



# SERVICE MANUAL

## MODELS

M - 30

M - 40

M - 50

P/N 200154



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**SECTION I - SPECIFICATIONS**

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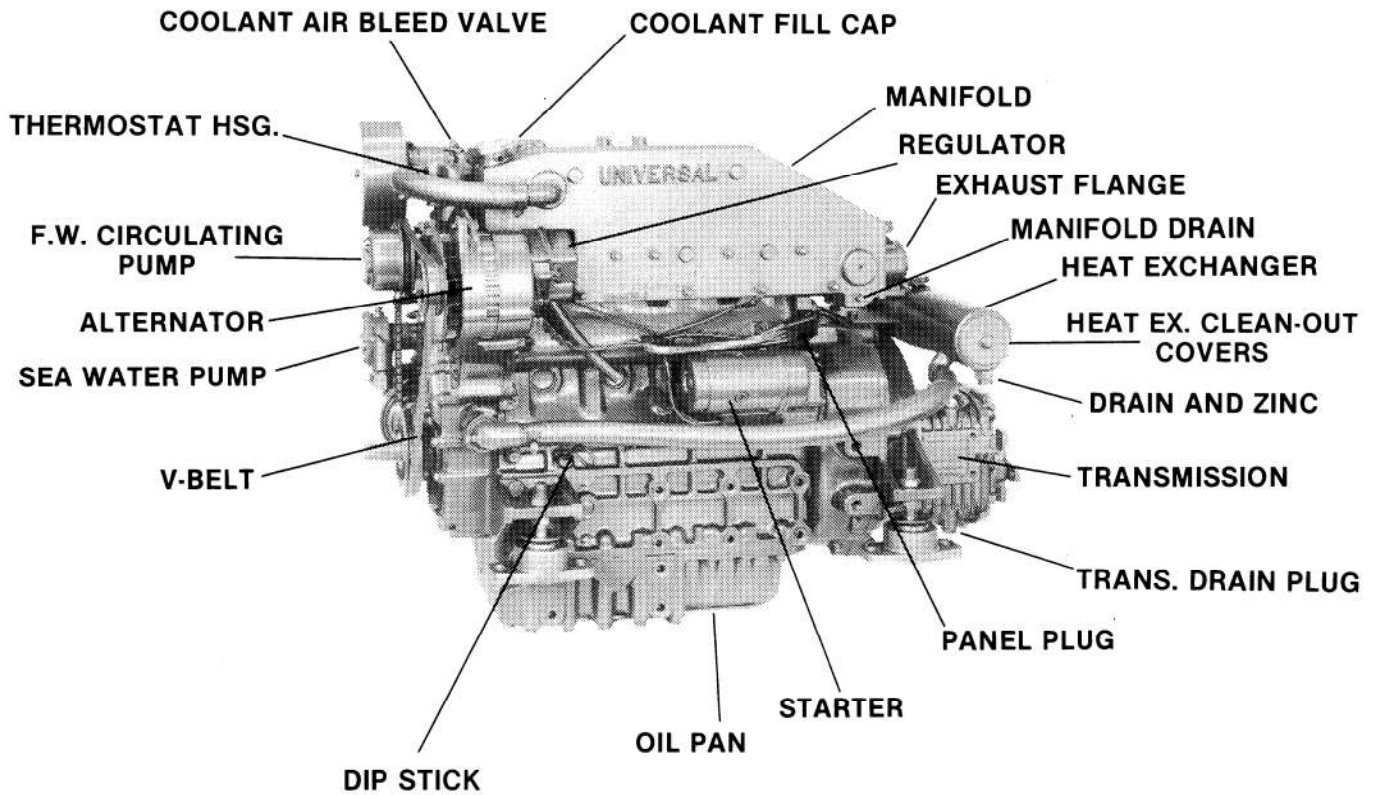
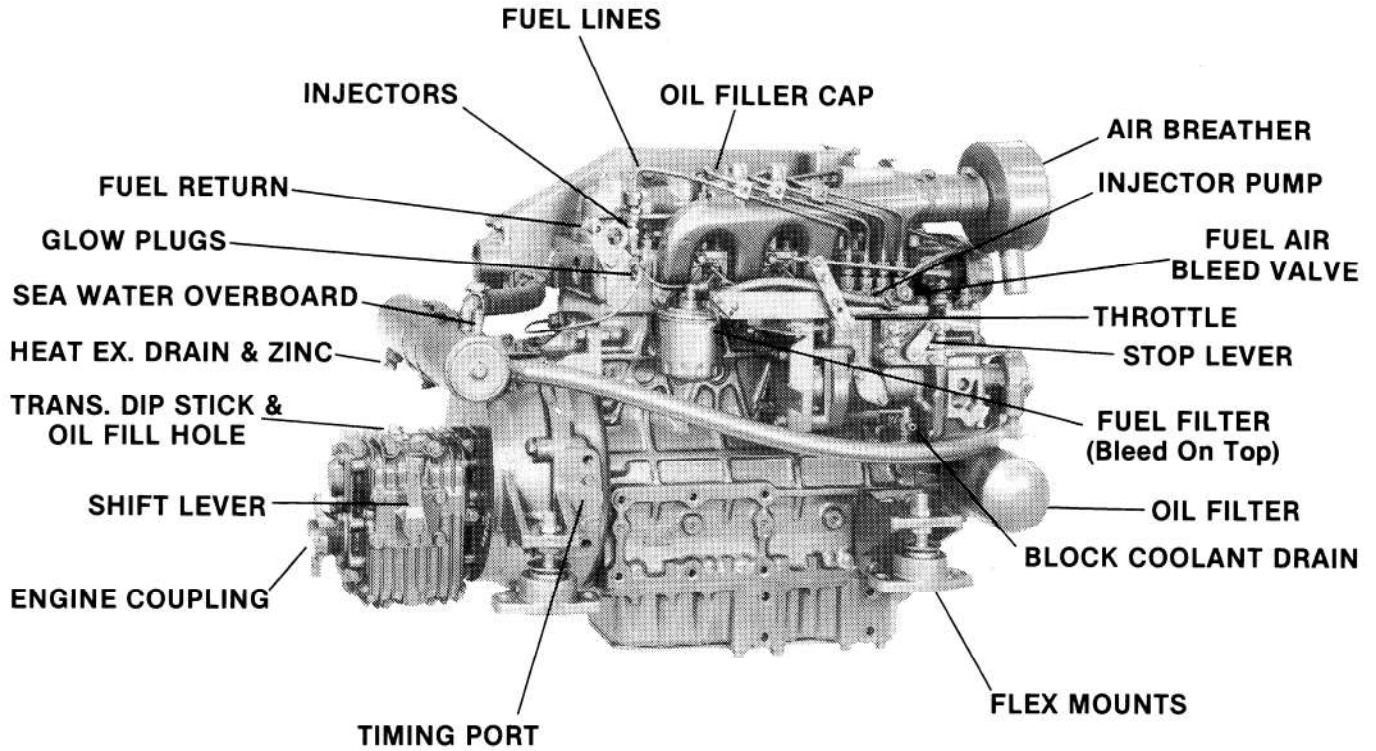
## UNIVERSAL MODEL M-30 SPECIFICATIONS

Horsepower	24 @ 2800
No. of Cylinders	3
Bore x Stroke	3.00 x 3.23
Cubic Inch	68
Maximum R.P.M.	2800
Cruising Range (Approx.)	2000-2400 R.P.M.
Compression Ratio	21:1
Electrical Equipment	12 Volt - 51 Amp W/Glow Plugs
Lubrication (Eng. Approx. Qts)	5.0 to 5.5
	(SAE 30 HD. (CD) or 10W40) <u>CAUTION: FILL ONLY TO FULL MARK ON DIPSTICK</u>
Lubrication (Trans.)	<u>FILL TO FULL RING ON DIPSTICK</u>
	(Type AFT. "A" or GM-DEXRON - II Do not mix different oils)
Transmission Reduction	2:1
Coolant FWC (50/50 Solution Approx.)	6 qts.
Exhaust Flange	1 1/4" N.P.T.
Fuel Type	#2 Diesel
Fuel Filter	P/N 298854
Oil Filter	P/N 300209
Eng. Operating Temp. Degrees F.	165° to 195°
Propeller Rotation	Right Hand
Weight (lbs.)	425 lbs.
Injection Nozzle	P/N 298787 & 298788

Engine is governor controlled to prevent overspeed. It is recommended to carry the following extra parts should the need arise: V-Belt, Sea Water Pump Impeller, Fuel & Lube Oil Filters, 1 Qt. of Trans. Oil, 2 Qts. Lub. Oil and 1 Gal. 50/50 Coolant.

All pictorial views and specifications subject to change without notice.

# UNIVERSAL MODEL M-30



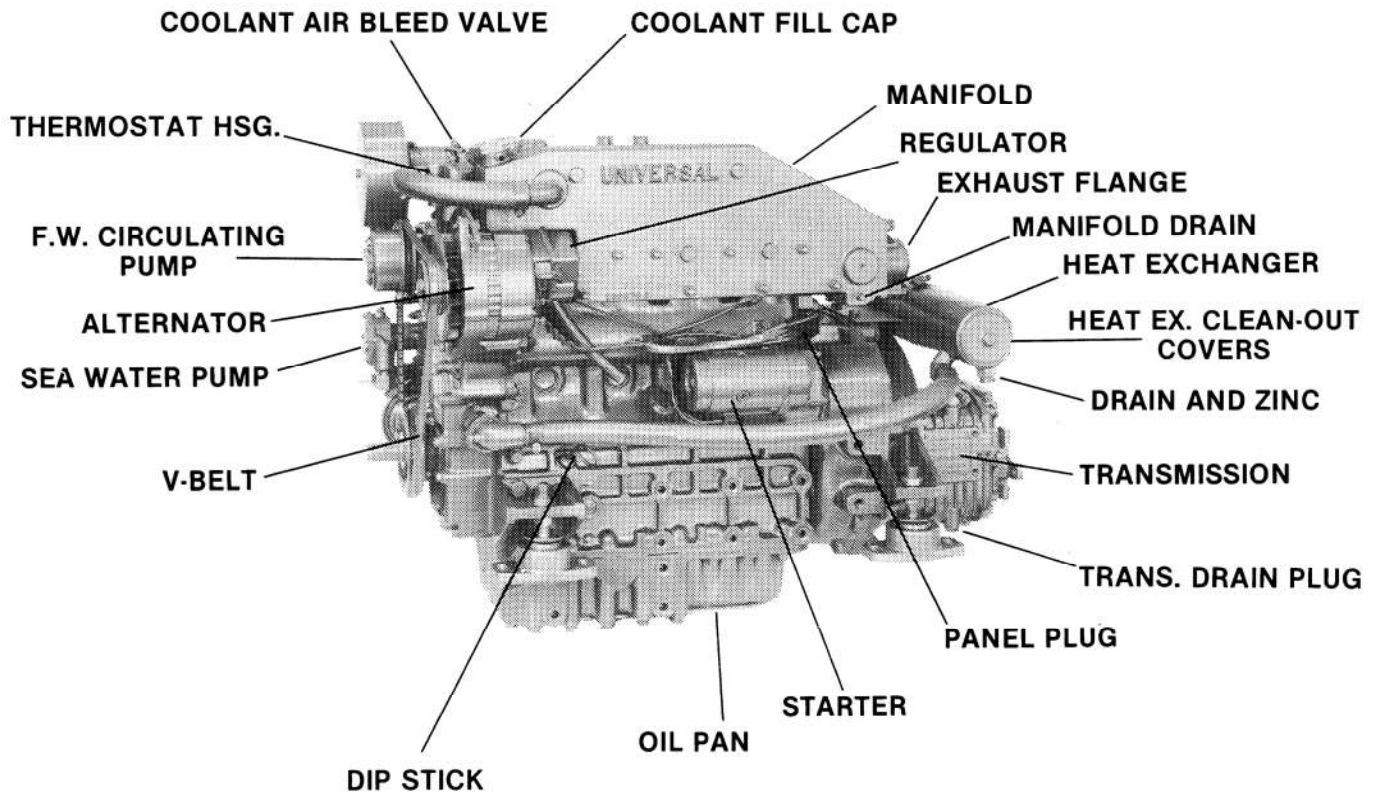
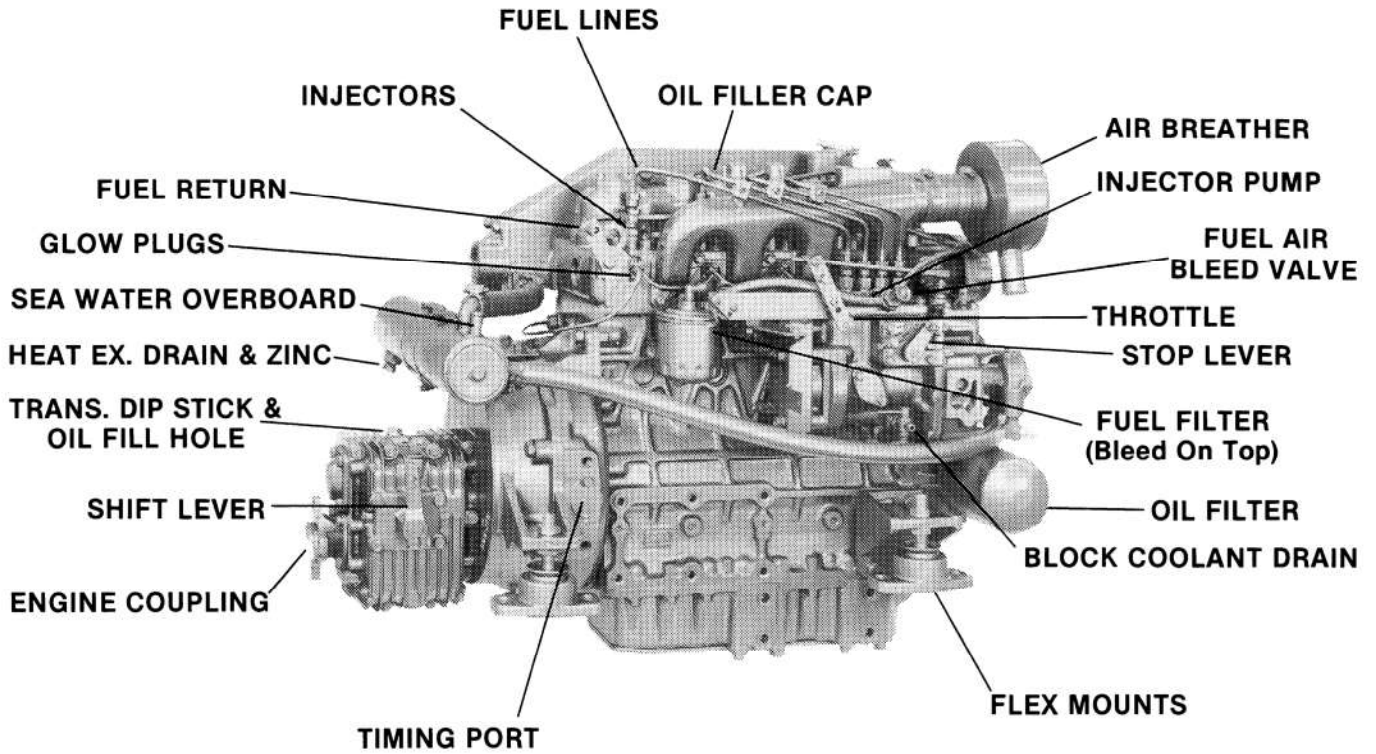
## UNIVERSAL MODEL M-40 SPECIFICATIONS

Horsepower	32 @ 2800
No. of Cylinders	4
Bore x Stroke	3.00 x 3.23
Cubic Inch	91
Maximum R.P.M.	2800
Cruising Range (Approx.)	2000/2500 R.P.M.
Compression Ratio	21:1
Electrical Equipment	12 Volt - 51 Amp W/Glow Plugs
Lubrication (Eng. Approx. Qts.)	8.0 to 8.5
	(SAE 30 HD. (CD) or 10W40) <u>CAUTION: FILL ONLY TO FULL MARK ON DIPSTICK</u>
Lubrication (Trans.)	<u>FILL TO FULL RING ON DIPSTICK</u>
	(Type AFT. "A" or GM-DEXRON — II Do not mix different oils)
Transmission Reduction	2:1
Coolant FWC (50/50 Solution Approx.)	8 qts.
Exhaust Flange	1 ¼" N.P.T.
Fuel Type	#2 Diesel
Fuel Filter	P/N 298854
Oil Filter	P/N 299927
Eng. Operating Temp. Degrees F.	165° to 195°
Propeller Rotation	Right Hand
Weight (lbs.)	545 lbs.
Injection Nozzle (Prior to Ser. #315023) (After Ser. #315023)	P/N 299517 & 299518 P/N 299567

Engine is governor controlled to prevent overspeed. It is recommended to carry the following extra parts should the need arise: V-belt, Sea Water Pump Impeller, Fuel & Lube Oil Filters, 1 Qt. of Trans. Oil, 2 Qts. Lub. Oil and 1 Gal. 50/50 Coolant.

All pictorial views and specifications subject to change without notice.

# UNIVERSAL MODEL M-40





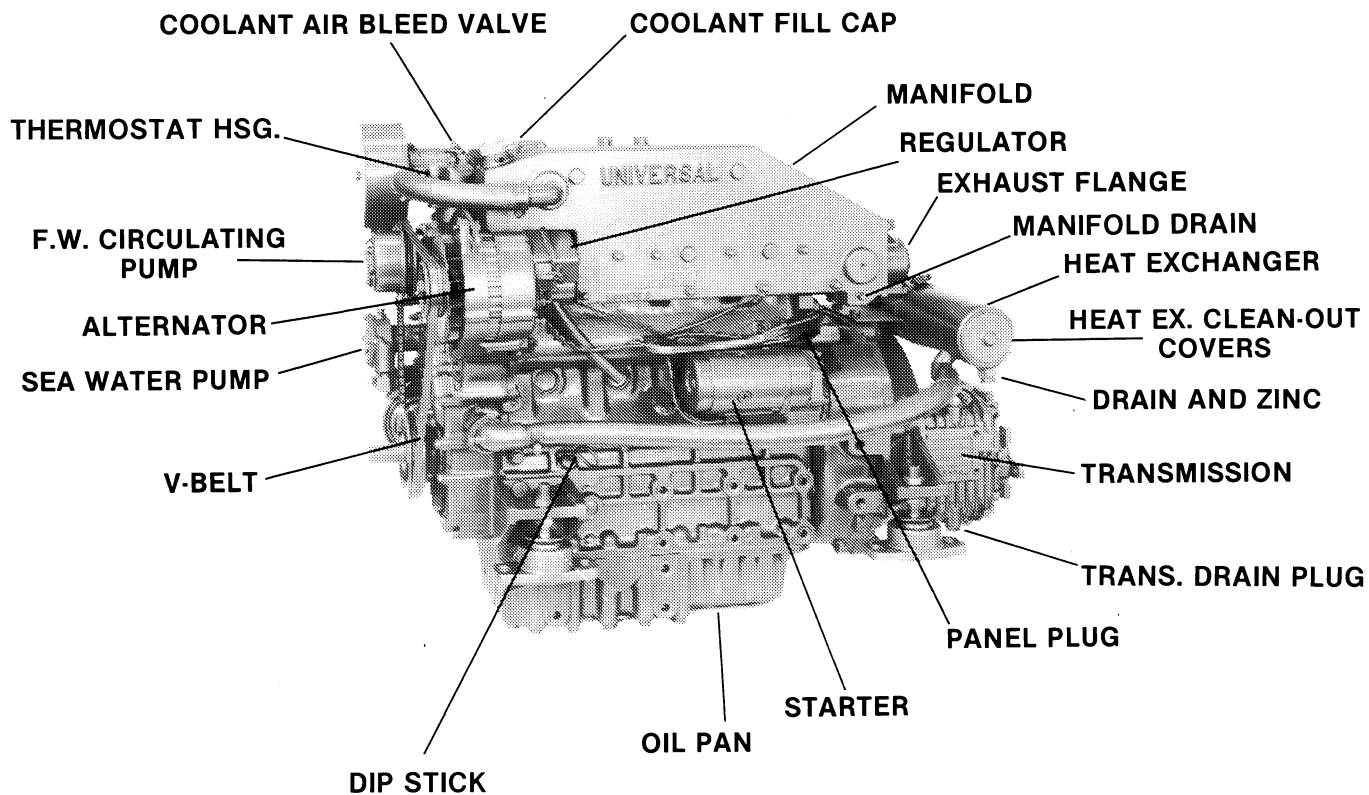
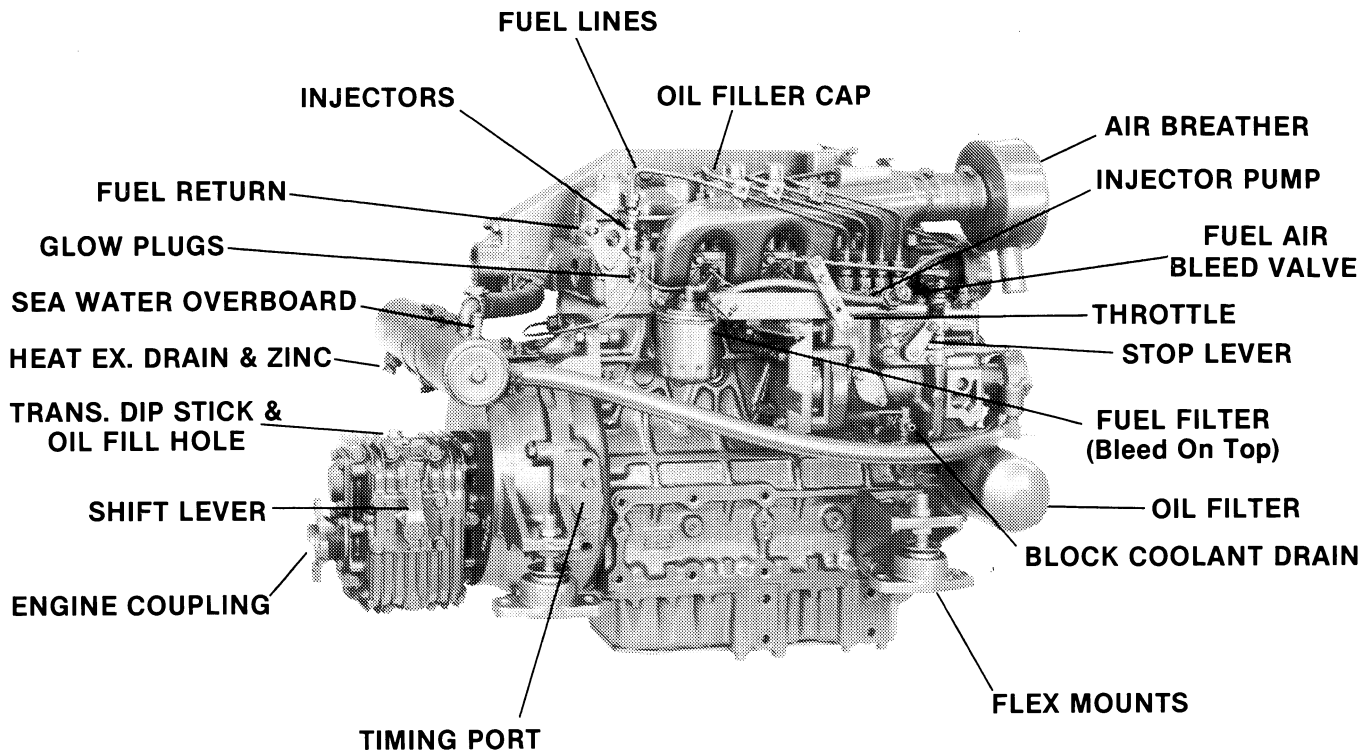
## UNIVERSAL MODEL M-50 SPECIFICATIONS

Horsepower	44 @ 3000
No. of Cylinders	4
Bore x Stroke	3.35 x 3.23
Cubic Inch	115
Maximum R.P.M.	3000
Cruising Range (Approx.)	2000/2500 R.P.M.
Compression Ratio	21:1
Electrical Equipment	12 Volt - 51 Amp W/Glow Plugs
Lubrication (Eng. Approx. Qts.)	8.5
	(SAE 30 HD. (CD) or 10W40) <u>CAUTION: FILL ONLY TO FULL MARK ON DIPSTICK</u>
Lubrication (Trans.)	<u>FILL TO FULL RING ON DIPSTICK</u>
Transmission Reduction	1.9:1
Coolant FWC (50/50 Solution Approx.)	8 qts.
Exhaust Flange	1 1/4" N.P.T.
Fuel Type	#2 Diesel
Fuel Filter	P/N 298854
Oil Filter	P/N 299927
Eng. Operating Temp. Degrees F.	165° to 195°
Propeller Rotation	Right Hand
Weight (lbs.)	545 lbs.
Injection Nozzle	P/N 299567

Engine is governor controlled to prevent overspeed. It is recommended to carry the following extra parts should the need arise: V-Belt, Sea Water Pump Impeller, Fuel & Lube Oil Filters, 1 Qt. of Trans. Oil, 2 Qts. Lub. Oil and 1 Gal. of 50/50 Coolant.

All pictorial views and specifications subject to change without notice.

# UNIVERSAL MODEL M-50



# ENGINE SPECIFICATIONS

## ENGINE BODY

### Cylinder Head

Item		M-30	M-40
Cylinder head surface flatness		0.05 mm (0.002 in.)	0.05 mm (0.002 in.)
Top clearance		0.7 to 0.9 mm (0.028 to 0.035 in.)	0.7 to 0.9 mm (0.028 to 0.035 in.)
Gasket thickness	Free	1.30 to 1.60 mm (0.051 to 0.063 in.)	1.30 to 1.60 mm (0.051 to 0.063 in.)
	Tightened	1.05 to 1.15 mm (0.041 to 0.045 in.)	1.05 to 1.15 mm (0.041 to 0.045 in.)
Gasket shim thickness		0.2 mm (0.008 in.)	0.2 mm (0.008 in.)
Compression pressure		448 psi	448 psi
Variance among cylinders		—	—

### Valves (IN., EX.)

Valve clearance (cold)	0.18 to 0.22 mm (0.007 to 0.008 in.)	0.18 to 0.22 mm (0.007 to 0.008 in.)
Valve seat width	2.1 mm (0.083 in.)	2.1 mm (0.083 in.)
Valve seat angle	45°	45°
Valve face angle	45°	45°
Valve recessing	1.1 to 1.3 mm (0.043 to 0.051 in.)	1.1 to 1.3 mm (0.043 to 0.051 in.)
Clearance between valve stem and guide	0.04 to 0.07 mm (0.001 to 0.003 in.)	0.04 to 0.07 mm (0.001 to 0.003 in.)
Valve stem O.D.	7.960 to 7.975 mm (0.313 to 0.314 in.)	7.960 to 7.975 mm (0.313 to 0.314 in.)
Valve guide I.O.	8.015 to 8.030 mm (0.315 to 0.316 in.)	8.015 to 8.030 mm (0.315 to 0.316 in.)

### Valve Timing

Inlet valve	Open	0.35 rad. (20° before TDC)	0.35 rad. (20° before TDC)
	Close	0.79 rad. (45° after TDC)	0.79 rad. (45° after TDC)
Exhaust valve	Open	0.87 rad. (50° before TDC)	0.87 rad. (50° before TDC)
	Close	0.26 rad. (15° after TDC)	0.26 rad. (15° after TDC)

### Valve Springs

Free length	41.7 to 42.2 mm (1.642 to 1.661 in.)	41.7 to 42.2 mm (1.642 to 1.661 in.)
Tilt	1.0 mm (0.039 in.)	1.0 mm (0.039 in.)
Tension	1.117 N. (12 kgf, 26.5 lbs.)	1.117 N (12 kgf, 26.5 lbs.)

## ENGINE SPECIFICATIONS

<b>M-50</b>			<b>Allowable Limit</b>
0.05 mm (0.002 in.)			—
0.7 to 0.9 mm (0.028 to 0.035 in.)			—
1.30 to 1.60 mm (0.051 to 0.063 in.)			—
1.05 to 1.15 mm (0.041 to 0.045 in.)			—
0.2 mm (0.008 in.)			—
448 psi			350 psi
—			10%

0.18 to 0.22 mm (0.007 to 0.008 in.)			—
2.1 mm (0.083 in.)			—
45°			—
45°			—
1.1 to 1.3 mm (0.043 to 0.051 in.)			1.6 mm (0.063 in.)
0.04 to 0.07 mm (0.001 to 0.003 in.)			0.1 mm (0.004 in.)
7.960 to 7.975 mm (0.313 to 0.314 in.)			—
8.015 to 8.030 mm (0.315 to 0.316 in.)			—

0.35 rad (20° before TDC)			—
0.79 rad. (45° after TDC)			—
0.87 rad. (50° before TDC)			—
0.26 rad. (15° After TDC)			—

41.7 to 42.2 mm (1.642 to 1.661 in.)			41.2 mm (1.622 in.)
1.0 mm (0.039 in.)			1.00 N (10.2 kgf, 22.5 lbs.)
1.117 N (12 kgf, 26.5 lbs.)			—

## ENGINE SPECIFICATIONS

### Rocker Arm

Item	M-30	M-40
Clearance between rocker arm and bushing	0.018 to 0.070 mm (0.0007 to 0.003 in.)	0.018 to 0.070 mm (0.0007 to 0.003 in.)
Rocker arm shaft O.D.	13.973 to 13.984 mm (0.550 to 0.551 in.)	13.973 to 13.984 mm (0.550 to 0.551 in.)
Rocker arm bushing I.D.	14.002 to 14.043 mm (0.551 to 0.553 in.)	14.002 to 14.043 mm (0.551 to 0.553 in.)

### Camshaft

Camshaft alignment	0.05 mm (0.002 in.)	0.05 mm (0.002 in.)
Cam height (IN., EX.)	33.36 mm (1.313 in.)	33.36 mm (1.313 in.)
Oil clearance of camshaft	0.050 to 0.091 mm (0.002 to 0.004 in.)	0.050 to 0.091 mm (0.002 to 0.004 in.)
Camshaft journal O.D.	39.934 to 39.950 mm (1.572 to 1.573 in.)	39.934 to 39.950 mm (1.572 to 1.573 in.)
Camshaft bearing I.D.	40.000 to 40.025 mm (1.575 to 1.576 in.)	40.000 to 40.025 mm (1.575 to 1.576 in.)

### Timing Gear

Timing gear backlash	0.042 to 0.115 mm (0.002 to 0.005 in.)	0.042 to 0.115 mm (0.002 to 0.005 in.)
Idle gear side clearance	0.20 to 0.51 mm (0.008 to 0.020 in.)	0.20 to 0.51 mm (0.008 to 0.020 in.)
Clearance between idle gear shaft and idle gear bushing	0.016 to 0.045 mm (0.0006 to 0.001 in.)	0.016 to 0.045 mm (0.0006 to 0.001 in.)
Idle gear shaft O.D.	15.973 to 15.984 mm (0.628 to 0.629 in.)	15.973 to 15.984 mm (0.628 to 0.629 in.)
Idle gear bushing I.D.	16.000 to 16.018 mm (0.621 to 0.630 in.)	16.000 to 16.018 mm (0.621 to 0.630 in.)

### Cylinder (Liner)

Cylinder (Liner) I.D.	76.000 to 76.019 mm (2.992 to 2.993 in.)	76.000 to 76.019 mm (2.992 to 2.993 in.)
Oversize of cylinder liner	+0.5 mm (+0.020 in.)	+0.5 mm (+0.020 in.)

### Piston/Piston Ring

Piston pin hole I.D.	23.000 to 23.013 mm (2.905 to 0.906 in.)	23.000 to 23.013 mm (0.905 to 0.906 in.)
Piston ring clearance	Compression ring 2	0.093 to 0.120 mm (0.004 to 0.005 in.)
	Oil ring	0.020 to 0.052 mm (0.0008 to 0.002 in.)
Ring gap	Compression ring 1, 2	0.30 to 0.45 mm (0.012 to 0.018 in.)
	Oil ring	0.25 to 0.45 mm (0.010 to 0.018 in.)
Oversize of piston rings	+0.5 mm (+0.020 in.)	+0.5 mm (+0.020 in.)

## ENGINE SPECIFICATIONS

<b>M-50</b>			<b>Allowable Limit</b>
0.018 to 0.070 mm (0.0007 to 0.003 in.)			0.15 mm (0.006 in.)
13.973 to 13.984 mm (0.550 to 0.551 in.)			—
14.002 to 14.043 mm (0.551 to 0.553 in.)			—

0.05 mm (0.002 in.)			—
33.36 mm (1.313 in.)			33.31 mm (1.315 in.)
0.050 to 0.091 mm (0.002 to 0.004 in.)			0.15 (0.006 in.)
39.934 to 39.950 mm (1.572 to 1.573 in.)			—
40.000 to 40.025 mm (1.575 to 1.576 in.)			—

0.042 to 0.115 mm (0.002 to 0.005 in.)			0.15 mm (0.006 in.)
0.20 to 0.51 mm (0.008 to 0.020 in.)			0.6mm (0.024 in.)
0.016 to 0.045 mm (0.0006 to 0.001 in.)			0.10mm (0.004 in.)
15.973 to 15.984 mm (0.628 to 0.629 in.)			—
16.000 to 16.018 mm (0.621 to 0.630 in.)			—
—			—
85.000 to 85.022 mm (3.346 to 3.347 in.)			+0.15 mm (+0.006 in.)
+0.5 mm (+0.020 in.)			—

23.000 to 23.013 mm (0.905 to 0.906 in.)			23.053 mm (0.907 in.)
0.093 to 0.120 mm (0.004 to 0.005 in.)			—
0.020 to 0.052 mm (0.0008 to 0.002 in.)			—
0.30 to 0.45 mm (0.012 to 0.018 in.)			1.25 mm (0.049 in.)
0.25 to 0.45 mm (0.010 to 0.018 in.)			1.25 mm (0.049 in.)
+0.5 mm (+0.020 in.)			—

## ENGINE SPECIFICATIONS

Item		M-30	M-40
Crankshaft alignment		0.02 mm (0.0008 in.)	0.02 mm (0.0008 in.)
Oil clearance between crankshaft journal and bearing		0.040 to 0.118 mm (0.002 to 0.004 in.)	0.040 to 0.118 mm (0.002 to 0.004 in.)
Journal O.D.	Front and intermediate	51.921 to 51.940 mm (2.044 to 2.045 in.)	51.921 to 51.940 mm (2.044 to 2.045 in.)
	Rear	51.921 to 51.940 mm (2.044 to 2.045 in.)	51.921 to 51.940 mm (2.044 to 2.045 in.)
Bearing I.D.	Front and intermediate	51.980 to 52.039 mm (2.046 to 2.049 in.)	51.980 to 52.039 mm (2.046 to 2.049 in.)
	Rear	51.980 to 52.025 mm (2.046 to 2.048 in.)	51.980 to 52.025 mm (2.046 to 2.048 in.)
Oil clearance between crank pin and bearing		0.035 to 0.093 mm (0.002 to 0.004 in.)	0.035 to 0.093 mm (0.002 to 0.004 in.)
Crank pin O.D.		43.959 to 43.975 mm (1.731 to 1.732 in.)	43.959 to 43.975 mm (1.731 to 1.732 in.)
Crank pin bearing I.D.		44.010 to 44.052 mm (1.733 to 1.734 in.)	44.010 to 44.052 mm (1.733 to 1.734 in.)
Crank shaft side clearance		0.15 to 0.31 mm (0.006 to 0.012 in.)	0.15 to 0.31 mm (0.006 to 0.012 in.)
Under sizes of crankshaft bearing and crank pin bearing		-0.02 mm, -0.04 mm (-0.008 in., -0.016 in.)	-0.02 mm, -0.04 mm (-0.008 in., -0.016 in.)
Oversizes of thrust bearing		+0.2mm, +0.4 mm (+0.008 in., +0.016 in.)	+0.02 mm, +0.04 mm (+0.008 in., +0.016 in.)

### Connecting Rod

Connecting rod alignment	0.02 mm (0.0008 in.)	0.02 mm (0.0008 in.,
Oil clearance between piston pin and small end bushing	0.014 to 0.038 mm (0.0006 to 0.001 in.)	0.014 to 0.038 mm (0.0006 to 0.001 in.)
Piston O.D.	23.002 to 23.011 mm (0.905 to 0.906 in.)	23.002 to 23.011 mm (0.905 to 0.906 in.)
Small end bushing I.D. (fitting)	23.000 to 23.013 mm (0.905 to 0.906 in.)	23.000 to 23.013 mm (0.905 to 0.906 in.)

### LUBRICATING SYSTEM

Oil pressure	At idle speed	1.0 kgf/cm <sup>2</sup> (14.2 psi)	1.0 kgf/cm <sup>2</sup> (14.2 psi)
	At rated speed	3.0 to 4.5 kgf/cm <sup>2</sup> (43 to 64 psi)	3.0 to 4.5 kgf/cm <sup>2</sup> (43 to 64 psi)

### Oil Pump

Rotor lobe clearance	0.10 to 0.16 mm (0.004 to 0.006 in.)	0.04 to 0.13 mm (0.002 to 0.005 in.)
Radial clearance between outer rotor and pump body	0.11 to 0.19 mm (0.004 to 0.007)	0.11 to 0.19 mm (0.004 to 0.007 in.)
End clearance between rotor and cover	0.105 to 0.150 mm (0.004 to 0.006 in.)	0.105 to 0.150 mm (0.004 to 0.006 in.)

### Oil Filter

Opening pressure of bypass valve	98 KPa 1.0 kgf/cm <sup>2</sup> (14.2 psi)	98 KPa 1.0 kgf/cm <sup>2</sup> (14.2 psi)
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## ENGINE SPECIFICATIONS

<b>M-50</b>			<b>Allowable Limit</b>
0.02 mm (0.0008 in.)			0.08 mm (0.003 in.)
0.040 to 0.118 mm (0.002 to 0.004 in.)			0.20 mm (0.008 in.)
51.921 to 51.940 mm (2.044 to 2.045 in.)			—
51.921 to 51.940 mm (2.044 to 2.045 in.)			—
51.980 to 52.039 mm (2.046 to 2.049 in.)			—
51.980 to 52.025 mm (2.046 to 2.048 in.)			—
0.035 to 0.093 mm (0.002 to 0.004 in)			0.20 mm (0.008 in.)
43.959 to 43.975 mm (1.731 to 1.732 in.)			—
44.010 to 44.052 mm (1.733 to 1.734 in.)			—
0.15 to 0.31 mm (0.006 in. to 0.012 in.)			0.5mm (0.020 in.)
-0.02 mm, -0.04 mm (-0.008 mm, -0.016 mm			—
+0.02 mm, +0.04 mm (+0.008 in., +0.016 in.)			—

0.02 mm (0.0008 in.)			0.05 mm (0.002 in.)
0.014 to 0.038 mm (0.0006 to 0.001 in.)			0.15 mm (0.006 in.)
23.002 to 23.011 mm (0.905 to 0.906 in.)			—
23.000 to 23.013 mm (0.905 to 0.906 in.)			23.053 mm (0.907 in.)

1.0 kgf/cm <sup>2</sup> (14.2 psi)			or more
3.0 to 4.5 kgf/cm <sup>2</sup> (43 to 64 psi)			2.5 kgf/cm <sup>2</sup> (35 psi)

0.04 to 0.13 mm (0.002 to 0.005 in.)			0.20 mm (0.008 in.)
0.11 to 0.19 mm (0.004 to 0.007 in.)			0.25 mm (0.010 in.)
0.105 to 0.150 mm (0.004 to 0.006 in.)			0.2 mm (0.008 in.)

98 KPa 1.0 kgf/cm <sup>2</sup> (14.2 psi)			—
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## ENGINE SPECIFICATIONS

### COOLING SYSTEM

#### Fan Belt

Item	M-30	M-40
Belt deflection under load of 98 N (10 kgf, 21 lbs.)	7 to 9 mm (0.275 to 0.355 in.)	7 to 9 mm (0.275 to 0.355 in.)

#### Heat Exchanger

Exchanger water tightness	1.2 kgf/cm <sup>2</sup> (14 to 15 psi)	1.2 kgf/cm <sup>2</sup> (14 to 15 psi)
Radiator cap opening pressure	0.9 to 0.6 kgf/cm <sup>2</sup> (15 to 9 psi)	0.9 to 0.6 kgf/cm <sup>2</sup> (15 to 9 psi)

#### Thermostat

Thermostat's valve opening temperature	60 C (140°) F	60 C (140°) F
Temperature at which thermostat completely opens	73.9 C (165°) F	73.9 C (165°) F

### FUEL SYSTEM

#### Injection Pump

Injection timing (static)	23° to 25° before TDC	23° to 25° before TDC
Fuel tightness of pump element	600 to 500 kgf/cm <sup>2</sup> (8532 to 7110 lbs.)	600 to 500 kgf/cm <sup>2</sup> (8532 to 7110 lbs.)
Fuel tightness of delivery valve	100 to 5 kgf/cm <sup>2</sup> (1422 to 71.1 lbs.)	100 to 5 kgf/cm <sup>2</sup> (1422 to 71.1 lbs.)

#### Injection Nozzle

Fuel injection pressure	140 to 150 kgf/cm <sup>2</sup> (1990 to 2133 lbs.)	140 to 150 kgf/cm <sup>2</sup> (1990 to 2133 lbs.)
Fuel tightness of nozzle valve seat	130 to 140 kgf/cm <sup>2</sup> (1848 to 1991 lbs.)	130 to 140 kgf/cm <sup>2</sup> (1848 to 1991 lbs.)

### ELECTRICAL SYSTEM

#### Starter

Commutator O.D.	32.7 mm (1.287 in.)	30.0 mm (1.181 in.)
Variance	45 A or less	90 A or less
Mica undercut	0.5 to 0.8 mm (0.092 to 0.032 in.)	0.5 to 0.9 mm (0.020 to 0.035 in.)
Brush length	19 mm (0.748 in.)	19 mm (0.748 in.)

#### Glow Plug

Resistance	Approx. 1.5 ohm	Approx. 1.5 ohm
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#### AC dynamo

No-load output	AC 20 volts or more 5200 RPM	AC 20 volts or more 5200 RPM
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#### Regulator

Regulating voltage	13.8 to 14.8 volts	13.8 to 14.8 volts
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## ENGINE SPECIFICATIONS

<b>M-50</b>			<b>Allowable Limit</b>
7 to 9 mm (0.275 to 0.355 in.)			—
1.2 kgf/cm <sup>2</sup> (14 to 15 psi)			—
0.9 to 0.6 kgf/cm <sup>2</sup> (15 to 9 psi)			—
60 C (140°) F			—
73.9 C (165°) F			—
23° to 25° before TDC			—
600 to 500 kgf/cm <sup>2</sup> (8532 to 7110 lbs.)			—
100 to 5 kgf/cm <sup>2</sup> (1422 to 71.1 lbs.)			—
140 to 150 kgf/cm <sup>2</sup> (1990 to 2133 lbs.)			—
130 to 140 kgf/cm <sup>2</sup> (1848 to 1991 lbs.)			—
30.0 mm (1.181 in.)			—
90 A or less			0.2 mm (0.008 in.)
0.5 to 0.9 mm (0.020 to 0.035 in.)			—
19 mm (0.748 in.)			12.7 mm (0.500 in.)
Approx. 1.5 ohm			—
AC 20 bolts or more 5200 RPM			—
13.8 to 14.8 volts			—

## BOLT TORQUES

As a lot of bolts and nuts in the engine are of special shape, be careful to tighten them correctly using a torque wrench. When tightening, follow this method: First tighten all the bolts 50% of the regular torque, then tighten them fully.

### TIGHTENING BOLTS OF IMPORTANT PARTS

Marked bolts must be tightened after applying oil.

MODEL		M-30	M-40
Head bolts and nuts		7.5 to 8.0 kgf/m (54.2 to 57.9 ft/lbs.)	7.5 to 8.0 kgf/m (54.2 to 57.9 ft/lbs.)
Bearing case bolts 1		3.0 to 3.5 kgf/m (21.7 to 25.3 ft/lbs.)	3.0 to 3.5 kgf/m (21.7 to 25.3 ft/lbs.)
Bearing case bolts 2		3.0 to 3.5 kgf/m (21.7 to 25.3 ft/lbs.)	3.0 to 3.5 kgf/m (21.7 to 25.3 ft/lbs.)
Flywheel bolts		10 to 11 kgf/m (72.3 to 79.6 ft./lbs.)	10 to 11 kgf/m (72.3 to 79.6 ft/lbs.)
Connecting rod bolts		3.7 to 4.2 kgf/m (26.8 to 30.4 ft/lbs.)	3.7 to 4.2 kgf/m (26.8 to 30.4 ft/lbs.)
Rocker arm bracket studs		1.7 to 2.1 kgf/m (12.3 to 15.2 ft/lbs.)	1.7 to 2.1 kgf/m (12.3 to 15.2 ft/lbs.)
Idle gear shaft bolts		1.0 to 1.15 kgf/m (7.23 to 8.31 ft/lbs.)	1.0 to 1.15 kgf/m (7.23 to 8.31 ft/lbs.)
Glow plugs (No need to apply oil)		2.0 to 2.5 kgf/m (14.5 to 18.1 ft/lbs.)	2.0 to 2.5 kgf/m (14.5 to 18.1 ft/lbs.)
Drain plugs		4.0 to 4.5 kgf/m (28.9 to 36.2 ft/lbs.)	4.0 to 4.5 kgf/m (28.9 to 36.2 ft/lbs.)
Nozzle holders		3 to 5 kgf/m (21.7 to 36.2 ft/lbs.)	3 to 5 kgf/m (21.7 to 36.2 ft/lbs.)
Oil Switch	Bis	0.14 to 0.2 kgf/m (10.1 to 14.5 ft/lbs.)	0.14 to 0.2 kgf/m (10.1 to 14.5 ft/lbs.)
	Taper screw	1.5 to 2.0 kgf/m (10.8 to 14.5 ft/lbs.)	1.5 to 2.0 kgf/m (10.8 to 14.5 ft/lbs.)
Fuel limit lock nut		2.8 to 3.5 kgf/m (20.3 to 25.3 ft/lbs.)	2.8 to 3.5 kgf/m (20.3 to 25.3 ft/lbs.)
Fuel limit cap nut		2.5 to 3.0 kgf/m (18.1 to 21.7 ft/lbs.)	2.5 to 3.0 kgf/m (18.1 to 21.7 ft/lbs.)
Injection pipes		1.5 to 2.6 kgf/m (10.8 to 18.8 ft/lbs.)	1.5 to 2.6 kgf/m (10.8 to 18.8 ft/lbs.)
Crankshaft nut		14 to 16 kgf/m (101 to 116 ft/lbs.)	14 to 16 kgf/m (100 to 116 ft/lbs.)
Air vent screw (on injection pump)		1.4 to 1.8 kgf/m (10.1 to 13.0 ft/lbs.)	1.4 to 1.8 kgf/m (10.1 to 13.0 ft/lbs.)

<b>M-50</b>		
7.5 to 8.0 kgf/m (54.2 to 57.9 ft/lbs.)		
3.0 to 3.5 kgf/m (21.7 to 25.3 ft/lbs.)		
3.0 to 3.5 kgf/m (21.7 to 25.3 ft/lbs.)		
10 to 11 kgf/m (72.3 to 79.6 ft/lbs.)		
3.7 to 4.2 kgf/m (26.8 to 30.4 ft/lbs.)		
1.7 to 2.1 kgf/m (12.3 to 15.2 ft/lbs.)		
1.0 to 1.15 kgf/m (7.23 to 8.31 ft/lbs.)		
2.0 to 2.5 kgf/m (14.5 to 18.1 ft/lbs.)		
4.0 to 4.5 kgf/m (28.9 to 36.2 ft/lbs.)		
3 to 5 kgf/m (21.7 to 36.2 ft/lbs.)		
0.14 to 0.2 kgf/m (10.1 to 14.5 ft/lbs.)		
1.5 to 2.0 kgf/m (10.8 to 14.5 ft/lbs.)		
2.8 3.5 kgf/m (20.3 to 25.3 ft/lbs.)		
2.5 to 3.0 kgf/m (18.1 to 21.7 ft/lbs.)		
1.5 to 2.6 kgf/m (10.8 to 18.8 ft/lbs.)		
14 to 16 kgf/m (101 to 116 ft/lbs.)		
1.4 to 1.8 kgf/m (10.1 to 13.0 ft/lbs.)		

