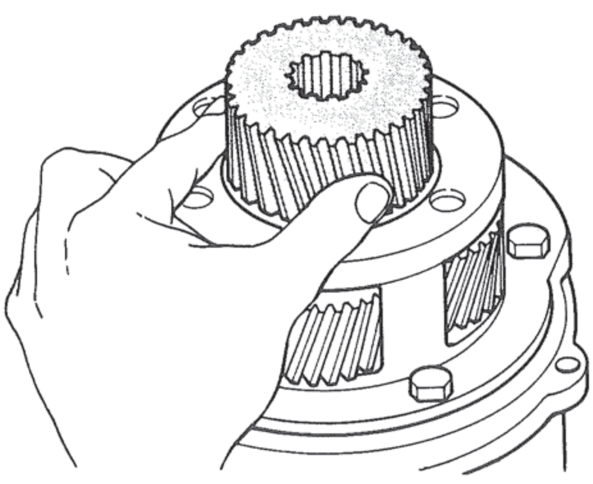


Figure 23. Installing Sun Gear.

C. Align the bolt holes in the adapter, strainer, and the pinion cage assembly, and install finger tight the six (6) 5/16 - 18 x 3/4 lock bolts and lockwashers. Figure 22.

D. Pull the pinion cage assembly squarely and evenly into contact with the oil strainer by tightening the six (6) lock bolts to specified torque.

4. Assemble sun gear on output shaft until contact is made with the shoulder on output shaft and the snap ring groove is fully exposed.

5. Install snap ring on output shaft in the groove provided. Figure 24. Tap snap ring after assembly with suitable tool to insure it is fully seated in groove.

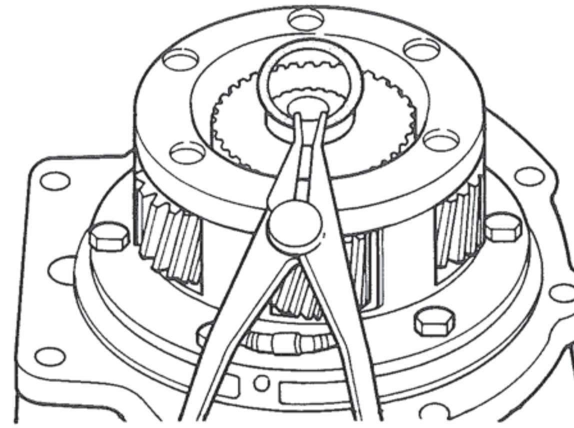


Figure 24. Installing Snap Ring.

Reduction Housing Bearing.

1. Place the reduction housing on an arbor press resting the front face on a clean flat surface. The position of the bearing parts are shown in Figure 25.

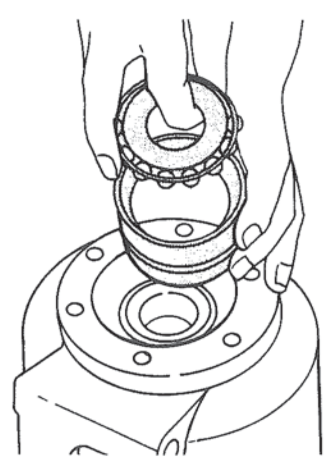


Figure 25. Installing Reduction Housing Bearing.

NOTE

Bearings are received in matched sets and match marks must check. One bearing cone will have a number with an "A" suffix, the other will have the same number without the "A" suffix. The outer race will have the same number with the suffix "A" on one end and no number on the other end. The parts with the "A" suffix should be placed together and the end of the outer race with no number should be placed with the bearing cone without the "A" suffix. Figure 26.

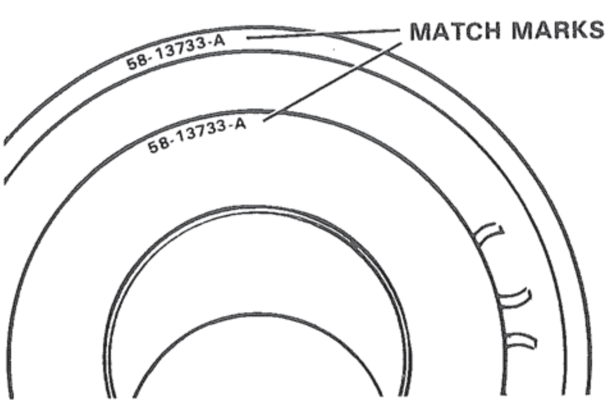


Figure 26. Inspecting Bearing Match Marks.

2. Install the first row of the tapered bearing so that the outer ring rests against the shoulder in the reduction housing.

3. Lubricate the outer diameter of outer race with automatic transmission fluid and press it into the reduction housing using a suitable tool until the outer race is seated firmly against the shoulder in the reduction housing.

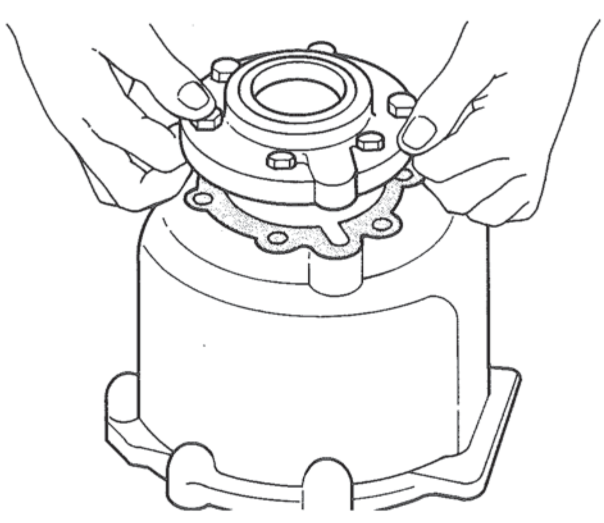


Figure 27. Installing Bearing Retainer and Gasket.

4. Install the rear set of tapered rollers and check again for agreement of match marks.

Bearing Retainer and Gasket.

1. Place the bearing retainer gasket on the reduction housing, aligning the slot in the gasket with the oil hole in the housing. Figure 27.

2. Inspect the rubber lip of oil seal for cuts, cracks or other damage that could cause leakage, and replace if necessary. Assemble the bearing retainer on the reduction housing, aligning the oil passages.

3. Install the six (6) 7/16 - 14 x 1-1/4 hex head bolts and six (6) 7/16 lockwashers and tighten to specified torque.

Ring Gear.

1. Install reduction unit main shaft in ring gear. Figure 28. Assembly is complete when the snap ring groove is fully exposed.

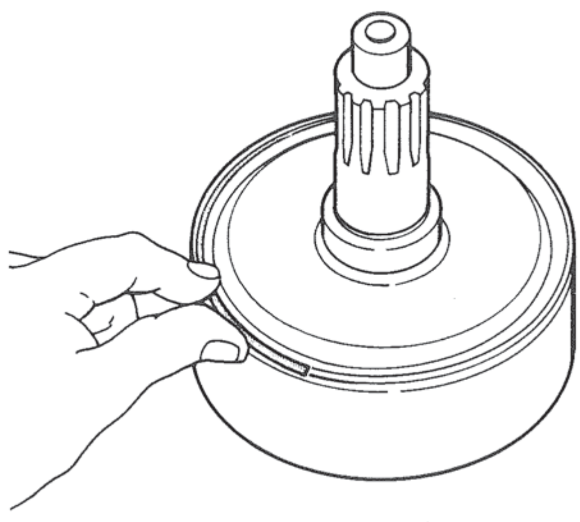


Figure 28. Installing Ring Gear Snap Ring.

2. Install ring gear snap ring in exposed snap ring groove. Figure 28. Tap ring with suitable tool to seat in groove.

Main Shaft, Coupling and Nut.

1. Place reduction housing assembly in position shown in Figure 29. Lubricate that portion of the reduction unit main shaft to be assembled into the bearing, and then install the ring gear and main shaft assembly into the bearing. The main shaft is fully assembled when the shoulder on the shaft contacts front face of bearing.

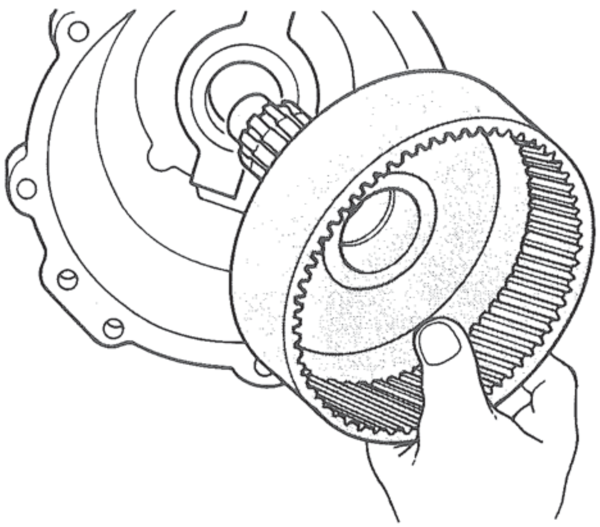


Figure 29. Installing Ring Gear and Main Shaft.

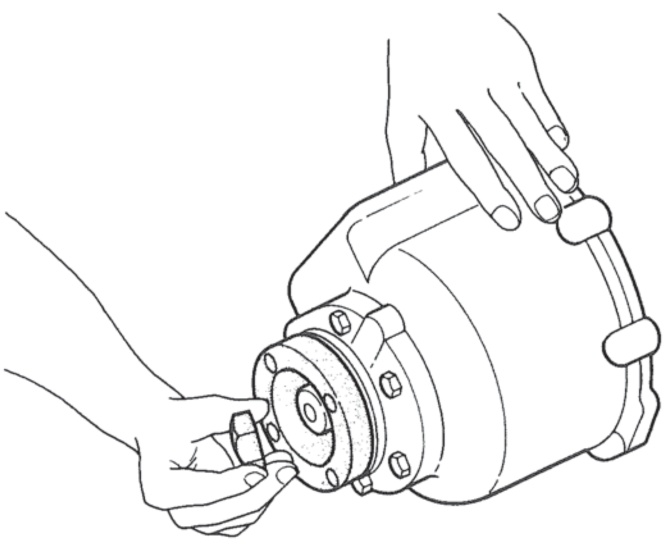


Figure 30. Installing Coupling and Nut.

2. Inspect the coupling sealing diameter to make sure there are no burrs or sharp edges which might damage the seal or prevent proper sealing. Replace if damaged. Lubricate the sealing diameter and the internal splines with automatic transmission fluid. Hold the ring gear and main shaft assembly in place. Align the splines of the coupling to those of the main shaft and assemble coupling until contact with the bearing inner race is made.

3. Continue to hold ring gear and main shaft assembly in place. Assemble the main shaft nut on the main shaft and tighten to specified torque. Figure 30.

Reduction Housing, Ring Gear and Main Shaft.

1. Support the ring gear and main shaft assembly on their front face on a clean flat surface or block. Install the reduction housing adapter gasket-rear on the adapter. Face of reduction housing adapter may be coated with petroleum jelly to retain it in place.

2. Place reduction housing assembly over the ring gear and main shaft assembly. Slowly rotate the coupling until the reduction ring gear mates with the reduction pinions then lower the assembly squarely until pilot diameter on the pinion cage assembly enters the pilot bore in the reduction housing. Align the bolt holes in the completed assembly.

3. Install the two (2) 7/16 - 14 x 1-3/4 hex head bolts with 7/16 lockwashers, and the six (6) 3/8 - 16 x 1-1/8 hex head bolts with 3/8 lockwashers. Tighten bolts to specified torque.

NOTE

Special service kits are available to the original equipment manufacturer for distribution to their various dealers. These kits offer convenience in repairing the various 70, 71 and 72 forward and reverse gear transmissions for which our standard marine warrant has expired. This section covers only the special service kits for repair of the fixed reduction portion of the 1.91 ratio forward and reverse gear transmission. For special service kit information pertaining to the forward and reverse section of the 1.91 reduction tramsmission refer to the appropriate 70C and 71C or 72C direct drive manual. Only those dealers who are well qualified in the repair of the marine transmission should be permitted to service planetary gear sets.

PLANETARY SERVICE KITS

These repair kits make possible replacement of individual pinions and related parts of the planetary gear sets and eliminate necessity of replacing the entire planetary assembly.

The parts shown in kit number A4867SS show the parts required to replace only one pinion in the 1.91 reduction planetary assembly. Figure 31. Separate kits must be ordered for each pinion which is to be replaced.

NOTE

In disassembling the individual gear sets the pinion shaft pin retaining the pinion pin should be removed intact after the removal of the oil collector ring. The pinion shaft pin should not

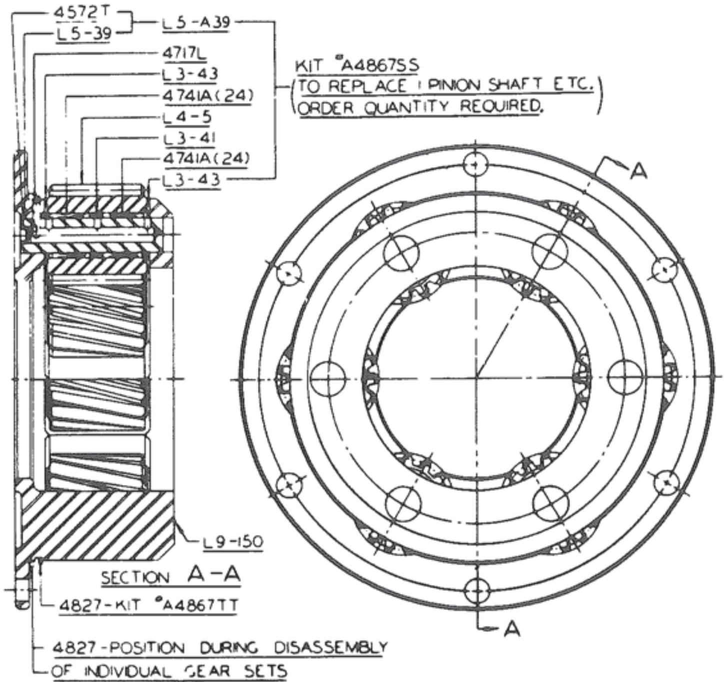


Figure 31. Reduction Pinion Cage Service Instruction.

be removed by pounding on the end of the pinion pin to break the retaining pin, as this distorts the immediate area of the pinion carrier and will produce a damaged thrust surface and improper pinion end clearance when the planetary is reassembled.

Reduction Planetary Retaining Ring Service Kit. The 4827 retaining ring in kit (A4867TT) retains the 4717L pin in the pinion and cage assembly (L9-A150). To remove pin 4717L, spread snap ring 4827 over diameter adjacent to rear face of flange.

CAUTION

Do not spread snap ring 4827 over the planetary pinions.

NOTE

Where needed, assembly instruction sheets are included in the service kits.

TORQUE SPECIFICATIONS

Part Number	Description	Application	Torque Lbs.-Ft.
179840	3/8-16 x 1-1/8 Hex Head Bolt	Reduction Unit Adapter to Reduction Housing	27-32 (3.72-4.41 kg/m)
179860	7/16-14 x 1-1/4 Hex Head Bolt	Bearing Retainer to Reduction Housing	42-50 (5.79-6.90 kg/m)
179864	7/16-14 x 1-3/4 Hex Head Bolt	Reduction Housing and Adapter to Case	42-50 (5.79-6.90 kg/m)
4853D	7/16-14 x 1 Hex Head Bolt, Locking	Reduction Unit Adapter to Case	42-50 (5.79-6.90 kg/m)
4853B	5/16-18 x 3/4 Hex Head Bolt, Locking	Pinion Cage Assembly to Reduction Adapter	17-22 (2.34-3.03 kg/m)
4775L	1-20 Nut	Output Shaft Nut	100-200 (13.79-27.59 kg/m)

REDUCTION GEAR ASSEMBLY 2.91:1 RATIO

GENERAL

This subsection covers the variations of the 2.91:1 ratio Reduction Gear Assembly.

DESCRIPTION

The reduction gear box consists of a planetary gear set which reduces the revolutions put into the unit by a 2.91 to 1 ratio and is always engaged. The direction of rotation of the output shaft of the reduction gear box is the same as the engine rotation. Lubrication pressure is supplied by the pump in the main transmission. The splined output shaft of the reduction gear box is coaxial with the input shaft of the main unit. The lubrication oil is transferred from the reduction gear box to the main transmission by gravity and jet flow.

Location of several transmission details are shown in Figures 1 and 2 as follows:

A. Oil Filler Cap

B. Oil Outlet Opening to Cooler

C. Oil Inlet Opening from Cooler

D. Mounting Pads and Mounting Bolt Holes

E. Shift Lever

F. Oil Drain Cap

G. Breather

H. Drive Gear

I. Valve Cover

J. Coupling

K. Oil Pump

L. Reduction Gear Box

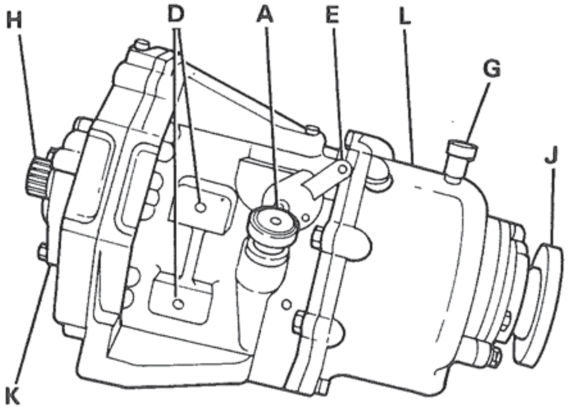


Figure 1. Left Side of Transmission.

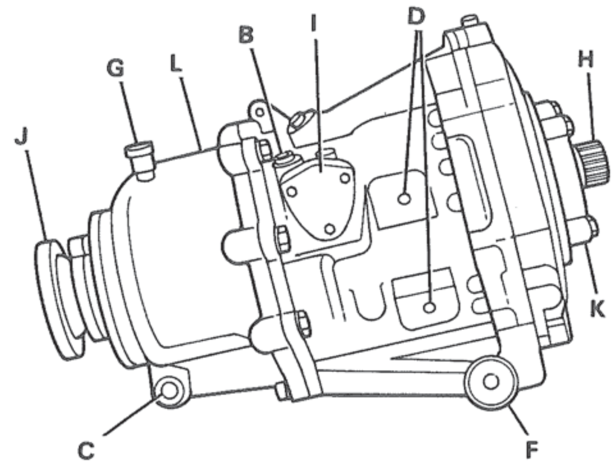


Figure 2. Right Side of Transmission.

DISASSEMBLY

Reduction Housing, Pinion Cage and Main Shaft Assembly.

1. Support the transmission assembly on the front face on a suitable clean flat block.

2. Remove the bolts and lockwashers, fastening the reduction housing to forward and reversing transmission case as shown in Figure 3, then remove the reduction housing and pinion gear and main shaft assembly from the forward and reverse transmission case. Figure 4.

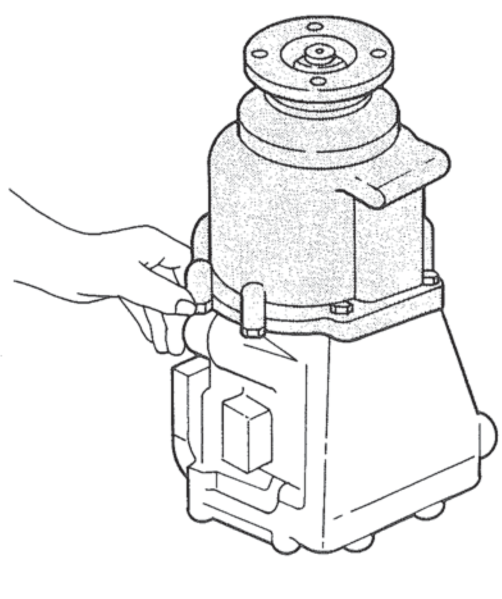


Figure 3. Removing Reduction Unit Bolts.

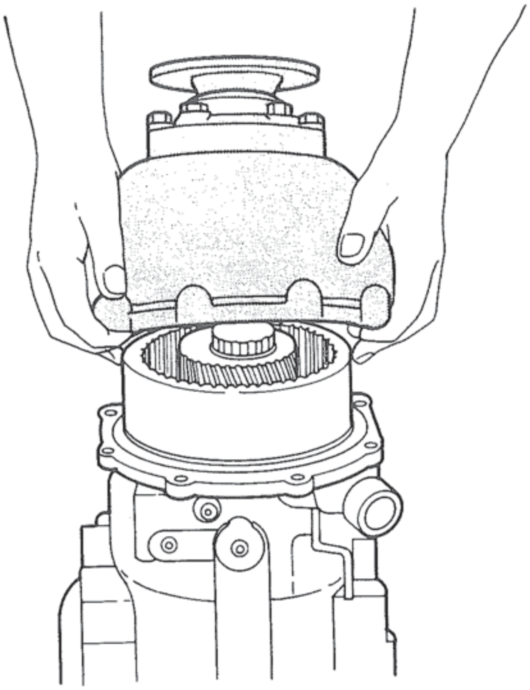


Figure 4. Removing Reduction Unit.

Pinion Cage and Main Shaft, Coupling and Bearing.

3. Remove the main shaft nut and coupling. Figure 5.

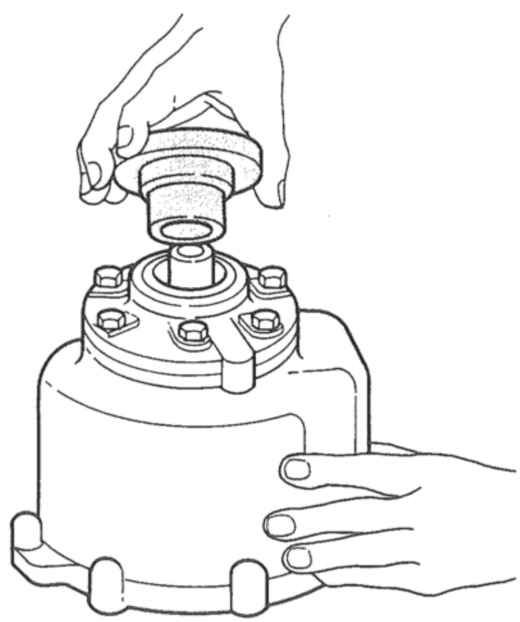


Figure 5. Removing Coupling Assembly.

