710 SERIES

ENGINE MAINTENANCE MANUAL

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PREFACE

FOREWORD

This manual contains maintenance information for EMD 710 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.**

NOTE

This manual includes information in regards to federally regulated emmisions standards from Tier 0 up to and including Tier 3 requirements. Always consult an order specific parts catalogue prior to initiating any engine maintenance or part replacement. Only use OEM approved parts, failure to do so will void warranty.

The illustrations generally depict a typical 16-cylinder engine model as representative of the location, size, and relative shape of various components and accessories. Some of the illustrations used may NOT be of actual components or accessories applied to a specific engine, but have been used as typical or representative examples where actual visual appearance will NOT affect positioning or placement during reassembly.

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.

NOTE

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation, or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser’s purposes, the matter should be referred to the Electro-Motive Division.

SERVICE DATA PAGES

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:

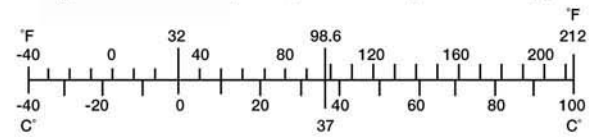
Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At the time of engine overhaul or any time unscheduled maintenance is performed, the service limits should *not* be exceeded. Engine components within these limits may be reused with the assurance that they will perform satisfactorily until the next scheduled overhaul. These limits are NOT to be used as a basis for component change-out on a running engine.

METRIC MEASUREMENT

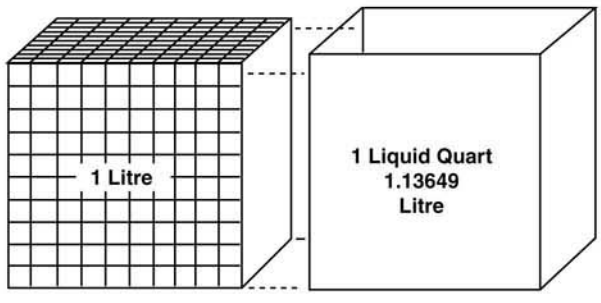
Units of measurement appearing in this manual are shown in metric units and U.S. standard units.

CONVERSION TABLES

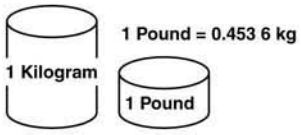
Multiply	by	to get equivalent number of:
	LENGTH	
Microinch	.025 4	micron (μ)
Inch	25.4	millimetres (mm)
Foot	0.304 8	metres (m)
Yard	0.914 4	metres
Mile	1.609 3	kilometres (km)
	AREA	
$Inch^2$	645.2	$millimetres^2$ (mm^2)
	6.45	$centimetres^2$ (mm^2)
$Foot^2$	0.092 9	$metres^2$ (m^2)
$Yard^2$	0.836 1	$metres^2$
	VOLUME	
Ounce	29.574	$centimetre^3$ (cm^3)
$Inch^3$	16 387.	mm^3
	16.387	cm^3
	0.016 4	litres (l)
Ft^3	0.028 3	$metre^3$ (m^3)
Imp. Quart	1.1364 9	litres
Imp. Gallon	4.545 8 9	litres
$Yard^2$	0.764 6	$metres^3$ (m^3)
	MASS	
Ounce	28.350	grams (g)
Pound	0 453 6	kilograms (kg)
Ton	907.18	kilogram
Ton	0.907	ton (metric)
	FORCE	
Kilogram	9.807	newtons (N)
Ounce	0.278	newtons
Pound	4.448	newtons
	TEMPERATURE	
Degree Farenheit	(t° F-32) ÷ 1.8	degrees Celsius (C)

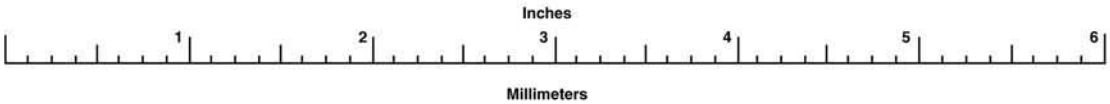


Multiply	by	to get equivalent number of:
	ACCELERATION	
$Foot/sec^2$	0.304 8	$metre/sec^2$ (m/s^2)
$Inch/sec^2$	0.025 4	$metre/sec^2$
	TORQUE	
Ounce-force-inch	0.007 06	newton-metre
	0.069 2	kilogram-metre
Pound-inch	0.112 98	newton-metres (N-m)
	0.011 52	kilogram-metres
Pound-foot	1.355 8	newton-metres
	0.138 25	kilogram-metres
	POPWER	
Horsepower	0.746	kilowatts (kW)
	PRESSURE OR STRESS	
Inches of water	0.249 1	kilopascals (kPa)
Pounds/sq. in.	6.895	kilopascals
	ENERGY OR WORK	
BTU	1 055.	joules (J)
Foot-pound	1.355 8	joules
Kilowatt-hour	3 600 000 or $3.6x10^6$	joules (J= one W's)
	LIGHT	
Footcandle	10.764	$lumens/metre^2$ (lm/m^2)
	FUEL PERFORMANCE	
Miles/gal (Imp.)	.354 0	kilometres/litre (km/l)
Imp. gal/mile	2.824 7	litres/kilometre/ (l/km)
	VELOCITY	
Miles/hour	1.609 3	kilometres/hr. (km/h)



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





SECTION 0. ENGINE INFORMATION

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0.1 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.



Figure 0-1. Three-Quarter Left Front View, 16-Cylinder



Figure 0-2. Three-Quarter Right Front View, 16-Cylinder

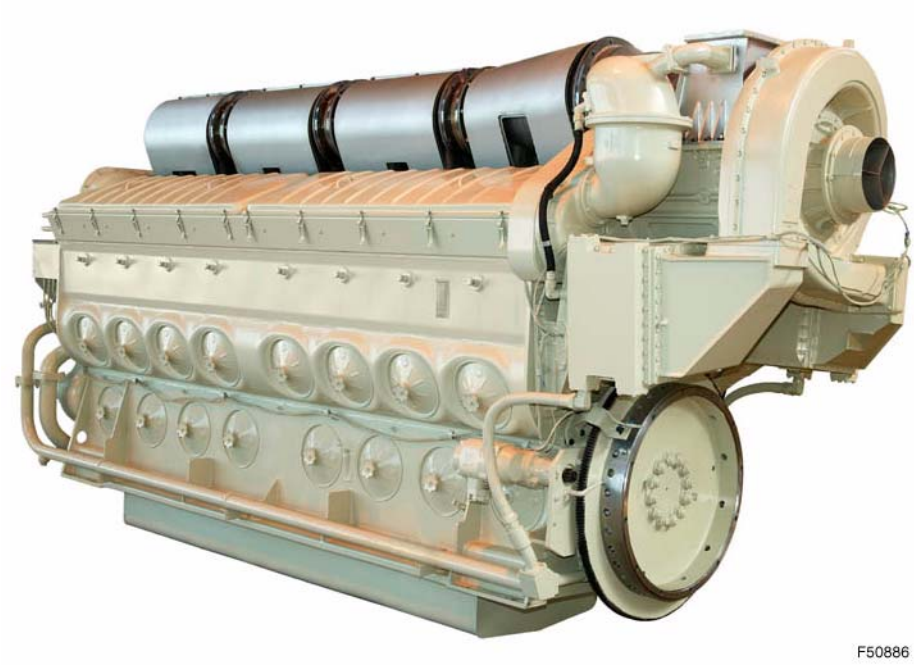


Figure 0-3. Three-Quarter Left Rear View, 16-Cylinder



Figure 0-4. Three-Quarter Right Rear View, 16-Cylinder

0.1.1 OPERATION - TURBOCHARGED ENGINES

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 Figure 0-5., “Schematic Illustration Of Engine Operation” on page 0-6, to efficiently provide the air needed for combustion and scavenging. The turbocharger provides an air supply greater than that provided by 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 Figure 0-5., “Schematic Illustration Of Engine Operation” on page 0-6. Thus cooled, air of greater comparable weight and having more oxygen is available to the engine.

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, remaining 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° after bottom dead center, the air intake ports will be closed by the piston. 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.

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.

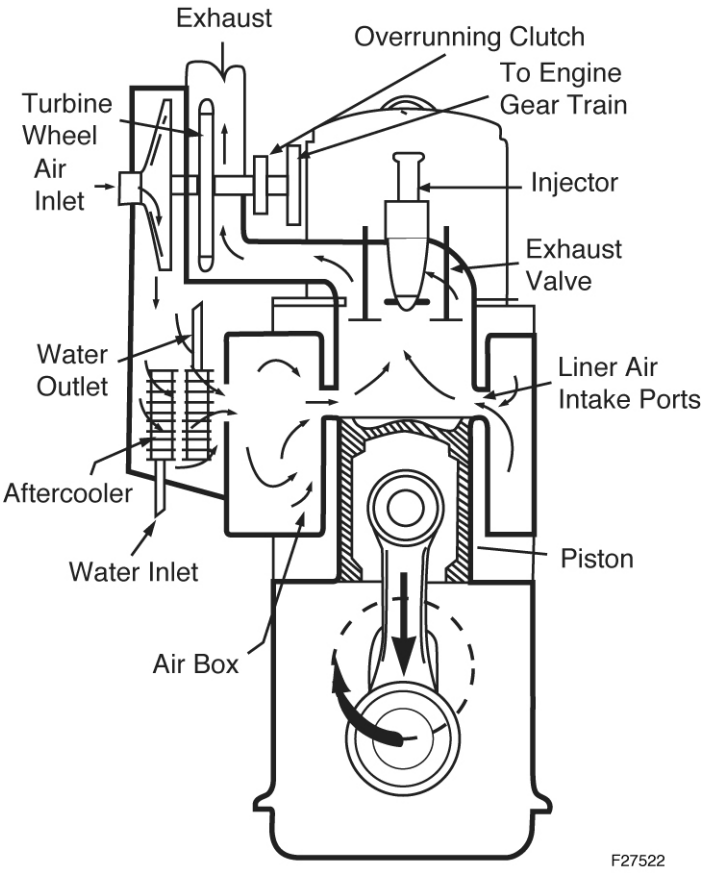


Figure 0-5. Schematic Illustration Of Engine Operation

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.

0.2 ARRANGEMENT

Cylinder location and the designation of the ends and banks of the engine, as referred to throughout the manual, are shown in Figure 0-6. The water pumps, and the lube oil pumps are mounted on the “front” of the engine. The turbocharger and the 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 Figure 0-5, page 0-6 Cross Section of Engine Operation.

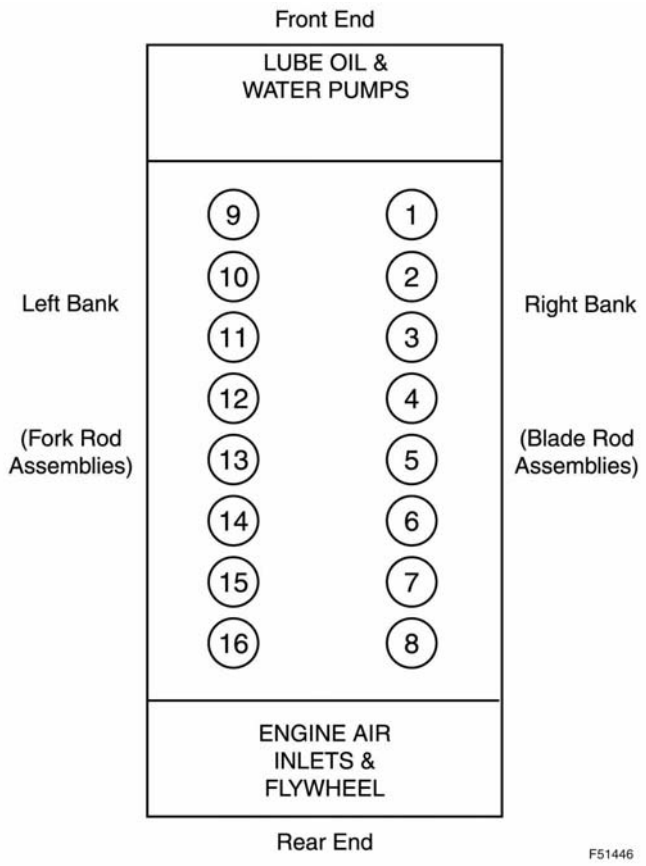


Figure 0-6. Engine Arrangement

0.2.1 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.



Figure 0-7. Engine Identification Plate

CRANKCASE - The 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.



Figure 0-8. Crankcase Serial Number

OIL PAN - serial number is located on the left side of the oil pan below the top rail at the rear end.



Figure 0-9. Oil Pan Serial Number

CRANKSHAFT - serial numbers are located on the web of both the first and last throws.

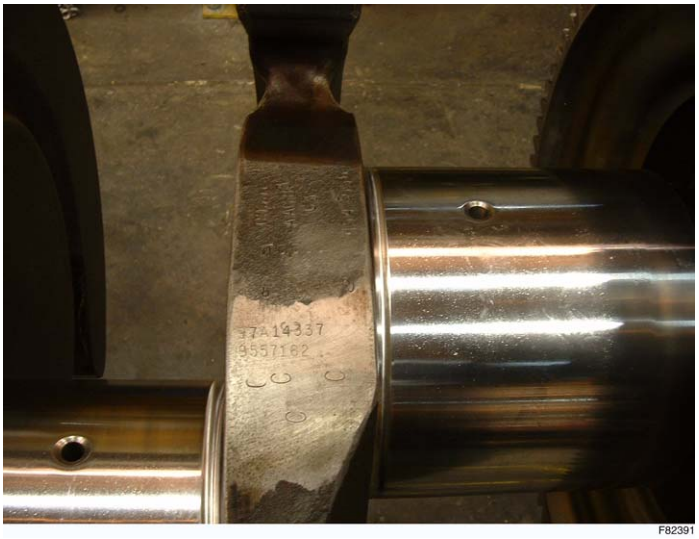


Figure 0-10. Crankshaft Serial

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

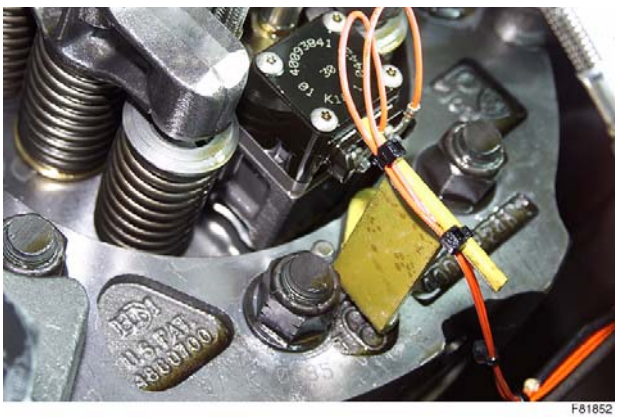


Figure 0-11. Cylinder Head Serial Number

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



Figure 0-12. Cylinder Liner Serial Number

FORK CONNECTING ROD - serial numbers are located in three different locations as the fork rod assembly consists of two basket halves that are matched to the fork rod. On both basket halves, the serial number is located above the left basket to rod bolthole. On the fork rod, the serial number is stamped in the center of the rod on the dowel (outboard) face between the serrations. Note that the serial number applies to the complete fork rod assembly, therefore all three numbers must match.

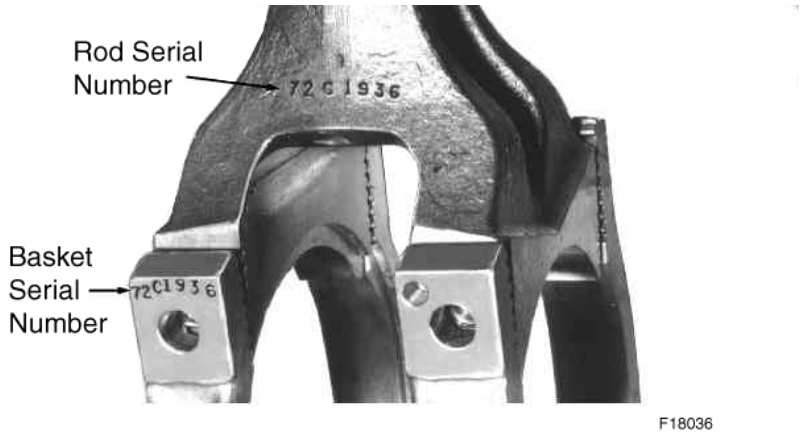


Figure 0-13. Fork Rod Serial Number

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



Figure 0-14. Blade Rod Serial Number

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



Figure 0-15. Camshaft Assembly Serial Number

WATER PUMP - serial number is located on the housing flange rim.



Figure 0-16. Water Pump Serial Number

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



Figure 0-17. Main Lube Pump Serial Number

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

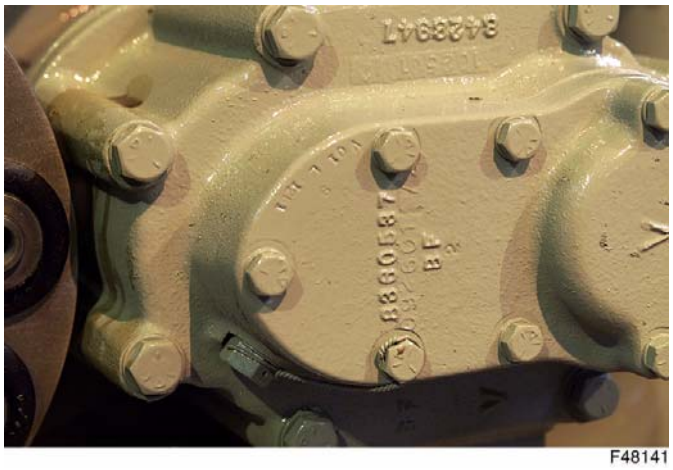


Figure 0-18. Scavenging Pump Serial Number

ELECTRONIC FUEL INJECTORS - serial numbers printed permanently on labels in numbers and bar codes.



Figure 0-19. Fuel Injector Serial Number

0.2.2 WEIGHTS - 710 ENGINES

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 are represented in kilograms and pounds per unit, as described.

DESCRIPTION	8-cyl.		12-cyl..		16-cyl.		20-cyl.	
	kg	Lb	kg	Lb	kg	Lb	kg	Lb
Engine assembly	10 523	23,200	14 855	32,750	17 962	39,600	21 047	46,400
Crankcase (includes bearings & caps)	2 758	6080	3 841	8408	5 798	12,783	6 992	15,415
Oil pan	643	1418	746	1644	1 019	2247	1 421	3132
Crankshaft	815	1796	991	2184	1 544	3403	1 653	3645
Torsional damper (gear type)	170	375	170	375	170	375	170	375
Torsional damper (pendulum type)	-	-	166	365	-	-	-	-
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	177	390	177	390
Cylinder power assembly								
w/ fork rod	200	440	200	440	200	440	200	440
w/ blade rod	179	395	179	395	179	395	179	395
Cylinder head assembly	66	145	66	145	66	145	66	145
Cylinder liner	64	140	64	140	64	140	64	140
Piston	27	59	27	59	27	59	27	59
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	64	142	90	198	114	252	138	304
Camshaft drive gear	40	89	40	89	40	89	40	89
Camshaft drive housing	162	357	162	357	162	357	162	357
Idler gear stubshaft assembly	46	101	46	101	46	101	46	101
Lower idler gear (No. 1)	28	62	28	62	28	62	28	62
Spring drive gear assembly (8-cyl.)	77	170	-	-	-	-	-	-
Clutch drive gear assembly (12, 16, & 20-cyl.)	-	-	91	200	91	200	91	200
Accessory drive cover assembly	60	132	60	132	60	132	xx	xxx
Overspeed trip/ Camshaft counter-weight housing assembly	19	42	19	42	19	42	19	42
Governor	54	120	54	120	54	120	54	120
Governor drive gear assembly	24	53	24	53	24	53	24	53
Governor drive housing assembly	18	40	18	40	18	40	18	40
“D” Water pump	49	109	59	130	59	130	59	130
“G” Water pump (High Capacity)	-	-	77	170	77	170	77	170
Water manifold assembly	16	35	20	45	31	68	31	68
Main lube & piston cooling oil pump assembly (8, 12, & 16-cyl.)	62	136	66	146	89	197	-	-
Lube oil pump assembly (20-cyl.)	-	-	-	-	-	-	89	197
Scavenging oil pump assembly	74	164	74	164	101	222	-	-

DESCRIPTION	8-cyl.		12-cyl..		16-cyl.		20-cyl.	
	kg	Lb	kg	Lb	kg	Lb	kg	Lb
Lube oil strainer assembly	92	203	92	203	92	203	68	150
Fuel oil filter assembly	22	49	30	65	30	65	25	55
Turbocharger assembly	816	1800	953	2100	953	2100	953	2100
Auxiliary drive assembly	37	81	37	81	37	81	37	81
Aftercooler duct	76	167	82	180	82	180	82	180
Aftercooler core, header, and cover	90	199	95	210	95	210	95	210
Oil separator assembly	-	-	-	-	-	-	-	-
Tier 0	33	73	33	73	33	73	33	73
Tier 1	33	73	33	73	33	73	33	73
Tier 2	33	73	55	121	55	121	55	121
Tier 3	66	145	66	145	66	145	66	145
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 (Electric)	35	78	35	78	35	78	35	78
Starting motor (Air)	-	-	-	-	32	69	32	69
Starting motor mounting bracket	26	58	26	58	26	58	26	58

0.3 TORQUE VALUES

NOTE

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

0.3.1 TOP DECK

	Nm	FT-LBS
Camshaft assembly segment & spacer nuts	47	35
Camshaft stubshaft bearing bracket bolts -		
5/8" hex head (lubricated)*	190	140
1/2" socket and hex head	102	75
Cylinder head crab nuts (studs and nuts lubricated)* -		
Initial	542	400
Final	3 254	2400
Cylinder head crab nuts (studs and nuts lubricated)*-		
Initial	407	300
Final	2440	1800
Injector crab nuts (lubricated)*	68	50
Cylinder head-to-liner (lubricated)* -		
Initial	95	70
Final	325	240
Top deck head frame bolts -		
(300M bolts with hardened washers)	54	40
(280M bolts with hardened washers)	41	30
Overspeed trip assembly (MUI)	32	24
Injector fuel (jumper) line bolts (MUI)	54	40
Injector fuel (jumper) line fittings (EUI)	54	40
Fuel manifold blocks and clamps	54	40
Camshaft bearing blocks	43	32
Rocker arm shaft nuts (lubricated)* -		
Initial	203	150
Final	407	300
Rocker arm oil line bolts	9.5	7
Cylinder test valve to cylinder head	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 bolts	108	80
Water discharge “Y” manifold (W/ gasket)	169	125
Lifting shackle (replaces “Y” manifold W/O gasket)	407	300
Cylinder test valve packaging nut	88	65

0.3.2 ACCESSORY END

	Nm	FT-LBS
Accessory drive housing-to-crankcase and oil pan (w/ sealing compound)†	88	65
Overspeed trip/ camshaft counterweight 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/camshaft counterweight housing	41	30
Fuel manifolds-to-filter	47	35
Oil strainer elbows-to-strainer housing	54	40
Accessory drive oil seal cover	54	40
Oil seal retainer to accessory drive oil seal cover	41	30
Accessory drive coupling retainer bolt -		
Initial	136	100
Final	881	650
Accessory drive coupling locking spring bolt	88	65
Governor drive gear assembly -		
Stubshaft-to-crankcase	102	75
Stubshaft dowel bolts	9.5	7
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
Counterweight-to-camshaft stubshaft -		
1/2"	122	90
5/16" (dowel bolts)	23	17
EMDEC pressure and temperature sensors	27	20

0.3.3 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. 1 idler gear thrust plate-to-crankcase -		
5/8"	251	185
7/8"	698	515
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 and counterweight-to-camshaft stubshaft -		
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 to exhaust duct - 3/8”	37	27
Oil separator expansion joint to ejector - 3/8”	32	24
Oil separator-to-turbocharger - 1/2”	122	90
Oil slinger-to-crankshaft gear	23	17
Oil retainer-to-camshaft drive housing	41	30
Exhaust silencer-to-turbocharger (lubricated)**	122	90
EMDEC pressure and temperature sensors	27	20

0.3.4 CRANKCASE AND OIL PAN

Main bearing nuts or bolts (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
Piston pin retainer bolts -		
5/16"-24 x 1"	36.6-40.7	27-30
Basket-to-connecting rod (lubricated)* -		
Initial	14	10
Final	258	190
Connecting rod basket	102	75
Piston cooling oil pipe bolts	27	20
Water jumper-to-liner	41	30
Water jumper saddle strap nuts	20	15
Torsional damper-to-crankshaft (lubricated)*	814	600
Accessory drive gear-to-crankshaft (lubricated)*	217	160
Coupling disc-to-crankshaft (lubricated)* -		
1-1/4"-12	1 830	1350
1-1/2"-12	2 440	1800
Coupling disc rim bolts	400	295
Ring gear & EMDEC timing plates-to-coupling disc	37	27

EMDEC timing sensor assembly-to-camshaft drive housing (w/ sleeves)	88	65
Handhole cover bolts	27-41	20-30
Engine mounting bolts (w/ sleeves)	881	650
Harmonic balancer-to-crankshaft (lubricated)*	678	500
Accessory drive gear to crankshaft (lubricated*)	407	300
Accessory drive gear oil slinger	33	24

*Lubricate with Texaco Threadtex No.2303

**Lubricate with Fel-Pro C5A or equivalent

†Apply Loctite Sealing Compound No. 242

0.4 EXTERNALLY THREADED FASTENERS

EMD Number	SAE Grade Number	Nominal Size Diameter (Inches)	Base Metal Rockwell Harness		Grade Indentification (Hex Head Only)
			Min.	Max.⑤	
255M①	1	#6 thru 1-1/2”	B70	B100	None
260M①	2	#6 thru 3/4”④	B80	B100	None
260M①	2	over 3/4” to 1-1/2	B70	B100	None
-③	4	1/4” thru 1-1/2”	C22	C32	None
280M①	5	#6 thru 1”	C25	C34	
280M①	5	over 1” to 1-1/2”	C19	C30	
290M②	7	1/4” thru 1-1/2	C28	C34	
300M①	8	1/4” thru 1-1/2	C32	C38	
455M①	None	#6 thru 1-1/2	B79	--	

F82395

NOTES:

1. Bolts, Screws and Studs.
2. Bolts and Screws only.
3. Studs only.
4. Grade 2 applies to bolts and screws 6" or shorter, and studs at all lengths. Grade 1 applies to bolts and screws longer than 6".
5. Surface hardness shall not exceed base metal hardness by more than 2 points (Rockwell “C” equivalent).

0.5 EQUIPMENT LIST

	PART NO.
Gasket sealing compound, Loctite No. 242 -0.47 liters (1 pt.)	8178639
Thread lubricant (high temperature), Fel-Pro C5A-0.946 liters (1 qt.)	8278929
Thread lubricant, Texaco Threadtex No. 2303 - approx. 18.93 liters (5 U.S. gal.)	8307731

SECTION 1. CRANKCASE AND OIL PAN

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1.1 CRANKCASE

1.1.1 DESCRIPTION

The crankcase, Figure 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 the liners and pistons, cleaning of the air box, and access to water manifold and oil pan mounting bolts.

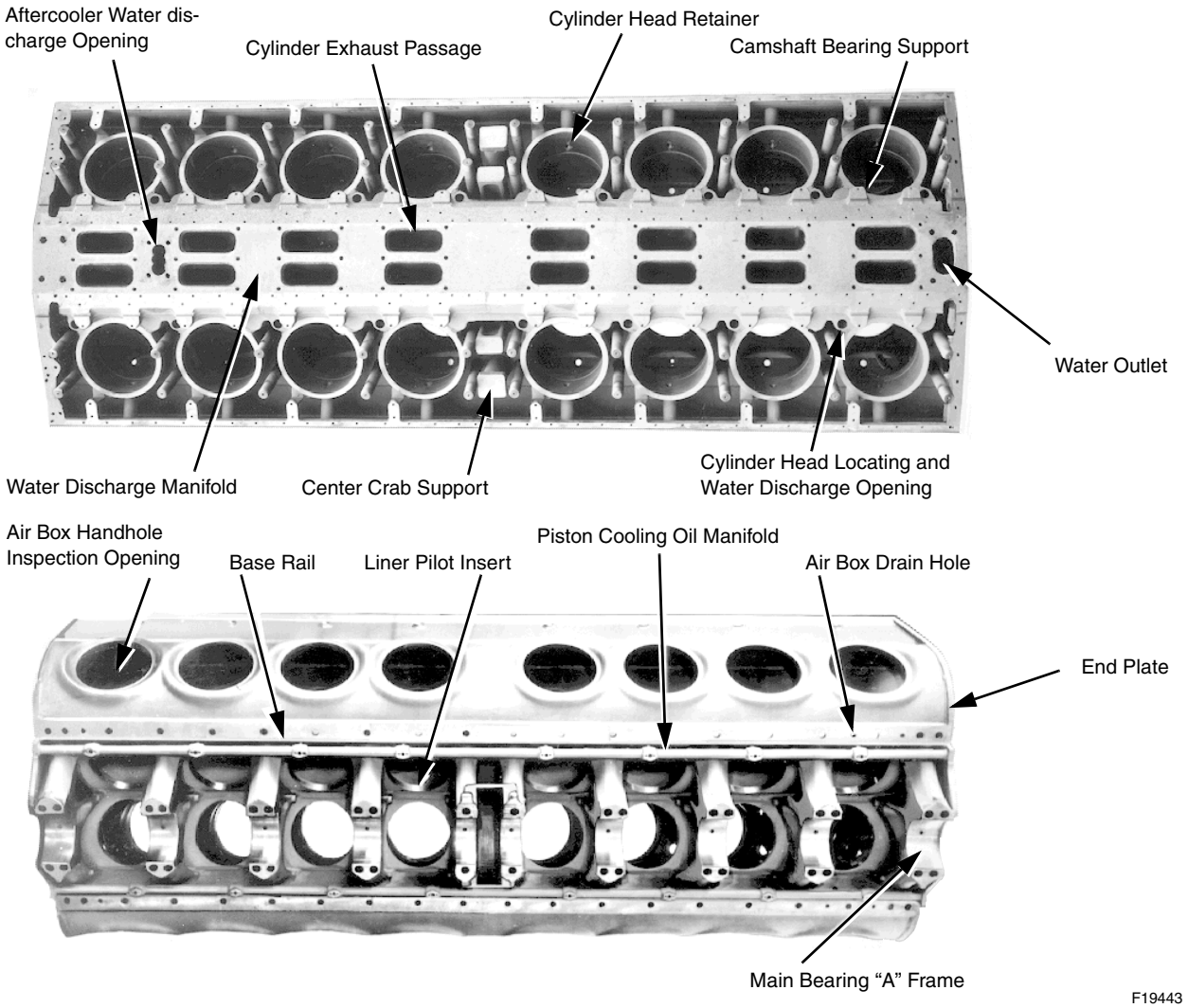


Figure 1-1. Crankcase, 16-cylinder

1.1.2 MAINTENANCE

1.1.2.1 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, bound-edge towels.

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

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

1.1.2.2 5INSPECTION

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.

1.2 LOWER LINER BORE INSERT

1.2.1 DESCRIPTION

A replaceable cast iron insert, Figure 1-2., “Lower Liner Bore Insert” on page 1-5, 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.

1.2.2 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.

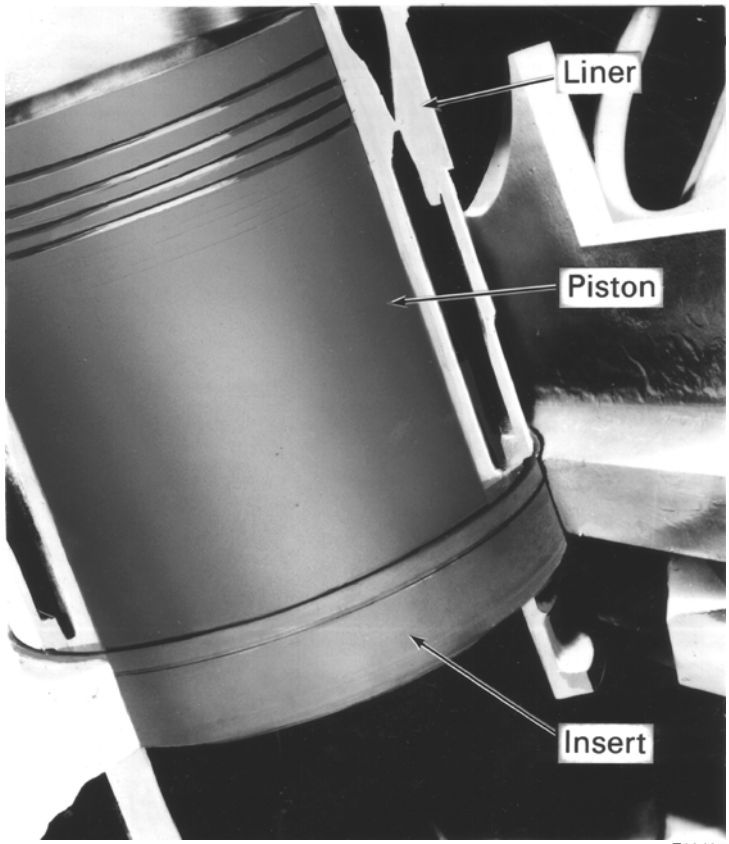


Figure 1-2. Lower Liner Bore Insert

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(s), Figure 1-3., "Liner Bore Insert Application And Removal Tool" on page 1-6 and Figure 1-4., "Assembly Of 710 Adapter To Application And Removal Tool" on page 1-7, are specifically designed to do this work. The basic 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.

NOTE

The basic insert application and removal tool assembly was originally designed for use with earlier model EMD engines. It can also be used as is for installing lower liner inserts on 710 engines. Removal of inserts on 710 engines; however, requires the use of adapter shown in "Figure 1-4. Assembly Of 710 Adapter To Application And Removal Tool on page 1-7. With this adapter installed on the tool, lower liner inserts can be removed from early model engines as well as 710 engines.

1.2.2.1 INSERT APPLICATION

The arrangement of the tool for insert application is shown in View "A" and View "C." The insert is installed as follows:

1. Coat the contact area of the outside diameter of the insert with mounting compound listed in the Service Data at the end of this section.
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 View "A" 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.
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.

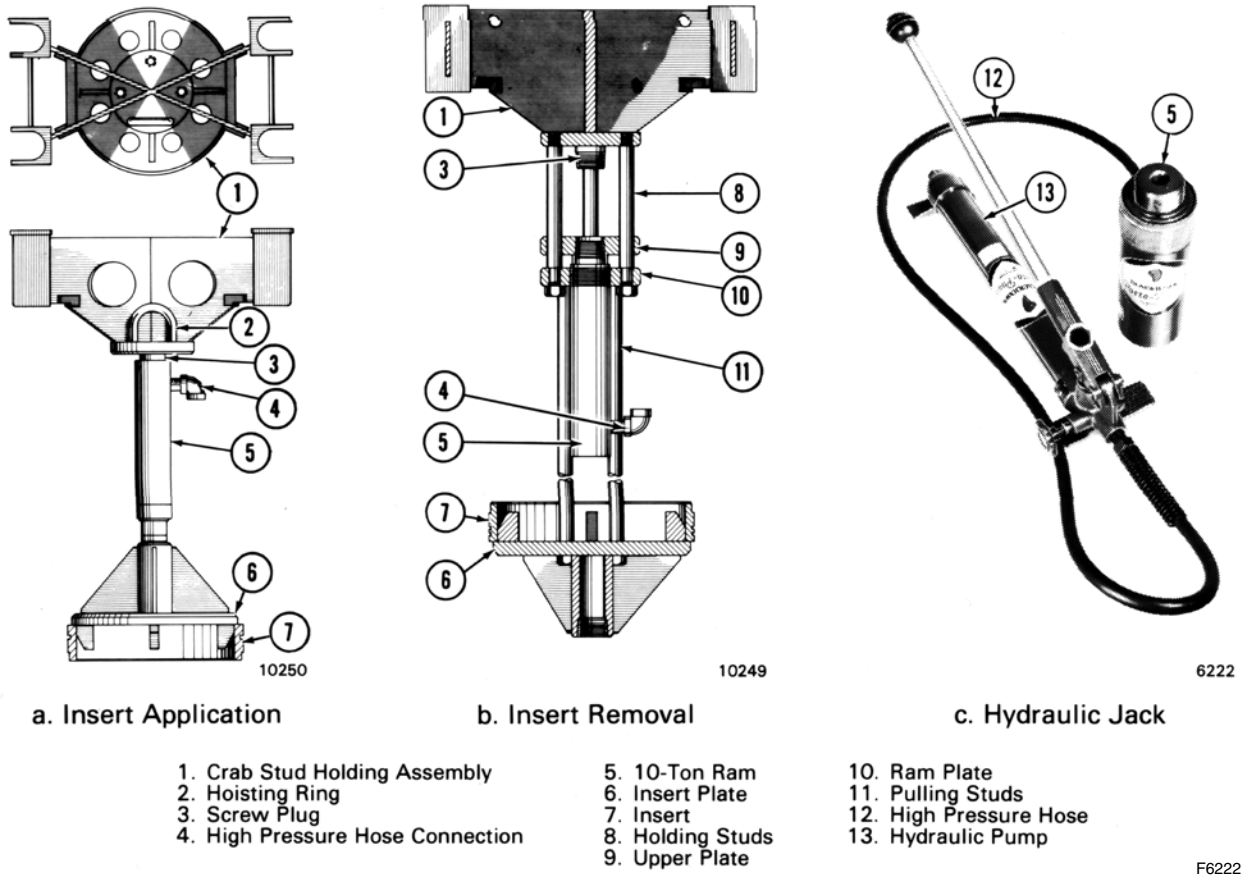


Figure 1-3. Liner Bore Insert Application And Removal Tool

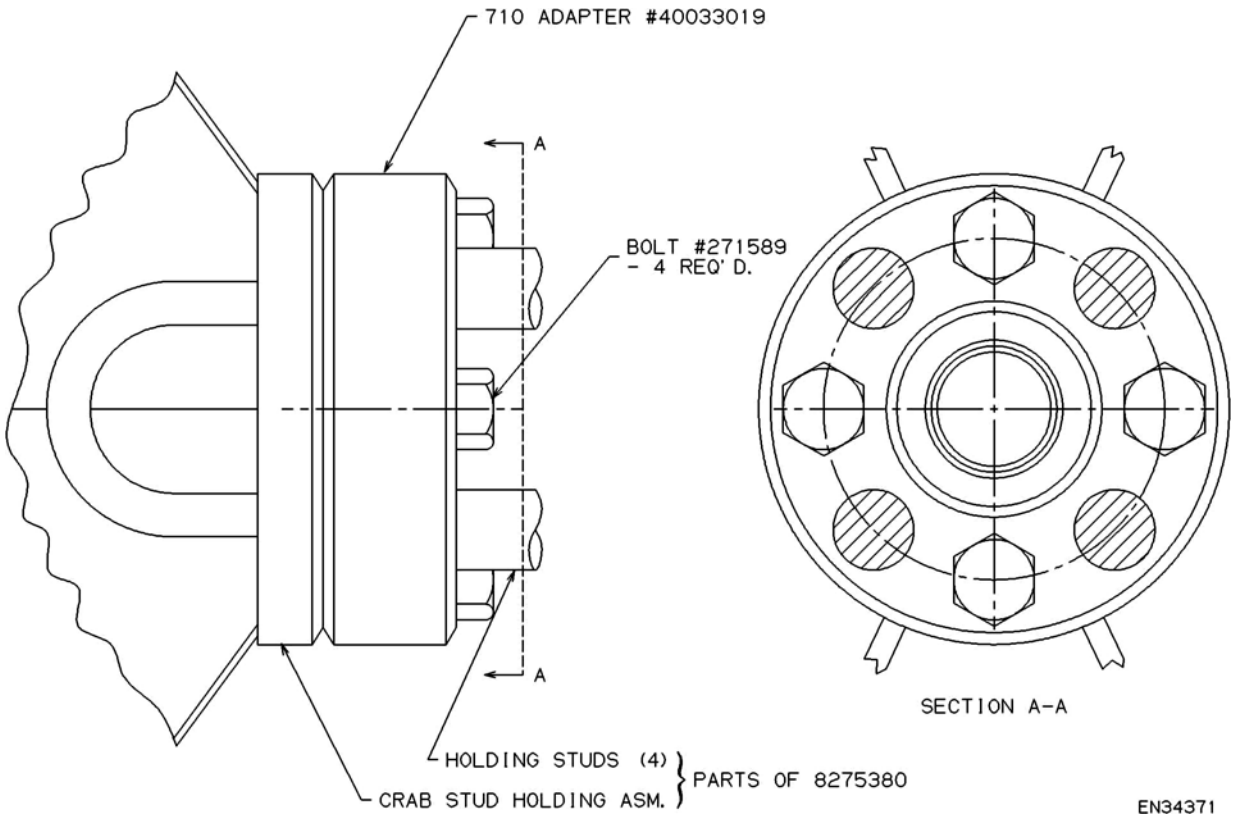


Figure 1-4. Assembly Of 710 Adapter To Application And Removal Tool

1.2.2.2 INSERT REMOVAL

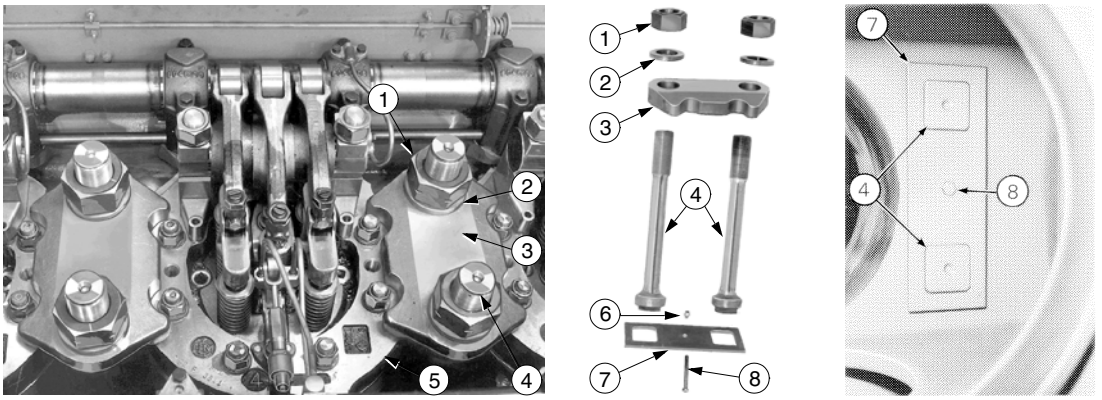
The arrangement of the tool for insert removal is shown in View "B" of Figure 1-3., "Liner Bore Insert Application And Removal Tool" on page 1-6 along with adapter shown in Figure 1-4. The insert is removed as follows:

1. Assemble the tool for removal as shown (w/ adapter) 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 View "B." 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.
5. 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.

1.3 CRAB BOLTS

1.3.1 DESCRIPTION

The cylinder head and liner are bolted together and this assembly is held in the cylinder head retainer by crab bolts, head crabs, hardened washers, and nuts, Figure 1-5. 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 while being torqued.



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

Figure 1-5. Crab Bolt Installation - 710 Engine.

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 centre crab bolts (16 cylinder) was broken, the other *three* bolts holding the cylinder 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.

1.3.2 MAINTENANCE

The 1-3/4"-12 UNR 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. Minor damage to crab bolt threads may be cleaned up using a thread file. 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 UNR (rolled threads), only the proper thread file should be used, as listed in the Service Data.

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.

1.4 MAIN BEARING BOLTING SYSTEMS

1.4.1 MAIN BEARING STUD BOLTS AND CAPS (EARLY DESIGN)

1.4.1.1 DESCRIPTION

The main bearing stud bolts used on early model engines are shown in Figure 1-6, page 1-10. Each main "A" frame member uses four 1-1/4"-12-UNR coated main bearing studs, except the center "A" frames (16 & 20-cyl.), which has two each. They pass through the "A" frame and main bearing caps. A transverse hole at the upper end of each stud accommodates a spring clip (or 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 passed through the nuts and studs.

1.4.2 MAIN BEARING BOLTS AND CAPS

1.4.2.1 DESCRIPTION

The main bearing bolts used on late model engines are shown in Figure 1-6, page 1-10. They replace the early design main bearing cap studs on a 1 for 1 basis. Each main "A" frame member is drilled and tapped with 1 1/4" - 12 UNRF threads.

NOTE

The late design bolting system cannot be re-engineered into an early design crankcase that uses the stud and nut arrangement.

1.4.2.2 MAINTENANCE

A thread file can be used to clean up minor damage to the bolt threads while a tap can be used on all tapped holes in the "A" frame members. To aid in obtaining correct torque values, the threads should be cleaned before parts application.

Upon application, guide studs may be used to assist installation of the main bearing caps to the crankcase “A” frame members. Two studs are applied diagonally into “A” frame member bolt holes, then main bearing cap with insert bearing is slid on over the studs. This will properly align the cap to the serrations on the “A” frame member. Two bolts are installed hand tight into the remaining two bolt holes and guide studs removed. All four bolts are then torqued.

NOTE

The bolts used are long enough to permit loosening in order to perform bearing inspections without removing the cap.

The four (4) bolts used at the #11 main “A” frame on 20-cylinder engines are longer than the other bolts as the cap used at that position is thicker.

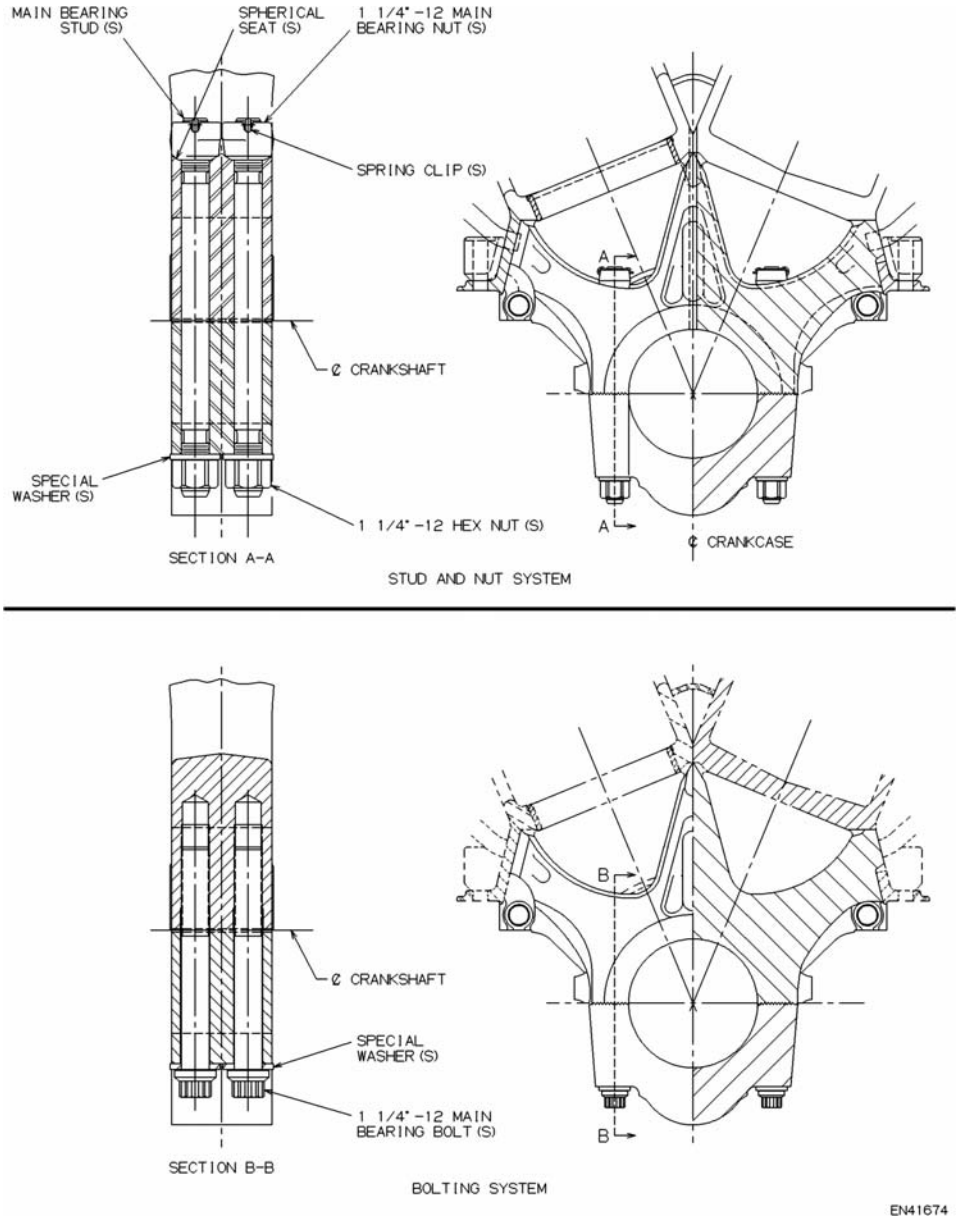


Figure 1-6. Engine Crankcase Main Bore Bolting Systems

1.5 OIL PAN

1.5.1 DESCRIPTION

The engine oil pan, Figure 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.