## Bolt Torques

Material Grade	Standard Bolt	Special Bolt	Special Bolt
Nominal Dia.	SS41,S20C	S43C, S48C (Refined)	SCR3, SCM3 (Refined)
M 6	5.8 - 6.9 lbs/ft.	7.2 - 8.3 lbs/ft.	9.0 - 10.5 lbs/ft.
M 8	13.0 - 15.2 lbs/ft.	17.4 - 20.3 lbs/ft.	21.7 - 25.3 lbs/ft.
M 10	28.9 - 33.3 lbs/ft.	35.4 - 41.2 lbs/ft.	44.8 - 52.1 lbs/ft.
M 12	46.3 - 53.5 lbs/ft.	57.1 - 66.5 lbs/ft.	75.9 - 86.8 lbs/ft.
M 14	79.6 - 92.6 lbs/ft.	91.1 - 108.5 lbs/ft.	123.0 - 144.7 lbs/ft.
M 16	123.0 - 141.0 lbs/ft.	144.7 - 166.4 lbs/ft.	191.7 - 224.2 lbs/ft.
M 18	180.0 - 209.8 lbs/ft.	202.5 - 235.1 lbs/ft.	253.2 - 296.5 lbs/ft.
M 20	245.9 - 289.3 lbs/ft.	271.2 - 318.2 lbs/ft.	361.6 - 419.5 lbs/ft.

Bolt material grades are shown by numbers punched on the bolt heads. Prior to tightening, be sure to check out the numbers as shown below:

Punched Number	Bolt Material Grade
None	Standard Bolts SS41, S20C
7	Special Bolts S43C, S48C (Refined)
9	Special Bolts SCM3, SCR3, (Refined)

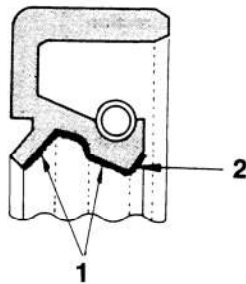
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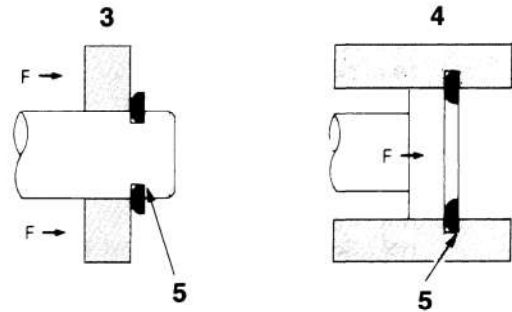
## GENERAL WARNINGS

- When disassembling engine, arrange each part on a clean surface. Do not mix them up. Replace bolts and nuts in their original positions.
- When servicing voltaged parts or connecting instruments to electrical equipment, first disconnect negative battery terminal.
- Replace gaskets or O-rings with new ones when disassembling, and apply grease on the O-ring and the oil seal when reassembling.
- When exchanging parts, use Universal genuine parts to maintain engine performance and safety.
- To prevent oil and water leakage apply non-drying adhesive to the gasket according to this manual before reassembling.
- When hoisting the engine, use the hook provided on the cylinder head.
- When installing external circlips or internal circlips, direct corner end to the non-loosening direction.

Applying grease to oil seal



Direction of installing circlips



1. Inside of Lip
2. Grease
3. External Circlip
4. Internal Circlip
5. Direct the Corner End to the Direction Subject to Force.

# MAINTENANCE CHECK LIST

To maintain long-lasting and safe engine performance, make it a rule to carry out regular inspections by following the table below.

Item	Service Interval									
	every 50 hrs.	every 100 hrs.	every 150 hrs.	every 200 hrs.	every 400 hrs.	every 500 hrs.	every one or two months	every three months	every one year	every two year
Checking fuel pipes and clamps	•									
Changing engine oil		•								
Cleaning air filter element		•								
Cleaning fuel filter		•								
Checking battery electrolyte level		•								
Checking fan belt tension and damage		•								
Checking oil or water leakage			•							
Checking water pipes and clamps			•							
Changing oil filter cartridge		•								
Changing fuel filter element					•					
Cleaning heat exchanger						•				
Recharging battery							•			
Changing coolant								•		
Changing air filter element									• or every 6 cleanings	
Checking valve clearance									•	
Checking nozzle injection pressure									•	
Changing battery										•
Changing water pipes and clamps										•
Changing fuel pipes and clamps										•



## POINTS OF INSPECTION AND CHANGING

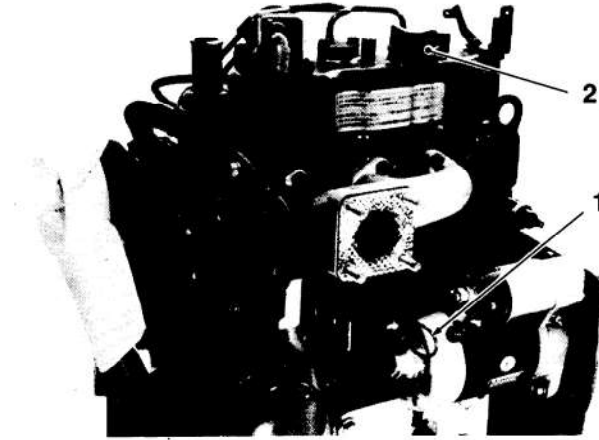
### ENGINE LUBRICATING OIL

Brand name oil (for diesel engines) or CC/CD class oils defined by SPI. It should be as follows according to temperature.

SAE-30 HD or 10W-40 HD

### CHECKING ENGINE OIL LEVEL

Stop for 5 minutes or more and remove the dip stick, wipe off dip stick and recheck. Read the engine oil level on the dip stick. If the oil level is below the lower mark on the dip stick, add sufficient oil to the full mark. DO NOT OVERFILL.

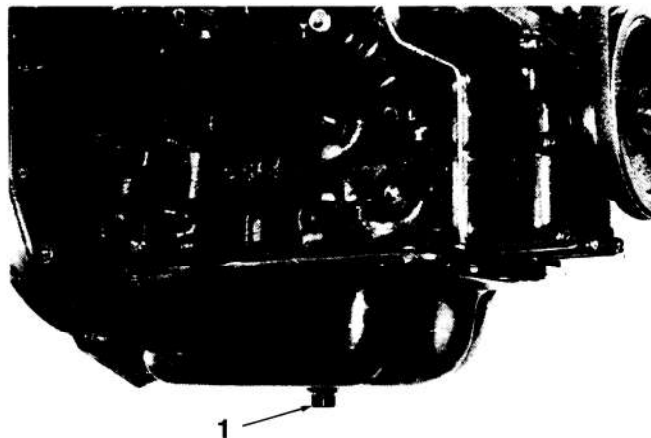


1. Dip Stick
2. Oil Filler Plug

### CHANGING ENGINE OIL

Drain the oil while the engine is still warm, by removing the drain plug on the oil pan and oil filler plug, or through the oil drain hose, so that the oil may completely drain.

Do not mix different brands of oil. If a different brand of oil should be employed, drain out the existing oil no matter how new it may be and then replace it. Do the same when using oil of a different viscosity.



1. Oil Drain Plug

## CHANGING ENGINE OIL FILTER CARTRIDGE

Remove the oil filter cartridge with a filter wrench.

Apply a slight coat of oil to the rubber gasket on the new cartridge.

Screw the new cartridge in by hand.

Over-tightening may cause deformation of rubber gasket.

After cartridge has been replaced, engine oil normally decreases a little. Check that the engine oil does not leak through the seal and be sure to read the oil level. Then, add engine oil up to the prescribed level.



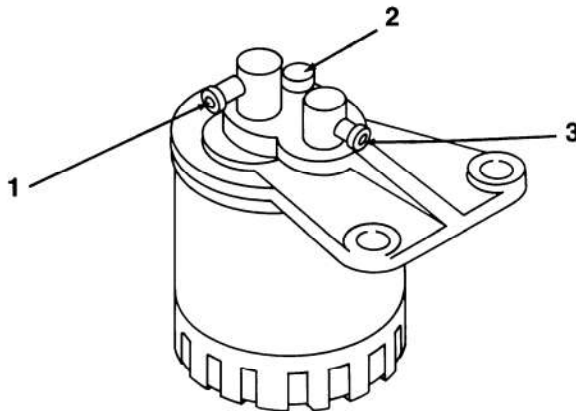
**1. Oil filter cartridge**

## INSPECTION OF FUEL FILTER

The fuel filter is installed in the fuel line from the fuel tank to the injection pump (between the tank and feed pump in the basic model).

As the fuel from the inlet of the cock body moves through the filter element, the dirt and impurities in the fuel are filtered, allowing only clean fuel to enter the inside of the filter element. The cleaned fuel flows out from the outlet of the cock body.

Before starting or after disassembling and reassembling, loosen the air vent plug to bleed the air in the fuel line.



- 1. Cock Body Inlet**
- 2. Cock Body Outlet**
- 3. Air Vent Plug**

## VENTING THE FUEL SYSTEM - Models 18, 25, 25XP and 35

Air must be vented when:

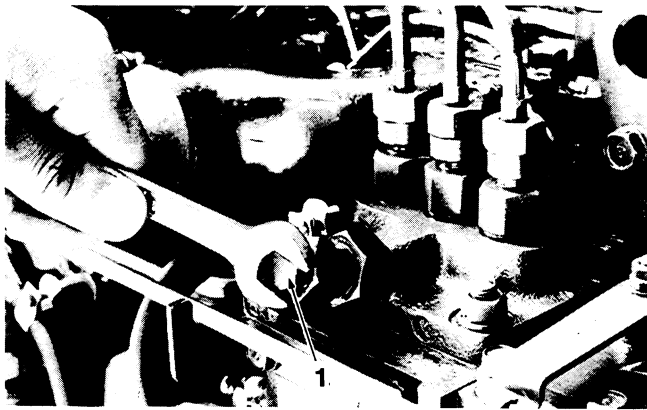
- The fuel filter and piping are removed.
- The fuel tank becomes completely empty.
- The engine has not been used for an extended time,

Venting procedure is as follows:

1. Fill the fuel tank with fuel, and open the fuel cock.
2. Twist off the air vent screw at the top of the filter by turning it twice.
3. When bubbles disappear from fuel coming out of the plug, twist it back on.
4. Open the air vent plug on the fuel injection pump.
5. Pull the engine stop lever back completely to stop the engine, and run the starter for about 10 seconds.
6. Close the air vent plug when air bubbles disappear from the fuel flowing out.

Models 12, 2-12, 3-20 and 4-30 have continuous bleed systems.

**IMPORTANT: Do not perform venting when the engine is hot.**



1. Air vent screw

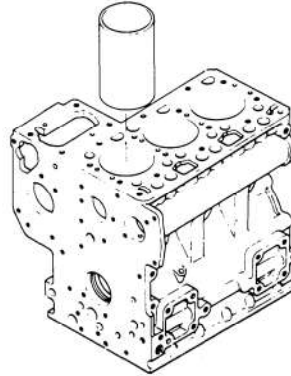
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## CYLINDER BLOCK

The engine features a high durability tunnel-typed cylinder in which the crank bearing part is constructed body. Furthermore, dry-type cylinder liners, being pressure-fitted into cylinders, allow effective cooling, less distortion, higher wear-resistance qualities and each cylinder having its own chamber helps to minimize noise.

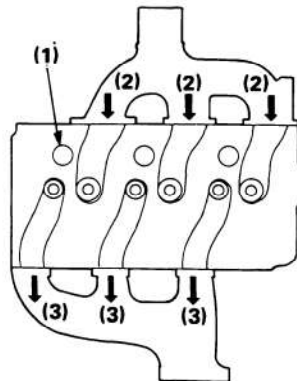
**Tunnel cylinder block**



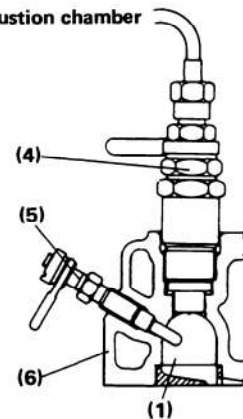
## CYLINDER HEAD

The cross-flow type inlet/exhaust ports in this engine have their openings at both sides of the cylinder head. Because overlaps of inlet/exhaust ports are smaller than in ports of other types which have openings one side, the suction air can be protected from being heated and expanded by heated exhaust air. The cool, high density suction air has a higher voluminous efficiency and raises the power of the engine. Furthermore, distortion of the cylinder head by heated exhaust air is reduced because suction ports are arranged alternately. The combustion chamber is exclusive spherical combustion chamber type. Suction air is whirled to be mixed effectively with fuel, prompting combustion and reducing fuel consumption. In the combustion chamber are installed throttle type injection nozzle and rapid heating sheathed type glow plug. This glow plug assures easier than ever engine starts even at  $-15^{\circ}\text{C}$  ( $15^{\circ}\text{F}$ ).

**Cross-flow type cylinder head**



**Combustion chamber**



1. Combustion chamber
2. Suction
3. Exhaust
4. Nozzle assembly
5. Glow plug
6. Cylinder head

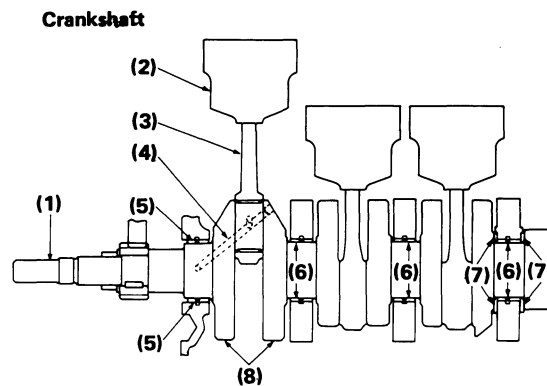
## CRANKSHAFT

The crankshaft is driven by the pistons and connecting rods, and translates its reciprocating movement into a circular movement. It also drives the oil pump, camshaft and fuel camshaft. Six counterweights are integrated into one unit to minimize bearing wear and lubricating oil temperature rise. Crankshaft journals, crankpins and oil seal sliding section are induction-hardened to raise wear resistance quality. Crankshaft journals are supported by the main bearing cases in which bearing is used.

Crankshaft bearing 1 at the front end is a wind type bushing and the three bearings 2 behind are split type bushings.

Side bearings 1,2 of split type are mounted on both sides of the main bearing case 1 at the flywheel side.

Crankshaft bearings and side bearings are plated with special alloy to raise wear resistance quality.



1. Crankshaft
2. Piston
3. Connecting rod
4. Oil passage
5. Crankshaft bearing 1
6. Crankshaft bearing 2
7. Side bearing
8. Counterweight

## PISTON AND PISTON RINGS

Piston circumference has a special elliptic shape in consideration of expansion due to explosion heat. Piston head is flat-formed. Furthermore, ribs are provided between the piston head and top ring to reduce distortion and to help heat radiation.

Piston is made of special aluminum alloy of low thermal expansion and high temperature resistance.

Top ring is of key stone type which can stand against heavy load, and the sliding surface to the cylinder wall is shaped into barrel face which is well fitted to the wall and plated with hard chrome.

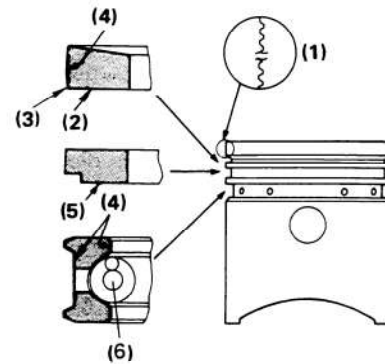
Second ring is of under-cut type which is effective to prevent oil rising.

Oil ring is effective to scrape oil because it is closely fitted to the cylinder wall by coil expander and the upper and lower ends of its sliding surface are cut diagonally to raise fare pressure to the cylinder walls.

A part of scraped oil is forced into the inside of piston through oil escape holes of rings and piston. The oil ring is plated with hard chrome to increase wear resistance quality.

1. Rib
2. Top ring
3. Barrel face
4. Hard chrome plating
5. Second ring
6. Coil expander ring

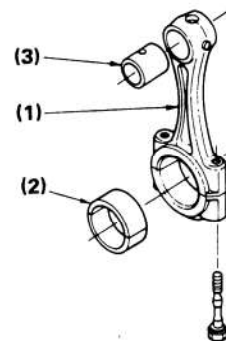
Pistons and piston rings



## CONNECTING RODS

Connecting rod is used to connect the piston with the crankshaft. The big end of the connecting rod has crankpin bearings (split type) and the small end has a bushing (solid type).

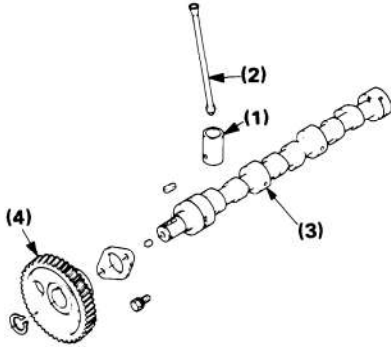
1. Connecting rod
2. Crankpin bearing
3. Bushing



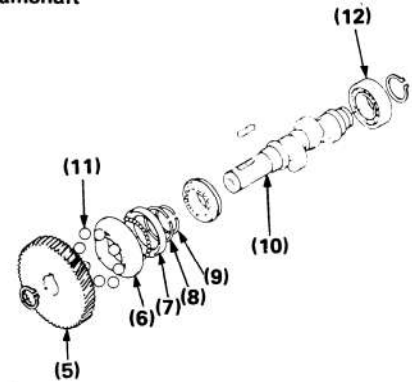
## CAMSHAFT AND FUEL CAMSHAFT

The camshaft is made of special cast iron and the journal and cam sections are chilled to resist wear. The journal sections are force-lubricated. The fuel camshaft controls the reciprocating movement of the injection pump, and is equipped with a ball to control the governor. Fuel camshaft is made of carbon steel and cam sections are quenched and tempered to provide greater wear resistance.

Camshaft



Fuel Camshaft

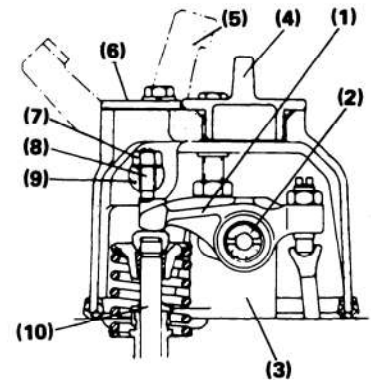


1. Tappet
2. Push rod
3. Camshaft
4. Camshaft gear
5. Injection pump gear
6. Governor sleeve
7. Governor ball case
8. Circlip
9. Circlip
10. Fuel camshaft
11. Ball
12. Ball bearing

## ROCKER ARM ASSEMBLY

The rocker arm assembly includes the rocker arms, rocker arm brackets and rocker arm shaft and converts the reciprocating movement of the push rods to an open/close movement of the inlet and exhaust valves. Valve control timing must be adjusted with screws on the rocker arms. Lubrication oil is pressurized through the bracket to the rocker arm shaft so that the rocker arm bearings and the entire system are lubricated sufficiently.

1. Rocker arm
2. Rocker arm shaft
3. Rocker arm bracket
4. Oil filler plug
5. Decompression lever
6. Decompression window cover
7. Decompression nut
8. Decompression bolt
9. Decompression shaft
10. Valve

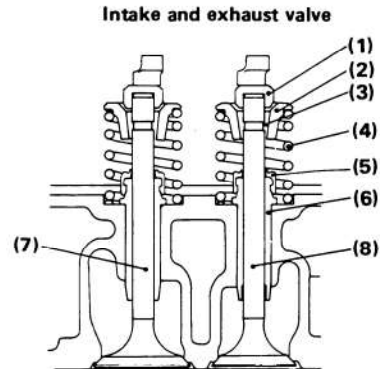




## INLET AND EXHAUST VALVES

The inlet and exhaust valves and their guides are different from each other. Other parts, such as valve springs, valve spring retainers, valve spring collets, valve stem seals, and valve caps are the same for both the inlet and exhaust valves. All contact or sliding parts are quenched and tempered to resist wear.

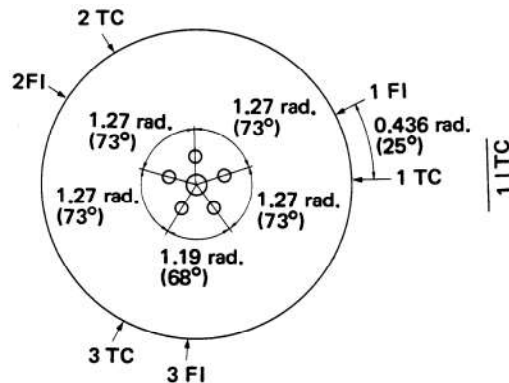
1. Valve cap
2. Valve spring Retainer
3. Valve spring Collets
4. Valve spring
5. Valve stem seal
6. Valve guide
7. Inlet valve
8. Exhaust valve



## FLYWHEEL

Flywheel is connected with the crankshaft. Storing explosive force by each cylinder as the force of inertia, the flywheel functions to rotate the crankshaft smoothly.

On the circumference of the flywheel are stamped marks for fuel injection timing and top dead center. The flywheel and crankshaft can be fixed to each other at a certain point according to the arrangement of flywheel mounting bolt hole.



1/TC. ....Mark for top dead center of 1st piston

1/FI. ....Mark for fuel injection of 1st piston

## SECTION IV - LUBRICATION, COOLING, AND FUEL SYSTEMS

### LUBRICATION SYSTEM

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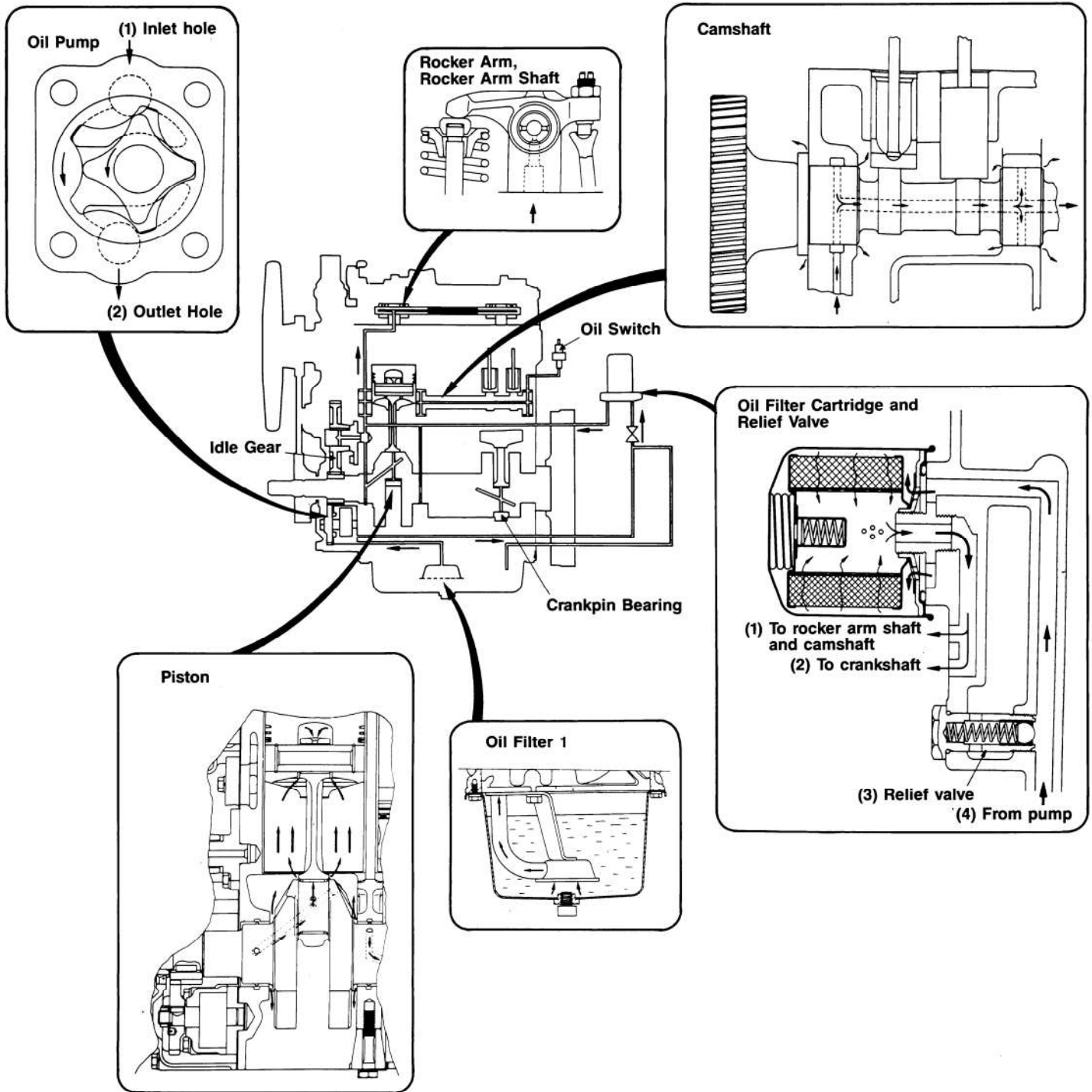
### COOLING SYSTEM

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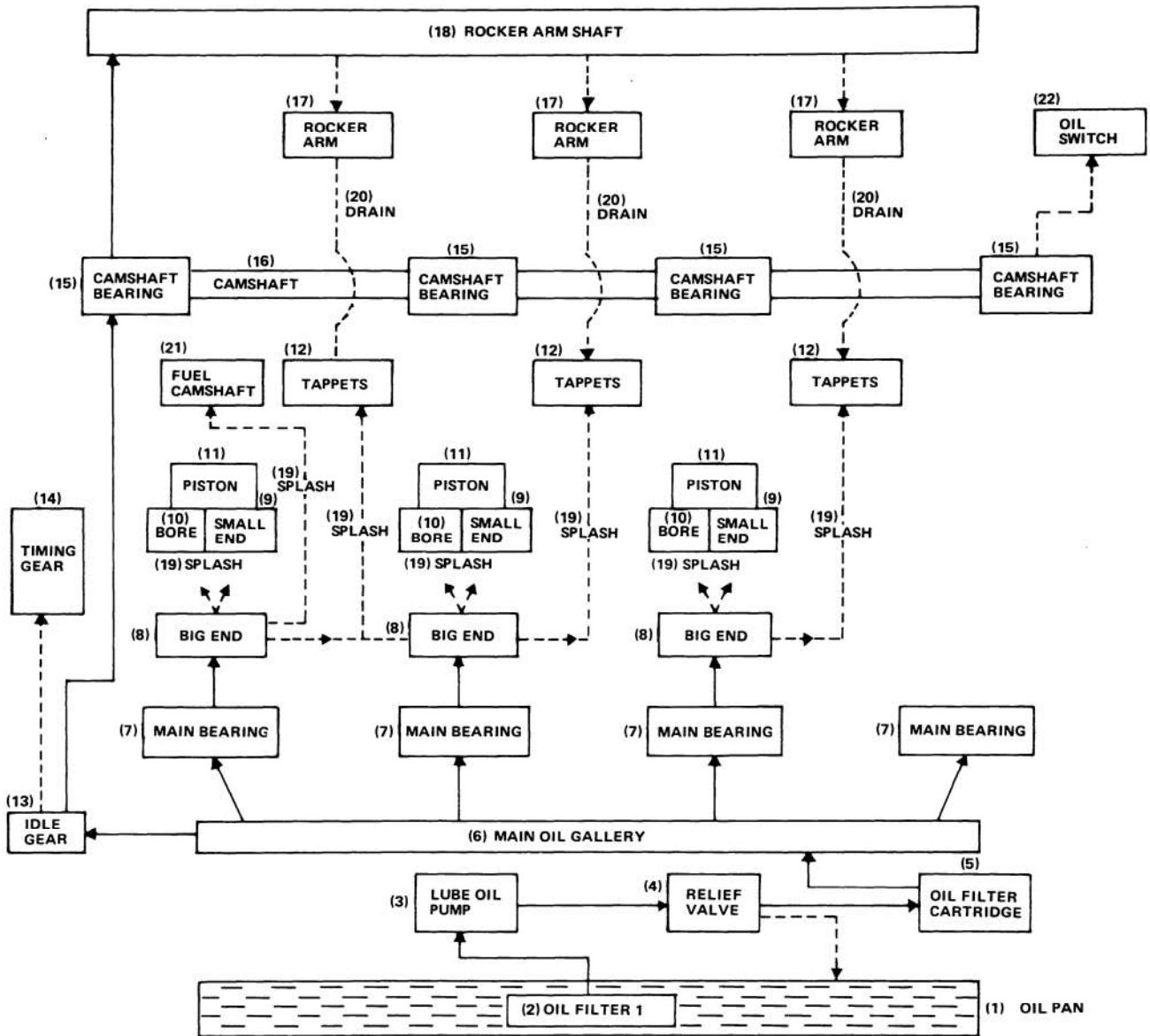
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# LUBRICATION SYSTEM



# ENGINE OIL FLOW



This engine lubrication system consists of oil filter 1 (strainer), oil pump, relief valve, oil filter cartridge and oil switch. The oil pump suctions lubrication oil from the oil pan through oil filter 1, and the oil flows down to the filter cartridge, where it is further filtered. Then the oil is forced to crankshaft, connecting rods, idle gear, camshaft and rocker arm shaft to lubricate each part. Some part of oil, splashed by the crankshaft or leaking and dropping from gaps of each part, lubricates these parts: pistons, cylinders, small ends of connecting rods, tappets, pushrods, inlet and exhaust valves and timing gears.

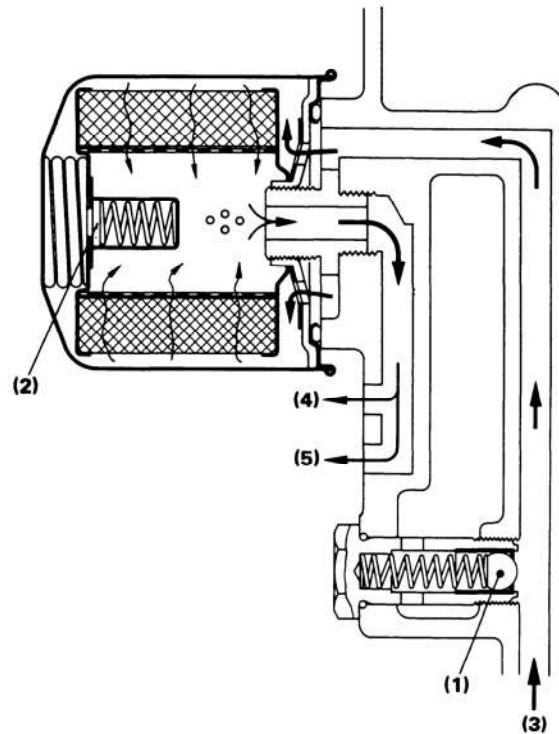
## RELIEF VALVE

Relief valve prevents damage to the lubrication system due to high oil pressure. Control range of the relief valve is 196 to 441 KPa, (28 to 64 psi.) When oil pressure exceeds the upper limit, the ball is pushed back by high pressure oil and the oil escapes.

## BY-PASS VALVE

Oil filter cartridge has a by-pass valve inside, to prevent the lack of lubrication oil in the engine, if the oil filter element is clogged. When the pressure difference before filtering and after is more than 98.1 kPa (14.2 psi), the by-pass valve opens and lets the oil pass to each part of engine without passing through the filter.

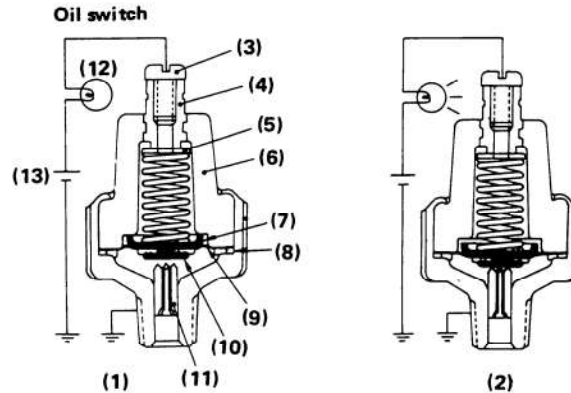
Relief valve and by-pass valve



1. Relief valve
2. By-pass valve
3. From pump
4. To rocker arm shaft and camshaft
5. To crankshaft

## OIL SWITCH

Oil switch is provided on the way for the oil pressure. If the oil pressure is proper, it is switched off, if oil pressure falls below 49.0 kPa (7.1 psi), the oil warning lamp etc. will light, warning the operator. In this case, stop the engine immediately and check the cause of the pressure drop.



1. When oil pressure is proper
2. When oil pressure falls
3. Screw
4. Terminal
5. Spring plate
6. Insulator
7. Spring retainer

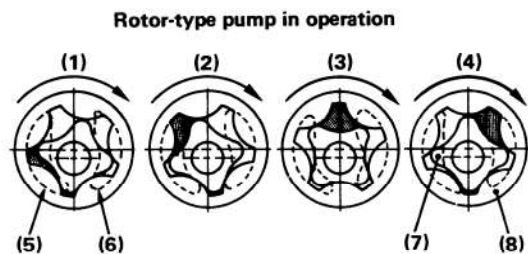
8. Rubber packing
9. Oil seat
10. Contact rivet
11. Contact
12. Lamp
13. Battery

## OIL PUMP

The oil pump is of rotor type and works smoothly and noiselessly. An inner and outer rotor turn inside a housing. In operation, the inner rotor is driven inside the outer rotor. The inner rotor has one less lobe than the outer rotor, so that only one lobe is in full engagement with the outer rotor at any one time. This allows the other lobes to slide over the outer lobes, making a seal to prevent back-up of oil.

As the lobes slide up and over the lobes on the outer rotor, oil is drawn in. As the lobes fall into the ring's cavities, oil is squeezed out.

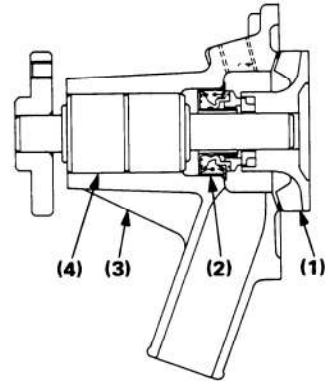
1. Draw in 1
2. Draw in 2
3. Draw in 3
4. Squeeze out
5. Inlet
6. Outlet
7. Inner rotor
8. Outer rotor



**WATER PUMP**

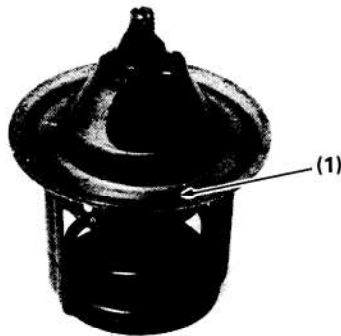
35 /min. (7.7 IMp.gals/min. 9.2 U.S. gals/min) of water is forced into the crank case and cylinder head to cool them. The impeller, of backward type, is bent as far as possible from the center, in the opposite direction to rotation. The bearing unit prevents cooling water from entering by a special mechanical seal.

- 1. Water Pump Impeller
- 2. Mechanical Seal
- 3. Water Pump Body
- 4. Bearing Unit

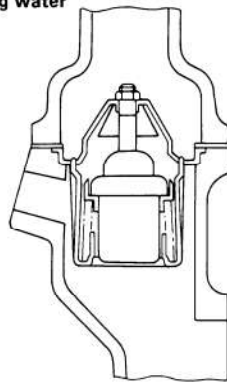


**THERMOSTAT**

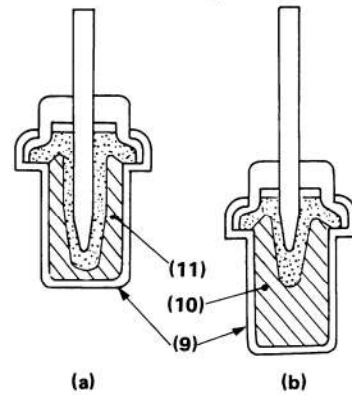
The thermostat maintains the cooling water at correct temperature and uses wax pellet type thermostat. Wax is enclosed in the pallet. The wax is solid at low temperatures, but turns liquid at high temperatures, expands and opens the valve.



Flow of cooling water



Temperature sensor of wax pellet type thermostat

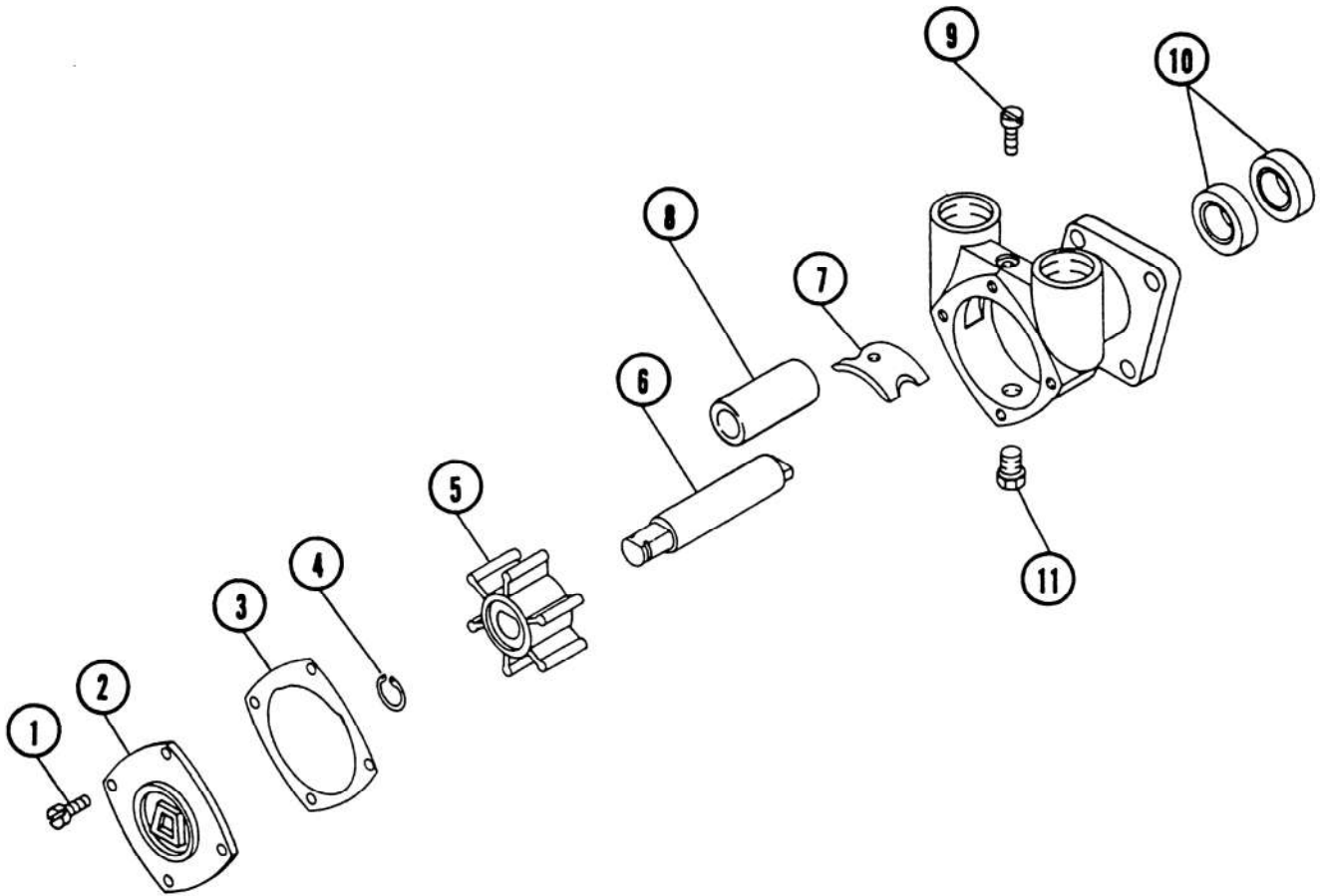


- 1. Leak hole
- 2. Water cover
- 3. Spindle
- 4. Pellet
- 5. Valve
- 6. Sheet

- 7. To radiator
- 8. To engine
- 9. Pellet
- 10. Wax (liquid)
- 11. Wax (solid)

- a) At low temperature
- b) At high temperature

# OBERDORFER WATER PUMP

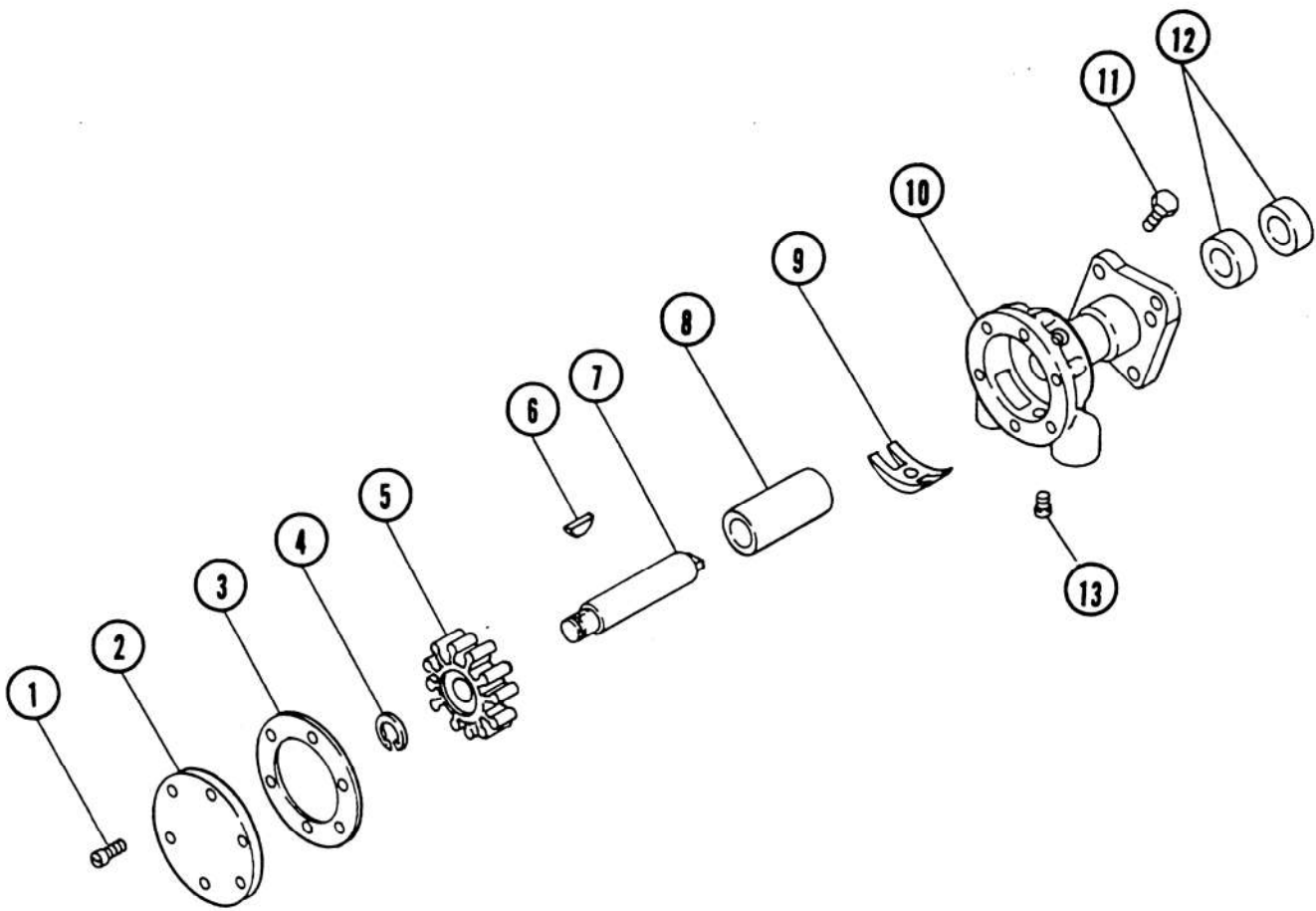


## PUMP ASSEMBLY 301357

Item	Unit	Description
1	4	Cover Screws
2	1	Pump Cover
3	1	Cover Gasket
4	1	Impeller Snap Ring
5	1	Impeller
6	1	PUMP Shaft Old Style
6A	1	1 pc. Shaft New Style
7	1	Cam
8	1	Carbon Bushing
9	1	Cam Locking Screw
10	2	Oil Seal
11	1	Drain Plug



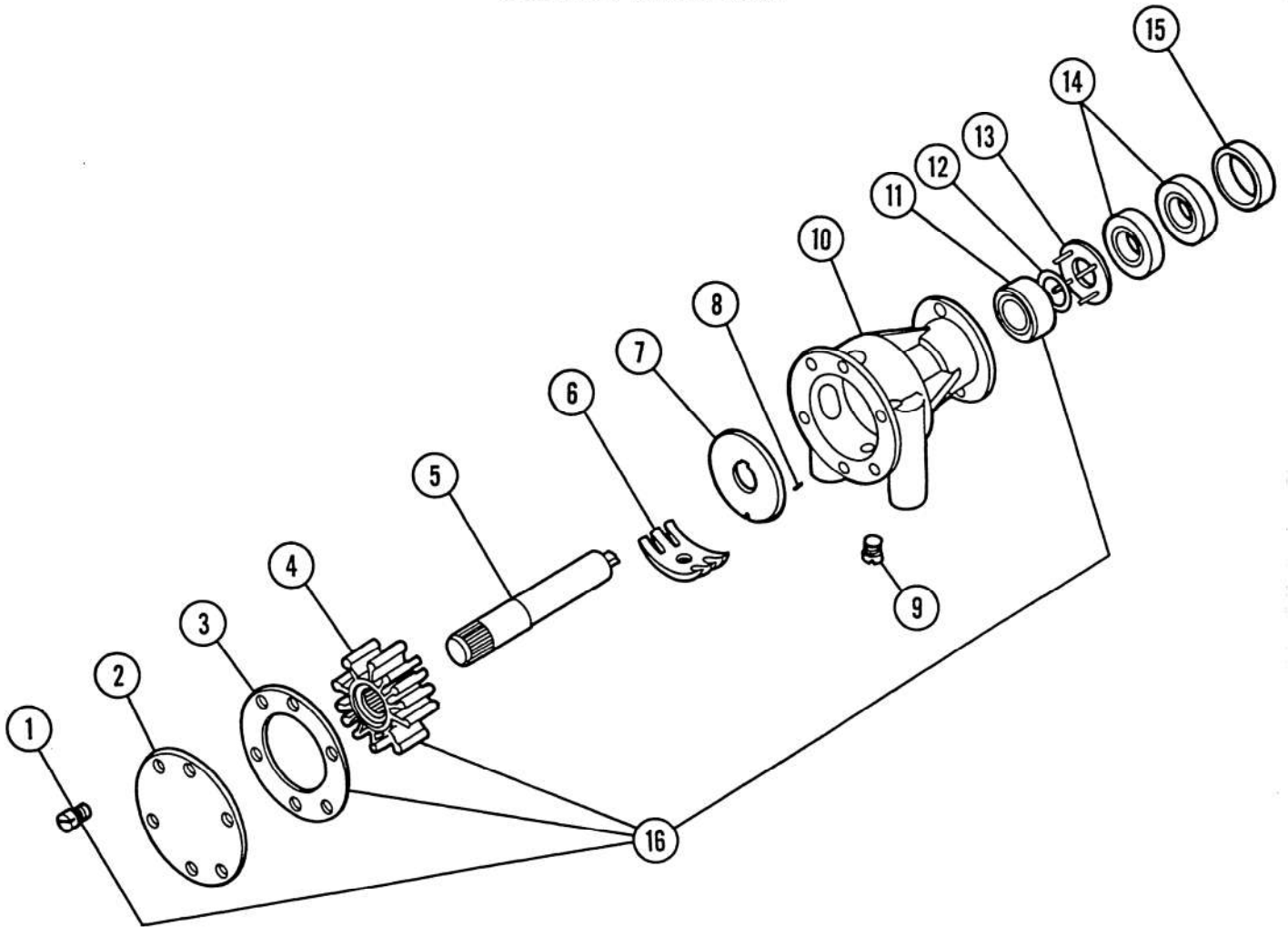
# SHERWOOD WATER PUMP



## PUMP ASSEMBLY 300986

Item	Unit	Description
1	6	Cover Screws
2	1	Pump Cover
3	1	Cover Gasket
4	1	Impeller Snap Ring
5	1	Impeller
6	1	Key
7	1	Pump Shaft Old Style
7A	1	1 pc. Shaft New Style
8	1	Water Seal
9	1	Cam
10	1	Pump Body
11	1	Cam Locking Screw
12	2	Oil Seal
13	1	Drain Plug

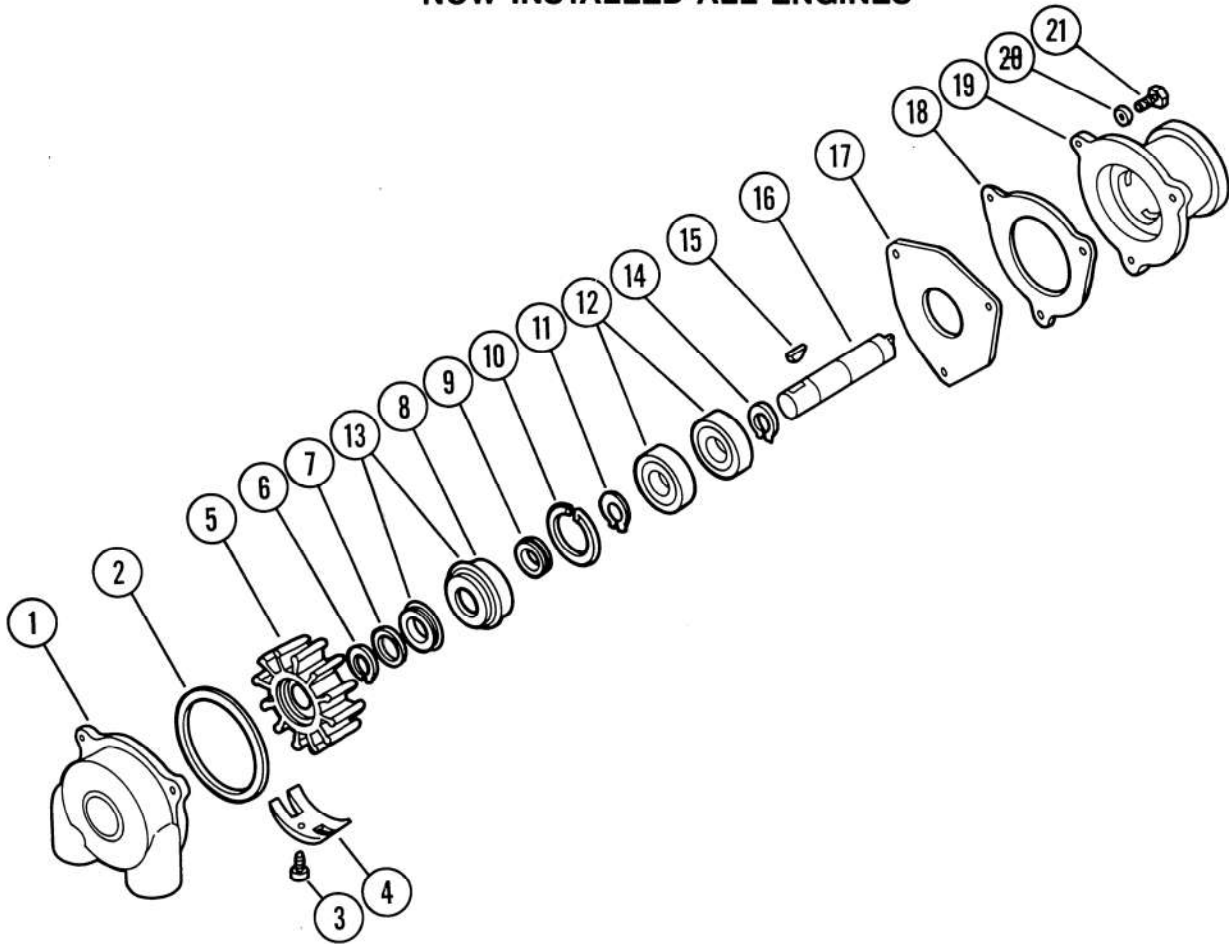
# JOHNSON WATER PUMP



## PUMP ASSEMBLY 302259

Item	Unit	Description
1	6	Cover Screws
2	1	Pump Cover
3	1	Cover Gasket
4	1	Impeller
5	1	Pump Shaft
6	1	Caqm
7	1	Wear Plate
8	1	Pin
9	1	Cam Locking Screw
10	1	PUmp Body
11	1	Lip Seal
12	1	O-Ring
13	1	Washer
14	2	Ball Bearing
15	1	Guide Ring
16	1	Service Kit

**NEW STYLE SHERWOOD WATER PUMP  
NOW INSTALLED ALL ENGINES**

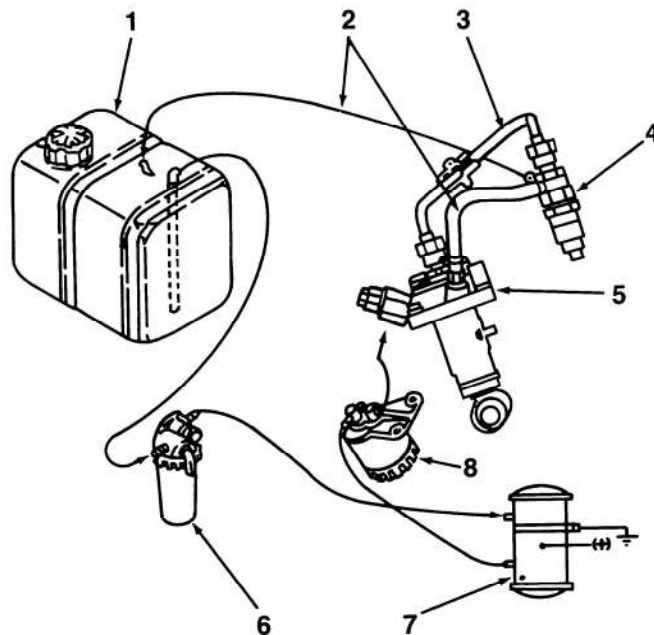


**PUMP ASSEMBLY 302648**

Item	Unit	Description
1	1	Impeller Housing
2	1	O-Ring
3	1	Cam Screw
4	1	Cam
5	1	Impeller
6	1	Cir-Clip
7	1	Flat Washer
8	1	Seal Seat
9		Not Available Order #13
10	1	Cir-Clip Internal
11	1	Cir-Clip External
12	2	Ball Bearing
13	1	Seal & Seat Assembly
14	1	Cir-Clip External
15	1	Key
16	1	Shaft
17	1	End Plate
18	1	Gasket
19	1	Pump Body
20	3	Lock Washer
21	3	Bolt

## FUEL SYSTEM

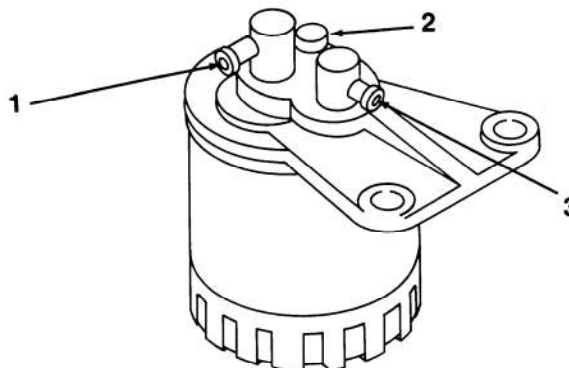
While the engine is running, fuel is fed from the fuel tank (optional part) through the fuel filter to the fuel pump, which feeds fuel to the injection pump. The injection pump then feeds the fuel through the injection pipes, to the nozzles which inject fuel to the cylinders for combustion. Any fuel leaking from nozzles is collected in the fuel overflow pipes which drain into the tank.