4. Remove the six (6) hex head bolts and lockwashers then remove the bearing retainer. Figure 6.

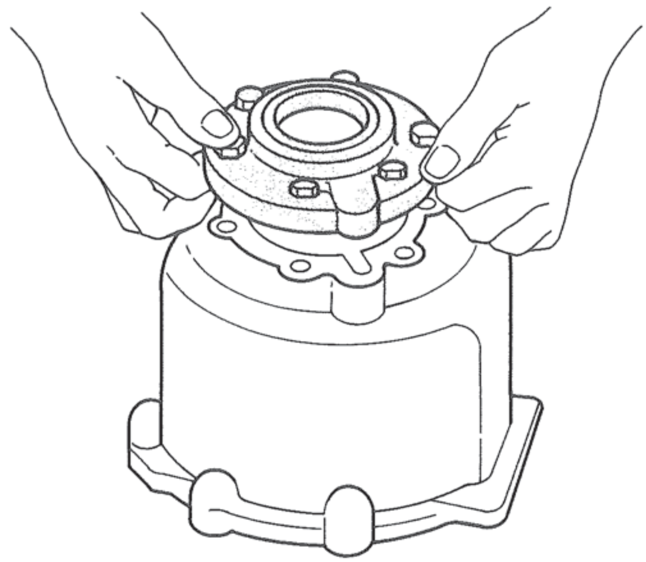


Figure 6. Removing Bearing Retainer.

5. Remove the rear inner race of the bearing, and remove the pinion cage and main shaft assembly.

6. Place the reduction housing on an arbor press supported on a clean flat surface and press the outer bearing race from the reduction housing by the use of a suitable tool locating on the front inner bearing race being careful not to drop the parts when they are free of the housing.

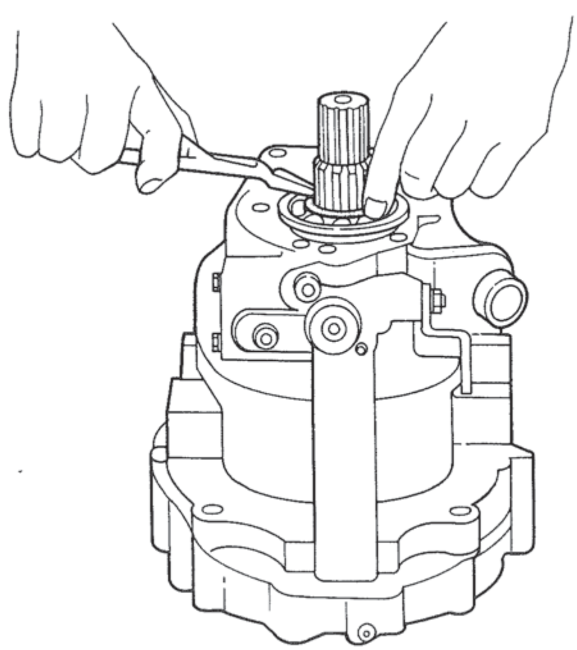


Figure 7. Removing Snap Ring.

Ring Gear, Stationary Gear Plate and Reduction Housing Adapter.

7. Remove the snap ring and sun gear. Figures 7 and 8.

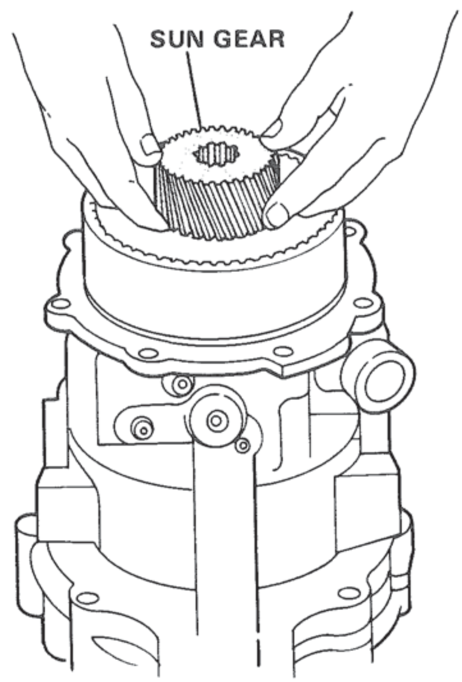


Figure 8. Removing Sun Gear.

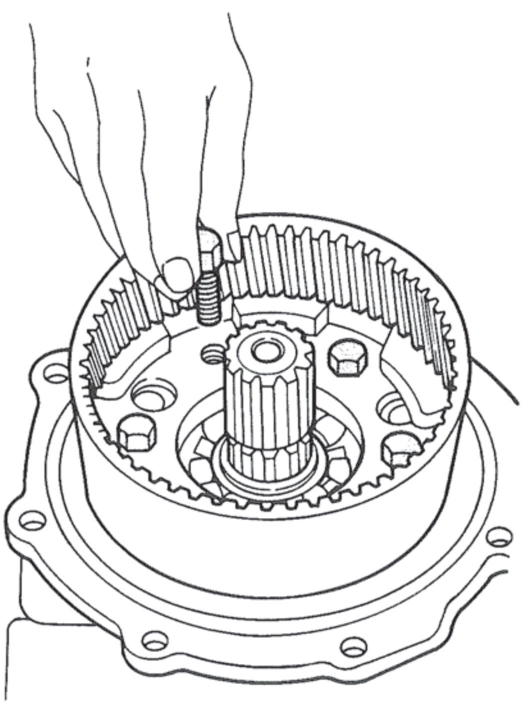


Figure 9. Removing Nylock Bolts.

8. Remove the six (6) nylock bolts and lockwashers and stationary gear plate and ring gear assembly. Figures 9 and 10.

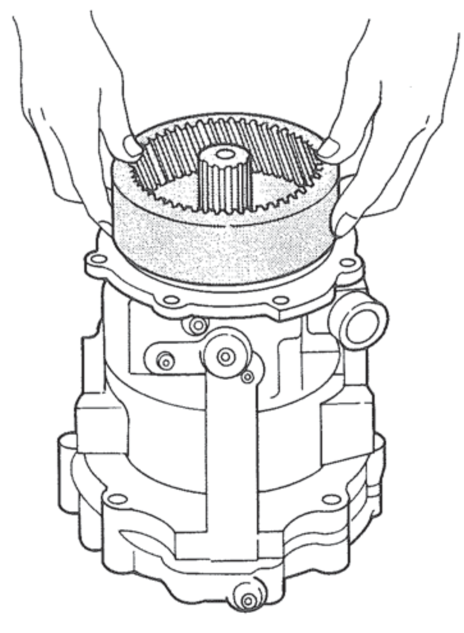


Figure 10. Removing Ring Gear Assembly.

9. Remove the reduction unit adapter. Figure 11.

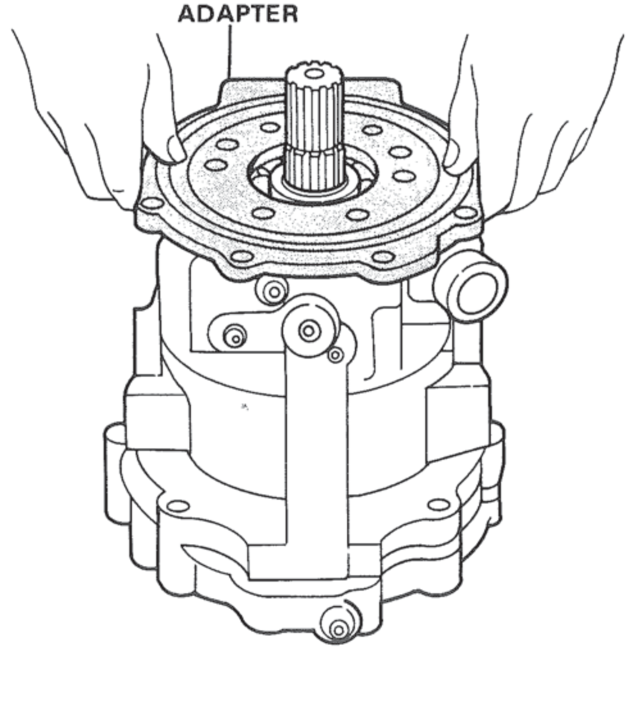


Figure 11. Removing Reduction Unit Adapter.

10. Remove the snap ring and separate the stationary gear plate and ring. Figures 12 and 13.

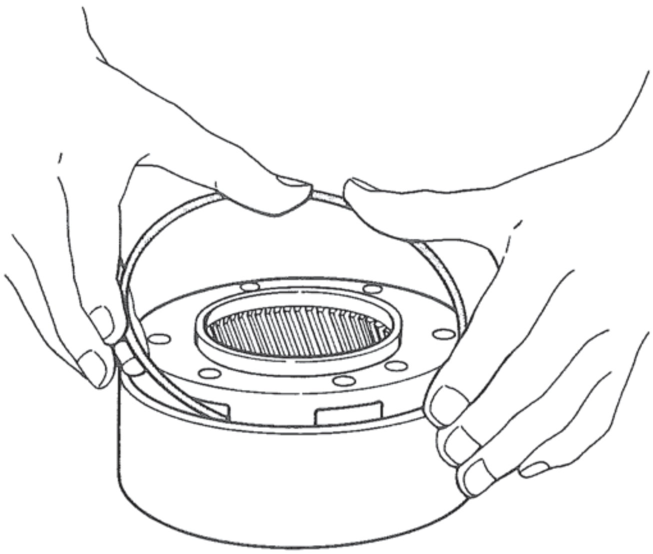


Figure 12. Removing Snap Ring.

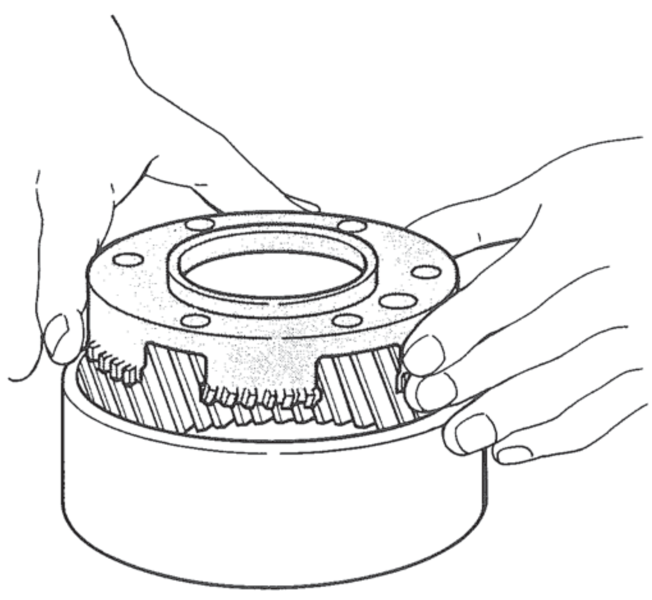


Figure 13. Removing Stationary Gear Plate Assembly.

11. Remove the snap ring from the main shaft.

INSPECTION AND GENERAL INSTRUCTIONS

1. Cleanliness is absolutely necessary during assembly to insure proper functioning of transmission. Transmission case passages should always have plugs removed to allow for thorough cleaning. When available, use compressed air to dry parts before they are assembled. Do not wipe parts with rags to clean or dry them as lint from the cloth may cause erratic valve action.

2. Inspect all parts for damage or wear. Replace defective parts.

3. All gaskets, oil seals and rubber sealing rings should be replaced except in relatively new units. Judgment should then be exercised as to the need for replacing these parts.

4. Oil seals and bearings are best installed by using an arbor press, suitable fixtures, and tools to properly align parts being assembled. Hammering seals and bearings into position can severely damage parts.

5. Automatic Transmission Fluid, type "A", suffix "A" should be used to lubricate parts as they are assembled. Petroleum jelly may be used on gaskets or other parts that must be held in position during assembly. All parts will assemble more freely if lubricated.

6. Tighten all bolts and screws evenly to the recommended torque.

7. Reduction pinion cage service instructions are covered under Planetary Service Kits in this manual.

ASSEMBLY

The assembly of the Forward and Reverse Transmission used in conjunction with the Reduction Gear Box will be the same as described earlier. Except for pinion cage output shaft and bearing section below.

Pinion Cage Output Shaft and Bearing.

1. Install the pinion cage and output shaft into the transmission case and press the bearing into the case and onto the output shaft as discussed in the forward and reversing manual. Install the snap ring on the output shaft to hold the bearing in position.

2. Proceed with the installation of the forward and reverse components as outlined earlier.

Stationary Gear Plate.

1. Install the stationary gear plate into the ring gear until it rests against the shoulder. Figure 14.

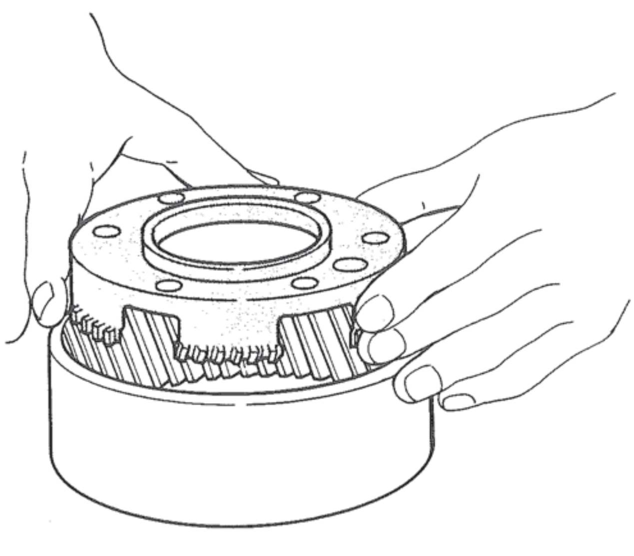


Figure 14. Assembling Stationary Gear Plate.

2. Install the snap ring firmly into the groove of the ring gear. Figure 15.

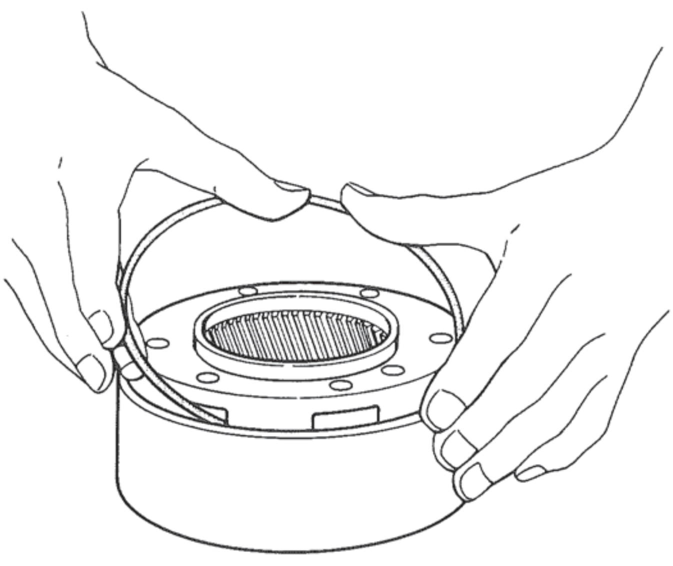


Figure 15. Assembling Snap Ring.

Reduction Unit Adapter and Ring Gear Assembly.

1. Support the forward and reverse transmission assembly on the forward face on a clean surface or suitable block.

2. Place the reduction unit adapter gasket-front in position on the rear face of the transmission. Figure 16. Gasket may be coated with petroleum jelly for easier assembly.

3. Install the reduction unit adapter on the rear of the transmission case located on the outer diameter of the bearing. Figure 17.

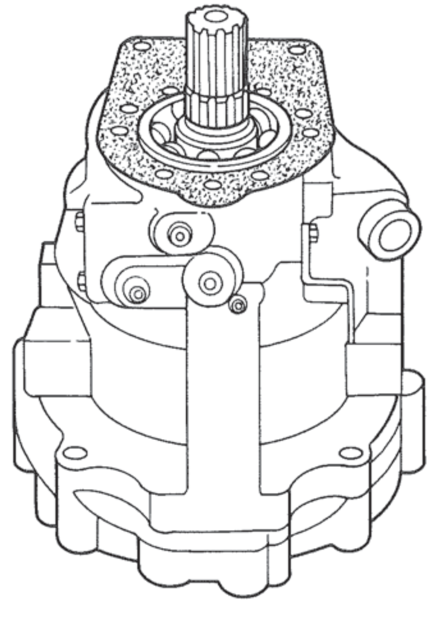


Figure 16. Assembling Gasket.

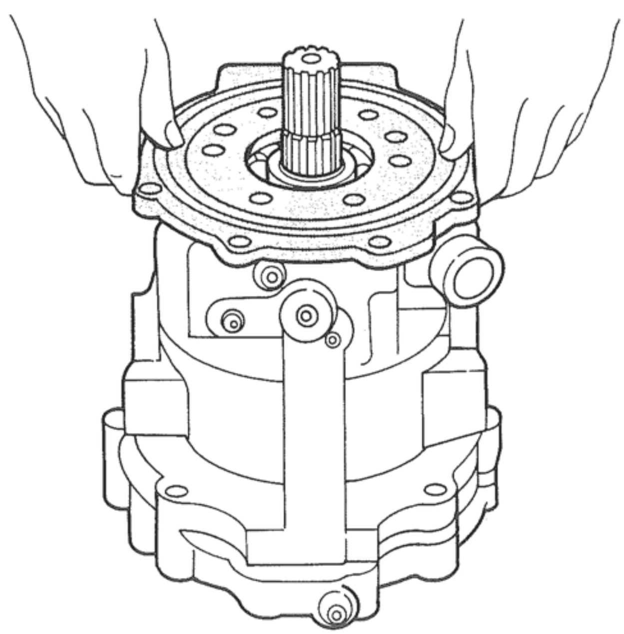


Figure 17. Assembling Reduction Unit Adapter.

4. Install the parts assembled in steps 3 and 4, locating the hub of the stationary gear plate in the bearing pilot bore of the reduction unit adapter. Figure 18.

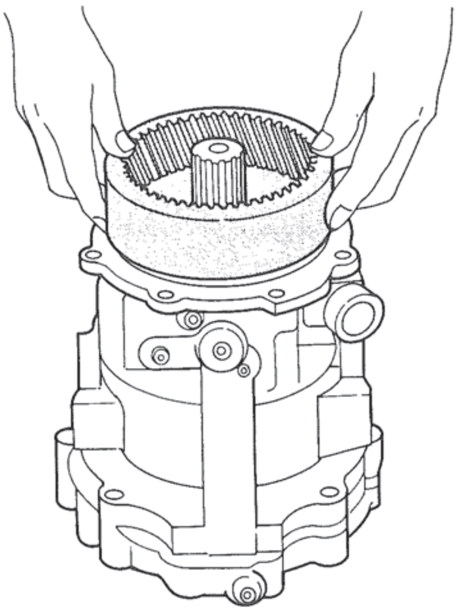


Figure 18. Assembling Ring Gear Assembly.

5. Install the six (6) new 7/16 - 14 x 1-1/4 nylock bolts and 7/16 lockwashers. Figure 19.

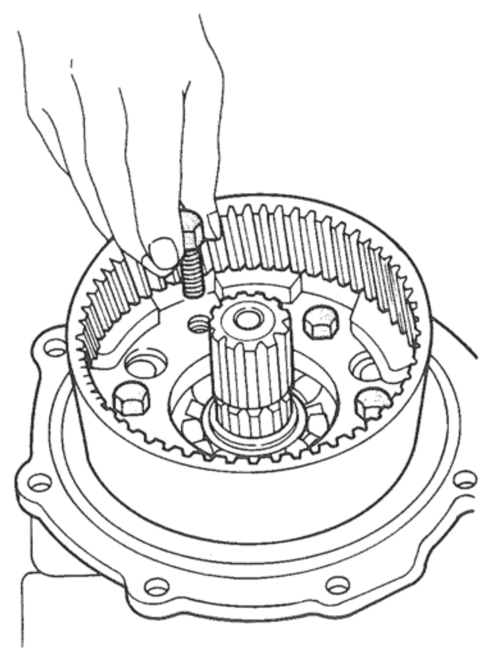


Figure 19. Installing Nylock Bolts.

Before tightening the six (6) nylock bolts assemble in place the two (2) 7/16 - 14 x 1-3/4 hex head bolts to insure alignment of all bolt holes. Tighten evenly in rotation the six (6) nylock bolts to the prescribed torque then remove the 7/16 - 14 x 1-3/4 hex head bolts.

Sun Gear.

1. Install the sun gear on the output shaft until it is seated against the shoulder. Figure 20.

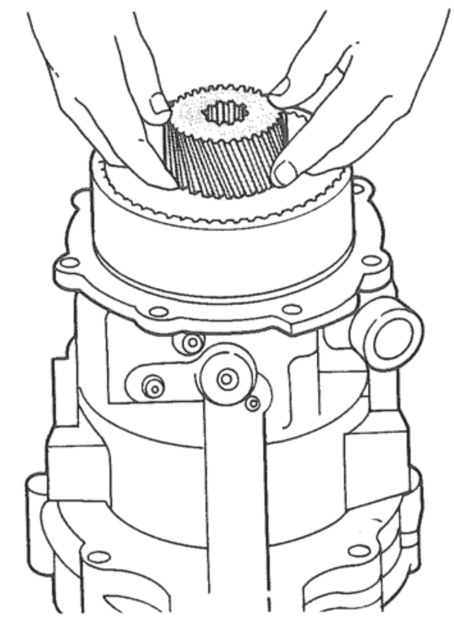


Figure 20. Installing Sun Gear.

2. Install the snap ring firmly into the groove. Figure 21.

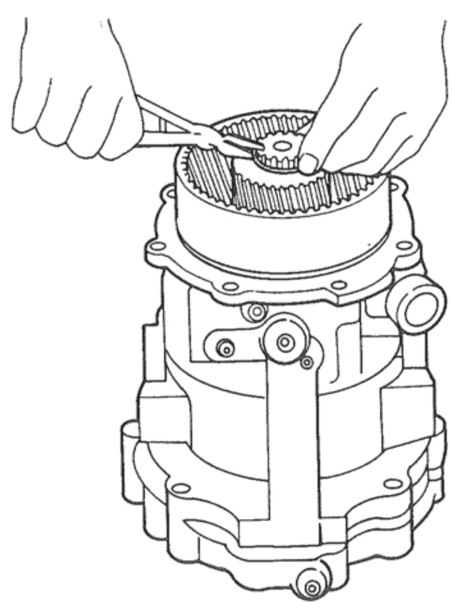


Figure 21. Installing Snap Ring.

Bearing.

1. Place the reduction housing on an arbor press resting the front face on a clean flat surface. The position of the bearing parts are shown in Figure 22.

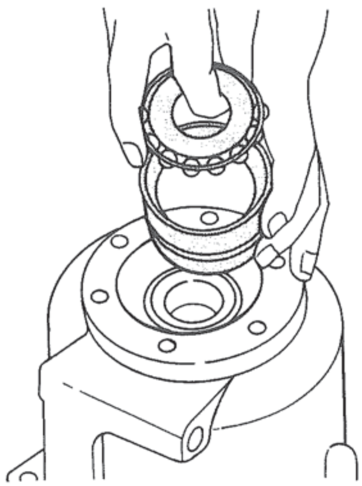


Figure 22. Installing Bearing.