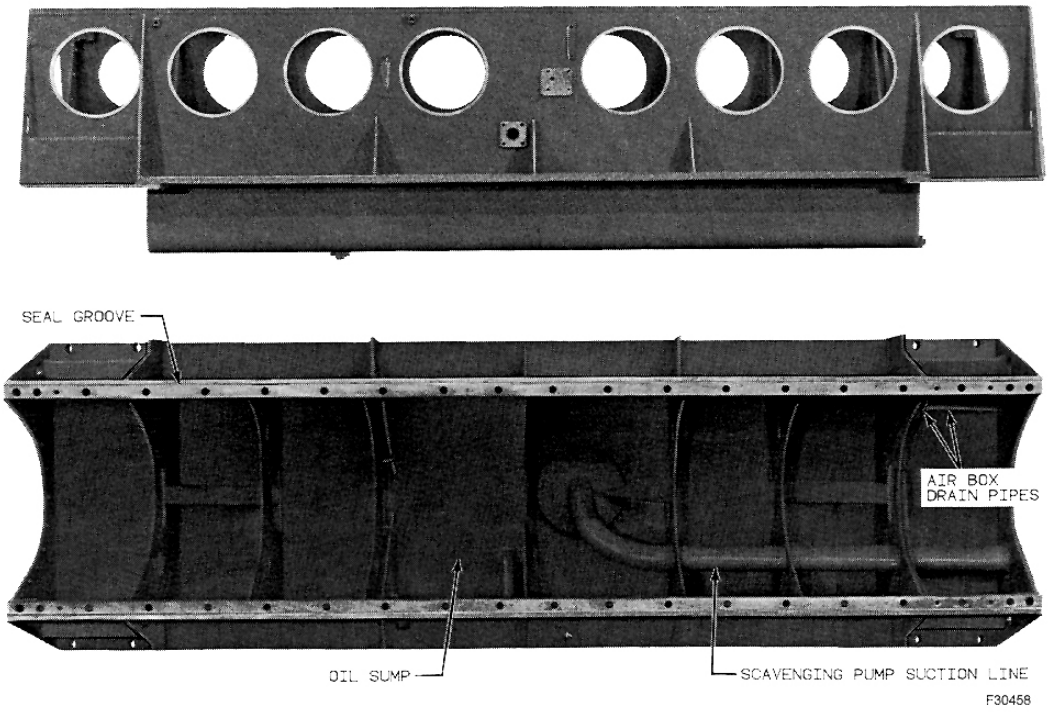


Figure 1-7. Typical Oil Pan (16-Cylinder)

1.5.2 MAINTENANCE

1.5.2.1 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.

1.5.2.2 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.

1.6 CRANKCASE TO OIL PAN SEAL

1.6.1 DESCRIPTION

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

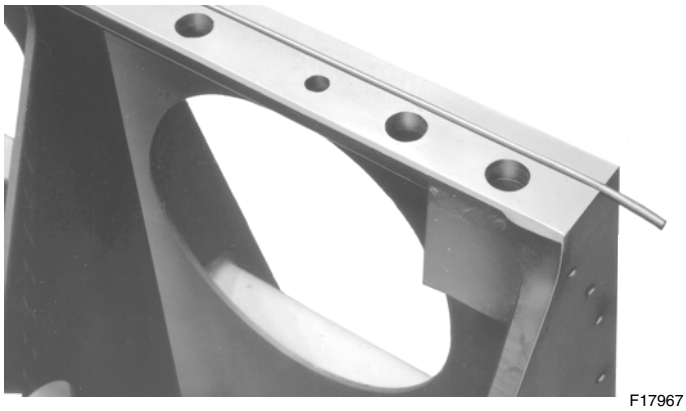


Figure 1-8. Crankcase To Oil Pan Seal

1.6.2 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

NOTE

Crankcase and oil pan were selectively matched and doweled together as a set for original assembly at the factory. Therefore, it is advisable to maintain this relationship whenever possible.

Place crankcase over oil pan and, using lineup pin guides in the four corner holes, lower crankcase on to oil pan. Apply taper dowel bolts and tighten. Check crankcase to oil pan alignment to ensure that longitudinal overlap is distributed evenly between the ends of the engine. Use care not to damage seal cord.

CAUTION

Do **not** pull or stretch the ends of the seal cord.

Assemble all crankcase to oil pan bolts with washers and snug four corner bolts to about 136 Nm (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 Nm (100 ft-lbs). After tightening bolts on both sides of engine to 136 Nm (100 ft-lbs), repeat tightening sequence bringing bolts to a final torque of 610 Nm (450 ft-lbs).

After all bolts have been tightened to 610 Nm (450 ft-lbs), cut the 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.

1.7 AIR BOX DRAINS

1.7.1 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, Figure 1-9. Both pipes connect to a common flange mounted on the oil pan end plate at the left-hand front of the engine.

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

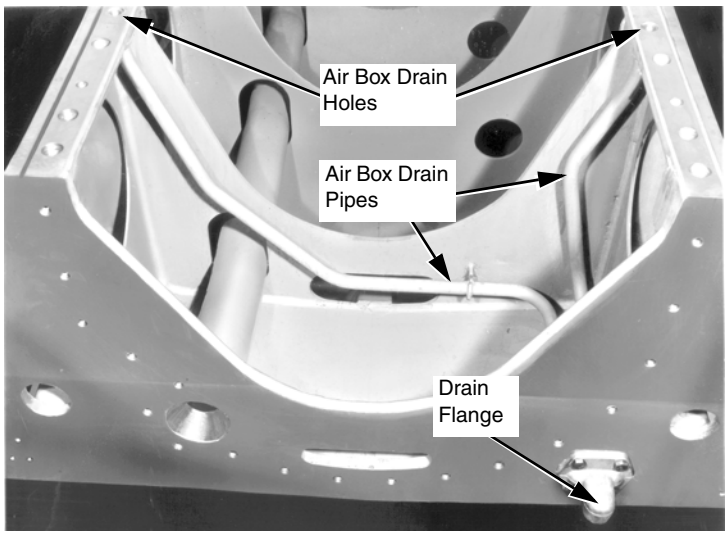


Figure 1-9. Typical Air Box Drain Installation

1.7.2 MAINTENANCE

Check operation of the air box drains and clean, if necessary, as 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 a 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 plumber’s 1/4" music wire snake as follows:

   Cut off the auger head, Figure 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.

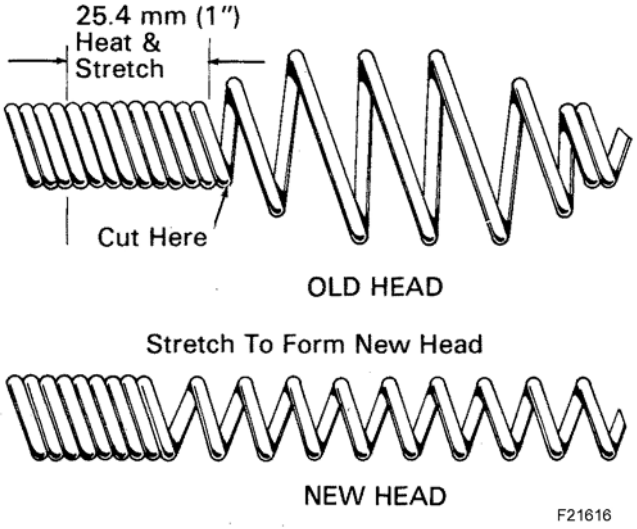


Figure 1-10. Snake Modification

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.

1.8 TOP DECK HEAD FRAME AND COVER

1.8.1 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.

1.8.2 MAINTENANCE

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

When applying new seals to the cover, coat seals liberally with EMD High Temperature resistant grease No. 4. This will facilitate ease of application and prevent the seal from sticking to the head frame, and being pulled loose or damaged, when the cover is raised.

1. Begin application of seal at a point approximately 25.4 mm (1") from upper left hand corner of cover, as shown in Figure 1-11, and make second joint (if required) at a similar point in the upper right hand corner.
2. Insert first one edge of the “V” shaped seal into cover groove, then push the other edge into groove with a blunt tool, such as a screwdriver blade or tool #8399008, being careful not to damage the seal. Proceed to apply seal in this manner or use a “V” notched tool which will compress the seal “V” together as it is drawn along the length of the seal around the cover groove.

NOTE

It is important to keep the seal compressed so that the total length fits into the groove without stretching.

3. When installing a new seal, it is important to position the joint formed by the seal ends in the proper location on the cover. This joint should be in the approximate center of the cover, to the inboard side toward the exhaust stacks. In any case, do not locate the joint any closer than 76.2 mm (3”) from either corner of the cover, as shown in Figure 1-11 below. Square off and butt ends of seal lengths tightly together.

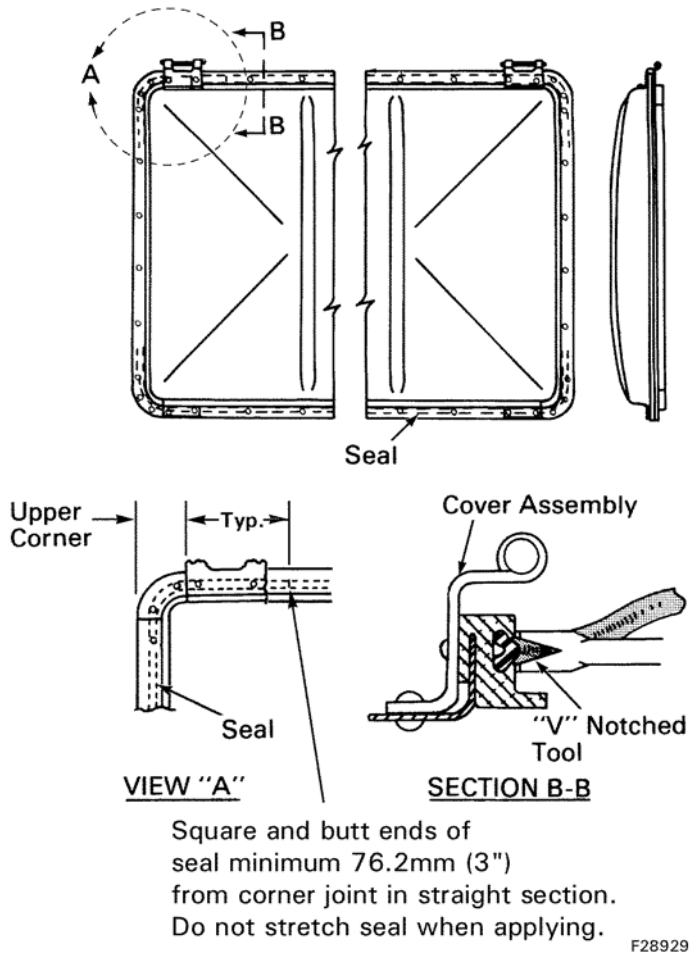


Figure 1-11. Cover Seal Application

NOTE

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.

1.8.3 HEAD FRAME TO CRANKCASE APPLICATION

1. Check sealing surfaces of head frame, crankcase and end housing for burrs, and wipe free of dust and dirt.
2. Apply a coat of Loctite #3025 "Hi-Tack" adhesive on head frame to crankcase joints. Apply head frame gasket sections to crankcase being sure gasket ends are properly joined and sealed.

NOTE

When applying end housing gaskets, coat all sealing surfaces with a generous amount of gasket sealing compound to ensure an oil tight seal.

3. Apply head frame to crankcase and install all bolts finger tight. If old bolts are being reused, apply a light coat of oil to the threads. New bolts may be installed without additional lubricant.

NOTE

Bolts used to attach head frame to crankcase and to housings at each end are of different lengths. Inboard and outboard bolts to crankcase are 3/4" long, 1-1/8" long bolts are used at the camshaft drive housing end, and 1-1/4" long bolts are used at the overspeed trip housing end. All bolts require use of 1/8" thick hardened washers for proper torque retention.

4. Torque all head frame mounting bolts to specified value in the following order:
   - End bolts to camshaft drive housing;
   - Inboard bolts in a row beginning at camshaft drive end;
   - Outboard bolts in a row from camshaft drive end;
   - End bolts to overspeed trip housing.

1.9 SERVICE DATA - CRANKCASE AND OIL PAN

1.9.1 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Upper liner pilot bore -
Max. ..... 307.44 mm (12.104")
Lower liner pilot insert bore (installed in crankcase) -
Min. ..... 263.58 mm (10.377")
Max. ..... 263.80 mm (10.386")
Lower liner pilot bore in crankcase -
Max. ..... 281.13 mm (11.068")

Main bearing bore with all caps applied and torqued to 1 017 Nm (750 ft -lbs). Take two sets of main bearing bore measurements at each bore, one set 12.7 mm (1/2") in from the accessory end of the bore and one set 12.7 mm (1/2") in from the generator end of the bore.

Diameter of main bearing bore -710 Engines
Max. ..... 235.039 mm (9.2535")
Min. ..... 234.886 mm (9.2475")

Bearing shell to crankshaft clearance

(Each side above serrations at split line) -
Min. ..... 0.038 mm (.0015")

1.9.2 EQUIPMENT LIST

	PART NO.
Crab stud thread protectors	8034600
Crab nut tap 1-3/4"-12	8050688
Main bearing nut tap 1-1/4"-12	8060387
Hydraulic jack -9 072 kg (10 ton)	8078281
Gasket sealing compound -.47 liter (1 pt.)	8178639
Spray gun (for engine cleaning)	8193041
Press and puller assembly, hydraulic (use w/8078281)	8275380
Thread lubricant, Texaco Threadtex No. 2303 -approx. 18.93 liters (5 U.S. gal.)	8307731

Silicone rubber sealing compound
-340 grams (12 oz.) cartridge 8366747
Mounting compound, Mobil Turex
-4.54 kg (10 lbs) 8366781
Torque indicator (wrench)..... 8377322
Head frame seal/inserter 8399007
Top deck cover seal inserter..... 8399008
High temperature resistant grease No. 4
-4.54 kg (10 lbs) 8425725
Main bearing stud nut socket (Short) 8474773
Main bearing stud nut socket (Long) 8474774
Main bearing power wrench set 8474808
Lower liner insert installer, manual..... 9528882
Lower liner insert remover, manual 9528883
Stud thread file 9549346
Crab nut wrench set (manual) 9551713
Upper main bearing remover 40004154
Lower insert removal tool adapter (use w/ 8275380) 40033019
Main bearing cap serration gauge 40038306
Main bearing bolt socket (Short, w/ “Tame” wrench) 40077260
Main bearing bolt socket (Long, w/ “Tame” wrench).....40077261
Main bearing bolt socket (Short, w/ “Sweeny” wrench).....40080595
Main bearing bolt socket (Long, w/ “Sweeny” wrench) 40080594
Head frame gasket adhesive, Loctite No. 3025
“Hi-Tack” -16 oz. spray can.....40086713

SECTION 2. CYLINDER HEAD AND ACCESSORIES

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2.1 CYLINDER HEAD

2.1.1 DESCRIPTION

The cylinder head, 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.

Figure 2-2., “Complete Cylinder Head Assembly, Exploded View” on page 2-4, 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.

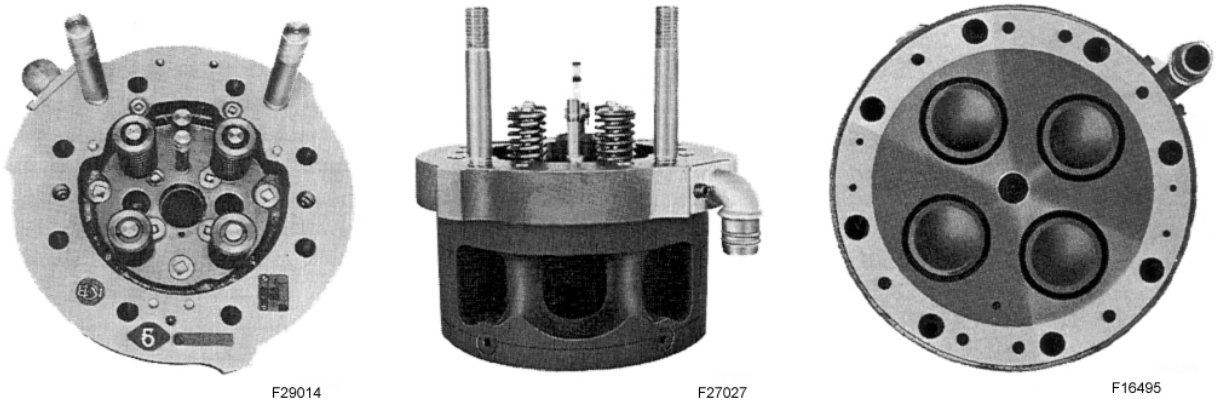


Figure 2-1. Cylinder Head With Valves

2.1.2 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.

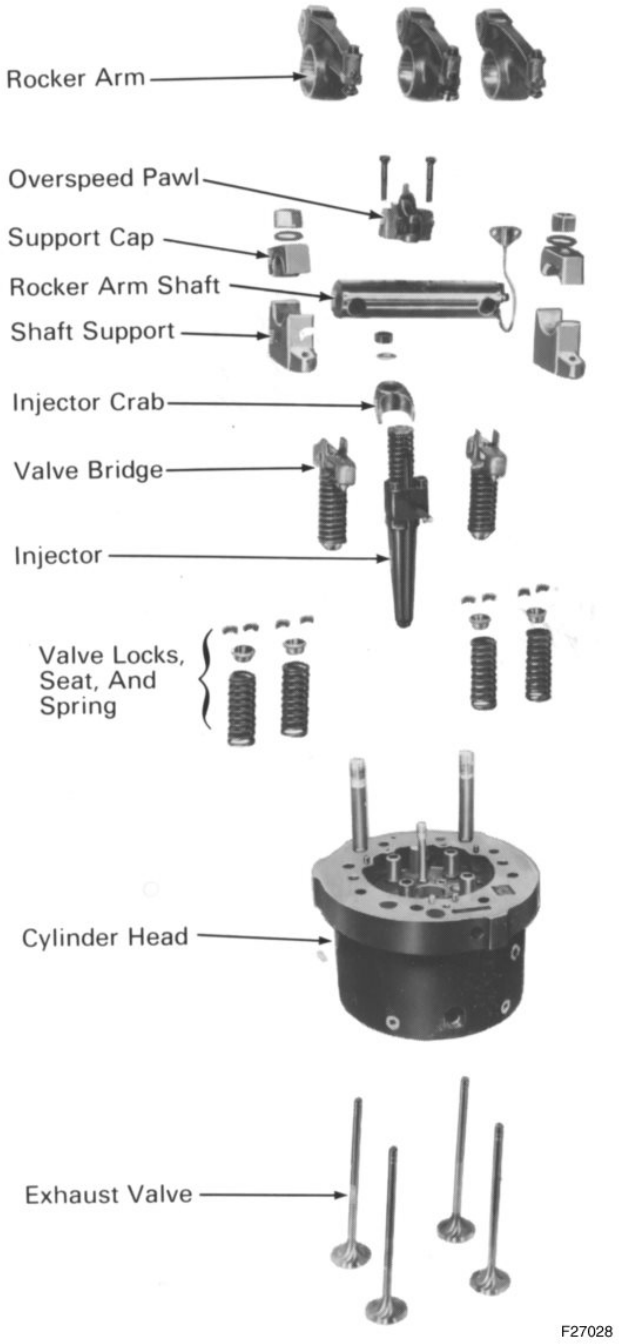
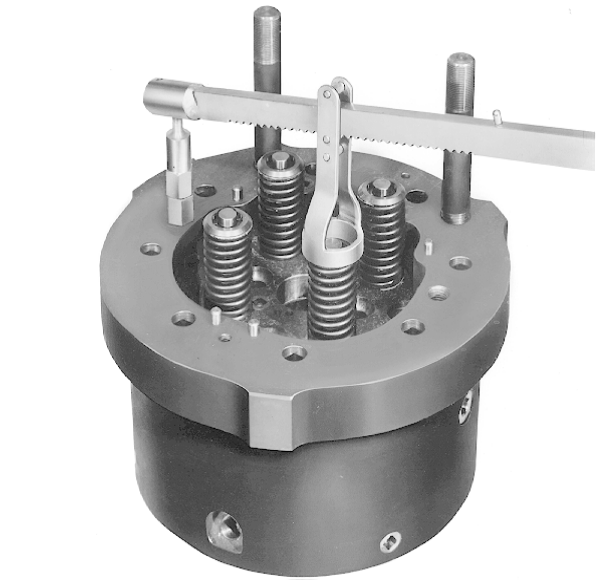


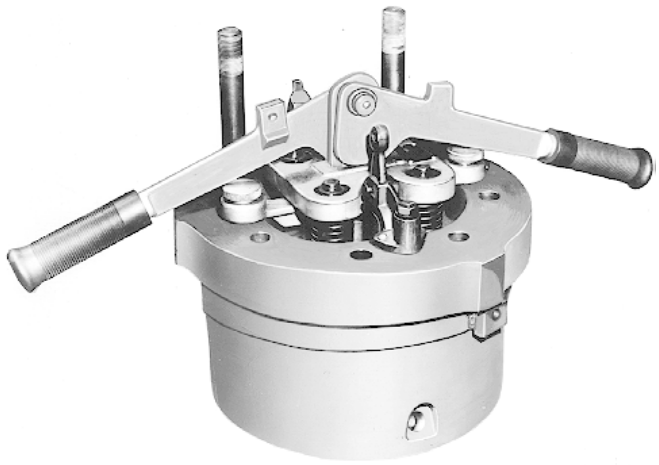
Figure 2-2. Complete Cylinder Head Assembly, Exploded View

2.1.2.1 EXHAUST VALVE AND SPRING REMOVAL

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



F27025



F27029

Figure 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.

2.2 EXHAUST VALVES

2.2.1 DESCRIPTION

The long stem exhaust valves, Figure 2-4., “Typical Exhaust Valve” on page 2-6, 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.

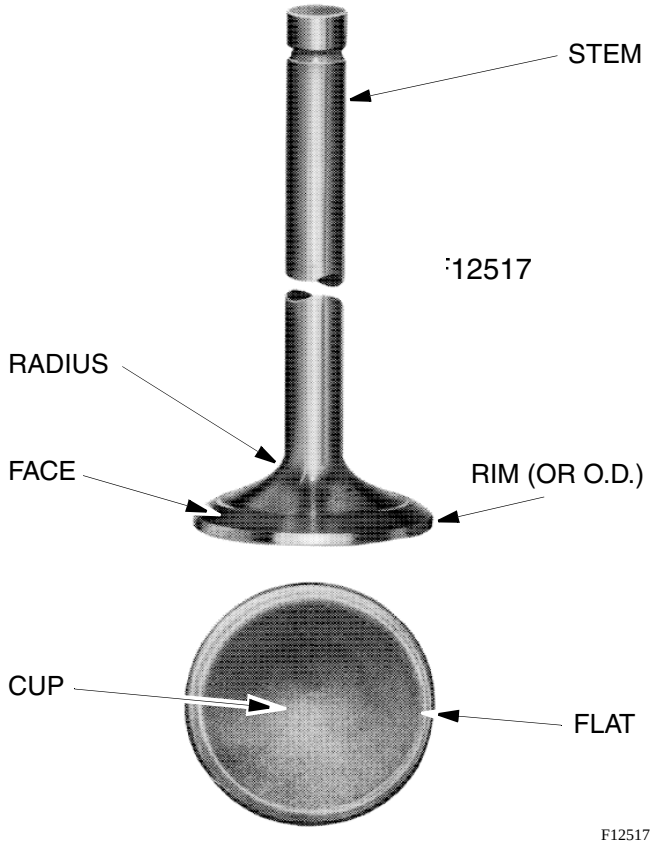


Figure 2-4. Typical Exhaust Valve

2.2.2 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 pressure checks to qualify 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, Figure 2-5., “Valve Spring Seat Lock” on page 2-7, for signs of wear on the upper portion of the bead and for evidence of fretting in the ground diameter which engages the valve stem. If these conditions exist, or as a matter of good rebuild practice, the locks should be replaced.

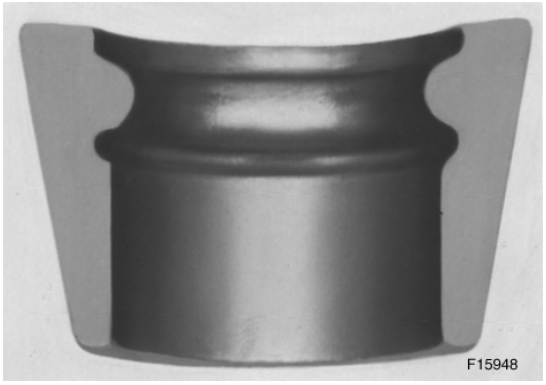


Figure 2-5. Valve Spring Seat Lock

2.2.3 EXHAUST VALVE SPRING RETAINERS AND LOCKS - NEW STYLE

New exhaust valve spring seat (retainer) and lock (keeper) systems are not interchangeable with previous types. Attention of identification, and caution, is required to prevent mixing different types of exhaust valve spring seats (retainers) and locks (keepers).

EMD introduced two new types of exhaust valve spring retainer and lock systems into production:

- P/N 40079543 exhaust valve seat, used exclusively with P/N 40079454 lock(s).
- P/N 40103102 valve rotator, used exclusively with P/N 40079454 lock(s).
- P/N 40074041 high capacity valve spring.

New valve spring seat P/N 40079543 and lock(s) P/N 40079454 improves contact with the valve stem and reduces the tendency for the valve to wear under the lock(s). The new retainer system was first introduced on Utex cylinder heads in 2002. Production of the new retainer system started fourth quarter of 2003 on new cylinder heads. The new system is a direct replacement for the previous system.

Previous valve spring seat P/N 8081795 and lock(s) P/N 40042790 will be phased out of production.



PREVIOUS SYSTEM
(1) VALVE SPRING SEAT P/N 8081795
(2) SPRING SEAT LOCK P/N 40042790



NEW SYSTEM
(1) VALVE SPRING SEAT P/N 40079543
(2) SPRING SEAT LOCK P/N 40079454



VALVE ROTATOR SYSTEM
(1) VALVE ROTATOR P/N 40103102
(2) SPRING LOCK SEAT P/N 40079454
(1) HIGH CAPACITY VALVE SPRING P/N 40074041

F80202

Figure 2-6. Valve Rotator System

The valve rotator design P/N 40103102 induces axial rotation of the valve. This results in a uniform temperature around the periphery of the valve head and lower thermal stress. The uniform peripheral temperature also keeps the valve more circular in shape and improves seating. The valve rotator is designed for the new lock (keeper) P/N 40079454 and high capacity valve spring P/N 40074041. The new lock(s) and valve spring improves contact with the valve stem and reduces the tendency for the valve to wear under the lock(s).

To avoid confusion, new P/N 40079543 (retainer) and P/N 40079454 (keeper) are produced with a shiny black oxide finish. The valve rotator system, high capacity spring, is painted green for identification. Care must be taken to assure parts are not mismatched. Four rules should be followed when assembling exhaust valve spring retainer systems:

1. Always install black spring seats (retainers) with black locks (keepers).
2. Always install black locks (keepers) with valve rotators.
3. Never install black locks (keepers) with previous P/N 8081795 valve spring seats (retainers).

4. Never install previous P/N 40042790 locks (keepers) with black spring seats (retainers) or valve rotators.



Figure 2-7. Valve Rotator System Assembly

2.3 EXHAUST VALVE BRIDGE ASSEMBLY

2.3.1 DESCRIPTION

The valve bridge, Figure 2-8., “Valve Bridge Assembly” on page 2-10, 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.

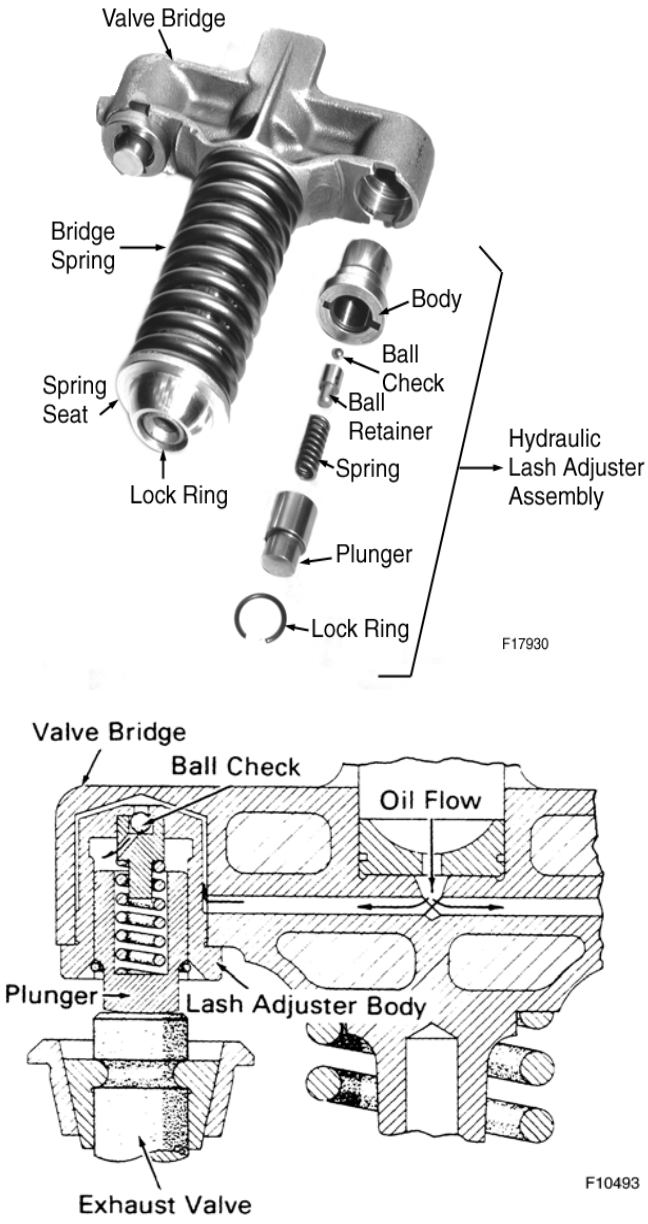


Figure 2-8. Valve Bridge Assembly

2.4 ROCKER ARM ASSEMBLY

2.4.1 DESCRIPTION

Three rocker arms, Figure 2-9. on page 2-11, 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.

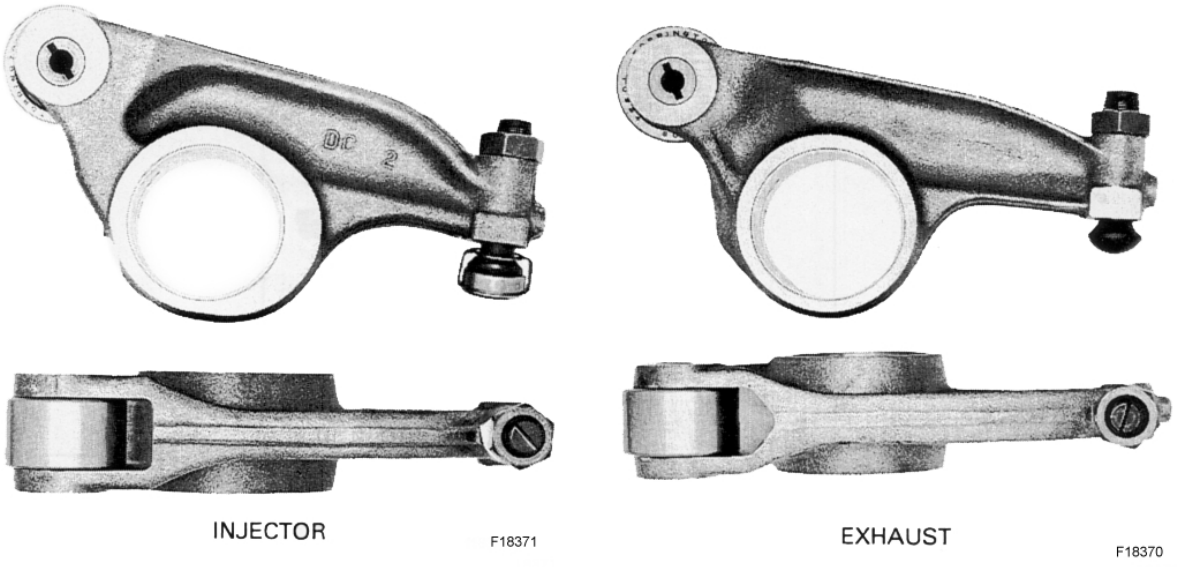


Figure 2-9. Typical Rocker Arms

2.5 ROCKER ARM SUPPORT ASSEMBLY

2.5.1 DESCRIPTION

The rocker arms are mounted on a rocker arm shaft which is held at each end between a shaft support and a shaft cap, Figure 2-10., “Rocker Arm Support Assembly” on page 2-12. 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.

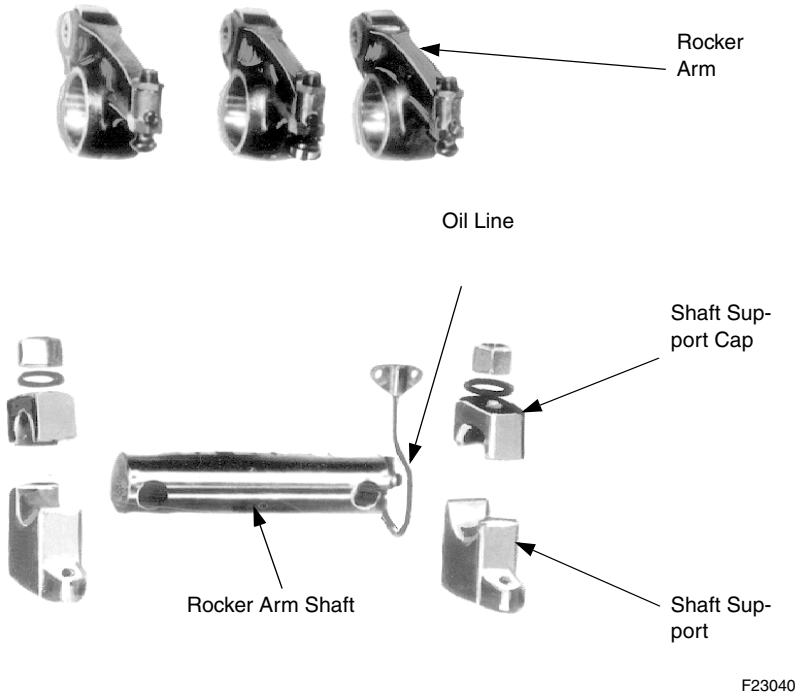


Figure 2-10. Rocker Arm Support Assembly

2.5.2 MAINTENANCE

At time of power assembly change out, thoroughly 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 within 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 0.15 mm (.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 12.7 mm (1/2") 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 arm shaft within 0.25 mm (.010") total indicator reading. Cracks in the cap or shaft support are cause for rejection.

2.6 CYLINDER TEST VALVE

2.6.1 DESCRIPTION

Cylinder test valves, 2-11, are provided on the engine at each cylinder. When maintenance or inspections are 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.

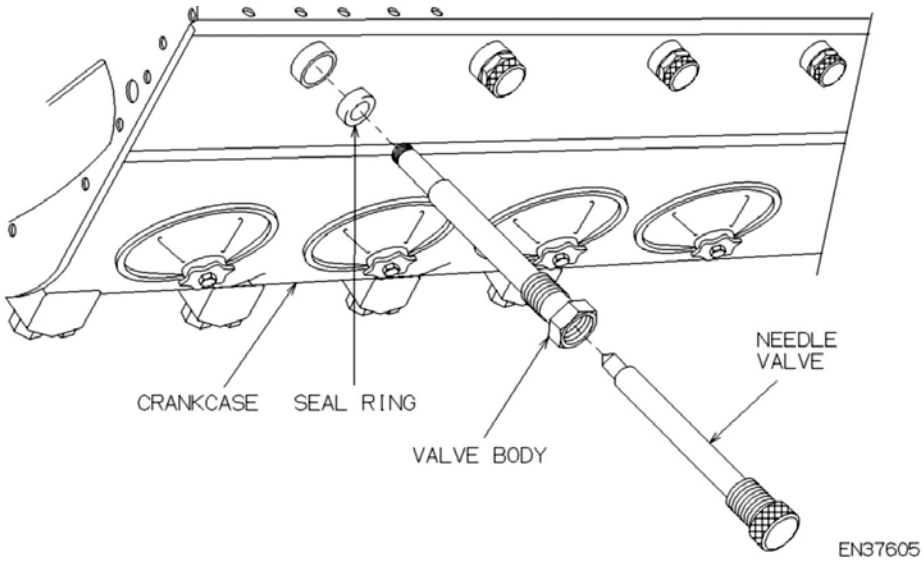


Figure 2-11. Typical Cylinder Test Valve

The cylinder test valve is inserted in a housing within the crankcase and screwed into the cylinder head. A cylinder test valve wrench, 2-12, is used to open and close the valves.

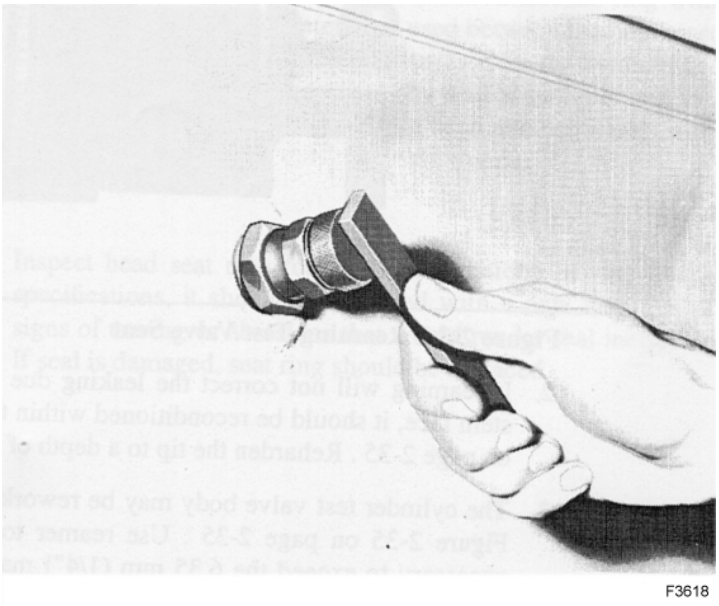


Figure 2-12. Test Valve Wrench

2.6.2 MAINTENANCE

If a cylinder test valve is leaking, check that the needle valve, Figure 2-11., “Typical Cylinder Test Valve” on page 2-13, has been properly tightened. Should the valve continue to leak, remove the valve from the engine and replace with a new valve.

2.7 CYLINDER HEAD SEAT RING

2.7.1 DESCRIPTION

The cylinder head seat ring is an aluminum bronze ring with an elastomer seal molded to the outer diameter. It is 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. The seal is incorporated to minimize oil draw into the exhaust stack and crankcase head retainer wear.

2.7.2 MAINTENANCE

Inspect head seat ring for proper dimensions. If ring does not meet required specifications, it should be replaced with a new ring. Inspect seal portion for signs of tearing or abrasions that would render seal ineffective for oil retention. If seal is damaged, seat ring should be replaced.

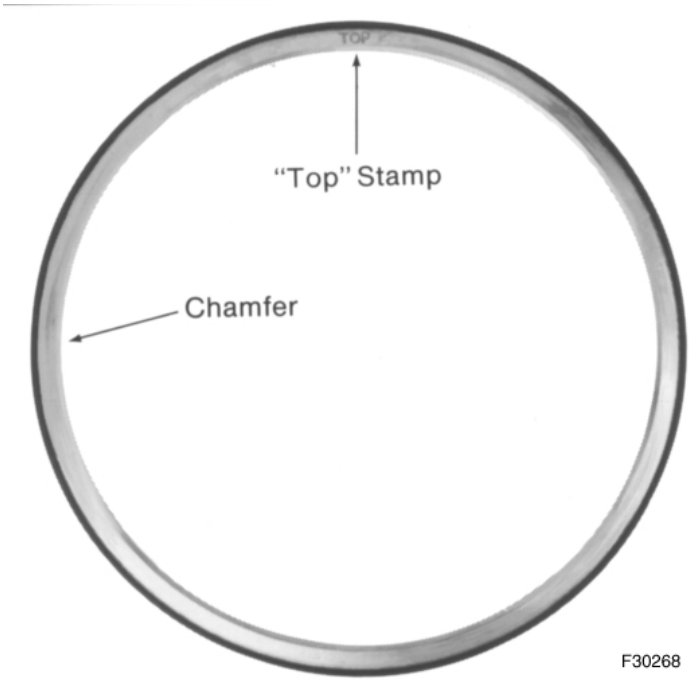


Figure 2-13. Cylinder Head Seat Ring

2.8 SERVICE DATA - CYLINDER HEAD AND ACCESSORIES

2.8.1 EQUIPMENT LIST

	PART NO.
Test valve wrench	8032587
Valve spring compressor (single)	8033783
Adapter (use with 8033783)	8034054
Crab stud protector tubes	8034600

SECTION 3. PISTON ASSEMBLY AND CONNECTING RODS

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3.1 PISTON ASSEMBLY

3.1.1 DESCRIPTION

The piston assembly consists of a cast iron alloy piston, Figure 3-2, page 3-4, four compression rings, and two oil control rings. A “trunnion” type piston carrier 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, Figure 3-2, page 3-4, 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.



Figure 3-1. Typical Cast Iron Alloy Piston

An insert bearing, Figure 3-2, fits into a broached slot in the carrier. The highly polished piston pin is applied in the carrier together with the insert bearing as a fitted assembly. Two retainers, one at each end, are bolted to the piston carrier to prevent the pin and bearing assembly from sliding out of the carrier. The assembly is bolted to the upper end of the connecting rod.

3.1.1.1 PISTON CARRIER & THRUST WASHER - 710 ENGINES



Figure 3-2. Piston Carrier And Thrust Washer - 710

The piston pin and insert bearing are of the “rocking” type design with offset piston pin center. This produces mechanical separations between the pin and bearing alternately on the three bearing lands during the course of a power cycle. This provides a pumping action for oil circulation through the pin and bearing area.

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.

3.1.2 MAINTENANCE

3.1.2.1 PISTON AND ROD INSPECTION

Piston and connecting rod assemblies 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.
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.

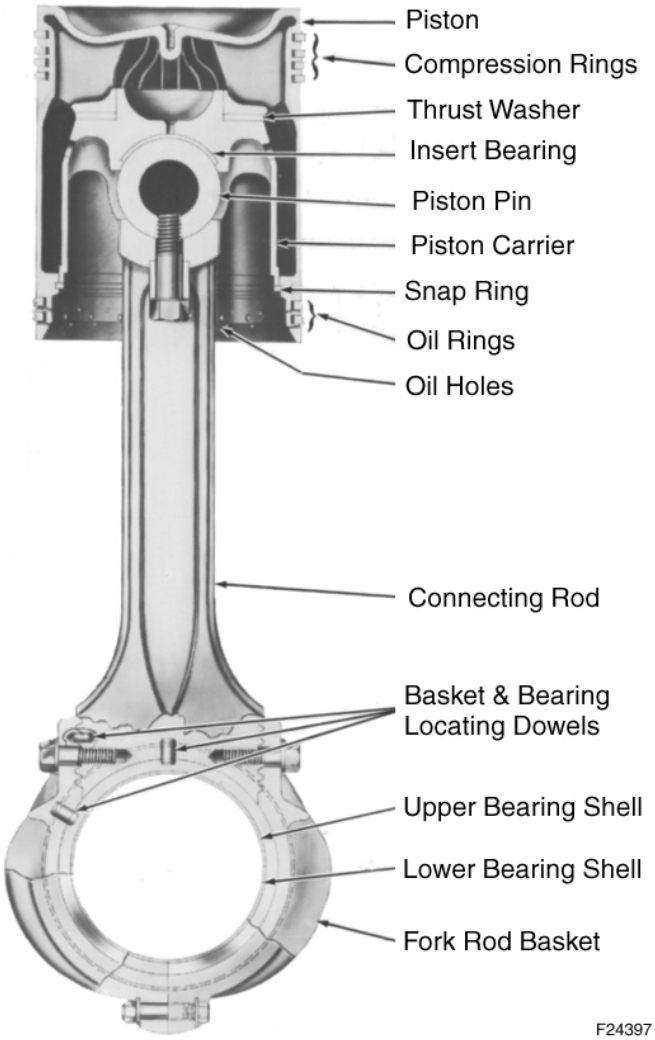


Figure 3-3. Piston And Connecting Rod Assembly, Cross-Section

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. Renew or replace power assembly when chrome plating is worn through on first ring. The chrome ring wear classifications shown in Figure 3-4. on page 3-6, 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. Renew or replace power assembly when this 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.

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

On 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.

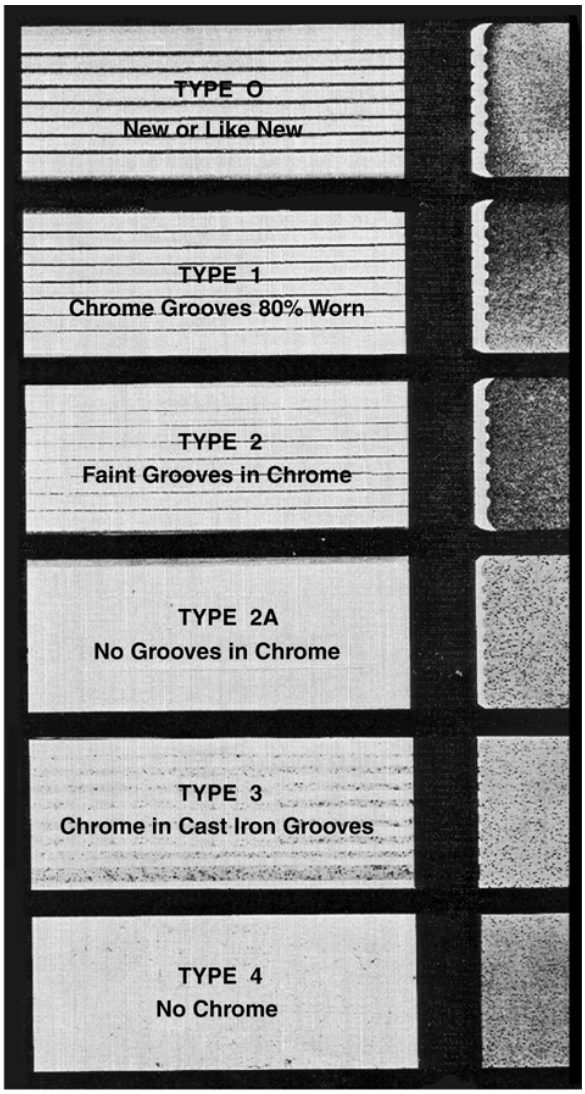
Chrome grooves are completely worn away, showing only a smooth chrome face. This will exist for the major portion of shallow groove ring life. It will be evident for a short time on only a small percentage of deep groove rings.

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

CAUTION

To prevent liner scoring, power assemblies with stainless steel rings should be renewed 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.



NOTE

When classifiying chrome plated stainless steel rings, subsitutute references to "cast iron" with "stainless steel". In addition, stainless steel rings have five grooves instead of seven.

F24849

Figure 3-4. Chrome Ring Wear Classification

3.1.2.2 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 significant increase since previous lead reading should be investigated as a possible component failure.

> **NOTE**
> Due to carbon buildup on both the fire face of the cylinder head and the crown of the piston during service life, lead wire readings should not be used as a basis for power assembly renewal or replacement due to wear. The proper wear factors considered for power assembly removal should be side clearance of the No. 1 compression ring and piston ring face wear.

3. With piston at top center, inspect lower liner walls for scoring.
4. Inspect oil pan for foreign matter.

3.2 CONNECTING ROD ASSEMBLY

3.2.1 DESCRIPTION

The “trunnion type” connecting rods, Figure 3-5, 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 the sides of the rod at the bottom match similar serrations on the fork rod basket, Figure 3-5. The rod basket consists of two halves, 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.