1. Fuel Tank
2. Fuel Overflow Pipe
3. Injection Pipe
4. Injection Nozzle
5. Injection Pump
6. Fuel Filter, Water Separator
7. Fuel Feed Pump (Elec.)
8. Fuel Filter

## FUEL FILTER

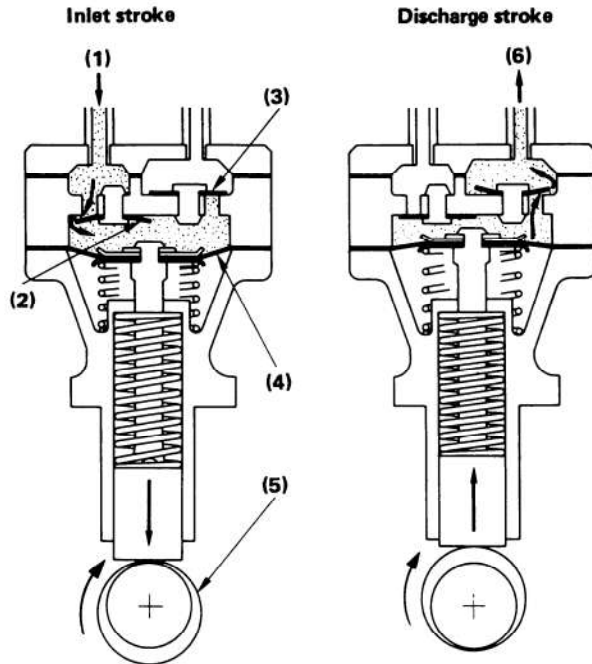
A fuel filter is used to prevent dirty fuel from reaching the injection pump and injection nozzles. The filter element will require occasional replacement to maintain an adequate flow of fuel to the injection pump. The frequency of this service will vary according to the cleanliness of available fuel and the care used in storage.



1. Cock Body Inlet
2. Cock Body Outlet
3. Air Vent Plug

## FUEL PUMP

Filtered fuel is forcibly sucked from the tank by the fuel pump and fed under pressure to the injection pump. Inlet and discharge pressures are produced by a vertical movement of the diaphragm which is caused by the special cam (for pump) of the fuel camshaft. Fuel is suctioned on the downward stroke, and discharged on the upward stroke. A system of two valves allows fuel to flow in only one direction.



1. From Fuel Filter
2. Inlet Valve
3. Outlet Valve
4. Diaphragm
5. Fuel Camshaft
6. To Injection Pump

## FUEL INJECTION PUMP

The K type mini pump is provided, it features high injection quality even at low engine speed. The fuel injection pump plunger is reciprocated by the fuel camshaft which is driven by the crankshaft through a system of timing gears. Fuel camshaft rpm is 1/2 of crankshaft rpm.



1. Delivery Valve Holder
2. Delivery Valve Spring
3. Delivery Valve
4. Plunger
5. Cylinder Pump Element
6. Control Rack
7. Tappet
8. Plunger Spring
9. Air Vent Screw

## Fuel Pressure-feed

### 1. Bottom dead center of plunger:

At bottom dead center, fuel enters the delivery chamber through the fuel chamber and the feed hole. (Fuel chamber is always kept full by the fuel pump.)

### 2. Pressure-feed start

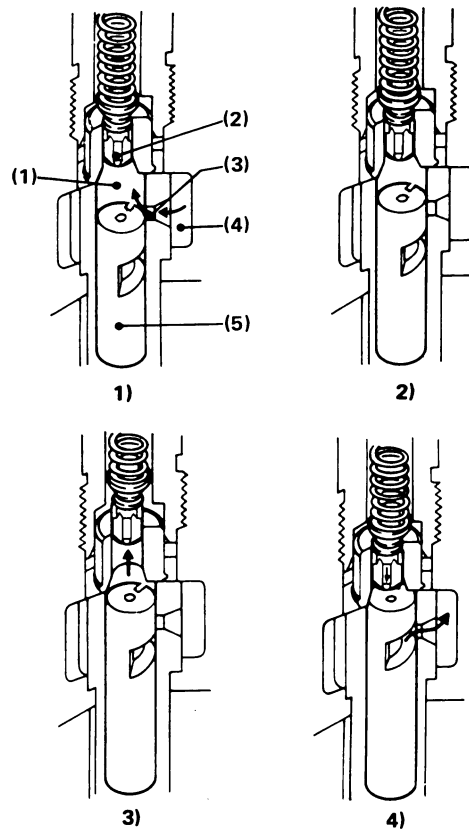
### 3. Pressure-feed process:

Plunger is pushed up by camshaft to close the feed hole, and fuel pressurization starts. As the plunger moves up, pressure increases, and delivery valve is opened. Then fuel is pressure-fed through the injection pipe and nozzle into the combustion chamber.

### 4. Completion of pressure-feed:

When plunger moves further up, the control groove and feed hole meet. Pressurized fuel in the delivery chamber is returned through the plunger's center hole, control groove, and feed hole to the fuel chamber. Then pressure falls and pressure-feed is completed.

Pressure-feed Start to Completion



1. Delivery Chamber
2. Delivery Valve
3. Feed Hole
4. Fuel Chamber
5. Plunger

## Injection Control

### 1. Injection "zero":

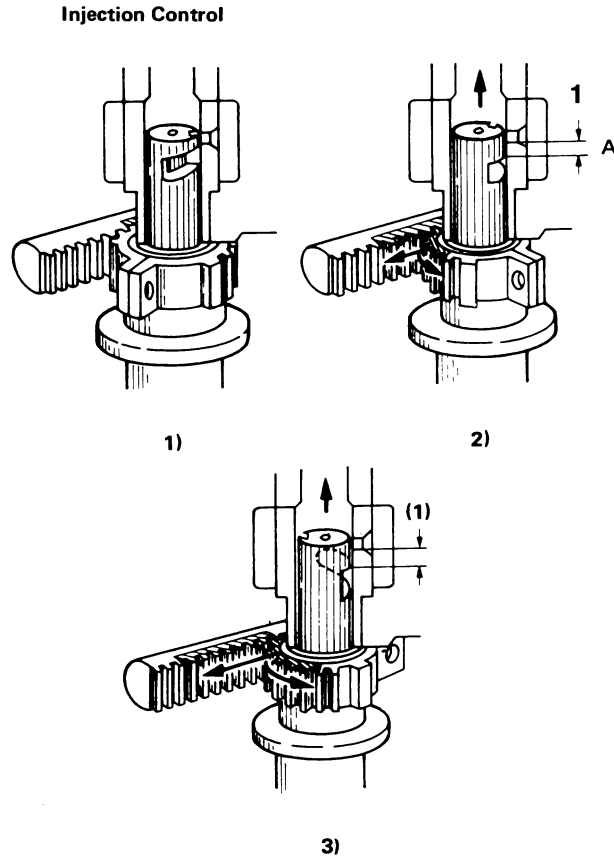
The feed hole meets the control groove before it is closed by the plunger top. Therefore, fuel is not pressurized, and is not injected even if the plunger moves up.

### 2. Injection "medium":

When the plunger is rotated a certain amount in the direction of the arrow by the control rack, stroke A is effective until the feed hole meets the control groove and fuel is injected as the stroke amount.

### 3. Injection "maximum":

When the plunger is rotated by the control rack to the maximum amount (in the direction of the arrow), effective stroke reaches maximum and maximum injection is provided.



### 1. Effective Stroke

## Delivery Valve

The delivery valve is composed of the valve and the valve seat. It performs two functions:

### 1. Reverse flow prevention:

If the circuit between the delivery chamber and the nozzle is always closed, a time lag will occur between pressure feed start of valve element and start of nozzle injection. This, in turn, will prevent injection from stopping properly until after completion of pressure-feed.

To eliminate this time lag, the valve lowers on completion of pressure-feed and the relief valve contacts the valve seat, and breaks the circuit between the injection pipe and plunger.

### 2. Fuel dribbling prevention:

After the relief valve contacts delivery valve seat, this valve lowers a little. Since the relief valve breaks the circuit pressure in the injection pipe is reduced as the valve lowers, preventing fuel dribbling from the nozzle.

## Pump Element

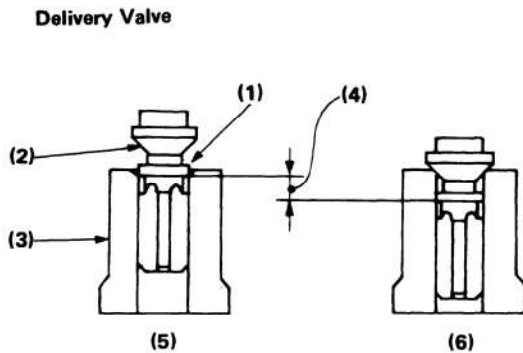
The pump element is composed of a cylinder and a plunger. Their contact surfaces are precision finished to provide a high injection pressure even at low speeds. The cylindrical surface of the plunger has slanted grooves, which are called control grooves, and a connecting hole for plunger head.

## Control Rack

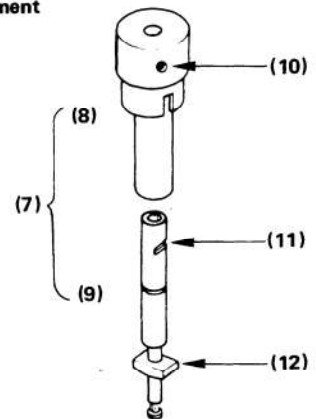
This is connected directly to the governor fork in the engine body. It is connected with the plunger by pinion to change injection volume.

## Tappet

The tappet converts rotating movement of the camshaft into a reciprocating movement to drive plunger. A roller is used where it contacts the cam to reduce friction.



Pump Element

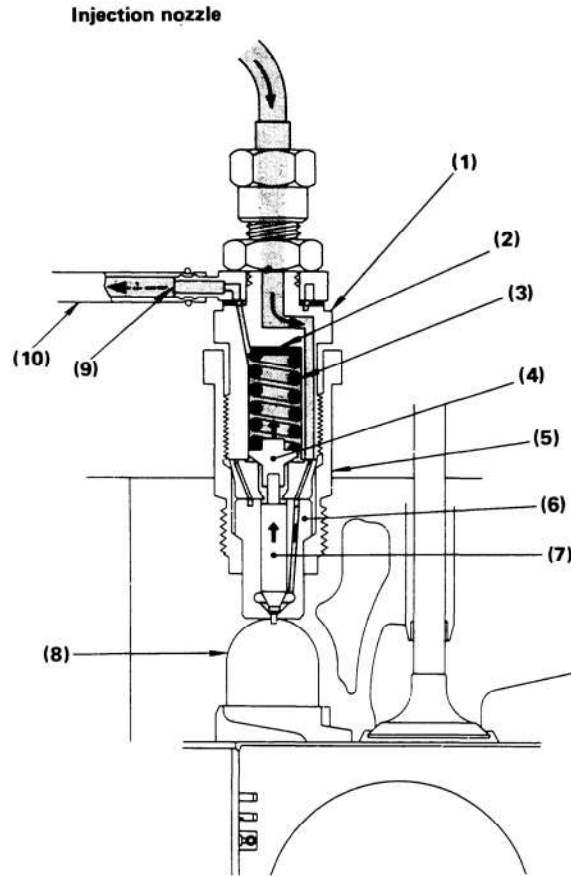


1. Relief Valve
2. Seat
3. Delivery Valve Seat
4. Pressure Decrease Because of Increase in this Volume
5. End of Pressure-feed and Start of Sucking Back
6. End of Sucking Back
7. Pump Element
8. Cylinder
9. Plunger
10. Feed Hole
11. Control Groove
12. Driving Face



## INJECTION NOZZLE

This nozzle is throttle-type. Fuel fed from the pump pressurized to push the needle valve up and the fuel is then injected. The needle valve is pressed by the nozzle spring through the push rod. Fuel overflow is passed from nozzle holder center through the fuel overflow nipple and the fuel overflow pipe to the fuel tank. Injection pressure can be controlled by inserting shims between nozzle holder body and adjusting washers. The pressure increases when a 0.1mm shim is inserted. Injection nozzle is also precision finished as is the injection pump, treat it carefully and protect from water and dust.



1. Nozzle Holder Body
2. Adjusting Washer
3. Nozzle Spring
4. Push Rod
5. Retaining Nut
6. Nozzle Body
7. Needle Valve
8. Combustion Chamber
9. Fuel Overflow Nipple
10. Fuel Overflow Pipe

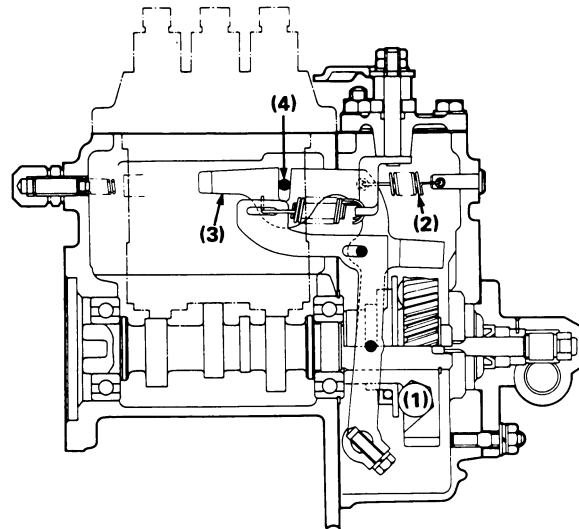
## GOVERNOR

With centrifugal ball weight system this mechanical governor works in the whole range of speeds. It keeps the engine speed and controls the engine output.

### **At Start**

When the engine is started, more fuel is required than in running. At starting, fork lever 1 is pulled rightward by starter spring because ball weights have no centrifugal force. Control rack moves to a position for overlimit discharging of fuel to assure easy starting.

At start

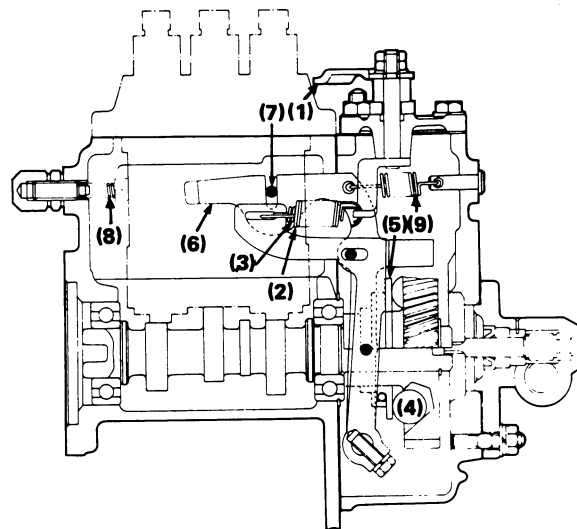


1. Ball Weights
2. Start Spring
3. Fork Lever 1
4. Control Rack

### **At Idling**

When speed control lever is set at idling position after the engine is started, high speed governor spring 1 does not work at all and also low speed governor spring 2 does only a little action. Therefore, governor sleeve is pushed leftward by a centrifugal force of ball weights. Fork lever 1 and control rack are moved leftward by the sleeve and then idling limit spring is compressed by control rack. As a result, the control rack is kept at a position where a centrifugal force of ball weights and forces start spring, governor spring 2 and idling limit spring are balanced, providing stable idling.

At idling

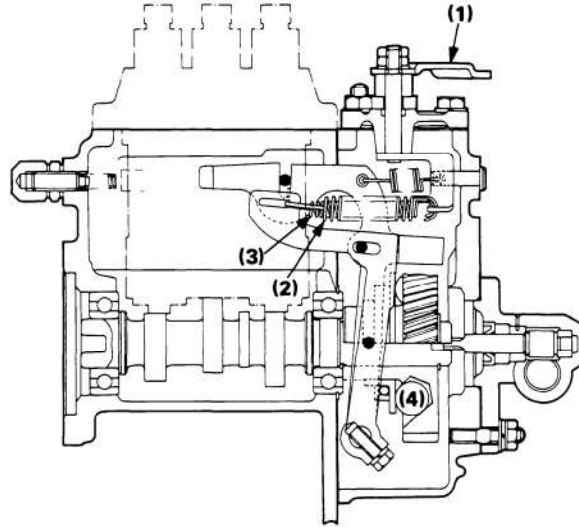


1. Speed Control Lever
2. Governor Spring 1
3. Governor Spring 2
4. Ball Weight
5. Governor Sleeve
6. Fork Lever 1
7. Control Rack
8. Idling Limit Spring
9. Start Spring

**At middle/high speed running**

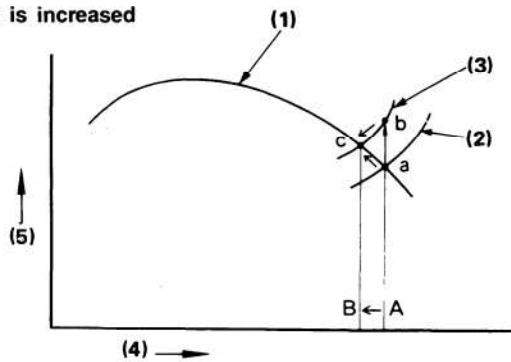
The engine speed is controlled when the tension of governor springs 1 and 2, which are pulled speed control lever, and the centrifugal force of ball weights are balanced. When the speed is reduced (A - B) with load increased (a - b), the centrifugal force of ball weights becomes smaller than the tension of governor springs 1 and 2. As a result, the control rack is moved rightward and fuel injection amount is increased to produce an engine torque required for the load. (a - c)

At middle/high speed running



- 1. Speed Control Lever
- 2. Governor Spring 1
- 3. Governor Spring 2
- 4. Ball Weights

When load is increased

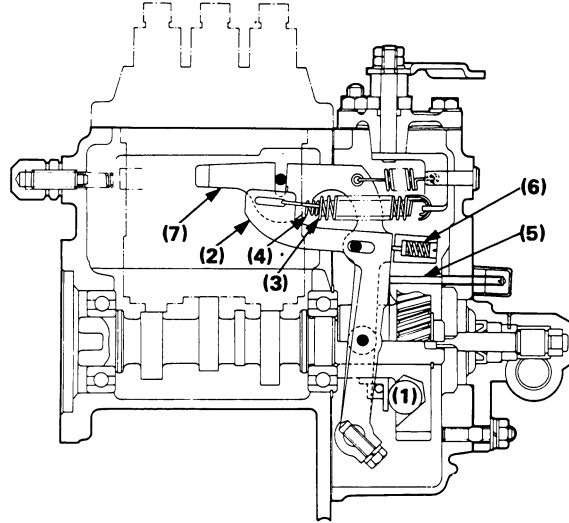


- 1. Engine Torque Curve
- 2. Small Loan Torque Curve
- 3. Large Load Torque Curve
- 4. Engine R.P.M.
- 5. Torque

### At high speed running with overload

When an overload is applied to the engine running at a high speed, the centrifugal force of ball weights become small as the speed is reduced, and fork lever 2 is pulled rightward by governor springs 1 and 2, increasing fuel injection. Fork lever 2 becomes ineffective to increase fuel injection when it is stopped by maximum output limit bolt. After that when the force of spring becomes larger than the centrifugal force of ball weights, fork lever 1 moves rightward to increase fuel injection, driving the engine continuously with a high torque.

At high speed running with overload

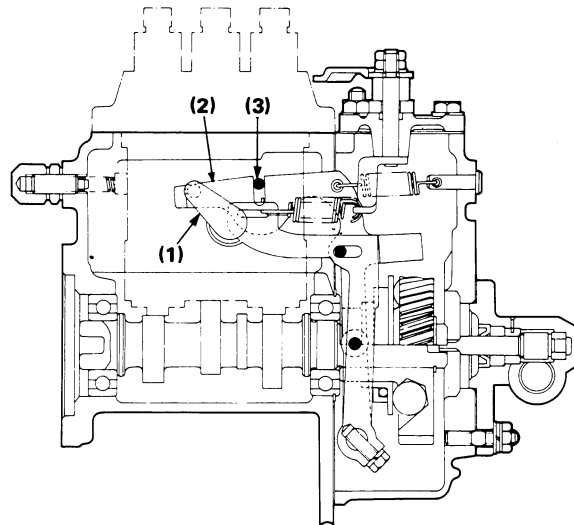


1. Ball Weight
2. Fork Lever 2
3. Governor Spring 1
4. Governor Spring 2
5. Maximum Output Limit Bolt
6. Spring
7. Fork Lever 1

### To stop engine

When stop lever is moved to "STOP" position, fork lever is moved leftward and then control rack is moved to the non-injection position, stopping the engine.

To stop engine



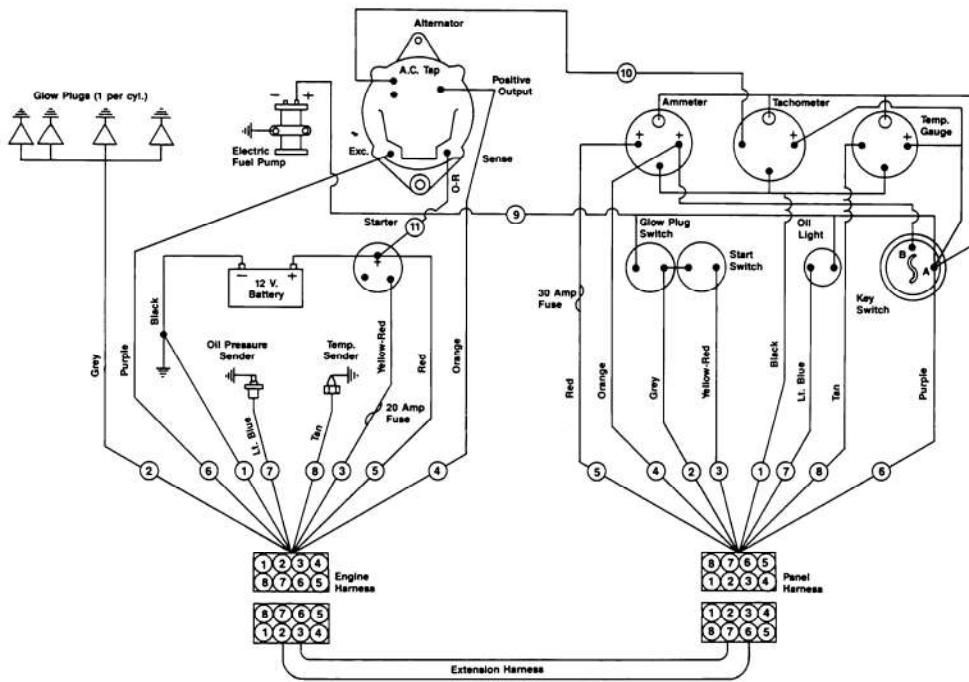
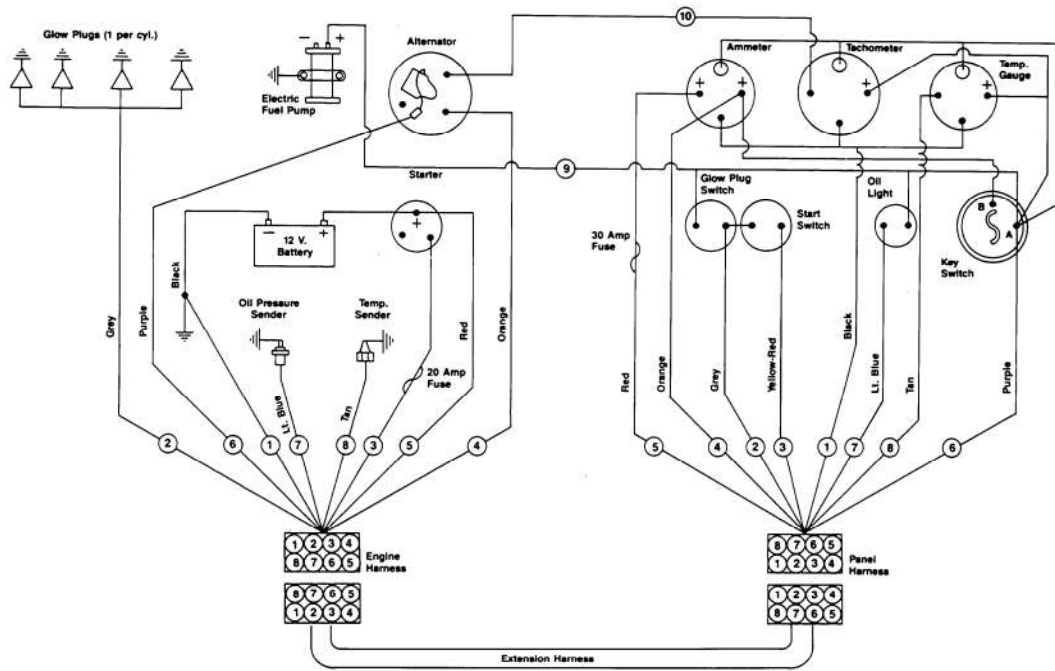
1. Stop Lever
2. Fork Lever 1
3. Control Rack

## NOTES

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# WIRING DIAGRAM



WIRE NO.	COLOR	WIRE SIZE
1	Black	#10
2	Grey	#10
3	Yellow-Red	#16
4	Orange	#10
5	Red	#10
6	Purple	#16
7	Lt. Blue	#16
8	Tan	#16
9	Open	#14
10	Grey	#16
11	Orange-Red	#14

## ELECTRICAL SYSTEM

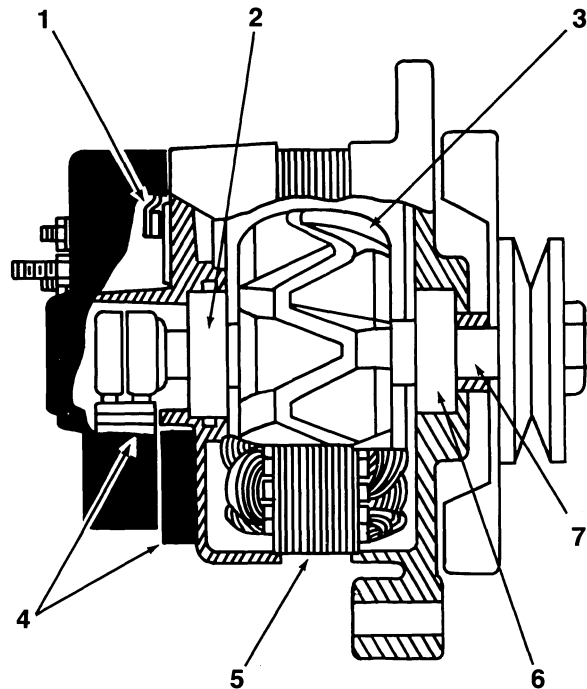
### General Information

The 8E series of charging systems were designed for the replacement of many current Motorola models. Models are available for 51 amp, 12 volt, negative ground systems with or without an integral, solid-state voltage regulator.

The integral voltage regulator incorporates an IC, all silicon semiconductors and thick-film construction.

The remote regulator model alternator is quipped with a blade terminal for connection to the associated remote regulator.

Serviceable features of previous Motorola Charging System designs have been retained in these units. The voltage regulator and brush assembly can be removed without disassembly of the alternator thus allowing for individual testing or inspection.



1. Long life silicon diodes
2. Permanently lubricated & sealed rear ball bearing
3. Quiet & trouble-free dynamically balanced rotor
4. Convenient regulator & brush replacement
5. Insulated stator prevents shorts
6. Permanently lubricated & sealed front ball bearing
7. Standard  $\frac{5}{8}$ " shaft

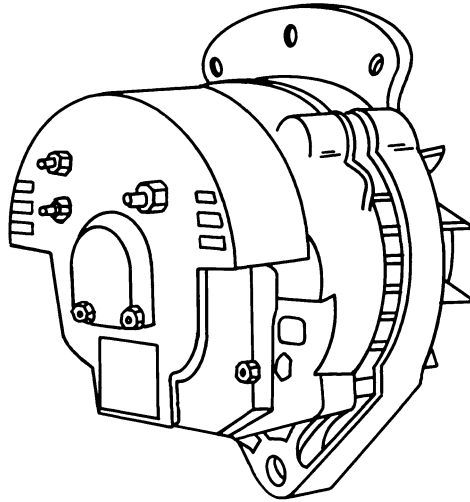
**CUTAWAY VIEW OF TYPICAL ALTERNATOR**



## ALTERNATOR

These alternators are available in two basic versions. One version includes a solid-state regulator and forms a complete charging system. The other version does not include a regulator. However, it is equipped with a blade terminal for connection to a remote regulator.

The alternator portions of these charging systems are three-phase, diode rectified machines with die cast aluminum housings to provide the necessary strength while keeping the weight to a minimum. The weight of a typical alternator, excluding pulley, is approximately 10 pounds.



**TYPICAL ALTERNATOR MODEL**

The field for the alternator is wound concentrically about the core of the rotor. The field structure contains twelve poles (six sets of pole pairs) and the rotor is dynamically balanced after assembly to minimize vibration. The rotor is supported in the alternator by a pair of sealed ball bearings.

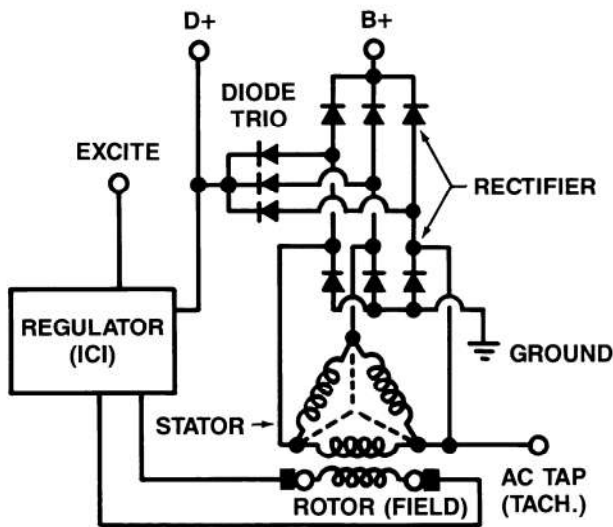
Field current of approximately 2.5 Amperes is supplied to the field through copper slip rings and a set of electrographite brushes. The slip rings are small in diameter for extended brush life.

**NOTE:** The design is a sealed brush design and therefore is suitable for marine applications. The brushholder is easily removed for either inspection or replacement. Removal does not require the disassembly of the alternator.

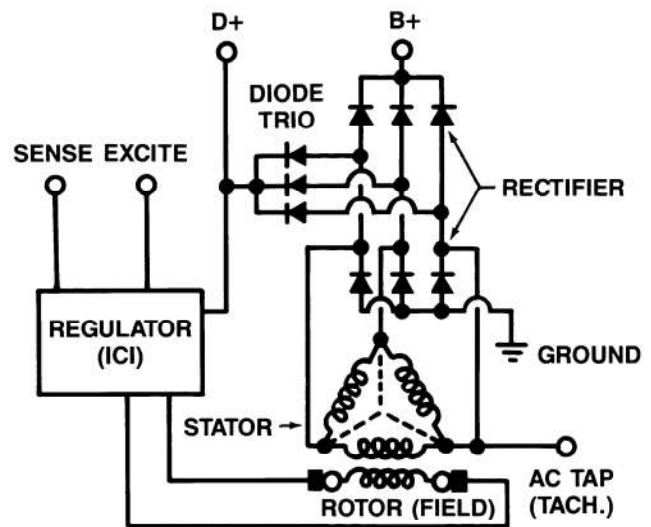
The stator is connected to a three-phase, full-wave bridge rectifier package which contains six diodes. The bridge converts the A.C. generated in the stator to a D.C. output for battery charging and accessories such as radio, heater, lights, ignition, etc. See illustrations below.

Power to the regulator and the field of the integral regulator alternators is provided by the field diode (or diode trio) package contained in the alternator. Remote regulator alternators obtain field power via the regulator in the charging system.

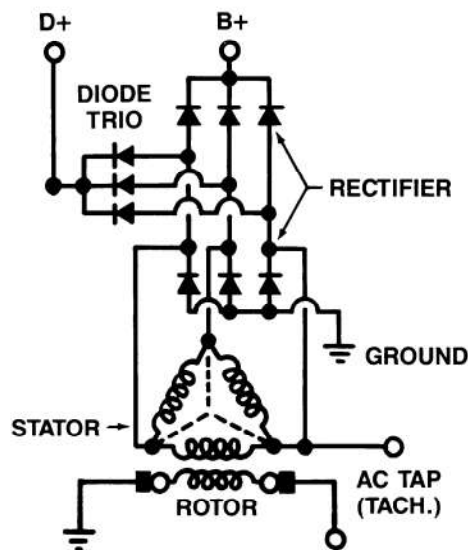
The alternator designs produce a rated output of 51 amperes. Rated output is achieved at approximately 6000 alternator RPM at an ambient temperature of 75 degrees F (23.8 degrees C). The alternator is designed to operate in an ambient of -40 degrees to 212 degrees F (-40 to 100 degrees C). To ensure proper cooling of the rectifier bridge and internal components of the alternator, it must be used with the proper cooling fan.



ALTERNATOR SENSE (INTEGRAL REG.)

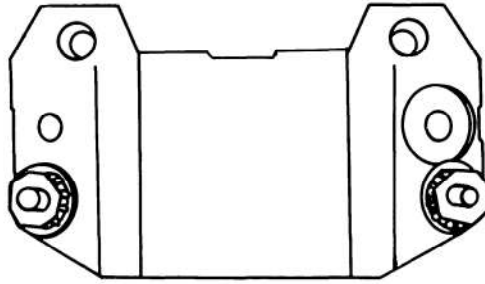


BATTERY SENSE (INTEGRAL REG.)



REMOTE REGULATOR

ALTERNATOR SCHEMATIC DIAGRAMS



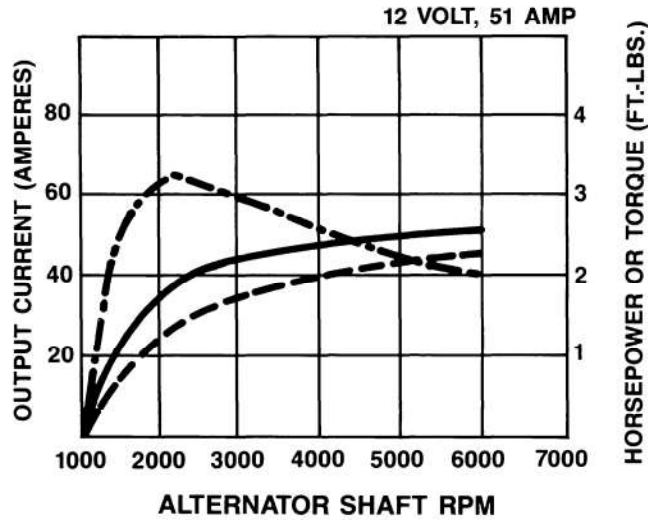
**INTEGRAL REGULATOR**

**Integral Voltage Regulator**

The voltage regulator is an electronic switching device which senses system voltage level and switches the voltage applied to the field in order to maintain proper system voltage.

The regulator design utilizes all silicon semi-conductors and thick-film assembly techniques. After the voltage has been adjusted to the proper regulating value, the entire circuit is encapsulated to protect the circuit and the components from possible damage due to handling or vibration and moisture encountered in a vehicle.

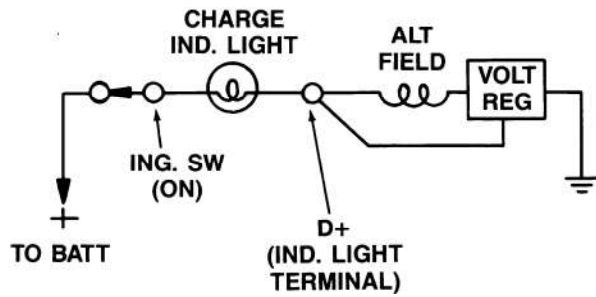
The voltage regulator is also temperature compensated to provide a slightly higher voltage at low temperatures and a lower voltage at higher temperatures to provide for charging requirements of the battery under these conditions.



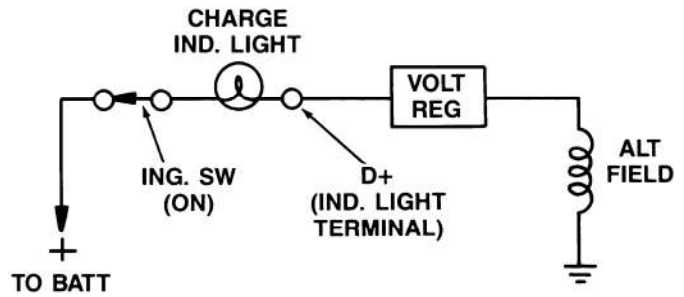
**TYPICAL PERFORMANCE CURVES  
@ AMBIENT TEMPERATURE OF 75°  
(23.8°C) SAE TEST METHOD**

## Alternator Excitation

The residual magnetism of an alternator is very low therefore some field current must be supplied to the rotor to initiate the generation of power by the machine.



**INTERGRAL REGULATOR ALTERNATOR EXCITATION CIRCUIT**



**REMOTE REGULATOR ALTERNATOR EXCITATION CIRCUIT**

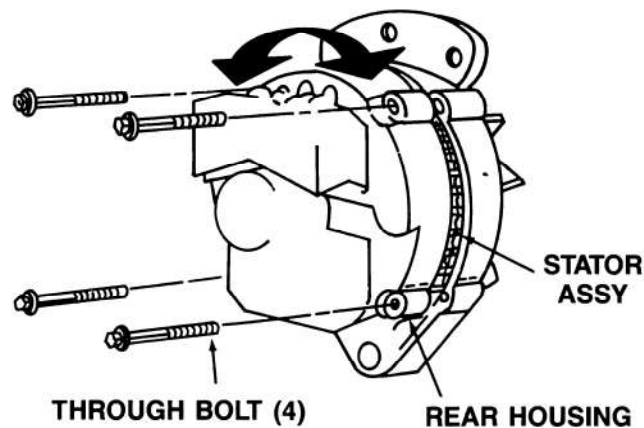
## Alternator Installation

Observe vehicle battery polarity prior to connecting output cables to the alternator. Reverse battery polarity will destroy the alternator rectifier diodes.

### ALTERNATOR REAR HOUSING ROTATION

For special installation requirements, the alternator rear housing may be rotated to one of four different positions that are spaced 90° apart. To rotate the rear housing, proceed as follows:

1. Detach plastic cover from rear housing.
2. Remove the four (4) through-bolts using a 1/4" nutdriver or socket. See illustration below.
3. Rotate the housing (clockwise or counter-clockwise) to the desired location. The stator assembly must be rotated with the rear housing.
4. Replace through-bolts. Tighten through-bolts alternately and evenly until tight. Check that rotor shaft turns freely after re-assembly.
5. Reattach plastic cover to rear housing. NOTE: Be sure felt gasket located on inside of cover is in place.

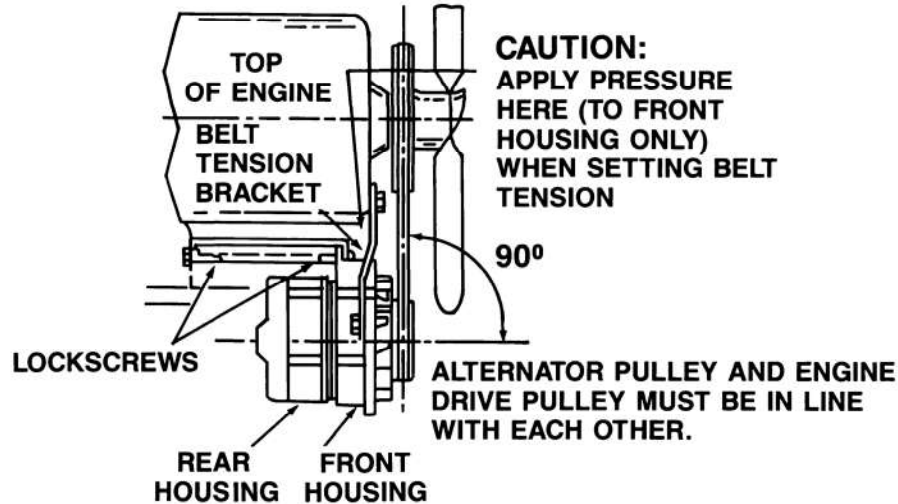


**THROUGH-BOLT REMOVAL**

## BELT INSTALLATION, ALIGNMENT & TENSIONING

Correct belt alignment is essential for maximum alternator and belt service life. The center line of all pulleys related to the alternator drive must be within 1/32" of the true center line. See illustration below.

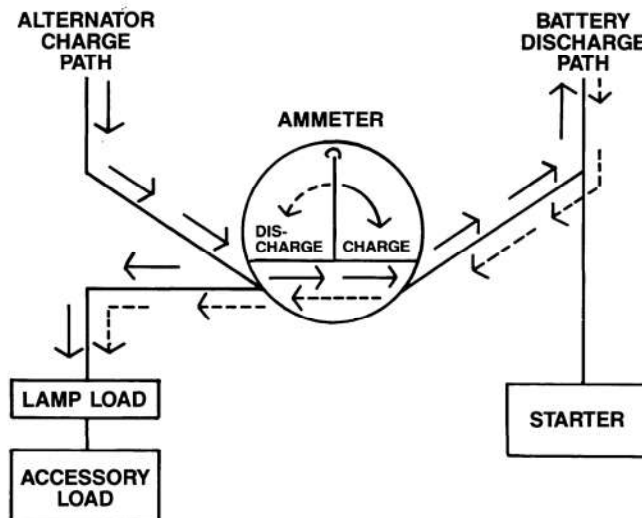
Tighten drive belts by applying pressure to the alternator front housing ONLY. DO NOT apply pressure to the rear housing or stator. Set belt tension to the engine manufacturer's recommendations. If this information is not available, tighten belts to the point where the alternator fan cannot be turned by hand.



**ALTERNATOR BELT ALIGNMENT**

## AMMETER

Ammeter requirements vary with application. An original equipment ammeter may be difficult to replace with a higher reading unit, due to limited panel space and the vehicle wiring system. For an ammeter to show alternator charge and accessory discharge, it must be connected as shown in illustration below.



**AMMETER CHARGE & DISCHARGE CIRCUIT**

An accessory ammeter may be used if it provides 75-0-75 scale information. Such meters are available in two types: direct reading, and external shunt types. Internal shunt (direct reading) ammeters are not usually recommended for charging systems of high output capability due to the long heavy gauge wiring required. Failure to provide adequate wiring will result in poor system performance.