2. Inspect bearing for match marks placed on by the manufacturer and match them in the assembly steps that follow. Install the first row of the tapered bearing so that the inner ring rests against the shoulder in the reduction housing.

3. Lubricate the outer diameter of outer ring with automatic transmission fluid and press it into the reduction housing using a suitable tool until the outer race is seated firmly against the shoulder in the reduction housing. Figure 23.

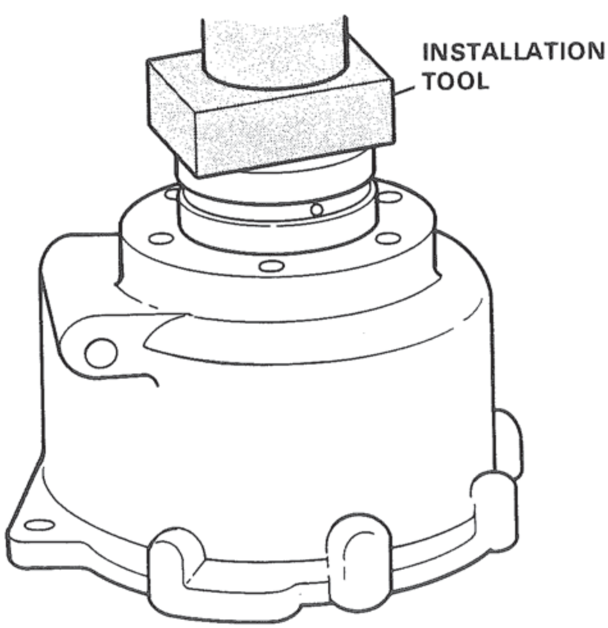


Figure 23. Installing Outer Bearing Race.

4. Install the rear row of tapered bearing into outer race.

Bearing Retainer, Breather Assembly, Main Shaft, Coupling and Main Shaft Nut.

1. Place the bearing retainer gasket on the reduction housing aligning the slot with the oil passage. Figure 24. The gasket may be coated with petroleum jelly for easier assembly.

2. Inspect the rubber lip of the oil seal for cuts, cracks or other damage which might cause leakage and replace if necessary. Assemble the bearing retainer onto the reduction housing aligning the oil passages.

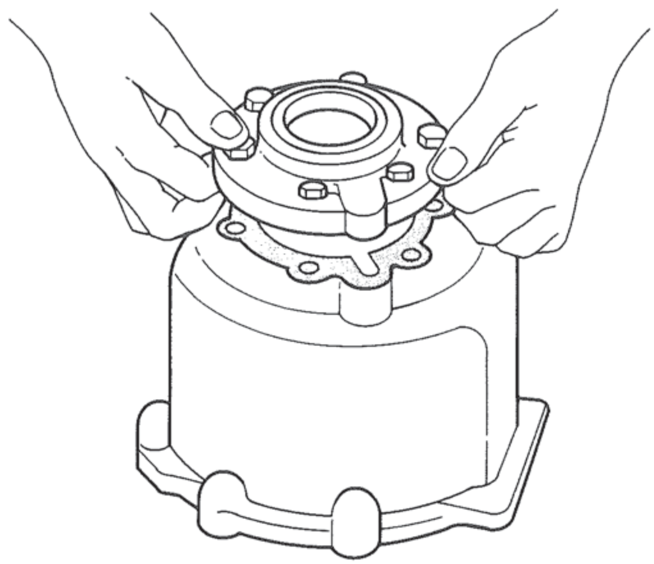


Figure 24. Installing Bearing Retainer and Gasket.

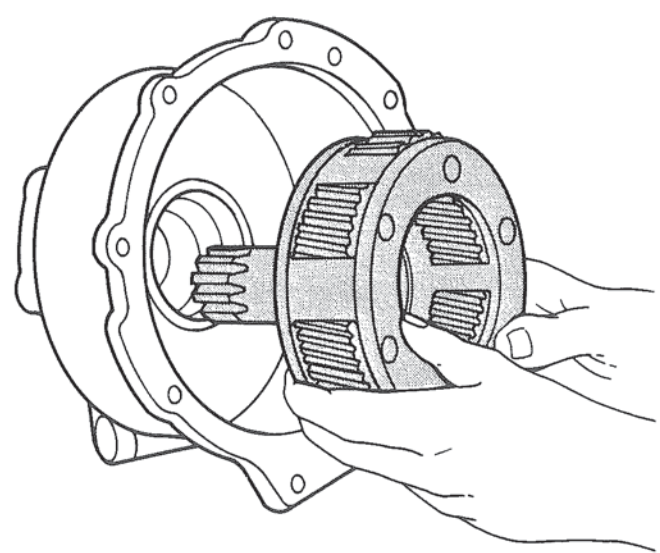


Figure 25. Installing Pinion Cage and Main Shaft.

3. Install the six (6) 7/16 - 14 x 1-1/4 hex head bolts and tighten to 50-55 ft. lbs. (6.90-7.59 kg/m).

4. Install the pinion cage and main shaft assembly into the bearing. Figure 25. If the main shaft does not assemble completely into rear bearing, do not use arbor press or force. The main shaft may be pulled fully into the bearing by use of the main shaft nut.

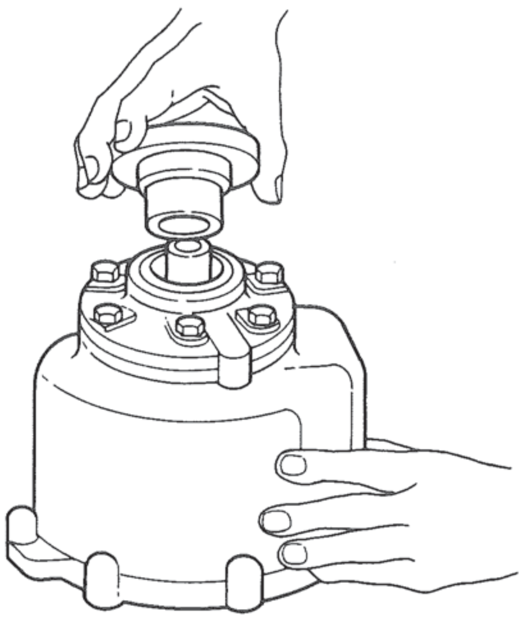


Figure 26. Assembling Coupling.

5. Inspect the coupling sealing diameter to make sure there are no burrs or sharp edges which might damage the seal or prevent proper sealing, replace if damaged. Figure 26. Lubricate the sealing diameter and the internal splines with automatic transmission fluid. Align the splines of the coupling to those of the main shaft and press the coupling down until contact with the bearing inner race is made.

6. Assemble the main shaft nut on the main shaft and tighten to 80-200 ft. lbs. (11.03-27.59 kg/m).

7. Assemble the breather assembly in the 3/8 in. pipe tapped hole provided in the reduction housing. Figure 27.

Reduction Housing and Pinion Cage and Main Shaft Assembly to Forward and Reverse Transmission Assembly.

8. Support the forward and reversing unit on a clean, flat surface or block. Install the reduction housing adapter gasket-rear on the adapter. Figure 28. Coat one side of gasket with petroleum jelly to hold it in position during assembly.

9. Install the reduction housing onto the forward and reversing unit by engaging the teeth of the pinion gears with the teeth of the sun gear and ring gear, then assemble until the reduction housing bore is engaged with the pilot diameter of the reduction unit adapter. The bolt holes should be properly aligned and the parts may be drawn together by use of the bolts.

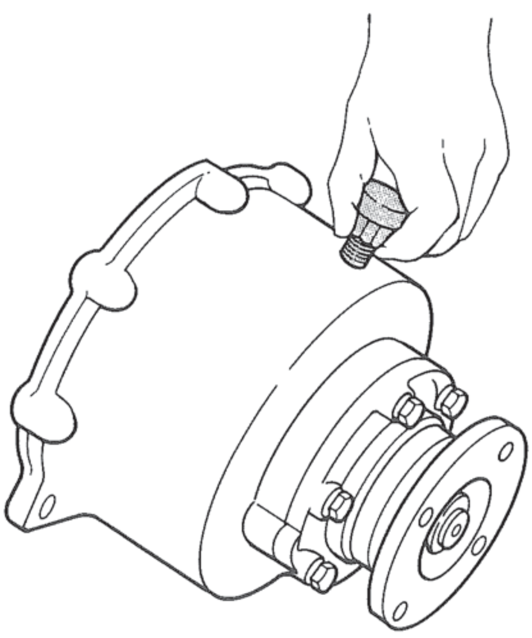


Figure 27. Assembling Breather.

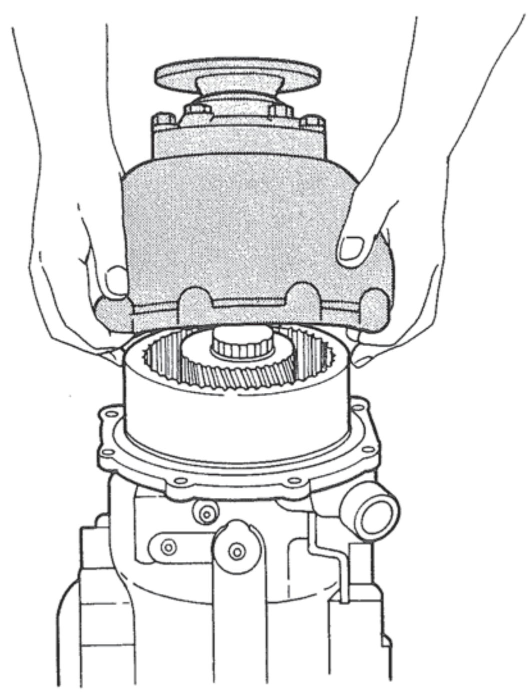


Figure 28. Installing Reduction Unit.

10. Install the two (2) 7/16 - 14 x 1-3/4 hex head bolts and 7/16 lockwashers, and the six (6) 3/8 - 16 x 1-1/8 hex head bolts and 3/8 lockwashers. Figure 29. Tighten the 7/16 bolts to 40-45 ft. lbs. (5.52-6.21 kg/m) and the 3/8 bolts to 28-30 ft. lbs. (3.86-4.14 kg/m).

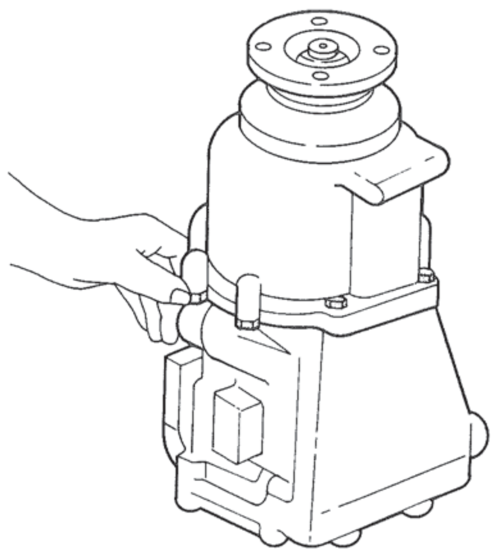


Figure 29. Securing Reduction Unit.

TORQUE SPECIFICATIONS

	Location	**Torque Ft. Lbs.**
7/16-14 x 1-3/4	Reduction Housing to Case	40-45 (5.52-6.21 kg/m)
3/8-16 x 1-1/8	Reduction Housing to Adapter	28-30 (3.86-4.14 kg/m)
7/16-14 x 1-1/4	Reduction Adapter to Transmission Case	40-45 (5.52-6.21 kg/m)
7/16-14 x 1-1/4	Bearing Retainer to Reduction Housing	50-55 (6.90-7.59 kg/m)
1-20	Main Shaft Nut	80-200 (11.03-27.59)

Subsection 11B

TWIN DISC DRIVE

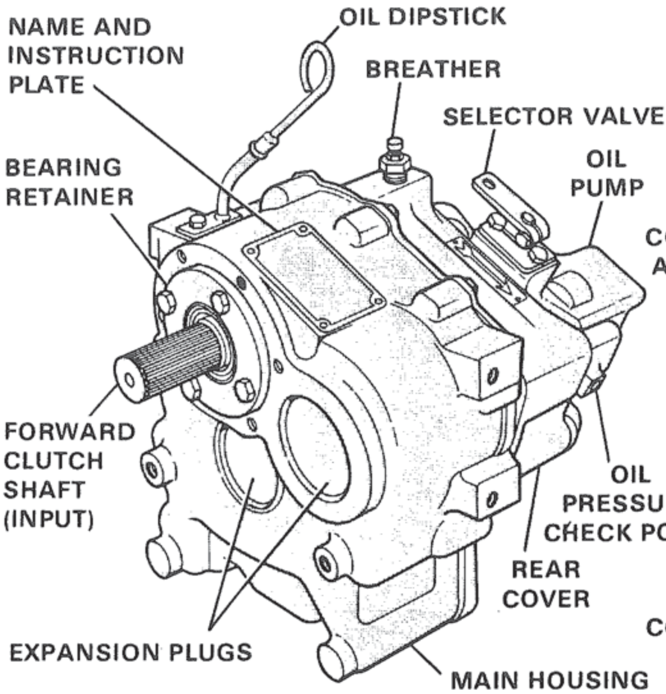


Figure 1. Marine Gear Model MG-502.

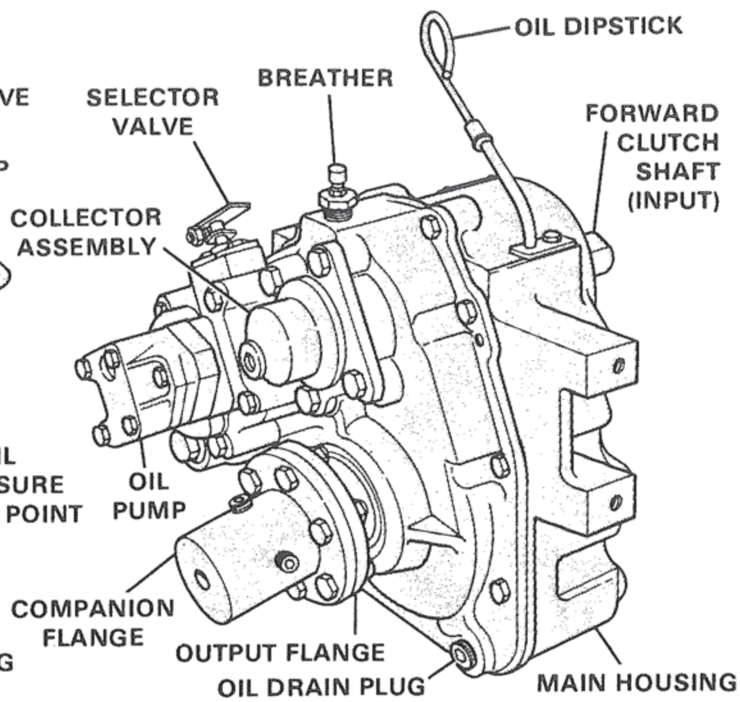


Figure 2. Marine Gear Model MG-502.

GENERAL

The Model MG-502 Marine Gear is a lightweight, high capacity gear designed for pleasure craft use. The output shaft exits from the gear at an angle of 10° downward from the input clutch shaft. This provides engine level mounting capability. Full power operation capability of the gear in either forward or reverse eliminates the need for opposite rotation engines. A similar marine gear, MG-502 "V" drive configuration will be treated in a separate manual. This subsection is devoted to the conventional MG-502 Marine Gear. Conical, helical gears are used for quiet, smooth operation.

NOTE

Throughout the text, there will be references to locations of parts, etc. These references are based on the following:

Front — Input or end of unit attached to prime mover.

Left — Viewed from front of engine (prime mover) position.

Right — Viewed from front of engine (prime mover) position.

Rear — Viewed from engine (prime mover) position, to be section farthest from prime mover.

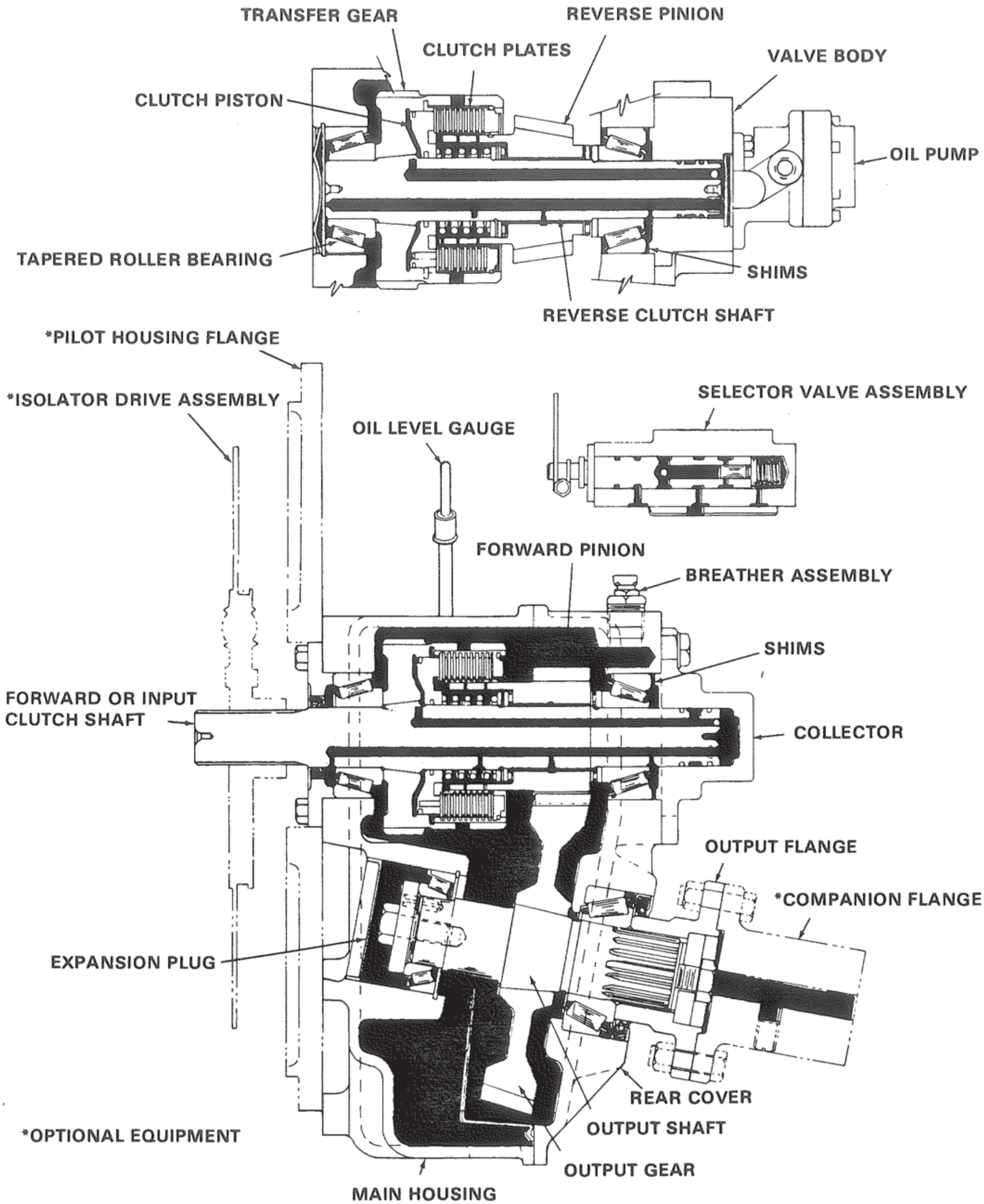


Figure 3. Marine Gear Model MG-502 Cross Section.

Reduction Ratios. The following ratios are available in the conventional MG-502 Marine Gear: 1.54:1, 2.00:1, 2.47:1. Ratios are varied by changes in clutch pinion and output driven gears.

Accessories or Optional Equipment. The following compatible equipment is available and recommended through Twin Disc, Incorporated for use with the MG-502:

A. **Oil Pressure Gauge.** This is a quality gauge available in a range of 0-400 psi. The scale on the gauge also has the equivalent values in the metric system, kilograms/cm², shown below the English.

B. **Oil Temperature Gauge.** An oil temperature gauge 150-300° F, (70-145° C) range, dual scale marked, with various length capillary tubing is available. The length of capillary tubing will accommodate distance separation between engine and control bridge or pilot house.

C. **Heat Exchanger.** Heat exchanger kits are available through Twin Disc for the MG-502. The purpose of the heat exchanger is to maintain the marine gear oil at a proper temperature. Kits are designed for either salt or fresh water operation. Specify type of water used when ordering. The hose sizes included in the kits are to be considered minimum in diameters. Do not add smaller hoses or fittings, introducing restriction to oil flows.

MAIN COMPONENTS

INPUT PARTS.

Torsional Isolator Drive. A torsional isolator drive couples the engine flywheel to the input clutch shaft. The unit consists of a flex drive plate and a torsional absorbing hub assembly. The flex drive plate is bolted to the flywheel while the input clutch shaft connects through a splined hub to the torsional damper hub. This drive tends to dampen engine torsional vibrations, protecting the marine gear from stress and noise. The customer (purchaser) supplies this drive, normally. Twin Disc will supply the drive when so ordered. The drive meets SAE No. J-620C-11.5 in. requirements.

Input Clutch Shaft. The input clutch shaft (forward) is the means by which the engine power is directed into the marine gear for reduction and direction of drive. The input clutch shaft (forward) is an extreme press taper fit to a transfer gear, meshed to a driven reverse clutch transfer gear on the reverse clutch shaft. A clutch pack and hub pinion couple the forward shaft to the output gear and shaft.

MAIN HOUSING PARTS.

1. **Rear Cover — Collector Assembly.**

A. **Rear Cover.** The rear cover attaches to the main housing with two dowel pins and nine (9) hex head cap screws.

CAUTION

Do not alter dowels or attempt their removal and replacement. Machining alignment of bores could be affected, resulting in early failure.

The cover and main housing are a sub-assembly, supplied for service replacement as a matched machined set, *only*. Neither the rear cover nor main housing is replaceable separately. The rear cover provides bearing bores to support the two clutch shaft assemblies and the output shaft assembly rear bearings. The rear cover completes the enclosure for the main marine gear components and provides, with the main housing, an oil sump area for the lubricating and hydraulic system oil.

Collector Assembly. The collector assembly fits over the rear end of the forward clutch shaft and attaches to the rear cover with four (4) hex head cap screws. The collector serves the purpose of a manifold to direct lubricating and clutch apply oil through the clutch shaft to the forward clutch assembly and bearings. A pair of connecting (jumper) tubes are used to join oil passages from the valve body to the collector. The pilot on the collector provides a means to shim-adjust and retain the forward clutch rear tapered roller bearing. A gear pan encloses the lower section of the output gear. The gear pan attaches to the inside forward face of the rear cover with two (2) hex head cap screws. The purpose of the gear pan is to prevent turbulence near the end of the pump suction tube which may cause cavitation of the pump with resultant pressure loss. Also, some oil retained in the pan will provide initial gear lubrication when unit is started after standing several hours. A plastic gasket compound is used between the collector and rear cover to seal the parting surfaces.