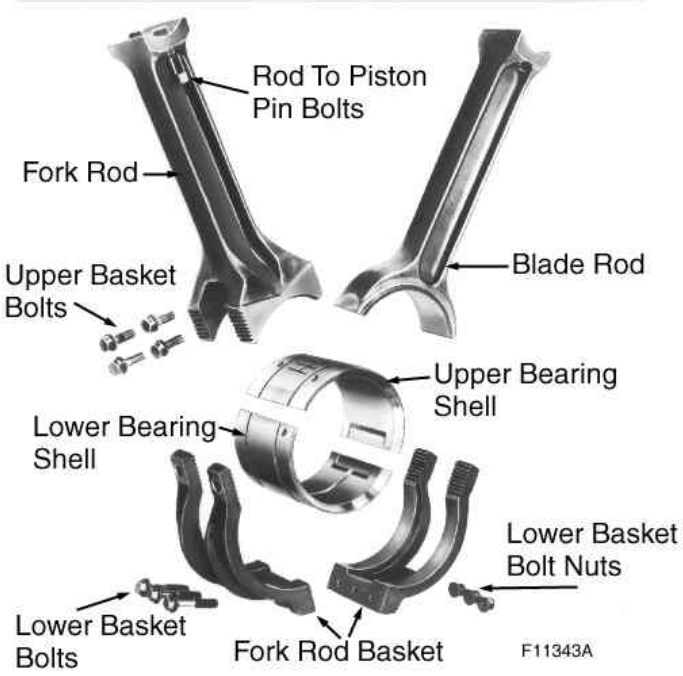


Figure 3-5. Connecting Rods, Bearing Shells, And Basket

3.2.2 CONNECTING ROD BEARINGS

3.2.2.1 DESCRIPTION

Connecting rod bearings consist of upper and lower shells, Figure 3-5. on page 3-8. 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 the 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.

3.2.2.2 MAINTENANCE

CHECKING CONNECTING ROD BEARINGS:

NOTE

Refer to EMD publication entitled: “INSPECTION & QUALIFICATION GUIDE ENGINE MAIN & CONNECTING ROD BEARINGS” for detailed information needed to conduct a thorough bearing examination. However, it is recommended that the bearings are changed out at time of power assembly replacement.

3.3 SERVICE DATA - PISTON ASSEMBLY AND CONNECTING RODS

3.3.1 REFERENCES

Removal Of Undercrown Deposits From Engine Pistons .....M.I. 1759

3.3.2 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Connecting rod bearings - Bearing inside diameter
(average of 3-60° measurements)-
- Min.....165.268 mm (6.5066")
- Max. .....165.354 mm (6.5100")

Bearing to crankpin clearance -
- Max. ..... 0.38 mm (.015")

Piston

Piston to cylinder head clearance -
- Min..... 0.51 mm (.020")
- New power assembly - Max. ..... 1.73 mm (.068”)
- Remanufactured power assembly - Max. ..... 2.03 mm (.080")
- Differential reading between ends of lead wire, on installation ..... 0.13 mm (.005")

NOTE

Due to carbon buildup on both the fireface of the cylinder head and the crown of the piston during service life, lead wire readings should not be used as a basis for power assembly change-out. Lead wire readings may continue to be used to indicate wear trends. Any significant clearance increases should be investigated as possible component failures.

Compression ring to land clearance -
No. 1 groove chrome sided (chrome face and barrel face) -
Limit for ring installation -
Max. ..... 0.30 mm (.012")
No. 2 and 3 groove (chrome face and filled face) -
Max. ..... 0.38 mm (.015")

No. 4 groove, taper ferrox ring -
Max. ..... 0.38 mm (.015")

Piston to liner clearance -

NOTE

The maximum piston to liner clearance limit was originally established to allow for selective fitting of pistons to liners in the rebuild process. This consideration is no longer valid as the practice is not recommended for current EMD 710 engines with hardened upper bore liners.

Oil ring to land clearance -
Std. ..... 0.05-0.15 mm (.002"-.006")

Piston Thrust Washer Thickness -
Min. ..... 4.44 mm (.175")

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

3.3.3 EQUIPMENT LIST

	PART NO.
Feeler gauge set	8067337
Torque wrench, -19.05 mm (3/4") drive 0-407 Nm (0-300 ft-lbs)	8157121
Snap ring remover	8171633
Torque wrench extension (used with torque wrench 8157121)	8210136
Wire holder (has contour of piston crown to hold lengths of lead wire for piston to head clearance check)	8243220
Wire, lead -3.18 mm (1/8") dia., used with holder 8243220 or alone, 2.27 kg (5 lb) spool	8243661

SECTION 4. CYLINDER LINER

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4.1 DESCRIPTION

The cylinder liner, Figure 4-1, consists of 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, Figure 4-2. on page 4-4, prevents the inlet water from impinging directly on the inner liner wall.

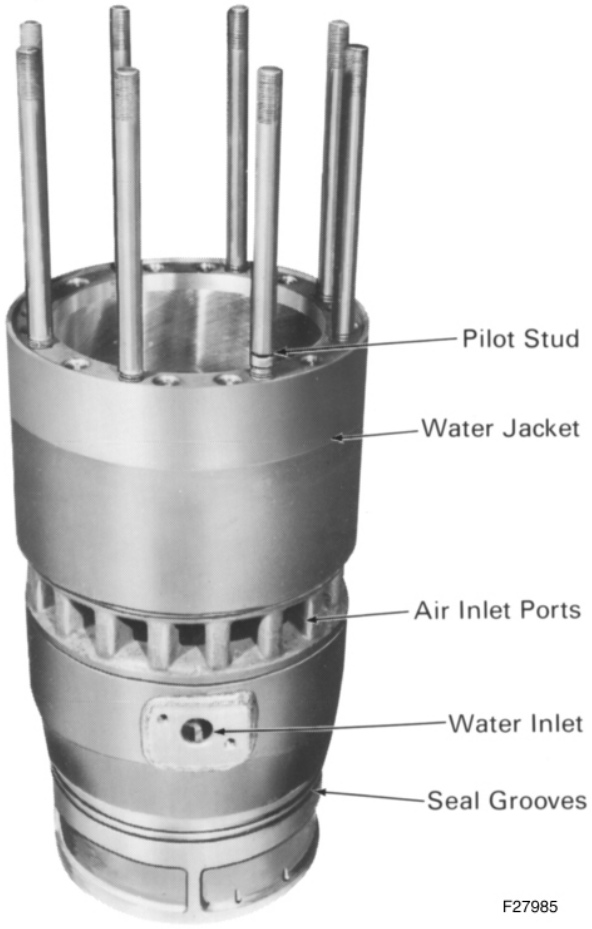


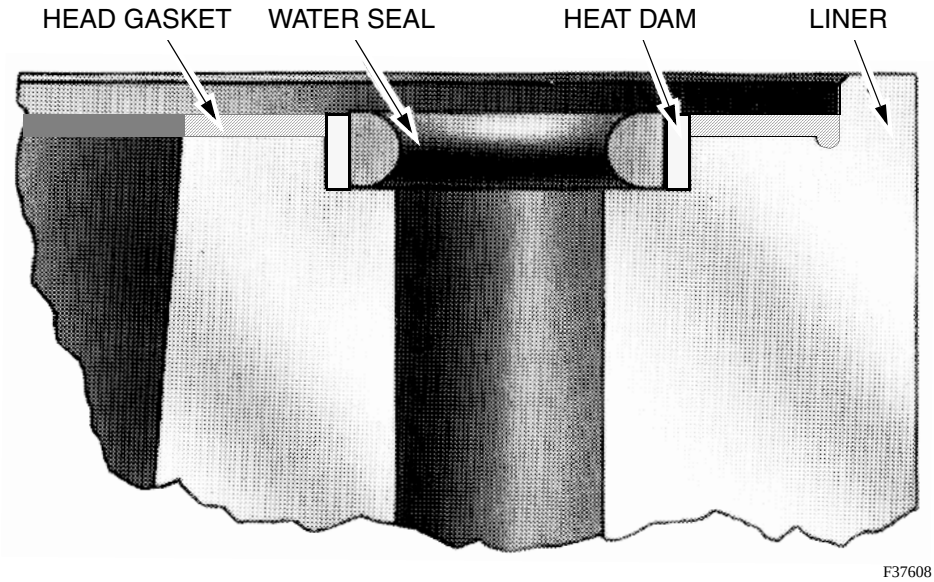
Figure 4-1. Cylinder Liner

The inlet water circulates around the bottom of the liner, progressing upward to discharge into the cylinder head through twelve drilled holes. A copper clad steel gasket provides a combustion seal between the cylinder head and the liner. The gasket is fitted with twelve seal assemblies, each consisting of a Teflon heat dam bonded to a Silicone rubber grommet. A counterbore around each drilled hole in the liner accommodates the seal assemblies, as shown in Figure 4-3. on page 4-4, to seal the water passages when the cylinder head is installed.



F16499

Figure 4-2. Water Inlet Deflector



F37608

Figure 4-3. Typical Water Seal Assembly In Counterbore (Seal Assembly Part Of "Unitized" Head Gasket)

4.2 MAINTENANCE

4.2.1 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 bar engine over to 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.

Inspect externally for evidence of water leaks at liner to cylinder head gasket and water inlet line.

NOTE

See 15.7 LINER/ PISTON VISUAL INSPECTION GUIDE on page 15-78 for in engine liner inspection, conditions and actions. Procedures for removal and installation of the liner, and of a complete cylinder power assembly are contained in Section 5.

4.3 SERVICE DATA - CYLINDER LINER

4.3.1 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Piston to liner clearance -

NOTE

The maximum piston to liner clearance limit was originally established to allow for selective fitting of pistons to liners in the rebuild process. This consideration is no longer valid as the practice is not recommended for current EMD 710 engines with hardened upper bore liners.

Crankcase upper pilot bore -

Max. ..... 307.44 mm (12.104")

Insert bore (installed in crankcase) -

Min. ..... 263.58 mm (10.377")
Max. ..... 263.80 mm (10.386")

Crankcase lower insert bore -

Max. ..... 281.13 mm (11.068")

4.3.2 EQUIPMENT LIST

-	PART NO.
Cylinder liner lifter	8116358
Cleaning tool (water seal counterbore)	File 686

SECTION 5. CYLINDER POWER ASSEMBLY

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5.1 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. Where applicable, references are provided which relate specific procedures to either governor controlled engines “With Mechanical Unit Injectors” (W/ MUI), or EMDEC controlled engines “With Electronic Unit Injectors” (W/ EUI).

NOTE

To ensure compliance with emissions regulations, always ensure the part number of the power assembly being installed is correct for the application.

5.1.1 COMPONENT BY COMPONENT REMOVAL

NOTE

EMD does not reccommend customers use the compnent by component method of power assembly change out. Unit removal and replacement is the recommended practice.

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. Bar the engine over until the fork rod piston assembly is l20° 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 (if used) and remove the cylinder test valve and seal-ring. 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, Figure 5-1, page 5-3 Also disconnect the line on the opposite cylinder, opposite bank. Remove the gaskets between the oil lines and the blocks.

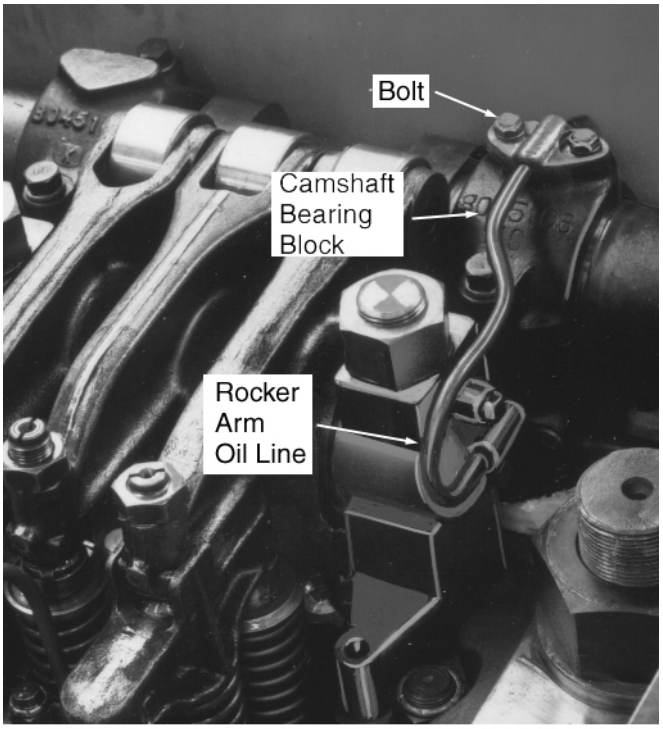


Figure 5-1. Rocker Arm Oil Line Removal

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, Figure 5-2

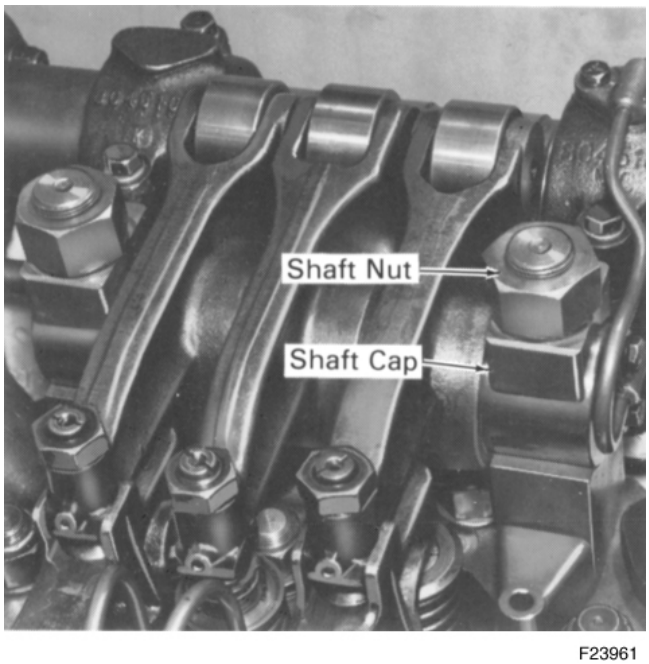


Figure 5-2. Rocker Arm Assembly Removal

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, 5-3 Also remove the fuel line assembly from the opposite cylinder on the opposite bank of the engine.

    With Mechanical Unit Injectors (MUI); care should be taken that the spherical seats used on fuel line ends are not scratched or nicked as this could cause leakage.

    With Electronic Unit Injectors (EUI); disconnect fuel jumper lines from the fuel manifold *only.*

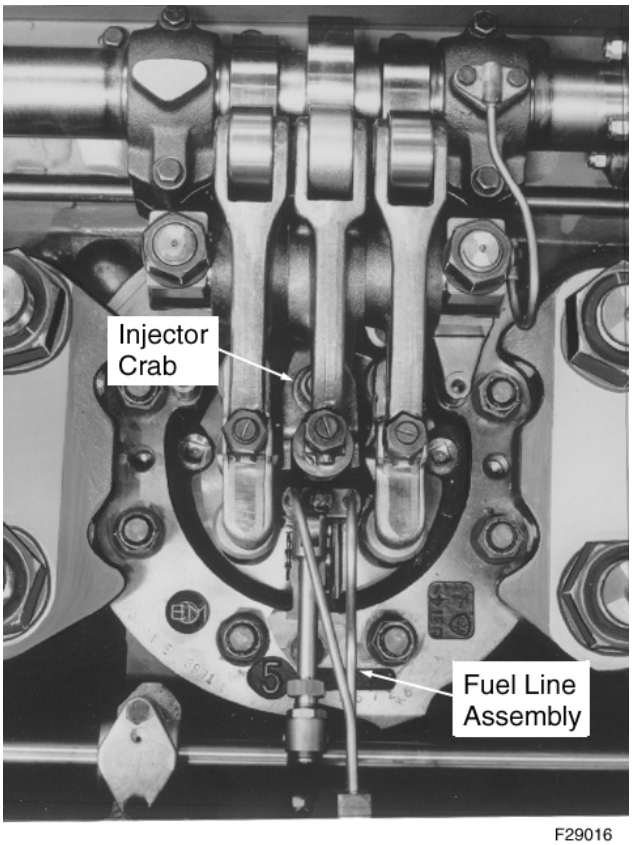


Figure 5-3. Typical Fuel Line Assembly Removal (shown W/ MUI)

15. With Mechanical Unit Injectors (MUI); remove the injector adjusting link assembly by removing the two spring retainers and the two clevis pins.

With Electronic Unit Injectors (EUI); disconnect the two wires with eyelet terminals from the injector and unbolt the cable tie bracket from the cylinder head. Fold the wires and attached bracket aside in such a manner that will protect them from damage during cylinder disassembly.

16. Remove the injector crab stud nut, spherical washer, and the injector crab.
17. With Mechanical Unit Injectors (MUI); use the injector pry bar, 5-4, and remove the injector from the tapered well in the cylinder head. Protect the injector from dirt and damage by using an injector holding rack.

    With Electronic Unit Injectors (EUI); carefully remove the injector making certain the adapter collar remains in the cylinder head. Drain any unused fuel from the injector and cap the fuel jumper lines. Place the injector in an injector holding rack to protect it, or into a shipping container if it is to be returned.

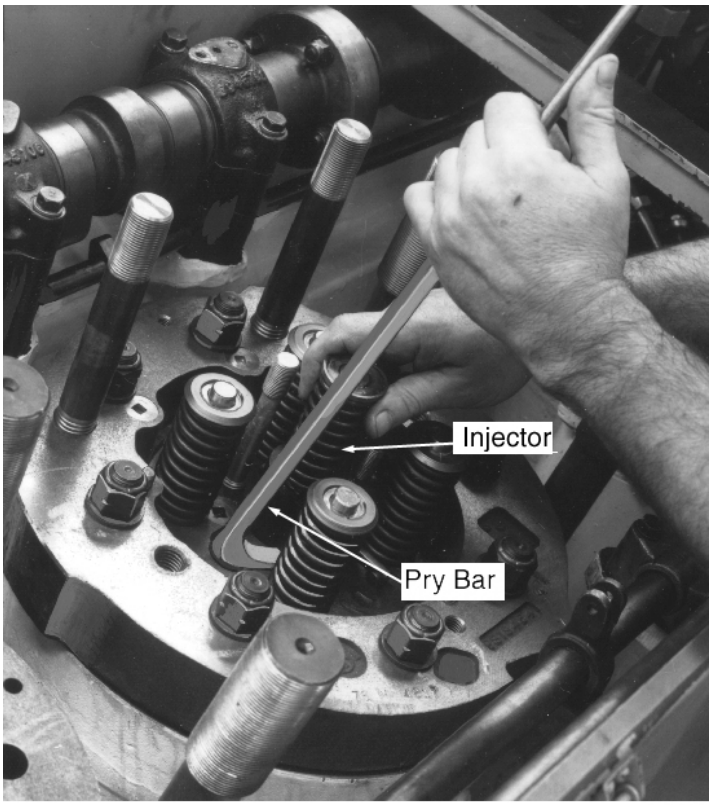


Figure 5-4. Removing Injector With Pry Bar

18. Remove the cylinder head overspeed trip assembly (used W/ MUI) 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 (used W/ MUI) from this cylinder.
20. Place a piston holding tool, Figure 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.

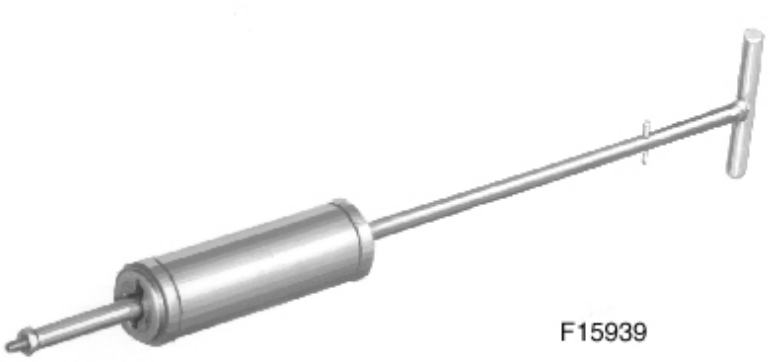
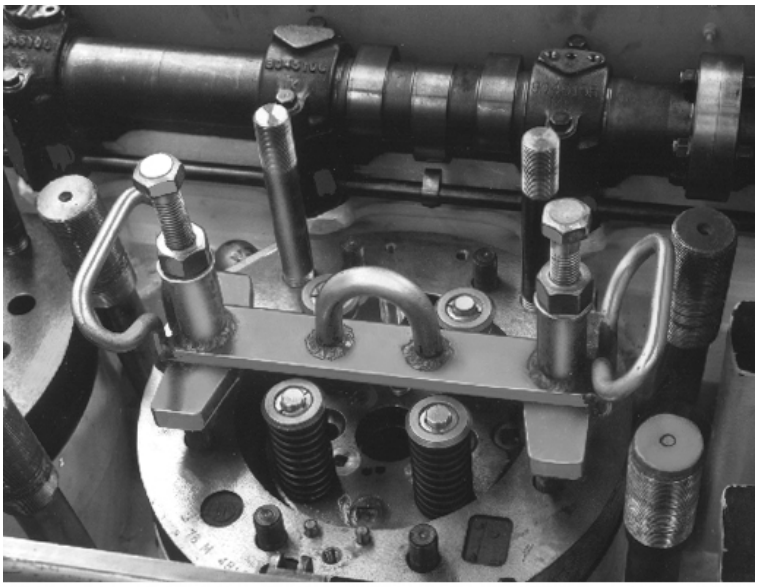


Figure 5-5. Piston Holding Tool

21. Remove the cylinder head-to-liner stud nuts and washers of the cylinder being removed.
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 310-345 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 nuts, washers, and 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, 5-6 Make sure that the bolts are bottomed to support the weight of the head.



F27035

Figure 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 (if used) 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.
34. Remove the lower basket bolts and self-locking nuts using the spring-loaded basket bolt wrench, 5-7, with a ratchet and extension.

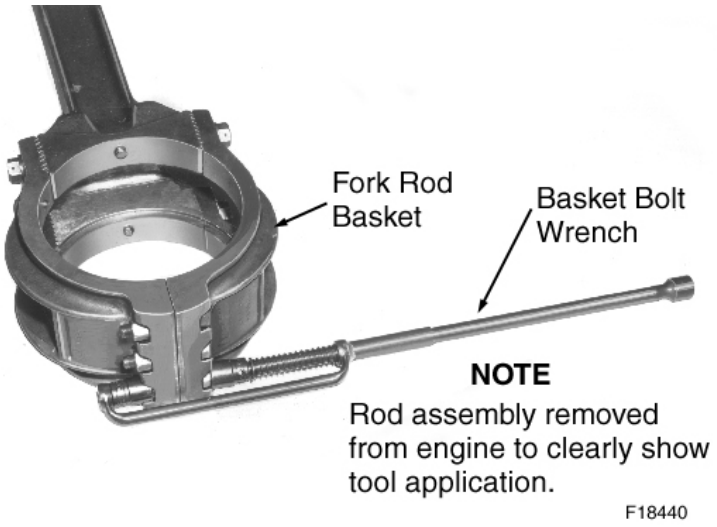


Figure 5-7. Basket Bolt Wrench Application

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, 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.



Figure 5-8. Connecting Rod Positioning Clamp Application

39. Using a suitable lifting device, raise the piston and fork rod assembly and apply fork rod support, 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.



Figure 5-9. Fork Rod Support

40. Lift the piston and blade rod assembly until a protective boot (if available) can be applied.
41. Remove the upper connecting rod bearing shell.
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.
44. Lift the piston and blade rod assembly so that the piston holding tool, Figure 5-5. on page 5-6, 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 a protective boot (if available).

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.

5.1.2 UNIT REMOVAL

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

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 for the opposite 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. Bar the engine over until the fork rod piston assembly 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 (if used) and remove the cylinder test valve and seal-ring. 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, Figure 5-1. on page 5-3, 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 about two complete turns on the three rocker arms.
11. Remove the rocker arm shaft nuts, washers, and the rocker arm shaft caps, Figure 5-2. on page 5-3.

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, Figure 5-3. on page 5-4. Also remove the fuel line from the opposite cylinder on the opposite bank of the engine. Care should be taken that the spherical seats used on some fuel line ends are not scratched or nicked as this could cause leakage.
15. With Mechanical Unit Injectors (MUI); remove the injector adjusting link assembly by removing the two spring retainers and the two clevis pins.

    With Electronic Unit Injectors (EUI); disconnect the two wires with eyelet terminals from the injector and unbolt the cable tie bracket from the head. Fold the wires and attached bracket aside in such a manner that will protect them from damage during cylinder disassembly.
16. Remove the injector crab stud nut, spherical washer, and the injector crab.
17. Using the injector pry bar, Figure 5-4. on page 5-5, remove the injector (injector and adapter collar W/ EUI) 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 (used W/ MUI) 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 (used W/ MUI) from this cylinder.
20. Remove the lower basket bolts and nuts using the spring-loaded basket bolt wrench, Figure 5-7. on page 5-8, 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, Figure 5-5. on page 5-6, 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, Figure 5-9. on page 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 310-345 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 nuts, washers, and crabs, place thread protectors over crab-bolts.
31. Apply and attach lifting clamp, 5-10, to cylinder being removed, and screw in the piston holding tool, Figure 5-11. on page 5-13.



Figure 5-10. Lifting Clamp Application



Figure 5-11. Piston Holding Tool Application

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.
33. Attach an overhead chain hoist to the lifting clamp. 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. Leave the blade rod resting on the upper bearing.
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 310-345 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 nuts, washers, and crabs, place thread protectors over crab bolts.

38. Attach the lifting clamp, Figure 5-10. on page 5-12, to the cylinder being removed and screw in the piston holding tool, as shown in Figure 5-11.
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.
40. Install the connecting rod positioning clamp on the fork rod, as shown in Figure 5-8. on page 5-8.
41. Using a suitable lifting device, lift the blade rod piston assembly and secure with piston holding tool. Remove the upper bearing shell.
42. Attach an overhead chain hoist to the lifting clamp, 5-12 While guiding the power assembly, remove it from the engine.



Figure 5-12. Power Assembly Removal With Lifting Clamp And Hoist

5.1.3 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.

1. Place a cleaned and inspected piston on a clean work bench.
2. Apply the spring-loaded oil control ring in the bottom groove.
3. Apply the spring into the groove first then, using the piston ring expander, apply the ring so that the spring fits 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 to be placed in the groove with this marking facing the crown of the piston (up).

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, 5-13 A ring marked “TOP GROOVE ONLY” must be installed in the No. 1 compression groove.



Figure 5-13. 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 insert bearing must be installed.
8. Carefully wipe out the insert slot in the carrier and examine the insert bearing and piston pin to make sure they are clean.
9. Thoroughly clean the two retainer bolt holes in the carrier with an appropriate solvent to remove any thread lubricant or contaminants.

NOTE

If retainer bolt holes in carrier require retapping for any reason, use 5/16"-24 UNF-2B tap to a depth of 14.5 mm (0.57").

10. Apply a light film of engine lube oil to the piston pin and bearing surface of the insert.
11. Place piston pin on insert bearing with piston pin 3/8" identification hole at end of insert with small identification hole, as shown in Figure 5-14.
12. Rotate pin on insert until connecting rod mounting holes are 180° from insert.
13. Examine all mating surfaces of the carrier, and piston pin and insert bearing, to be sure they are clean and smooth.
14. With the piston pin properly oriented on the insert bearing, slide the two pieces into the carrier slot so the identification marks of the pieces are on the same side of the carrier as the piston cooling oil hole.

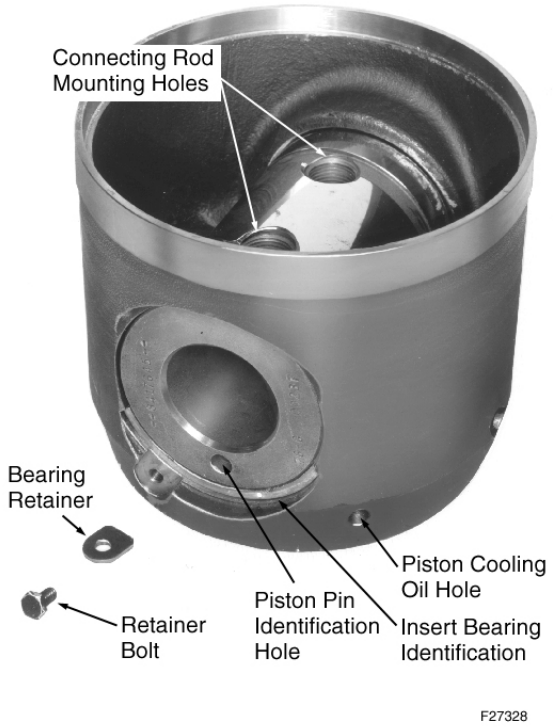
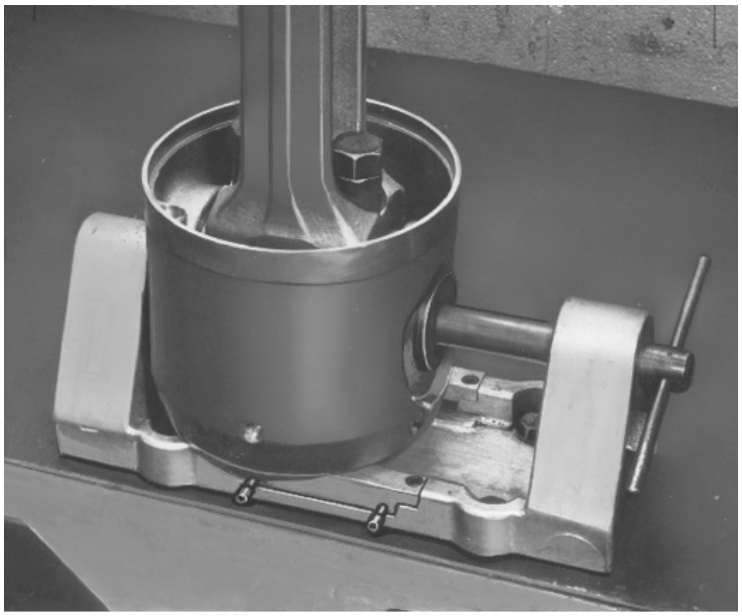


Figure 5-14. Piston Pin Insert Bearing Installation

15. Apply sealing compound listed in the Service Data over length of threads on retainer bolts, then apply a bolt with a retainer, 5-14, at each end of the insert bearing.
16. Torque the retainer bolts to specified value.
17. Place the carrier assembly in a carrier holding fixture, 5-15, and secure it with the T-handle.



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Figure 5-15. Carrier In Typical Holding Fixture

18. Apply Texaco Threadtex No. 2303 to the rod-to-piston pin bolts and thrust faces of rod and spacers. Place the connecting rod on the piston pin and apply the rod-to-piston pin bolt assemblies. Tighten bolts snugly (approximately 14 Nm [10 ft-lbs]) and perform a "finger tightness check." If a spacer can be rotated when a twisting effect is applied with a finger grip, the bolt assembly should be removed and inspected for the cause of not clamping.
19. 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.
20. Using a 300 ft-lb capacity torque wrench and extension, torque the piston pin bolts. To torque the bolts to the desired 610 Nm (450 ft-lbs), a torque reading of 300 ft-lbs is required when using the extension. The spacer should again be given a "finger tightness check" after the bolts are tight.
21. Place the piston and ring assembly on work bench with the open end up.
22. Check that the interior is clean and that the platform is free of any foreign material.

23. Apply some clean oil to the platform.
24. Place the thrust washer on the platform and apply clean oil to the thrust washer.
25. Carefully place the carrier and rod assembly into the piston and check the assembly for free rotation in the piston.
26. Using the snap ring tool, position the piston snap ring in the piston, Figure 5-16. on page 5-18.



Figure 5-16. Installing Piston Snap Ring

27. Check that the snap ring to carrier clearance does not exceed 1.07 mm (.042").

> **NOTE**
> Carrier to piston snap ring clearance that exceeds the maximum of 1.07 mm (.042") should not be used as a basis for power assembly change-out.

28. 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, as shown in Figure 5-17, page 5-19.

29. Wipe the inside of the liner with a clean, oily cloth.
30. Apply the liner lifter, 5-17, over the liner studs and secure with the stud nuts.

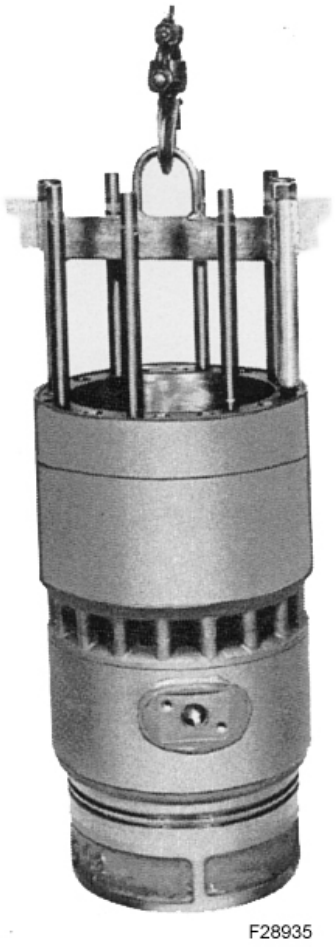


Figure 5-17. Liner Installation Using Liner Lifter

31. Attach a suitable lifting device to the liner lifter, raise slightly, and install lower liner seals (may be marked EMD VIT and with red paint) in lower grooves. Coat seals with an approved lubricant.
32. 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.
33. Place the piston ring compressor and guide over the studs on the cylinder liner.
34. Oil the ring compressor.
35. Place a protective boot over the end of the connecting rod.
36. Attach a suitable lifting device to the piston and rod assembly, and position it over the bore. Manually spread a film of oil on the outside of the piston.
37. Check that the ring gap positions have not changed.
38. Lower the piston and rod assembly into the liner.

39. Make sure that the serial number on the rod is facing outboard.
40. Lower the assembly until the piston crown is parallel to the top of the liner.
41. Oil the inside and outside surfaces of the connecting rod bearing shells and place the upper bearing in position on the connecting rod journal.
42. 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, Figure 5-9, page 5-9.

43. 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.
44. Be sure that the serial number on the basket matches the serial number on the connecting rod, 5-18

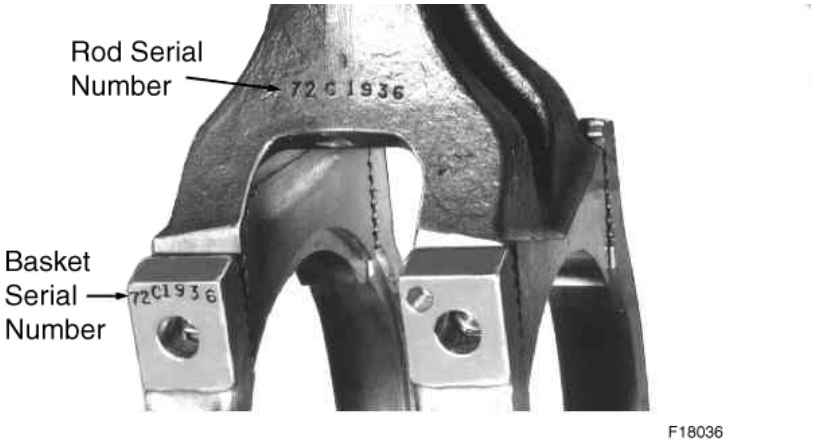


Figure 5-18. Rod And Basket Identification

45. 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.
46. Lubricate all upper basket bolt threads, bolt thrust faces and both sides of washers with Texaco Threadtex No. 2303. Start the basket-to-rod bolts by hand and tighten the upper basket fork rod bolts just enough to mate the serrations and hold the bearing in place.
47. Apply the other basket half to the fork rod with the lubricated bolts and washers. Start the basket-to-rod bolts by hand, then tighten the rod bolts enough to mate the serrations.

48. Apply the lower basket bolts, washers, and self-locking nuts, and tighten to 14 ± 7 Nm (10 ± 5 ft-lbs).
49. Snug the four top basket bolts to approximately 14 Nm (10 ft-lbs) to firmly mesh the serrations. Give each washer a “finger tightness check.” If a washer can be rotated when a twisting effect is applied with a finger grip, the bolt assembly should be removed and inspected for the cause of not clamping.

NOTE

Visually check the position of the basket strap to assure that the basket is not resting on the bronze of the top bearing shell or on the raised section of the lower bearing shell.

50. Torque the upper basket bolts to 258 Nm (190 ft-lbs).
51. Using a spring-loaded basket bolt wrench, Figure 5-7. on page 5-8, torque the lower basket bolts to specified value.
52. Remove the connecting rod positioning clamp and piston holding tool from the blade rod assembly on the opposite bank of the engine.
53. Disconnect the lifting device from the eyebolt.
54. Remove the piston ring compressor and guide from the engine. Remove the piston pulling eyebolt.
55. On older style head-to-liner gaskets, install water seals and heat dam insulators.

NOTE

Current head-to-liner gaskets use unitized water seal heat grommets.

56. Install the head-to-liner gasket, 5-19, making sure that the proper gasket is used and that the gasket is placed over the liner studs with the part number and TOP stamp facing up, and the notched ear of the gasket is placed over the pilot stud of the liner.

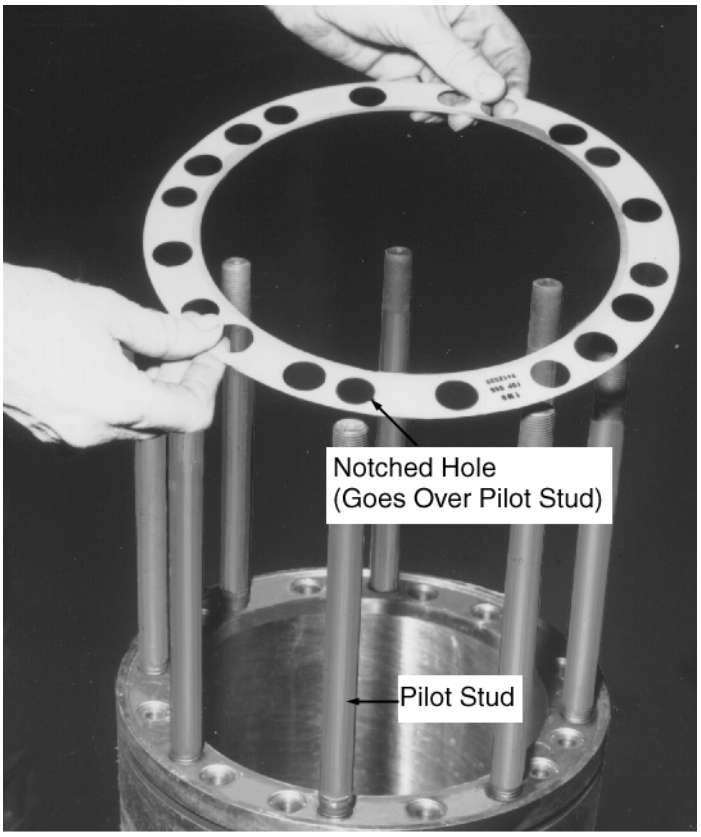


Figure 5-19. Head-To-Liner Gasket

57. 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.

58. Apply a light coat of Dow 4 silicone grease to water outlet (discharge) elbow seals and install two black 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.
59. Check that the bottom surface of the head is clean and place the seat ring, 5-20 on the head, making sure that the chamfered side is facing up.

    On head seat rings with elastomer seal rings molded to the outer diameter, the word "TOP" stamped on the chamfered side should be facing up. No other positioning reference is used.

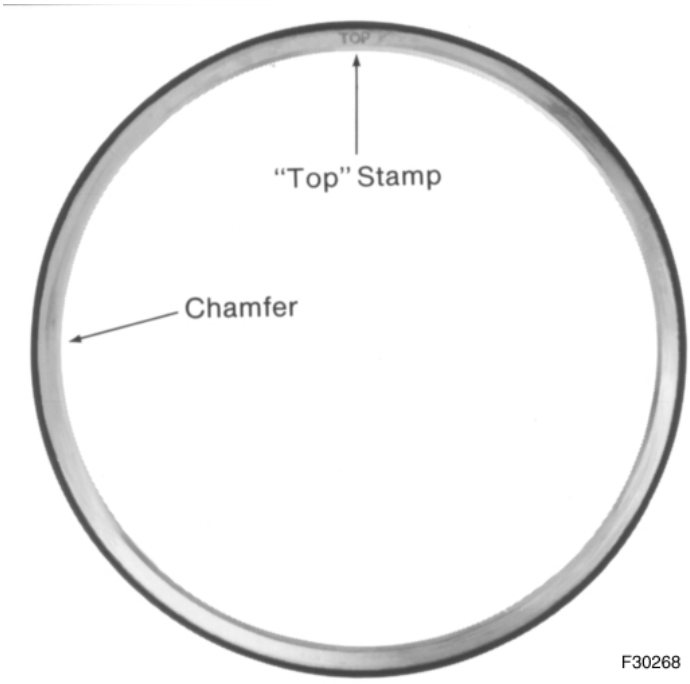


Figure 5-20. Cylinder Head Seat Ring

60. Lower the head slowly into position.
61. Line up the water discharge elbow with the mating hole in the crankcase, Figure 5-21. on page 5-23. Be careful that the seals are not damaged or twisted in the grooves while the head is being lowered into position. After head is seated in position on the liner, remove the head fixture and lifting device.

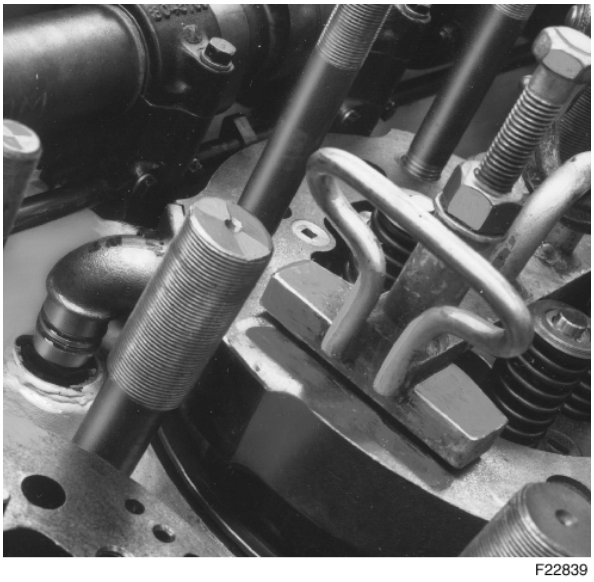


Figure 5-21. Water Discharge Elbow Alignment

62. Apply Texaco Threadtex No. 2303 to cylinder liner stud threads and thrust faces of stud nuts and washers. Damaged nuts or washers should not be reused.
63. Apply the liner washers and stud nuts, and snug them down.
64. Following the sequence as shown in 5-22, torque the head-to-liner nuts to an initial 95 Nm (70 ft-lbs).

NOTE

Do NOT final torque head-to-liner nuts until AFTER initial torque is applied to crab nuts. See Steps 67 and 68 following. This procedure is necessary in order to avoid damage to the water outlet elbows.

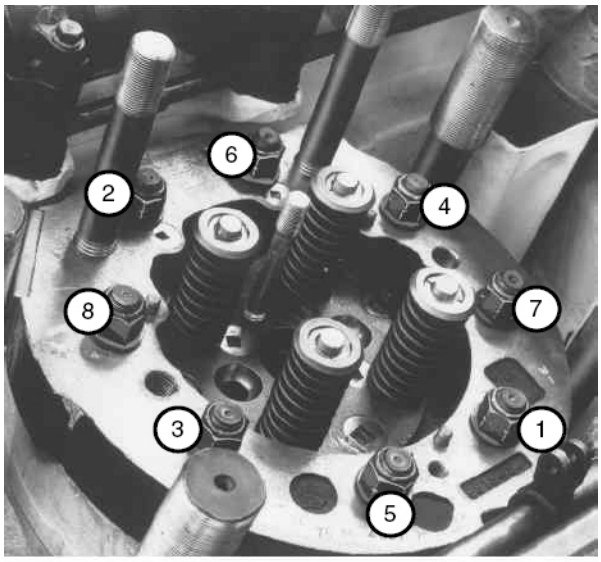


Figure 5-22. Head-To-Liner Nut Tightening Sequence

Remove all excess thread compound remaining on cylinder head and fasteners following head-to-liner torquing. Excess thread compound has been shown to hinder oil analysis.

65. Remove thread protectors, and make sure that crab bolts, crab seats, and crab nuts are free from burrs. Apply Texaco Threadtex No. 2303 to all exposed crab bolt threads and both sides of hardened washers.
66. Apply crabs, washers, and crab nuts. Center the crab bolts by manually seating the nuts while moving the crab bolts back and forth. Check that the crabs are positioned so that a wrench can be applied to the head to liner stud nuts.

NOTE

Crabs used at center intermediate positions on 12-cylinder engines are wider than those used at other intermediate positions.

67. After seating the crab nuts, torque them to approximately 542 Nm (400 ft-lbs). Torque outboard nuts first, then the inboard nuts.

NOTE

On any set of crabs, do not torque the inboard nut to 542 Nm (400 ft-lbs) until the outboard nut has been torqued to 542 Nm (400 ft-lbs).

68. Following the sequence shown in Figure 5-22, page 5-24, final torque the head-to-liner nuts to 325 Nm (240 ft-lbs).
69. 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 3 254 Nm (2400 ft-lbs). If a 12:1 power wrench is used with a 300 ft-lb capacity hand torque wrench, the pointer should indicate 200 ft-lbs for the final pass. Torque outboard nuts first, then the inboard nuts. For standard crabs the final torque is 2440.44 Nm (1800 ft-lb.)

NOTE

On any set of crabs, do not torque the inboard nut to full torque until the outboard nut has been torqued to full torque.

SPECIAL NOTE

Refer to Service Data for procedure which may be used to qualify torquing equipment using a “nut-rotation” method.

Remove all excess thread compound from crab plates, nuts and washers following crab bolt torquing.

70. Install the overspeed trip assembly (used W/ MUI) on the cylinder head, and torque the bolts to specified value.
71. Uncover the injector well and install the injector (injector into adapter collar W/ EUI) in the cylinder head. Check that the locating dowel, on the MUI injectors, is properly seated and that the injector is centered between the valves. Note the EUI injector does not have a locating dowel, therefore must be centered between the valves.
72. 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.
73. On a mechanical unit injector (MUI); be sure that the injector crab is not cocked at an angle so that it would prevent the entry of the timing tool. Torque the crab nut to specified value.
74. Install the injector adjusting link assembly (used W/ MUI) using the two clevis pins and spring retainers.

75. Attach the fuel manifold to the top deck cover frame and connect the fuel lines from the injector to the manifold.

    With Mechanical Unit Injectors (MUI); care must be taken not to damage the spherical seats used on fuel line ends as fuel leakage could occur. Torque bolts to specified value.

    With Electronic Unit Injectors (EUI); use new "O" rings at the manifold ends and apply as follows:

    a. Apply a light coat of silicon based lubricant to the new "O" rings and place one in each "O" ring land of the supply and return fittings of the fuel manifold. The grease will prevent binding of the "O" ring and hold it in place during jumper line installation.
    b. Facing the injector from the side of the engine, loosely connect the supply (left) jumper line to the top rail and the return (right) jumper line to the bottom rail of the fuel manifold.

CAUTION

Mismatching the fuel jumper lines will result in injector failure. Clearance between jumper lines and all operating mechanisms must be maintained at a minimum of 3.2 mm (1/8"). If any clearance is found to be less, jumper line must be repositioned before tightening.

    c. When tightening the jumper line fittings, use a 3/4" wrench to hold the hex of the jumper line connection in position, and tighten the hex swival nut with a 15/16" wrench. Torque each jumper line fitting to specified value.

NOTE

It is imperative that the fuel jumper lines not be kinked or twisted during application.

76. Position the valve bridges in the cylinder head (with protruding boss and oil passage plug toward camshaft for safety and uniform assembly).