## ALTERNATOR/REGULATOR TEST PROCEDURE

### **General**

It is desirable to test the charging system (alternator and voltage regulator) in the vehicle using the vehicle wiring harness and electrical loads that are a permanent part of the system. In-vehicle testing will then provide the technician with an operational test of the charging system as well as the major components of the electrical system.

### **Preliminary Checks & Tests**

Before starting the actual electrical test procedure, the charging system, battery and wiring should be checked to eliminate possible problem areas. The following procedure is recommended:

1. Check the condition and adjustment of belts.
  - A. If the alternator fan can be moved by pushing on a fan blade with your finger, the belts should be adjusted.
  - B. Replace any worn or glazed belts.
2. Check to see that all terminals, connectors and plugs are clean and tight.
  - A. Loose or corroded connections cause high resistance and this could cause overcharging, undercharging or damage to the charging system.
  - B. Badly corroded battery cables could prevent the battery from reaching a fully charged condition.
3. Check battery condition and change if necessary. A low or discharged battery may cause false or misleading readings on the in-vehicle tests.

### **Test Equipment Requirements**

The Alternator and Regulator tests outlined require electrical test equipment to measure voltage only; however, most commercial test equipment incorporates several testing devices in a single unit.

DC VOLTMETER: 0-20 Volt Scale

BATTERY TEST EQUIP.: Any commercial type, Hydrometer with temperature correction scale.

### **Storage Battery**

The vehicle storage battery circuit represents a continuous although variable electrical load to the alternator. If the circuit, positive or negative, is opened or broken while the alternator is charging, the loss of the battery will result in the charging voltage rising to unsafe levels.

### **Battery Inspection**

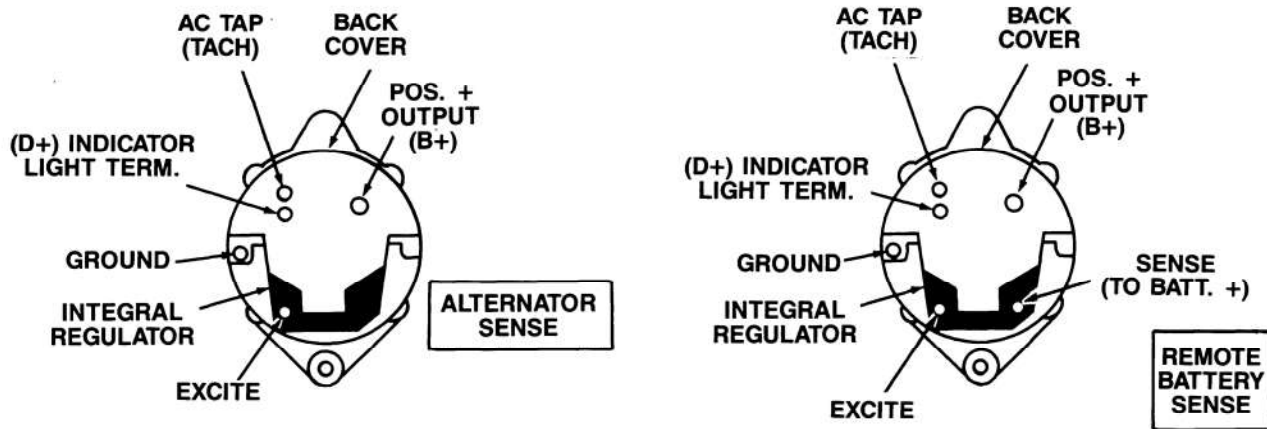
The following table illustrates typical ranges of specific gravity for a cell in various states of charge. THE BATTERY MUST BE AT LEAST 75% OF FULL CHARGE FOR EFFECTIVE ALTERNATOR TESTING.

<b>1.260 SP. GR BATTERY</b>	<b>1.280 SP. GR. BATTERY</b>	<b>CHARGE STATE</b>
1.260 Sp. Gr.	1.280 Sp. Gr.	100% Charged
1.230 Sp. Gr.	1.250 Sp. Gr.	75% Charged
1.200 Sp. Gr.	1.220 Sp. Gr.	50% Charged
1.170 Sp. Gr.	1.190 Sp. Gr.	25% Charged
1.140 Sp. Gr.	1.160 Sp. Gr.	Very Low Cap.
1.110 Sp. Gr.	1.130 Sp. Gr.	Discharged

After completing these preliminary checks and tests, proceed with the tests as outlined in the Trouble-Shooting Guide.

**TEST PROCEDURE - (INTEGRAL REGULATOR SYSTEMS)**

(See Pages 64-66 for Remote Regulator Systems)



**ALTERNATOR TERMINAL IDENTIFICATION (INTEGRAL REGULATOR)**

**TROUBLESHOOTING GUIDE  
INTEGRAL REGULATOR SYSTEMS**

PROBLEM	PROBABLE CAUSES	CORRECTIVE ACTION
<p>A. Battery undercharged — ammeter (if used) indicates constant discharge. — indicator lamp remains on.</p>	<ol style="list-style-type: none"> <li>1. Defective cables, dirty battery posts, corroded terminals, etc.</li> <li>2. Loose or broken belt.</li> <li>3. Worn or broken brushes.</li> <li>4. Defective alternator system.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check, clean, repair or replace - as needed.</li> <li>2. Check belt.</li> <li>3. Replace brush assy.</li> <li>4. Refer to "Problem Area Determination Section".</li> </ol>
<p>B. Battery undercharged — indicator lamp off with key on &amp; engine stopped. (Normal condition is lamp on.)</p>	<ol style="list-style-type: none"> <li>1. Indicator lamp burned out or defective wire harness.</li> <li>2. Broken brush.</li> <li>3. Defective alternator system.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check bulb &amp; harness.</li> <li>2. Replace brush assy.</li> <li>3. Refer to "Problem Area Determination Section".</li> </ol>
<p>C. Battery overcharges — excessive use of water. — ammeter (if used) shows constant excessive charge. — voltmeter indicates greater than 14.5 volts (connected across battery with no load) with engine idling.</p>	<ol style="list-style-type: none"> <li>1. Defective wire harness.</li> <li>2. Defective alt. system.</li> <li>3. Poor ground.</li> <li>4. Broken sense lead (remote battery sense only.)</li> </ol>	<ol style="list-style-type: none"> <li>1. Refer to "Problem Area Determination Section".</li> <li>2. Refer to "Problem Area Determination Section".</li> <li>3. Check ground.</li> <li>4. Check, clean, repair or replace as needed.</li> </ol>
<p>D. Battery charges at idle, but discharges under load conditions.</p>	<ol style="list-style-type: none"> <li>1. Slipping belts.</li> <li>2. Alternator defective</li> </ol>	<ol style="list-style-type: none"> <li>1. Check belts and adjust tension or replace as necessary</li> <li>2. Disassemble, check diodes.</li> </ol>
<p>E. Indicator lamp glows slightly under moderate load; battery appears charged.</p>	<ol style="list-style-type: none"> <li>1. Defective diode-trio.</li> </ol>	<ol style="list-style-type: none"> <li>1. Remove &amp; replace.</li> </ol>

**PROBLEM AREA DETERMINATION SECTION**

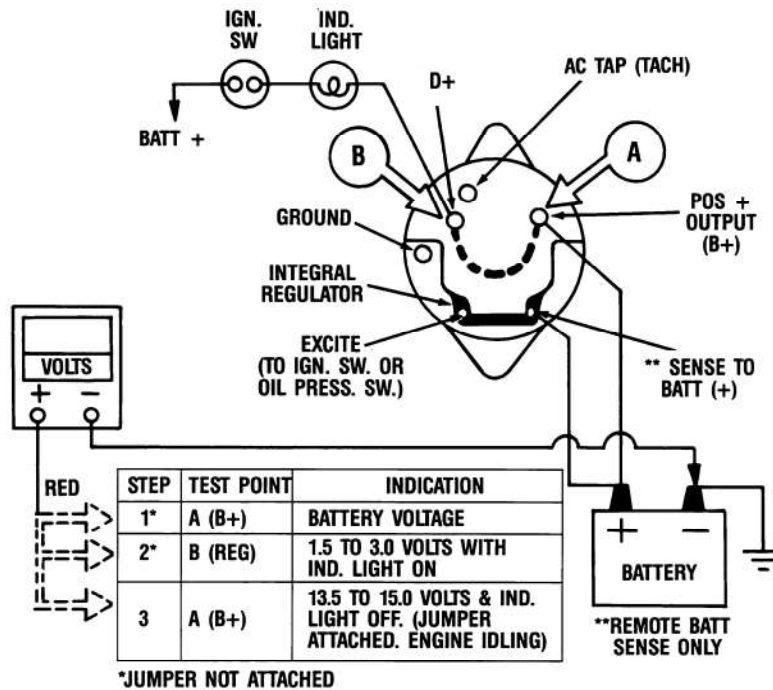
**CONDITIONS:** Engine Idling For All Tests (Unless otherwise specified)

**A. BATTERY UNDERCHARGED**

1. Remove Battery sense only.
  - a. Perform Harness Voltage Test (Test No. 3)
2. Indicator Lamp On
  - a. Perform Open Diode-Trio Test (Test No. 1)
3. Indicator Lamp Off (Ignition on and engine stopped)
  - a. Perform Regulator Test. (Test No. 2)
  - b. If Regulator is O.K., the cause is probably an open field circuit and Alternator must be removed for repair.
4. Further Investigation Requires Alternator Removal and Repair (diodes).

**B. BATTERY OVERCHARGED**

1. Regulator Shorted, Replace Regulator.



**OPEN DIODE-TRIO TEST**



## Alternator/Regulator Tests

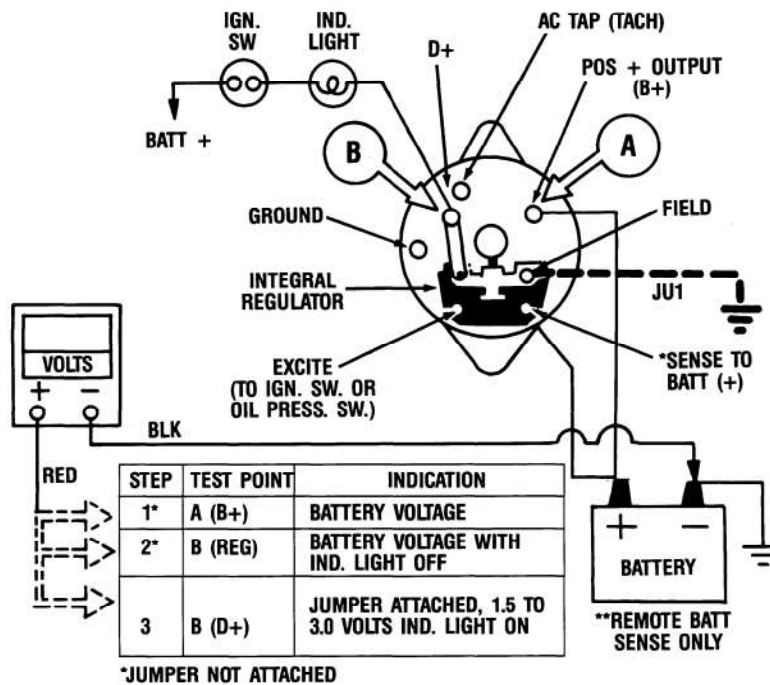
### Test No. 1 Open Diode-Trio Test

With ignition on and engine not running and jumper not attached (no electrical load), check for battery voltage at terminal A and for 1.5 to 3.0 volts at terminal B. Add jumper JU1 between terminals A and B. Start engine and run at idle. If indicator lamp now goes "off" and charging voltage is present at terminal A, the diode-trio is probably "open" (defective) and alternator should be removed for repair.

### Test No. 2 Open Regulator Test

NOTE: Test requires removal of back cover of alternator. To remove, disconnect wires from terminals extending through back cover. Remove back cover (two screws) and reconnect all wires.

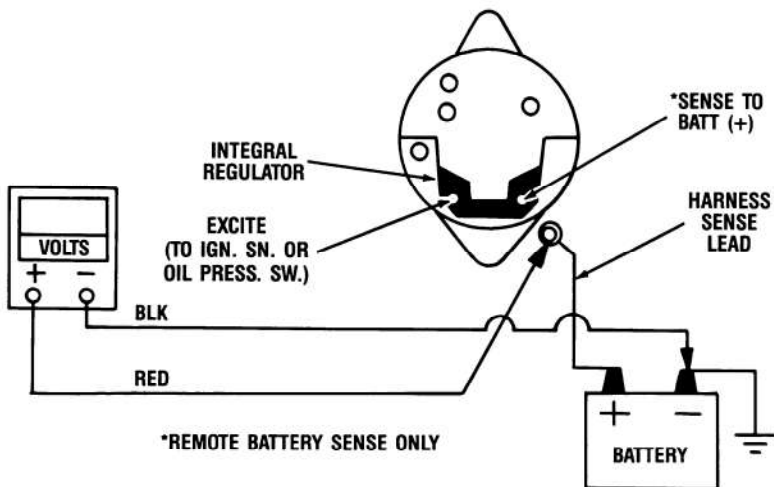
With ignition on and engine not running and jumper not attached, check for battery voltage at terminal A and terminal B. Indicator light will be off. Add jumper JU1 between field and ground. If 1.5 to 3.0 volts is present at terminal B and the indicator light is on, an open (defective) regulator is indicated. If lamp is still not "on", an open field circuit (brushes, slip-rings, etc.) is indicated and alternator repair is required.



**REGULATOR TEST (BACK COVER REMOVED)**

**Test No. 3 Harness Voltage Test (Remove Battery Sense Only)**

Remove harness sense lead from sense terminal and connect voltmeter leads as shown in Figure below. Voltmeter should indicate battery voltage (approx. 12.6 volts for a fully charged battery with ignition key off). If voltage is zero, the harness "sense" lead is open and should be repaired or replaced.

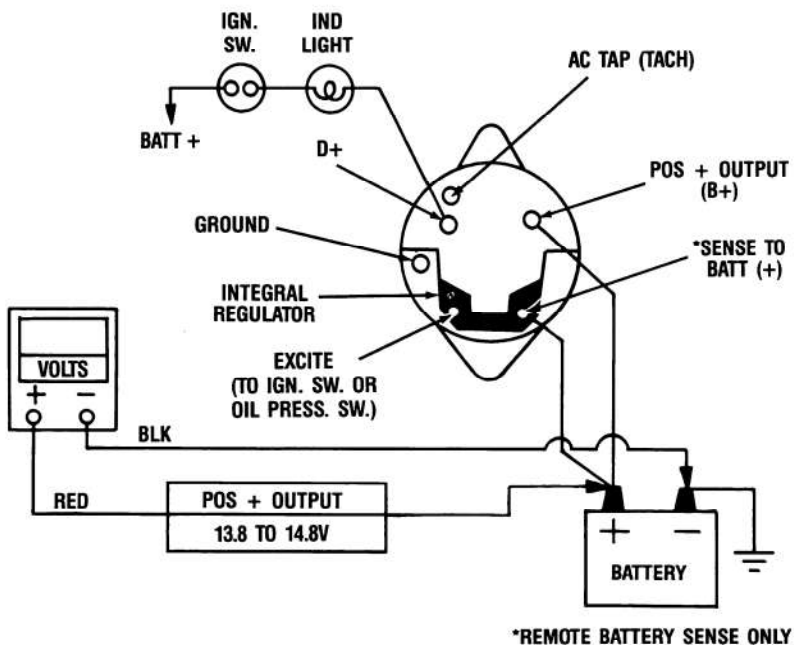


**CABLE HARNESS VOLTAGE TEST**

**Test No. 4 Alternator Ooutput Test**

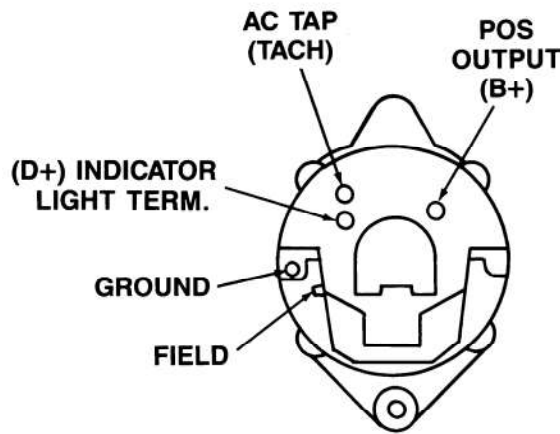
After voltmeter is connected, as shown in Figure below, start and run engine at a fast idle of approximately 1,500 RPM. Turn on vehicle headlights and blower fan (low speed). Check for nominal system output voltage of between 13.8-14.8 volts for a properly operating charging system. (Voltages may vary a few tenths of a volt (higher or lower) due to ambient temperature variations).

If the alternator output voltage does not fall within the proper range, the alternator should be disassembled for further inspection and tests.



**ALTERNATOR OUTPUT TEST**

TEST PROCEDURE-(REMOTE REGULATOR SYSTEMS)



**ALTERNATOR TERMINAL IDENTIFICATION (REMOTE REGULATOR)**

**TROUBLESHOOTING GUIDE  
REMOTE REGULATOR SYSTEMS**

<b>PROBLEM</b>	<b>PROBABLE CAUSES</b>	<b>CORRECTIVE ACTION</b>
A. Battery undercharged — ammeter (if used) indicates constant discharge. — indicator lamp remains on.	<ol style="list-style-type: none"> <li>1. Defective cables, dirty battery posts, corroded terminals, etc.</li> <li>2. Loose or broken belt.</li> <li>3. Worn or broken brushes.</li> <li>4. Defective alternator system.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check, clean, repair or replace as needed.</li> <li>2. Check belt.</li> <li>3. Replace brush assy.</li> <li>4. Refer to "Problem Area Determination Section".</li> </ol>
B. Battery undercharged — indicator lamp off with key on & engine stopped. (Normal condition is lamp on.)	<ol style="list-style-type: none"> <li>1. Indicator lamp burned out or defective wire harness.</li> <li>2. Broken brush.</li> <li>3. Defective alternator system.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check bulb &amp; harness.</li> <li>2. Replace brush assy.</li> <li>3. Refer to "Problem Area Determination Section".</li> </ol>
C. Battery overcharges — excessive use of water. — ammeter (if used) shows constant excessive charge. voltmeter indicates greater than 14.5 volts (connected across battery with no load) with engine idling.	<ol style="list-style-type: none"> <li>1. Poor ground.</li> <li>2. Defective alt. system.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check ground.</li> <li>2. Refer to "Problem Area Determination Section".</li> </ol>
D. Battery charges at idle, but discharges under load conditions.	<ol style="list-style-type: none"> <li>1. Slipping belts.</li> <li>2. Alternator defective</li> </ol>	<ol style="list-style-type: none"> <li>1. Check belts and adjust tension or replace as necessary</li> <li>2. Disassemble, check diodes.</li> </ol>
E. Indicator lamp glows slightly under moderate load; battery appears charged.	<ol style="list-style-type: none"> <li>1. Defective diode-trio.</li> </ol>	<ol style="list-style-type: none"> <li>1. Remove &amp; replace.</li> </ol>

## Problem Area Determination Section

### A. BATTERY UNDERCHARGED

1. Indicator Lamp On.
  - a. Perform Open Diode-Trio Test (Test No. 1).
2. Indicator Lamp Off (Ignition on and engine stopped).
  - a. Perform Regulator Test (Test No. 2)
  - b. If Regulator is O.K., the cause is probably an open field circuit and Alternator must be removed for repair.
3. Further Investigation Requires Alternator Removal and Repair (diodes).

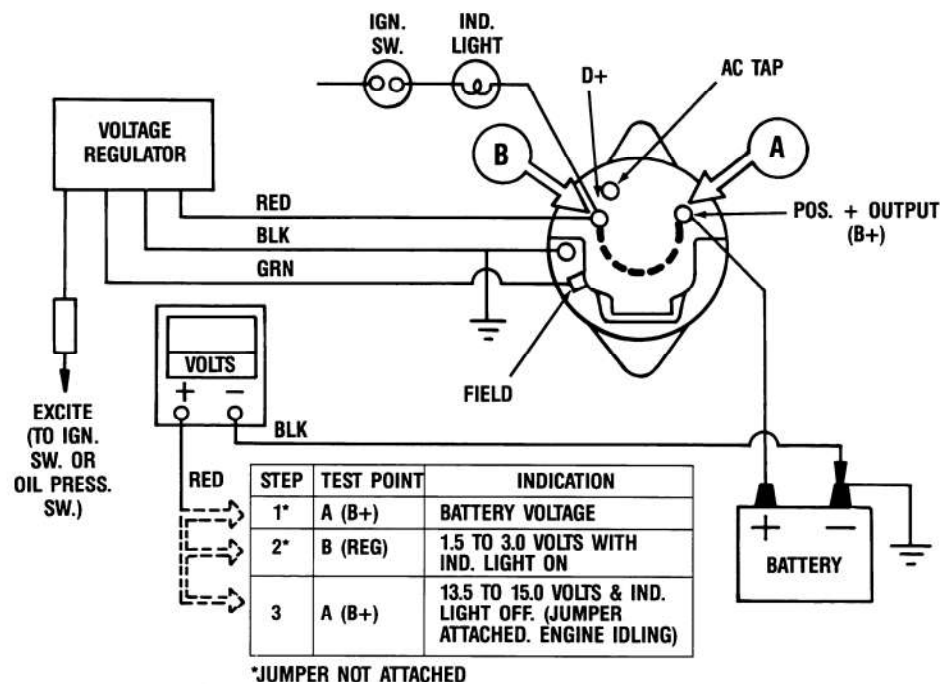
### B. BATTERY OVERCHARGED

1. Regulator Shorted, Replace Unit.

## Alternator/Regulator Tests

### Test No. 1 Open Diode-Trio Test

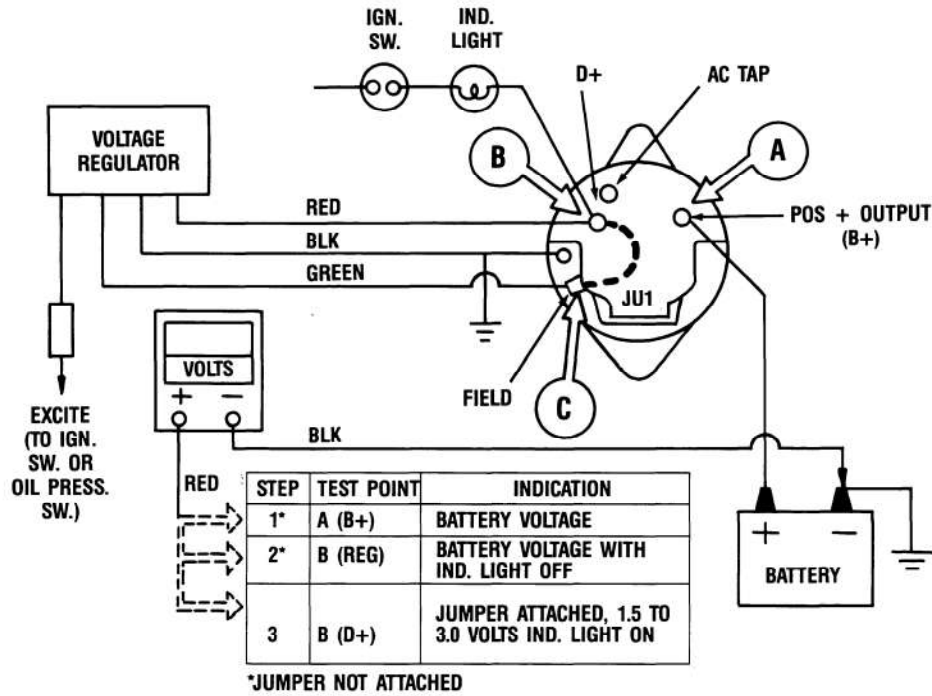
With ignition on and engine not running (jumper not attached and no electrical load), check for battery voltage at terminal A and for 1.5 to 3.0 volts at terminal B. Add jumper JU1 between terminals A and B. Start engine and run at idle. If indicator lamp now goes "off" and charging voltage is present at terminal A, the diode-trio is probably "open" (defective) and alternator should be removed for repair.



### OPEN DIODE-TRIO TEST

### Test No. 2 Open Regulator Test

With ignition on and engine not running and jumper not attached check for battery voltage at terminal A and terminal B. Indicator light will be off. Add jumper JU1 between terminals B and C. If 1.5 to 3.0 volts is present at terminal B and the indicator light is on, an open (defective) regulator is indicated. If lamp is still not "on", an open field circuit (brushes, slip-rings, etc.) is indicated and alternator repair is required.

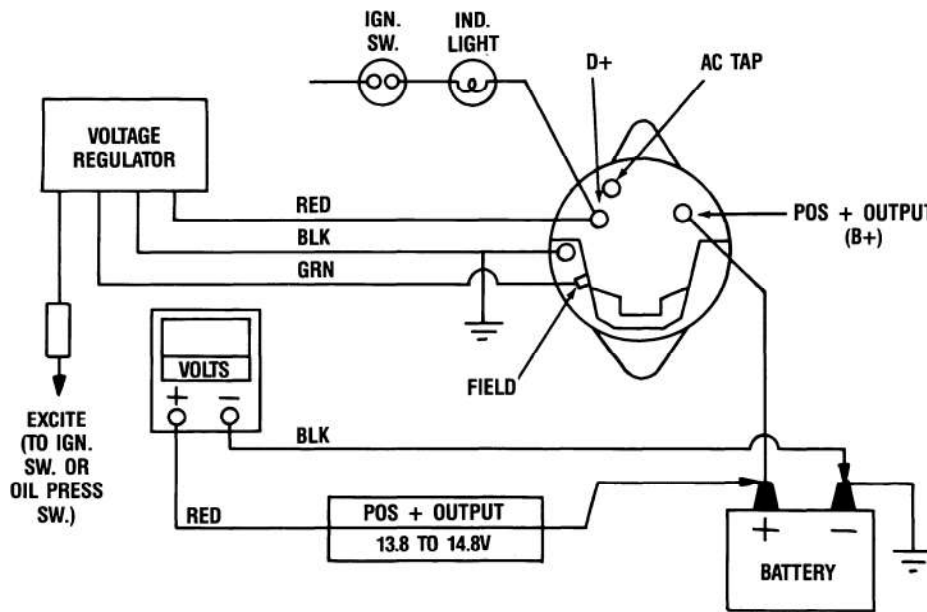


### OPEN REGULATOR TEST

### Test No. 3 Alternator Output Test

After voltmeter is connected, as shown in Figure below, start and run engine at a fast idle of approximately 1,500 RPM. Turn on vehicle headlights and blower fan (low speed). Check for nominal system output voltage of between 13.8-14.8 volts for a properly operating charging system. (Voltages may vary a few tenths of a volt (higher or lower) due to ambient temperature variations.)

If the alternator output voltage does not fall within the proper range, the alternator should be disassembled for further inspection and tests.



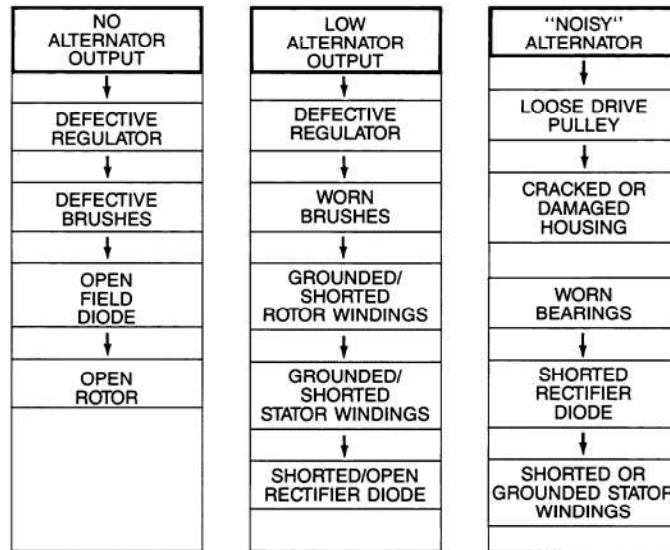
### ALTERNATOR OUTPUT TEST

## ALTERNATOR REPAIR PROCEDURE

### General

The following instructions are presented as a general overall procedure for complete disassembly of an alternator. However, it should be pointed out that following the complete procedure whenever a repair is necessary will seldom, if ever, be required. In cases where the causes of the malfunction are known, it is only necessary to follow that portion of the procedure directly related to resolving the problem. Similarly, when the reasons for the malfunction are uncertain, it will be necessary to follow the procedure in greater depth in order to isolate and correct the problem.

The following troubleshooting diagram should help identify some of the more common problems to concentrate on during the overhaul/repair procedure.

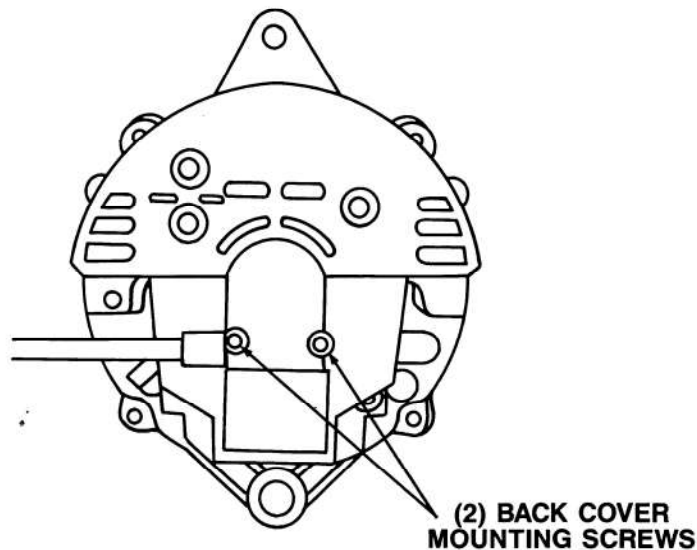


ALTERNATOR TROUBLESHOOTING-DIAGRAM

### Disassembly & Testing

Detach Back Cover:

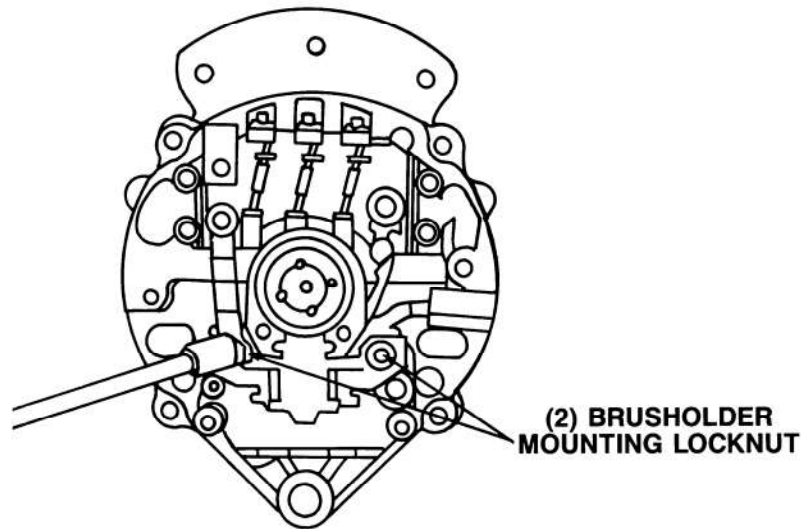
Remove nuts from terminals. Remove two screws securing back cover to rear housing.



REMOVING BACK COVER

Remove Brush Holder:

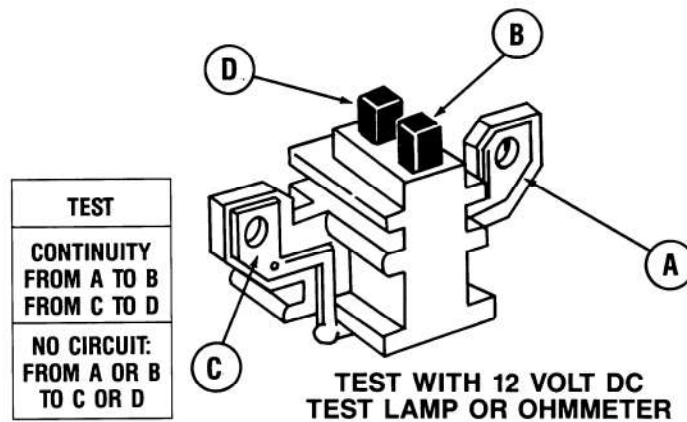
Remove two locknuts securing brush holder. Pull out brush holder. See illustration below.



### REMOVING BRUSH HOLDER

Inspect and Test Brush Assembly:

The illustration below shows the terminals brush arrangement and testing procedure. The original brush set may be reused if the brushes are 3/16" or longer, and if brushes are not oil soaked, cracked or show evidence of grooves on the sides of the brushes caused by vibration.

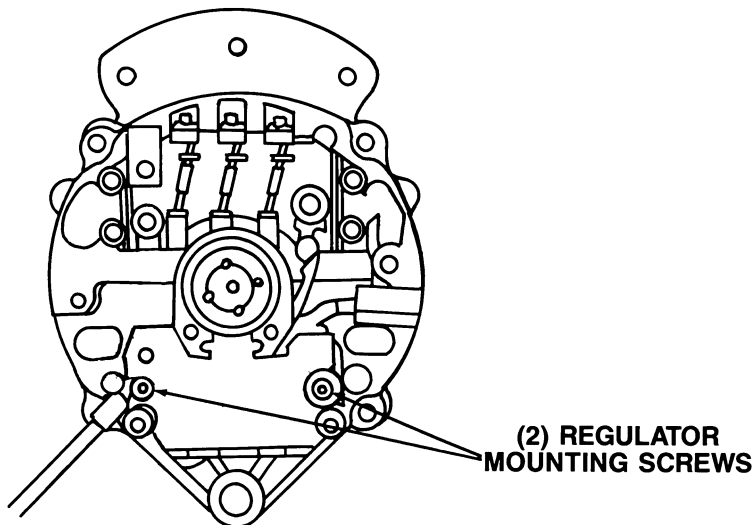


### BRUSH TEST

Remove Integral Voltage Regulator:

Remove two screws securing integral voltage regulator to rear housing.

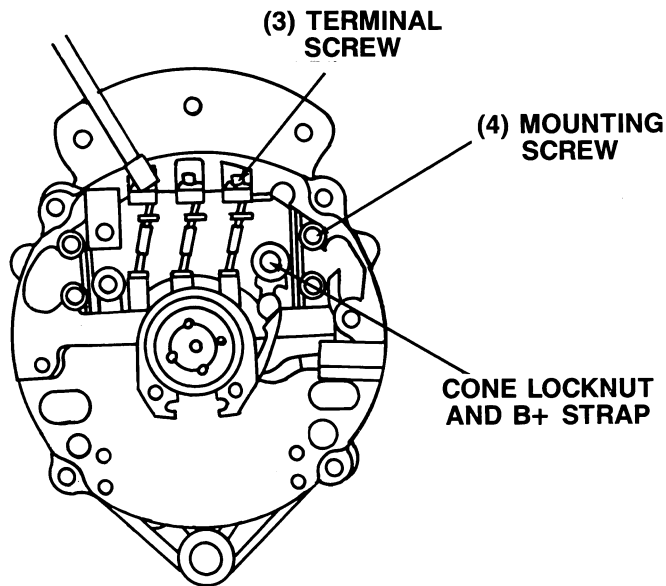
**NOTE:** Alternators with remote voltage regulator systems will have a space part mounted to the rear housing instead of the integral voltage regulator.



### REMOVING VOLTAGE REGULATOR

Remove Diode-Trio (Field Diode) and Rectifier Diode Bridge:

The diode-trio and rectifier diode bridge are detached as an assembly. Remove cone lockout from positive output (B+) terminal. Straighten B+ strap. Remove three terminal screws and four diode-trio mounting screws. Detach assembly from rear housing and separate diode-trio assembly from rectifier bridge. See illustration below.

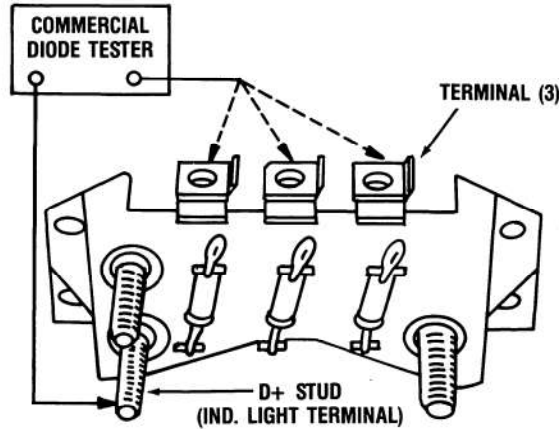


### REMOVING DIODE-TRIO AND RECTIFIER DIODE BRIDGE.



**Test Diode Trio Assembly:**

Using a commercial diode tester or 12 volt DC test lamp; check for continuity from each terminal separately to the D+ stud; continuity should be observed in one direction (polarity) only, and all diodes should check alike. If any diode is defective replace the entire diode trio assembly. See illustration below.

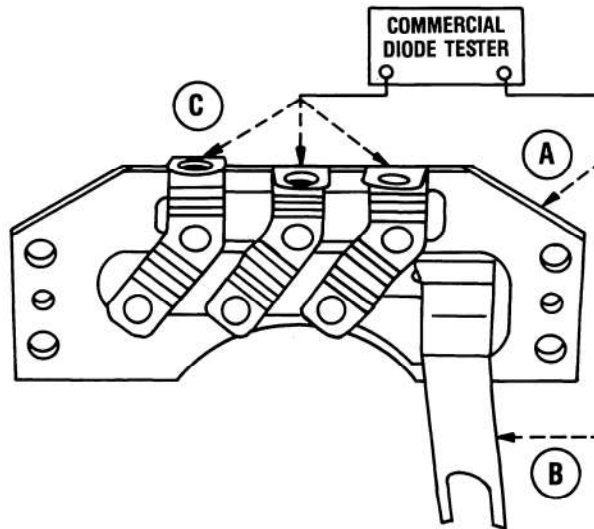


**TESTING DIODE-TRIO**

**Test Diode Rectifier Bridge Assembly:**

Using a commercial diode tested, check for continuity. Check between point A and each of three terminals C for negative diodes. Continuity should be observed in one direction (polarity) only, and all diodes should check alike. Then check between point B (B+ strap) and each of the three terminals C for positive diodes. Continuity should be observed in one direction only, and all diodes should check alike. See illustration below.

If any diode is defective, replace the entire diode rectifier bridge assembly.

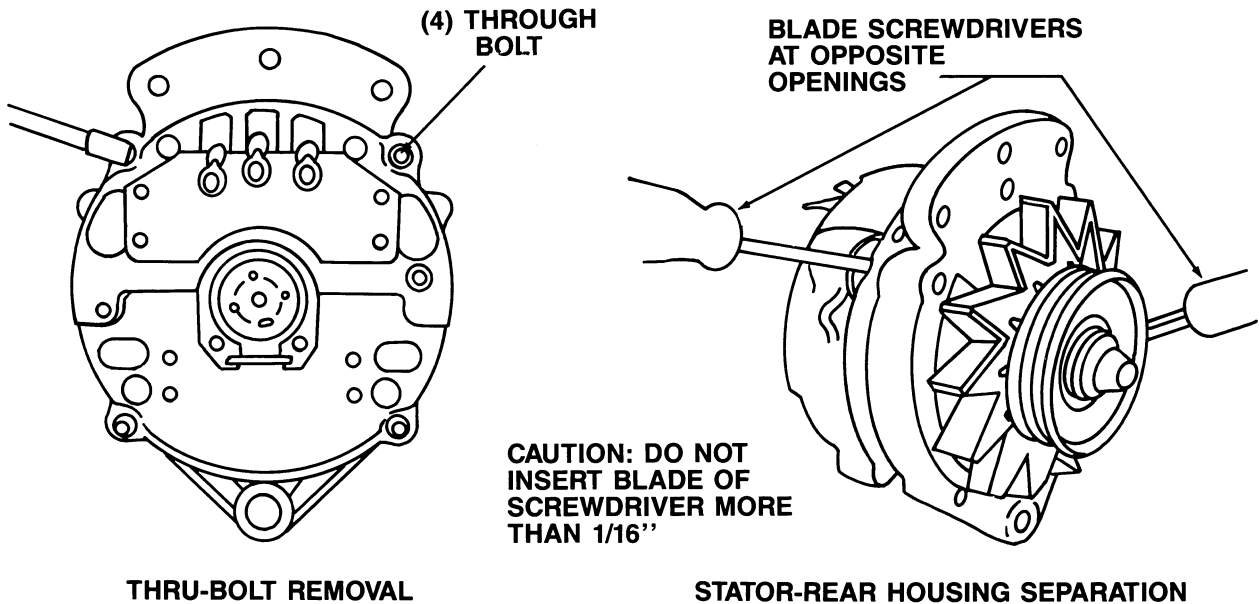


**TESTING RECTIFIER BRIDGE**

Separate Stator/Rear Housing Assy. from Front Housing:  
Remove four thru-bolts. See illustration below.

Carefully insert two screwdriver blades in opposite openings between the stator and front housing, as shown in illustration below. Pry units apart.

**CAUTION: Do not insert screwdriver blades deeper than 1/16'' to avoid damaging stator winding.**



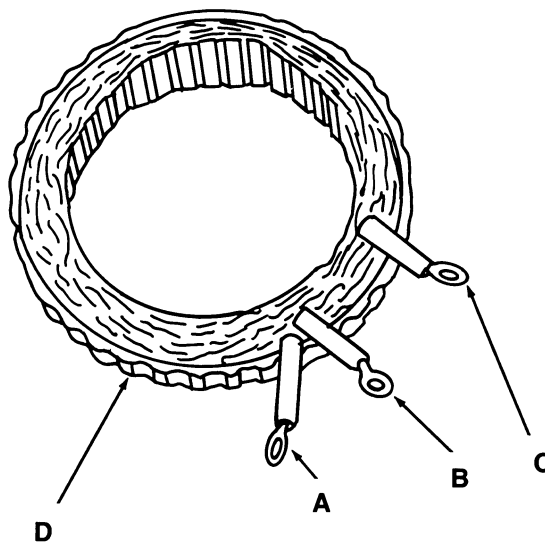
Inspect Rear Housing:

Inspect the rear housing for a cracked or broken casting, stripped threads or evidence of severe wear in the bearing bore due to a worn rear bearing.

If casting is to be reused, clean in solvent, dry with compressed air, and install a new rear bearing retainer if retainer is damaged.

Test Stator:

The stator assembly consists of three individual windings terminated in the delta type connections. Using an ohmmeter or a test lamp, check for winding continuity between terminals A, B and C. There should be no continuity from any terminal to point D (laminations). Also, stators showing any signs of winding discoloration should be discarded. See illustration below.



**STATOR WINDING TESTS**

**Remove Pulley, Fan and Spacer:**

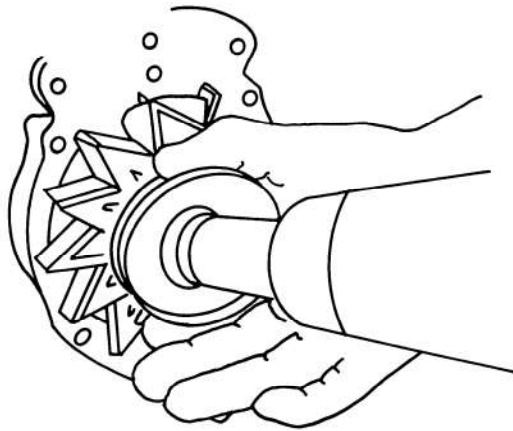
The pulley is a slip-fit on the rotor shaft, positioned with a Woodruff Key. Remove the nut and lockwasher from the shaft using an impact wrench or other suitable tool.

After nut and lockwasher are removed the alternator can be separated from the pulley.

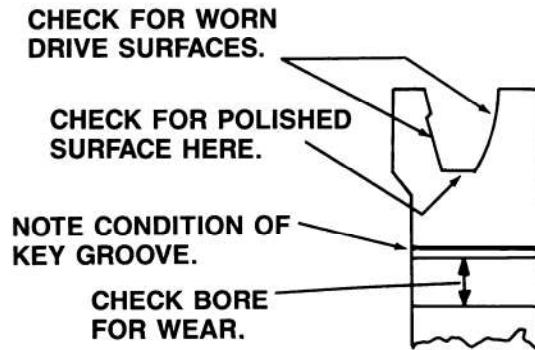
The fan will slide over the key. The key may be removed with diagonal pliers, or with a screwdriver.

Inspect the fan for cracked or broken fins, note the condition of the mounting hole. If worn from running loose, replace the fan to insure balance.

Inspect pulley for possible faults as listed in illustration below.



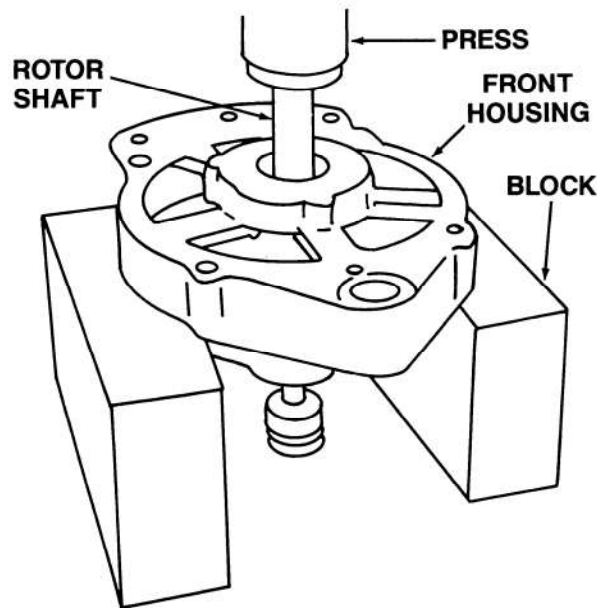
**PULLEY REMOVAL**



**PULLEY INSPECTION POINTS**

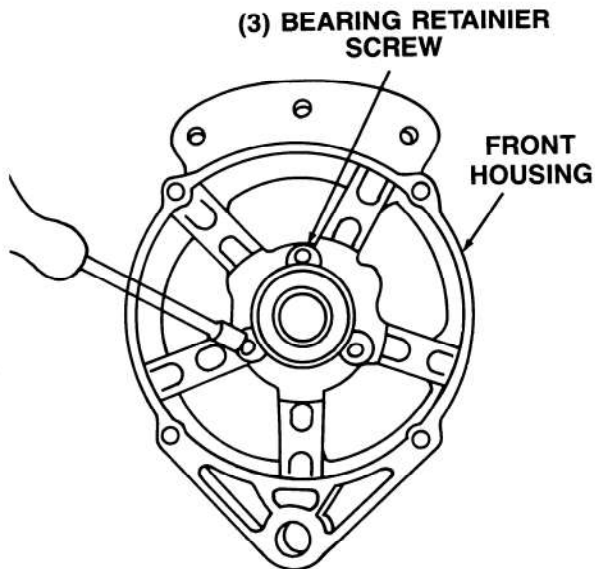
**Separate Rotor from Front Housing:**

Position front housing on support blocks placed on an arbor press. Push rotor assembly from housing. See illustration below.

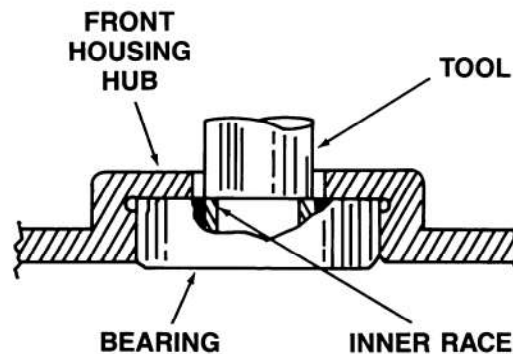


**SEPARATING ROTOR FROM FRONT HOUSING**

Remove Front Bearing from Housing:  
 Remove three bearing retainer screws. Position housing on support blocks placed on an arbor press. Using a tool that contacts inner race of bearing, press out front bearing. See illustrations below.



**REMOVING RETAINER SCREWS**



**PRESSING OUT BEARING**

Inspect Front Housing:  
 Check housing for cracks. Check condition of threads in adjusting ear. Check bore in mounting foot. Discard housing if bore shows signs of elongation (oval or out-of-roundness).

ROTOR INSPECTION AND ELECTRICAL TESTING

Check the rotor assembly for the following electrical properties. See illustration on page 89.