2. **Main Housing — Suction Tube.**

Main Housing. The main housing is not serviced separately. It is only supplied with the rear cover as a sub-assembly for service replacement. The main housing provides bearing bores for supporting the clutch and output shaft's front tapered roller bearings. The main housing with the rear cover contains all main components and provides a sump area for storage of lubricating clutch apply oil. Plastic gasket compound is used between the parting surfaces of main housing and rear cover to seal this joining point.

Suction Tube. The pump suction tube is considered as an integral part of the housing sub-assembly. The tube is not serviced separately. The pump end of the tube is rolled in the rear cover 0.59-0.65 in. below the rear cover rear face and must be a pressure tight fit.

Breather. The breather is assembled with a reducer into a tapped hole at the top of the rear cover. The breather vents any internal pressure into the atmosphere.

Oil Pump. A positive displacement, gear type, oil pump is used. The pump is mounted, with four (4) hex head cap screws and a gasket, on the valve body and is slot driven from the rear end of the reverse clutch shaft. The oil pump turns at all times that the engine is turning, being driven though the clutch shaft transfer gearing and slot at the end of the reverse clutch shaft and tang on the pump drive shaft.

New Pump Requirements. Pump to deliver 2.5 GPM @ 3000 RPM @ 300 PSI.

Normal Operating Conditions.

Pressure Range 300 — 350 PSI

Speed Range 600 - 4400 pump RPM

A filter screen, No. 50 square mesh brass or monel metal wire cloth, is installed in a cavity at the oil pump end of the pump suction tube. The screen is retained by an O-ring and plug in the selector valve body. The plug also serves as access to remove and clean the filter screen. Oil pump and system protection is provided by this screen.

To adapt an oil pump to either left or right hand engines, a left or right hand rotation oil pump is available. Each direction of rotation requires its separate pump. Field rebuilding repair of oil pump is not recommended. An exchange can be arranged with pump manufacturer.

Control and Regulator Valve Assembly. The control and regulator valve assembly (selector valve assembly) consists of a cast body in which the selector valve and a regulator valve are assembled. The regulator valve consists of a valve piston and a spring set; one inner and one outer spring, with a washer installed in a bore of the valve body integrally with the selector valve stem. The selector valve consists of a valve stem, detent plate, O-ring, and lever. The entire valve asembly attaches to the rear cover, behind the reverse clutch assembly. Two connecting tubes connect from the valve body to the collector to convey lubrication and clutch apply oil to the forward clutch shaft. The oil pump is attached to the rear surface of the valve body. Plastic gasket compound is used for a seal between the valve body assembly and the rear cover. Five (5) hex head cap screws retain the valve body to the rear cover.

REVERSE CLUTCH SHAFT AND GEAR ASSEMBLY.

Bearings. A tapered roller bearing is used on each end of the clutch shaft. The end play for the bearing set is adjusted with shims between the valve body assembly pilot and the rear bearing cup (outer race). End play range is 0.003-0.005 in.

CAUTION

The front bearing cup is machined square on the back face to seat on the snap ring. Do not change this cup with the other three or bearing failure will result.

Clutch Shaft. The clutch shaft is an integral part of the sub-assembly consisting of the clutch shaft and transfer gear. The gear is an extreme taper press fit on the shaft. These two pieces are serviced as an assembly, only, not separately. Passages for clutch application and lubrication are drilled longitudinally and cross-drilled in the clutch shaft.

Clutch Pack Assembly. The clutch pack assembly consists of a pinion gear and bushing assembly, a piston, piston return spring, and a nineteen plate clutch pack. The pack has two (2) sintered, faced-on-one-side only plates, eight (8) sintered, faced (both sides), and nine (9) steel plates. A backing plate and internal snap ring retain the plate stack in the hub. The sintrered (faced) plates are meshed with external teeth to the interal spline of the transfer gear. The steel plates are meshed with internal teeth to the external teeth of the clutch hub. External teeth on the clutch back plate mesh with the internal teeth of the transfer gear. In assembly, the one-side-sintered plates are used on the ends of the pack. The plate against the piston, contacts the piston surface with its steel side (unsintered). The plate on the back plate end of the pack, contacts the back plate with its steel side (unsintered). The plates between the two special end plates are alternately nine (9) steel and eight (8) sintered to make up the pack.

Thrust Bearings and Washers. The pinion hub assembly has thrust washers, and needle thrust roller bearings at each end to reduce the friction and load from these forces.

Oil Seal Rings. Two (2) oil seal, hooked end, piston type, seal rings are used in the grooves near the rear end of the clutch shaft to port the oil passages through which oil is directed down the clutch shaft drillings.

FORWARD (INPUT) CLUTCH SHAFT AND GEAR ASSEMBLY.

General. This clutch shaft and gear assembly is very much like the reverse clutch shaft assembly described above.

Bearings. A tapered roller bearing is used on each end of the forward clutch shaft. The end play for the bearing set is adjusted with shims between the collector at the rear of the rear cover and the rear outer bearing race (cup) of the tapered roller bearing assembly. The forward bearing cup or outer race is retained in position by a bearing retainer on the front of the main housing. The bearing end play range is 0.003-0.005 in.

Clutch Pack Assembly. The forward (input) clutch pack assembly is the same as the reverse clutch pack assembly described above.

Thrust Bearings and Washers. The reverse clutch and forward clutch are constructed the same in respect to the thrust washers and bearings.

Oil Seal Rings. As in the reverse clutch shaft assembly, the forward (input) clutch has two (2) oil seal rings of the hooked end, piston type design to port the clutch apply and lubrication oil through the shaft drillings.

OUTPUT SHAFT PARTS

The output shaft assembly consists of the output shaft, output gear, (pressed on shaft taper), two (2) tapered roller bearings, a spacer, a lathe-cut seal ring, a rear retainer washer, cap screw, output flange, a front retainer washer, cap screw, shims, a snap ring, and an expansion plug. A gear pan attached to the rear cover shrouds the lower section of the output gear.

Output Shaft. The output shaft is designed with a downward 10° angle toward the rear. The shaft is supported in a large tapered roller bearing at the rear and a smaller tapered roller bearing at the front. The front bearing outer bearing race (cup) is retained with an internal snap ring in its bore in the main housing. The larger tapered roller bearing cup at the rear is pressed into its bore to bottom in the rear cover. The output shaft bearings are adjusted for end play with shims located between the front end of the shaft and the front retainer washer. The end play range is 0.003 to 0.005 in.

Output Gear. The output gear is a press fit onto a taper on the shaft. The gear is a helical, conical, machined gear to compensate for the 10° of output shaft downward angle mounting.

Output Shaft Seals. Counting the expansion plug at the front of the output shaft in the main housing, three (3) seals are used on the output group of parts. A double-lip type seal, spring loaded on the oil control side, is pressed into the rear cover. The seal lips ride on a seal machined surface on the output flange. To seal possible leakage down the spline between the output flange and shaft, a lathe-cut seal ring is installed and retained with the flange retaining washer.

Output Flange. The output flange with a companion flange connects the shaft to the propeller. The output flange is constructed with a hub and flange section. The hub is internal splined to connect to the marine gear's output shaft. The external area of the hub is machined for a seal surface for the oil seal. The flange section is flat machined and drilled with six (6) equally spaced holes for attaching the companion flange. The flange face surface must not exceed .004 in. total indicator reading when installed in marine gear. The pilot of the flange, must not have more than .004 in. total indicated runout. A companion flange will be supplied by Twin Disc on order only. The companion flange will have six (6) bolts with self-locking nuts select ream-fitted to the holes. Also two (2) setscrews will be installed in the hub of the companion flange 90° apart. The hub will be shaft bored to accomodate customer's propeller shaft size (customer must specify). If the customer requires a key seat (keyway), he must machine this himself on a center line through the flange which divides the setscrew centerlines, placing these 45° to each side. The keyway must be milled opposite the bore side from the setscrew holes. A lathe-cut seal ring, retainer washer, and cap screw secure the output flange to the marine gear output shaft.

THEORY

GENERAL

Description. The Model MG-502 Marine Gear is a marine reverse and reduction gear available in three (3) ratios at this time; 1.54:1, 2.00:1, and 2.47:1. Within their rated capacities, all ratios may be operated continuously in either the forward or reverse position. Identical ratios in forward and reverse permit the type of installation known as "Twinning"; that is, mounting two gears on two right-hand (or left-hand) rotation engines and running one gear in forward and the other gear in reverse to obtain opposite rotation of the propellers (for counter-acting torque). This marine gear is completely hydraulic in all phases — all bearings are oil lubricated, both clutches are engaged by high pressure oil and both clutches are oil pressure lubricated and cooled.

Direction of Drive. The forward (input) clutch shaft and transfer gear always rotate in engine direction. The reverse clutch shaft and transfer gear always rotate in opposite direction. When the forward clutch is engaged, the output shaft driven gear will rotate opposite of engine direction, because it is meshed with the forward clutch shaft pinion. When the reverse clutch is engaged the output driven gear will rotate in engine direction because the output gear mesh with the reverse clutch shaft pinion.

POWER FLOW

Neutral. When in neutral, all moving parts turn at engine speed. The torsional isolator bolted to the engine flywheel connects the engine and the marine gear. The splined hub of the torsional isolator meshes with the splines on the forward (input) clutch shaft. The internal spline of the steel clutch plates mesh with the external splines of the pinion hub which is connected through the pinion to the output driven gear. The plates of the forward clutch connect directly to the internal splines of the forward clutch transfer gear with their external splines. The transfer gear connects, through its taper press fit, directly to the clutch shaft. Therefore, the clutch shaft, transfer gear, and faced clutch plates are turning in engine direction. The steel plates, hub and pinion, and output gear are not turning with the forward clutch disengaged. The reverse clutch transfer gear is constantly meshed with the forward clutch transfer gear. The transfer gears have the same number of teeth, so the drive-driven ratio is 1:1. The reverse transfer gear and clutch shaft are rotating in opposite engine direction at engine speed. The sintered faced reverse clutch plates are constantly meshed to the internal spline of the reverse transfer gear with their external spline. The reverse clutch steel plates are constantly meshed to the external hub spline of the reverse pinion with their internal spline. In neutral, the reverse transfer gear, clutch shaft, and sintered faced clutch plates are turning in opposite engine direction. The oil pump driven from the reverse clutch shaft also is turning opposite engine direction at engine speed. Both clutches, being disengaged, prevents further power flow in the marine gear.

Forward. When forward speed is selected, all the marine gear parts which were turning during neutral selection are still turning. However, when forward is selected, the forward clutch steel and faced plates are clamped together by the clutch piston and back plate. This connects the forward clutch shaft and transfer gear to the clutch pinion, meshed to the output gear. The output gear, taper press fitted to the output shaft then turns the output shaft, flange and propeller at a reduced speed opposite engine direction. The reduced speed results from ratio of pinion to output gear.

Reverse. When in reverse, all the marine gear parts that were rotating in neutral are still turning. However, when reverse is selected, the reverse clutch steel and faced plates are clamped together by the clutch piston and back plate. This connects the reverse clutch shaft and transfer gear to the clutch pinion which is meshed to the output gear. The output gear, taper press fitted to the output shaft, then turns the output shaft, flange, and propeller at a reduced speed in engine direction of rotation. The reduced speed results from ratio of reverse pinion to output gear.

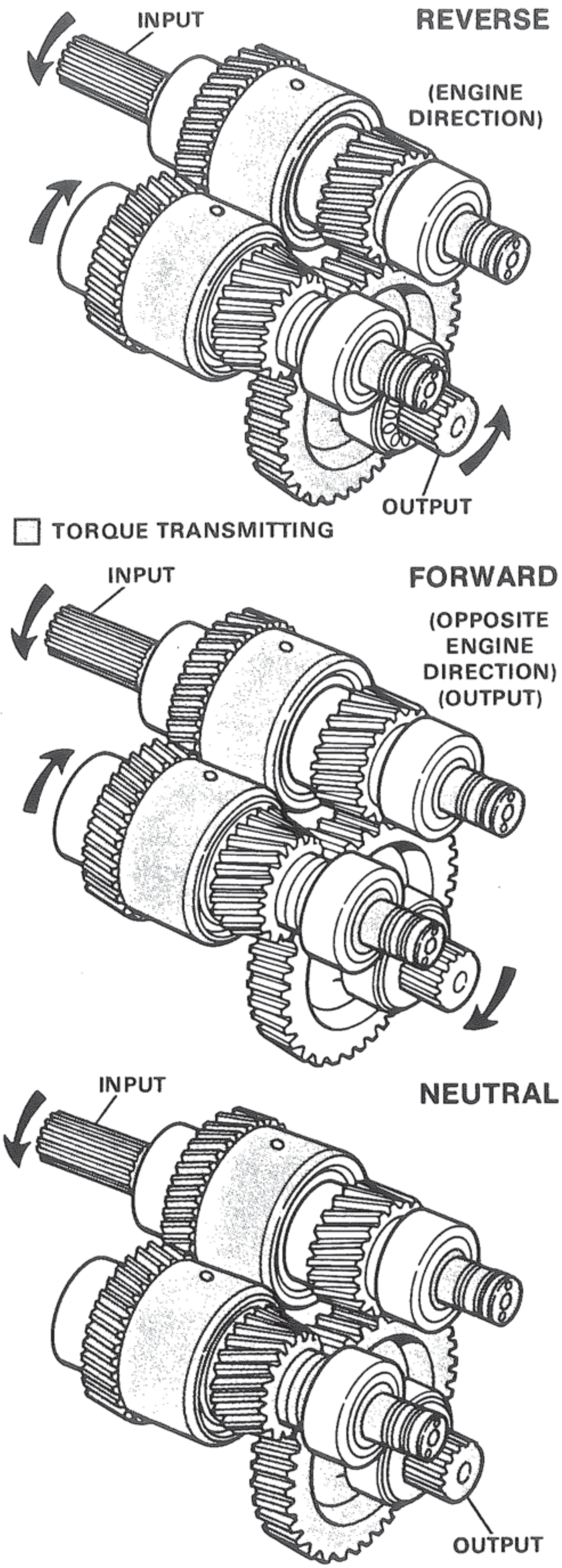


Figure 4. Power Flow Diagrams.

HYDRAULIC SYSTEM

GENERAL

Description. The hydraulic system in the Model MG-502 Marine Gear serves to deliver oil pressure for clutch engagements, lubrication, and cooling. The sump, which is located in the bottom section of the main housing, contains an adequate amount of oil for all hydraulic system requirements. The oil pump provides the source of oil pressure and volume for the system. The selector valve, integral with the pressure regulating valve, controls the oil routing and pressure regulation of the system. The valve body, connecting tubes and collector are further means for direction of the clutch apply and lubricating oil flows. The valve body and collector have drilled passages for this purpose. An oil suction strainer filters the oil before entering the oil pump to be pumped throughout the system. The clutch shafts have oil passages drilled longitudinally and crosswise to distribute the oil for clutch application, lubrication, and cooling. The only external plumbing involved, is that used for installing the heat exchanger. Connections for the heat exchanger are provided on the selector valve body (3/8-18 NPTF dry seal) for inlet from heat exchanger, and on the oil pump (3/8-18 NPTF dryseal) for outlet to the heat exchanger. The heat exchanger will keep the hydraulic system oil at the proper temperature. A 1/4-18 NPTF is tapped at the control valve and plugged to attach an oil pressure gauge connection.

Oil Circuit. The oil pump draws the oil from the sump through a strainer on the suction side of the pump. The pressure side of the oil pump displaces oil under pressure through the heat exchanger and into the selector valve where it is regulated for pressure. The overage oil from the pressure regulator valve is routed to the clutches through their shafts for lubrication and cooling. Regulated pressure oil from the regulator valve is directed to the selector valve. In the neutral position of the selector valve, the pressure oil is dead-headed, or blocked, and both clutch apply passages are open to exhaust (sump) through the valve. When the selector valve is rotated to the forward position (output shaft anti-engine direction), the clutch apply passages to the forward clutch are charged with pressurized oil to apply the clutch. The reverse clutch passages are connected through the selector valve at this time to exhaust to sump. When the selector valve is rotated to the reverse position (output shaft engine direction) the clutch apply passages to the reverse clutch are charged with pressurized oil to apply to the clutch. The forward clutch passages are connected through the selector valve at this time to exhaust to sump. (See schematic circuit drawing).

PREVENTIVE MAINTENANCE

GENERAL

Lubrication. All moving parts of the Marine Gear are lubricated by the oil within the sump as it travels throughout the hydraulic system. The preventive maintenance to keep the gear functioning properly consists of checking the oil level at given intervals and changing oil as recommended. Cleaning the oil strainer is also a part of preventive maintenance.

Overhaul Interval. A complete overhaul of the MG-502 Marine Gear should be made at the same time that the engine is overhauled. All parts showing signs of wear, fatigue, etc., should be replaced at that time.

HYDRAULIC SYSTEM

Oil Capacity and Weight. The oil capacity of the MG-502 Marine Gear is 3.5 pints (4.5 litre). This is less heat exchanger and connections. Fill to the "Full" mark on the oil level gauge with engine running at idle speed in "neutral." The oil used in the marine gear should be heavy duty type engine oil SAE 30 viscosity when the cooling water is above 85° F (29° C) and SAE 20 viscosity when 85° F (29° C) and below.

Oil Level. The oil level should be checked after each twenty hours of service or weekly. The oil level must be checked with the engine running in "neutral" at idle speed and operating temperature. Maintain level at the "Full" mark on oil level gauge.

Oil Change Interval. The oil must be changed, system flushed, and suction screen cleaned once yearly.

Draining. The oil sump is drained through the removal of the socket head drain plug located in the lower left corner of the rear cover. Allow sufficient time for draining and install the drain plug. Tighten the plug securely in place.

Filling. Make certain the drain plug is tight, and fill the sump with 3.5 pints (4.5 litre) of proper oil. Remove the breather and bushing (reducer) from the top of the rear cover. Pour the oil (with a small funnel) through the breather opening into the unit. Start the engine and run in "neutral" until oil is circulated throughout the hydraulic system. Check the oil level on the oil level gauge. With oil at operating temperature and engine running at low idle speed, fill the oil sump to read "Full" on the oil level gauge. Install and secure the breather and bushing.

HYDRAULIC SYSTEM COMPONENT PARTS.

Suction Strainer. The suction strainer access plug should be removed and the strainer removed and cleaned once yearly, at the same time the oil is drained and changed. Use a suitable solvent to clean the strainer, inspecting the strainer for any damage to wire gauze. Replace a strainer that is in any way damaged. Check the O-ring in the strainer access plug and install the plug and serviceable O-ring. Tighten plug securely.

Breather Cap. Remove and clean the breather cap at the yearly oil change interval.

Heat Exchanger and Hoses. During the annual oil change and flush period, disconnect hoses from heat exchanger and thoroughly flush exchanger with a suitable solvent. Inspect the zinc electrode used to protect the system from the effect of galvanic action. Replace zinc electrode showing extensive disintegration.

Oil Filter. Follow oil filter manufacturer's recommendations. Twin Disc type are changed every year or 1000 hours of operation, whichever occurs first.

PERIODIC VISUAL INSPECTION.

General. Inspect engine bay and marine gear daily, either at the time before morning start up, or at the end of the day's use, whichever is most convenient. Check the following points:

Oil Leakage. Check for oil leakage at the parting surfaces between the main housing and rear cover, rear output shaft flange seal, valve body and rear cover, oil pump and valve body, collector and rear cover, connecting tubes between valve body and collector, oil strainer access plug, and drain plug. Correct any leakage which is excessive. An excessive leak would be a leak resulting in oil puddles and oil consumption. An acceptable leak after 700 hours of operation, would be one which could be hand rag wiped clean daily. Repair as required in the event of excessive oil leakage.

Heat Exchanger Connecting Lines. Inspect these lines daily. Check for leakage, tight connections, physical damage, and routing or hanging. Replace damaged or defective lines.

Pressure and Temperature Gauges. Inspect the gauges for physical damage, or leaks at connections or lines. If a gauge is suspected of being inaccurate, replace the gauge with one of proven accuracy to determine the condition of removed gauge. Replace defective gauges.

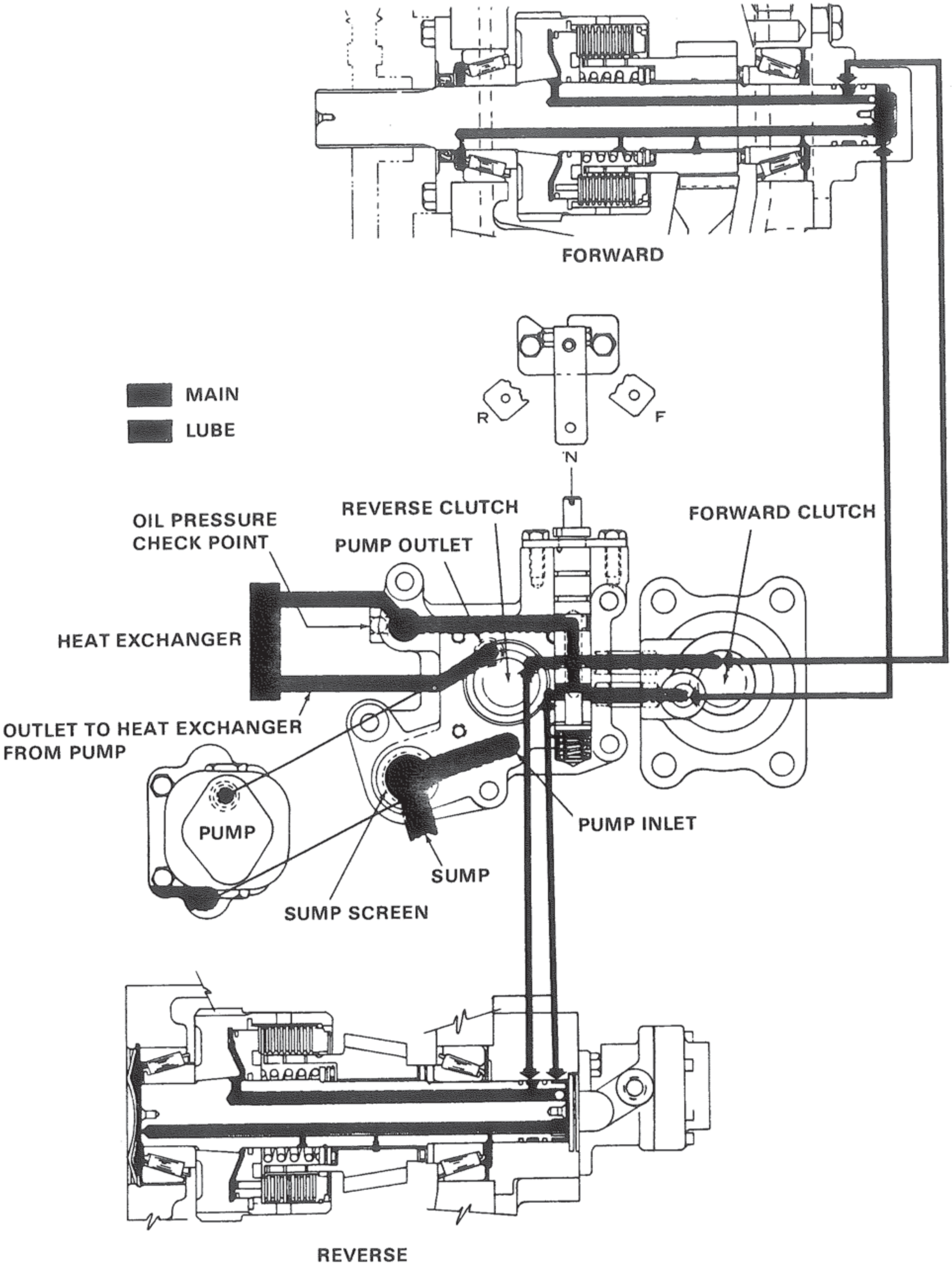


Figure 5. Oil Circuit Schematic.