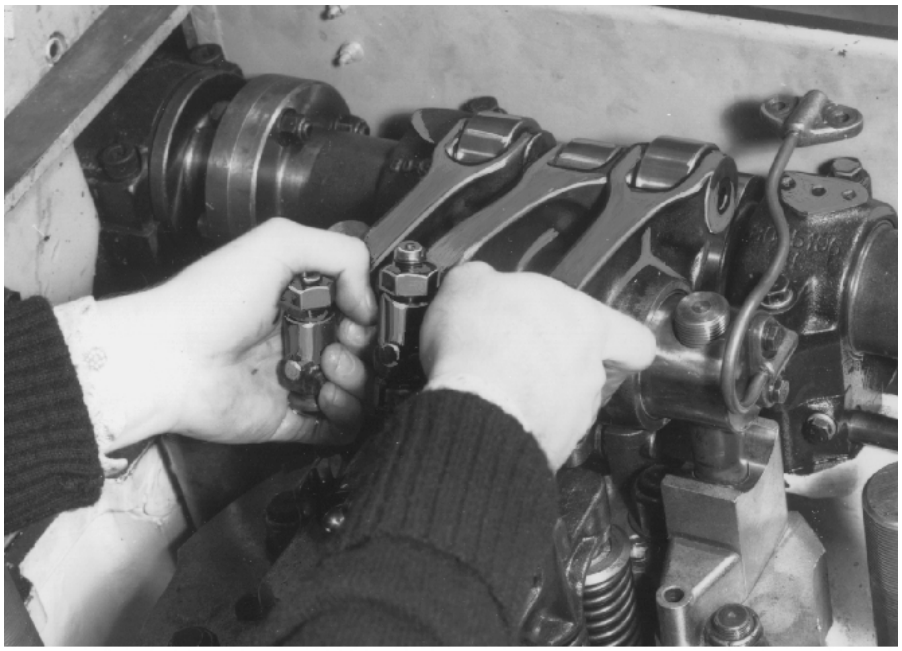
NOTE

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

77. Lubricate the shaft stud threads with Texaco Threadtex No. 2303. Apply rocker arm shaft support blocks and install the rocker arm shaft assembly, Figure 5-23. on page 5-27. Apply the shaft caps with the short toe facing out.

NOTE

Carefully observe CAUTION note above regarding clearance between fuel jumper lines and operating mechanisms when applying rocker arm shaft assembly.



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Figure 5-23. Rocker Arm Shaft Installation

78. 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.
79. Alternately torque the shaft nuts to 203 Nm (150 ft-lbs) on the first pass, and to a final torque of 407 Nm (300 ft-lbs).
80. Use a new gasket and attach the rocker arm oil line to the camshaft bearing bracket. Torque bolts to specified value. Refer to procedures near the back of this section for rocker arm adjustment of injector timing and hydraulic lash adjusters.
81. With Electronic Unit Injectors (EUI); reconnect the two wires with eyelet terminals to the injector and apply the cable tie bracket to the cylinder head. Tighten the bracket mounting bolt securely and position wires properly to avoid contact with fuel lines and valve bridges.
82. Coat a new seal with Dow 4 silicone grease and place in the groove at the liner end of the water inlet tube, Figure 5-24. on page 5-28.



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Figure 5-24. Applying Seal To Water Inlet Tube

83. Position saddle straps around the water manifold and then through the inlet tube flange.
84. 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.
85. 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.
86. Torque the strap nuts to specified value.
87. 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 specified value.
88. Using a new gasket, place the piston cooling oil pipe against the piston cooling oil manifold.
89. 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.
90. 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.
91. Install the fine thread bolts into the manifold, and the coarse thread bolts into the liner. Torque bolts to specified value.

92. Check proper alignment of the piston cooling oil pipe by barring the engine over to bottom dead center of the cylinder being checked. Make certain that the tube does not bind in the carrier hole. If an interference exists, indicating misalignment, replace the oil pipe.

NOTE

Unlike previous model EMD engines, the alignment of the piston cooling oil pipe to the inlet hole of the piston carrier on GB series engines can be done without an alignment gauge. This is because the oil tube itself extends into the carrier at the bottom dead center of the cylinder being checked.

93. 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, 5-25

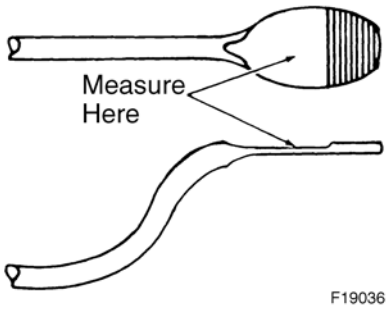


Figure 5-25. Lead Wire Measurement

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 between the two compressed ends should not exceed 0.13 mm (0.005") for new, remanufactured, or otherwise requalified clean parts. If it does, repeat the process as the wire may have changed position.

NOTE

Due to carbon buildup on both the fireface of the cylinder head and the crown of the piston during service life, lead wire readings should not be used as a basis for power assembly changeout. Lead wire readings may continue to be used to indicate wear trends. Significant clearance increases should be investigated as possible component failures.

94. Place a new seal-ring in the cylinder test valve bore and apply high temperature thread lubricant to valve body threads. Install the valve body.
95. Tighten the valve body into the cylinder head.
96. Torque the valve body to specified value and install the needle valve.
97. Refill the cooling system and check for water leaks.
98. Install the top deck and handhole covers.
99. Bar the engine over one complete revolution and close all the cylinder test valves.
100. Start the engine and raise the water temperature to 77°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, fuel, and water leaks.

5.1.4 UNIT INSTALLATION

Left and right banks of the engine are determined by looking toward the “front” (accessory end) of the engine while 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 power 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, Figure 5-26. on page 5-31, or expendable cardboard and wood container. The metal cover on the storage 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.



Figure 5-26. 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, 5-26
7. The assembly has been coated with an anti-rust compound which does not have to be removed and is totally compatible with lube oil.
8. Install the rocker arm shaft supports, if required, making sure that the locating dowel holes are properly positioned.
9. Install the lifting clamp, Figure 5-27. on page 5-32, and secure it with the rocker arm shaft nuts.

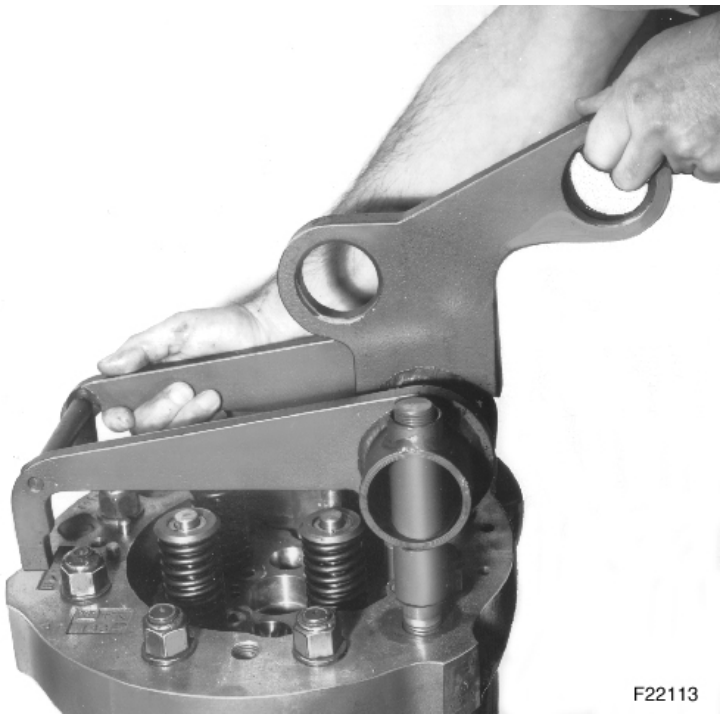


Figure 5-27. Lifting Clamp Application

10. Remove the rag from the injector well and apply the piston holding tool, 5-28.

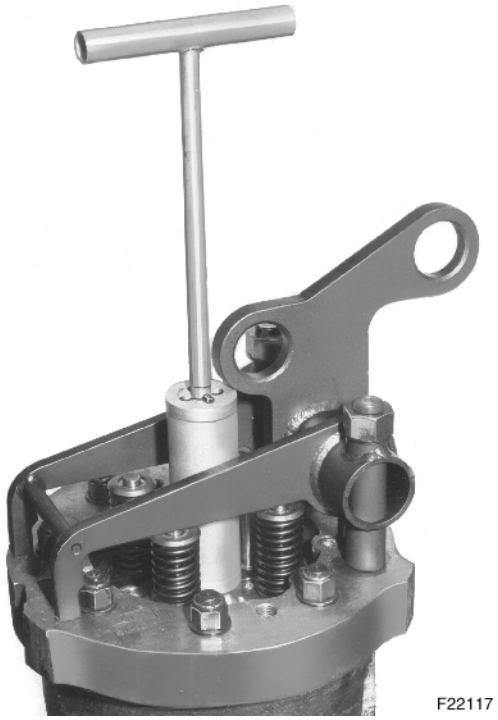


Figure 5-28. Piston Holding Tool Application

11. 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, 5-29.

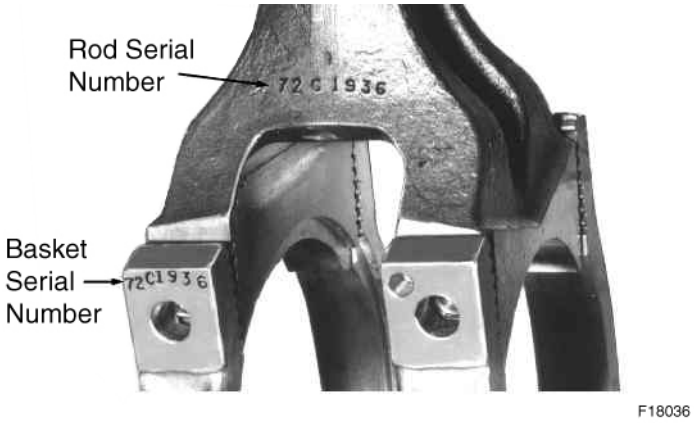


Figure 5-29. Rod And Basket Identification

14. Before applying the water discharge elbow, inspect the internal and external seal grooves. Apply a light coat of Dow 4 silicone grease to water outlet (discharge) elbow seals and install two black 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, 5-30, to position it at the proper angle for installation in the engine.

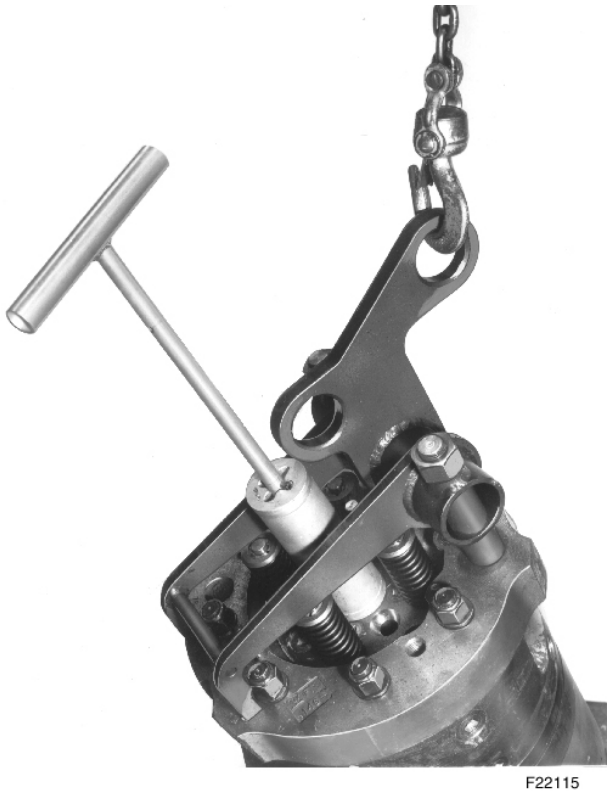
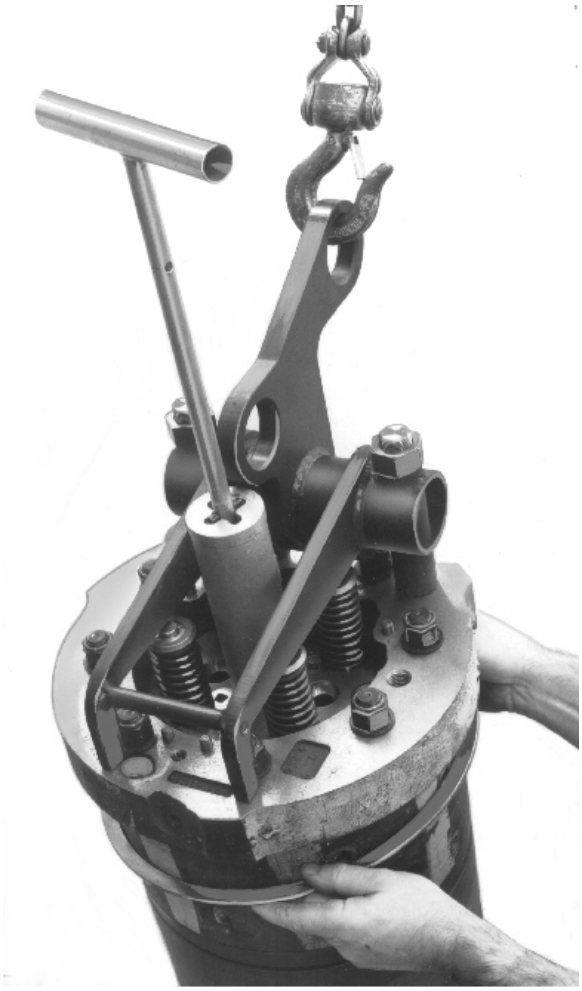


Figure 5-30. Power Assembly Installation With Clamp And Hoist

16. Raise assembly and install lower liner seals (may be marked EMD VIT and with red paint) in lower grooves. Coat seals with an approved lubricant.
17. Place the seat ring on the assembly, 5-31, making sure that the chamfered side with the word “TOP” stamped on the surface is facing up. Place thread protectors on cylinder head crab bolts.



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Figure 5-31. Seat Ring Installation

18. Lower the assembly slowly into the crankcase bore, lining up the water discharge elbow with the mating hole in the crankcase, Figure 5-32. on page 5-35. Be careful that the seals are not damaged or twisted in the grooves while the head is lowered into position.

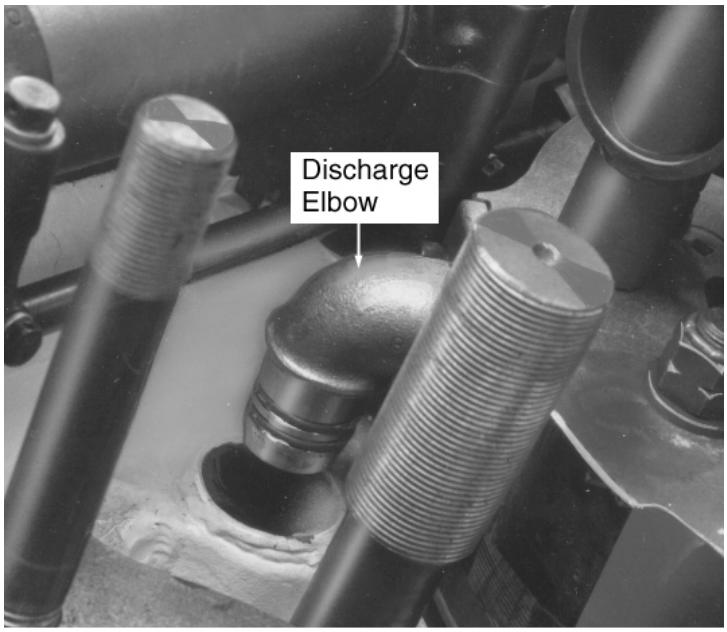


Figure 5-32. Water Discharge Elbow Alignment

19. Before the head contacts the crankcase, recheck the position of the seat ring.
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 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 bolt threads, bolt thrust faces and both sides of washers with Texaco Threadtex No. 2303. Start the basket-to-rod bolts by hand 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 with the lubricated bolts and washers. Start the basket-to-rod bolts by hand, then tighten the rod bolts enough to mate the serrations.
29. Apply the lower basket bolts, washers, and self-locking nuts and tighten to 14 ± 7 Nm (10 ± 5 ft-lbs).
30. Snug the four top basket bolts to approximately 14 Nm (10 ft-lbs) to firmly mesh the serrations. Give each washer a "finger tightness check." If a washer can be rotated when a twisting effect is applied with a finger grip, the bolt assembly should be removed and inspected for the cause of not clamping.
31. Visually check the position of the basket strap to assure that the basket is not resting on the bronze of the top bearing shell or on the raised section of the lower bearing shell.
32. Torque the upper basket bolts to 258 Nm (190 ft-lbs).
33. Using the spring-loaded basket bolt wrench, 5-33, torque the lower basket bolts to specified value.

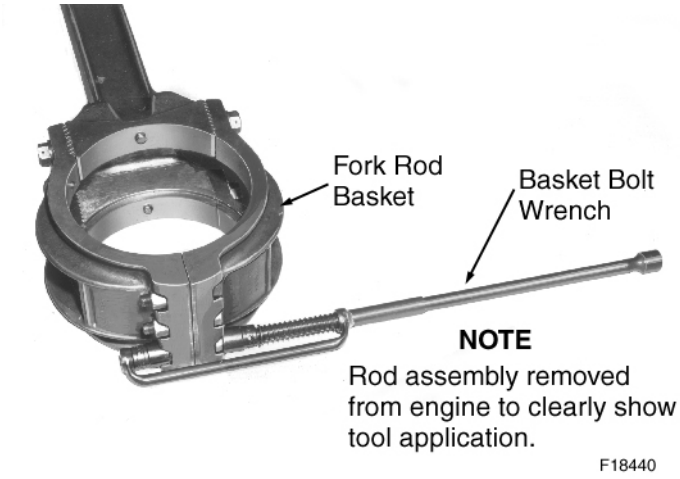


Figure 5-33. Basket Bolt Wrench Application

34. Remove thread protectors and make sure that crab bolts, crab seats, and crab nuts are free from burrs. Apply Texaco Threadtex No. 2303 to all exposed crab bolt threads and both sides of hardened washers.
35. Apply crabs, washers, and nuts. Center the crab bolts by manually seating the nuts while moving the crab bolts back and forth. Check that the crabs are positioned so that a wrench can be applied to the head-to-liner stud nuts.

NOTE

Crabs used at center intermediate positions on 12-cylinder engines are wider than those used at other intermediate positions

36. After seating the crab nuts, torque them to approximately 542 Nm (400 ft-lbs). Torque outboard nuts first, then the inboard nuts.

NOTE

On any set of crabs, do not torque the inboard nut to 542 Nm (400 ft-lbs) until the outboard nut has been torqued to 542 Nm (400 ft-lbs).

37. Check the head-to-liner stud nuts for specified torque, starting with the pilot stud and using the tightening sequence as shown in Figure 5-22., “Head-To-Liner Nut Tightening Sequence” on page 5-24.

NOTE

Do NOT final torque head-to-liner nuts until AFTER initial torque is applied to crab nuts in order to avoid damage to the water outlet elbows.

38. 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 3 254 Nm (2400 ft-lbs). If a 12:1 power wrench is used with a 300 ft-lb capacity hand torque wrench, the pointer should indicate 200 ft-lbs for the final pass. Torque outboard nuts first, then the inboard nuts. For standard crabs the final torque is 2440.44 Nm (1800 ft-lb).

NOTE

On any set of crabs, do not torque the inboard nut to full torque until the outboard nut has been torqued to full torque.

SPECIAL NOTE

Refer to Service Data for procedure which may be used to qualify torquing equipment using a “nut-rotation” method.

Remove all excess thread compound from crab plates, nuts and washers following crab bolt torquing.

39. Install the overspeed trip assembly (used W/ MUI) on the cylinder head, and torque the bolts to specified value.
40. Uncover the injector well and install the injector (injector into the adapter collar W/ EUI) in the cylinder head. Check that the locating dowel, on the MUI injectors, is properly seated and that the injector is centered between the valves. Note the EUI injector does not have a locating dowel, therefore must be centered between the valves.

41. 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.
42. Be sure that the injector crab is not cocked at an angle so that it would prevent the entry of the timing tool used on a mechanical unit injector (MUI), and torque the crab nut to specified value.
43. Install the injector adjusting link assembly (used W/ MUI) using the two clevis pins and spring retainers.
44. Connect the fuel lines from the manifold to the injector.

    With Mechanical Unit Injectors (MUI); care must be taken not to damage the spherical seats used on fuel line ends as fuel leakage could occur. Torque bolts to specified value.

    With Electronic Unit Injectors (EUI); use new "O" rings at the manifold ends and apply as follows:

    a. Apply a light coat of silicon based lubricant to the new "O" rings and place one in each "O" ring land of the supply and return fittings of the fuel manifold. The grease will prevent binding of the "O" ring and hold it in place during jumper line installation.
    b. Facing the injector from the side of the engine, loosely connect the supply (left) jumper line to the top rail and the return (right) jumper line to the bottom rail of the fuel manifold.

CAUTION

Clearance between fuel jumper lines and all operating mechanisms must be maintained at a minimum of 3.2 mm (1/8"). If any clearance is found to be less, jumper line must be repositioned before tightening.

    c. When tightening the jumper line fittings, use a 3/4" wrench to hold the hex of the jumper line connection in position, and tighten the hex swival nut with a 15/16" wrench. Torque each jumper line fitting to specified value.

NOTE

It is imperative that the fuel jumper lines not be kinked or twisted during application.

45. Position the valve bridges in the cylinder head (with protruding boss and oil passage plug toward camshaft for safety and uniform assembly).

NOTE

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

46. Lubricate the shaft stud threads with Texaco Threadtex No. 2303. Apply rocker arm shaft support blocks and install the rocker arm shaft assembly, Figure 5-23. on page 5-27. Apply the shaft caps with the short toe facing out.

NOTE

Carefully observe CAUTION note above regarding clearance between fuel jumper lines and operating mechanisms when applying rocker arm shaft assembly.

47. 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.
48. Alternately torque the shaft nuts to 203 Nm (150 ft-lbs) on the first pass, and to a final torque of 407 Nm (300 ft-lbs).
49. Use a new gasket and attach the rocker arm oil line to the camshaft bearing bracket. Torque bolts to specified value. Refer to procedures at the back of this section for rocker arm adjustment of injector timing and hydraulic lash adjusters.
50. With Electronic Unit Injectors (EUI); reconnect the two wires with eyelet terminals to the injector and apply the cable tie bracket to the cylinder head. Tighten the bracket mounting bolt securely and position wires properly to avoid contact with fuel lines and valve bridges.
51. Coat a new seal with Dow 4 silicone grease and place in the groove at the liner end of the water inlet tube, Figure 5-24., “Applying Seal To Water Inlet Tube” on page 5-28.
52. Position saddle straps around the water manifold and then through the inlet tube flange.
53. 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.
54. 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.
55. Torque the strap nuts to specified value.
56. 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 specified value.
57. Using a new gasket, place the piston cooling oil pipe against the piston cooling oil manifold.

58. 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.
59. 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.
60. Install the fine thread bolts into the manifold, and the coarse thread bolts into the liner. Torque bolts to specified value.
61. Check proper alignment of the piston cooling oil pipe by barring the engine over to bottom dead center of the cylinder being checked. Make certain that the tube does not bind in the carrier hole. If an interference exists, indicating misalignment, replace the oil pipe.

NOTE

Unlike previous model EMD engines, the alignment of the piston cooling oil pipe to the inlet hole of the piston carrier on GB series engines can be done without an alignment gauge. This is because the oil tube itself extends into the carrier at the bottom dead center of the cylinder being checked.

62. 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, Figure 5-34.

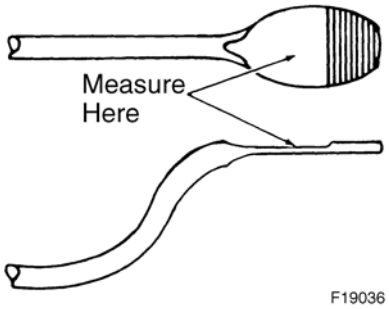


Figure 5-34. Lead Wire Measurement

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 between the two compressed ends should not exceed 0.13 mm (0.005") for new, remanufactured, or otherwise requalified clean parts. If it does, repeat the process as the wire may have changed position.

NOTE

Due to carbon buildup on both the fireface of the cylinder head and the crown of the piston during service life, lead wire readings should not be used as a basis for power assembly changeout. Lead wire readings may continue to be used to indicate wear trends. Significant clearance increases should be investigated as possible component failures.

63. Place a new seal-ring in the cylinder test valve bore and apply high temperature thread lubricant to valve body threads. Install the valve body.
64. Tighten the valve body into the cylinder head.
65. Torque the valve body to specified value and install the needle valve.
66. Refill the cooling system and check for water leaks.
67. Install the top deck and handhole covers.
68. Bar the engine over one complete revolution and close all the cylinder test valves.
69. Start the engine and raise the water temperature to 77°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, fuel, and water leaks.

5.1.5 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.

5.1.6 ADJUSTING HYDRAULIC LASH ADJUSTERS

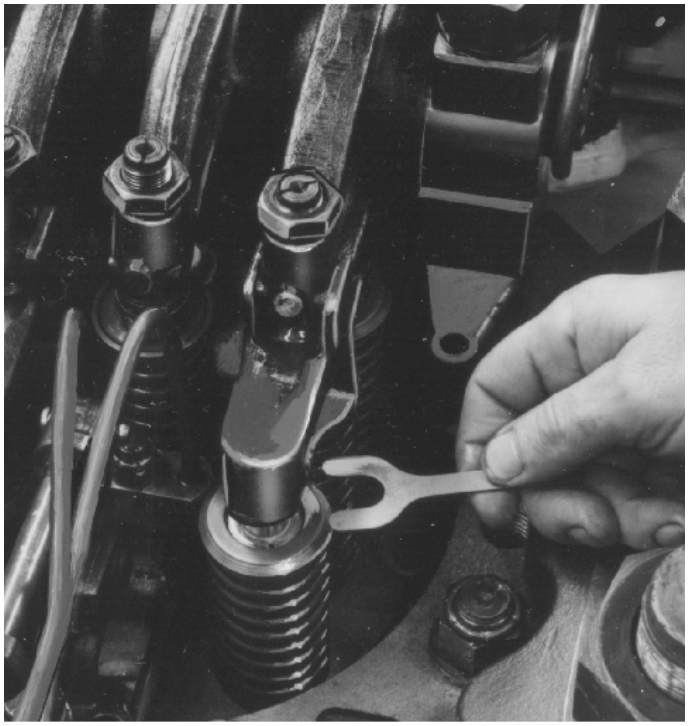
5.1.6.1 LASH ADJUSTER - P/N 8085254

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 valves 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 until a 0.001" shim is just snug between valve stem top and adjuster plunger. Remove shim, if used, then turn adjusting screw 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. Check to be certain valves are not held open.
5. Tighten rocker arm adjusting screw locknut to a torque of 108 ±7 Nm (80 ±5 ft-lbs).

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, Figure 5-35. on page 5-43, 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. Also, verify that there is no clearance between valve tip and adjuster plunger.



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Figure 5-35. Checking Lash Adjuster To Valve Clearance

5.1.6.2 LASH ADJUSTER - P/N 40118613

The new design lash adjuster P/N 40118613 uses the setting indicated below.

When using reconditioned cylinder heads, it will sometimes be necessary to turn the adjusting screw down less than 1-1/2 turns. This is necessary in order to compensate for a reconditioned cylinder head with excessive high valve stem height as a result from valve seat and valve face re-machining in combination with the shortened plunger stroke of the new designed lash adjuster.

The objective of the adjustment procedure is to position the lash adjuster plunger near the middle of its stroke. The 1-1/2 turns is a guide, not a requirement, again fewer turns will be necessary with some reconditioned cylinder heads.

This will have a negligible affect on the operation of the valve train and will not cause undue wear so long as the bronze spring seat of the valve bridge is preloaded against the spherical seat in the cylinder head.

A minimum of a quarter turn is required and will function properly if the lash adjuster plungers are properly positioned with a minimum of 1/16" between the tip of the valve and the lower surface of the lash adjuster body. This gap can be checked using EMD P/N 8107788 gage.

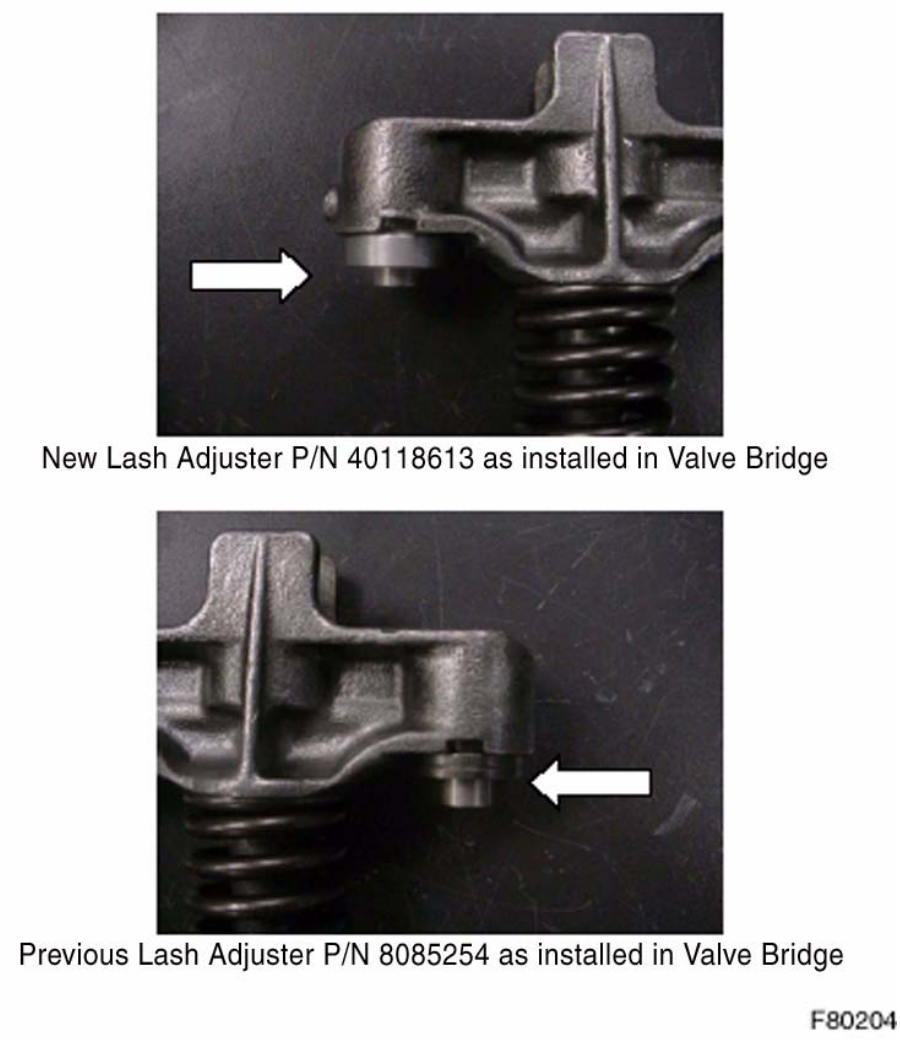


Figure 5-36. Lash Adjusters - 8085254 & 40118613

In some instances when a reconditioned cylinder head has excessive valve stem height and the new lash adjuster does not meet the minimum 1/16" clearance, it is advised to use the previous style lash adjuster. The previous style lash adjuster P/N 8085354 is still available as a component in a Utex Valve Bridge P/N 8361504. This is a temporary situation that will be resolved in the near future to allow the new lash adjuster design to be used in all rebuild cylinder applications

5.1.7 TIMING THE INJECTORS

With the injector installed, make timing adjustment as follows:

1. Bar engine over in the normal direction of rotation until flywheel pointer indicates the correct crankshaft position in degrees relative to top dead center of the cylinder being timed. Refer to setting instructions on Injector Timing Plate (located on right rear side of engine crankcase) and see Table 7-1 and Table 7-2 in Section 7 for top dead center settings.
2. For Mechanical Unit Injectors (MUI):
   a. Insert injector timing gauge into the hole provided for it in the injector body, Figure 5-37. on page 5-45
   b. 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.

   c. Tighten adjusting screw locknut while holding adjusting screw in position with a screwdriver.
   d. Recheck setting with gauge.

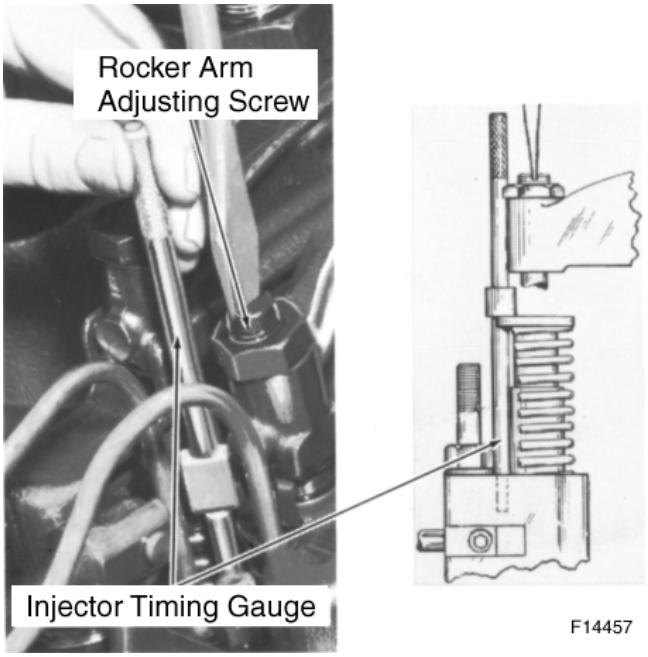


Figure 5-37. Timing Mechanical Unit Injector (MUI)

5. With Electronic Unit Injectors (EUI):
   a. Loosen locknut and slowly run each injector follower adjusting screw down clockwise (CW) until it bottoms, then back off adjustment by turning screw counter clockwise (CCW) 1-1/2 turns.
   b. Tighten adjusting screw locknut securely while holding adjusting screw in position with a screwdriver.

5.2 SERVICE DATA - CYLINDER POWER ASSEMBLY

5.2.1 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Carrier to piston snap ring clearance -

Min. ..... 0.05 mm (.002")
Max. ..... 1.07 mm (.042")

Piston to cylinder head clearance -

Min. ..... 0.51 mm (.020")

New power assembly -

Max. ..... 1.73 mm (.068”)

Remanufactured power assembly -

Max. ..... 2.03 mm (.080")

Differential reading between ends of lead wire, on installation ..... 0.13 mm (.005")

NOTE

Due to carbon buildup on both the fireface of the cylinder head and the crown of the piston during service life, lead wire readings should not be used as a basis for power assembly change-out. Lead wire readings may continue to be used to indicate wear trends. Any significant clearance increases should be investigated as possible component failures.

Carrier to piston snap ring clearance that exceeds the maximum of 1.07 mm (.042") should also not be used as a basis for power assembly change-out.

5.2.2 EQUIPMENT LIST

	PART NO.
Test valve wrench	8032587
Crab stud protector tubes	8034600
Mechanical Unit 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
Cylinder head removing fixture	8075894

Piston cooling pipe cleaning tool.....8087086
Lash adjuster minimum clearance gauge 8107788
Cylinder liner lifter.....8116358
Torque wrench, 19.05 mm (3/4") drive,
0-407 Nm (0-300 ft-lbs) 8157121
Snap ring remover 8171633
Torque wrench extension
(use w/ torque wrench 8157121).....8210136
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 -3.18 mm (1/8") dia., used with holder
8243220 or alone, 2.27 kg (5 lb) spool 8243661
Thread lubricant, high temperature
-0.946 liter (1 qt.) 8278929
Thread lubricant, Texaco Threadtex No. 2303
-approx. 18.93 liter (5 gal).....8307731
Piston ring expander.....8349892
Lifting clamp assembly 8417858
Piston holding tool 8417859
Connecting rod positioning clamp assembly.....8417881
Silicone grease -150 g (5.3 oz.) tube.....8425724
Injector holding rack 8431626
Loctite sealing compound - 250 cc 9087621
Piston ring compressor and guide (standard size) 9333846
Piston carrier holding fixture (2 mandrels) 9534635
Piston carrier holding fixture (single mandrel) 9542253
Crab nut wrench set (manual).....9551713
Crab nut wrench, air operated.....40014456

5.2.3 EQUIPMENT QUALIFICATION

5.2.3.1 CRAB NUT TORQUE WRENCHES

The following “nut-rotation” procedure may be used to qualify equipment used to torque crab nuts. EMD recommends that torquing equipment used be qualified on a routine basis in order to assure proper crab bolt clamp loading which is critical to the life expectancy of power assemblies.

NOTE

The following procedure presumes the use of a 12:1 power wrench with a 300 ft-lb capacity hand torque wrench.
The term “equivalent,” as used herein, is to be considered a reference parameter for this instruction only and does not imply a constant conversion relationship (equivalency) between torque and nut rotation.

1. On newly assembled engine, clean and remove oil from crab bolts, nuts, and the plate crab top surface.

2. Using chalk, or a white marking pencil, mark crab bolts, nuts, and plate crab in a line at the 12 o'clock position from the top of the crab bolt and nut to the plate crab, as shown in Figure 5-38. on page 5-49.

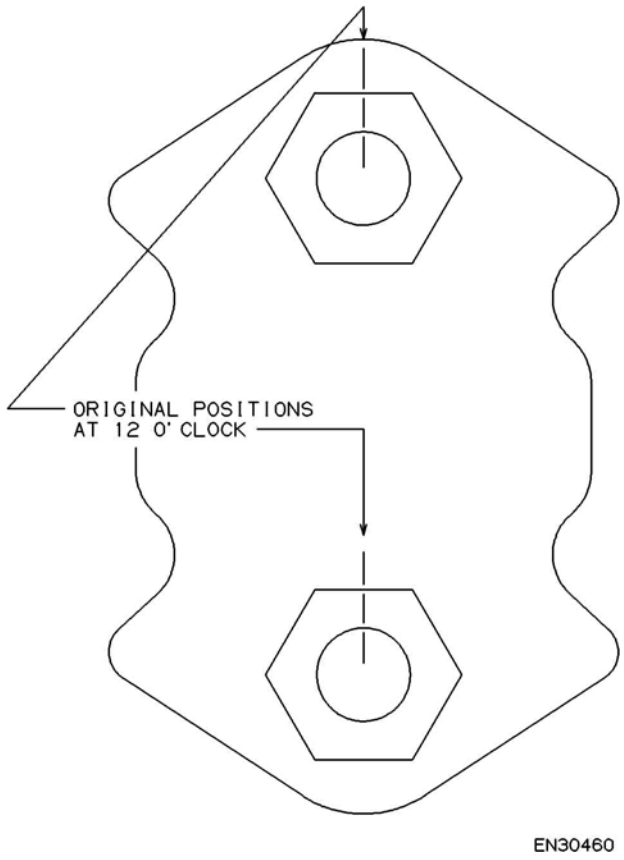


Figure 5-38. Marking Original Crab Nut Positions

3. Loosen both crab nuts to approximately 271 Nm (200 ft-lbs), loosening first the outboard nut and then the inboard nut. This can be accomplished by loosening the nuts 1/2 to 3/4 of a turn with an impact wrench, or if using a power wrench, by backing off to 414 kPa (60 psi). Do not allow the plate crab to shift position.
4. Using available shop calibration equipment, verify that torque wrench to be used is calibrated to 407 Nm (300 ft-lbs).
5. Tighten crab nuts to 407 Nm (300 ft-lbs), tightening first the outboard nut and then the inboard nut, using a steady even pull on the wrench in the clockwise direction until an exact reading of 407 Nm (300 ft-lbs) is obtained.

6. Measure the angle of nut rotation from the line on the plate crab and bolt to the line marked on the nut using the special protractor as depicted in angle “A,” Figure 5-39. on page 5-50. Align the protractor “0” degree mark to the 12 o’clock position, then measure the angle of degrees to the line marked on the crab nut in the counter-clockwise direction.

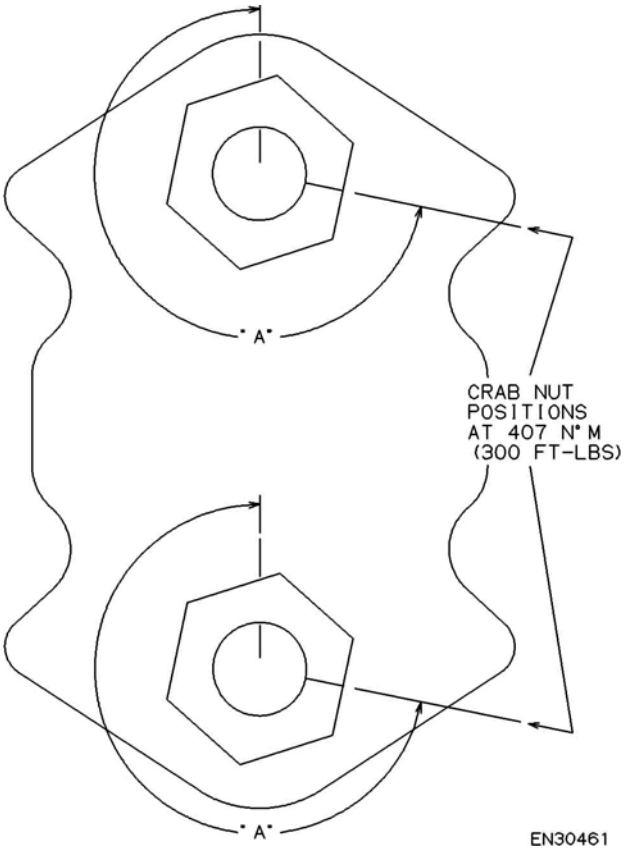


Figure 5-39. Crab Nut Angle “A” Positions

NOTE

Protractor, shown in Figure 5-40. Crab Nut Rotation Protractor on page 5-51, can be duplicated for use in the nut-rotation measurement. Copy sample exactly as shown (100%), preferably on clear (transparency) film, then cut out center circle to position protractor over crab bolt.

The required nut rotation for all standard intermediate plate crabs is 245° ± 60°.

The required nut rotation for all end position plate crabs (1, 4, 5, 8, 9, 12, 13, and 16), or when heavy plate crabs are used at intermediate positions, is 200° ± 50°.

To convert nut rotation to equivalent torque for standard intermediate plate crabs, use the following formula:

DEGREES COUNTER-CLOCKWISE ROTATION x 11.66 (8.6)+ 406.75 (300)=EQUIVALENT TORQUE IN Nm (ft-lbs).

NOTE

Even though the degrees rotation on the end, center, and heavy intermediate plate crabs will be slightly lower than standard intermediate plate crabs, the applied torque value is the same for all crab bolts.

When doing a nut rotation torque check, upon crab reapplication, perform the normal tightening procedure to the specified torque, then follow steps 2 through 6. Complete procedure by re-tightening crab nuts to required torque after recording the nut rotation.

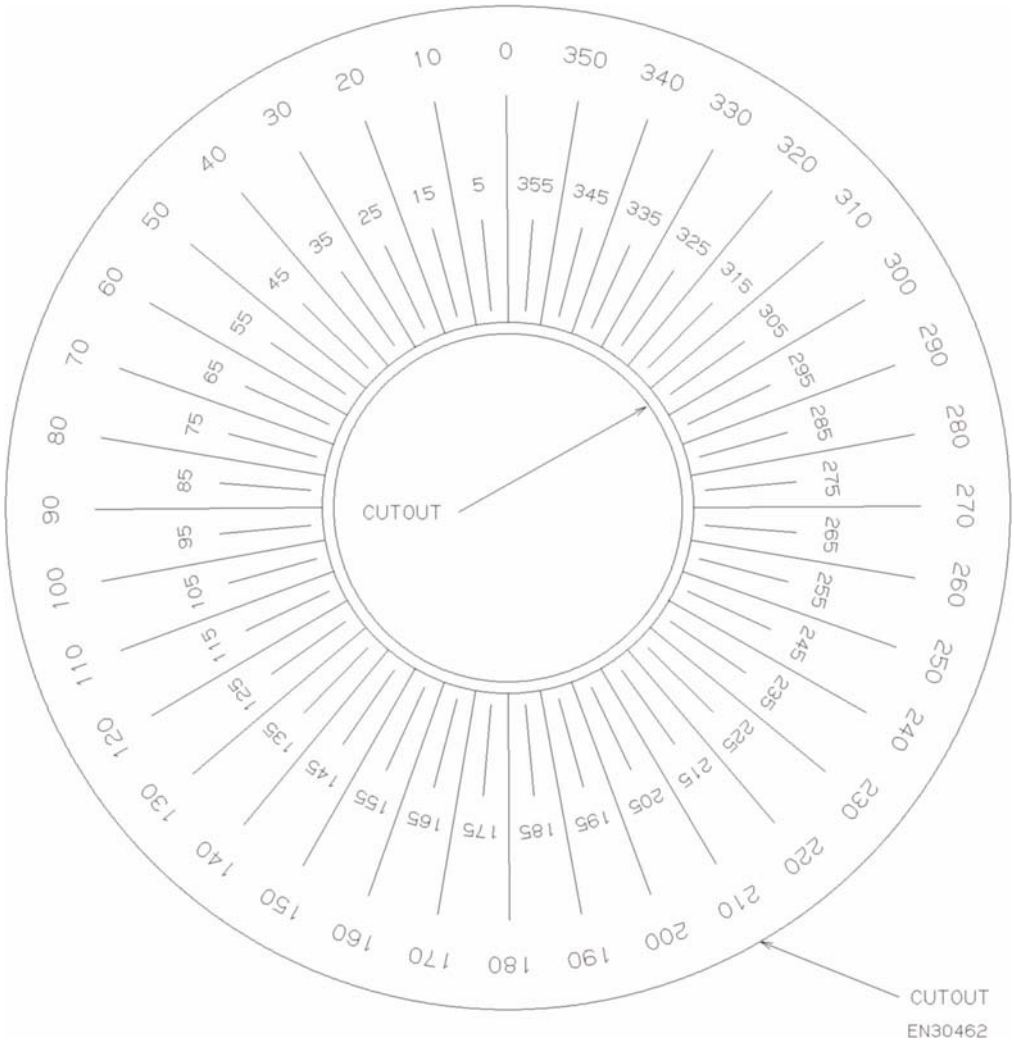


Figure 5-40. Crab Nut Rotation Protractor

SECTION 6. CRANKSHAFT ASSEMBLY AND ACCESSORY DRIVE GEAR TRAIN

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6.1 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 pump(s), water pumps, and the governor (if applied).

6.2 CRANKSHAFT

6.2.1 DESCRIPTION

The crankshaft, Figure 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 may be a one piece forging or made up of two sections whose center 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 Figure 6-2. on page 6-4.

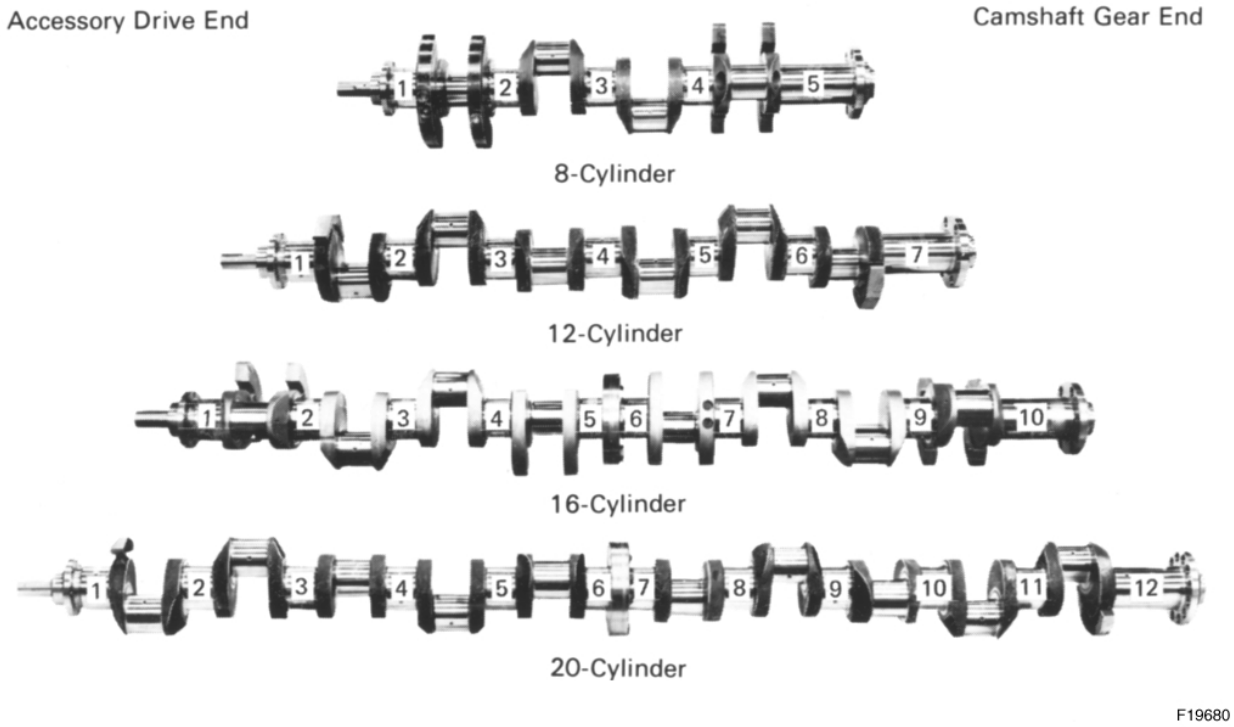


Figure 6-1. Typical Engine Crankshafts

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.