A. Current Draw or Resistance of the Winding

**CAUTION: Turn off DC power source before removing test leads to avoid arc damage to slip ring surfaces.**

1. CURRENT DRAW IN AMPERES, AT 70° TO 80°F.

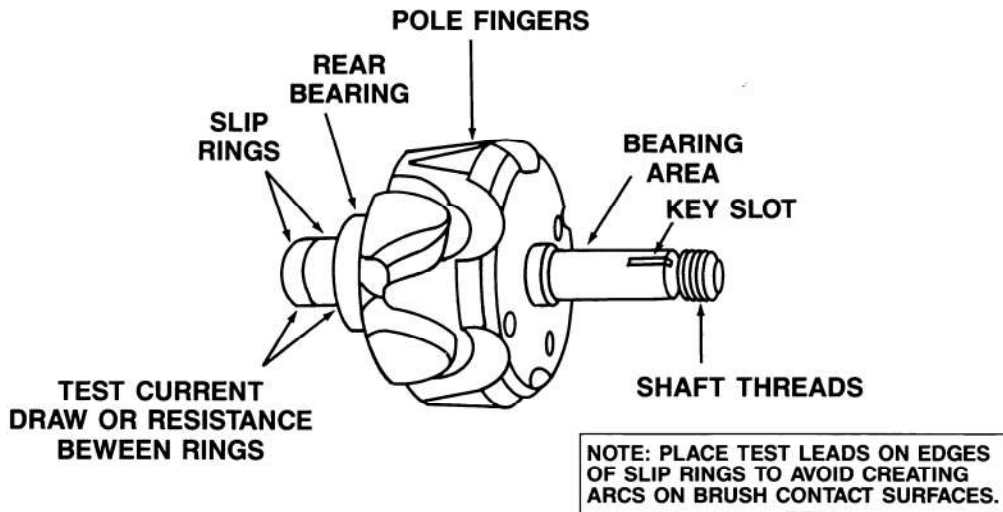
12 VOLT MODELS,  
 RATED AT:  
 51 AMPERES

**CORRECT  
 CURRENT DRAW  
 @ 15.0 V**  
 3.2 to 3.6 AMPERES

2. RESISTANCE OF WINDING IN OHMS, AT 70° TO 80° F.

12 VOLT MODELS,  
 RATED AT:  
 51 AMPERES

**CORRECT WINDING  
 RESISTANCE**  
 4.1 to 4.7 OHM



### ROTOR INSPECTION AND ELECTRICAL TESTING

#### B. Grounded Slip Ring or Winding

Use 12 volt DC test lamp, ohmmeter, or 110V AC test lamp. Place one test lead to the rotor body and the other on either slip ring. Open circuit from either slip ring to the rotor body is a correct condition.

#### C. Condition of Slip Rings

1. Clean brush contacting surfaces with fine crocus cloth, wipe dust and residue away.
2. If surfaces are worn beyond this restoration, replace the entire rotor assembly.

#### D. Rotor Shaft and Pole Pieces

1. Stripped threads on shaft
2. Worn key slot
3. Worn bearing surface
4. Scuffed pole fingers
5. Worn or dry rear bearing

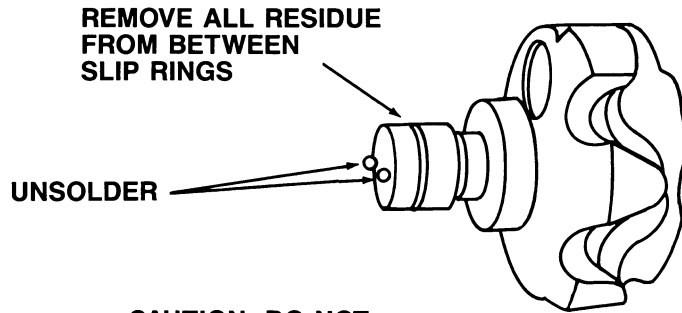
Replace rotor assembly if any of the above faults are noted with the exception of item 5.

NOTE: New rotors include a new rear bearing and new slip rings as part of the assembly.

If rear bearing requires replacement, follow instructions for this operation.

### Remove Slip Rings from Rotor Assembly

Unsolder the rotor leads from the slip ring terminals. Carefully unwind the ends of the rotor coil leads from the slip ring terminals, as shown in illustration below.

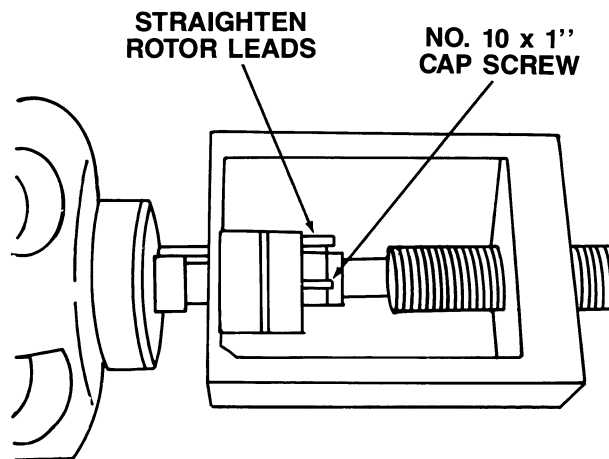


**CAUTION: DO NOT  
OVERHEAT**

### UNSOLDER ROTOR LEADS FROM SLIP RINGS

Straighten rotor leads. Insert a No. 10 x 1" cap screw into opening at center of slip ring assembly. Position bearing puller as shown in illustration below and pull slip ring assembly off rotor shaft.

**CAUTION: When holding rear end of rotor shaft in vise, be sure not to grip bearing area of rotor shaft.**

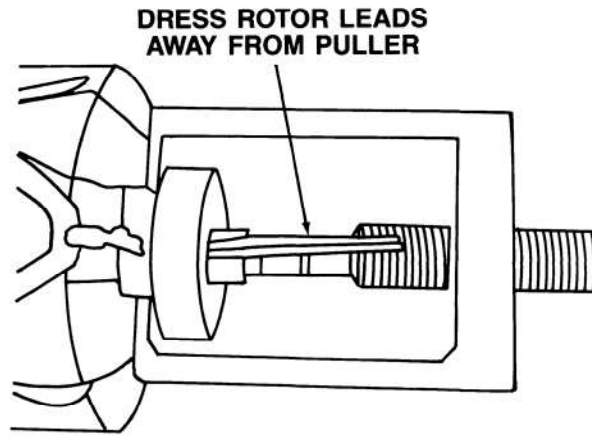


### REMOVING SLIP RING ASSY.

### Remove Rear Bearing from Rotor

Dress rotor leads away from the bearing puller contact area. Adjust puller to contact inner bearing race, carefully remove bearing from the shaft. See illustration at top of page 76.

This completes the disassembly of the alternator.



**REMOVING REAR BEARING**

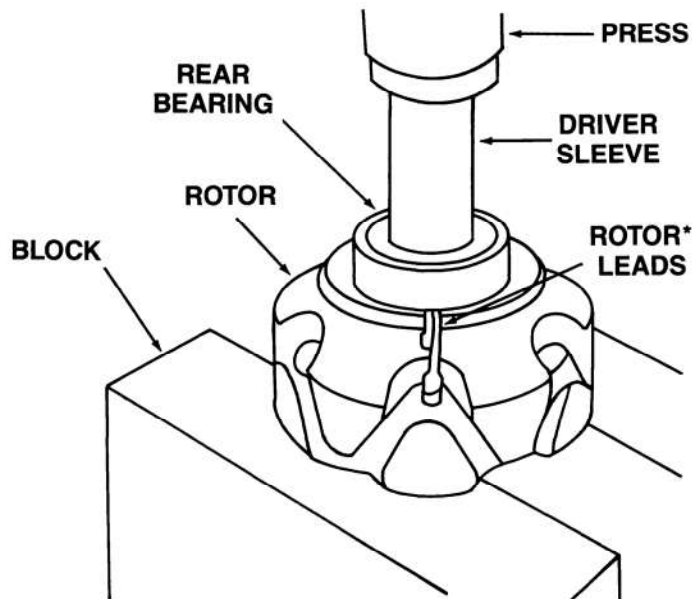
ALTERNATOR REASSEMBLY

**General**

The general reassembly instructions are reverse order to the procedures given for disassembly. Therefore, only information pertaining to special reassembly requirements will be covered in this section.

**Install Rear Bearing**

Place rotor on a press as shown in illustration below. Choose a driver sleeve that exerts pressure on inner race only and press bearing on rotor shaft until it contact shoulder. New replacement bearings should be used whenever bearing is removed during repair procedures or when bearing is rough, dry or noisy.

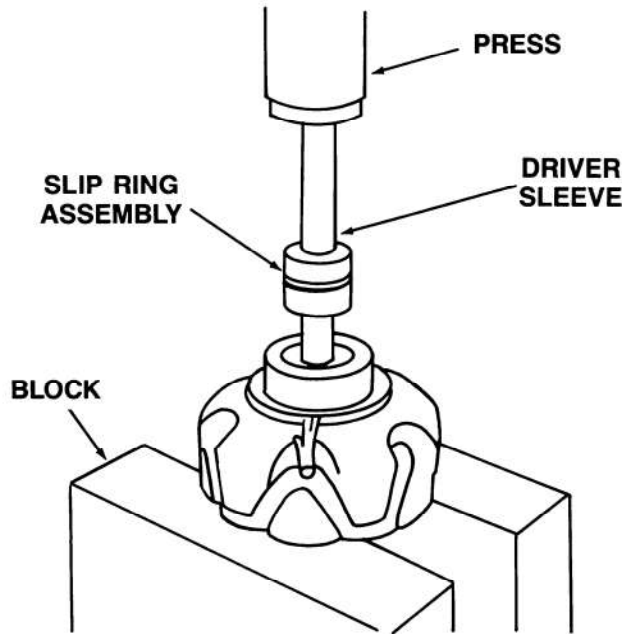


**INSTALLING REAR BEARING**

### Install Slip Ring Assembly

Guide rotor leads through one of the oval passages in the slip ring assembly. Be sure oval passages is in line with groove in rotor shaft. Place rotor on a press as shown in illustration below. Choose a driver sleeve with a diameter that clears leads.

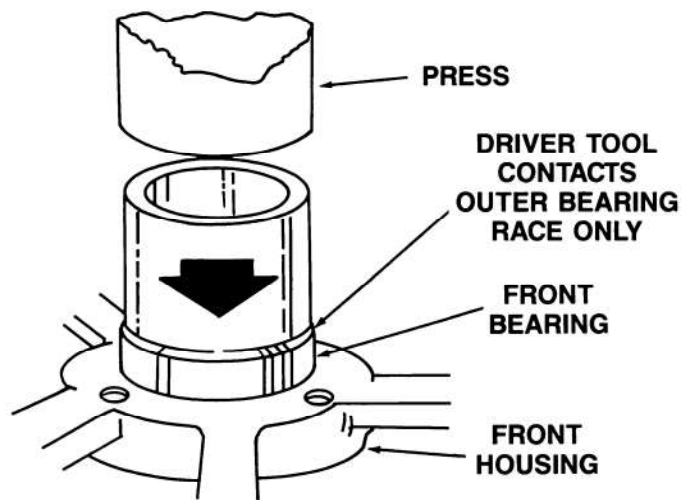
Press slip ring assembly on shaft. Solder rotor leads to leads on slip ring. Trim excess slip ring leads extending above solder connections.



**INSTALLING SLIP RING ASSEMBLY**

### Install Front Bearing

Place front bearing and housing in an arbor press, as in illustration below. Select a drive tool to contact the outer race only and press bearing into housing bore. Bearing replacement is recommended whenever bearing is removed during alternator repair procedures or if bearing is rough, dry or noisy. Install three bearing retainer screws. Torque to 25-30 pounds.



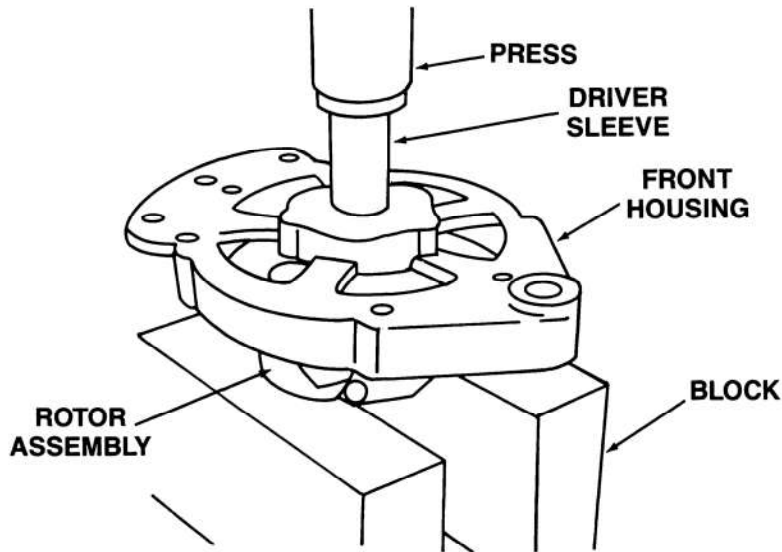
**INSTALLING FRONT BEARING**



### Assemble Rotor and Front Housing

Place the rotor on the bed of an arbor press, using two steel blocks for support, as shown in illustration below. Place front housing over shaft. Using driver sleeve that contacts inner bearing race only, press front housing down until inner bearing race contacts shoulder on the shaft.

**CAUTION:** Be sure rotor leads clear blocks.



**ASSEMBLING FRONT HOUSING TO ROTOR**

### Assembly Spacer, Fan and Pulley

Place pulley spacer over shaft. Install Woodruff Key. Install fan. Install pulley, lock washer and nut. Mount pulley as shown in left hand illustration on page 92. Tighten to 35 to 50 foot pounds.

Spin rotor by hand to test freedom of bearing.

### Assembly Front & Rear Housing

Place stator into front housing with stator leads at top and notches in laminations aligned with bolt holds. Position rear housing over slip rings with housing bolt holes aligned and stator leads extending through openings at top of rear housing.

Install through bolts and tighten evenly to between 50 to 60 inch pounds. Spin rotor by hand to test freedom of bearings.

**NOTE:** New front housings contain thru-bolt holes that are not tapped. Therefore, a socket wrench rather than a nut driver will be required to supply sufficient torque to drive the "thread forming" thru-bolts.

### Install Diode Rectifier Bridge and Diode Trio

Insert B + strap through slot in diode trio body. Bend strap over B + terminal and secure with cone locknut. Apply thin film of heat sink compound to back of diode rectifier bridge and to mating area on rear housing.

Install assembly to rear housing (four screws). Place strap (AC tap) in position and connect stator leads (three screws).

Install capacitor (where applicable).

### Install Integral Regulator

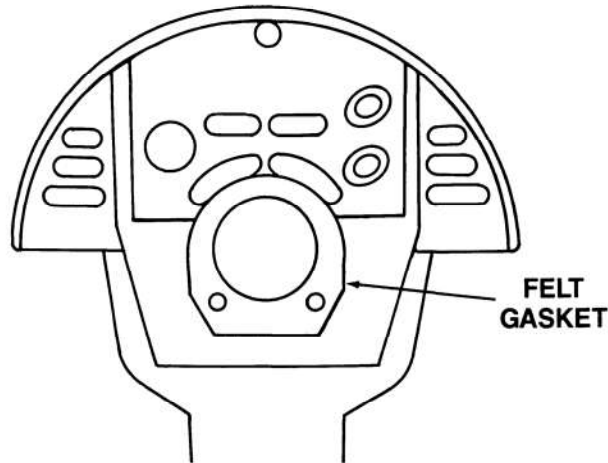
Install brush mounting screws (two) through openings in regulator body. Secure regulator to rear housing (two screws).

### Install Brush Assembly

Insert brush holder into grooves in hub of rear housing. Place D + strap (or male terminal where applicable) on stud and secure brush holder with locknuts (two places). Secure other end of D + strap.

### Install Rear Cover

Be sure felt gasket is in place (see illustration below). Position rear cover on rear housing and secure with two screws.



### INSTALLING REAR COVER

#### ALTERNATOR PERFORMANCE TESTS

The following tests will determine the current producing capability of the repaired alternator. Mount the alternator in a test fixture capable of providing 5000 alternator RPM. Select required battery voltage and circuit polarity.

- A. For remote regulator model, connect fixture circuit leads and instruments to the alternator terminals as shown in Diagram A on page 100. Place field rheostat in maximum resistance position.

Turn drive motor on, adjust to obtain 5000 alternator RPM. Slowly reduce field rheostat resistance, alternator should develop a charge. Continue to reduce resistance until alternator reaches rated current output in amperes. **CAUTION:** Limit output voltage to 15V maximum. **DO NOT** operate the alternator for more than a few minutes in the manner, due to the lack of voltage control. If the alternator will deliver its rated output, terminate the test.

- B. For integral regulator model, connect fixture leads and instruments to alternator terminals as shown in Diagram B on page 100.

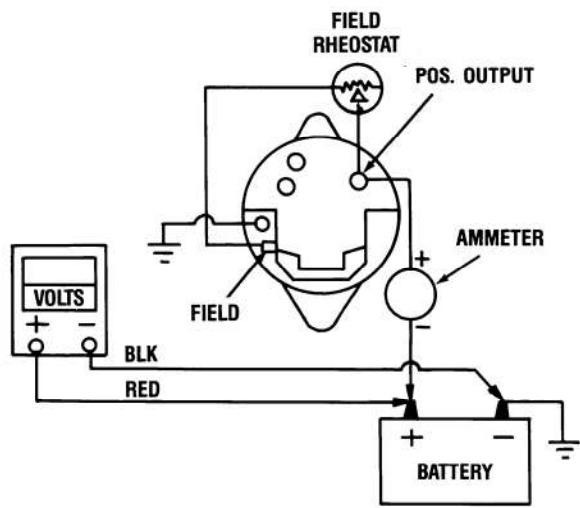
The Carbon pile or resistive load bank and ammeter must be capable of handling the alternator rated output alternator RPM.

**CAUTION: Make sure connections are well secured and tight to avoid possible damage to instrument, alternator or wiring due to short circuits.**

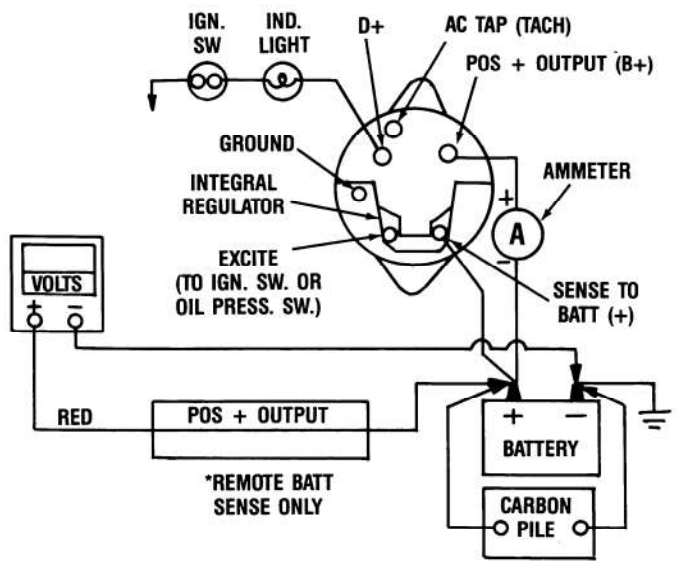
Starting with carbon pile off, slowly increase load while observing ammeter and maintaining 5000 RPM. Increase load until a minimum output voltage of approximately 13.7 volts is obtained. Record the output current at this point and refer to the chart for minimum acceptable ratings.

**MINIMUM ACCEPTABLE OUTPUT  
VALUES AT 70° TO 80°**

RATING	OUTPUT
51 AMP	46 AMP



**DIAGRAM A-REMOTE REGULATOR MODEL**



**DIAGRAM B-INTEGRAL REGULATOR MODEL**

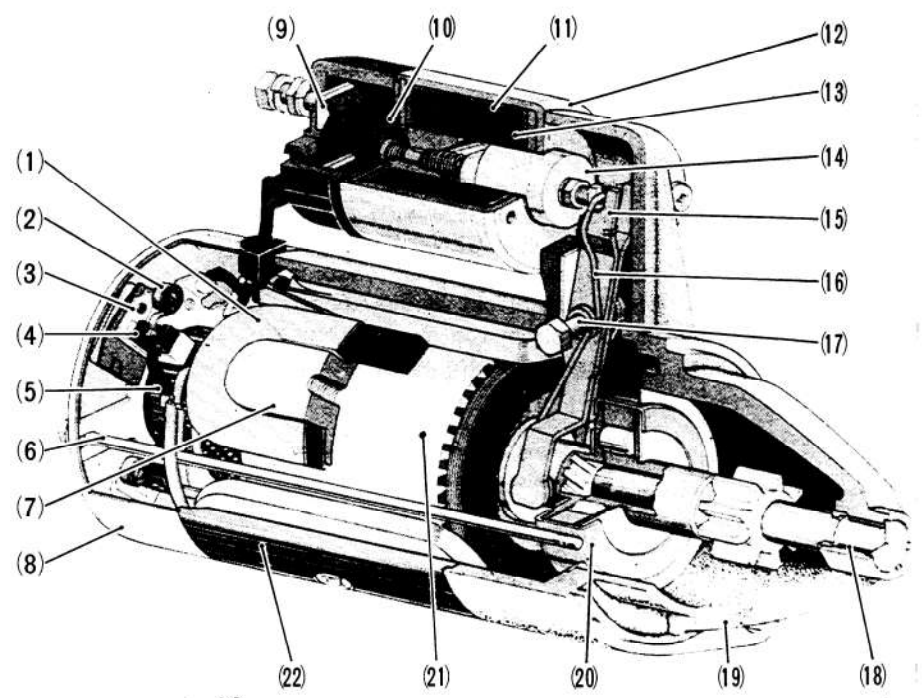
**TYPICAL ALTERNATOR PERFORMANCE TESTS**

CRANKING SYSTEM

**Starter**

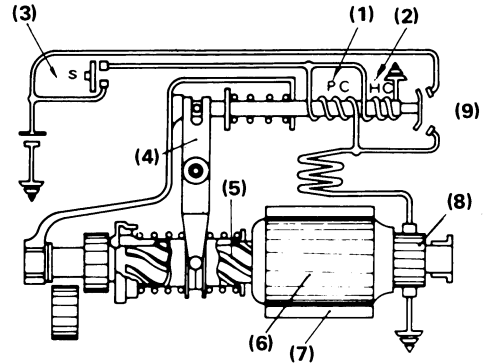
The magnet-switch type starter is composed of two main sections. The first section converts battery current into mechanical rotation to turn the engine crankshaft. It is composed of the field coil, armature, brush, commutator, pinion, overrunning clutch, etc. The second section allows the pinion and flywheel to engage together and current to flow through the motor section. It is composed of the pull-in coil, holding coil, drive lever, contract plate, etc.

1. Field Coil
2. Brush Spring
3. Brush Holder
4. Brush
5. Commutator
6. Through
7. Pole Core
8. End Frame
9. Contact Bolt
10. Contact Plate
11. Holding Coil
12. Magnet Switch
13. Pull-in Coil
14. Moving Core
15. Drive Lever
16. Drive Spring
17. Lever Set Bolt
18. Bearing
19. Drive Side Housing
20. Over Running Clutch
21. Armature
22. Yoke



1. PC :Pull-in Coil
2. HC :Holding Coil
3. S :Switch
4. Drive Lever clutch
5. Screw Spline
6. Armature
7. Pole Core
8. Commutator
9. Contact Plate

Starter circuit

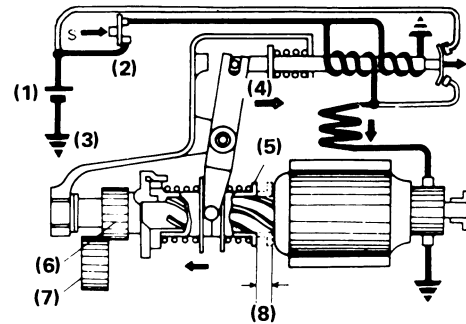


When Start Button is Pushed:

When the start button is pushed on, a current flows from the battery through the pull-in coil in the magnet switch section to the holding coil, energizing the plunger to pull it in. At this time, the pinion moves by the drive lever to engage with the ring gear.

When start button is pushed

1. Battery
2. Starter Switch
3. Ground
4. Return Spring
5. Spline Tube
6. Pinion
7. Ring Gear
8. Operated By Lever



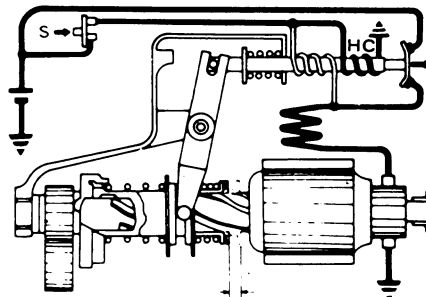
When contact plate is closed:

When the contact plate is closed, a large current flows through the motor section to generate a large mechanical power which turns the engine crankshaft.

At this time, the pinion is moved forward by the screw spline for more contact.

Since the pull-in coil ends are short-circuited by the contact plate, the plunger is held only by the force of the holding coil.

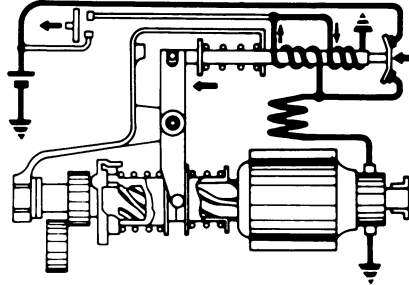
When contact plate is closed



When Push Button is Released:

When the push button is released, a current flows instantaneously through the pull-in coil in the opposite direction as shown in Figure below. Therefore, the forces of the holding coil and pull-in coil are balanced. As a result, the plunger is returned by the return spring. Simultaneously, the pinion is disengaged from the ring gear, the contact plate is disconnected, and the starter is promptly stopped by the armature brake.

When push button is released

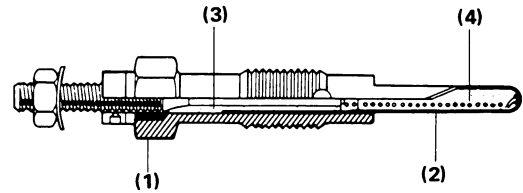


### Glow Plugs

Glow plugs are used for each pre-combustion chamber of the cylinder head to make starting easier. The glow plugs are quick-heating type, which make starting easier with short pre-heating time.

Construction of bar glow plug

1. Housing
2. Metal Tube
3. Insulating Powder
4. Heat Coil



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**ATTENTION:** When reassembling, replace all the O-rings and gaskets with new ones.

## CYLINDER HEAD

### REMOVING HEAD COVER

1. Remove the head cover nuts.
2. Remove the head cover.

**NOTE FOR REASSEMBLING:** Check to see if the head cover gasket is not defective. To prevent valve stem seizure, apply enough engine oil to the valve guide and valve stem.



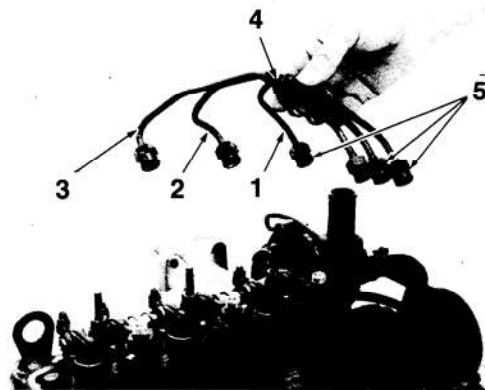
1. Head Cover

### REMOVING INJECTION PIPES 1,2 and 3.

1. Loosen the screws on the pipe clamps.
2. Detach the injection pipes in the order of 1, 2 and 3.

**NOTE FOR REASSEMBLING:** Send compressed air into the pipes to blow out dust. Then, reassemble the pipes in the reverse order. Tighten the retaining nuts to 15 to 25 Nm (1.5 to 2.5 kgf-m, 11 to 18 ft lbs).

1. Injection Pipe 1
2. Injection Pipe 2
3. Injection Pipe 3
4. Pipe Clamp
5. Retaining Nuts



### REMOVING NOZZLE HOLDER ASSEMBLIES

1. Remove the pipe clips holding the fuel overflow pipes, and detach the pipes.
2. Detach the nozzle holders using a 27mm (1-1/16") nozzle holder socket wrench, after loosening the rock nuts.
3. Detach the copper gaskets on the seats on which the nozzles are to be installed.

**NOTE FOR REASSEMBLING:** Return the nozzle holders after confirming that there are no metallic particles or foreign matter on the surface on which the nozzles are to be installed. Tighten the nozzles to 29 to 49 Nm (3.0 to 5.0 kgf-m, 22 to 36 ft-lbs.).

1. Nozzle Holder Socket Wrench
2. Rock Nut



### REMOVING AC DYNAMO AND FAN BELT

1. Remove the AC dynamo.
2. Detach the fan belt.

**NOTE FOR REASSEMBLING:** Check to see if the V-belt is placed in a correct position (where letters on the belt can be read from your side), and there is no oil or grease on the belt. Fan belt tension: The belt should deflect approx. 7 mm (0.28 in.) when the center of the belt is depressed with a finger pressure of 58.8 to 68.6 N (6 to 7 kgf-m, 13.2 to 15.4 lbs.)

1. AC Dynamo
2. Fan Belt



## REMOVING ROCKER ARM

1. Remove the set nuts for the rocker arm brackets.
2. Detach the whole rocker arm.

**NOTE FOR REASSEMBLING:** Always adjust the valve clearance. Before installing the rocker arm bracket, check to see if there are any metallic particles on the surface on which the assembly is mounted. Tighten the bolts to 17 to 21 Nm (1.7 to 2.1 kgf-m, 12 to 15 ft-lbs.).

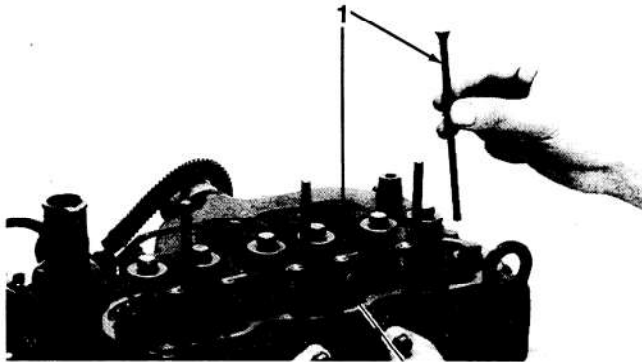


1. Rocker Arm

## REMOVING PUSH-RODS

1. Remove the push-rods.

**NOTE FOR REASSEMBLING:** Before inserting the push rods into the tappets, check to see if their ends are properly engaged with the grooves. If a push rod is roughly inserted, it may hit the shoulder of the tappet and be damaged.



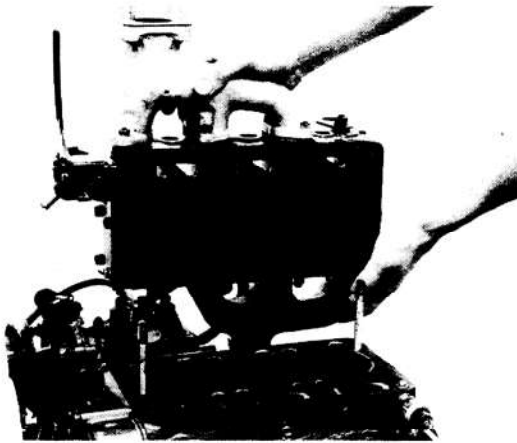
1. Push-rod

## REMOVING CYLINDER HEADS

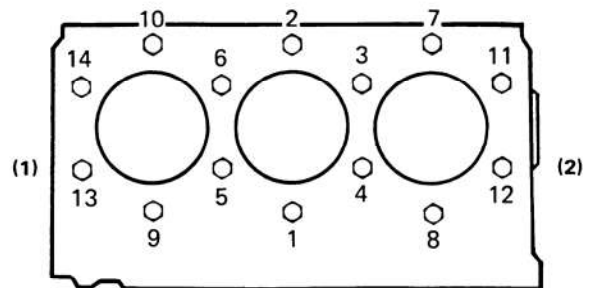
1. Remove the twelve cylinder head set bolts and two nuts.
2. Lift up the cylinder head to detach.

**NOTE FOR REASSEMBLING:** Tighten the bolts and nuts after applying sufficient oil. Tighten the bolts and nuts in diagonal sequence starting from the center. Tighten them uniformly, or the head may deform in the long run.

**IMPORTANT:** When overhauling the engine, replace the gasket with a new one without confusing its front and back. Retighten the cylinder head after running the engine for 30 minutes. Tighten the cylinder head bolts and nuts to engine specifications.



Cylinder head tightening sequence

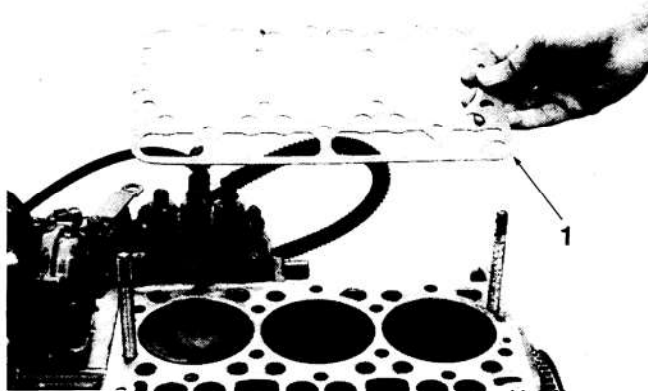


1. Gear Case Side
2. Flywheel Side

## REMOVING CYLINDER HEAD GASKET

1. Detach the cylinder head gasket, being careful not to scratch it.

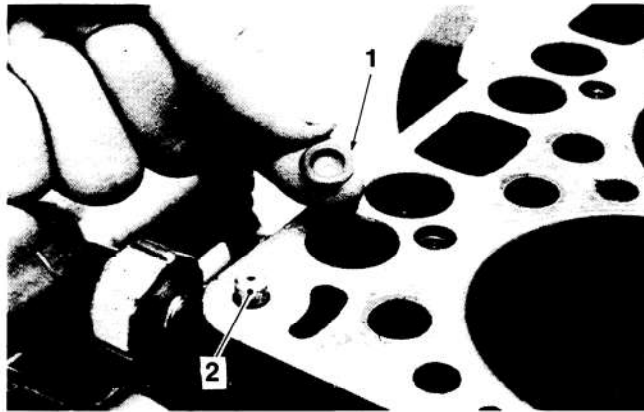
**NOTE FOR REASSEMBLING:** Before installing the gasket, check to see there is no foreign matter on the cylinder head and the cylinder.



1. Cylinder Head Gasket

## REMOVING O-RING

1. Remove the O-ring from the periphery of the oil pipe on the crankcase.

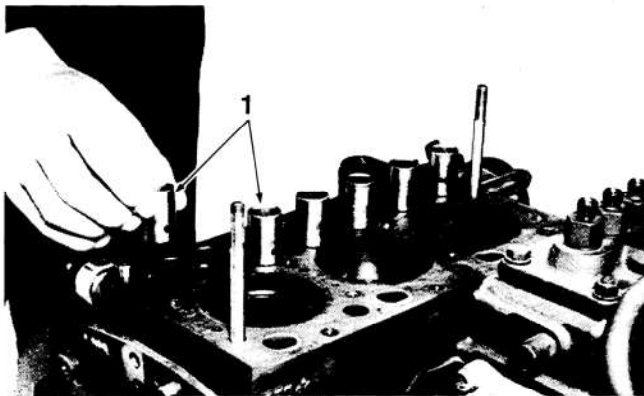


1. O-ring
2. Pipe Pin

## REMOVING TAPPETS

1. Remove the six tappets from the crankcase.

**NOTE FOR REASSEMBLING:** Visually check the contact between tappets and cams for proper rotation. If a defect is found, replace tappets. Before installing the tappets, apply engine oil thinly around them.



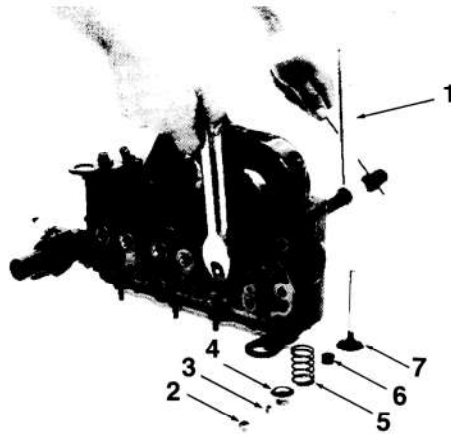
1. Tappets

## REMOVING VALVES

1. Remove the valve caps.
2. Remove the valve spring collet, pushing the valve spring retainer by valve spring replacer.
3. Remove the valve spring retainer, valve spring and valve stem seal.
4. Remove the valve.

**IMPORTANT: Don't change the combination of valve and valve guide.**

1. Valve Spring Replacer
2. Valve Cap
3. Valve Spring Collet
4. Valve Spring Retainer
5. Valve Spring
6. Valve Stem Seal
7. Valve



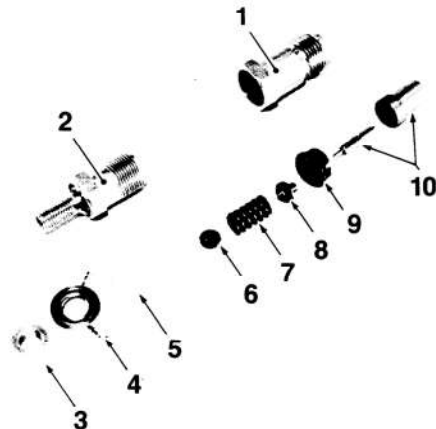
## **NOZZLE HOLDER**

### DISASSEMBLING NOZZLE HOLDER

1. Secure the retaining nut with a vise.
2. Remove the nut, the eye joint and the plain washer.
3. Remove the nozzle holder body and take out parts inside

**NOTE FOR REASSEMBLING:** When disassembling and reassembling the nozzle piece, dip it in clean fuel. Install the push rod, noting its direction (upside down). Tighten the retaining nut to 58.8 to 78.4 Nm (6 to 8 kgf-m, to 57.8 ft-lbs). Do not tighten it too much, or the needle valve will not slide easily and the injection performance will be decreased.

1. Retaining Nut
2. Nozzle Holder Body
3. Nut
4. Eye Joint
5. Plain Washer
6. Adjusting Washer
7. Nozzle Spring
8. Push Rod
9. Distance Piece
10. Nozzle Piece

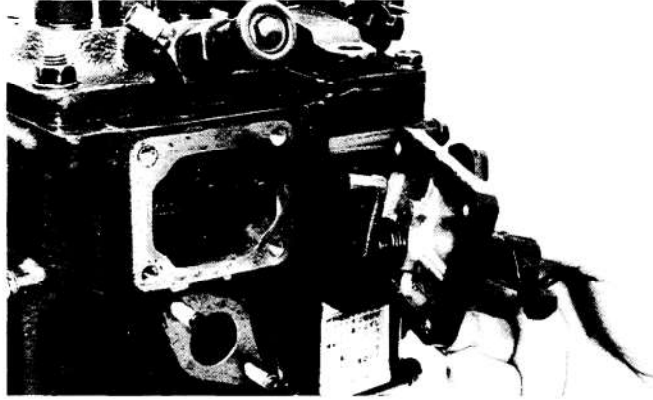


## INJECTION PUMP

### REMOVING INJECTION PUMP COVER

1. Remove the injection pump cover.

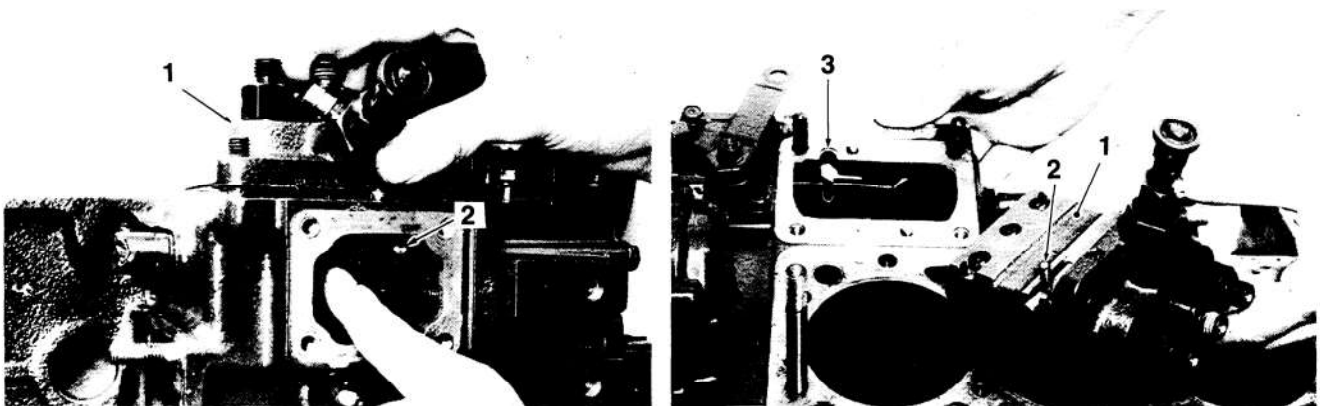
**NOTE FOR REASSEMBLING:** Before installing the pump cover gasket, apply a non-drying adhesive to it.



### REMOVING INJECTION PUMP

1. Remove the injection pump mounting bolts and nuts.
2. Detach the injection pump. To prevent the pump rack from being caught, detach the pump along the removal groove.
3. Align the control rack pin with the slot on the gear case and remove the injection pump.
4. In principle, the injection pump should not be disassembled.

**NOTE FOR REASSEMBLING:** Install the injection pump by aligning the control rack with the indicated position. Addition or reduction of one shim delays or advances the injection timing by 0.0262 rad. (1.5°). Install the injection pump shims after applying thinly a non-drying adhesive.



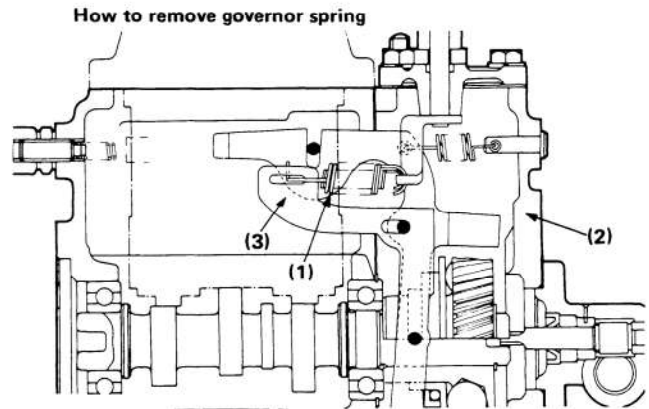
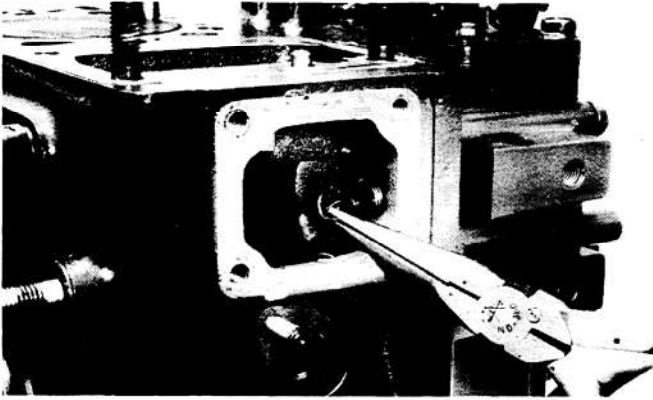
1. Injection Pump
2. Control Rack
3. Removal Groove

## GEAR CASE, TIMING GEAR, CAMSHAFT, OIL PUMP

### DETACHING GOVERNOR SPRING

1. Detach the governor springs 1 and 2 from governor fork lever 2.

**NOTE FOR REASSEMBLING:** Fix the governor spring to the speed control lever, and pull the spring or wire through the window of the injection pump, and spring will be able to be hooked on the governor fork with ease. Bend the end of the governor spring to prevent it from falling off.

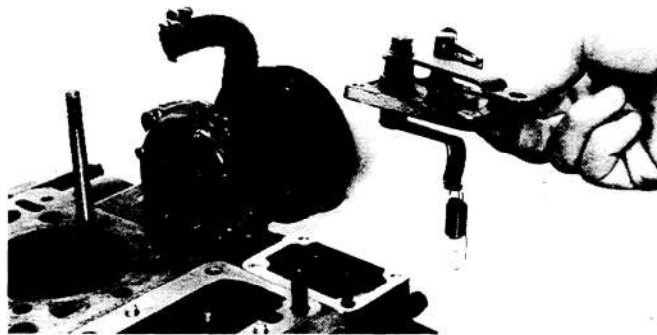


1. Detach Governor Spring on the Side of Fork Lever
2. Gear Case
3. Fork Lever 2

### REMOVING SPEED CONTROL PLATE

1. Remove the speed control plate and governor spring.

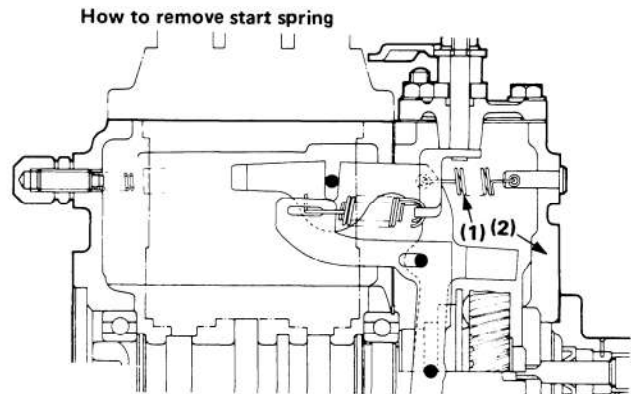
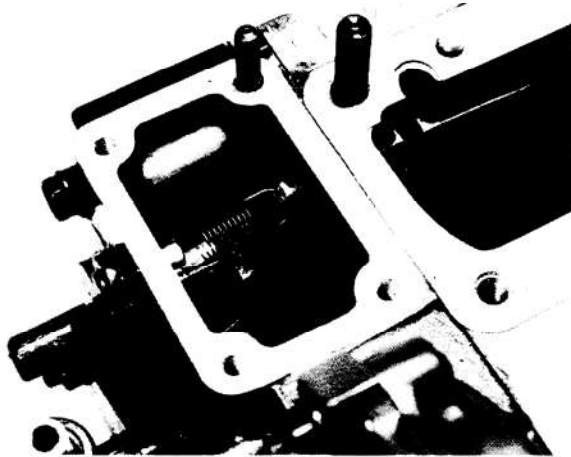
**NOTE FOR REASSEMBLING:** Be careful not to drop the governor spring in the gear case.





### DETACHING START SPRING

1. Remove the start spring from the gear case.



1. Detach Start Spring on the Side of Gear Case
2. Gear Case

### REMOVING FAN DRIVE PULLEY

1. Flatten the crankshaft washer.
2. Loosen and remove the crankshaft nut.
3. Draw out the pulley with a puller.

**NOTE FOR REASSEMBLING:** Bend the crankshaft washer against one side of the nut. Tighten the nut to 137.3 to 156.9 Nm (14.0 to 16.0 kgf-m, 101.3 to 115.7 ft-lbs.). Do not tighten the nut excessively; it may damage the oil slinger, causing oil leakage.

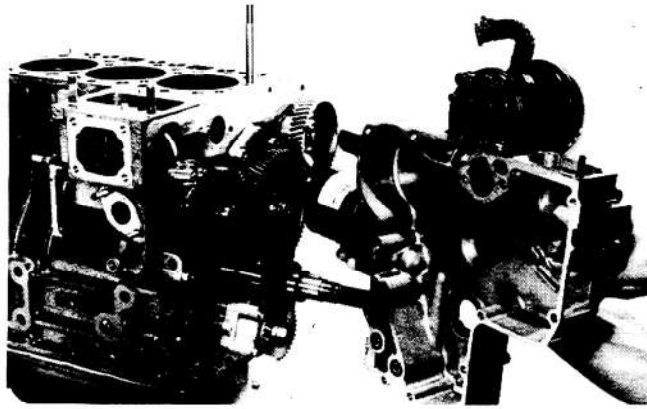


1. Fan Drive Pulley

## REMOVING GEAR CASE

1. Remove the gear case cover.
2. Remove the O-ring.

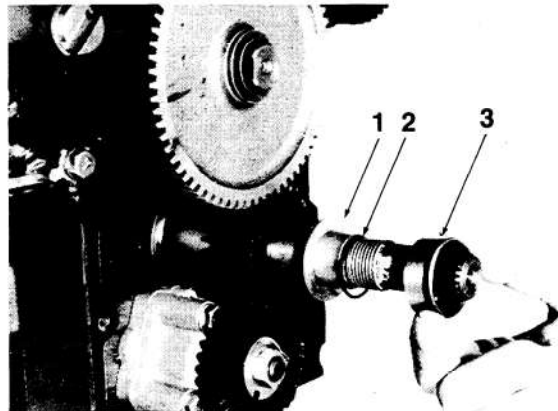
**NOTE FOR REASSEMBLING:** Check to see if there are three O-rings inside the gear case. Apply a thin film of engine to the oil seal, and install it, noting the lip come off. Before installing the gear case gasket, apply a non-drying adhesive. Tighten the oil filter cartridge by hand.