Marine Gear Mounting and Drive Fittings. Inspect the marine gear mounting for loose bolts or cracked brackets. Repair or replace. Inspect the output flange and companion flange for security of attachment. Repair as required.

TROUBLESHOOTING

General. This section of the manual has been prepared to assist maintenance personnel in troubleshooting the marine gear. When troubleshooting the marine gear, always remember to consider the entire power package.

PRESSURE AND TEMPERATURE CHECKS.

Main Pressure. Attach an 0-500 p.s.i. range pressure gauge to the (3/8-18 NPTF dryseal) selector valve inlet from the heat exchanger with a tee and read the following pressure for conditions given.

Input RPM	Selector Position	Min. PSI	Max. PSI
1800	Forward	310	340
	Neutral	310	340
	Reverse	310	340
600	Forward	290	335
	Neutral	290	335
	Reverse	290	335

Temperature. Attach a temperature gauge in the same line which the oil pressure gauge was used and check the operating temperature range. It should be 140° F (60° C) minimum to 180° F (82° C) normal. The maximum temperature at the heat exchanger inlet is 225° F (107° C) maximum. Measure this from a tee connected at the pump outlet to heat exchanger. Same thread size tapped hole as the heat exchanger outlet to the selector valve used for oil pressure check.

Troubleshooting Chart. The troubleshooting chart is prepared in three columns. Proper use of the chart will aid in the rapid determination and repair of any functional difficulties that may occur.

IN-BOAT REPAIRS

General. There are a few components which can be replaced while the marine gear is mounted in the boat on the engine. Because of its light weight and size, removing the unit from a boat should pose no great problems.

Oil Pump. The oil pump can be removed and replaced as follows: Disconnect the heat exchanger line from the pump outlet port and remove the four hex head cap screws which retain the pump to the selector valve body. Remove the oil pump and

TROUBLESHOOTING

Problem	Possible Cause	Test Procedure/Remedy
1. Low oil pressure.	1-A. Partially clogged oil strainer.	1-A. Remove and clean oil strainer.
	1-B. Stuck regulator valve piston in selector valve assembly.	1-B. Remove the selector valve and clean and inspect the regulator valve.
	1-C. Broken seal rings on clutch shaft.	1-C. Remove the collector and valve body and replace oil seal rings on shafts.
	1-D. Damaged or worn oil pump assembly.	1-D. Remove and replace oil pump assembly.
	1-E. Improper selector valve linkage adjustment.	1-E. Adjust control linkage to selector valve properly.
2. No oil pressure.	2-A. Low oil level or empty sump.	2-A. Check unit for oil leakage. Repair and refill properly.
	2-B. Fully clogged oil strainer.	2-B. Refer to Remedy 1-A.
	2-C. Damaged or worn oil pump assembly.	2-C. Refer to Remedy 1-D.
3. High oil pressure.	3. Stuck regulator valve piston in selector valve body.	3. Refer to Remedy 1-B.

Problem	Possible Cause	Test Procedure/Remedy
4. Overheating.	4-A. Insufficient heat exchanger capacity.	4-A. Install proper heat exchanger.
	4-B. Insufficient cooling water flow.	4-B. Inside diameter of water lines too small. Replace lines with ones of proper size.
	4-C. Clutch slipping.	4-C. Low oil pressure at clutch will cause slippage. Refer to Symptom 1.
	4-D. Oil level too high.	4-D. Correct oil level.
	4-E. Improper oil in sump.	4-E. Drain and fill marine gear with proper oil.
5. Excessive noise.	5-A. Excessive backlash in gears.	5-A. Backlash expected to be 0.005-0.016 in.
	5-B. Bearing failure.	5-B. Remove and overhaul marine gear, replacing the defective parts.
	5-C. Torsional isolator worn excessively.	5-C. Replace torsional isolator after marine gear removal.
6. No neutral.	6-A. Clutch plates warped.	6-B. Replace clutch plates. Overhaul unit.
	6-B. Selector valve incorrectly positioned.	6-B. Check and adjust control linkage.

gasket from the valve body. Remove the access plug and remove the pump suction strainer from the valve body. Clean and replace the oil strainer. Install the oil pump reversing the removal procedures. Tighten the pump retaining screws to 15 - 17 ft. lbs. (2.06 - 2.34 kg/cm) torque.

Selector Valve. The selector valve and/or the collector should be removed as a pair because of the jumper connecting tubes between them. They can be removed with the marine gear mounted in the boat. Remove the oil pump first as in pagagraph above. Then, remove the linkage from the selector valve and remove the five (5) hex head cap screws, three (3) short and two (2) longer ones from the selector valve body, which retain the body to the rear cover. Remove the four (4) hex head cap screws which secure the collector to the rear cover. Remove the valve body and collector from the rear cover as an assembly. Separate the valve body from the collector and connecting tubes. Pull the tubes from whichever part they remain in. Before installation of these parts, inspect the connecting tube O-rings to see if they are still serviceable and clean the mounting area on the rear cover of all old plastic gasket coumpound. Apply new plastic gasket compound to the valve body and collector mounting areas on the rear cover. Install the valve body and collector, using the reverse of the removal procedures. Tighten the cap screws on the valve body to 27 - 30 ft. lbs. (3.72 - 4.14 kg/cm) torque and the cap screws on the collector to 61 - 68 ft. lbs. (8.41 - 9.38 kg/cm) torque.

Output and Coupling Flanges. The output and coupling (companion) flanges can be removed with the marine gear mounted to the engine. However, a realignment check, as covered in the section at the rear of this manual, pertaining to marine gear installation, must be executed upon reinstallation. Remove the six (6) mounting bolts and nuts which retain the companion flange to the output flange. Be sure to match mark each flange as the holes are line reamed to each other. Remove the retaining cap screw, retainer washer (with lathe-cut seal ring), and the output flange from the output shaft. Use a puller to remove from the splined area of the shaft. The flange double-lipped oil seal can be removed and replaced at this time. The seal is destroyed in removal. Install the new seal squarely in the bore of the rear cover and tap the seal inward until the seal casement is flush with the exterior of the seal bore. Install these parts in the revrse order of removal procedures. Tighten the retaining screw into the

6. **Breather.** Remove the breather and reducer from the rear cover only if cleaning and/or replacement of the parts is necessary. Figure 11.

7. **Oil Level Gauge.** Remove the oil level gauge and screw from the oil level tube. Figure 11. Remove the tube from the main housing.

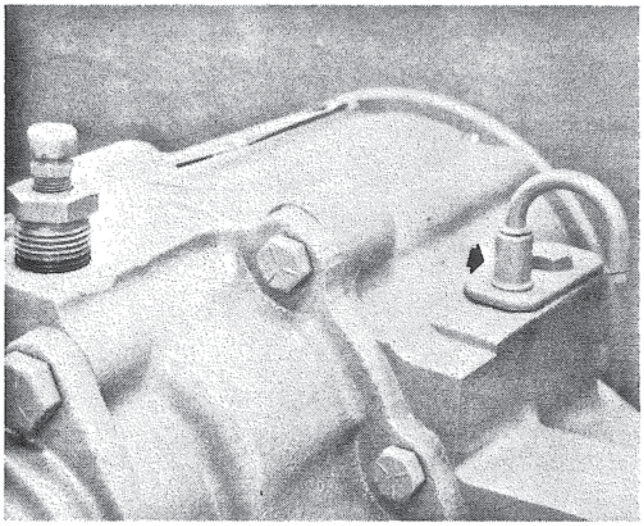


Figure 11. Breather and Oil Level Tube Locations.

8. **Expansion Plug.** Use a punch and remove the output shaft, front bearing bore, expansion plug. Figure 12.

Remove the reverse clutch shaft, front bearing bore, expansion plug only if replacement of the parts is necessary. Remove the reverse clutch shaft front bearing internal snap ring only if replacement of the part is necessary.

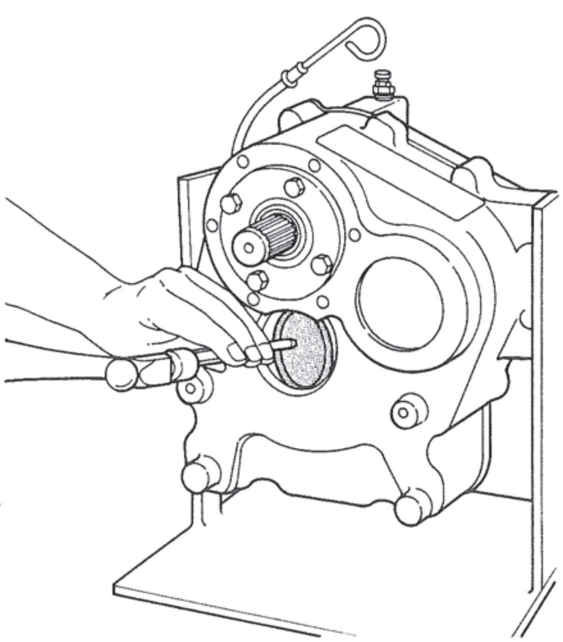


Figure 12. Removing Expansion Plug.

Output Shaft and Front Bearing.

1. Remove the bearing retainer washer, screw washer, and shims (3) from the bearing bore. Figure 13.

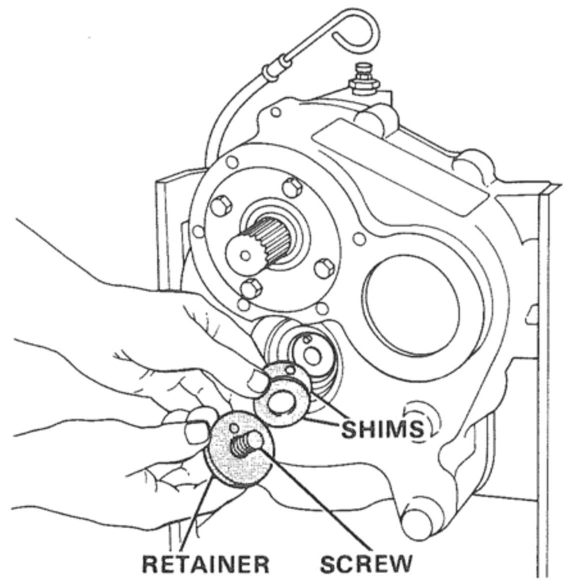


Figure 13. Removing Retainer, Screw and Shims.

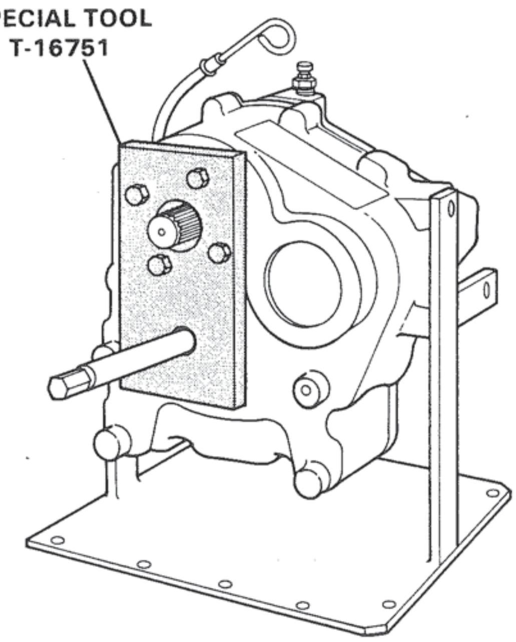


Figure 14. Special Tool No. T 16751 in Place.

2. **Output Shaft.** Remove the four (4) hex head cap screws which secure the bearing retainer onto the main housing over the input (forward) clutch shaft. Figure 14. Use longer screws (3/8-16 x 1-7/8) and attach Special Tool No. T 16751 output shaft remover onto the main housing on top of the bearing retainer.

Rear Cover Assembly. Remove the nine (9) hex head cap screws and remove the rear cover, pushing the output shaft from its front tapered roller bearing with the jack screw of Special Tool No. T 16751. Figure 15. The output shaft separates with the rear cover.

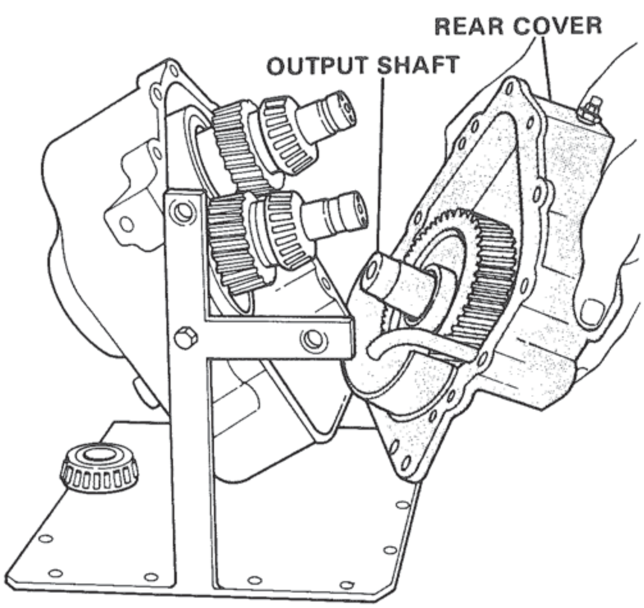


Figure 15. Removing Rear Cover Assembly.

Clutch Shaft Assemblies. Remove the reverse and forward clutch shaft assemblies from the main housing. Figures 16 and 17.

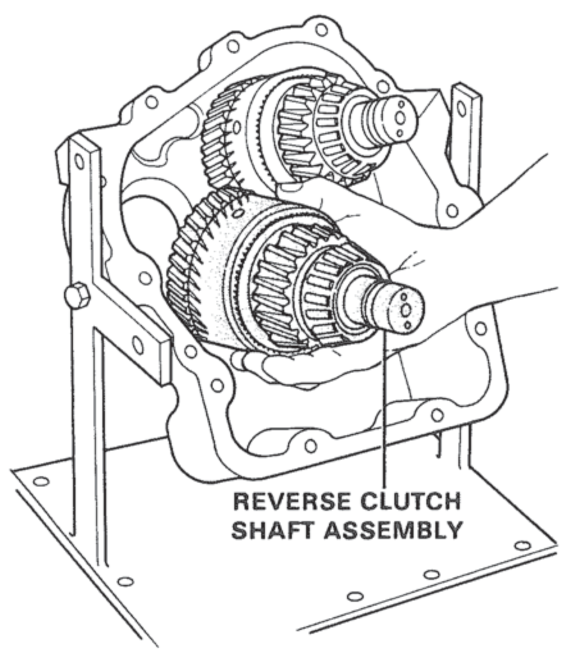


Figure 16. Removing Reverse Clutch Assembly.

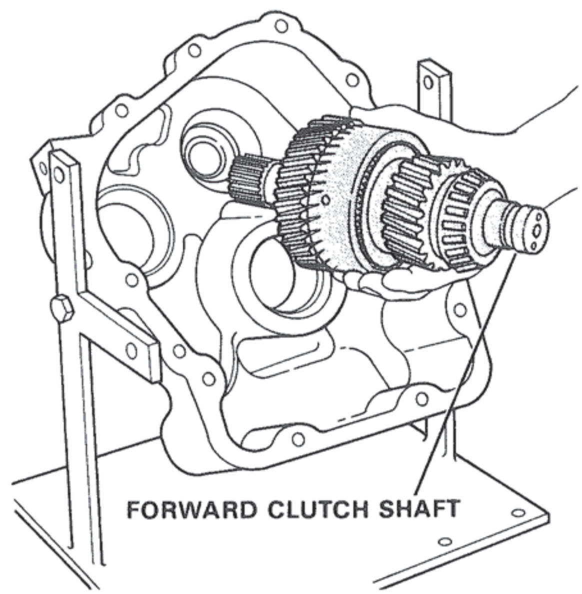


Figure 17. Removing Forward Clutch Assembly.

Output Shaft Flange.

1. Set the rear cover with attached parts on the bench so the output flange faces up. Remove the output flange retainer screw washer, and lathe-cut seal ring. Figure 18.

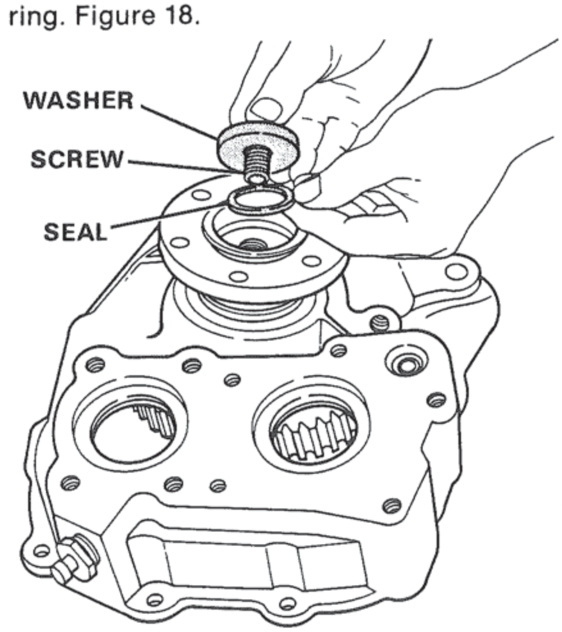


Figure 18. Removing Screw, Washer and Seal.

2. Use a puller, and remove the output flange from the output shaft. Figure 19.

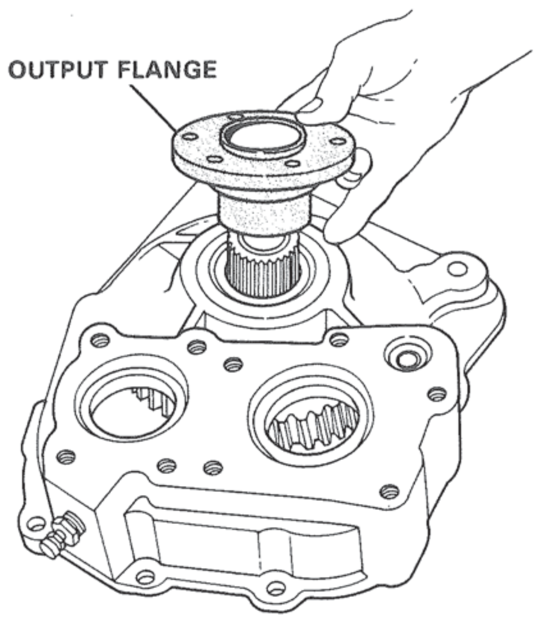


Figure 19. Removing Output Flange.

OUTPUT GEAR PAN AND SHAFT.

1. **Gear Pan.** Remove the two hex head cap screws and remove the gear pan from the rear cover. Figure 20.

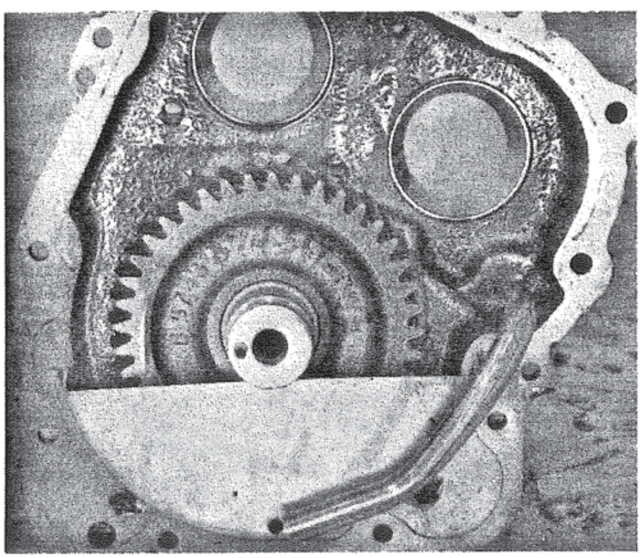


Figure 20. Removing Gear Pan.

2. **Output Shaft.** Install Special Tool No. T-16753 onto the rear cover. With this tool, pull the shaft and gear from the rear tapered roller bearing cone assembly. Figure 21.

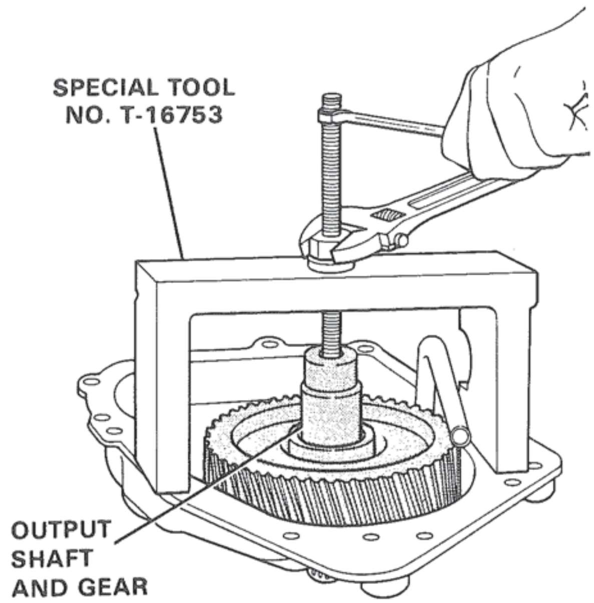


Figure 21. Removing Output Gear and Shaft from Rear Bearing Assembly. (Special Tool No. T-16753).