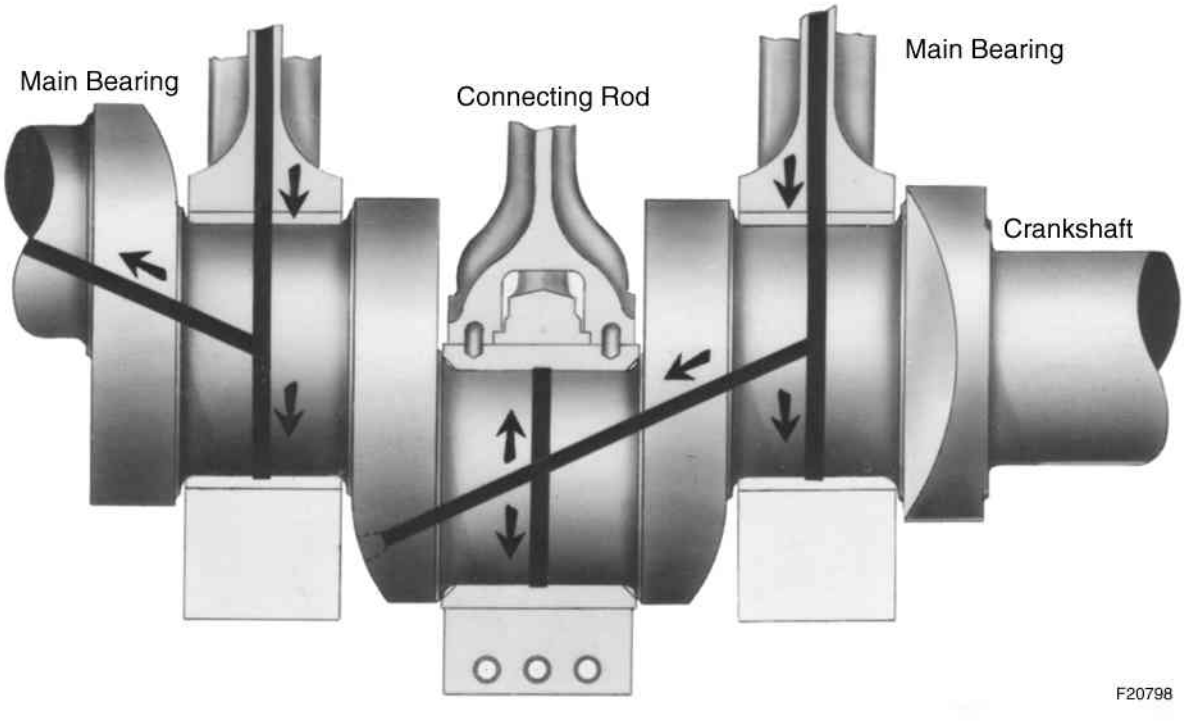


Figure 6-2. Crankshaft Oil Passages

6.2.2 MAINTENANCE

6.2.2.1 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, which 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 to EMD for regrinding. 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.

6.3 MAIN BEARINGS

6.3.1 DESCRIPTION

The main bearing shells, Figure 6-3, 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.

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.

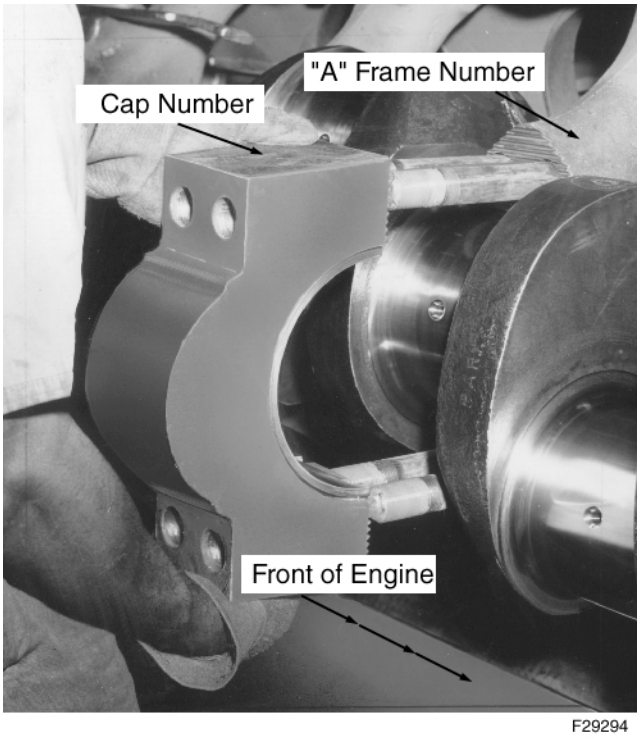


Figure 6-3. Main Bearing Shell And Cap (w/ stud mounting)

6.3.2 MAINTENANCE

NOTE

Refer to EMD publication entitled: "INSPECTION & QUALIFICATION GUIDE ENGINE MAIN & CONNECTING ROD BEARINGS" for detailed information needed (in addition to the following) to conduct a thorough bearing examination.

6.3.2.1 SCHEDULED RENEWAL

Lower main bearings should be renewed as 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.

6.3.2.2 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. The 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 as 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 Figure 6-1. on page 6-3 for main bearing numbering location.

NUMBER OF CYLINDERS	BEARING NUMBER TO BE INSPECTED
8	2, 4
12	2, 6
16	2, 6, 8, 9
20	2, 5, 8, 11

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 bolts, 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 or bolts 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.

6.3.2.3 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, Figure 6-1., "Typical Engine Crankshafts" on page 6-3, 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.

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.

6.4 THRUST COLLAR

6.4.1 DESCRIPTION

The two thrust collars, Figure 6-4, 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.

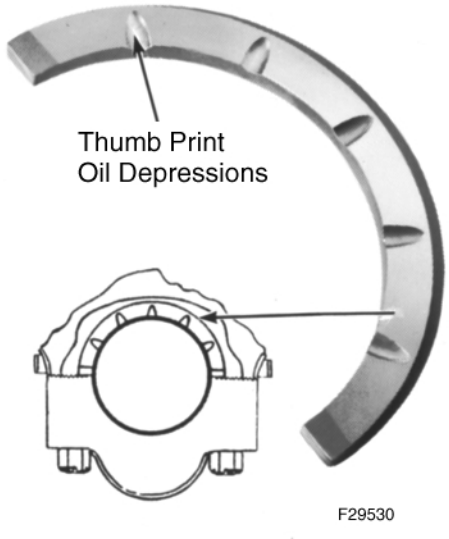


Figure 6-4. Crankshaft Thrust Collars (Two Collars For Each Engine)

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.

6.4.2 MAINTENANCE

Thrust collars which exceed clearance limit should be replaced.

6.5 GEAR TYPE TORSIONAL DAMPER

6.5.1 DESCRIPTION

The gear type damper, Figure 6-5, 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.

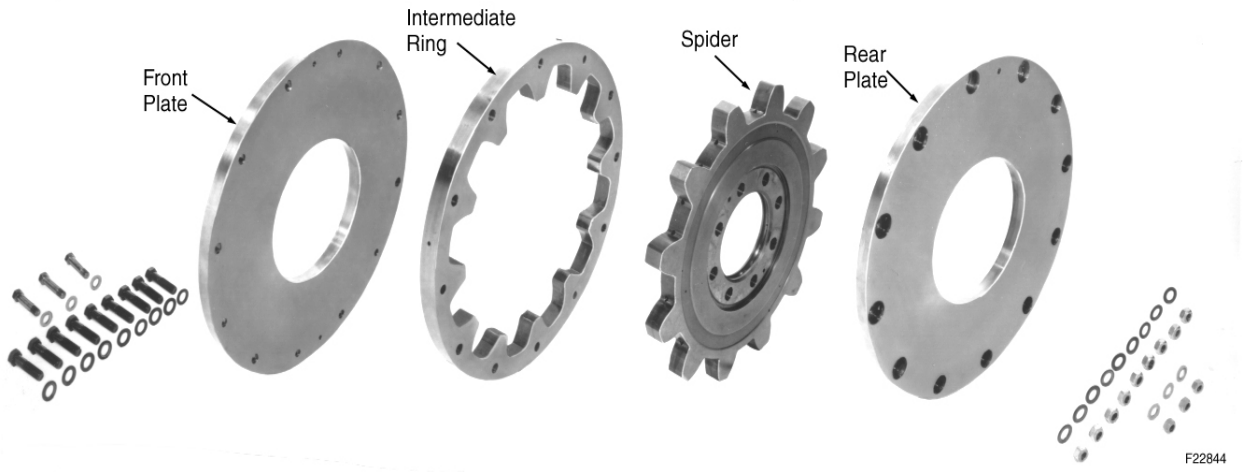


Figure 6-5. Gear Type Damper, Exploded View

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 to the radial holes.

The intermediate ring is ground on both sides to a uniform thickness, slightly thicker than the spider. 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.

6.5.2 MAINTENANCE

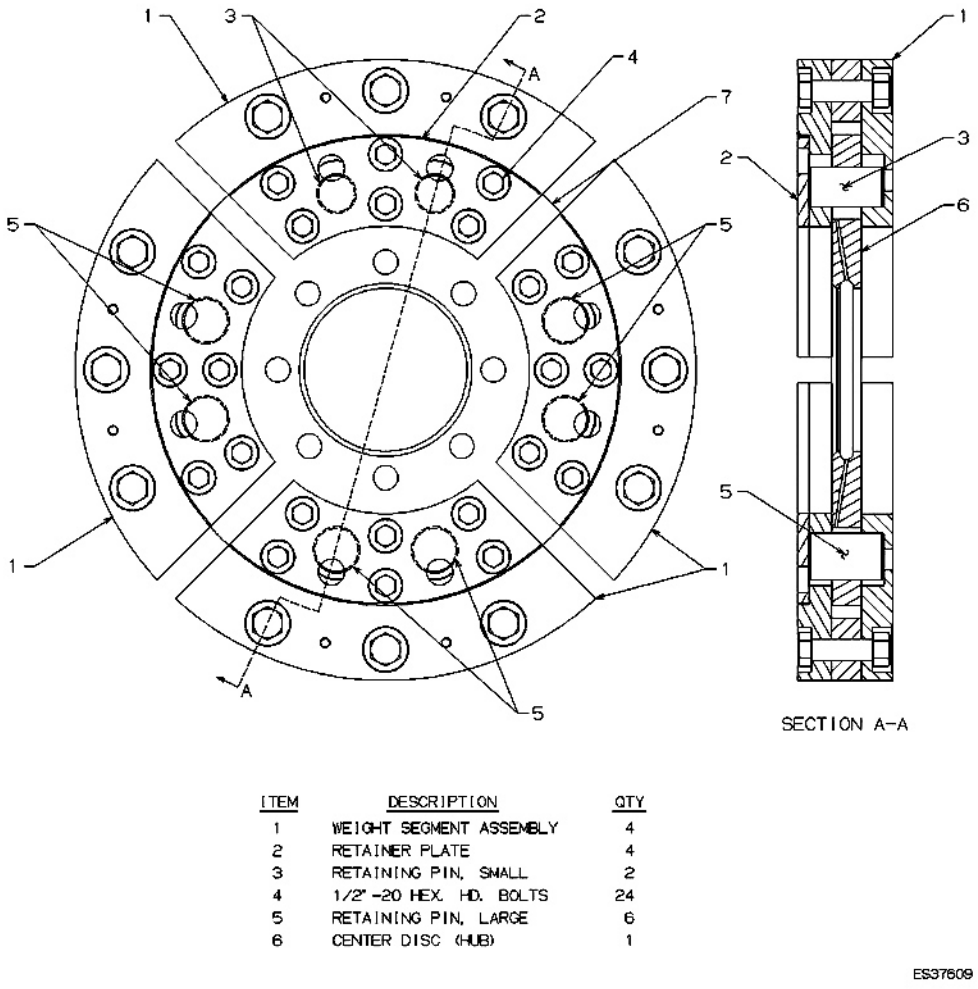
The damper requires no maintenance other than inspection at the time of normal overhaul. However, the damper should be checked for free movement at interval specified in the applicable Scheduled Maintenance Program. This check can be performed by removing the front handhole covers and rotating the damper about 10° in each direction. If the damper cannot be moved, it should be removed and disassembled.

6.6 PENDULUM TYPE TORSIONAL DAMPER (12N ENGINE ONLY)

6.6.1 DESCRIPTION

The pendulum type damper, Figure 6-6. on page 6-12, uses centrifugal “throw-out” weights attached to a center disc (hub) to absorb torsional vibrations of the crankshaft. The damper consists of four (4) weight segment assemblies that are each attached to the center disc using two (2) retaining pins that have a “rocking” motion in pockets within the center disc and weight segment. The pins are held captive in the pockets by a retainer plate which is bolted to the weight segment. The segments are made up of quarter-circular weights held between inner and outer side plates that are bolted and doweled together as an assembly.

All of the weight segment assemblies are identical; however, the retaining pins used with one segment are of a smaller diameter to “tune” the damper for the specific harmonic frequencies experienced with the 12N engine.



ITEM	DESCRIPTION	QTY
1	WEIGHT SEGMENT ASSEMBLY	4
2	RETAINER PLATE	4
3	RETAINING PIN, SMALL	2
4	1/2"-20 HEX. HD. BOLTS	24
5	RETAINING PIN, LARGE	6
6	CENTER DISC (HUB)	1

Figure 6-6. Pendulum Type Torsional Damper

Oil flows from a groove in the hub of the center disc to each retaining pin pocket. The clearance between the diameter of the pins and the pin pockets allows the weight segment to “swing” (rock) in the pocket. Purge holes are provided in the retainer plates to relieve oil from the pin pockets which allows the weight segments to return to a central position when they become displaced.

6.6.2 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 the interval specified in the applicable Scheduled Maintenance Program. This check can be performed by removing the front handhole covers and barring the engine over as necessary in order to push *inward* and/or *upward* on each weight segment. If any of the weight segments bind or cannot be moved, damper should be removed and disassembled.

6.6.3 HARMONIC BALANCER MAINTENANCE

The harmonic balancer should be inspected at intervals specified in the Scheduled Maintenance Program. The balancer should be removed from the crankshaft, disassembled, spring leaves or packs replaced, and push pins rotated to present a new contact surface to the springs.

6.7 ACCESSORY DRIVE GEAR TRAIN

6.7.1 DESCRIPTION

The accessory drive gear train is located at the front of the engine and provides power from the crankshaft to drive the oil pump(s), water pumps, and a governor (if used). Figure 6-7 shows a typical accessory drive gear train used with 8, 12, and 16-cylinder engines. This gear train consists of an accessory drive gear, a scavenging oil pump gear, a main lube oil pump gear, right and left hand water pump gears, and a governor drive gear (if used).

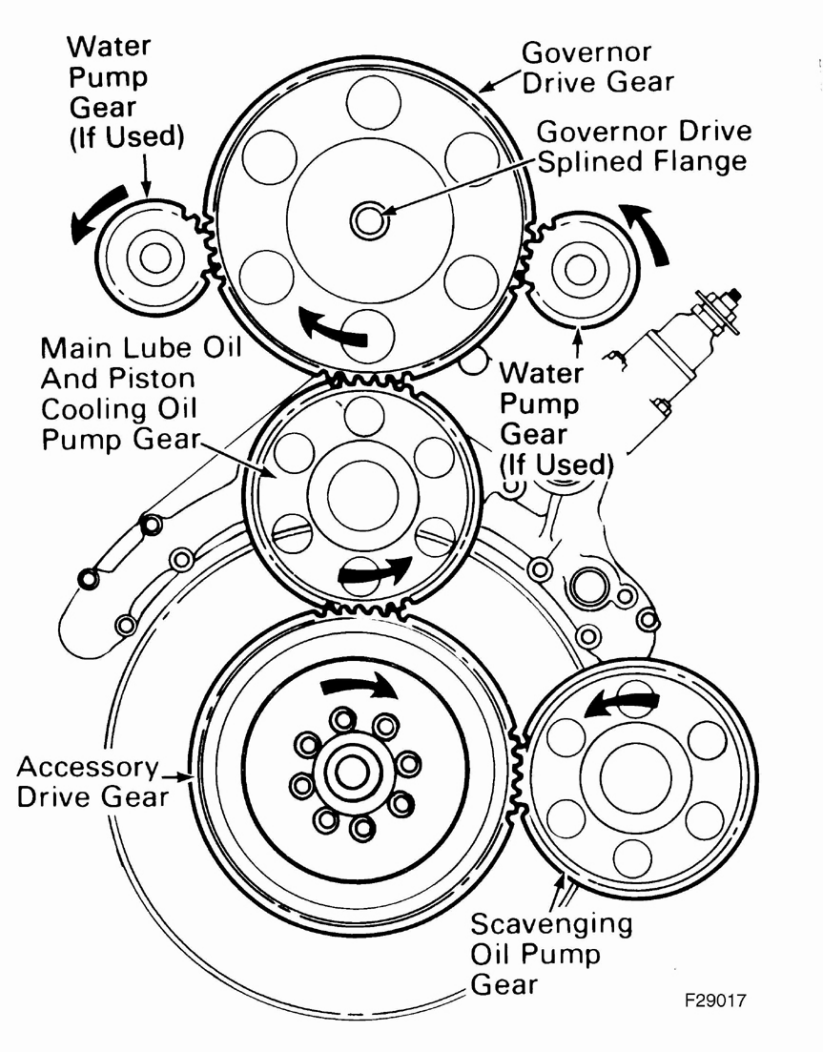


Figure 6-7. Typical Accessory Drive Gear Train (8, 12, and 16-Cylinder)

Figure 6-7 shows the accessory drive gear train used with 20-cylinder engines. This gear train consists of the accessory drive gear, a lube oil pump gear, and the right and left hand water pump drive gears.

The accessory drive gear, governor drive gear (if used) and the accessory drive housing are aligned and mounted directly on the engine. The oil pump(s), water pumps, and governor drive housing (if used) are mounted on the accessory drive housing.

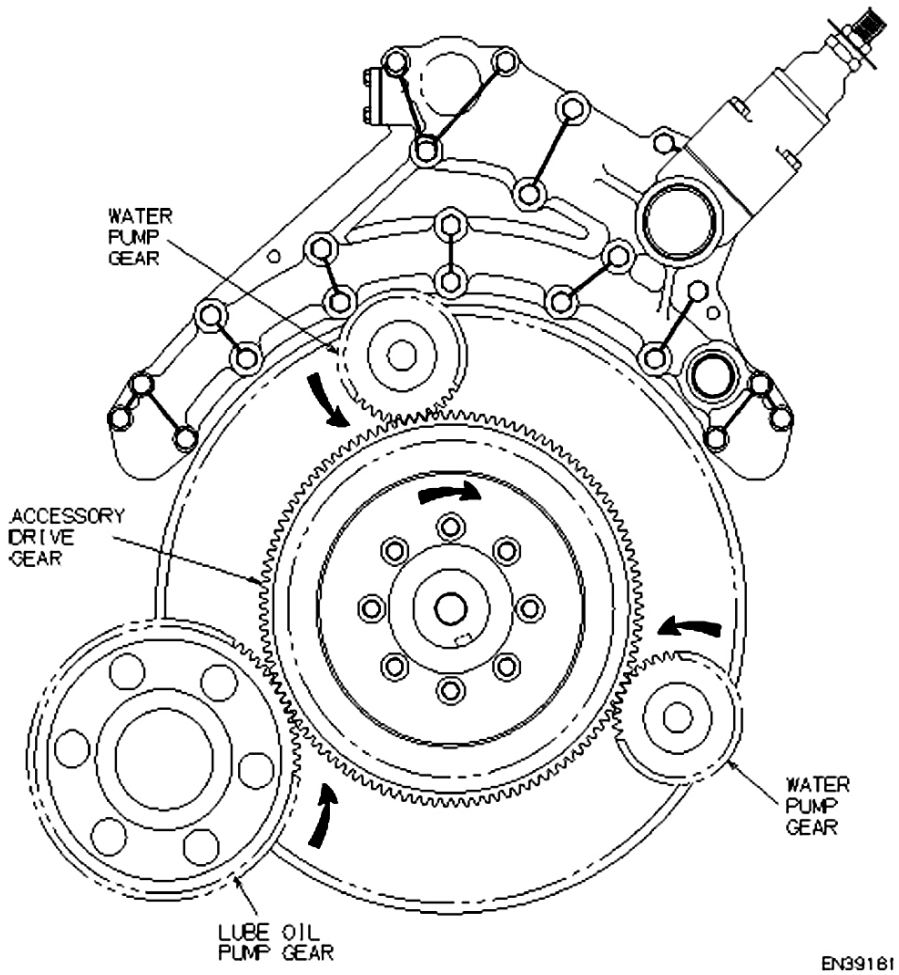


Figure 6-8. Typical Accessory Drive Gear Train (20-Cylinder)

6.7.2 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 pump(s), and governor drive assembly (when used) can be removed from the gear train as individual units. Removal of the accessory drive gear or the governor drive gear (if used) requires removal and realignment of the accessory drive housing.

6.8 ACCESSORY DRIVE GEAR

6.8.1 DESCRIPTION

The coil spring accessory drive gear train, Figure 6-9, 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 main lube oil and piston cooling oil pump and a lube oil scavenging pump (if used).

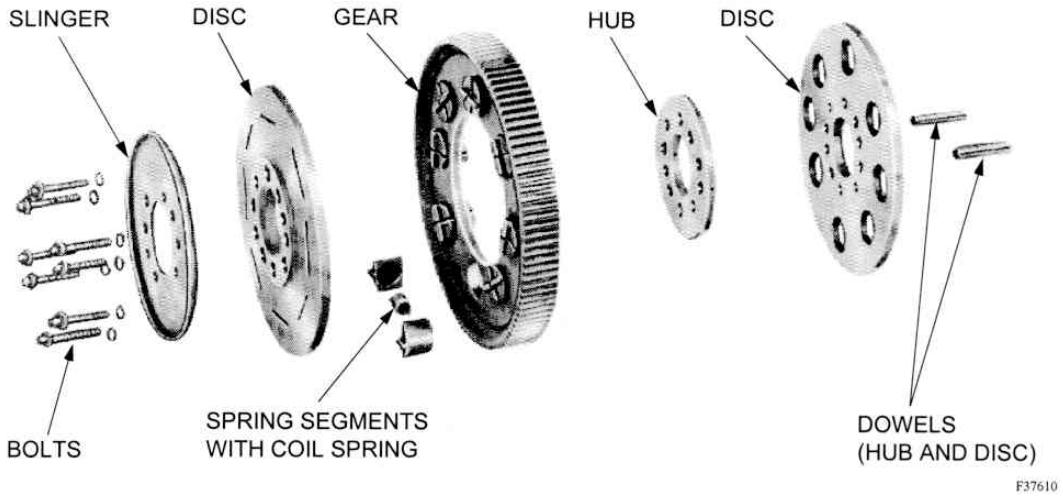


Figure 6-9. Accessory Drive Gear, Exploded View

6.8.2 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.

6.9 GOVERNOR DRIVE GEAR AND STUBSHAFT

6.9.1 DESCRIPTION

The governor drive gear, used on 8, 12, and 16-cylinder governor controlled engines, is mounted on the governor drive stubshaft, Figure 6-10, 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 (if used).

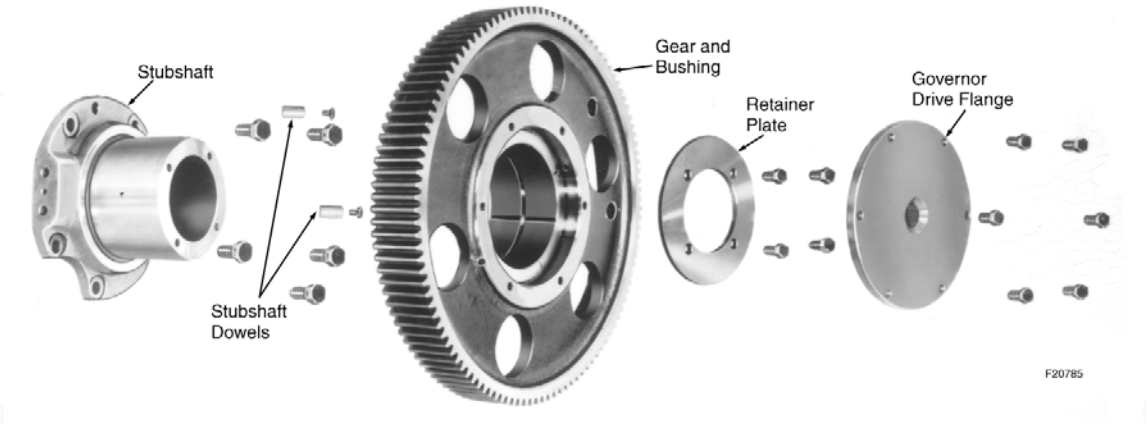


Figure 6-10. Governor Drive Gear And Stubshaft

6.9.2 MAINTENANCE

The governor drive gear and stubshaft require no maintenance other than inspection at the time of normal overhaul.

Inspect gear teeth for fatigue indications, cracks, pits or other evidence of failure. This can be done at time of water pump change out. If possible, a magnaflux inspection should be performed. Inspect the gear bushings and stubshaft for gouges or other damage and ensure that stubshaft oil passage is not plugged.

6.10 ACCESSORY DRIVE COUPLING

6.10.1 DESCRIPTION

The accessory drive coupling assembly, Figure 6-11, 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.

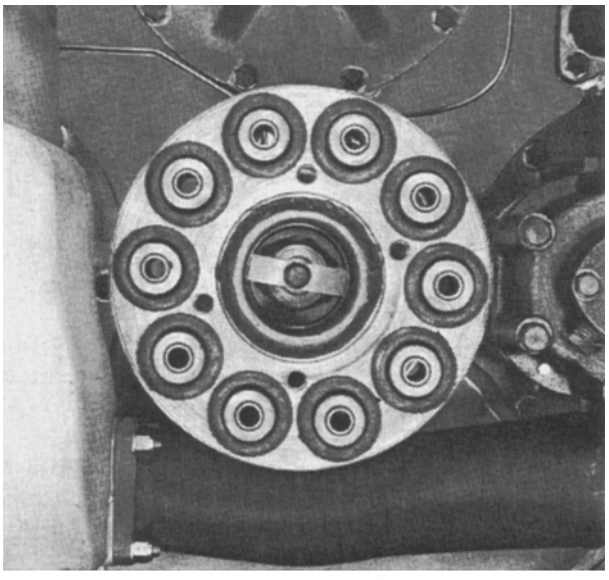


Figure 6-11. Accessory Drive Coupling

6.10.2 MAINTENANCE

The accessory drive coupling does not require any routine maintenance. However, the bonded rubber bushings should be replaced at the interval specified in the Scheduled Maintenance Program or sooner as evidenced by accumulations of small rubber particles directly under the coupling.

6.10.2.1 COUPLING APPLICATION

1. 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. Prior to mounting the coupling on the crankshaft, 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. Slide felt oil seal and oil seal retainer over barrel end of coupling flange, then fit coupling onto the shaft. Make certain 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 No. 2303. Torque the retaining bolt to 136 Nm (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 881 Nm (650 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 specified value.
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.
9. Carefully insert oil seal into groove of seal cover and apply seal retainer with 3/8"-16 hex head bolts torqued to specified value.

6.11 RING GEAR AND COUPLING DISC (FLYWHEEL)

6.11.1 DESCRIPTION

The ring gear, Figure 6-13, 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.

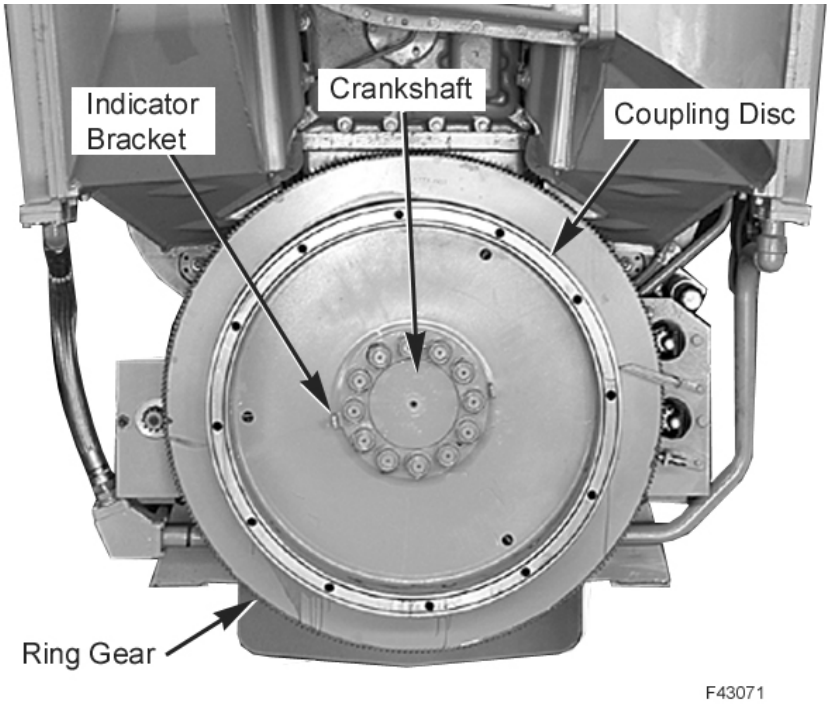


Figure 6-12. Typical Ring Gear And Coupling Disc Installation

6.11.2 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 requalified whenever the engine or the generator assembly is removed. Maximum trouble free performance of the engine-generator coupling can best be ensured by careful magnetic particle inspection of both discs prior to their reuse. This inspection is particularly important if it is known that the coupling has been subjected to unusual stress.

1. Inspect all teeth on ring gear for the following defects:

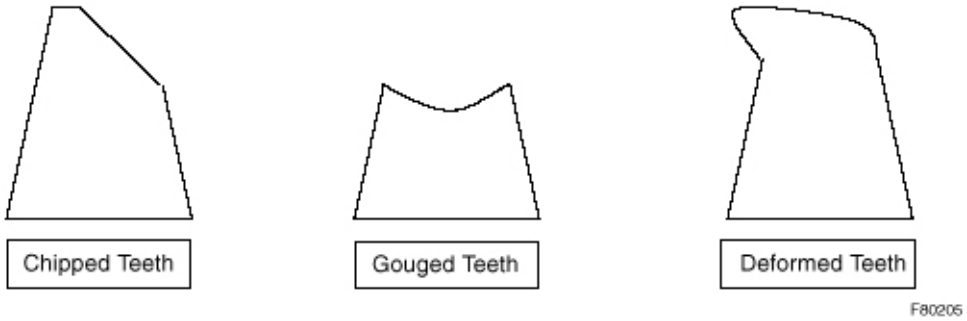


Figure 6-13. Ring Gear Teeth Defects

2. If any of the above conditions exist on the ring gear, it should be replaced immediately.

On Auto Engine Start Stop locomotives it has been determined that the electric starters may not survive until the recommended 3 year motor change out interval without periodic lubrication. This is a result of the greatly increased number of cycles on the starters. Recent teardowns indicate that the only component affected is the bronze bushing supporting the shaft in the end housing.

Failure to complete this maintenance can result in the pinion to ring gear mesh becoming mis-aligned and has resulted in cases of ring gear failure. There is a 3 piece ring gear available to allow replacement without splitting engine generator coupling.

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 “0” marks on the coupling disc and the crankshaft coinciding. This will position the coupling with the point 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 install indicator brackets with the first having the tapped hole lined up with the engine barring hole nearest the TDC mark and the second bracket 180° apart from the first. Tighten coupling bolts to specified value. Tighten the rim bolts uniformly (to avoid cocking the coupling on the serrations) to specified value. 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.

6.12 MAGNETIC SPEED PICKUP

Units equipped with an engine purge system utilize a magnetic pickup mounted on the starting motor bracket at the engine flywheel, Figure 6-14, by means of an “L” shaped bracket.

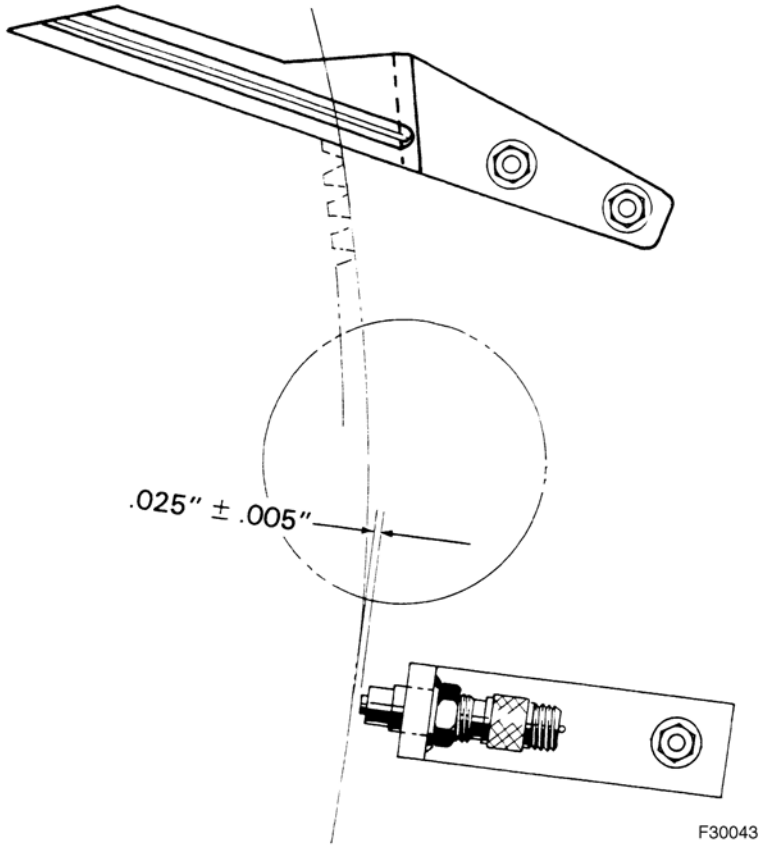


Figure 6-14. Mounting Of Magnetic Speed Pickup

Ring gear teeth passing by the pickup produce magnetic pulses which are used to generate an electrical signal voltage proportional to engine speed. The signal voltage is processed by the unit’s computer which in turn limits cranking speed to approximately 30 RPM during the first engine crankshaft revolution to protect against damage due to hydraulic lock.

If a magnetic pickup is removed to facilitate engine service or rebuild, clearance between flywheel ring gear teeth and pickup must be checked during replacement to ensure a gap of 0.025" ±0.005", as shown.

6.13 EMDEC TIMING TARGETS AND SENSORS

6.13.1 DESCRIPTION

Engines equipped with the EMDEC control system utilize a pair of magnetic pickups to provide engine timing reference signals to the master Electronic Control Module (ECM). These sensors, designated the Timing Reference Sensor (TRS) and the Synchronous Reference Sensor (SRS), are both mounted on a bracket assembly located on the camshaft gear train housing at the lower left-rear side of the engine.

Timing reference plates (targets) are mounted on the engine side (inside) of the coupling disc, Figure 6-15. Combinations of either three or six plates are used to construct a circular pattern of 36 equally spaced metal spokes (10 degrees apart, 360 degrees total), and one position indicator tab (at the 180° mark on coupling disc). As the plates pass by the sensors, the spokes are detected by the TRS to provide an advanced crank position signal for every cylinder in the firing order. The position indicator tab is detected by the SRS to provide a signal for each revolution of the crankshaft when the number one cylinder is 4° before top dead center.

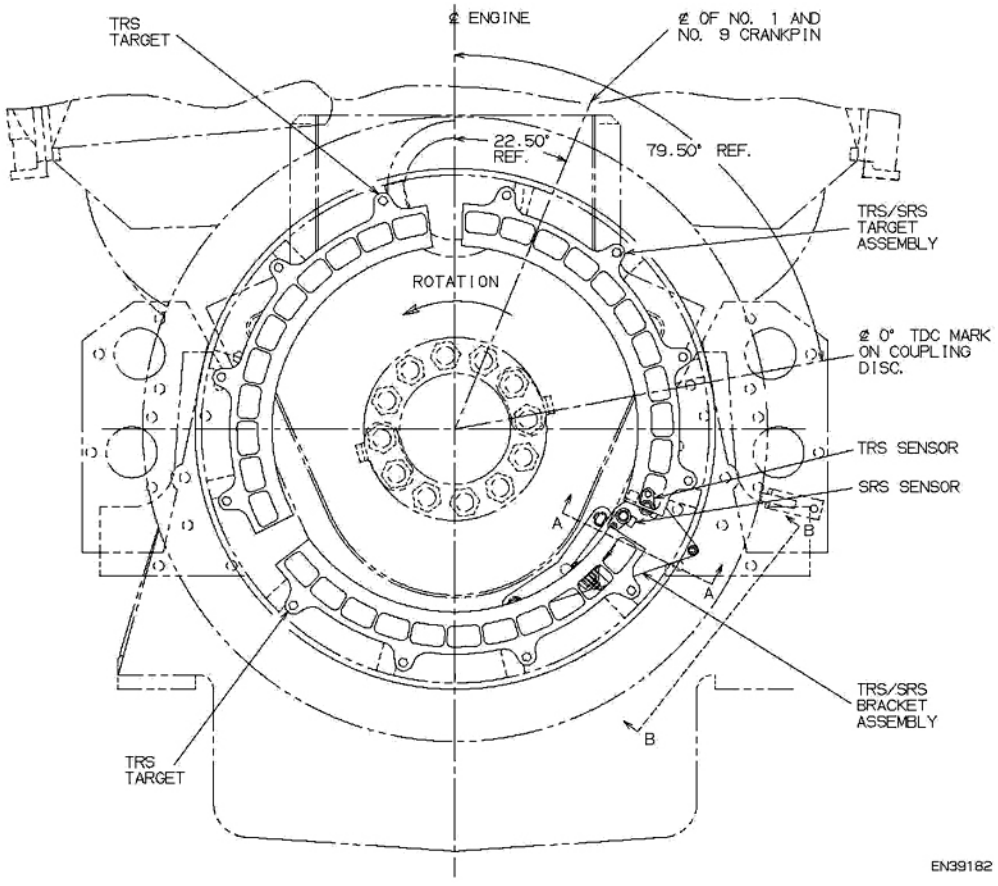


Figure 6-15. Typical Timing Reference Plate Arrangement On Coupling Disc (20-Cylinder Shown)

If either or both of the sensors are removed to facilitate engine service or to be replaced, clearance between the timing plate spokes (or indicator tab) and sensor tips must be checked to ensure an air gap of 3.81 mm (.150”) for each, as shown in Figure 6-16.

If any or all of the timing plates are removed from the flywheel during engine service, they should be handled with extra care to avoid <u>any</u> physical damage. It is also recommended that they be marked for position reference and replaced in the exact locations from which they were removed.

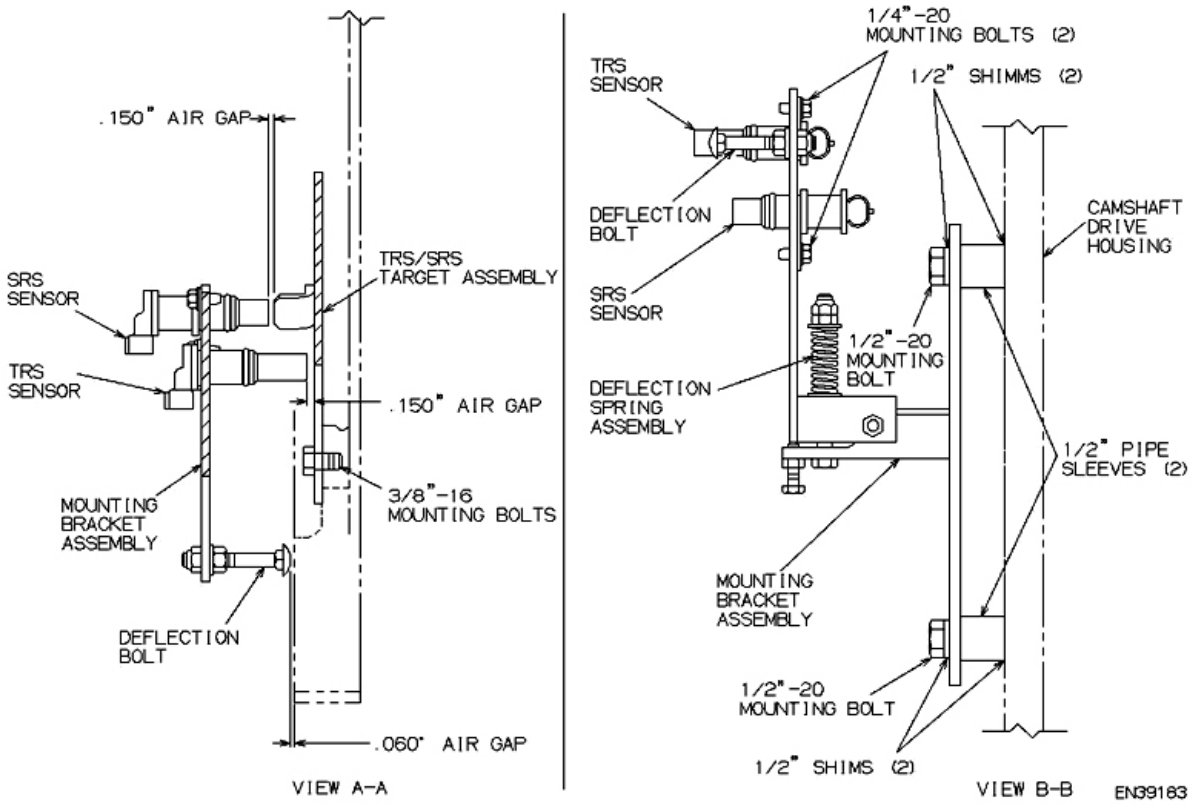


Figure 6-16. Mounting Of Timing Reference Sensors TRS and SRS (View A-A and B-B)

6.13.2 MAINTENANCE

Refer to Troubleshooting Section 15 for detailed information to check EMDEC system operation (including TRS and SRS sensors, wiring harness, and ECM modules) using “flash code” method or PC computer with special diagnostics program.

6.13.2.1 CHECKING/ SETTING SENSOR AIR GAP

1. Measure the air gap from the closest timing spoke to the TRS (outermost) sensor. It must be no greater than 3.81 mm (.150”).

> **NOTE**
> The air gap can also be measured from the SRS (innermost) sensor to the SRS tab on the target. It should also be no greater than 3.81 mm (.150”). If necessary, open the cylinder test valves and bar over the engine until a timing spoke is positioned in front of the TRS sensor.

2. If the air gap exceeds 3.81 mm (.150”), reset the gap using the adjusting screw located at the top of the bracket. Once the correct gap is achieved, tighten the locknut on the adjusting screw securely against the underside of the bracket. Adjusting the TRS sensor will also properly set the gap of the SRS sensor.
3. Adjust the deflection (bumper) bolt so that it has a 1.52 mm (.060”) air gap to the ring gear. Exercise the sensor bracket and verify that it returns to position and maintains the correct air gaps. If it does not, examine the bracket spring to make sure it is compressed to 1 1/2”. If the spring is properly compressed and the bracket does not return to position, replace the bracket.

6.13.2.2 REPLACING THE TRS/ SRS BRACKET

1. Remove flywheel cover (if applied). On 20-cylinder engines, remove the starting motors at the right side of the engine to allow access to the sensor bracket.
2. Open the cylinder test valves and bar the engine over until the flywheel pointer is at the 0° mark on the rim.
3. Disconnect the terminal connectors from the TRS and SRS sensors. Remove the two (2) 1/2”- 20 bolts that secure the sensor mounting bracket to the rear camshaft drive housing of the engine. Remove the mounting bracket from the engine. Remove each of the sensor mounting screws and both sensors from the bracket. Examine each for signs of damage and replace if necessary.
4. Reapply the sensors to the new mounting bracket using the self-tapping screws from the previous assembly. (The TRS is the outer-most sensor).
5. Position each of the pipe sleeve spacers included with the new sensor bracket so that the smaller diameter neck fits into the bracket slot. Mount the sensor bracket to the camshaft drive housing making sure the spacers remain between the housing and the bracket, then tighten the bolts finger tight.
6. With the flywheel pointer set at the 0° mark on the rim, adjust the sensor position until the tip of the TRS sensor is centered on the target spoke.
   Using a calibrated torque wrench, tighten the bracket mounting bolts to 88 Nm (65 ft lbs).

NOTE

Positioning the TRS sensor tip directly over the target spoke will ensure correct fuel injection timing upon engine start-up. The two slotted holes in the bracket allow adjustment of the TRS sensor for proper alignment with the center of the target spoke.

7. Set the air gaps between the sensors and target plates to 3.81 mm (.150”), and between the deflection (bumper) bolt and ring gear to 1.52 mm (.060”), as described in 6.13.2.1, “CHECKING/ SETTING SENSOR AIR GAP” on page 6-23.
8. Connect each of the harness terminals to the appropriate sensor. (Sensors have “keyed” connectors and cannot be reversed).
9. Replace flywheel cover and starting motors (if removed).
10. Bar the engine over slowly and check for obstructions. Close cylinder test valves. Upon next engine start, check for any EMDEC diagnostic faults resulting from the bracket change.

6.13.3 SETTING SRS AND TRS SENSORS

An improved feature on the 16-710G3C-T2 engine is the mounting and accessibility of the SRS and TRS sensors, Figure 6-17.



Figure 6-17. SRS and TRS Sensors

These sensors provide basic position and speed information to the EMDEC ECMs and as such are critical to engine performance. The adjustment of these sensors must be periodically checked, ensuring that alignment and air gap is correctly set. The adjust the sensors, use the following procedures:

1. Slightly loosen the sensor bracket mounting bolts as shown in Figure 6-18.



Figure 6-18. Sensor Bracket Mounting Bolts

Adjust the bracket so that the TRS air gap to the surface of the coupling disk is 0.050" ± 0.010" as shown in Figure 6-19. Note that the TRS sensor will be centered over the barring hole when Cylinder #1 is at top dead center as shown in Figure 6-21. The air gap gauge (40094650) should touch the metal surface of the coupling disk.

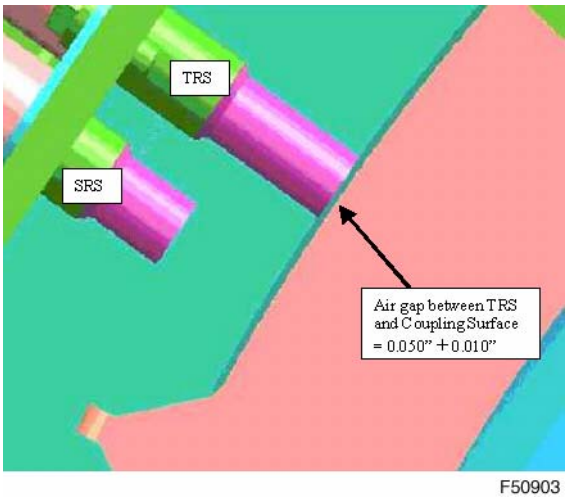


Figure 6-19. Setting TRS Air Gap

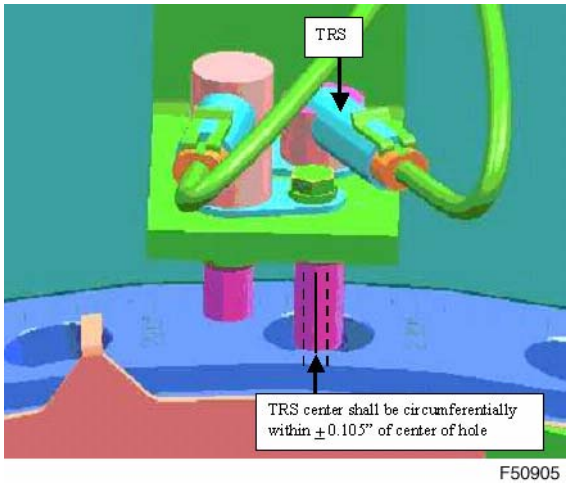


Figure 6-20. Sensor Locations

2. Tighten the 1/2"-20 bracket mounting bolts and torque to 65 ft-lbs (88 Nm).

3. Rotate the crankshaft until the SRS sensor is aligned with the SRS target, as shown in Figure 6-21, and verify that the air gap is 0.050" /+0.020" /-0.010". If the gap is incorrect, repeat the setting procedure.

