Barrington Diesel Club

645E3 TURBOCHARGED ENGINE

MAINTENANCE MANUAL

7th Edition

March 1979

for Club Member Use only

ELECTRO-MOTIVE

* * * * A Service Department Publication * * * *

Electro-Motive Division Of General Motors La Grange, Illinois 60525

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FOREWORD

This manual contains maintenance information for the 8, 12, 16, and 20 cylinder Model 645E3 diesel engines. The material describes the basic engine and common extra equipment. However, the coverage of any particular system or component does not imply that the equipment is part of any specific order.

The illustrations generally depict the 16-cylinder model as representative of the location, size, and relative shape of various components and accessories.

Units of measurement appearing in this manual are shown in metric units and U.S. standard units. A conversion table is provided to convert U.S. standard to metric units.

Special tools, referred to in the text and shown in many of the illustrations, are not supplied with the engine, but are available on order. File numbers contained in this manual represent detailed drawings for the construction of fabricated tooling. These drawings are available from Electro-Motive Service Department.

References, specifications, and a list of service equipment are presented as Service Data at the end of most sections.

Clearance and dimensional limits listed in Service Data are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

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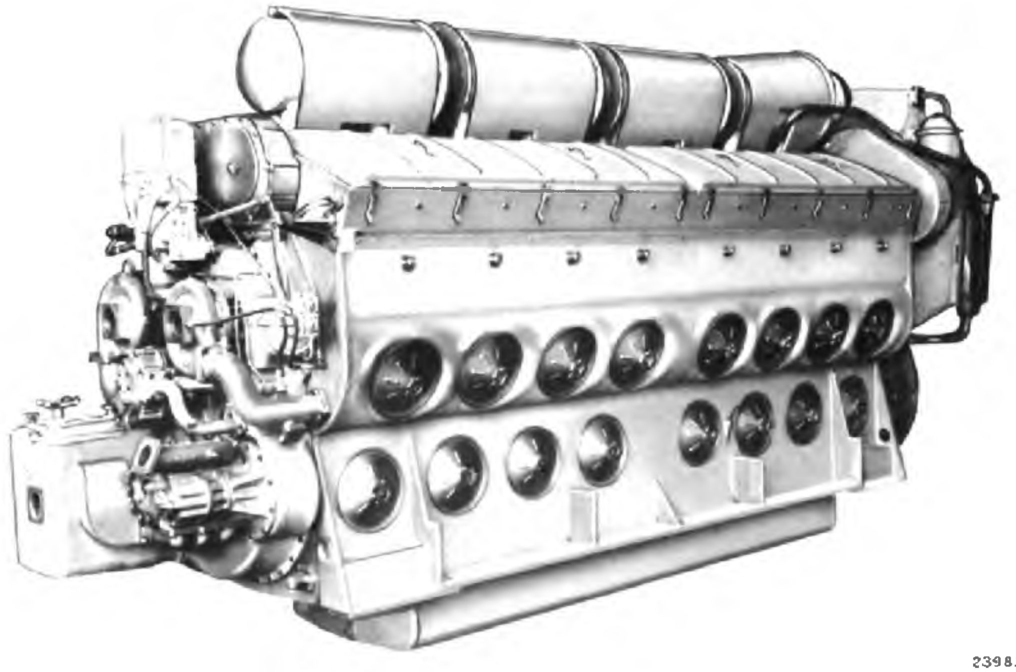
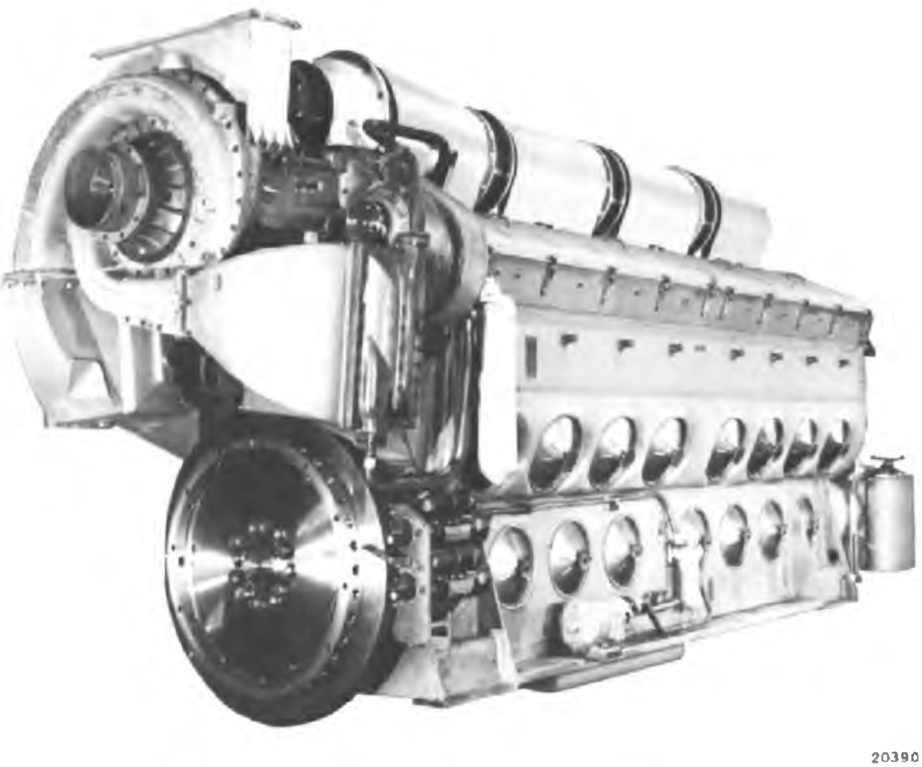


Three-Quarter Left Front View, 16-Cylinder



Three-Quarter Right Rear View, 16-Cylinder

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INDEX

	Section
ENGINE INFORMATION	0
CRANKCASE AND OIL PAN	1
CYLINDER HEAD AND ACCESSORIES	2
PISTON ASSEMBLY AND CONNECTING RODS	3
CYLINDER LINER	4
CYLINDER POWER ASSEMBLY	5
CRANKSHAFT ASSEMBLY AND ACCESSORY DRIVE GEAR TRAIN	6
CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES	7
AIR INTAKE AND EXHAUST SYSTEMS	8
LUBRICATING OIL SYSTEM	9
COOLING SYSTEM	10
FUEL SYSTEM	11
GOVERNOR	12
PROTECTIVE DEVICES	13
STARTING SYSTEM	14
TROUBLESHOOTING	15

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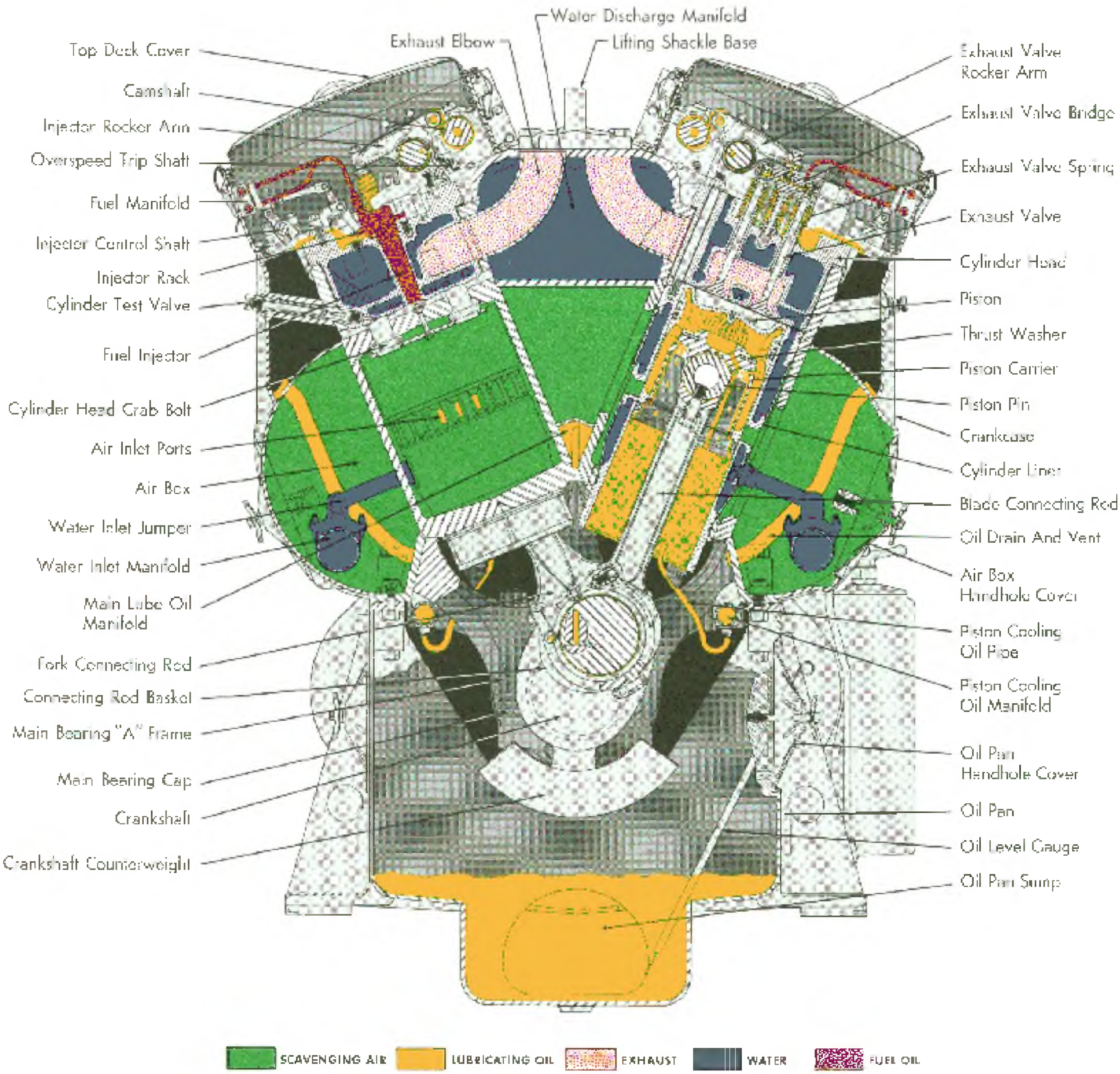

645 SERIES DIESEL ENGINE

ELECTRO-MOTIVE DIVISION

GENERAL MOTORS CORPORATION

LA GRANGE, ILLINOIS, U.S.A.

PLATE 13003

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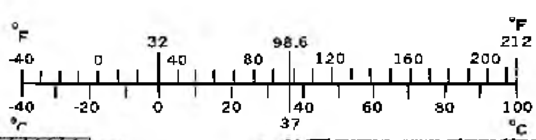
ELECTRO-MOTIVE

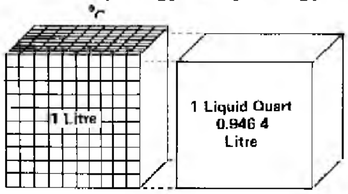
METRIC CONVERSION

TABLE OF FREQUENTLY USED UNITS

Multiply	by	to get equivalent number of:
LENGTH		
Microinch	.025 4	micron (p)
Inch	25.4	millimetres (mm)
Foot	0.3048	metres (m)
Yard	0.9144	metres
Mile	1.609	kilometres (km)
AREA		
VOLUME		
	29.574	centimetre3 (cm3)
Ounce	387.	mm3
Inch3 16	16.387	cm3
Ft3	0.0164	litres (l)
Quart	0.0283	metre3 (m3)
Gallon	0.9464	litres
Yard3	3.7854	litres
	0.7646	metres3 (m3)
MASS		
Ounce	28.350	grams (g)
Pound	0.4536	kilograms (kg)
Ton	907.18	kilogram
Ton	0.907	tonne (t)
FORCE		
Kilogram	9.807	newtons (N)
Ounce	0.278	newtons
Pound	4.448	newtons
TEMPERATURE		

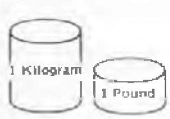


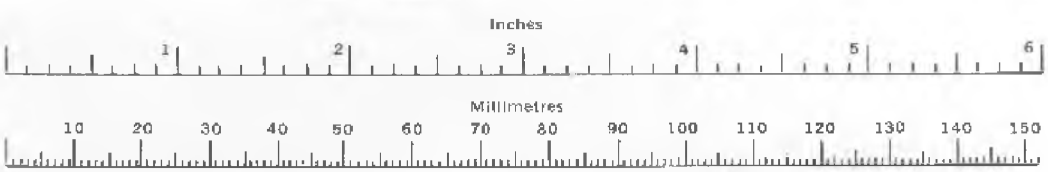
Multiply	by	to get equivalent number of:
ACCELERATION		
	0.3048	
Foot/sect	0.0254	metre/sect (m/s2)
Inch/sect		metre/sect
TORQUE		
Ounce-force-inch	0.00706	newton-metre
Pound-inch	0.0692	kilogram-metre
Pound-foot	0.11298	newton-metres (N-m)
	0.011 52	kilogram-metres
	1.3558	newton-metres
	0.13825	kilogram-metres
POWER		
Horsepower	0.746	kilowatts (kW)
PRESSURE OR STRESS		
Inches of water	0.2491	kilopascals (kPa)
Pounds/sq. in.	6.895	kilopascals
ENERGY OR WORK		
BTU	1055.	joules (J)
Foot-pound	1.3558	Joules (J = W's)
Kilowatt-hour 3	600 000 or 3.6x106	joules one
LIGHT		
Footcandle	10.764	lumens/metre2 (lm/m2)
FUEL PERFORMANCE		
Miles/gal	0.4251	kilometres/litre (km/1)
Gal/mile	2.3527	litres/kilometre (1/km)
VELOCITY		
Miles/hour	1.6093	kilometres/hr. (km/h)



The comparative dimensions of an inch ---- and a millimeter, a litre and a quart, and a kilogram and a pound are shown.

1 Pound = 0.453 6 kg Litre





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SECTION 0

ENGINE INFORMATION

CONTENTS	PAGE
DESCRIPTION	0-1
OPERATION	0-1
ARRANGEMENT	0-2
SERIAL NUMBER LOCATION	0-2
PAINTING	0-3
SERVICE DATA	
SPECIFICATIONS	0-5
RATINGS	0-5
CAPACITIES	0-6
WEIGHTS	0-6
TORQUE VALUES	0-9

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

ENGINE INFORMATION

DESCRIPTION

The turbocharged diesel engines are "V" type two-cycle engines incorporating the advantages of low weight per horsepower, positive scavenging air system, solid unit injection, and high compression.

OPERATION

In a two-cycle engine each cylinder completes a power cycle in one revolution of the crankshaft. The piston does not function as an air pump during one crankshaft revolution as is the case in a four-cycle engine which requires two revolutions of the crankshaft to complete one power stroke in each cylinder. A separate means is provided in a two-cycle engine to supply the needed air and to purge the combustion gases from the cylinder.

The engine is equipped with a turbocharger, shown schematically in Fig. 0-1, to efficiently provide the air needed for combustion and scavenging. The turbocharger provides an air supply greater than that provided by the positive displacement blowers used on other model engines.

During engine operation the turbocharger utilizes heat energy in the exhaust from the engine as well as power from the camshaft gear train to drive the turbine. However, when exhaust heat energy is sufficient to drive the turbine alone, the gear drive is disengaged by an overrunning clutch. The turbine then drives a centrifugal blower which furnishes air to the engine.

The air from the centrifugal blower is raised to a higher pressure and likewise to a higher temperature. It is desirable to reduce the air temperature to increase its density before it enters the air box surrounding the cylinders. The air temperature is reduced by passing it through the aftercoolers as shown in Fig. 0-1. Thus cooled air of greater comparable weight and having more oxygen is available to the engine.

Referring to Fig. 0-l, and assuming that the piston is at the bottom of its stroke and just starting up, the air intake ports and the exhaust valves will be open. Air under pressure enters the cylinder through the liner ports, pushes the exhaust gases left from the previous power stroke out through the exhaust valves and fills the cylinder with a fresh supply of air. When the piston is 45° past bottom dead center, the air intake ports will be closed by the piston as indicated on the timing diagram. Shortly after the air intake ports are closed, the exhaust valves will also be closed, and the fresh air will be trapped in the cylinder. Closing the exhaust valves after the intake air ports provides for the greatest efficiency in cylinder scavenging of combustion gases.

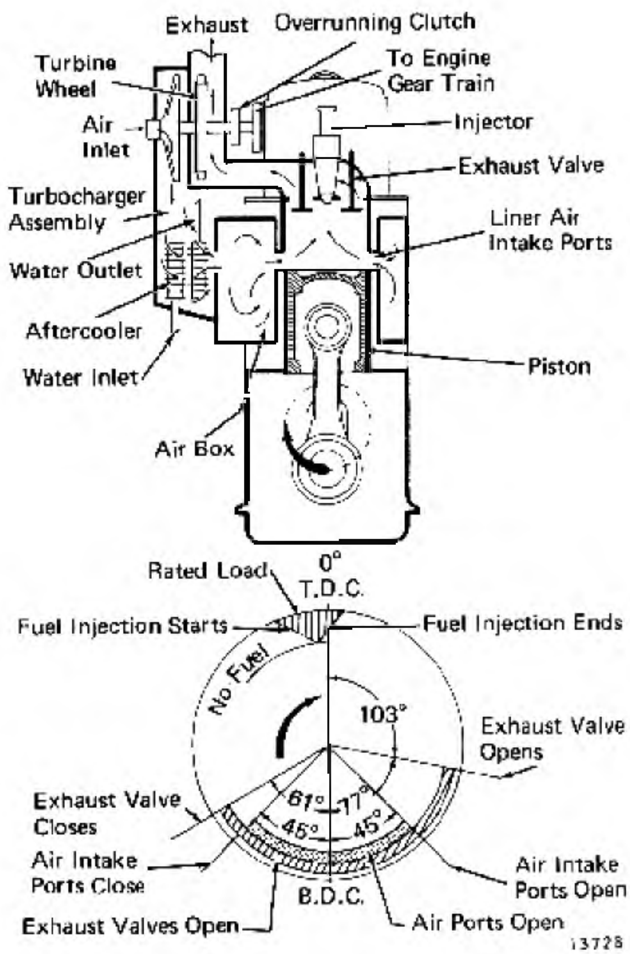

Fig. 0-1 - Schematic Illustration Of Engine Operation

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As the piston continues upward, it compresses the trapped air into a very small volume. Just before the piston reaches top dead center, the fuel injector sprays fuel into the cylinder. Ignition of the fuel is practically instantaneous, due to the temperature of the compressed air trapped in the top of the cylinder. The fuel burns rapidly as the piston is forced down on the power stroke of the piston. As shown in the timing diagram, the piston continues downward in the power stroke until the exhaust valves open.

The exhaust valves are opened ahead of the air intake ports to permit most of the combustion gases to escape and reduce the pressure in the cylinder. When the air intake ports are uncovered by the piston at 45° B.B.D.C. as it continues downward, air from the air box under pressure can immediately enter the cylinder, scavenging the remaining combustion gases from the cylinder and providing fresh air for combustion. The piston is again at the original starting point of the description and the cycle of events is repeated.

ARRANGEMENT

Cylinder location and the designation of the ends and banks of the engine, as referred to throughout the manual, are shown in Fig. 0-2. The governor, water pumps, and lube oil pumps are mounted on the "front" of the engine. The turbocharger and flywheel are located at the coupling end or "rear" of the engine. Left and right will be in respect to looking toward the "front" of the engine when standing at the "rear."
For identification and location of internal engine components refer to engine cross-section preceding

SERIAL NUMBERS

Major components of the engine are identified by serial numbers for historical record. When reference is made regarding a part having a serial number, the serial number should be included in the information as well as other identification used concerning the part. Following are major engine items identified with a serial number, and its location on the part.

ENGINE -- serial number is shown on the engine nameplate located at the right bank of the engine, and stamped on the left bank of the engine at the accessory end below the cover frame base.

CRANKCASE -- serial number is on the right side of the main bearing caps, right side of each end "A" frame, and at the top of the left bank at the rear end.

OIL PAN -- serial number is located on the left side of the oil pan below the top rail at the rear end.
CRANKSHAFT - serial numbers are located on the web of either the first or last throws (8 & 12-cyl.) and on the web of both the first and last throws (16 & 20-cyl.).

CYLINDER HEAD - serial number is located at the front center section of the top face.

CYLINDER LINER - serial number is located below the water inlet connection.

PISTON - serial number is located at the bottom inside diameter below the oil control ring.

PISTON CARRIER - serial number is located below the thrust washer platform on the outside diameter.

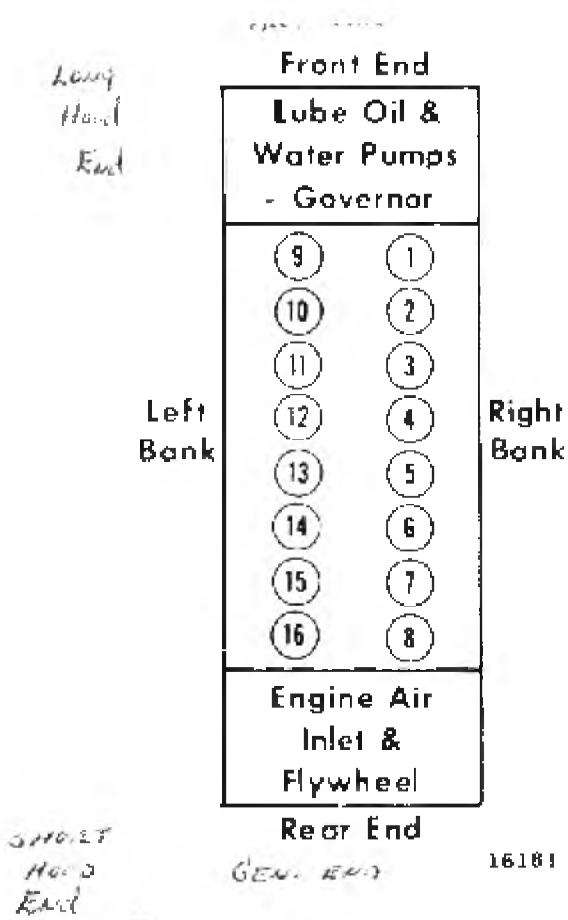

Fig. 0-2 - Engine Arrangement

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PISTON PIN - serial number is located at end of pin on same end as small identification hole.

FORK CONNECTING ROD - serial numbers are located in three different locations as the fork rod assembly consists of two basket halves and the rod. On basket half with dowel, number is located above basket-to-rod bolt hole. On other half, it is located below basket-to-basket bolt holes. On the rod, number is located to the left of center above serrations on the dowel side of rod.

BLADE ROD - serial number is located at end of slipper opposite the long toe.

CAMSHAFT ASSEMBLY - serial number of the assembly is located at the end of the accessory end stubshaft.

ENGINE GEARS - serial number is located on the rim of the gear.

GOVERNOR - serial numbers are provided on the governor nameplate.

WATER PUMP - serial number is located on the housing flange rim and is preceded by an "R" or "L" to show pump installation, at the right or left bank.

LUBRICATING OIL PUMP -- serial number is located at the front end cover and is preceded by the letter "L" to identify it as a lubricating pump.

SCAVENGING OIL PUMP - serial number is located at end cover and is preceded by the letter "S" to identify it as the scavenging pump.

FUEL INJECTORS - serial number is located on the same side as the injector rack, and is provided by injector manufacturer.

PAINTING

If an engine is to be removed from service and completely overhauled and the interior repainted, the parts to be painted must be cleaned in a vat of caustic solution to remove old paint, grease and oil from the pores of the metal. The caustic solution must be thoroughly removed by washing the parts in clean hot water, and drying with an air hose. (Aluminum parts must not be washed in the caustic solution.) If caustic cleaning is not done before painting, the paint will peel off the interior of the engine and contaminate the lube oil lines. Mask off parts not being painted.

Use zinc free crankcase primer sealer on the following: interior of crankcase, oil pan, air duct, top deck, cylinder head cover frames (except on seal surface), accessory and camshaft drive housings. Do not paint machined surfaces, liners, heads or seal surfaces.

To refinish the engine exterior, remove grease and oil with alkaline cleaner. Mask off water, fuel and oil fittings. If required, apply coat of primer. Then apply finish coat.

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SERVICE DATA
ENGINE INFORMATION

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. *New limits are those to which new parts are manufactured. (Drawing tolerances.)*
2. *Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused 'with the assurance that they will perform satisfactorily until the next scheduled overhaul.*

Bore	230.19 mm (9-1/16")
Stroke	254.0 mm (10")
Angle between banks	45°
Compression ratio	14.5:1
Displacement per cyl.	10 570 cm^3 (645 cu. in.)
Rotation (facing rear end)	Counterclockwise
Firing order -	
8-cyl.	1, 5, 3, 7, 4, 8, 2, 6
12-cyl.	1, 12, 7, 4, 3, 10, 9, 5, 2, 11, 8, 6
16-cyl.	1, 8, 9, 16, 3, 6, 11, 14, 4, 5, 12, 13, 2, 7, 10, 15
20-cyl.	1, 19, 8, 11, 5, 18, 7, 15, 2, 17, 10, 12, 3, 20, 6, 13, 4, 16, 9, 14
Exhaust valves (per cyl.)	4
Main bearings -	
8-cyl.	5
12-cyl.	7
16-cyl.	10
20-cyl.	12
Governor (Woodward)	PGR
Scavenging	Uniflow
Type of scavenging blower	Turbo-Centrifugal
Cooling system	Pressurized
Water pumps	Centrifugal
Lubricating oil system	Full pressure
Oil Pumps -	
Main oil pump and piston cooling pump	Two pumps in one housing siamesed inlet, double discharge
Scavenging oil pump	Helical gear type
Fuel injection	Unit injector with needle valve
Fuel pump	Positive displacement
Engine starting -	
12-cyl. w/AC generator, 16 & 20-cyl.	Dual electric motors
8 / 12-cyl. w/DC generator	Generator field

RATINGS

Low idle speed	255 RPM
Idle speed	318 RPM
Full speed	900 RPM
Output	
8-cyl.	1650 HP
12-cyl.	2300 HP
16-cyl.	3000 HP
20-cyl.	3600 HP

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CAPACITIES

Oil pumps	900 RPM LPM	900 RPM GPM
Main lube oil -		
8-cyl.	397	105
12-cyl.	594	157
16-cyl.	700	185
20-cyl.	867	229
Piston cooling		
8-cyl.	182	48
12-cyl.	250	66
16-cyl.	348	92
20-cyl.	413	109
Scavenging -		
8-cyl.	776	205
12-cyl.	1056	279
16 & 20 cyl.	1476	390
Fuel pump		
8-cyl.	8	2.1
12, 16, & 20-cyl.	17	4.5
Water pump		
8-cyl.	1 892	500
12-cyl.	2 498	660
16-cyl.	3 218	850
20-cyl.	4 164	1 100
Soak back pump		
8, 12, 16, & 20-cyl.	11	3

WEIGHTS

The weights as listed below are approximate maximum weights for the numbered cylinder engine shown. The weights are provided as an aid in determining the handling procedure to be used. Weights represent kilograms/pounds per unit, as described.

	8-Cyl.		12-Cyl.		16-Cyl.		20-Cyl.	
DESCRIPTION	Kg	Lb	Kg	Lb	Kg	Lb	Kg	Lb
Engine assembly	10 002	22,050	12 839	28,306	16 522	36,425	19 545	43,091
Crankcase (includes bearings & caps)	2 626	5790	3 561	7851	5 319	11,727	6 473	14,273
Oil pan	612	1350	710	1566	953	2100	1 315	2900
Crankshaft	775	1710	943	2080	1 442	3180	1 530	3375
Viscous damper	99	218	99	218	99	218	141	310
Accessory drive gear	42	92	42	92	44	98	44	98
Crankshaft gear	51	112	51	112	51	112	51	112
Ring gear	132	290	132	290	132	290	67	147
Coupling disc	147	325	147	325	147	325	177	390 .
Cylinder power pack assembly w/fork rod	185	408	185	408	185	408	185	408
w/blade rod	165	363	165	363	165	363	165	363
Cylinder head assembly	66	145	66	145	66	145	66	145
Cylinder liner	58	127	58	127	58	127	58	127
Piston	18	40	18	40	18	40	18	40
Connecting rod (fork)	23	50	23	50	23	50	23	50
Connecting rod (blade)	11	25	11	25	11	25	11	25
Camshaft w/stubshaft assembly	55	122	78	175	100	220	120	265

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SERVICE DATA (CONT'D)

DESCRIPTION	8-Cyl. Kg	8-Cyl. Lb	12-Cyl. Kg	12-Cyl. Lb	16-Cyl. Kg	16-Cyl. Lb	20-Cyl. Kg	20-Cyl. Lb
Camshaft drive gear	40	89	40	89	40	89	40	89
Camshaft drive housing	154	340	154	340	154	340	154	340
Idler gear stubshaft assembly	43	94	43	94	43	94	43	94
Low idler gear (No. l)	28	62	28	62	28	62	28	62
Spring drive gear assembly	77	170	77	170	77	170	77	170
Accessory drive cover assembly	60	132	60	132	60	132	60	132
Overspeed trip housing assembly	19	42	19	42	19	42	19	42
Governor	50	110	50	110	50	110	50	110
Governor drive gear assembly	24	53	24	53	24	53	24	53
Governor drive housing assembly	18	40	18	40	18	40	18	40
Water pump	49	109	49	109	49	109	49	109
Water manifold assembly	16	35	20	45	31	68	39	87
Main lube & piston cooling oil pump assembly	62	136	66	146	89	197	89	197
Scavenging oil pump assembly	73	162	74	164	101	222	101	222
Lube oil strainer assembly	92	203	92	203	92	203	92	203
Fuel oil filter assembly	22	49	22	49	22	49	22	49
Turbocharger assembly	816	1800	816	1800	816	1800	816	1800
Auxiliary drive assembly	37	81	37	81	37	81	37	81
Aftercooler duct	76	167	76	167	76	167	84	185
Aftercooler core, header, and cover	90	199	90	199	90	199	90	199
Oil separator assembly	33	73	33	73	33	73	33	73
Soak back oil motor/pump assembly . . .	34	75	34	75	34	75	34	75
Turbocharger oil filter assembly	13	28	13	28	13	28	13	28
Exhaust manifold chamber.	86	190	86	190	86	190	86	190
Expansion joint	14	32	14	32	14	32	14	32
Adapter and turbo screen	34	74	34	74	34	74	34	74
Starting motor	-	--	35	78	35	78	35	78
Starting motor mounting bracket	26	58	26	58	26	58	26	58

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TORQUE VALUES

NOTE

When torque values are listed as "initial" and "final", torquing procedures in the manual text *MUST* be followed.

TOP DECK

	N-m	FT-LBS
Camshaft stubshaft bearing bracket bolts		
5/8" hex head	285	210
1/2" socket head	102	75
Cylinder head crab nuts (studs and nuts lubricated)*		
Initial	407	300
Final	2440	1800
Injector crab nuts (lubricated)*	68	50
Cylinder head-to-liner nuts (lubricated)*		
Initial	102	75
Final	325	240
Top deck head frame bolts		
(300M bolts with hardened washers)	54	40
Overspeed trip mechanism	32	24
Injector fuel lines	54	40
Camshaft bearing blocks	43	32
Rocker arm shaft nuts (lubricated)*		
Initial	203	150
Final	407	300
Fuel manifold blocks	54	40
Cylinder test valve packing nut	88	65
Water outlet elbow-to-head bolts	41	30
Exhaust manifold-to-crankcase (lubricated)**		
Initial	68	50
Final	176	130
Exhaust manifold connector bolts	108	80
Exhaust manifold inspection cover (when equipped)	108	80

ACCESSORY END

Accessory drive housing-to-crankcase and oil pan	88	65
Overspeed trip housing-to-crankcase	88	65
Water pump mounting bolts	88	65
Water pump elbows	88	65
Scavenging oil pump mounting bolts	88	65
Scavenging oil pump elbows	88	65
Lube oil pump mounting bolts	88	65
Lube oil pump elbows	88	65
Oil strainer housing mounting bolts	88	65
Governor drive housing mounting bolts	88	65
Governor-to-drive housing	88	65
Overspeed trip cover-to-overspeed trip housing	41	30
Fuel manifolds-to-filter	47	35
Oil strainer elbows-to-strainer housing	54	40
Accessory drive oil seal cover	54	40
Accessory drive flange retaining bolt		
Initial	136	100
Final	678	500

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	N-m	FT-LBS
Accessory drive flange locking spring bolt	88	65
Governor drive gear assembly		
Stubshaft-to-crankshaft	102	75
Stubshaft dowel bolts	23	17
Oil jumper-to-stubshaft	47	35
Retainer plate-to-stubshaft	47	35
Governor drive flange-to-drive gear.	47	35

TURBOCHARGER END

Piston cooling manifold flange-to-crankcase	37	27
Idler gear stubshaft bracket-to-crankcase -		
1/2"	122	90
3/8"	37	27
5/16" (dowel bolts)	23	17
No. I idler gear thrust plate-to-crankcase	251	185
Camshaft drive housing-to-crankcase	88	65
Camshaft drive housing-to-crankcase lockwire anchor bolts	88	65
Oil manifold-to-oil manifold	50	37
Oil manifold-to-crankcase	43	32
Camshaft drive gear-to-camshaft		
1/2"	122	90
5/16" (dowel bolts)	23	17
Turbocharger mounting bolts		
3/4"	238	175
1/2"	88	65
Air ducts-to-turbocharger	81	60
Air ducts-to-crankcase	88	65
Auxiliary drive-to-turbocharger 3/8"	32	24
Auxiliary drive-to-camshaft drive housing 1 / 2"	88	65
Aftercooler-to-air duct	61	45
Aftercooler support pad bolts	176	130
Turbocharger-to-manifold (lubricated)**	122	90
Water piping-to-aftercooler	47	35
Water piping-to-engine	47	35
Oil separator expansion joint bolts	122	90
Oil slinger-to-crankshaft gear	23	17
Oil retainer-to-camshaft drive housing	41	30

CRANKCASE AND OIL PAN

Main bearing nuts (lubricated)*		
Initial	475-542	350-400
Final	1 017	750
Crankcase-to-oil pan		
Initial	136	100
Final . . . . . , ...	610	450
Connecting rod-to-piston pin (lubricated)*	610	450
Basket-to-connecting rod (lubricated)*		
Initial	13	10
Final	258	190
Connecting rod basket	102	75
Piston cooling oil pipe bolts	27	20

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SERVICE DATA (CONT'D)

	N-m	FT-LBS
Water jumper-to-liner	41	30
Water jumper saddle strap nuts	20	15
Torsional damper-to-crankshaft (lubricated)*	678	500
Bolt-on crankshaft stubshaft (lubricated) *(where applicable)	678	500
Bolt-on crankshaft stubshaft retention bolts	81	60
Accessory drive gear to crankshaft (lubricated)*	407	300
Accessory drive gear oil slinger	33	24
Coupling disc-to-crankshaft (8, 12, & 16-cyl.) (lubricated)*	2 441	1800
(20-cyl.) (lubricated)*	1 830	1350
Coupling disc rim bolts	400	295
Handhole cover bolts	27-41	20-30
Engine mounting bolts	617	455

WATER PUMP

	N-m	FT-LBS
Impeller-to-shaft	108	80
Drive gear-to-shaft	359	265
Stationary bushing	11.3	(100 in.-lbs)

*Lubricate with Texaco Threadtex No. 2303
**Lubricate with Fel-Pro C5A or equivalent

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SECTION 1

CRANKCASE AND OIL PAN

CONTENTS	PAGE
CRANKCASE	
DESCRIPTION	1-1
CLEANING	1-1
INSPECTION	1-2
LOWER LINER BORE INSERT	
DESCRIPTION	1-2
APPLICATION	1-2
REMOVAL	1-3
CRAB BOLTS	
DESCRIPTION	1-4
MAINTENANCE	1-4
MAIN BEARING STUD BOLTS	
DESCRIPTION	1-4
MAINTENANCE	1-4
CHECKING MAIN BEARING STEEL BORE DIMENSIONS	1-5
OIL PAN	
DESCRIPTION	1-6
CLEANING	1-6
INSPECTION	1-6
CRANKCASE TO OIL PAN SEAL	
DESCRIPTION	1-7
MAINTENANCE	1-7
AIR BOX DRAIN	
DESCRIPTION	1-8
TOP DECK HEAD FRAME AND COVER	
DESCRIPTION	1-8
MAINTENANCE	1-9
SERVICE DATA	
SPECIFICATIONS	1-11
EQUIPMENT LIST	1-11

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

CRANKCASE AND OIL PAN

CRANKCASE

DESCRIPTION

The crankcase, Fig. 1-1, is the main structural part of the engine. It is a steel fabrication forming a rigid self-supporting assembly to accommodate the cylinder power assemblies, crankshaft, and engine mounted accessories.

Handholes in the side panels, provided with gasketed covers, allow inspection of liners and pistons, cleaning of air box, and access to water manifold and oil pan mounting bolts.

MAINTENANCE

CLEANING

The crankcase should be cleaned to remove foreign material, after any work has been done on the interior of the engine, or if damage has occurred in the engine. This can be done by using a spray gun and solvent. The equipment near the engine should be protected against the spray. After spraying the top deck, wipe with towels saturated with solvent. Wipe all solvent trapped in corners and pockets. Use only lintless, boundedge towels.

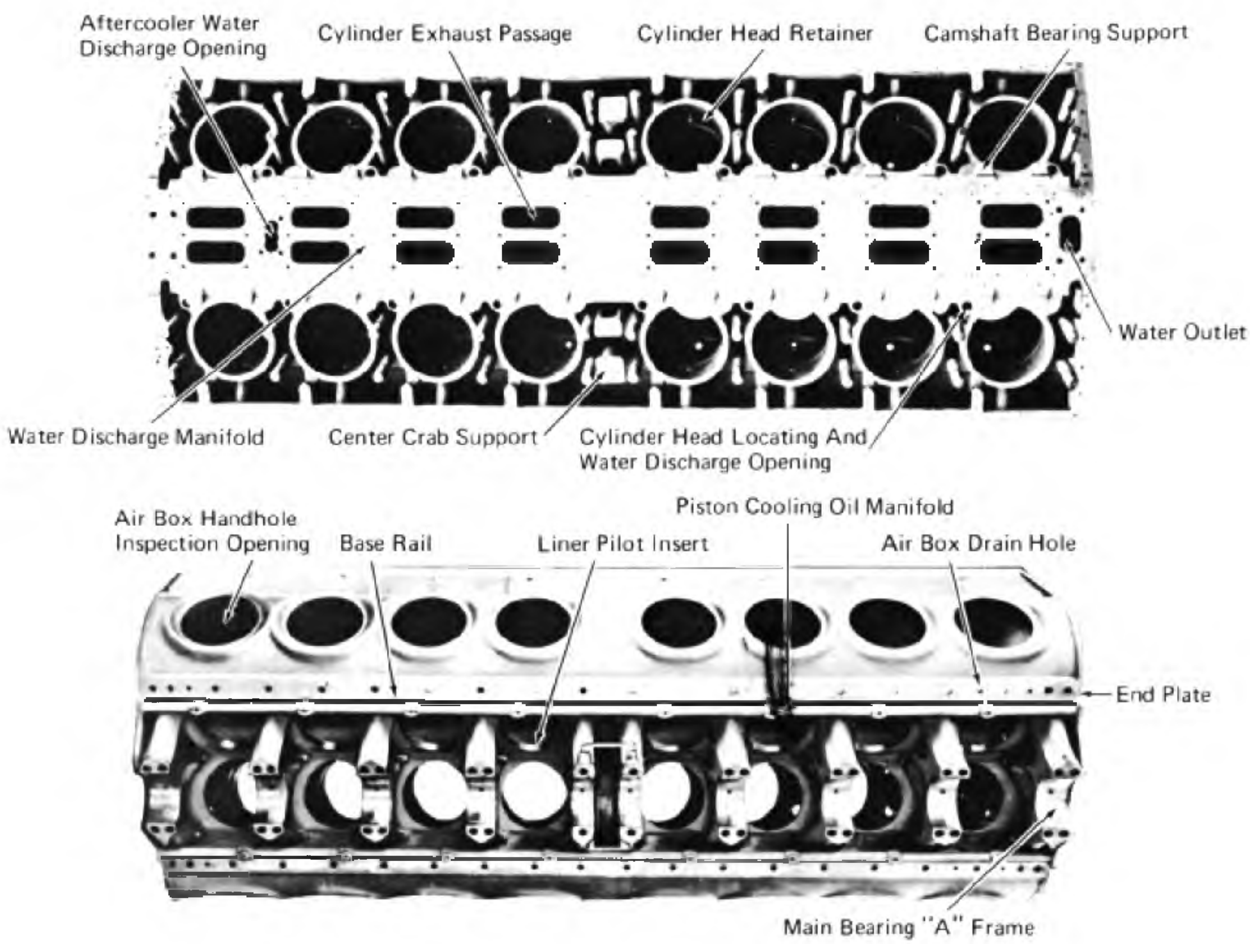

Fig. 1-1 -Crankcase, 16-Cylinder

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Cleaning of the air box with a spray gun while liners are in place is not recommended practice, due to possibility of dirt entering liners at the ports.

At any time cleaning is done oil the crankcase, protection should be given to oil passages, bearing surfaces, and gears, to prevent gritty material from being trapped. Cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

INSPECTION

Periodic inspection of the crankcase should be performed to detect minor discrepancies which, if not corrected, could result in major crankcase failure. Early detection and repair of the crankcase is essential since major repairs usually cannot be performed in the field. In instances where extensive welding is required, the crankcase must be stress relieved and remachined where necessary. Therefore, it is recommended that a crankcase requiring rebuild or reconditioning be returned to the manufacturer for repair.

LOWER LINER BORE INSERT

DESCRIPTION

A replaceable phosphate treated cast iron insert, Fig. 1-2, is used in each lower liner bore of the crankcase to provide a wear surface at the lower liner pilot. Seals held in grooves in the lower liner pilot, prevent air passage between the insert and the liner.

MAINTENANCE

When the inside diameter of the insert, installed in the crankcase, reaches the maximum limit. the insert should be removed and a new one installed. Replacement of the insert in the lower liner bore of the crankcase requires the use of a sturdily constructed tool to apply and remove the insert safely and efficiently. The lower liner insert application and removal tool, Fig. 1-3, is specifically designed to do this work. This tool consists of a press and puller assembly and a 10 ton hydraulic jack. The hydraulic jack consists of a 10 ton hydraulic ram, a high pressure hose. and a high pressure hydraulic pump.

INSERT APPLICATION

The arrangement of the tool for insert application is shown in Figs. 1-3a and 1-3c. The insert is installed as follows:

1. Coat the contact area of the outside diameter of the insert with mounting compound.

2. Manually place the insert (7) in place in the lower bore, and position it for the pressing operation by starting it uniformly in the bore.

3. Assemble the tool as shown in Fig. I-3a, with the ram screwed into the screw plug, and into the boss of the insert plate (6). The ram plunger should be in the retracted position. Disconnect the high pressure hose (12) if it is attached to the ram.

4. Lift the tool at the hoisting ring (2), and place the tool into the cylinder bore resting upon the cylinder retainer. The tool should be positioned so the hose connection is accessible from the stress plate inspection opening. Secure the tool using four crab nuts at the crab stud holding bosses.

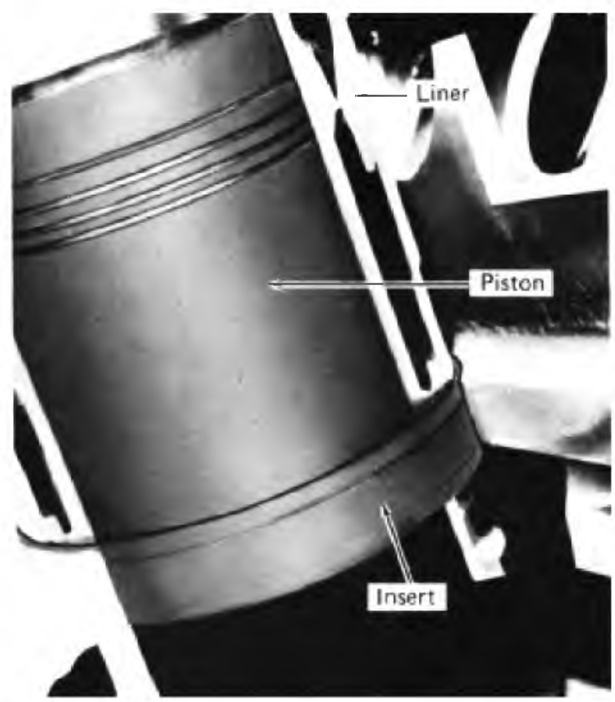

Fig. 1-2 - Lower Liner Bore Insert

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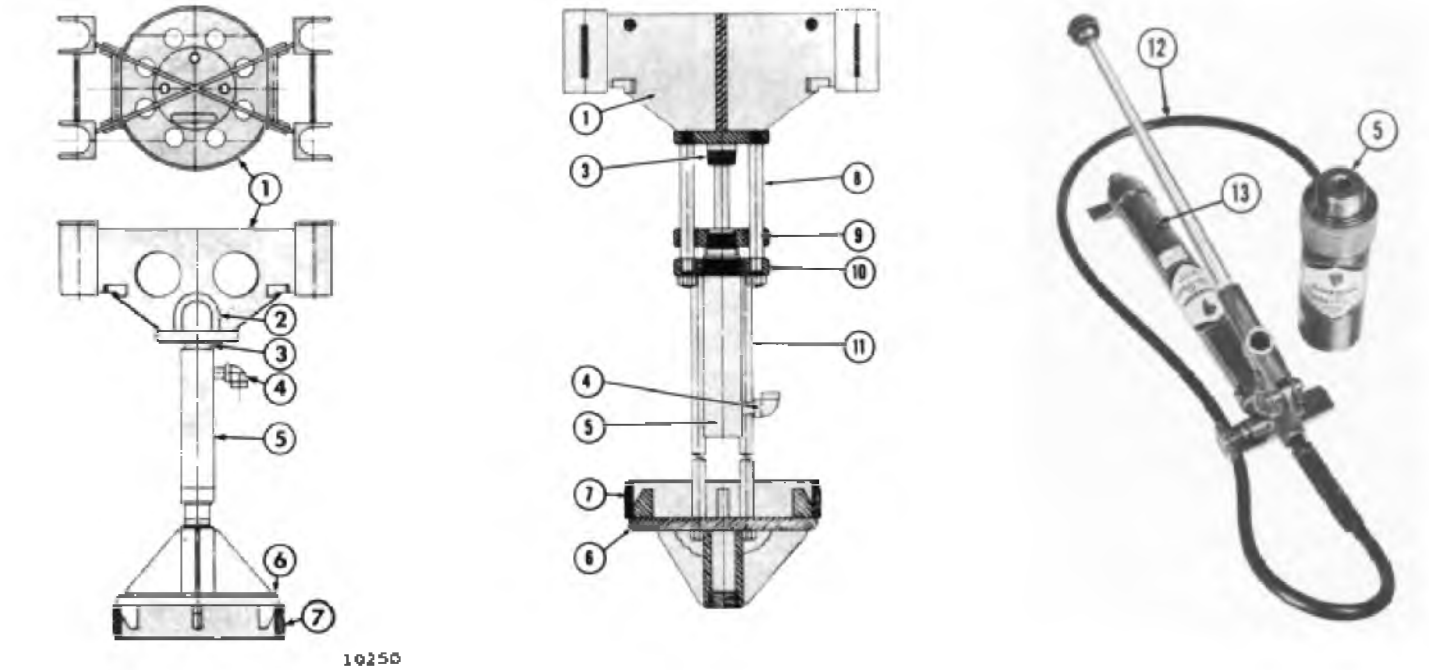

a. Insert Application

b. Insert Removal

c. Hydraulic Jack

1. Crab Stud Holding Assembly
2. Hoisting Ring
3. Screw Plug
4. High Pressure Hose Connection
5. 10-Ton Ram
6. Insert Plate
7. Insert
8. Holding Studs
9. Upper Plate
10. Ram Plate
11. Pulling Studs
12. High Pressure Hose
13. Hydraulic Pump

Fig. 1-3 - Liner Bore Insert Application And Removal Tool

5. Attach the high pressure hose (12) to the ram (5) at the ram connection (4), and using the hydraulic pump, extend the plunger to contact and press the bore until the shoulder is seated.

INSERT REMOVAL

The arrangement of the tool for insert removal is shown in Fig. 1-3b. The insert is removed as follows:

1. Assemble the tool for removal as shown and remove the four nuts holding the insert plate (6) and remove the plate. Also, remove the high pressure hose (12) from the ram (5) if it is connected.
2. Lift the tool using the hoisting ring and place in the cylinder, resting upon the retainer. Position the tool so that the hose fitting may be reached at the outboard side to permit hose application. Apply four crab nuts to secure the tool.
3. Place the ram plunger so that the insert plate bolts extend below the insert to permit insert plate application, as shown in Fig. 1-3b. Apply the insert plate and its holding bolts.
4. Connect the high pressure hose (12) to its fitting (4) on the ram (5) and using the pump (13) remove the insert (7) from the crankcase bore.

In the event that the insert application and removal tool is not available, the insert may be applied and removed using a mallet and a phenolic or wooden block.

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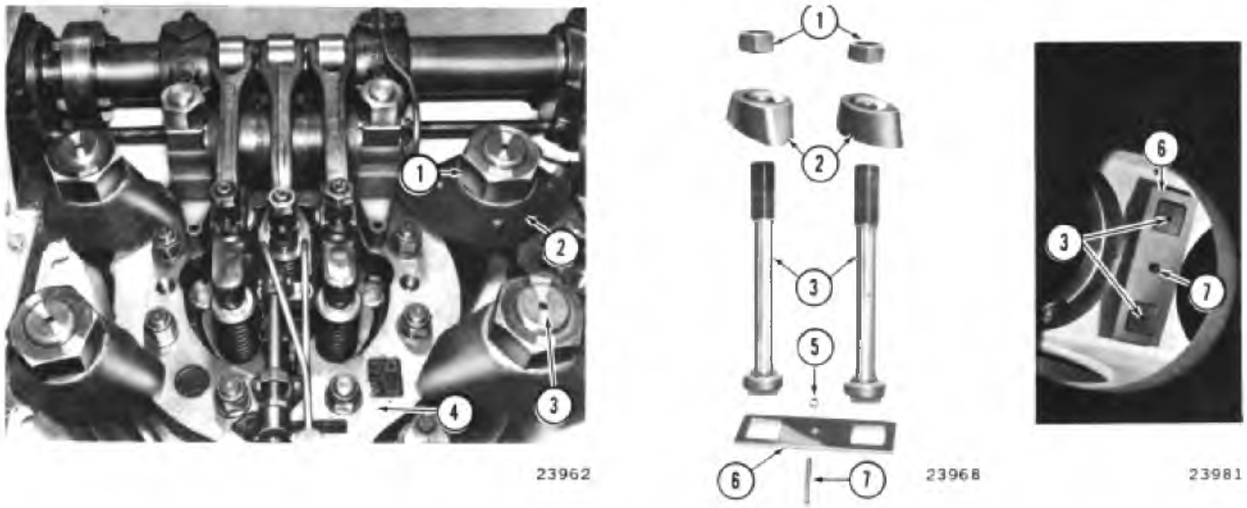

1. Crab Nut
2. Crab
3. Crab Bolt
4. Cylinder Head
5. Retainer Bolt Nut
6. Retainer Plate
7. Retainer Bolt

Fig. 1-4 - Crab Bolt Installation

CRAB BOLTS

DESCRIPTION

The cylinder head and liner are bolted together and this assembly is held in the cylinder head retainer by crab bolts, head crabs, and nuts, Fig. 14. The crab bolts extend up through the cylinder bank upper deck plate adjacent to each cylinder retainer. The bolt heads have a spherical seating surface which seats in a like surface, the bolts being held in position by a separate plate and bolt for each pair of bolts. The square bolt heads fit corresponding holes in the plate which prevents their turning when being torqued.

MAINTENANCE

The crab bolts can be removed through the air box by removing the crab bolt retainer plate bolt and retainer plate. The retainer plate and bolt are easily accessible only after liner has been removed. Crab bolt threads may be cleaned up using a 1-3/4"-12-UNR thread die. Crab nut threads may be cleaned up using a 1-3/4"-12 tap. Whenever crab bolt threads are exposed, they should be covered with thread protectors.

CAUTION: To prevent damage to crab bolts having rolled threads, only the UNR type thread die should be used. This die may also be used on crab bolts having the former cut threads.

If one of the two crab bolts located at either end of either bank, or one of the center crab bolts (16 & 20-cyl.) was broken, the other three bolts holding the cylinder head should be changed. If a broken crab bolt was in any other location, the remaining five crab bolts holding the heads held by the broken crab bolt should be changed.

MAIN BEARING STUD BOLTS AND CAPS

DESCRIPTION

The main bearing stud bolts are shown in Fig. 1-5. Each "A" frame has four 1-1/4" coated main bearing studs except the center "A" frames (16 & 20-c:yl.), which have two each. They pass through the "A" frame and main bearing caps, Fig. 1-5. A transverse hole at the upper end of each stud accommodates a bolt which passes through the stud and slots in the upper nut. Semicircular or D-shaped nuts are used at the upper end of the stud.

The upper nuts have a spherical seating surface to match a similar surface in the "A" frame. Since the center "A" frames (16 & 20-cyl.) are separated from each other, a retainer assembly is used to prevent the upper nuts from turning. The retainer assembly is held in place over the nuts by bolts which pass through the nuts and studs.

MAINTENANCE

A thread die can be used to clean up the stud bolts while a tap can be used on the slotted stud nuts. To aid

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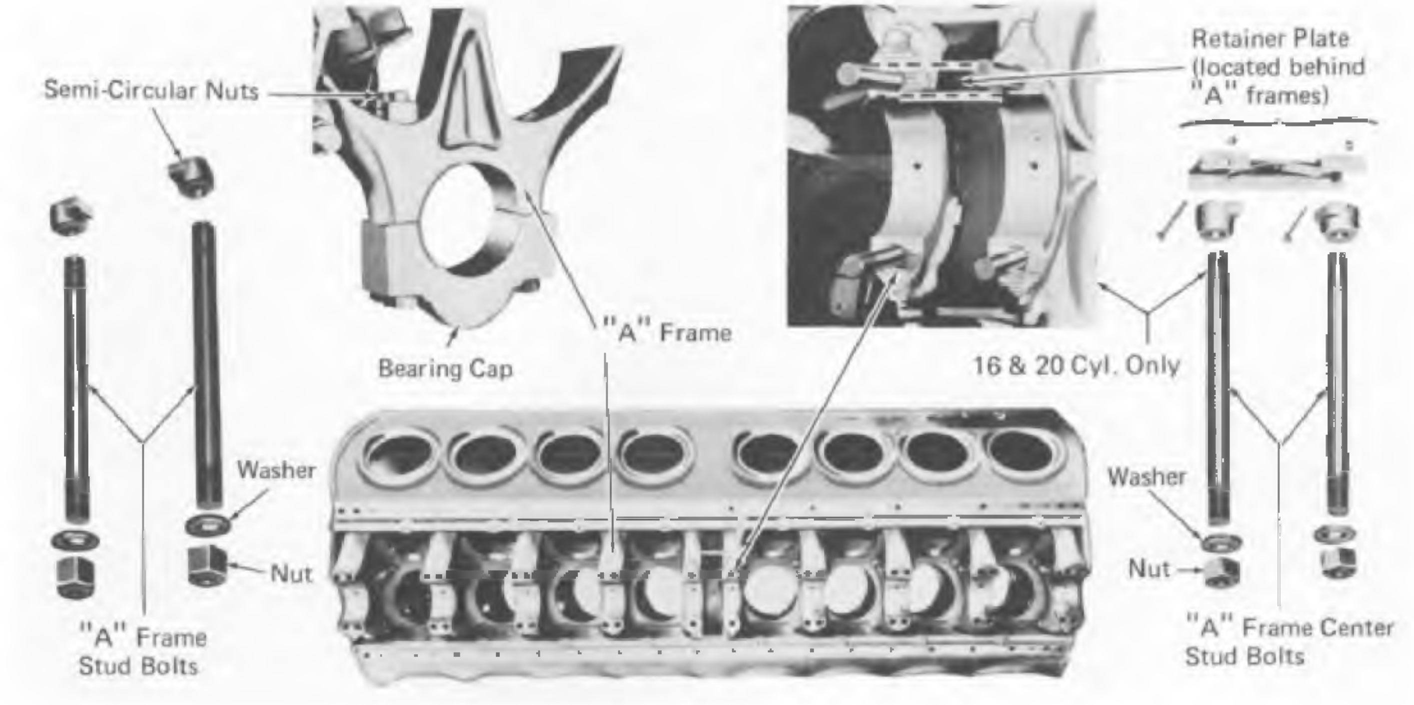

Fig. 1-5 - Main Bearing Stud Bolts

in obtaining correct torque values, the threads should be cleaned before parts application.

Upon application, each stud is inserted into its place in the "A" frame and run into its nut until the hole in the top of stud lines up with the bolt slot of the nut. The lower end of the stud should be 178 mm (7") from the serrations on the "A" frame when the stud is brought out with the spherical surface of the upper nut contacting the mating surface in the "A" frame. This is to ensure that the lower stud nuts can be properly tightened when the bearing cap is applied. The bolt and self-locking nut may then be applied except the center "A" frames (16 & 20-cyl.). The upper nut flats contact each other when in place on all "A" frames except the center "A" frames (16 & 20-cyl.), which are separated from each other. A retainer plate is used on the center "A" frame upper nuts to prevent them from turning. After the stud has been run into the nuts the proper amount, the retainer, which is like a channel, is placed over the nuts. The bolts are then applied through the retainer and stud and across the nut slots. The bolt slots in the retainer are of different widths, one slot being larger to secure the bolt head and prevent it from turning when being tightened. The retainers are cut away on one side to provide clearance for a stiffener plate between the center "A" frames (16 & 20-cyl.).

Main bearing caps are originally applied to the "A" frame and then are line bored; therefore, they are not interchangeable or available for replacement. They must be reapplied on the same "A" frame in the same position as removed. Each cap and "A" frame is stamped on the right side with their bearing number, and in addition, all caps and the end "A" frame are stamped with crankcase serial number. Before cap application, check serrations in cap and "A" frame and remove any burrs or foreign material that would prevent a good mating fit.

CHECKING MAIN BEARING STEEL BORE DIMENSIONS

At time of crankcase overhaul, or whenever a crankshaft is removed from an engine, it is necessary to determine whether main bearing steel bore dimensions arc within tolerance.

NOTE: Dimensional wear limits are contained in Service Data at the end of the section.

1. Place the crankcase on its side.
2. Be sure that the crankcase "A" frame bores and serrations are clean.
3. Lubricate the studs, nut seats, and hardened washers with Texaco Threadtex No. 2303.

CAUTION: Use of the hardened washer under the main bearing cap nut is mandatory to ensure proper bolt stretch and to retain nut torque. Damaged nut seat areas on the caps must be cleaned by spot-facing or by taking

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a cut (1.59 min [1/16"1 maximum depth) parallel to the serration surface.

4. Apply the main bearing caps, and torque the nuts in two passes. On the first pass, torque the nuts to 475-542 N-m (350-400 ft-lbs). On the second pass, final torque the nuts to 1 017 N-m (750 ft-lbs).

NOTE: No one nut on any one cap should be torqued to 1 017 N-m (750 ft-lbs) until all the nuts on that cap have been torqued to 475-542 N-m (350-400 ft-lbs).

NOTE: A procedure using stud stretch measurements as the criteria for monitoring torques when the engine is disassembled and on its side is available from your EMD service representative.

5. Check that the main bearing bore dimensions are within the minimum and maximum limits. Take two sets of measurements at each bore, one set 12.70 mm (1/2") in from the accessory end of the bore and one set 12.70 mm (1/2") in from the generator end of the bore at points shown in Fig. 1-6.

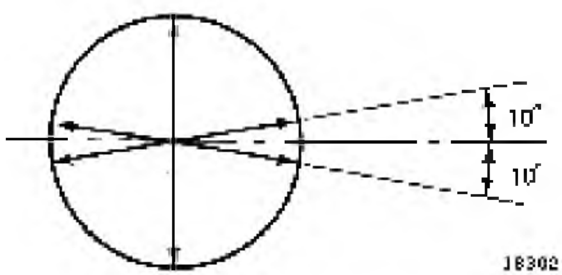

Fig. 1-6 - Main Bearing Bore Measurement

6. I any one diameter is out of tolerance -

   a. he crankcase may be shipped to EMD for remanufacture.

   b. f the engine owner has facilities for crankcase machining and wishes to do his own remanufacture, contact the EMD service representative for information concerning control of main bearing steel bores during remanufacture.

If an overheated bearing makes it necessary to check an "A" frame for "close-in" with the crankshaft in the engine, it may be checked using a new upper main bearing. The bearing must fit into the A" frame bore. Also, check the clear ance at each side between the bearing shell and the crankshaft at the split line above the serrations. Reference bearing inspection procedures in Section 6 for additional information.

A main bearing nut power wrench set may be obtained for use on the engine. This wrench, in use, is supported in the oil pan inspection opening. Also, an offset ratchet wrench set is available for running up and loosening main bearing nuts.

OIL PAN

DESCRIPTION

The engine oil pan, Fig. 1-7, is a fabricated steel assembly which supports the crankcase and serves as the engine base. The engine oil sump located centrally in the oil pan, is provided with oil drains.

A bayonet type oil level gauge extends from the side of the oil pan into the sump. A scavenging oil pump suction line is built into the oil pan extending from the sump to the front end plate. Openings in each end plate allow oil from the camshaft and accessory end housings to drain into the oil pan. Hand holes at each cylinder location, provided with gasketed covers, allow access to enclosed engine parts. Liquid accumulations from the air box are drained through pipes located at the front of the oil pan into a common flange for discharge.

MAINTENANCE

CLEANING

The oil pan should be thoroughly cleaned at the time of an oil change or any time the engine is damaged. Particular attention should be given the oil drain pipes to make certain there is no accumulation of foreign material. Wipe out accumulation from corners and pockets of pan and remove any loose or flaking paint from the pan interior.

INSPECTION

Inspect oil pan rails for nicks, burrs, or foreign material of any kind in seal grooves, and remove to provide a clean smooth surface. Any indentation in the seal grooves or base rails that would allow oil seepage must be filled with solder and finished flush with surrounding area. Also inspect air box drain pipes, end plates, and handhole cover gasket surfaces for any nicks or roughness.

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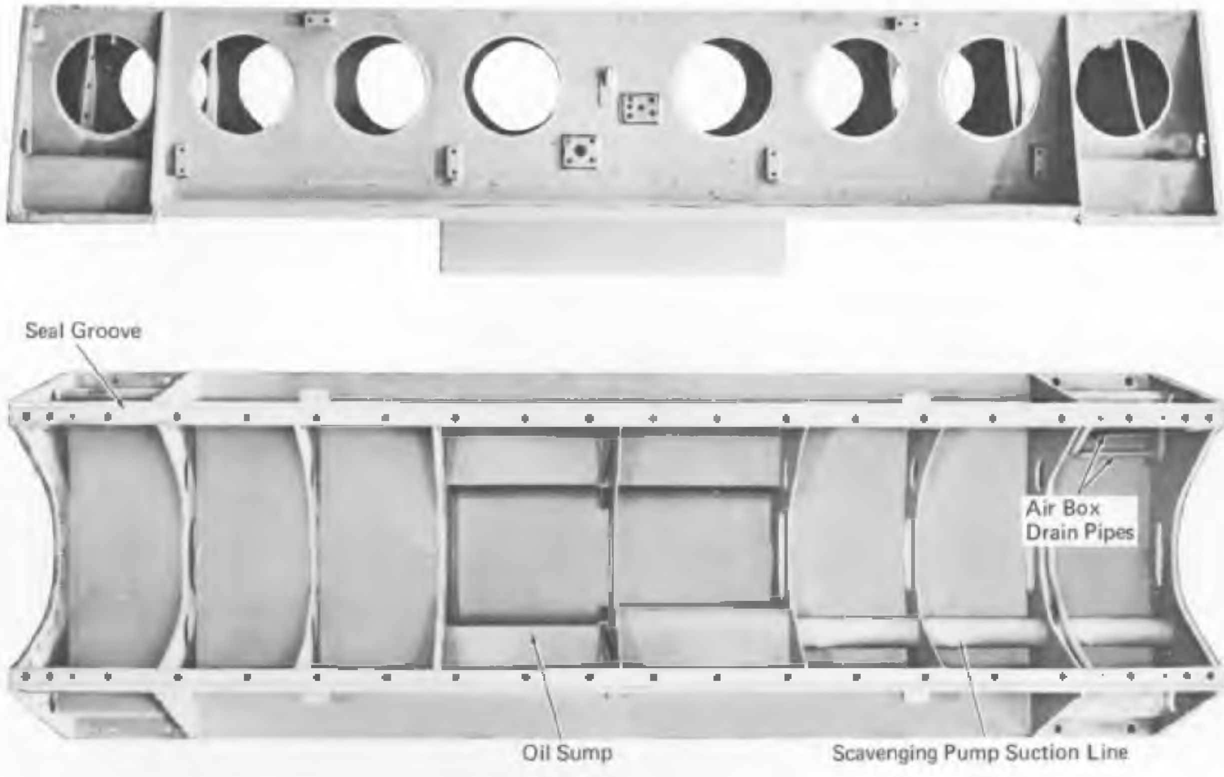

Fig. 1-7 - Typical Oil Pan (16-Cylinder)

CRANKCASE TO OIL PAN SEAL

DESCRIPTION

A round silicone seal cord placed in a groove, Fig. 1-8, in the oil pan mounting rail effectively prevents any leakage at the junction of the crankcase and oil pan.

Fig. 1-8 - Crankcase To Oil Pan Seal

MAINTENANCE

Install seals in the grooves without twisting or stretching, and without lubricant. The individual seals for each model engine are longer than required, but do not cut off seal ends at this time.

Place crankcase over oil pan, and using lineup pin guides in the four corner holes, lower crankcase on oil pan. Apply taper dowel bolts and tighten. Check crankcase to oil pan alignment, using care not to damage seal cord.

CAUTION: Do not pull or stretch the ends of seal cord.

Assemble all crankcase to oil pan bolts with washers and snug four corner bolts to about 136 N-m (100 ft-lbs) torque. Starting with the center bolt and alternating between the bolts to the left and right of center, tighten bolts to a torque of 136 N-m (100 ft-lbs). After tightening bolts on both sides of engine to 136 N-m (100 ft-lbs) repeat tightening sequence bringing bolts to a final torque of 610 N-m (450 ft-lbs).

After all bolts have been tightened to 610 N-m (450 ft-lbs), cut seal cord ends to provide a seal protrusion from face of end plates of 2.38 mm ± 0.40 mm (3/32" ± 1/64"). This seal protrusion will seal the three way joint of oil pan, crankcase, and end housing.

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AIR BOX DRAINS

DESCRIPTION

Accumulation of liquids from the engine air box is removed through drain holes in the base rails of the crankcase, which are aligned with pipes located on each side of the oil pan at the front of the engine, Fig. 1-9. Both pipes connect to a common flange mounted on the oil pan end plate at the left-hand front of the engine.

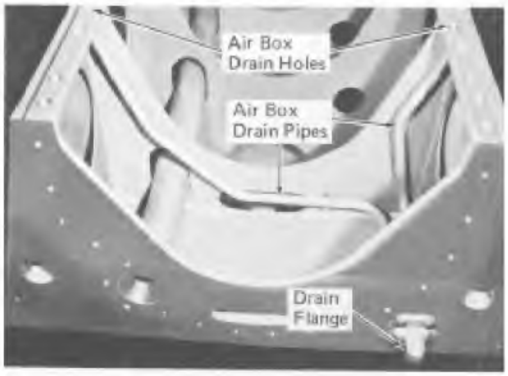

Fig. 1-9 - Typical Air Box Drain Installation

Off-engine piping connects to the flange and provides a constant draining feature for the air box.

MAINTENANCE

The air box drains should be cleaned at the intervals specified in the Scheduled Maintenance Program.

1. Disconnect external piping connected to the drain flange.

2. Remove the drain flange from the oil pan, and clean with brush and solvent.

3. Remove air box handhole covers nearest the drain holes.

4. Feed cleaning tool into the drain hole in the base rail, turning it and using a "rodding" motion to loosen carbon and sludge from inside of drain pipes.

   The cleaning tool can be fabricated from an ordinary plunber's 1/4" music wire snake as follows:

   Cut off the auger head. Fig. 1-10, and form new head by heating the first 25.4 mm (1 ") of the snake with a torch and stretching the tip area to form a loosely wound spiral.

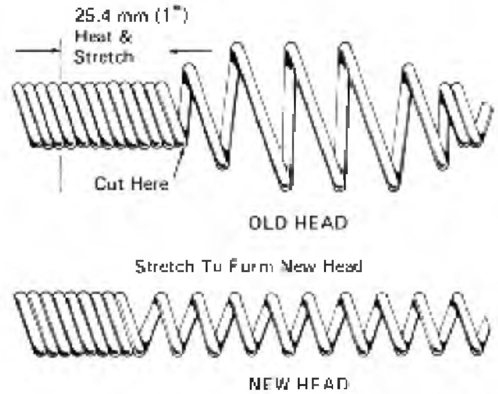

Fig. 1-10 - Snake Modification

5. Once both drains have been completely cleared, flush piping with fuel oil or similar solvent to remove loose material and dissolve additional residue.

6. Mount drain flange to oil pan, reconnect external piping, and reinstall air box handhole covers.

TOP DECK HEAD FRAME AND COVER

DESCRIPTION

Top deck cylinder head frames are mounted on the crankcase to protect and enclose the fuel lines and linkage, camshaft assemblies and rocker arm assemblies. The fabricated frames provide a flat seal surface for the top deck covers. The covers are held in place by easily released latches, making the top deck operating mechanism readily accessible. Support arms are provided to hold the cover open in any one of several positions. Special hinges provide easy removal of the cover for top deck maintenance.

A gasket between the bottom of the frame and crankcase and a rubber seal on the lower surface of the cover provide an air and oil tight seal.

When replacement of either the gasket or seal is necessary, see EMD parts catalog for the correct part numbers.

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MAINTENANCE

Replace top deck cover seals at intervals stated in the applicable Scheduled Maintenance Program, or earlier if the seals are damaged or deteriorated.

When applying new seals to the cover, coat the seal lightly with a small amount of EMD High Temperature resistant grease No. 4. This will prevent the seal from sticking to the frame and being damaged when the cover is raised.

New gaskets should be installed between the frame and crankcase whenever the frames are removed from the crankcase or sooner if the gaskets show signs of leaking.

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SERVICE DATA
CRANKCASE AND OIL PAN

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. *New limits are those to which new parts are manufactured. (Drawing tolerances.)*
2. *Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.*

Upper liner pilot bore -	
New	307.11-307.19 mm (12.091"-12.094")
Max.	307.44 mm (12.104")
Lower liner pilot insert bore (installed in crankcase) -	
New	263.58-263.75 mm (10.377"-10.384")
Max.	263.80 mm (10.386")
Lower liner pilot bore in crankcase -	
New	281.00-281.10 mm (11.063 "-11.067 ")
Max.	281.13 mm (11.068")

Main bearing bore with all caps applied and torqued to 1 017 N-m (750 ft-lbs). Take two sets of main bearing bore measurements at each bore, one set 12.70 mm (1/2") in from the accessory end of the bore and one set 12.70 mm (1/2") in from the generator end of the bore. Ref. Fig. 1-6.

Diameter of bore -	
Max.	209.652 mm (8.2540")
Min.	209.474 mm (8.2470")
Bearing shell to crankshaft clearance (Each side above serrations at split line)	
Min.	0.038 mm (.0015")

EQUIPMENT LIST

	Part No.
Crab stud thread protectors	8034600
Crab nut tap 1-3/4"-12	8050688
Towels (bound-edge wiping towels)	8052752
Main bearing bolt thread die 1-1/4"-12	8060349
Main bearing nut tap 1-1/4"-12	8060387
Crab stud thread die 1-3/4"-12-UNR	9511395
Hydraulic jack (10 ton)	8078281
Ratchet adapter	8140761
Main bearing nut offset ratchet wrench	8191591
Spray gun (for engine cleaning)	8193041
Crab nut power wrench set	8250855
Lower insert application and removal tool	8275379
Press and puller assembly	8275380
Thread Lubricant, Texaco Threadtex No. 2303	8307731
Main bearing stud nut power wrench	8335627
Torque indicator	8377322
High temperature resistant grease No. 4 (10 lbs)	8425725
Main bearing stud nut socket	8474773
Main bearing cap application and removal tool	8487487
Anchor plate assembly	9080987

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SECTION 2

CYLINDER HEAD AND ACCESSORIES

CONTENTS	PAGE
CYLINDER HEAD ASSEMBLY	
DESCRIPTION	2-1
MAINTENANCE	2-1
VALVE AND SPRING REMOVAL	2-2
VALVE GUIDES	2-3
CLEANING	2-3
CYLINDER HEAD LEAK TEST	2-3
INSPECTION	2-4
CYLINDER HEAD REBUILD	2-4
INJECTOR HOLE REWORK	2-4
FIREFACE REFINISHING	2-4
VALVE SEAT GRINDING	2-5
EXHAUST VALVES	
DESCRIPTION	2-8
MAINTENANCE	2-8
CLEANING	2-9
INSPECTION	2-9
GRINDING VALVES	2-10
VALVE SPRING, SEAT, AND LOCK	2-10
EXHAUST VALVE INSTALLATION	2-10
VALVE STEM HEIGHT CHECK	2-10
VALVE SEAT SEAL TEST	2-10
EXHAUST VALVE BRIDGE ASSEMBLY	
DESCRIPTION	2-11
CLEANING	2-11
DISASSEMBLY	2-12
INSPECTION	2-12
LASH ADJUSTERS	
DISASSEMBLY	2-13
CLEANING	2-13
INSPECTION	2-13
ASSEMBLY	2-13
QUALIFYING LASH ADJUSTERS	2-13
VALVE BRIDGE ASSEMBLY	2-14
ROCKER ARM ASSEMBLY	
DESCRIPTION	2-15
MAINTENANCE	2-15
ROCKER ARM SUPPORT ASSEMBLY	
DESCRIPTION	2-16
MAINTENANCE	2-16
CYLINDER TEST VALVE	
DESCRIPTION	2-16
MAINTENANCE	2-17/2-18
CYLINDER HEAD SEAT RING	
DESCRIPTION	2-17/2-18
MAINTENANCE	2-17/2-18
SERVICE DATA	
SPECIFICATIONS	2-19
EQUIPMENT LIST	2-20

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SECTION
2

ENGINE MAINTENANCE MANUAL

CYLINDER HEAD AND ACCESSORIES

CYLINDER HEAD

DESCRIPTION

The cylinder head, Fig. 2-1, is made of cast iron alloy with cast passages for water and exhaust gases. Drilled water holes at the bottom of the cylinder head match the water discharge holes in the liner. Cooling water is circulated through the head and is discharged through an elbow mounted on the side of the head mounting flange. Exhaust passages in the cylinder head line up with elbows in the crankcase, which conduct the exhaust gases through the water discharge manifold to the exhaust manifold.

A well is located in the center of the cylinder head for application of the unit fuel injector. To ensure correct positioning of the injector, a mating hole for the injector locating dowel is located in the head.

Fig. 2-2 shows the rocker arms, exhaust valves, valve bridges with springs, valve guides, overspeed trip pawl, fuel injector, and other related items making up a complete cylinder head assembly.

MAINTENANCE

NOTE: Procedures for disassembly, assembly, and qualification of cylinder head components are contained in this section. Procedures for removal and installation of a cylinder head or of a complete cylinder power assembly are contained in Section 5.

Fig. 2-1 - Cylinder Head With Valves

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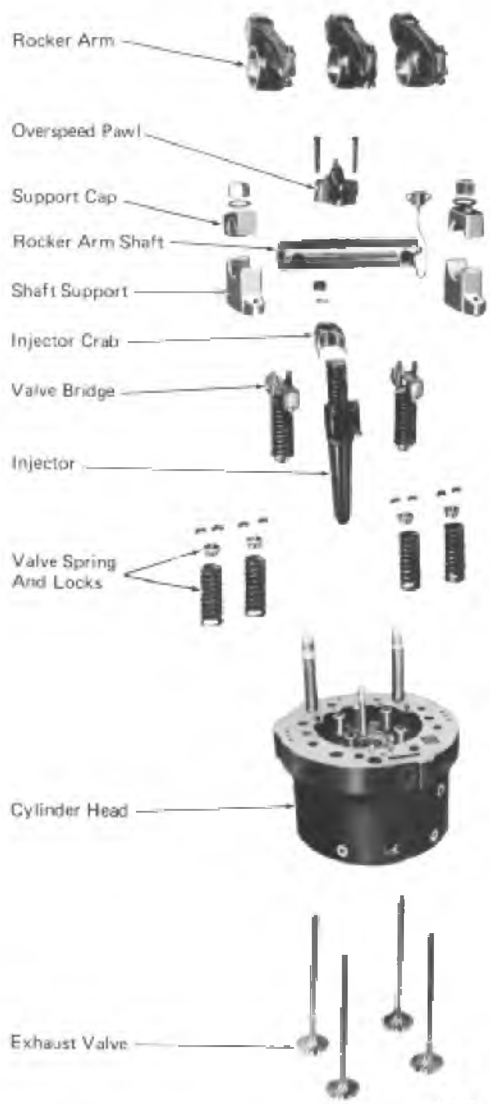

Fig. 2-2 - Complete Cylinder Head Assembly, Exploded View

EXHAUST VALVE AND SPRING REMOVAL

1. Remove exhaust valve springs using single valve spring compressor and adapter screwed into the head, or the multiple valve spring compressor, Fig. 2-3.

SINGLE

MULTIPLE

Fig. 2-3 - Compressing Valve Springs

2. Compress the springs sufficiently to remove the valve locks and spring seats, and then remove the springs.

3. After spring removal, the exhaust valves can be removed from the bottom of the head. NOTE: Valve springs can be removed and replaced without removing the cylinder head from the engine. If this is done, the piston must be at top center to prevent the valves from falling into the cylinder when the valve locks are removed.

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VALVE GUIDES

Cast iron valve guides are press fit in the cylinder head and can be pressed in or out without damage by using a valve guide installing or removing tool. Although the valve guides generally do not require reaming after assembly, it is recommended that a plug gauge he inserted alter guide installation to ensure minimum diameter.

CLEANING CYLINDER HEAD

1. Clean cylinder head in a suitable solvent to remove surface oil and loosen baked-on carbon. Cleaning should be in accordance with accepted practice or as recommended by supplier of the cleaning material.

CAUTION: Do not use any form of blast cleaning (glass, sand, or shot) on the fireface of the head as blasting tends to remove sharp edges of the phonograph grooves of the gasket surface, reducing its sealing effectiveness.

2. Remove loose material from stud holes using stud hole cleaner and 115 volt or 230 volt drill, Fig. 2-4.

Fig. 2-4 - Cleaning Stud Holes

3. Clean the cylinder test valve threads using standard 1/2" pipe thread tap.

4. Using valve guide cleaner and a 115 volt or 230 volt drill, clean guide as shown in Fig. 2-5. Any evidence of galling inside of guide must be entirely removed by reaming, or the guide should be replaced. The I.D. of the guide should not exceed the limit when measured at the bottom and 12.7 mm (1 /2") from top and bottom.

Fig. 2-5 - Cleaning Valve Guides

5. Clean phonograph finish of fireface using wire brush in a circular motion to remove dirt and carbon from phonograph grooves.

CYLINDER HEAD LEAK TEST

Seal all water passages in the head and apply 586 to 655 kPa (85 to 95 psi) air pressure to the passages. Immerse the head in water maintained at 71° C (160° F) for two minutes. Using this method, the leaks are easily detected and minor leaks are opened-up by the hot water for easy detection.

NOTE: When performing the cylinder head leak test, a scrap injector should be installed using an injector crab, spherical washer and nut. Torque nut to 81 ± 14 N-m (60 ± 10 ft-lbs) before immersion into the hot water.

Core plug leaks can usually be repaired by replacing the plug. Leaks caused by cracks, porosity, or dirt inclusion are cause for rejection.

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INSPECTION

Inspect cylinder head for cracks using magnaflux procedures. Small magnaflux indications in the blend between the injector hole and the fireface may be removed by machining or grinding.

Scratches or nicks in the sealing areas for the head gasket or the grommet sealing areas require fireface refinishing. Small scratches or nicks in the phonograph finish area outside the sealing areas for the head gasket or grommets do not require refinishing.

Small scratches and nicks are permissible in the area inboard of the combustion gasket sealing area on the fireface of the head. If such small defects exist, there is no need to re-finish the face.

Inspect valve seats for pits and burned areas and perform dimensional checks. Seats not meeting visual or dimensional criteria must be resurfaced.

NOTE: Any head removed from an engine that has been overheated enough to "cook out" the head-to-liner grommets should be scrapped due to irreparable damage to the head.

CYLINDER HEAD REBUILD

A cylinder head with damaged valve seats, flange seating surface, fireface surface, or injector hole should be reworked in accordance with the following procedures.

INJECTOR HOLE REWORK

1. Blend chatter marks and gouges smooth at injector hole to fireface surface, leaving no sharp corners on injector seat side or fireface side of the blend.

2. Do not exceed maximum injector hole diameter or maximum allowable blend radius, Fig. 2-6.

FIREFACE AND FLANGE SEATING SURFACE REFINISHING

Refinishing of the cylinder head fireface and flange requires special tooling and procedures.

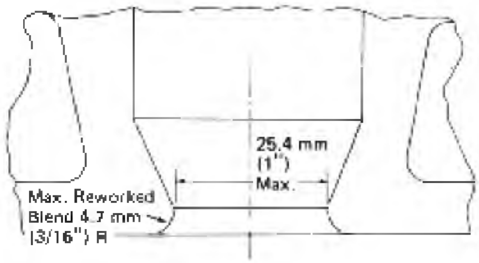

Fig. 2-6 - Injector Hole Rework

The following paragraphs contain recommendations for tooling and procedures to meet the required rework limits, Fig. 2-7.

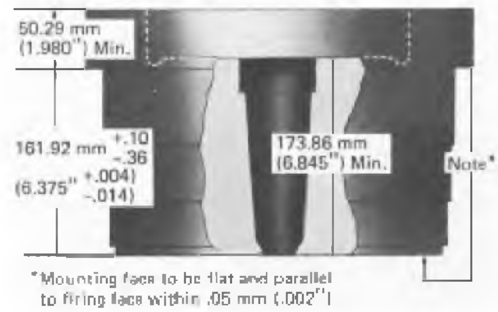

Fig. 2-7 - Rework Limits

1. A vertical lathe is recommended because of' ease of loading and unloading; although any machine capable of chucking and turning a head will do.

2. The following commercial tools are listed for reference:

   Insert-Valenite SPC-424 grade VC28 1/16" nose radius.

   Insert Holder-Valenite NVS-DN-12-C.

3. The depth of cut should be held to a minimum to extend the reconditioning life of the head. A cut of 0.152-0.203 mm (.006-.008") on the gasket surface and 0.254-0.406 mm (.010-.016") on the milled surface should be sufficient to clean up the fireface.

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NOTE: To minimize the depth of cut, care should be taken to set up off the fireface rather than locating off the top of the flange.

4. Set feed at 0.61 mm (.024") per revolution and the rpm varied to maintain 76.2 smpm (250 sfpm). To achieve this constant cutting speed, the spindle speed will have to be increased as tile tool approaches the center of tile head to avoid tearing the surface of the head around tile injector hole.

5. The distance between the underside of the flange and the gasket surface of the fireface must be maintained, Fig. 2-7. To hold this dimension within specification, it will generally be necessary to machine the fireface and underside of the flange simultaneously because of the tight requirement on parrallelism between tile underside of the flange and the fireface, Fig. 2-8. However the cut on the underside of the flange should be held to a minimum within the allowable range of the fireface to flange dimension.

6. Sharp edges in the chamfer blend from the injector hole to the fireface must be blended smooth by hand using emery cloth. Deep scratches or gouges should be reworked in accordance with "INJECTOR HOLE REWORK".

VALVE SEAT GRINDING

To ensure uniform seat width and proper location of the seating area relative to the seat on the exhaust valve, while holding the specified concentricity to the valve guide bore, the valve seat I.D., O.D., and seating surface must be ground relative to the centerline of the valve guide bore.

Using any one of the valve seat reconditioning tool sets listed in service Data, perform the following procedures.

1. Mount each of the three grinding wheels on its own holder and dress the 45° wheel to 65°, the 30° wheel to 20°, and the 30° finishing wheel to 30°, Fig. 2-9.

NOTE: Use separate dressing tool for each wheel to maintain seat angle accuracy.

Original Finish

Reworked Finish

Fig. 2-8 - Fireface And Flange Refinishing

a. Lubricate dressing tool pilot with light film of oil.

b. Mount grinding wheel and holder on dressing tool pilot, Fig. 2-10.

c. Check that dressing tool is adjusted to proper angle for tool being dressed.

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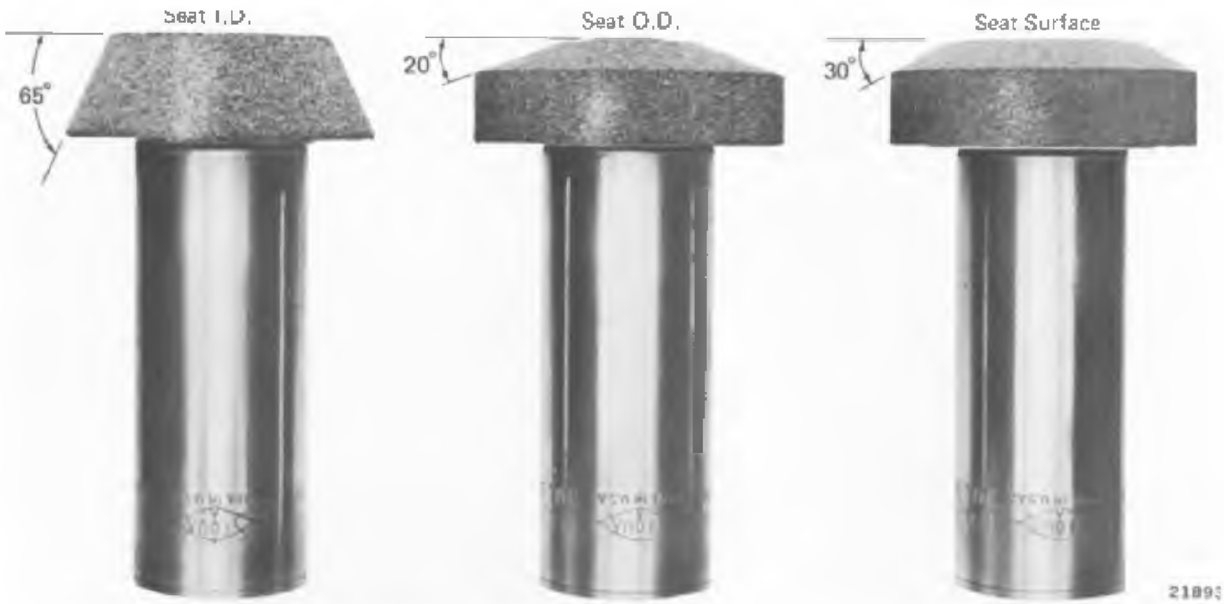

Fig. 2-9 - Valve Seat Grinding Wheels And Holders

Fig. 2-10 - Dressing Valve Seat Grinding Wheel

d. Apply driver to wheel holder and rotate wheel and holder at high speed, holding driver as straight as possible.

e. Move diamond steadily across wheel, taking light cuts until wheel face is smooth and at the proper angle.

2. Select a tapered pilot which will bring the shoulder on the pilot above the valve guide. Press pilot firmly into guide, using pin, Fig. 2-11. Wipe pilot with an oily cloth.

   A fixture, Fig. 2-12, is available for checking tapered pilots. To ensure satisfactory results, pilot runout should not exceed 0.013 mm (.0005 ").

3. Install lifter spring over tapered pilot, Fig. 2-13, and place 30° grinding wheel and holder over the pilot and spring.

4. Apply driver to wheel holder and grind the 30° seat angle until the width of the seat is at least 2.36 mm (.093") all the way around. The driving motor should be held as straight as possible, Fig. 2-14, and operated at top speed while grinding. Raise grinding motor off seat before stopping motor.

5. Remove 30° grinding wheel and apply 65° grinding wheel and holder over pilot and lifting spring.

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Fig. 2-11 - Tapered Pilot Installation

Fig. 2-12 - Tapered Pilot Checking Fixture

Fig. 2-13 - Lifting Spring Application

2-14 - Grinding Valve Seat

6. Grind 65° until the area adjacent to the 30° scat is smooth and clean.

NOTE: Grind away as little material as possible to maximiic the wear life of the scats.

7. Remove 65° grinding wheel and apply 20` grinding wheel and holder over pilot and lifting spring.

8. Grind 20° angle until the area adjacent to the 30° seat is clean and smooth. ('ontinue grinding until seat width is within the specified tolerance.

9. Check valve seat for proper dimensions, Fig. 2-15. If seat O.D. is too small, regrind seat with 30° grinder until O.D. is proper dimension. Then grind seat I.D. with 65° grinder until proper seat width is obtained.

   If seat O.D. is too large, regrind O.D. with 20° grinder until proper O.D. dimension is obtained. It' seat width is too small, grind seat with 30° grinder and O.D. with 20° grinder alternately until proper seat O.D. and scat width are obtained.

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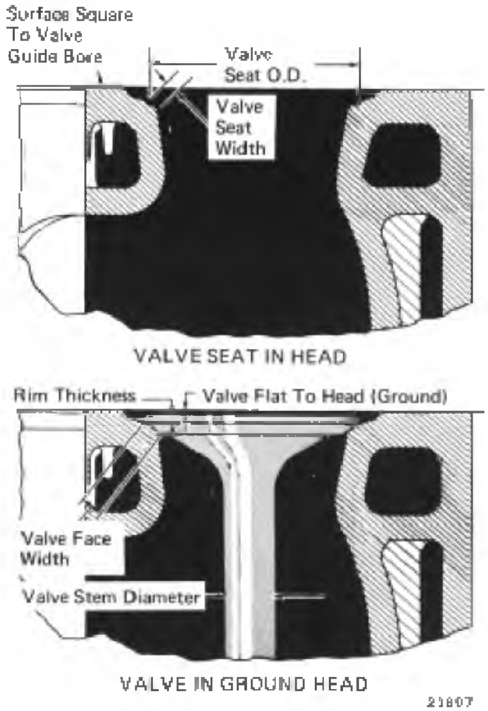

Fig. 2-15 - Valve Measurement Points

10. Reapply 30° wheel and grind seat lightly to remove burrs and improve the surface finish.

11. Use dial indicator included in the valve seat reconditioning set to measure trueness of valve seat. Place indicator over pilot, Fig. 2-16, and adjust so indicator is depressed slightly and

Fig. 2-16 - Checking Valve Seat Roundness

ball of valve seat rider is at the center of the valve seat. Rotate valve seat rider and observe indicator reading. Valve seat out-of-round will be indicated on the dial. Indicator reading must not exceed the limit.

12. With the head positioned with the fircface up, install new valve in each position and measure the vertical distance from the fireface of the head to the rim of the exhaust valve, Fig. 2-15.

EXHAUST VALVES

DESCRIPTION

The long stein exhaust valves, Fig. 2-17, are fabricated from a forged nickel-chromium alloy steel head and a tip hardened steel stem by means of friction welding. Single bead valve locks hold the valve in a tapered spring seat. Precision valve guides ensure proper valve seating.

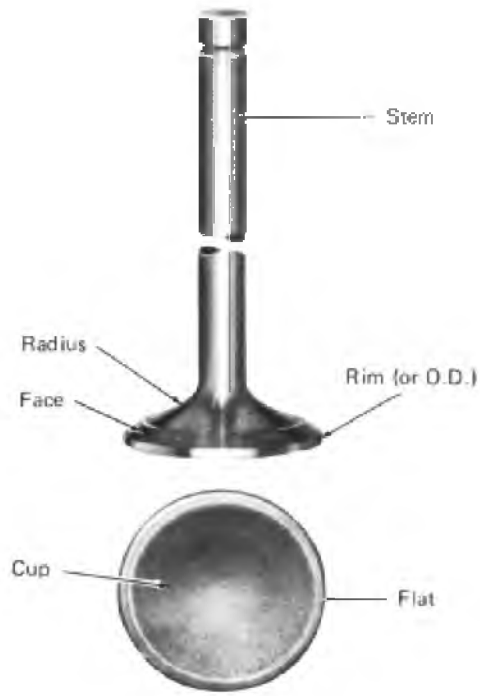

Fig. 2-17 - Exhaust Valve

MAINTENANCE

Handle valves carefully to avoid nicks and scuffs that might make the valve unfit for use. Piling valves on top of each other may cause nicks on the outside diameter or throat radius which can lead to valve failure. Before the valves can be reused, they must be reconditioned within the dimensional linlits listed in the Service Data at the end of this section.

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CLEANING

Thoroughly clean the exhaust valves using a suitable solvent to remove surface oil and loose carbon. If necessary, use glass bead and vapor blasting to remove hard carbon deposits from the valves. Grit vapor blast must be maintained at a small enough size so the surface finish of the valve stems is not roughened beyond 0.635 µm (25 µ in.). If glass bead blasting is not available, wire brushing may be used as an alternative.

INSPECTION

Exhaust valves must be qualified by visual and Zyglo inspection prior to reconditioning. Acceptable conditions which allow valve reuse, and rejectable conditions which are cause for scrapping the valve are listed below. The valve surfaces referenced are identified in Fig. 2-17.

Acceptahlc Conditions:

1. Light pitting on the valve face that can be cleaned up within the maximum allowable valve face limit.

2. Protruding nicks and gouges in the valve stem must be removed before the valve face is ground in order to avoid scuffing of the valve guide and to ensure proper valve face runout. Belt sanding or buffing may be used to polish off protrusions, provided that the surface finish of the stem is maintained at or below 0.635 µm (25 µ in.) with a circumferential lay.

Rejectable Conditions:

1. Indications found in the cup area, Fig. 2-18, are defects which require rejection of a valve.

2. Any cracks found on the outside diameter of ring section of the valve, Fig. 2-19 are cause for rejection. Since rim cracks usually extend some distance into the valve face, they usually lead to failure.

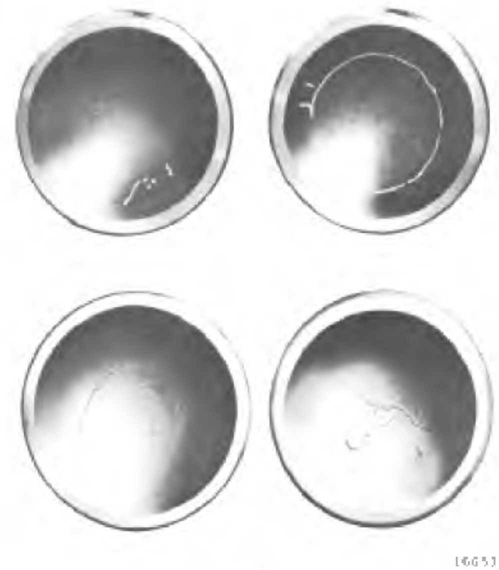

Fig. 2-18 – Cup Defects

Fig. 2-19 - Face And Ring Defects

The face area, Fig. 2-19, is the critical area of the valve. Grinding cracks, channeling, and thermal cracks are cause for valve rejection.

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3. Fretting or wear in the lock groove area of the stem is cause for rejection.

4. Reject valves that have been damaged to the extent that critical surfaces have been nicked or scuffed.

GRINDING VALVES

Follow instructions supplied with the 115 or 230 volt grinder for grinding valves. A complete listing of the eduiptrnent required for the machines is contained in the Service Tool Catalog.

VALVE SPRING, SEAT, AND LOCK

1. Inspect valve springs and valve bridge springs for any nicks or unusual wear. Valve springs should be cleaned with a suitable solvent and a soft wire brush. Do not hydro blast or grit blast. Valve springs should be protected to prevent rusting.

2. Perform dimensional and prcssurc checks to dualify valve springs.

3. Valve spring seats should be clean and smooth and the thickness of' the spring seating surface should not be less than the minimum limit.

4. Examine the valve locks, Fig. 2-20, for signs of excessive wear on the upper portion of' the bead and for evidence of' excessive fretting in the ground diameter which engages the valve stem. If these conditions exist, the locks should be replaced.

Fig. 2-20 - Valve Spring Seat Lock

EXHAUST VALVE INSTALLATION

After the exhaust valves have been reconditioned, they are applied to the reconditioned cylinder head. Position the head properly and complete the assembly of valve springs, spring seats, and valve locks.

VALVE STEM HEIGHT CHECK

1. Clean bottom of train feet, and that portion of the head on which the feet rest.

2. Apply tram firmly on cylinder head, Fig. 2-21.

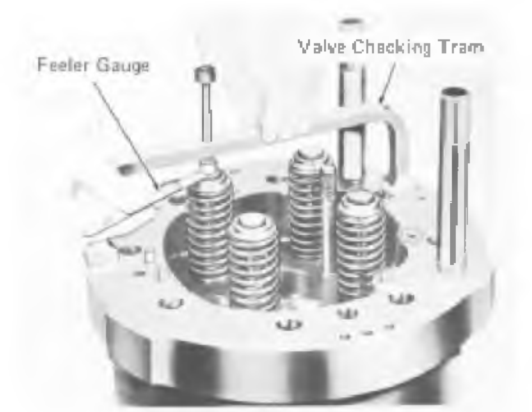

Fig. 2-21 - Checking Height Of Valve Sterns

3. Using feeler gauge and tram adjusting screw, determine difference in valve stern heights. The difference between valve stems under the same bridge should not vary more than 1.59 mm (1/16"). If the difference varies more than 1.59 mm (1/16"), the high valve should be replaced or the low valve ground in, provided this does not exceed the limit. Fnd of valve stem should not be ground off, as the tip is hardened.

VALVE SEAT SEAL TEST

1. Place head in an angular position, resting on the rocker arm studs with valve seats in the up position.

2. Wipe bottom of head to remove dirt and dust.

3. Apply a light film of oil to the concave surface of the tester vacuum cup and attach tester to cylinder head with handle in six o'clock position, and covering one valve, Fig. 2-22.

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Fig. 2-22 - Testing Valve Seat Seal

Ensure that tester cup is finely seated on fireface and not on the head of the valve.

4. It' tester suction to fireface is depleted in less than two minutes, the valve seating is defective and the head seat and/or valve face must be reworked.

5. Open trigger valve to remove tester from head surface.

6. Check valve seat seal tester by applying it to a vertical piece of glass, as the release valve or rubber cup may be defective.

EXHAUST VALVE BRIDGE ASSEMBLY

DESCRIPTION

The valve bridge, Fig. 2-23, operates two exhaust valves from one rocker arm. A spring and spring seat are held on the valve bridge stem by a lock ring. The spring seat rests in a socket in the cylinder head and the spring applies pressure to maintain contact between the valve bridge and the rocker arm.