## REMOVING CRANKSHAFT OIL SLINGER

1. Remove the crankshaft collar.
2. Remove the O-ring.
3. Detach the crankshaft oil slinger.

1. Crankshaft Oil Slinger
2. O-Ring
3. Crankshaft Collar



### REMOVING IDLE GEAR

1. Remove the external circlip.
2. Detach the idle gear collar 2.
3. Detach the idle gear
4. Detach the idle gear collar 1.

**NOTE FOR REASSEMBLING:** Check to see each gear is aligned with its aligning mark:

1. Idle gear and crank gear
2. Idle gear and camshaft gear
3. Idle gear and injection pump gear

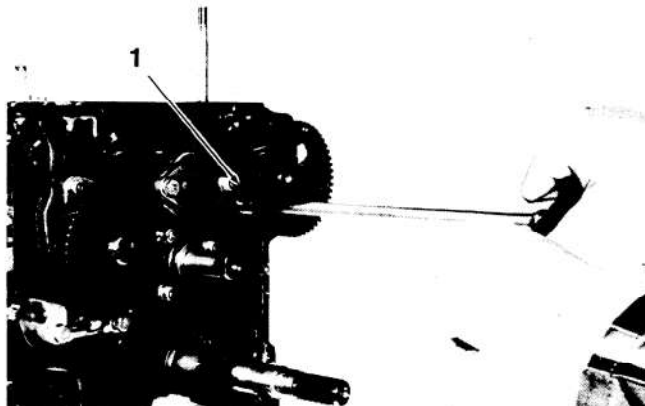
Tighten the idle gear shaft mounting bolt (7T) to 10 to 12 Nm (1.0 to 1.2 kgf8m, 7.2 to 8.7 ft-lbs).



1. Idler Gear
2. Alignment Mark

### REMOVING CAMSHAFT STOPPER

1. Align the round hole on the cam gear with the camshaft stopper mounting bolt position.
2. Remove the camshaft stopper mounting bolt.
3. Detach the camshaft stopper.

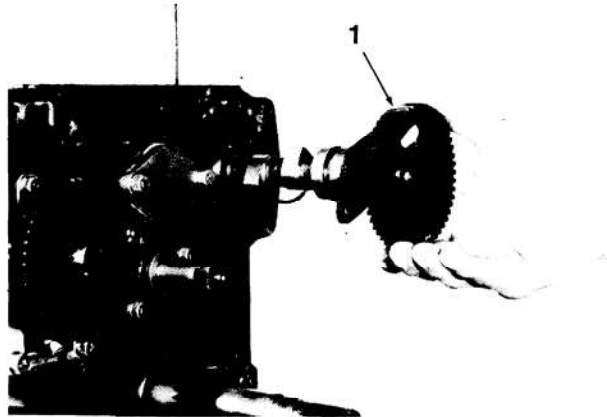


1. Camshaft Stopper

### REMOVING GEAR AND CAMSHAFT

1. Draw the camshaft and the cam gear.

**NOTE FOR REASSEMBLING:** Apply a thin film of engine oil to the camshaft before installation.

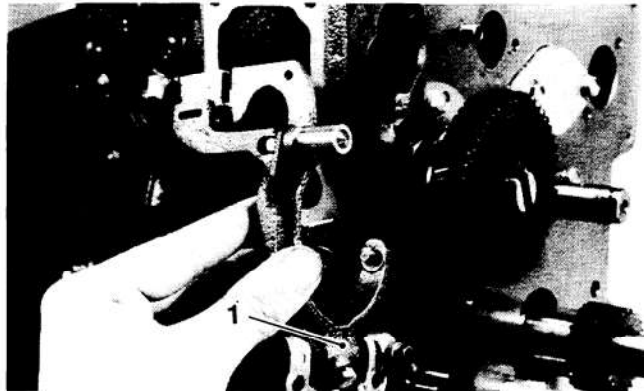


**1. Camshaft Assembly**

### REMOVING FORK LEVER ASSEMBLY

1. Remove the two fork lever holder mounting bolts.
2. Detach the fork lever assembly.

**NOTE FOR REASSEMBLING:** Install the fork lever holder and crankcase after cleaning their contact surfaces. Install the fork lever so that it will not hit the governor sleeve, and so that equal space is allowed on either side of the lever. After installation, check to see that the fork lever (1) is fixed to the fork lever shaft, and that it can turn smoothly in the holder.



**1. Fork Lever Assembly**

## REMOVING FUEL CAMSHAFT

1. Remove the fuel camshaft stopper.
2. Draw out the fuel camshaft and the injection pump gear.

**NOTE FOR REASSEMBLING:** Apply a thin film of engine oil to each part, and reassemble so that the drive groove at the end of the camshaft engages with the drive shaft of the hydraulic gear pump. The balls to be contained in the governor ball case are thirty 3.97 mm (0.1563 in.) diameter ones and eight 13.46 mm (0.5300 in.) diameter ones.



1. Fuel Camshaft Assembly
2. Fuel Camshaft Stopper

## REMOVING OIL PUMP DRIVE GEAR

1. Straighten the claw of the claw washer of the oil pan, and remove the nut.

**NOTE FOR REASSEMBLING:** Check to see if there is a feather key. Be sure to bend the claw of the claw washer.

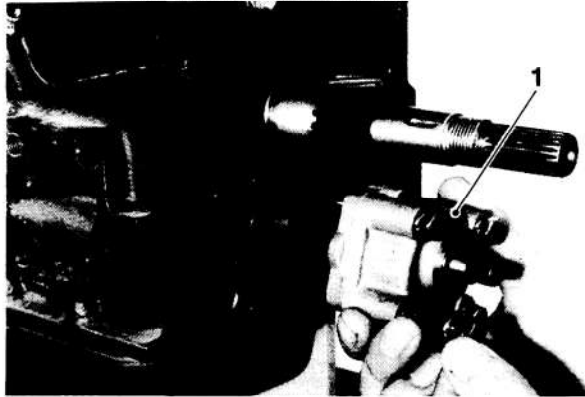


1. Crank Gear
2. Oil Pump Drive Gear

## REMOVING OIL PUMP

1. Remove the four pump mounting bolts. Detach the oil pump.

**NOTE FOR REASSEMBLING:** Tighten the bolts 10 to 12 Nm (1.0 to 1.2 kgf-m, 7.2 to 8.7 ft-lbs.).

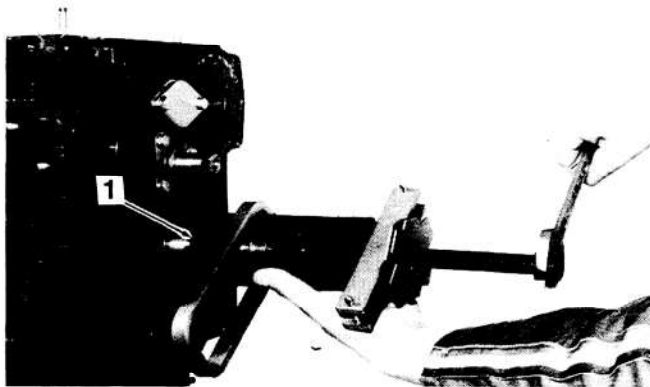


**1. Oil Pump Assembly**

## REMOVING CRANK GEAR

1. Set a special puller on the crank gear.
2. Screw in the center bolt of the puller, and draw out the crank gear.

**NOTE FOR REASSEMBLING:** Check to see that the key is on the crankshaft. Heat the crank gear to about 99°C (120°F), and fit on the crankshaft. If there is fear of the shaft being damaged, heat the gear more and fit.



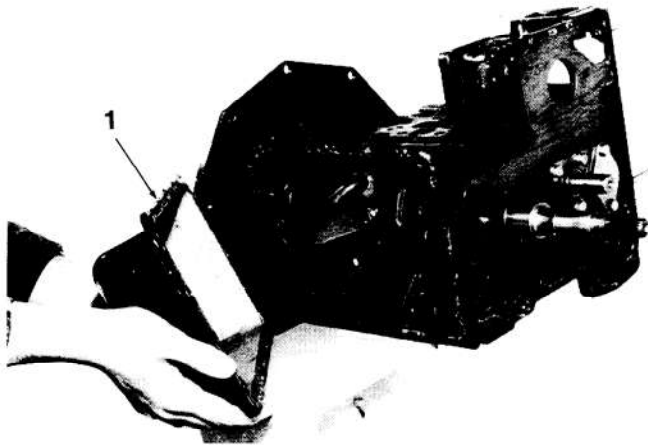
**1. 13T Gear (Crank Gear)**

## PISTON, CRANKSHAFT

### REMOVING OIL PAN

1. Lay the engine on the engine cradle on its side.
2. Remove the eighteen oil pan mounting bolts.
3. Detach the oil pan by lightly tapping the grove of the pan with a wooden hammer.

**NOTE FOR REASSEMBLING:** Wipe off oil on the oil pan mounting surface, apply a nondrying adhesive, and install the oil pan. To avoid uneven tightening, tighten mounting bolts in diagonal order from the center. Check to see that the drain plug is tight.



1. Oil Pan

### REMOVING OIL FILTER 1

1. Remove the mounting bolt of oil filter 1.
2. Detach oil filter 1, being careful of the O-ring.

**NOTE FOR REASSEMBLING:** After cleaning the oil filter, check to see that the filter mesh is clean, and install it. Visually check the O-ring, apply engine oil, and install it. After checking to see that the O-ring is securely installed, attach the oil filter.

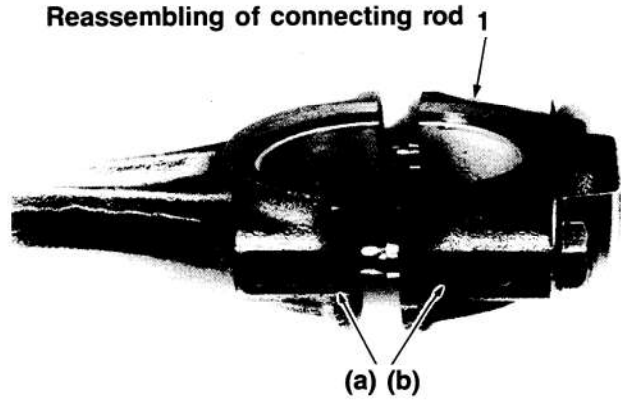


1. Oil Filter 1

## REMOVING CONNECTING ROD CAP

1. Remove the connecting rod bolts from connecting rod cap.
2. Detach the connecting rod caps.

**IMPORTANT:** Apply engine oil to the connecting rod bolts and tighten them to 26 to 30 Nm (2.7 to 3.1 kgf<sup>m</sup>, 20 to 22 ft-lbs).



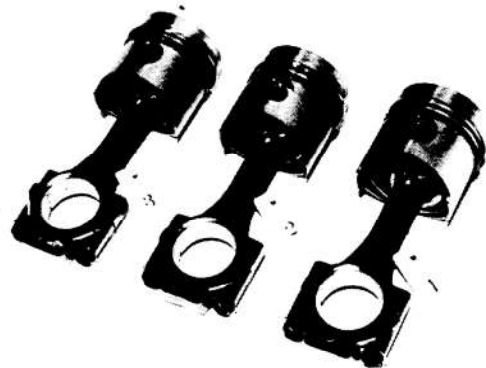
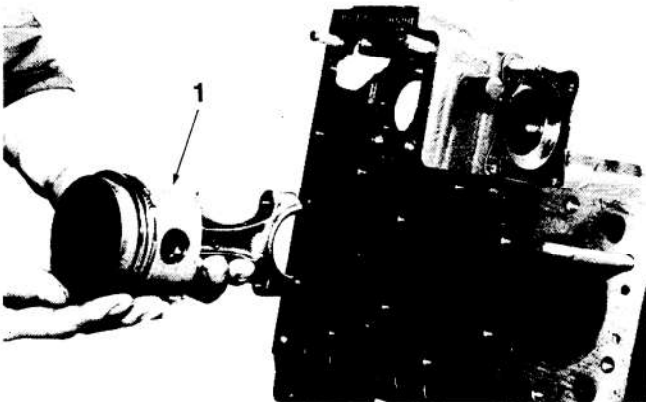
1. Connecting Rod Cap
  - a. Align the marks with each other.
  - b. Face the marks toward the injection pump.

## REMOVING PISTONS

1. Turn the crankshaft by 3.14 rad (180°) and bring the piston to top dead center.
2. Draw out the piston upward by lightly tapping it from the bottom of the crankcase with the grip of a hammer.
3. Draw out the other two pistons in the same method as above.

**NOTE FOR REASSEMBLING:** Before inserting the pistons into the cylinders, apply enough engine oil to the pistons.

**IMPORTANT:** Install the piston rings with their gaps making an angle of 2.09 rad (120°) or 3.14 rad (180°) to each other. (Place the top ring with their gaps on the opposite side of the combustion chamber.) Attach a ring to the pistons securely with a piston ring compressor, and set them to the cylinder, being careful about the cylinder number and the position of the connecting rod (Connecting rods must be installed with their ends being the number toward the fuel injection pump). Carefully insert the pistons. Otherwise, their chromeplated section may be scratched, causing trouble inside the liner.



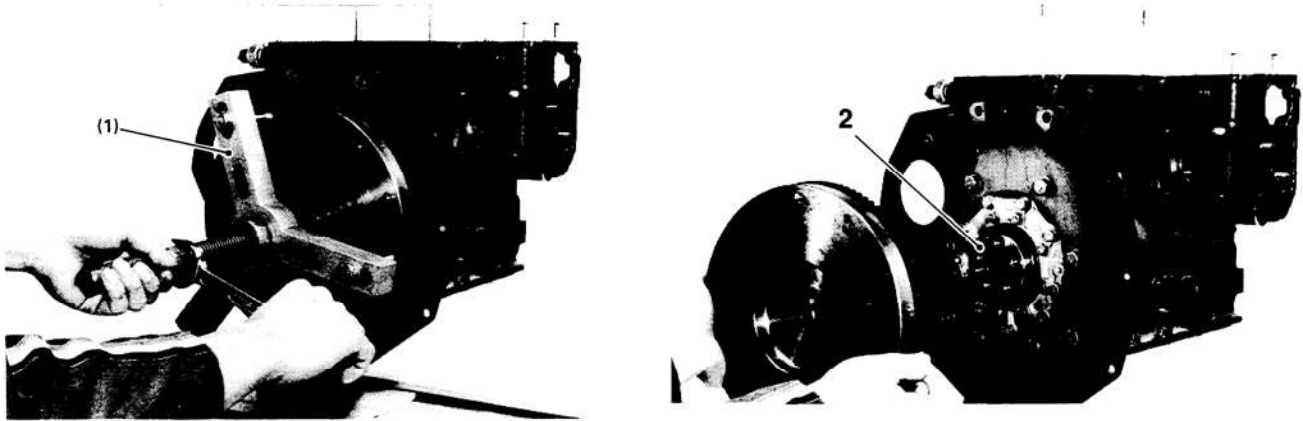
1. Piston



## REMOVING FLYWHEEL

1. Flatter the flywheel washers.
2. Remove the flywheel bolts, except for two which must be loosened and left as they are.
3. Set a flywheel puller, and remove the flywheel

**NOTE FOR REASSEMBLING:** Apply a thin film of grease to the bearing and oil seal at the back of the crankshaft. Check the ring gear for any uneven wear, lack or crack of teeth. Check to see that there are no metal particles left on the flywheel mounting surface. To ease alignment of the crankshaft and the flywheel, bring the crank of one of the cylinders to TC (top dead center). Make sure of the flywheel TC, align it with the punch mark of the rear end plate, and set the flywheel. Tighten the flywheel bolts to 54 to 59 Nm (5.5 to 6.0 kgf<sup>0</sup>m, 40 to 43 ft-lbs) in diagonal order. Bend the tangs of the flywheel washer against the bolts.



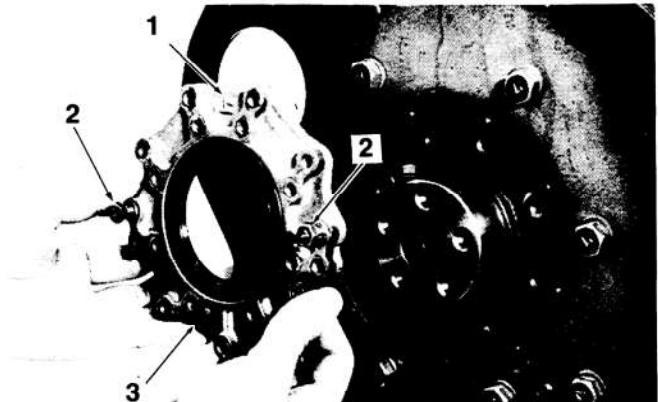
1. Flywheel Puller
2. Crankshaft

## REMOVING BEARING CASE COVER

1. Remove the bearings case cover mounting bolts. First unscrew the eight bolts inside, and then work on the nine outside.
2. Screw the two bolts removed above into the two right and left holes for the bearing case cover, and pull off the cover by jacking it up.

**NOTE FOR REASSEMBLING:** When installing the main bearing case cover, check to see that there are no scratches on the oil seal lip. Then, apply a thin film of engine oil, and install. Tighten the mounting bolts in diagonal order to 10 to 12 Nm (1.0 to 1.2 kgf<sup>0</sup>m, 7.2 to 8.7 ft-lbs).

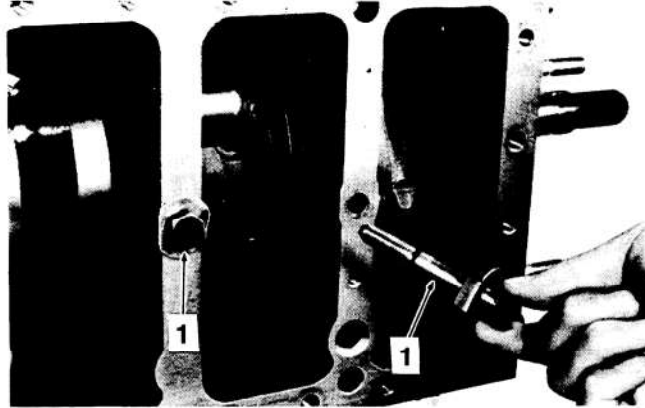
1. Lift Bolt
2. Bearing Case Cover



## REMOVING BEARING CASE BOLT 2

1. Straighten the washer for the bearing case bolt 2.
2. Detach the bearing case bolts.

**NOTE FOR REASSEMBLING:** When tightening the main bearing case bolts, align the direction of the holes so that the crankshaft can be easily installed. Tighten the bearing case bolts 2 to 30 to 34 Nm (3.0 to 3.5 kgf<sup>m</sup>, 22 to 25 ft-lbs). Securely bend tangs of the washer.



**1. Bearing Case Bolt 2**

## REMOVING CRANKSHAFT

1. Draw out the crankshaft from the back of the crankcase by lightly tapping it with a copper hammer.

**NOTE FOR REASSEMBLING:** Before installing the crankshaft, clean the oil holes in the crankshaft with compressed air.

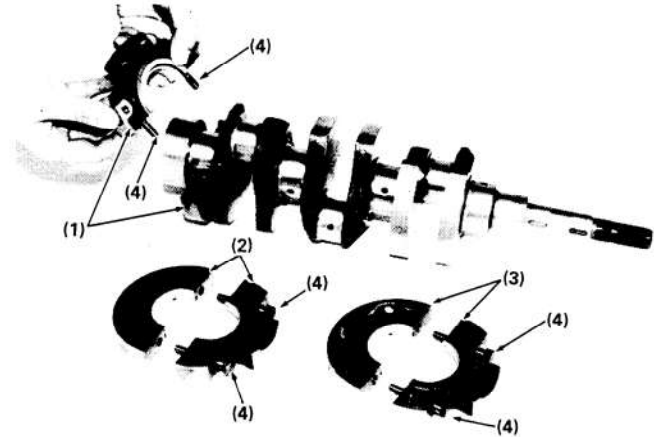


## REMOVING MAIN BEARING CASE

1. Remove the two mounting bolts for main bearing case assembly
2. Detach the main bearing case, being careful with the side and crankshaft bearings.
3. Detach the other bearing cases 2 and 3 in the same method. Be careful not to mix them up.

**NOTE FOR REASSEMBLING:** Clean the oil holes in the main bearing case. Install the main bearing case with their side marks toward the flywheel. Be sure to install main bearing 1 with its oil groove facing outward. Tighten the bearing case bolts 1 to 2 to 24 Nm (2.0 to 2.4 kgf<sup>0</sup>m, 15 to 17 ft-lbs).

1. Main Bearing Case Assembly 1
2. Main Bearing Case Assembly 2
3. Main Bearing Case Assembly 3
4. Bearing Case Bolt 1

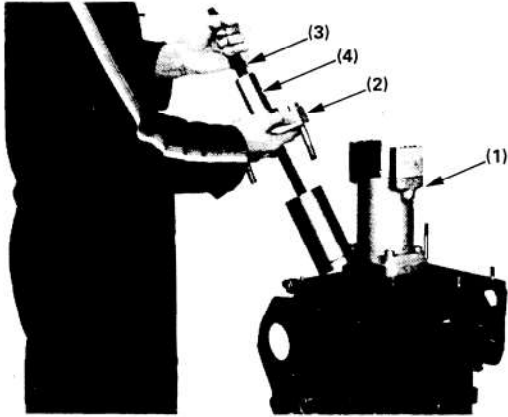


## REMOVING CYLINDER LINER (See illustration on page 105)

1. Grind the cylinder head mounting surface with an oil grinding stone.
2. Set a dry liner centering base and adaptor on the frame head
3. Set the dry liner centering base.
4. Set the bearing cradle to the dry liner centering base with the bearing on top.
5. Insert the pulling-out adaptor coupling and fix the center bolt.
6. Contact the pulling-out adaptor with the bottom of the liner from the bottom of the crankcase.
7. Pull out the liner by turning the nut with a ratchet handle.

**NOTE FOR REASSEMBLING:** Clean the frame holes and oil where the liner fits. Clean the surface of the liner and apply oil. Insert the liner with its most-chamfered end down. After installation, insert a feeler gauge through the check window on the bottom of the liner centering base and check to see the liner has been properly pressed in. Tolerance: Liner projection ( $\pm 0.0010$  in). Hone the cylinder liner. 1.2 u R max to 2 u R max.

1. Dry Liner Centering Base
2. Bearing Cradle
3. Center Bolt
4. Nut



## THERMOSTAT, WATER PUMP

### REMOVING THERMOSTAT

1. Remove the thermostat cover.
2. Remove the thermostat.

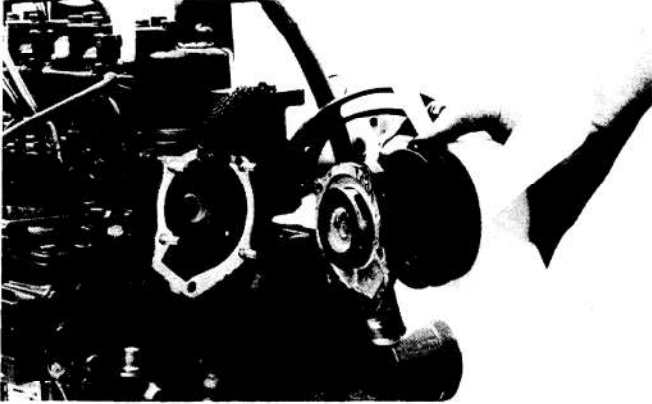
**NOTE FOR REASSEMBLING:** Apply a non-drying adhesive only at the thermostat cover side of the gasket.



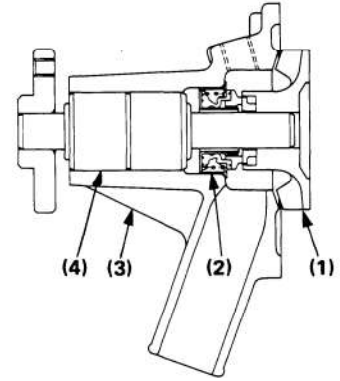
## REMOVING WATER PUMP

1. Remove the water pump from gear case cover.
2. Remove the fan and fan pulley.

**IMPORTANT:** If changing the water pump, change the whole pump. If disassembling the water pump, check to see the clearance between the water pump impeller and body.



Water pump assembly



1. Water Pump Impeller
2. Seal Set
3. Water Pump Body
4. Bearing

## CHECKING FLATNESS OF CYLINDER HEAD SURFACE (See illustration on page 107)

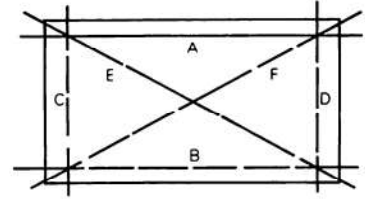
1. Clean the surface of the cylinder head.
2. Place a straight edge on each of the cylinder heads's four sides and two diagonally as shown at the left to check the straightness of the surface.
3. Insert a feeler gauge between the straight edge and the cylinder head surface.
4. The maximum thickness that can be inserted is the amount of flatness.
5. If the measurement exceeds the allowable limit, correct with a surface grinder.

**IMPORTANT:** Do not place the straight edge on the combustion chamber.

Allowable limit	0.05 mm (0.002 in.) per 100 mm (4 in.) of cylinder head surface length.
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How to check cylinder head surface



CHECKING FLAW OF CYLINDER HEAD SURFACE

1. Clean the surface of the cylinder head.
2. Spray the cylinder head surface with the red permeative liquid.
3. Wash away the red permeative liquid on the cylinder head surface with the detergent.
4. Spray the cylinder head surface with the developer. If flawed, it can be identified as red marks.

Reference	Should be no flaw.
-----------	--------------------

- A. Air spray red check**
1. Detergent
  2. Red Permeative Liquid
  3. White Developer

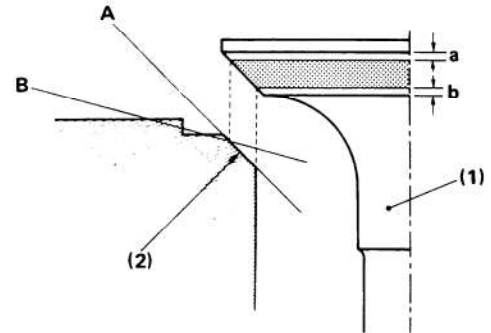


## REPAIRING THE VALVE SEAT

1. Clean the valve seat surface.
2. Use a 45° cutter suitable for the valve guide and the valve seat.
3. Grind the upper surface of valve seat with 15° cutter so that the valve seat fits to the valve center (so as to ensure  $a = b$  as shown in the figure.).

**NOTE:** After correcting the valve seat, check for valve recessing.

How to repair the valve seat

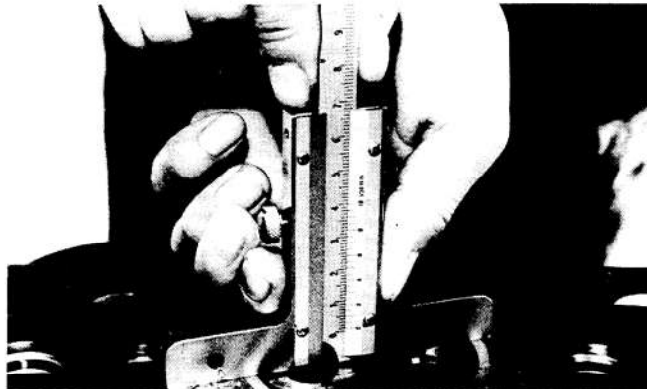


**A 45° cutter**  
**(1) Valve**

**B 15° cutter**  
**(2) Corrected surface of valve seat**

## CHECKING VALVE RECESSING

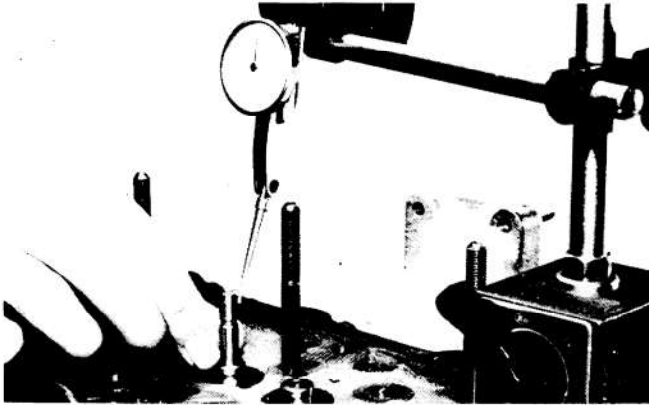
1. Clean the face of the valve.
2. Measure the recessing with a depth gauge.
3. See engine specifications.



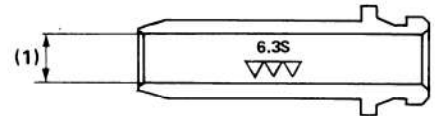
### CHECKING GUIDE CLEARANCE

1. Remove carbon from the valve guide.
2. After making sure that the valve stem is straight, insert the valve into the valve guide.
3. Measure the stem guide clearance with a dial gauge.
4. If the measurement exceeds the allowable limit, replace the stem guide and the valve.

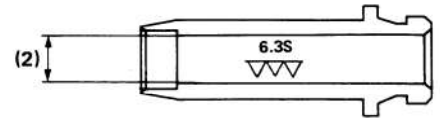
**IMPORTANT:** When changing the valve guide, be sure to ream as the figure indicates after inserting the valve guide. See engine specifications.



Finishing size of inlet valve guide

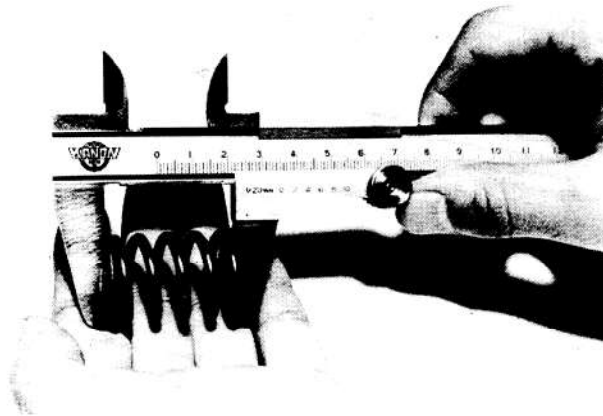


Finishing size of exhaust valve guide



### CHECKING VALVE SPRING FREE LENGTH

1. Measure the spring with a set of vernier calipers.
2. If the measurement exceeds the allowable limit, replace. See engine specifications.

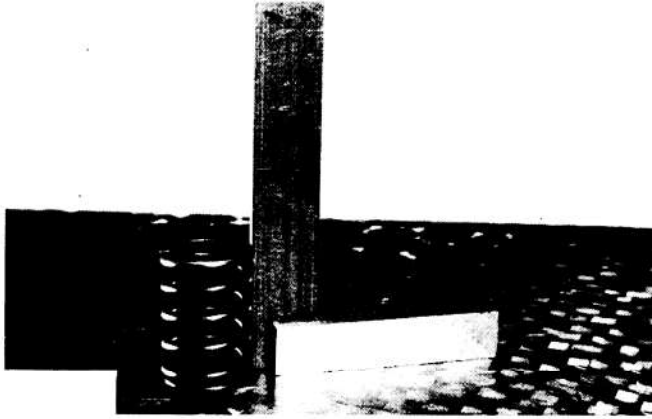




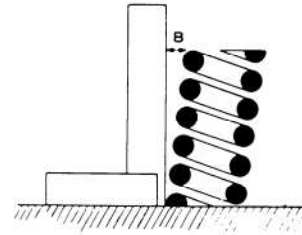
### CHECKING VALVE SPRING SQUARENESS

1. Put the spring on a surface plate, place a square on the side of the spring, and check to see if the entire side is in contact with the square.
2. Rotate the spring and measure the maximum B. (See illustration below.).
3. If the measurement exceeds the allowable limit, replace. The flat surface at the end of the spring coil must exceed the full circumference by two-thirds. Check the entire surface of the spring for scratches.

Allowable limit	1.3 mm 0.051 in.
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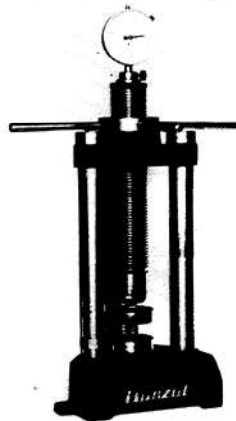


How to measure squareness of valve spring



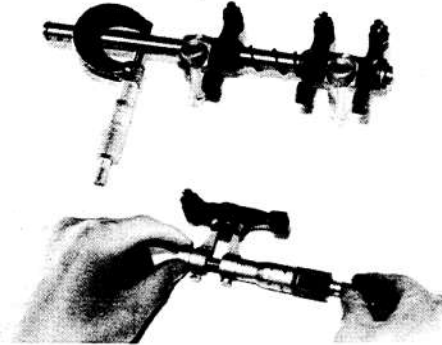
### CHECKING VALVE SPRING TENSION

1. Place the spring on a tester and compress it to the same degree that it is actually compressed in the engine, (31 mm, 12 in.)
2. Read the compression load on the gauge.
3. If the measurement exceeds the allowable limit, replace. See engine specifications.



## CHECKING OIL CLEARANCE BETWEEN ROCKER ARM SHAFT AND BUSHING

1. Measure the rocker arm I.D.
2. Measure the rocker arm O.D.
3. If the clearance exceeds the allowable limit, replace. See engine specifications.



## CHECKING TOP CLEARANCE

1. Remove the nozzle holder.
2. Lower the piston in the cylinder to be measured.
3. Insert a high-quality fuse from the nozzle holder hole. Be careful not to let the fuse touch the valve surface.
4. Rotate the engine with your hand.
5. Take the fuse out carefully.
6. Measure the place where the fuse was crushed with vernier calipers.
7. If the clearance is not within the reference value, adjust by inserting a shim between the cylinder head and the gasket.

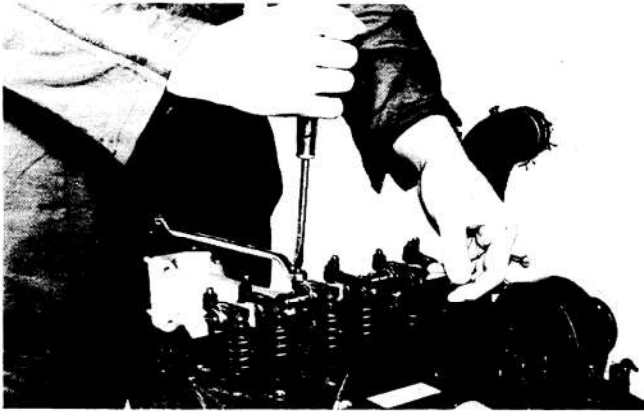


Reference value	0.6 to 0.8 mm 0.0236 to 0.00315 in.
Thickness of gasket when tightened	1.05 to 1.15 mm 0.0413 to 0.0453 in.
Thickness of gasket shim	0.20 mm 0.0079 in.

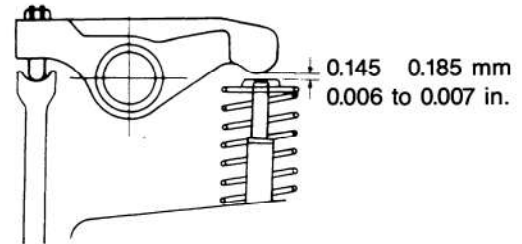
## ADJUSTING VALVE CLEARANCE

1. Measure the clearance with a feeler gauge after aligning each cylinder with the top dead center of compression.

**NOTE:** Align the flywheel mark (TC) with the timing check mark on the crankcase.



Valve clearance

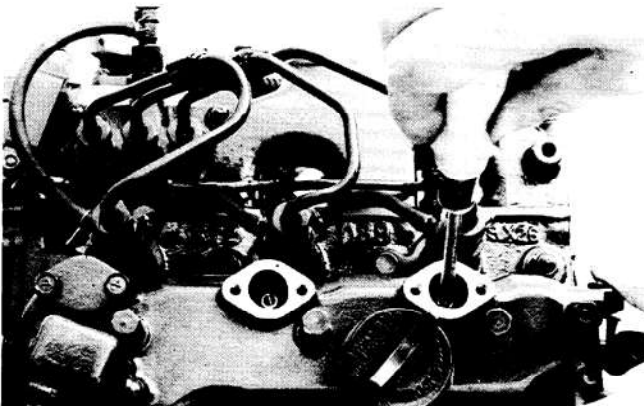


## ADJUSTING COMPRESSION RELEASE

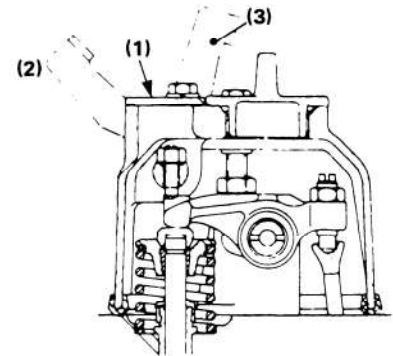
1. Close the exhaust valve completely.
2. Remove the compression release window cover from the head cover.
3. Pull the compression release lever.
4. Reduce the valve clearance to zero by the compression release adjustment bolt. Reach for the bolt through the window. Then, screw in the bolt by 1 to 1.5 turns and tighten the lock nut.

**NOTE:** After adjustment, turn the crankshaft by hand and check to see that the valve and the piston should not be in contact with each other.

Reference value	0.750 to 1.125 mm 0.0295 to 0.0443 in.
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Compression release adjustment



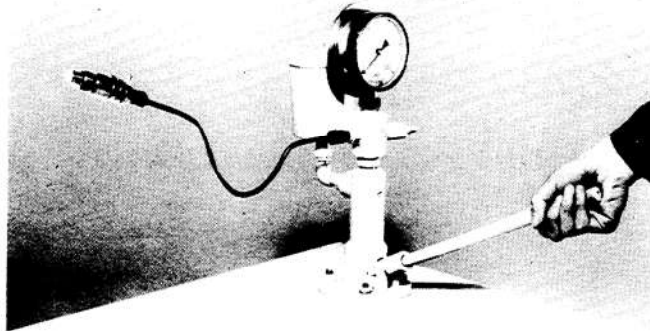
1. Compression Release Window Cover
2. Compression Position
3. Compression Release Position

## FUEL SYSTEM

### TESTING OPENING PRESSURE OF NOZZLE

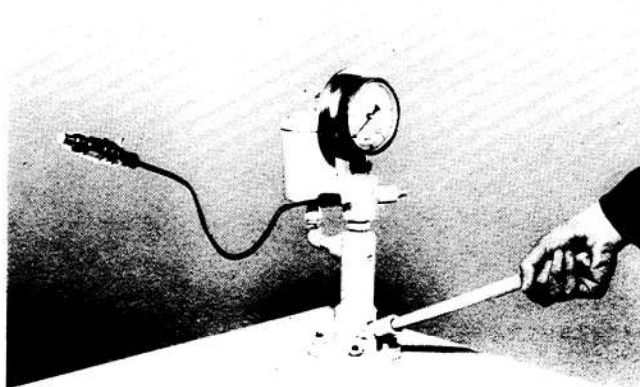
1. Move the tester handle up and down to prime fuel. Measure the pressure of fuel jetting from the nozzle tip.
2. If the measurement is not within the reference value, adjust with the adjustment washer inside the nozzle holder. Each extra 0.1 mm (0.0039 in.) of washer thickness causes an approximate 980.6 kPa (10 kgf/cm<sup>2</sup>, 142.2 psi) increase in fuel injection pressure.

**DANGER: Be careful not to come into direct contact with the injected fumes. The fumes destroy any cells they may touch. They may also cause blood poisoning. See engine specifications.**



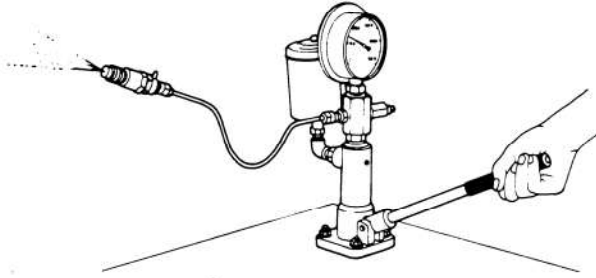
### CHECKING FUEL TIGHTNESS OF NOZZLE VALVE SEAT

1. Apply a pressure.
2. After keeping the nozzle under this pressure for 10 seconds, check to see if fuel leaks from the nozzle valve seat.
3. If fuel should leak, replace the nozzle piece. See engine specifications.

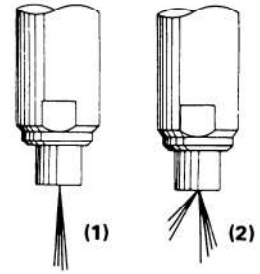


**CHECKING SHAPE OF FUMES ACROSS NOZZLE TIP**

1. Set the nozzle to a nozzle tester and shoot it in the air. Check the shape of the fumes.
2. If the shape is defective, replace the nozzle piece.



1. Good
2. Bad



**CHECKING FUEL TIGHTNESS OF FUEL INJECTION PUMP PLUNGER**

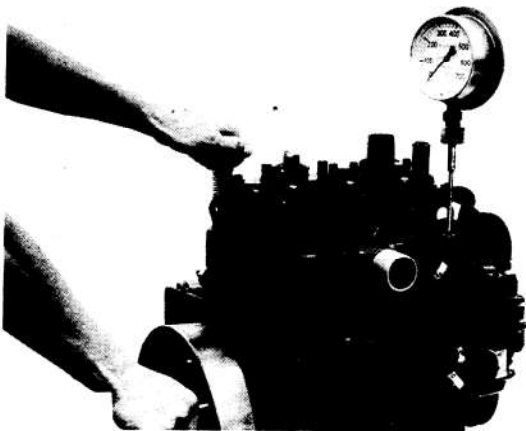
1. Set a pressure gauge to the pump.
2. Rotate the flywheel to increase the pressure to 58.8 MPa (600 kgf/cm<sup>2</sup>, 8532 psi).
3. Align the plunger with the top dead center.
4. Measure the time needed to decrease the initial pressure.
5. If the measurement is less than allowable limit, replace the pump element. In this case, ask a repair shop to do the replacement. Be sure to give them adjustment reference data on the fuel injection pump. (Shown below) See engine specifications.

Reference valve	8 seconds or more
Allowable limit	4 seconds

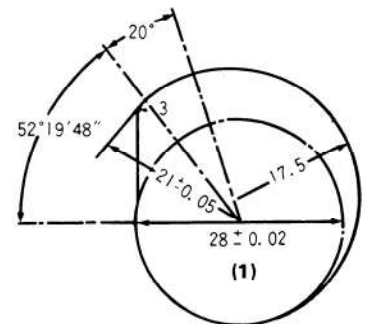
**Adjustment of Injection**

Control rack position (*1)	Speed (rpm)	Amount of injection (mm <sup>3</sup> /st)	Allowance (mm <sup>3</sup> ) (*3)
9	1400	22.5 to 23.5	±1.5 or less
8	1400	11.2 to 26.2	±3.8 or less
7	1400	6.0 to 21.0	±3.8 or less
0 to 3.5	1550	0.(*2)	

- \*1: Travel distance from non-injecting point of control rack
- \*2: Zero opening pressure and no injection
- \*3: Allowance on the basis of standard cylinder



Profile of fuel pump cam

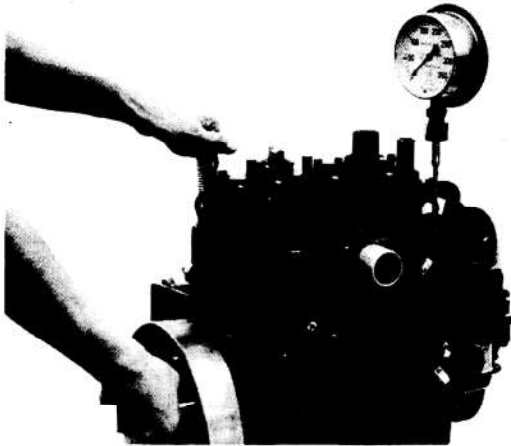


1. Base Circle

## CHECKING FUEL TIGHTNESS OF DELIVERY VALVE OF FUEL INJECTION PUMP

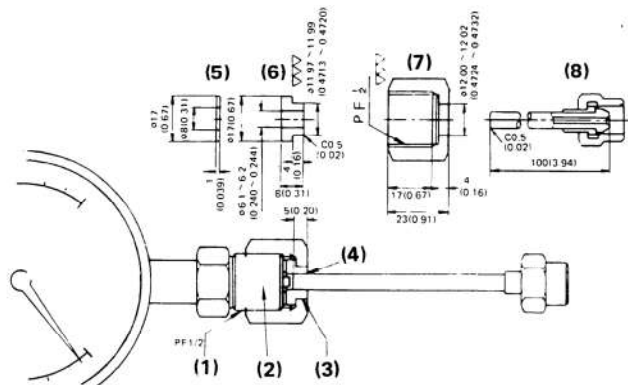
1. Set a pressure gauge to the pump.
2. Rotate the flywheel to increase the pressure to 9.8 MPa (100 kgf/cm<sup>2</sup>, 1422 psi).
3. Align the plunger with the bottom dead center.
4. Measure the time needed to decrease the initial pressure.
5. If the measurement is less than allowable limit, replace the delivery valve. See engine specifications.

Reference value	10 seconds or more
Allowable limit	5 seconds



Pressure gauge construction

Unit: mm (in.)

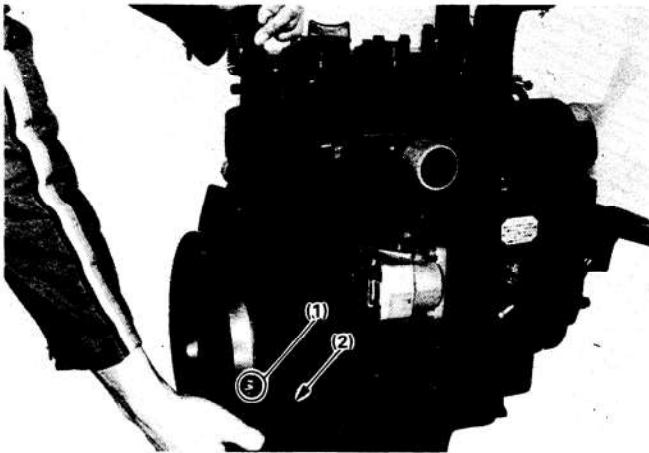


1. Connector
2. Pressure Sensor  
14.7 MPa (150 kgf/cm<sup>2</sup>, 2133 psi) and  
68.6 MPa (700 kgf/cm<sup>2</sup>, 9954 psi)
3. Non-drying Adhesive
4. Weld Entire Circumference
5. Copper Packing
6. S45C Steel Tube
7. S45C Hexagonal Steel Tube
8. Injection Pipe

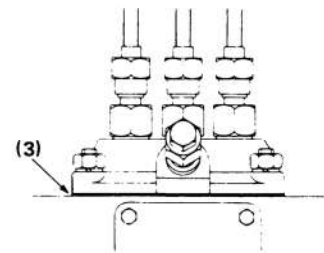
## CHOKING AND ADJUSTING INJECTION TIMING

1. Disconnect the injection pipe from the fuel injection pump.
2. Set the acceleration lever for maximum fuel discharge.
3. Turn the flywheel until fuel jets out from the delivery valve holder of the fuel injection pump.
4. Continue to turn the flywheel slowly, and stop it as soon as the fuel level at the tip of the valve holder begins to increase.
5. Check to see if the F1 mark on the flywheel is aligned with the dot mark.
6. If the timing is out of adjustment, readjust with shims.

**IMPORTANT:** Adding or removing one shim (0.15 mm, 0.0059 in.) varies the crank angle by approx. 1.5°. After adjustment, apply a thin film of non-drying adhesive to both sides of the shims. See engine specifications.



Adjustment of injection timing



1. F1 Mark
2. Mark
3. Injection Timing Adjusting Shim

## TIMING GEARS, CAMSHAFT

### CHECKING OIL CLEARANCE OF CAMSHAFT

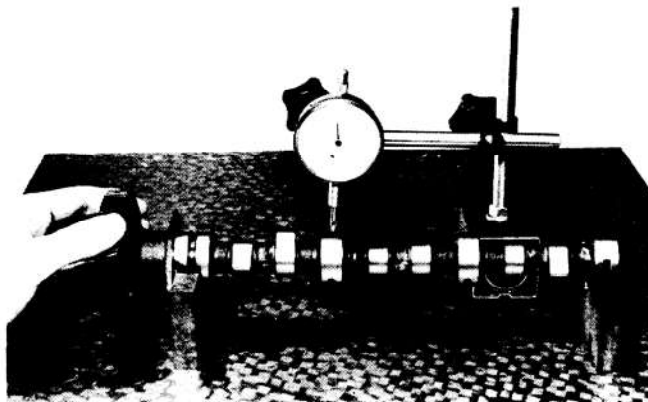
1. Measure the camshaft bearing in the crankcase with an inside micrometer.
2. Measure the camshaft journal with an outside micrometer. Calculate the clearance.
3. If the clearance exceeds the allowable limit, replace the camshaft. See engine specifications.