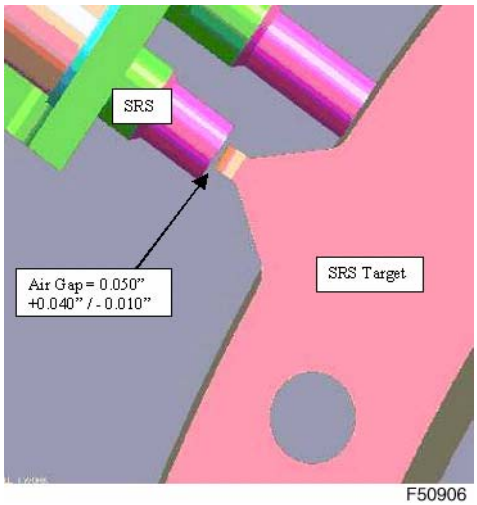


Figure 6-21. Checking SRS Air Gap

6.14 SERVICE DATA - CRANKSHAFT ASSEMBLY AND ACCESSORY DRIVE GEAR TRAIN

6.14.1 REFERENCES

Alignment Of Locomotive Rotating Equipment.....M.I.1753
Inspection & Qualification Guide -
Engine Main & Connecting Rod Bearings MM003003

6.14.2 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Crankshaft
Diameter, main journal -

Min..... 215.81 mm (8.4965")

Diameter, crankpin journal -

Min.....165.011 mm (6.4965")

Clearance (diametric main bearings to crankshaft) -

Min..... 0.190 mm (.0075")
Max. ..... 0.521 mm (.0205")

Thrust Bearing Clearance -

Min.....0.25 mm (.010")
Max. .....0.53 mm (.021")

Accessory End Gear Train Backlash (all drive gears) -

Min.....0.20 mm (.008")
Max. .....0.64 mm (.025")

Clearance between coupling discs at rim bolts,
after bolts are torqued -

Min..... 0.038 mm (.0015")

Coupling face runout -

Max. ..... 0.38 mm (.015") T.I.R.

Coupling rim eccentricity -

Max. ..... 0.13 mm (.005") T.I.R.

Magnetic pickup-to-ring gear gap .....0.51-0.76 mm (.020"-.030")

Accessory Drive Coupling -

Coupling advance- coupling-to-crankshaft

8323075 - Fabricated coupling ..... 0.51-1.52 mm (.020"-.060")
9517916 - Cast coupling..... 1.02-2.79 mm (.040"-.110")

Coupling rim runout -

Max. ..... 0.25 mm (.010") T.I.R.

6.14.3 EQUIPMENT LIST

	PART NO.
Upper main bearing shell remover	8055837
Gasket sealing compound - 0.47 liter (1 pt.)	8178639
Thread lubricant, Texaco Threadtex No. 2303 - approx. 18.93 liter (5 gal.)	8307731
Upper main bearing removal tool	40004154
Serration gauge	40038306
Gasket sealant, RTV	
- 300 ml container	40048258
- 85 gram container	40048259

SECTION 7. CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, AND CAMSHAFT ASSEMBLIES

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7.1 DESCRIPTION - TURBOCHARGED ENGINES

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. Figure 7-1 shows the gear train before the camshaft drive housing and turbocharger are installed, and Figure 7-2. on page 7-4 shows a cross-section of the gear train.

The gear train, Figure 7-1, consists of a crankshaft gear mounted on the crankshaft, No. 1 idler gear, a clutch (or spring) drive gear assembly, and the left and right camshaft drive gears. The clutch (or spring) drive gear assembly is made up of the No. 2 idler gear, a clutch (or spring) assembly, and the turbocharger drive gear.

7.2 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 clutch (or spring) drive gear assembly, each gear in the gear train can be removed independently.

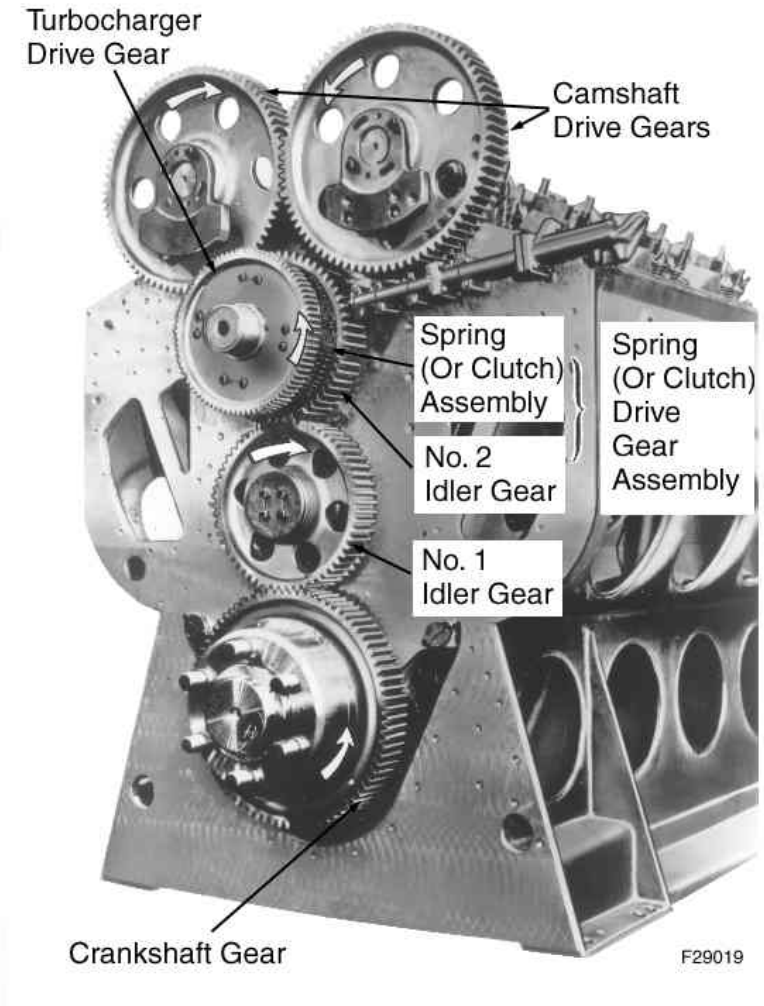


Figure 7-1. Camshaft Gear Train

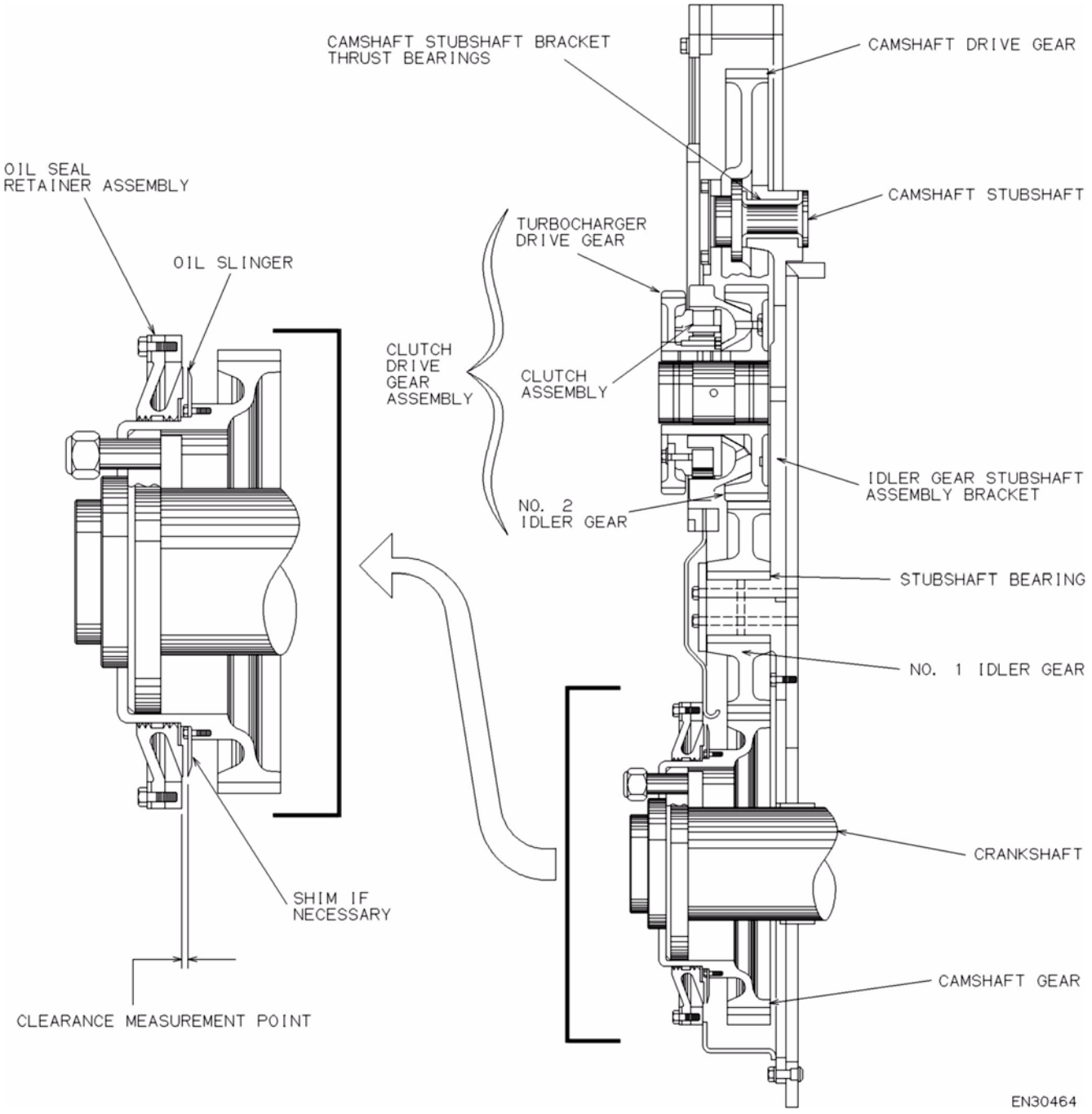


Figure 7-2. Camshaft Gear Train, Cross-Section

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 fuel injection durations. Backlash clearance limits are given in the Service Data 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.

7.2.1 CLUTCH DRIVE GEAR ASSEMBLY

7.2.1.1 (12, 16 AND 20-CYL. ENGINES)

The clutch drive gear assembly, Figure 7-3, consists of the No. 2 idler gear, the turbocharger drive gear, and an overrunning clutch assembly mounted between the two gears to provide a mechanical connection of the turbocharger to the engine gear train during engine start up, light load operation, and rapid acceleration. The clutch drive gear assembly should be removed as an assembly and replaced with a new or qualified unit.



Figure 7-3. Clutch Drive Gear Assembly

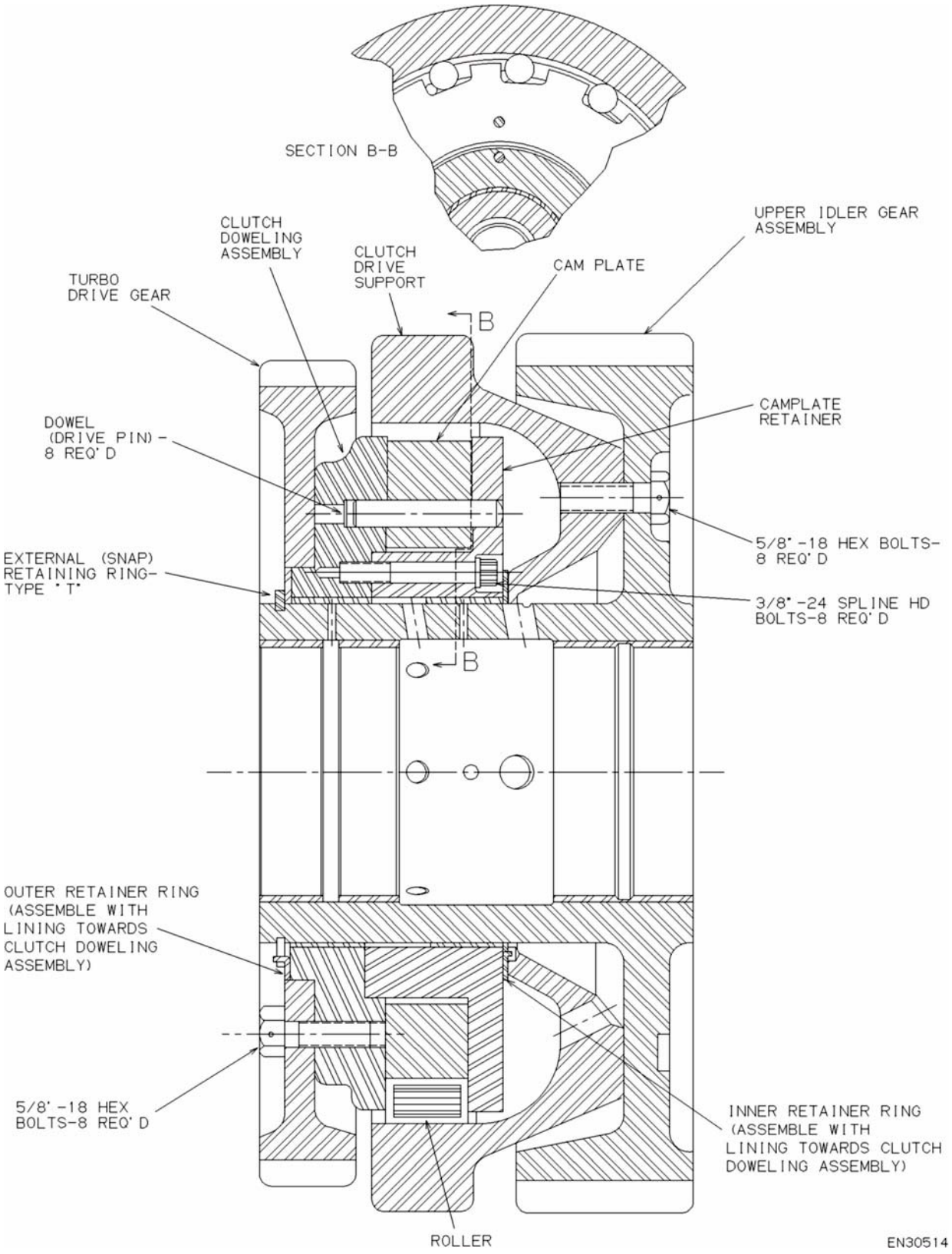


Figure 7-4. Clutch Drive Gear Assembly (Cross-Section)

7.2.1.2 INSTALLATION

1. Place the clutch drive gear assembly on the idler gear stubshaft being sure the tooth position marks are aligned as shown in Figure 7-17. on page 7-23.
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.

7.2.2 SPRING DRIVE GEAR ASSEMBLY

The spring drive gear assembly, Figure 7-5, 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.

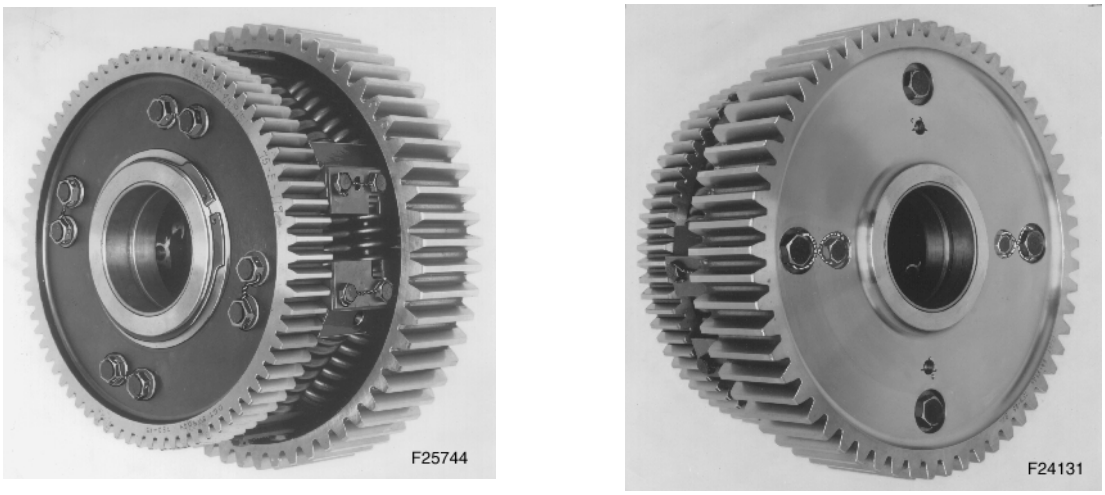


Figure 7-5. Spring Drive Gear Assembly

7.2.2.1 INSTALLATION

1. Place the spring drive gear assembly on the idler gear stubshaft being sure the tooth position marks are aligned as shown in Figure 7-17. on page 7-23.
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.

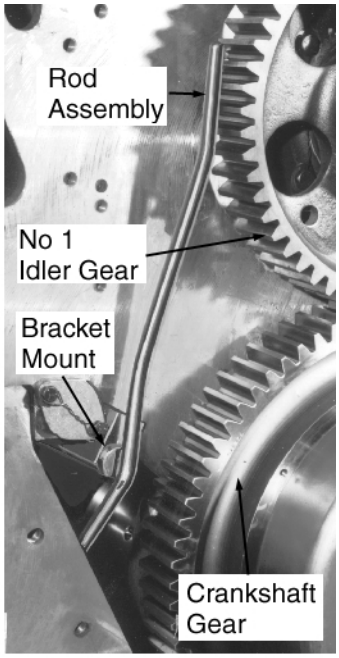
7.2.3 NO. 1 IDLER GEAR

7.2.3.1 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 clearance checking 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 end plate, and the top of the rod contacts the side of the No. 1 idler gear, Figure 7-6. Hand tighten the bracket bolt.

NOTE
Photo at right was taken without the camshaft drive housing to illustrate the rod assembly-to-idler gear application.



F17842

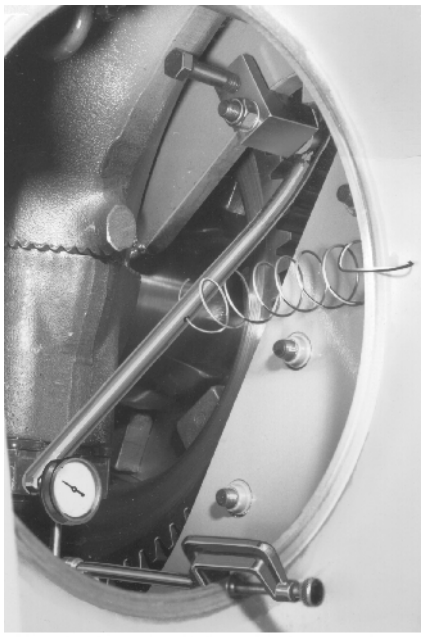

F17843

Figure 7-6. Application Of Parts For Checking Bearing Clearance

3. Apply the light tension spring between the lower part of the rod and the edge of the handhole opening, Figure 7-6, to maintain idler gear to rod contact.
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, Figure 7-6.
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.

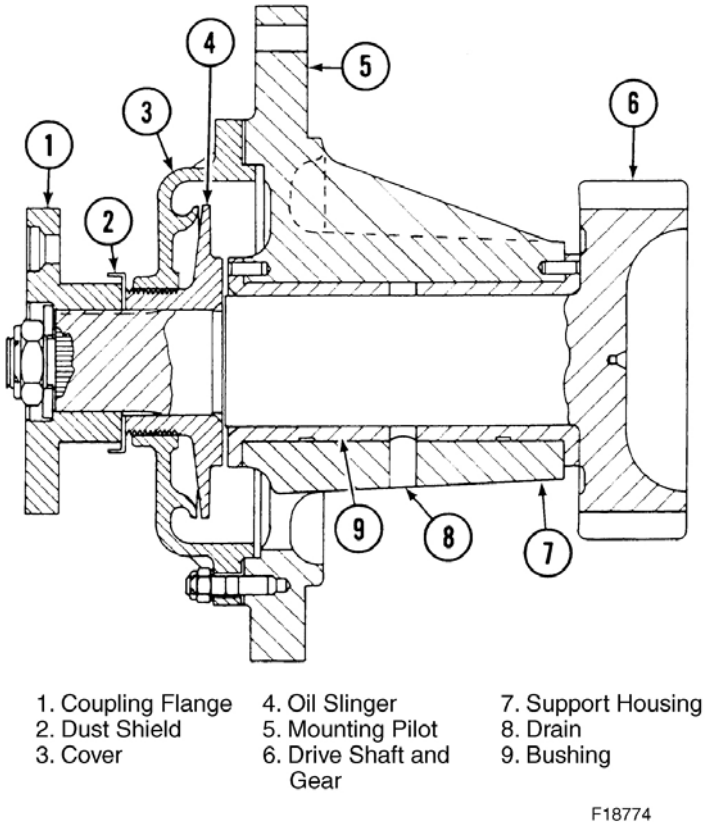
NOTE

It may be necessary to lock the left bank camshaft in order to provide 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 the Service Data.

7.2.4 AUXILIARY DRIVE ASSEMBLY

7.2.4.1 DESCRIPTION

The auxiliary drive assembly, Figure 7-7. on page 7-9, 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

Figure 7-7. Auxiliary Drive Assembly

7.2.4.2 MAINTENANCE

When new bearings are installed, they are pressed into the support housing and line reamed or bored to the dimension specified in the 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, Figure 7-8. on page 7-10. 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.

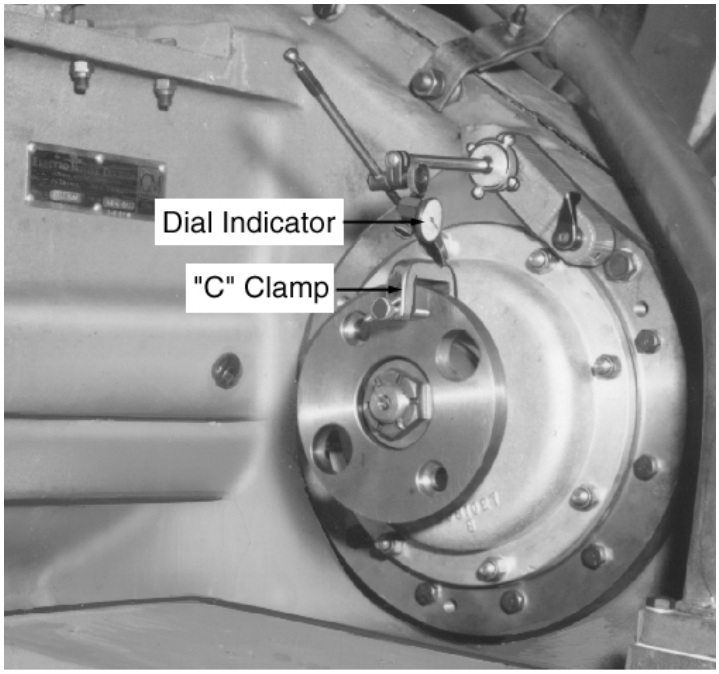


Figure 7-8. Checking Auxiliary Drive Gear Backlash

Refer to the Service Data for backlash limits. Backlash is adjusted by loosening the turbocharger mounting bolts and re-positioning 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.

7.2.5 CAMSHAFT ASSEMBLIES

7.2.5.1 DESCRIPTION

The camshaft assembly, Figure 7-9. on page 7-11, 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 Figure 7-9 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 position, equipped with steel-backed lead base babbitt lined inserts, support the camshaft.

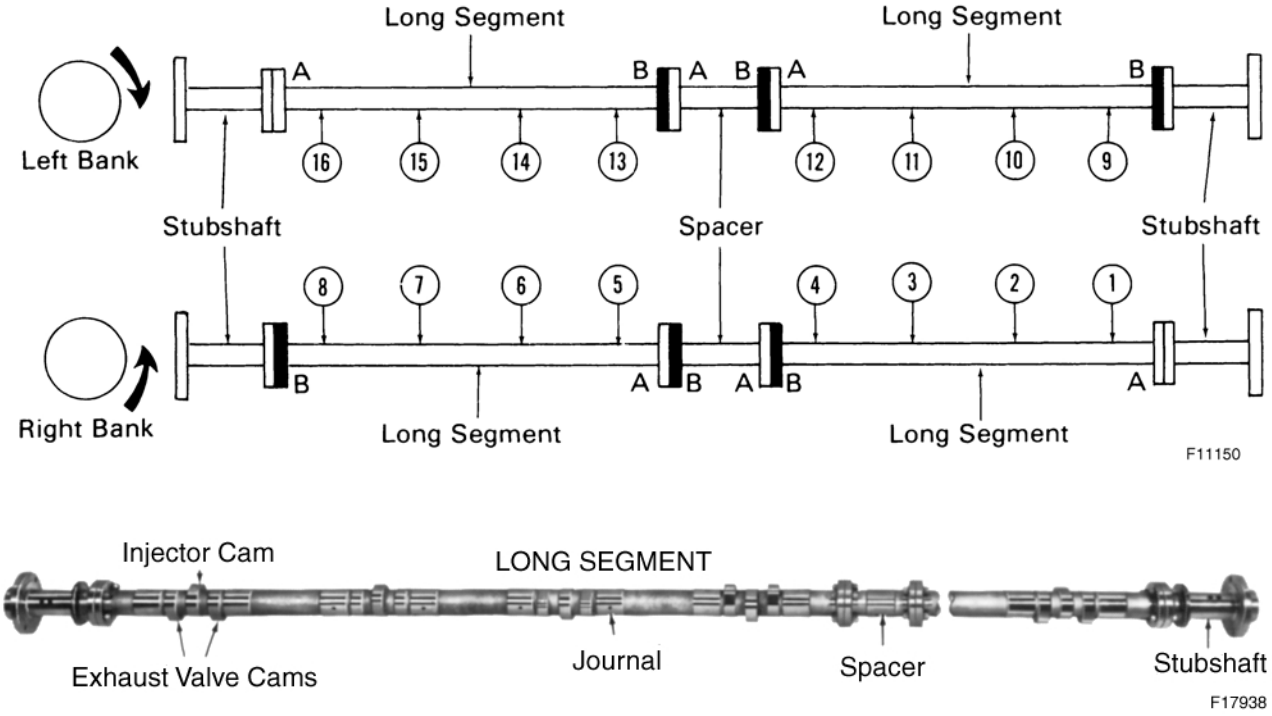


Figure 7-9. Typical Camshaft Assemblies (16-Cyl.)

7.2.5.2 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.

> **NOTE**
> Camshaft segment bearing blocks and caps are assembled new in mated pairs. This pairing must be maintained.

If the camshaft is removed for reasons other than bearing replacement, an attempt should be made to retain relative positions 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 camshafts 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.

Check segment journal to bearing diametric clearances of all camshaft and stubshaft bearings against limits listed in the Service Data.

7.2.5.3 ASSEMBLY

The camshaft must be assembled as shown in Figure 7-9. on page 7-11. 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.); 1, 7, 10, and 16 (16-cyl.); and 1, 9, 12 and 20 (20-cyl.) camshaft bearing journals. See the Service Data for limits.

7.2.5.4 INSTALLATION

Camshaft assemblies installed on an engine must conform to segment sequence and position as indicated in Figure 7-9., “Typical Camshaft Assemblies (16-Cyl.)” on page 7-11. 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.

NOTE

Stubshafts connected to segment flanges with “A” markings are a different configuration than those connected to segment flanges with “B” markings.

1. If cam bearing blocks have been removed from the engine, check bearing block pads and keyways for foreign material, nicks, and burrs. Use a fine file to smooth nicks and remove burrs, then wipe area clean. Install all bearing blocks, putting oiler blocks to the right hand side of each cylinder.
2. Wipe inside of camshaft bearings with a clean rag to remove any foreign material, then remove caps from bearing blocks and stubshaft brackets. Mark or otherwise arrange in order to maintain correct block to cap pairings.
3. Wipe bottom bearing shells clean once again and apply a liberal amount of engine oil to all lower bearings, including stubshaft bearings.
4. Install camshaft assembly on the engine in the proper orientation as previously described and shown in Figure 7-9. on page 7-11.
5. Apply a small amount of oil to each camshaft bearing journal, then rotate camshaft by hand to see if it turns freely and to distribute the oil evenly around the journals.
6. Apply all bearing caps to bearing blocks and stubshaft brackets. Snug down bolts on stubshaft bracket caps only to an initial torque not to exceed 13 Nm (10 ft-lbs).
7. Align bearing blocks to approximate center of bearing journals (if necessary) by tapping lightly with a copper or brass hammer.
8. Snug down all bolts on intermediate bearing block caps to an initial torque not to exceed 13 Nm (10 ft-lbs).
9. Final tighten all cap bolts to specified values.
10. Rotate camshaft by hand or by using a box wrench on a camshaft spacer nut to see if it turns freely. If camshaft binds, loosen bolts at one bearing block. If shaft still will not turn freely, continue loosening cap bolts one block at a time to determine which bearing is binding.

    lmpact that bearing block cap with a copper or brass hammer to seat the bearing shell. Re-tighten and torque all cap bolts and check camshaft again for free rotation.

NOTE

On occasion, it may be necessary to locate and impact more than one bearing and/ or change out a bearing block and cap or stubshaft bracket in order to allow free camshaft rotation.

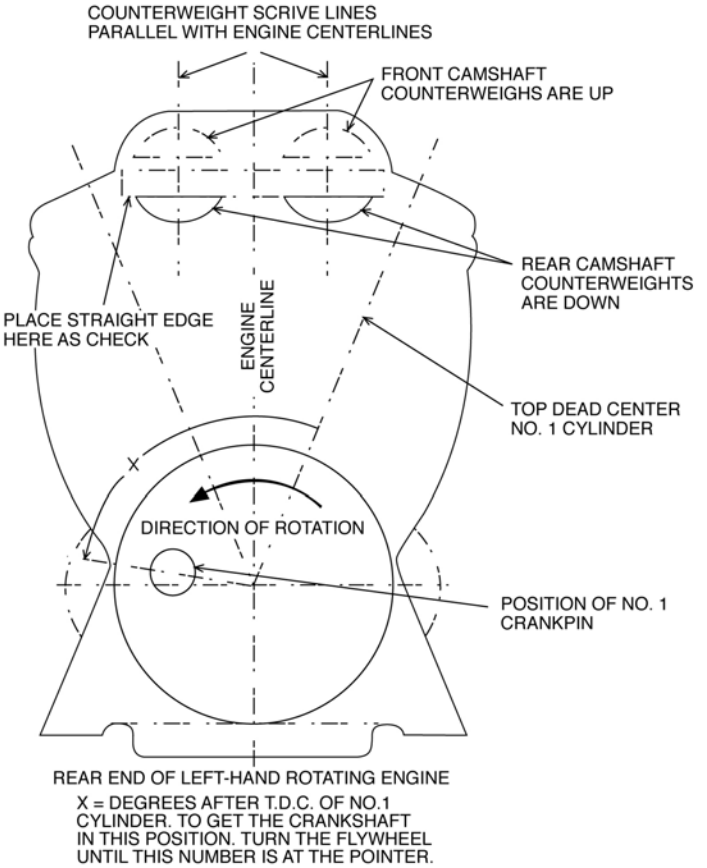
11. Check camshaft axial (thrust) clearance at rear stubshaft against limits listed in the Service Data.
12. If clearances are correct and no binding exists, apply flange dowel bolts and reassemble rocker arms and associated parts. Check valve timing of at least one cylinder to ensure that camshaft segment orientation is correct, then complete exhaust valve setting and injector timing adjustments.

7.2.5.5 CAMSHAFT COUNTERWEIGHT APPLICATION

Counterweight replacement usually is not necessary. However, when counterweights are installed, they should be applied in the position as shown in Figure 7-10. on page 7-14.

NOTE

If any additional information is needed to apply camshaft counterweights, contact the EMD Service Department.



8-CYL. ENG.	12-CYL. ENG.	12N-CYL. ENG.	16-CYL. ENG.	20-CYL. ENG.
X = 184°	X = 249-1/2°	X = 232-1/2°	X = 105°	X = 149-1/2°

ES37613

Figure 7-10. Camshaft Counterweight Timing

7.2.6 EXHAUST VALVE TIMING

7.2.6.1 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 7-1.

Items which govern correct valve timing are given in the following procedures.

Table 7-1. Firing Order and Top Dead Center

	8-Cylinder		12-Cylinder
Firing Order	**Top Dead Center**	**Firing Order**	**Top Dead Center**
1	0°	1	0°
5	45°	12	19°
3	90°	7	45°
7	135°	4	94°
4	180°	3	120°
8	225°	10	139°
2	270°	9	165°
6	315°	5	214°
-	-	2	240°
-	-	11	259°
-	-	8	285°
-	-	6	334°
12N-Cylinder			
Firing Order	**Top Dead Center**		
1	0°		
7	45°		
4	60°		
10	105°		
2	120°		
8	165°		
6	180°		
12	225°		
3	240°		
9	285°		
5	300°		
11	345°		

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	157-1/2°	15	117°
4	180°	2	144°
5	202-1/2°	17	153°
12	225°	10	180°
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°
-	-	4	288°
-	-	16	297°
-	-	9	324°
-	-	14	333°

7.2.7 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 the 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 12.7 [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, Figure 7-11. on page 7-17.

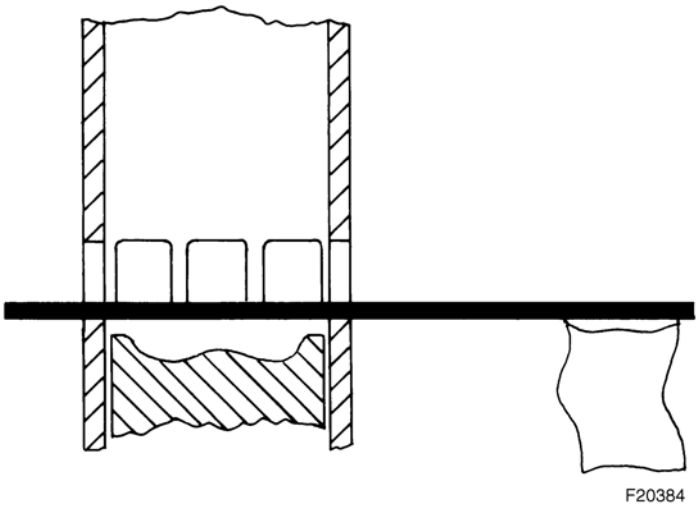


Figure 7-11. "Stop-Bar" Inserted Through Cylinder Ports

NOTE

A bar of sufficient length to prevent re-application 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, Figure 7-12.

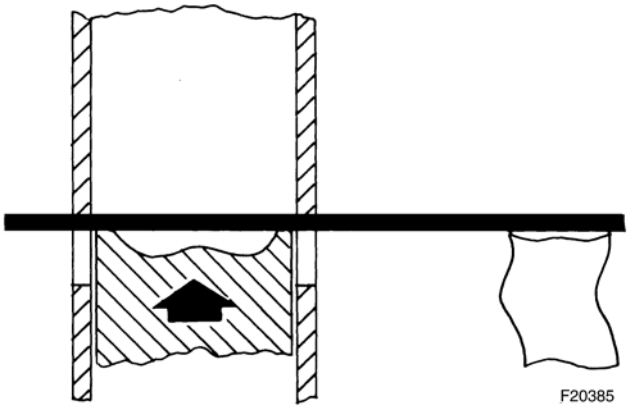


Figure 7-12. Piston Travel Limited By "Stop-Bar"

CAUTION

Use extreme care to avoid excessive force.

5. Mark the position of the flywheel pointer on the flywheel, Figure 7-13.

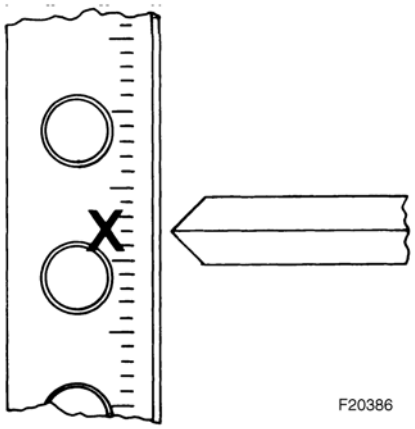


Figure 7-13. Limit Of Piston Travel Marked On Flywheel

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, Figure 7-14.

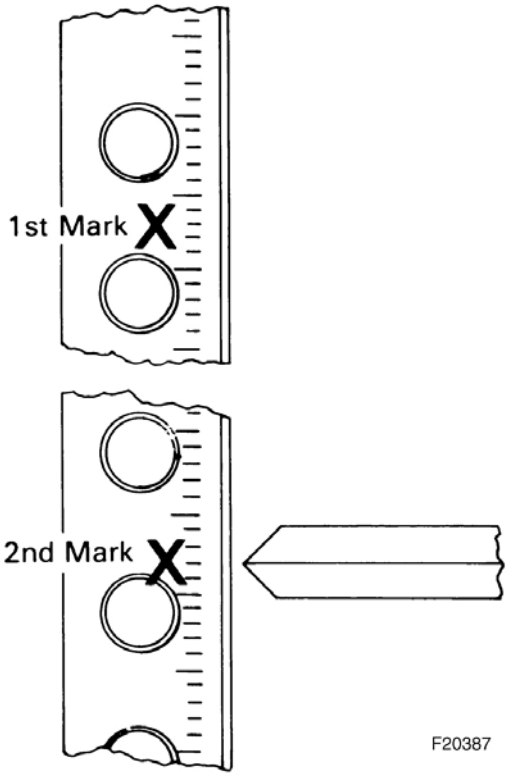
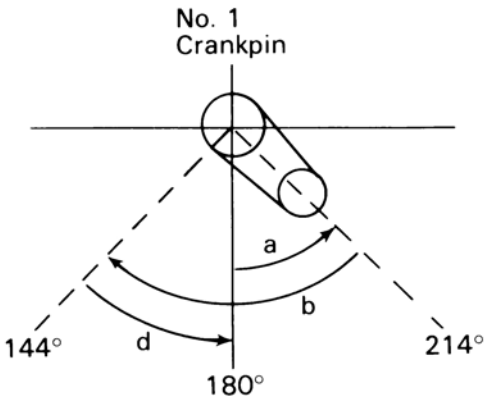


Figure 7-14. Second Limit Of Piston Travel Marked On Flywheel

8. Determine the number of degrees between the two marks on the flywheel. Divide that number by 2. See Figure 7-15 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.

$$\begin{array}{r} 214^\circ \\ -144^\circ \\ \hline 70^\circ \end{array} \qquad \frac{70^\circ}{2} = 35^\circ$$

d. Rotate 35°. Pointer should indicate 180°. If it does not, adjust pointer to indicate 180°.

F21158

Figure 7-15. 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 - 710 DURACAM:

To check timing, place a dial indicator on the rocker arm adjusting screw as shown in Figure 7-16. on page 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 (0.100") and set dial to zero.



F24878

Figure 7-16. Timing Exhaust Valves

Turn crankshaft in normal direction of rotation until flywheel is at 110.5° A.T.D.C. of cylinder being checked. All 710G3B engines are equipped with Duracams. On these engines, if timing is correct, the valve bridge will have moved down 0.66 mm (0.026"). Timing must not be later than 112°, nor earlier than 107.5° A.T.D.C. of cylinder being checked.

CHECKING EXHAUST VALVE TIMING FOR EARLY 710 ENGINES:

Turn crankshaft in normal direction of rotation until flywheel is at 110° 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 114.5° or earlier than 108.5° 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. 1 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, Figure 7-16. on page 7-20, as done in “Checking Exhaust Valve Timing.”
2. Remove lockwire from mounting bolts and dowel pin bolts securing rear camshaft counterweight to the stubshaft. Remove bolts, washers, dowel retainer plate and two 1/2" dowel pins. Remove counterweight and gear.
3. Using a socket and wrench on stubshaft flange bolt nuts, rotate the camshaft in its normal direction of rotation until the valve bridge on which the dial indicator is resting moves down 0.66 mm (.026").
4. Bar engine crankshaft over in the normal direction of rotation until the flywheel pointer is at 109.5° after top dead center for the cylinder being checked. Install camshaft gear and counterweight on stubshaft, secure in place with mounting bolts finger tight.
5. With flywheel at 109.5° 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 107.5° to 110.5° A.T.D.C., the dowel holes can be made to line up, then tighten the bolts to secure assembly for installation of dowel pins.
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.

CAUTION

Before reaming (or drilling) dowel holes, be certain extra measures are taken to contain any metal shavings or chips to prevent their entering oil drains or contaminating the gear train.

8. Insert 5/16"-24 bolts approximately 12.7 mm (1/2") into dowel pins.
9. Place dowels in counterweight 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 specified value.
12. Install dowel pin bolts and torque to specified value.
13. Lockwire mounting bolts and dowel pin bolts in groups of three. (Two mounting bolts and one dowel pin 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 0.66 mm (.026") when the flywheel timing pointer is at 107.5°-110.5° A.T.D.C. for the cylinder being checked.
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, as shown in Figure 7-17. on page 7-23. 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 the 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 +0.00 -0.03 mm (5.7495" +0.000" -0.001") flange O.D. for high spots and grind to proper dimension.

CAUTION

Repeat Step 3 if camshaft to crankshaft relationship has been disturbed.

g. Apply camshaft gear to stubshaft and secure with mounting bolts.

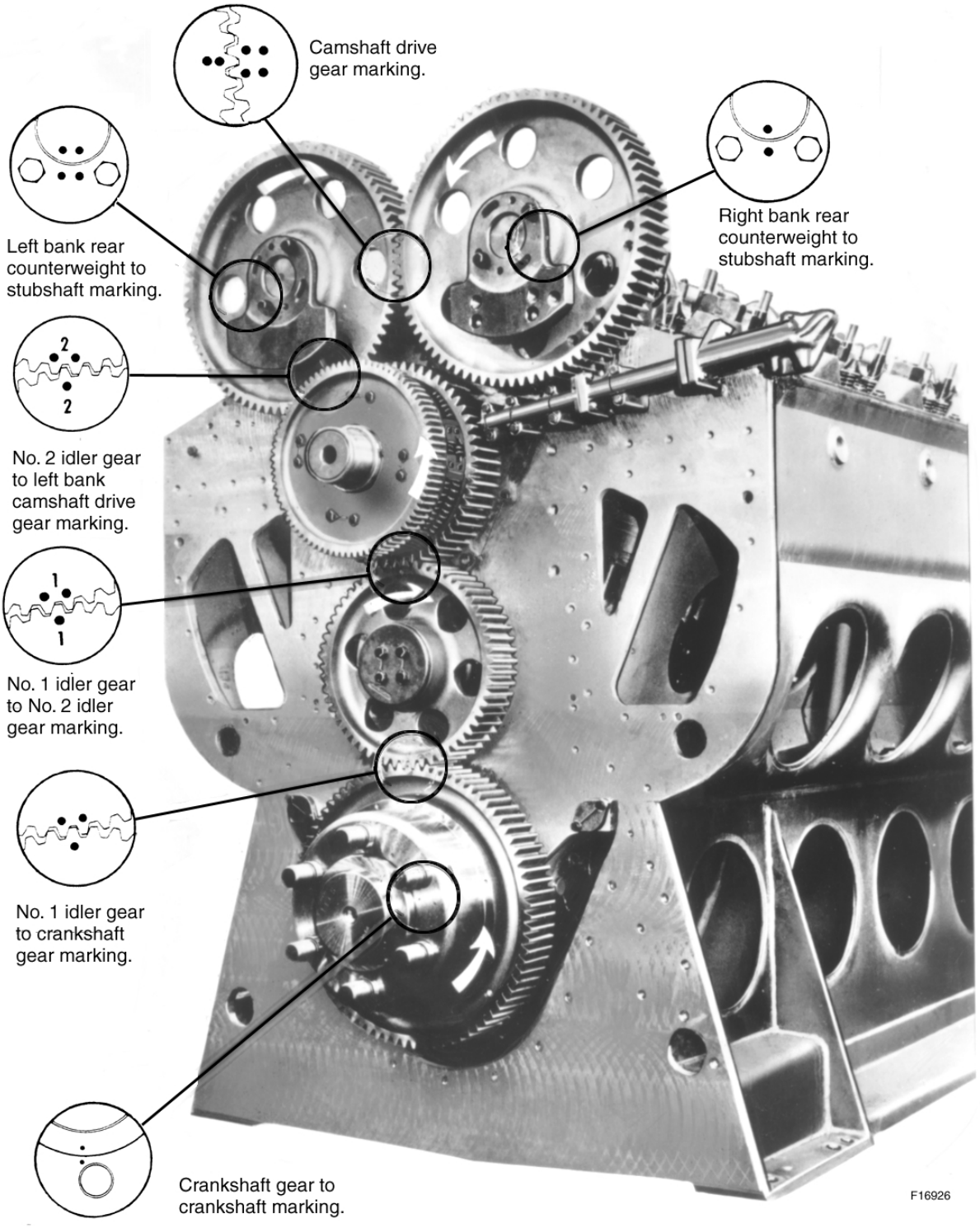


Figure 7-17. Typical Camshaft Gear Train Marking

8. Rotate engine crankshaft to position indicated in Figure 7-10. on page 7-14.
9. 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.
10. Install mounting bolts and tighten to secure gear and counterweight to stubshaft.
11. Drill and ream stubshaft dowel holes to 12.662 +0.13 -0.00 mm (.4985" +.005"
    -.000").
12. Perform Steps 8 thru 16.

7.3 PRETIMED CAMSHAFT GEAR TRAIN ASSEMBLY PROCEDURES

In the event that the rear gear train requires replacement of any component, use the following procedures for component replacement and orientation:

1. Rotate the crankshaft until #1 cylinder is at TDC. The “M” mark on the bell gear (crankshaft gear) tooth will be approximately in the 12:00 position. Refer to Figure 7-18.

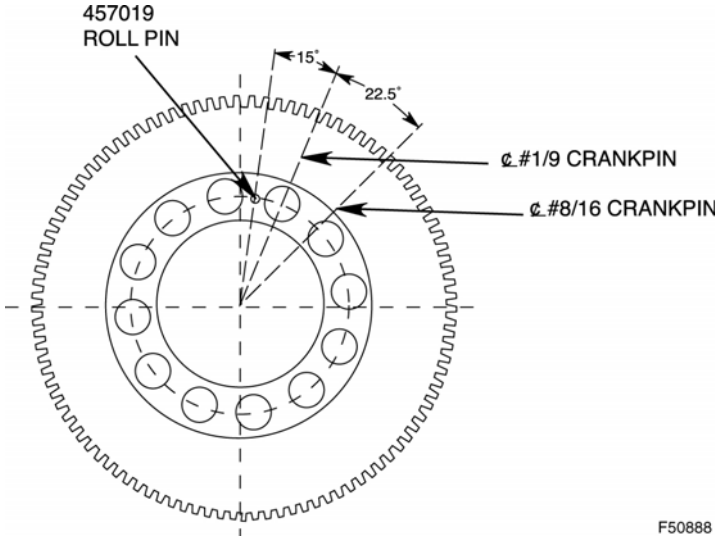


Figure 7-18. Alignment of Bell (Crankshaft) Gear

2. Rotate camshafts until dowel holes in the rear stubshafts are in the 12:00 position.
3. Install cam gears so that “EMD” is aligned across the meshing teeth as, shown in Figure 7-19.

NOTE

Cam gears are interchangeable for left and right camshafts, therefore some gear markings will not be used.