The hydraulic lash adjuster maintains zero lash between the end of the valve stem and the valve bridge. Lube oil flows from the rocker arm through a drilled passage in the valve bridge to the top of the lash adjuster, past the ball check, and into the body. When the rocker arm depresses the valve bridge, a slight movement of the plunger in the lash adjuster seats the ball check, trapping the oil. Since the oil is practically incompressible, further movement of the rocker arm causes the lash adjuster plunger to force open the exhaust valve.

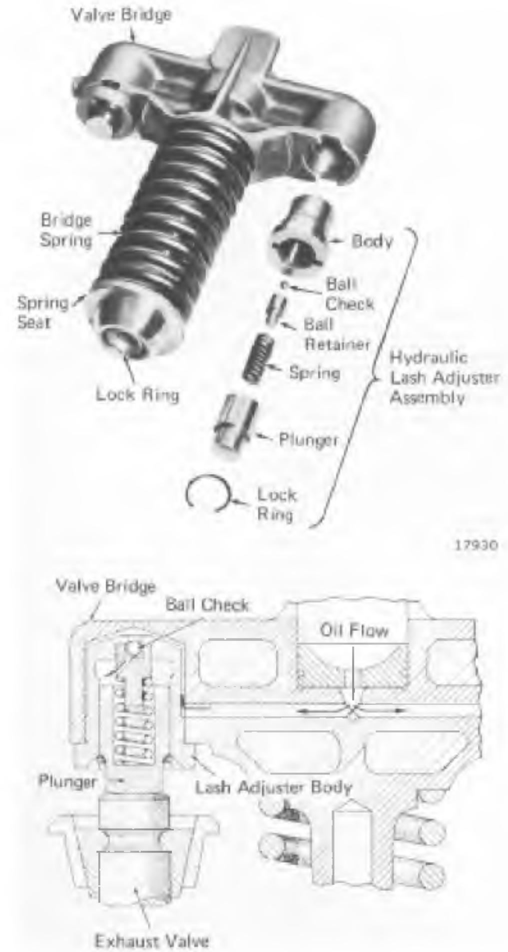

Fig. 2-23 - Valve Bridge Assembly

CLEANING

Prior to disassembly of the valve bridge, clean assembly with solvent. Do not use a caustic type cleaner, as the brass spring seat will be damaged.

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DISASSEMBLY

1. Remove lash adjuster assembly from bridge, using adjuster puller, Fig. 2-24.

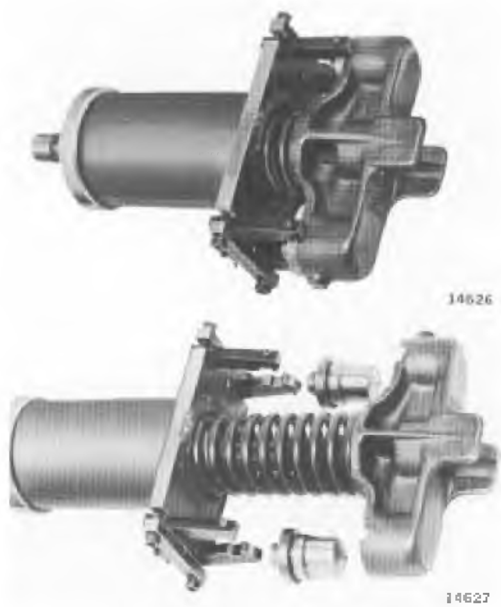


Fig. 2-24 - Removing Hydraulic Lash Adjuster

2. Mount valve bridge spring compressor in vise, Fig. 2-25. Install valve bridge in compressor, compress spring, remove lock ring, and remove spring seat and spring.

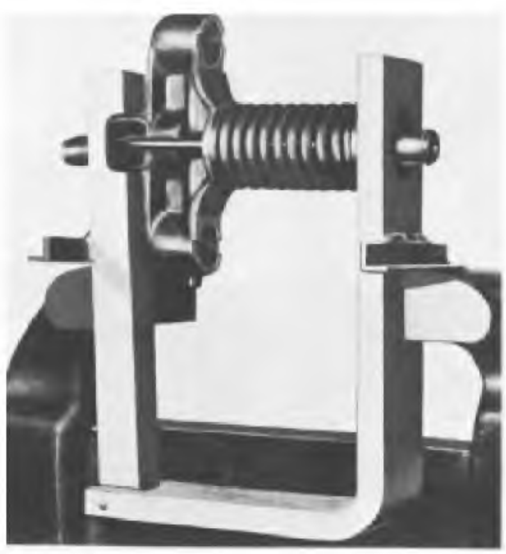
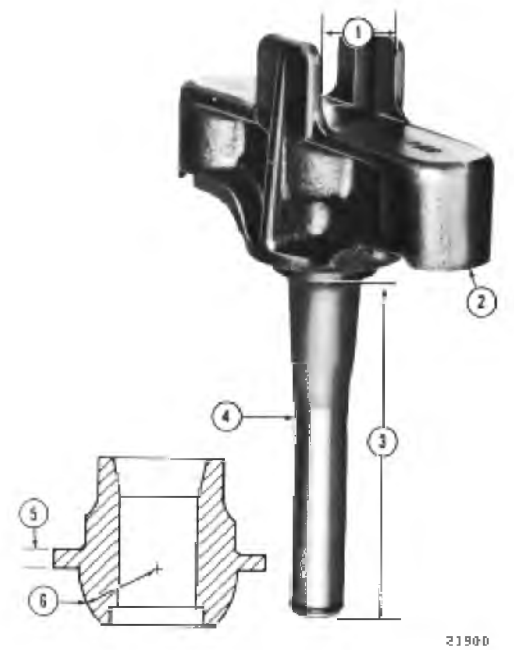


Fig. 2-25 - Compressing Valve Bridge Spring

INSPECTION

Visually inspect valve bridge parts and replace those that are damaged beyond repair. Check the pin in the end of the valve bridge to see that it is tight. Also check the valve bridge for a bent shank. If the shank is slightly bent, it may be straightened and re-used.

Inspect the valve bridge and spring seat at the points shown in Fig. 2-26, and refer to dimensions in the Service Data at the end of this section.



Refer to Service Data for applicable dimensions.

1. Distance between rocker arm guide ears.
2. Lash adjuster socket diameter.
3. Valve bridge shank length.
4. Shank diameter from shank end to 63.5 mm (2.50") above shank end.
5. Spring seat rim thickness.
6. Spring seat spherical radius.

Fig. 2-26 - Valve Bridge Measurement Points

Refer to "LASH ADJUSTER" portion of this section for maintenance and qualification of lash adjuster assemblies.

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LASH ADJUSTER

DISASSEMBLY

1. Depress lash adjuster plunger and remove locking ring, Fig. 2-23.

2. Carefully disassemble lash adjuster to avoid damaging the machined surfaces on the inside diameter of the body or the outside diameter of the plunger.

3. Replace spring and ball check with new parts prior to assembly of lash adjuster.

CLEANING

1. Lash adjuster parts may be cleaned using fuel oil. Lacquer deposits can be removed with alcohol, lacquer thinner, or other suitable solvent. Completely remove any dirt, lacquer, or metal particles.

2. Do not buff the outside or inside diameter of the body, the outside diameter of the plunger, or the spherical radius on the tip of the plunger.

INSPECTION

1. Inspect the body for scores, scratches, or galled areas on the machined outside diameter, and replace if any are found.

2. Inspect the plunger for scores, scratches, or galling on the outside diameter, and replace if evidenced. Also, inspect the plunger tip, and if the contact point is worn flat more than 6.35 mm (.250") in diameter, the plunger should be replaced.

3. Inspect the ball retainer 4.22 mm (.166") diameter counterbore depth at the center of the ball depression. Replace the ball retainer if the depth is greater than 3.63 mm (.143").

ASSEMBLY

Assemble lash adjuster in an area free of dirt. lint, and metal particles.

QUALIFYING LASH ADJUSTERS

It is recommended that lash adjuster test stand, Fig. 2-27, be used to qualify the lash adjusters for use in the engine. This test stand automatically measures the time required for the lash adjuster plunger to travel through 1.52 mm (.060") while it is subjected to a 13.6 kg (30 lbs) ram load, and rotated about 10 RPM relative to the lash adjuster body.

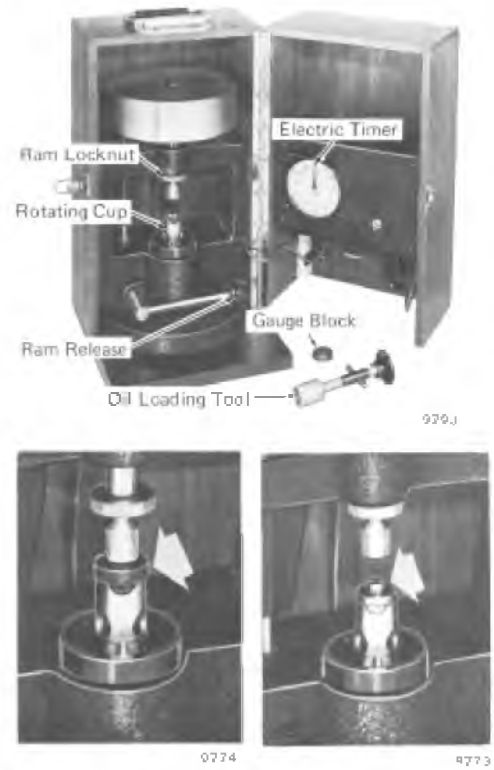

Fig. 2-27 - Lash Adjuster Test Stand

A gauge block and oil loading tool, Fig. 2-27, are supplied with the stand. The gauge block is used to check and adjust the tripping point of the microswitches, if necessary, to ensure that the leak down time is measured over exactly 1.52 mm (.060") travel of the lash adjuster plunger. The oil loading tool is used to charge the lash adjuster with oil and bleed off any air which might cause incorrect leak down time intervals. It is essential that only Electro-Motive hydraulic lash adjuster test oil be used in conjunction with this test stand since the operation of the test and limits governing the lash adjuster are based on the use of this oil.

TEST STAND OPERATION

The 1.52 mm (.060") travel of the ram starts when the tip of the ram is 9.52 mm (.375") from the top of the rotating cup. This starting point should be checked with the 9.52 mm (.375") gauge block supplied with the test stand, and it should be checked often enough to be sure it has not changed. This check is to be made by placing

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the gauge block on top of the rotating cup with the step facing up, and then lowering the ram by turning the ram release. The time clock on the test stand should start the very moment the ram load contacts the gauge block. If the timer does not start, or starts too soon, the ram should be readjusted. This is done by loosening the ram locknut, turning the ram tip up or down to the proper adjustment, and retightening the locknut. The time clock start and stop microswitches are permanently set so that the time for the 1.52 mm (.060") travel is automatically recorded on the time clock. (If a microswitch has to be replaced, the 1.52 mm (.060") between the microswitch positions should be set by inverting the gauge block which has a 1.52 mm (.060") step on it.)

TEST PROCEDURE

1. Place the lash adjuster assembly in oil loading tool and immerse it into a container of lash adjuster test oil that is deep enough for the hole in the lash adjuster to be well below the oil level.

2. Completely depress the lash adjuster plunger at least 10 times to ensure that any air trapped inside is pumped out.

3. Retract the spring-loaded plunger in the oil loading tool and allow the ball check to seat in the lash adjuster. Try to depress the lash adjuster plunger two or three more times to ensure that the ball check is seating. The assembly should feel firm, without any "give" to it.

4. Take the lash adjuster out of the test oil and remove the oil loading tool being careful that the spring-loaded plunger does not unseat the ball check. Wipe the excess oil off the lash adjuster and place it in the rotating cup on the test stand.

5. Turn the switch on to rotate the cup. Lower the ram until it rests on the lash adjuster plunger and release handle so that the plunger carries the full 13.6 kg (30 lbs) load.

NOTE: Be sure the lash adjuster body is rotating around the plunger.

6. The time for 1.52 mm (.060") travel (leak down time) will be automatically recorded on the time clock. The "leak down time" should be within limits of ten seconds minimum and 40 seconds maximum, based on a normal temperature of 24° C (75° F) for the oil and lash adjuster. If the temperature of the oil and lash adjuster is other than 24° C (75° F), the limits should be detennined by the following:

Oil And Lash Adjusters Temp. °C	°F	Min. Leak Down Time Seconds	Max. Leak Down Time Seconds
16	60	15.8	70.6
18	65	13.2	54.8
21	70	11.4	45.2
24	75 (Base)	10.0	40.0
27	80	9.0	36.0
29	85	8.0	32.6
32	90	7.2	30.2
35	95	6.6	28.4
38	100	6.2	27.8

The temperature of the test oil and lash adjuster should be allowed to become stable before leak down checks are made. If a lash adjuster fails to pass the minimum "leak down time," it should be refilled and retested to be sure that the failure was not due to air trapped in the lash adjuster.

ASSEMBLY OF VALVE BRIDGE

1. Using the valve bridge spring compressor, Fig. 2-25, assemble a qualified spring, spring seat and lock ring to the valve bridge.

2. Install the lash adjuster assembly in the valve bridge, using the installer tool, Fig. 2-28.

Fig. 2-28 - Installing Lash Adjuster

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ROCKER ARM ASSEMBLY

DESCRIPTION

Three rocker arms, Fig. 2-29, are mounted on the cylinder head. Two rocker arms actuate the four exhaust valves, the third operates the injector. The rocker arms are operated directly by the camshaft through a cam follower roller mounted at the fork end of each rocker arm. The opposite end of each rocker arm has an adjusting screw and locknut for setting the injector timing and adjusting the hydraulic lash adjusters. The injector rocker arm, although similar in appearance to the exhaust rocker arm, is stronger than the exhaust rocker arm, and can be identified by the yoke at the cam follower end which is square-shaped on the injector rocker arm, but V-shaped on the exhaust rocker arm. Also, only the injector rocker arm has the machined notch for the overspeed trip. Injector and exhaust rocker arms are not interchangeable.

Lubricating oil is supplied to the cam follower assembly and the adjusting screw end through drilled passages in the rocker arm.

MAINTENANCE

Remove adjusting screw and cam follower races, bushings, and pin and thoroughly clean all parts in fuel oil or similar solvent. Do not clean inner and outer races and bushings in a caustic solution. Handle parts with care to avoid nicking the bearing surfaces.

1. Inspect the rocker arm bushings, cam follower rollers, inner race, Fig. 2-30, and rocker arm shaft for evidence of heat discoloration, excessive wear, shelling or scuffing due to lack of lubrication and for fatigue cracks.

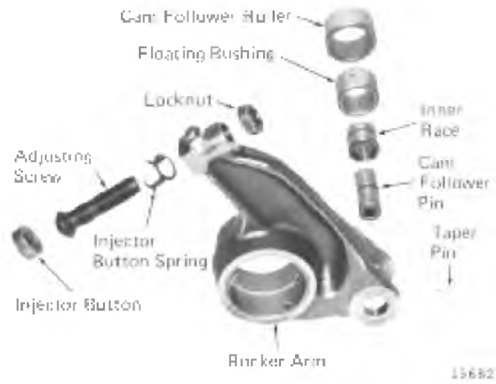

Fig. 2-30 - Injector Rocker Ann, Exploded View

2. Check that all oil holes and passages are clean.

3. All adjusting screws should be checked for hand-free operation and any galling on the ball end.

4. All adjusting screw buttons should be visually checked for galling or cracking.

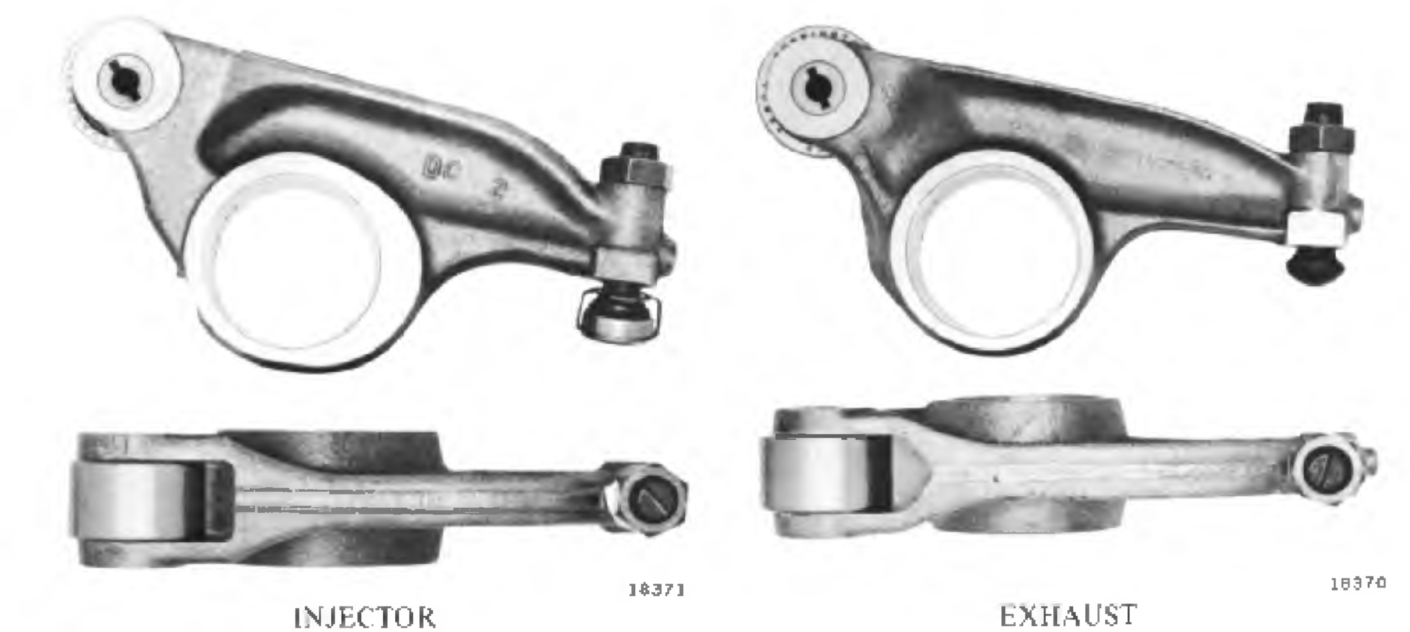

Fig. 2-29 - Rocker Arms

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ROCKER ARM SUPPORT ASSEMBLY

DESCRIPTION

The rocker arms are mounted on rocker arm shaft which is held at each end between a shaft support and shaft cap, Fig. 2-31. Lubricating oil is supplied to the rocker arms through drilled passages in the rocker arm shaft and an oil supply line from the cam shaft bearing bracket.

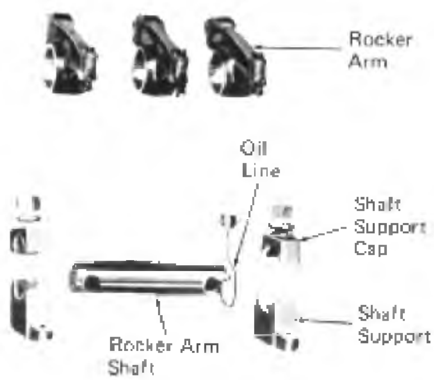

Fig. 2-31 - Rocker Arm Support Assembly

MAINTENANCE

Thorougly clean shaft, support caps, and support in suitable solvent. Check that oil passages in shaft and oil line are clean and free from obstructions.

Check shaft diameter at wear step for proper dimensions, and check for cracks, scratches, or galling in the bearing areas.

Check the shaft support for the correct height dimension between the base and bottom of the bore. Holding this dimension with the limits will ensure that the height mismatch between supports for any one cylinder will be 0.15 mm (.006") or less. Mismatch greater than 0.15mm (.006") can lead to camshaft lobe distress and broken rocker arm studs.

A flat and true nut seating surface must be provided on the support cap or broken washers and studs can result. If a seating surface is damaged, it may be remachined until a minimum dimension of 12.70 mm (I 2") is obtained between the seating surface and top of bore. The surface must be machined square with the stud hole and parallel with the centerline of the rocker rocker arm shaft within 0.25 mm (.010") total indicator reading. Cracks in the cap or shaft support are cause for rejection.

CYLINDER TEST VALVE

DESCRIPTION

Cylinder test valves, Fig. 2-32, are provided on the engine at each cylinder. Any time maintenance or inspection if performed, the valves are opened to relieve compression, reducing the effort required to rotate the crankshaft. With the test valves open, fuel and coolant leaks can be detected by fluid discharge at the valves while the engine is being barred over. The cylinder test valve is inserted in a housing within the crankcase and screwed into the cylinder head. A cylinder test valve wrench, Fig. 2-33, is used to open and close the valves.

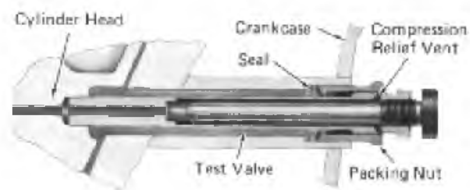

Fig. 2-32 - Cylinder Test Valve

Fig. 2-33 - Test Valve Wrench

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MAINTENANCE

1. If a cylinder test valve is leaking, check that packing nut, Fig. 2-32, has been torqued to 81-88 N-m (60-65 ft-lbs). If nut has been overtightened, change seal, Fig. 2-32, and correctly torque packing nut. Should valve continue to leak, remove the valve from the engine and ream the valve seat as shown in Fig. 2-34.

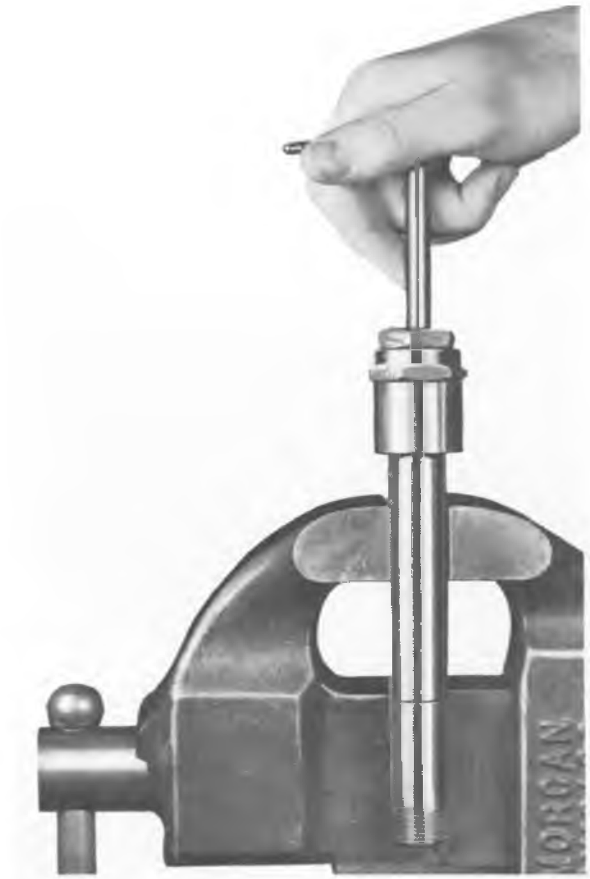

Fig. 2-34 - Reaming Test Valve Seat

2. If reaming will not correct the leaking due to a scored or damaged valve stem face, it should be reconditioned within the limits shown in Fig. 2-35. Reharden the tip to a depth of 0.13-0.25 mm (.005"-.010").

3. The cylinder test valve body may be reworked to the dimensions shown in Fig. 2-35. Use reamer to recondition the valve seat. If necessary to exceed the 6.35 mm (1/4") maximum diameter of valve seat, Fig. 2-35, recut bottom of 12.7 mm (1/2") diameter counterbore and reface hexagon end to hold the 153.99 mm (6-1/6") nominal dimension.

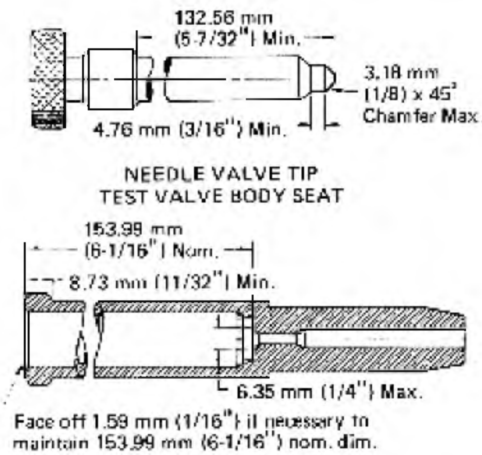

Fig. 2-35 - Test Valve Reconditioning Limits

4. After reconditioning, air test the valve assembly at 620 kPa (90 psi) air pressure.

CYLINDER HEAD SEAT RING

DESCRIPTION

The cylinder head seat ring is a brass ring used between the crankcase head seat and the cylinder head to provide a seating surface for the cylinder head and to maintain proper piston to head clearance.

MAINTENANCE

Inspect head seat ring for proper dimensions. If ring does not meet required specifications, it should be replaced with a new ring.

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SERVICE DATA

CYLINDER HEAD AND ACCESSORIES

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Cylinder Head

Valve seat angle	30°00'-30°15'
Valve seat width	2.36-3.18 mm (.093"-.125")
Variation of seat width on a given seat-Max.	0.38 mm (.015")
Diameter at top of valve seat (ground)	
Max.	61.90 mm (2.437")
Min.	60.33 mm (2.375")
Valve seat runout max. (measured at center of seat)	0.10 mm (.004")
Valve flat to head	
New	0.38 mm (.015")
Max.	2.36 mm (.093")
Valve lift	17.48 mm (.688")
Fireface surface (refinished - circumferential lay)	2 µm-3 µm (80 µ in.-120 µ in.)

Exhaust Valves

Stem diameter (measured within 12.7 mm (1/2") of weld and 12.7 mm (1/2") below P/N stencil on stem)	
New	15.786-15.812 mm (.6215"-.6225")
Min.	15.761 mm (.6205")
Diameter of head	63.50 mm (2.500")
Valve face angle	30°00'-29°45'
Valve seat runout - Max.	0.05 mm (.002")
Valve rim thickness-Min. (measured at O.D.)	2.77 mm (.109")
Valve face width-Max.	8.71 mm (.343")

Valve Springs

Free length (approximately)	
New	104.78 mm (4.125")
Min.	100.79 mm (3.968")
Length - valve open	68.28 mm (2.688")
Length - valve closed	85.72 mm (3.375")
Pressure to compress spring to 68.25 mm (2.687") length.	
New	96.6-102.1 kg (213-225 lbs)
Min.	79.4 kg (175 lbs)
Valve bridges spring - same as valve spring. Spring must not show any set after being compressed with coils touching:	
Valve spring seat thickness - Min.	3.68 mm (.145")

Rocker Arm

Rocker arm shaft diameter - Min.	57.05 mm (2.246")
Rocker arm bushing inside diameter - Max.	57.25 mm (2.254")
Press bushing to rocker arm	0.05-0.10 mm (.002"-.004")
Inner race outside diameter - Min.	26.62 mm (1.048")
Floating bushing inside diameter - Max.	26.80 mm (1.055")
Floating bushing outside diameter - Min.	36.665 mm (1.443511)
Cam follower roller inside diameter - Max.	36.843 mm (1.4505")

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Rocker Arm Shaft Support Assembly

Shaft support - support base to bottom of bore	55.47-55.63 mm (2.184"-2.190")
Shaft support cap - nut seating surface to top of bore - Min.	12.70 mm (.500")
Shaft diameter - Min. (measured at wear step)	57.05 mm (2.246")

Valve Guide

Inside diameter (not installed) - New	15.938-16.015 mm (.6275"-.6305")
(Installed in head) - Min. . . .	15.900 mm (.6260")
Max. limit - 12.70 mm (1/2") from bottom and top	16.08 mm (.633")
Valve stem to guide clearance - Max.	0.25 mm (.010")
Press fit in head	0.013-0.051 mm (.0005"-.0020")

Cylinder Head Seat Ring

Thickness standard - New	4.83-4.93 mm (.190"-.194")
Minimum thickness	4.67 mm (.184")
Uniform thickness within	0.06 mm (.0025")
Maximum wear step	0.08 mm (.003")

Valve Bridge

Refer to Fig, 2-26

Distance between rocker arm guide ears -	
Min.	23.75 mm (.935")
Max.	23.88 mm (.940")
Lash adjuster socket diameter -	
Min.	22.212 mm (.8745")
Max.	22.225 mm (.8750")
Valve bridge shank length -	
Min.	103.18 mm (4.062")
Max.	103.96 mm (4.093")
Shank diameter from shank end to 63.5 mm (2.50") above the shank end -	
Min.	15.799 mm (.6220")
Max.	15.837 mm (.6235")
Spring seat rim thickness -	
Min.	2.36 mm (.093")
Max.	3.18 mm (.125")
Spring seat spherical radius	
New	15.82 mm (.623")
Max. wear step on radius . .	0.79 mm (.031 ")

EQUIPMENT LIST

	Part No.
Test valve wrench	8032587
Valve spring compressor (single)	8033783
Adapter (use with 8033783)	8034054
Crab stud protector tubes	8034600
Valve seat reconditioning tool set (115 volt)	8035775
Valve seat reconditioning tool set (220 volt)	8041445
Valve checking tram	8042773
Electric drill, 1/4" (115 volt)	8045450
Electric drill, 1/4" (230 volt)	8062140
Cylinder test valve seat reamer	8064804
Valve bridge spring compressor	8070883
Valve bridge lock ring guide	8070903
Lash adjuster installer	8072927
Lock ring remover - lash adjuster	8080632
Valve guide cleaner	8141439
Tapered pilot checking fixture	8173996

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SERVICE DATA

CYLINDER HEAD AND ACCESSORIES

Cylinder head stud hole cleaner	8211907
Valve seat seal tester	8213518
Vacuum cup (spare for 8213518)	8213519
Valve spring compressor (multiple-crank type)	8215081
Valve guide installer - remover	8224241
Valve spring compressor (multiple)	8239430
Lash adjuster test stand	8267432
Lash adjuster test oil (18.93 litres [5 gal.]) .	8276528
Lash adjuster test stand (220 V 60 Hz)	8299249
Valve seat reconditioning tool set (air motor)	8332668
Lash adjuster puller	8394719
Lash adjuster pulling arm	8395481
Grinder-valve and tool-230 volts 60 Hz single phase	9310355
Grinder-valve and tool-230 volts 60 Hz three phase	9310356
Grinder-valve and tool-115 volts 50 Hz single phase	9310357
Grinder-valve and tool-230 volts 50 Hz single phase	9310358
Grinder-valve and tool-230 volts 50 Hz three phase	9310359
Grinder-valve and tool-115 volts 60 Hz single phase	9310360
Drive belt for valve grinders	9310380
Valve stem end grinding wheel	9310381
Valve face grinding wheel with hub	9310382

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SECTION 3

PISTON ASSEMBLY AND CONNECTING RODS

CONTENTS	PAGE
PISTON AND ROD	
DESCRIPTION	3-1
INSPECTION (IN ENGINE)	3-2
PISTON AND ROD DISASSEMBLY	3-3
PISTON CLEANING	3-5
PISTON PIN AND CARRIER CLEANING	3-6
PISTON INSPECTION	3-6
CARRIER INSPECTION	3-7
PISTON PIN INSPECTION	3-8
CONNECTING ROD	
DESCRIPTION	3-8
CLEANING	3-8
FORK ROD INSPECTION	3-9
BLADE ROD INSPECTION	3-10
CHECKING ROD LENGTH, TWIST, AND BORE PARALLELISM	3-11
CONNECTING ROD BEARINGS	
DESCRIPTION	3-11
CHECKING BEARINGS	3-11
SERVICE DATA	
SPECIFICATIONS	3-13
EQUIPMENT LIST	3-16

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ENGINE MAINTENANCE MANUAL

SECTION 3

PISTON ASSEMBLY AND CONNECTING RODS

PISTON ASSEMBLY

DESCRIPTION

The piston assembly. Fig. 3-1, consists of a cast iron alloy piston, four compression rings. and two oil control rings. A "trunnion" type piston carrier, Fig. 3-2, is used with the piston assembly to allow the piston to rotate or "float" during engine operation. The carrier supports the piston at the internal piston platform. A thrust washer, Fig. 3-2, is used between the platform and the carrier. The carrier is held in position in the piston by a snap ring inside the piston. Oil taken up by the two oil control rings passes through the oil holes at the bottom of the piston.

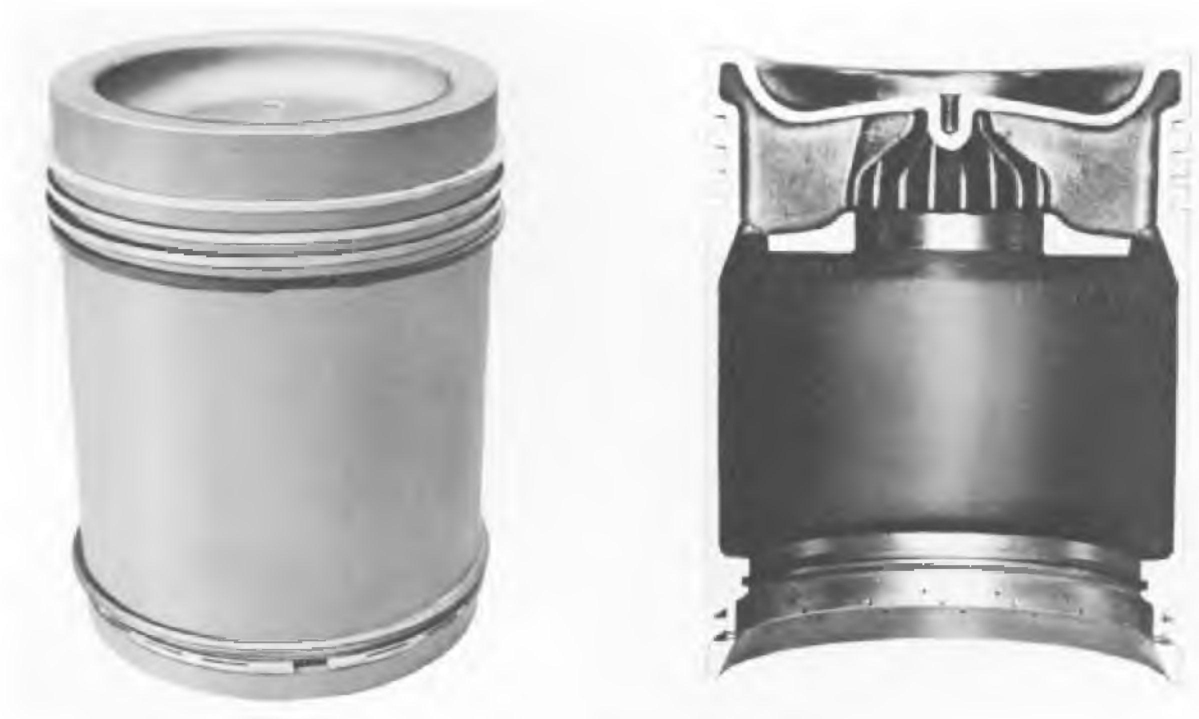

Fig. 3-1 -- Piston Assembly

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Fig. 3-2 - Piston Carrier And Thrust Washer

A bearing insert, Fig. 3-3, is applied in a broached slot in the carrier. Tangs at each end of the bearing insert are bent into a counterbore on the carrier to prevent endwise movement. The highly polished piston pin, Fig. 3-3, is applied in the carrier in contact with the bearing insert, and the assembly is bolted to the upper end of the connecting rod.

Internal parts of the piston are lubricated and cooled by the piston cooling oil. Cooling oil is directed through a drilled passage in the piston carrier, circulates about the underside of the piston crown area, and then drains through two holes in the carrier located at the taper as shown in Fig. 3-3.

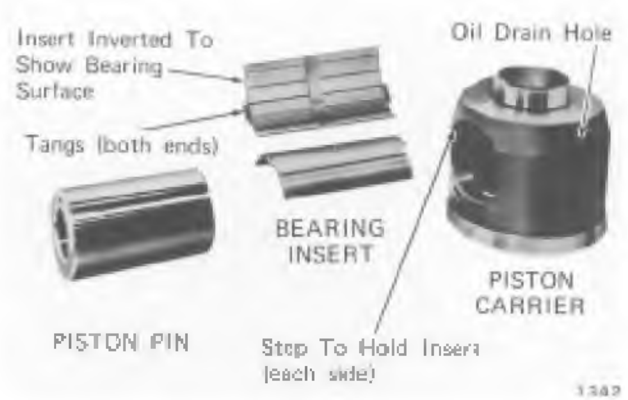

Fig. 3-3 - Piston Pin Insert And Carrier

MAINTENANCE

PISTON AND ROD INSPECTION

Piston and connecting rod assemblies, Fig. 3-4, can be inspected while installed in an engine provided the engine is shut down and the air box and oil pan inspection covers are removed.

Precautions should be taken, before proceeding, to prevent the engine from being started.

Open all cylinder test valves to facilitate rotation of the crankshaft. using the turning jack.

1. Rotate crankshaft until piston of cylinder being inspected is at bottom center.

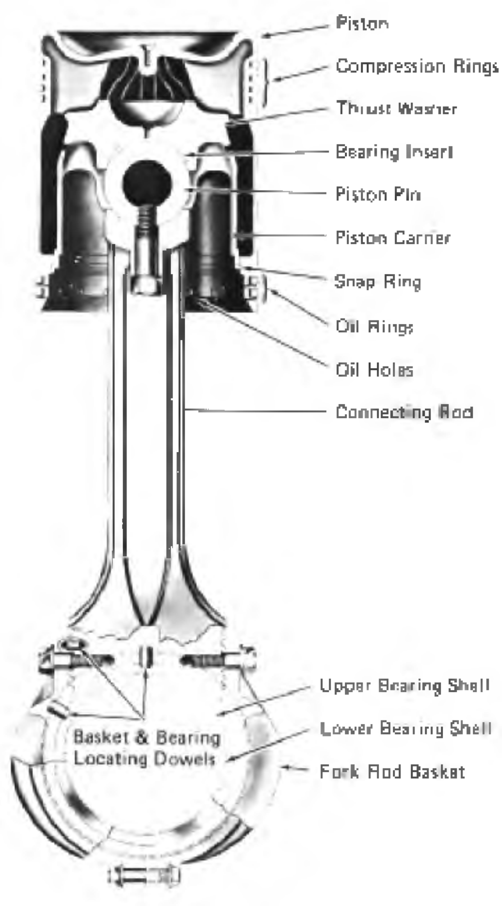

Fig. 3-4 - Piston And Connecting Rod Assembly, Cross-Section

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2. Inspect cylinder wall and top of piston. A wet piston crown would indicate a leaky injector. Check cylinder walls to make sure there is no scoring and inspect for water leaks.

3. Rotate crankshaft to move piston toward TDC until compression rings are visible through liner ports.

4. Visually inspect for the following ring conditions at the liner ports.

    a. Measure side clearance of the No. 1 compression ring between the top of the ring and the ring groove using a feeler gauge.

    b. A ring in good condition will be bright and free in its groove.

    c. Broken ring. The ring face will normally be black if broken opposite the gap. Milling may also be evident above and below the liner ports.

    d. Worn ring. Replace all rings when chrome plating is worn through on first ring. While the ductile cast iron used in the chrome plated top ring will function satisfactorily in contact with the liner, the degree to which a ring is allowed to wear before replacement should be governed to some extent by the severity of the service. An engine which seldom runs at full power is more tolerant of ring condition than an engine which usually operates at or near full load. The chrome ring wear classifications shown in Fig. 3-5, used in conjunction with the description of each ring wear "type," will serve as a guide during ring inspection.

    e. Ring blow-by. Vertical brown streaks on the face of the ring indicate blow-by. Replace these rings when the condition becomes severe.

5. Inspect piston skirt for scoring or scuffing.

6. Inspect air box for foreign material and any signs of water or oil leakage.

OIL PAN INSPECTION

1. Inspect back of upper connecting rod bearing for cutting or signs of overheating.

2. To check for thrust washer, piston pin bearing, and connecting rod bearing wear, take a lead reading of piston to cylinder head clearance. Any increase since previous lead reading will indicate wear.

3. With piston at top center, inspect lower liner walls for scoring.

4. Inspect oil pan for foreign matter.

PISTON AND ROD DISASSEMBLY

NOTE: Procedures for disassembly and qualification of piston and connecting rod assembly components are contained in this section. Procedures for removal, assembly, and installation of the piston and connecting rod assembly, and of a complete cylinder power assembly are contained in Section 5.

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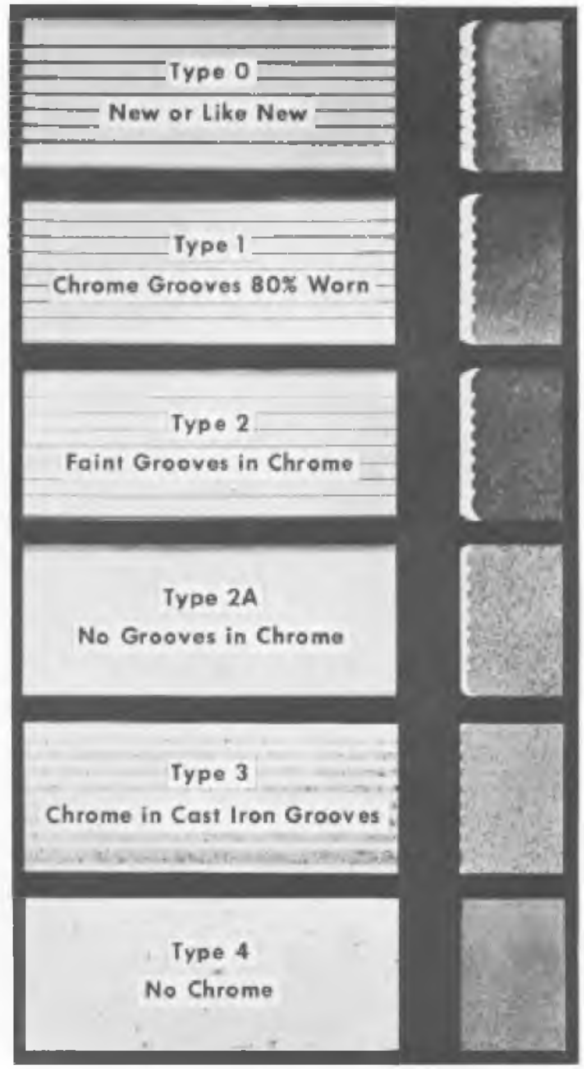

A new or like new ring. This classification will only be evidenced during the first phase of top ring life.

On a shallow groove ring, these classifications will be evident on the top ring for a relatively short time. On a deep groove ring, these classifications will be evident for the major portion of ring life.

Chrome grooves are completely worn away, showing only a smooth chrome face. This will exist for the major portion of shallow groove ring life. It will be evident for a short time on only a small percentage of deep groove rings.

Rings are starting to wear into the cast iron, except for the grooves, which still contain chrome.

CAUTION: To prevent liner scoring, stainless steel rings should be replaced at this time.

Chrome is completely worn off and wear is concentrated on the cast iron. Rings in this classification are to be considered worn out and should be replaced.

NOTE: When classifying chrome plated stainless steel rings, substitute references to "cast iron" with "stainless steel". In addition, stainless steel rings have five grooves instead of seven.

Fig. 3-5 -Chrome Ring Wear Classification

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1. Place piston and rod assembly on a wooden topped work bench and remove piston snap ring, Fig. 3-6, using snap ring remover. Care should be taken in handling piston assembly to avoid nicking or scraping the piston skirt.

Fig. 3-6 - Removing Piston Snap Ring

2. Place rod and carrier in holding fixture, Fig. 3-7, and remove piston pin bolts. This fixture has two mandrels which enter the piston pin bore to hold the pin while the rod bolts are removed. It must be securely mounted on a work surface. If fixture is unavailable, a vise having copper protected jaws may be used to hold the connecting rod. Clamp rod horizontally with pin close to vise so pin bolts may be removed without twisting rod.

Fig. 3-7 - Carrier Holding Fixture

3. Remove pin from carrier.

4. At the time of piston and rod disassembly, check that the thickness of the thrust washer exceeds the minimum dimension listed in the Service Data.

CLEANING

Cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

PISTONS

1. Remove the piston rings using ring expander as shown in Fig. 3-8, and discard the old rings.

2. Immerse the piston in an alkaline solvent solution and allow to remain until the carbon deposits are loosened.

3. Wash the piston using steam or hot water and blow dry using compressed air.

4. Remove any carbon deposits from the compression ring grooves. Light grit blasting or a piece of compression ring can be used for this purpose.

5. Using 3/32" and 5/32" drills in the respective holes, clean the oil passages in the oil ring grooves.

Fig. 3-8 - Removing Piston Rings

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PISTON PIN AND CARRIER

CAUTION: Abrasive material, including steel wool, should not be used to clean piston pins or bearing inserts.

1. It is recommended that the piston pin and carrier assemblies be cleaned using a high flash point petroleum solvent, such as Stoddards solvent [60° C 1140° F] flash point) or equal. These parts should never be washed in an alkaline or caustic solution.

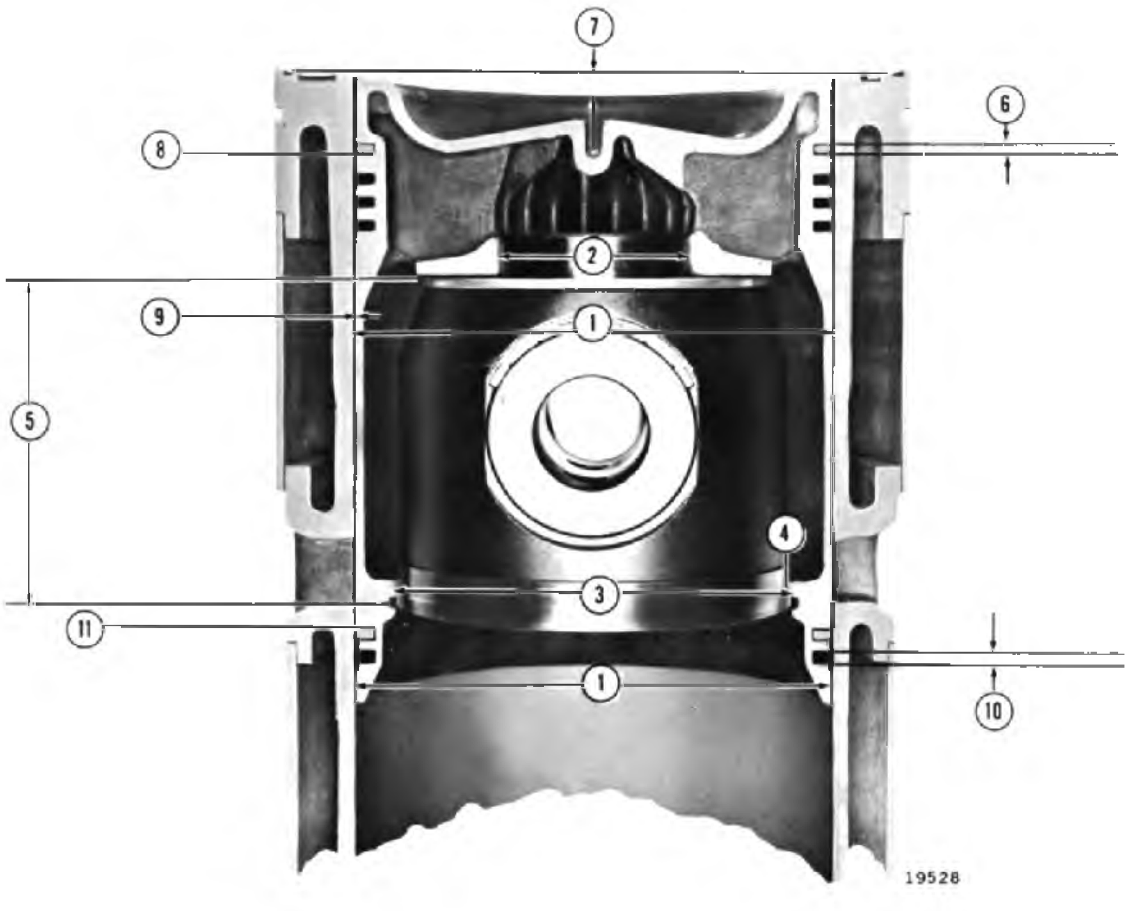
2. Clean the carbon from the oil grooves in the insert with a suitably pointed wooden stick. Embedded particles do no harm if they do not project above the bearing surface; no attempt should be made to remove them. Parts of the assembly should be adequately protected against rust and corrosion at all times.

INSPECTION

1. The phosphate treated surface of the piston skirt should be inspected for satisfactory condition. If the coating is worn through and bare metal in excess of approximately three square inches is exposed, the piston should be re-coated.

2. Inspect the piston surface for excessive scoring or other mutilation which would reject the piston.

3. Check all points of measurement as shown in Fig. 3-9. Discard any pistons that exceed the limits in the Service Data.



Refer to Service Data at end of section for applicable dimensions.

1. Piston Skirt Diameter
2. Piston Platform Bore
3. Piston Inside Diameter
4. Piston To Carrier Pilot Clearance
5. Piston Platform To Bottom Of Snap Ring Groove
6. Compression Ring Groove Width
7. Piston To Cylinder Head Clearance
8. Compression Ring To Head Clearance
9. Piston To Liner Clearance Clearance
10. Oil Ring Groove Width
11. Oil Ring To Land Cleararce

Fig. 3-9 - Piston Measurement Points

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4. Check piston ring groove wear step. Check wear step in top ring groove, Fig. 3-10. Top ring breakage can be caused by excessive wear step.

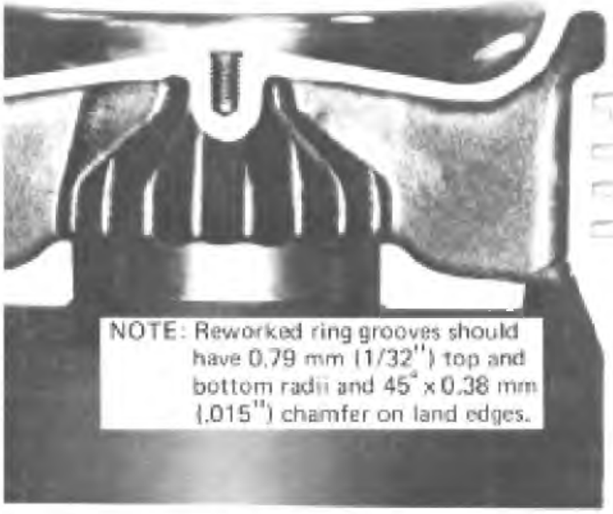

Fig. 3-10 - Typical Piston Ring Groove Wear Step

A piston ring groove gauge, Fig. 3-11, is available to make the wear step measurement. Gauges also are available for measuring wear step in oversize ring grooves. Each gauge consists of a number of separate width indicators precise to 0.001". Standard ring groove gauge has indicators from 0.194" through 0.203". See tool catalog for oversize ring gauge numbers.

Fig. 3-11 - Piston Ring Groove Gauge

To measure wear step, it is first necessary to determine the original ring groove width, because it may vary from 4.93 to 5.00 mm (.194" to .197"). Insert gauge blocks in ring groove, and by trial, determine the largest one which enters its full depth. This will indicate the original width of the ring groove being measured. Then insert the largest block that will enter the groove up to the wear step. The size of the wear step is determined by subtracting the small block dimension from the large block dimension.

When a wear step, in excess of maximum allowable, is found in the top compression ring groove, the groove may be recut to remove the wear step, provided the finished width does not exceed 5.10 mm (.201") for use with a standard ring.

If the ring groove is worn beyond a width of 5.10 mm (.201"), it is possible to machine the top ring groove to use oversize ring. See Service Data for limits.

When performing either of the preceding operations, care must be taken to keep the ring groove faces parallel to each other and at right angles to the centerline of the piston. The surface finish must be smooth to avoid excessive wear.

5. Inspect the piston for cracks using magnaflux procedure.

6. Remove undercrown deposits. Pistons that have been found dimensionally and structurally satisfactory for reuse, should also have the heat dam area thoroughly cleaned of undercrown deposits. Undercrown cleaning should be accomplished using a sand or grit blast cleaning in conjunction with liquid cleaning.

CARRIER

In this assembly, Fig. 3-3, a broached slot or recess in the carrier, receives a precision bearing insert. A hardened polished piston pin runs against the bearing insert.

Normal bearing wear does not affect the carrier. Maximum permissible wear on the insert piston pin, and carrier pilots are listed in Service Data. Used parts in good condition should not be interchanged. A new bearing insert should be

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Used when a new piston pin is used. The piston pin should always be applied in the same relative position to the bearing insert. The small hole in the piston pin should be matched with the piston cooling oil inlet hole in the carrier as a convenient means of keeping the pin and insert in the same relative position for maximum performance.

Except in extraordinary cases of pilot wear, carriers may be expected to have an indefinitely long life. Also, tile bearing insert need not be removed for measurement unless its appearance is questionable and/or the wear on the piston pin is well advanced.

Measure the carrier to determine that the dimensions do not exceed the limits shown in the Service Data.

PISTON PIN

1 . Inspect the pin. The bearing surface should be free of any roughness and have a mirror finish.

2. Fretting on the pin, only where it contacts the connecting rod. may be removed using a fine stone.

3. Check the 7/8"-14 bolt threads in the pin by retapping. It the threads are damaged, replace the pin.

4. Check piston pin wear step.

CONNECTING ROD ASSEMBLY

DESCRIPTION

The "trunnion type" connecting rods. Fig. 3-12. are interlocking, blade and fork construction. The blade rod moves back and forth on the back of the upper crankpin bearing and is held in place by a counterbore in the fork rod.

One end of the blade rod slipper foot is longer than the other and is known as the "long toe." The blade rods are installed in the right bank with the long toe toward the center of the engine.

The fork rods are installed in the left bank. Serrations on tile sides of the rod at the bottom thatch similar serrations on the fork rod basket, Fig. 3-12. 'The rod basket consists of two halves.

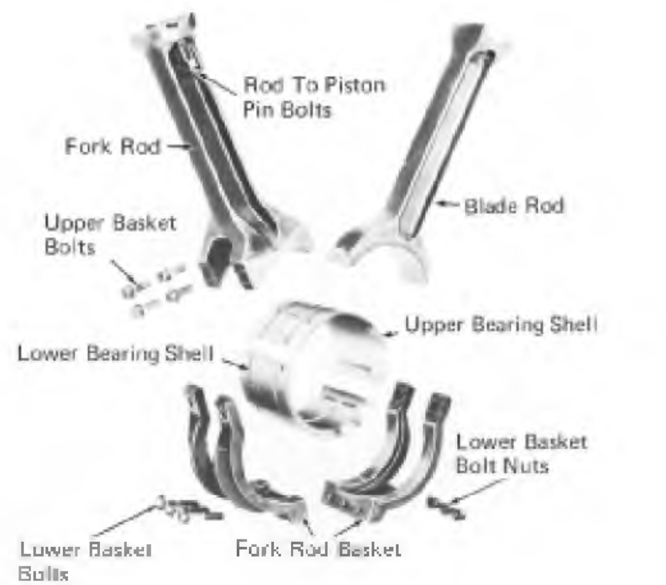

Fig. 3-12 -Connecting" Rods. Bearing Shells, And Basket

held together at the bottom by three bolts and self-locking nuts. The fork rod and basket are bolted together at the serrations. Fork rods and baskets are not interchangeable since they are line bored as an assembly. Both the fork rod and basket are stamped with an identical assembly serial number for matching and identification purposes.

MAINTENANCE

CLEANING

Cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

The glared finish and the bearing pattern oil stain usually found on the blade rod slipper surface is considered normal, and removal s1lou1d not be attempted.

CAUTION: Abrasive material, including steel Wool, should not be used to clean connecting rods or bearing shells.

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INSPECTION

FORK ROD

1. After all parts are clean, check the tapped holes in the fork rod. If threads are worn, the bolts holding the basket may loosen during operation and damage the engine.

   Plug gauge, Fig. 3-13, is available to check the fork rod bolt threads. One end of the gauge is marked "GO" and the opposite end "HI'. The gauge should be used according to the following procedure.

   a. Thread the "GO" portion of the gauge into each of the holes, Fig. 3-13, and check for binding, which may indicate damaged threads. Normally, this gauge should enter the holes freely and a slight shake or wobble is permissible.

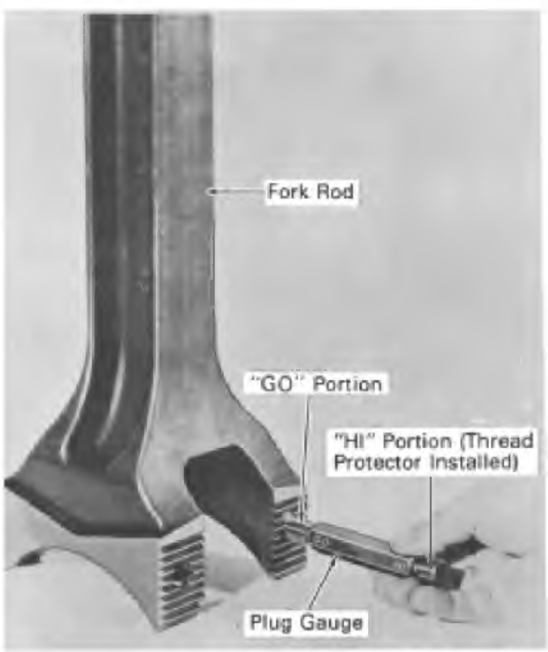

Fig.3-13 - Checking Fork Rod Bolt Threads

   b. An attempt should then be made to screw the "HI" portion of the gauge into each of the holes. This is not a "no go" gauge, therefore, rods may be entirely satisfactory even though the gauge may be screwed in the threads, even to the extent of bottoming.

   Normally, in rods having little wear, this gauge will be difficult to thread into the holes more than a couple of turns. In many cases, however, the gauge can be threaded into the rod but will be snug and tight. While threaded in, check for shake or wobble, taking care that the gauge is not bottomed in the hole, which would cause binding and a false reading.

   The fork should be scrapped if shake or wobble is experienced with the "HI" gauge. To further ensure proper torque values, it is recommended that new bolts be used. However, old bolts may be used if they are qualified by careful inspection. Discard any that may be bent or have threads showing signs of galling, wear, nicks or other imperfections.

2. Fork rod serrations should be checked for nicks, burrs, and cleanliness. Check tightness of upper bearing locating dowels. Step dowels are available in the event oversize dowels are required. Inspect for cracks in serrations and rod visually and by magnaflux.

3. To ensure proper clamping between the piston pin and rod saddle, protrusions in the saddle caused by nicks or fretting must be removed. Use grade 150 abrasive paper or a fine cylindrical stone.

4. Check fork rod bore by fastening basket securely in place using 238 N-m (175 ft-lbs) torque on upper basket bolts, Fig. 3-12. (Normal upper basket bolt torque is 258 N-m [190 ft-lbs] on assembly.) Torque lower basket (split line) bolts to specified value. Measure bore at points 60° apart as indicated in Fig. 3-14. Take one set of measurements at generator end of bore and one set at accessory end of bore. The average of each set of dimensions must not exceed the specified maximum. If bore is beyond this dimension, the rod and basket should be reworked.

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Fig. 3-14 - Checking Fork Rod Bore

5. Fork rod rework will be required for any of the following conditions:

   a. Average of three 60° measurements across fork rod and basket bore exceeds specified maximum.

   b. Nicks, burrs, or fretting on fork and basket serrations.

   c. Damaged threads in bolt holes (see Step 1), or loose dowels.

   d. Damaged or distorted basket.

   e. Out-of-parallel in excess of limit in length of saddle.

   f. Length of rod between bore centers is less than the minimum shown in Service Data.

   g. Fork counter bore exceeds maximum depth.

6. Fork rod assembly should be scrapped if any one or more of the following conditions exist:

   a. Fatigue cracks through basket serr a t rations o n s and rejectable magnaflux indications.

   b. Heat discoloration in basket or fork.

   c. Rod twisted, bent, out-of-parallel, or damaged beyond repair.

   d. Length of rod between bore centers is less than minimum shown in Service Data.

BLADE ROD

1. The blade rod is checked on a 7.692" diameter mandrel to observe slipper surface for "open" or "closed" ends. Blade surface should be smooth. Rod should be scrapped if this surface shows heat discolorations.

NOTE: The flame hardening process produces a blue black color on the top side of the blade rod slipper foot. This discoloration is normal and has not been caused by overheating during operation. The slipper surface, however, should show no discoloration.

2. To ensure proper clamping between the piston pin and rod saddle, protrusions in the saddle caused by nicks or fretting must be removed. Use grade 150 abrasive paper or a fine cylindrical stone.

3. Blade rod rework will be required for any of the following conditions.

   a. Scarred, pitted or deeply rust-etched slipper surface.

   b. End of slipper closed in beyond limit.

   c. End of slipper opened beyond limit.

   d. Out-of-parallel exceeds limit along saddle length.

   e. Length of rod between bore centers is less than minimum shown in Service Data.

4. Blade rod should be scrapped if any one or more of the following conditions exist.

   a. Rejectable magnaflux indications.

   b. Heat discoloration on slipper surface.

   c. Less than minimum flange thickness on slipper shoulder.

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d. Rod twisted, bent, out-of-parallel, or damage beyond repair.

e. Length of rod between bore centers is less than minimum rework limit shown in Service Data.

CHECKING ROD LENGTH, TWIST, AND BORE PARALLELISM

A connecting rod checking fixture is available for accurate inspection of the connecting rod length, twist, and parallelism of piston pin saddle to bearing bore. Refer to Service Data for tool part number.

The following Steps provide a general guideline for checking connecting rods using the tool mentioned above.

1. Set dial indicator reading to "0" using gauge block provided with checking fixture.

2. Place connecting rod on checking fixture, being sure that checking fixture mandrel and rod are clean.

3. Using the dial indicator reading at each top edge of piston pin saddle contour, center rod on mandrel by adjusting the vertical centering thumb screws.

4. Check slipper surface on blade rods for open ends by trying a .003" feeler gauge between slipper surface and mandrel, at each end. Blade rods with open ends may be used providing a .003" feeler gauge cannot be inserted more than 51 mm (2") at either end. A closed in slipper surface is evidenced by the ends having no clearance and the bearing surface being open. Rods with closed-in bearing surface may be used, provided a clearance less than the limit is obtained when measured any place between ends of the slipper surface and the mandrel.

5. Set dial indicator point at top inside edge of saddle. Sweep indicator along length of saddle. Indicator deflection shows rod twist in the length of the saddle which should not exceed limit shown in the Service Data.

6. Place indicator point at one end of bottom of saddle and note indicator reading. Check along length of saddle bottom, circumventing bolt holes, to check out-of-parallel. Indicator must not show more than maximum deflection along length of saddle.

7. To determine rod length, place dial indicator point on gauge plate and check "0" setting. Slide indicator button off block to bottom of saddle and not reading. Minimum reuseable and minimum rework rod dimensions are shown in the Service Data.

CONNECTING ROD BEARINGS

DESCRIPTION

Connecting rod bearings consist of upper and lower shells, Fig. 3-12. They are semicircular in shape and have a steel back with a layer of lead bronze bearing material covered by a lead tin coating on the inside diameter. The upper bearing has, in addition, a bearing surface in the center of the outer diameter consisting of a layer of bronze bearing material with a pure lead-flash overlay. This provides a bearing surface for the slipper of the blade connecting rod.

Dowels in the fork rod and basket hold the bearing shells in proper position. Two dowels in the fork rod locate the upper shell and one dowel in the basket locates the lower shell.

There is no provision for connecting rod bearing adjustment. When bearing clearance exceeds the limit given in Service Data, they should be replaced. After bearing shells are once used on a crankpin and have accumulated numerous dirt scratches, they must not be used on any other crankpin.

MAINTENANCE

CHECKING CONNECTING ROD BEARINGS

The connecting rod bearings should be checked whenever the piston and rod assembly is removed from the engine. To make this check, apply bearings to fork rod and basket in which they are to be used. Torque upper basket bolts to 258 N-m (190 ft-lbs), and torque lower basket (split line) bolts to 102 N-m (75 ft-lbs). Measure bearing bore at three points 60° apart. This is similar to the procedure used when checking fork rod basket bore, Fig. 3-14. The average of these three readings must not be less than is necessary to ensure a clearance between crankpin journal and bearing within the specified limits. After oper ation, rod bearings may give indication of being tight across the split line when

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loose on the crankpin. However, rod bearings intended for use should be mounted in the fork rod and then checked.

NOTE: After bearings have once been used, they should not be used on any other journal.

Check upper bearing step thickness as shown in Fig. 3-15. This will indicate blade rod bearing surface wear. Step thickness should not be less than minimum limit.

Bearing shells will usually be dirt scratched to some degree, but unless condition is severe, the bearings can be reused.

Fig. 3-15 - Checking Rod Upper Bearing Shell

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SERVICE DATA

PISTON ASSEMBLY AND CONNECTING RODS

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. *New limits are those to which new parts are manufactured. (Drawing tolerances.)*
2. *Minimum, maximum, and tolerance measurements are provided as service limits. A1 time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.*

Connecting Rod

Connecting rod basket bore (see text) -

New .... 193.62-193.68 mm (7.623"-7.625")

Max. .... 193.70 mm (7.626")

Max. difference of any two readings at each end of bore (out of round) ... 0.23 mm (.009")

Blade rod bearing seat diameter (See text) - New........ 195.38-195.40 mm (7.692"-7.693")

Clearance between shoulder on blade rod and counterbore in fork rod -

New .... 0.20-0.33 mm (.008"-.013")

Max. .... 0.64 mm (.025")

(This clearance measured by placing feeler gauge between blade rod and top of upper bearing.)

Depth of counterbore in fork rod for slipper on blade rod -

New .... 9.780-9.817 mm (.3850"-.3865")

*Max. .... 10.16 mm (.400")

(*Provided the preceding maximum 0.64 mm (.025") clearance is held.)

Blade rod shoulder thickness -

New .... 8.750-8.790 mm (.3445"-.3460")

*Min. .... 8.51 mm (.335")

(*Provided the preceding maximum 0.64 mm (.025") clearance is held.)

Connecting rod length - New .... 584.15-584.25 mm (22.998"-23.002")

(Generated bore centerline dimension) -

Min. .... 583.95 mm (22.990")

Min. rework .... 583.69 mm (22.980")

Saddle end for piston pin

Twist in length of saddle - Max......................... 0.15 mm (.006")

Parallelism in length of saddle - Max. .... 0.10 mm (.004")

Blade rod slipper surface

"Closed in" - Max. .... 0.18 mm (.007")

"Opened out" - Max. .... 0.08 mm (.003")

Connecting Rod Bearings

Bearing inside diameter (Average of three 60° measurements) -

New .... 165.268-165.354 mm (6.5066"-6.5100")

Bearing to crankpin clearance -

New . 0.18-0.28 mm (.007"-.011 ")

Max. .... 0.38 mm (.015")

Upper connecting rod step thickness - Min. .... 0.69 mm (.027")

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Piston

1 - Refer to Fig. 3-9 - circled numbers coincide with callouts on illustration.
Piston skirt diameter -
New .... 229.84-229.90 mm (9.049"-9.051")
Min. .... 229.77 mm (9.046")
Out-of-round - Max. .... 0.13 mm (.005")
(Check diameter below the oil ring grooves and at 63.5 mm to 69.8 mm [2.50" to 2.75"] below the compression ring grooves. Take two readings 90° to each other, at each location.)

2 - Piston platform bore (upper carrier pilot) -
New .... 90.55-90.60 mm (3.565"-3.567")
Max. .... 90.68 mm (3.570")
(Check at two places 90° to each other.) Piston platform should be square to piston O. D. within 0.08 mm (.003') total indicator reading.

3 - Piston inside diameter (lower carrier pilot) -
New .... 190.17-190.25 mm (7.487"-7.490")
Max. .... 190.35 mm (7.494")

4 - Piston to carrier pilot clearance -
New .... 0.08-0.18 mm (.003"-.007")
Max. . . . . .. 0.28 mm (.011 ")

5 - Piston platform to bottom of snap ring groove -
New .... 161.95-162.15 mm (6.376"-6.384")
Max. .... 162.28 mm (6.389")

6 - No. 1 compression ring groove width w/standard ring -
New .... 4.93-5.00 mm (.194"-.197")
Wear - Max. .... 5.10 mm (.201")

W/0.40 mm (1/64") O.S. ring
Remachined .... 5.31-5.38 mm (.209"-.212")
Wear - Max. .... 5.49 mm (.216")
W/0.79 mm (1/32") O.S. ring
Remachined .... 5.72-5.79 mm (.225"-.228")
Wear - Max. .... 5.89 mm (.232")

Wear step-Max. .... 0.08 mm (.003")

7 - Piston to cylinder head clearance -
New Min. .... 0.51 mm (.020")
New Max. .... 1.73 mm (.068")
Differential reading between ends of lead wire .... 0.13 mm (.005")
An increase in compression clearance of 0.76 mm (.030") from the assembly value at the time of installation condemns the assembly. Any sudden increase should be investigated immediately.

8 - Compression ring to land clearance –
No. 1 groove chrome ring -
New .... 0.102-0.216 mm (.0040"-.0085")
Max. limit for ring installation .... 0.30 mm (.012")
No. 2 and 3 groove chrome ring -
New .... 0.190-0.305 mm (.0075"-.0120")
Max. .... 0.41 mm (.016")
No. 4 groove, taper ferrox ring -
New .... 0.190-0.292 mm (.0075"-.0115")
Max. .... 0.41 mm (.016")

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SERVICE DATA

PISTON ASSEMBLY AND CONNECTING RODS

9 - Piston to liner clearance
Measured 152.40 mm (6") below liner gasket face -

New	0.216-0.330 mm (.0085"-.0130")
Max.	0.56 mm (.022")

NOTE: Maximum piston to liner clearance of 0.56 mm (.022") determines the maximum wear limit of a liner at the 152.40 mm (6") dimension. If pistons are selectively fitted to liners, a liner at 230.45 mm (9.073") could be used with a 229.90 mm (9.051") piston. If pistons and liners are not selectively fitted, the maximum wear limit of the liner at the 152.40 mm (6") dimension would be 230.33 mm (9.068") as the minimum wear limit of a used piston is 229.77 mm (9.046").

10 - Oil ring groove width -

New	6.38-6.45 mm (.251"-.254")

11 - Oil ring to land clearance -

New	0.05-0.15 mm (.002"-.006")

Piston rings

Top compression ring gap (new ring in 9.062" gauge)	1.02-1.52 mm (.040"-.060")
Second and third compression ring gap	1.02-1.27 mm (.040"-.050")
Fourth compression ring gap	0.89-1.27 mm (.035"-.050")

Carrier

Carrier height (top of platform to bottom of carrier) -

New	152.37-152.27 mm (5.999"-5.995")
Min.	152.20 mm (5.992")

Carrier top pilot diameter -

New	90.42-90.47 mm (3.560"-3.562")
Min.	90.35 mm (3.557")

Carrier bottom pilot diameter -

New	190.04-190.09 mm (7.482"-7.484")
Min.	189.99 mm (7.480")

Clearance (carrier to piston snap ring)

New	0.05-0.38 mm (.002"-.015")
Max.	0.64 mm (.025")

Carrier bearing insert thickness

New	3.81-3.83 mm (.150"-.151")
Min.	3.78 mm (.149")

Piston Pin

Diameter -

New	93.57-93.60 mm (3.684"-3.685")
Wear step - Max.	0.05 mm (.002")

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Piston thrust Washer
Thickness -
New . . . . 4.70-4.78 mm (.185"-.188")
Min. . . . . 4.44 mm (.175")

Thickness variation -
Max. . . . . 0.08 mm (.003")

EQUIPMENT LIST

	Part No.
Feeler gauge set	8067337
Piston cooling pipe cleaning tool	8087086
Torque wrench, (3/4" drive [0-300 ft-lbs])	8157121
Snap ring remover	8171633
Torque wrench extension (used with torque wrench 8157121)	8210136
Piston carrier holding fixture	8236589
Wire holder (has contour of piston crown to hold small lengths of lead wire for piston to head clearance)	8243220
Wire, lead, 1/8" dia., 5 lb spool (used with holder 8243220 or alone)	8243661
Fork connecting rod basket thread gauge	8265955
Piston ring groove gauge	
Standard (.194-.203")	8275503
1/64" O.S. (.210"-.219")	8331113
1/32" O.S. (.225"-.234")	8331043
Piston ring expander	8349892
Connecting rod checking fixture	8257730
Motor driven flexible shaft buffer, 115 V	9082182
Motor driven flexible shaft buffer, 230 V	9082183

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SECTION 4

CYLINDER LINER

CONTENTS PAGE

CONTENTS	PAGE
DESCRIPTION	4-1
INSPECTION IN ENGINE	4-1
CLEANING	4-1
MEASURING LINERS FOR WEAR	4-2
OVERSIZE LINERS	4-4
REMOVING LINER RIDGE	4-4
HONING	4-5
MARKING USED LINERS AND PISTONS	4-6
SERVICE DATA	
SPECIFICATIONS	4-7
EQUIPMENT LIST	4-8

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CYLINDER LINER

DESCRIPTION

The cylinder liner, Fig. 4-1, consists of a casting having two separate water jackets applied and brazed to the casting. A row of air inlet ports completely encircles the liner. A flange on the outboard side of the liner below the ports, provides a connection for the liner water supply line. A water deflector, Fig. 4-2, prevents the inlet water from impinging directly on the inner liner wall.

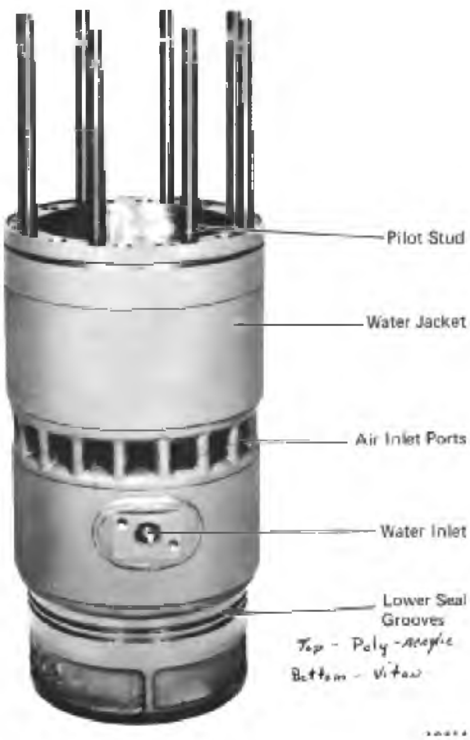

Fig. 4-1 - Cylinder Liner

The inlet water circulates around the bottom of the liner, progressing upward to discharge into the cylinder head through twelve drilled holes. A counterbore around each drilled hole accommodates a teflon heat dam and silicone water seal, Fig. 4-3, which seals the water passage when the cylinder head is installed. A copper clad steel gasket provides a combustion seal between the cylinder head and the liner.

MAINTENANCE

INSPECTION IN ENGINE

The air box handhole covers provide access to the cylinder liner upper bores while the oil pan handhole covers provide access to the lower bores.

1. Open the cylinder test valves and position the piston either below the ports for upper bore inspection or near top dead center for lower bore inspection.
2. Check the liner walls for scuffing or scoring above the ports.
3. Inspect externally for evidence of water leaks at liner to cylinder head gasket and water inlet line.

NOTE: Procedures for qualification of the liner are contained in this Section. Procedures for removal and installation of the liner, and of a complete cylinder power assembly are contained in Section 5.

CLEANING

General liner cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

All water scale deposits and other foreign materials, which are detrimental to water seal life, should be removed from the seal counterbores. The details for construction of a cleaning tool are shown in Fig. 4-4.

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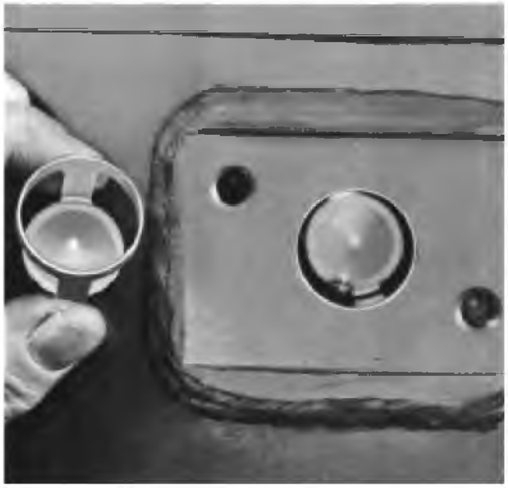

Fig. 42 -Water Inlet Deflector

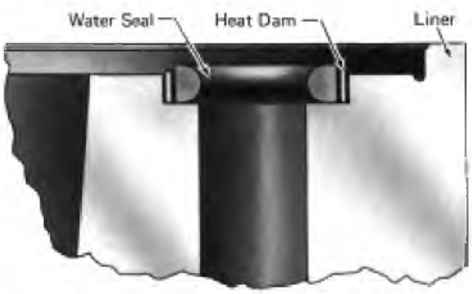

Fig 43 - Water Seal

With the liner removed from the engine, the tool should be used prior to washing the liner so that all the loosened deposits will be removed in the wash. Only the grade of abrasive as specified in Fig. 4-4 should be used to clean the counterbores without damaging the seating surfaces. Insert the tool in an electric or air powered drill which turns around 2000 RPM. Place a few drops of fuel or lubricating oil in the counterbore and, exerting a very light pressure on the tool, rock tool back and forth slightly for approximately five seconds per counterbore.

When the cylinder head is removed, but the liner remains installed in the engine, use the T-handle with the tool and manually clean counterbores so deposits will not enter cylinder.

MEASURING LINERS FOR WEAR

The cylinder liner should be measured in planes parallel and at right angles to the crankshaft. Wipe the interior of liner clean before measuring bore, and check for physical defects that would require rework on the liner. A liner bore gauge, Fig. 45, or standard inside micrometers may be used to measure liner bore diameter. The gauge is of a special design for liner bore measurement, and will provide accurate measurement when used carefully. It has a three-pronged centering and measuring end that fits the liner bore. A dial indicator, mounted on an upright that extends down to the measuring prongs, gives instant reading of bore diameter. The upright allows the gauge to be raised and lowered in the bore with visual measurement shown on the dial. A master gauge is used to calibrate the bore gauge.

A dial gauge locator should be used with the liner bore gauge. The gauge locator fits over the top of the liner and hangs down inside the liner bore. It has four 12.7 mm (1/2") drilled holes spaced at 50.8 mm (2"), 152.40 mm (6"), 304.8 mm (12"), and 406.40 mm (16") from the top to locate the measurement position.

A special box to protect the liner bore gauge also provides a place for the master gauge and the gauge locator.

NOTE: Dimensional wear limits are listed in Service Data at the end of the section. New cylinder liners have a bore diameter which falls between a low and a high limit. The bore diameter at the port relief zone has different dimensional limits.

Accumulated liner and piston wear will increase piston to liner clearance and this clearance is a limiting factor at time of reapplication. No liner should be matched with a new or used piston where the diameters result in a piston to liner clearance exceeding the maximum limit, at a point 152.4 mm (6") inches below the gasket face of the liner.

The liner bore should be checked for out-ofround at two points 50.8 mm (2") and 152.4

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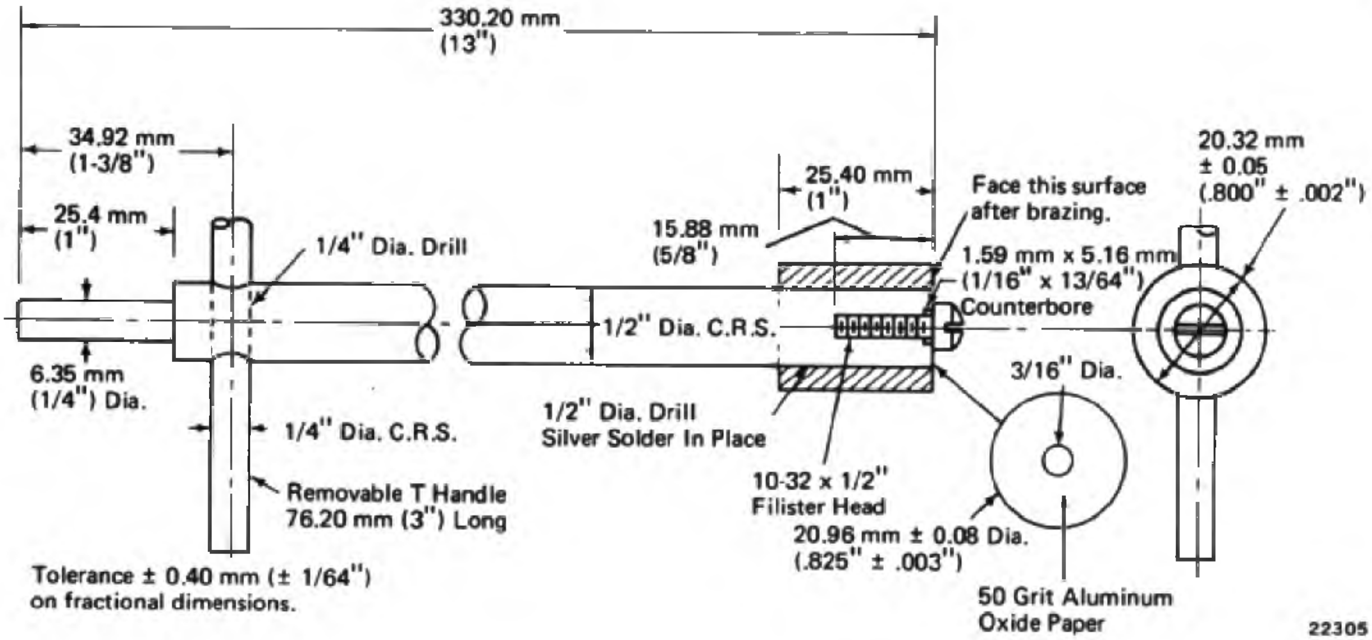

Fig. 4-4 - Counterbore Cleaning Tool

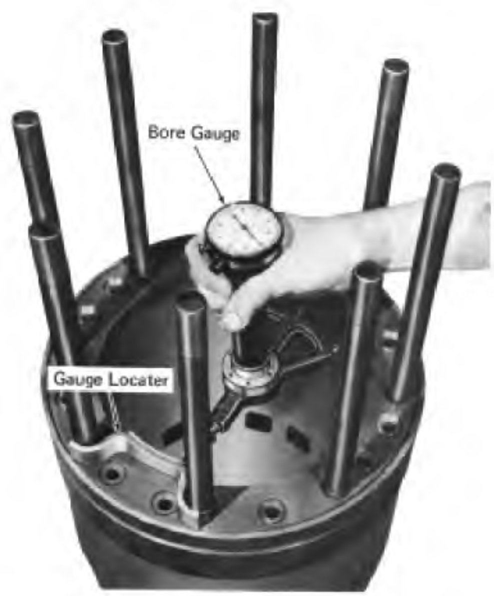

Fig. 4-5 - Liner Bore Gauge

mm (6") below top of liner, Fig. 4-6, using the dial gauge locator as a guide. Take two readings 90° apart to determine wear and out-of-round. Should the out-of-round exceed the limit, the liner must be rebored to the next oversize, regardless of other wear measurements which still may be within limits.

Using the maximum piston to liner clearance as a guide, worn liners may be used again, providing they are not over out-of-round limit, and are matched with pistons having a diameter which will not exceed the limit on piston to liner clearance. Maximum piston and liner

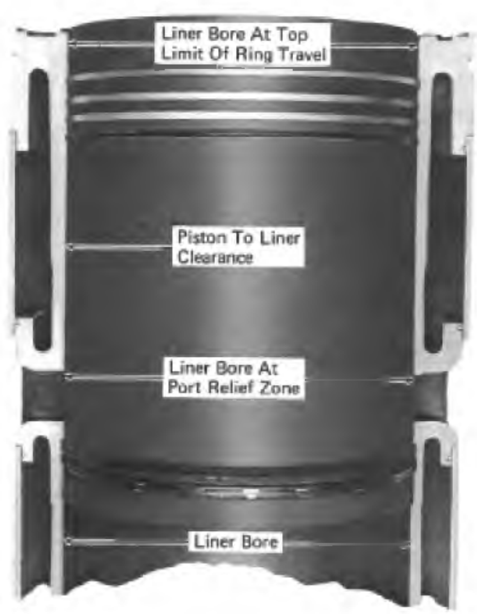

Fig. 4-6 - Liner Measurement Points

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usage is obtained by selective assembly within the clearance limit.

Liners will wear tapered, with maximum wear normally occurring approximately 152.40 mm (6") below the top limit of piston ring travel. Check that wear, taking two readings 90° apart, is within specified limit. A liner worn to this dimension will leave some stock to allow for cleaning up the bore to the first oversize. If this limit is exceeded, it may not be possible to rebore liner to the first oversize. It would then have to be rebored to the next oversize, losing a great amount of its wear life. Consequently, it is suggested that no liner be reinstalled if the bore diameter at point of maximum wear exceeds the allowable limit.

OVERSIZE LINERS

Liners can be rebored to 0.76 mm (.030") or 1.52 mm (.060") oversize. Oversize liner dimensions can be determined by increasing the standard liner figures in Service Data by 0.76 mm (.030") or 1.52 mm (.060") as the case may be. Standard or 0.76 mm (.030") oversize liners worn beyond their limits may be returned to ElectroMotive for refinishing to the next oversize. (Corresponding oversize piston assemblies must be used with oversize liners.)

REMOVING LINER RIDGE

After a long period of use, a wear ridge, caused by piston ring action, will appear near the top of the liner bore. After the liner is removed from the engine, the wear ridge must be entirely removed before honing the liner. Unless complete removal of the wear ridge is accomplished, it is not possible to properly hone the critical area of the liner at the top of the ring travel. In addition, removal of the wear ridge precludes any possibility of interference with new piston rings.

The cylinder liner ridge reamer, Fig. 47, is used to remove the ridge at the top inside bore of the liner. The reamer can also be used for the oversize liners. Reamers may either be manually or motor operated. If the reamer is motor operated, a speed reducer must be used, which is mounted on the reamer. The operating motor used with the speed reducer can be an ordinary heavy-duty electric drill having a no load speed of approximately 500 RPM.

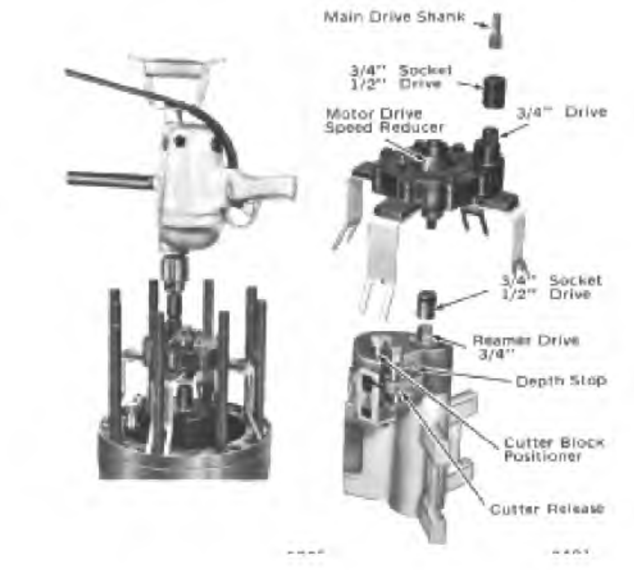

Fig. 4-7 - Application Of Liner Ridge Reamer And Speed Reducer

Extra cutting blades may be obtained for reamers. Refer to Service Data at the end of this section.

Reamer cutting blades also may be resharpened. To resharpen a dull cutter, it is necessary only to lightly grind the leading angle which does the cutting, using a grinding wheel suitable for grinding tungsten carbide tools. The clearance angle is 8° and must not be exceeded when grinding. It is better to provide "less" than more clearance, as these cutters will not stand up if given greater clearance.

In addition, a cutter should not be used if the guide portion has been reduced to a length of 16.67 mm (21/32") by resharpening, because the guide will not extend far enough past the pin hole to prevent undercutting. For resharpening service on the cutters, refer to the reamer manufacturer.

Liner ridge is removed as follows:

1. Oil liner wall just under the ridge, and see that felt pad in back of cutter is full of oil.

2. Retract cutting blade so it will be away from the liner wall when the reamer is installed, and position the depth stop on the blade retard cam. Position cutter blade at bottom of its travel.

3. Lower reamer into the liner until the depth stop rests on top of the liner.

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4. Tighten reamer centering nut to hold reamer in correct position in the liner. Rotate the reamer to check centering, and adjust if required.

5. Operate the blade retarder cam to swing stop out of the way and release cutter so it can move out to contact the liner wall.

6. Operate reamer manually or by motor until ridge is entirely removed, carrying the cut into chamfer at liner top if necessary.

7. After completing ridge removal, remove reamer, and clean liner by wiping off oil and cuttings.

HONING LINERS

After removing the cylinder liner ridge, the liner must be honed for the final finish. The purpose of honing is to remove glaze and to provide a proper seating surface for new piston rings. Light scuffing on the liner wall may also be removed by honing. However, if this condition is too advanced, the liner should be scrapped or rebored oversize, depending upon its condition.

Equipment required to perform the honing operation includes the honing kit, electric drill, stone cleaning brush, and cylinder honing fixture. As the operation is "wet" honing, a suitable container is required for the honing liquid and the honing fixture. See the Service Data at the rear of this section for description and part numbers of the equipment required.

HONING PROCEDURE

1. Ensure that honing kit is assembled per manufacturer's instructions and contains a matched set of stones and guides (identified by W47-J43 stamped on stones and guides).

2. Inspect stone cutting surfaces for cleanliness and clean with wire brush, if required.

3. Install the liner properly in the honing fixture.

4. Chuck the hone shank in the drill motor, and insert the hone into the liner, Fig. 48. Stones should not protrude more than 12.70 mm (1/2") out of liner bore.

5. Raise the center pinion assembly about 6.35 mm (1/4") and turn it counterclockwise to set the stones roughly against the bore diameter. Lower the pinion assembly until it engages with the gear in the hone body.
6. Expand the stones firmly against the liner wall by turning the wing-wrench portion of the pinion assembly in a clockwise direction.

7. Always maintain firm stone pressure against the liner wall to ensure fast stock removal and accurate work. It may be necessary to increase the pressure after several strokes. If pressure is correct, the stones will emit a steady grinding noise.

8. A continuous flooding of the liner surface must be maintained with kerosene or honing oil, during the honing operation.

9. If the liner is not scuffed, merely break the glazed surface by stroking at a rate of approximately 30 complete cycles per minute to produce the cross-hatched pattern shown in Fig. 49.

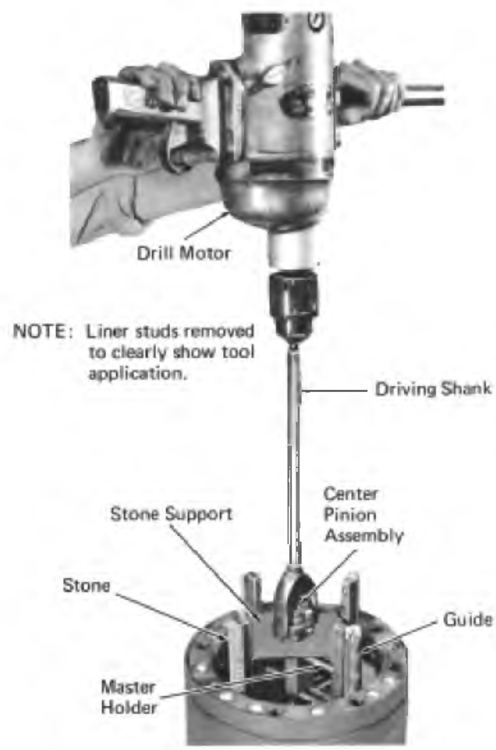

Fig. 4-8 - Honing Cylinder Liner

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10. If the liner is scuffed, remove material buildup, or scuffing. Do not attempt to remove any isolated dirt scratches as they do not significantly affect operation. Honing out these scratches needlessly reduces liner life. After the surface has been "cleaned up," the hone should be removed and the stones wirebrushed to remove any loading of the stones. The liner should then be honed with the clean stones, using heavy pressure to obtain a good cross-hatched pattern, Fig. 49. Do not remove any more metal than is necessary to obtain desired finish.

CLEANING

The liners must be thoroughly cleaned of abrasive and iron dust after honing. If the liners are not properly cleaned after honing, tiny particles left by the honing operation will attack the liners, rings, and pistons causing excessive wear in a short period of time. The liner is cleaned as follows:

1. Wash liner with detergent and hot water using a stiff fiber brush.
2. Rinse liner thoroughly with clean water and wipe dry.
3. Swab liner with clean rag dipped in SAE No. 10 oil. It is important to use oil to pull the abrasive materials from the pores of the liner.
4. Wipe liner with a clean dry cloth.
5. Repeat Steps 3 and 4 until there is no evidence of contaminants on the liner surface.

Fig. 49 - Honing Cross-Hatch Pattern

NOTE: If liner is to be stored, repeat Steps 3 through 5 prior to assembly.

MEASURING LINERS

After honing, the liners should be measured in planes parallel and at right angles to the crankshaft. Dimensional limits are listed in Service Data.

MARKING USED LINERS AND PISTONS IN STOCK

It is suggested that used pistons and liners, which are not going back into an engine immediately, but are to be placed in stock, be thoroughly cleaned, inspected and checked for size. The dimensions as checked can be chalk marked on the outside of the liners and on the crown of pistons. This will allow liner and piston combinations to be selected with a minimum of delay.

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SERVICE DATA

CYLINDER LINER

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. *New limits are those to which new parts are manufactured. (Drawing tolerances.)*
2. *Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.*

Cylinder liner bore (except through port relief zone) -
New . . . . 230.111-230.175 mm (9.0595"-9.0620")

Cylinder liner bore (port relief zone only) -
New . . . . 230.454-230.543 mm (9.0730"-9.0765")

Cylinder liner bore (measured 152.40 mm [6"] below liner gasket face) -
Max. . . . . 230.340 mm (9.0685")

Piston-to-liner clearance (152.40 mm [6"] below liner gasket face) -
New . . . . 0.216-0.330 mm (.0085"-.0130")
Max. . . . . 0.56 mm (.022")

NOTE

Maximum piston to liner clearance of 0.56 mm (.022') determines the maximum wear limit of a liner at the 152.40 mm (6") dimension. If pistons are selectively fitted to liners, a liner at 230.45 mm (9.073' could be used with a 229.90 mm (9.051"1 piston. If pistons and liners are not selectively fitted, then the maximum wear limit of the liner at the 152.40 mm (6") dimension would be 230.33 mm (9.068") as the minimum wear limit of a used piston as 229.77 mm (9.046").

Cylinder liner bore out-of-round (measure at two points 50.8 mm [2"1 & 152.40 mm [6"1 below top of liner - 90° apart)
Max. . . . . 0.13 mm (.005")

Cylinder liner bore (top limit of piston ring travel) -
Max. . . . . 230.63 mm (9.080")
Length of studs above top of liner . . . . 241.30 mm (9-1/2)

Crankcase upper pilot bore -
New . . . . 307.11-307.19 mm (12.091"-12.094")
Max. . . . . 307.44 mm (12.104")

Cylinder liner O.D. (at upper pilot)
New . . . . 306.997-307.073 mm (12.0865"-12.0895")
Min. . . . . 306.93 mm (12.084")

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Cylinder liner O. D. (bottom of liner) -

New	. . . .	263.462-263.538 mm (10.3725"-10.3755")
Min.	. . . .	263.42 mm (10.371")

Insert bore (installed in crankcase) -

New	. . . .	263.58-263.75 mm (10.377"-10.384")
Max.	. . . .	263.80 mm (10.386)

Crankcase lower insert bore -

New	. . . .	281.00-281.10 mm (11.063"-11.067")
Max.	. . . .	281.13 mm (11.068")

Cylinder liner stud torque -

Min.	. . . .	67.79 N-m (50 ft-lbs)

EQUIPMENT LIST

	Part No.
Wire brush (honing stones)	8078883
Stone and guide block set (W47-J43)	8084163
Drill (1/ 2" - 345-500 RPM, 155 volt [AC or DC])	8104770
Drill (1/ 2" - 345-500 RPM, 230 volt [AC or DC])	8104771
Reamer speed reducer (used with 8374969)	8228304
Liner bore gauge	8275258
Gauge locator	8278541
Cylinder liner ridge reamer	8374969
Master gauge (used with 8275258)	8374970
Cutter blade (reamer)	8379037
Hone kit (less motor)	8431585
Honing fixture (facility drawing)	File 543
Cleaning tool (water seal counterbore)	File 686

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SECTION 5

CYLINDER POWER ASSEMBLY

CONTENTS PAGE

CONTENTS	PAGE
COMPONENT BY COMPONENT REMOVAL	5-1
UNIT REMOVAL	5-5
COMPONENT BY COMPONENT INSTALLATION	5-7
UNIT INSTALLATION	5-14
ADJUSTING HYDRAULIC LASH ADJUSTERS	5-20
TIMING INJECTOR	5-20
CRAB NUT TIGHTNESS CHECK AND RETORQUING	5-21
SERVICE DATA	
SPECIFICATIONS	5-23
EQUIPMENT LIST	5-23

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

SECTION 5

CYLINDER POWER ASSEMBLY

DESCRIPTION

Sections 2, 3, and 4 contain information on the cylinder head, piston and connecting rod, and the cylinder liner respectively. Procedures are provided in these sections for disassembly and assembly of the power assembly components beyond what is done during removal from and installation into the engine. Also, the information concerning cleaning, inspection, and the qualification of components is detailed in these sections.

The following procedures are for the removal and installation of a cylinder power assembly, component by component, and the removal and installation of the power assembly as a unit.

COMPONENT BY COMPONENT REMOVAL

1. After draining the cooling system, remove the top deck cover over the affected cylinder. It is advisable to remove the front latches first, then the rear latches.

2. Remove the air box and oil pan handhole covers for the cylinder being removed and the opposing cylinder on the other side of the engine.

3. Remove the piston cooling oil pipe.

4. Remove the bolts holding the water inlet tube to the cylinder liner and remove the saddle strap nuts holding the tube to the water manifold.

5. Remove the gasket from the water manifold.

6. Open all cylinder test valves using the test valve wrench. This will facilitate manual barring of the engine.

7. When removing a fork rod assembly, bar the engine over until the piston is 120° after top dead center. This will allow removal of the basket halves and the connecting rod bearing shells at one crankpin position.

8. Loosen the cylinder test valve packing nut and remove the cylinder test valve and seal. The entire test valve assembly must be removed before removal of the head, or damage to the head and/or the test valve will occur.

9. Disconnect the rocker arm oil line at the camshaft bearing block, Fig. 5-1. Also disconnect the line on the opposite cylinder, opposite bank. Remove the gaskets between the oil lines and the blocks.

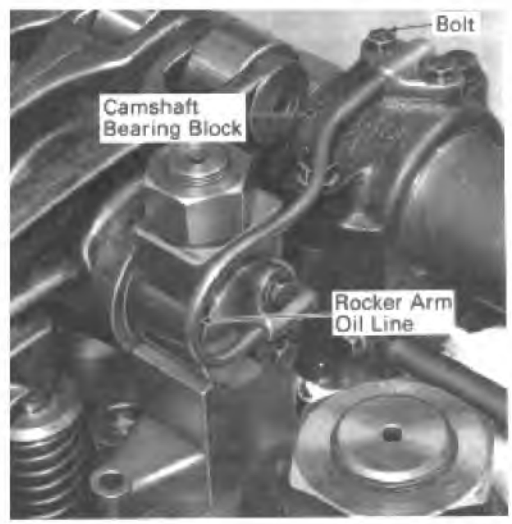

Fig. 5-1 - Rocker Arm Oil Line Removal

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10. Loosen the locknuts on the exhaust valve rocker arms and the injector rocker arm. Back off the adjusting screws about two complete turns on the three rocker arms.