There is normally, no reason to remove the output gear from the output shaft. If gear replacement is necessary, the gear can be pressed from the shaft using approximately 32 tons static force, pressing through gear hub.

REAR OUTPUT SHAFT FLANGE OIL SEAL — BEARING CUP.

Oil Seal and Bearing. Press the oil seal and bearing rearward from the rear cover. Figure 22. The bearing spacer should have removed from the shaft with bearing cone removal.

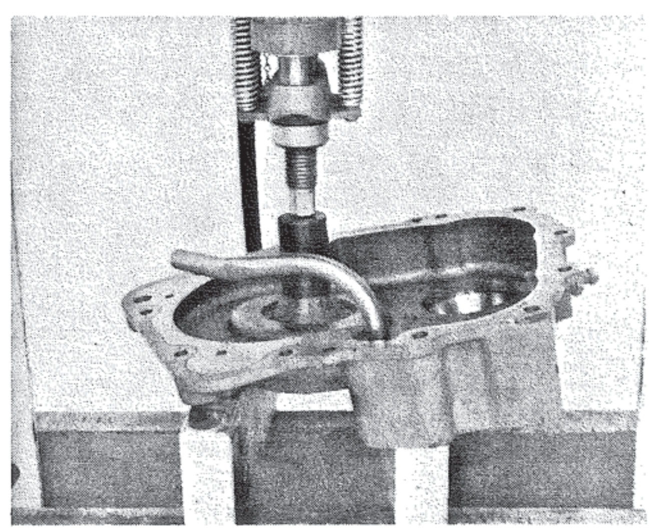


Figure 22. Removing Oil Seal and Bearing.

REVERSE CLUTCH SHAFT.

1. **General.** Place the reverse clutch shaft on the bench so the rear section faces up. Remove the two piston type hook end oil seal rings. Attach a bearing puller and remove the rear tapered roller bearing cone. Figure 23.

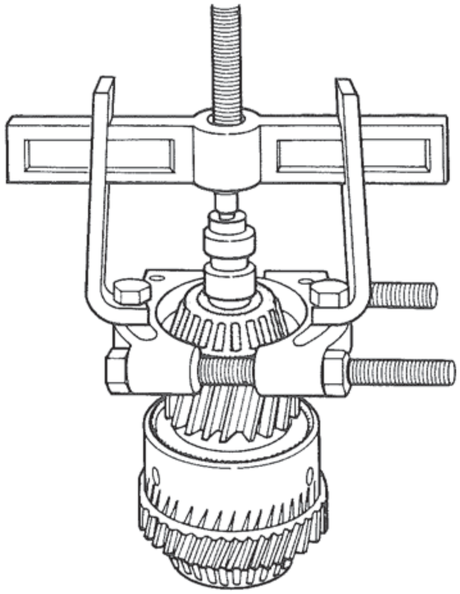


Figure 23. Pulling Rear Tapered Roller Bearing.

2. **Thrust Bearing Assembly.** Remove the thrust washer, needle thrust roller bearing and thrust washer from the clutch shaft. Figure 24.

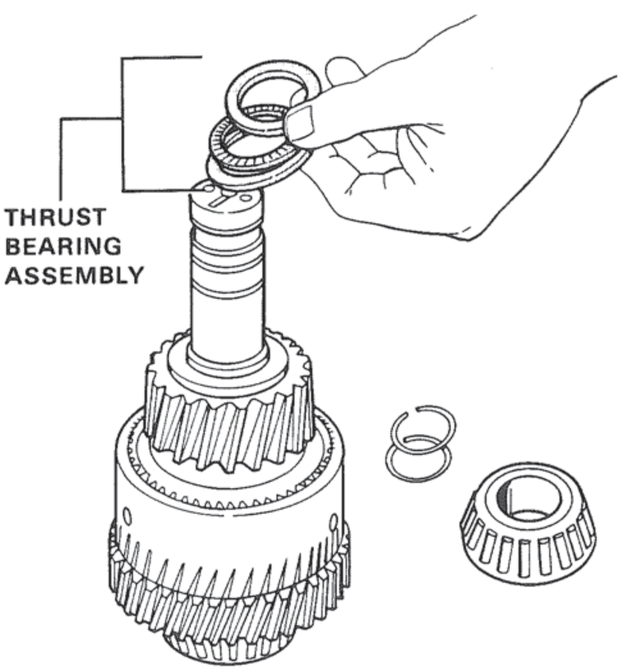


Figure 24. Removing Thrust Bearing Assembly.

3. **Reverse Pinion Gear.** Remove the reverse pinion and thrust bearing assembly from the clutch shaft. Figure 25.

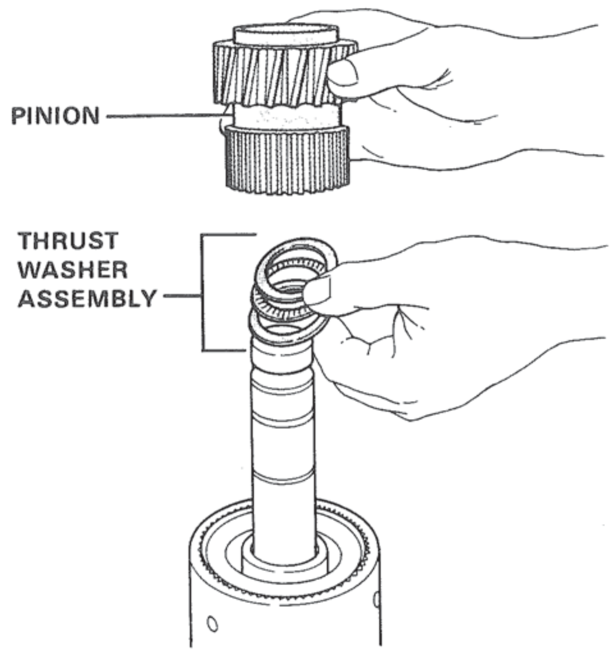


Figure 25. Removing Pinion and Thrust Bearing Assembly.

4. **Clutch Piston Return Spring.** Attach the spring compressor tool T-16752 to the clutch shaft and attached parts, and compress the spring with pressure on the spring retainer until the snap ring is exposed. Remove the snap ring with a snap ring plier. Figure 26.

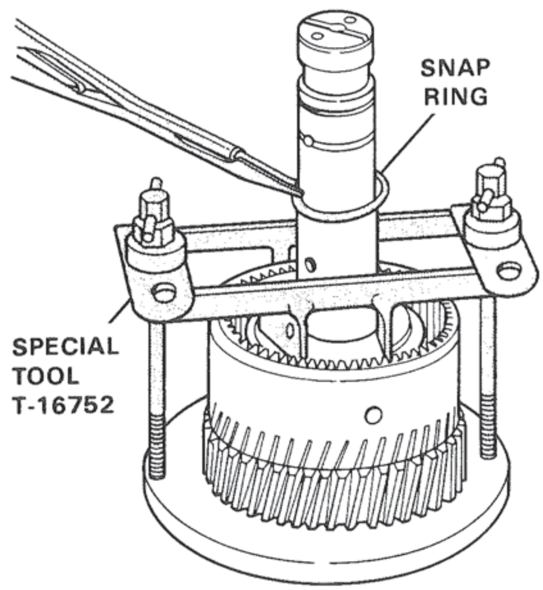


Figure 26. Removing Snap Ring. (Special Tool No. T-16752).

5. Remove the back plate retaining snap ring, and remove the back plate, the faced and steel clutch plates from the transfer gear and clutch shaft. Figure 27.

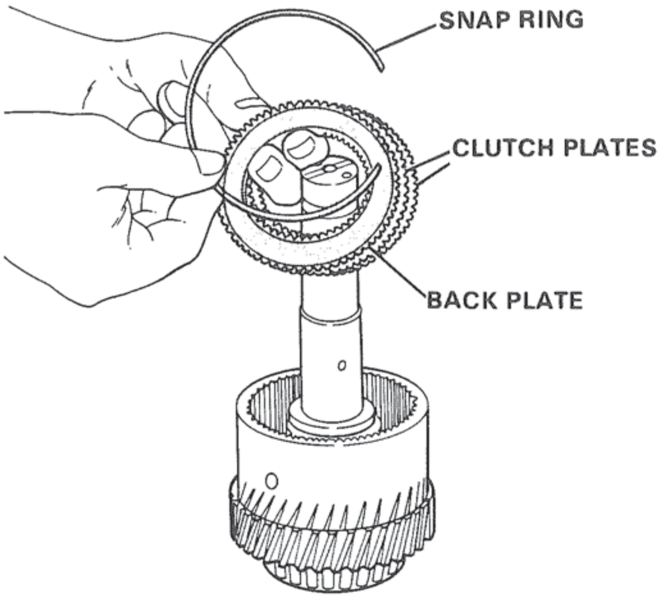


Figure 27. Removing Snap Ring, Back Plate, and Clutch Plates.

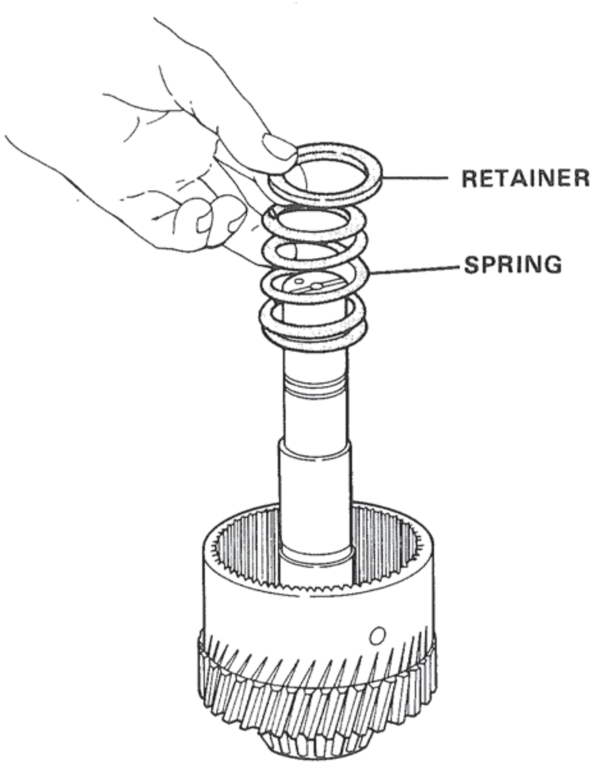


Figure 28. Removing Clutch Piston Return Spring and Retainer.

6. Remove the clutch spring retainer and clutch piston return spring from the clutch shaft. Figure 28.

7. **Clutch Piston.** Remove the clutch piston from the transfer gear and clutch shaft. Figure 29. Remove lathe-cut seal ring and piston type hook end ring from the piston.

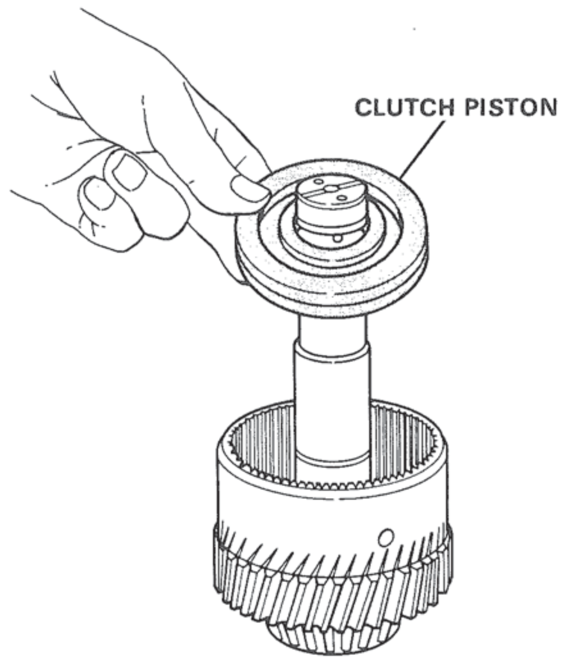


Figure 29. Removing Clutch Piston.

Forward (Input) Clutch Shaft Disassembly. The procedures of disassembly are the same for the forward clutch shaft assembly as those described in the paragraph for the reverse clutch shaft.

Suction Tube. The suction tube, rolled into the rear cover is not removed in the field, normally. The tube replacement requires special internal rolling tool.

CLEANING AND INSPECTION

GENERAL.

1. **Oil Seals.** Replace all oil seals.

2. **Gaskets.** Replace all gaskets.

3. **Piston or Lathe-Cut Oil Seal Rings.** Replace all piston or lathe-cut oil seal rings.

4. **O-rings.** Replace all O-rings.

5. **Expansion Plugs.** Replace all expansion plugs removed or leaking.

6. **Snap Rings.** Replace distorted or damaged snap rings.

7. **Shims.** Replace damaged shims.

CLEANING.

1. **Roller Bearings.** Use standard maintenance procedures to clean all roller bearings.

2. **Oil Pump Assembly.** Use fresh cleaning agent to flush the oil pump assembly.

3. **All Other Parts.** Thoroughly clean all other parts with a suitable cleaning agent. After cleaning, dry with compressed air. Lubricate all machined surfaces with clean oil. Examine each part after cleaning to make certain all foreign matter has been removed.

CAUTION

Do not use any abrasive material on selector valve parts as damage will result.

INSPECTION.

1. **Roller Bearings.** Use standard maintenance procedures to inspect all roller bearings.

2. **Castings.** Inspect all castings for cracks. Replace a cracked casting.

NOTE

The main housing and rear cover are not serviced separately.

Inspect all bearing bores and mounting faces for wear, grooves, scratches, etc. Remove burrs and scratches with a crocus cloth. Inspect tapped holes for damaged threads. Chase damaged threads with a used tap of the correct size. Replace castings which cannot be repaired.

3. **Splined Parts.** Inspect all splined parts for worn, twisted, chipped, or burred splines. If possible, remove these defects with a soft stone. Replace a splined part that cannot be repaired.

4. **Threaded Parts.** Inspect all threaded parts for damaged threads. Repair damaged threads with a thread die, or file, or a three-cornered fine file. Replace a threaded part that cannot be repaired.

5. **Pressure or Temperature Gauge.** Inspect the gauges and connecting lines for damage. Replace damaged parts.

6. **Torsional Isolator Drive.** Inspect the drive plate and hub of the torsional isolator for cracks, rivet looseness, etc. Replace a damaged or defective torsional isolator assembly.

7. **Heat Exchanger — Flexible Hose Lines.** Inspect the heat exchanger for leaks, damaged mounting brackets, and connections. Check the zinc electrode on salt water installations. Inspect the hoses for cracks, sponginess, or other damage. Repair or replace parts as required.

8. **Gear Teeth.** Inspect all gear teeth for cleanliness and damage. Foreign particles tend to collect in the root of the gear teeth. Clean thoroughly and repair minor damage with a fine file or crocus cloth. Replace a gear that cannot be repaired.

9. **Orifices and Small Oil Passages.** It is very important that all orifices and small oil passages be clean and clear. Inspect these in the selector valve body and collector. Also, the clutch shafts. Use a pipe stem cleaner or small wire to probe and clear the small oil passages.

10. **Clutch Plates.** Inspect the clutch plates for damaged spline teeth and excessive wear. The grooves in the faced plates control the flow of cooling and lubricating oil. When the grooves are very shallow, due to material wear, the plate is no longer serviceable and must be replaced. The exact serviceable depth of plate grooves is subject to so many variables that the best policy is to replace doubtful appearing plates. Replace plates with damaged or worn spline teeth.

ANAEROBIC SEALANT APPLICATION

This procedure is to be used for assembly of joints where anaerobic sealant is used to provide a seal between mating surfaces. It applies to joints where a seal against leakage of oil, grease, gasoline, diesel fuel, hydraulic fluid, water, and air is to be achieved.

Surface Condition. Machining accuracy of flange faces must provide .003 in. max. gap between assembled mating surfaces.

Surfaces of cup plugs, expansion plugs, and shims to be in "as received" condition but must also provide .003 in. max. gap.

Approved Sealant. The recommended sealant is "Loctite plastic gasket," Twin Disc part numbers M2828 and M2828A.

Application Procedure.

1. For previously sealed joints, scrape surfaces to remove old plastic gasket material. Gel type paint removers containing methylene chloride can be used to wipe off cured sealant.

CAUTION

This material may chemically burn skin so follow vendor's directions carefully.

1. **Thrust Bearing Assembly.** Install the thrust race against the spring retainer over the clutch shaft. Figure 33.

2. Install the needle thrust roller bearing over the clutch shaft against the thrust race. Install the thrust race over the clutch shaft against the needle thrust roller bearing.

1. **Clutch Hub and Pinion.** Install the clutch hub and pinion onto the clutch shaft and against the thrust bearing race. You will have to twist and shake the hub to mesh the splines of the hub with the internal spline teeth on the steel clutch plates.

1. **Thrust Bearing Assembly.** Install the thrust race against the hub and pinion, over the clutch shaft. Figure 34.

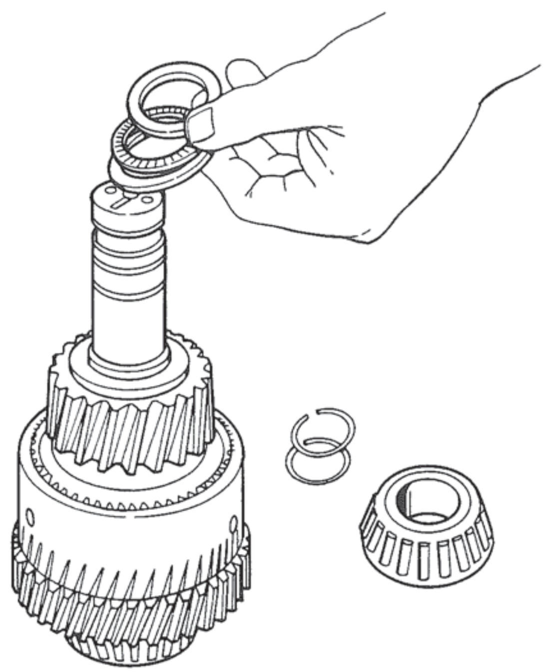


Figure 34. Installing Thrust Bearing Assembly.

2. Install the needle thrust roller bearing against the thrust race.

3. Install the thrust race against the needle thrust bearing.

1. **Tapered Roller Bearings.** Maintain shaft in an upright position. Heat and install the rear cone assembly.

2. Install front bearing cone assembly onto shaft. Don't hammer bearing cones into place as plates will jump out of their splines and cause a failure.

3. Pressing bearing cone assembly into place is acceptable. Press the front bearing cup into its bearing bore in the main housing to bottom against the snap ring. The back face of the cup is squarely machined to seat against the snap ring.

4. Press the rear bearing cup into its bore of the rear housing. Press the cup from the rear toward the front with the cup back face to the rear. Press the cup slightly below, or almost flush with the rear of rear cover.

Forward (Input) Clutch Assembly. The assembly of the forward or input clutch assembly is the same as the reverse clutch except for front tapered roller bearing cup installation.

OUTPUT SHAFT ASSEMBLY.

1. **Output Gear.** Assemble gear over shaft taper and seat with 500 lb. force. Press gear in place to achieve .050-.080 advance. Thirty-two (32) tons force is expected. Maximum runout from shaft centers to gear face opposite cone face .005 TIR.

2. Install the output shaft bearing spacer over the shaft and against the rear of the gear hub. Figure 35.

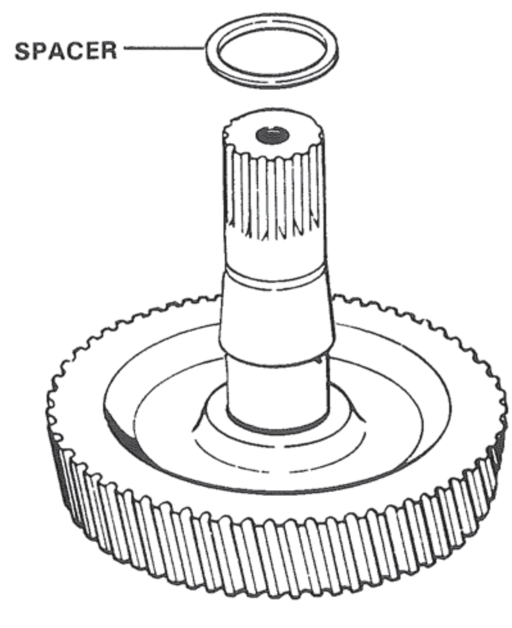


Figure 35. Assembling Ouput Shaft.

Output Shaft Rear Bearing Cup. Press the output shaft rear bearing cup into its bore in the rear cover assembly. The cup back face should bottom against the shoulder in the bore. The narrow front face of the cup faces rearward.

REAR COVER ASSEMBLY.

Output Shaft. Install the output shaft with attached parts into its bore of the rear housing. Check to see that bearing spacer remained in position on the output shaft. Heat and install the tapered bearing cone to butt tightly against spacer.

1. **Gear Pan.** Place the gear pan over the bottom section of the output gear against the rear cover.

2. Secure the gear pan to the cover with two (2) hex head cap screws (5/16-18 x 1/2). Tighten the screws to 15-17 ft. lbs. torque. Figure 36.

1. **Forward Clutch Shaft Rear Bearing.** Install the rear bearing cup in its bore of the rear cover.

2. Press the cup into the bore from the rear until the back face of the cup is flush or slightly forward of the rear surface of the rear cover.

MAIN HOUSING ASSEMBLY.

1. **Output Shaft Front Bearing Cup.** See respective page for procedures involved in use of anaerobic sealant application. Install the cup retaining and locating internal snap ring in the groove provided in the bearing bore.

2. Press the bearing cup from front to rear, back face first, to bottom against the snap ring. Figure 50.

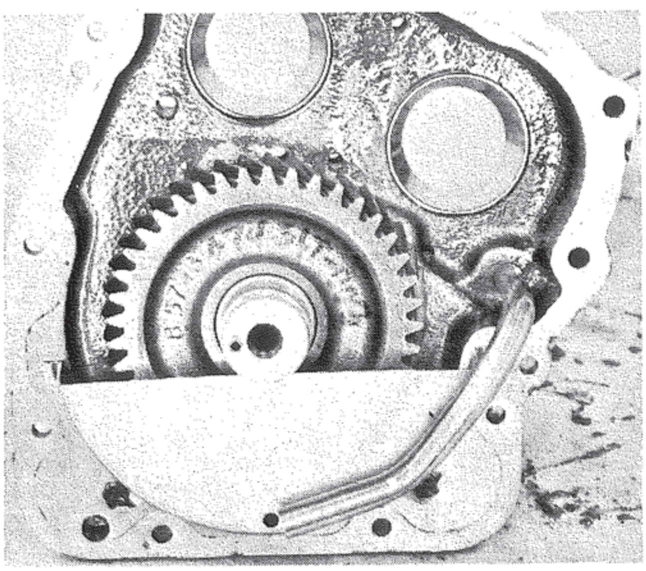


Figure 36. Installing Gear Pan.