### CHECKING CAMSHAFT ALIGNMENT

1. Gently put the camshaft on V blocks.
2. Set a dial gauge to the journal.
3. While slowly rotating the camshaft, read the dial gauge. The camshaft flexure is half of the reading.
4. If the measurement exceeds the allowable limit, replace the camshaft.

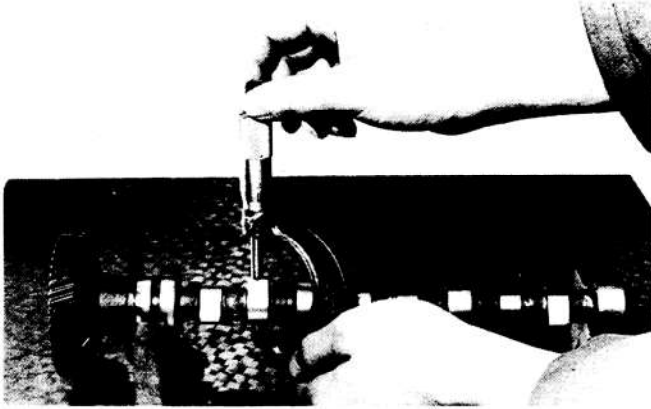
Allowable limit	0.08 mm 0.0031 in.
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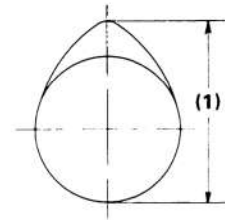


### CHECKING CAM HEIGHTS OF INTAKE AND EXHAUST

1. Measure the height of the cam at its highest point with a micrometer.
2. If the measurement exceeds the allowable limit, replace the camshaft. See engine specifications.



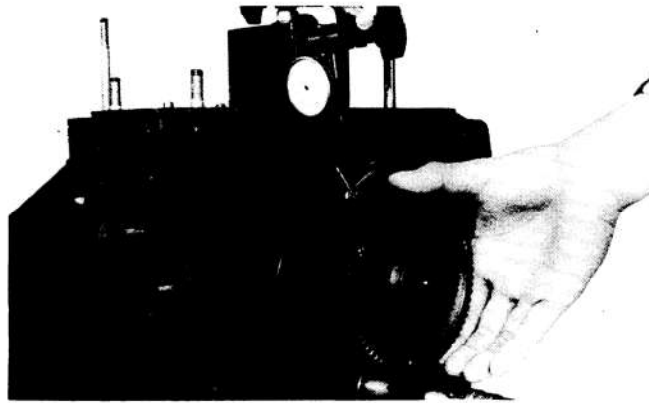
Cam height measuring points



#### 1. Cam Height

### CHECKING GEAR BACKLASH

1. Install a lever-type indicator between the gear teeth.
2. Clamp one gear, rotate the other and measure the backlash.
3. If the backlash exceeds the allowable limit, replace. See engine specifications.

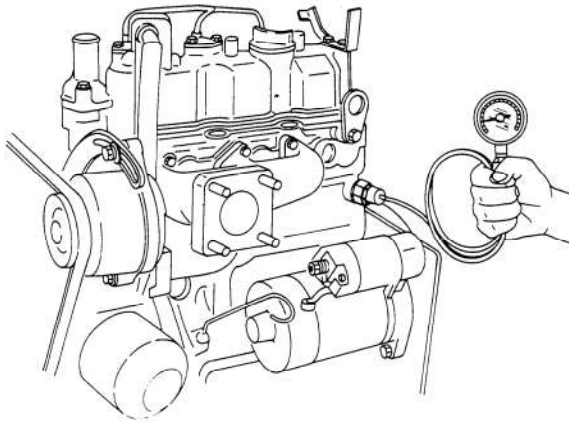


## LUBRICATION SYSTEM

### TESTING OIL PRESSURE

1. Remove the oil switch and set a pressure gauge.
2. Start the engine. Measure the oil pressure both at idling and at the rated speed.
3. If the measurement is not within the reference value, check the oil pump, oilways, oil clearances and pressure regulating valve.

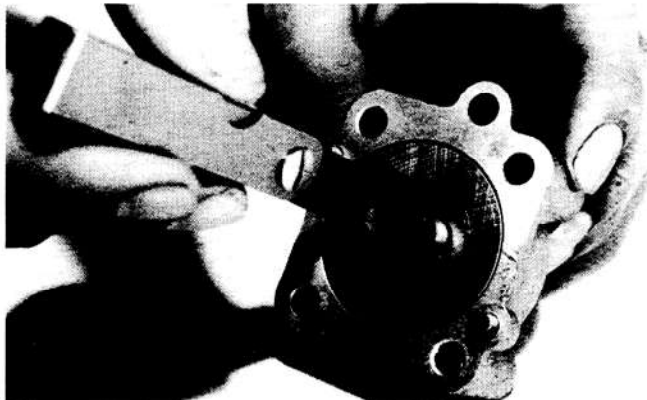
**NOTE FOR MEASURING:** Supply the specified amount of recommended oil. The oil filter must not be clogged or broken. See engine specifications.



### OIL PUMP (ROTOR TYPE)

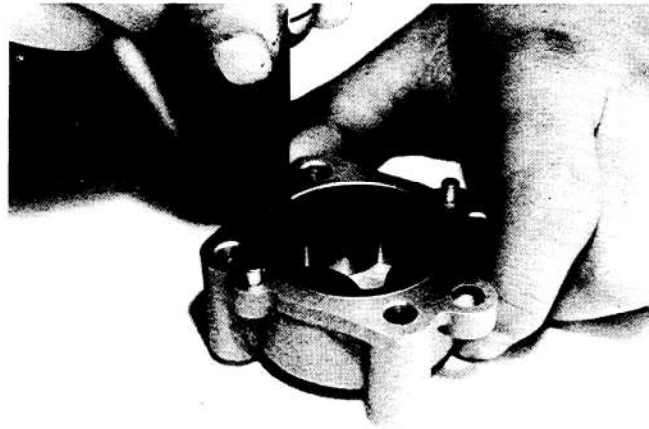
#### **Checking Rotor Lobe Clearance**

1. Insert a feeler gauge into the gap between the inner and outer rotors and measure the clearance.
2. If the clearance exceeds the allowable limit, replace. See engine specifications.



### Checking Radial Clearance Between Outer Rotor and Pump Body

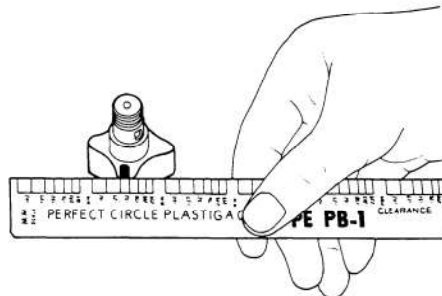
1. Insert a feeling gauge into the gap between the oil pump body and the outer rotor and measure the clearance.
2. If the measurement exceeds the allowable limit, replace. See engine specifications.



### Checking end Clearance Between Rotor and Cover

1. Paste a press gauge to the surface of the gear with grease.
2. Attach the cover.
3. Gently remove the cover. Measure the clearance by placing the gauge (paper) on the press gauge where it is crushed.
4. If the measurement is not within the reference value, replace.

Reference value	0.08 to 0.13 mm 0.0031 to 0.0051 in.
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## PISTON, CONNECTING ROD

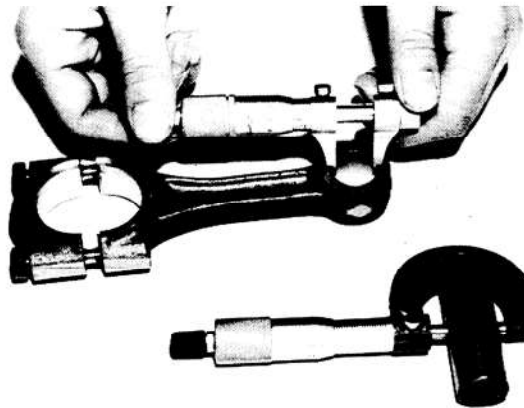
### CHECKING INSIDE DIAMETER OF PISTON BOSSES

1. Measure the piston bosses with a cylinder gauge. Set the cylinder gauge's reference measurement to 23 mm, and carry out zero point adjustment with an outside micrometer.
2. If the measurement exceeds the allowable limit, replace. See engine specifications



### CHECKING CLEARANCE BETWEEN PISTON PIN AND SMALL END BUSHING

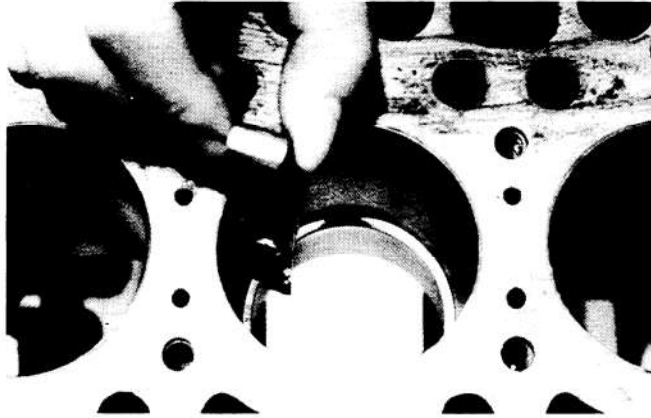
1. Measure the piston pin with an outside micrometer.
2. Measure the I.D. of connecting rod small end bushing with an inside micrometer. Calculate the clearance.
3. If the clearance exceeds the allowable limit, replace. See engine specifications



### CHECKING PISTON RING CLEARANCE

1. Put the piston ring in the cylinder.
2. Turn the piston upside down and push the ring into the cylinder with the piston head.
3. Insert a feeler gauge into the piston ring gap.
4. If the clearance exceeds the allowable limit, replace.

**IMPORTANT:** Measure the piston ring gap at the point of the minimum inside diameter of the cylinder liner. See engine specifications..



### CHECKING SIDE CLEARANCE OF RING IN GROOVE

1. Remove the piston ring from the piston.
2. Place the ring in its groove as it shown at left, and measure the clearance.
3. If the clearance is not within the reference valve, replace the ring.

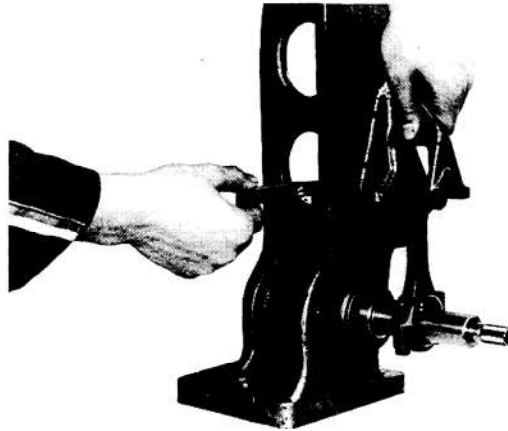
**NOTE:** As the top ring is a keystone type, it cannot be measured by this method. See engine specifications.



### CHECKING CONNECTING ROD ALIGNMENT

1. Remove the connecting rod crank pin bearing and tighten the rod bolts.
2. Set the connecting rod to a connecting rod aligner.
3. Place the gauge on the piston pin. Measure the gap between the pin of the gauge and the flat surface of the aligner.
4. If the measurement exceeds the allowable limit, replace

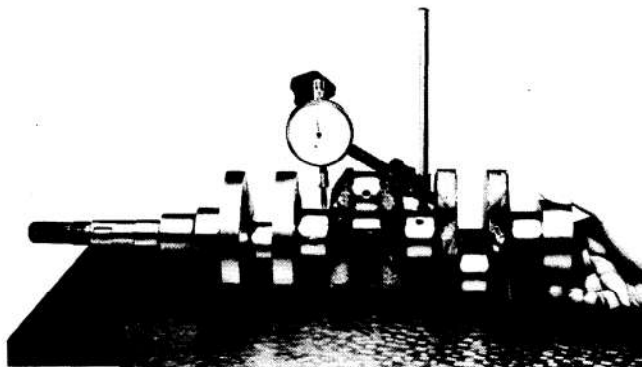
**IMPORTANT:** Because the I.D. of the connecting rod small end bushing is used as the basis for this check, check it is not worn beforehand. See engine specifications.



### **CRANKSHAFT**

#### CHECKING CRANKSHAFT ALIGNMENT

1. Place V blocks on the surface plate, and support the journals at both ends of the crankshaft on the V blocks.
2. Set a dial gauge to the central journal.
3. Read the dial gauge while rotating the crankshaft slowly. Crankshaft flexure is half of the reading.
4. If the reading exceeds the allowable limit, replace. See engine specifications.



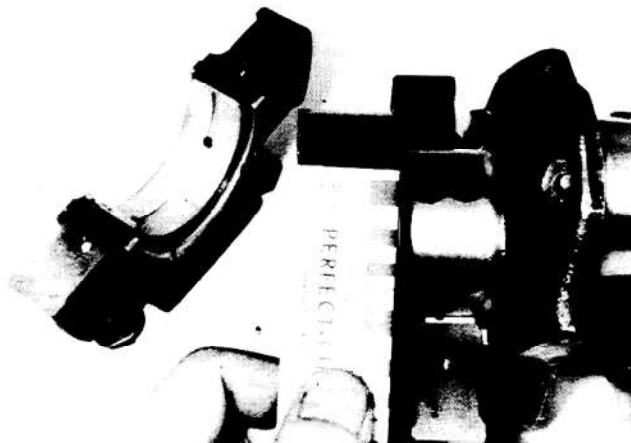
### CHECKING OIL CLEARANCE BETWEEN CRANKSHAFT JOURNAL AND CRANKSHAFT BEARING 1

1. Measure the crankshaft journal (on the side of the crankshaft bearing 1) with an outside micrometer.
2. Measure the crankshaft bearing 1 with an inside micrometer. Calculate the clearance.
3. If the clearance exceeds the allowable limit, replace the crankshaft bearing 1. See engine specifications.



### CHECKING OIL CLEARANCE BETWEEN CRANKSHAFT JOURNALS AND CRANKSHAFT BEARINGS 2

1. Paste a press gauge with grease on the crankshaft bearing.
2. Tighten the crankshaft bearing case onto the crankshaft journal to the specified torque 29.4 to 34.3 Nm (3.0 to 3.5 kgf<sup>0</sup>m, 21.7 to 25.3 ft-lbs).
3. Detach the bearing case slowly, and measure the depression of the press gauge with a sheet of gauge (paper).
4. If the measurement exceeds the allowable limit, replace the crankshaft bearing 2. See engine specifications.



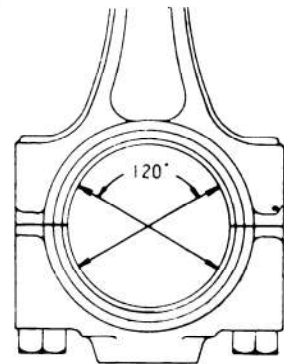
### CHECKING OIL CLEARANCE BETWEEN CRANK PINS AND CRANK PIN BEARINGS

1. Paste a press gauge onto the crank pin bearing with grease.
2. Tighten the connecting rod onto the crank pin to the specified torque 26.5 to 30.4 Nm. (2.7 to 3.1 kg<sup>f</sup>m, 19.52 to 22.42 ft-lbs).
3. Remove the connecting rod gently, and measure the depression of the press gauge with a sheet of gauge (paper).
4. If the measurement exceeds the allowable limit, replace the crankpin bearing.

**NOTE FOR MEASURING:** Fasten the crankshaft so that it does not turn. Do not insert the press gauge into the crank pin hole. Crankpin bearing measuring points are shown below. See engine specifications.



Crank pin measuring points



### CHECKING END PLAY OF CRANKSHAFT

1. Move the crankshaft to the crank gear side.
2. Set a dial gauge to the crankshaft.
3. Push the crankshaft toward the flywheel and measure the clearance.
4. If the measurement exceeds the allowable limit, replace the side bearing.

**IMPORTANT:** When replacing the side bearing, face the oil grooves of side bearing outward. See engine specifications.





## CYLINDER LINER

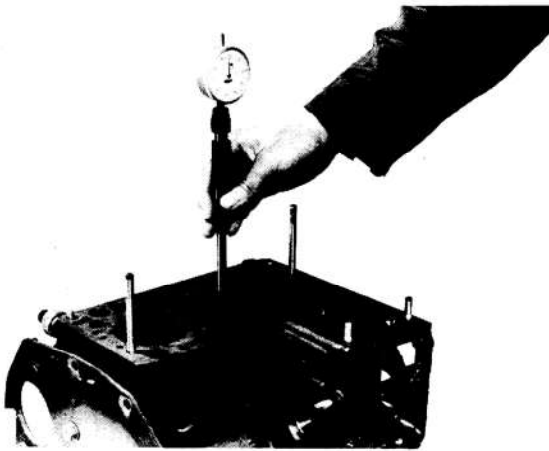
### CHECKING WEAR OF CYLINDER LINER

1. Set a cylinder gauge and adjust it to the reference valve of the cylinder liner with an outside micrometer.
2. To find out the maximum wear, measure the diameters at six points on the cylinder liner with the cylinder gauge, as shown below.

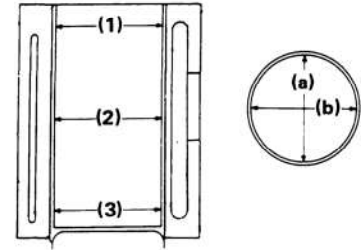
**NOTE:** When the cylinder liner is worn beyond the allowable limit, bore and hone it by 0.5 mm (0.0197 in.).

1. The cylinder liner which has been oversized by 0.5 mm (0.0197 in.) should use a piston and ring of the same oversize.

**NOTE:** When the oversized cylinder liner is worn beyond the allowable limit, replace the cylinder liner, and bore and hone it. See engine specifications.



Measuring points of cylinder liner



1. Top
2. Middle
3. Bottom (Skirt)

- a. Right-angle to the piston pin
- b. Parallel to the piston pin

## Reference

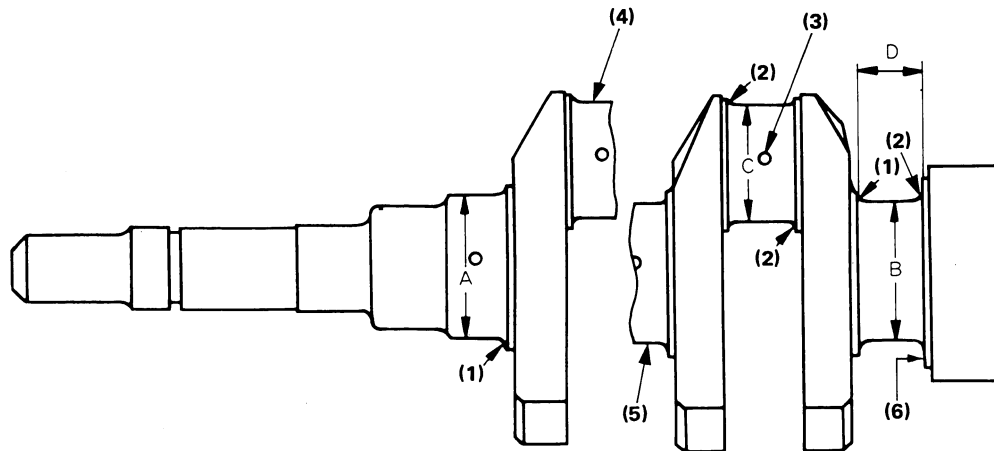
If the standard-size bearing cannot be employed due to excessive wear of the crankpin and crank journal, employ undersize or oversize bearings.

For undersize or oversize bearing use, follow the precautions noted below.

1. 3.3 to 3.7 mm (0.1300 to 0.1457 in.)
2. 2.8 to 3.2 mm (0.1102 to 0.1260 in.)
3. Oil hole must be 1 to 1.5 mm (0.0394 to 0.0591 in.).  
Be sure to chamfer the oil circumference with an oil stone.

### Undersize and Oversize

4. The crankpin must be fine-finished to higher than  $///$  (0.4-S).
5. The crank journal must be fine-finished to higher than  $///$  (0.4-S).
6. The crank journal side surface must be fine-finish to higher than  $///$  (0.4-S). See engine specifications



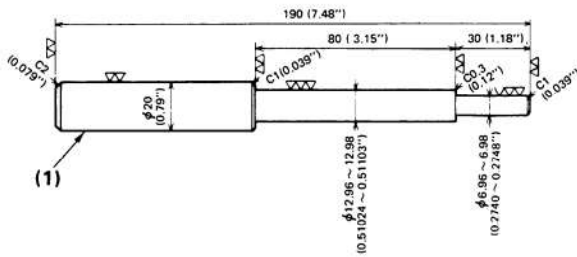
# REPLACING VALVE GUIDES, BUSHINGS AND BEARINGS

## REPLACING VALVES GUIDES

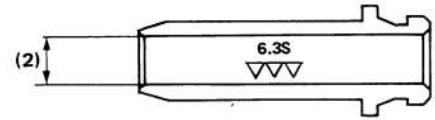
1. Prepare the necessary tool as shown in Fig (A).
2. Press out the used valve guide from the cylinder head's lower end.
3. Apply engine oil to the outer surface of the new valve guide; press fit the valve guide from the upper end of the cylinder head until the flange part of the valve guide contacts the cylinder head.
4. After press-fitting, finish the valve guide by means of reamer machining to dimensions shown in Figs. (B) and (C).

**NOTE:** Be careful not to strike valve guides with a hammer, during replacement.

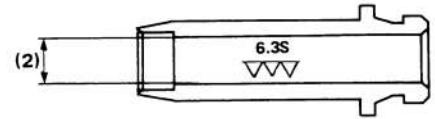
**(A) Tool for replacing valve guides**



**(B) Finishing size of inlet valve guide**



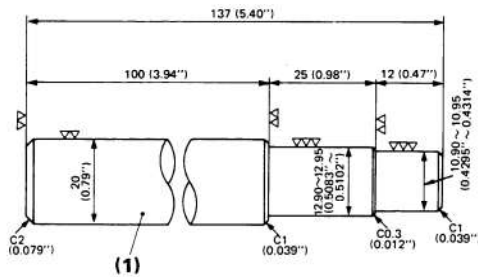
**(C) Finishing size of exhaust valve guide**



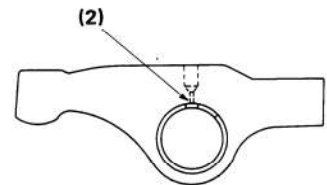
## REPLACING ROCKER ARM BUSHINGS

1. Prepare the necessary tool as shown in Fig. (A).
2. Press out the used bushing and, using this tool, press fit the new bushing, taking due care to see that the rocker arm hole matches the bushing hole.

**(A) Tool for replacing rocker arm bushing**



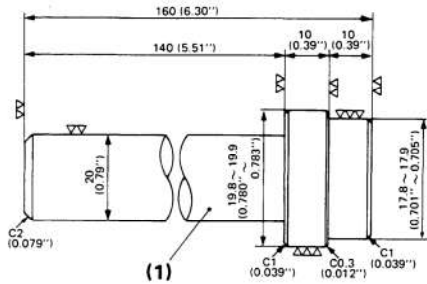
**(B) Rocker arm and bushing, as assembled**



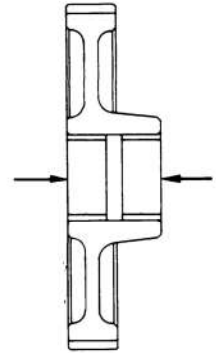
## REPLACING IDLE GEAR BUSHINGS

1. Prepare the necessary tool as shown in Fig. (A).
2. Press out the used bushing and press a new one, using this tool.

[A] Tool for replacing idle gear bushing



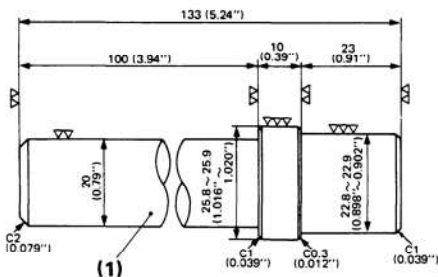
[B] Idle gear and bushing, as assembled



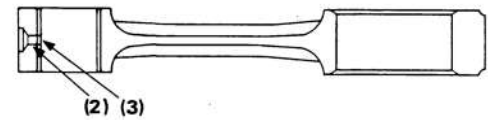
## REPLACING SMALL END BUSHINGS

1. Prepare the necessary tool as shown in Fig. (A).
2. Press out the used bushing, and press a new bushing in, taking due care to see that the connecting rod hole matches the bushing hole.

[A] Tool for replacing small end bushings



[B] Connecting rod and bushing, as assembled



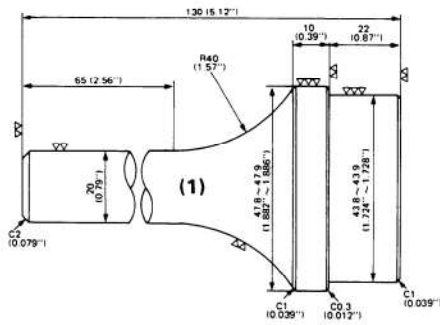
**1. Material: S43C**  
**Heat treatment: Quenching & tempering**

- 2. Connecting rod hole**
- 3. Bushing hole**

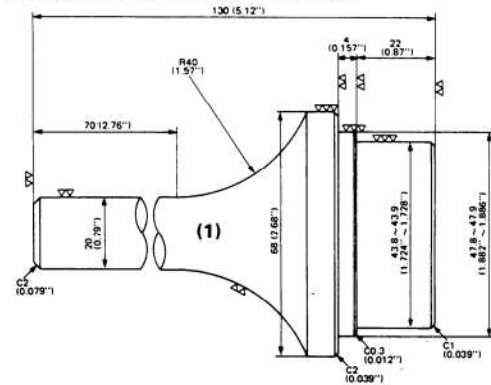
## REPLACING CRANKSHAFT BEARING 1

1. Prepare the necessary tool as shown in Figs (A) and (B).
2. Press out the bearing 1, using the extracting tool.
3. Insert a new bearing 1, using the inserting tool, taking due care to see that the contact edge of bearing 1 faces the exhaust manifold side.

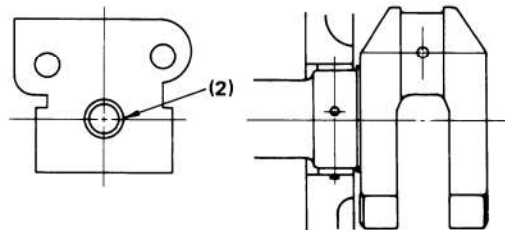
[A] Tool for extracting crankshaft bearing 1



[B] Tool for inserting crankshaft bearing 1



[C] Crankshaft and crankshaft bearing 1, as assembled



## SECTION VII - DYNAMO AND REGULATOR

### BATTERY

Checking Battery Charging Current .....	132
Checking AC Dynamo's No-load Voltage .....	132

### STARTER

No-load Testing of Starter .....	133
Motor Test .....	134
Checking Magnet Switch - Pull-in Coil Attraction Test .....	135
Holding Coil-Retention Test .....	135
Disassembly & Reassembly of Magnet Switch Type Starter .....	135-137
Reduction type Starter .....	138-139
Servicing Starter .....	140-147

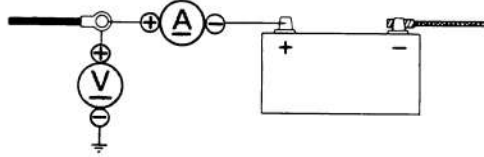
## BATTERY

### Checking Battery Charging Current

1. After starting the engine, disconnect + lead of the battery and connect an amperemeter.
2. Measure charging current with full electric load (with lights, etc).

NOTES ON CHECKING: Connect the amperemeter only after starting the engine. In the event of a lower electric load or fully charged battery, the stipulated value may not be given.

Reference value
14 to 15A with dynamo turning at 5200 rpm.

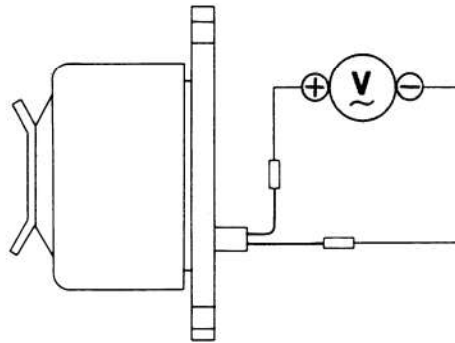


### 1. Battery + Lead

### Checking AC Dynamo's No-Load Voltage

1. Disconnect lead wire from the dynamo.
2. Start the engine and measure the voltage generated by the single dynamo.

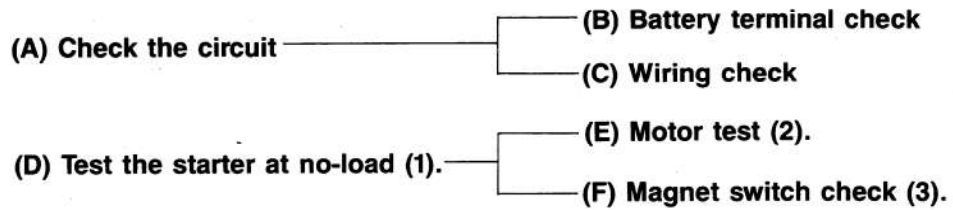
Reference value
AC 20V or more with the dynamo turning at 5200 rpm.



# STARTER

## Checking Sequence

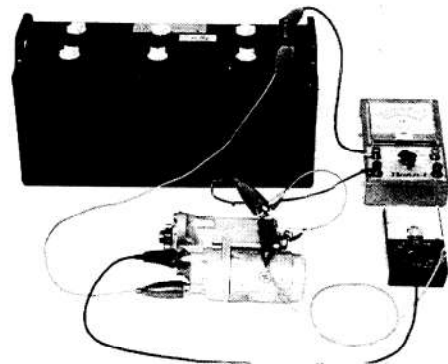
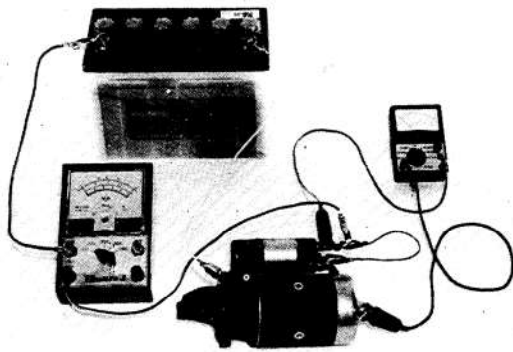
If the starter system malfunctions, do the following checks to locate the cause:



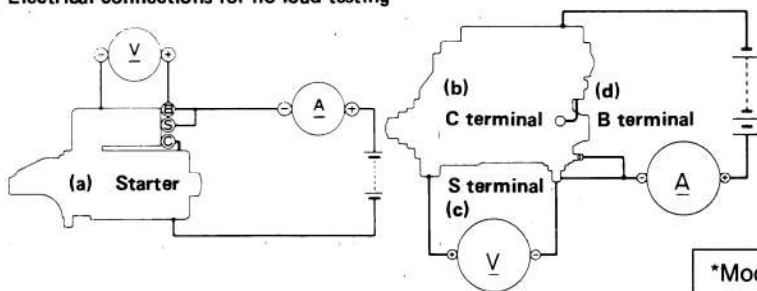
## No-Load Testing of Starter

1. Connect the ammeter's positive probe to the battery's positive terminal and the negative probe to the starter's B terminal.
2. Connect the battery's negative terminal to the starter body.
3. Connect the voltmeter's positive probe to the starter's B terminal and the negative probe to the starter body.
4. Set a tachometer.
5. Connect the starter's B terminal to the magnet switch's S terminal.
6. Check to see that the magnet switch is operating and that the specified speed, current and voltage are obtained.

**NOTE FOR CHECKING:** Use a fully charged battery. Use an ammeter and leads of about 200A rating because a large current flows when the starter is running.



Electrical connections for no-load testing

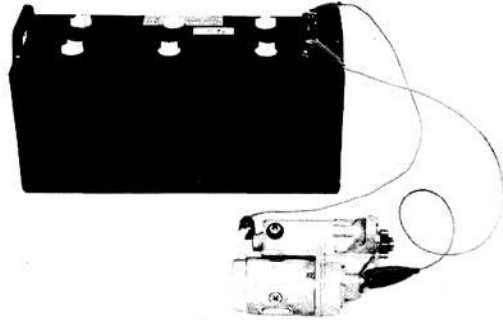
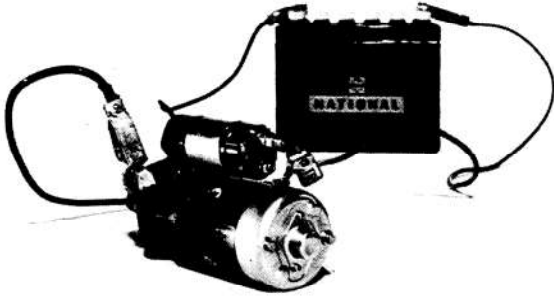


*Model	Current	Voltage	Rotational speed
M-30	45A or less	11.0 V	6000 rpm or more
M-40 M-50	90A or less	11.5 V	3000 rpm or more

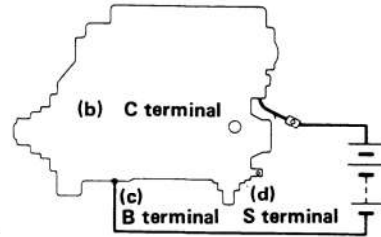
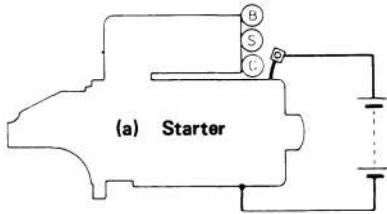


## Motor Test

1. Remove the connecting leads from the starter's C terminal and connect them directly to the battery's positive terminal. Then connect the battery's negative terminal to the starter body.
2. If the starter runs normally, the magnet switch is defective; if not, the motor is defective.



Electrical connections for motor test

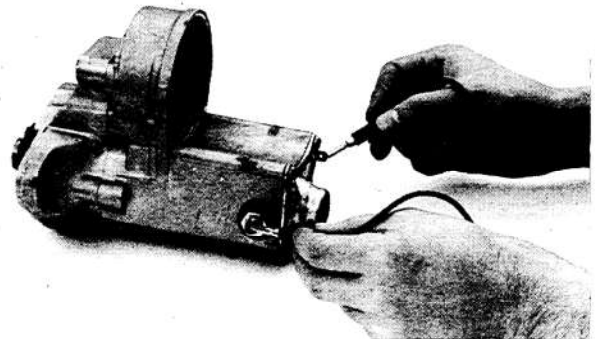
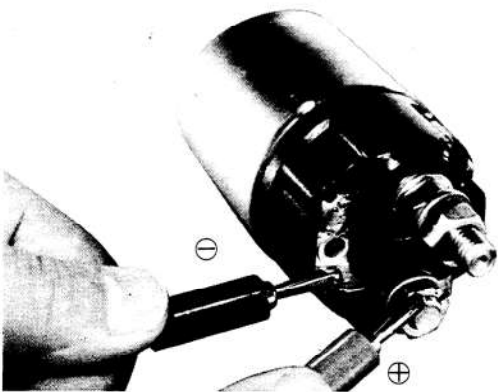


## Magnet Switch

### Pull-In Coil (Attraction Test)

1. Apply 1/2 the rated voltage (approx. 6V) across the S terminal and C terminal.
2. If the plunger is attracted strongly, the pull-in coil is good; if not, it is defective.

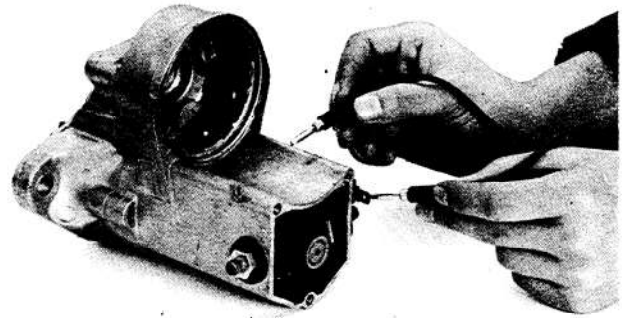
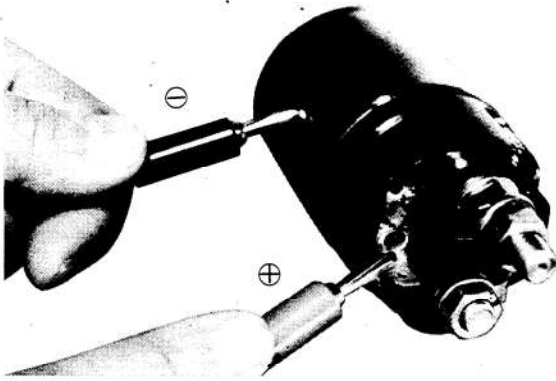
Reference value      The plunger should be attracted strongly.



### Holding Coil (Retention Test)

1. Apply 1/2 the rated voltage (approx. 6V) across the S terminal and the body, push the plunger in by hand, and then release it.
2. If the plunger stays attracted, the holding coil is good; if not, it is defective.

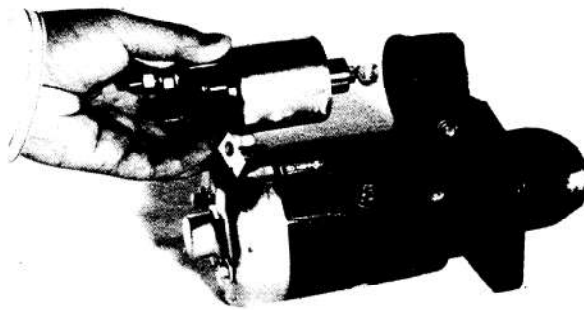
Reference value	The plunger remains attracted.
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### DISASSEMBLY AND REASSEMBLY OF MAGNET SWITCH TYPE STARTER

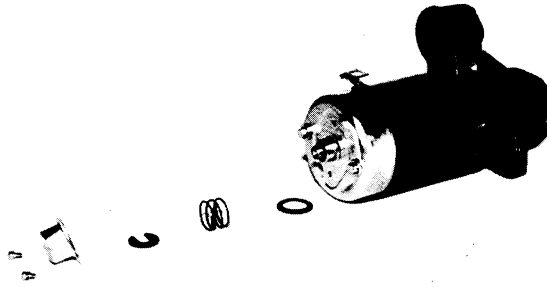
#### Removing Magnet Switch

1. Remove the connecting lead.
2. Remove the set screws.
3. Detach the magnet switch by lifting it up while taking care that it does not contact the drive lever.



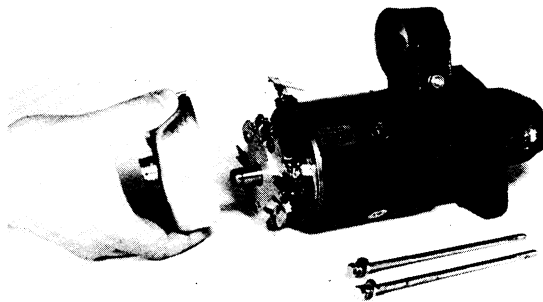
### Removing Armature Brake

1. Remove the end frame cap.
2. Remove the washers.
3. Remove the packing.



### Removing End Frame

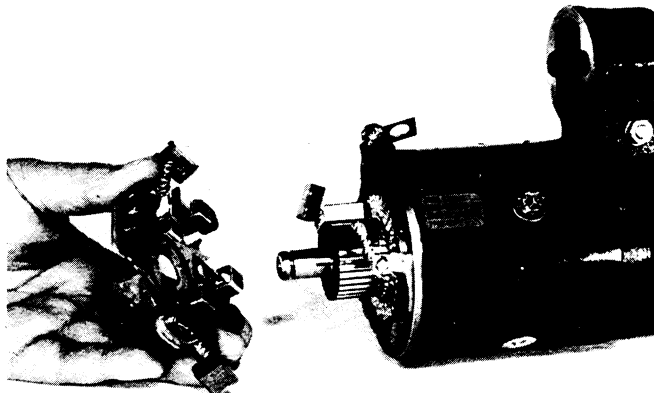
1. Remove the through bolts.
2. Remove the end frame.



### Removing Brush Holder

1. Draw out the brush from the holder while holding the spring up.
2. Take off the brush holder.

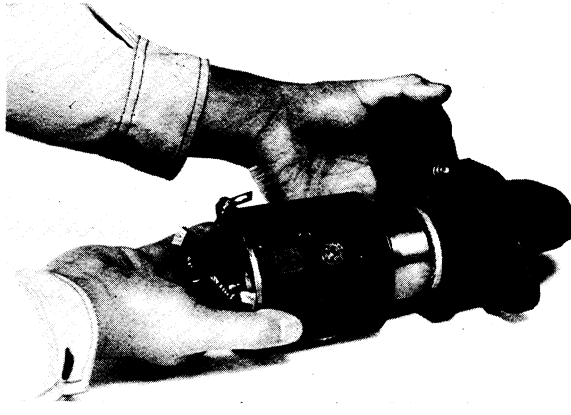
**NOTE FOR REASSEMBLING:** Be sure not to mistake the direction and position of the spring. Do not contact the body with the positive brush's lead.



### Remove Yoke

1. Draw out the yoke from the drive end frame.

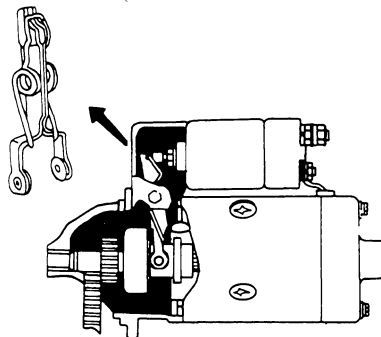
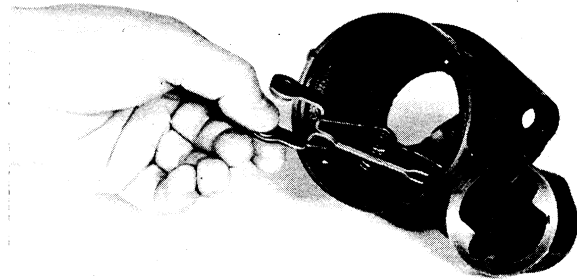
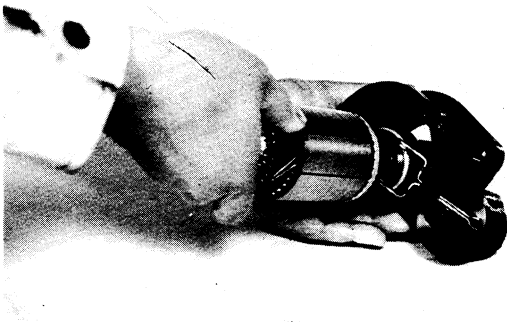
**NOTE FOR REASSEMBLING:** Take care for yoke knock pin.



### Removing Armature

1. Remove the set bolt from the drive lever.
2. Draw out the armature from the drive end frame.
3. Detach the drive lever.

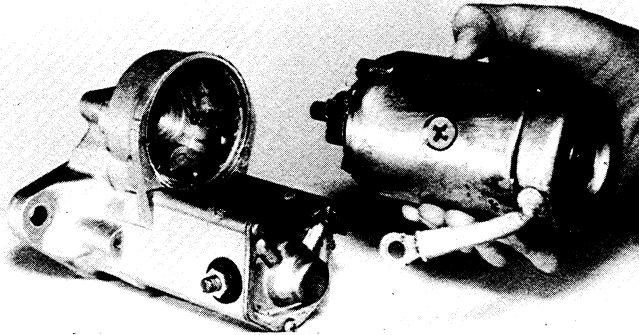
**IMPORTANT:** When reassembling, be sure not to mistake the installing direction of the drive lever.



## REDUCTION TYPE STARTER

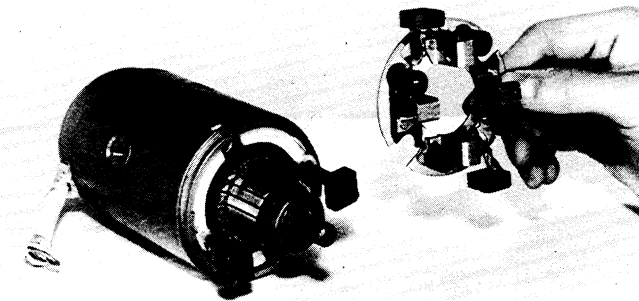
### Removing Motor

1. Disconnect the connecting lead.
2. Remove the through bolts.
3. Remove the motor unit.



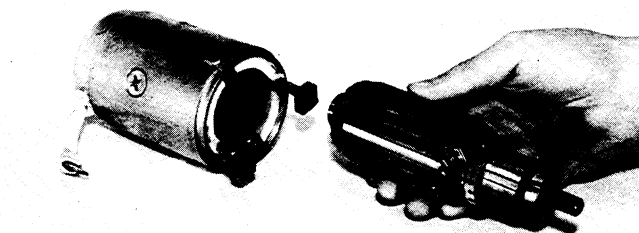
### Removing Brush Holder

1. Release the spring and draw the brush out from the holder.
2. Remove the brush holder.



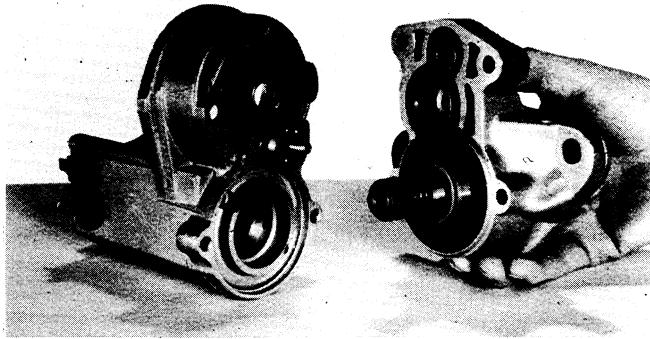
### Remove Armature

1. Draw the armature out.



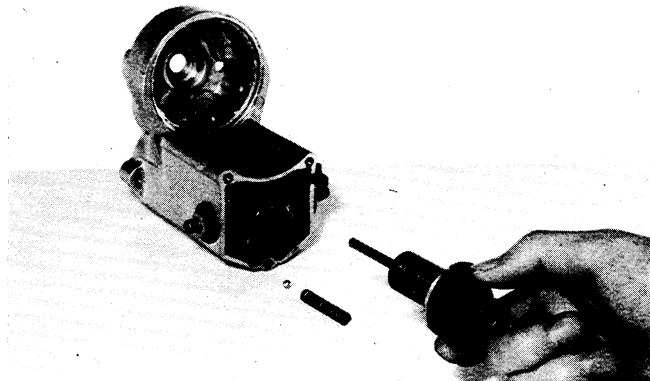
### Removing Drive End Frame

1. Remove the drive end frame.
2. Remove the gears (drive pinion, idler gear) and clutch.



### Remove Plunger

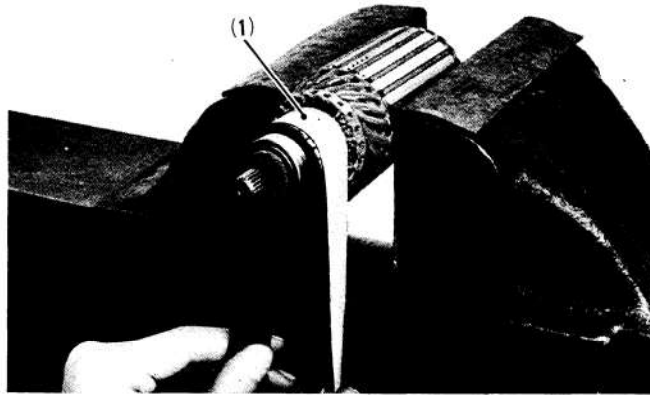
1. Remove the end cover from the magnet switch.
2. Draw the plunger out.
3. Remove steel balls.



## SERVICING STARTER

### Staining or Burning of Commutator

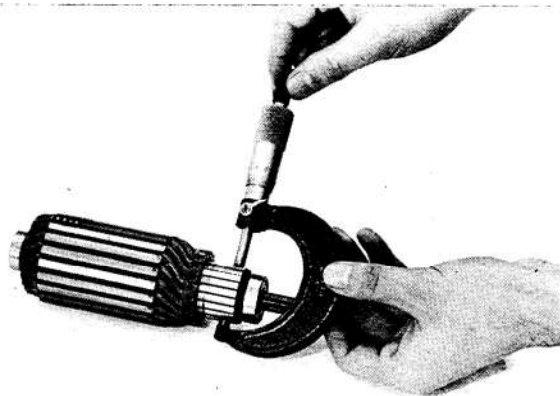
1. Check to see if the commutator surface is stained or burnt.
2. If it is burnt, grind off with fine-grain sand paper.