11. Remove the rocker arm shaft nuts, washers, and the rocker arm shaft caps, Fig. 5-2.

12. Take off the rocker arm shaft assembly with rocker arms, taking care not to drop the rocker arms.

13. Remove rocker arm shaft supports and valve bridge assemblies.

NOTE: For further breakdown of the valve bridge assemblies, refer to "Exhaust Valve Bridge Assembly" in Section 2.

14. Remove the fuel line assembly, Fig. 5-3. Also remove the fuel line from the opposite cylinder on the opposite bank of the engine. Care should be taken that the spherical seats on fuel line are not scratched or nicked as this could cause leakage.

15. Remove the injector adjusting link assembly by removing the two spring retainers and the two clevis pins.

16. Remove the injector crab stud nut, spherical washer, and the injector crab.

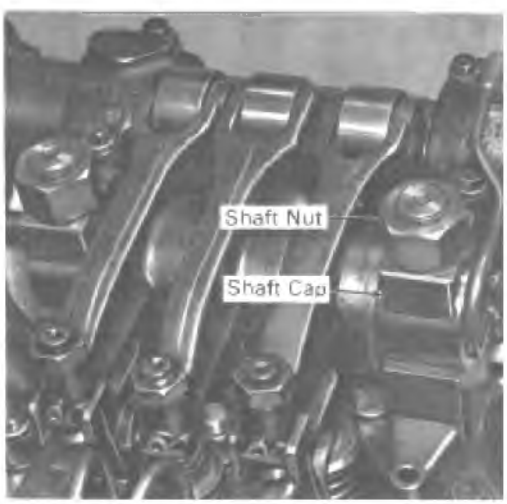

Fig. 5-2 - Rocker Arm Assembly Removal

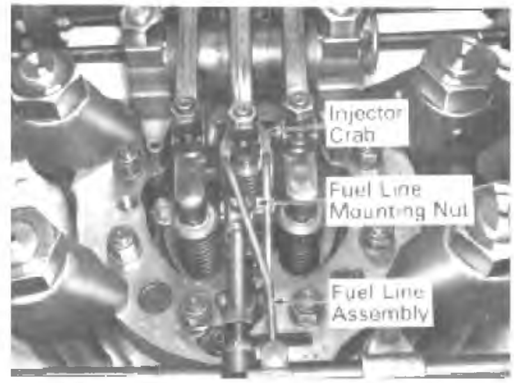

Fig. 5-3 - Fuel Line Assembly Removal

17. Using the injector pry bar, Fig. 5-4, remove the injector from the tapered well in the cylinder head. Protect the injector from dirt and damage by using an injector holding rack.

18. Remove the cylinder head overspeed trip assembly as it usually interferes with removal of the head.

19. The rocker arm shaft assembly with rocker arms and the injector on the opposite cylinder, opposite bank of the engine should also be removed. It is not necessary to remove the overspeed trip assembly from this cylinder.

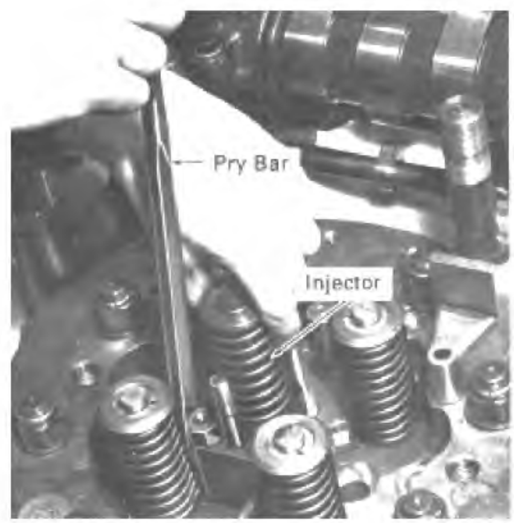

Fig. 5-4 - Removing Injector With Pry Bar

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20. Place a piston holding tool, Fig. 5-5, in the injector well on the opposite cylinder, opposite bank of the engine and thread the rod into the piston pulling eyebolt hole in the crown of the piston.

Fig. 5-5 - Piston Holding Tool

21. Remove the cylinder head to liner stud nuts and washers.

22. Remove the crab nuts from the crab bolts using an air torque multiplier set or equivalent. Place the drive socket on the crab nut to be removed and the anchor on the crab nut above or below the crab nut to be removed. Position the multiplier so that the output is over the drive socket.

23. Install the air motor and set the pressure between 310-344 kPa (45-50 psi). Squeeze the air valve and the crab nut should break loose. If the wrench stalls out, increase the air pressure until the crab nut breaks loose.

24. After removing all crabs, place thread protectors over crab bolts.

25. Be sure that the head puller holes, located at the 3 o'clock and 9 o'clock positions on the head, are free of dirt and oil and install the cylinder head removing fixture, Fig. 5-6. Make sure that the bolts are bottomed to support the weight of the head.

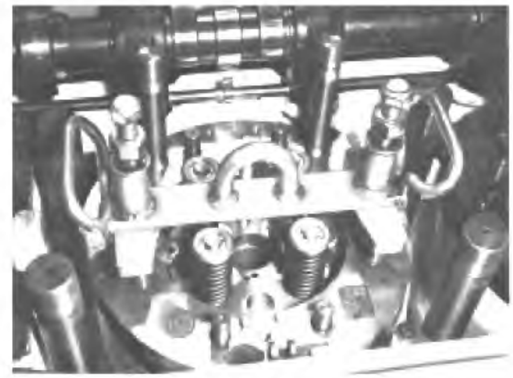

Fig. 5-6 - Cylinder Head Removing Fixture

26. Break the cylinder head free of the liner by turning the jacking screws, working first on one side and then the other until the head has broken free from the liner.

27. Using a suitable lifting device, remove the head.

28. Place the head in a cylinder head carrying basket having a soft wooden disc in the bottom to protect the machined fireface from being nicked or scratched.

NOTE: For further breakdown of the cylinder head, refer to "Exhaust Valve And Spring Removal" in Section 2.

29. Remove the lifting device and head removing fixture.

30. Remove the cylinder head seat ring.

31. Remove and discard the cylinder head to liner water seals and the head to liner gasket.

32. Install the piston pulling eyebolt in the threaded hole in the crown of the piston and hand tighten. Excessive pressure in the threaded hole may cause damage to the crown area.

If a power assembly containing a blade rod is to be changed out, the following Steps apply:

33. The opposing fork rod will have to be held out of the way so that the blade rod can be removed.

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34. Remove the lower basket bolts and nuts using the spring-loaded basket bolt wrench, Fig. 5-7. with a ratchet and extension.

NOTE: Rod assembly removed from engine to clearly show tool application.

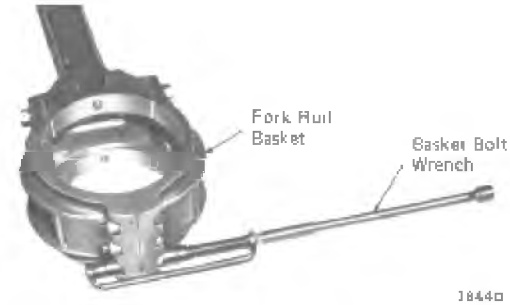

Fig. 5-7 - Basket Bolt Wrench Application

35. Remove the upper bolts from the inboard basket half.

36. Remove the bolts from the other basket half while holding the basket and lower connecting rod bearing shell.

37. Remove the bolts, basket, and bearing while maintaining the same relative upright position to prevent dropping the bearing shell or the basket into the oil pan.

38. Install the connecting rod positioning clamp on the blade rod, Fig. 5-8. The clamp should fit up far enough on the blade rod so that when the rod is lifted it will not strike the cylinder liner.

39. Using a suitable lifting device, raise the piston and fork rod assembly and apply fork rod support, Fig. 5-9, to the outboard side of the fork rod using two basket bolts. Rotate crankshaft in normal direction so that support will rest in oil pan. Protect upper bearing and continue rotation to position blade rod for removal.

40. Lift the piston and blade rod assembly until the protective boot can be applied.

41. Remove the upper connecting rod bearing shell.

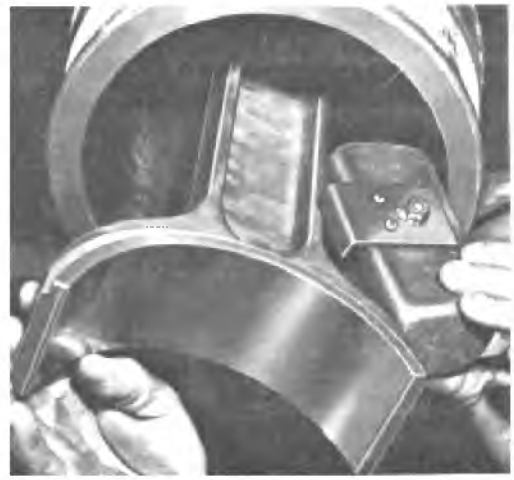

Fig. 5-8 - Connecting Rod Positioning Clamp Application

Fig. 5-9 - Fork Rod Support

42. Guide the blade rod assembly and remove it from the engine.

NOTE: For further disassembly of the connecting rod assembly, refer to Section 3.

If a power assembly containing a fork rod is to be changed out, the following Steps apply in addition to Steps 1 through 38.

43. Using a suitable lifting device, raise the piston and fork rod assembly enough so that the dowels in the fork rod clear the dowel holes in the upper connecting rod bearing and the inboard ends of the forks contact the bearing. As the fork rod is lifted, the upper connecting rod bearing should be held in place from the opposite side of the engine.

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44. Lift the piston and blade rod assembly so that the piston holding tool, Fig. 5-5, can be positioned to hold the piston and rod at the top of the liner. The upper bearing shell should be removed as the piston and blade rod assembly is being raised.

45. Install the positioning clamp on the fork rod, and apply the protective boot.

46. Guide the fork rod assembly and remove it from the engine.

NOTE: For further disassembly of the connecting rod assembly, refer to Section 3.

47. Place the cylinder liner lifter over the liner studs and secure it with the stud nuts.

48. Attach the lifting device and remove the liner from the engine.

UNIT REMOVAL

A complete cylinder power assembly consists of the head, valves, liner, piston and rings, piston pin, bearing insert, carrier, thrust washer, snap ring, connecting rod, and the basket on fork rod assemblies.

NOTE: Locomotive long hood need not be removed to change out a cylinder power assembly if the hoist set is used.

1. After draining the cooling system, remove the top deck cover over the affected cylinder. It is advisable to remove the front latches first, then the rear latches.

2. Remove the air box and oil pan handhole covers for the cylinder being removed and the opposing cylinder on the other side of engine.

3. Remove the piston cooling oil pipe.

4. Remove the bolts holding the water inlet tube to the cylinder liner and remove the saddle strap nuts holding the tube to the water manifold.

5. Remove the gasket from the water manifold.

6. Open all cylinder test valves using the test valve wrench. This will facilitate manual barring of the engine.

7. When removing an assembly with a fork rod, bar the engine over until the piston is 120° after top dead center in the cylinder being removed. This will allow removal of the basket halves and the connecting rod bearing shells at one crankpin position.

8. Loosen the cylinder test valve packing nut and remove the cylinder test valve and seal. The entire test valve assembly must be removed before removal of the cylinder or damage to the head and/or the test valve will occur.

9. Disconnect the rocker arm oil line, Fig. 5-1, at the camshaft bearing block. Also disconnect the line on the opposite cylinder, opposite bank. Remove the gaskets between the oil lines and the blocks.

10. Loosen the locknuts on the exhaust valve rocker arms and the injector rocker arm. After this has been accomplished, back off the adjusting screws on the three rocker arms.

11. Remove the rocker arm shaft nuts, washers, and the rocker arm shaft caps, Fig. 5-2.

12. Take off the rocker arm shaft assembly with rocker arms taking care not to drop the rocker arms.

13. Remove rocker arm shaft supports and valve bridge assemblies.

14. Remove the fuel line assembly, Fig. 5-3. Also remove the fuel line from the opposite cylinder on the opposite bank of the engine. Care should be taken that the spherical seats on the fuel line are not scratched or nicked as this could cause leakage.

15. Remove the injector adjusting link assembly by removing the two spring retainers and the two clevis pins.

16. Remove the injector crab stud nut, spherical washer, and the injector crab.

17. Using the injector pry bar, Fig. 5-4, remove the injector from the tapered well in the cylinder head. Protect the injector from dirt and damage by using an injector holding rack.

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18. Remove the cylinder head overspeed trip assembly as it usually interferes with cylinder removal.

19. The rocker arm shaft assembly with rocker arms and the injector on the opposite cylinder, opposite bank of the engine should also be removed. It is not necessary to remove the overspeed trip assembly from this cylinder.

20. Remove the lower basket bolts and nuts using the spring-loaded basket bolt wrench, Fig. 5-7, with a ratchet and extension.

21. Remove the upper bolts from the inboard basket half.

22. Remove the bolts from the other basket half while holding the basket and lower connecting rod bearing shell.

23. Remove the bolts, basket, and bearing while maintaining the same relative upright position to prevent dropping the bearing shell or the basket into the oil pan.

24. Install the connecting rod positioning clamp on the rod up far enough so that when the rod is lifted it will not strike the cylinder liner.

If a power assembly containing a blade rod is to be removed, the following Steps apply:

25. Screw the piston holding tool, Fig. 5-5, into the threaded hole in the crown of the piston and fork rod assembly.

26. Using a suitable lifting device, raise the fork rod assembly and apply the fork rod support, Fig. 5-9, while holding the upper bearing shell in place.

27. Rotate the crankshaft in normal direction so support will rest in oil pan. Protect the upper bearing and continue rotation to position blade rod for removal.

28. Remove the crab nuts from the crab bolts using an air torque multiplier set or equivalent. Place the drive socket on the crab nut to be removed and the anchor on the crab nut above or below the crab nut to be removed. Position the multiplier so that the output is over the drive socket.

29. Install the air motor and set the pressure between 310-344 kPa (45-50 psi). Squeeze the air valve and the crab nut should break loose. If the wrench stalls out, increase the air pressure until the crab nut breaks loose.

30. After removing all crabs, place thread protectors over crab bolts.

Fig. 5-10 - Lifting Clamp Application

Fig. 5-11 - Piston Holding Tool Application

31. Apply and attach lifting clamp, Fig. 5-10, to cylinder being removed, and screw in the piston holding tool, Fig. 5-11.

NOTE: If the hoist set is used, Fig. 5-12, disregard the lifting clamp and piston holding tool.

32. Lift the piston holding tool and remove upper bearing shell. Continue raising the piston and blade rod assembly until the piston holding tool can be secured to hold the assembly at the top of the liner.

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Fig. 5-12 - Power Assembly Hoist Set Application

33. Attach an overhead chain hoist to the lifting clamp or attach a hoist set. While guiding the power assembly, remove it from the engine.

If a power assembly containing a fork rod is to be removed, the following Steps apply in addition to Steps 1 through 24.

34. Screw the piston holding tool into the threaded hole in the crown of the piston and blade rod assembly.

35. Remove the crab nuts from the crab bolts using an air torque multiplier set or equivalent. Place the drive socket on the crab nut to be removed and the anchor on the crab nut above or below the crab nut to be removed. Position the multiplier so that the output is over the drive socket.

36. Install the air motor and set the pressure between 310-344 kPa (45-50 psi). Squeeze the air valve and the crab nut should break loose. If the wrench stalls out, increase the air pressure until the crab nut breaks loose.

37. After removing all crabs, place thread protectors over crab bolts.

38. Attach the lifting clamp to the cylinder being removed, and screw in the piston holding tool.

NOTE: If a hoist set is used, Fig. 5-12, disregard the lifting clamp and piston holding tool.

39. Lift the piston holding tool while holding the upper bearing shell. Continue raising until the piston holding tool can be secured to hold the assembly at the top of the liner.

Fig. 5-13 - Power Assembly Removal 22115 With Lifting Clamp And Hoist

40. Install the connecting rod positioning clamp on the fork rod.

41. Lift the blade rod assembly and remove the upper bearing shell.

42. Attach an overhead chain hoist to the lifting clamp, Fig. 5-13, or attach a hoist set, Fig. 5-12. While guiding the power assembly, remove it from the engine.

COMPONENT BY COMPONENT INSTALLATION

The power assembly components to be installed should be either new, remanufactured, or otherwise qualified parts. Prior to component installation, the crankcase upper and lower pilot bore should be checked and the dimensions should be within the tolerances shown in the Service Data pages of Section 4. In the case of the lower bore, the dimension is taken with the lower liner bore insert installed; if a rebuilt or remanufactured liner and/or piston is used, the piston to liner clearance will have to be measured as described in the Service Data pages of Section 3.

1. Place a clean and inspected piston on a clean work bench.

2. Apply the spring-loaded oil control ring in the bottom groove.

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3. Apply the spring to the groove first then, using the piston ring expander, apply the ring so that the spring will fit into the groove in the ring. The ends of the spring must be 180° from the ring gap. Rings that are marked "TOP" on one side of the ring are placed in the groove with this marking facing the crown of the piston.

CAUTION: Be sure the spring is fully seated in its groove in the back of the ring. Attempting to install the piston and ring assembly into the liner with the spring not fully seated, or with a loop of spring protruding between the ring groove and ring, will result in a badly kinked spring or broken ring.

4. Using the ring expander, apply the double hook scraper oil control ring in the next groove up.

5. Apply the compression rings to the piston beginning with the bottom compression ring and ending with the No. 1 compression ring, Fig. 5-14. A ring marked "TOP GROOVE ONLY" must be installed in the No. 1 compression groove only.

Fig. 5-14 - Installation Of Top Compression Ring

6. The compression rings must be staggered so that the gaps of the first and second rings are 180° to each other. the third, 90° to the second ring, and the fourth ring 180° to the third. The oil control ring gaps should be 180° to each other.

7. If a new piston pin is to be used, a new bearing insert must be installed.

8. Carefully wipe out the insert slot ill the carrier and examine the bearing insert to make sure that is is clean.

9. Apply the bearing insert in one end of the carrier slot and slide along the carrier bore. If a new bearing insert is not to be used, the old bearing insert must be applied in the same relative position from which it was removed.

10. Center the bearing insert so that the tangs, when bent, will be adjacent to the counterbores of the carrier to prevent endwise movement.

11. Using an indenter tool, Fig. 5-15, strike the center of tire tangs to bend them into the carrier counterbore.

Fig. 5-15 -- Piston Pin Bearing Insert Installation

12. Examine all mating surfaces of the carrier, piston pin, bearing insert, and connecting rod to be sure they are clean and smooth.

13. Manually coat the carrier bearing insert and the piston pin with clean oil, and insert the pin into the carrier.

14. Rotate the pin, while moving it slowly across the bearing insert, to check freedom of movement.

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15. Install the piston pin so that the small identification hole in the end of the pin is at the same end as the piston cooling inlet hole in the carrier. When reusing these components, they must be kept in their same relative position.

16. Place the carrier assembly in the carrier holding fixture, Fig. 5-16, and secure it with the T-handle.

Fig. 5-16 - Carrier In Holding Fixture

17. Lubricate piston pin bolts with Texaco Threadtex No. 2303. Place the connecting rod on the piston pin and apply the piston pin bolt assemblies. Tighten bolts snugly (approximately 13 N-m [10 ft-Ibs]) and perform a "finger tightness check." If a spacer can be rotated when a twisting effort is applied with a finger grip, the bolt assembly should be removed and inspected for the cause of not clamping.

18. When assembling the rod and carrier assembly, the piston cooling oil hole in the carrier must be on the same side as the dowel pin in the serrations of the fork rod and, on a blade rod, on the side opposite the long toe. This will ensure proper position of the hole when the assembly is installed in the engine.

19. Using a 300 ft-Ib capacity torque wrench and extension, torque the piston pin bolts. To torque the bolts to the desired 610 N -m (450 ft-Ibs), a torque reading of 300 ft-Ibs is required when using the extension. The spacer should again be given a "finger tightness check" after the bolts are tight.

20. Place the piston and ring assembly on work bench with the open end up.

21. Check that the interior is clean and that the platform is free of any foreign material.

22. Apply some clean oil to the platform.

23. Place the thrust washer on the platform and apply clean oil to the thrust washer.

24. Carefully place the carrier and rod assembly into the piston and check the assembly for free rotation in the piston.

25. Using the snap ring tool, position the piston snap ring in the piston, Fig. 5-17.

Fig. 5-17 - Installing Piston Snap Ring

26. Check that the snap ring to carrier clearance does not exceed 0.64 mm (.025').

27. Perform a pre-installation inspection of the cylinder liner. Inspect liner water seal counterbores for nicks which may cut the water seals. Make sure that the counterbores and liner bore are clean. Check that the water inlet tube deflector is the correct type and is properly fitted in position in the cylinder liner.

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28. Wipe the inside of the liner with a clean, oily cloth.

29. Apply the liner lifter, Fig. 5-18, over the liner studs and secure with the stud nuts.

Fig. 5-18 - Liner Installation Using Liner Lifter

30. Attach a suitable lifting device to the liner lifter, raise slightly, and install lower liner seal (marked EMD PA) in upper groove. Install lower liner seal (marked EMD VIT and with red paint) in lower groove. Coat seals with an approved lubricant.

31. Lower the cylinder liner into place in the crankcase bore. Preliminary alignment can be obtained by positioning the pilot stud of the liner at the 5 o'clock position.

32. Place the piston ring compressor and guide over the studs on the cylinder liner.

33. Oil the ring compressor.

34. Place a protective boot over the end of the connecting rod.

35. Position the piston and rod assembly over the bore, and manually spread a film of oil on the outside of the piston.

36. Check that the ring gap positions have not changed.

37. Lower the piston and rod assembly into the liner.

38. Make sure that the serial number on the rod is facing outboard.

39. Lower the assembly until the piston crown is parallel to the top of the liner.

40. Oil the inside and outside surfaces of the connecting rod bearing shells and place the upper bearing in position on the connecting rod journal.

41. Hold the bearing shell in place while lowering the blade rod to rest on the upper bearing surface. If applicable, remove the piston holding tool.

NOTE The blade or fork rod opposite to the rod being installed was positioned out of the way during "Component By Component Removal" by use of a piston holding tool for a blade rod or a fork rod support, Fig. 5-9.

42. If applicable, remove fork rod support and lower the fork rod until the rod makes contact with the bearing surface. The fork rod dowels should enter the bearing dowel holes without binding.

43. Be sure that the serial number on the basket matches the serial number on the connecting rod, Fig. 5-19.

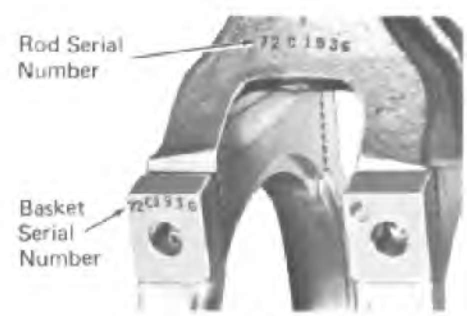

Fig. 5-19 - Rod And Basket Identification

44. Apply the lower connecting rod bearing to the dowel basket half, oil the bearing surface. and place the basket half on the fork rod. When applying fork rod baskets be sure that the serial number on the prong of the dowel half is on the dowel side of the rod.

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45. Lubricate all upper basket bolts with Texaco Threadtex No. 2303 and tighten the upper hasket fork rod bolts just enough to mate the serrations and to hold the bearing in place.

46. Apply the other basket half to the fork rod, tightening the rod bolts enough to mate the serrations.

47. Apply the lower basket bolts, washers, and locknuts.

48. Snug the four top basket bolts to approximately 13 N-m (10 ft-lbs) to firmly mesh the serrations. Give each washer a "finger tightness check." If a washer can be rotated by grasping with the fingers, the bolt assembly should be removed and inspected for the cause of not clamping.

49. Using the spring-loaded basket bolt wrench, Fig. 5-7, torque the lower basket bolts to 102 N-m (75 ft-lbs).

50. Torque the upper basket bolts to 258 N-m (190 ft-lbs) and perform a "finger tightness check" on the washers.

51. Remove the connecting rod positioning clamp and piston holding tool from the blade rod assembly on the opposite bank of the engine.
52. Disconnect the lifting device from the eyebolt.

53. Remove the piston ring compressor and guide from the engine. Remove the piston pulling eyebolt.

54. Install the liner to head water seals and heat dam insulators.

55. Install the head-to-liner gasket, Fig. 5-20, making sure that the proper gasket is used and that the gasket is placed over the liner studs with the part number and "EMD TOP 645" stamp facing up, and the the notched ear of the gasket is placed over the pilot stud of the liner.

56. Attach the head fixture and lifting device to the head, and partially raise head. Check that the injector well is covered.

NOTE: At time of head installation, the exhaust valves have already been applied to the head. For this installation, refer to "Exhaust Valve Installation" in Section 2.

57. Apply a light coat of silicone grease to water outlet elbow seals and install two brown seals to the grooves entering the crankcase and a red seal to the groove between the elbow and the cylinder head. Bolt elbow to cylinder head and torque to specified value.

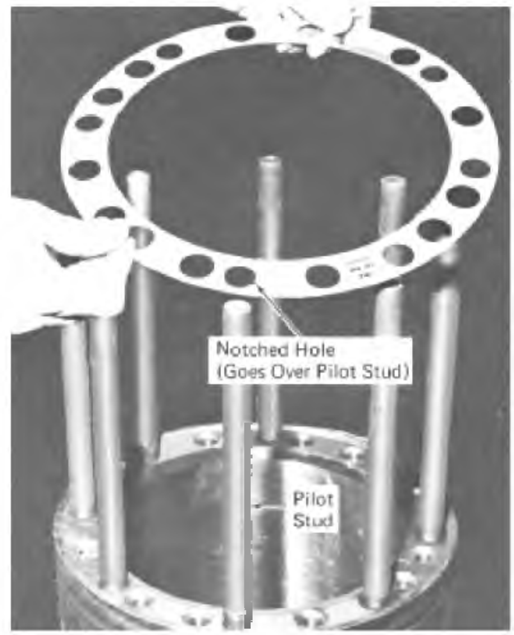

Fig. 5-20 - Head To Liner Gasket

58. Check that the bottom surface of the head is clean and place the seat ring, Fig. 5-21, on the head, making sure that the chamfered side is facing up.

Fig. 5-21 - Cylinder Head Seat Ring

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59. Lower the head slowly into position making sure that the notch in the seat ring is at the 6 o'clock position.

60. Line up the water discharge elbow with the mating hole in the crankcase, Fig. 5-22. Be careful that the seals are not damaged or twisted in the grooves while the head is lowered into position. Before the head contacts the liner, re-check the position of the seat ring notch and finish lowering the head. Remove the head fixture and lifting device.

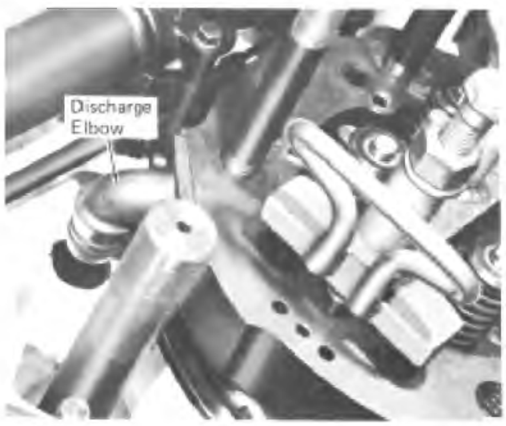

Fig. 5-22 - Water Discharge Elbow Alignment

61. Apply Texaco Threadtex No. 2303 to cylinder liner studs and stud nuts.

62. Apply the liner washers and stud nuts, and snug them down.

63. Following the sequence as shown in Fig. 5-23, torque the head-to-liner nuts to 102 N-m (75 ft-lbs).

64. Remove thread protectors, and make sure that crab bolts, crab seats, and crab nuts are free from burrs and are lubricated with Texaco Threadtex No. 2303.

65. Apply crabs and crab nuts. Center the crab bolts by manually seating the nuts while moving the crab bolts back and forth.

66. After seating the crab nuts, torque them to approximately 407 N-m (300 ft-lbs). Check that the crabs are positioned so that a wrench can be applied to the head-to-liner stud nuts.

Fig. 5-23 - Head-To-Liner Nut Tightening Sequence

67. Tighten the liner stud nuts to a final torque of 325 N-m (240 ft-lbs), following the same sequence as before.

68. Using an air motor and torque multiplier with a power ratio of 38:1, or any mechanical advantage wrench, final torque the crab nuts to 2 440 N-m (1800 ft-lbs). If a 12:1 power wrench is used with a 300 ft-lb capacity hand torque wrench, the pointer should indicate 150 ft-lbs for the final pass.

69. Install the overspeed trip mechanism, and torque the bolts to 32 N-m (24 ft-lbs).

70. Uncover the injector well and install the injector into the cylinder head. Check that the locating dowel is properly seated.

71. Lubricate the threads on the injector stud and nut. Place the injector crab over the crab stud. Place the spherical side of the washer into the spherical seat of the crab. Apply and snug down the nut.

72. Be sure that the injector crab is not cocked at an angle so that it would prevent the entry of the injector timing tool, and torque the crab nut to 68 N-m (50 ft-lbs).

73. Install the injector adjusting link assembly using the two clevis pins and spring retainers. 74. Attach the fuel manifold to the top deck cover frame. Connect the fuel lines from the manifold to the injector. Care must be taken not to damage the spherical seats of the fuel lines as fuel leakage could occur.

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75. Position the valve bridges in the cylinder head.

NOTE: At time of installation, valve bridges are an assembly. For buildup, refer to "Valve Bridge And Hydraulic Lash Adjuster" in Section 2.

76. Lubricate the shaft studs with Texaco Threadtex No. 2303 and install the rocker arm shaft assembly, Fig. 5-

24. Apply the shaft caps with the short toe facing out.

Fig. 5-24 - Rocker Arm Shaft Installation

77. Make sure that the hardened washer is used between the rocker arm shaft nuts and the shaft caps and that all contact surfaces are clean and free from burrs. Apply the washers and nuts to the shaft studs.

78. Alternately torque the shaft nuts to 203 N-m (150 ft-lbs) on the first pass, and to a final torque of 407 N-m (300 ft-lbs).

79. Use a new gasket and attach the rocker arm oil line to the camshaft bearing bracket. Refer to the procedures in this section for injector timing and adjustment of the hydraulic lash adjusters.

80. Coat a new seal with Dow 4 silicone grease and place in the groove at the liner end of the water inlet tube, Fig. 5-25.

81. Position saddle straps around the water manifold and then through the inlet tube flange.

Fig. 5-25 - Applying Seal To Water Inlet Tube

82. After the strap nuts have been applied and tightened finger tight, check that the seal is seated in the groove, position the tube on the finer, and finger tighten the bolts.

83. Take a new gasket and shape it to fit around the water manifold. Insert the gasket between the tube flange and manifold making sure the sides of the gasket are flush with the sides of the flange, and that the ends of the gasket are within the clamping radius of the flange.

84. Torque the strap nuts to 20 N-m (15 ft-lbs).

85. Prior to torquing the tube to liner bolts, remove the bolts and washers from the flange. If the tube moves, it must be repositioned on the water manifold; if no movement is detected, the tube to liner bolts and washers may be re-applied and torqued to 41 N-m (30 ft-lbs).

86. Using a new gasket, place the piston cooling oil pipe against the piston cooling oil manifold.

87. Place the nozzle end of the pipe into the liner bore so that the dowels on the pipe align with the dowel holes in the liner.

88. If the bolt holes in either of the flanges do not line up, replace the pipe. No attempt should be made to fit the pipe by bending it. This would place a stress on the pipe which could result in subsequent failure.

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89. Install the fine thread bolts into the manifold, and the coarse thread bolts into the liner. Torque bolts to 27 N-m (20 ft-lbs).

90. Check proper alignment of the piston cooling oil pipe by placing the alignment gauge into the nozzle of the pipe, Fig. 5-26. Bar over the engine to bottom dead center of the cylinder being checked. At the same time, rotate the gauge to make sure it does not bind in the carrier hole.

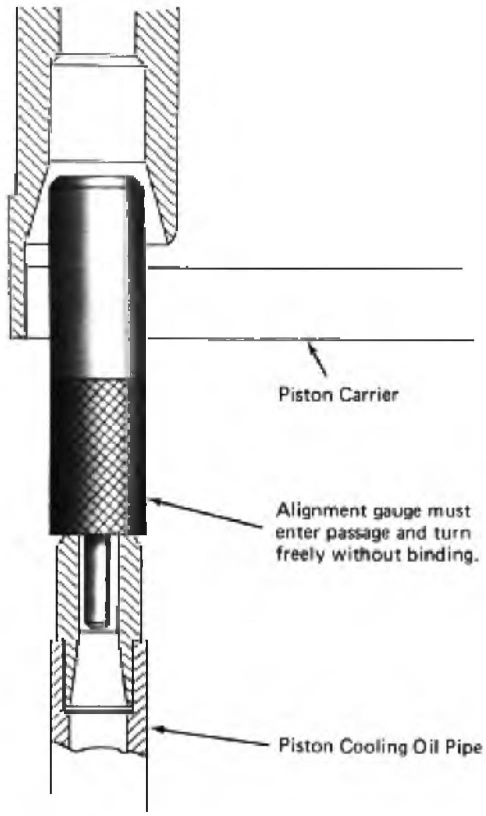

Fig. 5-26 - Piston Cooling Oil Pipe Alignment

91. If the gauge indicates misalignment, replace the pipe. Do not use the gauge to align the pipe.

92. It is important, after installing a power assembly, to determine the head to piston clearance. This will provide the information necessary to evaluate the amount of subsequent wear, or a change in head to piston relationship. The procedure for applying the lead wire in wire holder is as follows:

a. Place a length of 1/8" diameter lead wire in each end of the wire holder and position the holder on top of a piston of the same size as the one being checked in the engine. Each end of the wire should be at least 3.18 mm (1/8") from the outside diameter of the piston.

b. Bar the engine over until the piston being checked is at bottom dead center.

c. Apply the lead wire and holder through a liner port and position it on top of the piston so that it is parallel with the crankshaft.

d. Bar the engine over one complete revolution to compress the lead wire. Remove the wire from the engine and measure the inboard portion of both compressed ends of the wire, Fig. 5-27.

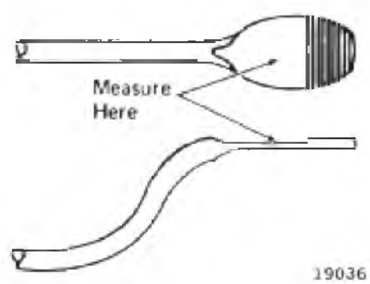

Fig. 5-27 - Lead Wire Measurement

NOTE: It is important that the thinner of the two compressed areas be measured to provide the minimum piston to head clearance.

e. Within the maximum clearance and minimum clearance, the difference in micrometer indications between the two compressed ends should not exceed 0.13 mm (0.005'). If it does, repeat the process as the wire may have changed position.

f. If the difference is still greater than 0.13 mm (0.005') after a second reading, change out the power assembly.

93. Place a new packing seal in the cylinder test valve bore and install the valve body and packing nut.

94. Tighten the valve body into the cylinder head and snug down the packing nut.

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95. Torque the packing nut to 88 N-m (65 ft-lbs) and install the needle valve.

96. Refill the cooling system and check for water leaks.

97. Install the top deck and handhole covers.

98. Bar the engine over one complete revolution and close all the cylinder test valves.

99. Start the engine and raise the water temperature to 76° C (170° F). After running the engine, shut it down and re-check the torque on the crab and liner stud nuts. Also re-check for oil and water leaks.

UNIT INSTALLATION

Left and right banks of the engine are determined by looking toward the "front" (governor end) of the engine when standing at the "rear" (coupling end) of the engine. The power assemblies with blade rods are installed in the right bank with the "long toe" of the slipper foot facing the center of the engine. The cylinder assemblies with fork rods are installed in the left bank.

1. The complete power assembly is packaged in either a storage type metal reinforced container, Fig. 5-28, or expendable cardboard and wood container. The metal cover on the stor age type container is removed by using a wrench and turning the hex head fasteners on the side of the container. The cover forms the top and three sides of the container.

Fig. 5-28 - Power Assembly And Container

2. Remove the card containing the applicable seals and gaskets and, if a power assembly with a fork rod, the small box containing the basket bolts.

3. Remove the two nuts and bolts holding the top mounting block to the rocker arm studs, and take off the block.

4. Remove the piston holding bolt and block.

5. Insert a clean rag into the injector well and remove the tape from around the liner ports. 6. If the power assembly has a fork rod, remove the connecting rod basket from the metal bracket at the front of the container, Fig. 5-28.
7. The assembly has been coated with an antirust compound which does not have to be removed and is totally compatible with lube oil.

8. Install the rocker arm shaft supports making sure that the locating dowel holes are properly positioned.

9. Install the lifting clamp, Fig. 5-29, and secure it with the rocker arm shaft nuts.

Fig. 5-29 - Lifting Clamp Application

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NOTE: If the hoist set is used, disregard references to the use of the lifting clamp and piston holding tool on the power assembly being installed.

10. Remove the rag from the injector well and apply the piston holding tool, Fig. 5-30.

Fig. 5-30 - Piston Holding Tool Application

11. Use the hoist set or attach a chain hoist to the eye at the center of the lifting clamp and remove the power assembly from the container.

12. Support the assembly on a suitable stand and attach the connecting rod positioning clamp.

13. Be sure and check, if a fork rod, that the rod and basket serial numbers match, Fig. 5-31.

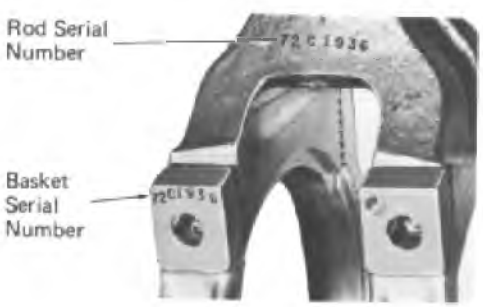

Fig. 5-31 - Rod And Basket Identification

14. Before applying the water discharge elbow, inspect the internal and external seal grooves. Apply a light coat of silicon grease to water outlet elbow seals and install two grey-brown seals to the grooves entering the crankcase and a red seal to the groove between the elbow and the cylinder head. Bolt elbow to cylinder head, and torque to specified value.

15. Change the hoist to the end hole of the lifting clamp, Fig. 5-32, to position it at the proper angle for installation in the engine.

Fig. 5-32 - Power Assembly Installation With Lifting Clamp And Hoist

16. Raise assembly and install lower liner seal (marked EMD PA) in upper groove. Install lower liner seal (marked EMD VIT and with red paint) in lower groove. Coat seals with an approved lubricant.

17. Place the seat ring on the assembly, Fig. 5-33, making sure that the chamfered side is facing up, and the notch is at the 6 o'clock position. Place thread protectors on cylinder head crab bolts.

18. Lower the assembly slowly into the crankcase bore, lining up the water discharge elbow with the mating hole in the crankcase, Fig. 5-34. Be careful that the seals are not damaged or twisted in the grooves while the head is lowered into position.

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Fig. 5-33 - Seat Ring Installation

Fig. 5-34 - Water Discharge Elbow Alignment

19. Before the head contacts the crankcase, recheck the position of the seat ring notch and lower the assembly into final position.

20. Remove the chain hoist from the lifting clamp and attach it to the piston holding tool in the power assembly being installed.

NOTE: The blade or fork rod opposite to the rod in the power assembly being installed was positioned out of the way during "Unit Removal" by use of a piston holding tool.

21. Oil the inside and outside surfaces of the connecting rod bearing shells and place the upper bearing in position on the connecting rod journal.

22. Hold the bearing shell in place while lowering the blade rod to rest on the upper bearing surface.

23. Lower the fork rod until the rod makes contact with the bearing surface. The fork rod dowels should enter the bearing dowel holes without binding.

24. Remove the hoist set or remove the piston holding tool and the lifting clamp and place a clean rag in the injector well.

25. Remove the connecting rod positioning clamp from each connecting rod. Also remove the piston holding tool from the opposite cylinder.

26. Apply the lower connecting rod bearing to the dowel basket half, oil the bearing surface, and place the basket half on the fork rod. When applying fork rod baskets be sure that the serial number on the prong of the dowel half is on the dowel side of the rod.

27. Lubricate all upper basket bolts with Texaco Threadtex No. 2303 and, tighten the upper basket fork rod bolts just enough to mate the serrations and to hold the bearing in place.

28. Apply the other basket half to the fork rod, tightening the rod bolts enough to mate the serrations.

29. Apply the lower basket bolts, washers, and locknuts.

30. Snug the four top basket bolts to approximately 13 N-m (10 ft-lbs) to firmly mesh the serrations. Give each washer a "finger tightness check." If a washer can be rotated by grasping with the fingers, the bolt assembly should be removed and inspected for the cause of not clamping.

31. Using the spring-loaded basket bolt wrench, Fig. 5-35, torque the lower basket bolts to 102 N-m (75 ft-lbs).

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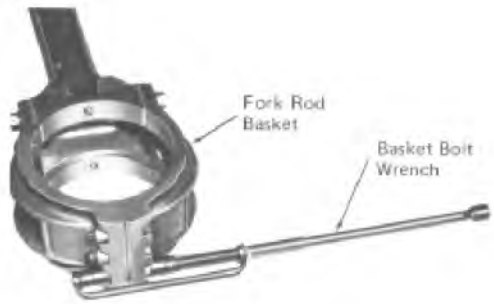

NOTE: Rod assembly removed from engine to clearly show tool application.

Fig. 5-35 - Basket Bolt Wrench Application

32. Torque the upper basket bolts to 258 N-m (190 ft-lbs) and perform a "finger tightness check" on the washers.

33. Remove thread protectors and make sure that crab bolts, crab seats, and crab nuts are free from burrs, and are lubricated with Texaco Threadtex No. 2303.

34. Apply crabs and nuts. Center the crab bolts by manually seating the nuts while moving the crab bolts back and forth.

35. After seating the crab nuts, torque them to approximately 407 N-m (300 ft-lbs). Check that the crabs are positioned so that a wrench can be applied to the head to liner stud nuts.

36. Check the head to liner stud nut torque of 325 N-m (240 ft-lbs) starting with the pilot stud and using the tightening sequence as shown in Fig. 5-23.

37. Using an air motor and torque multiplier with a power ratio of 38:1, or any mechanical advantage wrench, final torque the crab nuts to 2 440 N-m (1800 ft-lbs). If a 12:1 power wrench is used with a 300 ft-Ib capacity hand torque wrench, the pointer should indicate 150 ft-lbs for the final pass.

38. Install the overspeed trip mechanism, and torque the bolts to 32 N-m (24 ft-lbs).

39. Uncover the injector well and install the injector into the cylinder head. Check that the locating dowel is properly seated.

40. Lubricate the threads on the injector stud and nut. Place the injector crab over the crab stud. Place the spherical side of the washer into the spherical seat of the crab. Apply and snug down the nut.

41. Be sure that the injector crab is not cocked at an angle so that it would prevent the entry of the injector timing tool, and torque the crab nut to 68 N-m (50 ft-lbs).

42. Install the injector adjusting link assembly using the two clevis pins and spring retainers. 43. Connect the fuel lines from the manifold to the injector. Care must be taken not to damage the spherical seats of the fuel lines as fuel leakage could occur.

44. Position the valve bridges in the cylinder head.

NOTE: At time of installation, valve bridges are an assembly. For buildup, refer to "Valve Bridge And Hydraulic Lash Adjuster" in Section 2.

45. Lubricate the shaft studs with Texaco Threadtex No. 2303 and install the rocker arm shaft assembly, Fig. 5-24. Apply the shaft caps with the short toe facing out.

46. Make sure that the hardened washer is used between the rocker arm shaft nuts and the shaft caps and that all contact surfaces are clean and free from burrs. Apply the washers and nuts to the shaft studs.

47. Alternately torque the shaft nuts to 203 N-m (150 ft-lbs) on the first pass, and to a final torque of 407 N-m (300 ft-lbs).

48. Use a new gasket and attach the rocker arm oil line to the camshaft bearing bracket. Refer to the procedures in this section for injector timing and adjustment of the hydraulic lash adjusters.

49. Coat a new seal with Dow 4 silicone grease and place in the groove at the liner end of the water inlet tube, Fig. 5-25.

50. Position saddle straps around the water manifold and then through the inlet tube flange. 51. After the strap nuts have been applied and tightened finger tight, check that the seal is seated in the groove, position the tube on the liner, and finger tighten the bolts

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52. rake a new gasket and shape it to fit around the water manifold. Insert the gasket between the tube flange and manifold making sure the sides of' the gasket are flush with the sides of the flange, and that the ends of the gasket are within the clamping radius of the flange.

53. Torque the strap nuts to 20 N-m (15 ft-lbs). 54. Prior to torquing the tube to liner bolts, remove the bolts and washers from the flange. If the tube moves, it must be repositioned on the water manifold, if no movement is detected the tube to liner bolts and washers may be reapplied and torqued to 41 N-m (30 ft-lbs).

55. Using a new gasket, place the piston cooling oil pipe against the piston cooling oil manifold.

56. Place the nozzle end of the pipe into the liner bore so that the dowels on the pipe align with the dowel holes in the liner.

57. If the bolt holes in either of the flanges do not line up, replace the pipe. No attempt should be made to fit the pipe by bending it. This would place a stress on the pipe which Could result in subsequent failure.

58. Install the fine thread bolts into the manifold, and the coarse thread bolts into the liner. Torque bolts to 27 N-m (20 ft-lbs).

59. Check proper alignment of the piston cooling oil pipe by placing the alignment gauge into the nozzle of the pipe, Fig. 5-26. Bar over the engine to bottom dead center of the cylinder being checked. At the same time, rotate the gauge to make sure it does not bind in the carrier hole.

60. If the gauge indicates misalignment, replace the pipe. Do not use the gauge to align the pipe.

61. It is important, after installing a power assembly, to determine the head to piston clearance. This will provide the information necessary to evaluate the amount of subsequent wear, or a change in head to piston relationship. The procedure for applying the lead wire in wire holder is as follows:

    a. Using a piston of the same size as the one being checked in the engine, place a length of 1/8" diameter lead wire in each end of the wire holder. When positioned on top of- the piston, each end of the wire should be at least 3.18 mm (1/8") from the outside diameter of the piston.

    b. Bar the engine over until the piston being checked is at bottom dead center.

    c. Apply the lead wire through a liner port and position it on top of the piston so that it is parallel with the crankshaft.

    d. Bar the engine over one complete revolution to compress the lead wire. Remove the wire from the engine and measure the inboard portion of both compressed ends of the wire, Fig. 5-36.

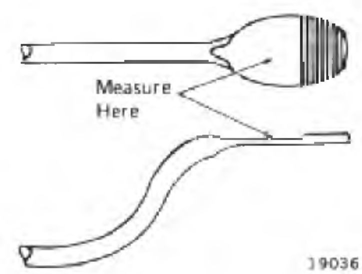

Fig. 5-36 - Lead Wire Measurement

NOTE: It is important that the thinner of the two compressed areas be measured to provide the minimum piston to head clearance.

    e. Within the maximum clearance and minimum clearance, the difference in micrometer readings should not exceed 0.13 mm (0.005"). If it does, repeat the process as the wire may have changed position.

    f. If the difference is still greater than 0.13 mm (0.005') after a second reading, change out the power assembly.

62. Place a new packing seal in the cylinder test valve bore and install the valve body and packing nut.

63. Tighten the valve body into the cylinder head and snug down the packing nut.

64. Torque the packing nut to 88 N-m (65 ft-lbs) and install the needle valve.

65. Refill the cooling system and check for water leaks.

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66. Install the top deck and handhole covers.

67. Bar the engine over one complete revolution and close all the cylinder test valves.

68. Start the engine and raise the water temperature to 76° C (170° F). After running the engine, shut it down and re-check the torque on the crab and liner stud nuts. Also re-check for oil and water leaks.

POWER ASSEMBLY PACKAGING

WARNING: Failure to comply with the proper packaging procedures, when returning power assemblies, can result in injury to personnel or costly damage to components.

The container, in which the power assembly is shipped, has been specially constructed to prevent damage to components. To properly package the assembly being returned, the following procedure should be used:

1. Before attempting to move the assembly, place the piston holding block over the injector hole and over the injector crab stud and secure with the bolt threaded into the threaded lifting eye hole in the crown of the piston.

2. Attach the lifting clamp assembly and hoist. 3. Position assembly in shipping container so that liner is firmly seated and connecting rod straddles support in bottom of container.

4. Remove hoist and lifting clamp assembly.

5. Place top mounting block over rocker arm shaft studs and secure with washers and nuts. Make sure that the block attaching bolts holding the block to the container are secure.

6. On fork rod assemblies, make sure each half of the basket is properly positioned and secured to the main body of the container.

7. Place container cover in position and secure.

ADJUSTING HYDRAULIC LASH ADJUSTERS

Application of properly operating lash adjusters, correct setting, and subsequent inspection at regular maintenance intervals is very important to valve operation. Improperly set or defective lash adjusters cause the exhaust valves to be subjected to increased stress which leads to ultimate failure and probable damage to the engine.

After complete cylinder head assembly or power assembly has been installed, the lash adjusters must be set.

1. Open cylinder test valve and rotate crankshaft so that piston is at or near top dead center of the cylinder being set.

2. Loosen rocker arm adjusting screw locknuts.

3. Turn rocker arm adjusting screw down until the last valve just touches the hydraulic lash adjuster plunger, or use a 0.001 " shim between valve tip and adjuster plunger, and then turn it down 1-1/2 turns.

4. Check valve bridge spherical seat to be sure that it is spring-loaded against the cylinder head spherical seat. If the bridge spring spherical seat is not spring-loaded against the cylinder head spherical seat, turn down the rocker arm adjusting screw until no movement is felt, and then turn it another 1/4 turn.

5. Tighten rocker arm adjusting screw locknut.

6. After running the engine until lube oil reaches operating temperature, check the clearance between lash adjuster bodies and the end of the valve stems with the piston near top center. If the clearance is less than minimum, the cylinder head should be removed for reconditioning or rejection. Use minimum clearance gauge, Fig. 5-37, to gauge clearance between lash adjuster and exhaust valve. This gauge is 1/16" thick and should fit between lash adjuster body and valve stem top, to ensure the minimum clearance.

TIMING THE INJECTOR

With the injector installed, make timing adjustment as follows:

1. Set the flywheel at 0° top dead center of the cylinder being timed. See Table 1 in Section 7 for top dead center settings.

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Fig. 5-37 - Checking Lash Adjuster To Valve Clearance

2. Insert injector timing gauge into the hole provided for it in the injector body, Fig. 5-38.

3. Loosen locknut and turn the rocker arm adjusting screw until the shoulder of the gauge just passes over the injector follower guide.

NOTE: Injectors cannot be timed if the overspeed has been tripped. It must first be reset and the engine crankshaft barred over at lease one revolution.

4. Tighten adjusting screw locknut while holding adjusting screw in position with a screwdriver.

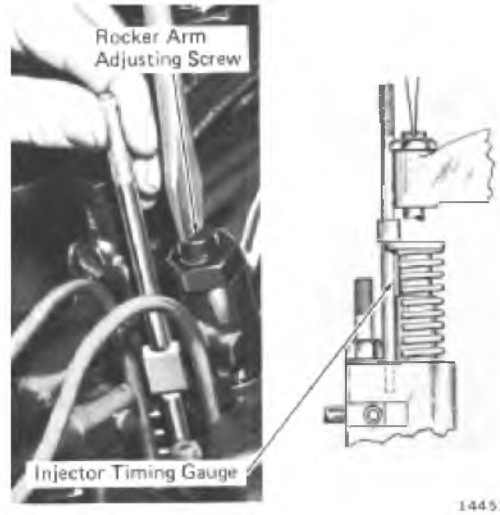

Fig. 5-38 - Timing Injector

5. Recheck setting.

CRAB NUT TIGHTNESS CHECK AND RETORQUING

All new or replaced power assemblies should have the crab nuts checked for tightness at interval specified in Scheduled Maintenance Program. Using a torque wrench, tighten to 2 440 N-m (1800 ft-lbs) any nut that turns at a lower value. If the nut does not turn at 2 440 N-m (1800 ft-lbs), do NOT tighten further.

Retorque crab nuts at intervals specified in Scheduled Maintenance Program. When retorquing crab nuts, loosen all nuts one flat [approximately 1 356 N-m (1000 ft-lbs)] and retorque to 2 440 N-m (1800 ft-lbs).

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SERVICE DATA
CYLINDER POWER ASSEMBLY

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Carrier to piston snap ring clearance -

New	0.05-0.38 mm (.002"-.015")
Max.	0.64 mm (.025")

Piston to cylinder head clearance -

New Min.	0.51 mm (.020")
New Max.	1.73 mm (.068")
Differential reading between ends of lead wire	0.13 mm (.005")

An increase in compression clearance of 0.76 mm (.030") from the assembly value at the time of installation condemns the assembly. Any sudden increase should be investigated immediately.

EQUIPMENT LIST

	Part No.
Test valve wrench	8032587
Crab stud protector tubes	8034600
Injector timing gauge	8034638
Piston pulling eyebolt	8040413
Injector prybar	8041183
Fork rod support	8052958
Cylinder head carrying basket	8060247
Blade rod protector boot	8062033
Fork rod protector boot	8062034
Crab nut socket	8065580
Piston cooling pipe alignment gauge	8071720
Cylinder head removing fixture	8075894
Crab nut box wrench handle (60")	8084091
Piston cooling pipe cleaning tool	8087086
Lash adjuster minimum clearance gauge	8107788
Cylinder liner lifter	8116358
Torque wrench (3/4" drive [0-300 ft-lbs])	8157121
Snap ring remover	8171633
Torque wrench extension (use w/torque wrench 8157121)	8210136
Piston carrier holding fixture	8236589
Basket bolt wrench	8236718
Wire holder (has contour of piston crown to hold lengths of lead wire for piston to head clearance check)	8243220
Wire (lead 1/8" dia., use with holder	8243220
5 lb spool)	8243661
Crab nut power wrench	8250855
Thread lubricant (5 gal.)	8307731
Bearing insert to carrier indenter tool	8311268
Piston ring compressor and guide (standard size)	8330363
Piston ring expander	8349892
Power assembly hoist set	8351724

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Lifting clamp assembly	8417858
Piston holding tool	8417859
Connecting rod positioning clamp assembly	8417881
Silicone grease (8 oz. tube)	8425724
Injector holding rack	8431626

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SECTION 6

CRANKSHAFT ASSEMBLY AND ACCESSORY DRIVE GEAR TRAIN

CONTENTS	PAGE
CRANKSHAFT	
DESCRIPTION	6-1
INSPECTION	6-1
INSTALLATION	6-2
MAIN BEARINGS	
DESCRIPTION	6-3
SCHEDULED RENEWAL	6-3
INSPECTION	6-3
REMOVAL AND APPLICATION	6-4
THRUST COLLAR	
DESCRIPTION	6-5
MAINTENANCE	6-5
GEAR TYPE TORSIONAL DAMPER	
DESCRIPTION	6-5
MAINTENANCE	6-6
ACCESSORY DRIVE GEAR TRAIN	
DESCRIPTION	6-7
MAINTENANCE	6-7
ACCESSORY DRIVE GEAR	
DESCRIPTION	6-7
MAINTENANCE	6-7
GOVERNOR DRIVE GEAR AND STUBSHAFT	
DESCRIPTION	6-9
MAINTENANCE	6-9
INSTALLATION	6-10
ACCESSORY DRIVE HOUSING APPLICATION AND ALIGNMENT	6-11
RING GEAR AND COUPLING DISC	
DESCRIPTION	6-12
MAINTENANCE	6-12
ACCESSORY DRIVE COUPLING	
DESCRIPTION	6-13
MAINTENANCE	6-13
SERVICE DATA	
REFERENCES	6-15
SPECIFICATIONS	6-15
EQUIPMENT LIST	6-16

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ENGINE MAINTENANCE MANUAL

ELECTRO-MOTIVE

SECTION 6

CRANKSHAFT ASSEMBLY AND ACCESSORY DRIVE GEAR TRAIN

GENERAL

The crankshaft assembly is made up of the crankshaft, main bearings and caps, thrust collar, torsional damper, and the accessory drive gear. Although the accessory drive gear is part of the crankshaft assembly, it will be described as part of the accessory drive gear train.

The accessory drive gear train provides power from the crankshaft to drive the oil pumps, water pumps and the governor.

CRANKSHAFT

DESCRIPTION

The crankshaft, Fig. 6-1, is a drop forging of carbon steel material with induction hardened main and crankpin journals. On 8 and 12-cylinder engines, the crankshaft is a one piece forging. On 16 and 20-cylinder engines, the crankshaft is made up of two sections whose flanges are bolted together. Counterweights are provided to give stable operation and all crankshafts are dynamically balanced. Drilled oil passages provide for lubrication of the main bearings as shown in Fig. 6-2.

Crankshafts with bolt-on accessory drive stubshafts are available for 12, 16, and 20-cylinder engines.

Refer to "Accessory Drive Gear" for removal and installation of stubshaft.

MAINTENANCE

INSPECTION

Whenever the main or connecting rod bearings are removed, the crankshaft journals should be inspected. Check for scoring and cracks, and signs of distress, as

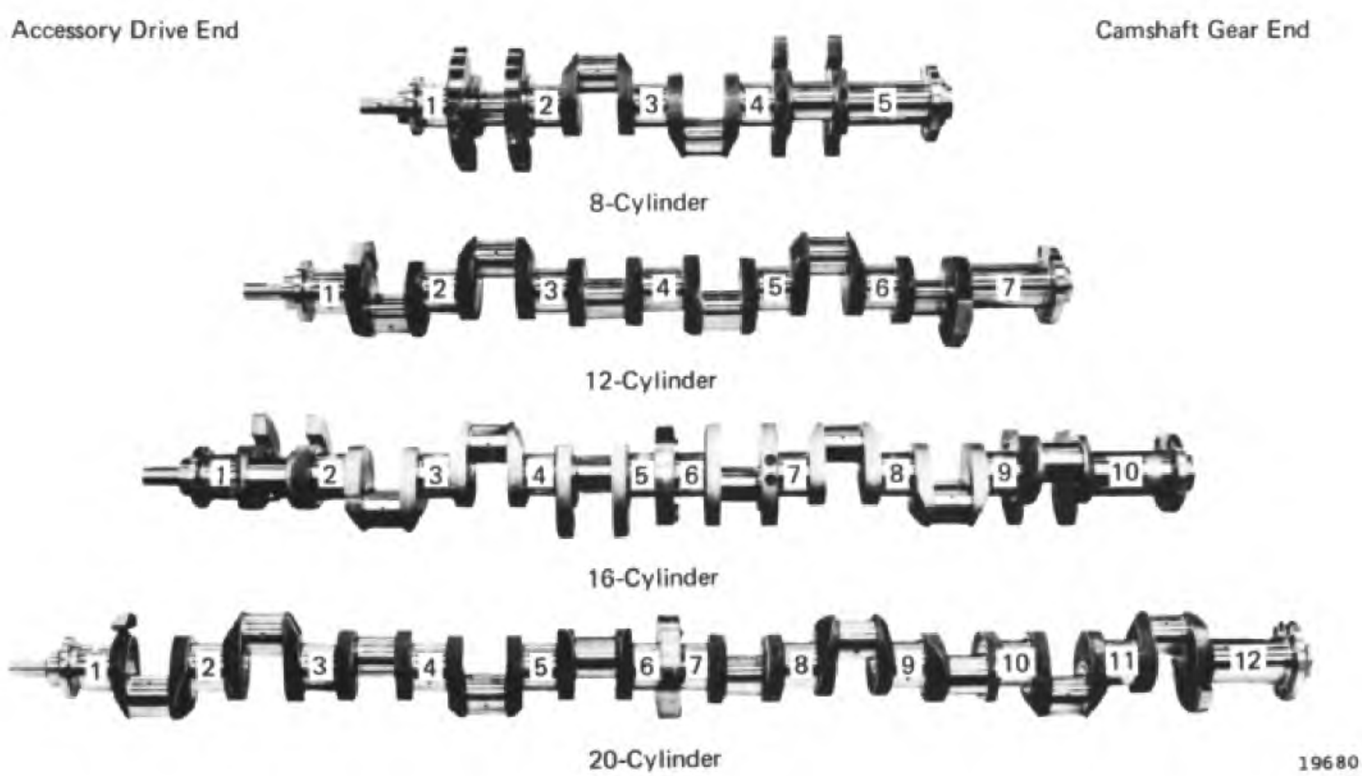

Fig. 6-1 - Engine Crankshaft

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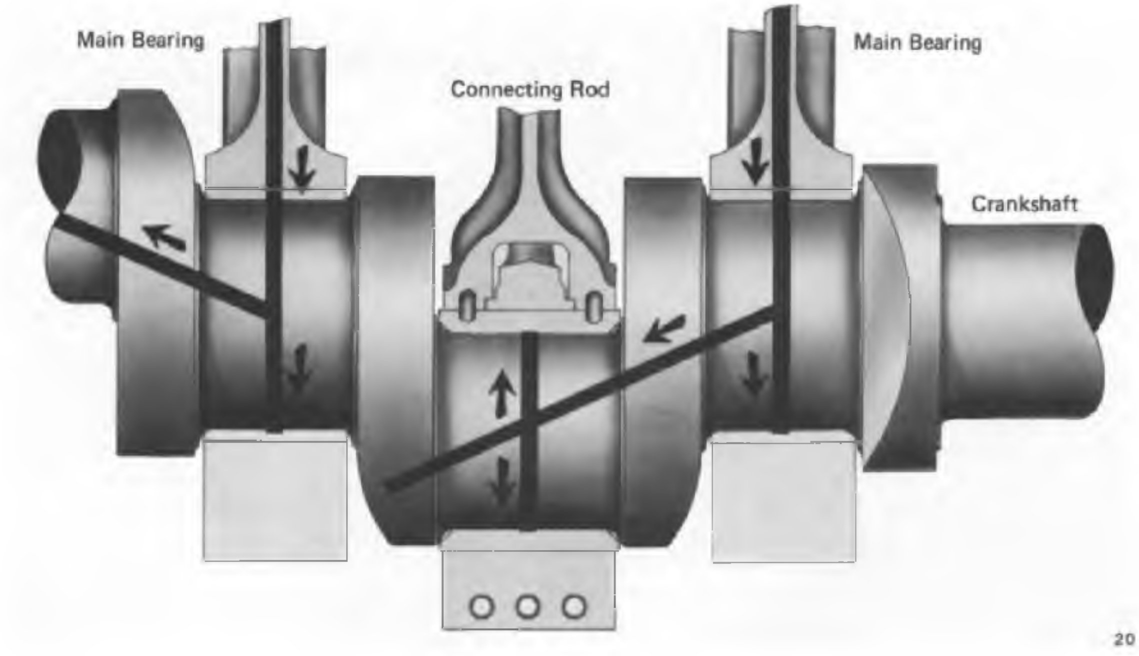

Fig. 6-2 - Crankshaft Oil Passages

will generally be evidenced first in the bearings. When the crankshaft is removed from the engine, it should be visually and dimensionally inspected, and magnaflux inspected if possible.

The journals of the crankshaft are induction hardened. Excessive heat resulting from lack of lubrication, insufficient bearing clearance, or other causes will usually produce thermal cracks on the journal. Damaged crankshafts can usually be reconditioned at EMD to re-establish journal size and condition to use standard size bearings. In some instances, crankshafts may have to be reground requiring the use of undersize bearings.

Attempts to grind crankshafts in the field have proven unsuccessful, as during the regrinding process, the depth of the induction hardened zone must be checked, and when necessary, rehardened. This requires special induction hardening equipment. It is therefore recommended that the crankshaft be returned for grinding. To aid identification, reground crankshafts with undersize journals or oversize thrust bearings will have this information stamped on the same cheek as the serial number.

INSTALLATION

1. Aply the main bearings to the "A" frame bores and to the bearing caps, lining up the bearing tangs.

NOTE: See "Main Bearings" for qualification of bearings.

2. Ispect the crankshaft and be sure it is clean. Oil the crankshaft journals and main bearing shells, using clean oil.

3. Pace the thrust collars in their respective "A" frame counterbores, as shown in Fig. 6-3.

4. Pace the crankshaft in the "A" frame bearing shells and apply the two end and two center (16 & 20-cyl.) bearing caps to hold the crankshaft in place. Check that the studs, nut seats, and washers are lubricated with Texaco Threadtex No. 2303 and secure the caps. Tighten the nuts until they contact the bearing caps.

5. Rmove the hoist or crane hooks.
6. Aply the remaining bearing shells and caps. Manually tighten the nuts until hardened washers are seated on bearing cap.

7. Uing a power wrench, all nuts are torqued to 475-542 N-m (350-400 ft-lbs). After all nuts have been tightened to this torque, final torque nuts to 1 017 N-m (750 ft-lbs). Do NOT overtorque.

NOTE: No one nut on any one cap should be torqued to 1 017 N-m (750 ft-lbs) until all nuts on that cap have been torqued to 475-542 N-m (350-400 ft-lbs).

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Fig. 6-3 - Applying Thrust Collar (16 & 20-Cyl.)

MAIN BEARINGS

DESCRIPTION

The main bearing shells, Fig. 6-4, are precision type steel-backed lead-bronze, with a thin layer of lead-tin. Tangs in the bearings locate them in the proper axial position and prevent bearing turning. Upper and lower bearing shell halves are not interchangeable.

Fig. 6-4 - Main Bearing Shell And Cap

Lower main bearing shells have two tangs on each side which fit into the main bearing cap. Upper main bearing shells have one tang which fits into a groove on the right side of the "A" frame bore. Upper shells can be rotated out, in a direction opposite to normal crankshaft rotation, when the lower bearing and cap are removed.

MAINTENANCE

SCHEDULED RENEWAL

Lower main bearings should be renewed at the intervals specified in the Scheduled Maintenance Program. Upper main bearings need not be removed when lower main bearings are renewed unless the lower bearings show definite signs of distress. Upper main bearings may be changed out individually as required, not in sets.

INSPECTION

UPPER MAIN BEARINGS

Inspection of upper main bearings is not recommended; however once the upper main bearings are removed, they should not be reinstalled.

LOWER MAIN BEARINGS

Lower main bearing inspection should be performed only when necessary as an element of risk is involved whenever main bearings are disturbed.

1. he lower main bearings should be inspected when abnormal conditions are observed in the engine, such as contamination of lube oil due to dilution with fuel or water, or the presence of foreign material in the lube oil filters, screens, or engine oil pan.

2. Lower main bearings need not be inspected in routine service, but should be renewed at the intervals specified in the Scheduled Maintenance Program.

INSPECTION SAMPLE

Unless evidence is present calling for other action, inspection of main bearings should be limited to the following "selected" lower bearings, which experience has shown to be the most critical. See Fig. 6-1 for main bearing numbering location.

Number Of Cylinders	Bearing Number To Be Inspected
8	2,4
12	2,6
16	2,6,9
20	2,5,8,11

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DISQUALIFICATION CRITERIA

All lower main bearings are to be renewed if any one lower main bearing is disqualified at any one of the "selected" bearing locations indicated above, or at any additional locations inspected for other reasons.

The following numbered paragraphs give examples of conditions requiring renewal of all lower main bearings.

1. Any one bearing shows evidence of overheat. An overheat condition results in flowing of the overlay, and discoloration of exposed bronze. (An upper main bearing is to be renewed when the corresponding lower bearing shows evidence of overheat.)

2. Any one bearing shows a milky white color on the overlay. (This is evidence of an extremely thin overlay and indicates water contamination.)

3. Any one bearing has an area of wear-exposed bronze 3.18 mm (1/8") or more wide running along either edge, or if two or more bearings have any exposed bronze.

NOTE: The lead-tin overlay on the bearings must be present to provide an adequate safety margin against temporary marginal lubrication or corrosive conditions. Exposed bronze in healed dirt cuts does not affect bearing operation, but exposed bronze due to wear does cause a bearing to lose its protection against temporary marginal lubrication conditions.

4. Exposed bronze due to isolated abnormal wear or overlay flaking.

5. Severe fretting along the mating edge of the upper and lower bearing. (The corresponding upper bearing should be renewed at any location exhibiting severe fretting, and bearing cap serrations inspected for possible damage.)

6. Severe dirt scratches or dirt impregnation resulting in an abrasive surface.

CAUTION: Dirt impregnation or scratches are evidence that bearing oil is not properly filtered. The filtration system should be checked, and scheduled pressure monitoring of lube oil filter condition established.

INSPECTION PROCEDURE

A visual inspection is made by dropping the main bearing cap, with the bearing in it, low enough to make the inspection without removing the cap from the studs or the bearing from the cap. Removal of a reusable main bearing from the cap may result in improper reseating. Bearing removal also allows the possibility of replacing the bearing in a reversed position or at the wrong journal location. Either condition can lead to early failure. In addition, removal of the cap from the studs involves the risk of damage by dropping and the risk of replacing the cap backwards.

If a reusable bearing is inadvertently removed from the cap during inspection, perform the following:

1. Determine the previous bearing position by matching the wear patterns on the cap bore and the back of the bearing. If this cannot be done, a new bearing should be installed. This is the only case where a lower main bearing may be renewed independently.
2. When previous position is determined, mark a mud pocket to identify right or left bank side.
3. Thoroughly clean the bearing back and cap bore. Remove any raised material in fretted areas. High spots may distort the bearing and cause premature failure.
4. Thoroughly clean the cap and "A" frame serrations before assembly.

REMOVAL AND APPLICATION

Lower main bearings are to be removed with the bearing caps, and new bearings installed in the caps before the caps are reapplied. It is recommended practice to install new bearings with the part numbers towards the accessory end of the engine. A main bearing cap application and removal tool is available for removal and application of main bearing caps.

All upper main bearings, except No. 5 on 8-cylinder engines, No. 7 on 12-cylinder engines, Nos. 5 and 6 on 16-cylinder engines, and Nos. 6 and 7 on 20-cylinder engines, Fig. 6-1, are removed by inserting the upper main bearing shell remover into the journal oil passage and rotating the crankshaft opposite to the normal direction of rotation. Upper main bearings on journals without oil holes or which are fretted (or welded) to the "A" frame bore can be removed by using upper bearing removal tool.

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New upper main bearings are to be fitted by hand between the crankshaft and steel bore. If the bearings can not be hand fitted, the reason must be found and corrected. The engine may have to be removed and the crankcase remanufactured.

To apply the main bearings, see the instructions for installation of crankshaft.

SPECIAL PROCEDURES FOR OVERHEATED BEARINGS

If an overheat condition is detected, all lower main bearings are to be renewed. Upper main bearings are to be renewed only at the overheat locations. In addition to routine cleanup of main bearing caps and "A" frame serrations, perform the following:

1. Measure main bearing cap serration spacing, using serration gauge. If the gap is closed in more than 0.51 mm (.020") from nominal (dial indicator on gauge set to zero with master bar), the engine should be removed and the crankcase remanufactured.

2. If new upper main bearings can not be hand fitted between the crankshaft and the steel bore, the reason must be found and corrected. The engine may have to be removed and the crankcase remanufactured.

3. If crankcase inspections proved satisfactory and new bearings are installed, perform a "feel over" check after the break-in run. The main bearing caps should be lowered on the studs at the locations where the overheat was detected, and a bearing inspection made.

4. Bearing inspection should be repeated at the overheat locations at the end of one month of operation, and at the end of three months of operation.

THRUST COLLAR

DESCRIPTION

The two thrust collars, Fig. 6-5, are solid bronze and are semicircular in shape. One face of each collar has "thumb print" oil depressions to ensure adequate lubrication. They are placed in the counterbore of each center bearing"A" frame and are held in position by the bearing caps. Their purpose is to limit the longitudinal movement of the crankshaft.

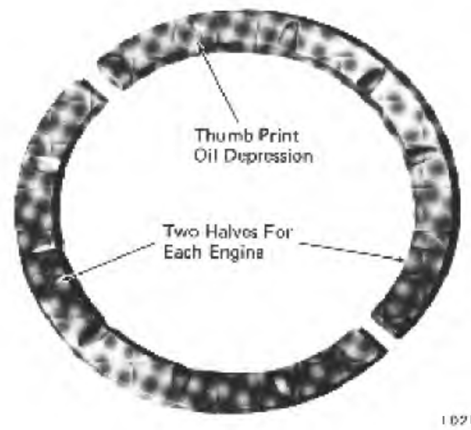

Fig. 6-5 - Crankshaft Thrust Collars

The thrust surfaces are lubricated by main bearing leak-off oil and are installed with their "thumb print" oil depressions away from the "A" frame in which they are placed.

MAINTENANCE

Thrust collars which exceed clearance limit should be replaced.

GEAR TYPE TORSIONAL DAMPER

DESCRIPTION

The gear type damper, Fig. 6-6, is a hydraulic paddle wheel device which absorbs torsional vibrations of the crankshaft by forcing engine lubrication oil through narrow passages in the damper. The damper consists of a spider, with external spur teeth, an intermediate ring, with internal spur teeth, and two outer side plates secured with bolts and nuts. A continuous circulation of oil is provided to the damper through an oil passage in the crankshaft.

Oil flows from the chamber in the center of the damper through radial holes, beginning in the spider hub and ending at the fillet radius at the base of each tooth. The passages contain a narrowed section at the spider hub to provide an oil flow restriction. The spider is designed so that each tooth is directly supplied with oil. An auxiliary circumferential oil groove is machined into each side face of the spider to supply oil for the rubbing surfaces between the spider and outer plate. These grooves are supplied by means of passages connecting the grooves of the radial holes.

The intermediate ring is ground on both sides to a uniform thickness, slightly thicker than the spider.

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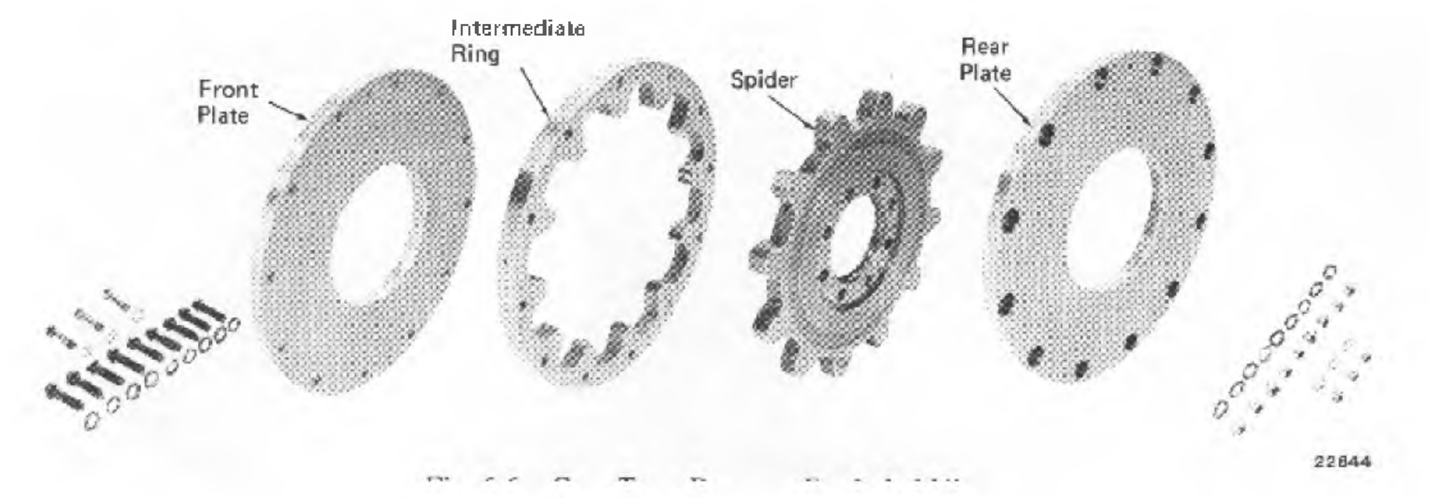

Fig. 6-6 -- Gear Type Damper, Exploded View

This difference in thickness provides the axial clearance necessary for proper oil passage. In addition, clearance between the intermediate ring and the spider is provided to allow the ring to "float" on the oil film generated at the tips of the spider teeth.

Four vent holes are drilled through the rim of the intermediate ring to relieve oil pressure and readjust the ring to a central position when it becomes displaced. The holes, which are equally spaced around the ring, are normally covered by the tips of the spider teeth. However, oil is permitted to vent when the intermediate ring becomes displaced and the spider teeth no longer cover the holes; thereby reducing pressure. The higher pressure on the opposite side of each tooth then prevails and restores the intermediate ring to its correct position. This design is used to prevent sudden bumping of the teeth.

Two identical outer side plates are secured to the intermediate ring by means of through bolts. The inner faces of the plates (adjacent to the spider) are covered with oil which flows through the clearance between the spider and the outer plates and drains to the crankcase.

MAINTENANCE

The damper requires no maintenance other than inspection at the time of normal overhaul. However, the damper should be checked for free movement at intervals specified in the applicable Scheduled Maintenance Program. This check can be performed by removing the rear handhole cover and rotating the damper about 10° in each direction by pressing against the inner plate. If the damper cannot be moved, it should be removed and disassembled.

DISASSEMBLY

1. Scribe a line across the outer plate, intermediate ring, and outer plate. Also mark the relationship of the spider to the outer plate. These marks will be used during reassembly of the unit.
2. Using 1-1/8" thinwall sockets, remove nine 3/4" bolts, washers and nuts from damper.
3. Using 15/16" thinwall sockets, remove three 5/8" bolts, washers and nuts from damper.
4. Remove front plate, intermediate ring, and spider from rear plate.

INSPECTION

1. Inspect four vent holes in intermediate ring for sludge or other obstructions. Remove debris using wire or thin metal rod.
2. Clean oil holes in spider with wire or thin metal rod.
3. Clean all components with fuel oil and examine all surfaces for excessive scratching or scoring.

ASSEMBLY

1. Place front plate with stamped serial number and part number facing down.
2. Apply a liberal coating of engine oil to all contact surfaces between the spider and the intermediate ring, and the inner and outer plates.
3. Place spider on front plate with stamped "FRONT" facing down, and align scribe mark on spider to line on front plate.

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4. Place intermediate ring on front plate so internal teeth mesh with teeth of spider and scribe mark on ring is aligned with mark on front plate.

5. Position rear plate on intermediate ring and align scribe marks.

6. Apply Texaco Threadtex No. 2303 to threads of three 5/8" body bolts and install bolts and washers in 5/8" holes of rear plate, intermediate ring, and front plate.

7. Install 5/8" washers and nuts and torque to 203 N-m (150 ft-lbs).

8. Apply Texaco Threadtex No. 2303 to threads of nine 3/4" bolts and install bolts and washers in remaining holes of rear plate and secure with washers and nuts torqued to 325 N-m (240 ft-lbs).

INSTALLATION

Install damper on crankshaft with side of spider stamped "FRONT" facing away from engine. A "0" stamped above one of the mounting holes is to be applied in line with the number one crank pin. Apply Texaco Threadtex No. 2303 to mounting bolt threads and install eight mounting bolts and hardened washers. Torque to specified value.

ACCESSORY DRIVE GEAR TRAIN

DESCRIPTION

The accessory drive gear train, Fig. 6-7, is located at the front of the engine, and provides power from the crankshaft to drive the oil pumps, water pumps, and the governor.

The gear train consists of the accessory drive gear, scavenging oil pump gear, main lube oil pump gear, right and left hand water pump gears, and the governor drive gear.

MAINTENANCE

Unless a complete engine disassembly is being undertaken it is unlikely that the entire gear train would be removed from the engine at one time. The water pumps, oil pumps, and governor drive assembly can be removed from the gear train as individual units. Removal of the accessory drive gear or the governor drive gear requires removal and realignment of the accessory drive housing.

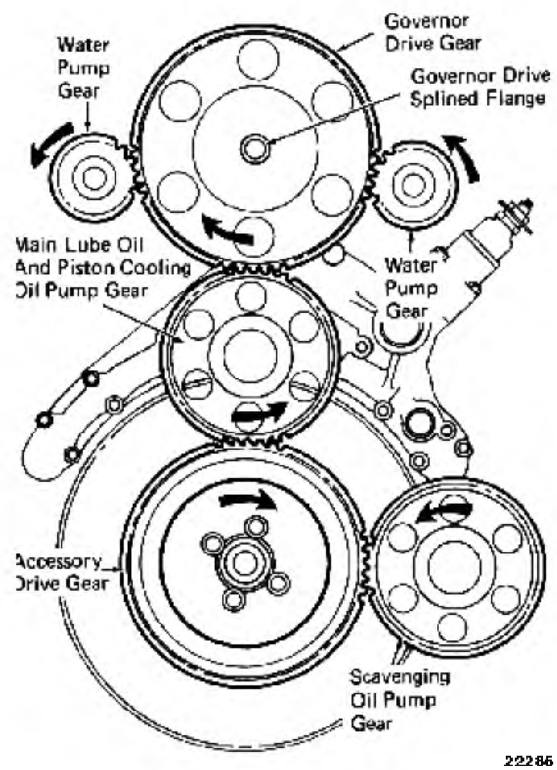

Fig. 6-7 - Accessory Drive Gear Train

ACCESSORY DRIVE GEAR

DESCRIPTION

The coil spring design accessory drive gear, Fig. 6-8, damps the transmission of crankshaft torsional vibrations to the accessory gear train. The accessory drive gear meshes directly with and provides the drive for the lube oil scavenging pump and the main lube oil and piston cooling oil pump.

MAINTENANCE

The accessory drive gear should be removed and inspected at the time of a complete engine overhaul. The accessory drive gear requires very little maintenance. At inspection intervals, it should be disassembled for inspection of parts.

Parts which show obvious damage should be replaced.

REMOVAL

The following removal procedures apply to gears mounted on standard crankshafts and to gears mounted on bolt-on stubshafts.

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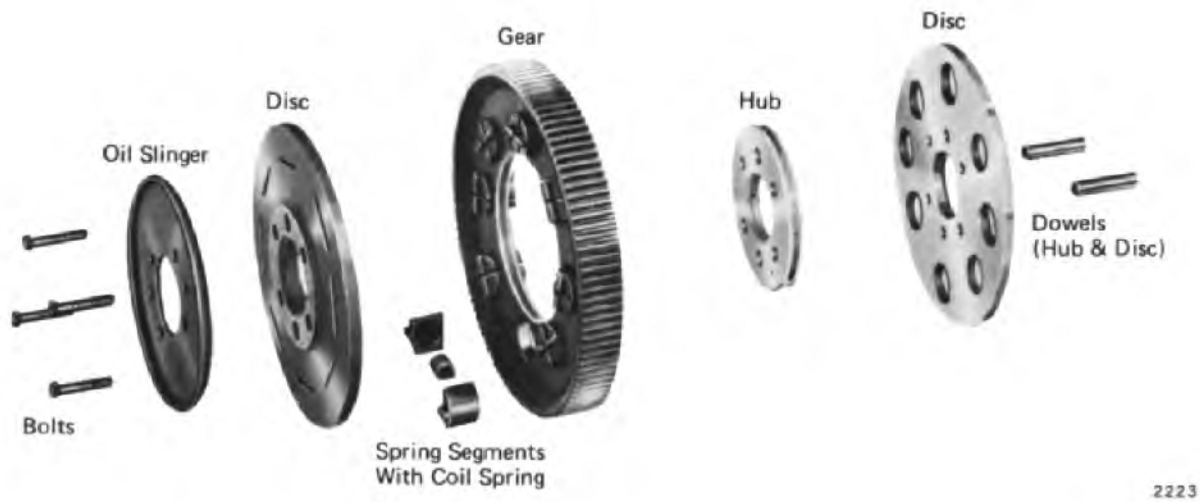

Fig. 6-8 - Accessory Drive Gear, Exploded View

STANDARD CRANKSHAFT

1. Remove four accessory drive gear mounting bolts and hardened washers securing gear to crankshaft.
2. Remove oil slinger.
3. Remove gear from crankshaft. BOLT-ON

STUBSHAFT

WARNING: Accessory drive gear mounting bolts also secure bolt-on stubshaft to crankshaft. Prior to removal of mounting bolts, apply blocking or secure gear and stubshaft with holding device.

1. Remove four oil slinger mounting bolts and remove oil slinger from gear.
2. Remove six spline head mounting bolts and hardened washers securing gear and stubshaft to crankshaft.
3. Remove gear and stubshaft from crankshaft.

BOLT-ON STUBSHAFT WITH IDENTIFICATION GROOVE

NOTE: Current configuration of stubshaft has a 1/8" wide groove on the face of the small end of the taper. This stubshaft is mounted to the crankshaft with two 1/2"-13 retention bolts which allows removal and application of the accessory drive gear and crankshaft damper without removing the stubshaft from the crankshaf't.

1. Remove four oil slinger mounting bolts and remove oil slinger from gear.
2. Remove six spline head mounting bolts and hardened washers securing gear to stubshaft.
3. Remove gear from stubshaft.

GEAR

The gear should be inspected for rough or scored surfaces on the gear teeth, and magnaflux inspected. If wear in excess of maximum limit occurs on the drive side of holes, the gear should be reversed. The serial number side of the gear is placed adjacent to the oil slinger at original installation. To identify the drive side when gear is reversed, the original serial number should be ground off and restamped on the opposite side.

The maximum bore diameter is permissible, provided that the hub to gear clearance does not exceed the maximum limit. (This bore may be chrome plated and reground to new dimension.)

HUB

A hub having a 190.436 mm (7.4975") diameter may be used if the maximum hub to gear clearance is not exceeded.

DISC

The disc may be re-used providing the spring segment bores do not exceed maximum diameter and are otherwise in good condition.

SPRING SEGMENTS

Spring segments should be marked, prior to dis-assembly, as to their relative position in the gear.

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Wear should be checked on the right-hand segment half (viewed at 12 o'clock position) where the segment contacts the gear bore when driving the gear. If wear at this point exceeds maximum limit, the segment half should be replaced.

When reassembling spring segments, re-locate the segment, originally on the driven side, to the drive side, and place the replacement segment at the driven side of the gear.

SPRINGS

Springs may be re-used providing a pre-load exists at assembly of the spring and segments in the gear.

PHOSPHATE TREATMENT

It is recommended that the gear, hub, discs, and segments be phosphate treated before reassembly.

ASSEMBLY

Before reassembling the drive gear, be sure all parts are clean and well lubricated. Place the slotted disc on the bench with the slots facing down, and apply the gear over the disc. Align the holes in the gear and disc. Place a coil spring between two segments, and with the tabs down, and the assembly pressed together, start it into the gear. Drive the assembly all the way down, using a rawhide mallet, until the tabs enter the slot in the disc. Repeat this operation for the remaining spring assemblies. After they are in place, install the hub in the gear bore, and the remaining spring assemblies. After they are in place, install the hub in the gear bore, and apply the top disc. Line up the dowel holes in both discs and hub, and apply the dowels. A snug dowel fit should be maintained by reaming, and if necessary, applying oversize dowels. A bolt and nut should be used to clamp the assembly together until it is applied to a crankshaft.

INSTALLATION

The following procedures apply to crankshaft mounted gears and to bolt-on stubshaft mounted gears.

CRANKSHAFT MOUNTED

1. Install accessory drive gear on crankshaft and align mounting holes with holes in crankshaft.

2. Install oil slinger and align mounting holes with holes in gear.

3. Lubricate four mounting bolts with Texaco Threadtex No. 2303. Install bolts and hardened washers and torque to specified value.

BOLT-ON STUBSHAFT MOUNTED

1. Place gear on stubshaft and align mounting holes.

2. Place gear and stubshaft against crankshaft and align mounting holes of stubshaft to crankshaft.

3. Lubricate six spline head mounting bolts with Texaco Threadtex No. 2303. Install bolts and hardened washers and torque to specified value.

4. Secure oil slinger to gear with four mounting bolts and torque to 33 N-m (24 ft-lbs).

BOLT-ON STUBSHAFT WITH IDENTIFICATION GROOVE MOUNTED

1. If stubshaft has not been installed, align stubshaft retention bolt holes with holes in crankshaft and secure stubshaft to crankshaft with two 1/2"-13 bolts torqued to specified value.

2. Place gear on stubshaft and align mounting holes.

3. Lubricate six spline head mounting bolts with Texaco Threadtex No. 2303. Install bolts and hardened washers and torque to specified value.

4. Secure oil slinger to gear with four mounting bolts and torque to 33 N-m (24 ft-lbs).

GOVERNOR DRIVE GEAR AND STUBSHAFT

DESCRIPTION

The governor drive gear is mounted on the governor drive stubshaft, Fig. 6-9, and is driven by the main lube oil and piston cooling pump gear. The governor drive gear is used to drive the right and left bank water pumps and the governor drive assembly.

MAINTENANCE

The governor drive gear and stubshaft require no maintenance other than inspection at the time of normal overhaul.

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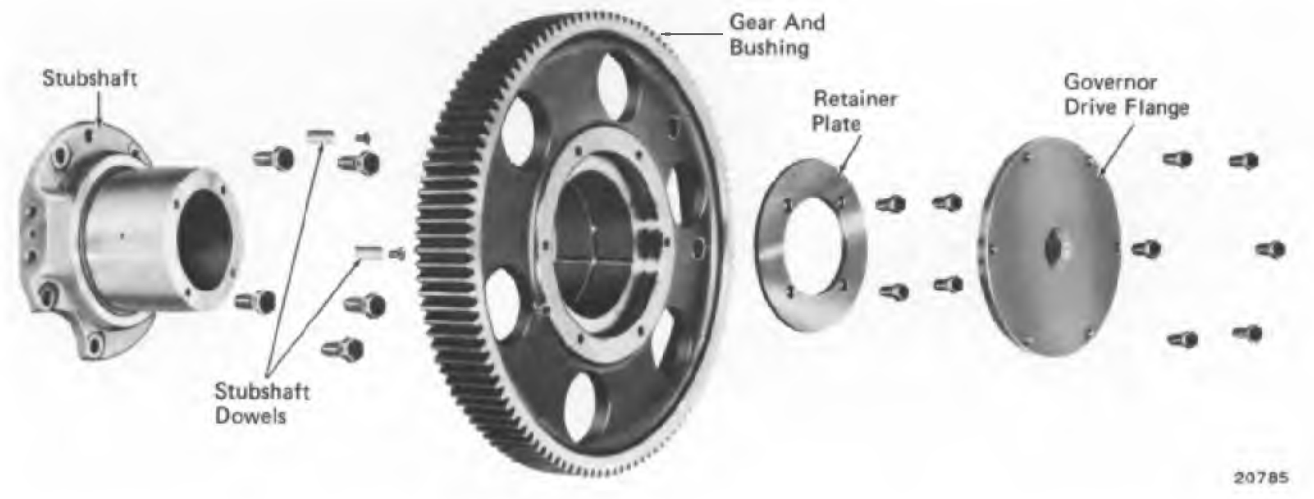

Fig. 6-9 - Governor Drive Gear And Stubshaft

Inspect gear teeth for fatigue indications, cracks, pits or other evidence of failure. If possible, a magnatlux inspection should be performed. Inspect the gear bushings and stubshaft for gouges or other damage and ensure that stubshaft oil passage is not plugged.

INSTALLATION

1. Position stubshaft on crankcase with oil inlet on left side.

2. Secure stubshaft to crankcase using four 1/2"-20 hex head drilled bolts. Do not torque bolts at this time.

3. Apply governor drive gear assembly to stubshaft.

4. Place "dummy" main lube oil pump gear on top of accessory drive gear with teeth meshed with accessory drive gear and governor drive gear.

5. Raise or lower governor drive gear stubshaft until backlash between governor drive and main lube oil pump gear is 0.41-0.81 mm (.016"-.032").

NOTE: Since the "dummy" oil pump gear is resting on the accessory drive gear with zero backlash, the backlash between the "dummy" gear and the governor drive gear is twice the normal requirement of 0.20-0.41 mm (.008"-.016").

6. Remove "dummy" gear and governor drive gear.

7. Tighten governor drive stubshaft bolts to 102 N-m (75 ft-lbs).

8. Ream the two dowel holes in the governor drive stubshaft with a 0.494" tapered reamer and a 0.4998" ± 0.0002" bottoming reamer, being sure to use cutting oil.

NOTE: If the dowel holes in governor drive stubshaft do not align with holes in crankcase, drill and ream for oversize dowels as required to produce full circumference fit. See parts catalog for listing of oversize dowels.

9. Use an air hose to blow chips and oil out of the dowel holes, and insert 1/4"-28 bolts approximately 6.35 mm (1/4") into the dowel pins.
10. Place dowels in dowel holes in the stubshaft and drive into the crankcase end plate.

11. Torque the dowel bolts to 23 N-m (17 ft-lbs) and lockwire stubshaft mounting bolts and dowel bolts in groups of three or less.

12. Apply gasket between oil jumper and oil passage on stubshaft. Secure oil line to stubshaft using two 3/8"-24 hex head drilled bolts and torque to 47 N-m (35 ft-lbs). Lockwire mounting bolts.

13. Apply governor drive gear to stubshaft.

14. Install retainer plate and secure to stubshaft using four 3/8"-24 hex head bolts torqued to 47 N-m (35 ft-lbs).

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15. Lockwire retainer plate mounting bolts.

16. Apply governor drive flange to governor drive gear and secure with six 3/8"-24 hex head drilled bolts torqued to 47 N-m (35 ft-lbs).

17. Lockwire flange bolts to two groups of three bolts each.

ACCESSORY DRIVE HOUSING APPLICATION AND ALIGNMENT

The following procedure is provided to properly align the accessory drive housing to the accessory drive and governor drive assemblies for subsequent application of the water and lube oil pumps.

1. Apply sealing compound to accessory drive housing mounting flange, and apply gasket.

2. Place mounting bolts and washers in housing mounting holes.

3. Using holding fixture (File 758) and a suitable lifting device, position housing to crankcase and secure with one mounting bolt on each side of housing, Fig. 6-10.

4. Remove holding fixture from housing.

5. Hand-tighten all mounting bolts.

6. Apply left-hand water pump alignment gauge (File 761) to left pump opening in housing so that gauge gear teeth mesh with governor drive gear, Fig. 6-11.

7. Apply right-hand water pump alignment gauge (File 762) to right pump opening in housing so that gauge gear teeth mesh with governor drive gear.

8. Apply oil pump alignment gauge (File 763) to the main lube oil pump opening in housing so that gauge gear teeth mesh with accessory drive gear. This same gauge is used to align the housing to the governor drive gear.

9. Apply another oil pump alignment gauge (File 763) to scavenging oil pump opening in housing so that gauge gear teeth mesh with accessory drive gear.

10. Position jacking tool (File 759) over the end of the accessory drive shaft until the adjusting nuts are in line with the accessory drive opening, Fig. 6-11.

Movement of the vertical adjusting nuts will affect the gauge readings of the governor drive gear and the accessory drive gear that are taken by the alignment gauge applied to the main lube oil pump opening.

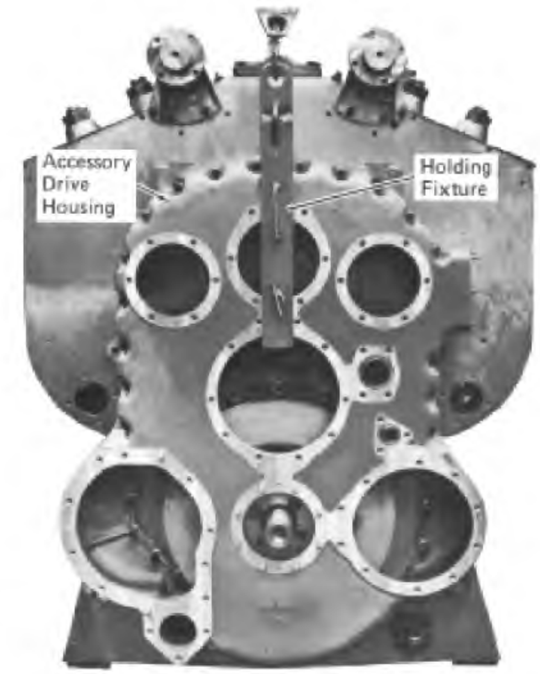

Fig. 6-10 - Accessory Drive Housing Positioning

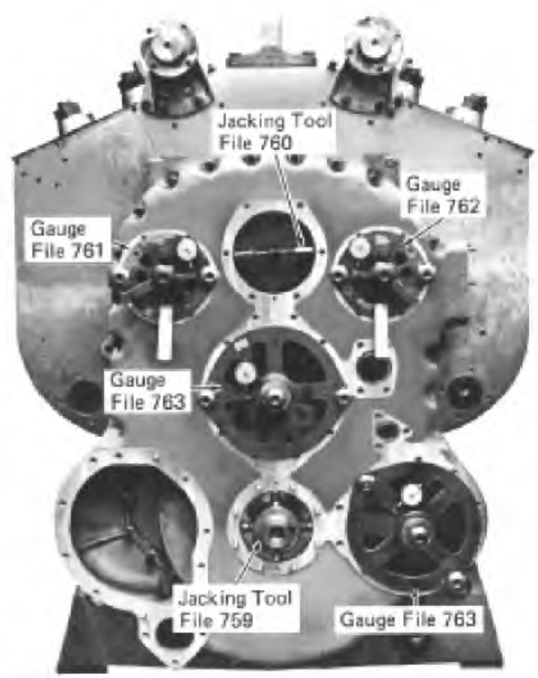

Fig. 6-11 - Accessory Drive Housing Alignment

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Movement of the horizontal adjusting nuts will affect the gauge reading of the accessory drive gear which is taken by the alignment gauge applied to the scavenging oil pump opening.

11. Insert spline end of jacking tool (File 760) into splines of the governor drive gear flange until the adjusting nuts are in line with the governor drive opening. Adjusting nuts should be in a horizontal position, Fig. 6-11. Movement of the adjusting nuts affects the gauge readings of the governor drive gear which are taken by the alignment gauges mounted at the water pump openings.

12. Adjust both jacking tools until all four gauges indicate within 0.20-0.41 mm (.008"-.016") clearance between the gauge gears and the engine-mounted gears.

13. Disengage the gear of the alignment gauge mounted in the main lube oil pump opening from the accessory drive gear and rotate approximately 180° to mesh with the governor drive gear. Recheck all gauge indications of 0.20-0.41 mm (.008"-.016") clearance.

14. Tighten four mounting bolts, preferably one on each side, and one at top and bottom.

15. Remove both jacking tools from housing.

16. Check all alignment gauges. If all indications are within 0.20-0.41 mm (.008"-.016"), tighten remaining housing mounting bolts to 88 N-m (65 ft-lbs).