1. **Assembly of Components into Main Housing.** Mount the main housing in the stand or fixture in a position with the rear or open end up. Place the reverse clutch shaft assembly into its bore of the housing.

2. Place the forward (input) clutch shaft into its bore of the main housing. Apply a thin line of anaerobic plastic gasket compound having a viscosity of 20,000 centipoises to the mating (parting) surface of the main housing and rear cover. The Twin Disc Part Numbers M2828 and M2828A meets these requirements. The plastic gasket must be capable of sealing at operating temperatures of 0° F to 210° F. Carefully set the rear cover with attached parts onto the main housing, locating the clutch shafts in their bores and the output shaft in its bore of the main housing.

3. Index the rear cover onto the dowel pins of the main housing and tap the cover in place over the dowels.

4. Secure the rear cover to the main housing with nine (9) hex head cap screws (3/8-16 x 7/8). Tighten the cap screws to 27-30 ft. lbs. (3.72 - 4.14 kg/cm) torque.

ADJUSTMENT OF BEARING END PLAY

General. There is only one acceptable method to measure the bearing end play for the tapered roller bearings used in the marine gear. This method is to dial indicate the shaft end play. Trial shim packs can be selected by use of depth micrometer measurements, but actual end play of the shafts must be taken as final check.

Select Trial Shim Pack. Use a depth micrometer and measure the distance from the collector pilot to the machined surface. Figure 37.

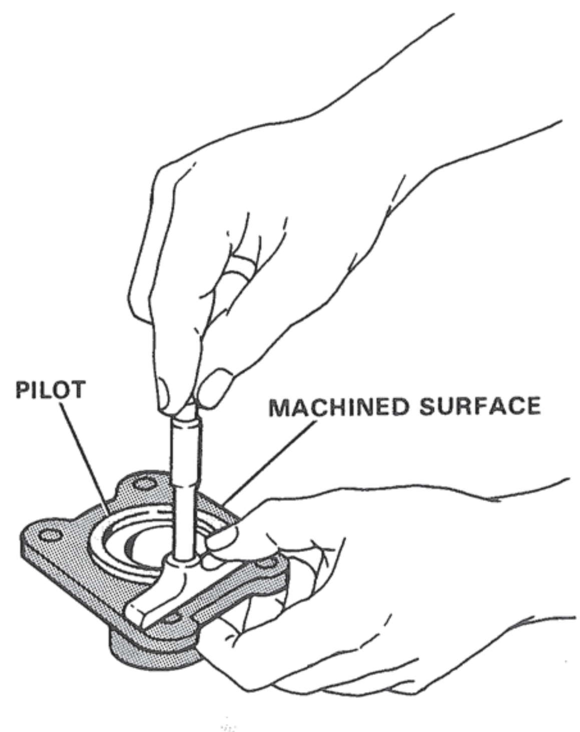


Figure 37. Measuring Collector Pilot to Machined Surface.

1. **Reverse Clutch Shaft End Play.** Install the trial shim pack behind the rear bearing cup of the reverse clutch shaft. Figure 38.

2. Install the valve body over the reverse clutch shaft and onto the rear cover. Secure the valve body with three (3) hex head cap screws (3/8-16 x 2-1/2), one (1) hex head cap screw (3/8-16 x 5), and one (1) hex head cap screw (3/8-16 x 4-1/4). Tighten cap screws to 27-30 ft. lbs. (3.72 - 4.14 kg/cm) torque.

3. Attach a lifting eye with a ten in. stem into the threaded hole of the clutch shaft. Figure 39. The hole is a (5/16-18 x 5/16) thread. Mount a dial indicator so the stem or finger of the indicator contacts the end of the clutch shaft outside the eye bolt hole. This is necessary to permit the shaft to rotate with the dial indicator in position. Mark a spot next to the indicator stem. Apply a 100-300 lbs. force, approximately, downward on the clutch shaft, and while maintaining this force turn the shaft two (2) full turns. Continue the pushing force and zero the dial indicator. Pull steadily with a 100-200 lbs. force (hoist) while turning the shaft through two (2) complete turns. Continue the force, and read the indicator stopped on the selected spot. The indicator now shows the actual bearing end play. Select shims to obtain the end play of 0.003-0.005 in., preferably near the low end of this range. Mark and set the final selected shim pack aside for final assembly later.

1. **Forward (Input) Clutch Shaft End Play Check.** The same procedures covered above in the previous paragraph are used for the forward clutch shaft and collector, exception being in checking end play from opposite end.

2. The method of pushing and pulling the clutch shaft varies because of the inaccessability of the rear of the shaft with collector mounted.

3. Install an oil seal double lip type into the bore of the bearing retainer. Press the seal, dust lip outboard and oil lip inboard, into the bore from the front until the seal casement is flush with the outer surface of front of bore. Prelubricate the seal.

4. Apply plastic gasket to mounting area of retainer and main housing.

5. Install the bearing retainer over the input end (splined) of the forward clutch shaft and against the main housing. Secure the retainer with four (4) hex head cap screws (3/8-16 x 7/8). Tighten the cap screws to 27-30 ft. lbs. (3.72 - 4.14 kg/cm).

6. Follow the same procedure for checking the end play as given for the reverse clutch shaft. Use cardboard or reasonable facsimile to protect the splines, and with a vise grip plier apply force downward and upward as described.

7. The collector mounting cap screws — four (4) hex head (1/2-13 x 1-1/4) are tightened to 61-68 ft. lbs. (8.41 - 9.38 kg/cm) torque for the end play check.

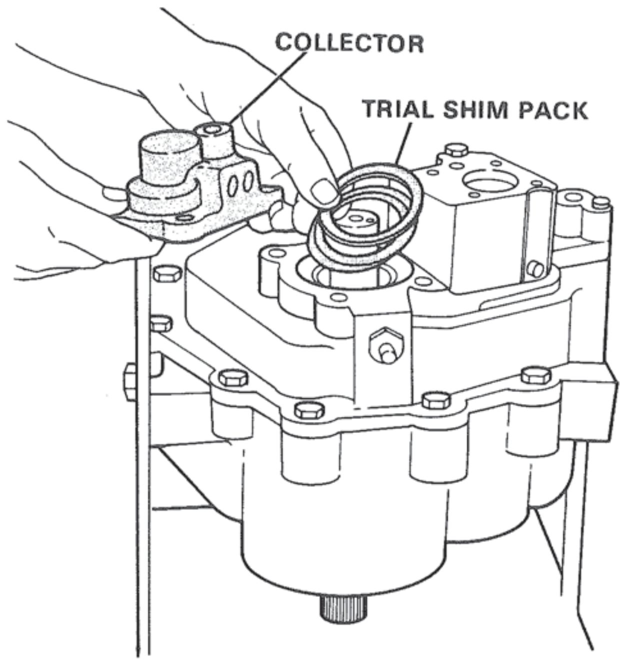


Figure 38. Installing Trial Shim Pack and Collector.

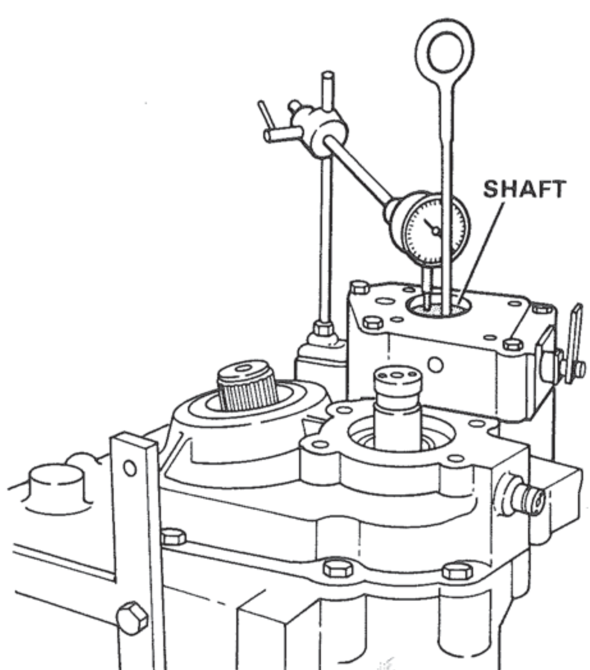


Figure 39. Dial Indicator Mounted for End Play Check-Reverse Clutch Shaft.

1. **Final Assembly of Valve Body and Collector.** Install the thrust race, springs and regulator piston into their bore of the valve body.

2. Install the O-ring into its groove on the valve stem. Prelubricate the O-ring and valve stem and install the stem into the valve bore against the regulator piston and springs. Be sure the piston enters its hole in the valve stem.

3. Secure the valve stem in the valve body with the detent plate and two (2) hex head cap screws (5/16-18 x 3/4). Figure 40. Tighten the cap screws to 5-17 ft. lbs. (.69 - 2.34 kg/cm) torque.

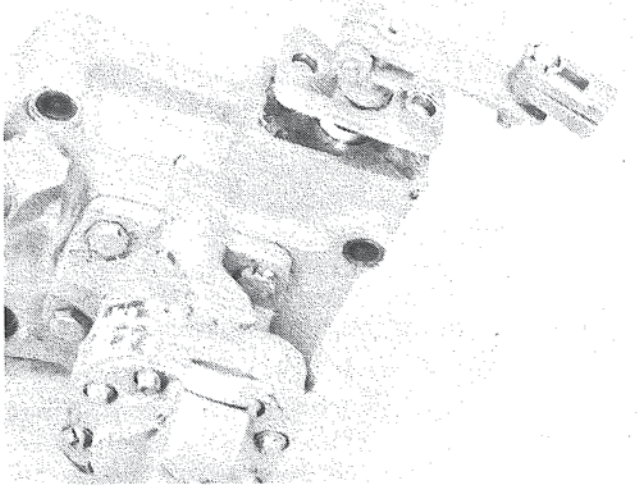


Figure 40. Installing Valve.

4. Attach the lever to the valve stem and retain the lever to the stem with hex head cap screw (1/4-20 x 1) and nut. Do not torque tighten at this time.

5. Install O-rings in their grooves of the connecting tubes. Prelubricate the O-rings and connecting tube bores of the collector and valve body. Install the connecting tubes into the collector bores, and install the valve body over the connecting tubes.

6. Apply a strip of plastic gasket to the valve body, collector, and rear cover mounting areas.

7. Install two (2) piston type oil seal hook end rings in the end grooves on the reverse shaft and two (2) similar oil control rings in the end grooves of the forward (input) clutch shaft. Prelubricate the rings. Figure 41.

8. Install the valve body and collector over their clutch shafts and onto the rear cover. Secure the collector and valve bodies to the rear cover. Use four (4) hex head cap screws (1/2-13 x 1-1/4) to secure collector. Figure 42. Tighten screws to 61-68 ft. lbs. (8.41 - 9.38 kg/cm) torque. Use three (3) hex head

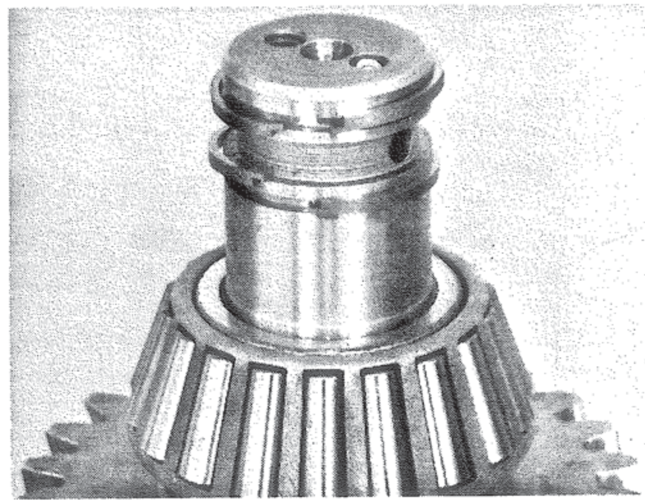


Figure 41. Installing Ring.

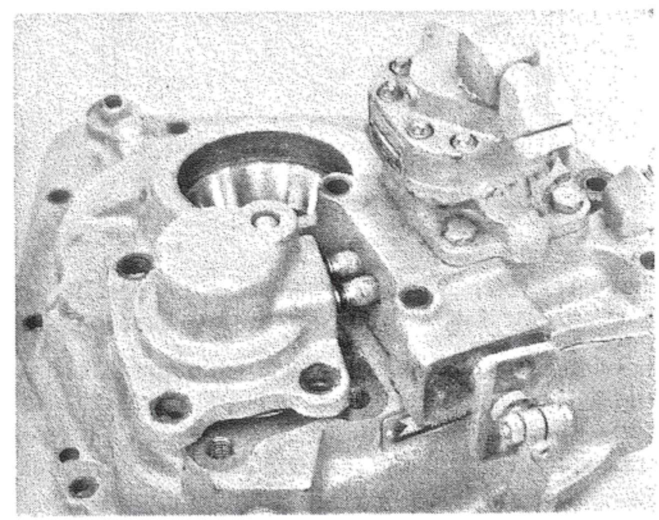


Figure 42. Installing Valve and Collector.

cap screws (3/8-16 x 2-1/2), one (1) hex head cap screw (3/8-16 x 5), and one (1) hex head cap screw (3/8-16 x 4-1/4). Tighten these cap screws to 27 ft. lbs. (3.72 kg/cm) torque.

1. **Output Shaft.** Install the double lip type oil seal into the bore of the rear cover with the oil lip inboard and the dust lip outboard. Press the seal into the bore until the seal casement is flush with the outer surface of the bore. Prelubricate the seal.

2. Heat the output flange to 150° F. Use a portable hydraulic press set and install the output flange. Install the lathe-cut seal ring, retainer washer, and hex head cap screw. Tighten the cap screws to 125-140 ft. lbs. 17.24 - 19.31 kg/cm) torque.

3. Place a support (steel or wood block) under the flange with the marine gear input end up. Figure 43.

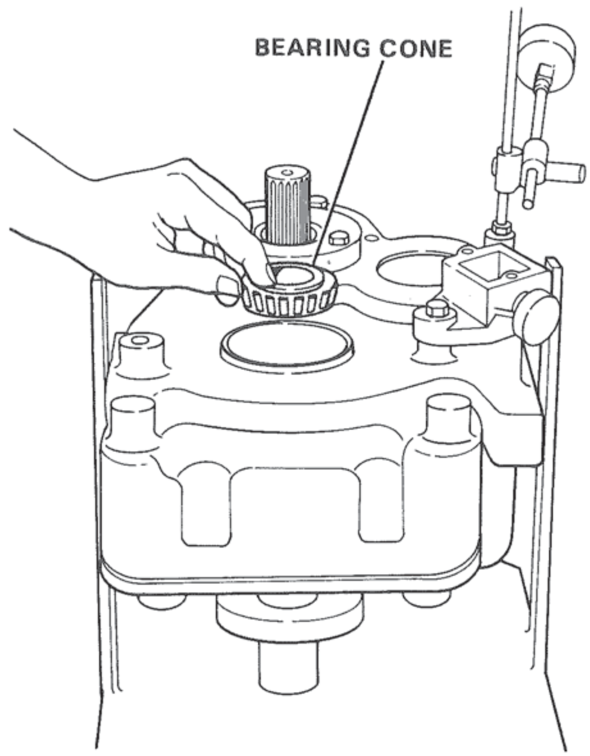


Figure 43. Installing Bearing Cone.

Install the roll pin into its hole in the front end of the output shaft if it was removed during disassembly.

4. Install the tapered bearing cone squarely on the end of the output shaft. Use the retainer washer and cap screw to advance the bearing cone approximately 3/4 up on the shaft. Do not seat bearing cone all the way. Once seated, you lose all end play and have to disassemble and start procedure over again.

5. Remove a screw and a washer and install trial shim pack. Measure the thickness of shim pack removed on disassembly and add approximately 0.005 in. more shim. Shims are available in 0.005, 0.007, and 0.020 in. sizes. Trial shim pack must be larger than desired shim pack.

6. Install the retainer washer, cap screw with trial shim pack, and using the cap screw advance the bearing cone onto the end of the shaft as far as shim pack will permit. Tighten the screw to 125-140 ft. lbs. (17.24 - 19.31 kg/cm) torque.

7. Turn the unit over in the stand and mount a dial indicator on the rear cover so the stem or finger rides on the output flange. Mark a spot on the flange next to the indicator stem. Figure 44.

8. Apply 100-300 lbs. force downward on the flange while rotating the output shaft through two (2) full turns. Continue the pushing force while setting dial

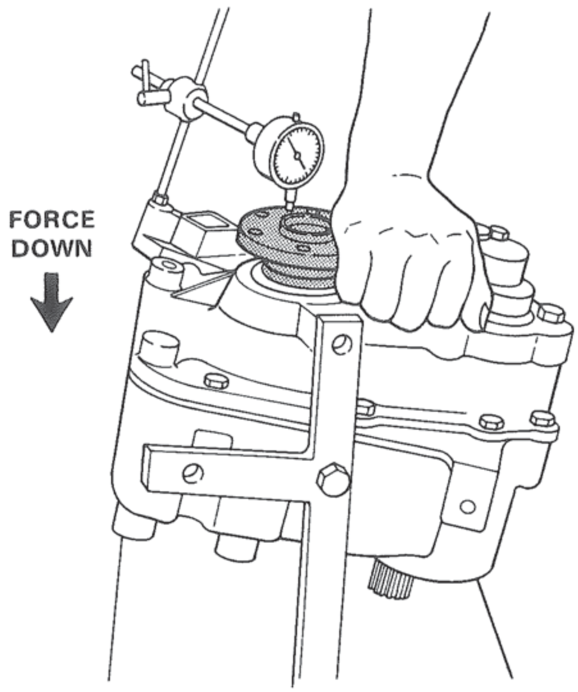


Figure 44. Checking End Play-Downward Force Used.

indicator to zero with the finger (stem) on selected spot.

9. Apply a 100-300 lbs. force upward on the flange while rotating the shaft two (2) full turns. Figure 45. Continue the upward force, while reading the dial indicator with the stm stopped on the selected spot. The indicator should now show the acutal end play of the bearings.

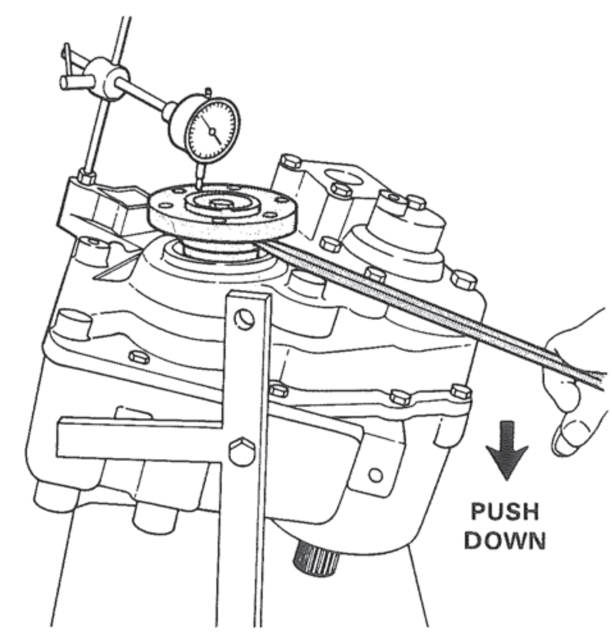


Figure 45. Checking End Play-Output Shaft.

10. Remove shims as required to bring the end play within the specified tolerance of 0.003-0.005 in.

11. After the output shaft end play has been adjusted, install the expansion plug. Apply plastic gasket to the bore area which contacts the expansion plug and install the plug.

MISCELLANEOUS AND EXTERNAL PARTS.

1. Drain Plug. Install the drain plug and tighten securely. Figure 46.

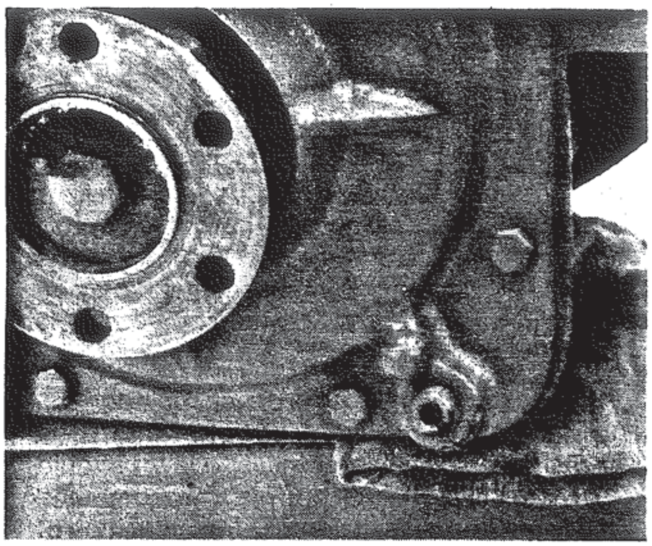


Figure 46. Installing Drain Plug.

2. **Oil Level Gauge Tube.** Install the oil level gauge tube into the main housing. Figure 47. Secure the tube in the housing with the two (2) hex head cap screws (5/16-18 x 5/8). Tighten the tube screw to 15-17 ft. lbs. torque. Install the oil level gauge into its tube.

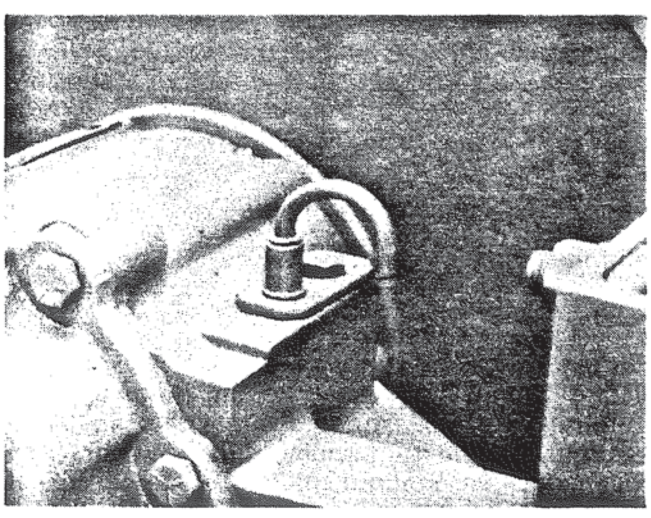


Figure 47. Installing Oil Level Gauge.

3. **Oil Strainer.** Install the oil strainer into its bore in the selector valve and rear cover. Figure 48. Install the O-ring and plug to cover the strainer opening in the valve body.