### Checking Commutator Wear

1. Check to see if the contact face of the brush is scored.
2. If scored, grind off with sand paper or on a lathe.
3. If the commutator diameter must be ground to below the allowable limit, replace it.

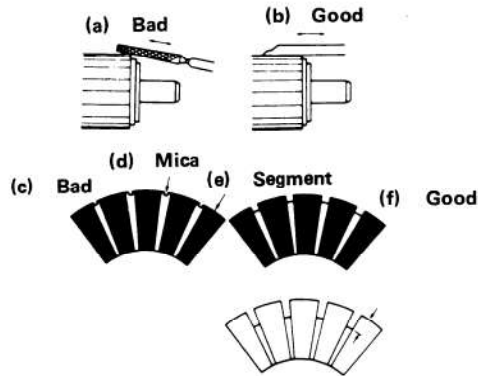
Commutator diameter		
Model	Reference value	Allowable limit
M-30	32.7 mm 1.2874 in.	32.5 mm 1.2795 in.
M-40 M-50	30.0 mm 1.1811 in.	29.0 mm 1.1417 in.



### Checking Mica (Undercut)

1. Check to see the mica undercut.
2. If it has high mica, rectify with a saw blade. As the edge of the segment will be rough, chamfer it.

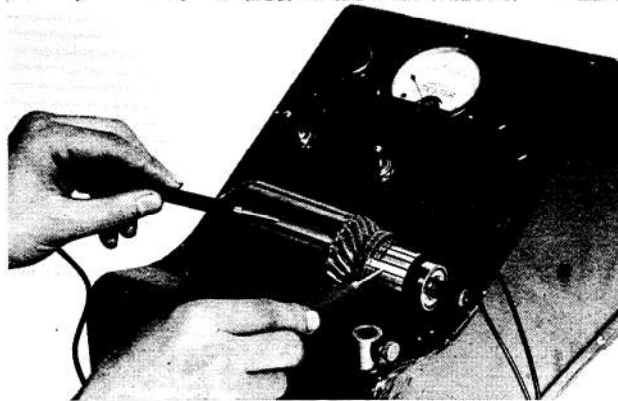
Mica depth		
Model	Reference value	Allowable limit
D1102-B D1302-B	0.5 to 0.8 mm 0.0197 to 0.315 in.	0.2 mm 0.0079 in.
D1402-B V1502-B V1702-B V1902-B	0.5 to 0.9 mm 0.0197 to 0.0354 in.	



### Grounding of Armature Coil

1. Check conduction across the commutator and the armature shaft.
2. If conducting, replace.

Reference value	Should not be conducted.
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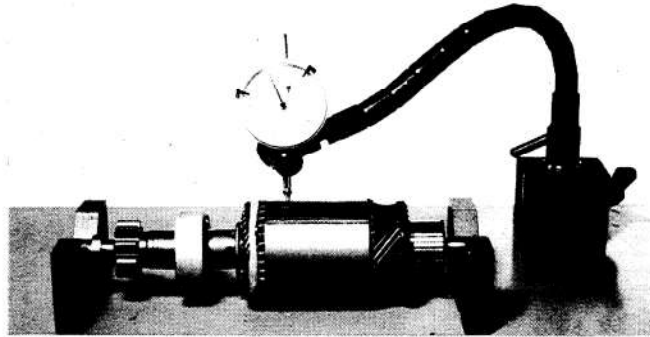




### Checking Armature Flexure

1. Measure the amount of flexure; if the measurement exceeds the reference value, replace. Carefully check to see if the core is scratch.

Reference value	0.1 mm 0.0039 in.
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### Checking Armature Coil Short-Circuited

1. Set the armature on the armature tester. Rotate the armature while touching it with steel piece.
2. If the steel piece starts to vibrate or to be attracted somewhere on the armature, this suggests that the coil contains a layer short at the point.
3. If faulty, replace.

Reference value
The armature should not be short-circuited.

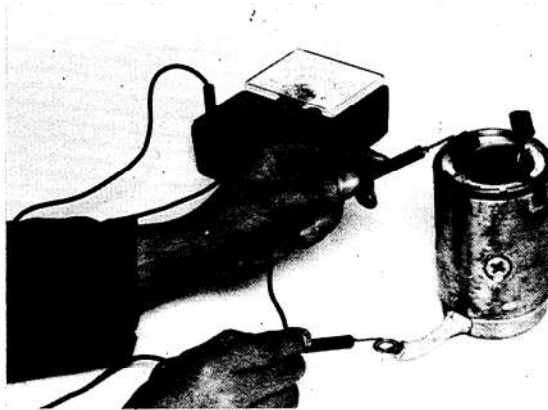


### Checking Field Coil Breakage

1. To check conduction, place the tester probes onto the lead and brush.
2. If either are not conducting, replace.

Reference value

Should be conducted.

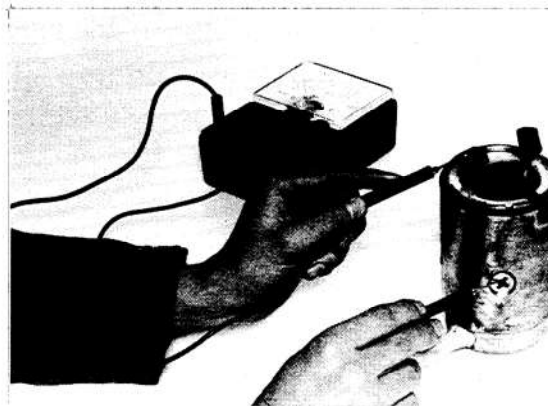


### Grounding of Field Coil

1. To check the conduction. Place the tester probes onto the field coil and yoke.
2. If either are conducting, replace.

Reference value

Should not be conducted.

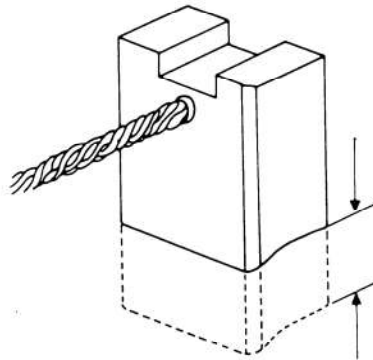


### Checking Brush Wear

1. Check to see if the brush has worn to more than 2/3 below the standard dimensions.
2. If wear exceeds the allowable limit, replace.

Reference value	
Allowable limit	Longer than 12.7 mm

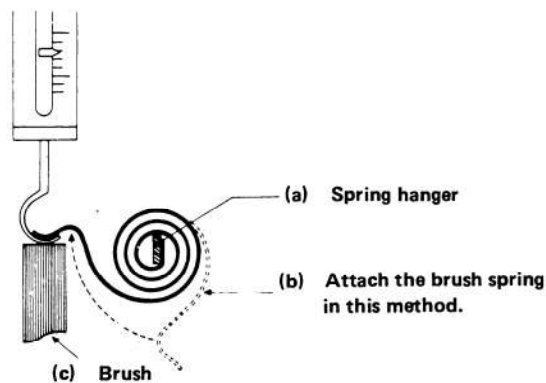
Model	Length	Width	Thickness
M-30	19 mm 0.7480 in.	12 mm 0.4724 in.	7 mm 0.2756 in.
M-40 M-50	19 mm 0.7480 in.	25 mm 0.9843 in.	8mm 0.3150 in.



### Checking Brush Spring Tension

1. Measure the tension with a new brush in place.
2. Replace if the tension is under the reference value.

Reference value		
Model	Spring tension	Commutator diameter
M-30	11.8 N. 1.200 g 2.64 lb	32.7 mm 1.2874 in.
M-40 M-50	17.5 to 23.7 N. 1,785 to 2,415 g 3.94 to 5.53 lb	30.0 mm 1.1811 in.

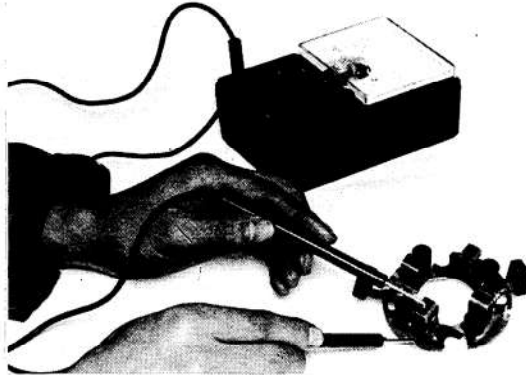


### Grounding of Brush Holder

1. Check the insulation of the positive brush holder.
2. If the insulation is defective, replace.

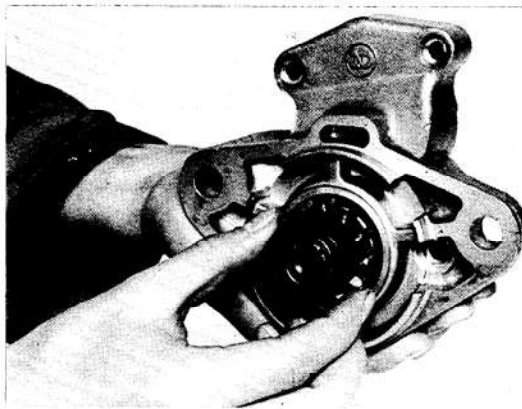
Reference value

Should not be conducted.



### Checking Clutch

1. Check to see if the clutch gear is worn or damaged.
2. Check to see if the gear locks in the driving direction and rotates smoothly in reverse.

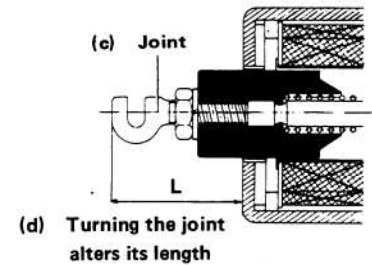
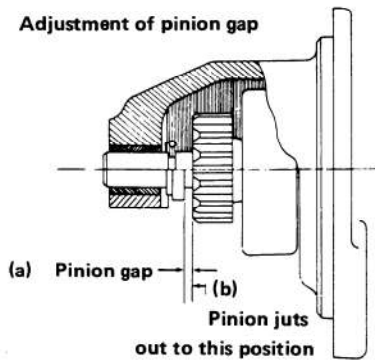


### Checking and Adjusting Pinion Gap (Magnet Switch Type)

1. Disconnect the connecting lead from C terminal.
2. Energize the magnet switch and measure the gap between the pinion tip and the stop collar.
3. To adjust the gap, change the length of the magnet switch joint to the specified one.

Reference value	0.1 to 0.4 mm 0.0039 to 0.0157 in.
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Adjustment of pinion gap



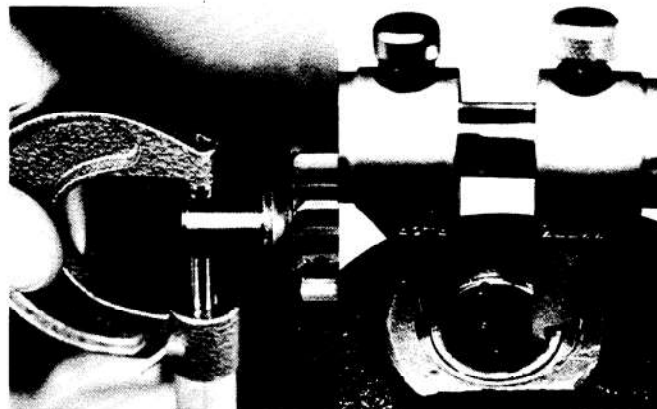
### Checking Gap between Shaft and Bush (Magnet Switch Type)

1. Measure the inside diameters of the bearing bushings on the side of the drive and commutator.
2. Measure the drive-side and commutator-side shaft diameters and calculate the gap.
3. If the gap exceeds the allowable limit, use an undersize bush.

	Model M-30
Drive shaft dia.	12.5 mm, 0.4921 in.
Commutator shaft dia.	12.5 mm, 0.4921 in.
Drive bushing ID	12.54 mm, 0.4937 in.
Commutator bushing ID	12.56 mm, 0.4945 in.

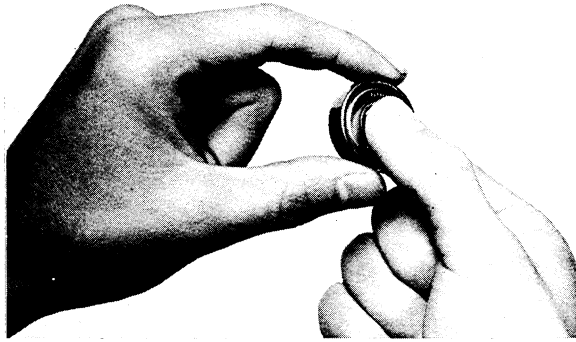
Model M-30

	Reference value	Allowable limit
Commutator side	0.06 mm 0.0024 in.	0.2 mm 0.0079 in.
Drive	0.04 mm 0.016 in.	

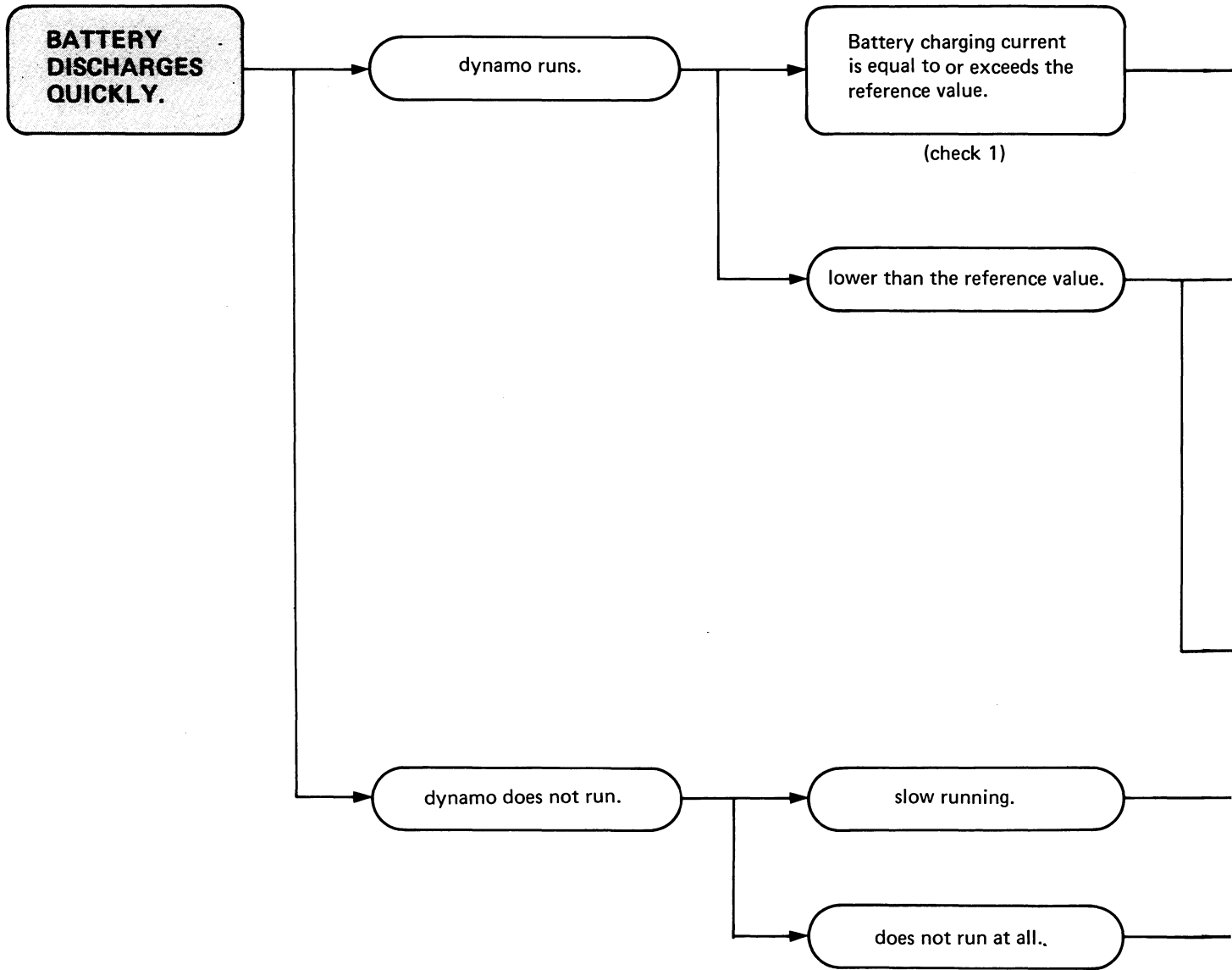


### Checking Bearing (Reduction type)

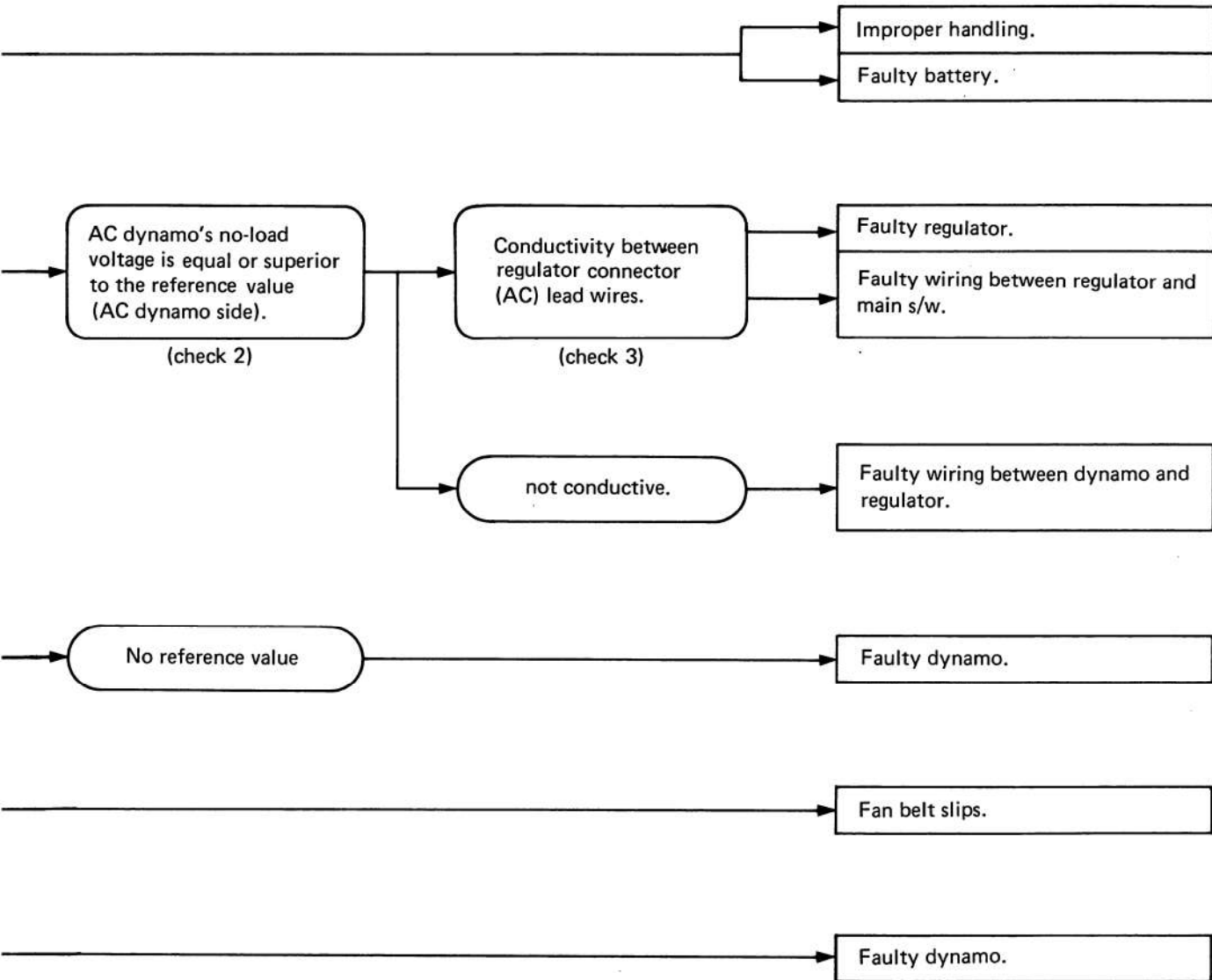
1. Apply torque to the inner ring with your finger tips and check to see if it turns smoothly.
2. Check to see if there are any strange noises when driven quickly.



# TROUBLESHOOTING

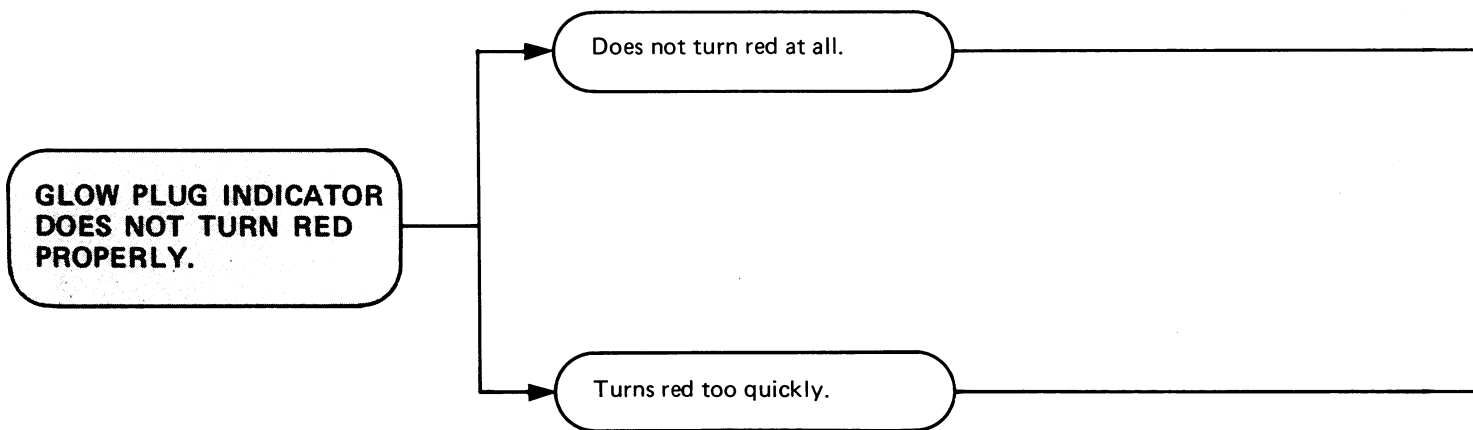
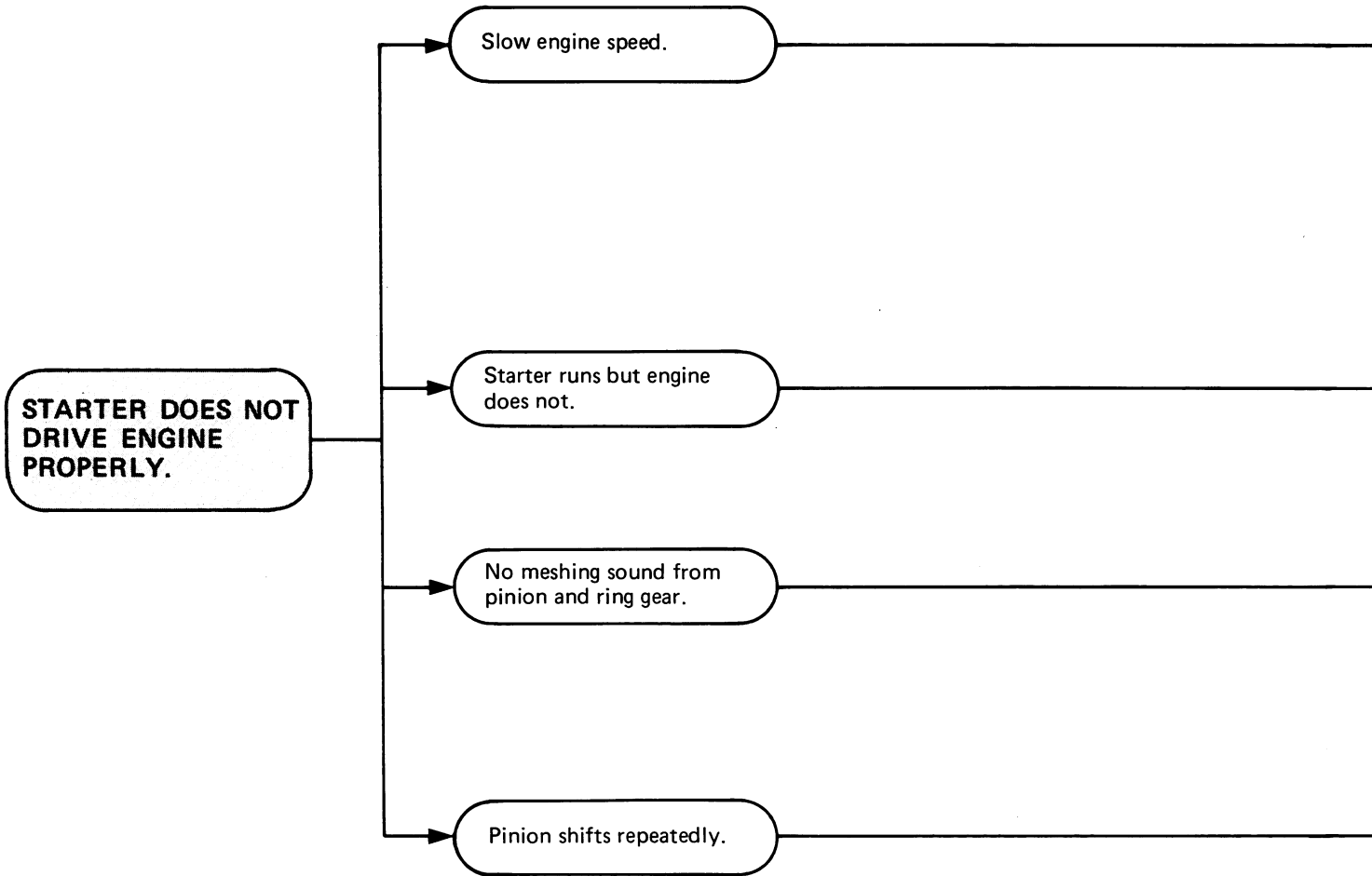


# TROUBLESHOOTING

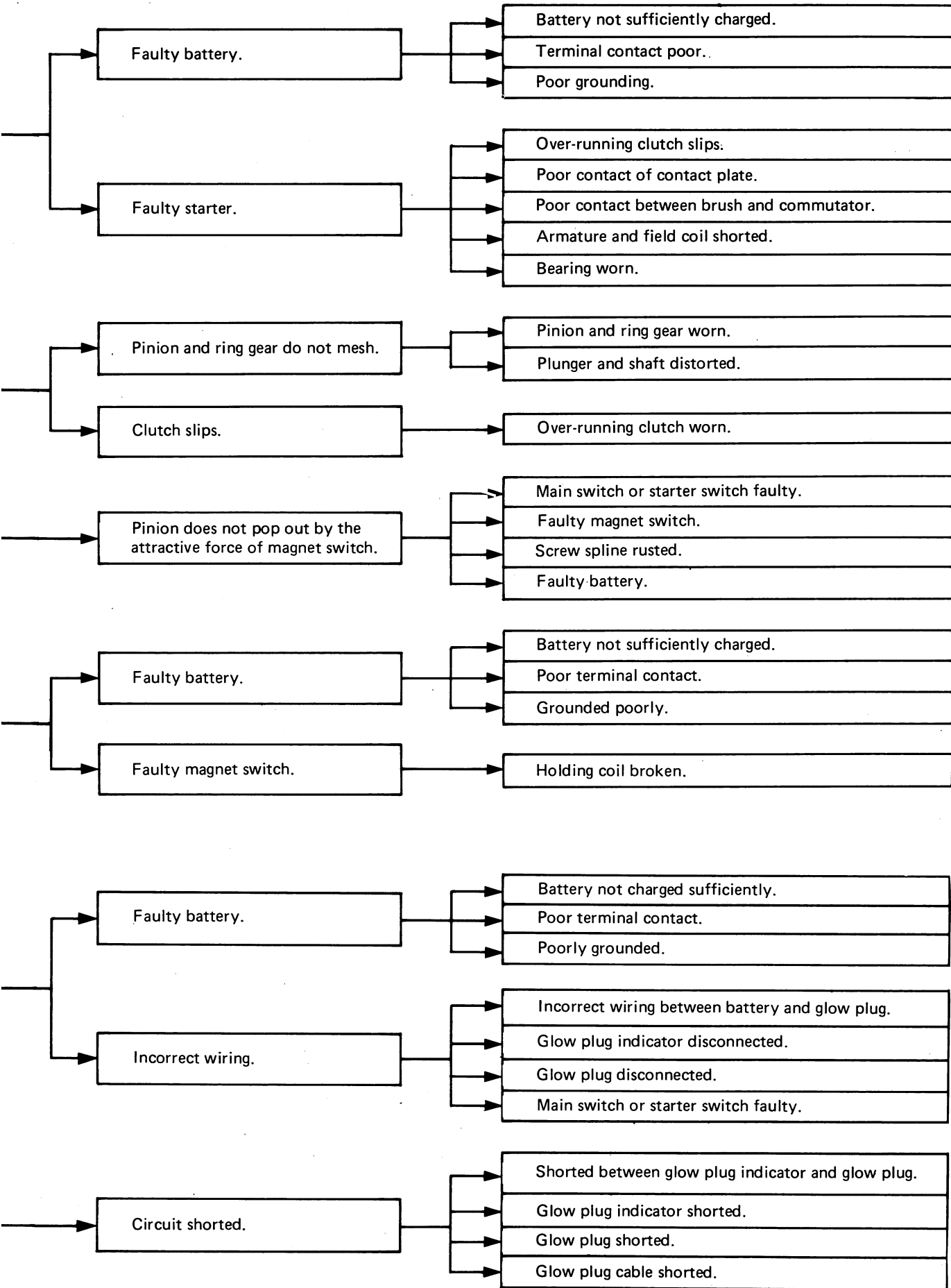




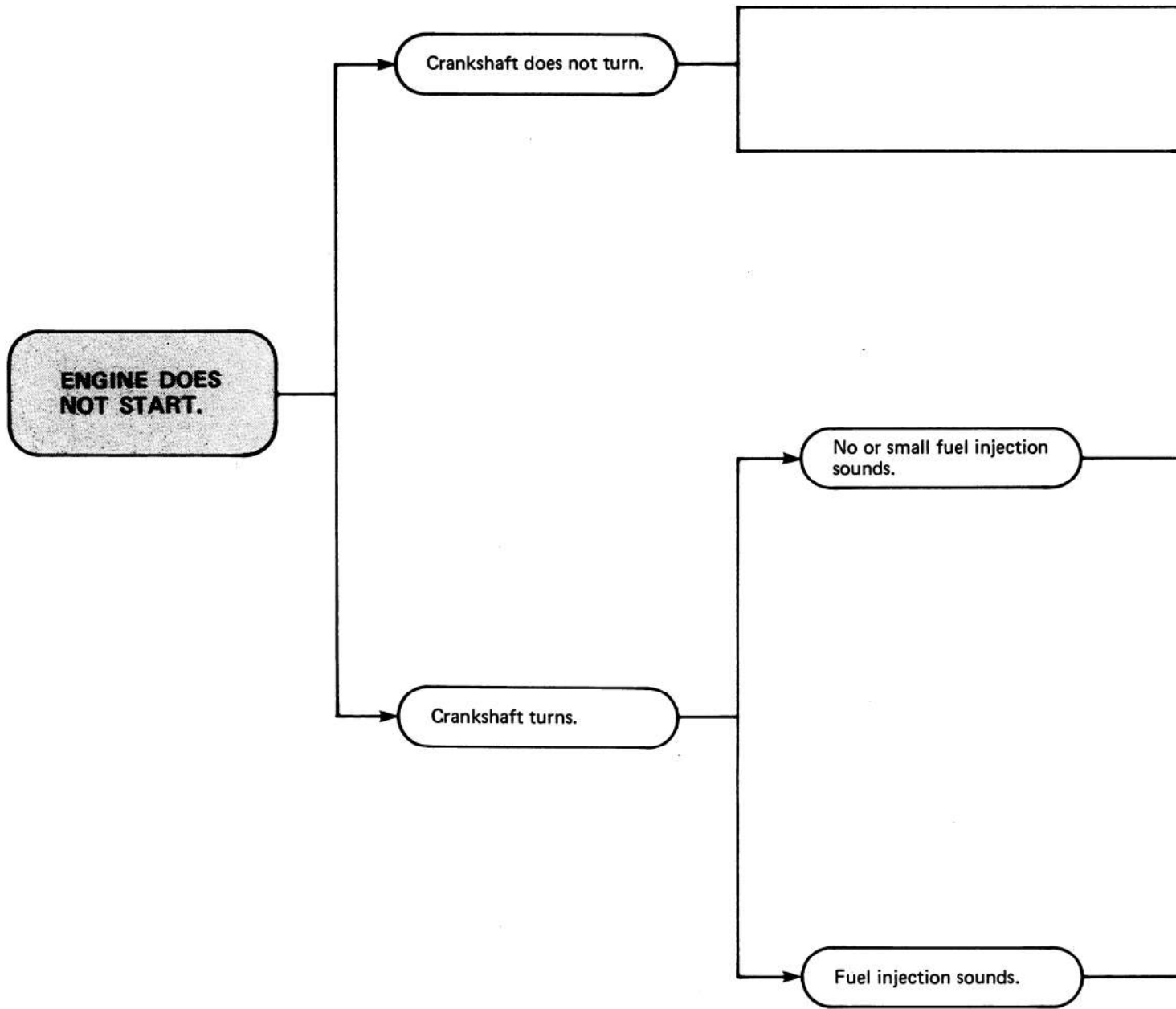
# TROUBLESHOOTING



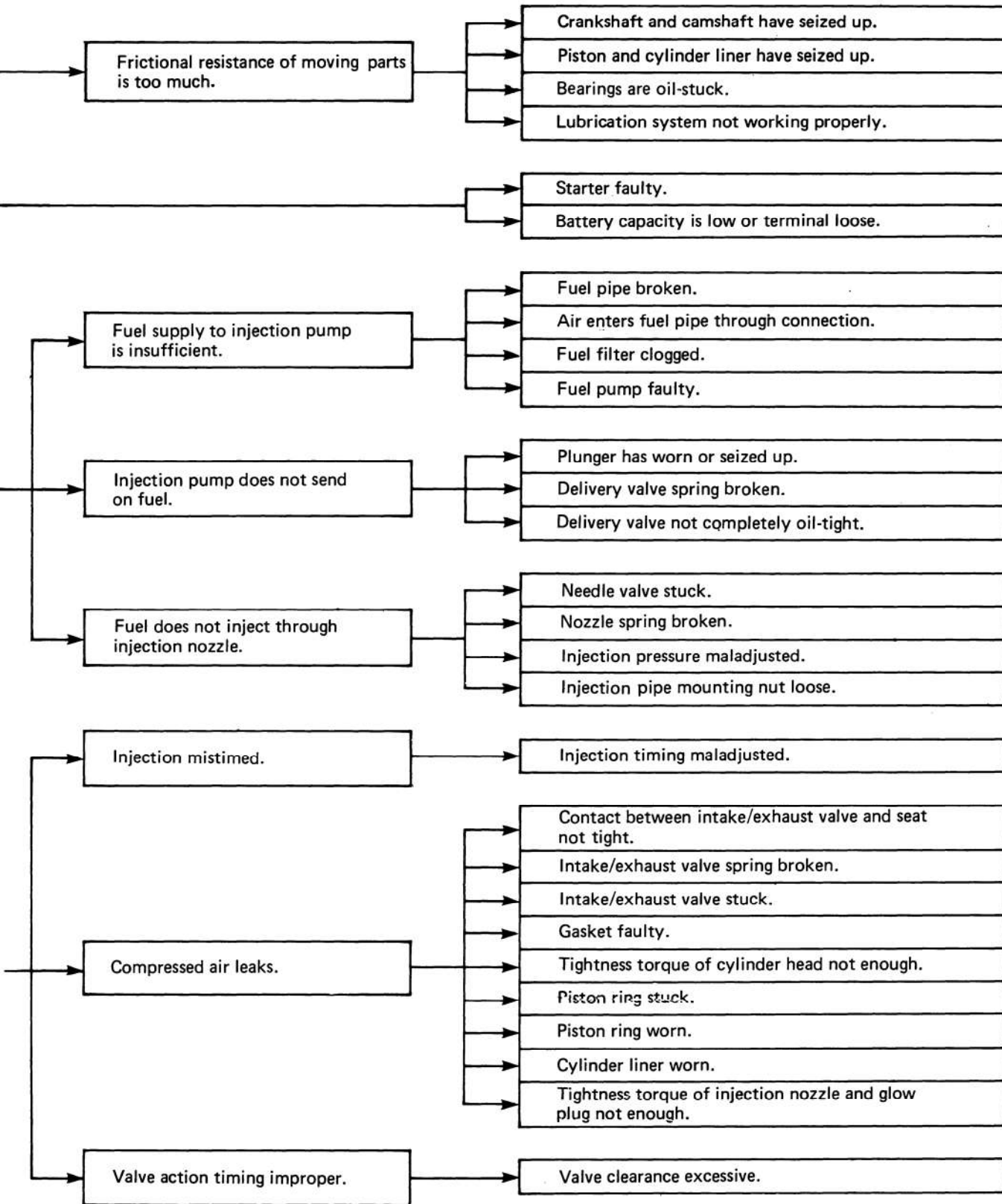
## TROUBLESHOOTING



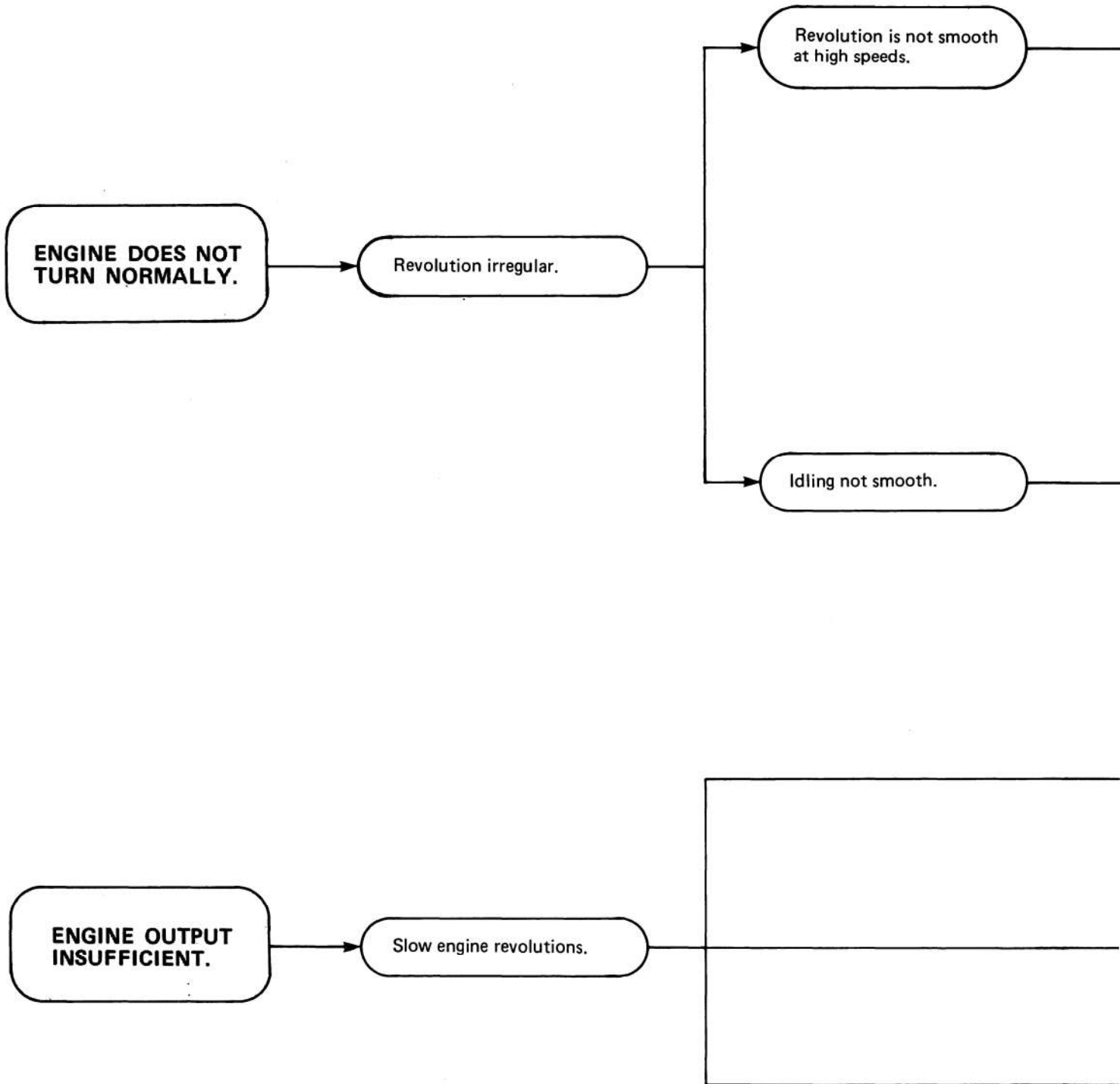
# TROUBLESHOOTING



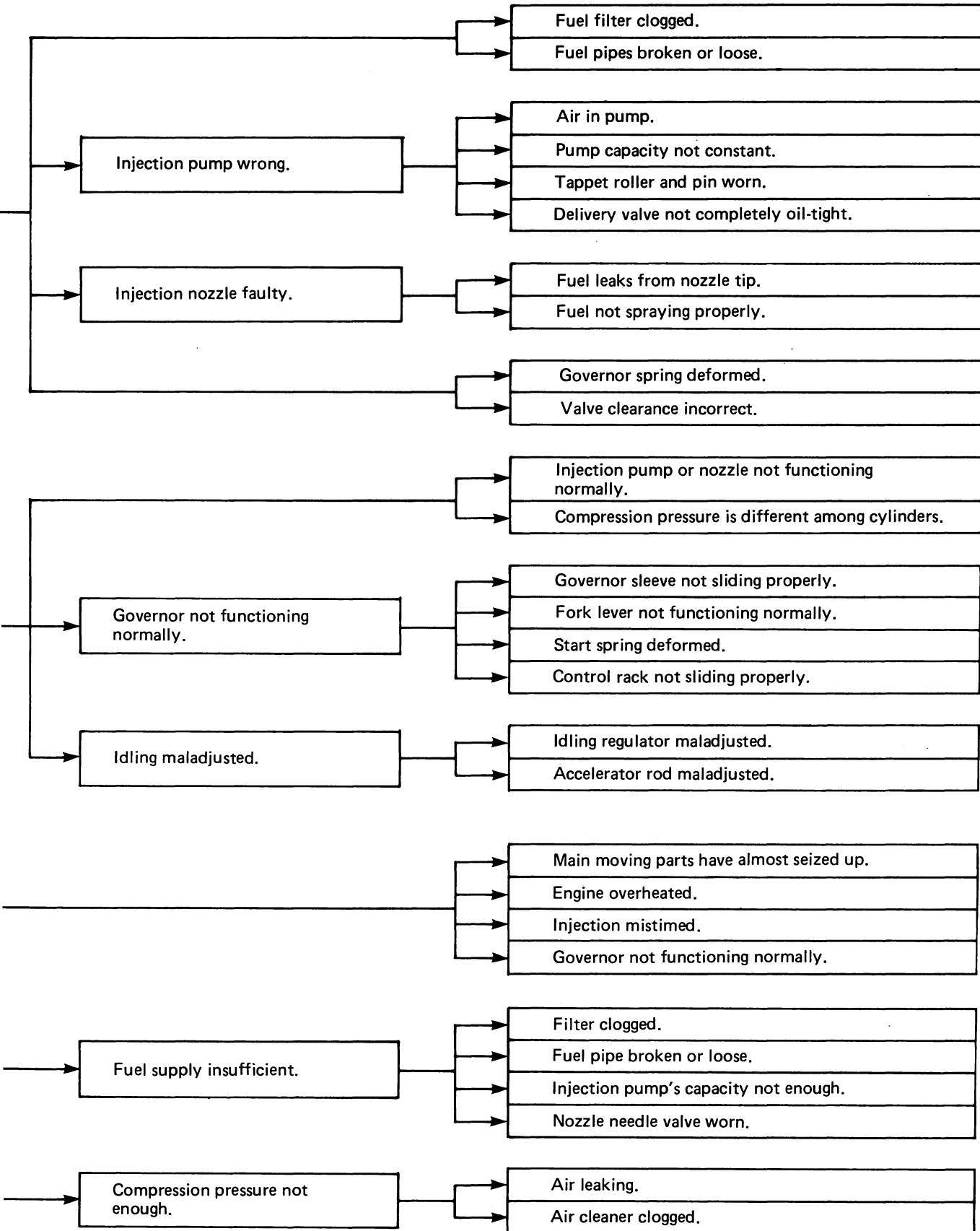
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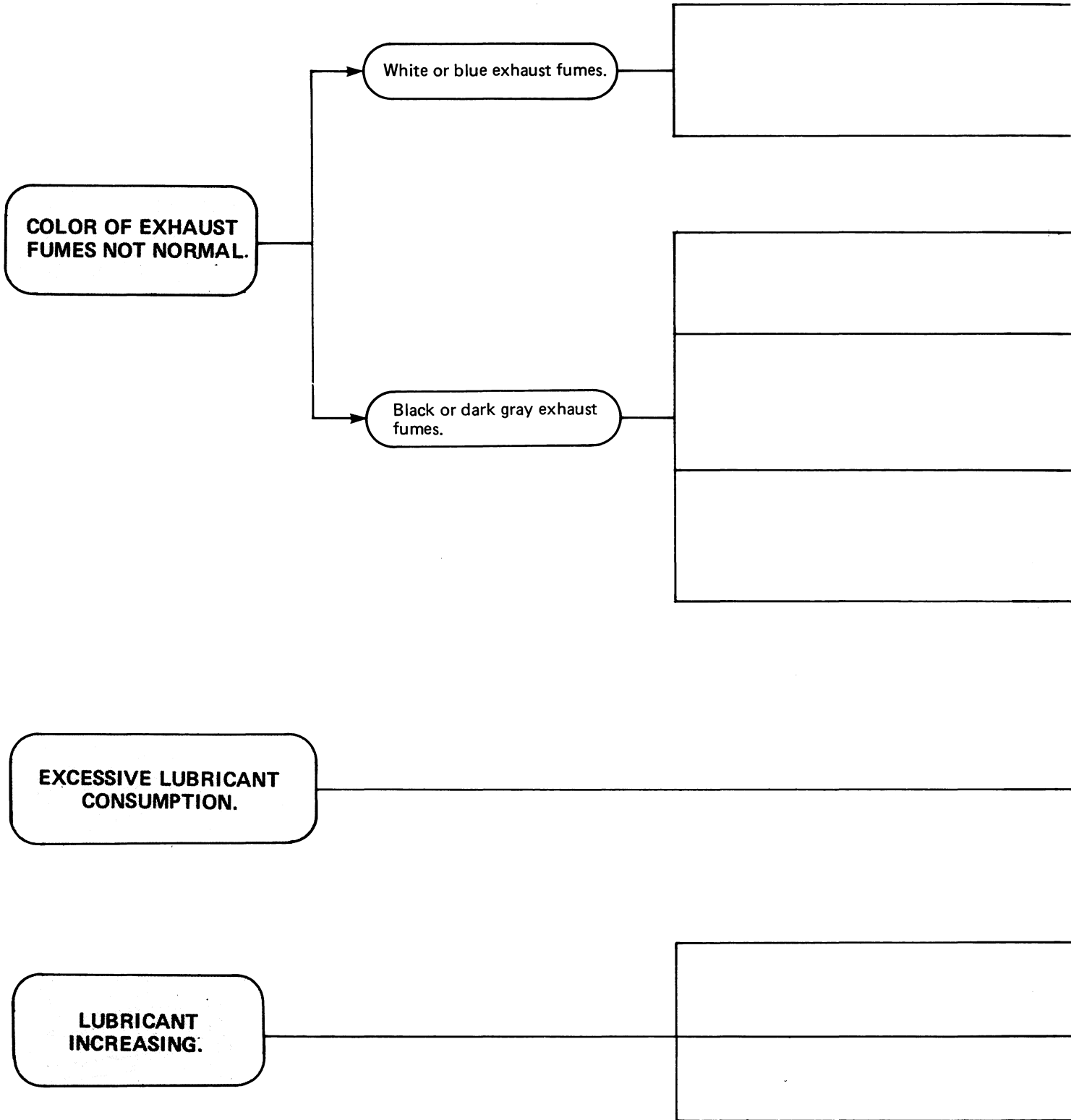
# TROUBLESHOOTING



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