RING GEAR AND COUPLING DISC (FLYWHEEL)

DESCRIPTION

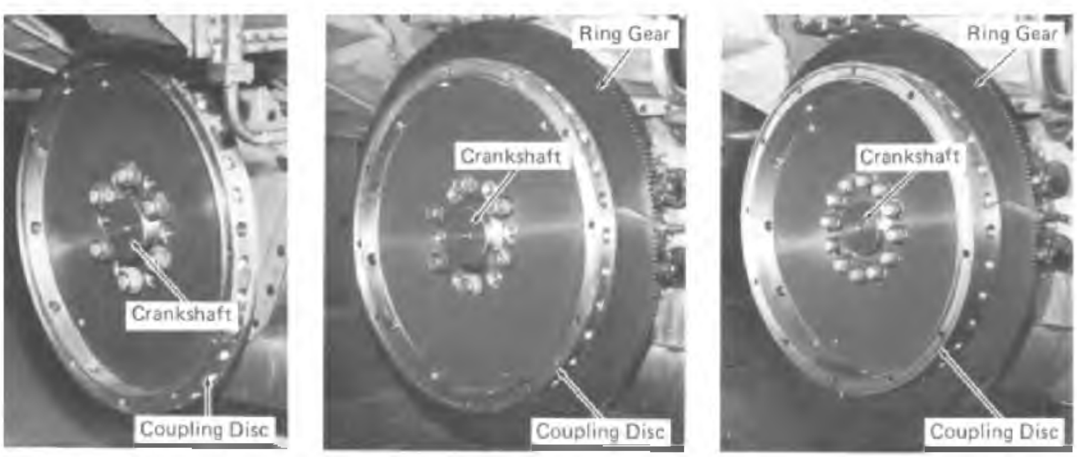
The ring gear, Fig. 6-12, is used on engines equipped with starting motors. Engaging the teeth on the ring gear rotates the crankshaft for engine starting or selects a crankshaft position when using an engine turning gear device. The ring gear pilots on the engine side of the coupling disc and is bolted to the coupling disc.

The coupling disc serves as the coupling between the engine crankshaft and the driven shaft. Degree and top dead center markings are stamped on the outer rim of the coupling disc. Holes are also provided around the circumference of the rim for insertion of a turning bar to manually rotate the crankshaft.

MAINTENANCE

Inspect the engine coupling disc for cracks or damaged surfaces. Also inspect the coupling disc to crankshaft bolt holes for elongation or fretting at the bolt head mating surface. If the surface is fretted the area may be spotfaced up to 1.59 mm (1/16") deep as long as the minimum disc thickness is maintained. See Service Data for limits.

Engine to generator coupling discs should be re-qualified whenever the engine or the generator assembly is removed. Maximum trouble free per-formance of the engine-generator coupling can best be ensured by careful magnetic particle inspection of both discs prior to their reuse. This inspection is particulary important if it is known that the coupling has been subjected to unusual stress.



8 & 12-Cyl. (w/DC Gen.) | 12-Cyl. w/AC Gen. & 16-Cyl. | 20-Cyl.

Fig. 6-12 - Ring Gear And Coupling Disc Installations

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Engine coupling discs of the same type are interchangeable, providing top dead center pointer location on the engines is the same. The serrated coupling is assembled without using body bound bolts and for this reason has no reamed holes. All rim bolts are the same size. The coupling disc should be applied to the crankshaft with the small "O" marks on the coupling disc and the crankshaft coinciding. This will position the coupling with the pointer at the 0° mark on the rim when the No. 1 piston is at TDC.

Apply Texaco Threadtex No. 2303 to engine coupling bolts and tighten bolts to a torque value of 2440 N-m (1800 ft-lbs) on the 8, 12, and 16-cylinder engines and 1830 N-m (1350 ft-lbs) on the 20-cylinder engine. Tighten the rim bolts uniformly (to avoid cocking the coupling on the serrations) to a torque value of 400 N-m (295 ft-lbs). The gap between the coupling halves at the rim bolts should not be less than minimum after the rim bolts have been properly torqued.

CAUTION: The coupling bolts must be applied with the chamfered side of the head placed adjacent to the crankshaft fillet.

Face runout and rim eccentricity should be checked after installation of coupling disc to crankshaft, and with crankshaft positioned to avoid thrust interference. Eccentricity of rim outside diameter and runout on rim face should not exceed maximum indicator reading listed in Service Data.

ACCESSORY DRIVE COUPLING

DESCRIPTION

The accessory drive coupling assembly, Fig. 6-13, is bolted and keyed to the tapered front end of the crankshaft to provide a power takeoff connection for components driven from the front of the engine. In some applications, the coupling is bolted to a tapered stubshaft.

Fig. 6-13 - Accessory Drive Coupling

MAINTENANCE

The accessory drive coupling does not require any routine maintenance. However, replacement of the rubber center-bonded joints may be required or desired. See the applicable Maintenance Instruction for replacement of rubber joints.

COUPLING APPLICATION

If the coupling has been removed, it is essential that the proper application procedure is used to avoid severe damage to the crankshaft of either the driven unit or the engine.

1. Prior to mounting the coupling on the crankshaft (stubshaft), inspect the two tapered surfaces to ensure the mating surfaces are free of nicks or burrs. Use aluminum oxide cloth of a 180J grit to clean the tapered surfaces and the crankshaft key slot.
2. Hand fit 2-1/2" key so it is tight in the engine crankshaft key slot. Tap the key in the slot so the end of the key is flush with the end of the crankshaft.

NOTE: If the key slides in the keyway, scrap the key.

3. Fit the coupling flange on the shaft, making sure that the key remains flush with the end of the shaft.
4. Lubricate the threads on the retaining bolt and both sides of the washer with Texaco Threadtex. Torque the retaining bolt to 136 N-m (100 ft-lbs).
5. Attach a dial indicator to the coupling with the button of the indicator on the accessory housing or on one of the studs at the coupling seal. Zero the indicator.
6. Torque the retaining bolt to 678 N-m (500 ft-lbs) and record the advance, measured to the nearest thousandth. Failure to obtain a reading within the limits given in the Service Data is usually caused by imperfections found on one of the tapered surfaces or within the keyway. These surfaces should be free of all nicks or burrs.
7. Install the lock spring, lockwasher,and 1/2"-20 bolt in the head of the retaining bolt and torque to 88 N-m (65 ft-lbs).
8. With a dial indicator button resting on the outside diameter of the coupling flange, record the T.I.R. of the rim to be sure it does not exceed the limits given in the Service Data.

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SERVICE DATA CRANKSHAFT ASSEMBLY AND ACCESSORY DRIVE GEAR TRAIN

REFERENCES

Alignment of locomotive rotating equipment .... M.I. 1753

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Crankshaft	
Diameter, main journal -	
New	190.45-190.50 mm (7.498"-7.500")
Min.	190.411 mm (7.4965")
Diameter, crankpin journal -	
New	165.05-165.10 mm (6.498"-6.500")
Min.	165.011 mm (6.4965")
Clearance (diametric main bearings to crankshaft) -	
New	0.190-0.368 mm (.0075"-.0145")
Max.	0.521 mm (.0205")
Thrust Bearing Clearance -	
(8 & 12-Cyl.) -	
New	0.20-0.38 mm (.008"-.015")
Max.	0.76 mm (.030")
(16 & 20-Cyl.) -	
New	0.20-0.46 mm (.008"-.018")
Max.	0.76 mm (.030")
Thrust Bearing Collar Thickness -	
8, 16 & 20-Cyl.	9.35-9.37 mm (.368"-.369")
12-Cyl.	22.07-22.10 mm (.869"-.870")
Accessory End Gear Train	
Backlash (all drive gears) -	
New	0.20-0.41 mm (.008"-.016")
Max.	0.64 mm (.025")
Accessory Drive Gear	
Hub to gear clearance -	
New	0.038-0.08 mm (.0015"-.003")
Max.	0.089 mm (.0035")
Diameter of gear spring segment holes - New -	
(8 & 12-Cyl.)	50.95-51.05 mm (2.006"-2.010")
(16 & 20-Cyl.)	62.05-62.15 mm (2.443"-2.447")
Wear on drive side of gear -- Max.	0.02 mm (.001 ")

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Gear bore diameter -	
New	190.50-190.53 mm (7.50"-7.501 ")
Max.	190.55 mm (7.502")
(If hub to gear maximum clearance is not exceeded)	
Hub outside diameter - Min.	190.436 mm (7.4975")
(If hub to gear maximum clearance is not exceeded)	
Disc spring segment bore -- Max.	
(8 & 12-Cyl.)	51.08 mm (2.011 ")
(16 & 20-Cyl.)	62.18 mm (2.448")
Spring segment wear (right half as viewed from 12 o'clock position) - Max.	0.02 mm (.001 ")

Governor Drive Gear

Governor drive gear to stubshaft clearance	
New	0.08-0.15 mm (.003"-.006")
Max.	0.20 mm (.008")
Thrust clearance	
New	0.15-0.36 mm (.006"-.014")
Max.	0.51 mm (.020")

Flexible Coupling

Crankshaft pilot diameter - Max.	203.264 mm (8.0025")
Mounting bolt hole diameter - Max.	45.212 mm (1.780")
Thickness at mounting bolt holes - Min.	17.462 mm (.6875")
Clearance between coupling discs at rim bolts, after bolts are torqued -- Min.	0.038 mm (.0015")
Coupling face runout -- Max.	0.25 mm (.010") T.I.R.
Coupling rim eccentricity -- Max.	0.13 mm (.005") T.I.R.

Accessory Drive Coupling

Coupling advance -- coupling-to-stubshaft	1.27-11.52 mm (.050"-.060")
Coupling rim runout - Max.	0.25 mm (.010") T.I.R.

EQUIPMENT LIST

	Part No.
Upper main bearing shell remover	8055837
Sealing compound gasket (1 pt.)	8178639
Thread lubricant (5 gal.)	8307731
Pinion and flange remover	8309742
Main bearing cap application and removal tool	8487487
Upper main bearing removal tool	8488833
Adapter nipple	8496555
Serration gauge	9081052
Accessory drive housing holding fixture	File 758
Accessory drive housing jacking fixture	File 759

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SERVICE DATA
CRANKSHAFT ASSEMBLY AND
ACCESSORY DRIVE GEAR TRAIN

Accessory drive housing jacking fixture . . . . File 760
Accessory drive housing aligning gauge -
L.H. water pump application . . . . File 761
Accessory drive housing aligning gauge -
R.H. water pump application .... File 762
Accessory drive housing aligning gauge -
Oil pump application . . . . File 763

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SECTION 7
CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

CONTENTS PAGE

CONTENTS	PAGE
CAMSHAFT GEAR TRAIN	
DESCRIPTION	7-1
MAINTENANCE	7-1
CAMSHAFT DRIVE GEARS	
REMOVAL	7-3
INSPECTION AND INSTALLATION	7-3
SPRING DRIVE GEAR	
DISASSEMBLY	7-4
INSPECTION, ASSEMBLY, AND INSTALLATION	7-4
NO. 1 IDLER GEAR	
BEARING CLEARANCE CHECK	7-4
REMOVAL, INSPECTION, AND INSTALLATION	7-5
IDLER GEAR STUBSHAFT	
REMOVAL	7-5
INSPECTION	7-5
BEARING AND SLEEVE REPLACEMENT, AND INSTALLATION	7-6
CRANKSHAFT GEAR	
REMOVAL INSPECTION, AND INSTALLATION	7-6
CAMSHAFT GEAR TRAIN ASSEMBLY	7-6
AUXILIARY DRIVE	
DESCRIPTION	7-11
MAINTENANCE	7-11
CAMSHAFT	
DESCRIPTION	7-11
REMOVAL, INSPECTION, ASSEMBLY, AND INSTALLATION	7-12
COUNTERWEIGHT APPLICATION	7-13
EXHAUST VALVE TIMING	
LOCATING TOP DEAD CENTER	7-13
CHECKING VALVE TIMING	7-15
TIMING VALVES	7-15
SERVICE DATA	
SPECIFICATIONS	7-19
EQUIPMENT LIST	7-21

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ENGINE MAINTENANCE MANUAL

SECTION 7

ELECTRO-MOTIVE

CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

CAMSHAFT GEAR TRAIN

DESCRIPTION

Power necessary to drive the camshafts, and the turbocharger before it becomes free wheeling, is supplied through the gear train at the rear of the engine. Fig. 7-1 shows the gear train before the camshaft drive housing and turbocharger are installed, and Fig. 7-2 shows a cross-section of the gear train.

The gear train, Fig. 7-1, consists of a crankshaft gear mounted on the crankshaft, No. 1 idler gear,

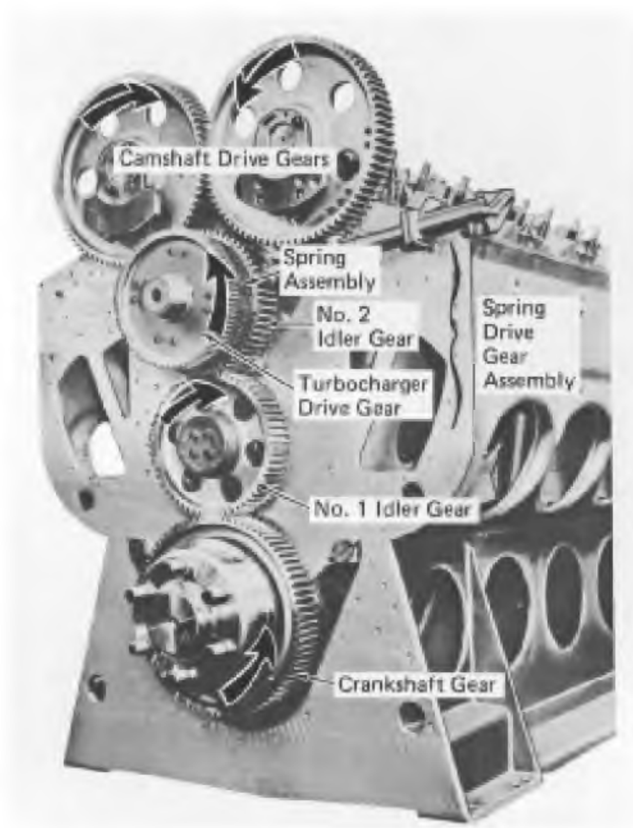

Fig. 7-1 - Camshaft Gear Train

a spring drive gear assembly, and the left and right camshaft drive gears. The spring drive gear assembly is made up of the No. 2 idler gear, a spring assembly, and the turbocharger drive gear.

MAINTENANCE

Unless a complete engine disassembly is being undertaken, it is unlikely that the entire gear train would be removed from the engine at one time. With the exception of the No. 2 idler gear and the turbocharger drive gear, which are part of the spring drive gear assembly, each gear in the train can be removed independently.

When any of the gears are removed from the gear train, they should be inspected for excessive backlash upon reassembly by inserting a feeler gauge the entire width of the gear face. Excessive backlash can cause improper valve operation and injection periods. Backlash clearance limits are given in the Service Data page at the end of this section. Clearances between gear stubshaft and bearings and thrust clearances must also be maintained within specified limits.

NOTE: Refer to "No. 1 Idler Gear" for a bearing clearance check without disassembly.

The turbocharger, aftercooler ducts, auxiliary drive assembly, and coupling disc must be removed from the engine to facilitate access to the camshaft gear train. If removal of the No. 1 idler gear or the crankshaft gear is required, the camshaft gears, oil retainer, and camshaft drive housing must be removed.

NOTE: Engine timing will not be disturbed during idler gear removal as long as the camshafts and crankshaft are not moved when gears are removed.

If original idler gears are to be reapplied and it is desired to retain timing mark orientation for future work, mark the gears as they lie before removal.

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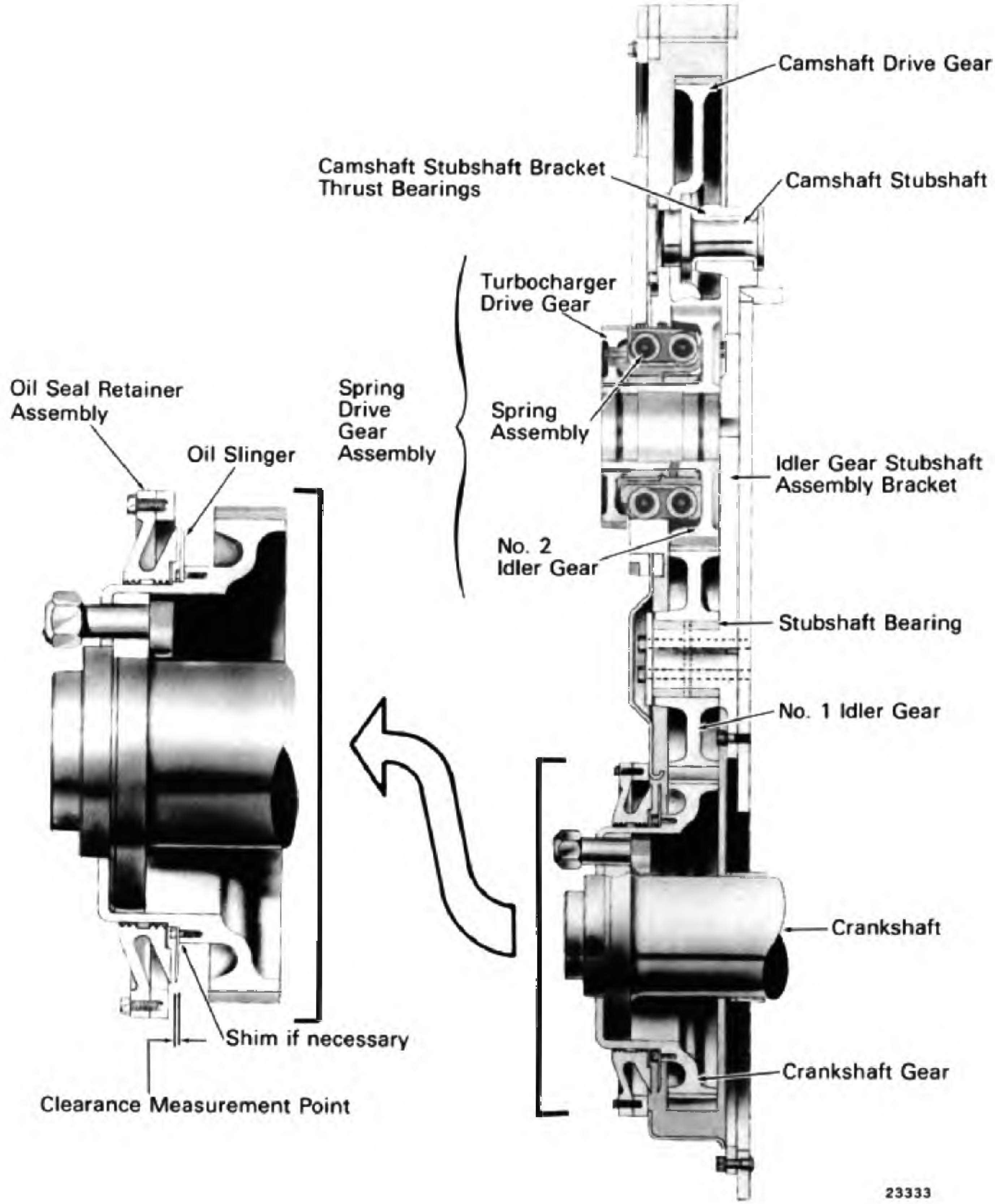

Fig. 7-2 - Camshaft Gear Train, Cross-Section

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The following paragraphs contain the removal, inspection, and installation procedures for each gear in the train.

CAMSHAFT DRIVE GEARS

REMOVAL

1. Remove the Lockwire and the four bolts holding the counterweight and camshaft drive gear to the stubshaft.

2. Remove the dowel bolts and the retainer plate.

3. The counterweight and camshaft drive gear can now be removed from the stubshaft.

4. Remove the dowels from the counterweight and camshaft drive gear by driving them out from the back side of the gear.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks or other evidence of failure. If possible, a magnaflux inspection should be performed.

In addition to the above, also check the camshaft gear which mates with the auxiliary drive gear for a wear step. Normal discoloration, due to a narrow gear mating with a wider gear, should not be considered as a wear step.

An accurate measurement can be made using a 0.420"-0.430" diameter roller. Place the roller on the unworn portion of the gear tooth so it is suspended over the worn portion. The distance between the roller and the worn gear tooth should not exceed the limit given in the Service Data. If wear step exceeds the wear limit, the camshaft gear and the auxiliary drive gear should be replaced. Pitting or gouging of the cam gear teeth, where the auxiliary drive gear mates, indicates misalignment. The cause should be determined before applying replacement gears.

INSTALLATION

1. Install the camshaft drive gear on the stubshaft being sure to position it on the stubshaft so the position markings line up with the markings on the mating parts, as shown in Fig. 7-21.

2. Install counterweight on stubshaft with counterweight to stubshaft marks aligned.

3. Install dowels, dowel retainer plate, and counterweight to stubshaft bolts. Torque bolts to 122 N-m (90 ft-lbs).

4. Install dowel bolts and torque to 22 N-m (17 ft-lbs).

5. Lockwire mounting bolts and dowel bolts in groups of three (two mounting bolts and one dowel bolt).

6. If any gears in the camshaft gear train are replaced or the relationship of the crankshaft to the camshaft has been disturbed, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears.

SPRING DRIVE GEAR ASSEMBLY

The spring drive gear assembly, Fig. 7-3, consists of the No. 2 idler gear, the turbocharger drive gear, and a spring assembly mounted between the two gears to absorb any torsional vibration which might be transmitted through the gear assembly to the turbocharger. The spring drive gear assembly should be removed as an assembly and then disassembled for inspection.

Fig. 7-3 - Spring Drive Gear Assembly

DISASSEMBLY

1. Remove the spring drive gear assembly from the stubshaft and check for any loose gearto-spider bolts. Discard any loose bolts. This is necessary because loose bolts caused by movement of the spiders due to high loads will have damaged threads. Damaged bolts will result in unsatisfactory clamp load.

2. Remove Lockwire and the eight 1/2"-1 3 bolts that hold the turbocharger drive gear to the outer spider.

3. Remove the snap ring near the inner circumference of the gear. The turbocharger drive gear can now be separated from the assembly.

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4. Next remove the spring assembly from the idler gear by removing the 5/8"-11 bolts and the 1/2" dowels from the idler gear.

5. It should not be necessary to further disassemble the spring drive gear assembly. The spiders, springs, and spring seats making up the spring assembly do not require any routine type of maintenance. If the spring drive gear assembly is found to be defective, it should be replaced with a qualified assembly.

WARNING: Any attempt to disassemble the spring assembly with the use of vises, clamps, rams, or pinch bars can be extremely hazardous and is not recommended.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks, pits, or other evidence of failure. If possible, a magnaflux inspection should be performed on the gears. Inspect the idler gear bearings to see that they are not gouged or damaged in any way. Also check oil holes to see that they are not plugged.

ASSEMBLY

1. Thoroughly clean four 5/8"-11 idler to spider mounting bolts to remove all traces of thread lubricant. Use cleaner activator listed in Service Data. Also clean spider bolt holes of lubricant and contaminants, using the same cleaner.

2. Slide spring assembly over the idler gear hub. Apply sealing compound to the 5/8"-11 bolts and install bolts through the idler gear into the inner spider. Torque to 224 N-m (165 ft-lbs). If the same idler gear and spring assembly are used, install the gear to spider dowels to 6.35 mm (1/4") below the surface and stake the dowel holes in three places, 120° apart.

   If a new idler gear and spring assembly are being used, drill two holes through the gear web and into the spider. Drill 37.34 mm (1-5/16") deep and line ream the holes to 34.52 mm (1-9/32") deep x 12.662 mm plus 0.013 mm minus 0.000 mm (.4985" plus .005" minus .000"). Locate the holes 100.00 mm ± 0.08 mm (3.937" ± .003") above and below the idler gear centerline and in line with two gear mounting bolt holes. Drive two dowels to 6.35 mm (1/4") below the surface and stake the holes at three places, 120° apart.

3. Install the turbocharger drive gear on the idler gear hub and install the snap ring in the idler gear hub groove.

4. Apply thread lubricant to the bolt threads and washer surfaces and install the eight 1/2"-13 x 1-1/4" bolts with hardened washers (replace 1-1/8" bolts used on early models and add washers) through the turbocharger drive gear into the outer spider. Torque bolts to 111 N-m (82 ft-lbs) and lockwire the bolt heads.

INSTALLATION

1. Place the spring drive gear assembly on the idler gear stubshaft being sure the tooth position marks are aligned as shown in Fig. 7-21.

2. If a new gear is used, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears. Timing procedures are not required if camshaft and crankshaft positions have not been disturbed.

NO. 1 IDLER GEAR

BEARING CLEARANCE CHECK WITHOUT DISASSEMBLY

The No. 1 idler gear bearing clearance can be checked without any disassembly of the engine.

1. Remove the rear left bank oil pan handhole cover and insert the rod assembly into the camshaft drive housing so that the end with the flattened side is at the bottom.

2. Position the rod so that the bracket mount straddles the crankcase endplate, and the top of the rod contacts the side of the No. 1 idler gear, Fig. 7-4. Hand tighten the bracket bolt.

3. Apply the light tension spring between the lower part of the rod and the edge of the handhole opening, Fig. 7-4, to maintain idler gear to rod contact.

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NOTE: Photo at right was taken without the camshaft drive housing to illustrate the rod assembly-to-idler gear application.

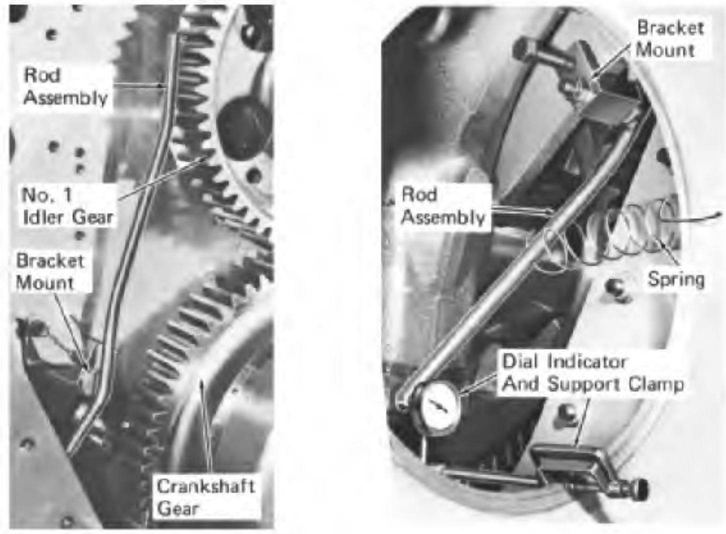

Fig. 7-4 - Application Of Parts For Checking Bearing Clearance

4. Secure the support clamp of' a dial indicator to the edge of the handhole opening. Position the indicator plunger so that it contacts the flattened side of the rod, Fig. 7-4.
5. With the cylinder test valves closed, use the engine turning bar, and manually rock the crankshaft as many times as necessary to remove the oil from the idler gear bearing. This will be evidenced on the dial indicator by no increase over previous reading taken for each direction of crankshaft travel.
6. Bar the crankshaft slightly in one direction until there is no further dial indicator movement, and set the indicator to zero. Bar the crankshaft in the opposite direction until there is no further dial indicator movement, and note reading. Multiply the reading by 1.3 to obtain No. 1 idler gear bearing clearance. Refer to limits in Service Data.

NOTE: It may be necessary to lock the left bank camshaft in order to provide sufficient load on the No. 1 idler gear to obtain full movement. This should be done if clearance does not fall within the limits given in Service Data.

If idler gear is to be removed, refer to the following procedures.

REMOVAL

1. Remove the four bolts and washers holding the thrust plate and idler gear.
2. Remove the thrust plate and idler gear from the stubshaft.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks, pits, or other evidence of failure. If possible a magnaflux inspection should be performed.

INSTALLATION

See "Camshaft Gear Train Assembly" information for complete installation procedure.

IDLER GEAR STUBSHAFT ASSEMBLY

REMOVAL

1. After the spring drive gear assembly, the No. 1 idler gear and the attached oil lines have been removed, the stubshaft assembly can be taken off.
2. Remove the lockwire, dowel bolts, and the locating dowels.
3. Remove the mounting bolts and stubshaft assembly.

INSPECTION

1. Check that oil passages are not plugged.
2. Check alignment of oil holes in upper stubshaft sleeve with holes in stubshaft. Inspect sleeve for nicks or gouges.
3. Inspect upper stubshaft seal and replace, if necessary.
4. Check bearing on lower stubshaft and sleeve on upper stubshaft to see that they are not gouged or damaged in any way.

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NO. 1 STUBSHAFT BEARING REPLACEMENT

1. Remove pressfit bearing from stubshaft by heating bearing until it can be removed.
2. Install new bearing by heating bearing in oil to 149°-163° C (300°-325° F) and pressing on stubshaft. Make certain that oil hole through bearing is at the 12 o'clock position.

NO. 2 STUBSHAFT SLEEVE REPLACEMENT

1. Remove 3/8" dowel which pins sleeve to stubshaft. Heat sleeve until it can be removed from stubshaft.
2. Install new sleeve by heating sleeve in oil to 260° C (500° F) and pressing on stubshaft. Oil holes in sleeve should be aligned to within 1/32" of oil passages in stubshaft. Install new dowel.

INSTALLATION

If a new stubshaft assembly is to be applied, see "Camshaft Gear Train Assembly" for installation procedure. If the stubshaft assembly that was removed from the engine is to be re-used, see the following installation procedure.

1. Attach the stubshaft assembly to the crankcase with the three vertically centered mounting bolts, and finger tighten.
2. Apply the lower idler gear to the stubshaft assembly to mesh with the crankshaft gear.
3. Place a feeler gauge between the lower idler and crankshaft gear teeth, and check the backlash. Backlash limits are in the Service Data.
4. If necessary, reposition the stubshaft assembly until the allowable backlash is obtained.
5. Apply the remaining stubshaft assembly mounting bolts, and torque all bolts.
6. Install dowels and dowel bolts, and lockwire all bolts.
7. Apply the oil lines to the stubshaft bracket.

CRANKSHAFT GEAR

REMOVAL

1. Remove the crankshaft gear from crankshaft.
2. The oil slinger can be removed from the crankshaft gear by removing the oil slinger to crankshaft gear bolts.

INSPECTION

Inspect the gear teeth for fatigue indications, cracks, pits, or other evidence of failure. If possible a magnaflux inspection should be performed. Inspect the oil slinger and oil seal retainer to see that they are not bent or damaged in any way.

INSTALLATION

See the "Camshaft Gear Train Assembly" information for complete installation procedure.

CAMSHAFT GEAR TRAIN ASSEMBLY

If the complete gear train has been disassembled (not including the camshaft stubshaft brackets), the following procedure should be used to install and align the various components.

STUBSHAFT BRACKET APPLICATION

1. Inspect the crankcase end plate for any burrs or damaged areas.
2. Clean any dirt or debris from the holes in the end plate or the end plate surface.
3. Wipe the crankshaft gear teeth clean, insert the coupling bolts in the gear from the back side and install it in its proper position on the crankshaft, as shown in Fig. 7-21. Secure the crankshaft gear with two nuts, moderately tightened.

   If a new gear is used, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears. Timing procedures are not required if camshaft positions have not been disturbed.
4. Inspect the stubshaft bracket rear surface for burrs and wipe clean, making sure all oil passages are clean and free of dirt.
5. Install two temporary locating pins, Fig. 7-5, into the idler gear stubshaft bracket mounting holes in the crankcase end plate.
6. Install the stubshaft bracket in position and apply the three vertically centered 1/2"-20 mounting bolts with hardened washers. Finger tighten the mounting bolts.
7. Apply the idler gear gauge (File 768) to the No. 1 idler gear stubshaft, Fig. 7-6, and place a feeler gauge between the idler gear gauge teeth and the crankshaft gear teeth to check the gear backlash which is specified in the Service Data at the end of this section.

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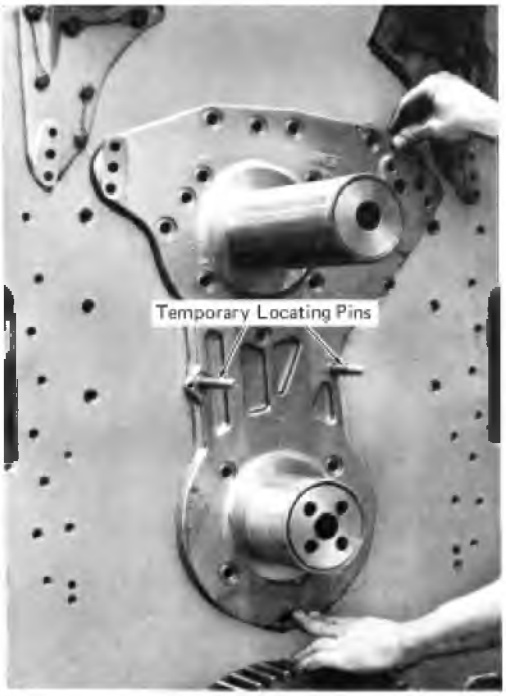

Fig. 7-5 - Idler Stubshaft Bracket Application

NOTE: The No. 1 idler gear may be used if a gauge is not available.

8. If the backlash is not within limits specified, gently tap the stubshaft bracket with a brass hammer until it is in position to obtain the proper backlash.

CAUTION: Do not tap on machined surfaces of the stubshaft bracket.

9. When the stubshaft bracket is properly aligned, tighten the bottom bolt to the proper torque and re-check the backlash.

10. Apply an idler gear stubshaft to camshaft stubshaft gauge (File 769), Fig. 7-7, and check the dimension between the No. 2 idler gear stubshaft and the left bank camshaft stubshaft making sure both stubshafts are wiped clean. Gauge must indicate less than 0.005 ".

NOTE: The No. 2 idler gear and left bank camshaft drive gear may be applied and backlash reading taken between No. 2 idler gear and camshaft drive gear if gauge is not available. See Service Data for limits.

Fig. 7-6 - Checking No. 1 Idler Gear To Crankshaft Gear Backlash

11. If the dimension is not within limits, gently tap the stubshaft bracket until it is properly positioned.

CAUTION: Do not tap on machined surfaces of the stubshaft bracket.

12. When the stubshaft bracket is properly positioned, tighten the top and center mounting bolts to the proper torque and recheck the backlash between the idler gear gauge and the crankshaft gear.

13. If the backlash is not within the proper limits, the three vertical mounting bolts must be loosened and Steps 7 thru 12 repeated.

14. Remove the idler gear gauge and apply the remaining stubshaft mounting bolts and washers.

NOTE: One 3/8"-24 bolt is used at the edge of the stubshaft bracket directly below the lube oil manifold connection to the stubshaft bracket.

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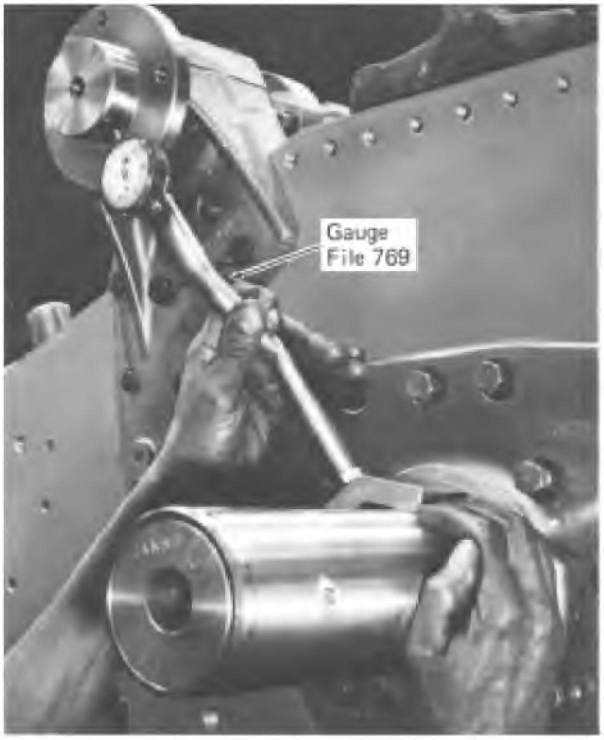

Fig. 7-7 - Idler Gear Stubshaft Bracket Alignment

15. Remove the two temporary locating pins and apply the two mounting bolts and washers. Then tighten all mounting bolts to the proper torque.

16. Ream the two dowel holes with a 0.494" tapered reamer and a 0.4998" ± 0.0002" bottoming reamer while using cutting oil.

NOTE: If dowel holes in idler gear stubshaft bracket do not align with holes in crankcase, drill and ream for oversize dowels as required to produce full circumference fit. See parts catalog for listing of oversize dowels.

17. Use an air hose to blow chips and oil out of the dowel holes.

18. Insert 5/16"-24 bolts approximately 12.70 mm (1/2") into the dowel pins.

19. Place dowels in dowel holes of stubshaft bracket and drive into crankcase end plate.

20. Torque the dowel bolts to 23 N-m (17 ft-lbs) and lockwire all mounting and dowel bolts in groups of three or less.

21. Using a No. 1 stubshaft to No. 2 stubshaft gauge (File 770) check parallelism between the No. 1 and No. 2 stubshafts, Fig. 7-8. Take one indicator reading with gauge as close to the stubshaft bracket as possible and the other reading with gauge near the end of the No. 1 stubshaft. Dial indicator readings must be within 0.004".

NOTE: Parallelism may also be checked by applying both idler gears, then checking gear teeth mesh and taking backlash measurements. See Service Data for backlash limits.

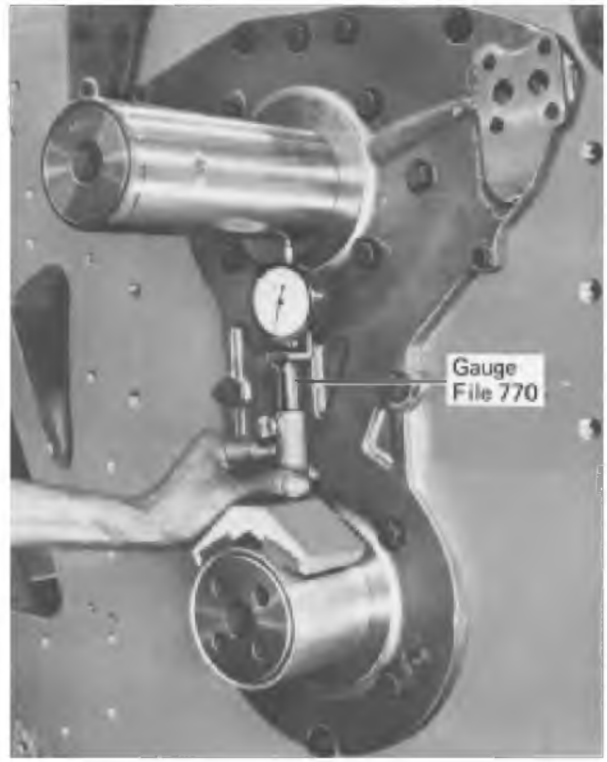

Fig. 7-5 - Checking Parallelism Of No. 1 And No. 2 Stubshafts

22. After a double idler stubshaft bracket has been applied to the crankcase rear end sheet, with all bolts torqued, the assembly should be checked for gaps in excess of .004" which could cause a critical loss of oil pressure. To perform this check, run a .004" feeler gage around the periphery of the bracket. If the feeler gage can be inserted into an oil passage, the bracket must be removed and the cause eliminated.

23. Re-check the dimension between the No. 2 idler stubshaft and the left bank camshaft stubshaft.

NO. 1 IDLER GEAR APPLICATION

1. Apply a light coat of lubricating oil to the No. 1 idler gear stubshaft and place the idler gear on the stubshaft so the tooth position marks are aligned as shown in Fig. 7-21.

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If a new gear is used, refer to "Exhaust Valve Timing" at the end of this section for information on positioning and marking of gears. Timing procedures are not required if camshaft and crankshaft positions have not been distrubed.

2. Install the No. 1 idler gear thrust plate, hardened washers, and bolts. Tighten bolts to the proper torque and lockwire in pairs using a crisscross pattern.

3. Use a feeler gauge to check that the No. I idler gear thrust clearance is within the limit specified in the Service Data.

4. Re-check the backlash between the crankshaft gear and the No. 1 idler gear as in Step 7 of "Stubshaft Bracket Application."

PISTON COOLING FLANGES AND LUBE OIL MANIFOLD APPLICATION

l. If the flanges Governing the piston cooling manifold openings on the crankcase end plate have been removed, install the flange gaskets, flanges, and 3/8"-24 bolts, Fig. 7-9. Torque the bolts to 37 N-m (27 ft-lbs) and lockwire.

m.

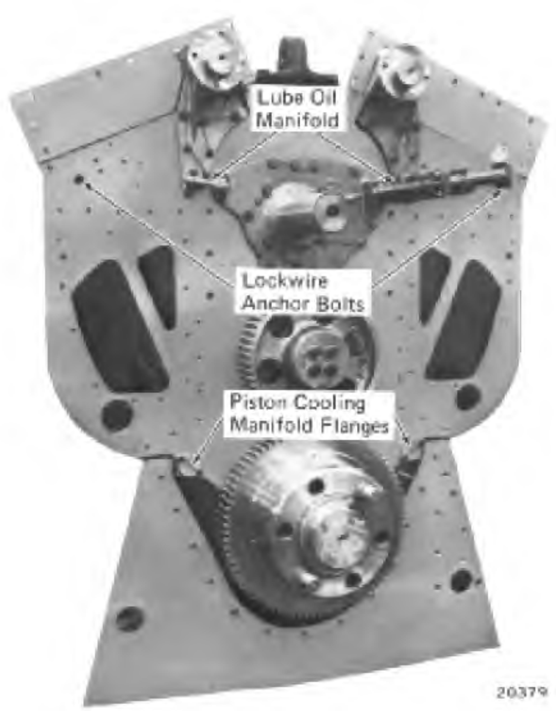

Fig. 7-9 -- Lube Oil Manifold Application

2. Assemble the end and center oil manifold sections being sure to install a gasket between them. Use 3/8"-24 bolts with locknuts and tighten to 37 N-m (27 ft-lbs).

3. Install the previously assembled manifold section and the stubshaft to left bank camshaft oil line, Fig. 7-9, being sure to place gaskets under the manifold sections. Tighten the 3/8"-24 bolts to 37 N-m (27 ft-lbs) and lockwire.

NOTE: If the stubshaft to left bank camshaft manifold does not have the pipe plug installed, coat the threads with high temperature thread compound and install in the manifold.

4. Install two 1/2"-20 bolts, Fig. 7-9, and tighten to 88 N-m (65 ft-lbs) torque. These bolts will be used for an anchor for lockwiring camshaft drive housing to crankcase bolts.

CAMSHAFT DRIVE HOUSING APPLICATION

1. Check the camshaft drive housing seal surfaces for burrs and wipe free of dust and dirt.

2. Apply a coat of gasket sealer to the camshaft drive housing. Apply the gasket in sections to the camshaft drive housing being sure the gasket interlocks are joined properly.

3. Apply the camshaft drive housing to crankcase bolts to the housing and wipe the crankcase end plate clean.

4. Trim the rubber crankcase to oil pan gasket extending from the joint at the crankcase end plate and apply Permatex to the joint area.

5. Locate the camshaft drive housing in its proper position and snug down several of the bolts to hold it in place.

6. 7-10, to act as positioning points for a dial indicator.

7. Install the camshaft drive housing alignment gauge (File 771) on the left bank camshaft stubshaft, and sweep the left bank locating pin, Fig. 7-10. The camshaft drive housing is properly aligned when an 0.008"-0.010" reading is obtained on the dial indicator.

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Fig. 7-10 - Camshaft Drive Housing Alignment

8. Repeat Step 7 on the right bank camshaft stubshaft.

9. If the housing is not aligned properly, place a wedge (File 772) between the camshaft stubshaft bracket and the housing, and drive the wedge in with a brass hammer.

10. If the dial indicator shows the camshaft drive housing to be properly aligned, torque the mounting bolts to the proper torque, then remove the wedge and recheck the alignment.

11. Ream the two dowel holes in the camshaft drive housing with a 0.494" tapered reamer and a 0.4998" ± 0.0002" bottoming reamer, being sure to use cutting oil.

NOTE: If dowel holes in camshaft drive housing do not align with holes in crankcase, drill and ream for oversize dowels as required to produce full circumference fit. See parts catalog for listing of oversize dowels.

12. Use an air hose to blow chips and oil out of the dowel holes, and insert 5/16'-24 bolts approximately 12.70 mm (1/2") into the dowel pins.

13. Place dowels in dowel holes in the housing, and drive into the crankcase end plate. Remove the dowel bolts.

14. Install the two remaining camshaft drive mounting bolts in the holes next to the dowel pins, and torque to the specified torque.

15. Lockwire the camshaft drive housing upper bolts in three groups of three each, and the two remaining mounting bolts to the bolts previously installed in the end plate for anchoring the lockwire.

16. Install the remaining oil manifold section, being sure to apply the proper gasket between the manifold and crankcase and between the manifold section previously installed and the one being applied. Use locknuts on the bolts connecting the two sections, and lockwire the manifold to crankcase bolts. If the turbocharger filter is not installed at this time, temporary bolts and spacers should be applied to the filter mounting bolts.

17. Install the oil slinger and the oil slinger-to-crankshaft gear bolts.

18. Prior to installation of the oil seal retainer, measure the distance from the inner face of the retainer mounting flange to the inner face of the retainer tapered flange, Fig. 7-2. Then measure the distance from the outer face of the camshaft drive housing to the face of the oil slinger with the crankshaft positioned toward the rear of the engine. The difference between the two measurements should equal the clearance specified in Service Data. If required, add or remove oil slinger shims to obtain proper clearance.

19. If oil retainer has dowels, remove the dowels.

20. Apply oil retainer gasket and oil retainer. Install four equally spaced bolts and washers finger tight.

21. Center the retainer by tapping the OD with a soft-faced hammer until the radial clearance between the retainer ID and the gear sealing surface OD is uniform around the circumference, as measured with a feeler gauge. Refer to Service Data for proper radial clearance.

22. Apply the remainder of the 24 bolts and washers and torque to 41 N-m (30 ft-lbs).

23. Recheck for uniform clearance to ensure that the retainer has not shifted.

24. Apply camshaft drive gears and spring drive gear assembly as previously described.

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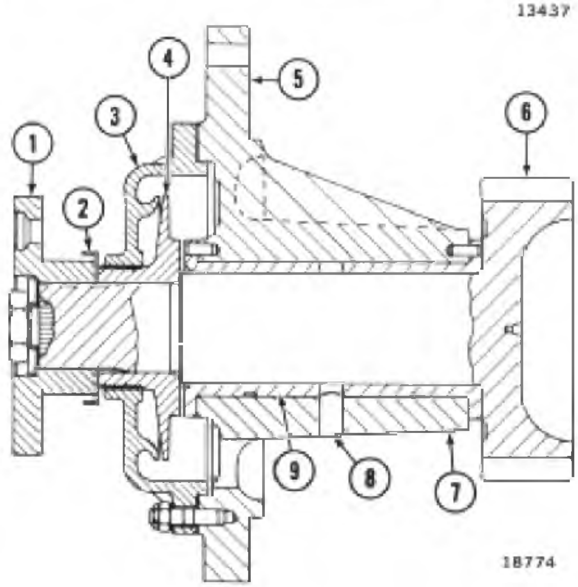
AUXILIARY DRIVE ASSEMBLY

DESCRIPTION

The auxiliary drive assembly, Fig. 7-11, is mounted on the turbocharger housing and is driven from the right bank camshaft drive gear.



1. Coupling Flange
2. Dust Shield
3. Cover
4. Oil Slinger
5. Mounting Pilot
6. Drive Shaft And Gear
7. Support Housing
8. Drain
9. Bushing

Fig. 7-11 - Auxiliary Drive Assembly

MAINTENANCE

When new bearings are installed, they are pressed into the support housing and line reamed or bored to the dimension specified in Service Data. After mounting the assembly on the turbocharger housing, the backlash between the gears must be checked and adjusted, if necessary.

Check the backlash with a dial indicator, Fig. 7-12. Attach a small "C" clamp to the coupling flange so that clamp contacts the outer edge of the flange. Position the dial indicator with the contact point touching the "C" clamp. Remove play from gear teeth by turning the coupling flange. Set the dial indicator to zero and move flange in the opposite direction of the previous movement and note reading on dial indicator.

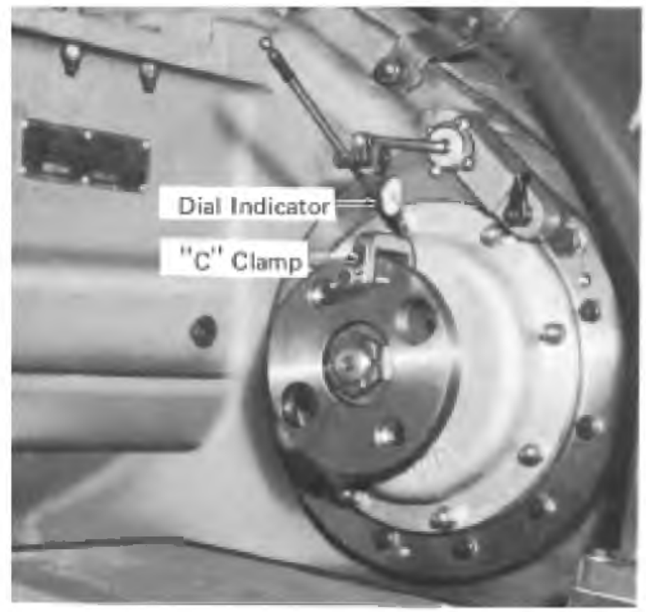


Fig. 7-12 - Checking Auxiliary Drive Gear Backlash

Refer to Service Data for backlash limits. Backlash is adjusted by loosening the turbocharger mounting bolts and repositioning the turbocharger on the camshaft drive housing.

After correct backlash is obtained, the turbocharger mounting bolts are tightened, and the backlash checked to see that it has not changed.

CAMSHAFT ASSEMBLIES

DESCRIPTION

The camshaft assembly, Fig. 7-13, consists of flanged segments, front and rear stubshafts, and a spacer is used on 12, 16, and 20-cylinder engines between the center segments. Each segment spans three (12-cyl.), four (8 & 16-cyl.), and five (20-cyl.) cylinders. Segment flanges are marked as shown in Fig. 7-13 to aid in correct assembly. At each cylinder there are two exhaust cams, one injector cam, and two bearing journals. Two bearing blocks at each cylinder, equipped with steel-backed lead base babbit lined inserts, support the camshaft.

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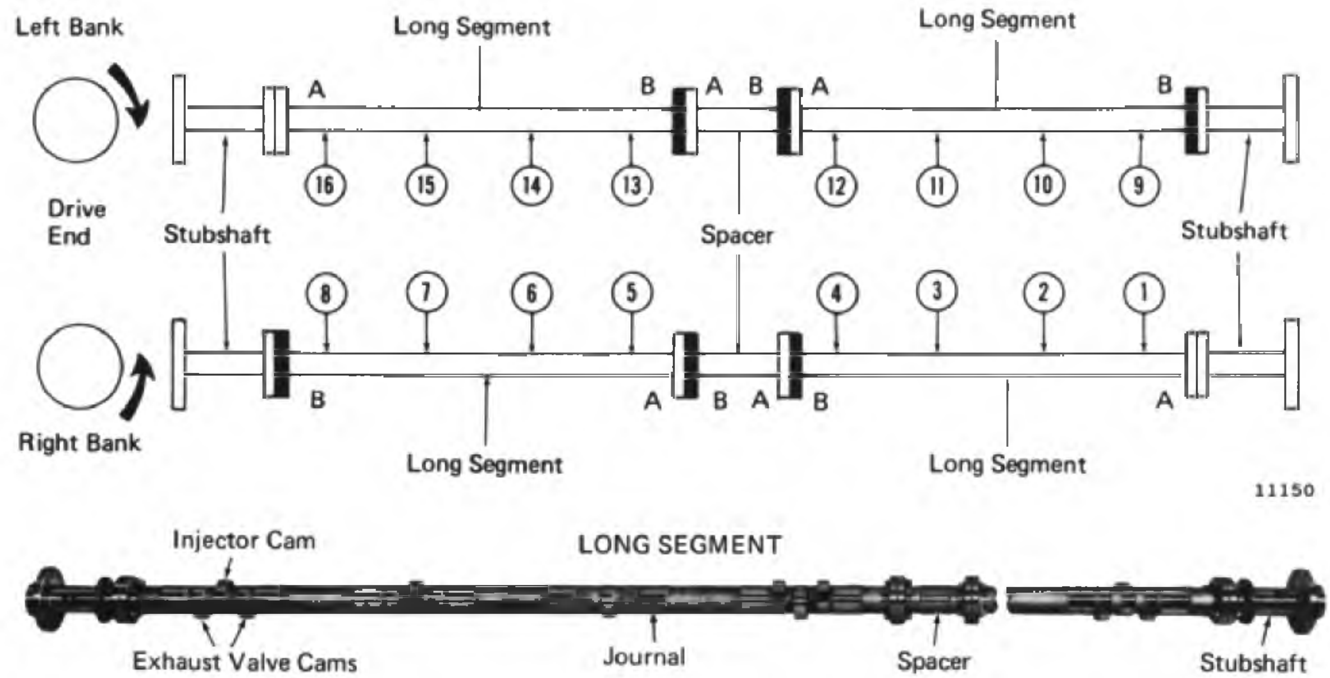

Fig. 7-13 - Camshaft Assembly (16-Cyl.)

MAINTENANCE

REMOVAL

The camshaft may be removed without disturbing the stubshafts by removing the dowel bolts connecting the segment and stubshaft flanges, removing oil lines from segment bearing blocks to rocker arms, and removing rocker arms. Remove segment bearing block caps to allow camshaft removal. If the camshaft is removed for reasons other than bearing replacement, an attempt should be made to retain relative position of the bearing shells on reinstallation of the camshaft. This may be accomplished by immediately replacing caps after camshaft removal, or if the entire block is removed, by inserting block bolts and wiring the free ends of the bolts. It is possible to remove a segment of the 16 and 20-cylinder camshaft without removing the entire camshaft. However, the entire camshaft must be removed on a 12-cylinder engine to change a segment.

INSPECTION

After removal of camshaft, wash and remove all dirt from oil passages. Visually inspect stubshafts and segments paying particular attention to cam lobes and journals for pitting, chipping, excessive scoring and heat discoloration. Journals and cams with light pit marks, minute flat spots, and light score marks may be reused after blending and removal of sharp edges by hand polishing. Check inside of dowel bolt holes for burrs, and remove.

Camshaft segments and stubshafts that show heat discoloration should be magnaflux inspected and hardness tested. Discoloration on the unfinished portion of the camshaft should be disregarded as it results from a production process and may be seen even on a new camshaft.

ASSEMBLY

The camshaft must be assembled as shown in Fig. 7-13. One dowel bolt hole in each segment flange is smaller than the others to ensure correct angular position. After assembly of camshaft and stubshaft, check for concentricity between the stubshaft and camshaft journals and maximum runout over total length of the shaft. Support the camshaft on precision rollers at the number 2 and 7 (8-cyl.); 1, 6, 7, and 12 (12-cyl.); l, 7, 10, and 16 (16-cyl.); and 1, 9, 12 and 20 (20-cyl.) camshaft bearing journals. See Service Data for limits.

INSTALLATION

Camshaft assemblies installed on an engine must conform to segment sequence and position as indicated in Fig. 7-13. On right bank camshafts, the "A" marking on each flange is toward the front of the engine. On left bank camshafts, the "B" marking on the flange must be toward the front of the engine.

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Stubshafts connected to segment flanges with "A" markings are a different configuration than those connected to segment flanges with "B" markings.

Check segment journal to bearing clearance and thrust clearance at rear stubshafts. Limits are listed in the Service Data. Clearance measurement can be obtained with feeler gauges.

Upon installation or replacement of the camshaft, lubricate freely all moving parts, place the assembly in properly aligned position after replacing blocks and bearings as removed. Rotate camshaft to check for binding. Apply flange dowel bolts and reassemble rocker arms and associated parts. Check valve timing of at least one cylinder to check segment positioning, and then make other adjustments such as exhaust valve setting and injector timing.

CAMSHAFT COUNTERWEIGHT APPLICATION

Counterweight replacement usually is not necessary. However, when counterweights are installed, they should be applied in the position as shown in Fig. 7-14.

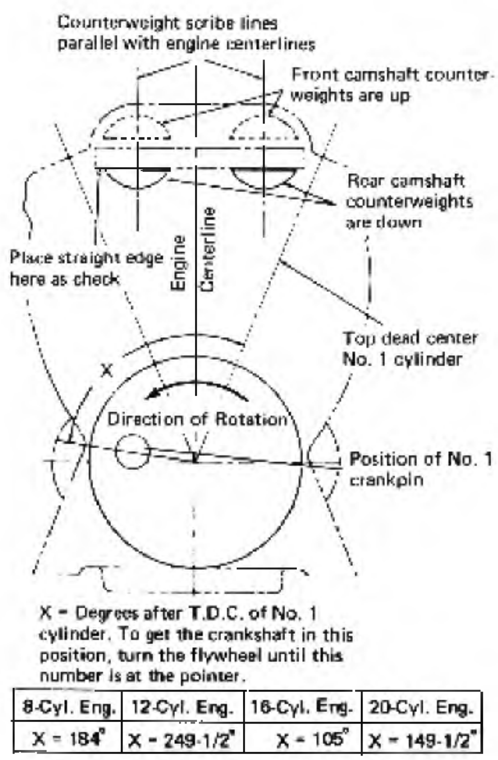

Fig. 7-14 - Camshaft Counterweight Timing section

EXHAUST VALVE TIMING

DESCRIPTION

Exhaust valve timing is very important as it ensures correct relationship of valve operation with the other events in the cylinder power cycle. To check or adjust exhaust valve timing, it is necessary to know the top dead center of each cylinder as shown in Table 1.

	8-Cylinder		12-Cylinder
Firing Order	Top Dead Center	Firing Order	Top Dead Center
		1	0°
1	0°	12	19°
5	45°	7	45°
3	90°	4	94°
7	135°	3	120°
4	180°	10	139°
8	225°	9	165°
2	270°	5	214°
6	315°	2	240°
		11	259°
		8	285°
	16-Cylinder		20-Cylinder
Firing Order	Top Dead Center	Firing Order	Top Dead Center
1	0°	1	0°
8	22-1/2°	19	9°
9	45°	8	36°
16	67-1/2°	11	45°
3	90°	5	72°
6	112-1/2°	18	81°
11	135°	7	108°
14	157-1/20	15	1170
4	180°	2	144°
5	202-1/2°	17	153°
12	2250	10	1800
13	247-1/2°	12	189°
2	270°	3	216°
7	292-1/2°	20	225°
10	315°	6	252°
15	337-1/2°	13	261°

Table 1 - Firing Order And Top Dead Center

Items which govern correct valve timing are given in the following procedures.

MAINTENANCE

LOCATING TOP DEAD CENTER

If it should become necessary to check the position of the flywheel or the flywheel pointer for top dead center, proceed as follows:

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1. Remove an air box handhole cover at the No. 1 cylinder.

2. If necessary, bar the engine to position the No. 1 piston below the cylinder liner ports.

3. Insert a brass "stop-bare (minimum 1/2" hexagonal or square preferred) of suitable length through the ports of the No. 1 cylinder so that the end of the bar passes through a port on the opposite side of the cylinder, Fig. 7-15.

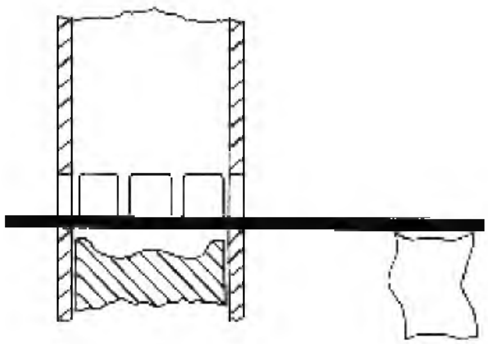

Fig. 7-15 - "Stop-Bar" Inserted Through Cylinder Ports

NOTE: A bar of sufficient length to prevent reapplication of the handhole cover while the bar is in place is recommended. A flag on the end of the bar will caution against inadvertent rotation of the engine with the bar in place.

4. Manually bar the engine slowly in the normal direction of rotation until piston travel is stopped by the bar against the upper surfaces of the cylinder ports, Fig. 7-16.

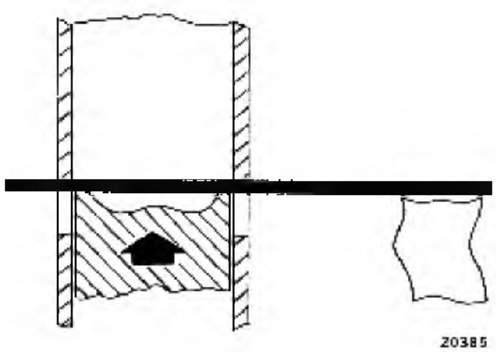

Fig. 7-16 - Piston Travel Limited By "Stop-Bar"

CAUTION: Use extreme care to avoid excessive force.

5. Mark the position of the flywheel pointer on the flywheel, Fig. 7-17.

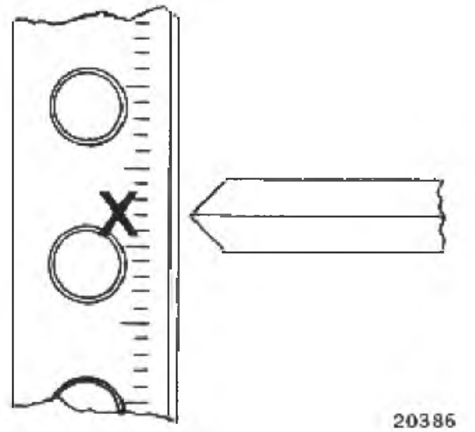

Fig. 7-17 - Limit Of Piston Travel Marked On Flywheel

6. Manually bar the engine slowly in the opposite direction from normal rotation until piston travel is again stopped by the bar against the upper surfaces of the cylinder ports.

7. Mark the second position of the flywheel pointer on the flywheel, Fig. 7-18.

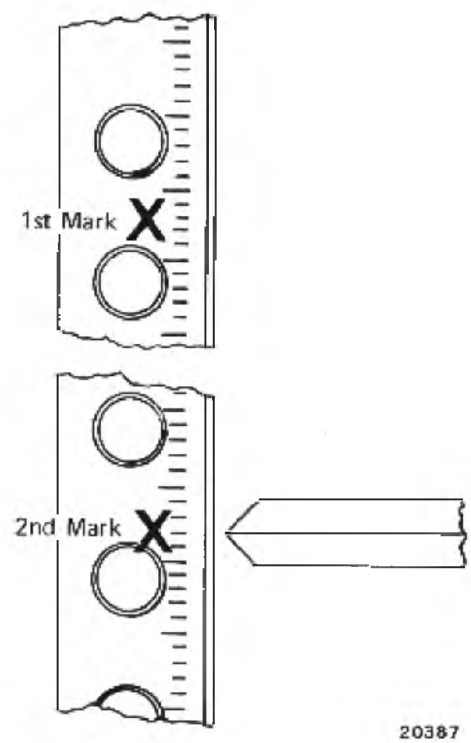

Fig. 7-18 - Second Limit Of Piston Travel Marked On Flywheel

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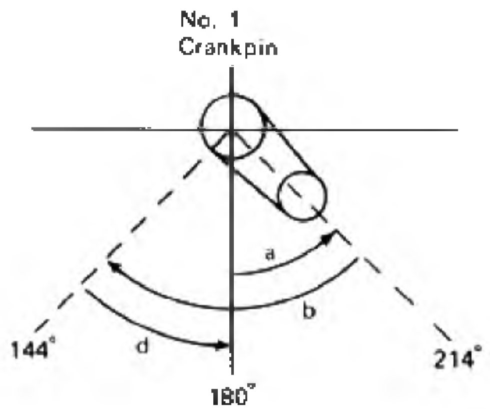
8. Determine the number of degrees between the two marks on the flywheel. Divide that number by 2. See Fig. 7-19 for a sample calculation.



a. Mark flywheel as indicated in Step 5.
b. Mark flywheel as indicated in Step 7.
c. Determine number of degrees as indicated in Step 8. Divide by 2.

$$\begin{array}{r} 214° \\ -144° \\ \hline 70° \end{array} \qquad \frac{70°}{2} = 35°$$

d. Rotate 35'. Pointer should indicate 180'. If it does not, adjust pointer to indicate 180`. 21158

Fig. 7-19 - Sample Calculation

9. Rotate the crankshaft in the normal direction of rotation the exact number of degrees determined in Step 8 above. Remove the brass "stop-bar" from the engine.

10. The pointer should indicate 180° (bottom dead center). If it does not, position the pointer so that it does indicate 180°. The pointer will now indicate top dead center for the No. 1 crankpin when the engine is rotated so that the pointer is at zero degrees (0°).

CHECKING EXHAUST VALVE TIMING

To check timing, place a dial indicator on the rocker arm adjusting screw as shown in Fig. 7-20. Valve end of rocker arm must be in its highest position, so that the exhaust valves are closed. Press indicator down approximately 2.54 mm (.100") and set dial to zero.

Turn crankshaft in normal direction of rotation until flywheel is at 106° A.T.D.C. of cylinder being checked.

If timing is correct, the valve bridge will have moved down 0.36 mm (.014"). Timing must not be later than 110° or earlier than 104° A.T.D.C. of cylinder being checked.

Fig. 7-20 - Timing Exhaust Valves

It timing is incorrect, check for:

1. Proper installation of camshaft.
2. Camshaft gear train correctly timed.
3. Excessively worn gears.

TIMING EXHAUST VALVES

The exhaust valves should be timed when any gear or stubshaft of the camshaft gear train is replaced, with the exception of the No. I or No. 2 idler gears. To do this, the camshaft on each bank must be timed to the crankshaft, but only one cylinder of each bank needs to be timed.

CAUTION: To prevent possible valve damage, remove or loosen all rocker arm assemblies, except the one on the cylinder being timed. If rocker arm assemblies are removed, hydraulic lash adjusters should be checked for proper clearance to valve stems. See Section 5 for instructions.

1. Apply dial indicator to the rocker arm adjusting screw, Fig. 7-20, as done in "Checking Exhaust Valve Timing."
2. Remove the dowels and bolts from the camshaft counterweight and remove counterweight and gear. The camshaft can be rotated by placing a socket and wrench on flange bolt nuts.
3. Rotate the camshaft in its normal direction of rotation until the valve bridge on which the dial indicator is resting moves down 0.36 mm (.014").

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4. Turn the crankshaft in the normal direction of rotation until the flywheel pointer is at 105° after top dead center for the cylinder being checked. Install camshaft gear and counterweight on stubshaft, but do not tighten bolts at this time.

5. With flywheel at 105° A.T.D.C. of the cylinder being checked, the dowel holes in the camshaft drive gear, counterweight, and the camshaft stubshaft should be in line or approximately in line with each other. If by turning the crankshaft from 104° to 106° A.T.D.C., the dowel holes can be made to line up, then the bolts should be tightened.

6. If the dowel holes do not line up within this tolerance, remove the camshaft counterweight and gear from the stubshaft. Rotate the gear 180° and replace on stubshaft or move the gear one tooth and replace gear and counterweight on the stubshaft.

7. If dowel holes still do not line up but misalignment is less than 0.190 mm (.0075"), the holes may be reamed for installation of 0.005", 0.010", or 0.015" oversize dowels.

   If misalignment of dowel holes is greater than 0.190 mm (.0075 ")proceed to Step 17.

8. Insert 5/16"-24 bolts approximately 12.7 mm (1/2") into dowel pins.

9. Place dowels in dowel holes and drive into stubshaft. Remove dowel bolts from pins.

10. Remove counterweight to stubshaft bolts.

11. Install dowel retainer plate, and counterweight to stubshaft bolts. Torque bolts to 122 N-m (90 ft-lbs).

12. Install dowel pin bolts and torque to 23 N-m (17 ft-lbs).

13. Lockwire mounting bolts and dowel bolts in groups of three. (Two mounting bolts and one dowel bolt.)

14. The crankshaft should now be rotated in its normal direction and the timing checked so that the valve bridge of the valve being checked has moved down 0.36 mm (.014") when the flywheel timing pointer is at 104°-106° A.T.D.C.

15. Repeat the operation on one cylinder on the opposite bank.

16. After timing has been completed, the relative position of the mating parts should be identified similar to the method used on new engines, shown in Fig. 7-21. The mating parts are marked with No. 1 piston at top dead center. This completes valve timing procedures.

17. Remove counterweight and gear from stubshaft.

18. Plug dowel holes in stubshaft as follows:

    a. Drill and tap the two dowel holes for 3/4"-16 NF thread with a minor diameter of 0.7031" + 0.005" - 0..000" and pitch diameter of 0.7094" + 0.0016" - 0.0000".

    b. Countersink 1.6 mm (1/16") on gear mounting side.

    c. Drive threaded, hex head plugs into holes. See Service Data for plug part number.

    d. Cut plug head off and flare by peening into countersink.

    e. Grind plugs flush with flange face.

    f. Check 146.037 mm + 0.00 mm - 0.03 mm (5.7495" + 0.000" - 0.001") flange O.D. for high spots and grind to proper dimension.

CAUTION: If camshaft to crankshaft relationship has been disturbed, repeat Step 3. 19. Apply camshaft gear to stubshaft and secure with mounting bolts.

20. Rotate engine crankshaft to position indicated in Fig. 7-14.

21. Remove gear mounting bolts and position gear and counterweights on stubshaft with counterweight in down position and counterweight scribe line parallel with engine centerline. Ensure that gear and counterweight dowel holes are aligned.

22. Install mounting bolts to secure gear and counterweight to stubshaft.

23. Drill and ream stubshaft dowel holes to 12.662 mm + 0.13 mm - 0.00 mm (.4985" + .005" - .000").

24. Perform Steps 8 thru 16.

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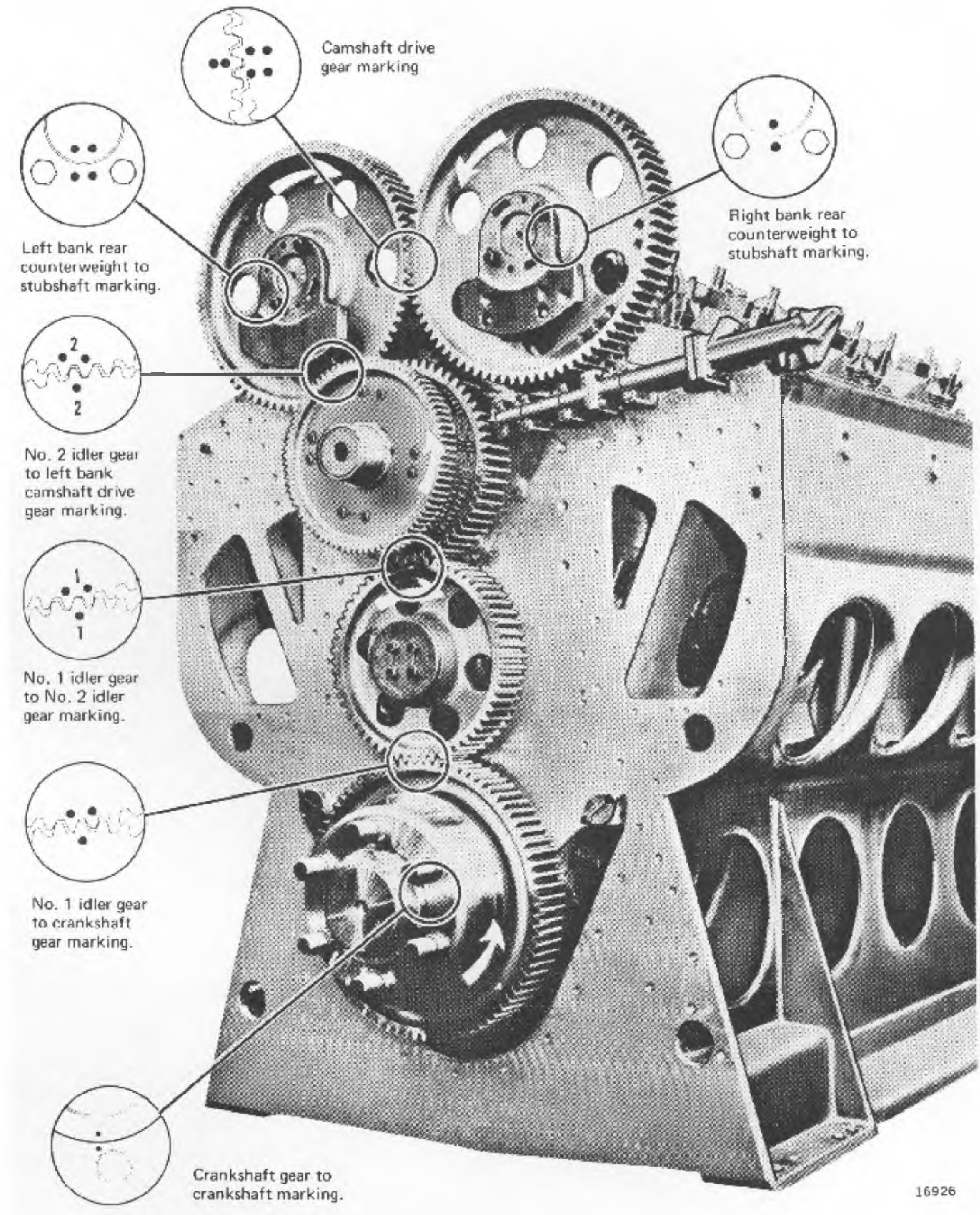

Fig. 7-21 - Camshaft Gear Train Marking

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SERVICE DATA
CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Crankshaft Gear

Oil slinger to oil retainer clearance	2.29-2.79 mm (.090"-.110")
Shims to obtain required clearance	
8035526	0.25 mm (.010")
8035527	0.51 mm (.020")
8035528	0.76 mm (.030")
Oil retainer ID to crankshaft gear sealing surface OD radial clearance	0.38-0.51 mm (.015"-.020")

Camshaft Drive Gear

Wear step where mated with auxiliary drive gear -- Max.	0.05 mm (.002")

Gear Backlash

Crankshaft gear to No. 1 idler - New	0.18-0.36 mm (.007"-.014")
No. 1 idler to No. 2 idler on spring drive gear assembly -- New	0.18-0.36 mm (.007"-.014")
No. 2 idler on spring drive gear assembly to camshaft drive - New	0.18-0.41 mm (.007"-.016")
Camshaft drive to camshaft drive -- New	0.18-0.56 mm (.007"-.022°')
Auxiliary drive to camshaft gear - New	0.25-0.56 mm (.010"-.022")
Max. (all gears above)	0.64 mm (.025")
Turbocharger drive to turbocharger -	
New	0.13-0.25 mm (.005"-.010")
Max.	0.51 mm (.020")

Gear Train

(Idler gears and stubshafts include sleeve and bearings where applicable.)

No. 1 idler gear assembly (through bolted, fixed bearing stubshaft assembly)

Idler gear bore diameter -	
New	117.48-117.50 mm (4.625"-4.626")
Max.	117.58 mm (4.629")
Stubshaft diameter -	
New	117.27-117.35 mm (4.617"-4.620")
Min.	117.14 mm (4.612")
Idler gear to stubshaft clearance -	
New	0.13-0.23 mm (.005"-.009")
Max.	0.43 mm (.017")
Thrust clearance -	
New	0.20-0.51 mm (.008"-.020")
Max.	0.71 mm (.028")

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No. 2 idler gear assembly (part of spring drive gear assembly)

Idler gear bore diameter -
- New . . . . 101.73-101.75 mm (4.005"-4.006")
- Max. . . . . 101.83 mm (4.009")

Stubshaft diameter -
- New . . . . 101.57-101.62 mm (3.999"-4.001")
- Min. . . . . 101.52 mm (3.997")

Idler gear to stubshaft clearance -
- New . . . . 0.10-0.18 inm (.004"-.007")
- Max. . . . . 0.30 mm (.012")

Thrust clearance -
- New . . . . 1.14-2.11 mm (.045"-.083")
- Max. . . . . 2.31 mm (0.91")

Auxiliary Drive

Housing

Pilot diameter -
- New . . . . 215.85-215.87 mm (8.498"-8.499")
- Min. . . . . 215.80 mm (8.496")

Bearing diameter (in support housing after line reaming) -
- New . . . . 63.564-63.589 mm (2.5025"-2.5035")
- Max. . . . . 63.65 mm (2.506")

Thrust dimension
- New . . . . 164.77-164.97 mm (6.487"-6.495")
- Min. . . . . 164.54 mm (6.478")

Drive Shaft

Bearing diameter -
- New . . . . 63.47-63.50 mm (2.499"-2.500")
- Min. . . . . 63.462 mm (2.4985")

Thrust dimension -
- New . . . . 165.23-165.30 mm (6.505"-6.508")
- Max. . . . . 165.40 mm (6.512")

Clearance

Shaft to bushing -
- New . . . . 0.064-0.114 mm (.0025"-.0045")
- Max. . . . . 0.190 mm (.0075")

Thrust -
- New . . . . 3.43-3.81 mm (.135"-.150")
- Max. . . . . 4.04 mm (.159")

Camshaft And Stubshaft

Camshaft journal diameter -
- New . . . . 63.40-63.45 mm (2.496"-2.498")
- Min. . . . . 63.37 mm (2.495")

Diametric clearance, segment journal to bearing -
- New . . . . 0.05-0.15 mm (.002"-.006")
- Max. . . . . 0.25 mm (.010")

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SERVICE DATA
CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

Taper length of journal -- Max.	0.02 mm (.001 ")
Runout (journal) T.I.R. when supported on adjacent journals - Max.	0.05 mm (.002")
Runout (base circle relative to journal) - Max.	0.08 mm (.003")
Mounting flange (not convex) flat within* - Max.	0.013 mm (.0005")
Mounting flange square with longitudinal centerline within T.I.R.* -- Max.	0.02 mm (.001")

*(Correct by grinding faces)

Concentricity between stubshaft and camshaft journals and maximum runout over total length of shaft (T.I.R.) Max.	0.10 mm (.004")
Dowel bolt holes in flanges	
One hole	11.15 mm (.439")
Three holes	12.738 mm (.5015")
Stubshaft journal diameter	
New	63.42-63.45 mm (2.497"-2.498")
Min.	63.37 mm (2.495")
Diametric clearance, journal to bearing -	
New	0.089-0.190 mm (.0035"-.0075")
Max.	0.25 mm (.010")
Stubshaft thrust clearance -	
New	0.18-0.38 mm (.007"-.015")
Max.	0.64 mm (.025")
Dimension between thrust faces -- Max.	106.55 mm (4.195")

Camshaft Timing

Ideal timing setting, valve open 0.36 mm (0.014") - A.T.D.C.	106°
Timing of new gear train not earlier than -- Max.	2°
or	
at 0.36 mm (0.014") valve opening A.T.D.C.	104°
Limit of lag - camshaft behind crankshaft due to worn gears -- Max.	4°
or	
at 0.36 mm (0.014") valve opening -- A.T.D.C.	110°
Flywheel pointer setting - T.D.C. of No. 1 cylinder	0°

EQUIPMENT LIST

	Part No.
Feeler gauge set	8067337
Camshaft stubshaft plug	8166882
No. 1 idler gear clearance checking spring	8235573
Dial indicator	8255423
Loctite cleaner activator 170 grams (6 oz.)	8352873
No. 1 idler gear clearance checking bar	8466308
Loctite sealing compound 250 cc bottle	9085183
No. 1 idler gear to crankshaft gauge	File 768
Idler gear stubshaft to camshaft stubshaft gauge	File 769
No. 1 stubshaft to No. 2 stubshaft gauge	File 770
Camshaft drive housing alignment gauge	File 771
Camshaft drive housing alignment wedge	File 772

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SECTION 8

AIR INTAKE AND EXHAUST SYSTEMS

CONTENTS	PAGE
TURBOCHARGER	
DESCRIPTION	8-1
REMOVAL	8-2
AIR BOX INSPECTION	8-2
GEAR TRAIN INSPECTION	8-3
EXHAUST MANIFOLD INSPECTION	8-3
LUBE SYSTEM MAINTENANCE	8-3
AIR FILTER INSPECTION	8-3
INSTALLATION	8-3
AIR DUCT AND AFTERCOOLER APPLICATION	8-4
FINAL ASSEMBLY	8-5
ENGINE START	8-5
EXHAUST MANIFOLD	
DESCRIPTION	8-5
MAINTENANCE	8-6
SERVICE DATA	
SPECIFICATIONS	8-9
EQUIPMENT LIST	8-10

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

SECTION 8

AIR INTAKE AND EXHAUST SYSTEMS

TURBOCHARGER

DESCRIPTION

The turbocharger assembly, Fig. 8-I, is primarily used to increase engine horsepower and provide better fuel economy through the utilization of exhaust gases. As shown in cross-section, the turbocharger has a single stage turbine with a connecting gear train. The connecting gear train is necessary for engine starting, light load operation, and rapid acceleration. Under these conditions there is insufficient exhaust heat energy to drive the turbine fast enough to supply the necessary air for combustion, and the engine is actually driving the turbocharger through the gear train assisted by exhaust gas energy. When the engine approaches full load, the heat energy in the exhaust, which reaches temperatures approaching 1000° F., is sufficient to drive the turbocharger without any help from the engine. At this point, an overrunning clutch in the drive train disengages and the turbocharger drive is mechanically disconnected from the engine gear train.

The turbine shaft is driven by the engine gear train through a series of gears in the turbocharger. A turbocharger drive gear, which is a part of the spring drive gear assembly, meshes with the turbocharger idler gear, driving the carrier drive gear. The carrier shaft drives the sun gear on the turbine shaft through three planet gears when the turbocharger is being driven by the engine. The sun gear meshes with the planet gears which, in turn, mesh with a ring gear in the overrunning clutch assembly. The ring gear is fixed, when the engine is driving the turbine, because the direction of torque at the ring gear locks the overrunning clutch. When the turbine is being driven entirely by exhaust gas energy, the direction of torque is reversed and the clutch overruns, allowing the ring gear to rotate.

The overrunning clutch consists of 12 rollers in tapered slots. The slots are formed by the combination of a stationary clutch support and the pockets in the cam plate. The cam plate, ring gear support, and the ring gear are dowelled and bolted together, and rotate as a unit. When the engine is driving the turbine, the rollers are wedged in the

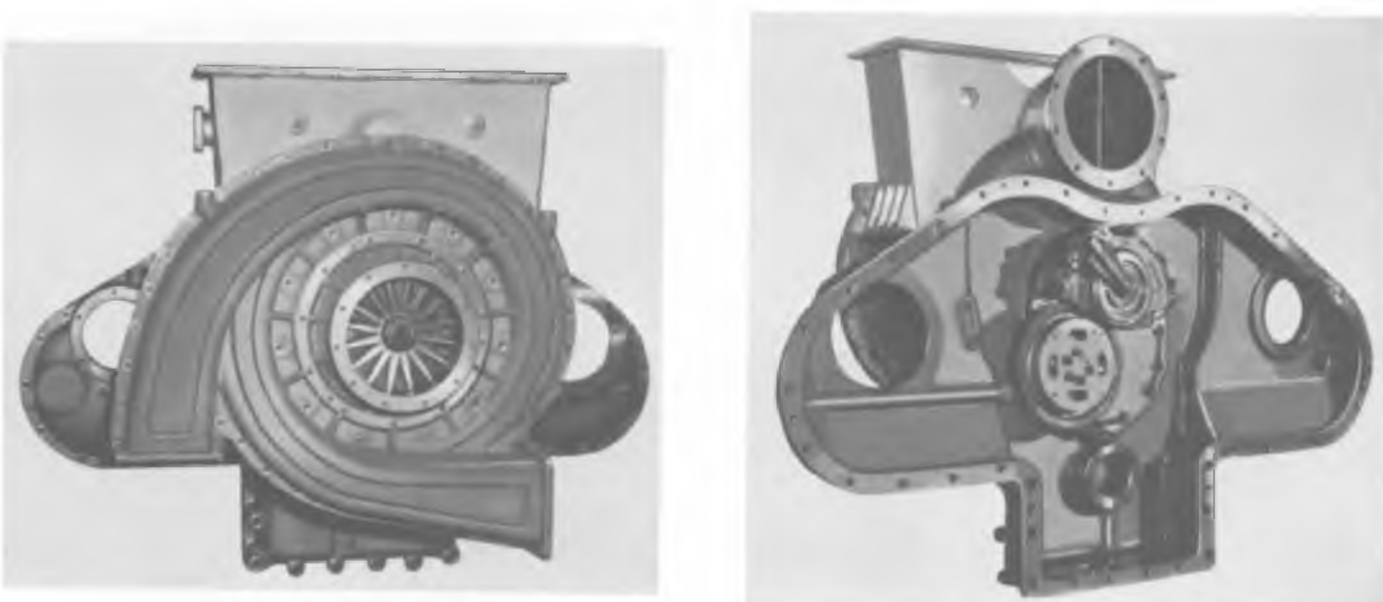

Fig. 8-1 - Turbocharger Assembly

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small side of the cam plate pockets, as a result of the direction of torque, locking the cam plate to the stationary clutch support. This locking action prevents the ring gear from turning. Because the planet gear shafts are driven as a part of the carrier shaft, the planet gears rotate in the locked ring gear to drive the sun gear on the turbine shaft. When the exhaust energy becomes great enough to drive the turbine without help from the engine, the torque at the sun gear, planet gears, and ring gear reverses direction. This causes the rollers to move to the wide end of the cam plate pocket, unlocking the clutch, permitting it to overrun, and allowing the ring gear to rotate. From this point on, with increased load and speed, the turbocharger overruns the engine drive and the planet gears slowly turn the ring gear.

MAINTENANCE

Since it would not be practical to attempt any reconditioning of the turbocharger in the field, it is recommended that it be returned to EMD for this service. The following removal and installation procedures are provided for field service.

REMOVAL

1. Remove roof hatch.
2. Disconnect and remove the water lines to and from the aftercooler assemblies.
3. It is advisable to remove the aftercoolers from the ducts rather than to remove them as an assembly, because of the weight involved.
4. Remove the oil line clamp from the right aftercooler duct.
5. Remove both aftercooler duct assemblies. 6. Remove the auxiliary drive assembly.
7. Remove the oil separator assembly.
8. Remove the expansion joint between the turbocharger and the engine exhaust manifold.
9. Disconnect the exhaust elbow from the top of the turbine exhaust duct. Remove the elbow.
10. Remove air duct assembly from turbocharger air inlet assembly and remove air inlet.
11. Connect lifting chains to eyes screwed into the four tapped bosses on the turbocharger. Maintain even tension on all four chains so that turbocharger will hang properly. If a hand-operated chain hoist is available, it should be used between the chain device and the main lifting crane to simplify vertical positioning and tension adjustment during turbocharger removal. Do not allow chains to drag against the exhaust duct.
12. Remove bolts attaching turbocharger housing to camshaft gear train housing. The turbocharger is now held in position by the No. 2 idler gear stubshaft and lifting device.

CAUTION: Before removing the turbocharger, be sure to remove (if applied) two studhead bolts which hold the aftercooler piping bracket to the turbocharger.

13. Using jackscrews between the turbocharger housing and the gear train housing, jack the turbocharger away from the engine until the turbocharger clears the No. 2 stubshaft.

NOTE: Care should be exercised, when removing turbocharger, that No. 2 idler gear is not disengaged from camshaft drive gear, as engine timing will have to be checked if gear is disengaged.

14. Using a 1-ton crane, lift the turbocharger clear of the engine and place it in shipping container for transportation.

PREPARATION FOR INSTALLATION

The following Steps should be adhered to if the turbocharger is being replaced because of a failure, if not, some of the Steps may be ignored. The turbocharger should remain in the shipping container until actual application.

AIR BOX INSPECTION

1. Clean the air box to remove all evidence of aluminum dust and chromate or borate water stains.
2. Inspect the cylinder assemblies for broken valves, valve blow, cracked pistons, broken piston rings, scored pistons and liners.
3. Determine the cause of the turbocharger failure and correct any conditions that might have aggravated the failure.
4. Clean all gasket surfaces on the engine, the turbocharger to be applied, and the air ducts.

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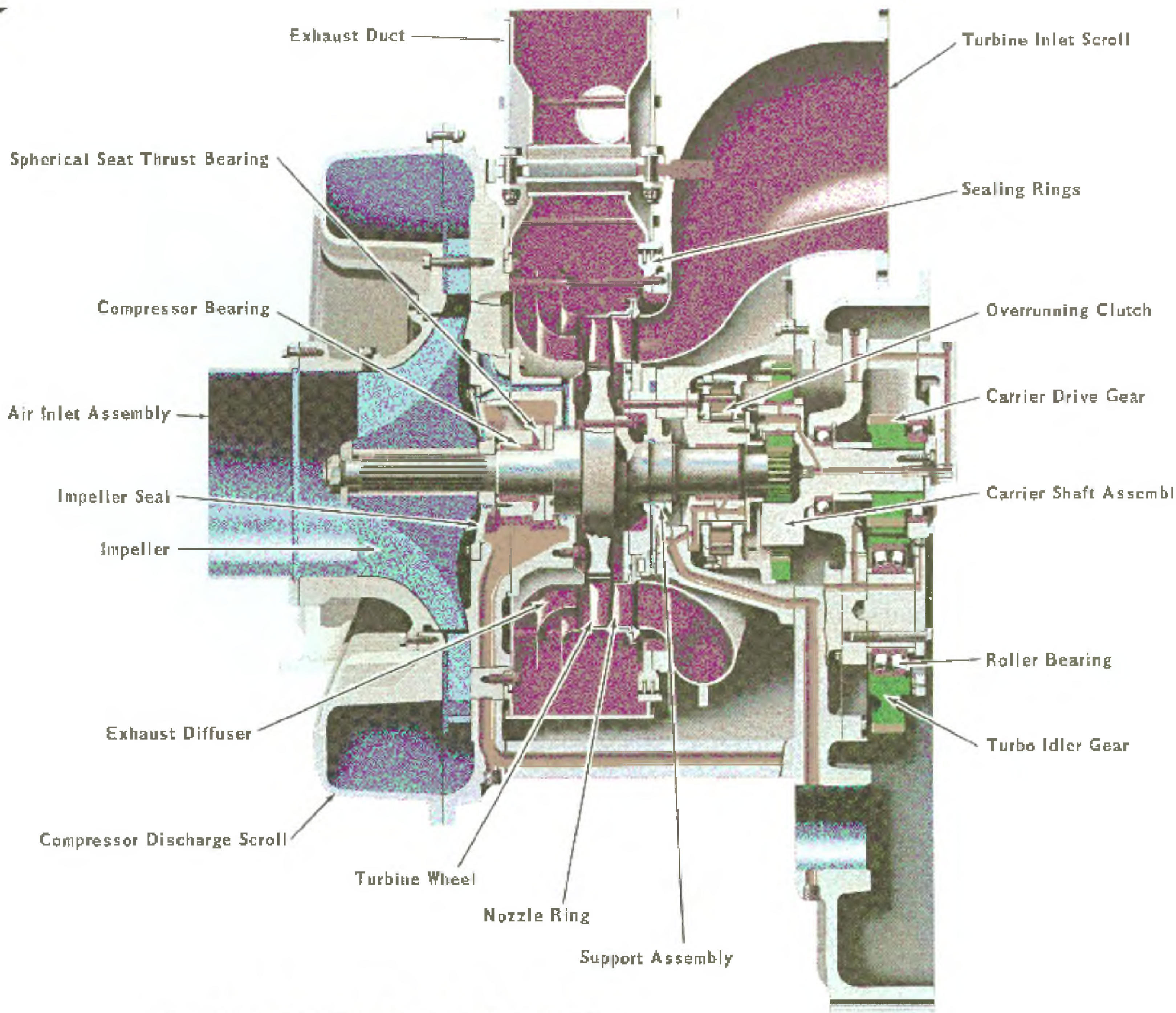

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Remove any nicks or burrs so as to present a smooth surface.

GEAR TRAIN INSPECTION

1. Visually check the gear train for nicks, burrs, evidence of improper backlash, and uneven or excessive wear. Make any necessary corrections.

2. Clean the No. 2 idler turbocharger locating stub-shaft, using an oil stone. Remove all indications of fretting. Inspect the seal groove for nicks and burrs, and smooth the surface after removal of any nicks or burrs.

3. Check the gear train area and remove any metallic debris that might be found.

EXHAUST MANIFOLD INSPECTION

1. Inspect the exhaust manifold for foreign material, and completely remove any found. The manifold should be removed, if in doubt, to look for cracked leg baffles which should be removed, and cracked expansion joints, which should be replaced.

2. Inspect the condition of the exhaust manifold leg gaskets and the torque on the bolts, which should be 176 N-m (130 ft-lbs). Also, check the manifold connector fasteners which should be 108 N-m (80 ft-lbs). Check the condition of the adapter to turbocharger bellows connections, and other locations where possible leaks might occur in the exhaust system.

3. Inspect the adapter assembly between rear expansion joint and chamber assembly for condition of screen. If foreign material is present in the exhaust manifold, it is recommended that the screen be magnaflux inspected.

CAUTION: Inspect the exhaust silencer (if applicable) for foreign material and remove any which may be found.

LUBRICATING OIL SYSTEM

1. Remove the disposable turbocharger oil filter and the soak back oil filter elements. Install new elements and check that the filter bowls are full of clean lubricating oil, and that the springs and gaskets are in place.

2. If required, drain and completely clean the system.

   a. If the oil system is contaminated with debris, flush the system and install new filter elements.

   b. Install new main oil filter elements, and clean and check the main oil filter relief valves.

   c. Recharge the oil system after the replacement turbocharger is applied and the oil system and all filters have been conditioned to receive the new clean oil.

   d. Check the soak back pump function and operation. Check the pump bypass relief valve for proper operation.

AIR INTAKE FILTER INSPECTION

Before installing the turbocharger, the engine air intake filters should be checked for foreign material. Completely clean filter if foreign material is found.

INSTALLATION

1. Apply the lifting device to the turbocharger as described in the turbocharger removal procedure. (The turbocharger shipping container, plus the masking of all openings on the turbocharger is the best protection and insurance against damage, rust, and contamination that can be given the turbocharger prior to installation.)

2. To determine the impeller eye clearance, remove the air inlet assembly before removing the turbocharger from the container pedestal. Chalk mark an impeller blade at the 12 o'clock position so that the impeller can be returned to this position when the eye clearance is rechecked after turbocharger installation. Two sets of feeler gauges should be used when making this check. Clearances should be determined with a heavy drag on the feelers. Perform check as follows:

   a. Insert approximately the same feeler gauge thicknesses at the ends of the impeller blades at the 3 and 9 o'clock positions simultaneously to determine the available horizontal clearance. Record the clearances.

   b. A feeler gauge should be used at the 12 o'clock position to determine the upper vertical clearance. Leaving the feeler gauge in position at the 12 o'clock position, use another

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feeler to determine clearance at the 6 o'clock position. Record the clearances obtained.

3. Apply a thin coat of gasket compound to the camshaft drive housing and apply a new gasket to the housing.

4. Apply a new "O" ring seal to the engine No. 2 idler stubshaft.

5. Apply some clean lubricating oil to the No. 2 idler stubshaft and to the turbocharger drive gear.

6. Lift the turbocharger and remove covering from all openings, except the exhaust stack and exhaust inlet duct.

7. Align the turbocharger, guiding it onto the No. 2 idler stubshaft and into position. Care must be taken to ensure proper mesh of the turbocharger idler gear and the turbocharger drive gear on the engine.

8. Use hardened washers and damper springs with the 3/4" bolts, and apply all the turbocharger to camshaft drive housing bolts before removing the lifting device. Snug up bolts, but do not tighten.

9. Install the auxiliary drive assembly on the turbocharger and check the gear backlash between the camshaft drive gear and the auxiliary drive gear.

   Check the backlash with a dial indicator, Fig. 8-2. Attach a small "C" clamp to the coupling flange so that clamp contacts the outer edge of the flange. Position the dial indicator with the contact point touching the "C" clamp. Remove play from gear teeth by turning the coupling flange. Set the dial indicator to zero and move flange in the opposite direction of the previous movement and note reading on dial indicator. Refer to Service Data for backlash limits. Backlash is adjusted by loosening the turbocharger mounting bolts and repositioning the turbocharger on camshaft drive housing.

10. When the correct backlash is obtained, torque the 1/2" turbocharger and auxiliary drive mounting bolts to 88 N-m (65 ft-Ibs), the 3/4" bolts to 238 N-m (175 ft-lbs), and the 3/8" bolts to 32 N-m (24 ft-lbs). After the bolts are properly tightened, recheck the auxiliary drive gear backlash.

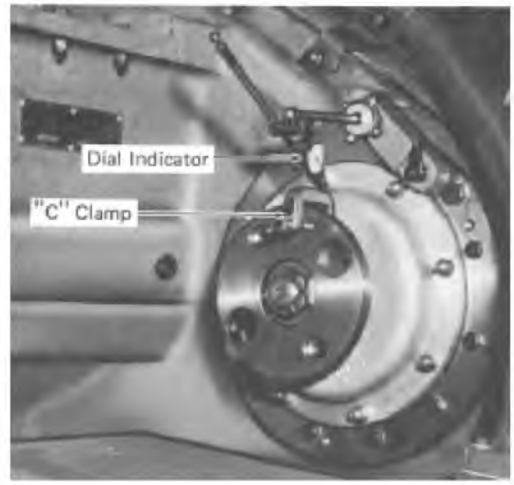

Fig. 8-2 -Checking Auxiliary Drive Gear Backlash

AIR DUCT AND AFTERCOOLER APPLICATION

If a different aftercooler core is to be installed, proper core alignment to the duct must be ensured before application can be made. The air ducts must be removed from the engine to accomplish alignment. Remove the lockwire from the support pad bolts at the rear of the duct, and loosen the bolts. Position the core in the duct until the dowels on the core align with the dowel holes in the support pad. Tighten support pad bolts, torque to 176 N-m (130 ft-lbs), and lockwire. Remove the core and proceed as follows with application.

1. Apply the gaskets to the air duct assemblies.

2. Carefully maneuver the right bank air duct into position and apply the bolts at the engine and turbocharger flanges. Four bolts at the engine flange must be installed from inside the duct. Make sure that air duct flange on the engine side is not touching the camshaft drive housing. Snug the bolts only at the turbocharger end, but torque the bolts at the engine end to 88 N-m (65 ft-Ibs). Then remove the bolts from the turbocharger end of the air duct and with the gasket in place, and using a 0.20 mm (.008") feeler gauge, determine the clearance at the mating flanges. If a 0.20 mm (.008") feeler gauge can be entered between the turbocharger and the air duct, the duct must be relocated. If necessary, the holes in the engine flange may be enlarged to position the duct properly.

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3. Apply the left bank air duct using the same procedure as used on the application of the right bank air duct.

4. Place the hardened washers on bolts and tighten the air duct to turbocharger bolts to 81 N˙m (60 ft-lbs). Refer to Service Data for correct bolt application.

5. Using a 0.001 " feeler gauge, check that no clearance exists between the gasket and turbocharger flange, and the gasket and air duct flange.

6. Apply gaskets to air ducts. Using a lifting device, install aftercoolers in air ducts. Apply attaching bolts, and beginning at the center bolt and moving to the ends, torque bolts to 61 N˙m (45 ft-lbs).