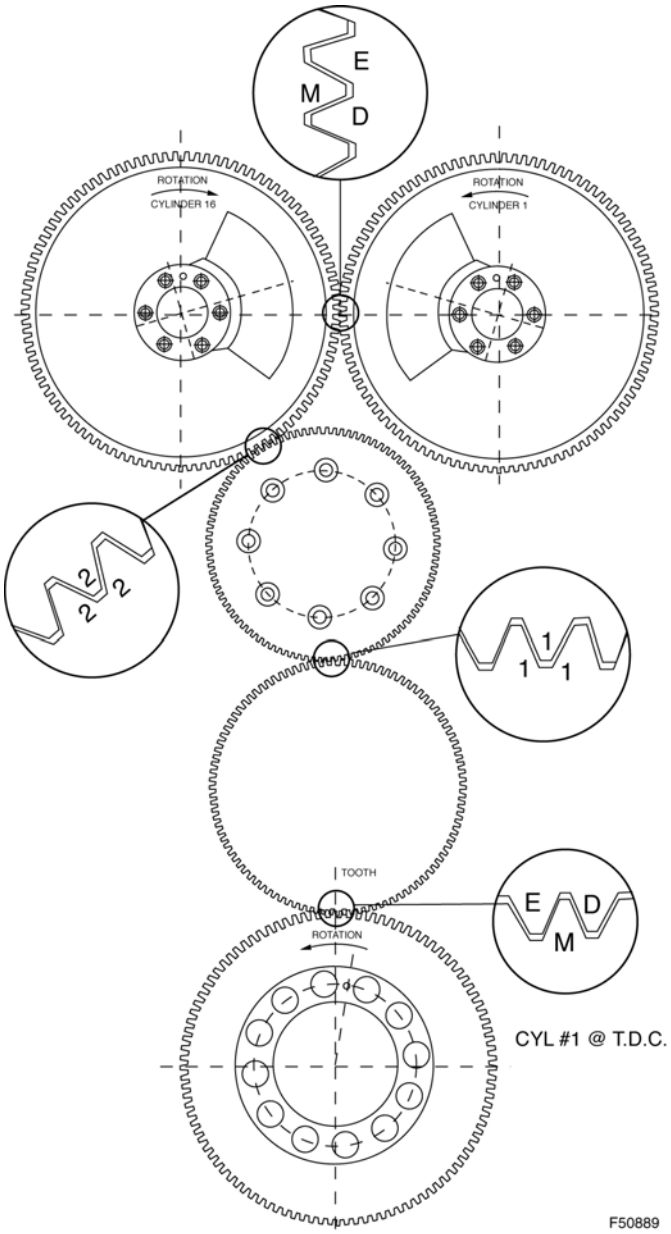


Figure 7-19. Camshaft Gear Train Timing Marks

4. Install lower (#1) idler gear on lower stubshaft. Align the teeth so that “EMD” is aligned across the mesh.

5. Install upper idler (#2) / clutch assembly to the upper stubshaft ensuring that the teeth are aligned so that “1 1 1” is aligned with the lower idler gear and that “2 2 2” is aligned with the left bank camshaft gear. It may be necessary to rotate the camshafts slightly to install the gear and maintain all alignment.

6. Position the counterweights, aligning dowel holes, gears, and camshafts. Install dowel pins, torque mounting bolts, and safety wire all hardware.

7.4 SERVICE DATA - CAMSHAFT GEAR TRAIN, AUXILIARY DRIVE, CAMSHAFT ASSEMBLIES

7.4.1 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Gear Backlash

Crankshaft gear to No. 1 idler -

Std.....0.18-0.64 mm (.007"-.025")

No. 1 idler to No. 2 idler on clutch (or spring) drive gear assembly -

Std.....0.18-0.64 mm (.007"-.025")

No. 2 idler on clutch (or spring) drive gear assembly to camshaft drive -

Std.....0.18-0.64 mm (.007"-.025")

Camshaft drive gear to camshaft drive gear -

Std.....0.18-0.64 mm (.007"-.025")

Auxiliary drive gear to camshaft drive gear -

Std.....0.25-0.64 mm (.010"-.025")

Turbocharger drive gear to turbocharger idler gear -

Min. ..... 0.15 mm (.006")
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 to stubshaft clearance -

Min. ..... 0.13 mm (.005")
Max..... 0.43 mm (.017")

No. 2 idler gear assembly (part of clutch, or spring, drive gear assembly)

Idler gear bore diameter -

Max.....101.83 mm (4.009")

Stubshaft diameter -

Min. .....101.52 mm (3.997")

Idler gear to stubshaft clearance -

Min. ..... 0.10 mm (.004")
Max. ..... 0.30 mm (.012")

Thrust clearance -

Min. ..... 1.14 mm (.045")
Max. ..... 2.31 mm (.091")

Camshaft Timing

Ideal timing setting, valve open 0.66 mm (0.026") -

A.T.D.C. ..... 110.5°

Timing of new gear train not earlier than -Max. ..... 3°

OR

at 0.66 mm (0.026") valve opening - A.T.D.C. ..... 107.5°

Limit of lag - camshaft behind crankshaft (worn gears) -

Max. ..... 1.5°

OR

at 0.66 mm (0.026") valve opening - A.T.D.C. ..... 112°

Flywheel pointer setting - T.C.C. of No. 1 cyl. ..... 0°

7.4.2 EQUIPMENT LIST

	PART NO.
Feeler gauge set	8067337
No. 1 idler gear clearance checking spring	8121868
Gasket sealing compound -0.47 liter (1 pt.)	8178639
Dial indicator	8255423
Thread lubricant, high temperature -0.946 liter (1 qt.)	8278929
Loctite cleaner activator -0.17 kg (6 oz.)	8352873
No. 1 idler gear clearance checking bar	8466308
Camshaft stubshaft plug	9082284
Loctite sealing compound -250 cc bottle	9085183
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

SECTION 8. AIR INTAKE AND EXHAUST SYSTEMS

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8.1 TURBOCHARGER

8.1.1 DESCRIPTION

The turbocharger assembly, Figure 8-1, is primarily used to increase engine horsepower and provide better fuel economy through the utilization of exhaust gases. As shown in cross-section, Figure 8-3. on page 8-8 and Figure 8-4. on page 8-9, 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 538°C (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.

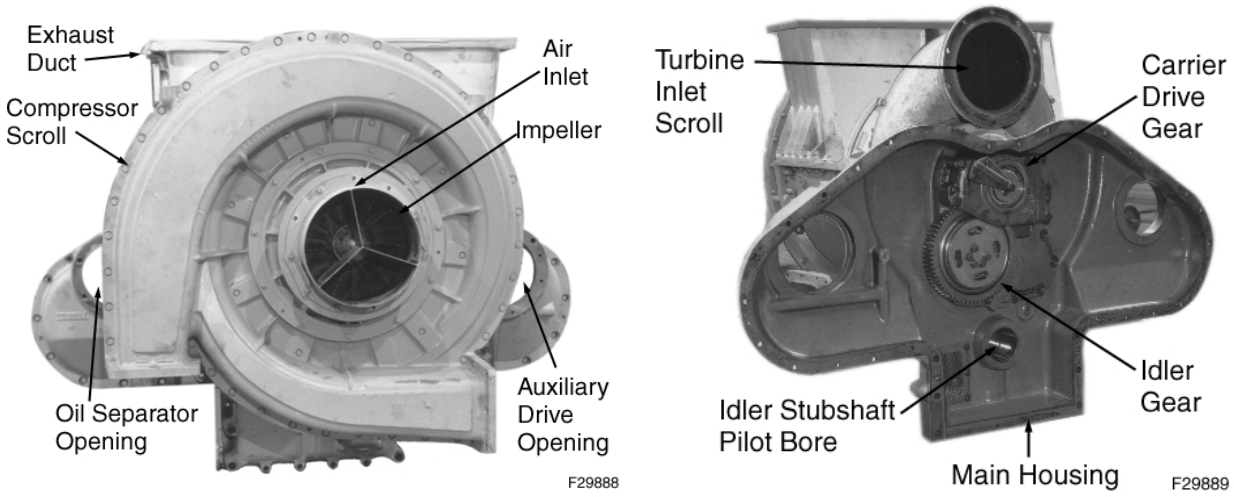


Figure 8-1. Typical Turbocharger Assembly

On turbochargers for 8-cyl. engines, 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 doweled and bolted together, and rotate as a unit. When the engine is driving the turbine, the rollers are wedged in the 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.

On turbochargers for 12, 16 and 20-cyl. engines, 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 clutch 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 fixed ring gear in the carrier shaft support assembly. When the turbine is being driven entirely by exhaust energy, the direction of torque transmitted back through the gears in the turbocharger unlocks the overrunning clutch.

The overrunning clutch consists of 16 rollers in tapered slots. The slots are formed by the combination of a clutch drive support and the pockets in a cam plate. The cam plate, a clutch support, and a cam plate retainer are doweled and bolted together, and rotate as a unit. The unit in turn bolts to the turbocharger drive gear. The clutch drive support is bolted to the No. 2 idler gear. When the engine is driving the turbine, the rollers are wedged in the small side of the cam plate pockets, as a result of the direction of torque, locking the cam plate to the clutch drive support (turbocharger drive gear to the No. 2 idler gear).

Because the planet gear shafts are driven as a part of the carrier shaft, the planet gears rotate in the fixed 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 back through the turbocharger gears reverses direction. This causes the rollers to move to the wide end of the cam plate pocket, unlocking the clutch, permitting it to overrun. From this point on, with increased load and speed, the turbocharger overruns the engine drive.

8.1.2 MAINTENANCE

Since it is not practical to attempt any reconditioning of the turbocharger in the field, it is recommended that it be returned to EMD as a complete unit for this service.

The following removal and installation procedures are provided for field service:

8.1.2.1 REMOVAL

1. Remove roof hatch.
2. Disconnect and remove the water lines to and from the aftercooler assemblies.
3. Remove the auxiliary drive assembly.
4. Remove the oil separator/ ejector assembly.
5. It is advisable to remove the aftercoolers from the ducts rather than to remove them as an assembly, because of the weight involved.

NOTE

On tier 2 engines the aftercoolers are an integral part of the duct, therefore unremovable from the duct.

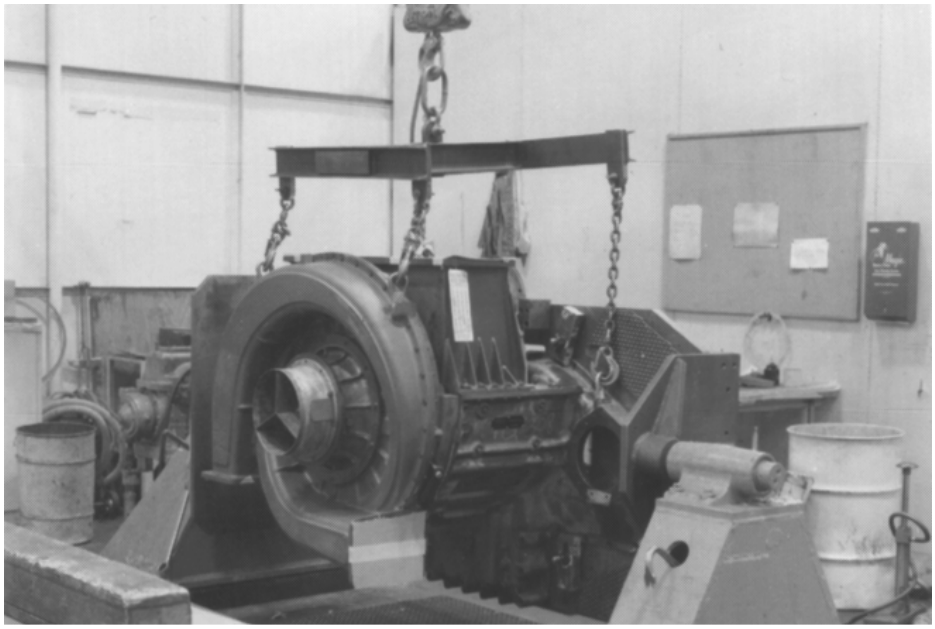
NOTE

Procedures for removal and installation of aftercoolers are contained in Section 10 of this manual.

6. Remove the oil line clamp from the right aftercooler duct.
7. Remove both aftercooler duct assemblies.
8. Remove the expansion joint between the turbocharger and the engine exhaust manifold.
9. Disconnect the exhaust silencer from the top of the turbine exhaust duct. Remove the silencer.
10. Disconnect speed pickup and cable (if provided) from turbo air inlet housing and tie it back away from turbocharger to prevent it’s being damaged during turbo removal.
11. Remove air duct assembly from turbocharger air inlet assembly and remove air inlet.
12. Connect lifting chains to eye-bolts screwed into the four 5/8"-11 UNC 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 press against the exhaust duct.

A turbocharger lifting sling, Figure 8-2. on page 8-6, is available which maintains the proper attitude of the turbocharger during removal. Refer to the Service Data for lifting sling and eye-bolt part numbers.



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Figure 8-2. Lifting Device Applied To Turbocharger

13. 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 the 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.

14. Using jackscrews between the turbocharger housing and the gear train housing, jack the turbocharger away from the engine until the turbocharger pilot bore clears the No. 2 stubshaft.

NOTE

Engine timing will not be disturbed during turbocharger removal as long as the camshafts and crankshaft are not moved when gears are disengaged.

15. Using a 1-ton (or 1000 kg) crane, lift the turbocharger clear of the engine and place it in a shipping container for transportation.

8.1.2.2 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 brought about the failure.
4. Clean all gasket surfaces on the engine, the turbocharger to be applied, and the air ducts.

   Remove any nicks or burrs.

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 pilot stubshaft, 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. If manifold condition is in doubt, remove the manifold and 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 check that the torque of the bolts is as specified. Also, check the manifold connector fasteners for specified torque. Check the condition of the adapter to turbocharger bellows connections, and other locations where possible leaks might occur in the exhaust system.

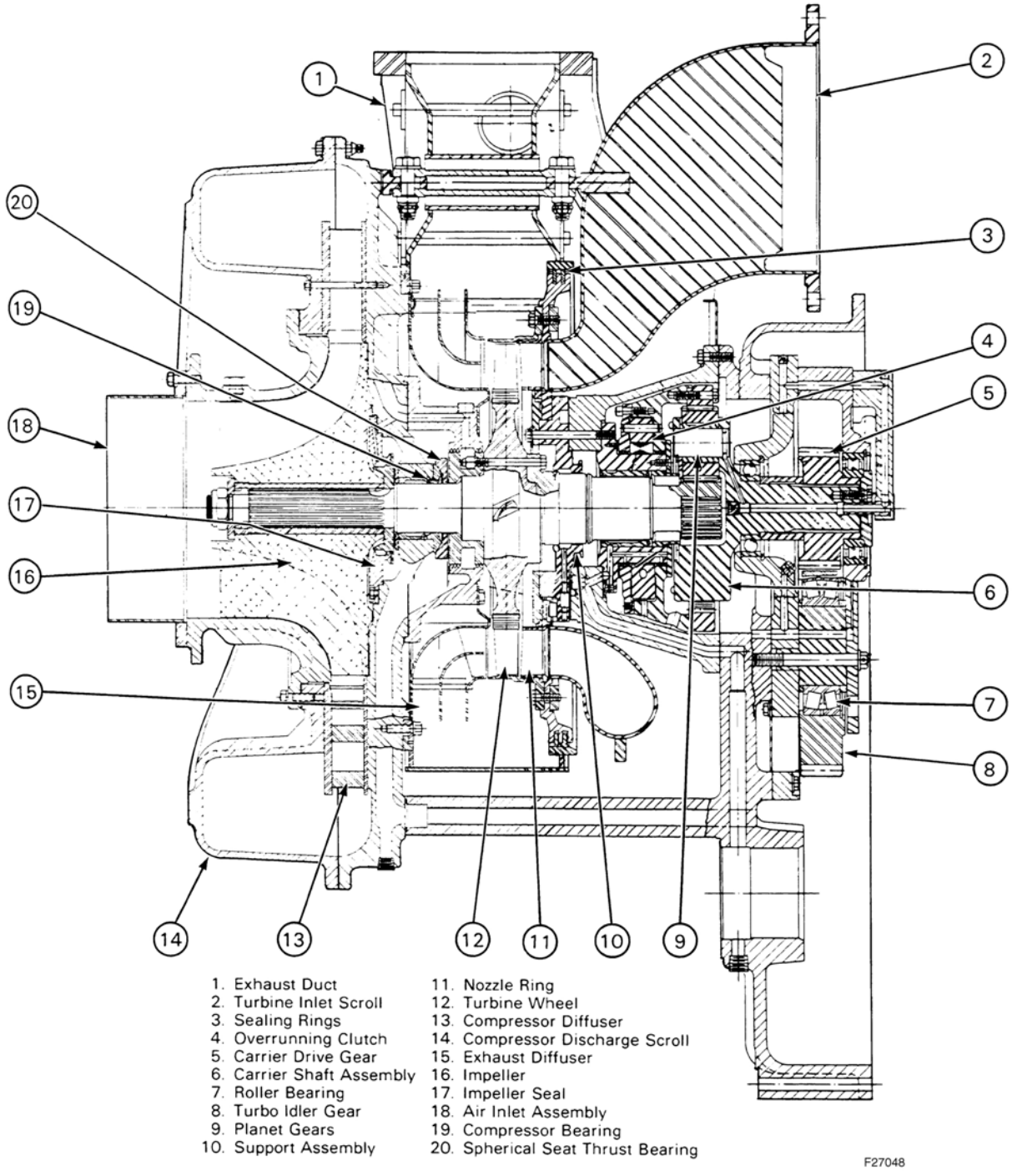


Figure 8-3. Typical Turbocharger Cross Section - Internal Clutch

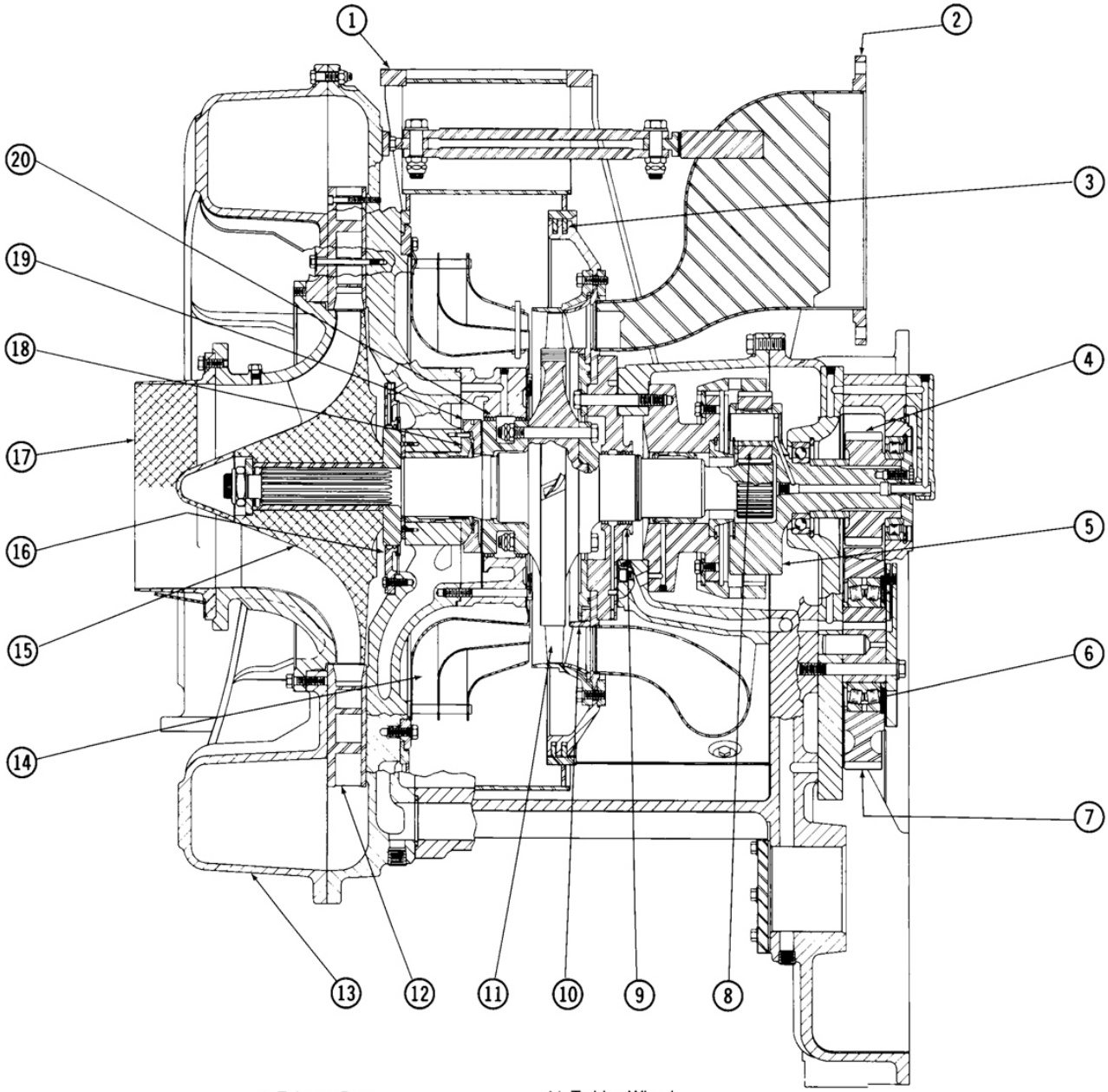


Figure 8-4. Typical Turbocharger Cross Section - External Clutch

3. Inspect the adapter assembly, Figure 8-5, between rear expansion joint and exhaust manifold assembly for condition of exhaust inlet screen. This screen functions as a protective device for the turbocharger by minimizing the possibility of foreign material, such as broken piston rings and small exhaust valve pieces, entering the turbine and damaging the turbine vanes. Current screen designs include a small trap box at the base of the adapter assembly to remove foreign material from the exhaust flow, thereby preventing it from continuously hitting the screen and breaking into smaller pieces. If foreign material is present in the exhaust manifold or screen trap box, it is recommended that screen be magnaflux inspected.

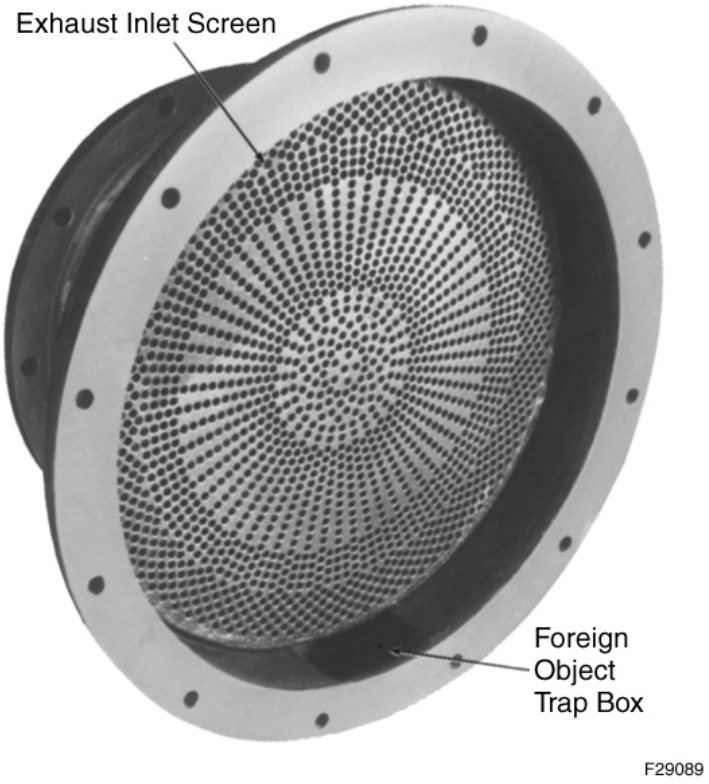


Figure 8-5. Typical Exhaust Manifold-To-Turbocharger Adapter Assembly

Exhaust inlet screen is also susceptible to plugging with carbon and water treatment residue. Should screen become plugged, performance of the turbocharger and the engine will be adversely affected. Plugged screens must be removed from the exhaust manifold for cleaning with a stiff wire brush. Before reinstalling screen, cause of plugging should be determined and corrected.

NOTE

Inspect the exhaust silencer (if applied) for foreign material and remove any which may be found.

On units with offset (low-profile) silencers, silencer may be suspended by its four lifting eyes and swung on the chains to check for the rattling of debris within the shell. If foreign material is detected, it can be removed by raising silencer to convenient height to access each of the eight expansion slots above its bottom flange by hand.

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.

NOTE

If turbocharger oil filter is of the disposable (spin on) type, element will mount directly to an adaptor on the filter head assembly.

2. To replace “spin-on” filter element, perform the following:
   a. Unscrew the element by hand or using a strap wrench, if necessary, and discard.
   b. Fill the replacement element housing with new engine oil to within 50.8 mm (2") of the top. Also, apply a thin film of oil to the element gasket.
   c. Apply the new element to the filter head by hand and turn until gasket contacts the adapter, then tighten one-half turn ONLY.
   d. Check for leaks when the engine is started.

5. If required, drain and completely clean the oil 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 and relief valves 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 housing and replace filter elements if foreign material is found.

8.1.2.3 INSTALLATION

NOTE

If camshaft to crankshaft relationship has been disturbed, engine timing must be checked before installing turbocharger. Refer to Section 7 for engine timing procedures.

1. Apply the lifting sling 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 collar. 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 thickness at the ends of the impeller blades at the 3 and 9 o'clock positions simultaneously to determine the available horizontal clearance. Record the clearance.
   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 feeler to determine clearance at the 6 o'clock position. Record the clearances obtained.
3. Apply a thin coat of gasket sealing 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 coverings 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. Before removing lifting sling, apply the 3/4" turbocharger mounting bolts with hardened washers and bolt dampers, and all 1/2" mounting bolts. Snug up bolts, but do <u>not</u> 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, Figure 8-6, page 8-13. 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 the Service Data for backlash limits. Backlash is adjusted by loosening the turbocharger mounting bolts and repositioning the turbocharger on camshaft drive housing.

NOTE

This procedure not required on engines not equipped with auxiliary drive gear.

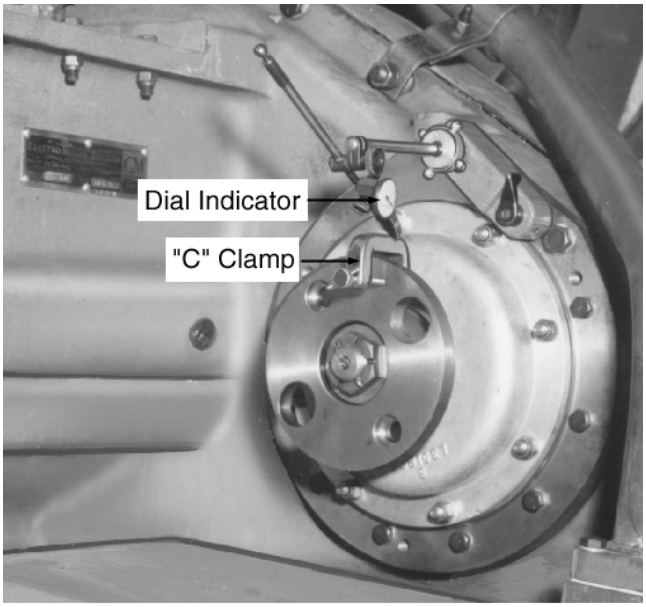


Figure 8-6. Checking Auxiliary Drive Gear Backlash

10. When the correct backlash is obtained, torque the turbocharger and auxiliary drive mounting bolts to specified values. After the bolts are properly tightened, recheck the auxiliary drive gear backlash.

NOTE

Bolts used at positions where water pipe support brackets are applied should not be torqued until brackets are in place.

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 specified value, and lockwire. Remove the core and proceed as follows with application.

1. Air duct flanges should be thoroughly cleaned of any old gasket material, sealant, adhesive, dirt and grime (or any debris). Inspect for surface damage, including; gouges, deep scratches, voids, weld or braze splatter, excessive grinding or scraping marks, and other imperfections. If damage is beyond practical repair, flange should be replaced. If this is not possible, an approved anaerobic sealing compound (as listed in the Service Data) may be used to supplement the gasket to provide a “spot fix”.

CAUTION

Aftercooler duct-to-crankcase gaskets used on all 710G3B engines are of the “printed bead” type with a thin steel core and require special handling in order to avoid damage during assembly. Do NOT pull on the printed bead or rub it against other objects. Avoid excessive bending or flexing of the gasket to prevent damage of the steel core. This gasket should never be wedged or forced between flanges that are pried apart as this could damage the printed bead and create a leak path.

NOTE

The use of adhesives is NOT recommended for use with the printed bead type gaskets as leak paths may develop if adhesive cures before full bolt torque is applied.

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 or from inside the air box. 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 the specified value. Then remove the bolts from the turbocharger end of the air duct and with the gasket in place, and using an 0.008" feeler gauge, determine the clearance at the mating flanges. If an 0.008" 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.
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 or spacers on bolts, then tighten the air duct to turbocharger bolts to specified torque. Refer to the Service Data for correct bolt, spacer or washer application.

NOTE

All bolts fitted with spacers are to be torqued to the same specification as the shorter bolts fitted with washers only.
Printed bead type duct-to-crankcase gaskets can not be reused after being torqued once. If for any reason aftercooler duct is removed, it should be fitted with a new gasket upon reassembly onto the engine.

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. Coat aftercooler to air duct gaskets with light engine oil and 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 specified value.
7. Attach water pipes to aftercoolers and torque bolts to specified value.
8. Attach water pipes to engine and torque bolts to specified value.
9. Clamp turbocharger oil filter line to tapping pad on right aftercooler air duct.

8.1.2.4 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 by external viewing of the expansion joint.
3. Coat the threads of the expansion joint bolts with high temperature thread lubricant, apply and torque to specified value.
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 cannot 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 silencer to the top of the turbine exhaust duct with bolts coated with high temperature thread lubricant, and torque to specified value.

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 air inlet assembly on turbocharger and apply speed pickup and cable. Tighten pickup into inlet housing snugly, using care to avoid overtightening. Check for interference between speed pickup and impeller by rotating impeller by hand.
8. Install the air duct assembly to air inlet on turbocharger.
9. Replace decking and panels.

8.1.2.5 STARTING THE ENGINE

1. Perform engine prelube, as described in Section 9, and make sure soak back oil pump is operating.
2. Make the necessary preparations and start the engine.
3. When starting a governor controlled engine, do not force the injector hand control lever beyond the idle (one-third rack) 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.

8.2 EXHAUST MANIFOLD

8.2.1 DESCRIPTION

The exhaust gases from the engine cylinders are discharged from the cylinder heads into the exhaust manifold, Figure 8-7, 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.

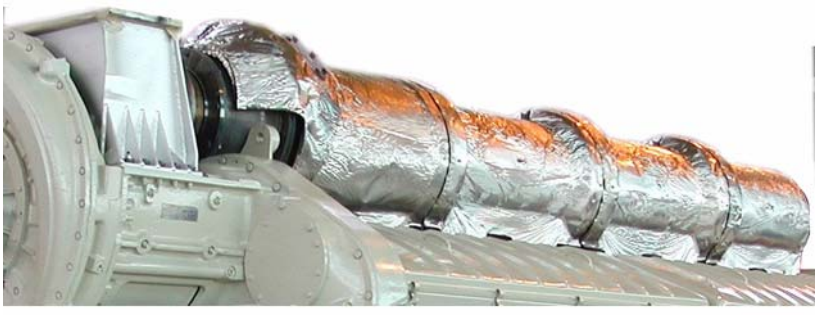


Figure 8-7. Typical Exhaust Manifold

The exhaust manifold is made up of chamber assemblies, expansion joints, and adapter assembly. The expansion joints, which are used between chamber 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.

8.2.2 EXHAUST MANIFOLD INSULATION REMOVAL AND INSTALLATION

CAUTION

The metal encapsulated insulation is manufactured from a thin stainless steel foil that can produce sharp edges. As a precaution, it is advised that thin gloves be worn to lower the risk of cuts and scratches while handling the insulation.

8.2.2.1 REMOVAL PROCEDURE

1. Using wire snips; cut the stainless steel lockwire at each location or remove retaining springs depending on which application was used. At this point, the insulation components will be supported at the base and held in place by the bolt and nut atop the exhaust manifold.
2. Starting at the left bank rear end of engine (closest to turbo, opposite of inspection port), remove the bolt and nut while holding the left and right insulation assembly in place. A clamp can be used to hold parts in place during this step. Replace the nut and bolt to support the insulation assembly on the reverse side you are working. Remove the insulation assembly closest to you from the engine, being careful not to puncture the assembly.

NOTE

If the nut and bolt is not replaced, the insulation on the reverse side will fall off the engine

3. Repeat Step 2 for the remaining left bank assemblies.
4. Finish removal procedure on right bank by removing the nut and bolt; this time, start from the front of the engine and work towards the turbo.

8.2.2.2 INSTALLATION PROCEDURE

1. Using Figure 8-8, organize the insulation around the engine according to the proper position. If any parts are punctured, they should not be used. If parts are bent or depressed, the parts are still usable as long as they can fit onto the exhaust manifold.

2. Starting from the inspection port, place the two bottom tabs of the insulation piece into the clips of the exhaust chamber. Push the insulation so the top tab of the insulation rests against the center tab of the exhaust manifold. Align the bolthole of the insulation with the manifold hole. Refer to Figure 8-9, page 8-19, to see which bolthole aligns with the manifold. Using a clamp, or vice grips hold the insulation in place at the top tab.

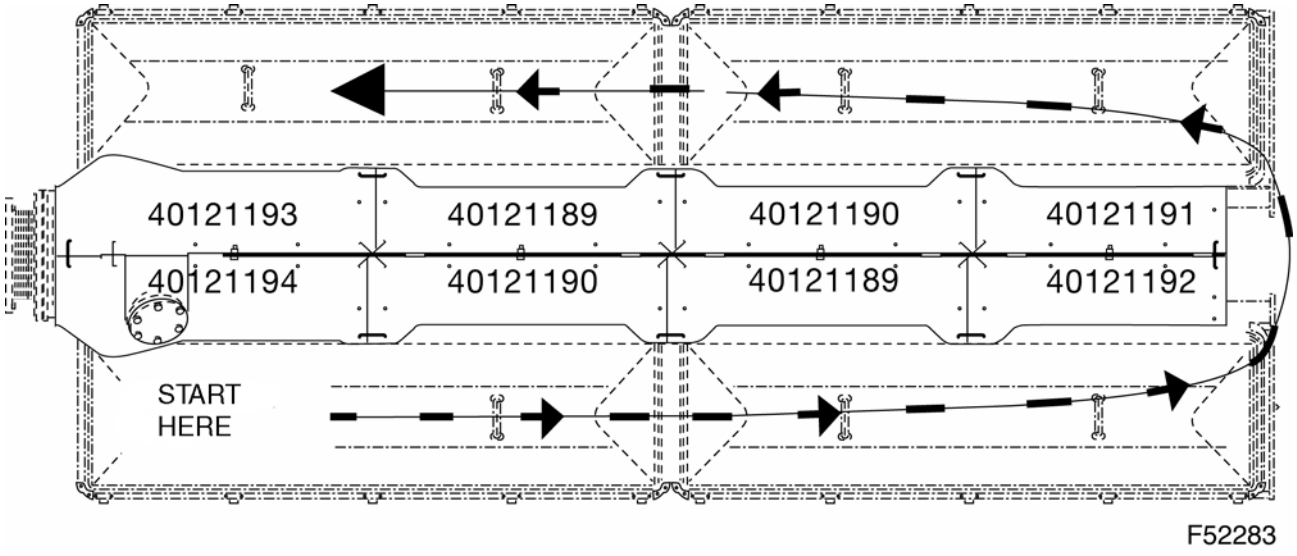


Figure 8-8. Location and Assembly Direction of Insulation Parts

3. Moving from left to right, secure the second insulation piece in place. Again, use a clamp to hold the insulation in place. Continue this for the entire bank of the engine. When this step is completed, four insulation pieces on the right bank will be in place and held down by a clamp or vice grips.
4. Go to the other side of the engine, start from the accessory end. This continues the left to right movement. Place the lower tabs into the exhaust manifold clips. As you bring the top tab into position, hold both the right bank and left bank insulation parts with one hand while removing the clamp. Re-apply the clamp when the holes in the top tabs align. Use a bolt, nut and two washers (as called out on the print) to secure the parts in place. Remove the clamp.
5. Moving from left to right, complete the mounting of the remaining blankets according to the procedure set in the previous step.
6. When all the insulation parts are in place, torque the bolts to 35 ft-lbs.

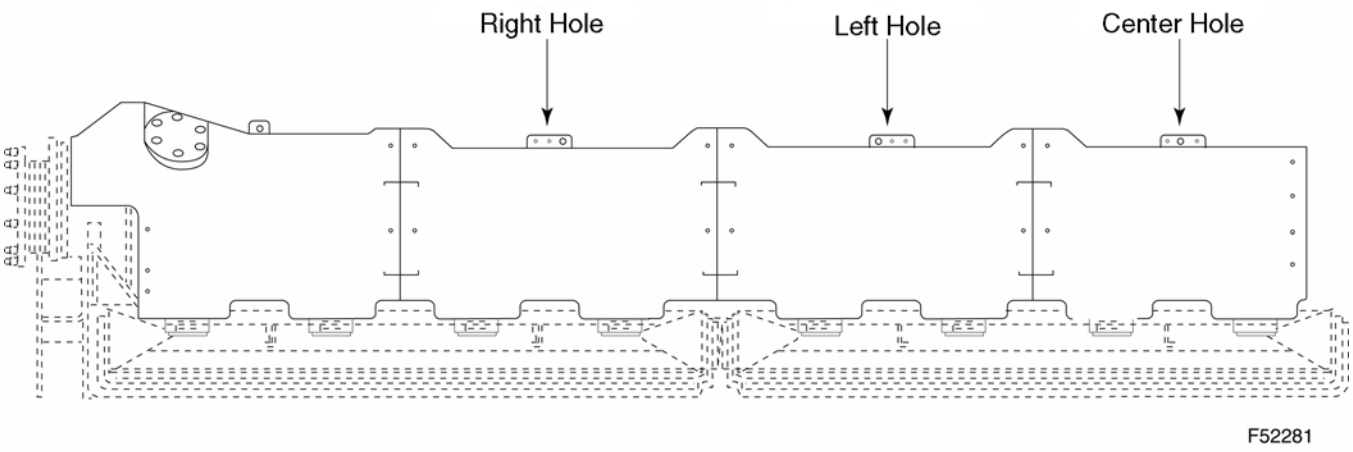


Figure 8-9. Bolt Hole Location of Insulation Parts

7. Apply springs PN 40154472 to connect adjacent insulation components (only where specified). Details of how to connect springs to the capstans together are shown in Figure 8-10.

NOTE

Not all locations need to have springs applied. Check the application print for detail on spring locations.

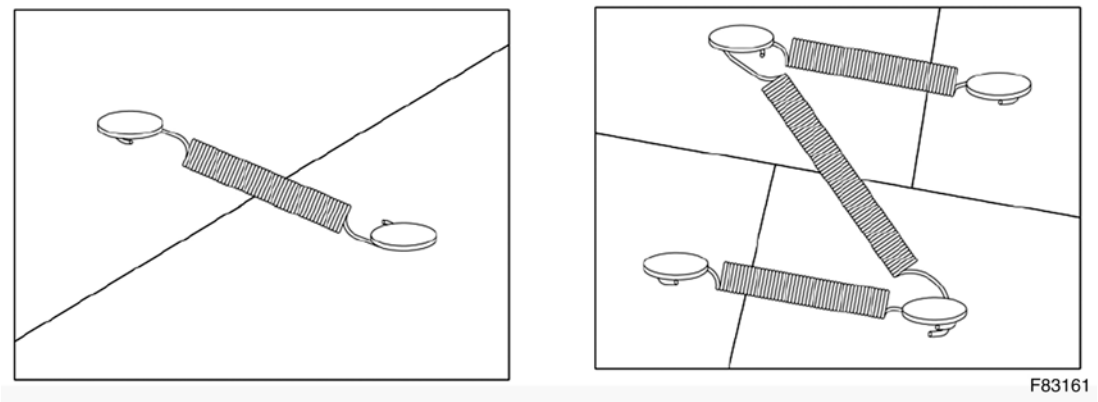


Figure 8-10. Spring Detail & Spring Detail at Corner Junction

8.2.3 MAINTENANCE

Remove inspection plate and 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. Install new gasket and reapply inspection plate. Torque bolts to specified value.

NOTE

The trap type screen must be inspected and cleaned as 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:

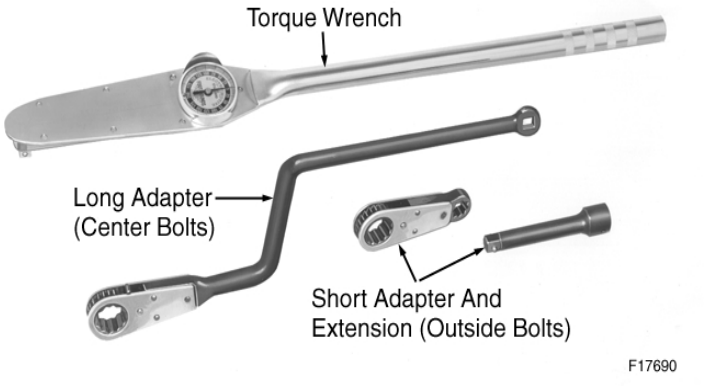
When applying the exhaust manifold gasket, it is important that the gasket be positioned properly, and that the bolts be torqued and retorqued as recommended. Gasket should be applied as follows:

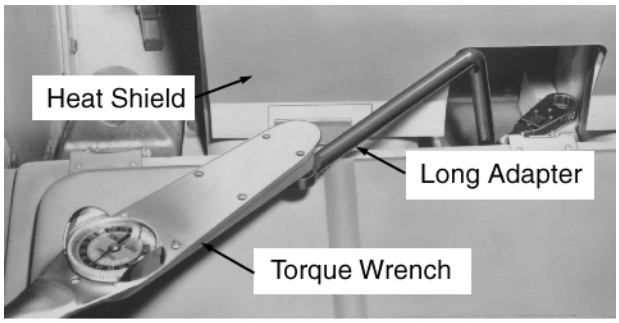
1. Carefully clean all dirt and debris from the top center “vee” of the crankcase.
2. Chase all 5/8”-18 manifold mounting bolt holes in the top “vee” of the crankcase with a bottoming tap or a 5/8”-18 bolt.
3. Blow out any debris from tapped holes with compressed air.
4. Apply the gasket making sure 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.

5. Lubricate manifold 5/8”-18 mounting bolts with high temperature thread lubricant, then apply bolts with spacers, starting bolts by hand for the first 2 or 3 turns to prevent cross-threading. Torque the bolts in two passes, using the manifold torque tool set, Figure 8-11. on page 8-21. The first (initial) pass torque should be approximately 68 N·m (50 ft-lbs), followed by a second pass at 176 N·m (130 ft-lbs). When long adapter, Figure 8-11. on page 8-21, is used, the torque wrench dial should show 103 N·m (76 ft-lbs). This will provide the required 176 N·m (130 ft-lbs). When short adapter, Figure 8-11. on page 8-21, is used, the torque wrench dial should show 176 N·m (130 ft-lbs) for the required torque.





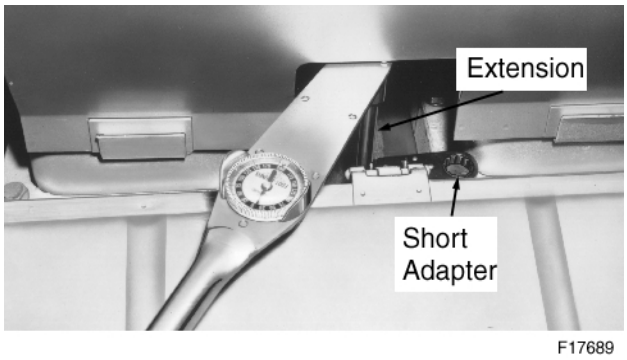


Figure 8-11. Manifold Gasket Torquing

NOTE

To correctly torque the center bolts, the torque wrench must be attached to the long adapter in a straight line as shown in Figure 8-11, page 8-21. To obtain maximum service life from the gasket application, retorquing instructions MUST be followed.

6. After the gaskets have been applied, and the bolt and spacer assemblies torqued on the second pass at 176 Nm (130 ft-lbs), they must be retorqued to 176 Nm (130 ft-lbs) after a ten (10) minute waiting period, but before the engine is run. (*A single pass for the retorquing is sufficient*.)

7. After the engine is run for the first time after re-gasketing (Engine test or Load Box test), the bolt and spacer assemblies must be retorqued a second (final) time at 176 N·m (130 ft-lbs).

   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 must be facing toward the front of the engine, ensuring flat side of the flange goes on the bottom. This weldment will not be visible from the exterior of the expansion joint.

   In bolting the expansion joints to the chamber assemblies, it is recommended that one flange or 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 cannot be acquired through repositioning the expansion joint, enlarge the holes in the flange until bolts can be freely inserted and tightened.

8.2.4 AIR INTAKE FILTER (16-CYL.)

8.2.4.1 DESCRIPTION

The air intake filter is an integral part of the locomotive carbody. It is located just above the engine blowers and is accessible for element replacement through a hatch in the side of the carbodv.

Two types of disposable elements are available. One is a pleated paper element and the other is a fiberglass bag-type element, see Figure 8-12.

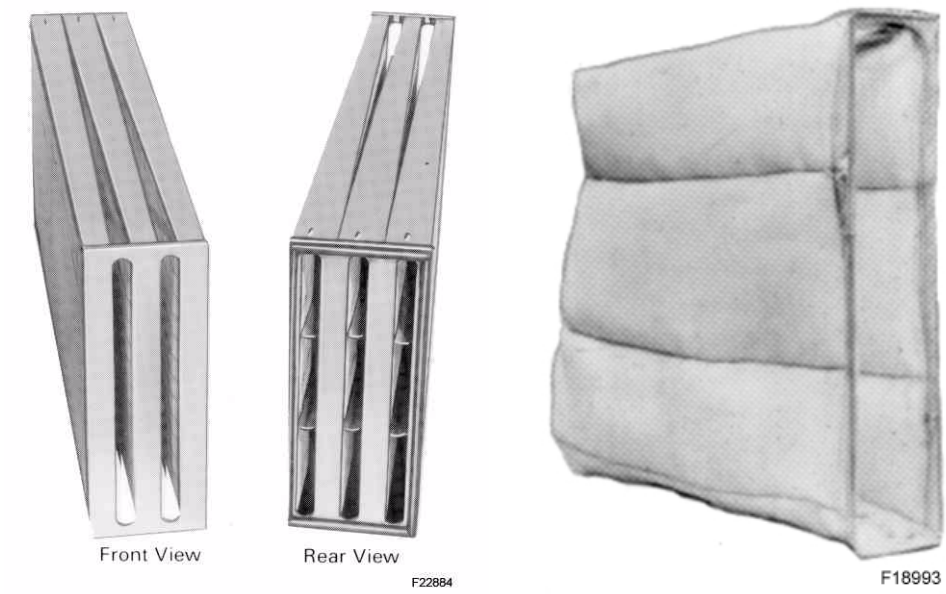


Figure 8-12. Pleated Paper Elements and Fiberglass Bag Type Filters

8.2.4.2 MAINTENANCE

Replace filter elements in accordance with instructions in the applicable Locomotive Service Manual. Replace elements as follows:

1. Open the filter compartment hatch.
2. Remove the element retaining frame(s), and then each element individually. Used elements should be discarded. No attempt should be made to clean used elements, as cleaning may rupture the media and result in serious damage to the engine.
3. Carefully install new elements one at a time. Be sure gasket end of each paper element seats against the plenum framework. Fiberglass elements seat at the retaining frame only.
4. Check the paper elements to see that they are evenly spaced. Replace the element retaining frame(s) and install the fasteners finger tight. Then tighten each fastener one or two turns at a time until each one is fully tightened to ensure that all gaskets are properly compressed and seated
5. Close and latch the filter compartment hatch.

8.2.5 ANNUAL EXHAUST MANIFOLD RETORQUE PROCEDURE

The following procedure should be done on a annual basis to prevent exhaust manifold base gasket leaks.

NOTE

Gasket part number 40055466 is the correct gasket for all EMD turbocharged engines

8.2.5.1 APPLICATION OF EXHAUST MANIFOLD MOUNTING BOLTS

The exhaust manifold to crankcase gasketed joint is a critical application. To help ensure that the joint is sound, the following steps must be followed when installing the exhaust manifold to crankcase gasket:

WARNING

Before attempting to replace the manifold base or expansion joint gaskets allow the engine to cool down so it is safe to touch the manifold sections with your hand.

1. If the exhaust manifold to crankcase base gasket is found to be leaking or blown out all the gaskets and all hardware need to be replaced on that manifold section. This includes expansion joint gaskets and hardware. Only EMD bolt PN 8287827 and nut 9338626 are recommended for expansion joint hardware due to the operating environment.

2. After the old gaskets have been removed, carefully clean all dirt and debris from the top center “vee” of the crankcase.

3. Clean both the exhaust manifold base flanges and expansion joint flanges of dirt and debris.

4. Chase all 5/8" - 18 manifold mounting holes in the top “vee” of the crankcase with a bottoming tap.

5. Blow out any debris from tapped holes with compressed air.

6. When replacing manifold sections, after installing new gasket, start the 5/8"-18 mounting bolts by hand for the first 2 to 3 turns to prevent cross threading.

7. Lubricate all mounting bolts with high temperature thread lubricant and torque the bolts in two (2) passes, using the manifold torque tool set PN 8463511, and thread lubricant PN 8278929. The first (initial) pass should be in an X pattern at approximately 68 Nm (50 ft-lbs), followed by a second pass in an X pattern at 176 Nm (130 ft-lbs). Figure 8-13.