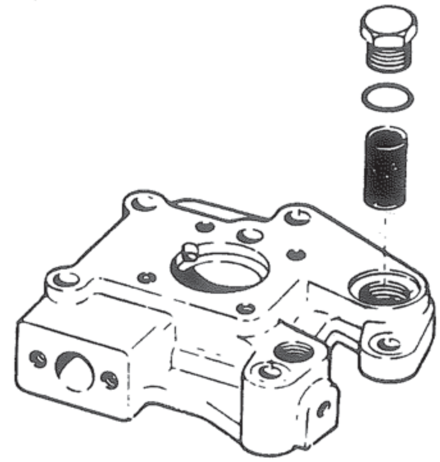


Figure 48. Installing Oil Strainer.

4. **Rotation Indicator.** Install the engine rotation indicator plate and secure it to the rear cover with two (2) drive screws if it was removed during disassembly.

5. **Name and Instruction Plate.** Install and secure the name and instruction plate to the top of the main housing with four (4) drive screws.

6. **Oil Pump.** Place an oil pump mounting gasket onto the valve body and secure the oil pump to the valve body with four (4) hex head cap screws (5/16-18 x 3-1/2). Figure 49. Tighten the cap screws to 15-17 ft. lbs. torque.

Figure 49. Installing Oil Pump.

7. **Breather and Reducer Bushing.** Install the reducer bushing and breather assembly into the provided threaded hole at the top of the rear cover. Figure 50. Later production units replace breather and bushing and incorporate breather function in new designed oil level gauge. A plug is used when breather and bushing are eliminated.

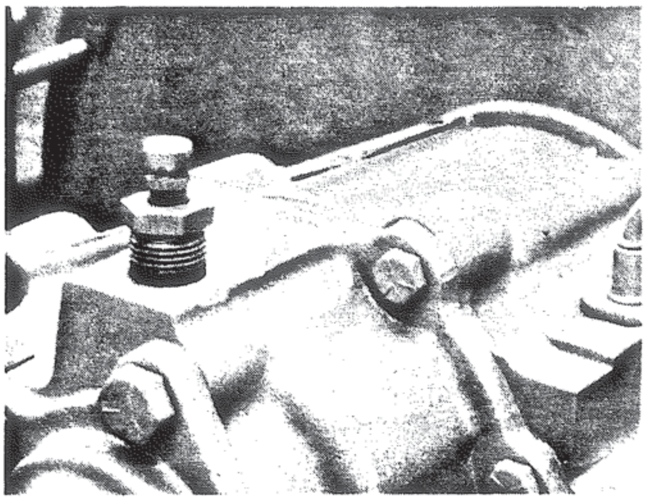


Figure 50. Breather Installation.

Runout Checks.

Input Shaft. Check the runout between the input shaft and the O.D. surface or pilot of the front bearing retainer. Maximum of 0.003 inch total indicator reading.

Flywheel Adapter (Optional from Twin Disc). Check the runout between the input shaft and flywheel adapter mounting surface on main housing, just beyond the bearing retainer. Approximately 2-1/4 inches from centerline of input shaft. Maximum allowable runout is 0.003 inch total indicator reading.

Output Flange. Check the runout between the output flange pilot and the rear cover. The maximum total indicator reading allowed is 0.004 inches. Check the runout between the flange face and rear cover. The maximum total indicator reading allowed is 0.004 inch.

Backlash. Roll all gears to insure no binding, then check the backlash. Roll the gears by rotating the input and output shafts. Attach a piece of (1/4 x 1) bar stock, approximately two (2) in. long with a hole near one end, to one of the holes in the output flange. The stock should extend beyond the periphery of the flange. Mark the bar stock four (4) in. out from the output shaft center line. Attach a dial indicator to the rear cover so the stem (finger) of the indicator can be adjusted to contact the bar stock at marked edge.

Rock the flange back and forth to feel the points of output and pinion gear tooth contact in each direction of rotation. Adjust the dial indicator at either point and rotate to either point noting indicator reading. Should read minimum of 0.005 in. backlash. Check the input transfer gear and reverse transfer gear backlash in a similar manner, using an extension radially from the spline of the input shaft of 2-1/4 in. from shaft centerline, and attaching dial indicator to main housing. Backlash should be minimum of 0.005 in.

CAUTION

MOUNTING TWIN DISC PRODUCTS

It is possible, due to mis-match of components or many other reasons, to have flywheel to driven component interference. As a result, it is necessary that engine crankshaft end play be measured before the driven component is installed.

After installation of the driven component, crankshaft end play should again be measured. This second measurement should be the same as the first end play measurement. If it is not the same, it could be an indication of interference. Consequently, the driven component should be removed, the source of interference found and corrected.

Twin Disc will not be responsible for system damage caused by engine to Twin Disc component interference regardless of the cause of the interference. This engine crankshaft end play check is considered mandatory.

Output Shaft Seals. Counting the expansion plug at the front of the output shaft in the main housing, three seals are used on the output group of parts. A double-lip type seal, spring loaded on the oil control side, is pressed into the rear cover. The seal lips ride on a seal-machined surface on the output flange. To seal possible leakage down the spline between the output flange and shaft, a lathe-cut seal ring is installed and retained with the flange retaining washer.

Output Flange. The output flange with a companion flange connects the shaft to the propeller. The output flange is constructed with a hub and flange section. The hub is internally splined to connect to the marine gear's output shaft. The external area of the hub is machined for a seal surface for the oil seal. The flange section is flat machined and drilled with six equally spaced holes for attaching the companion flange. The flange face surface must not exceed .004 inch total indicator reading when installed in marine gear. The pilot of the flange, must not have more than 0.004 inch total indicated runout. A companion flange will be supplied by Twin Disc on order only. The companion flange will have six bolts with self-locking nuts select ream-fitted to the holes. Also two setscrews will be installed in the hub of the companion flange ninety degrees apart. The hub will be shaft bored to accommodate customers propeller shaft size (customer must specify). If the customer requires a key seat (keyway), he must machine this himself on a center line through the flange which divides the setscrew centerlines, placing these forty-five degrees to each side. The keyway must be milled opposite the bore side from the setscrew holes. A lathe-cut seal ring, retainer washer, and cap screw secure the output flange to the marine gear output shaft.

Pertinent Information and Data. The following table of information provides important service information in one location.

TABLE I
SPECIFICATIONS

Oil Capacity. 3-1/2 pints U.S. measure (does not include heat exchanger and connections used externally). Fill to "full" mark on oil level gauge with engine at low idle speed and marine gear in neutral.

Oil Pressures. *Minimum oil pressure when cruising — 275 p.s.i. Oil pressure gauge attached to oil pump at port to heat exchanger (3/8-18 NPTF. Dry Seal). Use a "tee" connection fitting when heat exchanger is used.

OIL TEST PRESSURES

Input RPM	Shift	Min. PSI*	Max. PSI*
1800	Forward	310 (21.8 kg/cm²)	340 23.9 kg/cm²)
	Neutral	310 (21.8 kg/cm²)	340 (23.9 kg/cm²)
	Reverse	310 (21.8 kg/cm²)	340 (23.9 kg/cm²)
600	Forward	275 (19.3 kg/cm²)	335 23.6 kg/cm²)
	Neutral	290 (20.4 kg/cm²)	335 23.6 kg/cm²)
	Reverse	275 (19.3 kg/cm²)	335 23.6 kg/cm²)

** Oil temperature for test 85-95° F (29-35° C) viscosity 200-260 SUS.

Type Oil for Temperature. Engine HD SAE 30 at cooling water temp. 85° F (29° C) and above.

Engine HD SAE 20 at cooling water temp. 85° F (29° C) and below.

Oil Change Interval. check oil weekly or every 20 hours of operation. Clean suction screen and refill unit with clean oil yearly. To drain oil, remove drain plug, or use suction drain hose attached to oil level gauge tube. Fill oil to "full" mark on gauge with engine at idle speed and marine gear in neutral.

OIL PUMP CAPACITY.

New Pump Requirements. Pump to deliver 2.5 GPM @ 3000 pump RPM @ 330 p.s.i.

Normal Operating Conditions.

Pressure range .... 300-350 p.s.i. (21.1-24.6 kg/cm²)
Speed Range ....600-4400 pump RPM

Maximum Permissible Marine Gear Speed. 4000 RPM.

Dry Weight. 132 lbs.

1. Torque values for cap screws and bolts also apply to use in aluminum provided the thread engagement is twice the normal thread diameter and a hardened flat steel washer is used under the head. This table covers tightening torques for the majority of Twin Disc's use of cap screws and bolts in threaded steel, cast iron, aluminum and brass parts. Individual assembly drawings will show special requirements.

2. Use for all cap screws, bolts and nuts when dry or coated only with a rust preventative which is dry to the touch.

3. Use for all fasteners lubricated with moly-disulfide, when plated with zinc or cadmium, or when dipped in lubricating oil.

4. Socket head screws and 12 point head screws with full body are also grade 8.

TORQUE VALUES

FOR TIGHTENING CAP SCREWS, BOLTS & PIPE PLUGS.

CAPSCREWS, BOLTS & NUTS (1)					
TORQUE (FT.—LBS.) FOR COARSE AND FINE THREADS					
NOMINAL THREAD DIAMETER (INCHES)	SAE GRADE 5		SAE GRADE 8 (4)		Screws for Univ. Joint Bearing Caps
	DRY (2)	OILED (3)	DRY (2)	OILED (3)	OILED (3)
1/4	11-10	9-8	16-14	13-11	
5/16	21-19	17-15	30-27	24-21	
3/8	38-34	30-27	53-48	42-38	
7/16	55-50	44-40	78-70	62-56	67-60
1/2	85-77	68-61	118-108	95-86	105-95
9/16	125-115	100-90	177-162	140-127	
5/8	175-160	140-125	245-225	195-177	200-180
3/4	300-270	240-215	420-380	335-305	345-315
7/8	450-405	360-325	630-570	505-460	535-485
1	680-610	545-490	1100-1000	880-792	
1-1/8	860-770	690-620	1390-1250	1110-1010	
1-1/4	1150-1030	920-830	1860-1670	1490-1350	

3 DASHES
120° APART

6 DASHES
60° APART

SAE STANDARD HEX BOLT HEAD MARKINGS

12 Pt. Head
Undercut
Body

PIPE PLUGS		
RECOMMENDED TORQUE (FT.—LBS.)*		
NPT DIAMETER (INCHES)	IRON, STEEL & BRASS PLUG OR FITTINGS	
	IN CAST IRON OR STEEL	IN ALUMINUM
1/16	6.2-4.5	
1/8	10-7.5	
1/4	20-15	
3/8	25-19	
1/2	47-35	
3/4	59-44	
1	100-80	
1-1/4	130-105	
1-1/2	150-120	

* Must be used with compound, John Crane insoluble plastic lead seal No. 2 or equivalent.

This table covers tightening torques for leak proof joints sealing oil up to 500 p.s.i. and air up to 100 p.s.i. and vacuum lines. Can use 2/3 of above values if not over 5 p.s.i. oil or 3 p.s.i. air is being sealed. Torqueing hot units tends to cause more difficult plug removal.

TORQUE VALUES — FOR TIGHTENING BEARING LOCK NUTS

Size	M-2012	M-2281	Torque Lb. Ft. (2)	M-2012	Torque Lb. Ft. (2)	M-2037	Torque Lb. Ft. (2)
03	A		44-40				
04	B		77-70				
05	C	C	88-80				
06	D		110-100				
07	E		165-150			E	240-220
08	F	F	190-170	AF	265-240	F & AA	300-270
09	G	G	220-200	AG(1)	320-290	G	320-290
10	H	H	290-260	AH	410-370	H	420-380
11	J	J	320-290	AJ	440-400	J	440-400
12	K	K	375-340	AK	520-470	K	540-490
13	L		450-410	AL	660-600	L	660-600
14	M	M	510-460	AM	740-670	M	730-660
15	N	AJ	620-560	AN	890-810	N & AN	900-820
16	P	P	680-620	AP	1000-910	P	960-870
17	Q		780-710	AQ	1120-1020	Q	1100-1000
18	R		990-900	AR	1460-1560	R	1430-1300
19	S	S & AH	1180-1070	AS	1720-1560	S	1640-1490
20	T		1360-1240	AT	1960-1780	T	1820-1650
21	U		1410-1280	AU	2020-1840	U	2000-1820
22	V	V	1600-1450	AV	2320-2110	V	2130-1940
24	W		1890-1720	AW	2800-2550	W	2460-2240
26	X	X	2420-2200	AX	3520-3200	X	3040-2760
28	Y		2860-2600	AY	4180-3800	Y	3520-3200
30	Z		3410-3100	AZ	5170-4700	Z	4750-4320

1. M-2281-Ag Torque Same as M-2012-AG.
2. Torque values apply to solid shafts.
   Torque values may or may not be satisfactory on thin-walled shafts.
   Torque values apply to threads lubricated with oil.

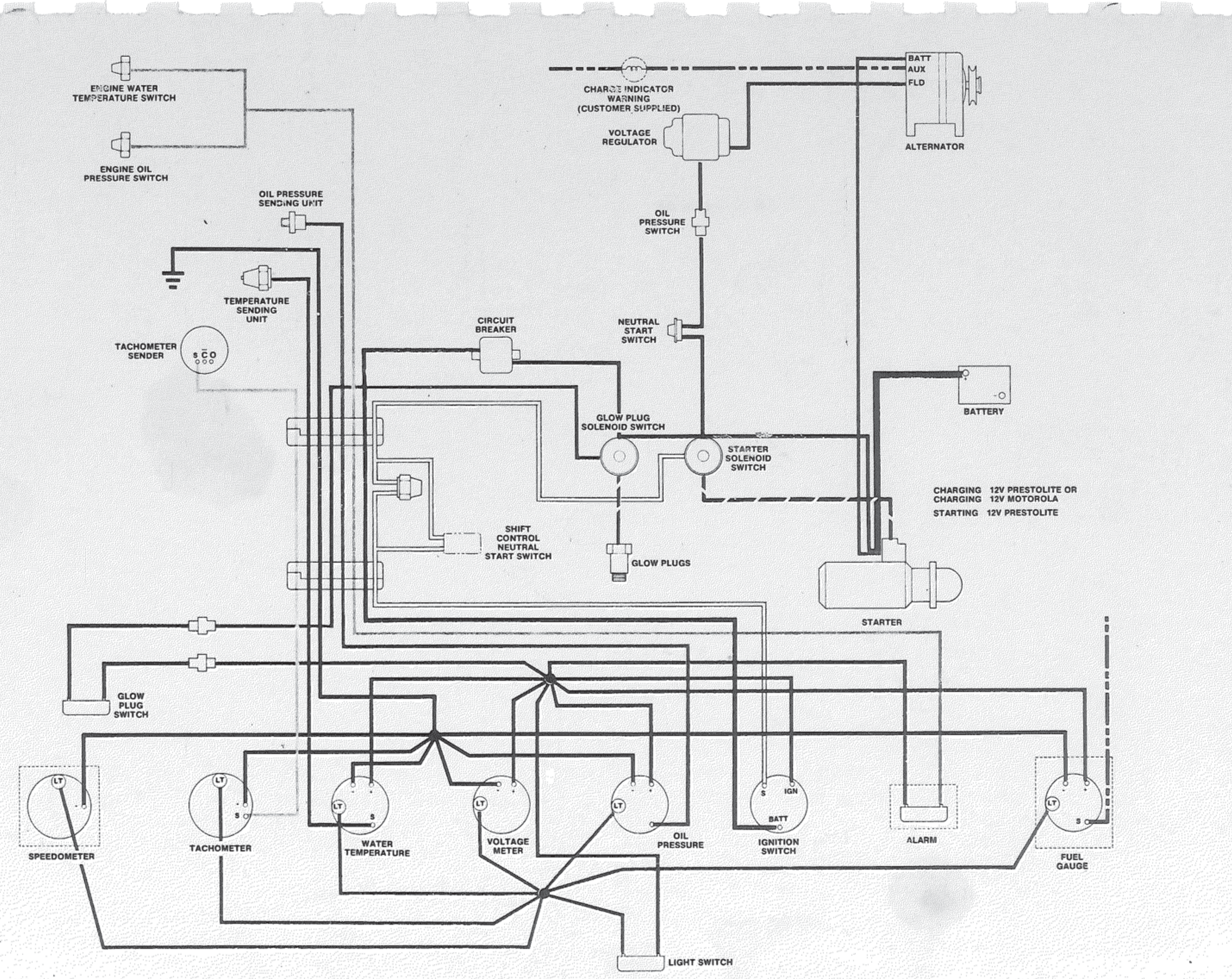
Notes:

Belts
3VX530-50 } NAPA
25-09783 }

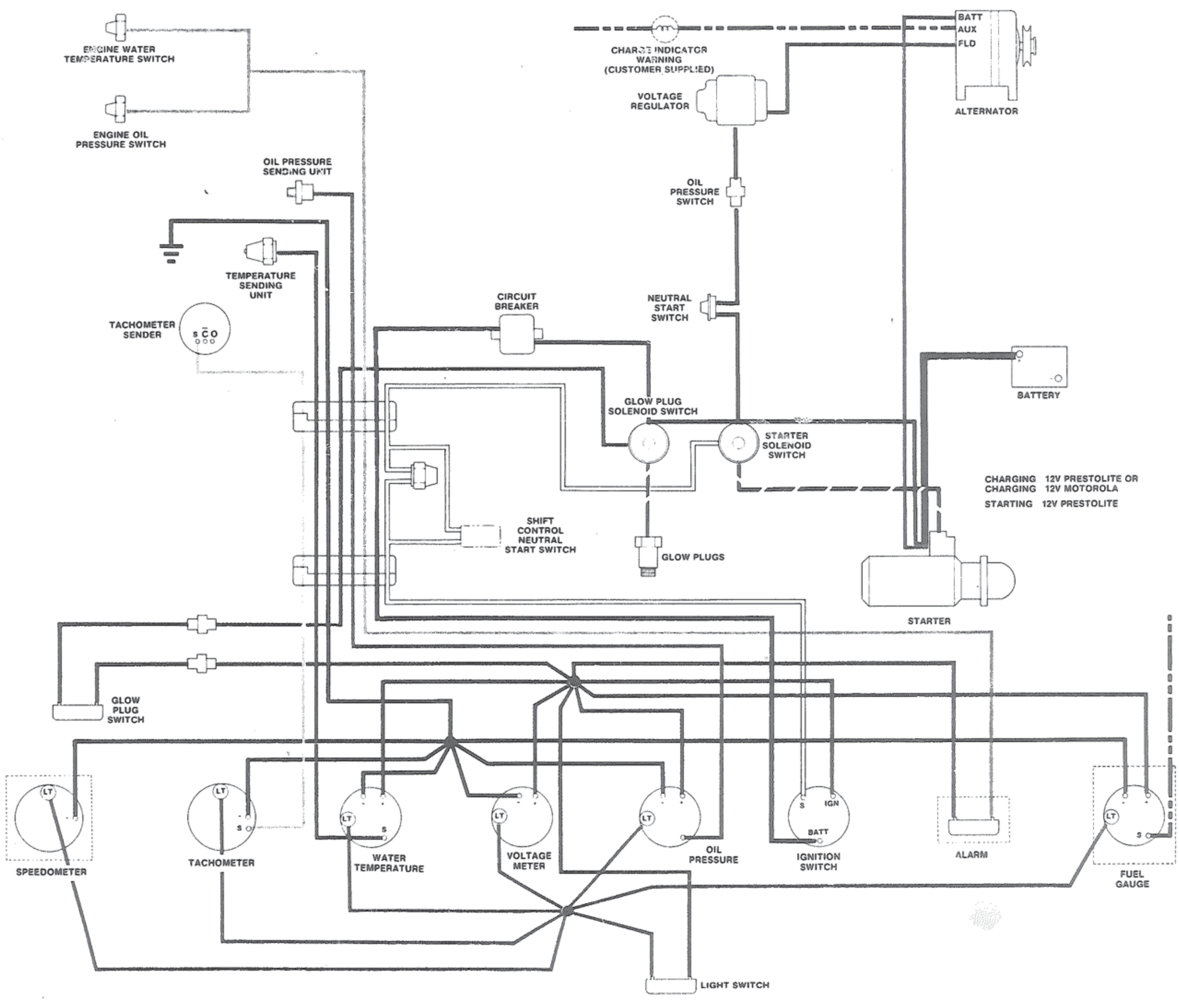
Fuel
Sec. Filters-Fuel
#3110 NAPA
PRIMARY

OIL filter

Notes:



ENGINE WATER TEMPERATURE SWITCH
ENGINE OIL PRESSURE SWITCH
OIL PRESSURE SENDING UNIT
TEMPERATURE SENDING UNIT
TACHOMETER SENDER
S C O
CHARGE INDICATOR WARNING (CUSTOMER SUPPLIED)
VOLTAGE REGULATOR
OIL PRESSURE SWITCH
NEUTRAL START SWITCH
BATT
AUX
FLD
ALTERNATOR
CIRCUIT BREAKER
GLOW PLUG SOLENOID SWITCH
STARTER SOLENOID SWITCH
BATTERY
CHARGING 12V PRESTOLITE OR
CHARGING 12V MOTOROLA
STARTING 12V PRESTOLITE
SHIFT CONTROL NEUTRAL START SWITCH
GLOW PLUGS
STARTER
GLOW PLUG SWITCH
SPEEDOMETER
TACHOMETER
WATER TEMPERATURE
VOLTAGE METER
OIL PRESSURE
IGNITION SWITCH
S
IGN
BATT
LT
ALARM
FUEL GAUGE
LIGHT SWITCH



ENGINE WATER TEMPERATURE SWITCH
ENGINE OIL PRESSURE SWITCH
OIL PRESSURE SENDING UNIT
TEMPERATURE SENDING UNIT
TACHOMETER SENDER
S C O
CHARGE INDICATOR WARNING (CUSTOMER SUPPLIED)
VOLTAGE REGULATOR
OIL PRESSURE SWITCH
NEUTRAL START SWITCH
CIRCUIT BREAKER
BATT
AUX
FLD
ALTERNATOR
BATTERY
GLOW PLUG SOLENOID SWITCH
STARTER SOLENOID SWITCH
CHARGING 12V PRESTOLITE OR
CHARGING 12V MOTOROLA
STARTING 12V PRESTOLITE
SHIFT CONTROL NEUTRAL START SWITCH
GLOW PLUGS
STARTER
GLOW PLUG SWITCH
LT
S
SPEEDOMETER
TACHOMETER
WATER TEMPERATURE
VOLTAGE METER
OIL PRESSURE
IGN
BATT
IGNITION SWITCH
ALARM
FUEL GAUGE
LIGHT SWITCH

CHRYSLER

Diesel Engines

Undersize bearings call 269 673 6933 email; PartsAndGaskets@gmail.com

gaskets and gasket sets:
email: partsdz@gmail.com
Phone: 269 673 2128 (leave message)