7. Attach water pipes to aftercoolers and torque bolts to 47 N-m (35 ft-lbs).

8. Attach water pipes to engine and torque bolts to 47 N-m (35 ft-lbs).

9. Clamp oil line to tapping pad on right aftercooler air duct.

FINAL ASSEMBLY

1. Apply gaskets and install oil separator/ejector assembly.
2. Install the expansion joint between the turbine inlet scroll and the engine exhaust manifold. When assembling the expansion joint, the tapered end of the interior liner should be facing toward the front of the engine. This taper will not be evidenced b y external viewing of the expansion joint.
3. Coat the threads of the expansion joint bolts with high temperature thread lubricant, apply, and torque to 122 N-m (90 ft-ibs).
4. In bolting the expansion joint in the manifold, it is recommended that one flange of the expansion joint be securely bolted to the manifold before attempting to bolt the other flange. If the holes of the second flange do not align with the flange of the inlet scroll, do not pry into alignment. This will result in undue stress placed on the expansion joint and will also reduce the internal liner clearance required for trouble-free operation. If alignment can not be acquired through repositioning the expansion joint, enlarge the holes in the flange until bolts can be freely inserted and tightened.

5. Attach the exhaust elbow to the top of the turbine exhaust duct with bolts coated with high temperature thread lubricant.

6. Check the impeller eye clearance as previously done in Step 2 of "Installation" to see if the measurements can be duplicated. If the clearances cannot be duplicated, it indicates that the turbocharger has been distorted in installation. In this event, the air ducts should be removed and eye clearance rechecked. If turbocharger is still distorted the turbocharger mounting bolts must be loosened and the turbocharger realigned so that no stresses or distortion are introduced during installation.

7. Install the air inlet assembly and air duct assembly on turbocharger.
8. Replace decking and panels.

STARTING THE ENGINE

1. Make sure the soak back pump is running.
2. Make the necessary preparations and start the engine.
3. When starting the engine, do not force the injector hand control lever beyond the idle position in an effort to aid the engine in starting. If the engine is forced on starting, the excess fuel and the resulting engine exhaust might cause an increase in load on the turbocharger thrust bearing when it should not be loaded.
4. Perform load test to qualify engine for service.

EXHAUST MANIFOLD

DESCRIPTION

The exhaust gases from the engine cylinders are discharged from the cylinder heads into the exhaust manifold, Fig. 8-3, and to the turbocharger turbine. Going through the turbine, the gases expand to atmospheric pressure, pass through the turbocharger ducting, and are then expelled from the engine.

The exhaust manifold is made up of chamber assemblies, expansion joints, and adapter assembly. The expansion joints, which are used between chamber

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Fig. 8-3 - Exhaust Manifold

assemblies and between the adapter and screen assembly and the turbocharger, provide the necessary flexibility to compensate for expansion and contraction of the manifold due to temperature changes. The adapter assembly contains a trap type screen to prevent the entry of foreign objects into the turbocharger. A trap box is attached to the outer body which collects small debris.

MAINTENANCE

Inspect the adapter and screen assembly between rear expansion joint and chamber assembly for condition of screen. If foreign material is present in the exhaust manifold it is recommended that the screen be magnaflux inspected.

NOTE: The trap type screen must be removed and cleaned out at intervals specified in the Scheduled Maintenance Program.

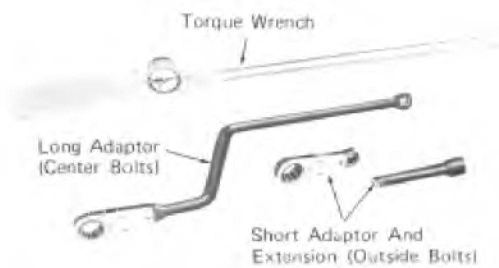
The exhaust manifold is essentially "maintenance free." but should the manifold be disassembled for any reason. the following assembly provisions should be observed.

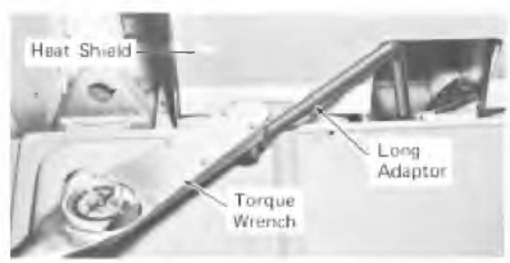
When applying the exhaust manifold gasket it is important that the gasket be positioned properly, and that the bolts be torqued and retorqued as recommended. Gasket should be applied as follows:

1. Check that the gasket area on the engine is clean and free of obstructions.
2. Apply the gasket making sure that the side of the gasket having the part number and the stamp "THIS SIDE UP" is in the UP position. This will ensure that the crimped side of the gasket is down.

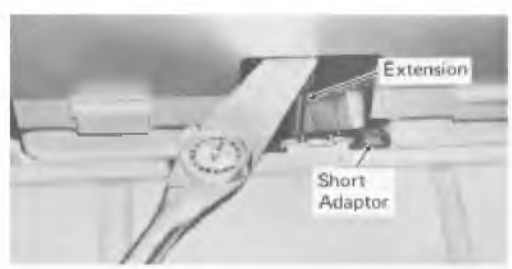
CAUTION: If the gasket is incorrectly installed (crimped side up), gasket damage and subsequent exhaust leakage will occur.

3. Lubricate manifold mounting bolts with high temperature thread lubricant and torque the bolts in two passes, using the manifold torque tool set. Fig. 8-4. The first pass torque should be approximately 68 N-m (50 fl-Ibs). The final torque is 176 N-m (130 ft-Ibs). When long adapter, Fig. 8-4, is used the torque wrench





OUTSIDE BOLT TIGHTENING



CENTER BOLT TIGHTENING

Fig. 8-4 - Manifold Gasket Torquing

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dial should show 103 N-m (76 ft-lbs). This will provide the required 176 N-m (130 ft-lbs). When short adaptor, Fig. 8-4, is used, the torque wrench dial should show 176 N-m (130 ft-lbs) for the required torque.

NOTE: To correctly torque the center bolts, the torque wrench must be attached to the long adaptor in a straignt line as shown in Fig. 8-4.

To obtain maximum service life from the gasket application, retorquing instructions MUST be followed.

1. On new units, bolts MUST be retorqued at intervals stated in the Scheduled Maintenance Program.

2. If an engine has been overhauled or changed out, the bolts MUST be retorqued after load box test, in addition to the intervals stated in the Scheduled Maintenance Program.

3. If the engine is not tested, the bolts MUST be retorqued after approximately eight hours of service.

When retorquing, it is not necessary to remove the heat shields, if the torque tool set is used.

On 20-cylinder engines, the flange at one end of the center and two intermediate chamber assemblies has an offset bolt hole at the bottom of the flange. To prevent misalignment during assembly, the flange with the offset hole must face toward the accessory end of the engine. The offset hole in the adjacent expansion joint must mate with the chamber flange offset hole.

When assembling the expansion joints, the welded end of the interior liner should be facing toward the front of the engine. This weldment will not be evidenced by external viewing of the expansion joint.

In bolting the expansion joints to the chamber assemblies, it is recommended that one flange of the expansion joint be securely bolted to the chamber assembly before attempting to bolt the other flange. If the holes of the second flange do not align with the flange of the turbocharger inlet scroll, do not pry into alignment. This will result in undue stress being placed on the expansion joint and will also reduce the internal liner clearance required for trouble-free operation. If alignment can not be acquired through repositioning the expansion joint, enlarge the holes in the flange until bolts can be freely inserted and tightened.

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SERVICE DATA
AIR INTAKE AND EXHAUST SYSTEMS

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Aftercooler To Turbocharger Air Duct Bolt Application

8-cyl. & 12-cyl.

Right Bank
- (8) 7/16"-14 x 1-7/8" bolts
- (16) 7/16" hardened washers (under bolts heads & nuts)
- (8) 7/16"-14 nuts

Left Bank
- (4) 7/16"-14 x 2-1/4" bolts
- (4) 7/16"-14 x 1-1/2" bolts
- (12) 7/16" hardened washers (under bolt heads & nuts)
- (4) 7/16" nuts (use with 7/16"-14 x 2-1/4" bolts)

16-cyl. & 20-cyl.

Right Bank
- (6) 7/16"-14 x 1-7/8" bolts (use w/spline nuts)
- (2) 7/16"-14 x 1-1/4" bolts
- (8) 7/16" hardened washers

Left Bank
- (7) 7/16"-14 x 1-7/8" bolts (use w/spline nuts)
- (1) 7/16"-14 x 1-1/4" bolt
- (8) 7/16" hardened washers

Clearances And Backlash

Backlash between camshaft and auxiliary drive gears	0.25-0.56 mm (.010"-.022")
Clearance between turbocharger and turbocharger end of air duct (with turbocharger to duct bolts removed)	Less than 0.20 mm (.008")
Clearance between gasket and turbocharger flange (bolts installed and torqued, and using a 0.001 " feeler gauge) . . .	0.0 mm (.000")
Clearance between gasket and air duct flange (same condition as Step above)	0.0 mm (.000")

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EQUIPMENT LIST

	Part No.
Thread lubricant high temperature (1 qt.)	8278929
Turbocharger Lifting Sling	8293333
Exhaust manifold torque tool kit	8463511
Long adaptor	8463512
Short adaptor	8463513
Extension	8463514
Torque wrench	8463515

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SECTION 9

LUBRICATING OIL SYSTEM

CONTENTS PAGE

CONTENTS	PAGE
MAIN LUBRICATING OIL SYSTEM	9-1
PISTON COOLING SYSTEM	9-2
SCAVENGING OIL SYSTEM	9-2
OIL GAUGE	9-2
MAIN LUBRICATING OIL PRESSURE	9-2
PISTON COOLING OIL PRESSURE	9-3
MAIN LUBE OIL AND PISTON COOLING OIL MANIFOLD	
DESCRIPTION	9-3
PRESSURE RELIEF VALVE	
DESCRIPTION	9-3
SPRING, GUIDE, AND VALVE INSPECTION	9-4
INSTALLATION	9-4
PRESSURE SETTING	9-4
PISTON COOLING OIL PIPE	
DESCRIPTION	9-4
MAINTENANCE	9-4
CHECKING OIL VISCOSITY	9-5
CHANGING OIL	9-5
OIL STRAINER HOUSING	
DESCRIPTION	9-6
MAINTENANCE	9-7
LUBE OIL SEPARATOR	
DESCRIPTION	9-8
MAINTENANCE	9-8
MAIN LUBE OIL AND PISTON COOLING OIL PUMPS	
DESCRIPTION	9-9
DISASSEMBLY	9-9
CLEANING	9-10
INSPECTION	9-10
ASSEMBLY	9-11
ASSEMBLY INSPECTION	9-13
SCAVENGING OIL PUMP	
DESCRIPTION	9-13
DISASSEMBLY	9-14
CLEANING, INSPECTION, AND ASSEMBLY	9-14
ASSEMBLY INSPECTION	9-15
TURBOCHARGER OIL FILTER	
DESCRIPTION	9-15
MAINTENANCE	9-16
SOAK BACK OIL SYSTEM	
DESCRIPTION	9-16
MAINTENANCE	9-17
PRELUBRICATION OF ENGINES	9-17
OIL SYSTEM INFORMATION	9-17
SERVICE DATA	
SPECIFICATIONS	9-19
EQUIPMENT LIST	9-20

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

SECTION 9

LUBRICATING OIL SYSTEM

DESCRIPTION

The complete engine lubricating oil system is a combination of three separate systems. These are the main lubricating system, the piston cooling system and the scavenging oil system. Each system has its own oil pump. The main lube oil pump and piston cooling oil pump, although individual pumps, are both contained in one housing and driven from a common drive shaft. The scavenging oil pump is a separate pump. All the pumps are driven from the accessory gear train at the front of the engine. Parts of the complete oil system and a schematic arrangement of oil circulation are shown in Fig. 9-1.

MAIN LUBRICATING OIL SYSTEM

The main lubricating oil system supplies oil under pressure to most of the moving parts of the engine. The main lube oil pump takes oil from the strainer housing at the right front of the engine. Oil from the pump goes into the main oil manifold which is located above the crankshaft, and extends the length of the engine. Maximum oil pressure is limited by a relief valve in the passage between the pump and the main oil manifold

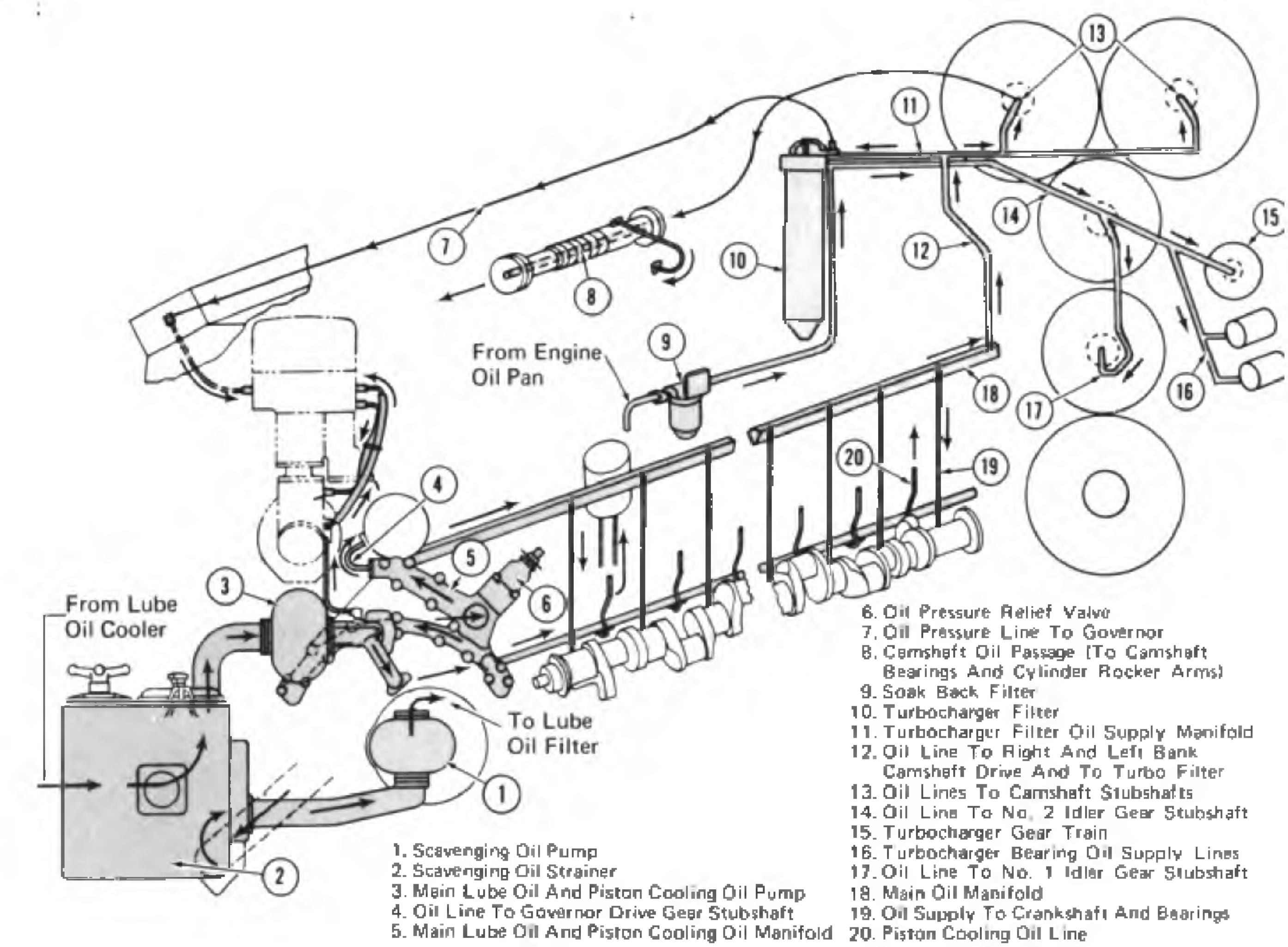

Fig. 9-1 - Lubricating Oil System

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Oil tubes at the center of each main bearing "A" frame conduct oil from the main manifold to the upper half of the main crankshaft bearings. Drilled passages in the crankshaft supply oil to the connecting rod bearings, damper, and accessory drive gear at the front of the crankshaft. Leak-off oil from the adjacent main bearings lubricates the crankshaft thrust bearings.

Oil from the main lube oil manifold enters the gear train at the rear of the engine, at the idler gear stubshaft bracket. Oil passages in the stubshaft bracket distribute the oil. One passage conducts oil to both the right and left bank camshaft drive gear stubshaft brackets and to a manifold connected to the turbocharger oil filter. After passing through the filter, the oil enters the return line in the manifold and flows back to the idler gear stubshaft. A passage in the idler gear stubshaft bracket directs lube oil to the upper and lower stubshaft bearings. Filtered oil enters the turbocharger oil system from the upper idler gear stubshaft.

An oil passage in the turbocharger filter head, parallel to the filter output line, is connected to a passage in the turbocharger oil manifold. An oil pressure line is connected between the manifold passage and the low oil pressure device in the governor.

Oil enters the hollow bore camshafts from the camshaft drive stubshafts. Radial holes in the camshaft conduct oil to each camshaft bearing. An oil line from one camshaft bearing at each cylinder supplies oil to the rocker arm shaft, rocker arm cam follower assemblies, hydraulic lash adjusters, and the injector rocker arm button. Leak-off oil returns to the oil pan through passages between the top deck and the oil pan.

Passages in the turbocharger conduct oil to the turbocharger bearings, idler gear, planet gear assembly, and auxiliary drive bore.

Considerable heat will remain in the metal parts of the turbine when the engine is shut down, and if the oil supply to the turbocharger was shut off suddenly, this heat would penetrate the turbo-charger bearing area. To prevent possible over-heating of the turbocharger, oil is automatically supplied to the turbocharger after stopping the engine.

Protection is provided against a hot oil condition by a thermostatic valve. Descriptive information is contained in Section 13, Protective Devices.

PISTON COOLING OIL SYSTEM

The piston cooling oil system pump receives oil from a common suction with the main lube oil pump and delivers oil to the two piston cooling oil manifolds extending the length of the engine, one on each side. A piston cooling oil pipe at each cylinder directs a stream of oil through the carrier to cool the underside of the piston crown and the ring belt. Some of this oil enters the oil grooves in the piston pin bearing and the remainder drains out through holes in the carrier crown to the sump.

SCAVENGING OIL SYSTEM

The scavenging oil system pump, Fig. 9-I, takes oil through the scavenging oil strainer from the oil pan sump or reservoir. The pump then forces the oil through the oil filters and oil cooler which are located near the engine. Oil then returns to the strainer housing to supply the main lube oil pump and piston cooling oil pump with cooled and filtered oil. Excess oils spills over a dam in the strainer housing and returns to the oil pan.

OIL GAUGE

An oil level gauge, Fig. 9-2, extends from the side of the oil pan into the oil pan sump. The oil level should be maintained between the low and full marks on the gauge, with the reading taken when the engine is at idle speed and the oil is hot.

Fig. 9-2 - Oil Level Gauge

MAINTENANCE

MAIN LUBRICATING OIL PRESSURE

Adequate lubricating oil pressure must be main-tained at all times when the engine is running.

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Upon starting and idling the engine, it should be noted that the oil pressure builds up almost immediately. In the event of cold oil, the pressure may rise to the relief valve setting of approximately 862 kPa (125 psi).

Lubricating oil pressure is not adjustable. The operating pressure range is determined by such things as manufacturing tolerances, oil temperature, oil dilution, wear, and engine speed. The pipe plug can be removed from the opening in the pump discharge elbow and a gauge installed to determine the pressure.

The minimum oil pressure is approximately 55-83 kPa (8-12 psi) at idle and 172-200 kPa (25-29 psi) at full speed. In the event of insufficient oil pressure, a shutdown feature built into the governor will automatically protect the engine by shutting it down. Maximum pressure is determined by the relief valve setting.

PISTON COOLING OIL PRESSURE

Pressure of the piston cooling oil will be governed by oil viscosity, speed of engine, temperature of oil, and wear of pump parts. The pipe plug can be removed from the opening in the pump discharge elbow and a gauge installed to determine the pressure.

MAIN LOBE OIL AND PISTON COOLING OIL MANIFOLD

DESCRIPTION

The main lube oil and piston cooling oil manifold, Fig. 9-3, is a one piece casting with cored passages. The manifold is mounted and doweled in the front end plate, under the accessory drive cover.

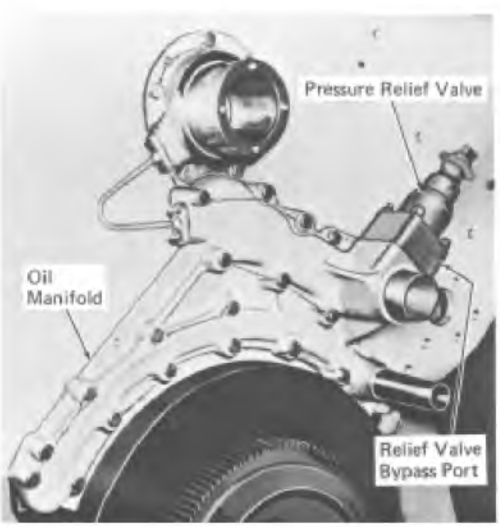

Fig. 9-3 - Lube Oil Manifold And Relief Valve

Connecting tubes passing through the accessory drive cover, protected against leakage by seal rings, connect the manifold to the discharge side of the main lube oil piston cooling oil pumps.

The purpose of the manifold is to transfer the oil supplied by the pumps to the main bearing oil header in the center of the engine. The manifold also transfers oil to the piston cooling oil header pipes on each side of the crankcase, just inside the oil pan mounting flange.

LUBE OIL PRESSURE RELIEF VALVE

DESCRIPTION

The lube oil pressure relief valve, Fig. 9-4, is installed on the lube oil manifold, inside the accessory gear train housing on the left side of the engine, Fig. 9-1. A cover plate provides access to the valve for inspection and adjustment.

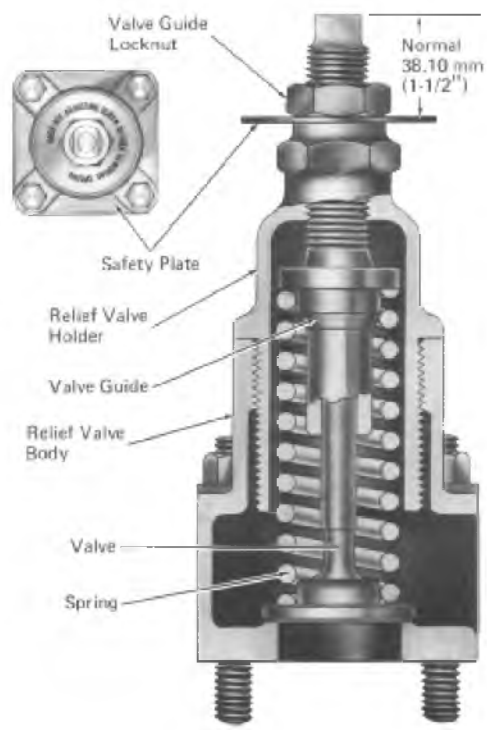

Fig. 9-4 - Lube Oil Pressure Relief Valve

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The purpose of the valve is to limit the maximum pressure of the lube oil entering the engine oil system. When the lube oil pump pressure exceeds the spring tension on the valve, the valve will be lifted off its seat and relieve the excess pressure. This oil drains into the accessory housing and then into the oil pan.

MAINTENANCE

The oil pressure relief valve should be removed and the parts inspected at intervals specified in the Scheduled Maintenance Program.

Disassemble the valve and wash all the parts thoroughly. As stated on the safety plate on the valve, back off on the valve guide all the way before removing the valve holder and spring.

Inspect the parts as follows to determine their condition for reuse.

VALVE SPRING

Check the valve spring for any nicks which could cause subsequent spring failure.

Test the valve spring by applying a load of 141 kg (310 lbs). Under this load the spring length should not be less than 114.30 mm (4-1/2").

VALVE GUIDE

Using a telescoping gauge, check the valve guide inside diameter.

If the inside diameter is rough or lightly scuffed, clean up the bore but do not exceed the maximum diameter.

VALVE

Examine the valve stem for roughness and light scuffing. The stem may be handstoned and buffed to remove high spots. Replace the valve if the stem is badly galled.

Check that the outside diameter of the valve stem is not less than the minimum limit.

Also, check for a possible bent valve or distorted face by checking the squareness of the valve face to the stem, measuring from the outer edge of the valve face. Total indicator reading should be as specified.

INSTALLATION

When installing relief valve on engine, make sure that the bypass port is positioned in the downward direction, Fig. 9-3.

SETTING OIL PRESSURE RELIEF VALVE

The setting of the oil pressure relief valve connected to the lube oil manifold determines the maximum oil pressure at the main lube oil pump. It is not set by pressure gauges, but by a specific dimension from the top of the valve guide to the top of the valve holder. To set valve, loosen the locknut, Fig. 9-4, and position the valve guide so that it extends 38.10 mm (1-1/2") above the safety plate.

This setting will permit a maximum oil pressure of about 862 kPa (125 psi) under cold oil conditions, and allow an adequate pressure for normal operation and hot oil.

Lubricating oil manifold pressure or pressure at the valve can be determined by applying a pressure gauge at the main lube oil pump discharge elbow.

PISTON COOLING OIL PIPE

DESCRIPTION

The piston cooling oil pipe is bolted at one end to a flange on the piston cooling oil manifold, and at the other end to the bottom of the cylinder liner. A pipe is located at each cylinder to direct a stream of oil through the piston carrier to the undercrown of the piston. Alignment of the piston cooling oil pipe is very important.

MAINTENANCE

The alignment of the piston cooling oil pipe to the inlet hole in the piston carrier is checked with an alignment gauge as shown in Fig. 9-5. The small end of the gauge fits into the nozzle of the pipe and by bringing the piston to bottom center the gauge should enter the inlet hole in the piston carrier and turn freely in this position. This gauge is not to be used for bending the pipe in case of misalignment. If the gauge will not freely enter the carrier hole, the pipe should be removed and replaced with a new or correctly aligned one.

In addition to the alignment check, the piston cooling pipe nozzle should be examined for ragged edges which might cause the oil to spray out instead of shoot out in a stream.

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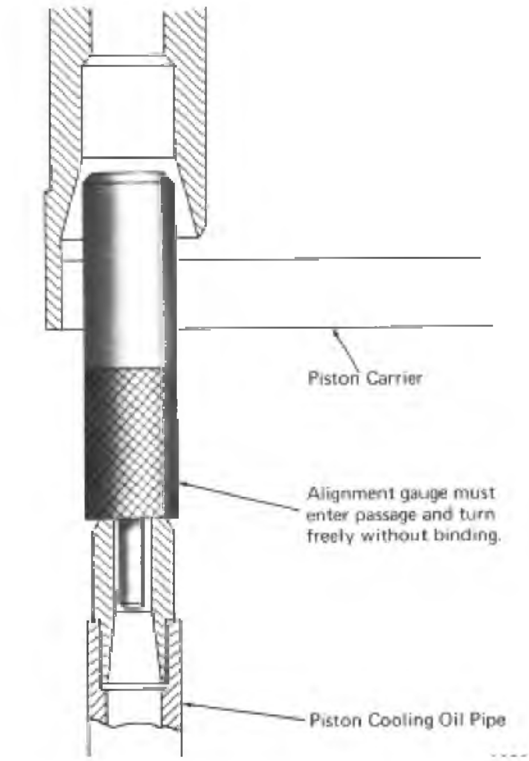

Fig. 9-5 - Piston Cooling Oil Pipe Alignment

CHECKING OIL VISCOSITY

Oil viscosity should be checked at intervals as specified in the Scheduled Maintenance Program. By comparing the viscosity at different intervals, taken at the same temperature, excessive fuel dilution may be detected by an unusual drop in viscosity. Excessive oxidation of the oil may be detected by an unusual rise in viscosity within the recommended oil drain periods. The viscosity limits are directly related to the type of oil being used and the type of viscosity measurements being made. The oil suppliers will furnish these values, which should correspond to a maximum of 5% fuel dilution and a 35% viscosity rise.

Operating an engine with badly oxidized oil or poor oil filtration will result in oil cooler core plugging, carbon buildup on piston undercrowns, ring grooves, oil rings, and piston pin bearing grooves. and limitation of oil flow to the main and connecting rod bearings with subsequent engine damage.

To provide protection to the engine, the oil and system components should be carefully observed for proper functioning and corrective measures taken where necessary. Oil and filter change periods should be followed closely since the oil is not only oxidizing, but contaminants are corning into the engine from fuel combustion, as well as the normal air-borne contaminants which are not caught by the air filters. It is therefore beneficial to drain the oil and eliminate these contaminants as specified in the Scheduled Maintenance Program.

CHANGING OIL

Engine lube oil should be drained. filters replaced. and strainers and screens cleaned at intervals outlined in the Scheduled Maintenance Program. Before the oil is drained, its viscosity should be checked for any indication of fuel dilution. If fuel leakage is indicated, the leak should be corrected before charging the engine with new oil.

GENERAL PROCEDURE

1. Shut down the engine.
2. Open drain valve in the oil strainer housing to drain oil into the engine oil pan sump.
3. Provide a container or oil runoff line for drained oil.
4. Remove pipe plug from oil drain valve and open valve to drain all the oil from the engine oil pan sump.
5. Remove pump strainers from strainer housing, and remove the oil filters from the filter housing.
6. Clean the strainers using a suitable cleaner, and rinse thoroughly.
7. Wash down top deck, oil pan, and filter housings using fuel oil or kerosene. Drain off cleaning fluid and wipe areas free of excess fluid. using bound edge absorbent towels.
8. Replace pipe plugs in drain lines, where required, and close valve. Where necessary, renew gaskets.
9. Install clean strainers and screens. Install new elements in filter containers. Prepare system to receive new oil.

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10. Recharge engine with new lubricating oil qualified for use. Add oil through square filler opening in strainer housing.

CAUTION: Ensure that strainer housing internal drain valves are closed and oil strainer is filled to overflow before starting engine.

Sufficient oil will be retained in the housing to supply main lube and piston cooling oil pumps on starting. Engine oil level is shown on the oil gauge. Pour a liberal quantity of oil over cylinder heads and top deck components before starting.

11. Inspect engine prior to starting, then start engine. Check oil level with engine at idle speed. If oil level is not to "full" mark on gauge, add oil to bring level to "full" mark, with engine at idle speed and with hot oil.

NOTE: Under some conditions the oil level may be above the bottom of the oil pan handles so care must be taken when the oil pan handhole covers are removed.

OIL STRAINER HOUSING

DESCRIPTION

The oil strainer housing. Fig. 9-6, is a large box-shaped cast aluminum housing which is mounted on the right front side of the engine on the accessory drive cover. It contains independent strainers for the main oil pump supply and scavenging oil pump. There are two strainers for the main lube pump oil and one strainer screen for scavenging pump oil. with a separate oil inlet and discharge for each of the systems.

The two main lube oil pump strainers. Fig. 9-7, each consists of a replaceable element of a pleated perforated metal core covered with mesh screening, and a metal cylinder which encloses the element. The cylinder prevents collapse of the element in the event of a high pressure drop. The element is attached to the cylinder by a through bolt in the cylinder which runs through the base of the element and is secured with a locknut. The unperforated outer cylinder provides a constant head of oil since suction is from the bottom only and not through the entire length of the screen.

The flow of oil is from the bottom of the strainer between the cylinder and the mesh screen, through the mesh screen and the perforated metal core into the center of the element, then out the top of the strainer.

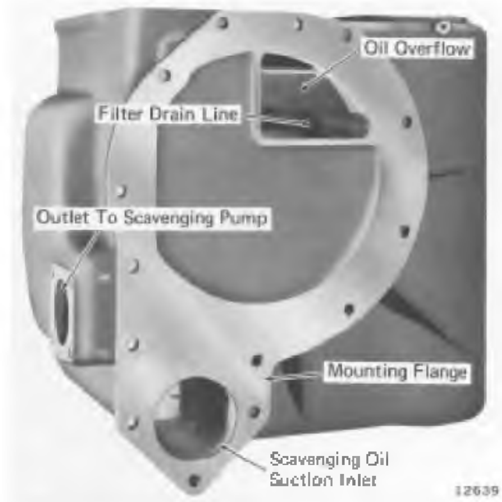

Fig. 9-6 - Oil Strainer Housing

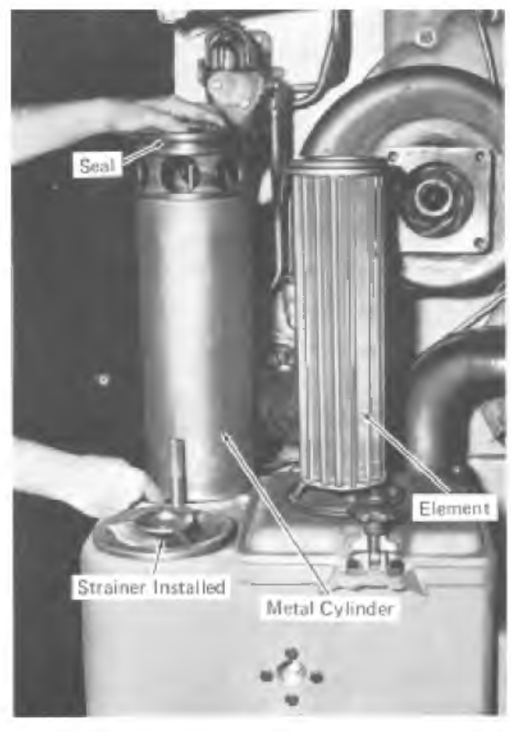

Fig. 9-7 - Main And Piston Cooling Oil Pump Strainers

When in place, they are held by a crab and handwheel on the stud between the holes. Each strainer is sealed at the top by a seal ring. Also, oil under pump pressure is admitted to a groove around each strainer, just below the seal, to prevent air

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entry in event of a leaky seal. A partition adjacent to the strainers, open at the bottom, separates them from the oil inlet area of the housing. Oil enters the strainers at the partition bottom and is taken up by thy pump through a cast passage in the housing.

The scavenging oil pump strainer, Fig. 9-8, has a rigid perforated metal screen which retains its shape and is easily cleaned. When the strainer is installed in the housing, it is held in position with three nuts. Two handwheels on swivel bolts secure a cover over the strainer and drain valves. The scavenging oil strainer inlet and outlet openings are shown in Fig. 9-6.

An oil level is maintained in the strainer housing up to the bottom of the overflow opening, Fig. 9-6. Excess oil returns to the oil pan sump. A spring-loaded valve, Fig. 9-9, is provided to drain the oil from the strainer housing into the oil pan sump, at the time of an oil change. An additional valve, Fig. 9-9, is used to drain the oil filter housing. Both valves are located under the filler cover and must be kept closed at all times except for the period of draining.

Fig. 9-8 - Scavenging Oil Pump Strainer

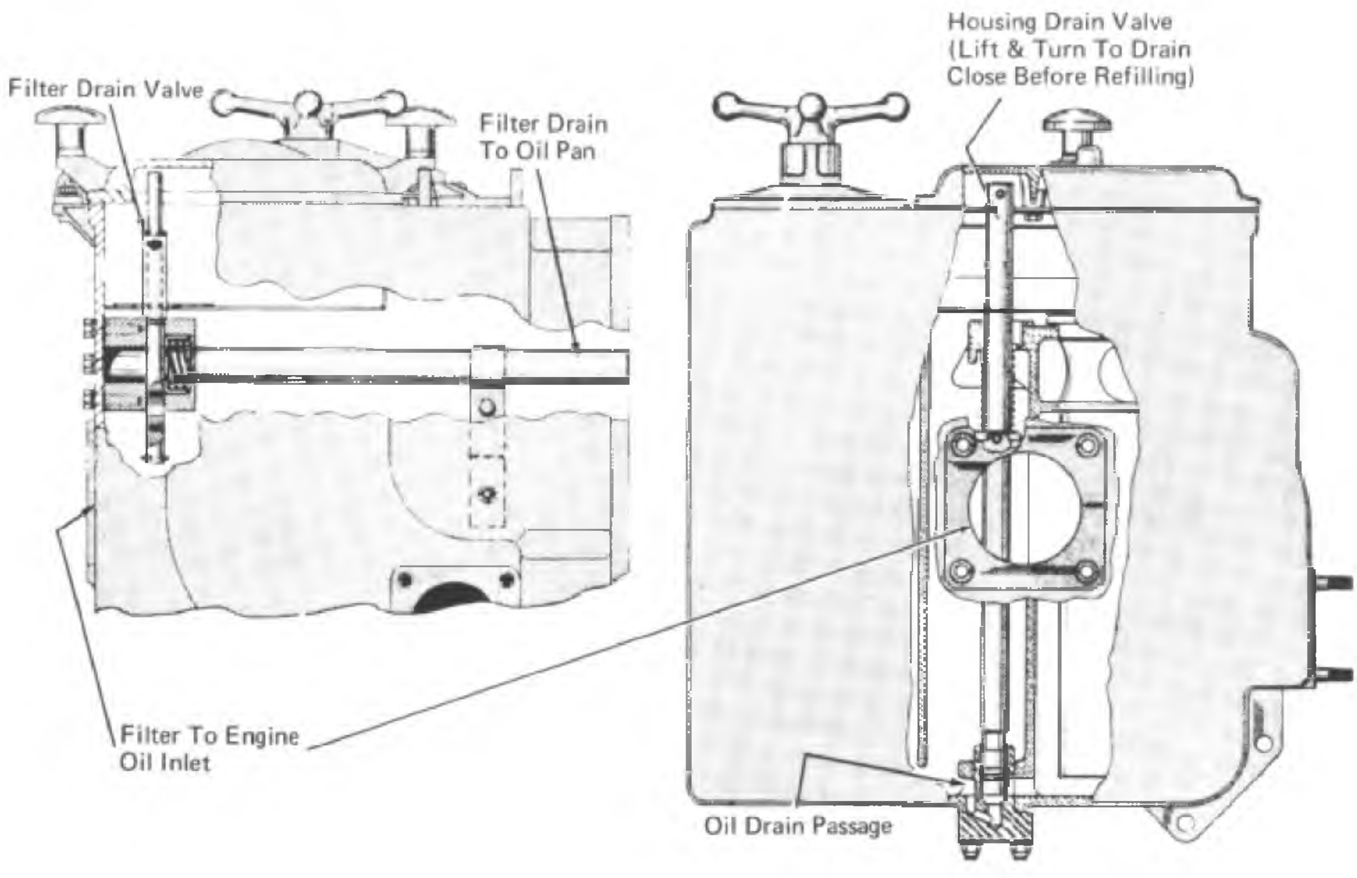

Fig. 9-9 - Strainer Housing Drain Valves

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MAINTENANCE

Lube oil strainers should be removed at each oil change and strainers and housing thoroughly cleaned, using a petroleum solvent.

As previously described, the engine lube oil strainers have a seal of oil under pressure in addition to the seal rings. The oil under pressure will leak out under the strainer flanges if the seal rings are not seated properly or are damaged. When strainers are replaced, care should be taken to see that the sealing surfaces are free from nicks and scratches and seal rings are in good condition. Also, that the oil passages to the seals are open and clear.

The pressure oil seal may be checked, with the engine at idle speed, by loosening the large handwheel until the seal ring of the furthest strainer from the engine is free of the housing. Oil should leak out around the strainer flange. If no oil appears, the engine should be shut down and the oil supply passages inspected and cleaned. Any air which might enter system at this location will be discharged with the lubricating oil and may cause damage, even though normal oil pressure is indicated.

When replacing the scavenging strainer, be sure the strainer is seated properly or the scavenging pump will lose suction causing a loss of lube oil pressure.

LUBE OIL SEPARATOR

DESCRIPTION

The oil separator is an elbow-shaped cylindrical housing containing a wire mesh screen element. It is mounted on the turbocharger housing. An elbow assembly connects the oil separator to the eductor tube assembly in the exhaust stack, Fig. 9-10. The exhaust gases in the stack create a suction in the eductor tube, which draws up oily vapors from the engine through the separator element. The oil collects on the element and drains back into the engine. The gaseous vapors going through the element are discharged into the exhaust stack and vented to atmosphere.

MAINTENANCE

The screen should be removed from the oil separator and cleaned at intervals specified in the Scheduled Maintenance Program.

Fig. 9-10 - Lube Oil Separator

1. Shut down the engine.
2. Remove bolts from the separator cover.
3. Disconnect the flexible exhaust tube assembly from the eductor tubes and remove the housing cover and exhaust tube elbow as an assembly.
4. Remove eductor assembly tubes from stack.
5. Separate inner eductor tube from outer tube by inserting screwdriver at the top of the eductor flanges.
6. Clean carbon deposits from inside and outside of both eductor tubes.
7. Remove screen clement from separator cover and wash in petroleum solvent. Rinse clement in hot water and blow dry with compressed air.
8. Insert inner tube into outer tube with hole in inner tube flange aligned with pin in outer tube flange.
9. Place eductor assembly into stack with the word TOP, stamped on the inner tube flange, facing upward.
10. Install screen element into cover and mount cover to separator with mounting bolt.
11. Attach exhaust elbow and eductor assembly to exhaust stack with four mounting bolts.

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MAIN LUBE OIL AND PISTON COOLING OIL PUMPS

DESCRIPTION

The main lube oil and piston cooling oil pumps, Fig. 9-11, are contained in one housing. The two pumps are separated by a spacer plate between the sections of the pump body. Each has its individual oil inlet and discharge opening. The piston cooling pump gears at the end are narrower than the lube oil pump gears. The lube oil and piston cooling oil pump assembly is mounted in the center of the accessory drive housing and is driven by the accessory drive gear.

MAINTENANCE

NOTE: In the following "Disassembly" and "Assembly" procedures, disregard references to "center body" for 8 and 12cylinder engines. Also disregard "center gear" for 8 and 12-cylinder engines.

DISASSEMBLY

1. Clean the pump externally before disassembly.

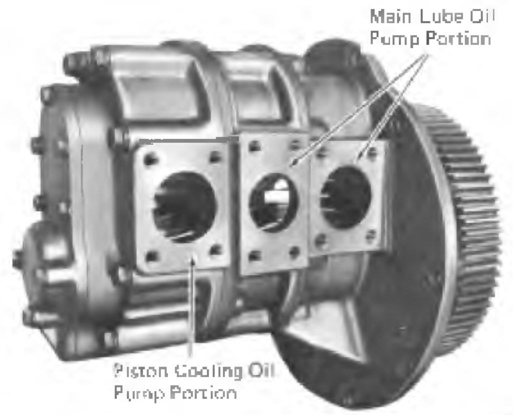

Fig. 9-11 - Main Lube Oil And Piston Cooling Oil Pumps (16-Cyl.)

2. Hold the pump in a suitable vise.

   As a safety precaution, provide an additional support at the center of the pump until the front body and bushing and piston cooling pump gears are removed.

3. Remove the long bolts holding the front body to the center body, Fig. 9-12

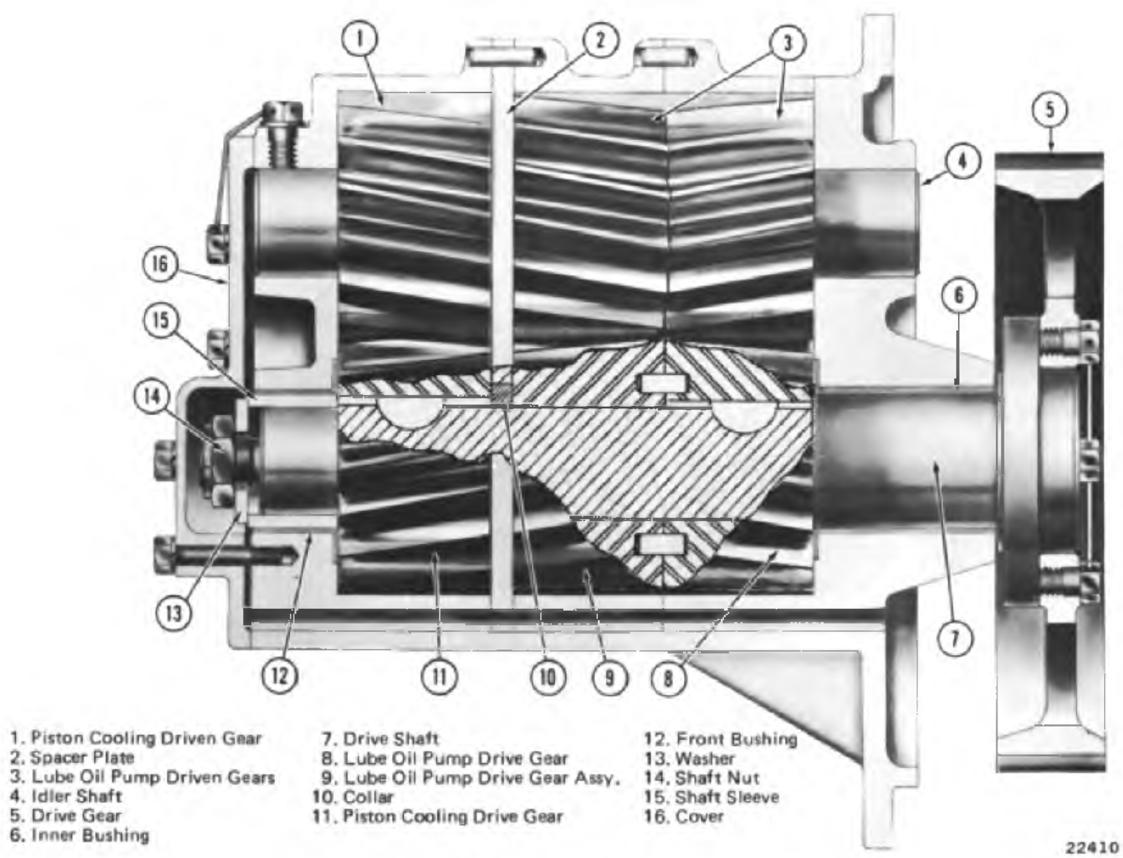

Fig. 9-12 - Main Lube Oil And Piston Cooling Oil Pumps, Cross-Section (16 Cyl.)

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4. Using a rawhide mallet, tap the front body at the inlet and outlet openings, to remove -the front body, cover, idler shaft, and outer driven gear as an assembly.

5. Remove the drive shaft nut, and washer.

6. Support pump on its flange, pump drive gear down, so that gear is free to move downward. 7. Apply pressure to shoulder of drive shaft and press the shaft down a maximum of 12.70 mm (1/2").

CAUTION: If shaft is pressed down too far, the piston cooling pump gear key will shear the collar in the spacer plate.

8. Manually raise pump drive gear and drive shaft until a 12.70 mm (1/2") clearance is obtained between the drive shaft sleeve and the piston cooling pump drive gear.

9. Attach a puller to the drive shaft sleeve and remove sleeve from the drive shaft.

10. Remove the piston cooling pump drive gear and its key.

11. Remove the spacer plate and collar.

12. Remove the tube oil pump center driven gear and drive gear assembly.

13. Using a rawhide mallet, remove the center body portion of the pump.

14. Remove the tube oil pump inner driven gear, drive gear, and key.

15. The pump drive gear and shaft assembly is then removed.

16. Keep all parts of the one pump assembly together.

CLEANING

Clean all the individual parts of the pump using a petroleum solvent. After cleaning, dry the parts with compressed air.

INSPECTION PUMP BODIES

1. Check the surface of the pump bodies for nicks, dents or scratches which may have protrusions above the normal surface. Smooth down any evidence of roughness.

2. Inspect the drive shaft bushings for imbedded dirt, metallic particles, flaking and pitting. Bushings with light scratches and small quantities of imbedded dirt may be reused after smoothing up, provided bore sizes are within the maximum limits.

3. Replace the bushings if any other adverse conditions exist. Details of construction and application of bushing installation and removal tools are shown in Fig. 9-13.

4. Using fine abrasive cloth on a smooth surfaced tool, clean off the gasket face of the pump bodies.

SPACER

Inspect the sides of the spacer for smoothness. If necessary, smooth the sides using fine abrasive cloth held flat on a flat surfaced tool.

GEARS

1. Inspect the gear teeth for nicks, pitting, and excessive wear. Light nicks are permissible provided they are blended by filing and stoning.

2. Gears having tooth faces pitted in excess of 30% of tooth contact area should not be reused.

3. Inspect the driven gear bushing inside diameter for wear and possible damage.

4. Driven gear bushing installation and removal tool construction and application is shown in Fig. 9-14.

5. Inspect the keyways in the drive gears for any damage which would interfere with the key application.

6. The drive shaft gear may be magnaflux inspected.

DRIVE SHAFT, KEYS, AND IDLER SHAFT

1. Inspect the shafts for any roughness. Check the drive shaft keyways and key fit. making sure the keys fit snugly in the shaft.

2. Check the drive shaft diameter to determine whether the drive shaft to body bushing clearance is within maximum limits.

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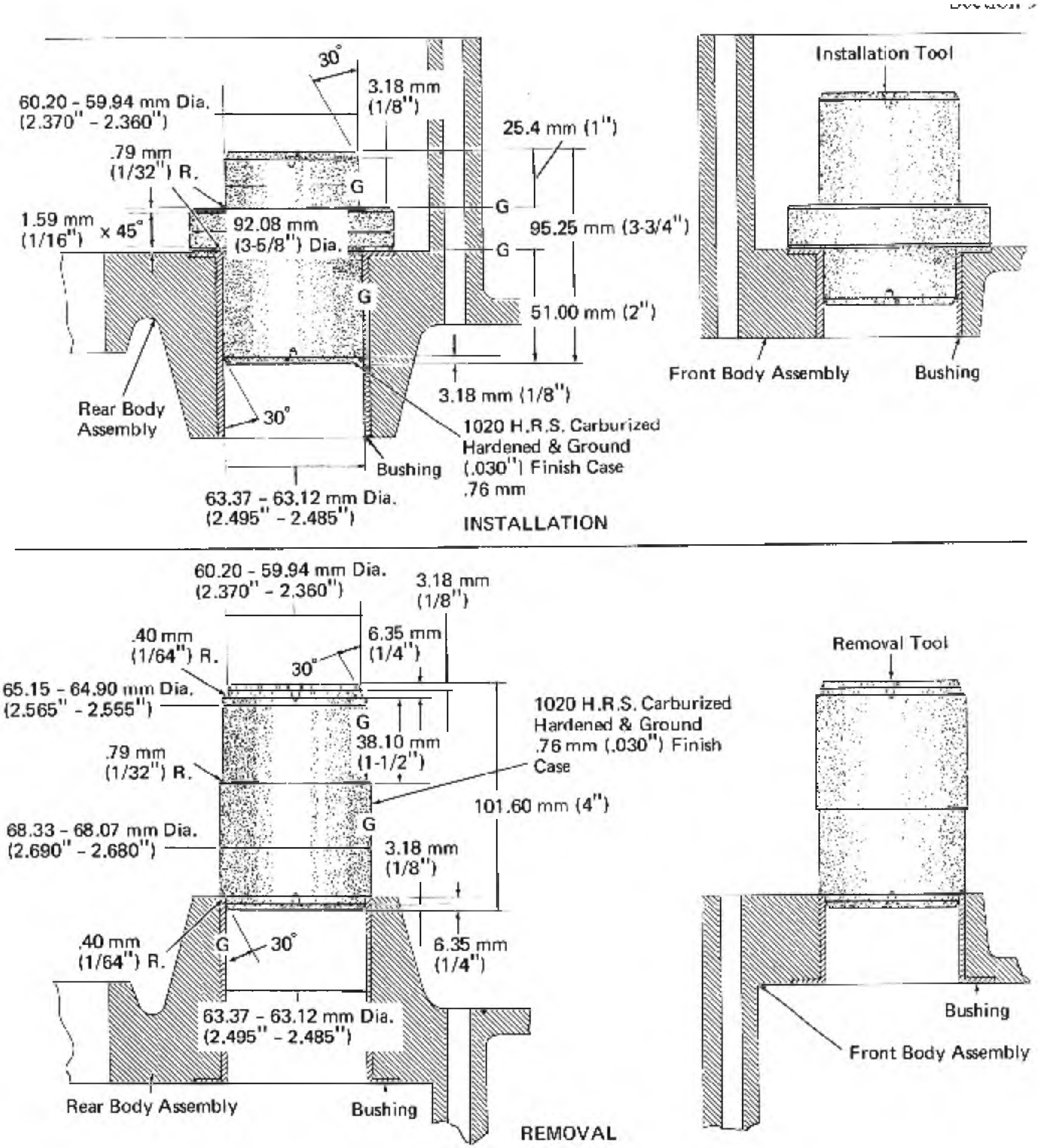

Fig. 9-13 - Oil Pump Body Bushing Tools

3. Also check the idler shaft to make certain that the shaft to bushing clearance is within maximum limits.

ASSEMBLY

1. Place the mounting flange of the cleaned and inspected rear body, Fig. 9-12, in the bench vise with the drive shaft bore facing up.

2. With the pump drive gear applied to the drive shaft, lightly oil the shaft journal and insert the shaft in the rear body bushing.

3. Place the inner drive gear key in the drive shaft and install the inner drive gear on the shaft with the dowel holes in the gear facing toward the front of the pump.

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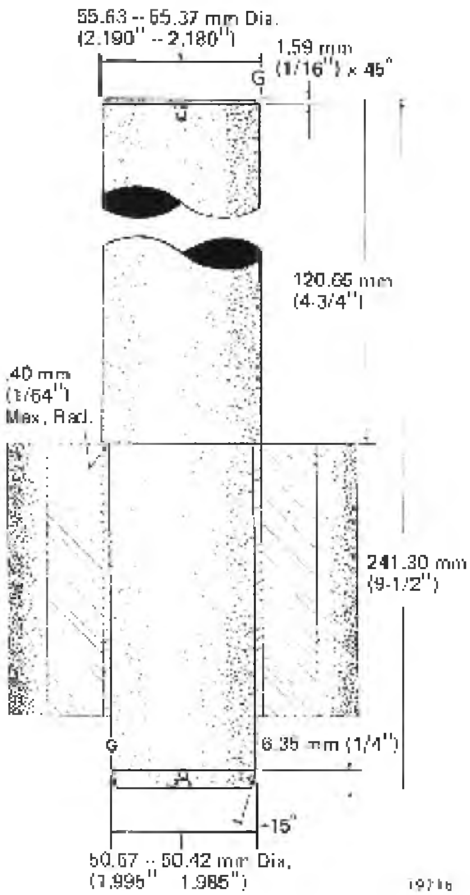

Fig. 9-14 - Oil Pump Driven Gear Bushing Tool

CAUTION: Refer to Service Data for diagram of helix angle position of abutting gears.

4. After oiling the bushing, apply the mating driven gear, meshing it with the drive gear.

5. Oil the pump rear body to center body gasket and apply it to the gasket face of the rear body, being careful to align the bolt and dowel holes.

6. Apply the center body to the rear body.

7. Apply center drive gear assembly to drive shaft with dowels aligned with holes in rear drive gear. Slide center gear toward rear of pump until dowels and dowel holes are fully mated.

8. Install center driven gear to mate with center drive gear assembly.

9. Oil the body gasket and apply to the center body.

10. Apply the spacer plate to the center body and the collar to the drive shaft.

11. Install the piston cooling drive gear key in the drive shaft and apply the drive gear.

NOTE: The use of the cleaner activator and retaining compound, as described in the following Steps, does not apply to 8 and 12-cylinder engines.

12. Make sure that sleeve and drive shaft are free of dirt, oil, and grease. Spray cleaner activator on the I.D. of the sleeve and the O.D. of the shaft, and wipe off.

13. Respray sleeve and shaft and allow to dry for about 10 minutes. Do not wipe off.

14. Coat entire surface of shaft, which is covered by the sleeve, by applying retaining compound in small amounts.

15. Apply sleeve and wipe off excess compound at each end of sleeve. Apply heavy duty washer and nut. Tighten nut to 441-475 N˙m (325-350 ft-lbs) torque.

NOTE: Retaining compound sets quickly so that delay in torquing nut could result in improper clamping of gears.

16. Check that all excess compound is removed before proceeding with assembly.

17. Oil the spacer plate gasket and apply to the spacer.

18. Completely coat the bushing in the front body with oil.

19. Apply the piston cooling pump driven gear to the idler shaft which was left assembled to the front pump body and cover, and apply this assembly to the pump. If the front body, cover, and idler shaft were disassembled, apply these parts individually using a new oiled gasket between the cover and the front body.

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20. Complete assembly of the pump by installing the long bolts through the cover. Tighten securely.

21. If possible, allow pump to remain unused for approximately 24 hours after torquing to ensure sleeve to shaft retention.

ASSEMBLY INSPECTION

1. After pump assembly, rotate the pump drive gear to check for gear noise or tight assembly.

2. Check the thrust of the drive gears. This may be done by securing an indicator on the pump flange with the indicator button contacting the rim of the pump drive gear, Fig. 9-15. Push the drive gear inward so that all clearance is located at one end, then set the indicator to zero. Pull the drive gear outward to determine the amount of thrust clearance.

3.

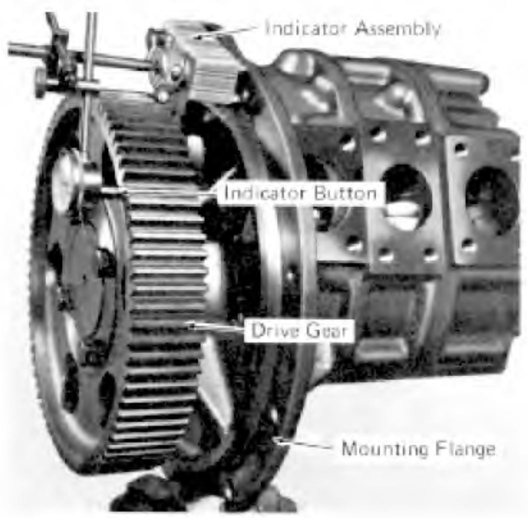

Fig. 9-15 - Checking Pump Drive Gear End Thrust

3. Leaving the indicator button on the outside of the pump drive gear rim, rotate the drive gear to check the gear runout. Drive gear runout should not exceed specified total indicator reading, with thrust in one direction.

4. Check the pump flange runout. Mount the indicator clamp on the drive gear and place the indicator button to contact the pump flange. Set the indicator to zero, and with the thrust held in one direction, rotate the drive gear. The runout of the pump flange face should not exceed specified total indicator reading.

5. Check the pump gears to body radial clearance. Clearance should be within the specified limits.

6. Additional clearances and limits are listed in the "Service Data" at the end of the section. Some of these clearances must be obtained by comparing the individual mating parts, or by assembly and disassembly using lead wire or other suitable means to obtain the part to part clearance.

7. After pump inspection, seal off the pump body openings, and provide protection for the teeth of the pump drive gears.

SCAVENGING OIL PUMP

DESCRIPTION

The scavenging oil pump, Fig. 9-16, is a positive displacement, helical gear type pump. The pump body, split transversely for ease of maintenance, contains sets of mated pumping gears. The driving gears are retained on the pump drive gear shaft by keys. The idler shaft is held stationary in the housing by a set screw, and the driven pump gears rotate on this shaft on bushings pressed into the gear bores. The drive shaft turns in bushings pressed into the pump body. These bushings are made with thrust collars which protrude slightly above the pump body and absorb the thrust of the drive gears. The scavenging pump is mounted on the accessory housing in line with and to the left of the crankshaft, and is driven by the accessory drive gear.

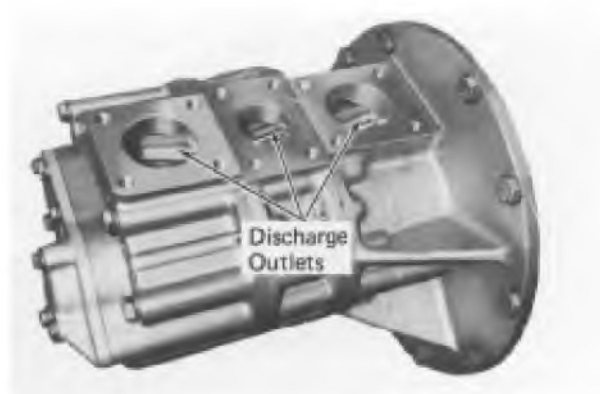

Fig. 9-16 - Scavenging Oil Pump (16 & 20-Cyl.)

MAINTENANCE

NOTE: In the following "Disassembly" and "Assembly" procedure, disregard references to "center body" for 8 and 12-cylinder engines. Also disregard "center gear" for 8 and 12-cylinder engines.

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Construction and maintenance of the scavenging oil pump is similar to the main lube oil and piston cooling oil pump, except for the use of the spacer in the main lube oil pump.

DISASSEMBLY

1. Clean the external surfaces of the pump before disassembly.

2. Hold the pump in a suitable vise. As a safety precaution, provide additional support until the rear body is removed.

3. Remove the long bolts holding the pump bodies together.

4. Using a rawhide mallet, tap the front body at the oil inlet and outlet openings to remove the front body, idler shaft, and cover as an assembly.

5. Remove the drive shaft nut, washer, and sleeve from the drive shaft.

6. Remove the outer drive gear, key and driven gear.

7. Remove the center body.

8. Remove the center drive gear, key, and the mating driven gear.

9. Remove the rear drive gear, key, and driven gear.

10. Remove the pump drive gear and shaft as an assembly from the rear pump body.

11. Keep all parts of the same pump together.

CLEANING

Clean all the individual parts of the pump using a petroleum solvent and rinse in hot water. Dry the parts, using compressed air.

INSPECTION

Refer to the corresponding procedures in the preceding "Main Lube Oil And Piston Cooling Oil Pumps" coverage. Also, refer to "Service Data" at the end of the section.

ASSEMBLY

1. Place the cleaned and inspected rear body, Fig. 9-17, in the vise with the drive shaft bore facing up.

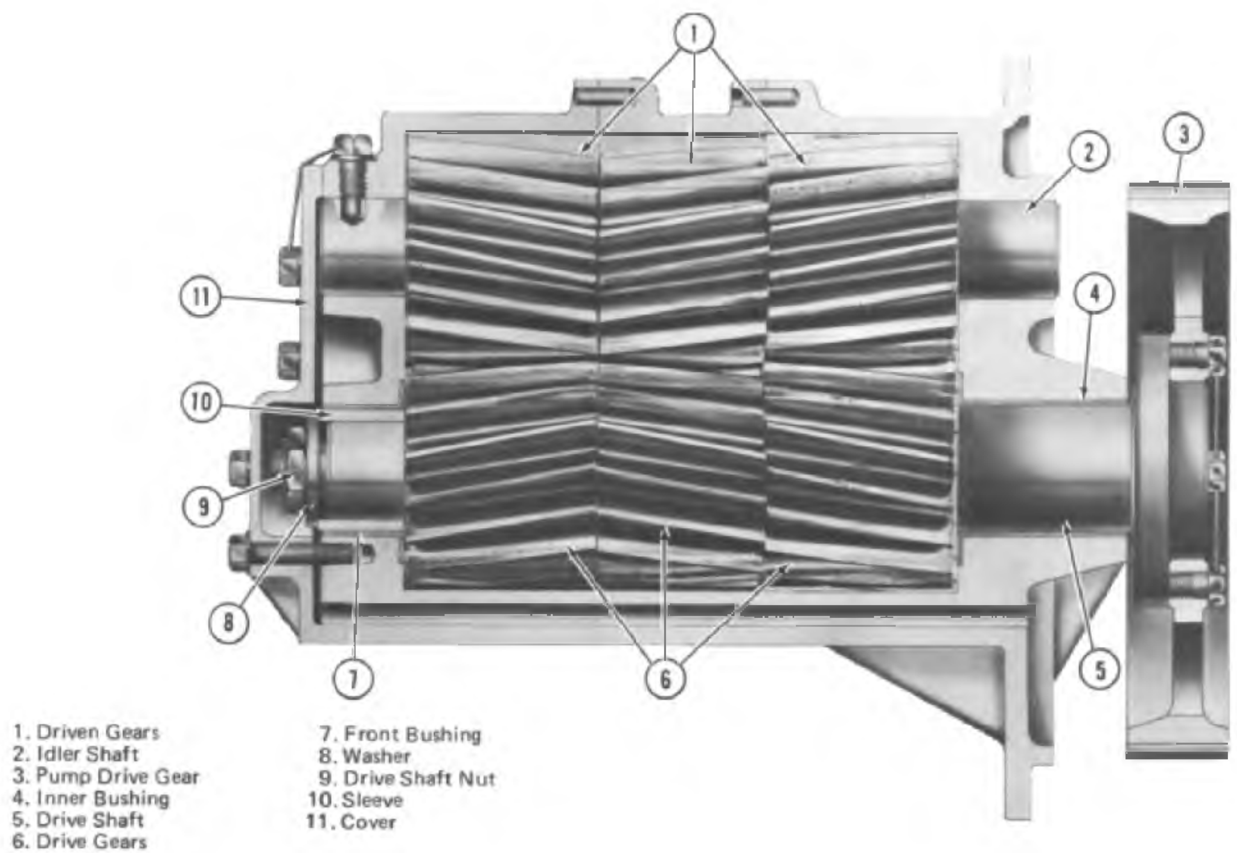

Fig. 9-17 - Scavenging Oil Pump, Cross-Section (16 & 20-Cyl.)

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2. Oil the drive shaft journal sparingly, and apply the pump drive gear and shaft as an assembly to the rear body.

3. Apply the drive gear key to the drive shaft and apply the inner drive gear. Apply the mating driven gear.

CAUTION: Refer to Service Data for diagram of helix angle position of abutting gears.

4. Fit the center drive gear key to the shaft.

5. Oil the body gasket and apply it to the rear body.

6. Apply the center body to the rear body.

7. Install the center drive gear to the drive shaft.

8. Place the center driven gear in the body in mesh with drive gear.

9. Apply an oiled gasket to the face of the center body.

10. Apply the outer drive gear key to the drive shaft and install the outer drive gear.

11. Apply the sleeve, heavy duty washer, and drive shaft nut to the shaft. Tighten nut to 441-475 N-m (325-350 ft-lbs).

12. Since the front body, idler shaft, and cover were left as an assembly, these parts may be applied to the pump together. Apply the outer driven gear to the idler shaft and apply this assembly to the pump.

13. Install the long bolts through the cover and tighten securely.

ASSEMBLY INSPECTION

1. After pump assembly, rotate the pump drive gear to check for gear noise or tight assembly.

2. Check the thrust of the pump drive gears. This is done using the same indicator arrangement shown in Fig. 9-15 for the main lube oil pump. Attach the indicator holder to the pump flange with the indicator button contacting the rim of the pump drive gear. Push the drive gear inward to take up all thrust in one direction. Set the indicator button to zero and pull the drive gear outward to determine clearance. Thrust clearance using new parts should be within the specified limits.

3. With the indicator button on the outside of the pump drive gear rim, as when checking thrust clearance, rotate the gear with the thrust held in one direction to check drive gear runout. Drive gear runout should not exceed specified total indicator reading.

4. Check the pump flange runout. Mount the indicator clamp on the drive gear and place the indicator button to contact the pump flange. Set the indicator to zero, and with the thrust held in one direction, rotate the drive gear. The runout of the pump flange face should not exceed specified total indicator reading.

5. Check the pump gears to body radial clearance. Clearance should be within the specified limits.

6. Additional clearances and limits are listed in the "Service Data" at the end of the section. Some of the clearances must be obtained by comparing the individual mating parts, or by assembly and disassembly using lead wire or other suitable means to obtain the part to part clearance.

7. After pump inspection, seal off the pump body openings and provide protection for the drive gear teeth.

TURBOCHARGER OIL FILTER

DESCRIPTION

The turbocharger oil filter, Fig. 9-18, provides additional protection for the high speed bearings and other lubricated areas of the turbocharger, by filtering the oil just before it is admitted to the turbocharger. Oil enters the filter through a cast manifold and, after passing through the filter, returns to the upper idler gear stubshaft and into the turbocharger. The filter element is of pleated paper construction, and is disposable. The filter is mounted on the camshaft drive housing at the right bank of the engine.

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The filter head contains two check valves, Fig. 9-18. one to prevent lube oil from the soak back system from going into the turbocharger filter during soak back pump operation and the other to prevent lube oil from the turbocharger filter from entering the soak back system when the engine is running.

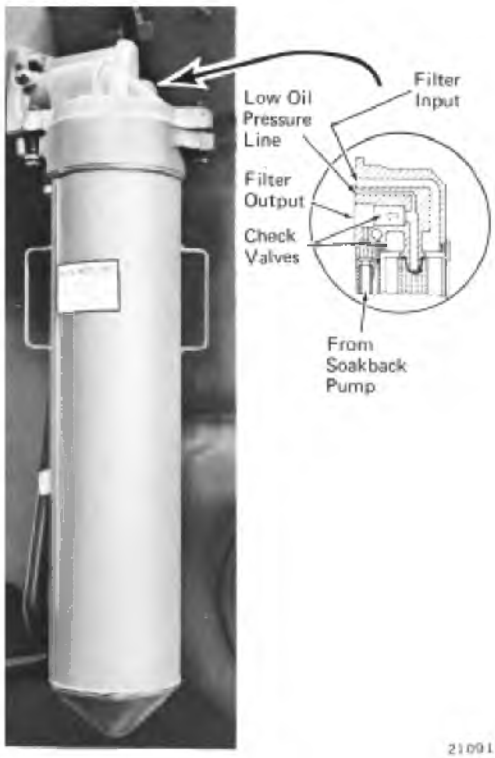

Fig. 9-18 - Turbocharger Oil Filter

MAINTENANCE

The turbocharger filter should be serviced at intervals as specified in the Scheduled Maintenance Program or more frequently if experience indicates it is necessary.

To remove turbocharger filter assembly, loosen the two nuts holding the container to the upper housing until. using the handles on each side of the container, the container can be rotated to disengage from the upper housing. Remove the paper element and dispose of it. Thoroughly clean the container, install a new element, check the seal and replace, it' required. Fill the container with clean oil and reassemble to the upper housing. Do not overtighten attaching bolts as the seal may be damaged.

NOTE: Whenever oil is detected coming from the camshaft bearings with the engine shut down and the soak back pump running. the turbo filter outlet check valve should be inspected.

SOAK BACK OIL SYSTEM

DESCRIPTION

To ensure lubrication of the turbocharger bearings prior to engine start. and the removal of residual heat from the turbo after engine shutdown, a separate lube oil pressure source is provided. This pressure source is controlled automatically through the engine "start" and "stop" controls.

An electrically driven pump drawing lube oil from the oil pan, pumps the oil through a soak back filter, Fig. 9-19, and the head of the turbocharger oil filter directly into the turbocharger bearing area, Fig. 9-1. The motor driven pump and filter are mounted on the side of the oil pan, Fig. 9-19.

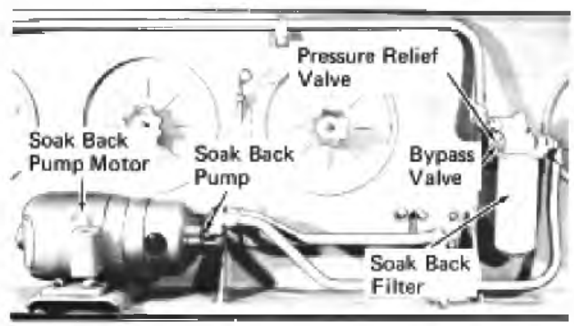

Fig. 9-19 - Soak Back Oil Motor, Pump, And Filter Installation

CAUTION: If the soak back pump should fail to operate when the engine is shut down. restart the engine <u>immediatelv</u> and allow it to run for 15 minutes at idle speed with no load, to prevent damage to the turbocharger.

If engine is not restarted <u>within two minutes</u> of shutdown, do not restart the engine until soak back pump operation is restored and the engine has been allowed to cool down.

A pressure relief valve, Fig. 9-19, set at 379 kPa (55 psi), is located in the head of the filter. When the engine starts, and the motor driven pump is still running, main lube oil pressure from the engine driven pump becomes greater than the motor driven pump pressure. As there is no outlet for the lower pressure oil. the relief valve will open when the

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pressure builds up to 379 kPa (55 psi), and the oil will return to the oil pan through a passage in the filter head mounting flange. Also located in the filter head is a bypass valve, Fig. 9-19, set at 483 kPa (70 psi). This valve will open to permit motor driven pump pressure to bypass a plugged filter element so that lubrication can be supplied to the turbocharger to prevent turbo damage.

MAINTENANCE

The oil filter element should be serviced at the intervals as specified in the applicable Scheduled Maintenance Program, or more frequently if experience indicates it is necessary.

To remove the element from the filter, Fig. 9-19, remove the two bolts from the top of the head and remove the bowl, element and spring from the upper housing.

PRELUBRICATION OF ENGINES

Prelubrication of a new engine, an engine that has been overhauled, or an engine which has been inoperative for more than 48 hours is a necessary and important practice. Prelubrication alleviates loading of unlubricated engine parts during the interval when the lube oil pump is filling the passages with oil. It also offers protection by giving visual evidence that oil distribution in the engine is satisfactory.
Perform prelubrication as follows:

1. Remove the pipe plug at the main lube oil pump discharge elbow, and connect an external source of clean, warm oil at the discharge elbow. Prelube engine at a minimum of 69 kPa (10 psi) for a period of not less than three and not more than five minutes (approximately 57 lpm [15 gpm] using a 1.1 to 1.5 kW [1-1/2 to 2 hp] motor).

2. While oil pressure is being applied, open the cylinder test valves and bar the engine over one complete revolution. Check all bearings at the crankshaft, camshafts, rocker arms, and at the rear gear train for oil flow. Also check for restrictions and excessive oil flow. If fluid discharge is observed from any cylinder test valve, find the cause and make the necessary repairs.

3. On new or overhauled engines remove the pipe plug at the piston cooling oil pump discharge elbow and connect the external oil source at that opening. Check for unrestricted oil flow at each piston cooling tube.
4. Disconnect the external oil source and replace the pipe plugs at the pump discharge elbows. Close the cylinder test valves.

5. Pour a liberal quantity of oil over the cylinder mechanism of each bank.

6. Check oil level in strainer housing and, if required, add oil to strainer housing until it overflows into the oil pan.

7. Replace and securely close all handhole covers and engine top deck covers.

NOTE: When an engine is replaced due to mechanical breakdown, it is important that the entire oil system, such as oil coolers, filters, and strainers, be thoroughly cleaned before a replacement engine or the reconditioned engine is put in service. A recurrence of trouble may be experienced in the clean engine, if other system components have been neglected.

In some cases engines have been removed from service and stored in the "as is" condition by draining the oil and applying anti-rust compound. When these engines are returned to service, care must be taken to see that any loose deposits are flushed out before adding a new oil charge. The entire engine should be sprayed with fuel, to break up any sludge deposits, and then drained, being careful that the drains are not plugged. Fuel should not be sprayed directly on the valve mechanism or bearings, as lubrication will be removed or dirt forced into these areas. The surfaces should then be wiped dry before new oil is added to the engine.

OIL SYSTEM INFORMATION

Additional information on the oil system and components is given in the latest revisions of Maintenance Instruction bulletins. These instructions cover important items such as the Scheduled Maintenance Program, which outlines maintenance intervals, and flushing and cleaning information.

Engine lubricating oil should be qualified for use.

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SERVICE DATA
LUBRICATING OIL SYSTEM

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Lube Oil Pressure Relief Valve

Valve guide inside diameter - Max.	12.764 mm (.5025")
Valve stem outside diameter - Min.	12.484 mm (.4915")
Valve face to stem squareness (outer edge of valve face) - T.I.R. Max.	0.05 mm (.002")

Oil Pumps

Drive shaft to rear housing bushing clearance -	
New	0.038-0.114 mm (.0015"-.0045")
Max.	0.18 mm (.007")
Sleeve to bushing clearance -	
New	0.038-0.127 mm (.0015"-.0050")
Max.	0.18 mm (.007")
Idler shaft to gear bushing clearance -	
New	0.038-0.130 mm (.0015"-.0051")
Max.	0.18 mm (.007")
Driven gears - total thrust clearance -	
New	0.41-0.61 mm (.016"-.024")
Max.	0.61 mm (.024")
Thrust face of bushing to body clearance (front and rear) -	
New	0.02-0.18 mm (.001 "-.007")
Min.	0.000 mm (.000")
Drive and driven gear backlash -	
New	0.30-0.41 mm (.012"-.016")
Max.	0.76 mm (.030")
Radial clearance of drive and driven gear to body -	
Min.	0.038 mm (.0015")
Max.	0.25 mm (.010")
*Drive shaft thrust clearance (pump assembled)	0.20-0.56 mm (.008"-.022")
**Drive shaft thrust clearance (pump assembled)	0.13-0.56 mm (.005"-.022")
Pump drive gear face runout - T.I.R. Limit	0.08 mm (.003")
Pump flange face runout - T.I.R. Limit	0.13 mm (.005")
Pump flange pilot concentricity - T.I.R. Limit	0.05 mm (.002")

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Pump drive gear to accessory drive gear backlash

New . . . . 0.20-0.41 mm (.008"-.016")

Max. . . . . 0.64 mm (.025")

NOTE: *Scavenging pump only

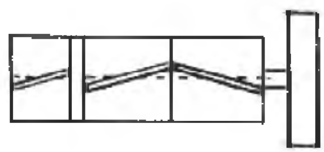
**Lube and piston cooling pump only

Pump/motor assembly

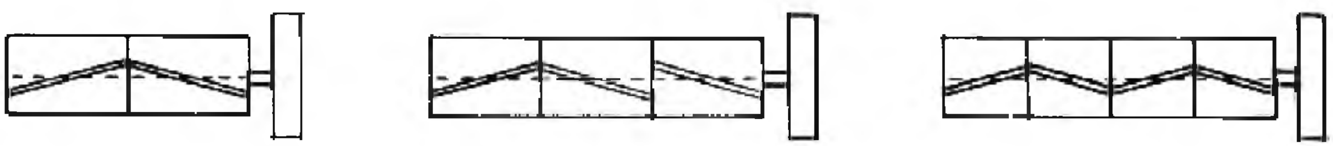
Parallel coupling alignment - Max. . . . . 0.38 mm (.015")

Axial clearance between jaw and spider - Min. 0.76 mm (.030')

HELIX ANGLE POSITION OF OIL PUMP GEARS



MAIN LUBE OIL AND PISTON COOLING PUMPS



SCAVENGING OIL PUMPS

EQUIPMENT LIST

	Part No.
Gauge - piston cooling oil pipe alignment	8071720
Cleaner - piston cooling oil pipe	8087086
Spray gun	8193041
Cleaner activator (170 grams [6 oz]).	8352873
Retaining compound (50 cc)	8366781

Mich. Oil Filter should be changed with 25 psi or above.

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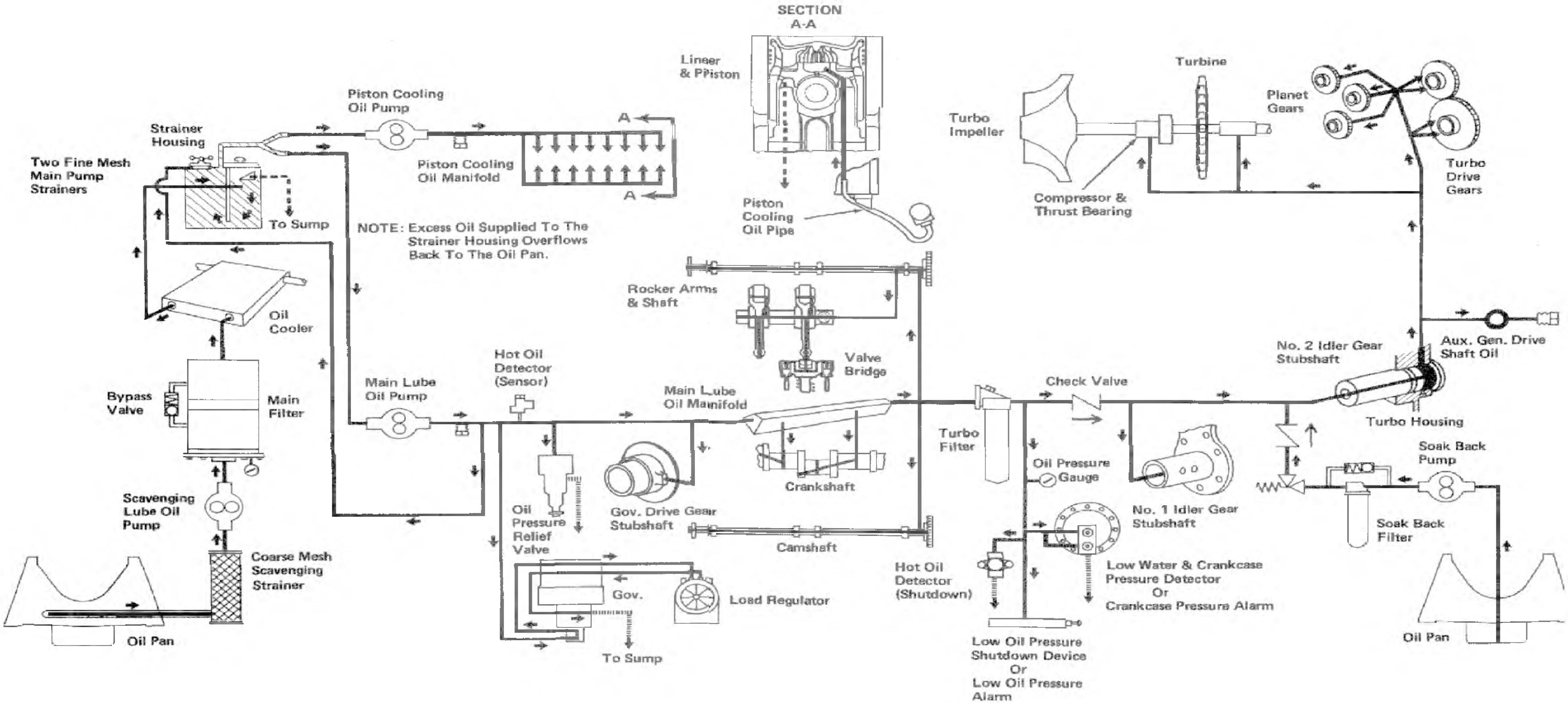
LUBE OIL SYSTEM —— TURBOCHARGED ENGINES



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SECTION 10

COOLING SYSTEM

CONTENTS	PAGE
WATER TEMPERATURE	10-1
COOLANT SOLUTION	10-2
PIPING	
DESCRIPTION	10-2
INSTALLATION	10-2
WATER LEAKS	10-3
AFTERCOOLER	
DESCRIPTION	10-3
REMOVAL	10-4
CLEANING	10-4
CORE REPLACEMENT	10-4
INSTALLATION	10-5
WATER PUMPS	
DESCRIPTION	10-5
REMOVAL	10-7
HOUSING, DRIVE GEAR, SHAFT AND BEARING ASSEMBLY, AND IMPELLER REMOVAL	10-7
SEAL REMOVAL AND APPLICATION	10-8
BEARING REMOVAL	10-8
SHAFT, BEARING, AND DRIVE GEAR ASSEMBLY	10-9
IMPELLER INSTALLATION	10-9
IMPELLER HOUSING INSTALLATION	10-9
PUMP INSTALLATION	10-10
SERVICE DATA	
SPECIFICATIONS	10-11
EQUIPMENT LIST	10-11

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

SECTION
10

COOLING SYSTEM

DESCRIPTION

The engine cooling system consists of engine driven centrifugal water pumps, replaceable inlet water manifolds with an individual jumper line to each liner, cylinder head discharge elbows, and an outlet manifold through which cooling water is circulated. The two centrifugal water pumps (one on 8-cyl.) are mounted on the accessory drive housing and are driven by the governor drive gear. A representative illustration of the engine cooling system is shown in Fig. 10-1.

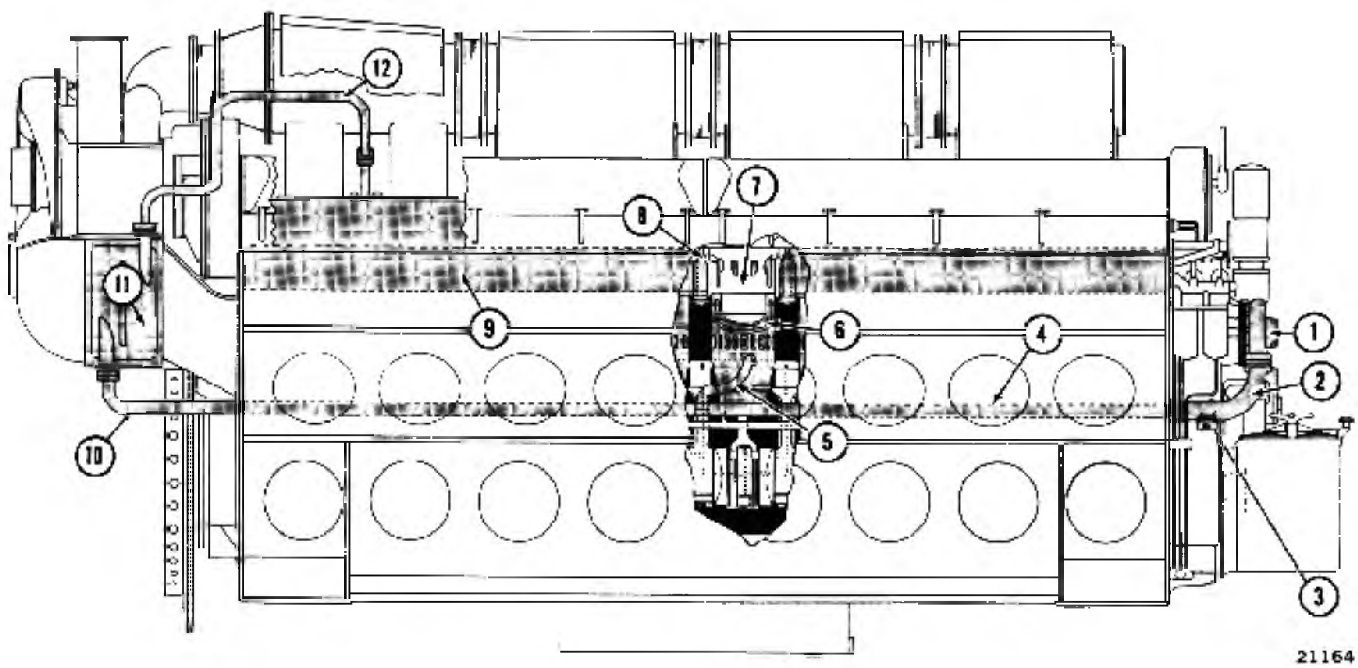
Engine water is also circulated through each aftercooler, Fig. 10-1, located in the turbocharger air discharge duct, to cool the air before it enters the engine air box.
The engine discharge water flows through an external cooling system to dispel the heat taken up in the engine. This system consists of a water tank, water level gauges, temperature gauges, radiators, and connecting piping.

MAINTENANCE

ENGINE WATER TEMPERATURE

Temperature gauges are provided in the cooling system to visually check that the engine water temperature is within the recommended limits. Automatic temperature controls are set to maintain the water temperature within set limits.

CAUTION: It is desirable that engine coolant temperature be 49° C (120° F) or higher before full load is applied to the engine. After idling at low ambient temperature, increase to full load level should be made gradually.



1. Water Pump
2. Water Inlet Elbow
3. System Drain Flange
4. Water Inlet Manifold
5. Water Inlet Tube
6. Liner Water Passage
7. Cylinder Head
8. Cylinder Head Outlet Elbow
9. Water Discharge Manifold
10. Water Line To Aftercoolers
11. Right Bank Aftercooler
12. Aftercooler Water Discharge

Fig. 10-1 - Typical Cooling System Schematic

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A hot engine alarm indicates excessively high water discharge temperature. Hot engine water could result from faulty water cooling equipment or excessive loss of cooling water. In the event of a hot engine alarm, engine load should be reduced in an attempt to obtain normal temperature. Before resuming operation, the cause of the hot engine water should be found and the condition corrected.

ENGINE COOLANT SOLUTION

Coolant solutions are composed of water, corrosion inhibitor and, if necessary, antifreeze. The selection and maintenance of a proper coolant solution are necessary for efficient cooling system operation. Failure to recognize the importance of these factors can result in cooling system damage, increased maintenance costs, and unnecessary equipment down time.

Coolant samples should be taken from the cooling system for analysis at intervals as specified in the Scheduled Maintenance Program.

COOLING SYSTEM PIPING

DESCRIPTION

Refer to Fig. 10-2 for piping details. Pump outlet elbows conduct water from the pumps to the removable water inlet manifolds located in each air box. Each manifold is connected at the rear end plate to an aftercooler water inlet pipe. The rear end flange of the manifold is equipped with two seals, which prevent the leakage of air from the air box. A flange at the front end of the manifold contacts the outer face of the front end plate when the manifold is installed.

Each liner is individually supplied with coolant from the water manifold through a water inlet tube assembly. A deflector is used at each liner water inlet to divert the water and prevent direct impingement on the inner liner wall. Water enters the cylinder head through 12 discharge holes at the top of the liner. A counterbore around each hole accommodates a heat dam and a water seal. A water discharge elbow is bolted to each cylinder head to provide a water passage to the water discharge manifold which extends along the top of the crankcase. The crankcase has two "built-in" siphon tubes inside the water discharge manifold. One is located at the second cylinder from the rear end on the right bank, and the other at the second cylinder from the front end on the left bank. When engine water is drained, this will provide for engine cooling water draining in the event the engine is not level.

MAINTENANCE

PIPING INSTALLATION

After the cylinder head and liner are properly installed in the engine, the water inlet manifold and liner water inlet tube may be applied.

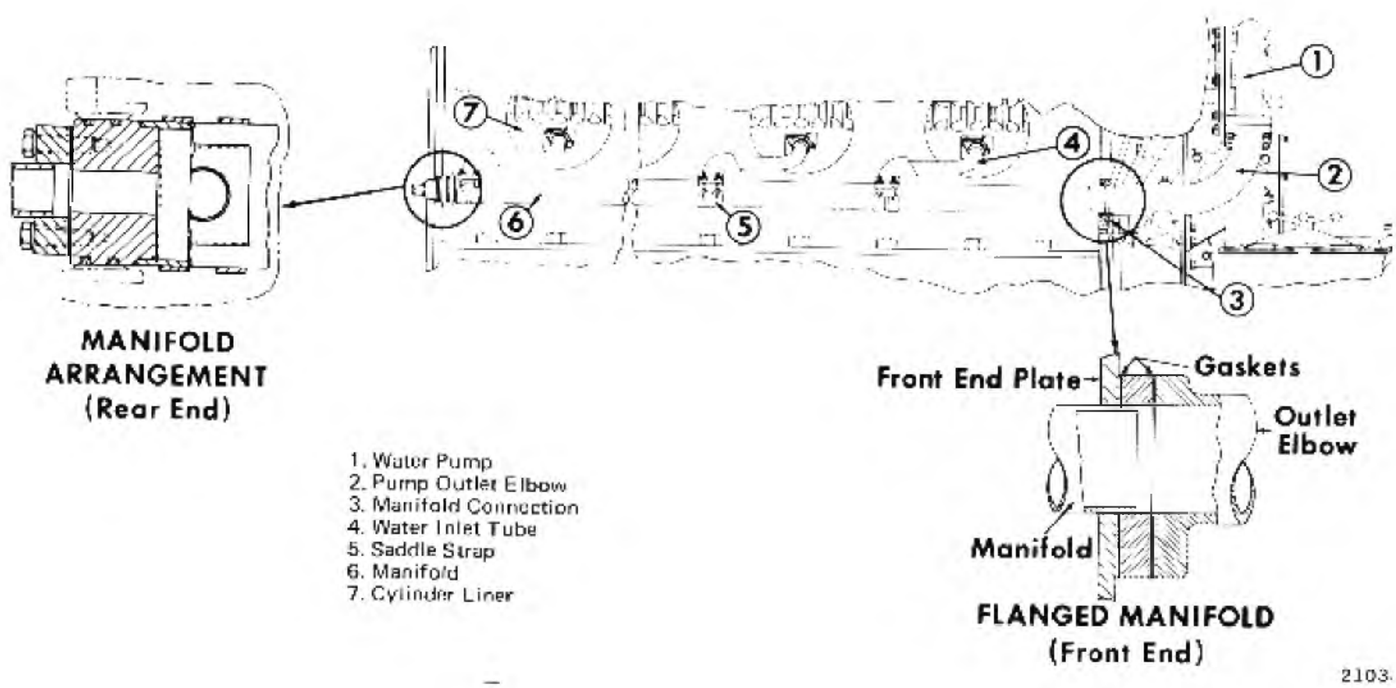

Fig. 10-2 - Cooling System Piping

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1. Inspect the water manifold for any dirt or roughness in the area of the discharge holes and at the front end plate flange.

2. Place the manifold flange gasket over the manifold and insert the manifold into the air box.

3. Carefully guide the end of the water manifold into the rear end plate so that seals are not damaged. When positioned correctly, the manifold should be firmly supported at the end.

4. Apply and tighten the manifold flange to front end plate bolts. Temporary bolts may be used if the water pump discharge elbow is not ready to be applied.

5. Place a new seal in the groove at the liner end of the water inlet tube.

6. Position saddle straps around the water manifold, and through the inlet tube flange.

7. After the strap nuts have been applied and tightened finger tight, check that the seal is seated in the groove, position the tube on the liner, and finger tighten the bolts.

8. Take a new gasket and shape it to fit around the water manifold. Insert the gasket between the tube flange and manifold making sure the sides of the gasket are flush with the sides of the flange, and that the ends of the gasket are within the clamping radius of the flange.

9. Torque the strap nuts to 20 N-m (15 ft-lbs). 10. Prior to torquing the tube to liner bolts, remove the bolts and washers from the flange. If the tube moves, it must be repositioned on the water manifold; if no movement is detected, the tube to liner bolts and washers may be re-applied and torqued to 41 N-m (30 ft-lbs).

11. After all liner water inlet tubes are properly applied, the manifold will be securely held and the temporary bolts, if applied, should be removed and the water pump discharge elbow connected.

WATER LEAKS

If loss of water in the cooling system is noticed, check for leakage at piping, pump seals, jumper tube connections, cylinder head discharge elbow, junction of head to liner, and check for liner or cylinder head cracks.

Unless very obvious, the location of a crack in the cylinder head or liner is very difficult to find, and requires careful examination. Any indication of a water leak in the head or liner requires removal and thorough inspection. Inspect cylinder interior through liner ports. Water may leak and enter the lube oil at the cylinder head discharge elbow seals. These seals can be replaced without disturbing the cylinder head, provided a crab nut and crab are removed and the water is drained. Water contamination of lubricating oil will necessitate draining the oil. Before the oil is renewed, the system should be flushed.

Lube oil contamination is best determined by laboratory analysis, but in the absence of such means, the following method of checking for water in the oil may be used.

Draw or dip a gallon of lube oil from the bottom of the engine lube oil sump. Let it stand for about 10 minutes, then spill about 3/4 of the oil from the container. Place the remaining 1/4 in a glass bottle and allow sample to stand another 10 minutes. If any water is indicated in the bottom of the bottle, it is recommended that the lube oil system be drained and flushed. Replace with new oil after source of contamination is eliminated.

AFTERCOOLER

DESCRIPTION

An aftercooler is located on each side of the turbocharger to cool the air entering each bank of the engine. Cooling the air compressed in the turbocharger reduces the temperature of the air, which increases air density and improves engine operating efficiency.

The aftercoolers are heat exchangers of box-like construction consisting of a tube nest, through which water is circulated, and fins to aid in the transfer of heat from the compressed air entering the engine air box. The aftercoolers receive water directly from the discharge side of the engine water pumps, and the water leaving the aftercoolers is piped to the engine discharge manifold. No valves are located in the aftercooler piping, so cooling water is provided whenever the engine is running.

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MAINTENANCE

With the engine shut down, an interior inspection of the engine end of the aftercooler air duct will usually detect any sign of core leakage. Evidence of leakage will necessitate removal of the aftercooler.

A check for aftercooler plugging may be made by removing two mounting bolts (5th from top) across the aftercooler core and applying hoses from a water manometer at the bolt holes (with engine shut down or at idle speed).

CAUTION: Do not remove hoses with engine at high speed. Do not apply or remove hoses singly.

With engine at full speed, with or without load, the maximum allowable depression across the aftercooler is listed in the Service Data.

The aftercooler should also be removed and cleaned at intervals as specified in the Scheduled Maintenance Program.

REMOVAL

1. After draining the engine water, disconnect the water discharge or vent line flange at the top of the aftercooler.
2. Loosen the water inlet line at the bottom of the aftercooler.
3. Remove the mounting bolts securing the aftercooler to the air duct, both at the front and at the back, and free the assembly. Jacking screws in the aftercooler flange will break the joint between the air duct and aftercooler.
4. When the aftercooler is sufficiently free, apply an aftercooler lifting tool, Fig. 10-3, and using a suitable hoist, remove the entire assembly from the air duct.

CLEANING

CAUTION: Do not use a caustic cleaner, as aluminum core fins will be damaged. Cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

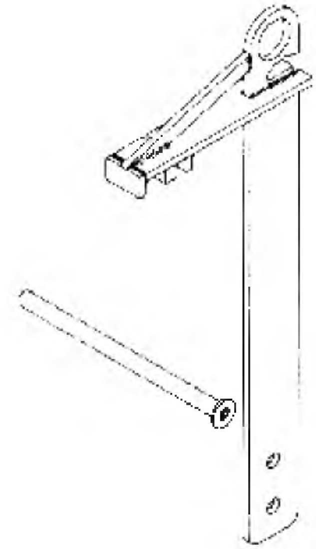

Fig. 10-3 - Aftercooler Lifting Tool

CORE REPLACEMENT

In the event that an aftercooler is removed due to a leaking core, the core may be replaced using the following procedure.

1. Gaskets used in the aftercooler assembly should be prepared in advance of assembly by being soaked in ASTM (American Society For Testing Materials) No. 3 oil for 15 minutes at a temperature of 71° C. (160° F.). After soaking, the gaskets should be removed and permitted to drain before using.
2. Place the core on the work bench and apply the cover gasket and cover.
3. Apply the cover bolts and tighten to 47 N-m (35 ft-lbs). Tighten from the center bolt out to the end bolts.
4. Invert the assembly and apply the header to core gasket and header.
5. Apply the header to core bolts and tighten from the center bolt out to the end bolts. Tighten the bolts to 47 N-m (35 ft-lbs).
6. After the assembly has been completed, blank off all flanges except one, and apply an air test arrangement on the remaining flange.
7. With 345 kPa (50 psi) air pressure in the water passage of the core, submerge the assembly in water and check for leaks.
8. After water test, recheck the torque of the header and cover bolts to 47 N-m (35 ft-lbs).

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INSTALLATION

1. Check the air duct and aftercooler mounting surfaces to make certain that there are no nicks, dirt or roughness on these areas.

2. Apply the support pad to the back plate dowels of the aftercooler, Fig. 10-4, with the gasket in position at the outside so as to contact the air duct.

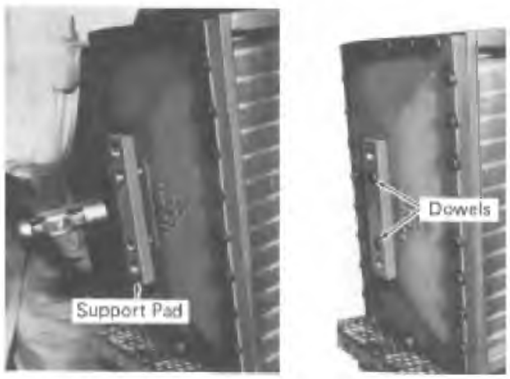

Fig. 10-4 - Support Pad To Dowel Installation

3. Apply the aftercooler to air duct gasket over two guide dowels, and using the aftercooler lifting tool and hoist, install the aftercooler in the air duct.

4. Line up the support pad bolt holes, Fig. 10-5, at the back of the air duct and apply, but do not tighten the support pad bolts.

5. Correctly position the aftercooler flange over the air duct gasket and flange holes, apply and tighten the bolts holding the aftercooler to the air duct.

6. When the aftercooler flange bolts have been tightened, tighten the support pad bolts at the back of the air duct, Fig. 10-5, to 176 N-m (130 ft-lbs) and lockwire.

WATER PUMPS

DESCRIPTION

The two engine cooling water pumps (one on 8-cyl. engines), Fig. 10-6, are self-oiling and selfdraining centrifugal pumps, which rotate in the opposite direction of the engine crankshaft. The components of the water pump are identified in Fig. 10-7.

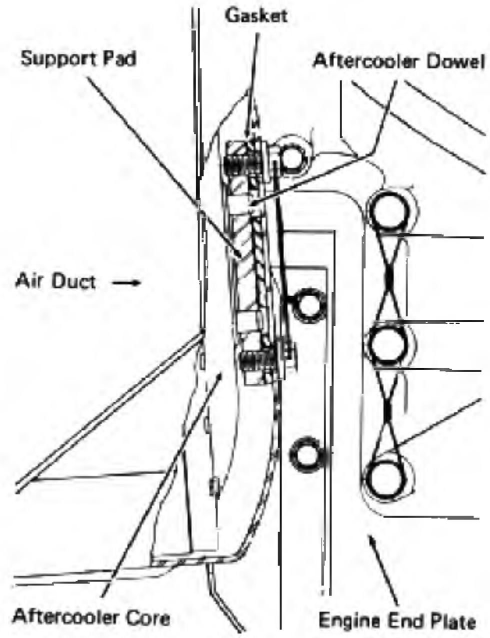

Fig. 10-5 - Air Duct Support Pad Application

Fig. 10-6 - Water Pump Installation

The pumps are carried under two part numbers to identify the right and left bank pumps. The only difference between right and left bank pumps is the position of the impeller housing in relation to the pump shaft housing. The position of the impeller housing may be changed on either pump to permit use on the opposite bank.

The pump drive shaft is supported in the main pump housing by two ball bearings separated by a steel spacer. The bearings receive lubricating oil from the engine oil system through a drilled passage in the pump housing. The outer bearing adjoins a water slinger which bears against a shoulder on the staft.

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The inner bearing is held in place by a retainer and snap ring to absorb any thrust in the shaft. The pump drive gear is keyed to the pump shaft abutting the inner bearing, and is held on the shaft by a washer and nut.

The stationary bushing, Fig. 10-7, is applied to the drive shaft housing. The carbon of the seal assembly, Fig. 10-8, faces against the smooth inner surface and is held by a spring. Any water leakage past the seal is indicated at a tell-tale drain in the drive shaft housing, which permits runoff, and prevents water from reaching the engine side of the pump.

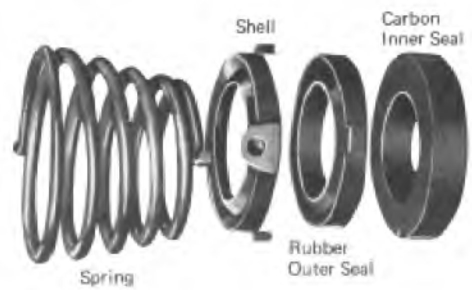
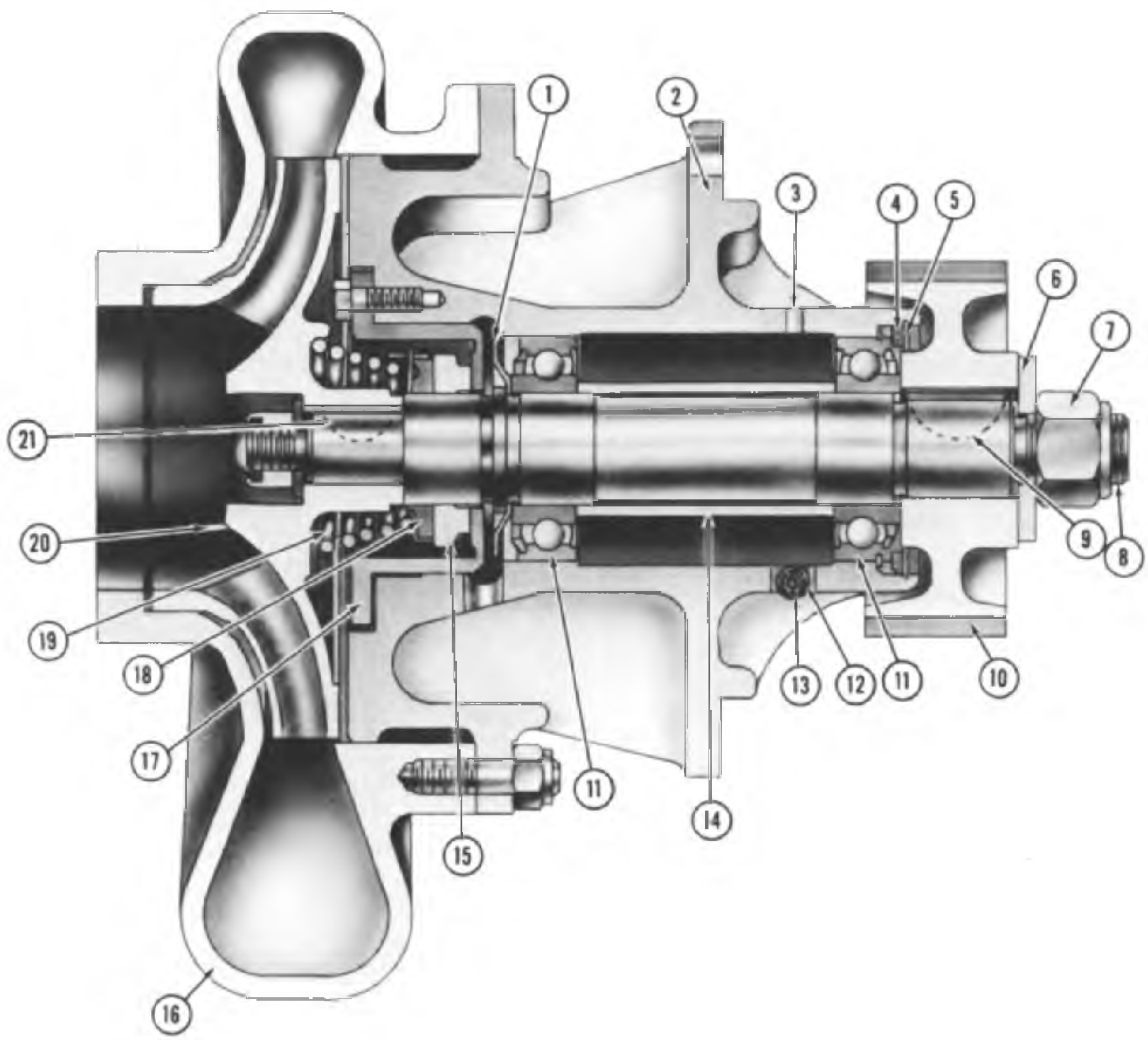


Fig. 10-8 - Spring And Seal Assembly



1. Water Slinger
2. Support Housing
3. Oil Inlet
4. Bearing Retainer Ring
5. Snap Ring
6. Gear Retainer Washer
7. Gear Retaining Nut
8. Water Pump Shaft
9. Drive Gear Key
10. Drive Gear
11. Bearing Assembly
12. Oil Outlet
13. Roll Pin And Spring
14. Bearing Spacer
15. Carbon Seal
16. Impeller Housing
17. Stationary Bushing
18. Outer Seal
19. Seal Retainer Spring
20. Impeller
21. Impeller Retainer Key

Fig. 10-7 - Water Pump, Cross-Section

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The impeller is keyed to the pump shaft and is secured to the shaft by a washer and nut. It is enclosed by the impeller housing, which is assembled to the main pump housing by eight studs and nuts.

MAINTENANCE

PUMP REMOVAL

1. Drain cooling system.
2. Remove water pump inlet connection.
3. Disconnect pump discharge flange connection.
4. Remove mounting bolts and pump from engine.

HOUSING, DRIVE GEAR, SHAFT AND BEARING ASSEMBLY, AND IMPELLER REMOVAL

1. Remove nuts securing impeller housing to pump support housing.
2. Assembly threaded pressure plate, Fig. 10-9, to hydraulic ram head.
3. Place socket end of ram adapter over nut securing impeller to shaft so adapter bottoms out on impeller.
4. Secure pressure plate to impeller housing with four 1 /2-13x l 1/2" hex head bolts. Ensure that ram head is aligned with machined end of adapter.
5. Operate hydraulic ram until impeller housing separates from pump support housing.

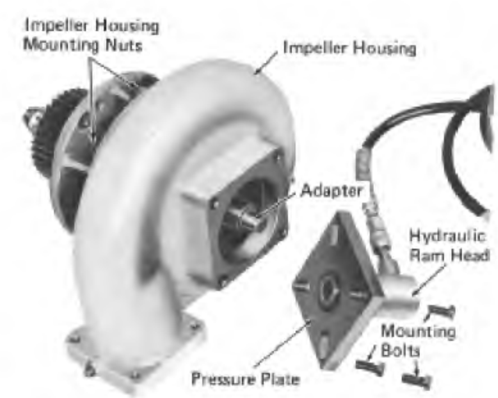

Fig. 10-9 - Impeller Housing Removal

6. Place mounting flange of pump in a vise having jaw protectors.
7. Remove drive gear nut and washer.
8. Using a block of wood to prevent impeller movement, remove the impeller nut and washer.
9. Apply impeller gear puller, Fig. 10-10, and remove pump drive gear and key.
10. Remove snap ring and bearing retainer ring. Fig. 10-7.
11. Place the extension tip of the impeller puller over shaft threads at impeller end of pump. 12. Apply impeller puller with legs placed behind support housing flange, Fig. 10-11.

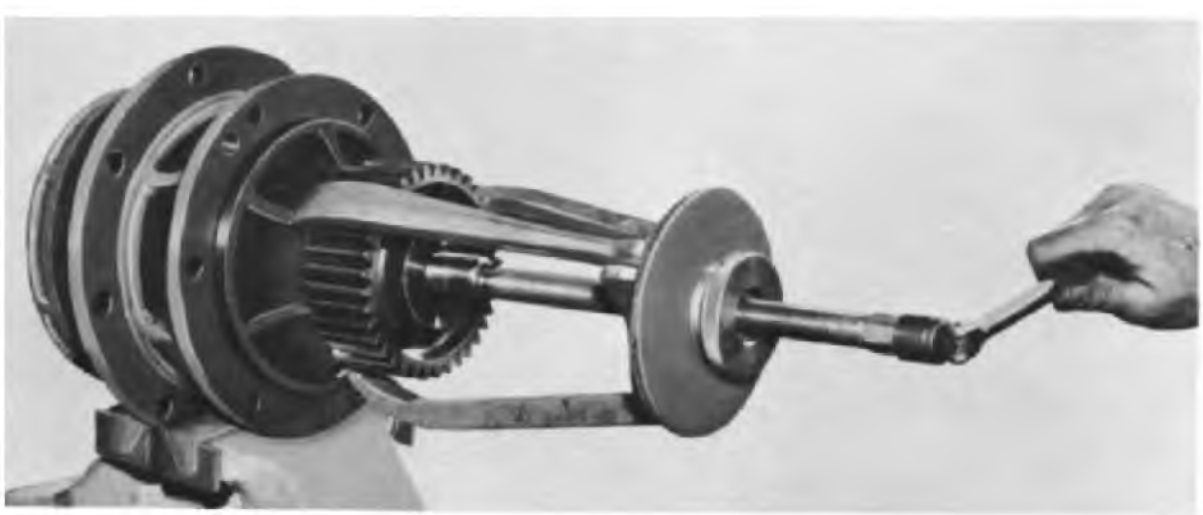

Fig. 10-10 - Drive Gear Removal

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Fig. 10-11 - Impeller Removal

13. Apply wrench to the nut part of the tool and turn until shaft and bearing assembly is free of pump housing. Remove impeller.

REMOVAL AND APPLICATION OF PUMP SEALS
SEAL REMOVAL

1. After impeller removal. remove spring and seal assembly, Fig. 10-7. Use care to prevent damage to the stationary bushing seal surface.

2. Remove the bolts from the stationary bushing in the event the bushing is not easily removed, insert 3/8" x 2" bolts in the puller holes provided in the bushing and force the bushing out from the housing. Sometimes the bushing may be loosened by tapping on the bushing flange with a rawhide mallet, allowing removal without using puller bolts.

SEAL APPLICATION

1. Clean the stationary bushing and pump shaft.

CAUTION: The sealing surface of the stationary bushing must be absolutely smooth and flat to prevent wear of the carbon washer. A stationary bushing having a rough surface must be replaced with a new bushing.

2. Before applying the stationary bushing, be sure the bushing and mounting surfaces are clean. Foreign material can cause the bushing to cock and interfere with effective sealing. Also, be sure that the smooth flat carbon seal surface of the bushing is clean and dry. Apply new stationary bushing gasket and bushing.

   Tighten the bolts evenly and torque to 11.3 N-m (100 in-Ibs).

   After applying the stationary bushing. check runout of' the carbon seal surface using an indicator mounted on the end of the pump shaft. If runout limit is exceeded, reposition bushing 180° and/or scrape off mounting surface in area of' high reading.

3. Install the new seal assembly. Fig. 10-8. Apply carbon inner seal with the narrow end contacting the stationary bushing. Check carbon face for cleanliness. Apply rubber outer seal to shell, and apply to carbon seal so cars of shell fit into the slots in the carbon seal. One end of the drive spring fits into the shell while the other end must be fitted into a slot at the bottom of the impeller when it is assembled.

BEARING REMOVAL

1. Place shaft and bearing assembly in arbor press and remove bearings. Bearing at impeller end may have remained in housing when shaft was removed.

2. Clean and inspect parts for defects and replace damaged parts.

   Bearings with seals or shields on both sides should be wiped clean but not washed. Inspect bearings for excessive end play, roughness, seizing. galled. worn or abraded surfaces. broken or bent seals or shields. and fractured outer races.

   Pump shaft seal contact surfaces must be smooth.

   See Service Data at end of section for wear limits.

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SHAFT, BEARING, AND DRIVE GEAR ASSEMBLY

1. Assemble water slinger, outer bearing, spacer, and inner bearing to the pump shaft, making sure that the rear bearing with the retainer ring is positioned correctly with the retainer ring to the outside. These parts are assembled, Fig. 10-7, first with the slinger next to the shoulder on the shaft, concave side toward the impeller end, followed by the outer bearing (without retainer), spacer and inner bearing, abutting each other snugly. The seal sides of the bearings go toward the outer ends of the assembly, being distinguished by the seal side of the bearing protruding slightly beyond the outer race.

2. Place the drive shaft housing in a vise with jaw protectors.

3. Clean dirt and oil from support housing outboard bore and outer race of outboard bearing, and apply a thin coating of silicone rubber sealing compound to housing outboard bore.

4. Insert the shaft and bearing assembly, slinger end first, from the drive gear end of the housing. Using a rawhide mallet, lightly tap the assembly until it aligns with and enters the first bearing bore and continue tapping the assembly until it is properly seated in the housing.

5. Apply the bearing retainer and snap ring back of the rear bearing.

6. Place key in shaft and assemble drive gear to shaft, using a rawhide mallet. Check shaft key and keyway fit. Check that pump shaft diameter to gear bore fit is within the maximum limit. Inspect gear nut insert for any signs of disintegration. Nuts may be reused if fiber collar drag is 10.4 N-m (92 in-lbs). Gear nut W'44) torque is 359 N-m (265 ft-lbs).

7. Replace seal assembly as previously described.

INSTALLING IMPELLER

1. Fig. 10-12 shows the impeller installer being used to assemble the impeller to the drive shaft housing. The threaded bushing is screwed on pump shaft threads and then by turning outer portion of installer tool, the impeller is pressed into position. Care must be taken to start the impeller straight on the

Fig. 10-12 - Installing Pump Impeller

shaft and to see that the key and keyway are aligned. Before the impeller is brought all the way down, check the underside to see that the seal spring is in the spring slot under the impeller and then finish the impeller application.

2. Check the insert in the impeller shaft nut to see that it is free from tears and disintegration. Nuts may be reused if the fiber drag is 3.6 N·m (32 in-lbs). Apply the impeller retaining washer and nut. Torque value of the impeller nut is 108 N-m (80 ft-lbs).

INSTALLING IMPELLER HOUSING

1. Check that drilled drain passage is free of obstruction.

2. Determine whether the pump is to be used on the right or left bank of the engine since the impeller housing is positioned differently in each case.

3. An arrow is cast at the bottom of the pump shaft housing and the impeller housing has a letter "R" and "L". For a right bank pump, assemble the impeller housing so that "R" is opposite the arrow on the shaft housing or for a left bank pump, the "L" is opposite the arrow, as shown in Fig. 10-13.

4. Install housing in the correct position, using new gasket between the impeller and shaft housing. Apply housing nuts to studs and tighten to 88 N-m (65 ft-lbs).

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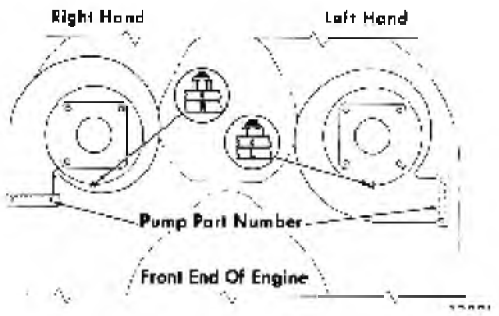

Fig. 10-13 - Pump Housing Positioning

INSTALLING PUMP

1. The pumps are installed in the position shown in Fig. 10-13 for the right and left bank. Torque value for the pump to accessory cover mounting bolts is 88 N-m (65 ft-lbs).

2. The part number of the pump is located on a plate attached to the pump discharge flange, as shown in Fig. 10-13.

   It should also be noted on pump installation, that the water inlet elbow is the proper one as listed in the parts book for the engine installation.

3. When installing a water pump, care should be taken with the application of the water inlet connection. This connection consists of a sleeve, synthetic rubber seals, seal retainers, and bolted clamps.

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SERVICE DATA
COOLING SYSTEM

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Pump drive gear backlash -		
New		0.20-0.41 mm (.008"-.016")
Max.		0.76 mm (.030")
Bearing bores in support housing may be oversize or bearing outer diameter undersize. The limits governing the fit are:	Interference - Max.	0.002 mm (.0001")
	Clearance - Max.	0.051 mm (.0020")
Pump shaft bearing mounting diameters to bearing bores. No wear allowed. The limits governing the fit are:	Interference - Max.	0.023 mm (.0009')
	Clearance - Max.	0.002 mm (.0001 ")
Pump shaft drive gear mounting diameter to gear bore. The limits governing the fit are:	Interference - Max.	0.013 mm (.0005')
	Clearance - Max.	0.02 mm (.001")
Pump shaft impeller mounting diameter to impeller bore. The limits governing the fit are:	Interference - Max.	0.064 mm (.0025")
	Interference - Min.	0.013 mm (.0005")
Stationary bushing seal seat squareness with drive shaft - T.I.R. Max.		0.025 mm (.001")
Maximum depression allowed across aftercooler core (engine at full speed)		254 mm (10") H_2O

EQUIPMENT LIST

	Part No.
Impeller installer	8052959
Hydraulic jack (10 ton)	8263531
Water pump impeller puller	8354367
Silicone rubber sealing compound (5 oz)	8453256
Adapter	9312770
Pressure plate	9312771
Aftercooler lifting tool	File 690

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SECTION 11

FUEL SYSTEM

CONTENTS — PAGE

CONTENTS	PAGE
DESCRIPTION	11-1
FUEL INJECTORS	
DESCRIPTION	11-2
INSTALLATION	11-4
TIMING INJECTOR	11-4
STICKING INJECTORS	11-4
SERVICING	11-4
INJECTOR TEST STAND	11-5
SETTING UP TEST STAND	11-5
CHECKING AND OPERATING TEST STAND	11-5
TEST PREPARATION	11-6
HOLDING PRESSURE AND LEAK TEST	11-6
RACK FREENESS TEST	11-6
BINDING PLUNGER TEST	11-6
REPLACING FILTERS	11-7
STORAGE	11-7
INJECTOR LINKAGE	
DESCRIPTION	11-7
CHECKING AND SETTING RACKS	11-7
FUEL FILTER	
DESCRIPTION	11-9
MAINTENANCE	11-9
SERVICE DATA	
SPECIFICATIONS	11-11
EQUIPMENT LIST	11-11

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ENGINE MAINTENANCE MANUAL

SECTION 11

ELECTRO-MOTIVE

FUEL SYSTEM

DESCRIPTION

The engine fuel system, Fig. 11-1, consists of the fuel injector, the engine mounted fuel filter, and fuel supply and return manifolds.

Components external to the engine such as the motor driven fuel pump, fuel tank, fuel suction strainer, and connecting lines complete the fuel system.
In operation, fuel from the fuel tank is drawn up by the fuel pump through a suction strainer and is delivered to the engine mounted filter. It then passes through the filter elements to the fuel manifold supply line and injector inlet filter at each cylinder into the injector. A small portion of this fuel supplied to each injector is pumped into the cylinder, at a very high pressure, through the needle valve and spray tip of the injector.

The quantity of fuel injected depends upon the rotative position of the plunger as set by the injector rack and governor. The excess fuel not used by the injector, flows through the injector, serving to lubricate and cool the working parts.

The fuel leaves the injector through the return fuel filter. This filter protects the injector in the event of a backward flow of fuel into the injector from the return fuel line. From the return fuel filter in the injector, the excess fuel passes through the fuel return line in the manifold to the relief valve inlet of the "return fuel" sight glass on the engine mounted fuel filter. This valve restricts the return fuel, maintaining a back pressure on the injectors. The fuel continues into the "return fuel" sight glass, filling the glass, down through the standpipe under the glass and through the return line to the fuel supply tank

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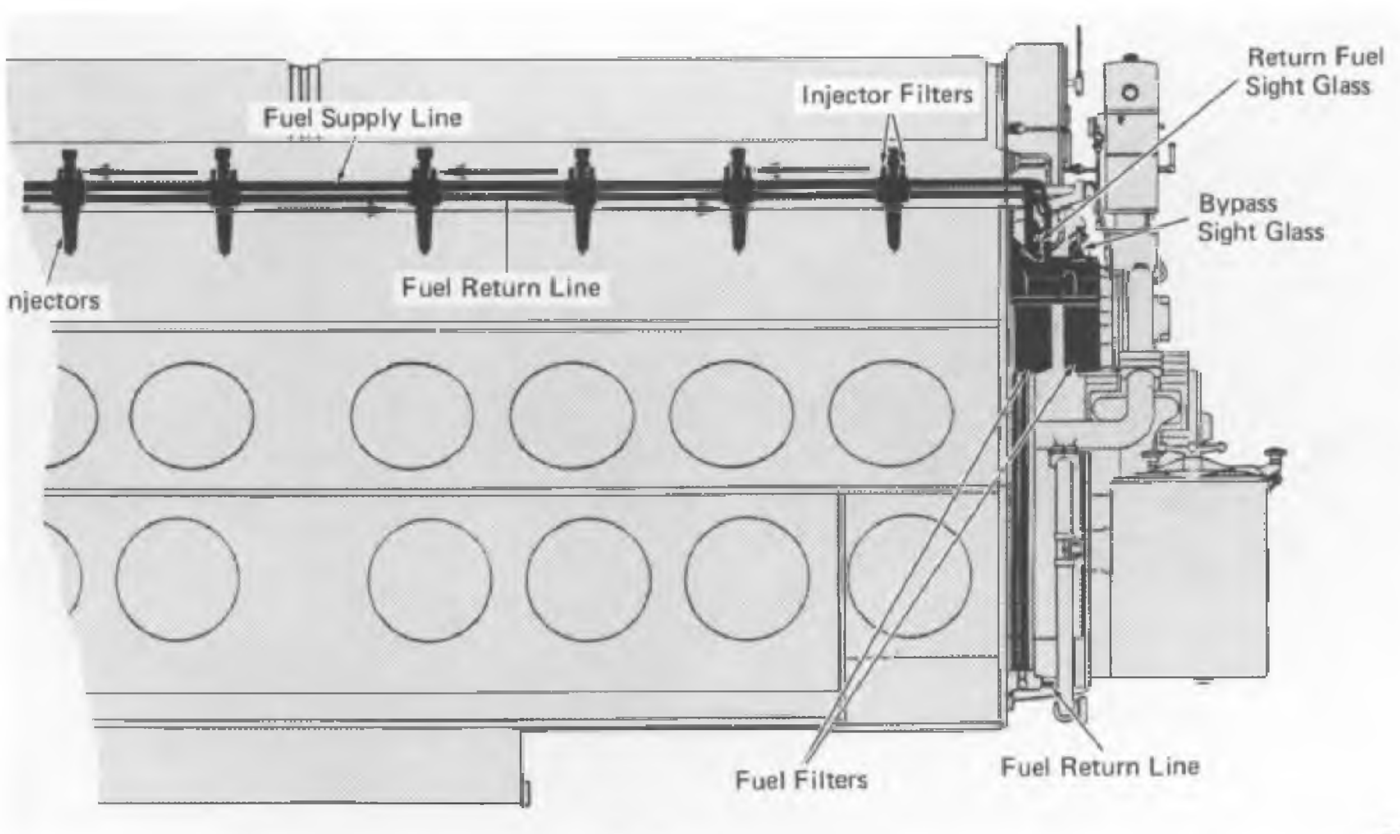

Fig. 11-1 - Typical Fuel System

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FUEL INJECTORS

DESCRIPTION

An injector, Fig. 11-2, is located and seated in a tapered hole in the center of each cylinder head, with the spray tip protruding slightly below the bottom of the head. It is positioned in the head by a dowel and held in place by an injector crab and nut.

The external working parts of the injector are lubricated by oil from the end of the injector rocker arm adjusting screw. The internal working parts are lubricated and cooled by the flow of fuel oil through the injector.

A cross-section of the unit injector and names of the various parts are shown in Fig. 11-3.

Fig. 11-2 - Fuel Injector

The plunger is given a constant stroke reciprocating motion by the injector cam acting through the rocker arm and plunger follower. The timing of the injection period during the plunger stroke is set by an adjusting screw at the end of the rocker arm. Fig. 11-4 shows flow of fuel through the injector during one downward stroke. Rotation of the plunger, by means of the rack and gear, controls the quantity of fuel injected into the cylinder during each stroke. Rack position is controlled by the governor through the injector control lever and linkage. The gear is keyed to and is a sliding fit on the plunger to allow plunger vertical movement.

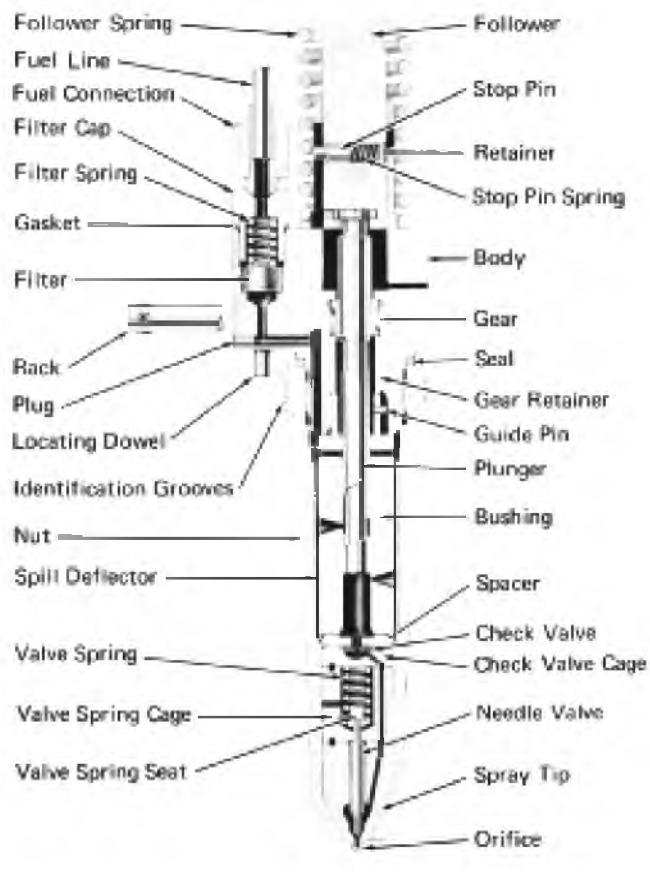

Fig. 11-3 - Fuel Injector, Cross-Section

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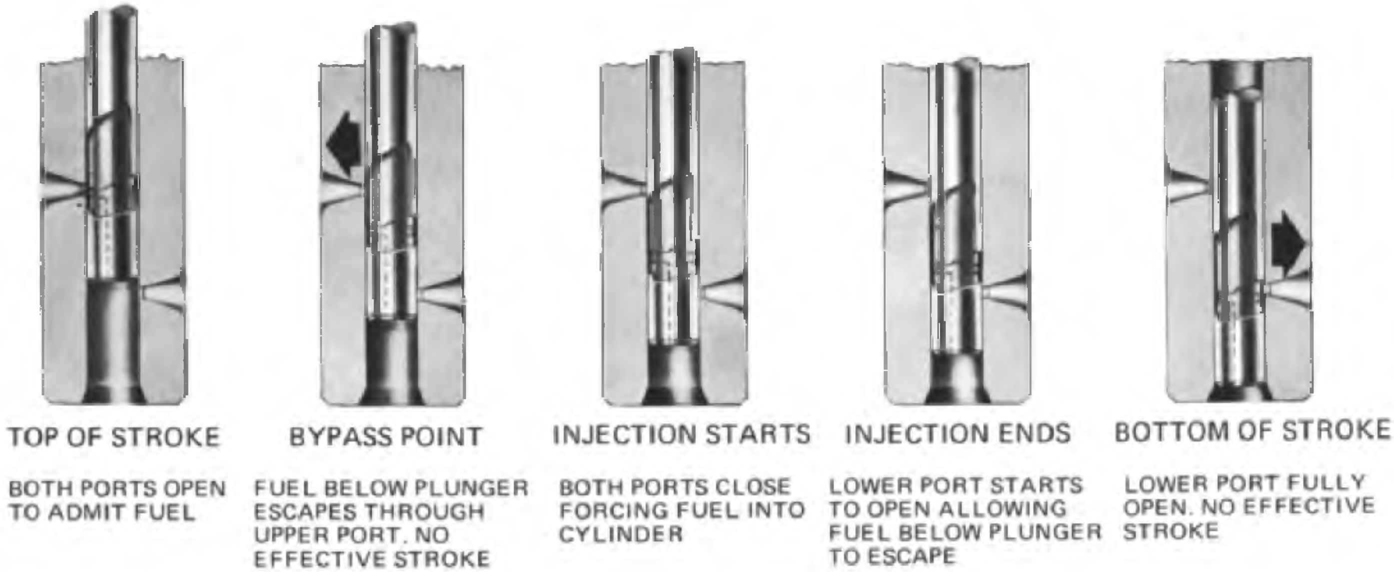


ONE COMPLETE DOWN STROKE OF PLUNGER AT "HALF LOAD" POSITION

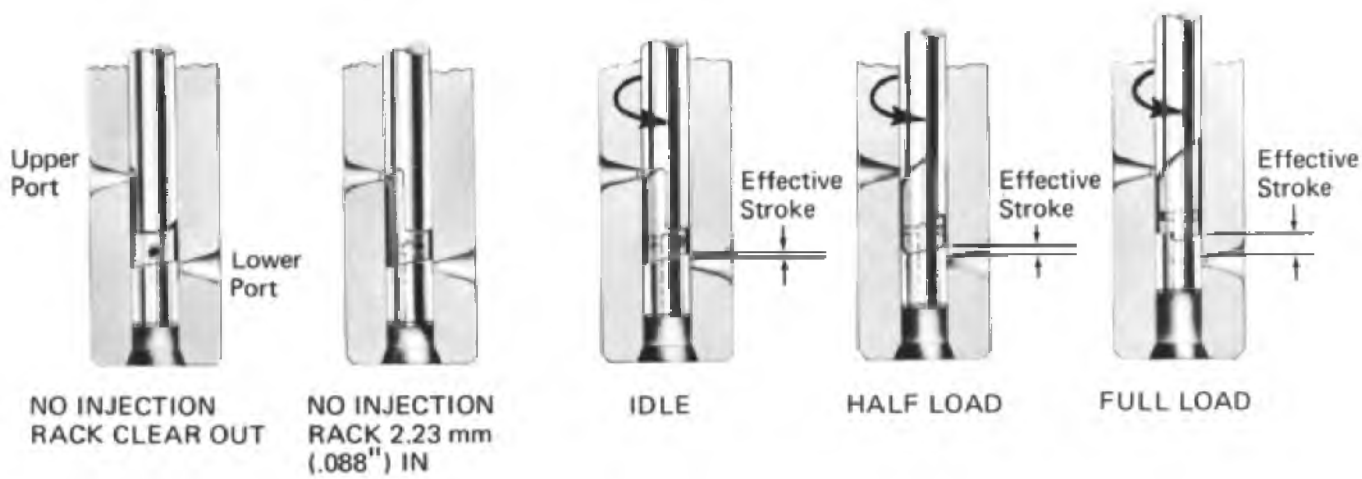
Fig. 11-4 -- Injector Fuel Flow

The helices near the bottom of the plunger control the opening and closing of both fuel ports of the plunger bushing. Rotation of the plunger regulates the time that both ports are closed during the downward stroke, thus controlling the quantity of fuel injected into the cylinder, as shown in Fig. 11-5. As the plunger is rotated from idling position to full load position, the pumping part of the stroke is lengthened, injection is started earlier, and more fuel is injected.

Proper atomization of the fuel is accomplished by the high pressure created during the downward stroke of the plunger, which forces fuel past the needle valve and out through the spray holes in the tip of the injector.

The injectors have an adjustable calibrating slide mounted on the side of the injector body, adjacent to the rack. This slide is incorporated solely as a means of adjusting injector output on the calibrating stand.

Filters at the fuel inlet and outlet connections protect the working parts of the injector.



QUANTITY OF FUEL INJECTED IS CONTROLLED BY ROTATING PLUNGER WITH RACK

Fig. 11-5 -Plunger Fuel Control

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MAINTENANCE

INSTALLATION

1. When installing an injector in an engine, make sure it is the correct injector for the engine in which it is to be applied.
2. See that injector body and tapered hole in cylinder head are clean.
3. Install injector and apply injector crab, spherical washer, and nut. Torque nut to 68 N·m (50 ft-lbs).
4. Connect injector rack to lever assembly.
5. Install and tighten fuel supply and return lines to injector and engine fuel manifold.
6. Install rocker arm shaft and rocker arms. Loosen injector rocker arm locknut and back off on adjusting screw before tightening rocker arm shaft nuts. Injector is now ready for timing.

TIMING THE INJECTOR

With the injector installed, make timing adjustment as follows:

NOTE: Injector cannot be timed if the overspeed has been tripped. It must first be reset and the engine crankshaft barred over at least one revolution.

1. Set the flywheel at 0° top dead center of the cylinder being timed.
2. Insert injector timing gauge into the hole provided for it in the injector body, Fig. 11-6.
3. Loosen locknut and turn the rocker arm adjusting screw until the shoulder of the gauge just passes over the injector follower guide.
4. Tighten adjusting screw locknut while holding adjusting screw in position with screwdriver.
5. Recheck setting.

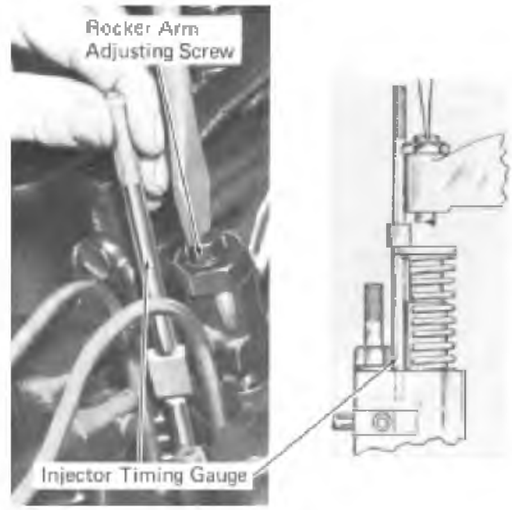

Fig. 11-6-Timing Injector

STICKING INJECTORS

Engines may encounter sticking injectors due to fuel, lube oil, or filter maintenance conditions. Since these conditions very often are momentary, injector removal may be minimized by utilizing alcohol to free up injectors while installed. This is done by applying. ordinary commercial methanol to the injectors through a hole opposite the timing tool hole, and "popping" the injectors or motoring the engine. This sticking condition usually occurs on injectors which are held with the plungers down when the engine is stopped. Should injector racks show signs of sticking, they should be checked for gum or varnish deposits. If present, the rack should be cleaned with alcohol and rechecked. If sticking persists, the injectors should be removed and replaced with operational injectors. In no case should injectors be it crutched out" or cut out and the engine operated. If injectors operating unsatisfactorily cannot be remedied or replaced, the engine should be shut down until corrective action has been taken.

SERVICING INJECTORS

When servicing injectors, clean working conditions must be maintained. Dust or dirt in any form is a frequent cause of injector failure. When an injector is in an engine it is protected against dirt, dust, and other foreign materials by the various filters employed. When an injector is in storage, it is protected against harmful material by the filters sealing the body openings, which are in turn protected by shipping blocks.

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However, an entirely different set of conditions is encountered when it becomes necessary to disassemble an injector for repair or overhaul. These conditions necessitate special shops, equipment. and trained personnel. It is recommended that non-operational injectors be returned to Electro-Motive for rebuild or unit exchange.

INJECTOR TEST STAND

In order to ensure efficient engine performance, injectors should be tested whenever removed from an engine, regardless of the reason for removal. It is advisable to test the complete engine set during each annual inspection. It is recommended that injectors be tested with the same oil used for protection against rust as given under "Storing Injectors."

It is important that the individual doing the testing understands the basic principles of injector operation and testing procedures in order to prevent acceptance of defective injectors and rejection of good ones. Instructions in the use of the injector test stand and an outline of each separate test procedure along with a basic explanation of operation follows:

These instructions cover the testing of all needle valve injectors using the test stand shown in Fig. 11-7. The procedures are not applicable to other types of testing equipment, since injector leak-off rates vary greatly in proportion to the volume of fuel contained in the high pressure portion of the test stand.

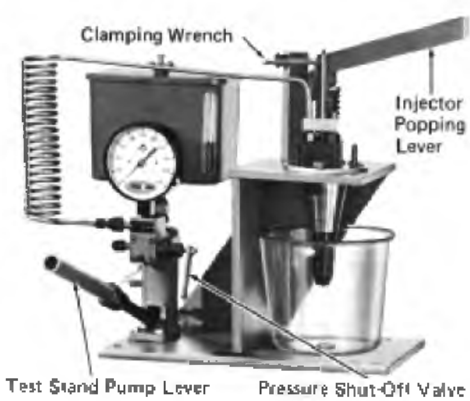

Fig. 11-7 - Injector Test Stand

SETTING UP TEST STAND

Basically, the stand consists of a fuel reservoir, filter, high pressure pump, pressure gauge, and necessary connecting lines and fittings to supply fuel to the injector under test. The test stand should be set up as instructed by the manufacturer. Inspect carefully for dirt or foreign material in the tank and lines. Fill the tank with clean fuel and operate the pump to purge all free air from the system.

Investigation has shown that the viscosity of the fuel oil used in the test stand has a marked effect on the test results obtained. Regular fuel oil may be used provided the viscosity is not less than 32 S.S.U. at 38° C (100° F). Do not reuse fuel oil which has been pumped through the injectors into the plastic bowl.

CHECKING TEST STAND

Install the test block in place of an injector in the stand and pump up pressure to 13 790 kPa (2000 psi), as indicated by the gauge. After five minutes, the pressure should not have dropped below 13 618 kPa (1975 psi). Release the block and recheck at 3448 kPa (500 psi) and 6895 kPa (1000 psi). These pressures should hold one minute with no apparent gauge drop. Make these tests with the pressure shutoff valve, Fig. 11-7, open all the way. If the tests are satisfactory, all injector tests may be made without using the shutoff valve. If the preceding tests indicate leakage in the stand, repeat the tests, closing the shutoff valve before timing the leakoff rates. If the tests are satisfactory with the shutoff valve closed, it will be necessary to use the shutoff valve when making the injector holding pressure test.

When placing a new test stand in operation, or after removing and replacing the gauge, fuel tank, filter, or pump, for any reason, the test block should be installed and pressure raised to 17 237 kPa (2500 psi) and vented at least six times before making an operational check.

TEST STAND OPERATION

The operator must consider the test stand as an instrument, rather than a tool. Every effort should be made to make the manual operation of repeated tests the same. The following general information is provided to help in obtaining uniform operation:

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GENERAL INFORMATION

1. When operating the pump, use a rate of 40 strokes per minute. This provides a fuel rate to operate the check valve smoothly and to circulate fuel within the injector.

2. When using the popping lever, do not use such force as to damage either the injector or the lever. Do not permit the lever to fly up freely.

3. In making holding tests, do not pump the stand above 17 238 kPa (2500 psi).

4. Test stands regularly in use should be checked daily for leaks, using the test blocks.

5. Fuel oil used for testing should not be reused.

INJECTOR TESTS

PREPARATION

1. Install the injector in the test stand.

2. Fill the injector with fuel oil, but do not connect the fuel line from pump to injector at this time.

3. Set the injector rack at maximum fuel output position (minimum rack length).

4. "Pop" the injector with the popping lever, Fig. 11-7, using approximately 40 smooth even strokes per minute. A finely atomized spray should show at each of the holes in the tip. Rapid closing of the needle valve should produce a sharp "chatter."

   If the valve opens without producing a finely atomized spray or the valve seats without producing a sharp "chatter," make several rapid strokes with the lever to dislodge any foreign material on the valve seat. If the needle valve still fails to function properly, a stuck needle, dirt on the valve seat, or a defective valve seat may be the cause.

HOLDING PRESSURE AND LEAK TEST

1. All injectors lose pressure due to leakage at any of several points, but this leakage must be controlled during injector manufacture to prevent engine lube oil dilution. The holding pressure test will qualify injectors having specified leakoff rates, providing this leakage is at the proper point and is satisfactorily controlled.

2. Manually hold the test stand fuel line block on the injector. Pump until fuel is discharged from filter cap on opposite side, to remove air. Apply 12 411 kPa (1800 psi) to 13 790 kPa (2000 psi) pressure to the injector. No leakage is permitted at the nut to body seal, filter cap gasket, body plugs, or between spray tip and injector nut.

3. Injectors should be qualified on the pressure holding test by timing the interval for a drop in pressure from 13 790 kPa (2000 psi) to 10 342 kPa (1500 psi). If this interval is less than 20 seconds (used) or 30 seconds (new or reconditioned), repeat the test, but close the pressure shutoff valve on the test stand immediately after establishing the 13 790 kPa (2000 psi) pressure. This is to ensure that the leakdown time is not being affected by the possible leakage in the test stand itself. If the timed interval for the pressure drop from 13 790 kPa (2000 psi) to 10 342 kPa (1500 psi) is still less than 20 seconds (used) or 30 seconds (new or reconditioned), the injector should be rejected. To relieve the pressure before removing the injector from the test stand, wrap a cloth around the injector fuel line connections and back off on the clamping wrench, Fig. 11-7.

RACK FREENESS TEST

1. The rack engages with a small pinion on the injector plunger and serves to rotate the plunger with respect to two ports in the injector bushing, which regulates the amount of fuel injected with each stroke of the plunger. Binding of the rack is generally caused by damaged gear teeth, scored plunger and bushing, or galling of rack itself. A binding rack may cause sluggish or erratic speed changes and overspeed trip action.

2. To be considered satisfactory, the rack must fall in and out through full travel by its own weight when injector is held horizontally and rotated about its axis.

BINDING PLUNGER TEST

1. Failure of the injector plunger to move up and down freely indicates scoring of the plunger and bushing or

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weak or broken spring. A binding plunger will cause erratic cylinder firing and, in extreme cases, overspeed trip action.

2. Place injector in test stand but do not attach the fuel line. Place rack in the full fuel position and pump all the fuel out of the injector with injector popping lever, Fig. 11-7. When all of the fuel has been removed, depress the injector plunger to full extent of its travel. Slowly release popping lever and simultaneously move injector rack repeatedly in and out through its full travel.

REPLACING INJECTOR FILTERS

Injector filters should not be disturbed or removed except during injector reconditioning (when all parts are completely washed), or in the event of fuel stoppage to the injector.

STORING INJECTORS

When injectors are not to be used for a considerable length of time, they should be protected against rust by using a stable, noncorrosive straight-run petroleum distillate in the kerosene volatility range. It is also recommended that injectors be tested using this oil. If this is done, treatment will be taken care of at time of injector test.

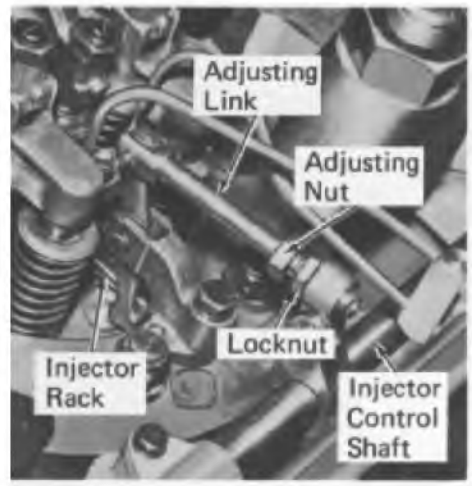
After treatment, the injectors should be stored in a protective container until needed. This container should accommodate an injector holding rack similar to that shown in Fig. 11-8.

Fig. 11-8 - Injector Holding Rack

INJECTOR LINKAGE

DESCRIPTION

The injector linkage, Fig. 11-9, consists of the mechanical arrangement between the governor and the injector permitting all injector rack positions to be changed simultaneously when the governor terminal shaft is rotated. Two injector control rods connect the lever on the governor terminal shaft to the injector control shafts. The injector control shafts, one for each bank, extend the length of the cylinder banks under the cylinder head cover frames. At each cylinder location, a lever is pinned to the control shaft. An adjusting link connects the control shaft lever to an injector control lever mounted on the cylinder head, one end of which straddles the ball at the end of the injector rack.



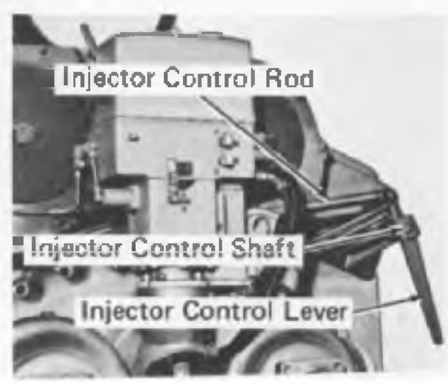


Fig. 11-9 - Injector Linkage

MAINTENANCE

Before attempting to set injector racks, all racks and linkage should be checked for binding, sticking, or wear which would affect operation.

SETTING INJECTOR RACKS

Injector racks should be set with the engine at operating temperature. If racks are set when engine

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is not at operating temperature, the settings should be rechecked when operating temperature is reached. As engine temperature increases, the right bank rack length shortens and the left bank rack length increases. The change on the left bank is insignificant, but the change on right bank may shorten the racks beyond the minus 0.40 mm (1/64") tolerance.

NOTE: Every time a governor is installed on an engine the injector rack setting should be checked. Due to manufacturing tolerances in governor mounting bolt holes, the position of the governor in relation to the injector linkage can change the rack setting.

Set the injector rack on the engine as follows:

1. Install the injector linkage setting jack, Fig. 11-10.

Fig. 1 I-10 - Injector Rack Positioning

2. Adjust the setting jack until the pointer on the governor aligns with governor terminal shaft scale at the 1.00" mark.

3. Use the injector rack gauge, Fig. 11-11, to set the racks within the setting range marks on the gauge.

   The rack setting gauge is an 8 to 1 multiplying gauge which indicates the 0.40 mm (1/64") tolerance by marks 3.18 mm (1/8") each side of the center mark on the gauge scale.

   It is important that the proper rack gauge be used, as previous model rack gauges will measure the rack length from the body of the injector instead of from the face of the calibrating slide. The correct gauge for setting injectors with calibrating slides can be readily identified by a single locating button on the front face of the gauge. This gauge can be used for all injectors.

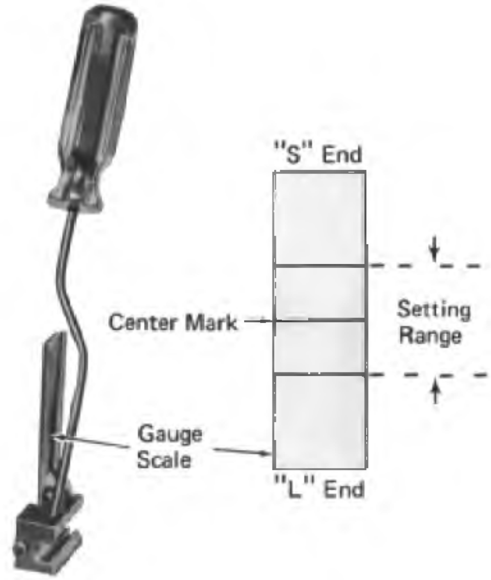

Fig. 11-11 - Injector Rack Gauge

4. Place the gauge over the injector rack and hold the gauge firmly against the face of calibrating slide on the injector, Fig. 11-12, and check the gauge pointer. If the pointer is at the short ("S") end of gauge scale, outside of the setting range, the rack is not extending out far enough from the injector. Loosen the locknut on the adjusting link, Fig. 11-9, and turn adjusting nut on link until pointer is at the long ("L") end of the scale; then reverse pointer travel until it is within the scale setting range. Hold the adjusting nut and tighten locknut. The reason for exceeding the setting range when making adjustment is so that, in setting all the racks, the backlash will be taken up in the same direction.

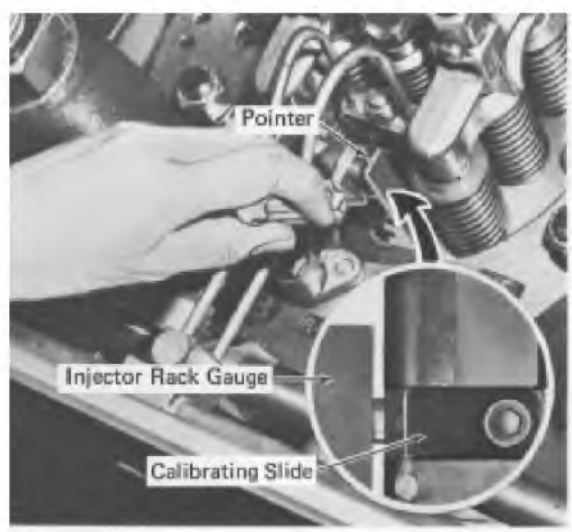

Fig. 11-12 - Injector Rack Gauge Application

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5. When pointer is at the long ("L") end of scale, set pointer within the setting range. The accuracy of the injector rack gauge can be checked by inserting the master block in the gauge body. Pointer should align with center mark on scale.

FUEL FILTER

DESCRIPTION

The engine mounted fuel filter, Fig. 11-13, is located at the right front of the engine. Two sight glasses are provided on top of the filter housing to provide a visual indication of the condition of the fuel system. The flow diagram, Fig. 11-14, indicates fuel flow through the filter.

Fig. 11-13 - Fuel Filter

Fuel returning from the injectors passes through the "return fuel" sight glass nearer the engine and returns to the fuel tank. Under normal operation this glass is full of fuel. A 69 kPa (10 psi) relief valve at the inlet to the "return fuel" sight glass establishes a fuel back pressure at the injectors for improved operation.

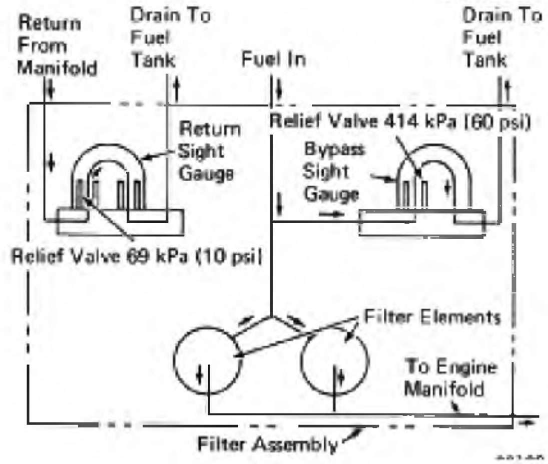

Fig. 1 1-14 - Fuel Flow Through Filter

Air or gas in the fuel system will appear in the 'return fuel" sight glass as bubbles. Air entering the fuel at any place in the suction line may cause the engine to misfire or stop. Bubbles in the "return fuel" sight glass with the fuel pump running and the engine stopped, indicates air entering the suction side of the fuel pump. If bubbles appear only when the engine is running, it indicates leaky valves in the fuel injectors, allowing combustion gases to get into the fuel. Little or no fuel in the "return fuel" sight glass, with the "bypass" sight glass empty, indicates insufficient fuel supply to the engine.

Under normal operation the "bypass" sight glass farther from the engine should be empty of fuel. As the elements of the filter become dirty, the fuel pressure in the filter will increase. When fuel pressure in the element housing is approximately 414 kPa (60 psi), the relief valve under the glass will open, fuel will enter and fill the "bypass" sight glass, and then return to the fuel tank, starving the engine.

The disposable filter elements are mounted directly to the filter body. The element consists of pleated paper around a perforated metal tube. The case is an enameled steel shell capable of withstanding internal pressures in excess of 1 034 kPa (150 psi). A neoprene gasket attached to the top of each element ensures sealing.

MAINTENANCE

The filter elements should be removed and new ones installed at intervals specified in the Scheduled Maintenance Program.

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At the time of element replacement, the filter body and sight glasses should be cleaned.

1. Shut down the engine and the engine fuel supply.

2. Unscrew the elements, using a strap wrench if necessary, and discard them.

3. Apply a firm of oil to the gasket of a new element and apply element to filter body.

4. Hand tighten until the gasket contacts the filter body, then tighten 1/2 turn.

5. Check the condition of the sight glasses, and clean.

6. Check for leaks when the engine is started.

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SERVICE DATA
FUEL SYSTEM

EQUIPMENT LIST

	Part No.
Injector timing gauge	8034638
Injector prybar	8041183
Plastic spray cup (extra - used with Injector Test Stand)	8171780
Oil (injector test, storage, and rust prevention - 50 gal. drum)	8203258
Injector rack gauge	8339610
Injector holding rack	8431626
Injector linkage setting jack	8432485
Injector test stand (complete)	8478027

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SECTION 12

GOVERNOR

CONTENTS PAGE

PGR GOVERNOR
DESCRIPTION 12-1
OPERATION 12-3
MAINTENANCE
GOVERNOR REMOVAL 12-4
GOVERNOR INSTALLATION 12-4
GOVERNOR COMPENSATION 12-5
ENGINE SPEED CONTROL 12-5
ENGINE SHUTDOWN 12-8
AIR PRESSURE SENSOR ASSEMBLY 12-9
FUEL LIMITER 12-11
SETTING REBALANCER ROCKER ARM STOP SCREW 12-12
LOAD REGULATOR PILOT VALVE AND ASSOCIATED LINKAGE 12-12
OVERRIDING SOLENOID 12-14
LOW OIL PRESSURE SHUTDOWN 12-15
OIL FILTER 12-17
FLUSHING GOVERNOR 12-17
GOVERNOR OIL SUPPLY 12-18
GOVERNOR STORAGE 12-18
GOVERNOR DRIVE ASSEMBLY 12-18
SERVICE DATA
SETTING AND ADJUSTMENT TABLES 12-19
SPECIFICATIONS 12-20
EQUIPMENT LIST 12-20
MATERIAL SPECIFICATIONS 12-20

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ENGINE MAINTENANCE MANUAL

SECTION 12

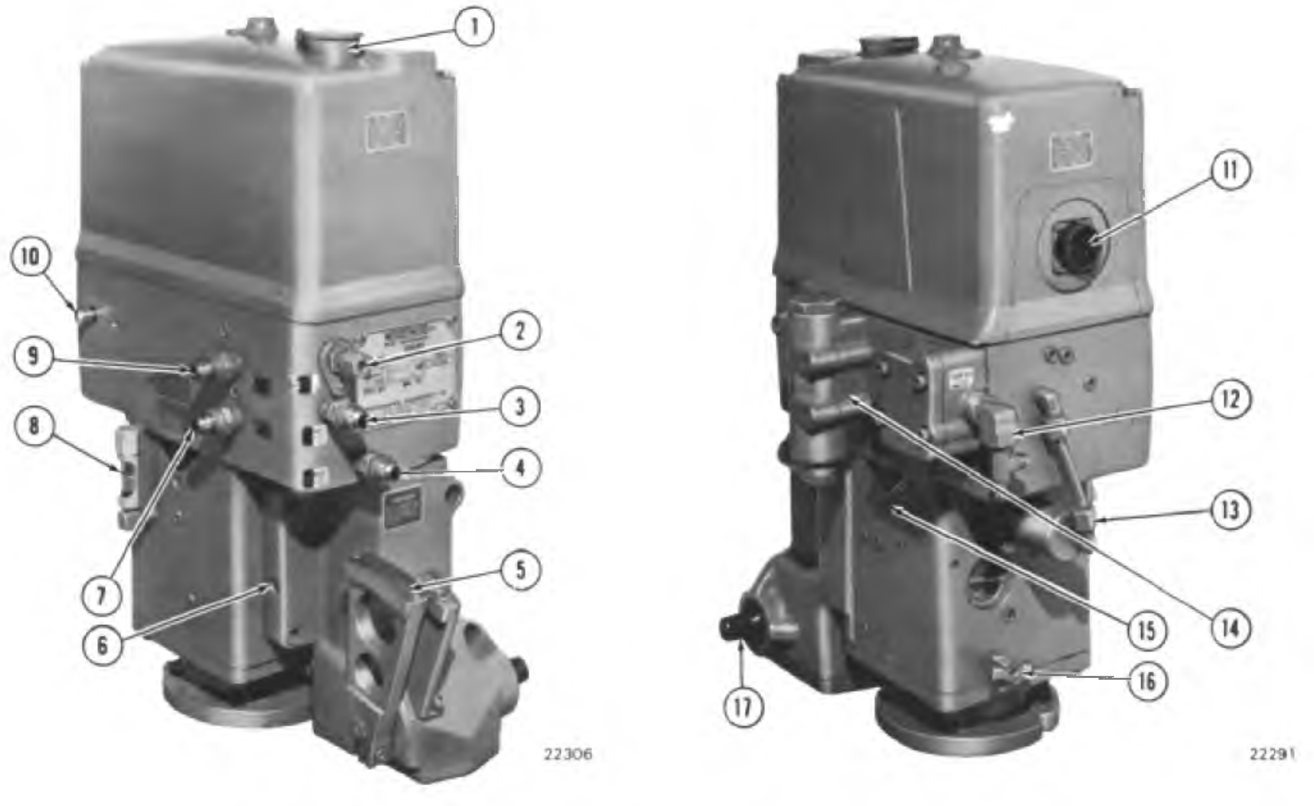
ELECTRO-MOTIVE

GOVERNOR

DESCRIPTION

The limiting and rebalancing type PGR governor, Fig. 12-1, is used on the turbocharged engine. An electro-hydraulic speed control maintains the engine speed selected by the engine operator. The governor is provided with a sensor assembly, sensitive to absolute air pressure, which operates to adjust the engine load in proportion to the air supply, within the range of the load regulator, to ensure correct air-fuel ratio. In addition, a rocker arm and lever arrangement is provided on the governor to stop upward movement of the power piston through the action of the fuel limiter.

The governor incorporates an engine protective device, Fig. 12-2, which shuts the engine down when actuated by low engine oil pressure, high oil temperature, or as a result of the operation of the low water and crankcase pressure detector. A visual indication and an alarm is actuated in the event of an engine protection shutdown. A normal engine shutdown is obtained by actuating one of the speed solenoids with the stop button. Other auxiliary devices which are a part of the governor include the load regulator pilot valve, which controls oil to the load regulator, and the ORS solenoid which when energized raises the load regulator pilot valve to the minimum field position.



1 Oil Filler
2 Air Box Pressure Connection
3 Pilot Valve Engine Oil Supply
4 Pilot Valve Oil Drain
5 Terminal Shah Scale
6 Compensating Needle Valve
7. Vane Motor Oil Line Connection; Increase Excitation .
8. Oil Level Sight Glass
9. Vane Motor Oil Line Connection; Decrease Excitation
10. Low Oil Pressure Shutdown Plunger
11. Electrical Receptacle
12. Engine Oil Pressure Connection
13. Time Delay Accumulator
14. Rebalancing Servo Oil Filter
15. Vent Plug
18. Oil Drain Cods
17. Terminal Shaft Control

Fig. 12-1 - Electro-Hydraulic Governor

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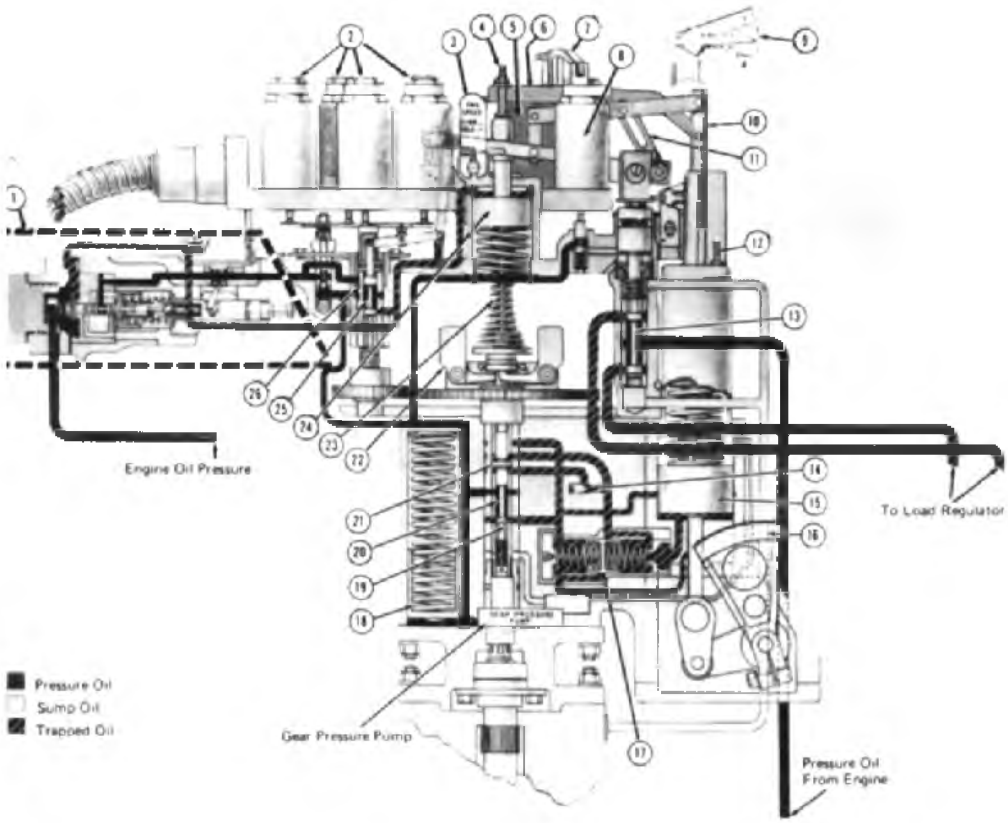

1. Low Oil Pressure Shutdown
2. Speed Control Solenoids
3. Speed Scale
4 Shutdown Rod
5 Air Pressure Sensor Assembly
6 Fuel Limit Lever
7 Rebalancing Rocker Arm 8 Overriding Solenoid
9 Pilot Valve Scale
10. Power Piston Tail Rod
11. Plot Valve Linkage And Eccentric
12. Power Piston Stop Screw
13. Load Regulator Pilot Valve
14 Compensating Needle Valve
15 Power Piston
16. Terminal Shaft Scale
17 Buffer Piston
18. Governor Oil Pressure Accumulator
19. Regulating Port
20. Power Piston Plot Valve
21. Compensating Receiving Piston
22. Ballhead Assembly
23. Speeder Spring
24. Speed Setting Piston
25. Speed Control Pilot Valve
26. Speed Control Rotating Bushing

Fig. 12-2 - Governor Schematic Diagram

The main parts of the speed and fuel control portions of the governor are: a speed sensing arrangement (speeder spring and flyweights), fuel adjustment control (power piston), compensating mechanism (compensating land integral on power piston pilot valve and buffer piston and springs), and an independent oil system (oil sump, oil pump, accumulators, external filter, and connecting passages).

The governor has a self-contained hydraulic oil system, consisting of storage sump, rotary gear pump, and accumulators. The oil lubricates the moving parts and provides force necessary to operate various parts of the governor.

To vary the speed of the engine with throttle changes, or to maintain a constant engine speed with load changes, the amount of fuel injected into the cylinder must be varied. This is determined by the position of the power piston. To move the power piston, the tension on the speeder spring is varied. Whether the throttle changes or the engine speed changes (due to a load change), the flyweights will move. This changes the position of the pilot valve plunger and controls the supply of oil to the power piston.

The power piston moves the injector control rack through the governor rotary shaft and injector linkage. The upward motion of the power piston results from oil under pressure, controlled by the power piston pilot valve plunger, raising the piston against the pressure of the power piston spring.

The compensating mechanism prevents the engine from racing or hunting by arresting the movement of the power piston after it has traveled an amount sufficient to give the desired speed. The compensating mechanism includes the integral receiving compensating piston, buffer piston and springs, and compensating needle valve.

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The governor drive shaft, pump gears, rotating bushing and flyweights rotate together. Two accumulators provide for the storage of governor oil under pressure, and the maximum pressure of this governor oil is regulated by a bypass in one of the accumulators. A buffer piston centered by springs is located between the pilot valve plunger and the power piston. This piston is bypassed by the needle valve, and also by passages which are uncovered when it moves a certain distance away from its central position. The small difference in oil pressure on the two sides of the buffer piston is transmitted to the receiving compensating piston on the pilot valve plunger.

OPERATION

Fig. 12-3 illustrates the operation of the fuel control portion of the governor. The power piston spring acts to shut off fuel to the engine. Oil under pressure is used only to raise the power piston and increase the supply of fuel to the engine. The following paragraphs describe the sequence of events under different operational conditions.

LOAD DECREASED OR THROTTLE DECREASED

As shown in Fig. 12-3, the engine is running normally under steady load and at constant speed. The flyweights, pilot valve plunger, and buffer piston are in normal position. The control land on the pilot valve plunger covers the regulating port holes in the rotating bushing. The power piston is stationary.

Assume that the engine load is decreased, thus increasing the speed. As the speed increases, the flyweights move out, raising the control land of the pilot valve plunger and uncovering the regulating ports in the rotating bushing. Uncovering the regulating ports in this direction permits oil to escape from the area to the right of the buffer piston; it then moves to the right, as spring pressure forces the power piston down. It is apparent that since this compresses the right-hand buffer spring, the oil pressure on the left of the buffer piston is a little higher than that on the right. These pressures are connected to the areas above and below the receiving compensating piston on the pilot valve

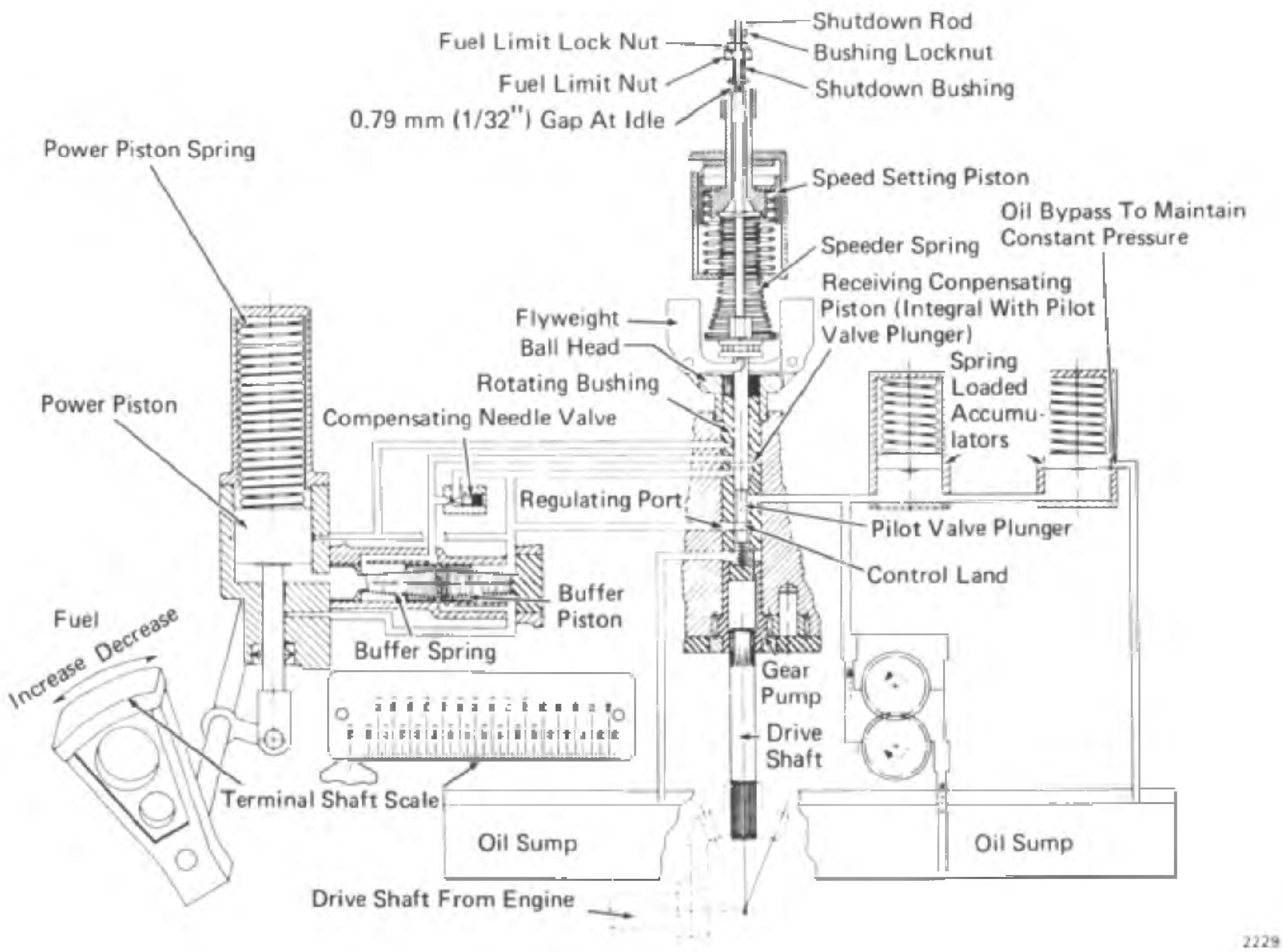

Fig. 12-3 - Fuel Control Schematic Diagram

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plunger, and since the higher pressure is above this it is forced downward so that the land of the pilot valve plunger starts to close the ports and stop the power piston movement. If the governor is properly adjusted, this action will stop the movement of power piston when it has moved far enough to correct for the load change that started the action.

Oil leaking through the compensating needle valve then allows the buffer piston to return to center, which gradually releases the force on top of the receiving compensating piston. This force is no longer needed to hold the pilot valve plunger in its central position, because during this time the engine speed has been returning to normal, and the outward force of the flyweights has been reduced until it is balanced by the speeder springs.

It is apparent that the compensating mechanism described above produces stable operation by permitting the governor to move rapidly in response to a speed change, and then wait for the speed to return to normal.

LOAD INCREASED OR THROTTLE INCREASED

As before, all parts of the governor are centered, and there is no power piston movement. Assume that the engine load is increased, resulting in a decrease in speed. The governor will go through a cycle of operations as follows: The decrease in speed will cause the flyweights to move inward, which lowers the pilot valve plunger and opens the port. Oil from the accumulators passes through the pilot valve, forces the buffer piston to the left, and moves the power piston upward to give the engine more fuel. The compression of the left-hand buffer spring is a result of a higher pressure on the right-hand side of the buffer plunger and on the underside of the receiving compensating piston. This pressure moves the pilot valve plunger upward and stops the movement of the power piston when it has moved far enough to correct for the load change that started the action.

Oil leaking through the compensating needle valve gradually releases the force under the receiving compensating piston, allowing the buffer piston to return to center. This force is no longer needed to hold the pilot valve plunger in its central position, because during this time the engine speed has been returning to normal.

In the preceding description of operation, speed changes as a result of load changes have been considered. Similar governor movements occur when a difference between actual governor speed and governor speed setting is produced by changing speeder spring tension through the speed adjusting control used on the governor. With large speed changes the buffer piston travel is much greater, to the left or right, depending on increase or decrease in speed, opening a passage for the flow of oil to or from the power piston.

Under normal operation, the air pressure sensor assembly and rebalancing arrangement will automatically adjust itself to provide correct operation. However, if air box pressure or fuel demand is not normal during operation, the rebalancing and fuel limit arrangement, explained in the following pages, will automatically make an adjustment to compensate for the condition.

MAINTENANCE

GOVERNOR REMOVAL

Remove the governor from the engine as follows:

1. Open drain cock on side of governor and drain oil into suitable container.
2. Remove right and left bank control rods from governor to control rod lever.
3. Disconnect electrical connector and all external lines and hoses.
4. Remove the four stud nuts securing governor to mounting surface, and lift governor off of studs. Remove the gasket from between the governor and the mounting surface.

CAUTION: Use care when handling governor and avoid striking the end of the drive shaft or the terminal shaft. Damage can be done to the shafts, bearings, and governor oil pump gears.

5. Remove governor to control rod lever from governor terminal shaft.

GOVERNOR INSTALLATION

Install governor on engine as follows:

1. Apply governor to control rod lever to governor terminal shaft.

CAUTION: Ensure that unsplined area of the lever I.D. is properly aligned to the keyway (missing spline) on the terminal shaft.

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2. Install gasket on governor mounting surface. 3. Install governor on mounting surface with terminal shaft pointing toward engine.

4. Apply four stud nuts and torque to specified value.

5. Connect electrical connector and all external lines and hoses.

6. Connect right and left bank control rods to governor to control rod lever.

NOTE: Every time a governor is installed on an engine the injector rack setting should be checked. Due to manufacturing tolerances in governor mounting bolt holes, the position of the governor in relation to the injector linkage can change the rack setting.

GOVERNOR COMPENSATION

DESCRIPTION

The compensating mechanism prevents the engine from racing or hunting by arresting the movement of the power piston after it has traveled a sufficient amount to give the desired speed. The compensating mechanism includes the integral compensating receiving piston, buffer piston and springs, and compensating needle valve.

When the engine is started the first time or after installation of a new or reconditioned governor or one that has been drained and cleaned and new oil added, the governor will require compensation adjustment. This is necessary to purge the governor oil system of trapped air.

MAINTENANCE

COMPENSATION ADJUSTMENT

1. See that the governor oil is at the proper level in the sight glass. Then operate the governor at idle speed.

2. Open the compensating needle valve, Fig. 12-1, several turns. Loosen the vent plug, Fig. 12-1, several turns, but do not remove the plug.

3. The governor will hunt and surge, and air will bleed from the system at the vent plug. When only oil flows from the vent plug, the system is free of air, and the compensating needle valve should be closed slowly until the hunting condition stops or is lessened. Allow the governor to run until normal operating temperature is reached. Tighten the vent plug to prevent oil leakage, and add the oil necessary to obtain the proper level in the governor.
4. After normal temperature has been reached, again open the compensating needle valve and allow the governor to hunt. Then close the needle valve until hunting stops. The needle valve will be open approximately one-quarter to three turns depending upon the engine characteristics.

5. Test the governor stability by manually changing the speed to observe governor recovery. If the governor returns to a steady speed, the compensating adjustment is satisfactory. If hunting is resumed, close the compensating needle valve slightly and test again.

6. Keep the compensating needle valve open as far as possible to prevent sluggishness and still maintain even governor operation. After compensation is made, it should not require another adjustment, unless a permanent temperature change effects the viscosity of the governor oil.

ENGINE SPEED CONTROL

DESCRIPTION

Speed setting with the electro-hydraulic governor is accomplished in steps by energizing different combinations of the "A," "B," "C," and "D" solenoids, Fig. 12-4. Solenoids "A," "B," and "C" have plungers bearing on a triangular fulcrum plate at varying distances from a set fulcrum point. The triangular plate fulcrum bears on a lever which is connected to the speed control pilot valve inside a rotating bushing. The "D" solenoid plunger bears on the rotating bushing through its cap and bearing.

To increase engine speed, the speeder spring must be compressed; or compression lessened to decrease speed. The speed setting piston position must be changed to satisfy these conditions. This is accomplished by admitting or releasing governor oil above the speed setting piston. Admission or release of oil to or from the speed setting piston is controlled by the solenoids through the speed pilot valve and rotating bushing.

When a solenoid or different combinations of "A," "B," or "C" solenoids are energized, the triangular

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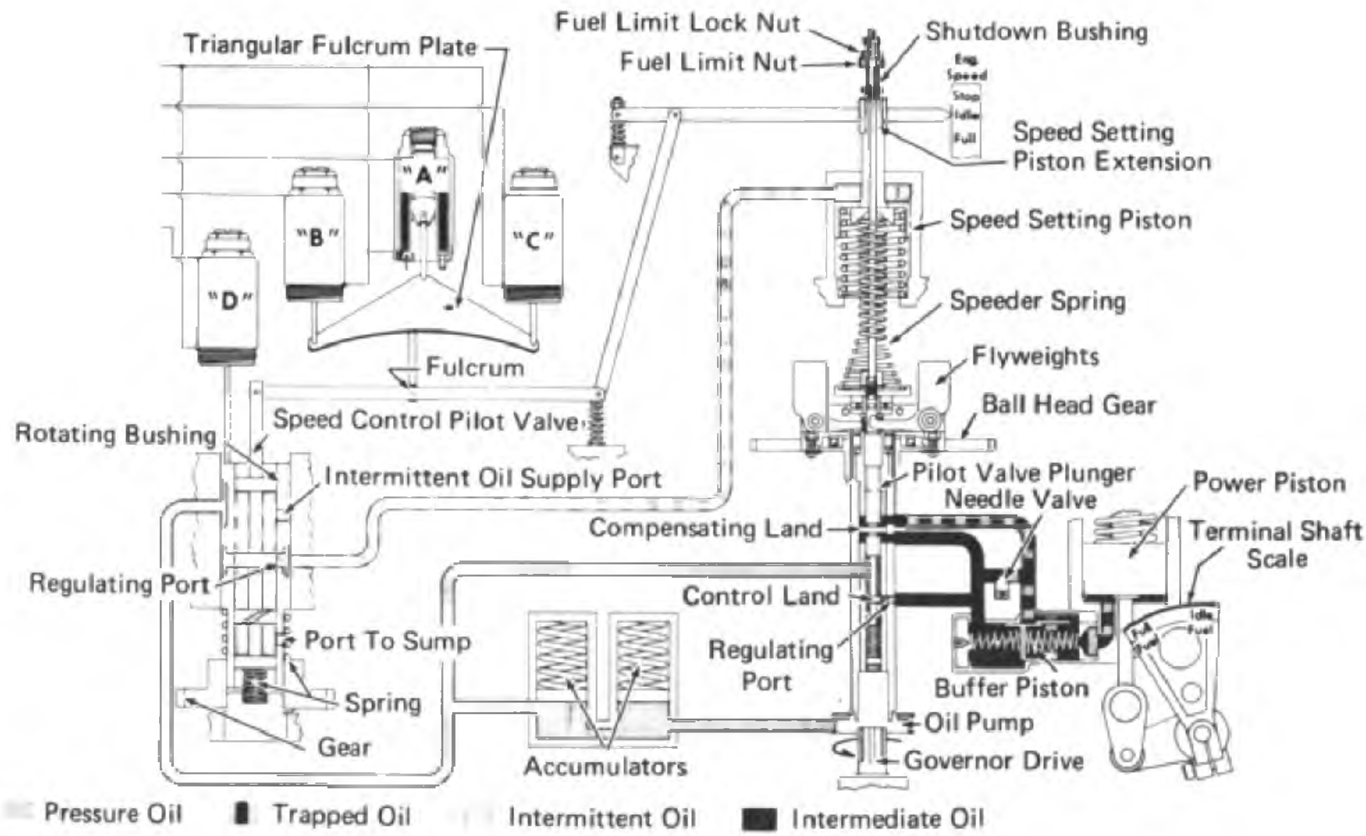

Fig. 12-4 - Speed Control Schematic Diagram

fulcrum plate is forced down a distance depending on the solenoids energized. This causes the speed control pilot valve to go down. The regulating port in the rotating bushing is uncovered, permitting governor oil under pressure to force the speed setting piston down and compress the speeder spring. As the speed setting piston moves downward, the linkage raises the speed control pilot valve to again close the regulating port when the desired piston position has been reached.

Compression of the speeder spring forces the flyweights in, allowing the governor pilot valve plunger to lower and permit oil to raise the power piston to increase fuel to the engine. Unbalanced oil pressure on the compensating land of the pilot valve plunger closes the regulating port when the power piston has been raised enough for the desired speed. When the new engine speed is reached, the flyweights will return to balance position against speeder spring pressure.

When a solenoid or a combination of "A," "B," or "C" solenoids is de-energized, the triangular fulcrum plate will rise, and the speed control pilot valve will also be moved upward. Since the pilot valve is raised, oil above the speed setting piston drains through the regulating port to the oil sump. The speed setting piston is raised by its spring. As the piston moves up, the connecting linkage causes the speed control pilot valve to move down and close the regulating port when the desired position is reached.

Since the speed setting piston was raised, speeder spring compression is lessened. The flyweights will move outward under centrifugal force to lift the pilot valve plunger. Oil will then be released from under the power piston and it will move downward to decrease fuel supply and engine speed.

Energizing the "D" solenoid in combination with other solenoids lessens their effect on engine speed, since the "D" solenoid pushes down the rotating bushing and lowers the regulating port. When only the "D" solenoid is energized, it opens the regulating port in the rotating bushing to sump, permitting oil above the speed setting piston to be released. The piston then raises and the piston extension lifts the shutdown bushing, causing the governor to shut off the engine fuel supply.

Note that oil enters the speed control rotating bushing through an intermittent supply port. This port is of such size as to allow the speed setting piston to move a full stroke in a specified time. Consequently speed increase is controlled under all conditions of operation. Time of speed decrease is controlled by a slot in the lower land.

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MAINTENANCE

It is recommended that a suitable test stand be used when making engine speed settings.

NOTE: Test stand must have provision to energize A and D solenoids simultaneously for setting low idle speed.

When setting engine speeds, the governor solenoids are adjusted to provide specified speeds at idle, intermediate, and full speed throttle positions. For applicable speeds at each throttle setting refer to Table A in the Service Data at the end of this section.

In addition to the other information on the governor name plate each name plate has an insert, Fig. 12-5, which shows the full speed of the engine and the full load injector rack length (BAL. PT.) for the engine speed given in the insert. If the governor is reset to a different full load injector rack length or engine speed, a new insert should be applied having the correct information.

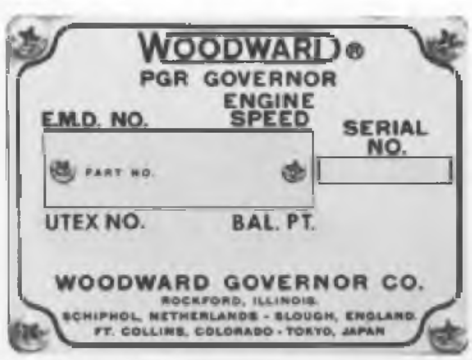

Fig. 12-5 - Governor Nameplate

Everytime a governor is installed on an engine the injector rack length settings should be checked. Before attempting to set speeds, the governor should be operated with the heated test stand oil 82°-93° C (180°-200° F) for a sufficient length of time to allow the temperature to equalize.

To facilitate setting speeds, the solenoid adjustment wrench may be used. This tool provides a means for holding the solenoid case while making locknut and stop screw adjustments.

Establish absolute air pressure to bellows, as given in Table B. Adjust the solenoids to obtain the speeds given in Table A as described below.

1. Place the throttle in No. 6 position and bring speed to specified RPM by adjusting fulcrum nut, Fig. 12-6, at the end of the linkage. Raising the fulcrum nut increases speed.

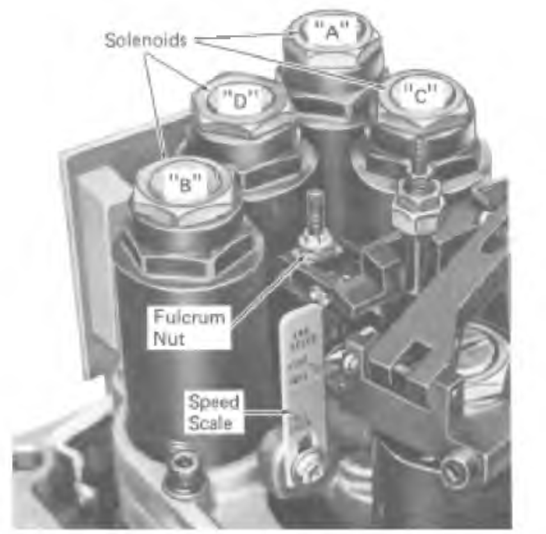

Fig. 12-6 - Speed Control Adjustment Points

2. Move the throttle to No. 8 position and set speed by adjusting the "D" solenoid stop screw. Back off stop screw to increase speed.
3. With the throttle in No. 4 position, adjust the "B" solenoid stop screw to set speed. Turn stop screw in to increase speed.
4. Place throttle in low idle position. and set speed by adjusting "C" solenoid stop screw. Turning stop screw in, increases speed.
5. With throttle in idle position adjust "A" solenoid to set speed. Turn screw in to increase speed.
6. Check above settings and, readjust for proper speeds, if required.
7. Check engine speed at all throttle positions. All speeds must be within limits shown in Table A.
8. Adjust speeder servo scale as follows:

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a. With governor operating at low idle speed, loosen scale locking screw and locate scale *so stamped* IDLE mark is aligned with pointer. Tighten locking screw.

b. With governor at idle speed, scribe a line on scale opposite pointer.

c. With governor at throttle 8 position, scribe a line on scale opposite pointer.

ENGINE SHUTDOWN

DESCRIPTION

Engine shutdown can normally be accomplished by depressing the STOP button or placing the throttle in the STOP position. Either action will energize the "D" solenoid, Fig. 12-4. This action depresses the speed control rotating bushing so its port is below the land of the speed control pilot valve. This allows the trapped oil above the governor speeder spring piston to drain. The spring under the piston forces the speeder spring piston upward and the piston extension contacts the shutdown bushing on the shutdown rod. Raising the shutdown rod also lifts the power piston pilot valve. Oil will then be released from under the power piston, causing the power piston through the associated linkage to bring the injectors to the "no fuel" position.

MAINTENANCE

SOLENOID ADJUSTMENT

No additional adjustment is required on the governor solenoids. The "D" solenoid which causes engine shutdown is adjusted at the time of speed adjustment.

SHUTDOWN ADJUSTMENT

CAUTION: Shutdown adjustment must be made on governor test stand, since this adjustment establishes the basis for fuel limit settings.

1. Operate governor at low idle speed.

2. Loosen shutdown bushing locknut, Fig. 12-7, and adjust shutdown bushing by turning the fuel limit nut until there is 0.79 mm (1/32) " clearance between the bottom of the shutdown bushing and of the speed setting piston fulcrum assembly.

3. Tighten bushing locknut.

Fig. 12-7 - Shutdown Adjustment Location

4. Turn test stand selector switch to OFF position and loosen speed setting piston stop screw locknut.

5. Adjust speed setting piston stop screw, Fig. 12-8, to position the speed indicator pointer at or slightly above the STOP mark on the speed scale.

6. Tighten stop screw locknut.

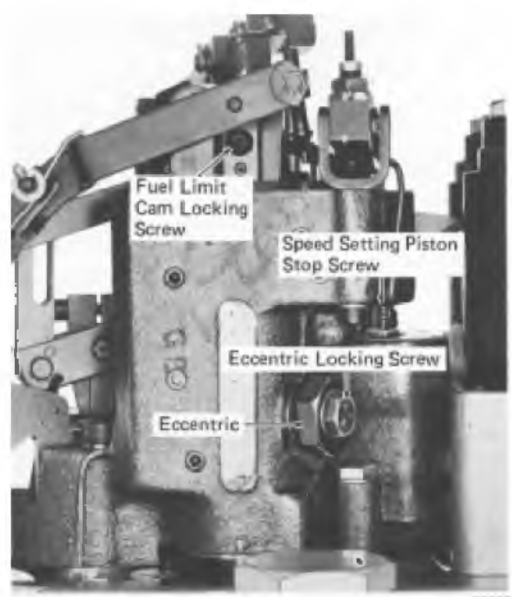

Fig. 12-8 - Speed Setting Piston Stop Screw

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AIR PRESSURE SENSOR ASSEMBLY

DESCRIPTION

The purpose of the sensor assembly, Fig. 12-9, is to adjust the fuel limiter and pilot valve rebalancer arrangement in accordance with the absolute air pressure. The automatic positioning of these two controls is dependent upon engine air box pressure and atmospheric pressure.

The pressure sensor is a force-balance device consisting of an inlet check valve, an orifice pack restriction, a piston and cam assembly, a restoring spring, a bleed valve, an absolute pressure bellows arrangement, and a hydraulic amplifier.

Pressured oil enters the sensor through the inlet check valve, and is directed to the upper side of the sensor piston and through the orifice pack restriction to the under side of the sensor piston. The inlet check valve prevents siphoning of the oil from the limiter housing during shutdown periods.

The bleed valve regulates the rate of oil flow from the area under the sensor piston to the sump as a function of manifold air pressure. When the bleed valve bypasses a greater flow of oil from this area than is admitted through the orifice pack, the sensor piston moves downward. Conversely, reducing the bypass oil flow to less than that admitted causes the sensor piston to rise. When the inflow and outflow of oil are equal, the piston remains stationary.

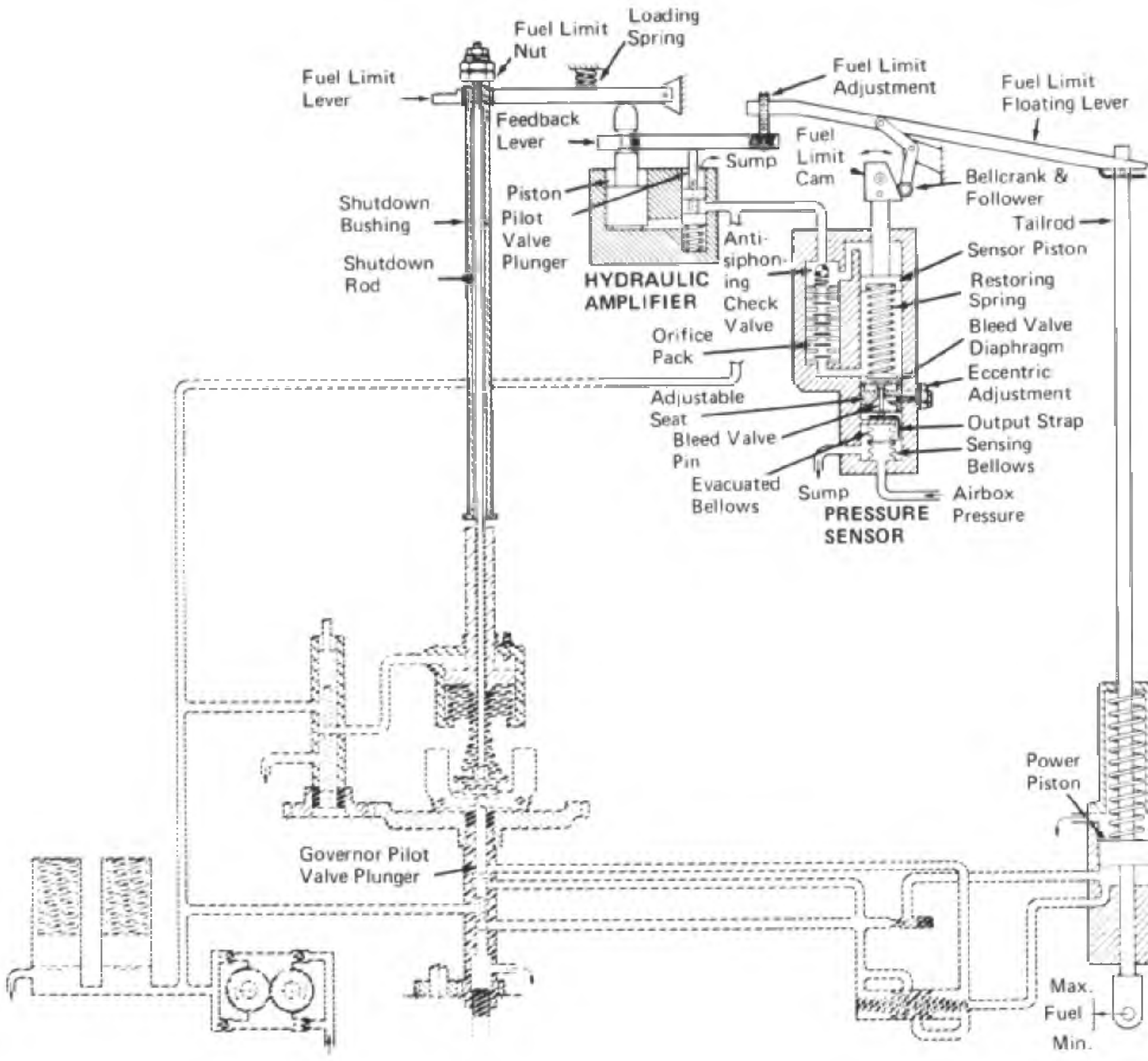

Fig. 12-9 - Air Pressure Sensor Assembly Schematic

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The sensing element consists of two opposed, flexible, metallic bellows. The upper bellows is evacuated, and the lower bellows senses air box r Pressure. A spacer joins the bellows at the center wnile the outer end of each bellows is restrained to prevent movement. Air box pressure acting internally on the sensing bellows produces a force causing the spacer to move towards the evacuated bellows. The evacuated bellows provides an absolute reference, therefore the sensing bellows force is directly proportional to the absolute air box pressure. Movement of the bellows spacer is transmitted through an output strap and a bleed valve pin to the bleed valve diaphragm.

When the governor speed setting is advanced, the governor power piston moves upward supplying additional fuel. Since air box pressure lags engine acceleration, the fuel limiter cam and bellcrank initially remain stationary until air box pressure rises. As the governor power piston moves upward increasing fuel, the fuel limit floating lever depresses the right end of the feedback lever on the hydraulic amplifier. This pushes the amplifier pilot valve plunger below center, allowing pressured oil to flow into the area under the amplifier piston, causing the piston to rise. As the piston rises, it lifts the fuel limit lever. When the fuel limit lever contacts the fuel limit nut on the shutdown bushing it begins lifting the shutdown rod to recenter the governor pilot valve plunger. The upward movements of the fuel limit and feedback levers continue until the left end of the feedback lever raises far enough to recenter the amplifier pilot valve plunger and stop the flow of oil to the amplifier piston. At this point, the fuel limit lever recenters the governor pilot valve plunger, stopping the upward movement of the governor power piston. Although the governor flyweights are in an underspeed condition at this time, the power piston remains stationary until air box pressure rises.

As engine speed and load increases, air box pressure begins to rise after a short time lag. The increase in air box pressure produces an increase in the sensing bellows force. The bellows force, causes the bleed valve diphragm to move further off its seat. This allows a greater flow of oil to the sump than is admitted through the orifice pack. Governor oil pressure acting on the upper side of the sensor piston forces the piston downward and further compresses the restoring spring. The piston continues its downward movement until the net increase in restoring spring force equals the bellows force. This restores the bellows and bleed valve diaphragm to their original positions. At this point, the outflow of oil is again equal to the inflow and movement of the piston is halted.

As the sensor piston and cam move downward in response to a rise in air box pressure, the bellcrank rotates in a clockwise direction. This allows the floating lever pivot point, the left end of the lever, and in turn the hydraulic amplifier pilot valve plunger to rise.
When the pilot valve plunger rises above center, the oil under the amplifier piston bleeds to sump through a drilled passage in the center of the plunger. The passage in the plunger restricts the rate of oil flow to sump and decreases the rate of movement of the amplifier piston to minimize hunting. As the amplifier piston moves downward, the left end of the fuel limit lever also moves downward. This lowers the shutdown rod which in turn lowers the governor pilot valve plunger and increases engine fuel.

The sequence of events described above occurs in a continuous and rapid sequence. Normal governor operation is overridden during an acceleration transient and engine fuel is scheduled as a function of air box pressure, regardless of governor speed setting. During steady state operation, air box pressure is normally greater than that at which fuel limiting occurs, and the sensor piston and cam will be positioned below the effective limiting point.

MAINTENANCE

1. Operate governor at idle speed.

2. Connect air line to AIR PRESSURE TO LIMITER fitting on governor.

3. Adjust air pressure to 36" Hg Abs.

NOTE: If test stand is equipped with an absolute pressure manometer, read inches of mercury absolute directly from manometer. If test stand is equipped with a mercury column and a barometer, subtract barometric pressure from absolute pressures given in this instruction and establish pressure difference as inches of mercury on the mercury column.

4. Loosen eccentric locking screw, Fig. 12-8, and turn eccentric clockwise until sensor piston travels to the top of its stroke.

5. Measure and record the height of the fuel limiter cam, Fig. 12-10, from a convenient reference surface.

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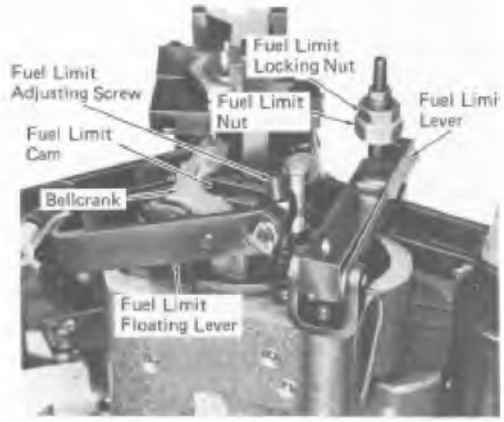

Fig. 12-10 -Fuel Limit Adjustments

6. Tighten eccentric locking screw slightly and turn eccentric counterclockwise until fuel limit cam travels downward 2.36 mm ± 0.38 mm (3/32" ± 1/64"). Tighten locking screw.

7. Rapidly increase and decrease the air box pressure to the bellows. (This may be done by application of a vent valve between the mercury column and the governor air connection.) Observe the limiter cam motion. This should follow the pressure changes closely. If the limiter cam does not follow a decreasing air pressure, check the limiter oil supply filter and orifice stack for plugging.

8. Adjust air pressure to 36" Hg Abs., and check for fuel limit cam position obtained in Step 5.

FUEL LIMITER

DESCRIPTION

The purpose of the fuel limiter is to prevent supplying fuel to the engine in excess of that which can be properly consumed with the available air supply.

In response to a demand for fuel, the governor pilot valve is lowered to permit governor oil to raise the power piston. The power piston upon being raised will also lift the fuel limit floating lever, Fig. 12-10. If sufficient air is not available for proper combustion, the hydraulic amplifier piston, contacts the fuel limit lever which will raise the shutdown bushing and governor power piston pilot valve. The governor oil port to the power piston will then be closed and the upward or increase fuel movement of the power piston will be stopped.

Since the limiter floating lever has a movable fulcrum, the fulcrum position is automatically varied to correspond to air box pressure. This will adjust the limiter action in proportion to the available air box pressure.

MAINTENANCE

1. With the governor operating at full speed, establish the absolute pressure to the sensor assembly bellows specified in Table C l in the Service Data at the end of the section.

2. Adjust test stand air valve linkage to position the power piston at the rack length specified in Table C 1.

3. Loosen and back off the fuel limit locking nut and the fuel limit nut to the top of shutdown bushing threads.

4. Adjust fuel limit adjusting screw until fuel limit lever is in the horizontal position (determined visually).

5. Adjust fuel limit nut until it just contacts the fuel limit lever.

6. Tighten fuel limit locking nut.

7. Back off fuel limit adjusting screw until fuel limit lever loses contact with the fuel limit nut. 8. Adjust fuel limit adjusting screw until fuel limit lever contacts limit nut and limiter reduces speed 10 to 15 rpm.

9. Slowly adjust test stand air valve linkage to reduce governor speed by 100 rpm.

10. Observe terminal shaft scale. Rack length must be specific value of Table C1 +0.00" -0.02". If rack length is not within specified tolerance, inspect fuel limiter amplifier piston for leakage.

11. Reduce absolute pressure to 42" Hg.

12. Adjust test stand air valve linkage until full governor speed is obtained.

13. Very slowly adjust test stand air valve linkage to decrease rack length until 10 to 15 rpm speed reduction occurs.

14. Injector rack length must be as specified in Table C2.

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If rack is not as specified, loosen fuel limit cam locking screw, Fig. 12-8, slightly, and tilt top of cam toward bellcrank to increase rack length, or away from bellcrank to decrease rack length. Tighten locking screw and repeat Steps 12 and 13.

15. Repeat steps I through 14 until all conditions of Table C I and C2 are met.

SETTING REBALANCER ROCKER ARM STOP SCREW

DESCRIPTION

The rebalancer rocker arm, Fig. 12-11, adjusts the load to the air available for combustion. The setting of the rebalancer rocker arm stop screw determines the balanced injector rack position at the minimum air box pressure required for full load. At air box pressures below that require for full load, the rebalancer rocker arm positions the pilot valve to limit the load in proportion to the available air pressure.

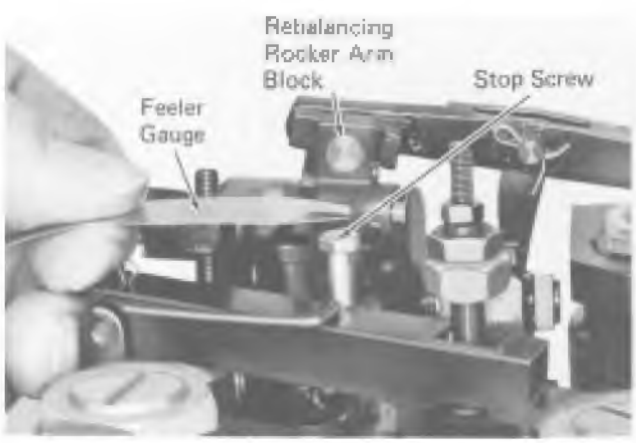

Fig. 12-11 - Rebalancing Stop Screw Adjustment

MAINTENANCE

It is recommended that the governor be placed on a suitable test stand to perform the following maintenance.

1. Loosen the locknut and screw down the rebalancer rocker arm stop screw, Fig. 12-11, to ensure no interference during loading of the governor on the test stand.

2. Operate governor at injector rack length, engine speed, and pressure as shown in Table B. 3. Using a 0.001"-0.002" feeler gauge under the rebalancer rocker arm block, Fig. 12-11, run the screw up until a drag is felt on the gauge as it is pulled from under the block. Tighten locknut. 4. Check the above setting by reducing the absolute pressure on the sensor assembly bellows by 5" to 6" Hg and then reestablishing the pressure shown in Table B, as in Step

2. Again using 0.001 "-0.002" feeler gauge under the rebalancer rocker arm block, check to see that the same drag is felt on the gauge as in Step 3.

LOAD REGULATOR PILOT VALVE AND ASSOCIATED LINKAGE

DESCRIPTION

The load regulator pilot valve, Fig. 12-12, is a device in the governor for controlling the oil to the vane motor of the load regulator. In addition to this, the load control is also made dependent upon absolute air pressure, since the rebalancer will vary the position of the load control pilot valve in response to variations in engine air box and barometric pressures.

The pilot valve linkage, Fig. 12-12, consists of the rebalancer rocker arm, horizontal floating link, slotted link, eccentric and clevis, the latter being threaded on the pilot valve plunger.

The pilot valve in conjunction with the load regulator requires the engine to assume a predetermined load for each throttle position by controlling the loading of the main generator through the battery field.

The action of the rebalancing linkage is such that the lower set of predetermined load valves is established when the air box pressure falls below the minimum that has been established for full load operation.

Fig. 12-12 shows a partial governor section through the pilot valve and associated parts. When engine output is correct for a certain throttle position, the lands of the pilot valve plunger close ports "B" and "C" in the pilot valve bushing. In this plunger position no oil can flow through the ports to or from the load regulator vane motor. This position is the balanced position of the pilot valve. As shown, lubricating oil under pressure enters the valve at a point between the lands of the plunger and is trapped when the pilot valve is balanced.

When the horsepower demand on the engine is greater or less than the engine is adjusted to develop at a given

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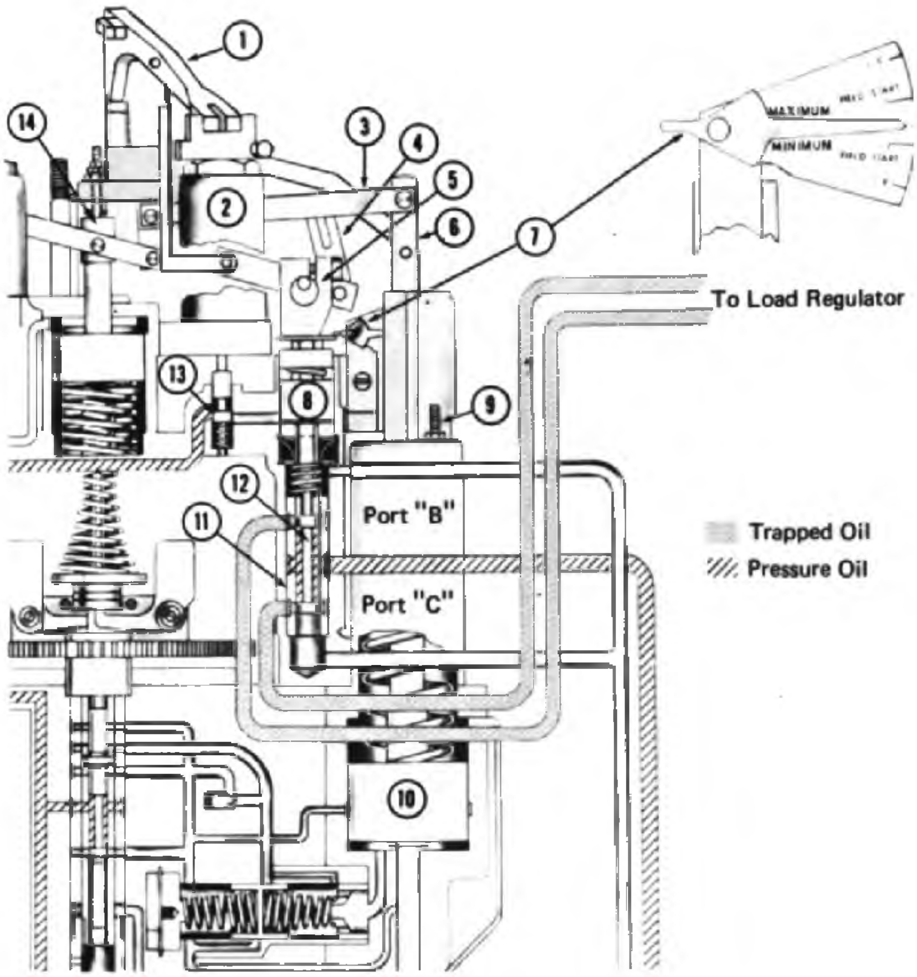

1. Rebalancing Rocker Arm
2. Overriding Solenoid
3. Floating Link
4. Slotted Link
5. Eccentric And Clevis
6. Power Piston Tailrod
7. Pilot Valve Scale
8. Overriding Piston
9. Power Piston Stop Screw
10. Power Piston
11. Pilot Valve Bushing
12. Pilot Valve Plunger
13. Overriding Valve
14. Speed Setting Piston Extension

Fig. 12-12 - Load Regulator Pilot Valve, Schematic Diagram

throttle position, a change will be made in the position of the governor power piston to meet the changed horsepower demand. Since the throttle position has not changed, the pilot valve plunger will either be raised or lowered through the movement of the power piston and linkage. This action unbalances the pilot valve and the oil thus permitted to flow causes the load regulator to adjust the generator load to the desired engine output.

If a more than proper load is placed on the engine, the piston will move upward to increase fuel. This action raises the pilot valve plunger, Fig. 12-12, opening port "B" with its upper land. Oil under pressure can then flow through port "B" to the vane motor of the load regulator. This causes the load regulator movement to reduce main generator output. As the vane rotates it pushes oil ahead of it through oil line port "C" of the pilot valve and then to the engine oil sump. As the load on the engine is reduced, the power piston and pilot valve plunger move down to normal position. The pilot valve plunger again closes both ports "B" and "C."

The operation of the pilot valve for less than proper load on the engine is opposite that given for an overload, again adjusting generator load to permit the engine to assume its proper load for a certain throttle position.

The rate of movement of the vane or brush holder of the load regulator is automatically controlled by orifices and slots in port "C," or lower port of the pilot valve bushings, as oil from the load regulator must return through port "C" when oil to the load regulator leaves through port "B" or when oil to regulator passes through port "C." The slot and orifices in the pilot valve bushing lower port are designed to provide for a

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definite rate of load regulator movement.

Normal action of the load regulator pilot valve, as previously described, can be nullified or overriden be energizing the overriding solenoid. This action raises the pilot valve above the normal range of travel determined by the mechanical linkage, causing the load regulator to move toward the minimum field position. When the solenoid is deenergized the pilot valve and load regulator position is again determined by the mechanical linkage. See "Overriding Solenoid."

MAINTENANCE

Is it recommended that the governor be placed on a suitable test stand to perform the following maintenance.

SETTING PILOT VALVE LINKAGE

PREPARATION

Before setting the pilot valve, the speeds, the air pressure sensor assembly, and the rebalancer rocker arm stop screw must be correctly set as previously outlined.

Ensure that terminal shaft scale can travel from 1.96" to .62". If not, loosen rack stop screw locknut and adjust rack stop screw until full range of travel is obtained.

SETTING PROCEDURE

1. Operate the governor on the test stand at full load rack length, engine speed, and pressure on the sensor assembly 1"-2" Hg above that shown in Table B in Service Data at end of section.
2. Pointer on the test stand servo indicator should be balanced at some point well away from either end of its travel with the settings as given in Step 1. If not, loosen the eccentric clevis lockscrew, Fig. 12-13, and using a screwdriver, adjust the eccentric to bring the pilot valve to the balance position. Then tighten the clevis lockscrew. The pointer of the pilot valve scale should be at "0" with pilot valve balanced. If necessary, relocate the scale to position the pointer at "0".
3. Operate the governor test stand to simulate idle engine speed, so that the terminal shaft pointer and the pressure on the sensor assembly are as shown in Table B.
4. Pilot valve scale pointer should be at MAXIMUM FIELD START position. If the pointer is below the MAXIMUM FIELD START position, remove setting lock pin, Fig. 12-13, and turn floating link adjusting screw to lengthen dimension "A." If above, dimension "A" should be shortened. On this correction, adjust dimension "A" I / 2 required, then return to the conditions to set "0" or balance as outlined under Step I.

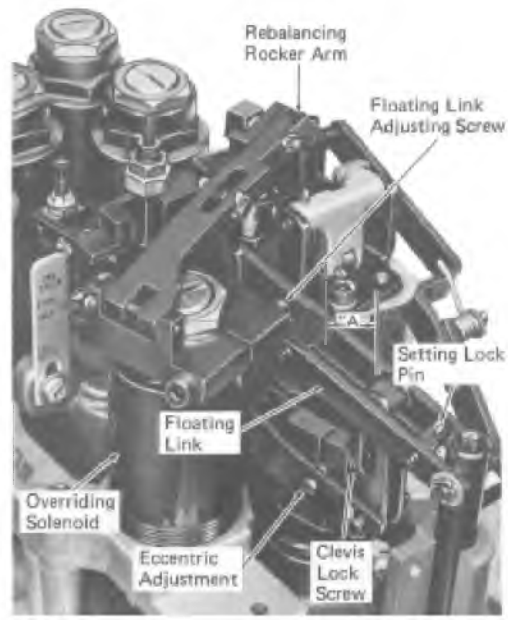

Fig. 12-13 - Pilot Valve Linkage

5. Recheck the settings to conform to conditions given in Steps 1, 2, 3, and 4 to obtain the correct adjustment for full speed conditions and idle speed conditions or readjust the linkage as outlined until correct positions are obtained.
6. Install new setting lock pin.

Once the pilot valve is properly set, it should not be changed to correct engine output until all other conditions are investigated.

OVERRIDING SOLENOID

DESCRIPTION

The overriding solenoid "O", Fig. 12-12, is employed on the governor to override normal action of the pilot valve linkage and move the load regulator in the direction of minimum field. The solenoid is energized by external circuits which may be determined by consulting the specific wiring diagram covering the particular

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governor application. When the overriding solenoid is energized, it moves a small cylindrical valve downward, permitting governor accumulator oil pressure to flow under the overriding cylinder piston. This piston moves up carrying the load regulator pilot valve plunger with it. When the solenoid is de-energized, a spring moves the pilot valve back to normal position.

MAINTENANCE

SOLENOID ADJUSTMENT

1. With governor operating at IDLE speed, loosen locknut on overriding solenoid and run the screw down until the load control pilot valve moves up.

2. Carefully back off the screw until pilot valve starts down, then back off screw a full quarter turn more, and lock it.

Improper adjustment of the overriding solenoid may result in a loss of governor accumulator oil pressure. This is caused by the overriding solenoid adjusting screw being backed off too far, allowing its valve to open the supply port, permitting governor oil pressure to be bypassed directly back to the governor oil sump.

In cases where the engine dies in the lower throttle positions, the adjustment of the overriding solenoid should be one of the checks made.

LOW OIL PRESSURE SHUTDOWN

DESCRIPTION

The low oil pressure shutdown device, Fig. 12-14, is an integral part of the governor. The device will respond, by shutting the engine down, when a low oil condition is created. This can be caused by any of the following:

1. A true system low oil pressure.

2. A positive crankcase pressure or a low water supply which, through the low water and crankcase pressure detector, will relieve pressure from the oil pressure line to the governor.

3. Overheated lube oil, which will also relieve oil pressure from the line to the governor through the hot oil detector.

A time delay of approximately 50-60 seconds at idle engine speed is provided before the alarm switch trips and the engine shuts down. This allows operating pressures to be reached after starting engine, and to provide time to locate trouble spot in the event of malfunction. Repeated engine starting to locate cause of shutdown should not be attempted. The time delay is voided above third throttle, and shutdown will occur in approximately two seconds.

Since oil pressure is the lowest at the rear of the engine, an oil line runs from this point to the shutdown device in the governor.

The shutdown device in the governor, Fig. 12-14, consists of an oil failure diaphragm and plunger, time delay accumulator, oil failure piston, ball valve, shutdown rod, and an alarm switch.

Engine pressure oil is admitted to the left of the oil failure diaphragm. A spring also exerts pressure on the left side of the diaphragm. Pressure oil from the governor speed setting piston pushes against the right side of the oil failure diaphragm. The pressure of the oil from the speed setting piston varies with engine speed. The highest pressure is at full engine speed and the lowest is at idle engine speed. If engine oil pressure is reduced below a safe level, the speed setting piston oil pressure will become greater than engine oil pressure and move the oil failure diaphragm and plunger to the left. This permits governor oil pressure to move the shutdown plunger to the right, releasing the trapped oil above the speed setting piston allowing the piston to travel upward. When the piston extension contacts and lifts the shutdown bushing on the governor pilot valve shutdown rod, resultant movement of other governor components places the terminal shaft, injector control lever, and the injector racks in a no fuel position and the engine will shut down.

When the shutdown plunger moves out, an alarm switch is actuated and a colored band is visible on the plunger indicating that the device has been tripped. After being tripped, the plunger must be manually reset to permit the governor to control engine operation. If conditions warrant the engine being shutdown, the action will occur even though the plunger were to be held in manually. When the oil failure piston moves to the right, it contacts the valve pin and unseats a ball valve releasing speed setting piston oil pressure through the ball valve.

The time delay feature of the device is controlled by engine speed. When engine speed is below fourth throttle position, governor pressure oil must pass through a time delay device before reaching the oil

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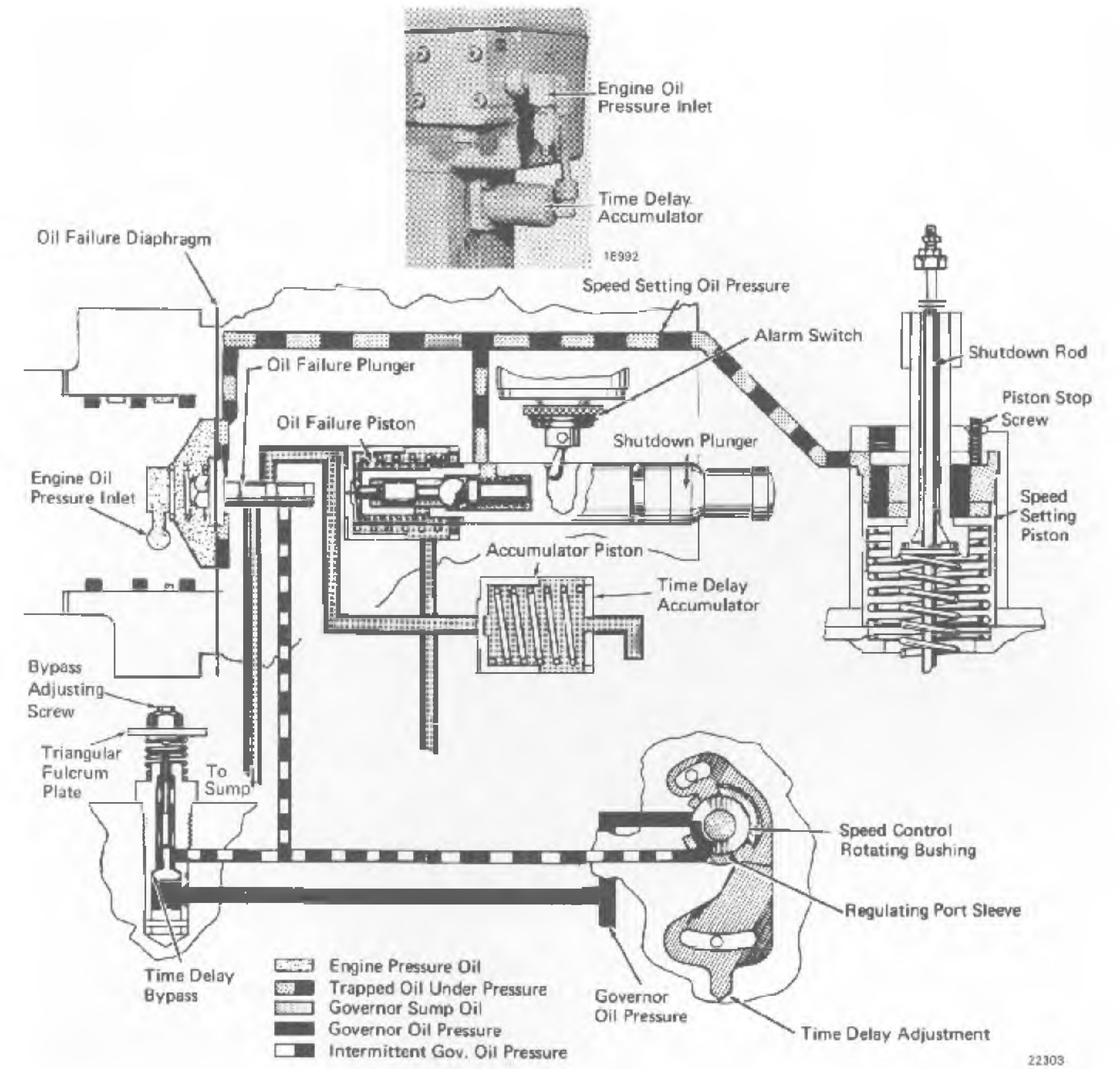

Fig. 12-14 -- Low Oil Pressure Shutdown Device

failure piston. The time delay is brought about by the governor oil passing through an intermittent flow orifice toward the top of the speed control rotating bushing. At each revolution of the bushing, a slot in the bushing aligns with the oil line to the oil failure piston. The amount of oil discharge through the slot is regulated by adjusting the port sleeve. The amount of oil discharged determines the time required to admit a sufficient amount of oil to move the accumulator piston through its full travel and operate the oil failure piston. When engine speed is above third throttle position, the speed solenoids bearing on the triangular fulcrum plate of the governor, opens the time delay bypass. When the bypass is open, governor oil goes directly to the oil failure piston, and shutdown will occur in about two seconds.

MAINTENANCE

SETTING TIME DELAY BYPASS

1. Operate governor at throttle 2 position with normal oil pressure to governor.

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2. Back off several turns on the bypass adjusting screw, Fig. 12-14, located in the triangular plate between the "A," "C," and "D" solenoids.

3. Open lube oil pressure bleed valve and close lube oil pressure supply valve to drop oil pressure to zero as rapidly as possible.

   The shutdown plunger should not trip in less than 30 seconds.

4. Turn the bypass adjusting screw in slightly, and repeat steps 1 and 3 until the shutdown plunger trips in 2 seconds or less, after the oil pressure is rapidly dropped to zero.

5. Back out bypass adjusting screw 1/4 to 3/ 8 of a turn.

6. Repeat step 3 for low idle, idle, and throttle 2 positions. Shutdown should not occur in less than 30 seconds.

7. Repeat step 3 for throttle 4 position. Shutdown must occur within 2 seconds.

SETTING TIME DELAY

1. Operate the governor at idle speed.

2. Open lube oil pressure bleed valve and close lube oil pressure supply valve to drop the oil pressure to zero as rapidly as possible. This should cause the shutdown plunger to trip within 50-60 seconds.

3. If the time delay is not within the 50-60 second limit, adjust the time delay adjustment, Fig. 1214, located under the "A" and "C" solenoids. Movement of the adjustment in the counterclockwise direction increases the time delay.

OIL FILTER

DESCRIPTION

The oil filter, Fig. 12-15, is used on the governor to protect the servo bellows assembly screen and orifice stack. The filter is contained in a housing that is mounted on the side plate.

MAINTENANCE

The design of this filter is such that under normal service it is expected to stay in service without cleaning or other attention. Maintenance may be done at the annual inspection with other governor work. However, if the sensor assembly bellows operation does not follow air pressure changes

Fig. 12-15 -Oil Filter

closely, the filter should be checked for cleanliness. If required, the filter may be cleaned by washing in solvent.

FLUSHING GOVERNOR

Governor flushing is not recommended as a regular maintenance item. Instead, the governor should be disassembled and cleaned if operation is impaired due to dirt or other foreign particles in the governor. In cases of necessity where the governor is suspected of being dirty and it would not be practical to remove the governor from the engine, it may be flushed on the engine as follows:

1. The engine should be shut down and the drain plug removed from the governor case, or petcock opened. Close valve or replace plug and add two pints of filtered kerosene to governor and start engine. Using the injector control lever, vary the speed of the engine from 400 to 500 RPM, for about five minutes. Shut the engine down and drain kerosene from governor. Repeat this operation several times until the kerosene drained from the governor appears clean.

2. Add two pints of recommended oil to the governor and repeat the above procedure and drain. This will remove any kerosene trapped in the governor.

3. Fill the governor with recommended oil to the proper level and start the engine. Adjust the governor compensation as previously described. The oil level should then be checked and oil added, if necessary.

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GOVERNOR OIL SUPPLY

With the engine at idle speed, the governor oil should be maintained at proper level in the sight glass. The vent at the top of the sight glass must be open to ensure correct readings. Governor oil specification is listed on Service Data page.

GOVERNOR STORAGE

When a governor is to be stored, governor oil should be drained. If the governor has been operating with oil that meets specifications, no further treatment is necessary. If governor oil does not meet the recommended specifications, drain and fill with the recommended oil and, if possible operate the governor for several minutes, then again drain the oil.

The recommended oil should be used when the governor is returned to service.

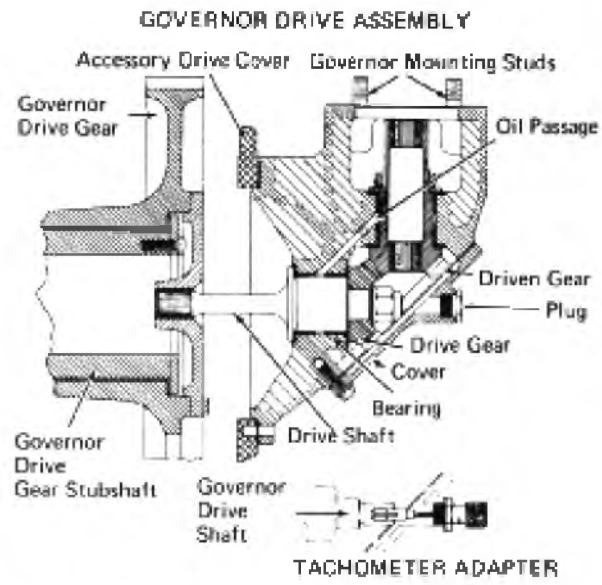

Fig. 12-16 - Governor Drive Application

GOVERNOR DRIVE ASSEMBLY

DESCRIPTION

The governor drive assembly, Fig. 12-16, is mounted at the front of the engine on the accessory drive cover adjacent to the water pumps. The governor is mounted on the housing and driven through the 90° bevel gear drive. The serrated end of the drive shaft is mated into a drive plate on the governor drive gear in the accessory gear train. Lubrication of the governor drive bearings is provided through drilled passages in the drive housing.

A cover having a removable plug, is provided on the housing so that a tachometer adapter, Fig. 12-16, can be inserted in the drive shaft end. The adapter end is inserted into a reamed hole in the end of the governor drive shaft and has a friction fit.

MAINTENANCE

The governor drive assembly normally does not require servicing except at the time of general engine overhaul or reconditioning. At this time or when conditions warrant, the governor drive assembly should be removed and parts inspected and checked. After removal of the governor, the governor drive assembly can be easily removed. A mounting dowel correctly positions the governor drive housing on the accessory drive cover.

After the governor drive assembly has been removed and disassembled, visually inspect the bushing bores and thrust faces for flaking, imbedded dirt, chipping, or scoring. Bushings that are chipped or flaked or have large quantities of imbedded dirt should be replaced with new bushings. Check oil passages in the housing to be sure they are free of restrictions. Inspect bevel gears for nicks, pitting, or visible wear on the loaded tooth faces. Nicks, burrs, or any high spots should be stoned out or the gears replaced. If it is necessary to replace a gear, it is recommended that both gears be replaced as a set. Check individual parts and assembly to be sure dimensions are within limits given in Service Data.

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SERVICE DATA
GOVERNOR

PGR GOVERNOR SETTING AND ADJUSTMENT TABLES

SPEED SETTINGS -- TABLE A

Adjustment Sequence	Adjust	Throttle Position	Speed (RPM)		Solenoid Energized			
			Eng.	Gov.	A	B	C	D
		STOP						
14	C	LOW IDLE	255±4	278±4				"
5	A	IDLE	318±4	347±4	*			*
		1	318±4	347±4				
		2	388±15	423±15	*			
		3	497±15	542±15			*	
3	B	4	570±4	621±4	*		*	
		5	566±15	714±15	*	*	*	
1	FULCRUM NUT	6	730±4	796±4	*	*	*	*
		7	829±15	904±15		*	*	
2	D	8	904±4	985±4	*	*	*	

+If governor is being adjusted on a locomotive without a low idle panel, place throttle to position 2 and adjust "C" solenoid to obtain throttle 2 engine RPM.

NOTE: Governor PRM is provided for use with test stands calibrated in governor speeds instead of engine speeds.

PILOT VALVE
TABLE B

Governor	Throttle Position	Injector Rack Length In.	Pilot Valve Position	Air Pressure H mm	g Abs. In.
8483536	8 Idle	.83 1.75	Balance Max. Fld.	1460 Atmospheric	57.5 Atmospheric
9322619	8 Idle	.87 1.75	Balance Max. Fld.	1575 Atmospheric	62.0 Atmospheric

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FUEL LIMITER
TABLE C1

Governor	Throttle Position	Engine Speed	Absolute Pressure		Limiting Point
			mm Hg	In. Hg	In.
8483536	8	904±4	1460	57.5	.75
9322619	8	904±4	1575	62.0	.79

TABLE C2

8483536	8	904±4	1067	42.0	.96±.02
9322619	8	904±4	1067	42.0	1.02±.02

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

GOVERNOR DRIVE ASSEMBLY

Bushing bore diameter (as assemblied in housing) - Max. .... 47.739 mm (1.8795")
Distance between bushing thrust faces - Min. .... 47.42 mm (1.867")
Diameter of drive shaft journal - Min. .... 47.536 mm (1.8715")
Governor drive shaft thrust face to shoulder - Max. .... 47.73 mm (1.879")
Driven gear thrust face to shoulder - Max. . . . . 47.78 mm (1.881 ")
Diameter of driven shaft journal - Min. .... 47.536 mm (1.8715")
Bevel gear backlash - Max. .... 0.33 mm (.013")
Thrust clearance .... Limit is governed by gear backlash

EQUIPMENT LIST

	Part No.
Hand tachometer (Mechanical)	8107967
Controller adapter (use with 8227463 and 8469431)	8210156
Tachometer drive adapter	8210556
Rotary shaft bearing remover-installer	8225658
Rotary shaft oil seal driving rod	8225659
Rotary shaft oil seal remover	8225660
Engine speed controller (use with 8210156 and 8469431)	8227463
Solenoid adjustment wrench (PGR)	8343447
Governor adapter (use with 8210156 and 8227463)	8469431
Hand tachometer (Digital) ....,,,,,,,,,,,,,,,,.	9319424

MATERIAL SPECIFICATIONS

Governor oil M.1. 1764

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SECTION 13

PROTECTIVE DEVICES

CONTENTS PAGE

CONTENTS	PAGE
LOW OIL PRESSURE SHUTDOWN	13-1
DIFFERENTIAL WATER & CRANKCASE PRESSURE DETECTOR	
DESCRIPTION	13-1
MAINTENANCE	13-2
OVERSPEED TRIP	
DESCRIPTION	13-3
MAINTENANCE	13-4
ADJUSTING SPRING TENSION	13-5
HOT OIL SHUTDOWN	13-5
SERVICE DATA	
SPECIFICATIONS	13-7
EQUIPMENT LIST	13-7

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

SECTION 13

PROTECTIVE DEVICES

GENERAL

This section contains the description and maintenance information for engine protective devices. These devices are designed to shut down the engine in the event of a malfunction occurring during engine operation.

LOW OIL PRESSURE SHUTDOWN

DESCRIPTION

The low oil pressure shutdown plunger, Fig. 13-I, is part of the low oil pressure shutdown device, which is contained in the governor. Although it is a protective device it is not an accessory to the engine. Refer to Section 12 for description and maintenance of the low oil pressure shutdown device.

Fig. 13-1 - Low Oil Pressure Shutdown Plunger

DIFFERENTIAL WATER AND CRANKCASE PRESSURE DETECTOR ASSEMBLY

DESCRIPTION

The combination differential water and crankcase pressure detector, Fig. 13-2, is a mechanically operated, pressure-sensitive device used to determine abnormal conditions of the engine cooling system and crankcase pressures. If potentially harmful conditions exist, this protective device will cause engine shutdown.

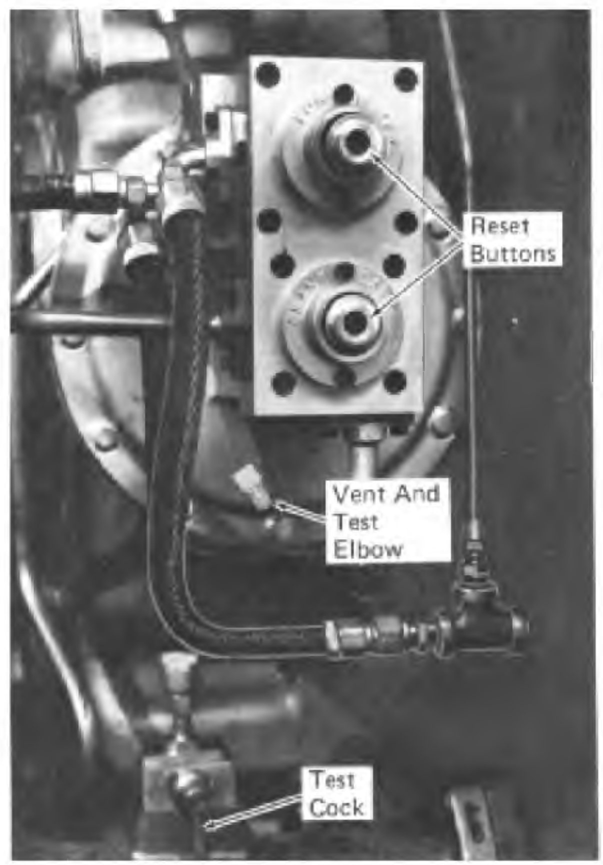

Fig. 13-2 - Differential Water And Crankcase Pressure Detector Installation

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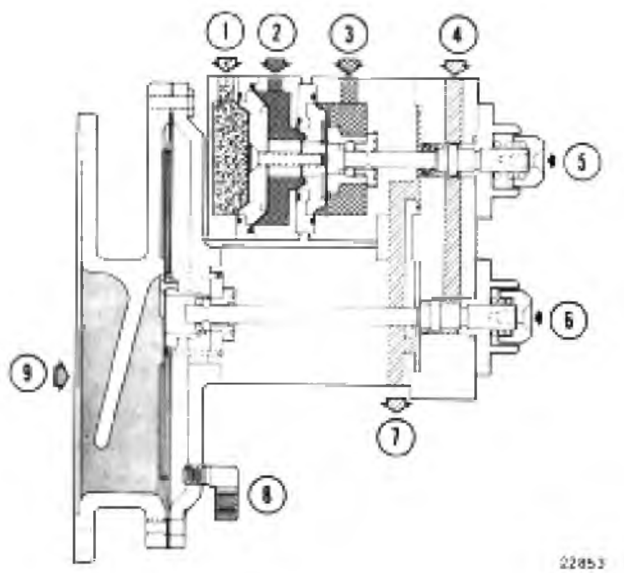
The water pressure portion of the detector balances the differential pressure of the water pump output and the water pump input against the air box pressure to hold an oil relief valve in the latched position. When the differential pressure across the water pump becomes less than the air box pressure, Fig. 13-3, the diaphragm moves causing the oil drain valve to open and dump engine oil from the low oil sensing device in the governor. The governor senses low oil pressure and initiates low oil shutdown. Bleed holes are provided between the pump inlet and outlet diaphragms and the pump inlet and air box diaphragms to visually indicate a leak. This device provides protection against water pump cavitation, which can result from low coolant level, excessive coolant temperature, exhaust gases in the cooling system, or several other cooling system failures. The water portion of the detector will trip whenever the cooling system is drained.

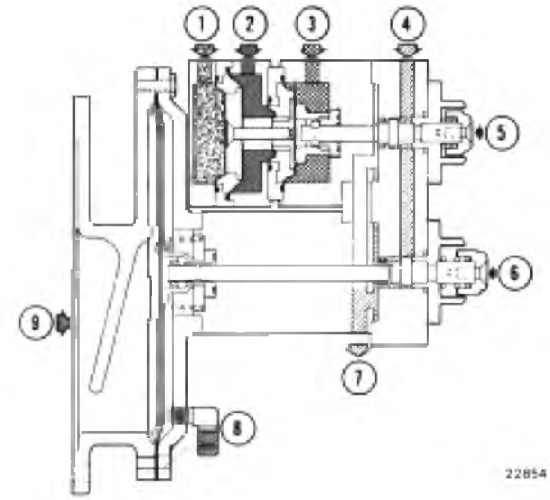
NOTE: To latch the water portion, the engine must be running and the cooling system vented.



1 Water Pump Discharge Pressure
2 Water Pump Inlet Pressure
3 Air Box Pressure
4 Oil In From Governor
5. Trip Position
6. Latch Position
7. Oil Return To Crankcase
8. Vent Elbow
9. Crankcase Pressure Negative

Fig. 13-3 - Low Differential Water Pressure Condition

The crankcase pressure portion of the device consists of an oil relief valve, comparable to the one in the water portion, held in a latched position until a positive pressure is built up in the crankcase. The oil relief valve is released and lube oil pressure to the engine governor is relieved, Fig. 13-4. As in the water portion, the governor senses low oil pressure and initiates engine shutdown.



1. Water Pump Discharge Pressure
2 Water Pump Inlet Pressure
3 Air Box Pressure
4 Oil In From Governor
5 Latch Position
6 Trip Position
7 Oil Return To Crankcase
8 Vent Elbow
9 Crankcase Pressure Positive

Fig. 13-4 -- Positive Crankcase Pressure Condition

WARNING: Following an engine shutdown because the engine pressure detector has been actuated, do NOT open any handhole or top deck covers to make an inspection until the engine has been stopped and allowed to cool off for at least two hours. Do NOT attempt to restart the engine until the cause of the trip has been determined and corrected. The action of the pressure detector indicates the possibility of a condition within the engine, such as an overheated bearing, that may ignite the hot oil vapors with an explosive force, if air is allowed to enter. If crankcase pressure detector can not be reset, do NOT operate the engine until the detector has been replaced, since the diaphragm backup plates may be damaged.

MAINTENANCE

The differential water and crankcase pressure detector should be tested periodically to ensure proper operation.

A test valve, Fig. 13-5, is installed in the water pump outlet line to the water safety portion and provides a means of manually dumping the water pressure on the diaphragm and, in turn, provides a check on the tripping action of the water detector. By rotating the test valve handle to the horizontal position, the discharge of coolant from the small orifice hole in the valve should be a steady flow. Because of contaminants in the coolant, the small orifice in the

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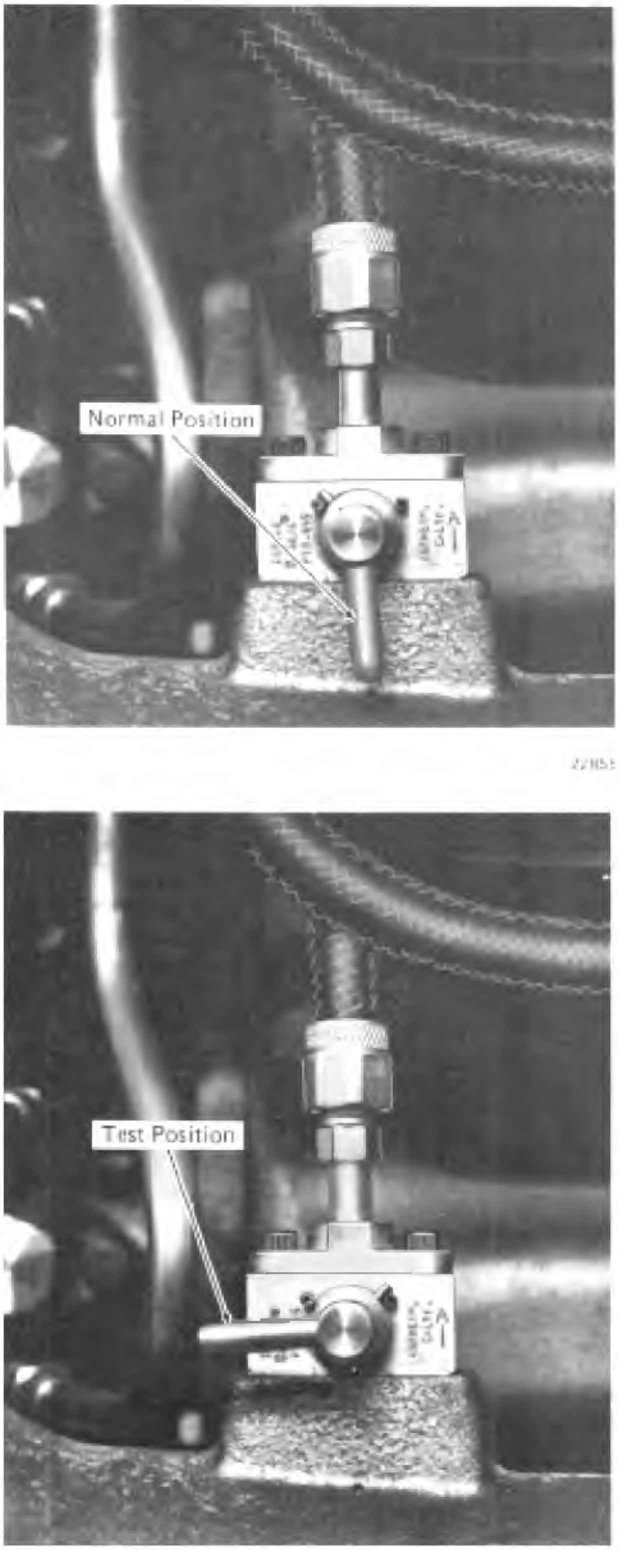

Fig. 13-5 - Test Valve Positions

valve may become plugged, reducing or restricting the bleed off of pressure on the diaphragm. In most cases, rapidly opening and closing the test valve a few times will dislodge the obstruction and allow the water detector to trip. Plugging of the test valve in no way affects the operation of the water device. With the engine running at idle speed, opening the test valve and obtaining a free flow of coolant, should trip the device on the first or second try. If the device does not trip, the device should be taken off and checked on a test panel to determine the cause of malfunction. It is recommended that the operation of the water detector be checked monthly with the test valve. Test valve handle must be returned to vertical position, Fig. 13-5, before starting engine.

To test the crankcase pressure portion without starting the engine, use a hydrometer bulb, tocreate a suction on the vent elbow. This should trip the reset stem, as it simulates a positive pressure being applied to the opposite side of the diaphragm.

CAUTION: Diaphragm can be damaged by applying a positive pressure through vent tube. Exhaust air from bulb before testing.

If this test is unsatisfactory, repeat the test. If the detector still does not trip, replace the detector. The pressure detector can also be tested by using a hand operated vacuum pump. Connect the vacuum pump to a tee in a line between the vent elbow and a water manometer. Operate the pump slowly until the detector trips. Reset the detector and repeat the procedure, checking the manometer for tripping pressure. See the Service Data for limits.

OVERSPEED TRIP

DESCRIPTION

An overspeed mechanism is provided as a safety feature to stop the injection of fuel into the cylinders should the engine speed become excessive.

Fig. 13-6 shows the mechanical ovespeed trip mechanism. If the engine speed should increase to the specified limits, the overspeed mechanism will shut down the engine.

A trip shaft extending the length of each engine bank under the camshaft is provided with a cam at each cylinder, which when rotated, contacts a spring-loaded catch pawl mounted on each cylinder head, and located directly under the injector rocker arm. In the overspeed trip housing on the front of the engine, the trip shafts are connected to springoperated links and a lever mechanism. A reset lever on the trip lock shaft, when pulled towards the right bank, puts tension on an

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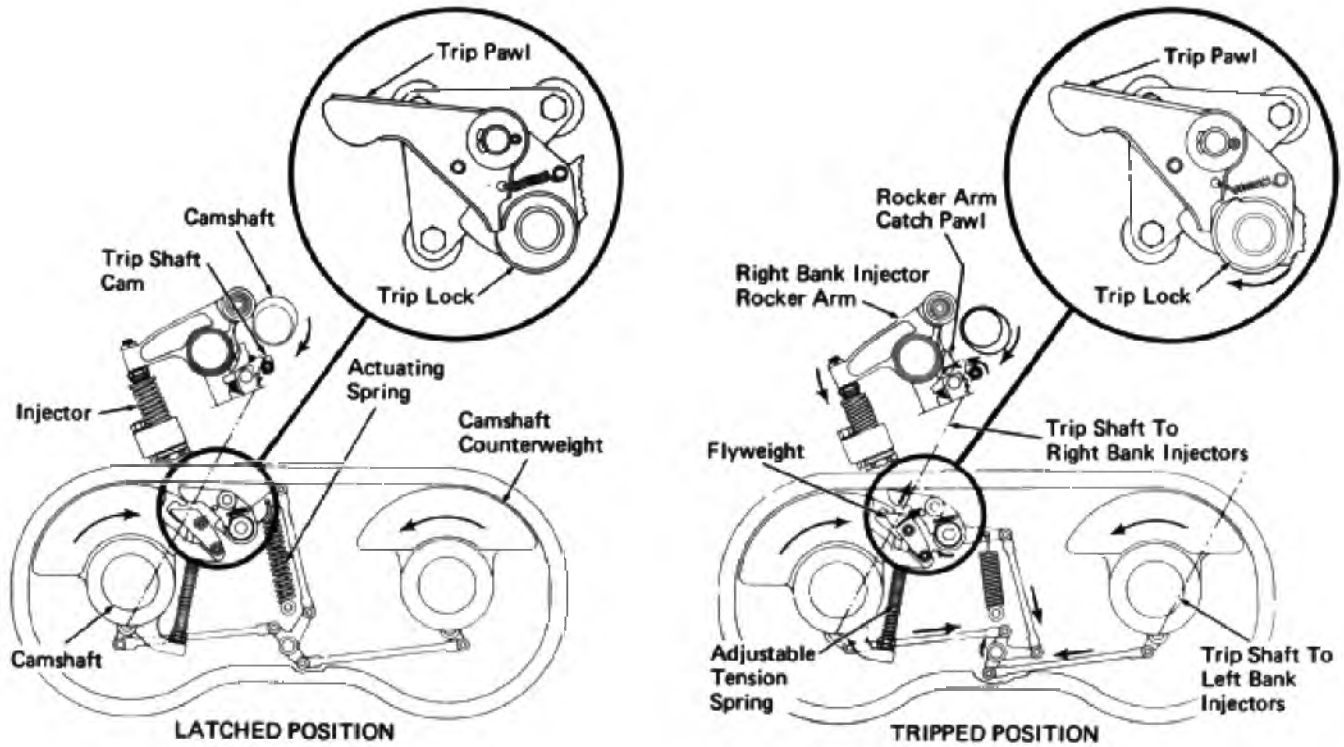

Fig. 13-6 - Overspeed Trip

actuating spring; this tension being held by a trip pawl engaging a notch in the trip lock lever shaft. This is the normal running position, in which the cams on the trip shaft are held away from the rocker arm catch pawls.

The overspeed trip release mechanism is incorporated in the right bank front camshaft counterweight. It consists of a flyweight held by an adjustable tension spring. When engine speed exceeds the set limit, the tension of the spring is overcome by the centrifugal force acting on the flyweight, causing the flyweight to move outward to contact the trip pawl. This allows the actuating spring, acting through connecting links, to rotate the trip shafts. Consequently, the trip shaft cams contact and raise the injector rocker arm pawls preventing full effective injector rocker arm roller contact on its cam. This prevents fuel injection and stops the engine.

Upon resetting, by counterclockwise movement of the reset lever, Fig. 13-7, the trip shaft cams release the injector rocker arm catches. Rotation of the camshafts on starting the engine lift the rocker arms slightly allowing the catch pawls to resume unlatched position, releasing the injector rocker arm for normal operation.

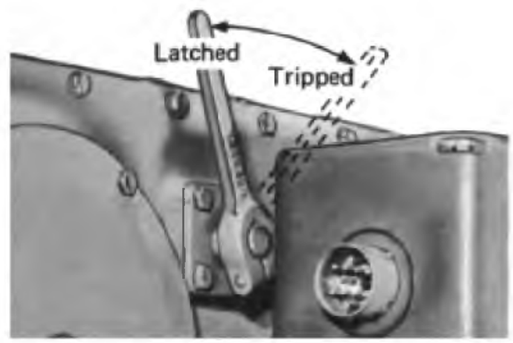

Fig. 13-7 - Reset Lever Positions

MAINTENANCE

DRAIN SLEEVE REMOVAL

Lubricating oil from the overspeed trip housing drains into the top of the accessory drive housing through two removable cast aluminum drain sleeves, Fig. 13-8. Each sleeve has two rubber O-ring seals.

If oil leakage is detected between the housings, the sleeves should be removed and the O-ring seals replaced as follows:

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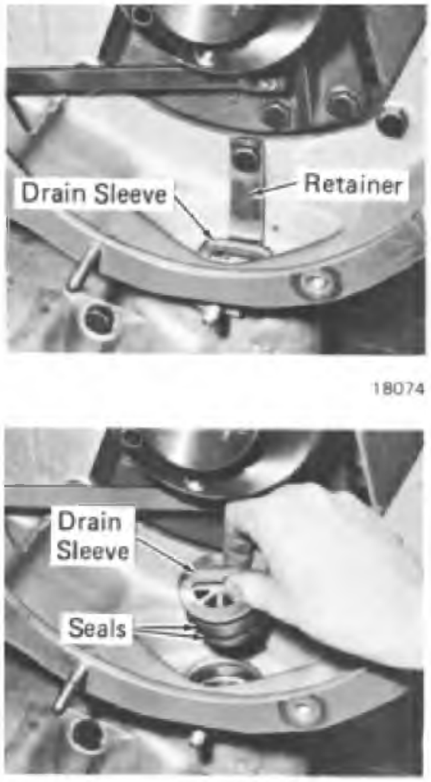

Fig. 13-8 - Overspeed Trip Housing Drain Sleeves

1. Remove the overspeed trip housing cover.

2. Bar over the engine until the counterweights are positioned at the top of the engine.

3. Remove the bolt and steel retainer strap, Fig. 13-8, holding the sleeve.

4. Using a suitable pry bar, insert under sleeve handle, and carefully remove sleeve from housing. Remove seals and clean sleeves.

5. Install seal marked with red dot in upper groove of sleeve and unmarked seal in lower groove.

6. Apply film of oil on seals and sleeve and install sleeve, bolt, and retainer strap.

ADJUSTING MECHANICAL OVERSPEED TRIP

To adjust the overspeed trip, shut engine down, remove the cover from right side of overspeed trip housing and turn adjusting nut, Fig. 13-9, to increase or decrease spring tension as required. To increase engine speed at which overspeed trip operates, increase spring tension.

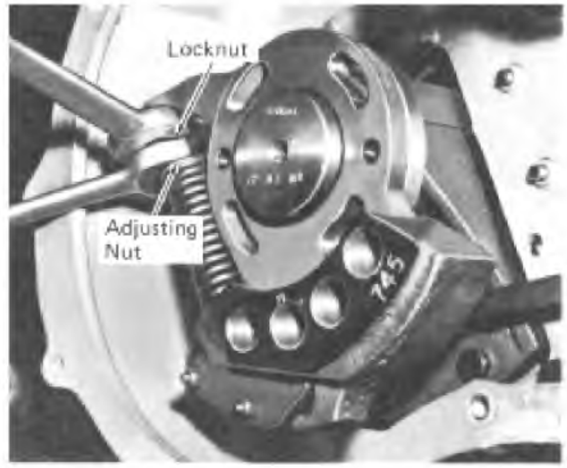

Fig. 13-9 - Overspeed Trip Adjusting Nut

After the adjusting nut has been moved, the locknut must be tightened and the engine run to test speed at which trip operates. The speed rise of the engine from idle to trip should be made in 20 to 30 seconds. Several adjustments may be required before final setting of tripping speed is reached.

HOT OIL SHUTDOWN

DESCRIPTION

The hot oil shutdown device, Fig. 13-10, consists of a thermostatic valve and the associated piping.

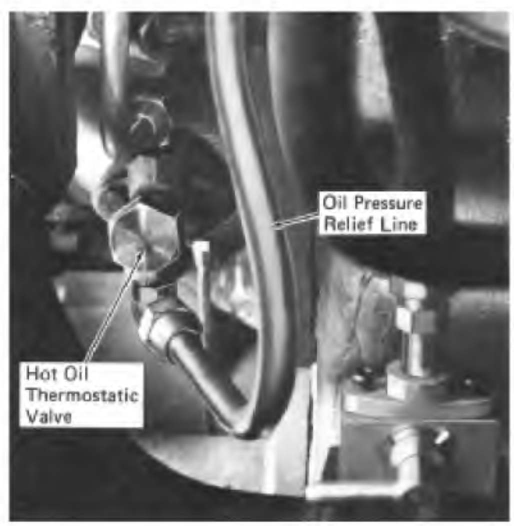

Fig. 13-10 -Hot Oil Shutdown Installation

The valve is located in the discharge elbow of the main lube oil pump. Piping from the valve is connected into the oil pressure line between the

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differential water and crankcase pressure detector and the governor. There is also drain line piping from the valve to the governor drive housing.

When oil temperature rises to 124°-126° C (255°260° F), the thermostatic valve will open and the pressure oil is allowed to pass through the valve and drain into the governor drive housing. The governor senses the resultant low oil pressure, and initiates an engine shutdown.

MAINTENANCE

The thermostatic valve should be removed and tested at intervals specified in the applicable Scheduled Maintenance Program.

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SERVICE DATA
PROTECTIVE DEVICES

SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Differential Water and Crankcase
Pressure Detector

Water Portion

Tripping pressure - (With no pressure on the water chambers, increase air box pressure from zero to tripping pressure.)

*New - Min. . . . . 508 mm (20") H_2O
Used - Min. . . . . 762 mm (30") H_2O

Crankcase portion

Tripping pressure -

*New . . . . 20.32-45.72 mm (.8"-1.8") H_2O
Used . . . . 20.32-76.20 mm (.8"-3.0") H_2O

*Meaning new or rebuilt devices with less than 3 months service.

Overspeed Trip

Clearance, trip latch to flyweight - Min. . . . . 0.25 mm (.010")
Trip setting . . . . 990-1005 RPM

EQUIPMENT LIST

	Part No.
Hydrometer bulb	8140866
Test panel	9339066
Vacuum pump	8470956

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SECTION 14

STARTING SYSTEM

CONTENTS PAGE

CONTENTS	PAGE
DESCRIPTION	14-1
MAINTENANCE	14-2
INSPECTION	14-2
STARTING MOTOR TESTS	14-2
DISASSEMBLY	14-3
CLEANING	14-4
ARMATURE SERVICING	14-4
FIELD COIL CHECKS	14-5
FIELD COIL REMOVAL	14-5
ASSEMBLY	14-5
PINION CLEARANCE	14-6
SERVICE DATA	
SPECIFICATION	14-7
EQUIPMENT LIST	14-7

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ELECTRO-MOTIVE

ENGINE MAINTENANCE MANUAL

SECTION 14

STARTING SYSTEM

DESCRIPTION

The system consists of dual starting motors with heavy duty sprag drives associated electrical wiring and controls. The dual starting motors are mounted one above the other and bolted to a bracket assembly which, in turn, is attached to the rear end plate of the engine, Fig. 14-1. The flywheel pointer is bolted on the face of the bracket assembly.

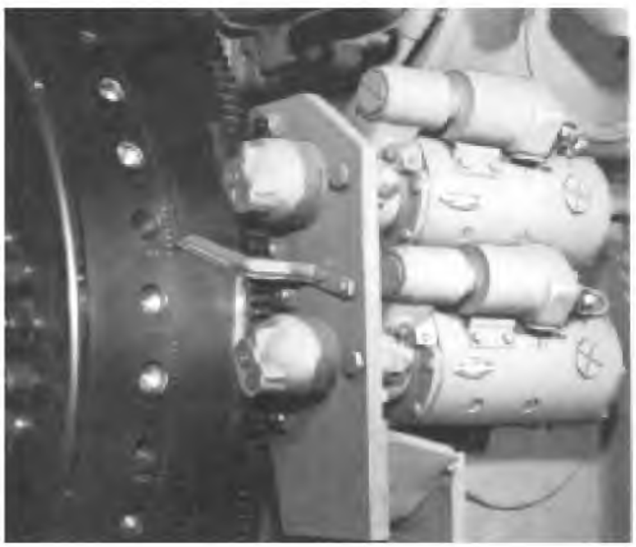

Fig. 14-1 - Typical Dual Electric Starting Motor Application

When the electrical engine starting sequence is initiated, the actuating solenoid is energized. The solenoid plunger is drawn into the solenoid and the bottom arm of the connecting linkage pushes the clutch to engage the pinion gear with the ring gear which is mounted on the engine flywheel. The pinion gear will remain engaged until the start switch is released.

If the pinion to ring gear engagement is properly made, the solenoid plunger will have moved to the full extent of its travel. Near the end of its travel, the solenoid plunger closes contacts within the solenoid housing. This initiates control circuits to energize an auxiliary starting contactor, which permits the starting motor to crank the engine.

CAUTION: Do not operate starting motors more than 20 seconds at a time, and allow a 2 minute cooling period before repeating starting procedures. Overheating, caused by excessive cranking, will seriously damage the motors.

The heavy duty sprag drive of each motor, Fig. 14-2, provides the physical connection between the motor and the ring gear. To prevent damage to the ring gear, a positive engagement feature of the sprag drive ensures that power is not applied to the ring gear until the pinion gear is meshed with the ring gear.

Fig. 14-2 - Starting Motor

The starting motor solenoid, through the shift lever linkage, pushes the pinion gear toward the ring gear. If tooth abutment occurs between the pinion gear and the ring gear, a spiral spline on the pinion gear sleeve is pushed through the pinion gear, causing the gear to rotate. This permits meshing of the pinion gear and ring gear before power is applied.

The torque required to turn the engine over is carried through the sprag sections located between two concentric races inside the drive. The upper and lower surfaces of each sprag are curved and offset from each other so that, when the sprag rotates in one direction, its radial height increases.

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When the sprag rotates in the opposite direction, its radial height decreases. While the motor armature is driving the engine, the frictional forces between the contacting surfaces of the sprags and races cause the sprags to go toward their maximum radial height. This wedges the sprags between the two races and transmits the torque from the motor armature to the engine. As the engine starts, the pinion gear is forced by the engine to rotate faster than the armature. The frictional forces now acting upon the sprags cause them to decrease their radial height and prevent the engine from driving the motor armature.

Positive lubrication is provided to the bushings in the commutator end frame, the shift lever housing, and the nose housing by an oil saturated wick which projects through each bushing and contacts the armature shaft.

MAINTENANCE

Under normal operating conditions, no maintenance should be required other than that suggested in the applicable Scheduled Maintenance Program.

INSPECTION

At periodic intervals, the starting motor should be inspected to determine its condition. The response of the motor during engine start will indicate whether or not inspection and maintenance is required. In addition to an operational check, the following conditions should be noted.

1. heck that the starter solenoid mounting bolts are secure and terminals are in good condition. If the solenoid switch is defective, it should be replaced as an assembly.

2. emove the brush inspection plugs and check the commutator, brushes, and internal wiring. Check for evidence of solder thrown from the commutator.

If the commutator shows signs of surface roughness or high mica and thrown solder, it will be necessary to remove it from the motor for maintenance. Glazing on the commutator can be removed by holding a strip of "00" sandpaper against the commutator with a piece of wood while operating the motor for a few seconds. Inspect the brushes to make sure they are not binding, and that they are positioned against the commutator with enough tension to provide good contact. Check the brush leads, screws, and brush holders for condition and security. If the brushes are worn to 1 / 2 their original (new) length, they should be replaced.

STARTING MOTOR TESTS

NOTE: In some locomotive applications, the starting motors are 32V and are connected in series. In other locomotive applications, the starting motors are 64V and are connected in parallel. Where test procedures differ, the application (32V of 64V) will be shown. Where procedures are the same for both types, the application will not be shown.

To obtain full performance data on a starting motor, or to determine the cause of abnormal operation, the starting motor should be subjected to the following tests. These tests are performed with the starting motor removed from the engine. Failure of the starting motor to perform according to published specifications will require disassembling the motor for further checks and adjustments.

With the starting motor removed from the engine, the armature should be checked for freedom of operation by turning the drive. Tight, dirty, or worn bearings, bent armature shaft or loose pole shoe screw will cause the armature to drag. If the armature does not turn freely (though some brush drag is normal), the motor should be disassembled without further testing. If, however, the armature does operate freely, the motor should be tested electrically before disassembly.

NO LOAD TEST

Connect the starting motor in series with a DC power source, an ammeter capable of reading several hundred amperes, and a variable resistance, as shown in Fig. 14-3. Also connect a voltmeter from the motor terminal to the motor frame. An RPM indicator is necessary to measure armature speed. Proper voltage can be obtained by varying resistance.

32V MOTOR

Run the motor free at 30 volts for a maximum period of 30 seconds. Speed should be 5300-7700 RPM. Current should be 70-105 amperes.

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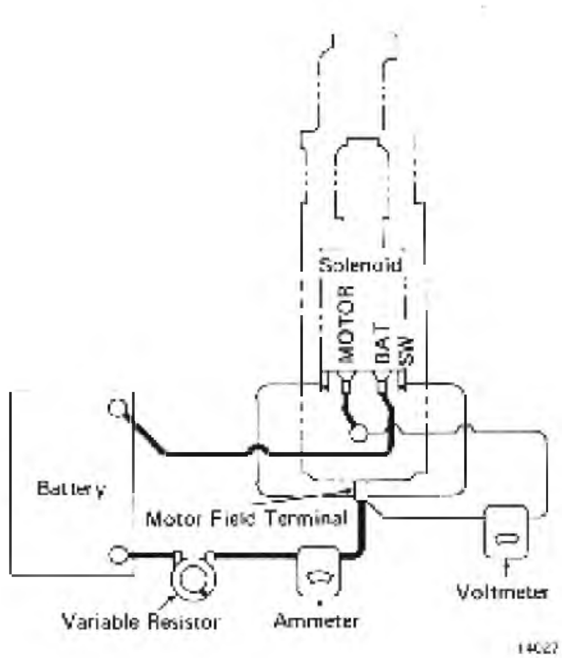

Fig. 14-3 - Motor Test Circuit

64V MOTOR

Run the motor free at 30 volts for a maximum period of 30 seconds. Speed should be 5300-7700 RPM. Current should be 60-95 amperes.

TEST INDICATIONS

1. Rated current draw and no-load speed indicates normal condition of the starting motor.

2. Low free speed and high current draw indicate:

   a. Too much friction. Tight, dirty, or worn bearings, bent armature shaft, or loose pole shoes allowing armature to drag.

   b. Shorted armature. This can be further checked on a growler after disassembly.

   c. Grounded armature or fields. Check further after disassembly.

3. Failure to operate with high current draw indicates:

   a. A direct ground in the terminal or fields.

   b. "Frozen" bearings. This should have been determined by turning the armature by hand.

4. Failure to operate with no current draw indicates:

   a. Open field circuit. This can be checked after disassembly by inspecting internal connections and tracing circuit with a test lamp.

   b. Open armature coils. Inspect the commutator for badly burned bars after disassembly.

   c. Broken brush springs, worn brushes, high insulation between the commutator bars or other causes which would prevent good contact between the brushes and commutator.

5. Low no-load speed and low current draw indicate:

   High internal resistance due to poor connections, defective leads, dirty commutator and causes listed under Step 4.

6. High free speed and high current draw indicate shorted fields. If shorted fields are suspected, replace the field coil assembly and check for improved performance.

DISASSEMBLY

SOLENOID ASSEMBLY REMOVAL

1. Disconnect motor terminal lead from solenoid terminal, Fig. 14-4.

2. Remove plug from lever housing to expose nut securing plunger and spring assembly to shift lever.

3. Remove four screws holding solenoid assembly to field frame and remove solenoid.

4. Remove nut from plunger by holding large end of plunger which was separated from solenoid housing.

DRIVE CLUTCH REMOVAL

1. Mark position of nose housing in relation to lever housing and remove the six screws securing nose housing to lever housing.

2. Remove nose housing being careful not to damage shaft bushing.

3. Remove clutch assembly by pulling from armature shaft.

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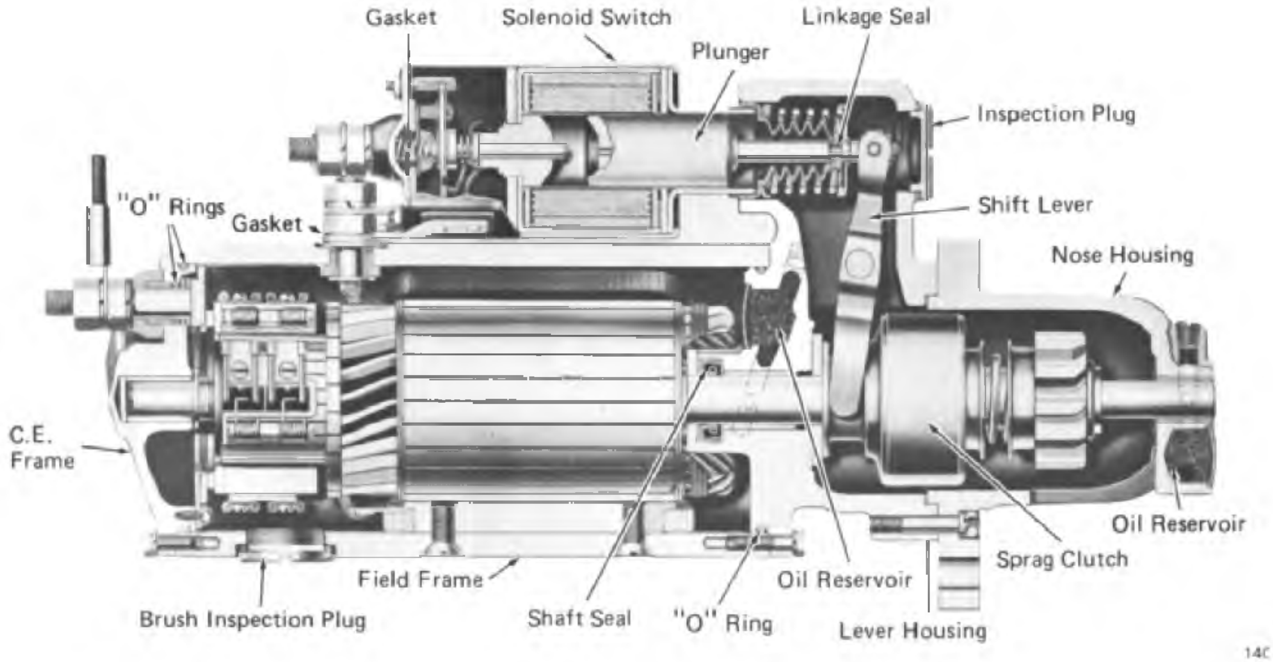

Fig. 14-4 - Typical Electric Starting Motor, Cross-Section

ARMATURE REMOVAL

1. Mark the relative position of lever housing and C.E. frame to the field frame.
2. Remove seven screws securing lever housing to frame. Carefully remove lever housing and armature from field frame. Note condition of oil seal, bushing, and "O" ring at frame contact area.

C.E. HOUSING REMOVAL

1. Remove three brush inspection plugs and remove brush lead screws. This will also disconnect the field leads to brush holders.
2. Remove six screws securing C.E. frame to field frame and remove C.E. frame. Note condition of bushing and "O" ring at frame contact area.

CLEANING

The overrunning clutch, armature, and fields should not be cleaned in any degreasing tank or with grease dissolving solvents, since these would dissolve the lubricant in the clutch mechanism and damage the insulation in the armature and field coils. All parts except the clutch should be cleaned with oleum spirits and a brush. The clutch can be wiped with a clean cloth.

If the commutator is dirty, it may be cleaned with No. 00 sandpaper. NEVER USE EMERY CLOTH TO CLEAN COMMUTATOR.

ARMATURE SERVICING

If the armature commutator is worn, dirty, out of round, or has high insulation, the armature should be put in a lathe so the commutator can be turned down. The insultation should then be undercut 0.79 mm (1 / 32") wide and 0.79 mm (I / 32") deep, and the slots cleaned out to remove any trace of dirt or copper dust. As a final step in this procedure, the commutator should be sanded lightly with No. 00 sandpaper to remove any burrs left as a result of the undercutting.

The armature should be checked for opens, short circuits, and grounds as follows:

1. Opens - Opens are usually caused by excessively long cranking periods. The most likely place for an open to occur is at the commutator riser bars. Inspect the points where the conductors are joined to the commutator bars for loose connections. The poor connections cause arcing and burning of the commutator bars as the starting motor is used. If the bars are not too badly burned, repair can often be effected by welding the leads in the riser bars and turning down the commutator in a lathe to removes the burned material. The insulation should then be undercut.

2. Short circuits - Short circuits in the armature are located by use of a growler. When the armature is revolved in the growler with a steel strip such as a hacksaw blade held above it, the blade will

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vibrate above the area of the armature core in which the short circuit is located. Shorts between bars are sometimes produced by brush dust or copper between the bars. These short can be eliminated by cleaning out the slots.

3. Grounds -- Grounds in the armature can be detected by the use of a 110-volt test lamp and test points. If the lamp lights when one test point is placed on the commutator with the other point on the core or shaft, the armature is grounded. Grounds occur as a result of insulation failure which is often brought about by overheating of the starting motor produced by excessively long cranking periods or by accumulation of brush dust between the commutator bars and the steel commutator ring. If any of these conditions can not be corrected, the armature must be replaced.

FIELD COIL CHECKS

The field coils can be checked for grounds and opens by using a test lamp. See Fig. 14-5 for applicable wiring diagram.

1. Grounds -- Connect one lead of the 110-volt test lamp to the field frame and the other lead to the field connector. If the lamp lights, at least one field coil is grounded and must be repaired or replaced.
2. Opens -- Connect test lamp leads to ends of field coils. If lamp does not light, the field coils are open.

FIELD COIL REMOVAL

Field coils can be removed from the field frame assembly by using a pole shoe screwdriver. A pole shoe spreader should also be used to prevent distortion of the field frame. Careful installation of the field coils is necessary to prevent shorting or grounding of the field coils as the pole shoes are tightened into place. Where the pole shoe has a long lip on one side and a short lip on the other, the long lip should be assembled in the direction of armature rotation so it becomes the trailing (not leading) edge of the pole shoe.

ASSEMBLY

To assemble the motor, proceed as follows:

1. Lubricate armature bearings in commutator end frame, shift lever housing, and nose housing with SAE No. 10 oil, Fig. 14-4.

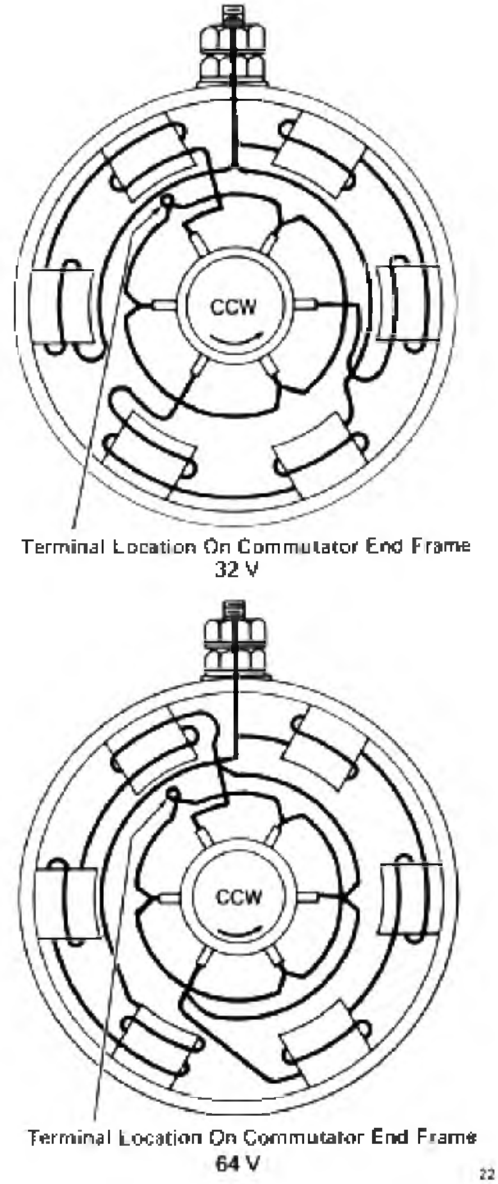

Fig. 14-5 --Wiring Diagrams

2. Install armature into field frame assembly.
3. Assemble the commutator end frame to the field frame by pulling the armature out of the field frame just far enough to permit the brushes to be placed over the commutator.

   Push the commutator end frame and the armature in until the end frame mates with the field frame, being sure the "O" rings are in place. Install and tighten the six screws that hold the end frame to the field frame.

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4. Connect the field and brush leads and install the three brush inspection plates.

5. Mate the lever housing to the field frame being sure the locating marks are aligned and the "O" rings are in place. Install and tighten the seven screws which hold the lever housing to the field frame.

6. Apply a thin coating of SAE No. 10 oil to the armature shaft splines and the mating clutch assembly splines, and also to the clutch assembly spiral splines and the mating piston gear splines.

7. Apply grease to the two bushings in the clutch assembly bore.

8. Install the clutch assembly and nose housing to the lever housing being sure the two housings are aligned as they were before disassembly. Install the six screws and tighten to 18-23 N-m (13-17 ft-Ibs) torque.

9. Insert solenoid assembly in lever housing. Connect plunger and shift lever by screwing nut on plunger shaft.

10. Install four screws, which hold solenoid assembly to field frame, and connect the motor field terminal lead to solenoid terminal "SW." The inspection plug in the lever housing can be left out until the pinion clearance is adjusted.

11. Add SAE No. 10 oil to each wick lubricator by removing plugs on the outside of the motor for the three lubricating points.

PINION CLEARANCE

Check pinion clearance after assembly of motor to make sure the clearance is within Limits. Refer to Fig. 14-6.

NOTE: The pinion must be held in cranking position electrically, utilizing the solenoid hold-in coil, to achieve proper relationship of pinion, solenoid shaft, and contact disc.

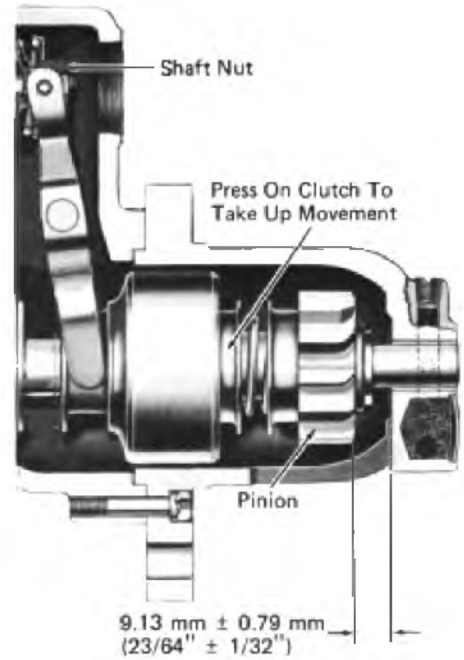

Fig. 14-6 - Checking Pinion Clearance

To check pinion clearance, follow the steps listed below:

1. Disconnect the lead, connecting the solenoid switch "SW" terminal to the motor field terminal, at the motor field terminal.

2. Connect a battery, of the same voltage as the solenoid, from the solenoid battery "BA"I" terminal to the unnamed flat terminal on the solenoid. This will energize the solenoid hold-in coil.

3. Momentarily flash the lead from the solenoid switch "SW" terminal to the solenoid unnamed flat terminal. The pinion will now shift into cranking position and remain so until the battery is disconnected.

4. Push the pinion back toward the commutator end to eliminate slack movement.

5. Measure the distance between pinion and pinion stop. This should be 9.13 mm ±0.79 mm (23/64" ± 1/32"). To adjust pinion clearance, the plug is removed from the solenoid linkage portion of the lever housing, and the solenoid shaft nut is turned until proper pinion adjustment is achieved.

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SERVICE DATA
STARTING SYSTEM

SPECIFICATION

Clearance and dimensional limits listed below are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)

2. Minimum, maximum, and tolerance measurements are provided as service limits. At time of rebuild or any time unscheduled maintenance is performed, the service limits should not be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul.

Starting Motor

Commutator Diameter -

New	58.62-58.88 mm (2.308"-2.318")
Min.	55.45 mm (2.183")
Mica groove depth	0.64-0.81 mm (.025"-.032")
Mica groove width	0.76 mm (.030")
Parallelism of pinion and ring gear teeth	0.051 mm (.002')
Backlash between ring gear and starter pinion	0.38-1.02 mm (.015"-.040")
Brush spring tension (with new brush)	2.04-2.27 kg (4-1/2-5 lbs)

EQUIPMENT LIST

	Part No.
Ductor ohmmeter	8068118
Insulation resistance tester	8174880
Brush spring tension scale	8415805

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SECTION 15

TROUBLESHOOTING

CONTENTS PAGE

CONTENTS	PAGE
ENGINE TROUBLESHOOTING	15-1
ENGINE STARTING SYSTEMS	15-1
FUEL SYSTEMS	15-4
LUBRICATING OIL SYSTEMS	15-5
COOLING SYSTEM	15-12
ENGINE PERFORMANCE	15-14
INJECTOR PRESSURE TEST	15-24
EXHAUST VALVE TIMING	15-24
ADJUSTING HYDRAULIC LASH ADJUSTERS	15-27
TIMING THE INJECTOR	15-28
ONE REVOLUTION INSPECTION SEQUENCE CHARTS	15-30
GOVERNOR	
TROUBLESHOOTING	15-39
TURBOCHARGER TROUBLESHOOTING	15-45

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ENGINE MAINTENANCE MANUAL

SECTION 15

TROUBLESHOOTING

This troubleshooting section is divided into three parts. The first part, ENGINE TROUBLESHOOTING, is intended as a general guide for troubleshooting all 645 engines. Within the context of this general guide, particular applications are noted. The second and third parts; GOVERNOR TROUBLESHOOTING, and TURBOCHARGER TROUBLE-SHOOTING, contain information applicable only to the specific model designated on the cover of the manual.

ENGINE TROUBLESHOOTING

ENGINE STARTING SYSTEMS

STARTER WILL NOT CRANK ENGINE

If the engine fails to crank, release the starting switch immediately and perform the following steps:

1. Test for proper battery charge and inspect cable connections of control circuit batteries.

2. Check that all switches and circuit breakers in the engine control and protective circuits are properly positioned.

3. If the equipment has an Isolation switch make sure it is in the START position.

4. On a turbocharged engine, make sure that the turbocharger lube pump circuit breaker is closed.

5A. Engines with electric starting:

   a. Check that the battery switch is fully closed.

   b. Test the starting fuse for continuity.

5B. Engines with air starting:

   a. Check that the starting reservoirs are fully charged to the proper pressure and are free of water accumulation.

   b. Check that all valves in the air line to the starter motors are open.

   c. If the engine is equipped with a turbo pump or priming pump security interlock, make certain that the pump has been activated and the interlock functions properly.

When these steps have been performed, another start can be attempted. If the engine still does not crank, release the starting switch immediately and proceed to the next step.

NOTE: No further starting attempt should be made until it is determined if the engine will rotate freely. This can be done by opening all the cylinder test valves and engaging the manual barring tool.

If the engine can be barred over one complete revolution, proceed to ENGINE CRANKING PREVENTED BY STARTER MALFUNCTION. If the engine cannot be barred over one complete revolution, proceed to ENGINE CRANKING PREVENTED BY MECHANICAL OBSTRUCTION.

ENGINE CRANKING PREVENTED BY MECHANICAL OBSTRUCTION

1. Remove all air box handhole covers and perform a complete visual inspection. Look at all assemblies for broken or damaged components. Check for debris in the air box and liner port area.

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2. Remove all oil pan handhole covers and inspect for:

    a. Damaged or bent connecting rods.

    b. Damaged counterweights.

    c. Evidence of overheated main bearings and supporting "A" frames.

    d. Damage to the lower skirt of any cylinder liner.

3. Check that all piston cooling oil pipes are in place and intact. If a damaged piston cooling oil pipe is found, the related power assembly should be inspected closely for damage.

NOTE: If the engine was recently overhauled, then inspect all fork rod power assemblies for proper matching of serial numbers on the basket assemblies. A mismatched basket could result in a pinched connecting rod bearing shell.

4A. If the previous steps have not disclosed any evidence of a failure and it is not possible to rock the crankshaft back and forth, then a main bearing inspection should be performed. If the engine is turbocharged, proceed to Step 5.

4B. If the previous steps have not disclosed a failure and it is possible to rock the crankshaft back and forth, and there is no other evidence of bearing failure, then engine driven accessories and equipment should be examined for seizure. Check the air compressor for mechanical damage or loss of lubricant. Check the main generator (where applicable) for signs of bearing heating or rotor to stator contact. If both the air compressor and the main generator are in satisfactory condition, then inspect the front (accessory) and rear (auxiliary) gear trains of the engine. A failed component or gear bushing could cause the gear train to bind which might prevent the engine from cranking.

5. On turbocharged engines that cannot be barred over in the direction of normal rotation, reverse the direction of engine barring by installing the barring tool on the opposite side of the engine. If the engine can be barred over in the reverse rotation direction, then carefully inspect the turbocharger for rotor shaft binding.

NOTE: If the rotation of the turbocharger rotor is obstructed or the shaft has failed, the one-way clutch will engage, preventing engine rotation in the normal turning direction. By reversing the direction of rotation, the clutch is disengaged, which takes the turbocharger out of the system.

ENGINE CRANKING PREVENTED BY STARTER MALFUNCTION

Engine starting systems using separate electrical starting motors.

1. Establish whether or not there is voltage potential across the starting motors with the engine start switch in the START position.

2A. If voltage is present across the starter motors, then remove the starter motors and bench test in accordance with instructions in the engine maintenance manual.

2B. If voltage is not present across the starter motors, then determine whether or not the ST and STA (if so equipped) contactors have picked up.

3A. If the star starting contactor(s) has picked up, then check its internal contacts for damage, and check for loose starting cables.

3B. If the starting contactor(s) has not picked up, then trace the starting control circuit for open interlocks, or loose or broken wiring.

Engine starting systems using main generator for starting.

1. Establish if there is a voltage potential across the generator start winding terminals at the generator with the engine start switch in the START position.

2A. If voltage is present at the generator start winding terminals, examine the generator itself for damage to the bus bars connecting the starter windings, or possible loose connections to this circuit.

2B. If voltage is not present at the generator start winding terminals, determine whether or not the GS contactor has picked up.

3A. If the GS contactors has not picked up, check its internal contacts for damage, and check for loose starting cables.

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3B. If the GS contactor has not picked up, trace the starting control circuit for possible open interlocks or broken wiring.

Engine starting systems using air starters.

1. Establish if there is air pressure available at the starter(s) with the engine start switch in the START position.

2A. If air pressure is available at the starter(s), then the starter(s) should be removed and bench tested in accordance with instructions in the engine maintenance manual.

2B. If air pressure is not available at the starter(s), check the air start control valve for failure to pick up, and check for closed valves or restrictions in the starter air supply lines.

STARTER ENGAGES BUT CRANKING SPEED IS TOO SLOW TO START ENGINE

Engine starting systems using electrical starting motors.

1. Check for proper battery charge, preferably by testing each cell with a hydrometer.

2. Check battery cabling for loose connections or broken cable.

3. Check that the starting motors are of the proper voltage, and are connected correctly for the battery voltage in use.

NOTE: Installations with starter motors connected in parallel across the battery require that the starters have a voltage rating equivalent to battery voltage. Installations with starter motors connected in series across the battery (two motors) require motors which have an individual voltage rating 1/2 that of the battery. Starter motors with different operating voltage ratings are never mixed in the same installation.

Engine starting systems using main generator for starting.

1. Check for proper battery charge, preferably by testing each cell with a hydrometer.

2. Check battery cabling for loose connections or broken cable.

Engine starting systems using air starters.

1. Check that there is adequate air pressure in the reservoirs and that they are free of water accumulation.

2. Check that all air line valves are fully open. 3. Check that there is no restrictions in, or damage to the air supply lines to the starters.

ENGINE WILL NOT START WHEN CRANKED AT PROPER SPEED

1. Check that the governor low oil button is not out. Reset if necessary.

2. Check that the engine was assisted in starting by advancing the injector control lever approximately 1/4 of the total rack travel.

NOTE: If no advance of the injector control lever was made, it takes about 30 seconds of engine cranking for the governor to move the injector rack from fuel off to idle position which allows the engine to start.

3. Check the fuel supply to the cylinders by opening each cylinder test valve and cranking the engine with the injector control lever advanced. A dense spray of fuel should be emitted from each cylinder.

4A. If a dense spray of fuel is observed at each cylinder then the following steps should be performed:

a. Check for correct injector timing and rack setting.

b. Inspect air box for evidence of broken rings or cylinder scoring. Either one can cause compression loss which could prevent starting.

c. If the previous checks disclose no problems, qualify the engine valve timing by performing an exhaust valve timing check (refer to EXHAUST VALVE TIMING in this section) on both banks of cylinders (only one power assembly on each bank need be checked). If the engine is out of time, check the condition of the timing gear train by performing an idler gear check (refer to EMM).

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4B. If a dense spray of fuel is not observed at each cylinder then the following steps should be performed.

a. Check that the overspeed trip lever is not in the tripped position. Reset if necessary.

b. On units with an electric fuel pump make certain that the control and fuel pump switch is on and that fuel flow can be seen in the return fuel sight glass when the pump switch is in the "FUEL PRIME" position. If no fuel flow is seen, check for adequate fuel level in the fuel tank and possible suction leaks, or a plugged suction strainer. If fuel flow is seen in the bypass fuel sight glass, change the engine mounted fuel filters.

c. On engine driven/manual prime fuel pump installations, make sure that the system was properly primed with the hand priming pump prior to starting. If no resistance was noticed while using the hand pump, check for adequate fuel level in the fuel tank, suction leaks, a plugged suction strainer, or a jammed fuel line check valve. If extreme resistance was noticed while using the hand pump, check for plugged fuel filters.

FUEL SYSTEM

LOW FUEL OIL PRESSURE

1. Check for adequate fuel supply in main fuel or day tank.

2A. On locomotive installations and installations with engine mounted fuel sight glasses, observe the 60 psi bypass sight glass to make certain that the relief valve on the sight glass assembly was not stuck open.

2B. On other installations that have a bypass or pressure relief valve from the inlet side of the fuel filters to a tank return, check that the bypass or relief valve is not stuck open.

3. Observe pressure drop across the fuel filters. If pressure drop is near or above the changeout value given for the filters, replace the filter elements and again observe fuel pressure.

NOTE: Use only recommended filter elements.

4. Check engine oil level to determine if fuel oil might be leaking into the engine lubricating oil system. Inspect the top deck area of both cylinder banks for leakage from injectors, injector jumper lines, or top deck fuel manifolds.

5A. Installations with no return fuel sight glass or with engine driven fuel pump:

a. Inspect all suction lines for air leaks into the lines.

b. Check pipe connections and unions for proper tightness.

c. Remove and inspect the screen in the suction strainer. Clean if necessary.

d. Check that all suction piping is the recommended diameter or larger.

5B. Installations with a return fuel sight glass and electric fuel pump:

If bubbles are seen in the fuel sight glass while the engine is running, then shut the engine down, hold fuel prime/engine start switch in FUEL PRIME, and continue to observe the sight glass.

If the bubbles disappear after the engine is shut down, then the probable cause of the bubbles was an injector with tip leakage.

If the bubbles continue after the engine is shut down and the fuel prime/engine start switch is held in the FUEL PRIME position, then the probable cause is a fuel suction leak. This fuel suction leak may cause air binding of the system and loss of fuel pressure. The following steps should be followed to eliminate fuel suction leaks:

a. Inspect all pipe connections and unions in the fuel suction line for proper tightness.

b. On locomotive installations, inspect the condition and check for tightness of all piping leading in and out of the fuel tank. Clean the screen or element of the fuel suction strainer if necessary.

6. On units equipped with a fuel preheater:

a. Remove the body end caps and inspect the internal header bends for possible trapped material obstructing the flow of fuel through the heater.

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b. Inspect the supply and bypass circuits in the fuel suction lines for partially closed valves.

7. Inspect the fuel pump itself for leaks or damage. Inspect the pump drive coupling and check drive shaft keying or lock screws.

8. Foreign material in the fuel supply tank may be intermittently obstructing the pick-up of fuel. Drain the fuel tank. If that doesn't solve the problem, then it may be necessary to open the fuel tank and inspect for foreign material.

LUBRICATING OIL SYSTEM

NOTE: Many oil system problems, as well as overall engine troubleshooting problems, can be easily identified through lube oil analysis. Refer to Table 1 for interpretation of analysis statement.

LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM

ALL INSTALLATIONS EXCEPT MARINE ENGINES WITH ENGINE MOUNTED RAW WATER PUMP

Preliminary set up for troubleshooting the scavenging oil system should include the installation of a pressure gauge (0-50 psi) at the quick disconnect fitting on the Michiana filter tank. An external source of clean engine lube oil must be supplied to the main oil gallery while troubleshooting the lube oil system. A sufficient quantity of lube oil is necessary to protect the engine bearings.

BEFORE STARTING THE ENGINE:

1. Check for adequate supply of oil in oil pan.

2. Make sure that the strainer housing is full of oil to within about 51 mm (2") of the screen under the large cover.

3. Also under the large cover, make sure that the Michiana tank drain valve (with the "T" handle) is fully closed.

4. Remove the scavenging pump coarse strainer element which is held into the strainer box by three bolts. Inspect the interior of the suction strainer for foreign material and clean if necessary. Make certain that the clean strainer is installed with a gasket and tighten securely.

5. Remove several oil pan handhole covers and inspect the entire length of the oil suction line leading from the governor end of the engine into the oil sump. Any mechanical damage to this line must be repaired before operating the engine.

START THE ENGINE AND OBSERVE THE OIL LEVEL IN THE STRAINER BOX

1. If the oil level in the strainer box does not return to approximately 51 mm (2") of the screen, within 45 seconds of engine start, then take a reading on the Michiana tank pressure gauge (at idle) and shut the engine down. The engine can be shut down by pulling out the oil trip button on the governor (rail engines) or by tripping the overspeed shutdown lever (marine engines).

   a. If the pressure reading was low or zero, then the scavenging oil pump and its suction line to the strainer box should be inspected. If necessary the scavenging oil pump should be removed and overhauled.

   b. If the pressure reading was higher than 69 kPa (10 psi), then change the oil filter elements and repeat the procedure. If the pressure is still high, then remove and clean the oil cooler core.

2. If the oil level in the strainer box does return to within 51 mm (2") of the screen after engine startup, then operate the engine and slowly increase the speed. Observe the oil level in the strainer box at all engine speeds. At maximum operating speed take a reading of the Michiana tank pressure.

NOTE: The pressure readings given here are applicable only to installations with radiator type oil cooler cores. For switcher locomotives and industrial engines with shell and tube type (bundle) coolers, use the alternate pressure readings provided in "Switcher Locomotive And Industrial Engines ".

   a. If pressure reading is above 172 kPa (25 psi), change filter elements.

NOTE: Use only EMD oil filter elements or equivalent in the Michiana oil filter tank.

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b. If pressure reading is 69 kPa (10 psi) after changing filter elements, remove and clean the oil cooler core.

c. If the pressure reading is 21 kPa (3 psi), check the Michiana tank bypass valve to determine if it is jammed open.

SWITCHER LOCOMOTIVES AND INDUSTRIAL ENGINES

1. Change filter elements at 345 kPa (50 psi).

2. If pressure is above 138 kPa (20 psi) after filter change, then clean oil cooler.

3. If pressure is below 69 kPa (10 psi), then check bypass valve to determine if it is stuck open.

MARINE ENGINE INSTALLATIONS WITH ENGINE MOUNTED RAW WATER PUMP

NOTE: These engines are considerably different from other EMD engines in that much of the oil system and piping is installed by outside contactors. These variations cause the normal pressure characteristics of the oil system to be altered.

Preliminary set up for troubleshooting the scavenging oil system should include the installation of a pressure gauge (0-50 psi) at the filter tank connection labelled INLET. An external source of clean engine lube oil must be supplied to the main oil gallery while troubleshooting the lube oil system. A sufficient quantity of lube oil is necessary to protect the engine bearings.

BEFORE STARTING THE ENGINE:

1. Check for adequate supply of oil in oil pan.

2. Remove the strainer(s) and check for any obstructions to oil flow. Clean strainers if necessary. Reinstall strainers with a good gasket and tighten securely.

3. Check scavenging pump suction line in the oil pan. Any mechanical damage to this line must be repaired before starting the engine.

4. Make sure that the lube oil system is primed (hand pump) and the drain valve is fully closed.

START THE ENGINE AND OBSERVE PRESSURE OUTPUT OF SCAVENGING PUMP ENGINE AT IDLE SPEED

1. If pressure output is less than 69 kPa (10 psi), qualify the following components (in the order listed) and specifically check the valves to make certain they are not stuck open:

   a. Main lube pump suction relief valve

   b. Filter bypass relief valve

   c. Lube oil cooler bypass relief valve d. Scavenging oil pump

2. If pressure output is greater than 276 kPa (40 psi):

   a. Check pressure differential across lube oil filter elements. If pressure differential exceeds 69 kPa (10 psi), then change filters and retest.

   b. Check pressure differential across oil cooler. If pressure differential exceeds 69 kPa (10 psi), then clean oil cooler core.

ENGINE AT FULL SPEED

1. Check pressure differential across lube oil filter elements. Pressure differential must not exceed 138 kPa (20 psi).

2. Check pressure differential across oil cooler. Pressure differential must not exceed 138 kPa (20 psi).

NOTE: Due to greater oil system capacity and in-line strainer, the scavenging oil pump on 20 cylinder engines occasionally exhibits a non-linear oil pressure response (oil pressure does not follow engine RPM).

EXCESSIVE USE OF LUBRICATING OIL

A preliminary inspection checklist is provided to indicate possible areas of oil loss.

1. Inspect stack and carbody roof for evidence of oil loss.

2. Inspect engine exterior for leaks.

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3. Air box drain should be inspected for oil loss. 4. Cooling water expansion tank should be inspected for any indication of an oil film on top of the sight glass water surface.

5. Inspect all drains to determine if they are partially open or obstructed.

6. Check oil level in governor sight glass. Engine oil could be leaking into the governor oil which would raise the level in the sight glass. If this occurs considerable external oil leakage will also be visible.

7. On locomotive installations, inspect all external piping to the load regulator vane motors for oil leakage.

8. On marine and stationary installations using pedestal bearings, inspect the bearing housing and all external oil lines for any sign of oil leakage.

NOTE: The brand name and viscosity of the lubricating oil should be established. Use of oils should be confined to those that meet the qualifications published by EMD. Use of an improper oil or oil that is not the correct viscosity can be a contributing factor to excessive oil consumption.

OIL LOSS OUT THE EXHAUST STACK

1. Perform an air box inspection and pay particular attention to the condition of the piston, rings, and liner. Worn rings should be replaced if wear exceeds recommended limits provided in Fig. 15-1. Broken rings should be replaced immediately regardless of their wear state.

NOTE: The condition of the piston crowns may be used as an indicator to isolate the troubleshooting procedure to a specific cylinder. Excessively wet crowns and carbon throwoff from the inlet ports may point out cylinders with oil control problems.

2. The oil separator should be disassembled to verify the presence of the separator screen. On a turbocharged engine, the absence of this screen can cause excessive oil consumption and oil out the stack. On a blower engine, the absence of this screen can cause excessive oil consumption.

3A. On blower engines the air chutes from the blower to the air box should be inspected from inside the air box for any evidence of oil delivery down the chutes. If oil is found running down the chute, the blower should be removed and the blower rotor end seals replaced.

3B. On turbocharged engines the turbocharger screen and taper joint should be removed. The exhaust manifold interior should be inspected to determine if the oil loss is originating from the engine or the turbocharger.

NOTE: In many instances this exhaust manifold inspection will reveal a specific cylinder responsible for the oil loss.

4. On turbocharged engines, if inspection of the exhaust manifold indicates that the problem is originating in the turbocharger, then inspect the air inlet system for plugged filters. Plugged filters could cause a high inlet vacuum and draw oil past the turbocharger labyrinth seals. If the external systems are found to be in good condition, then changeout of the turbocharger may be necessary.

NOTE: Engines which are operated for extended periods of time under light or no load may experience varnishing of the cylinder walls. This varnishing greatly reduces the effectiveness of the oil control rings and can cause a condition known as " souping." "Souping" can cause light brown or tan deposits on cylinder liner walls. If light load operation is continued, then these varnish deposits may interfere with ring to liner seal effectiveness. In extreme instances of light load operation it may be necessary to load the engine either through temporary change of service or through use of a load box in order to remove these deposits and restore the efficiency of the ring set.

In instances where extremely severe oil loss through "souping" at the stack or through air box drainage is experienced, shop overhaul practices should be investigated. On EMD 645 engines, piston rings in the No. 4, No. 5, and No. 6 grooves are directionally

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A new or like new ring. This classification will only be evidenced during the first phase of top ring life.

On a shallow groove ring, these classifications will be evident on the top ring for a relatively short time. On a deep groove ring, these classifications will be evident for the major portion of ring life.

Chrome grooves are completely worn away, showing only a smooth chrome face. This will exist for the major portion of shallow groove ring life. It will be evident for a short time on only a small percentage of deep groove rings.

Rings are starting to wear into the cast iron, except for the grooves, which still contain chrome.

CAUTION: To prevent liner scoring, stainless steel rings should be replaced at this time.

Chrome is completely worn off and wear is concentrated on the cast iron. Rings in this classification are to be considered worn out and should be replaced.

NOTE: When classifying chrome plated stainless steel rings, substitute references to "cast iron" with "stainless steel". In addition, stainless steel rings have five grooves instead of seven.

Fig. 15-1 - Chrome Ring Wear Classification

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sensitive at installation and all six rings in the set must be properly oriented in the correct slot. The installation and directional orientation of each ring is provided.

No. 1 ring is labeled "TOP GROOVE ONLY" and stamped with a part number. It may be installed with either side up.

No. 2 ring and No. 3 ring are identical. They are both stamped with a part number and may be installed with either side up.

No. 4 ring is labeled "TOP" and has a part number stamped on it. It must be installed with the "TOP" label upwards and only in the No. 4 slot. If this ring is installed upside down, its tapered face will tend to pump oil past the upper compression rings.

No. 5 ring is a double hook scraper and must be installed with the hooks pointing down. If this ring is installed upside down, it will cause heavy oil loss through the air ports and considerable oil draining from the air box.

No. 6 ring is a special spring loaded scalloped oil control ring and must be installed with the scallops downward. If this ring is installed upside down, its oil control efficiency will be greatly reduced and may result in excessive oil loss.

NOTE: At time of overhaul or if rings are removed while troubleshooting excessive use of lube oil, make certain that the oil drain holes under the oil control rings are not clogged.

EXTERNAL ENGINE LEAKS

Leakage of oil from the engine will generally require tightening of the affected part or replacement of gaskets.

LOSS OF OIL FROM AIR BOX DRAIN

1. Perform a complete air box inspection. Replace any power assemblies that are found to be scored or running with excessively worn rings.
2. Inspect the air delivery chutes for any sign of oil leakage into the air box from the roots blower or the turbocharger.
3. Investigate shop practices for proper installation of piston rings as noted under "OIL LOSS OUT THE EXHAUST STACK."
4. Inspect for excessive oil leakage from around the power assemblies or from the center gallery of the air box. Leakage here might indicate a failed or absent seal or component.
5. Inspect air box piping in the oil pan for any evidence of leakage or external damage to the piping which could cause oil loss.

OIL IN WATER EXPANSION TANK

This indication is usually seen on installations with shell and tube type oil coolers because in these coolers the local oil pressure is higher than the cooling water pressure.

On installations with fin type oil coolers and pressure cooling systems the water pressure is higher than the oil pressure in the cooler. Because of these pressure differences inside the cooler, an internal leak usually results in water contamination of the lube oil. Pressure test and qualify the oil cooler core for leakage.

LEAKING SUMP DRAIN

The pipe plug should be tightened and the valve (if so equipped) qualified or replaced.

LOSS OF OIL INTO GOVERNOR

The low oil pressure actuating diaphragm of the governor should be replaced.

LOAD REGULATOR PIPING OR VANE MOTOR LEAKING

Tighten or replace as applicable.

IMPROPER VISCOSITY OR OIL CONTAMINATION

If either improper viscosity or oil contamination is suspected, immediately take a lube oil sample for analysis. Follow the specified corrective actions as indicated in Table 1 - "Interpretation of Lube Oil Sample Analysis." If necesary pressure test the fuel or cooling systems as required to isolate the source of contamination. Refer to Dilution of Lubricating Oil.

PEDESTAL BEARING LEAKAGE (MARINE)

Replace the bearing seals and check the return line for continuity. Check that the orifice is in place on the supply line.

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LOW ENGINE OIL PRESSURE

When troubleshooting low engine oil pressure it must first be determined if the problem is an inadequate supply of oil to the pump input, a worn or defective pump, or some component in the pump output circuit causing the pressure loss.

NOTE: Lubricating oil should be qualified to ensure that it is not diluted, which could cause a pressure drop.

1. Check for adequate oil level in the engine oil pan.

2. Observe the level of oil in the strainer box (if so equipped). With the engine idling the oil should be visible about 51 mm (2") below the screen (inside the rectangular cover). If the oil level in the strainer box is low, then the scavenging oil system is suspect. Inspect the scavenging pump, the scavenging pump strainer, the Michiana filter tank, and the oil cooler as outlined in LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM.

If the oil sypply to the main pump is found to be adequate, an auxiliary oil pressure gauge (0-150 psi) should be installed at the outlet elbow on the main lube oil pump using the 3/4" NPT plug hole.

If the main pump pressure as read on the auxiliary gauge is still low, then the following checks should be made:

1. Remove the two fine screen strainers in the strainer housing. Clean the strainers and inspect the seals for possible suction leaks. Drain the strainer box and inspect the chamber for any foreign material. Remove and blow compressed air through the seal vent line to make certain that it is not obstructed.

2. Remove all oil pan handhole covers. Visually inspect the external surfaces of the main and connecting rod bearings for evidence of heating and look for missing or loose components.

3. Operate the engine at idle and remove the engine protector. Observe the pressure relief valve, located directly behind the engine protector, for excessive oil loss. If the valve is found to be stuck in the open position it should be removed and replaced with a qualified valve.

4. Check for suction leaks at the main pump inlet elbow where it mates to the main pump and to the strainer housing. Replace gaskets if necessary.
5. Remove and qualify the main oil pump.

If it was found that the main pump pressure was adequate after installation of the auxiliary gauge, then the following steps should be performed:

1. On turbocharged engines, change the turbo-charger oil filter element.

2. Qualify the main engine oil pressure gauge and inspect for any closed valves in the supply line to the gauge. There is a 1 / 8" diameter line leading through the right bank top deck of the engine to the pressure gauge. Inspect this line carefully for damage. If necessary disconnect the line at both ends and blow air through it to make certain it is clear of obstructions.

If the main engine oil pressure gauge is found to be correct, then a defective engine protective device could be causing a false oil pressure drop. The engine protective devices must be checked:

1. Disconnect and block the connecting line from the oil pressure sensing line to the engine protector and the hot oil shutdown device (if so equipped). If this results in restoration of a normal oil pressure reading on the main engine gauge it indicates one of the following areas:

   a. The "O" ring seals on the engine protector plunger may have failed.

   b. The activating section of the hot oil detector may be jammed open.

2. Qualify both of these devices.

If: -

1. The engine protective devices are found to be in proper operating condition.

2. The auxiliary oil pressure gauge indicates an adequate main pump output pressure.

3. The main oil pressure gauge is still indicating inadequate oil pressure.

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Then investigate the rear gear train of the engine for possible causes of low oil pressure. This should include the following:

NOTE: The engine must be shut down for these checks.

1. Use the recommended tool to check the clearance in the No. 1 idler stubshaft bushing and, at the same time, inspect the interior of the end housing for debris under the gear train.

2. On turbocharged engines, remove the auxiliary generator drive (if so equipped) or the cover plate on the rear of the right bank. Inspect the manifolding to the turbocharger filter for loose or missing components or seals. Make certain that the upper pipe plug is installed in the gauge line connecting block, and inspect the cam manifolds.

3. On blower engines, remove the auxiliary generator drive (if so equipped) or the engine oil separator housing. Inspect the oil jumper lines to the camshaft bearing brackets for loose or missing components or seals.

DILUTION OF LUBRICATING OIL

1. Check to make certain that all the fuel jumper tubes to the injectors are not cracked and are properly seated.

2. Inspect all brazed joints in the top deck fuel manifold and check all manifold pipe plugs for leakage.

3. Check injectors and injector filter cap gaskets for leaks.

4. Check for stuck piston rings.

5. Check for leaking valves in the fuel lines.

6. If water contamination of the lube oil is suspected, then visually inspect for water in the oil pan and on the top of the cylinder heads and take an oil sample for analysis.

TURBOCHARGER PRELUBRICATION (SOAK BACK) SYSTEM

If the turbocharger soak back pump fails to operate when the engine is shut down, then immediately restart the engine and allow it to idle for 15 minutes. This allows the oil temperature to drop which cools the turbocharger bearings. The engine can then be shut down and the electrical control and soak back pump circuits can be investigated to determine the cause of the malfunction.

If the engine cannot be restarted within 2 minutes of shutdown, then do not restart the engine until the operation of the soak back pump has been restored and the engine has been allowed to cool down.

1. Inspect the camshaft bearings on the engine top deck while the soak back pump is operating. If oil flow is observed around the bearings it is an indication that the check valve (located in the soak back filter housing) has jammed open. This is a very undesirable condition because it makes it possible to backflush oil contaminants into the main gallery. Remove the housing immediately and inspect the check valve.

2. The soak back pump filter is mounted in a small canister close to the pump itself. There is also a bypass valve and a pressure relief valve mounted above the filter canister.

CAUTION: There is no backup filtration for the soak back system. If the filter clogs, then the bypass will allow dirty oil to reach the turbocharger bearings. Never extend the changeout intervals of the soak back pump filter beyond those specified in the Scheduled Maintenance Program.

3. The turbocharger oil filter is in the large canister on the back of the right bank of the engine. There is no bypass valve for the turbocharger oil filter so clogging of the filter may result in a low oil pressure shutdown. This shutdown can occur because the oil pressure sensing line to the governor low oil pressure shutdown is taken off of the discharge side of the turbocharger element. Use only EMD recommended filter elements. These are resin coated cotton paper with a 30 micron rating. Never use a wood pulp filter in an EMD engine. (Note: The Michiana tank filter elements have a 13 micron rating and cannot be used in the turbocharger filter).

CAUTION: Changeoutintervals for engine mounted turbocharger filter elements should never be extended beyond the recommendations given in the Scheduled Maintenance Program.

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4. To check oil delivery from the soak back system while the pump is operating, first remove the rear oil pan handhole cover on the left bank of the engine. Inspect under the gear train for oil return draining from the turbocharger. If oil drainage is not evident, then check the motor to pump coupling, the motor brushes, and the pump itself for failure or restriction of oil delivery.

NOTE: Many installations are equipped with an indicator light to show that the soak back pump is being energized. Electrical power to the pump does not necessarily mean that the pump is delivering oil to the system.

5. Some installations are equipped with a security interlock which will not allow the engine to be cranked for starting unless the preliminary turbocharger soak back or priming pump sequences have been completed. If the engine fails to crank, then investigate these security interlocks for failures.

COOLING SYSTEM

LOW WATER PRESSURE (PRESSURE COOLING SYSTEMS ONLY)

Install a pressure gauge on the expansion tank and monitor the pressure rise at the tank as the engine heats up to normal operating temperature.

1. If the pressure reading was inadequate, then shutdown the engine. Test the manual vent valve (next to the expansion tank filler cap) for leaking when closed. This is done by placing a bucket of water so that the end of the vent line extends several inches below the surface of the water. The release of bubbles or coolant inhibitor through the water indicates that the vent valve is not seating properly and must be replaced.

WARNING: Do not get hands or face close to the water bucket while performing this test.

2. Blow down the tank pressure by opening the manual vent valve.

3. When the tank pressure is completely dissipated, remove and inspect the expansion tank fill valve. Check for proper seating of the snifter valve (metal disc) in the center of the cap and check the condition of the gasket. Make certain the pressure range marked on the cap is correct for the installation. If there is any indication of a faulty filler cap, remove and check it on an external pressure tester. Replace cap if necessary.

WARNING: On installations with manual vent (blowdown) valves, use only the expansion tank caps with the crosswise bar. This is a protective system designed to prevent injury of personnel from expansion of hot coolant, its purpose is defeated if a plain expansion tank cap is used.

HIGH COOLANT TEMPERATURE

INSTALLATIONS WITH RADIATORS

1. Check coolant level in expansion or supply tank. Check for adequate cooling system pressure (some installations have quick disconnect fittings for this purpose). If the cooling system pressure is not adequate for the installation, then check the condition of the expansion tank filler cap (if used) and make sure the cap is marked with the proper pressure range.

2. Cycle the radiator shutters (if so equipped) with the temperature switch test button or the shutter test valve. Make certain that the shutters are opening completely. If necessary check the temperature at which the shutter control operates. This can be done by either operating the engine until it reaches the temperature at which the shutters open or by removing the temperature switch and testing it separately. The switch can be tested off the engine by placing the heat sensing element in a pan of hot water with a thermometer and noting the temperature where the switch operates.

3. Make certain that all radiator and water pump vent lines are in place and not obstructed. Disconnected radiator vent lines can cause air binding in the radiators which results in a loss of cooling efficiency. Water pump vent lines that are disconnected or not the correct size can cause cavitation of the water pump which results in a loss of coolant delivery pressure.

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4A. On installations with electric cooling fans, check for proper operation of all fan motors and temperature control switches. Check all the fan fuses for continuity and proper rating.

4B. On installations with belt driven cooling fans, inspect the belts and make certain that they are properly tensioned.

5. Inspect the exterior of the radiators for clogging and restriction of air flow. Clean radiator baffles (fins) if necessary. Carefully check the cores for leaks.

6. Hydro-test the cooling system for leaks. Coolant leaks decrease cooling capacity and could introduce exhaust gases into the cooling system. Gases in the cooling system might cause air binding of the radiators or water pumps.

NOTE: Do not exceed 172 kPa (24 psi) during hydro-test. This limit is notably conservative to account for older equipment that might have some long service deterioration. The engine alone can be blanked off and tested with air and water at 620 kPa (90 psi).

INSTALLATIONS WITH HEAT EXCHANGERS (AND KEEL COOLERS)

1. Check coolant level in expansion or supply tank. On pressure-type systems check both the cooling system pressure and the condition of the filler cap.

2. Check that all vent lines are in place and not obstructed. Make certain that all cooling system piping is physically located below the level of coolant in the tank.

3. Check that all cooling system piping connections are tight and that all gaskets are in good condition. Leakage on the presure or output side of the water pump will cause coolant loss and decreased coolant pressure throughout the system. Leakage on the suction or input side of the water pump will draw air into the system which results in cavitation at the pump.

4. Check the operation of the temperature control (thermostatic) valve if the installation has this equipment.

5A. On installations with engine mounted raw water pumps, check the valve positioning on the suction and discharge circuits of the pump. Make certain that piping connections are properly sealed and tightened and that gaskets are in good condition.

5B. On installations with belt or shaft driven raw water pumps, check the shaft couplings and belt tension. Check that all valves are open in the suction and discharge lines to the pump.

6. Monitor the temperature change across the engine cooling side of the heat exchanger, and if possible, across the raw water pump from suction to discharge side. If the temperature change is too small across either the cooling side of the heat exchanger (drop) or the raw water pump (rise), then clean the radiating surfaces, or, it may be necessary to rod out the exchanger (shell and tube types).

7. Hydro-test the cooling system for leaks. Coolant leaks decrease cooling capacity and could introduce exhaust gases into the cooling system. Gases in the cooling system might cause air binding of the exchanger or water pumps.

NOTE: Do not exceed 172 kPa (25 psi) during hydro-test. This limit is notably conservative to account for older equipment that might have some long service deterioration. The engine alone can be blanked off and tested with air and water at 620 kPa (90 psi).

HIGH LUBRICATING OIL TEMPERATURE-RELATED TO OIL COOLER (COOLANT TEMPERATURE) PROBLEMS

1. Check oil level in oil pan and monitor main oil pump pressure.

2. Remove the square cover from the scavenging delivery compartment in the strainer housing. Check for sufficient oil delivery from the scavenging oil pump. The oil level should not be more than two to three inches below the screen with the engine running. If scavenging oil delivery is inadequate, the Michiana filter tank pressure should be checked as a test for plugged filters and/or a jammed bypass valve.

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NOTE: The purpose of the oil cooler is to use engine coolant to remove excess heat from the lubricating oil. This relationship leads to high oil temperature if engine coolant temperature becomes too high.

3. Determine if the engine has had high water temperature problems. High water temperature reduces the efficiency of the oil cooler thereby causing a higher oil temperature. If the engine has an above normal water temperature, follow the troubleshooting guide for that particular problem.

4. Marine and Stationary Power installations are frequently equipped with a temperature control (thermostatic) valve. If the engine has this equipment, then qualify the opening of the valve. On some installations, failure of the valve to function can deprive the oil cooler of coolant.

5. Put inline thermometers or temporary thermometers in the wells provided in the engine cooling water piping. Monitor temperatures in and out of both the oil and water sides of the oil cooler. Compare these readings with a standard chart (locomotive installations) or with installation records to determine oil cooler efficiency. Reduced efficiency is caused by oil cooler plugging, scale or corrosion. If oil temperature drop or coolant temperature rise through the cooler are not adequate, then remove the cooler for inspection and cleaning.

ENGINE PERFORMANCE

UNEXPECTED ENGINE SHUTDOWNS

NOTE: Quite often on startup, and occasionally on shutdown, the engine protector buttons may be activated by pressure differential transients. These may cause a false indication of engine problems during routine startup and shutdown.

If an engine shuts down unexpectedly while operating under load, the following steps should be performed:

1. Check the position of the overspeed trip lever and reset if necessary. Consult the applicable section of this troubleshooting guide for further investigative procedures.

2. Make certain that the engine did not run out of fuel and that the emergency fuel cutoff or engine stop switch was not activated.

3. On locomotive installations only: -

   a. Check that the engine was not inadvertently shutdown by moving the throttle handle beyond the detent position at the right end of the quadrant.

NOTE: Moving the throttle handle to the right beyond the detent position will also shutdown all other locomotive units connected in tandem.

   b. Check the annunciator module for fault indications and look for an illuminated alarm indicator light on the engine control panel.

4. Observe the engine protector crankcase pressure button.

WARNING: If this button has popped out, do not work on the engine for at least two hours. Do not open any of the air box, oil pan, or top deck access covers.

After two hours has passed the engine can be opened up to inspect for the cause of the crankcase overpressure. Consult the applicable section of this troubleshooting guide for further investigative procedures.

5. Observe the engine protector differential water pressure button. If this button has popped out, check the engine coolant level in the supply or expansion tank. If the coolant level is low, carefully inspect the engine and piping for internal or external leakage. Pressure test the system if necessary but limit maximum pressure to 172 kPa (25 psi).

WARNING: Remove expansion tank filler cap cautiously as steam pressure may be present.

Check that all drain valves are fully closed on the engine and in the external piping. On locomotive installations, check that all cab heater drains are closed. Refill the cooling system with the proper coolant and attempt to restart the engine. Monitor the engine temperature after load is applied. If the temperature rises beyond the normal level, then consult the "HIGH COOLANT TEMPERATURE" section of this troubleshooting guide.

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NOTE: The engine protector crankcase pressure and differential water pressure buttons shut down the engine by dropping all oil pressure to the governor engine oil pressure sensing diaphragm. Therefore, the governor low oil button should always pop out if one of the engine protectors is activated. This series of events takes place in the normal actuation of a crankcase overpressure or differential water pressure shutdown and has an entirely different significance than the governor low oil button popping out by itself.

6. Check the governor low oil button. If this button alone has popped out, then check the oil level in the engine oil pan and in the engine mounted oil strainer box.

WARNING: On locomotive installations, the hot oil detector can also cause the low oil button to pop out. When the low oil button is popped out, and a hot engine condition is suspected, wait two hours before checking the oil level.

   a. If the engine oil level is unusually low, check for a partially open oil pan drain valve and a loose or missing drain pipe plug.

   b. If low oil is evident in the chamber below the screen in the square section of the strainer box, check the scavenging oil system as indicated in the appropriate section of this troubleshooting guide.

   c. If the oil levels at both locations were adequate, inspect the inside of the oil pan for evidence of overheated metal surfaces or extruded metal around the main and connecting rod bearings. Inspect under the lower end of both gear trains for debris.

If all the preceding steps do not point out the reason for the governor low oil indication, then close up the engine and attempt to restart the engine. If the engine starts, then closely observe the engine oil pressure gauge. If the engine does not develop oil pressure on the gauge, then peform the procedure as indicated under "LOW ENGINE OIL PRESSURE" of this troubleshooting guide.

On locomotive installations only, if after the engine starts the oil pressure gauge builds up to normal, it could have been the hot oil detector that caused the low oil shutdown. The hot oil detector might have shut the engine down and then reset itself during the cool off. Load the engine and watch the engine temperature gauge closely for possible overheating.

7. If after any of the preceding steps, the engine cranked over readily but failed to start, a fuel system failure is probable. Check for adequate fuel supply in the storage or day tank. Check for fuel pressure (duplex fuel filters) or for fuel flow (sight glass) at the engine. If fuel pressure or fuel flow is not evident, then perform the procedure outlined under "LOW FUEL OIL PRESSURE" in this troubleshooting guide.

8. On installations with electric fuel pumps, the shutdown could have been caused by an interruption or fault in the fuel pump control circuit. Use the appropriate wiring diagram to qualify switchgear and wiring connections and check for continuity through electrical interlocks.

9. On turbocharged engines only, if the engine unexpectedly shut down when the throttle was reduced, accompanied by bogging of the engine and heavy smoke, the turbocharger clutch may be failing to engage properly. Check the operation of the turbocharger clutch using the EMD turbocharger troubleshooting procedures.

10. On locomotive installations only, several unique characteristics of the control systems could cause an unexpected reduction in engine speed while operating under load:

    a. Unexpected locomotive engine speed reductions can be caused by activation of THL or EFL protective relays. These relays function to reduce engine power if a hot engine or clogged air filter condition occurs. On most freight locomotive applications, pickup of THL or EFL will reduce No. 8 throttle engine speed to No. 6 throttle speed and reduce No. 7 throttle engine speed to No. 5 throttle speed. Check the annunciator indications and the fault lights on the engine control panel. Check the engine temperature control system or change the air filter elements as necessary to correct the problem.

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b. Qualify the control stand microswitches. Inspect the connection of the control wire flexible cable to the governor for tightness and terminal engagement.

c. Pickup of the ground protective relay will cause engine speed to be reduced to idle regardless of throttle position. This action is accompanied by an annunciator indication, an engine control panel light, and an alarm.

LOSS OF POWER

NOTE: On installations with a load regulator or load control system, the correct injector is essential to the proper loading of the system. Whenever improper loading occurs with this type system, check the injector part numbers to make certain they are correct for,the installation.

ENGINE RUNS WITH CLEAN STACK

1. Shut down the engine.

2. Open all top deck covers and visually inspect the injectors, racks, and followers. Make certain that all injector racks are engaged to the transfer arms and that all pins and linkages are in place and properly tightened. Observe fuel jumpers, rocker arms, and exhaust valve bridges for any abnormal conditions.

3. Close top deck covers and prepare for a normal startup. Check fuel supply. Prime engine fuel system and check for adequate return fuel flow (sight glass) or fuel supply pressure (duplex filters).

4. Start the engine and allow it to reach normal operating temperature. Observe fuel system pressure or delivery. If fuel system shows any indication of inadequate delivery, then follow the procedure outlined under "LOW FUEL OIL PRESSURE" in this troubleshooting guide. If bubbles are evident in the return fuel sight glass, see Section 5B of Low Fuel Oil Pressure Troubleshooting.

NOTE: The following procedures apply only to engines with notched or continuous throttles; Woodward PG, PGR, or PGA governors.

5. With the engine not under load, attempt to slowly increase engine speed from idle to maximum RPM. On installations with PG or PGR governors, check that all assigned engine speeds are properly activated. On installations with a PGA governor, check that the engine responds evenly to increased throttle throughout the operating range from idle to maximum RPM. Use a hand tachometer to check that the engine has reached maximum speed. If the engine failed to reach maximum RPM, check governor solenoids on PG or PGR governors and the control air supply and pressure settings on PGA governors. Return engine speed to idle and attempt to load the engine. Advance the throttle slowly and smoothly from minimum to maximum speed.

Qualify the maximum speed of the engine with a hand tachometer. If the engine cannot reach its maximum speed rating under load, examine the position of the rack as indicated by the quadrant on the governor and verify the following conditions (while under full load). If the governor rack is shorter than the specified maximum position on the governor nameplate (while under full load), and the engine is running at or below maximum rated RPM, then:

1. On locomotive installations, check the position of the load regulator.

   a. If the load regulator has moved to minimum field position, the problem is most likely of a mechanical nature. Carefully inspect the mechanical condition of the injectors and check them for correct part numbers. The injectors should also be pressure tested. (Refer to INJECTOR PRESSURE TEST in this section.) The governor part number should be checked to make sure it is the right one for the installation. If necessary, the governor should be removed to check the load regulator.

   b. If the load regulator has moved to maximum field position, the problem could be of either a mechanical or electrical nature. Injectors should be checked for proper part number and then pressure tested. The electrical excitation system should be qualified according to the procedures established in the appropriate locomotive service manual.

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c. On a marine or power generating installation, an overload condition or a mechanical problem with the fuel injectors is most likely. Pressure test the injectors after checking them for correct part numbers. (Refer to INJECTOR PRESSURE TEST in this section.) Make certain that the governor part number is correct for the installation. If the governor and injectors are functioning properly and their part numbers are verified for the installation, then an electrical or mechanical overload condition is probable. On power generating installations, refer to load rating conditions in the applicable manuals. On marine gear box installations, refer to the applicable propeller cube curves to determine if an overload condition exists.

If the governor rack is longer than the specified maximum position on the governor nameplate, and the engine is operating below its maximum speed, attempt to increase fuel injection (shorten rack dimension) by manually advancing the layshaft lever.

1. If increased resistance prevented the injector control lever from being manually advanced to the specified maximum position, then suspect either an engine injector rack is binding or the governor stop adjustment on the power piston is improperly set.

2. If it was possible to manually advance the injector control lever to maximum fuel position, the engine speed increased, then suspect:

   a. Improper governor setting (high speed unloader limit).

   b. (Marine only) Deliberate speed limiting setting.

   c. (Locomotive only) Improper adjustment of governor.

On PG and PGR governors (rail and drill rig), the governor should be removed from the engine and operated on a governor test stand to make adjustments. Check governor and injectors part numbers to make sure they are correct for that particular application.

ENGINE RUNS WITH DIRTY STACK

1. Open top deck covers and perform a visual inspection of all injectors, racks, and followers. Make certain that all injector racks are engaged to the transfer arms and that all pins and linkages are in place and properly tightened. Check injectors for proper part number and pressure test injectors for leakage. (Refer to INJECTOR PRESSURE TEST in this section.)

2. Close the top deck covers and prepare the engine for a normal startup. Observe fuel system pressure or delivery for any abnormal conditions. If fuel system delivery or pressure is low, refer to "LOW FUEL OIL PRESSURE" section of this troubleshooting guide. If bubbles are evident in the return fuel sightglass see Section 5B of "LOW FUEL OIL PRESSURE" troubleshooting.

3. With the engine at normal operating temperature and not under load, slowly advance the throttle from idle to maximum speed. Check that all engine speeds are reached smoothly and verify maximum engine speed with a hand tachometer.

4. With engine at maximum speed, with full load applied, use a water manometer to check exhaust back pressure.

   On blower engines, the back pressure should not exceed 559 mm (22") of water.

   On turbocharged engines, the back pressure should not exceed 127 mm (5") of water.

   If the exhaust pressure is too high, then check for obstructions in the exhaust risers and stack extensions.

5. With engine at maximum speed, with no load applied, use a water manometer to check engine air inlet depression.

   If inlet depression exceeds the value provided in "Air Filter Pressure Drop" data, either change or clean filters.

NOTE: All air filter pressure drops are measured in clean air plenum downstream of the filter elements.

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Application	Turbocharged				Blower Type Engines							
	Paper		Fiberglass		Oil		Paper		Fiberglass		Oil	
	In.	mm	In.	mm	In.	mm	In.	Mm	Im.	Mm	In.	mm
Marine	14*	356*	7	178	16*	406*	18**	457**	7	178	20**	508**
Marine Drill	14*	356*	7	178	16*	406*	18**	457**	7	178	20**	508**
Stationary	14*	356*	7	178	16*	406*	18**	457**	7	178	20**	508**
Drill Rig											20**	508**
	Inertial + Paper		Inetial + Fiberglass		Inertial+ Oil		Inertial + Paper		Inetial + Fiberglass		Inertial + Oil	
	In.	mm	In.	mm	In.	mm	In.	Mm	Im.	Mm	In.	mm
Locomotive	14	356	14	356	16	406	18	457	18	457	14.5	368

NOTE

Inertial filter readings should not exceed 5.5” (140 mm).

*For remote mounted filter applications, subtract 3” (76 mm) H_2O

**For remote mounted filter appliacation, subtract 10” (254 mm) H_2O

Air Filter Pressure Drop

6. Attempt to load the engine. If the engine bogs and smokes, check for excessive air box accumulations blocking the inlet ports. On turbocharged engines only, check for a plugged exhaust screen and qualify the condition of the turbocharger by performing the inspections outlined in the Turbocharger Troubleshooting Section.
7. If all the preceding checks prove negative, qualify engine timing by checking exhaust valve timing on both cylinder banks.

CYLINDER MISFIRE

1. Pressure test all injectors using the appropriate EMD tool. This tool checks for free follower action and adequate injection force.
2. Inspect the part numbers on the bodies of all injectors to verify that the entire engine set is correct for the installation.

CAUTION: EMD does not make hollow rack injectors. Hollow rack injectors cannot be set correctly with an EMD injector rack tool. If they are mixed in an EMD engine set with EMD injectors, and set with EMD tool, then these cylinders will be too light on fuel volume (rack too long). This can result in misfire, vibration, poor overall fuel economy, and possibly, serious damage to the engine.

3. On installations with fuel sight glasses, check for adequate fuel flow through the return sight glass. If fuel flow is inadequate, refer to the "LOW FUEL OIL PRESSURE" section of this troubleshooting guide. If bubbles are evident in the return fuel sightglass see section 513 of "LOW FUEL OIL PRESSURE" Troubleshooting.
4. On installations with fuel block and duplex filters, check for adequate fuel supply pressure. If fuel pressure is inadequate, refer to the "LOW FUEL OIL PRESSURE" section of this troubleshooting guide.
5. Inspect the exhaust valves and check for valves that are stuck partially open, operating with damaged heads, or misadjusted so that they cannot seal completely.

ENGINE KNOCKS

2. Perform a complete top deck inspection. Check all injectors and injector control linkage. If bubbles are evident in the return fuel sightglass with engine running, see Section 513 of "LOW FUEL OIL PRESSURE" Troubleshooting.

2. Repair any injector linkage with loose adjusting and locknuts or missing pin clips. Make certain that all injectors are properly engaged between their racks and the control linkage. Pressure test all the injectors (refer to INJECTOR PRESSURE TEST in this section).

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3. Set and time all injectors in accordance with procedures provided at the end of this section.

4. Check exhaust valve lash adjustment. Remove and test any valve bridge which shows inadequate lash adjuster tension or which operates loudly when the engine is running.

5. Check all injector part numbers to make certain that the entire engine set is correct for the installation.

6. Check for engine overloading or overheating problems. Observe the load and temperature gauges with engine in operation. If necessary, refer to the applicable section of this trouble-shooting guide for corrective action.

7. If all the preceding steps prove negative, then perform the following steps; although these are more unlikely to be the cause of engine knocking:

    a. Check the exhaust valve timing on both cylinder banks.

    b. Carefully inspect the engine to make certain that 567 and 645 power assemblies have not been mixed in the same engine. 567 and 645 power assemblies cannot be operated, at the same time, in the same engine because the difference in weight make counterbalancing impossible.

NOTE: An entire set of 645 power assemblies can be used in certain 567 engines providing that all instructions in the EMD Modernization Recommendation on this subject are followed. Consult your dealer or EMD representative for more information.

    c. Make certain that blower-type pistons and turbocharger pistons are not mixed in the same engine by checking piston part numbers (bottom of piston skirt) from inside the oil pan.

    d. Take lead wire readings to check for bent rods or piston pin insert distress.

EXCESSIVE VIBRATION

1. Open top deck covers and perform a visual inspection of all injectors, racks, and followers. Make certain that all injector racks are engaged to the transfer arms and that all pins and linkages are in place and properly tightened. Pressure test injectors for leakage (refer to INJECTOR PRESSURE TEST in this section). If bubbles are evident in the return fuel sightglass with engine running, see Section 513 of "LOW FUEL OIL PRESSURE" Troubleshooting.

2. Inspect engine to generator coupling disc for any evidence of failure.

3. On marine installations, inspect torque tube couplings for evidence of failure.

4. Inspect all drive shafts that operate auxiliary equipment for any sign of failure.

5. Remove all oil pan handhole covers. Visually inspect crankshaft area for loose or damaged main bearing caps and connecting rod baskets. Look for signs of overheated or extruded metal.

6. Inspect for debris under the gear trains at both ends of the engine. Visually qualify the crankshaft damper. Check engine records to make certain that crankshaft damper is not past changeout date.

7. Inspect top deck on both banks of cylinder for broken rocker arms or broken rocker arm shaft mounting studs.

8. If installation has been subjected to any shock loadings, check engine to generator or engine to gearbox alignment.

9. If engine was recently overhauled, check camshaft counterweight timing.

ENGINE SMOKING (DARK SMOKE)

1. Check the governor rack quadrant with the engine at maximum rated RPM and full load. If the indicated governor quadrant dimension is shorter than the limit specified on the governor identification plate, then the engine may be operating overloaded. If bubbles are evident in the return fuel sightglass see Section 513, of "LOW FUEL OIL PRESSURE" Troubleshooting.

2. Check maximum engine RPM with a hand tachometer on the end of the camshaft. If the engine is running below its maximum rated RPM and short on rack, then overloading is the most probable cause and the following steps should be taken:

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a. On locomotive and power generating installations, standardize horsepower output and check all calibrating and load control adjustments. If possible, adjust to obtain proper rated output.

b. On marine gear box installations, it may be necessary to adjust pitch or diameter of the propeller if continual overloading is experienced.

3. If the engine was operating below its load limit, then remove the load and run the engine to its maximum rated RPM without load.

a. Check the engine air filter inlet depression with a water tube manometer. If the inlet depression exceeds the value provided in "Engine Runs With Dirty Stack," then change or clean the air filters.

b. Check the exhaust back pressure. If the exhaust back pressure exceeds 127 mm (5") of water on turbocharged engines or 559 mm (22") of water on blower engines, then look for blockages or restrictions in the exhaust system.

4. If the preceding checks prove negative, shut the engine down and perform a complete inspection of the injectors. Make certain that all injectors are the correct part number for installation. Check injector timing and rack setting. Pressure test all injectors for leakage. (Refer to INJECTOR PRESSURE TEST in this section.)

5. Check the exhaust valve timing on both banks of cylinders.

6. Perform a complete air box inspection. Check for broken compression rings. CAUTION: Never operate an EMD engine in routine service with broken compression rings. Ring fragments can be drawn through the liner air ports into the inlet air stream where they may damage the liner, piston, cylinder head, and exhaust valves. Pieces of ring can also be drawn up the exhaust stack where they could damage the turbocharger (if so equipped).

7A. On blower engines only, check for leaking shaft end seals by observing the air box end of the air delivery chutes for oil flow. Leaking end seals can be an indication of impending bearing failure with possible rotor damage.

7B. On turbocharged engines only, remove the inlet boot and inspect the inlet impeller for damage. Remove the section of the exhaust manifold adjacent to the turbocharger. Examine the condition of the protective screen and clean if necessary. Inspect the interior of the exhaust manifold for debris. Have someone else rotate the turbo shaft from the inlet end while you inspect the exhaust blades with a flashlight. Refer to Turbocharger Troubleshooting in this section.

SPEED DEPARTURE (ENGINE SPEED HUNTING)

1. Make certain that the injector control linkage is working properly. Replace any injector which shows evidence of rack binding. If bubbles are evident in fuel return sightglass, see Section 5B of "LOW FUEL OIL PRESSURE" Troubleshooting.

2. Check governor for correct oil level. Either too high or too low oil level in the governor may cause engine hunting. If the governor "manufactures" oil (oil level constantly rising) or if the governor oil becomes excessively dirty after a short operating time then engine lube oil is getting into the governor oil. Check for the following possibilities:

a. The governor oil pressure sensing diaphragm may be ruptured.

b. The load control pilot valve (if so equipped) may have a failed seal.

NOTE: These problems may require removal of the governor for correction or rebuild.

3. With the engine running, vent the air bleed screw in the governor body to remove any trapped air from the governor control passages. Adjust the compensating needle valve to limit the hunting condition as much as possible.

4. If hunting continues, the cause may be the following:

a. On locomotive installations, the operation of protective devices such as current overload relays and excitation limiting may be causing hunting. Check the electrical system to make certain that the excitation circuits are functioning properly.

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b. On drill rig and DC power generating installations, the cycling of calibrating and overload relays may cause hunting. Check the circuits for proper operation.

NOTE: Marine engine gear box installations may exhibit a load fluctuation in rough or shallow water which should not be confused with hunting.

PROTECTIVE DEVICES

CRANKCASE PRESSURE DETECTOR

WARNING: After a crankcase pressure detector shutdown, do not open any engine handhole cover, top deck cover, or oil strainer housing cover for at least two hours.

NOTE: Combustion is created in the oil pan when oil vapors come into contact with an overheated engine component. The force generated by this combustion frequently bends or damages the sensing diaphragm backup plates in the crankcase pressure detector. If oil pan combustion is suspected in a crankcase pressure shutdown, then the detector must be removed and qualified on a suitable test stand.

1. Check for plugged separator screen in the crankcase aspirator unit.

NOTE: Do not remove any of the calibrating orifices that are part of the total crankcase aspirator system installed at the factory.

2. Check oil level in the engine

3. On turbocharged units, check if there is carbon blocking the angled end of the eductor tube which projects into the stack riser.

4. After the engine has been shut down for two hours, remove the oil pan and air box handhole covers and check for the following problems:

   a. Cracked pistons.

   b. Broken cylinder crab studs.

   c. Cracked cylinder head.

   d. Badly worn valve guides.

   e. Hardened lower liner seals.

   f. Inadequate injector crab nut torque.

   g. Extreme cylinder scoring which could allow air box blowdown past oil control rings.

   h. If engine was recently overhauled, investigate shop practices for installation of oil control rings on rebuilt power assemblies.

   i. Inspect the interior of the air box for evidence of carbon combustion which could cause seal hardening and component failure.

   j. Inspect oil pan for any indication of overheated metal surfaces.

   k. Check for debris under the gear trains at both ends of the engine.

   1. If the preceding steps did not disclose the cause of the shutdown, then while the engine protector is still off the engine, examine the oil pressure relief valve. This valve is mounted on the oil distribution manifold directly behind the mounting opening of the engine protector. The port on the oil pressure relief valve should be facing downward and 90° away from the end sheet of the engine. If the relief valve is installed either facing the end sheet or at 180° to the end sheet, then the oil discharge may hit the actuating diaphragm of the engine protector causing a false actuation.

OVERSPEED TRIP

1. Check the possibility that the load on the engine was suddenly dropped. Check the operation of overcurrent protective and excitation limiting relays. On locomotive or generating installations, look for annunciator or engine control cabinet indications.

2. Run the engine to maximum possible speed with no load and check the speed with a hand tachometer. Use the hand tachometer, through the access cover on the end of the camshaft counterweight cover, to read camshaft RPM.

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This is a valid indication because the camshaft is in a 1:1 overall drive ratio to the engine crankshaft.

3. While the governor is maintaining the engine at maximum speed, increase fuel injection by manually overriding the governor with the injector control lever until the overspeed device trips. Note the speed that the overspeed device trips on the hand tachometer.

   a. If the overspeed does not trip when engine RPM reaches approximately 10% over rated speed, back off the injector control lever and shut the engine down. With the engine shut down, remove the front cam counterweight cover and check the overspeed mechanism.

   b. If the overspeed tripped at too low of an RPM, it may be necessary to increase the spring tension on the overspeed flyweight. This is mounted on the front camshaft counterweight on the right bank of the engine. Retest until proper RPM trip value is obtained. Correct trip speed should be approximately 10 percent over the maximum RPM rating of the engine. For example, a 645 engine with a maximum governor speed tolerance of 908 RPM should trip the overspeed at about 1000 RPM.

4. With the overspeed trip qualified, run the engine to full rated RPM under load and observe its operation. It may be necessary to bleed air from the governor or adjust the governor compensating needle valve if the governor shows any tendency to hunt. Consult the "SPEED DEPARTURE" section of this troubleshooting guide.

5. On locomotive installations, repeated overspeed tripping under load may be caused by electrical malfunction causing the load to be interrupted. Consult the appropriate locomotive service manual for troubleshooting the electrical excitation and protection systems.

6. On marine engines that are operated over extremely rough or shallow water, considerable load fluctuations are possible. This should not be confused with load hunting. These sudden load variations might cause the engine to overspeed. If this problem occurs, consult your service engineer or the EMD Service Department for recommendations based on the requirements of your installation.

TRACING DEFECTIVE OR NOISY CYLINDERS

These are several checks and procedures which have proven useful to determine if a particular cylinder is experiencing mechanical or fuel supply problems. Cylinders with these difficulties may show symptoms of smoking, misfiring, or operating with an unusually low stack temperature. The following is a summary of cylinder problems and their related symptoms.

EXHAUST TEMPERATURE

1. On marine engine installations with exhaust stack pyrometers, check readings between cylinders with the engine running under load.

NOTE: Exhaust pyrometers are unreliable indicators of engine malfunctions. Do not use only one set of pyrometer readings as a basis for an exploratory teardown of a power assembly. Always compare readings of the individual pyrometers by switching the sensing bulbs between the suspected defective cylinder and one cylinder which is indicating properly.

2. On locomotives and stationary power installations, an approximation of individual cylinder exhaust temperature can be obtained with a hand held pyrometer. The pyrometer must be used on individual riser legs with the engine under load. These readings are useful only for comparison between cylinders. Because the pyrometer is being positioned outside the manifold, the readings alone should not be used as a basis for power assembly teardown. Only the range relationship between cylinders is meaningful to detect a suspicious cylinder.

STACK SOUND

1. Using a four foot length of 1/2" or 3/4" pipe held against the riser leg, listen to the sound of the exhaust in each stack riser. A defective exhaust valve or a cylinder with an injector not functioning can often be located this way.

2. Disconnect the injector rack link on the suspect cylinder. With the engine at idle speed, slowly open the rack for that cylinder and then return it to idle position. If the injector is functioning properly, a pronounced laboring of the cylinder will be evident with the rack advanced.

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INJECTOR TESTING

Refer to INJECTOR PRESSURE TEST in this section, to check injectors for leakage.

AIR BOX INSPECTION

Heavy cylinder scoring or badly worn or broken compression rings can cause smoking, high oil consumption, or loading and operational problems. Consult the appropriate one revolution inspection sequence charts that are provided. These charts give detailed data about each period of crankshaft rotation for different engine configurations. This information is necessary to perform a thorough air box inspection and will also minimize the amount of engine barring needed to do the inspection.

INJECTOR TIMING AND RACK SETTING

Injectors must all be set properly to achieve even loading of the engine. Unevenly set injectors can contibute to excessive vibration, smoking, and premature wear on power assemblies. To set the injectors refer to "SETTING INJECTOR RACKS."

NOTE: Do not rely on body grooves or any other superficial means of identifying injectors. Check the injectors only by part number and then make certain, through the appropriate EMD parts catalog, that all the injectors in an engine are correct for that installation.

ENGINE WILL NOT SHUT DOWN

INJECTOR CONTROL LEVER IN STOP POSITION

1. Injector linkage may be improperly adjusted.
2. Injector rack may be stuck or incorrectly meshed with injector gear.

EMERGENCY SHUTDOWN PROCEDURE

RAILROAD INSTALLATIONS

1. Push one of the three emergency fuel cutoff buttons. These are located one on either side of the locomotive on the catwalk edge above the fuel tank and one in the locomotive cab. (The function of these buttons is not trainlined).
2. Move the throttle handle in the controlling unit to the extreme right corner of the quadrant by pulling out the handle enough to clear the detent. This will shut down that unit and all units in an MU equipped consist which have isolation switches in the RUN position. This will not shut down other units that are isolated.
3. Turn off the control and fuel pump switch on a single unit or the lead unit in an MU consist. This will stop the fuel pump and result in engine shutdown from lack of fuel. This procedure will only shut down trailing units that have their control and fuel pump switches in the OFF position.
4. A unit can be shut down from the right catwalk by pulling the injector control lever all the way towards the outside of the unit and holding it there until the engine is completely stopped.

   A unit can be shutdown from the left catwalk by pulling out the low oil trip button on the governor.

MARINE AND STATIONARY INSTALLATIONS

On installations with emergency fuel cutoff switches, this switch should be used for emergency shutdown only, otherwise any of the following procedures should be used.

1. Push the manual shutdown button on top of the governor (if so equipped).
2. Trip the overspeed shutdown with the manual lever on top of the camshaft counterweight housing.
3. Energize the governor shutdown solenoid (controlled electrically from primary control location).
4. If the governor did not go to the fuel shut off position, then override the control linkage with the injector control lever by pulling the lever out as far as it will go and holding it until the engine is completely stopped.
5. On marine engines, if the overspeed lever did not shut the engine down, then engage the ahead or astern clutch to stop the engine provided that the vessel is not in motion.

NOTE: In an extreme emergency an EMD engine can be shut down by depriving it of fuel by opening the suction strainer.

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INJECTOR PRESSURE TEST

Special tool 8414877 is used to pressure test injector for leakage while they are installed in the engine. Pressure test injectors as follows:

1. Ensure that engine fuel lines are fully charged.

2. Place straightedge across exhaust and injector cam rollers. If injector cam roller is higher than the exhaust cam rollers, bar engine over until injector roller is below the exhaust rollers.

3. Apply test tool to the injector rocker arm of the injector being tested. The tool should straddle the rocker arm with the lower end of tines under the rocker arm shaft and the top end of tool covering the rocker arm adjusting screw lock nut.

4. Remove retainer spring and clevis pin securing injector control lever to adjusting link.

5. Place injector rack in full fuel position.

6. Apply 1/2" drive torque wrench to pressure test tool and apply 107 N-m (80 ft-lbs) of torque.

   Hold torque for a minimum of five seconds. If torque indication drops off, or wrench must be moved to maintain torque, the injector is leaking and must be replaced. If torque remains constant for five seconds without movement of the wrench, the injector is acceptable.

7. Remove torque wrench and pressure test tool from the injector rocker arm.

8. Connect adjusting link to injector control lever with clevis pin and retainer spring.

9. Test all remaining injectors.

EXHAUST VALVE TIMING

DESCRIPTION

Exhaust valve timing is very important as it ensures correct relationship of valve operation with the other events in the cylinder power cycle.
To check or adjust exhaust valve timing, it is necessary to know the top dead center of each cylinder as shown in Table 2.

Items which govern correct valve timing are given in the following procedures.

MAINTENANCE

LOCATING TOP DEAD CENTER

If it should become necessary to check the position of the flywheel or the flywheel pointer for top dead center, proceed as follows:

1. Remove an air box handhole cover at the No. 1 cylinder.

2. If necessary, bar the engine to position the No. 1 piston below the cylinder liner ports.

3. Insert a brass "stop-bar" (minimum 13 mm [1/2"] hexagonal or square preferred) of suitable length through the ports of the No. 1 cylinder so that the end of the bar passes through a port on the opposite side of the cylinder, Fig. 15-2.

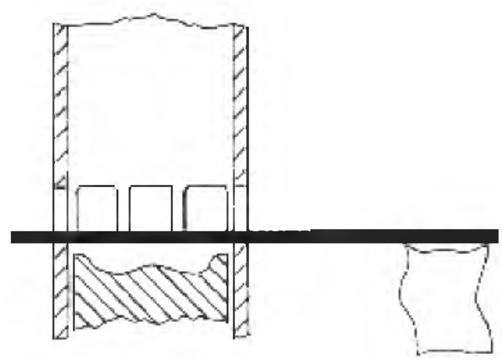

Fig. 15-2 -- "Stop-Bar" Inserted Through Cylinder Ports

NOTE: A bar of sufficient length to prevent reapplication of the handhole cover while the bar is in place is recommended. A flag on the end of the bar will caution against inadvertent rotation of the engine with the bar in place.

4. Manually bar the engine slowly in the normal direction of rotation until piston travel is stopped by the bar against the upper surfaces of the cylinder ports, Fig. 15-3.

CAUTION: Use extreme care to avoid excessive force.

5. Mark the position of the flywheel pointer on the flywheel, Fig. 15-4.

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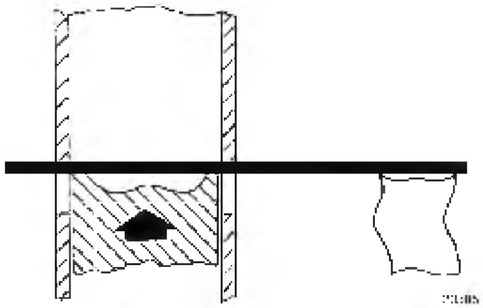


Fig. 15 3 – Piston Travel Limited By "Stop Bar"

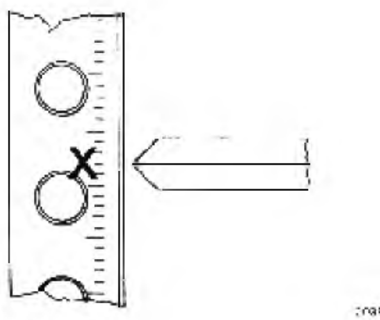


Fig. 15-4 - Limit of Piston Travel Marked On Flywheel

6. Manually bar the engine slowly in the opposite direction from normal rotation until piston travel is again stopped by the bar against the upper surfaces of the cylinder ports.

7. Mark the second position of the flywheel pointer on the flywheel, Fig. 15-5.

8. Determine the number of degrees between the two marks on the flywheel. Divide that number by 2. See Fig. 15-6 for a sample calculation.

9. Rotate the crankshaft in the normal direction of rotation the exact number of degrees determined in Step 8 above. Remove the brass "stop-bar" from the engine.

10. The pointer should indicate 180° (bottom dead center). If it does not, position the pointer so that it does indicate 180°. The pointer will now indicate top dead center for the No. 1 crankpin when the engine is rotated so that the pointer is at zero degrees (0°).

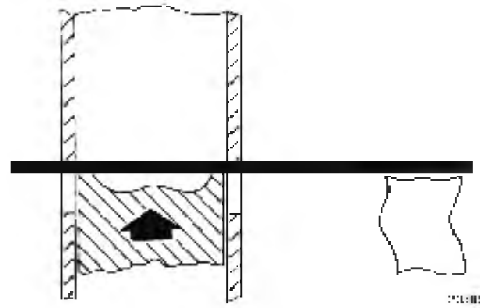


Fig. 15 3 – Piston Travel Limited By "Stop Bar"

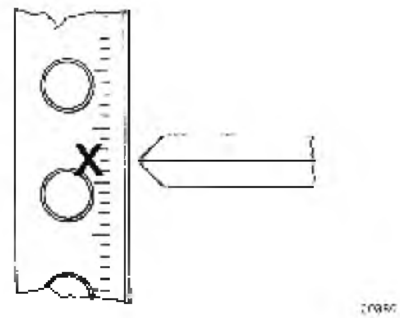
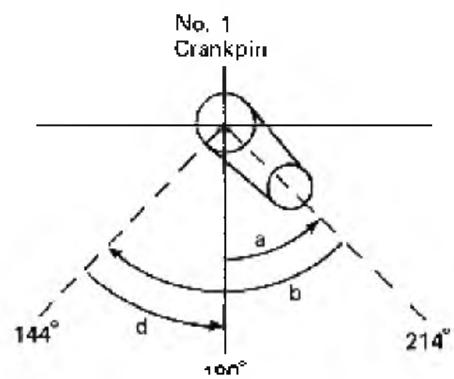


Fig. 15-5 -- Second Limit Of Piston Travel Marked On Flywheel



a. Mark flywheel as indicated in Step 5.
b. Mark flywheel as indicated in Step 7.
c. Determine number of degrees as indicated in Step 8. Divide by 2.

$$\begin{array}{r} 214^\circ \\ -\ \underline{144^\circ} \\ 70 \end{array} \qquad \frac{70^\circ}{35^\circ} = 35^\circ$$

d. Rotate 35 '. Pointer should indicate 180°. If it does not, adjust pointer to indicate 180°.

Fig. 15-6 - Sample Calculation

CHECKING EXHAUST VALVE TIMING

To check timing, place a dial indicator on the rocker arm adjusting screw as shown in Fig. 15-7. Valve end of rocker arm must be in its highest position, so that

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Fig. 15-7 -- Timing Exhaust Valves

the exhaust valves are closed. Press indicator down approximately 2.54 mm (.100") and set dial to zero.

Turn crankshaft in normal direction of rotation until flywheel is at 106° A.T.D.C. of cylinder being checked. If timing is correct, the valve bridge will have moved down 0.36 mm (.014"). Timing must not be later than 110° or earlier than 104° A.T. D.C. of cylinder being checked.

If timing is incorrect, check for:

1. Proper installation of camshaft.
2. Camshaft gear train correctly timed.
3. Excessively worn gears.

TIMING EXHAUST VALVES

The exhaust valves should be timed when any gear or stubshaft of the camshaft gear train is replaced, with the exception of the No. I or No. 2 idler gears. To do this, the camshaft on each bank must be timed to the crankshaft, but only one cylinder of each bank needs to be timed.

CAUTION: To prevent possible valve damage, remove or loosen all rocker arm assemblies, except the one on the cylinder being timed. If rocker arm assemblies are removed, hydraulic lash adjusters should be checked for proper clearance to valve stems. Refer to "Adjusting Hydraulic Lash Adjusters".

1. Apply dial indicator to the rocker arm adjusting screw, Fig. 15-7, as done in "Checking Exhaust Valve Timing."
2. Remove the dowels and bolts from the camshaft counterweight and remove counterweight and gear. The camshaft can be rotated by placing a socket and wrench on flange bolt nuts.
3. Rotate the camshaft in its normal direction of rotation until the valve bridge on which the dial indicator is resting moves down 0.36 mm (.014").
4. Turn the crankshaft in the normal direction of rotation until the flywheel pointer is at 105" after top dead center for the cylinder being checked. Install camshaft gear and counterweight on stubshaft, but do not tighten bolts at this time.
5. With flywheel at 105° A.T.D.C. of the cylinder being checked, the dowel holes in the camshaft drive gear, counterweight, and the camshaft stubshaft should be in line or approximately in line with each other. If by turning the crankshaft from 104° to 106° A.T. D.C., the dowel holes can be made to line up, then the bolts should be tightened.
6. If the dowel holes do not line up within this tolerance, remove the camshaft counterweight and gear from the stubshaft. Rotate the gear 180° and replace on stubhshaft or move the gear one tooth and replace gear and counterweight on the stubshaft.
7. If dowel holes still do not line up but misalignment is less than 0.19 mm (.0075"), the holes may be reamed for installation of 0.005", 0.010", or 0.015" oversize dowels.

   If misalignment of dowel holes is greater than 0.19 mm (.0075) proceed to Step 17.
8. Insert 5/16"-24 bolts approximately 12.70 mm (1/2") into dowel pins.
9. Place dowels in dowel holes and drive into stubshaft. Remove dowel bolts from pins.
10. Remove counterweight to stubshaft bolts. 11. Install dowel retainer plate, and counterweight to stubshaft bolts. Torque bolts to 122 N-m (90 ft-lbs).

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12. Install dowel pin bolts and torque to 23 N-m (17 ft-lbs).

13. Lockwire mounting bolts and dowel bolts in groups of three. (Two mounting bolts and one dowel bolt).

14. The crankshaft should now be rotated in its normal direction and the timing checked so that the valve bridge of the valve being checked has moved down 0.36 mm (.014") when the flywheel timing pointer is at 104°106° A.T.D.C.

15. Repeat the operation on one cylinder on the opposite bank.

16. After timing has been completed, the relative position of the mating parts should be identified similar to the method used on new engines. The mating parts are marked with No. 1 piston at top dead center. This completes valve timing procedures.

17. Remove counterweight and gear from stubshaft.

18. Plug dowel holes in stubshaft as follows:

    a. Drill and tap the two dowel holes for 3/4"-16 NF thread with a minor diameter of 0.7031" + 0.005" - 0.000" and pitch diameter of 0.7094" + 0.0016" - 0.0000".

    b. Countersink 1.6 mm (1/ 16") on gear mounting side.

    c. Drive threaded, hex head plugs (8166882) into holes.

    d. Cut plug head off and flare by peening into countersink.

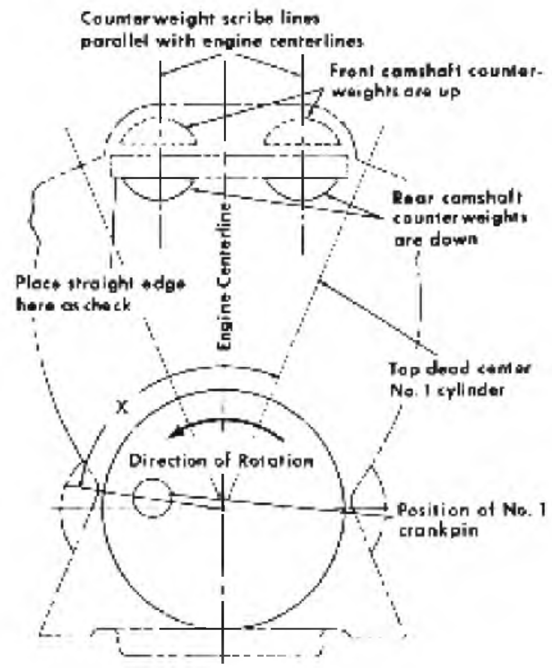
    e. Grind plugs flush with flange face.

    f. Check 5.7495" + 0.000" - 0.001" flange O.D. for high spots and grind to proper dimension.

CAUTION: If camshaft to crankshaft relationship has been disturbed, repeat Step 3.

19. Apply camshaft gear to stubshaft and secure with mounting bolts.

20. Rotate engine crankshaft to position indicated in Fig. 15-8.



X = Degrees after T.D.C. of No. 1 cylinder. To get the crankshaft in this position, turn the flywheel until this number is at the pointer.

8-Cyl. Eng.	12-Cyl. Eng.	16-Cyl. Eng.	20-Cyl. Eng.
X = 184°	X = 249-1/2°	X = 105°	X = 149-1/2°

Fig. 15-8 -- Timing Relationship Between Crankshaft and Camshaft Counterweights

21. Remove gear mounting bolts and position gear and counterweights on stubshaft with counterweight in down position and counter-weight scribe line parallel with engine centerlie. Ensure that gear and counterweight dowel holes are aligned.

22. Install mounting bolts to secure gear and counterweight to stubshaft.

23. Drill and ream stubshaft dowel holes to 12.662 mm + 0.13 mm - 0.00 mm (.4985" + .005" - .000").

24. Perform Steps 8 thru 16.

ADJUSTING HYDRAULIC LASH ADJUSTERS

Application of properly operating lash adjusters, correct setting, and subsequent inspection at regular maintenance intervals is very important to valve

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operation. Improperly set or defective lash adjusters cause the exhaust valves to be subjected to increased stress which leads to ultimate failure and probable damage to the engine.

After complete cylinder head assembly or power assembly has been installed, the lash adjusters must be set.

1. Open cylinder test valve and rotate crankshaft so that piston is at or near top dead center of the cylinder being set.

2. Loosen rocker arm adjusting screw locknuts.

3. Turn rocker arm adjusting screw down until the last valve just touches the hydraulic lash adjuster plunger, or use a 0.03 mm (.001") shim between valve tip and adjuster plunger, and then turn it down I-1 2 turns.

4. Check valve bridge spherical seat to be sure that it is spring-loaded against the cylinder head spherical seat. If the bridge spring spherical seat is not spring-loaded against the cylinder head spherical seat, turn down the rocker arm adjusting screw until no movement is felt, and then turn it another 14 turn.

5. Tighten rocker arm adjusting screw locknut.

6. After running the engine until lube oil reaches operating temperature, check the clearance between lash adjuster bodies and the end of the valve stems with the piston near top center. If the clearance is less than minimum, the cylinder head should be removed for reconditioning or rejection. Use minimum clearance gauge, Fig. 15-9, to gauge clearance between lash adjuster and exhaust valve. This gauge is 1.59 mm (1/ 16") thick and it should fit between lash adjuster body and valve stem top, to ensure the minimum clearance.

TIMING THE INJECTOR

With the injector installed, make timing adjustment as follows:

1A. On a blower engine, set the flywheel at 4° before top dead center of the cylinder being timed.

1 B. On a turbocharged engine, set the flywheel at 0° top dead center of the cylinder being timed.

NOTE: Refer to Table 2 for top dead center settings.

2. Insert injector timing gauge into the hole provided for it in the injector body, Fig. 15-10.

Fig. 15-9 - Checking Lash Adjuster To Valve Clearance

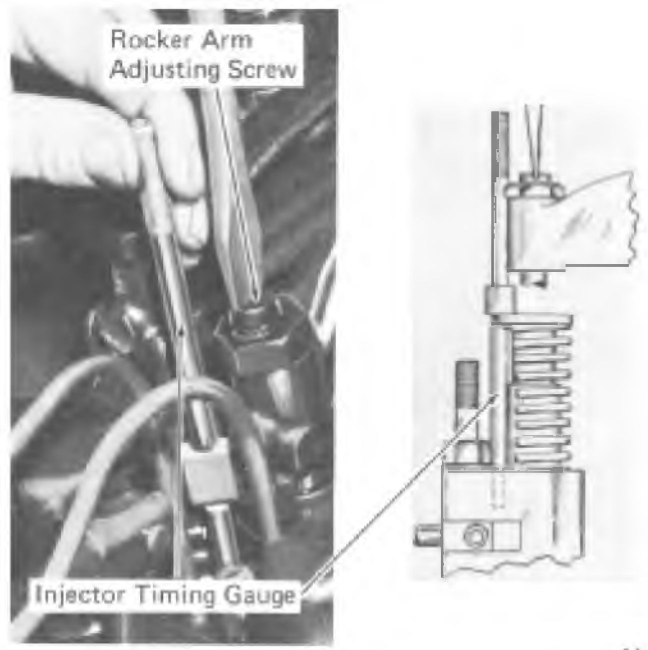

Fig. 15-10 - Timing Injector

3. Loosen locknut and turn the rocker arm adjusting screw until the shoulder of the gauge just passes over the injector follower guide.

NOTE: Injectors cannot be timed if the overspeed has been tripped. It must first be reset and the engine crankshaft barred over at least one revolution.

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4. Tighten adjusting screw locknut, holding adjusting screw in position with a screwdriver.

5. Recheck setting.

SETTING INJECTOR RACKS

Injector racks should be set with the engine at operating temperature. If racks are set when engine is not at operating temperature, the settings should be rechecked when operating temperature is reached. As engine temprature increases, the right bank rack length shortens and the left bank rack length increases. The change on the left bank is insignificant, but the change on right bank may shorten the racks beyond the minus 0.40 mm (l / 64") tolerance.

NOTE: Every time a governor is installed on an engine the injector rack setting should be checked. Due to manufacturing tolerances in governor mounting bolt holes, the position of the governor in relation to the injector linkage can change the rack setting.

Set the injector rack on the engine as follows:

1. Install the applicable injector linkage setting jack, Fig. 15-11.

2. For engines equipped with PG or EGB-10 governors, adjust the setting jack until the pointer on the governor aligns with governor terminal shaft scale at the 1.00 mark.

   For engines equipped with UG-8 governors, turn the LOAD LIMIT knob on the governor to the maximum load position. Adjust the setting jack until the terminal shaft is in full fuel position.

3. Use the rack gauge, without the adapter, Fig. 15-12, for setting the rack on engines having PG or EGB-10 type governors. Set the rack within the setting range marks on the gauge. Use the rack gauge with the adapter, Fig. 1512, for setting the racks on engines having UG-8 governors. Set the rack within the setting range marks on the gauge.

   The rack setting gauge is an 8 to I multiplying gauge which indicates the 0.40 mm (l,'64") tolerance by marks 3.18 mm (I / 8") each side of the center mark on the gauge scale.

   It is important that the proper rack gauge be used, as previous model rack gauges will measure the rack length from the body of the injector instead of from the face of the calibrating slide. The correct gauge for setting injectors with calibrating slides can be readily identified by a single locating button on the front face of the gauge. This gauge can be used for all injectors.

PG EGB – 10 UG-8

Fig. 15-11 - Injector Rack Positioning

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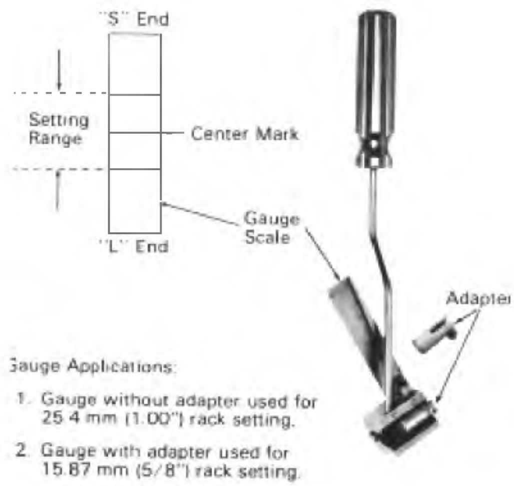

Fig. 15-12 - Injector Rack Gauge

4. Place the gauge over the injector rack and hold the gauge firmly against the face of the calibrating slide on the injector, Fig. 15-13, and check the gauge pointer. If the pointer is at the short ("S") end of gauge scale, outside of the setting range, the rack is not extending out far enough from the injector. Loosen the locknut on the adjusting link and turn adjusting nut on link until pointer is at the long ("L") end of the scale; then reverse pointer travel until it is within the scale setting range. Hold the adjusting nut and tighten locknut. The reason for exceeding the setting range when making adjustment is so that, in setting of the racks, the backlash will be taken up in the same direction.

5. When pointer is at the long ("L") end of scale, set pointer within the setting range. The accuracy of the injector rack gauge can be checked by inserting the master block in the gauge body. Pointer should align with center mark on scale.

"ONE REVOLUTION" INSPECTION SEQUENCE CHARTS

The following engine "one revolution" inspection sequence charts show the power assembly checks that can be visually made during one revolution of the engine crankshaft. Select the chart which is applicable to the number of cylinders and the direction of rotation of the engine to be inspected.

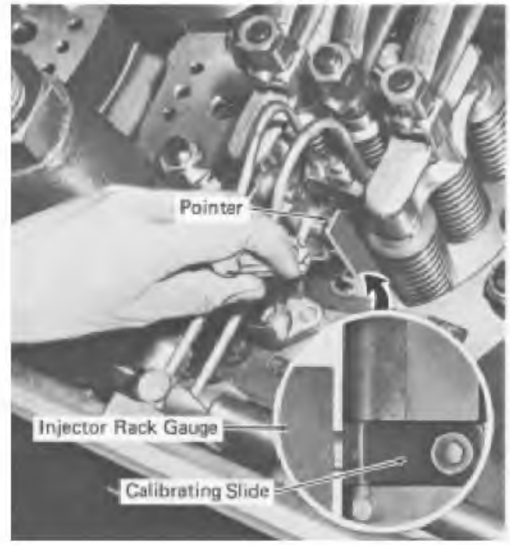

Fig. 15-13 - Injector Rack Gauge Application

NOTE: The right-hand rotation charts are applicable only to right-hand rotation marine engines.

Start with the engine flywheel at "0" degrees on the pointer. Bar the engine over slowly in the normal direction of rotation and read the chart to the right of "flywheel degrees" for the cylinder number and the check to be made. Column headings are as follows:

FLYWHEEL DEGREES

BLOWER - Indicates the flywheel setting required on a blower-type engine to perform the applicable inspections.

TURBOCHARGED -Indicates the flywheel setting required on a turbocharged engine to perform the applicable inspections.

SET INJECTOR - The number appearing in this column opposite "flywheel degrees" indicates that the injector of that cylinder can be timed.

No. 1 RING

U P -The number appearing in this column indicates that the compression rings in that cylinder are moving upward past the ports of the liner, and can be inspected.

DOWN - The number appearing in this column indicates that the compression rings in that cylinder are moving downward past the ports of the liner, and can be inspected.

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PISTON COOLING OIL PIPE - The number appearing in this column indicates that the clearance between the piston cooling oil pipe and the piston carrier can be observed and the alignment gauge can be used.

PISTON - The number appearing in this column indicates that the skirt of the piston in that cylinder can be inspected through the liner ports.

LINER - The number appearing in this column indicates that the piston in that cylinder is at or near bottom dead center, which allows inspection of the liner bore through the liner ports.

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8-CYLINDER ENGINE (LEFT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1					4
18 ½	_		7	2			
41	45	5					8
63 ½	67'/2		4	6	4-6	1-7	
86	90	3					2
108 ½	112'/2		8	1			
131	135	7					6
153 ½	157'/2		2	5	2-5	3-8	
176	180	4					1
198 ½	202'/2		6	3			
221	225	8					5
243 ½	2471/2		1	7	1-7	4-6	
266	270	2					3
288 ½	292'/2		5	4			
311	315	6					7
333 ½	337'/2		3	8	3-8	2-5	

12-CYLINDER ENGINE (LEFT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1	3	2	3-2	8	
15	19	12	10	11	10-11	4	
							5
41	45	7	9	8	9-8	3-6	
							2
66	70					10-1	
							11
90	94	4	5	6	5-6	9-12	
							8
116	120	3	2	1	2-1	7	
135	139	10	11	12	11-12	5	
							6
161	165	9	8	7	8-7	2-4	
							1
186	190					11-3	
							12
210	214	5	8	4	8-4	8-10	
							7
236	240	2	1	3	1-3	9	
255	259	11	12	10	12-10	6	
							4
281	285	8	7	9	7-9	1-5	
							3
306	310					12-2	
							10
330	334	6	4	5	4-5	7-11	
							9
356	0	1	3	2	3-2	8	

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16-CYLINDER ENGINE (LEFT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1	6	13	6-13	7-16	4
18'/2	22'/2	8	11	2			5
41	45	9	14	7			12
63'/2	67'/2	16	4	10	4-10	1-11	13
86	90	3	5	15	5-15	8-14	2
108'/2	112'/2	6	12	1			7
131	135	11	13	8			10
153'/2	157'/2	14	2	9	2-9	3-12	15
176	180	4	7	16	7-16	6-13	1
198'/2	202'/2	5	10	3			8
221	225	12	15	6			9
243'/2	247'/2	13	1	11	1-11	4-10	16
266	270	2	8	14	8-14	5-15	3
288'/2	292'/2	7	9	4			6
311	315	10	16	5			11
333'/2	337'/2	15	3	12	3-12	2-9	14

20-CYLINDER ENGINE (LEFT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
TURBO-CHARGED	SET INJECTOR	UP	DOWN			
0	1	15	3	15-6	4	10
9	19	17	6	15-6	16	12
36	8	17	6	17-4	9	3
45	11	12	4	17-4	14	20
72	5	12	4	12-9	1	6
81	18	20	9	12-9	19	13
108	7	20	9	20-1	8	4
117	15	13	1	20-1	11	16
144	2	13	1	13-8	5	9
153	17	16	8	13-8	18	14
180	10	16	8	16-5	7	1
189	12	14	5	16-5	15	19
216	3	14	5	14-7	2	8
225	20	19	7	14-7	17	11
252	6	19	7	19-2	10	5
261	13	11	2	19-2	12	18
288	4	11	2	11-10	3	7
297	16	18	10	11-10	20	15
324	9	18	10	18-3	6	2
333	14	15	3	18-3	13	17
360	1	15	3	15-6	4	10

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(MARINE ONLY) 8-CYLINDER ENGINE (RIGHT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1					4
18 ½	22 ½		8	3			
41	45	6					
63'/2	67 ½		4	5	4-5	1-8	
86	90	2					3
108 ½	112 ½		7	1			
131	135	8					5
153 ½	157 ½		3	6	3-6	2-7	
176	180	4					1
198 ½	202 ½		5	2			
221	225	7					6
243 ½	247 ½		1	8	1-8	4-5	
266	270	3					2
228 ½	292 ½		6	4			
311	315	5					8
333 ½	337 ½		2	7	2-7	3-6	
356	0	1					4

(MARINE ONLY) 12-CYLINDER ENGINE (RIGHT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1	2	3	2-3	8	
							9
22	26	6	5	4	5-4	7-11	
							10
46	50					2-12	
							3
71	75	8	9	7	9-7	1-5	
							4
97	101	11	10	12	10-12	6	
116	120	2	3	1	3-1	9	
							7
142	146	5	4	6	4-6	8-10	
							12
166	170					11-3	
							1
191	195	9	7	8	7-8	2-4	
							6
217	221	10	12	11	12-11	5	
236	240	3	1	2	1-2	7	
							8
262	266	4	6	5	6-5	9-12	
							11
286	290					10-1	
							2
311	315	7	8	9	8-9	3-6	
							5
337	341	12	11	10	11-10	4	
356	0	1	2	3	2-3	8	

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(MARINE ONLY) 16-CYLINDER ENGINE (RIGHT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1	13	6			4
18 ½	22 1/2	15	12	3			14
41	45	10	5	16	5-16	8-13	11
63 ½	67 ½	7	4	9	4-9	1-12	6
86	90	2	14	8			3
108 ½	112 ½	13	11	1			16
131	135	12	6	15	6-15	7-14	9
153 ½	157 ½	5	3	10	3-10	2-11	8
176	180	4	16	7			1
198 ½	202 ½	14	9	2			15
221	225	11	8	13	8-13	5-16	10
243 ½	247 ½	6	1	12	1-12	4-9	7
266	270	3	15	5			2
288 ½	292 ½	16	10	4			13
311	315	9	7	14	7-14	6-15	12
333 ½	337 ½	8	2	11	2-11	3-10	5
356	0	1	13	6			4

(MARINE ONLY) 20-CYLINDER ENGINE (RIGHT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES	SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
TURBO-CHARGED		UP	DOWN			
0	1	20	7	13-7	5	10
27	14	20	7	20-5	11	17
36	9	12	5	20-5	8	2
63	16	12	5	12-8	19	15
72	4	17	8	12-8	1	7
99	13	17	8	17-1	14	18
108	6	15	1	17-1	9	5
135	20	15	1	15-9	16	11
144	3	18	9	15-9	4	8
171	12	18	9	18-4	13	19
180	10	11	4	18-4	6	1
207	17	11	4	11-6	20	14
216	2	19	6	11-6	3	9
243	15	19	6	19-3	12	16
252	7	14	3	19-3	10	4
279	18	14	3	14-10	17	13
288	5	16	10	14-10	2	6
315	11	16	10	16-2	15	20
324	8	13	2	16-2	7	3
351	19	13	2	13-7	18	12
0	1	13	7	13-7	5	10

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INTERPRETATION OF LUBE OIL SAMPLE ANALYSIS

LUBE OIL ANALYSIS	BASIS FOR ANALYSIS	NORMAL No Action Required	BORDERLINE Take Extra Oil Samples	HIGH Correct Condition	RECOMMENDED ACTION WShut Down Engine. Drain Lube Oil. Change Filters.
Fuel Leak	Viscosity & Flash Point -- Check for dilution if flash point less than 400° F or oil viscosity drops 15% or more.	0 to 2%	2 to 5%	Above 5%	Borderline find and fix fuel leak. High - check main bearings per maintenance manual.
Water Leak	Free Water	None		Any	Resample with dry container. Find and fix leak. Check main bearings per maintenance manual.
	Chromate Inhib.	0 to 20 PPm	20 to 40 PPm	Above 40 PPm	Find and fix water leak. Check lube oil filter
	Boron Inhibitor	0 to 10 ppm	10 to 20 ppm	Above 20 ppm	tank pressure.
Air Filtration	Silicon	0 to 5 ppm	5 to 10 ppm	Above 10 ppm	Improved air filter maintenance required.
Excessive Oxidation	Viscosity Rise, TBN, pH (p e r A S T M D664 method), & Pentane Insol.	Normal		Viscosity 30% rise,' TBN 0.5 min., pH 5.0, P.I. 2% max. Change oil.	I If short oil life persists, check lube oil quality, fuel sulphur content, oil cooler efficiency, engine temperature controls, power output (governor and rack settings), engine condition (worn rings, cracked pistons, poor combustion), oil filtration, or oil pump suction leak.
Contami-nated fuel (cracking catalyst)	Aluminum Magnesium		Above 5 PP m		Check fuel cleanliness. Notify fuel supplier. If engine smokes, check injector calibration and tip erosion. Check if piston rings are excessively worn.
Oil Contami-nation	Zinc	0 to 10 ppm	Above 10 dangerous values.	ppm becomes more with increasing	Check if oil is contacting galvanized or zinc painted surfaces. Check if make up oil in stock is within specifications. Notify lube oil supplier. Check for silver bearing fail ures.
	Silver	0-1 ppm	1-2 ppm	Above 2 ppm	Check if oil contains zinc or is corrosive to silver. Check for broken piston cooling tubes, inefficient oil cooler, or improper temperature control. Feel sides of insert bearings for signs of distress. Measure piston to head clearance with lead readings. Oil draining is not mandatory. Check strainers and bottom of oil pan for debris. Consider turbo bearing condition.
Abnormal Wear or Corrosion (Rapid increases within normal range should be considered borderline condition) condition)	Chromium (Not appli cable if chromate coolant inhibitor is used)	0 to 10 ppm	10 to 20 ppm	Above 20 ppm	Check for rapid wear of rings & liners.
	Copper	0 to 75 ppm	75 to 150 ppm	Above 150 ppm	Measure piston to head clearance with lead readings to locate worn piston thrust washers.
	Iron	0 to 75 ppm	75 to 125 ppm	Above 125 ppm	Check for rapid wear of rings & liners.
	Lead	0 to 50 ppm	50 to 75 ppm	Above 75 ppm	Most likely lead flash is dissolving off bearings. Premature lead removal, before bearings are broken in, can lead to bearing distress. Inspect and replace upper con rod bearings in service less than 6 months if lead flash has been removed from the unloaded area of the fishback bearing surface on turbocharged engines. If con rod bearings require replacement, wrist pin bearings should also be checked and replaced if lead
In Combina-tion	Copper Iron Lead		Two out of in borderline three elements or high range.		Check for debris under crankshaft gear indicative of gear train bushing distress. Check idler gear bearing clearances. Check main and con rod bearings per maintenance manual. Oil draining is not mandatory.

*In areas where fuel sulfur content exceeds 0.5% {a TBN (D664) level of 1.0 should be maintained
{a TBN (D2896) level of 3.0 should be maintained.

Table I - Interpretation 01- Lube Oil Sample Analysis

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Firing Order	8-Cylinder Top Dead Center	Firing Order	8-Cylinder Top Dead Center
1	0'	1	0'
5	45'	6	45"
3	90'	2	90'
7	135'	8	135'
4	180'	4	180°
8	225°	7	225°
2	270°	3	270'
6	315°	5	315'
12-c Firing	ylinder Top Dead Center	Firing Order	12-Cylinder Top Dead Center
1	0'	1	0'
12	19'	6	26'
7	45*	8	75*
4	94'	11	101'
3	120°	2	120°
10	139°	5	146°
9	165°	9	195°
5	214°	10	221°
2	240°	3	240'
11	259°	4	266'
8	285°	7	315'
6	334°	12	341'
Firing Order	16-Cylinder Top Dead Center	Firing Order	16-Cylinder Top Dead Center
8	22-1/2'	15	22-1/2'
9	45'	10	45'
16	67-1/2'	7	67-1/2
3	90'	2	90'
6	112-1/2'	13	112-1/2'
11	135'	12	135'
14	157-1/2'	5	157-1/2'
4	180'	4	180'
5	202-1/2'	14	202-1/2'
12	225'	11	225'
13	247-1/2'	6	247-1/2'
2	270'	3	270'
7	292-1/2'	16	292-1/2'
10	315'	9	315'
15	337-1/2'	8	337-1/2'
Firing Order	20-Cylinder Top Dead Center	Firing Order	20-Cylinder Top Dead Center
19	9"	14	27'
8	36'	9	36"
11	45,	16	63°
5	72"	4	72°
18	81'	13	99'
7	108°	6	108°
15	117'	20	135'
2	144°	3	144°
17	153	12	171°
10	180	10	180°
12	189	17	207°
3	216°	2	216°
20	225°	15	243'
6	252'	7	252°
13	261°	18	279°
4	288'	5	288°
16	297°	11	315°
9	324'	8	324°
14	333,	19	351°

Note

Locomotive, drilling rig, and power generating installations are available only with left-hand rotating engines.
Only marine and industrial installations are available with either a left or righthand rotating engine.

Table 2 - Firing Order And Top Dead Center For 645 Engines

from the library of Barrington Diesel Club

GOVERNOR AND GOVERNOR RELATED TROUBLESHOOTING

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
Insufficient travel of injector adjusting link to obtain correct in jector rack setting.	1. Wrong terminal shaft lever applied to governor.	1. Change terminal shaft lever. Lever should measure 106.4 mm (4-3/16") between hole centers.
	2. Terminal shaft lever improperly applied to governor.	2. If lever has no double serration, apply new lever. Lever should have double width serration matched with missing serration of terminal shaft.
	3. Wrong terminal shaft on governor.	3. Replace governor. Missing serration should be at 3 o'clock position.
	4. Wrong terminal shaft scale on governor.	4. Replace governor. Scale should be graduated from 1.96" to .62".
Governor low oil plunger trips when starting engine.	1. Governor low oil time delay too short, or engine slow in developing oil pressure.	1. Reset governor low oil plunger immediately, and crank engine again. With engine operating at idle, check and reset time delay, if necessary. See EMM Governor Section.
	2. Differential water or crankcase pressure detector tripped.	2. Check detector reset buttons to ensure they are in the set position.
	3. Engine oil pressure line to governor broken or crimped.	3. Replace oil line.
	4. Hot oil shutdown valve stuck open or leaking.	4. Replace valve if defective. See LSM Lubricating Oil Section.
	5. True low engine oil pressure.	5. See EMM Lubricating Oil Section.

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TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
Governor fails to control engine speed when starting engine.	1. Insufficient fuel. (Terminal shaft goes to full-fuel position.)	l. Replace fuel filter elements. Clean fuel strainer element.
	2. Insufficient oil in governor. (Terminal shaft goes to no-fuel position.)	2. Check governor sight glass for proper oil level. See EMM Governor Section for procedure and M.I. 1764 for correct lubricating oil.
	3. Governor shutdown bushing not properly adjusted. (Terminal shaft goes to no-fuel position.)	3. Remove governor cover and check that shut down bushing to speed setting piston extention clearance is 1132" when the speed indicating pointer moves to Idle as engine is cranked. If not, remove governor and reset per EMM Governor Section.
	4. Defective governor. (Terminal shaft goes to no-fuel position.)	4. Remove governor cover and check to see that speed indicator pointer moves from STOP to IDLE position when cranking engine. Replace governor if speed indicating pointer does not move.
	5. Incorrect injector rack setting.	5. Reset injector racks. See EMM Fuel Section.
Idle speed approximately 50 rpm low.	The cap under the "D" solenoid is cocked or the spring around the "D" solenoid plunger rod is not installed correctly.	Install Parts correctly. See EMM Governor Section.

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Governor hunts.	1. Compensating needle valve not properly adjusted. 2. Too much or too little oil in governor. 3. Governor hunts for a short time when engine oil and governor oil are cold. 4. Insufficient fuel. 5. Binding injector control shaft linkage or sticking injector. 6. Wheel slip action due to variations in locomotive wheel diameter. 7. Governor binding internally.
Governor hunts only at full load.	1. Insufficient fuel to maintain engine speed at full load. Partial fuel restriction. 2. Defective load regulator rheostat. 3. Other electrical problems.
Engine overloaded. Gov ernor terminal shaft at full fuel position, but engine speed bogs down. Load regulator in minimum field position.	1. Insufficient fuel. 2. Over excitation of main generator. Fault in power control circuits.

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1. See EMM Governor Section.

2. See EM M Governor Section for procedure, and M. I. 1764 for correct oil.

3. Run engine for a short period of time to warm the oil.

4. Fuel return sight glass must be full and relatively clear at all speeds and loads. Replace fuel filter elements and clean fuel strainer element. Check that fuel pump is of adequate capacity.

5. Make certain that all control shaft linkage is free. (Replace sticking injector or free up linkage.)

6. Match wheel diameters.

7. Replace governor.

1. Replace fuel filter elements. Clean fuel strainer element. Fuel return sight glass must be full.

2. Qualify rheostat.

3. See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual.

1. Check fuel filter and strainer. Return fuel sight glass must be full.

2. See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual.

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TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
Engine underloaded. (Not producing proper horsepower.) Engine at rated speed. Governor terminal shaft at longer than specified rack, and load regula tor in maximum field position.	Under excitation of the main generator. Fault in power control circuits.	See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual.
Engine is loaded and runs at rated speed, but Governor terminal shaft is at longer than speci- fied rack length.	1. Governor terminal shaft quadrant pointer off location.	1. With engine shut down, quadrant scale should indicate 1.96". Relocate quadrant pointer and reset injector racks.
	2. Low air box pressure.	2. Run engine at 8th throttle, no load. Air box pressure should be within one-half psi of that of similar unit at 8th throttle, no load. If air box pressure is low check:
Load regulator is bal- anced.		a. Turbocharger impeller for damage. b. Aftercooler and filters for plugging. c. Aftercooler duct for leakage. d. Exhaust manifold for leakage.
	3. Leak or restriction in air line from air box to governor.	3. Remove air line and check. Replace if necessary.
	4. Locknut on overriding solenoid backed off, holding rebalancing rocker arm up.	4. Readjust governor overriding solenoid and tighten locknut. See EMM Governor Section.
	5. Improperly set governor.	5. Replace governor.

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Engine is loaded and runs at rated speed, but Governor terminal shaft is at shorter than specified rack length.	1. Governor terminal shaft quadrant pointer off location. 2. Improperly set governor.
Load regulator is balanced.	1. Insufficient fuel. 2. One or more injectors defective.
Load regulator stays in minimum field position with the engine at idle.	3. Governor overriding solenoid stuck, or spring under over riding solenoid plunger broken. 4. Injector rack length not properly set at 1.00" on governor terminal shaft scale. 5. Governor to load regulator lines reversed.
Governor fills with oil.	1. Ruptured low oil pressure diaphragm. 2. Defective seal on load control pilot valve plunger. 3. Porous column casting.
Governor loses oil.	1. Defective drive shaft seal. 2. Defective terminal shaft seal.

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1. With engine shut down, quadrant scale should indicate 1.96". Relocate quadrant pointer, and reset injector racks.

2. Replace governor.

1. Check fuel filter and strainer.
Return fuel sight glass must be full.

2. Qualify injector.
See EMM Fuel Section.

3. Replace governor.

4. Reset injector rack length.
See EMM Fuel Section.

5. Reapply lines correctly.

1. Replace diaphragm or change out governor.

2. Replace governor.

3. Replace governor.

1. Replace drive shaft seal or replace governor.

2. Replace governor.

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TROUBLE REPORT	I POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
Governor does not change speed when throttle is changed.	1. Loose governor plug.	1. Check governor plug for looseness. Replace governor.
	2. Solenoids do not respond to throttle setting.	2. Replace governor. Make certain that control circuits are providing power to energize solenoids.
	3. Locomotive in consist does not reduce engine speed for corresponding throttle reduction. Low voltage feed in trainline holds solenoids(s) in once ener gized.	3. Correct control circuit problem.
Engine speed will not increase beyond 6th throttle speed.	1. Engine air filters clogged.	1. Replace engine air filter elements
	2. Engine filter switch defective.	2. Replace engine air filter switch.

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TURBOCHARGER TROUBLESHOOTING

GENERAL

More than 50% of turbocharger failures are caused by conditions external to the turbocharger. If these conditions are not corrected, the replacement turbocharger may also fail in a very short time. In other cases, an engine problem is attributed to a failed turbocharger, while in fact, nothing is wrong with the turbocharger. Therefore, troubleshooting a turbocharger requires two decisions.

1. Whether or not the turbocharger has actually failed and requires replacement.

2. The actual cause of the failure.

Any turbocharger suspected of being defective should be inspected for obvious damage. The entire housing should be inspected for cracks and oil leaks. Some oil leaks can be repaired merely by tightening a pipe plug or by applying silastic rubber sealant, but an intolerable leak from a crack or from an inaccessible area requires turbocharger changeout.

INSPECTION BEFORE ENGINE START

IMPELLER INSPECTION

An impeller inspection should be made on all turbochargers suspected of a failure except those suspected of exhaust gas leaks.

1. Remove the rubber air intake boot and flange.
2. Inspect the impeller for broken or nicked vanes or any visible signs of rubbing. On Unit Exchange turbochargers do not confuse smooth blends in the impeller surface or on the vane with sharp nicks caused by foreign material.
3. Turn the impeller by hand to check for a lockedup condition or a badly damaged clutch. It should turn freely in the counterclockwise direction, but engage when turned clockwise.
4. Displace the impeller laterally, vertically, fore, and aft to determine excessive radial or end thrust clearance.
5. Inspect the clearance between the impeller and the cover to reveal any impeller contact.

Any defective condition found during this inspection requires turbocharger replacement. If no defective condition is found, reinstall the flange and boot.

ENGINE INSPECTION

Often a reported turbocharger failure is actually a failure of some other engine component. The engine should be barred over to determine if it is damaged before a starting attempt is made and inspection continued.

INSPECTIONS AFTER ENGINE START

TURBOCHARGER REPORTED MAKING UNUSUAL NOISE

Identical turbocharger components can make varied sounds due to the tolerances within which the components are manufactured. The sum of these individual sounds results in a wide range of noise such a whining, chirping, singing, and humming. A different sounding turbocharger is not necessarily defective. Obvious exceptions are severe humming or the loud screech of distressed metal associated with gear failures or bearing failures. Normally these noises are accompanied by visual damage, leaving little doubt about the failure.

When a turbocharger is reported defective because of noise, the following should be performed.

1. Inspect the impeller as outlined above.
2. Remove a handhole cover and check for metallic debris under the crankshaft gear. Such debris is indicative of a gear train problem.

TURBOCHARGER REPORTED THROWING OIL OUT OF THE EXHAUST STACK

Inspect the exhaust stack to ensure that the oil is actually coming out of the stack.
A plugged and leaking turbocharger seal cannot be found through external inspection, so it must be determined by process of elimination only if no other faulty condition is discovered.

1. Shut the engine down and remove the expansion joint and turbocharger exhaust inlet screen from the engine. Varnish, oil, and heavy carbon on the screen indicates the oil is not coming from the turbocharger, but from the engine.
2. Inspect for blocked air filters and renew paper or fiberglass elements if necessary. Clean oil bath filters. A portion of the turbocharger

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b. Check for an air box leak, especially at the turbocharger discharge scroll gaskets and the air box covers.

c. Check the pressure drop across the after-coolers, and correct if necessary.

d. Check for exhaust leaks at manifold or expansion joints. check for leaky gaskets or a leaking pipe plug on top of the turbocharger exhaust inlet scroll.

e. A low pressure reading can occur when a clutch is in extremely bad condition so that it will slip when the turbocharger is driven by the gear train. This condition may cause poor starting as well as smoking or burping. Take off the rubber boot and clear the area around the turbocharger inlet of all foreign material. Observe the impeller while attempting to start the engine. A badly damaged clutch will slip consistently.

4. If the pressure readings taken on the unit under inspection and the reference unit are equal, and there is a definite malfunction, the problem may be a slipping turbocharger clutch or some external malfunction. It is usual for a malfunctioning clutch to slip only intermittently, therefore only occasionally causing burping and smoking by its failure to engage. A failed clutch requires turbocharger changeout.

   a. Idle the engine.

   b. Operate the injector rack manual control lever to increase engine speed to about 700 RPM. Then pull the manual control lever to the "no fuel" position. This action will allow the turbocharger to spin free from the decelerating engine and disengage the clutch.

   c. When the engine has almost stopped, return the injector rack manual control lever to the idle position. The engine will accelerate and the clutch should engage.

   d. Repeat the procedure until the clutch fails to engage. A worn clutch may fail to engage only once in as many as 30 attempts. When it fails to engage, the injector racks will move toward "full fuel" position, the engine will produce heavy black smoke, and rumbling noises may come from the engine.

TURBOCHARGER EXHAUST LEAK REPORTED

Start the engine and determine if it is actually leaking exhaust. Some turbochargers look sooty because of exhaust leaks at expansion joints or manifold gaskets. Most turbocharger exhaust leaks occur at cracks in the exhaust inlet scroll or at the sealing areas on either side of the exhaust duct. These types of leaks cannot be repaired in the field and require turbocharger changeout.

FAILURE PREVENTION

After turbocharger failure has been varified, it is very important to determine the cause of the failure and take preventive measures to ensure that the replacement turbocharger will not fail.

While the turbocharger is removed from the engine, inspect all open areas.

1. Impeller.

2. Exhaust duct.

3. Inlet scroll (nozzles and turbine blades).

4. Gear train (also inspect for debris at both turbo oil drain passages).

Any sign indicating that failure was caused by an external source should be investigated and corrective action taken before the unit is returned to service. The following paragraphs list some common failures.

FOREIGN MATERIAL DAMAGE TO THE IMPELLER

This failure, Fig. 15-16, usually results from one of the following.

1. Previous Turbocharger Failure - When a turbocharger is operating and pieces are broken off the impeller, the force drives the pieces into the air filter. Later, they may be pulled loose and damage the new impeller.

2. Misapplication Of The Compressor Inlet Boot - If the boot travels, a clamp may enter the impeller and destroy it.

3. Loose Material In The Air Filter Housing - Material left in the housing can enter the impeller.

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Fig. 15-16 - Impeller Damaged By Foreign Material

If an impeller has rubbed the cover or has pieces broken out, the air filter housing, ducts, and filters should be inspected. Paper or fiberglass elements should be scrapped if the inspection reveals aluminum in the air duct, filter housing, or in the filters.

As the turbocharger rotating assembly slows down during a failure, pieces of the impeller may enter the air duct and damage the aftercoolers. The aftercooler area should be inspected following damage to the impeller.

CAUTION: In many cases, rubbing and loss of pieces from the impeller are caused by an unbalanced condition within the turbocharger. Therefore, the turbocharger should be inspected for other defects which cause imbalance when impeller rubbing and loss of pieces are found.

FOREIGN MATERIAL DAMAGE TO TURBINE BLADES

Foreign material damage can be found by inspecting blades and nozzles as detailed in the section under "Turbocharger Reported Burping And Smoking Excessively". The nozzles may be dented or closed, and at times, larger pieces of foreign material may be stuck in them. If the rotating assembly is not frozen, inspect the leading edges of all the blades by turning the impeller. The leading edges of some or all of the blades will be nicked and, in some cases, a blade may break at a nick, Fig. 15-17. The mechanical breakup of any part of the power assemblies or the exhaust system may result in

Fig. 15-17 - Nicked Blades

foreign material damage to the turbine blades and nozzles. The most common sources are broken exhaust valves and broken piston rings. The turbocharger is protected from this material by the inlet screen, but the screen in not 100% effective, since it is designed to pass a large volume of air while inducing only a small drop in pressure. It will however, stop and hold most pieces of material. This material must be removed at the earliest opportunity, or it will break up and pass through the screen, causing turbine blade damage.

A newly designed screen with a trap at the bottom is now available. The trap collects foreign material and prevents it from continuously hitting the screen, breaking up, and entering the turbocharger. The screen assembly is now applied to new engines and is available from Electro-Motive Part Centers.

Failures can be reduced by performing preventive maintenance to:

1. Preclude ring breakage. Top ringside clearance measurement can be used as a method to determine when the ring is entering a dangerous stage.

2. Prevent valve blow from progressing to valve breakage. Maintain valve and injector timing as specified in the Engine Maintenance Manual.

3. Determine if power assembly or exhaust system pieces are missing, and locating and removing them from the exhaust system.

OVERHEAT/ OVER SPEED

Overheat/ overspeed is the most destructive and costly type of failure and may result in almost total destruction of the turbocharger. Since it is caused by excessive heat energy in the exhaust system which increases turbine

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wheel speed to an unacceptable level, the only cure is to remove the source of the heat energy.

An overheat/ overspeed failure can be recognized by:

1. Turbine blades that are stretched and have rubbed the shroud; some of the blades may have pulled apart. Often the turbocharger is frozen and the impeller cannot be rotated, therefore, only a limited view of the blades is available, Fig. 15-18.

Fig. 15-18 - Stretched Blades That Have Rubbed The Shroud

2. Viewing down the exhaust duct; the exhaust diffuser may be warped and the shroud may be bulged. Both may be torn by broken blades, Figs. 15-19 and 15-20.

3. An impeller that rubs the cover; the overheat/ overspeed condition may result in a bearing failure that allows the impeller to move forward, or an unbalanced condition may occur when blades are pulled apart.

The usual sources of excess heat are:

1. Air box fire. White ash should be visible in the inner air box, on the stress plates, end plates, or liners. The paint on the handhole covers may be blistered. Clean if necessary.

   Any condition that increases either the air box temperatures or the amount of deposit formation in the air box should be corrected. These conditions are:

   a. Dirty aftercoolers.

   b. Broken compression rings.

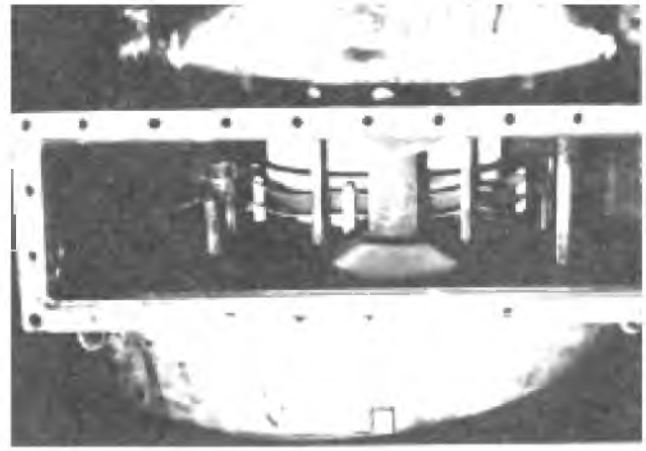

Fig. 15-19 - View Down The Exhaust Stack - Warped Diffuser

Fig. 15-20 - View Down The Exhaust Stack Of A Warped Diffuser And Damage From Broken Blades

   c. Late injector timing. d. Incorrect valve timing.

   e. Plugged turbocharger exhaust inlet screen.

   f. Plugged air filters or other restrictions in the air intake system.

2. Damaged injectors.

3. Broken valves (sometines causing damaged injectors).

4. Mis-timed engine, valves, and injectors.

5. Exhaust manifold fire.

6. Excessive electrical overload.

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BEARING FAILURE

A bearing failure is characterized by:

1. Heavy rubbing of the impeller vanes.
2. Excessive rotor end thrust.
3. Possible excessive up and down play in the rotor bearings.
4. No sign of turbine overheat/ overspeed or foreign material damage.

Some bearing failures are avoidable. Starting or stopping the engine with no turbo lube pump oil flow can result in a bearing failure. The turbo lube pump provides oil to the turbocharger's hydrodynamic bearings when the engine is started or stopped. At engine start the oil lubricates the bearing and, after engine shutdown, the oil cools the bearing and protects against residual heat in the turbocharger.

Scheduled monthly inspection should include visual inspection through a rear oil pan handhole cover to verify oil flow down the gear train after the engine is shut down. A check at the top deck should also be made to ensure that oil is not flowing from the camshaft bearings, indicating an inoperative check valve that is allowing oil from the turbo lube pump to backflush the turbocharger filter into the engine bearings. Also, when an engine is shut down, any battery switch, fuse, or circuit breaker that deactivates the turbo lube pump must remain closed until the bearing has cooled.

Bearing failures can also occur due to turbocharger housing distortion from misalignment of the aftercooler air ducts. Follow the procedures outlined in the Engine Maintenance Manual when installing the air ducts.

GEAR TRAIN FAILURE

When turbocharger gear train damage is evident, the following should be performed:

1. Check for debris in the lube oil system, oil pan, strainers, and filters.
2. Inspect the timing gear housing for debris.
3. Inspect the entire engine gear train to determine which gears require replacement. For engines using spring drive gears, the gear retaining bolts should be checked for tighness. Discard any loose bolts and apply new bolts.

NOTE: The eight bolts holding the turbocharger drive gear to the spider should be 31.8 mm (1-1/4") long, with hardened washers between the gear and bolt heads.

EXHAUST LEAKS

Improper application of lifting chains (allowing them to press against the exhaust duct when the turbocharger is suspended) can lead to bending of the lap joint between the exhaust duct and the compressor bearing supply. Once this joint is deformed, a permanent exhaust leak may result.

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