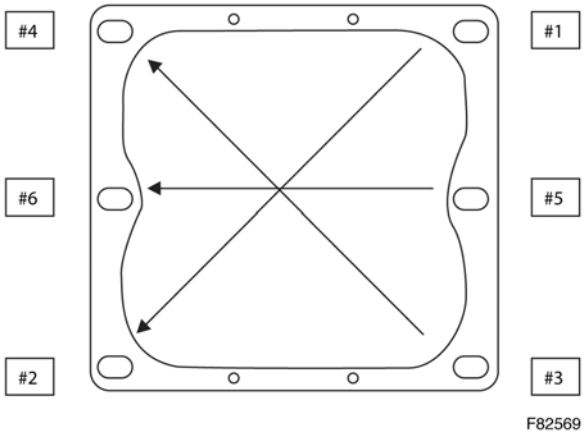


Figure 8-13. Bolt torque sequence of the gasket joint on top deck of the crankcase

8. After the gaskets have been applied, and the bolt and spacer assemblies must be torqued on the second pass at 176 Nm (130 ft-lbs), they must be retorqued in an X pattern to 176 Nm (130 ft-lbs) after a ten (10) minute waiting period, but before the engine is run. (A single pass for the retorquing is sufficient). Figure 8-13.

9. Torque the expansion joint bolts to 122 Nm (90 ft- lbs), in a rotating X pattern. Figure 8-14.

10. Run the engine in load test or on a load box until the engine temperature stabilizes or at least one cooling fan is running.

11. After the engine is run for the first time after re-gasketing (Engine Test or Load Box), the bolt and spacer assemblies and expansion joints must be torqued a third and final time.

WARNING

Allow the engine to cool down until the manifold sections are safe to be touched with your hand. Torque the manifold base bolts in an X pattern at 176 Nm (130 ft-lbs). Figure 8-13.

12. Torque the expansion joint bolt part number 8287827 and nut 9338626 to in a rotating X pattern to 122 Nm (90 ft- lbs). Figure 8-14.

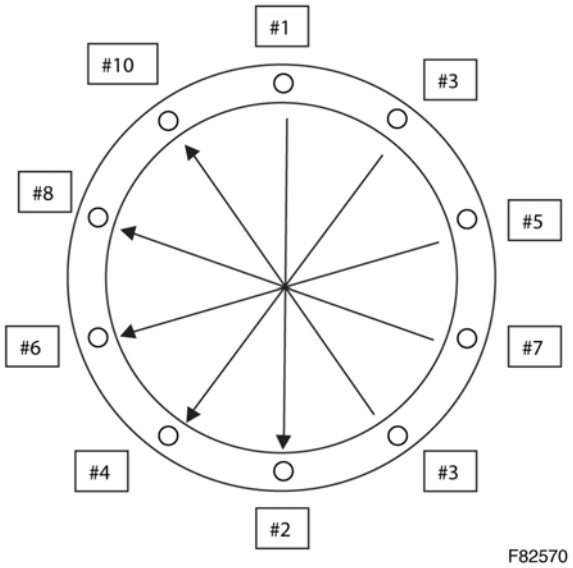


Figure 8-14. Bolt torque sequence for gasket joint between the barrel flanges

8.3 SERVICE DATA - AIR INTAKE AND EXHAUST SYSTEMS

8.3.1 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

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 (with 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")

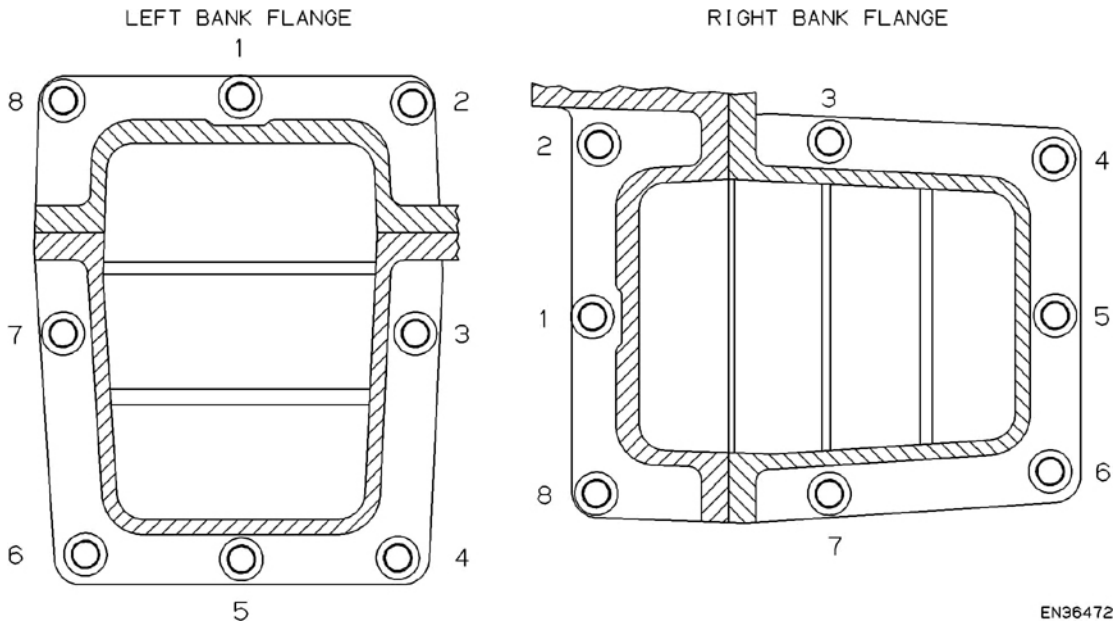


Figure 8-15. Aftercooler Duct-To-Turbocharger Joint Flange Hole Location. (All Turbochargers)

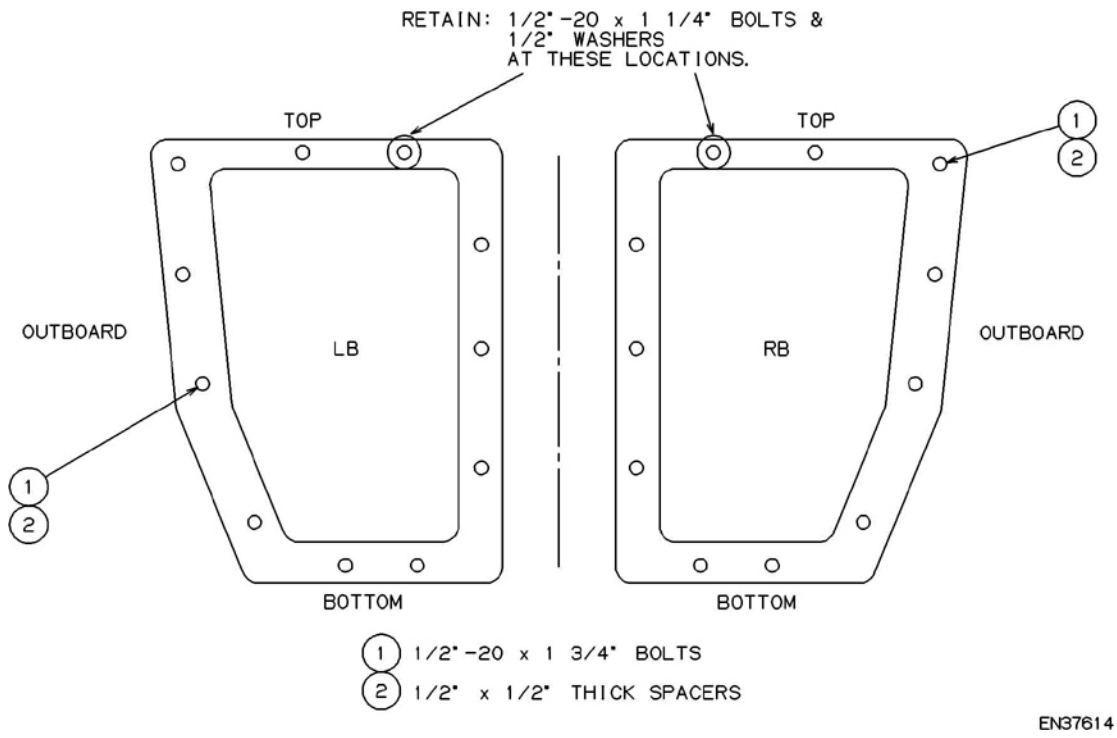


Figure 8-16. Aftercooler Duct-To-Crankcase Spacer & Long Bolt Application. (All Turbochargers)

Aftercooler To Turbocharger Air Duct Bolt Application (for bolt locations, see Figure 8-15. on page 8-27.)

8-cyl.

Left Bank -
(1) 7/16"-14 x 1-1/4" bolt - (location #5)
(1) 7/16" hardened washers - (location #5)
(7) 7/16"-14 x 1-3/4" bolts - (locations #1, 2, 3, 4, 6, 7 & 8)
(7) 7/16"x 1/2" thick spacers - (locations #1, 2, 3, 4, 6, 7 & 8)

Right Bank -
(1) 7/16"-14 x 1-1/4" bolt - (location #2)
(1) 7/16"-14 x 1-7/8" bolt - (location #5)
(2) 7/16" hardened washers - (locations #2 & 5)
(1) 7/16"-14 x 1-3/4" bolt - (location #7)
(5) 7/16"-14 x 2-1/2" bolts - (locations #1, 3, 4, 6 & 8)
(6) 7/16"x 1/2" thick spacers - (locations #1, 3, 4, 6, 7 & 8)

12, 16 & 20-cyl.

Left Bank -
(2) 7/16"-14 x 1-7/8" bolts - (locations #3 & 5)
(2) 7/16" hardened washers - (locations #3 & 5)
(6) 7/16"-14 x 2-1/2" bolts - (locations #1, 2, 4, 6, 7 & 8)
(6) 7/16"x 1/2" thick spacers - (locations #1, 2, 4, 6, 7 & 8)

Right Bank -
(2) 7/16"-14 x 1-7/8" bolts - (locations #3 & 5)
(2) 7/16" hardened washers - (locations #3 & 5)
(6) 7/16"-14 x 2-1/2" bolts - (locations #1, 2, 4, 6, 7 & 8)
(6) 7/16"x 1/2" thick spacers - (locations #1, 2, 4, 6, 7 & 8)

8.3.2 AIR INTAKE AND EXHAUST SYSTEM SPECIFICATIONS

900 RPM

Blower speed - RPM
8 & l6-Cylinder 2450
12-Cylinder 1825

Blower capacity - approximate cfm.
8 & 16-Cyl. 3550
12-Cyl. 2650

Blower pressure - Inches of mercury
(Based on engine speed of 900 RPM) 7-9

Timing gear backlash -
New ..... 0.013 mm-0.10 mm (.005"-.004")
Max. ..... 0.140 (.0055")

Blower base twist or warp - Max.
Front rotor bearing diametric clearance -
New ..... 0.08 mm-0.140 mm (.003"-.0055")
Max. ..... 0.015 mm(.006")

Front rotor bearing thrust clearance
New ..... 0.05 mm-0.10 mm (.0025"-.004")
Max ..... .0.10 mm (.004")

Rear rotor bearing diametric clearance
New ..... 0.063 mm-0.10 mm (.0025"-.004")
Max ..... 0.114 mm (.0045")

Timing gear face runout - T.I.R.
Max. Rotor-to-front end plate clearance
New. ..... 0.216 mm-0.495 mm (.0085"-.0195")
Max. ..... 0.56 mm (.022")

Rotor-to-rear end plate clearance
New ..... 0.30 mm-0.58 mm (0.12"-.023")
Max ..... .0.64 mm (0.25")

Rotor-to-rotor clearance - Upright and Inverted
New ..... 0.25 mm-0.56 mm (.010"-.022")
Max. ..... 0.56 mm (.022")

Rotor-to-housing clearance - Upright
New ..... 0.30 mm-0.51 mm (.012"-.020")
Max. ..... 0.51 mm (.020")

Rotor-to-housing clearance - Inverted

New .....0.38 mm-0.53 mm (.015"-.021")
Max. ..... 0.53 mm (.021")

Quill shaft runout (after assembly) T.I.R.

Max. ..... .64 mm (.025")

Static or dynamic balance of rotor assembly -

Max. .....007 Nm (1 ounce-inch)

8.3.3 EQUIPMENT LIST

	PART NO.
Gasket sealing compound -0.47 liter (1 pt.)	8178639
Thread lubricant, high temperature -0.946 liter (1 qt.)	8278929
Turbocharger lifting eye-bolts	8496116
Exhaust manifold torque tool kit	8463511
Long adaptor	8463512
Short adaptor	8463513
Extension	8463514
Torque wrench	8463515
Turbocharger lifting sling	9570412
Sealant, Supplementary Anaerobic	
-50 ml container	40047938
-300 ml container	40047939

SECTION 9. LUBRICATING OIL SYSTEM

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9.1 DESCRIPTION 8, 12, AND 16-CYLINDER ENGINES

The engine lubricating oil system used on 8, 12, and 16-cylinder engines 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. These pumps take oil from the strainer housing at the right front of the engine. The scavenging oil pump is a separate pump which takes oil from the engine oil pan sump and pumps it through the off-engine lube oil filter and cooler assemblies before returning to supply the strainer housing. All the pumps are driven from the accessory gear train at the front of the engine. Parts of this oil system and a schematic arrangement of oil circulation are shown in Figure 9-1.

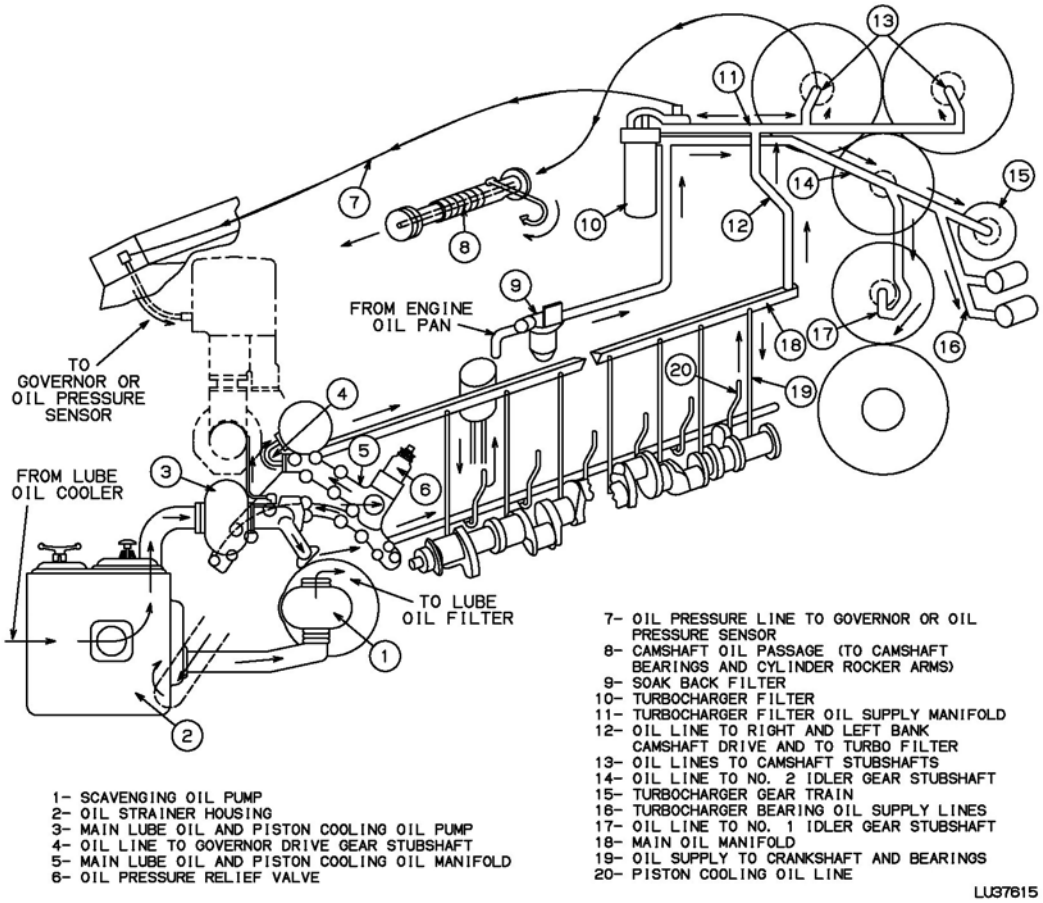


Figure 9-1. Typical Lubricating Oil System (8, 12, or 16-Cylinder Governor Controlled Engine Shown)

9.2 20-CYLINDER ENGINES

The engine lubricating oil system used on 20-cylinder engines combines the three systems (main lubricating system, piston cooling system and the scavenging oil system) into one system using a single high capacity oil pump. This pump “scavenges” oil from the engine oil pan through the supply manifold and strainer assembly, then pumps it through the off-engine lube oil filter and cooler assemblies. Oil is returned to the engine through a “Y” branch manifold which divides it proportionally between the main lubricating oil system and the piston cooling oil system. The pump is driven from the accessory gear train at the front of the engine. Parts of this oil system and a schematic arrangement of oil circulation are shown below in Figure 9-2.

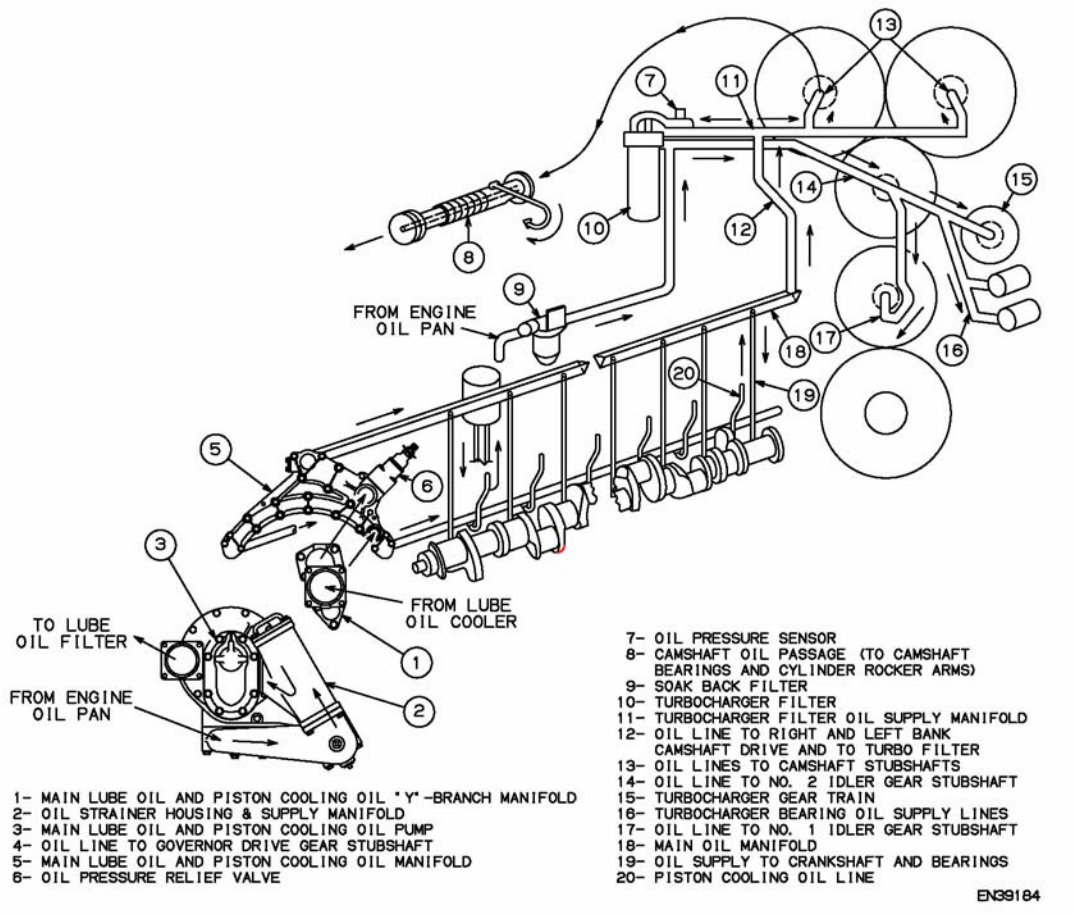


Figure 9-2. Typical Lubricating Oil System (20-Cylinder EMDEC Controlled Engine Shown)

9.2.1 MAIN LUBRICATING OIL SYSTEM

The main lubricating oil system supplies oil under pressure to most of the moving parts of the engine. Oil is pumped 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.

Oil tubes at the center of each main bearing “A” frame conduct oil from the main manifold to the upper half of the 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. On governor controlled engines, an oil pressure line is connected between the manifold passage and the low oil pressure device in the governor. On EMDEC controlled engines, a sensor is used to detect low oil pressure directly at the manifold passage or connected to it by an oil pressure line. Descriptive information for each low oil pressure detection system is contained in Section 13, Protective Devices.

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 turbocharger bearing area. To prevent possible overheating 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 (on governor controlled engines) or a sensor (on EMDEC controlled engines). Descriptive information for each is contained in Section 13, Protective Devices.

9.2.2 LUBE OIL COOLER

The lube oil cooler, Figure 9-3, is mounted on the equipment rack and serves to transfer excess heat from the lube oil system to the cooling system. The assembly consists of a central coolant core surrounded by a steel housing.

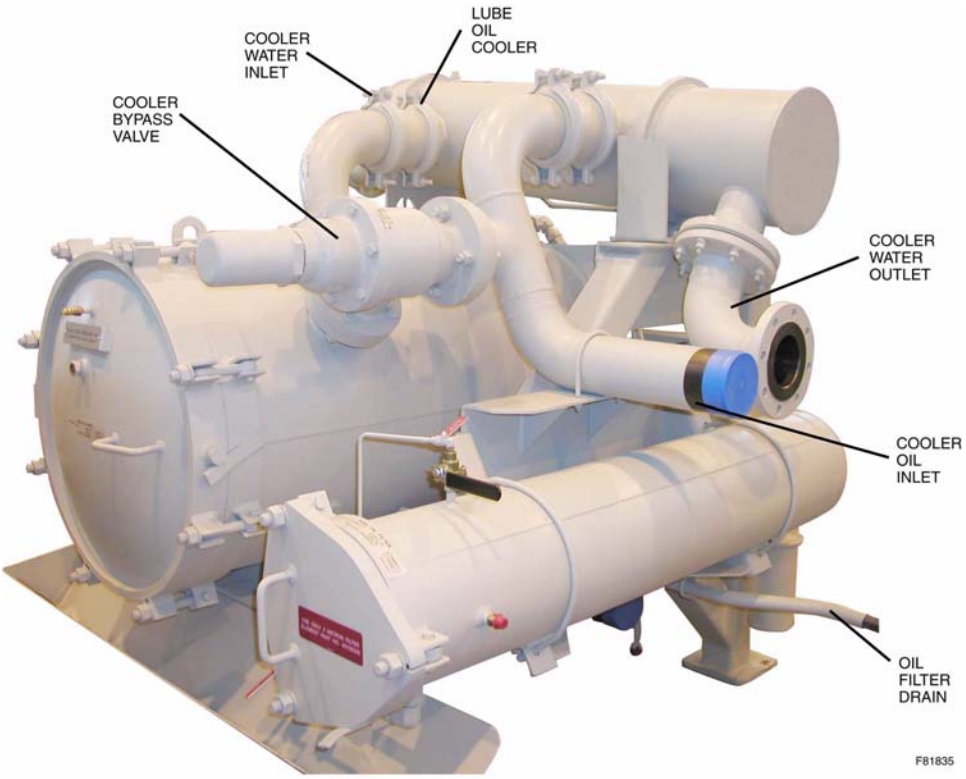


Figure 9-3. Lube Oil Cooler

Coolant returning from the radiators flows into the rear connection, and exits by a flange connection out to the water pump inlet. Lubricating oil from the scavenging pump is brought into the outer housing and directed around the tubes of the core by internal baffles. Cooled lube oil flows to the filter housing. Note that the cooler is equipped with an external bypass valve mounted on the lube oil filter tank.

Do not perform major oil cooler service, except for the following reasons:

- Operation is unsatisfactory.
- Oil cooler core leak(s) suspected.
- Cooling water/ engine lube oil temperature differential is too great (contact service representative for limits).

9.2.2.1 LEAK DETECTION

There are no simple methods of detecting water leaking into the oil side of the lubricating oil cooler assembly. However, evidence of water contamination will show up in the routine engine oil samples taken and analyzed as prescribed in the Scheduled Maintenance Program. Any such evidence calls for a close examination of the cooler and inspection of the engine. Maintenance Instructions for cleaning and repair of the lubricating oil cooler are listed on the Service Data at the end of this section.

9.2.2.2 DIRTY CORE DETECTION

Proper lubricating oil cooling depends on maximum lube oil cooler performance. Engine shutdowns caused by hot oil may indicate oil cooler efficiency loss.

To correctly evaluate oil cooler performance, record oil and water temperature levels while operating the locomotive at full-rated load and engine speed long enough to stabilize the temperatures. Oil and water temperature can be easily checked using the EM2000/Fire screen data meter functions (signal OTEgIF for oil temperature into the engine and signal EngTmpF for coolant temperature into the engine). The EMDEC service tool kit may also be used, however, note that the connection point for this tool is now located on the ECM interface board in the Electrical Locker.

Record temperature readings and compare with lubricating oil cooler service limits (contact service representative for limits).

When oil temperature for a given water temperature is higher than limit indicated, remove and service the oil cooler.

WARNING

After determining that hot oil has caused an engine shutdown, make no further engine room inspections until engine has cooled sufficiently to prevent any possibility of igniting hot oil vapors. Allow at least two hours for an adequate cool down of the engine.

When a low oil shutdown occurs, always make sure there is an adequate supply of water and oil before attempting to restart the engine. Check engine water temperature. Do not add cold water to an overheated engine.

The EMDEC service tool kit will enable you to verify oil pressure, water pressure, and oil temperature simultaneously. Anytime there is a problem encountered, a fault will be logged in the EMDEC fault archive. Experience has shown that EMDEC equipped engines with hot oil shutdown faults, require thorough inspection of the cooling system for signs of overheat and/or water pump failure.

9.2.3 PISTON COOLING OIL SYSTEM

The piston cooling oil system receives oil from a common supply with the main lube oil system and delivers it 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 piston 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.

9.2.4 SCAVENGING OIL SYSTEM

The scavenging oil system takes oil through a scavenging oil strainer from the oil pan sump or reservoir. A pump then forces the oil through the oil filters and oil cooler which are located near the engine. Oil then returns to the engine to supply the main lube oil and piston cooling oil systems with cooled and filtered oil. On 8, 12, and 16-cylinder engines, the oil passes through the strainer housing to the main lube oil and piston cooling oil pumps. Excess oil spills over a dam in the strainer housing and returns to the oil pan. On 20-cylinder engines, the oil returns directly to the main lube oil and piston cooling oil systems.

9.2.5 OIL GAUGE

An oil level gauge, Figure 9-4, extends from each 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.



Figure 9-4. Typical Oil Level Gauge (One Each Side Of Oil Pan)

9.3 MAINTENANCE

9.3.1 MAIN LUBRICATING OIL PRESSURE

Adequate lubricating oil pressure must be maintained at all times when the engine is running.

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, either a shutdown feature built into the governor or an EMDEC sensor will automatically protect the engine by shutting it down. Maximum pressure is determined by the relief valve setting.

9.3.2 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.

9.3.3 LUBE OIL PRESSURE RELIEF VALVE - TIER 2

The lube oil pressure relief valve, Figure 9-5, is installed on the lube oil manifold, inside the accessory gear train housing on the left side of the engine. Access for valve inspection and adjustment is provided by removal of the engine protector.

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.



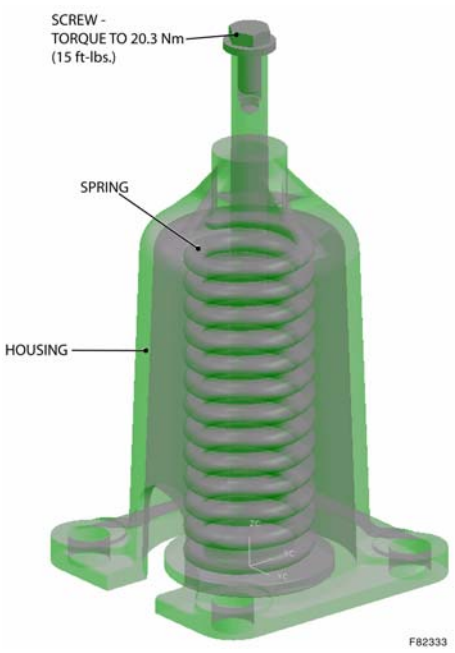


Figure 9-5. Lube Oil Pressure Relief Valve

9.3.3.1 INSPECTION AND MAINTENANCE

The oil pressure relief valve should be removed and replaced with a qualified valve at six year intervals:

CAUTION

Be aware that a damaged or improperly installed relief valve or gasket will cause low oil pressure problems.

9.3.3.2 INSTALLATION

When installing relief valve on engine, make sure that the bypass port is positioned in the downward direction.

9.4 PISTON COOLING OIL PIPE

9.4.1 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.

9.4.2 MAINTENANCE

Unlike previous EMD engines, the alignment of the piston cooling oil pipe to the inlet hole in the piston carrier on 710G3B engines does NOT require the use of an alignment gauge as the oil pipe nozzle itself extends into the carrier at bottom dead center, as shown in Figure 9-6. on page 9-11.

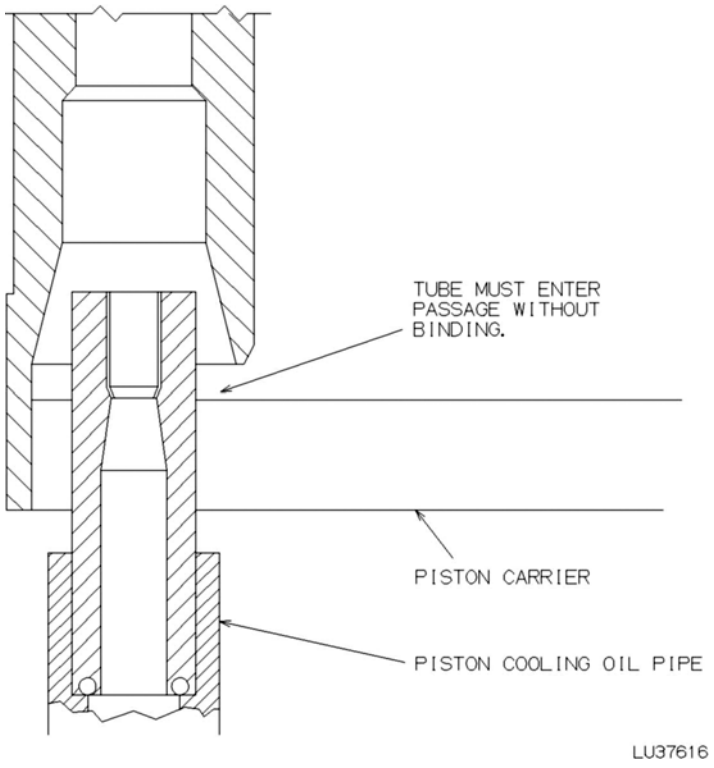


Figure 9-6. Piston Cooling Oil Pipe Alignment

A visual inspection can be done by bringing the piston to bottom dead center. The nozzle of the oil pipe should enter the inlet hole in the piston carrier without binding in this position. If an interference exists, 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.

CAUTION

On 8, 12, and 16-cylinder engines, the piston cooling section of main lube oil pump has been modified for use with the new piston cooling oil pipe used on 710G3B engines. Care must be used during any service of the oil pumps or piston cooling oil pipes on 710G3B engines to ensure that there is no intermix of parts with other EMD engine models. Do NOT apply any of the older type piston cooling oil pipes to 710G3B EMD engines. Do NOT apply any of the 710G3B main lube oil and piston cooling oil pump assemblies to other EMD engines with older type piston cooling oil pipes.

9.5 CHECKING OIL VISCOSITY

Oil viscosity should be checked on a routine basis to monitor the suitability of the oil for continued use. By comparing the viscosity at different intervals taken at the same temperature, excessive 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 and 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 coming into the engine from fuel combustion, as well as the normal airborne contaminants which are not caught by the air filters. It is therefore beneficial to drain the oil and eliminate these contaminants.

9.6 CHANGING OIL

Engine lube oil should be drained periodically, filters replaced, and strainers and/or screens cleaned as 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.

9.6.1 GENERAL PROCEDURE

1. Shut down the engine.
2. On engines provided with an engine mounted box style oil strainer housing, open drain valve in housing to drain oil into the engine 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 strainer(s) from strainer housing, and remove the oil filters from the filter housing(s).
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/or screens. Install new elements in filter housing(s). Prepare system to receive new oil.
10. Recharge engine with new lubricating oil qualified for use. On 8, 12, and 16-cylinder engines, add oil through square filler opening in strainer housing box. On 20-cylinder engines, add oil through the capped filler opening on the upper right side of the accessory drive cover. Check engine oil level on the oil gauge.

CAUTION

On 8, 12, and 16-cylinder engines, ensure that strainer housing box 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 cooling oil pumps on starting

11. Pour a liberal quantity of oil over cylinder heads and top deck components before starting.
12. 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 handholes, so care must be taken when the oil pan handhole covers are removed.

9.7 OIL STRAINER HOUSING

9.7.1 DESCRIPTION 8, 12, AND 16-CYLINDER ENGINES

The oil strainer housing used on 8, 12, and 16-cylinder engines, shown in Figure 9-7, page 9-14, 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.

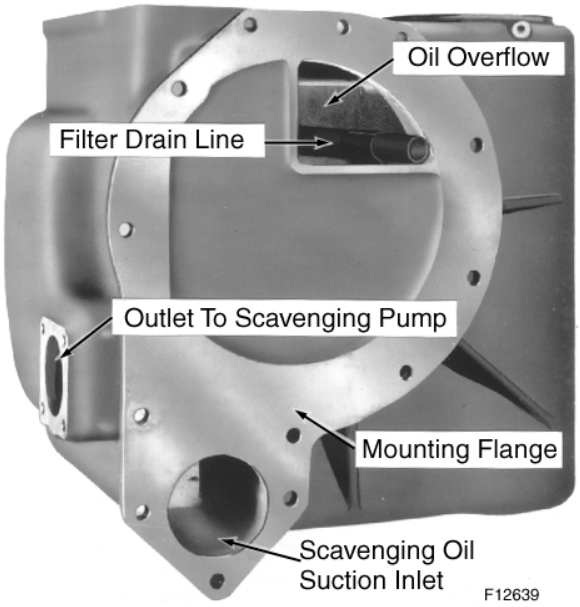


Figure 9-7. Oil Strainer Housing (8, 12, and 16-Cylinder Engines)

The two main lube oil pump strainers, Figure 9-8. on page 9-15, 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. 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 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 the pump through a cast passage in the housing.

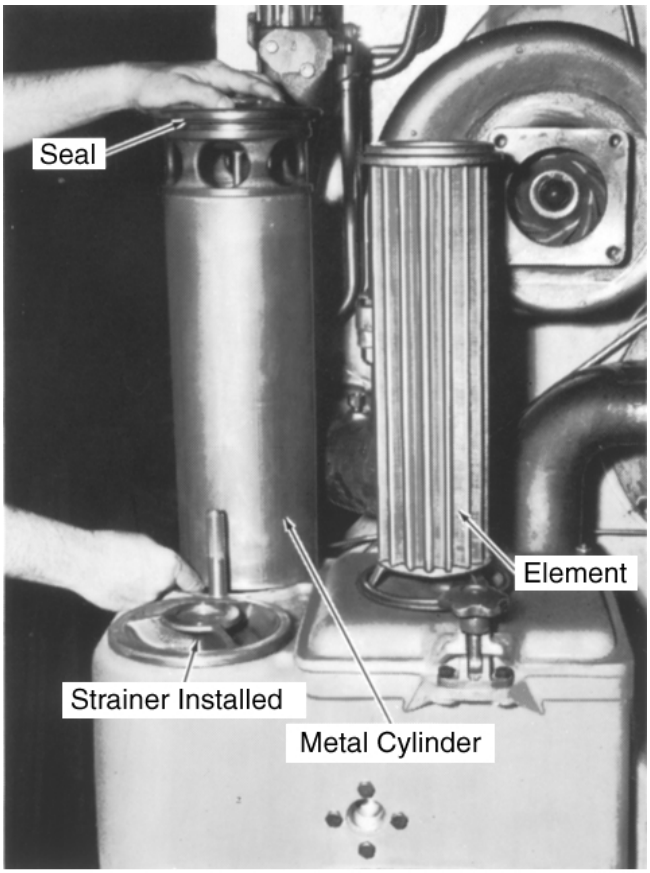


Figure 9-8. Main & Piston Cooling Oil Pump Strainers (8, 12, and 16-Cylinder Engines)

The scavenging oil pump strainer, Figure 9-9. on page 9-16, 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 Figure 9-7. on page 9-14.

An oil level is maintained in the strainer housing up to the bottom of the overflow opening Figure 9-7. on page 9-14. Excess oil returns to the oil pan sump. A spring-loaded valve, Figure 9-10. on page 9-16, 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, Figure 9-10, 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 during the period of draining.

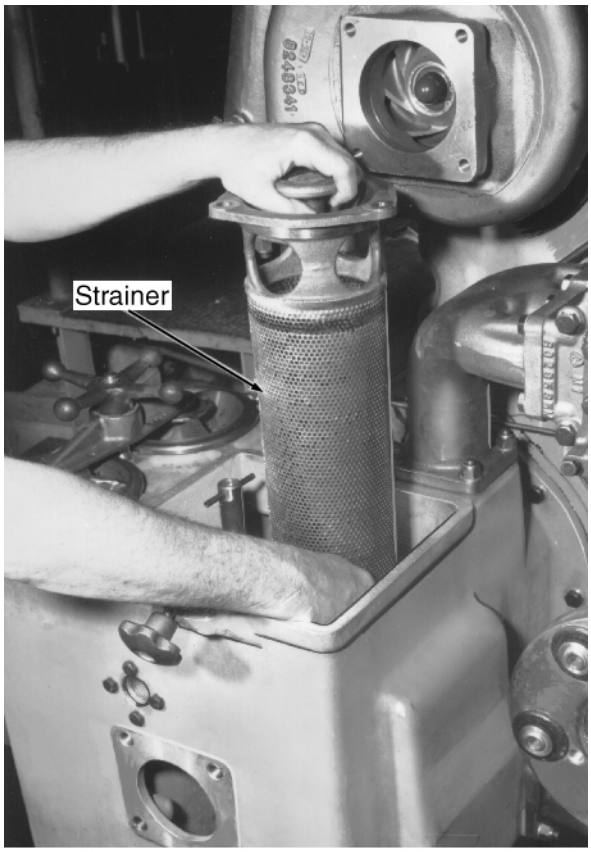


Figure 9-9. Scavenging Oil Pump Strainer (8, 12, and 16-Cylinder Engines)

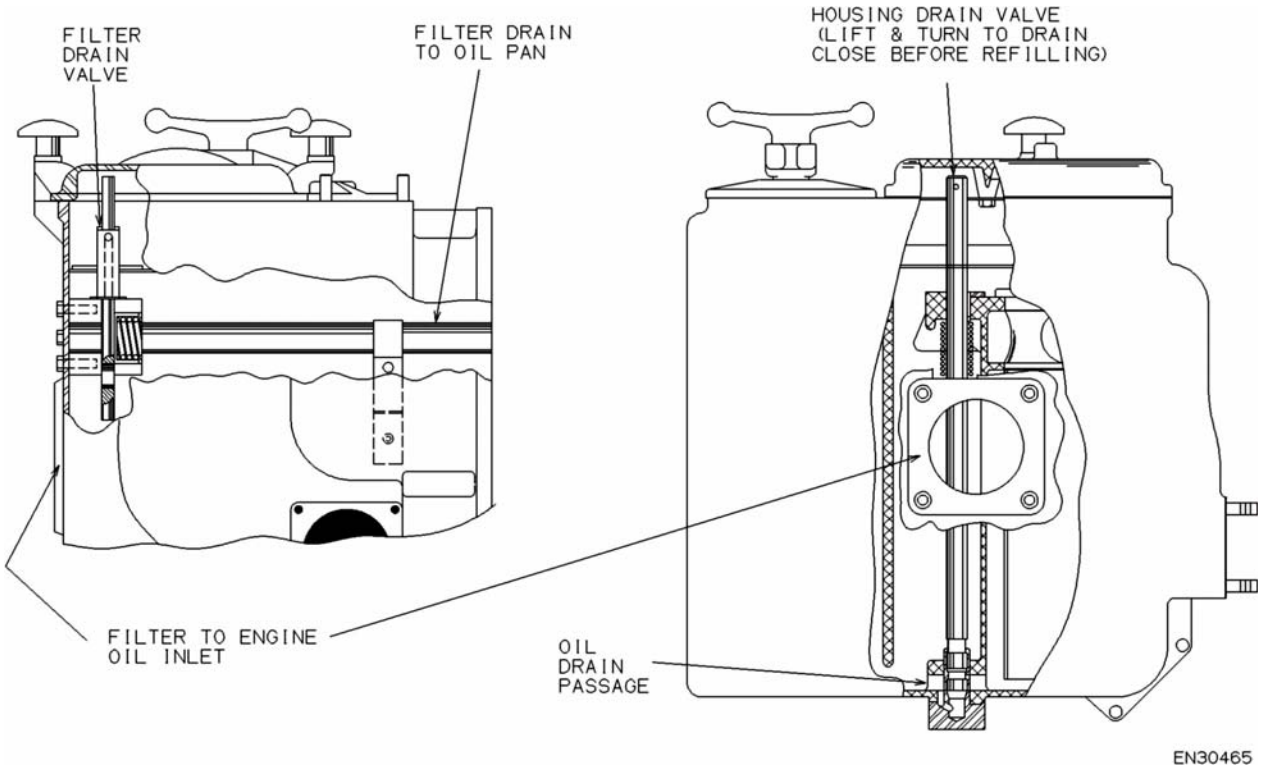


Figure 9-10. Strainer Housing Drain Valves (8, 12, and 16-Cylinder Engines).

9.7.2 20-CYLINDER ENGINES

The oil strainer housing used on 20-cylinder engines, shown in Figure 9-11, is a cylindrical shaped cast iron housing which mounts between the oil pump and supply elbow on the right front side of the engine on the accessory drive cover. It contains a single “in-line” strainer for the oil pump supply.

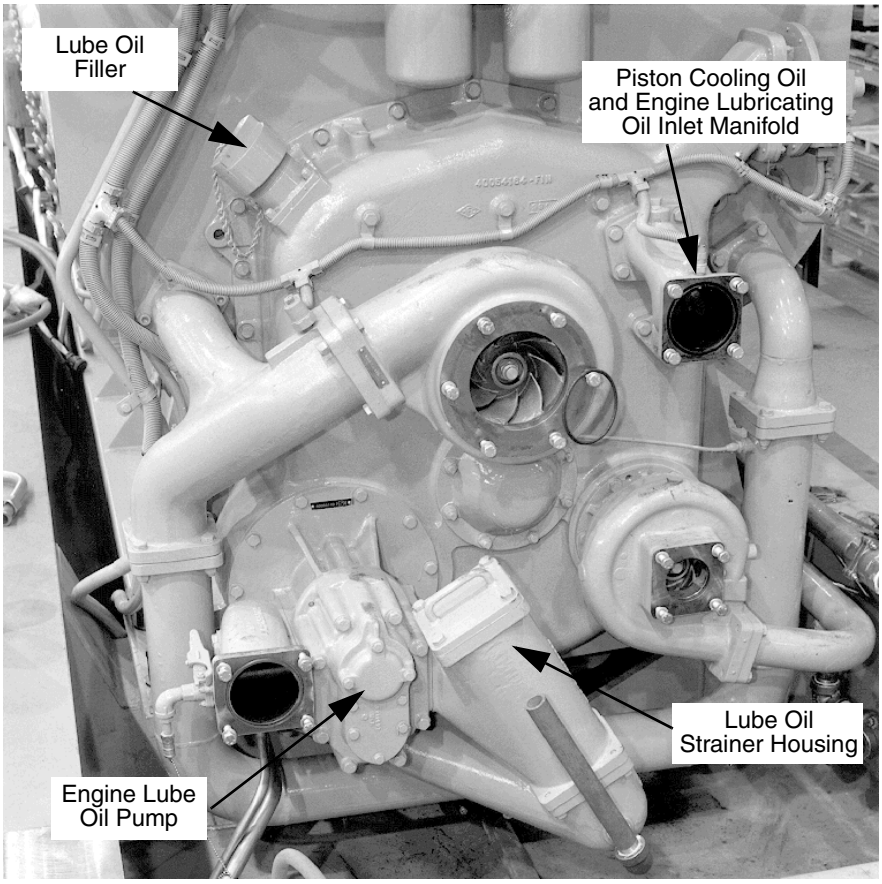


Figure 9-11. Oil Strainer Housing (20-Cylinder Engines)

9.7.3 MAINTENANCE

All lube oil strainers should be removed at each oil change, and strainers and housings thoroughly cleaned using a petroleum solvent.

As previously described, the engine lube oil strainers used in the strainer housing box of 8, 12, and 16-cylinder engines 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, ensure 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 strainer furthest 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.

9.8 LUBE OIL SEPARATOR

9.8.1 DESCRIPTION

The oil separator, Figure 9-13, is an elbow-shaped housing containing a securely held wire mesh screen element. It is mounted on the turbocharger housing. An ejector assembly, mounted on the separator cover, is connected to the inner and outer eductor tubes in the exhaust stack by a flanged pipe elbow and flexible tube assembly.

Air under pressure passing through the ejector assembly creates a suction which draws up engine oil vapors through the screen element. In addition, the eductor tube inserted into the turbine exhaust also creates a suction on the oil vapors. The oil collects on the screen element and drains back into the engine. The remaining gaseous vapor is discharged into the exhaust stack and vented to the atmosphere.



Figure 9-12. Lube Oil Separator

9.8.2 MAINTENANCE

The screen should be removed from the oil separator and cleaned at the interval specified in the Scheduled Maintenance Program.

1. Shut down the engine and disable the Auto Start system. To disable the Auto Start system, press the EMERGENCY FUEL CUT OFF & ENGINE STOP push-button and, if required by railroad rules, lock it down.
2. Disconnect the flexible air line at the ejector and remove the bolts from the separator cover.
3. Unbolt the flexible tube and elbow assembly from the exhaust stack. Remove the separator cover, ejector, flexible tube and elbow as an assembly.
4. Remove eductor assembly tubes from the stack.
5. Separate inner eductor tube from outer tube by inserting a screwdriver at the top of the eductor flanges.

NOTE

With exhaust stack connected to the silencer, viewing down the stack to inspect the turbocharger diffuser is prevented. This inspection can be performed instead by using a light and mirror through the eductor tube connection when eductor assembly is removed for cleaning.

6. Clean carbon deposits from the inside and outside of both eductor tubes.
7. Remove screen element from separator cover and wash in petroleum solvent. Rinse element 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. Replace the element and cover, ejector, flexible tube and elbow assembly. Verify the element is not installed upside down as this will cause low vacuum problems
11. Connect the flexible air line to the ejector. Blow out this line before application to verify there are no obstructions or restrictions.

For lube oil separator to operate properly, crankcase suction needs to be in a range of from 50.8 mm (2") H_2O to 203 mm (8") H_2O. If crankcase suction falls outside of this range after engine maintenance work, a thorough engine inspection should be performed to determine the cause. If no obvious cause is found, crankcase suction can be brought back into range by substituting a different size air ejector nozzle. See Service Data for listing of available nozzles.

Crankcase suction can be measured by connecting a U-tube manometer to an oil dipstick tube. Measurement should be taken at full load and speed, preferably after at least one hour of running time as crankcase suction tends to decrease as the engine temperature increases.

9.9 LUBE OIL SEPARATOR - TIER 3

9.9.1 DESCRIPTION

The oil separator, Figure 9-13, is an elbow-shaped housing containing a securely held wire mesh screen elements. It is mounted on the turbocharger housing. An ejector assembly, mounted on the separator cover, is connected to the inner and outer eductor tubes in the exhaust stack by a flanged pipe elbow and flexible tube assembly.

Air under pressure passing through the ejector assembly creates a suction which draws up engine oil vapors through the screen element. In addition, the eductor tube inserted into the turbine exhaust also creates a suction on the oil vapors. The oil collects on the screen elements and drains back into the engine. The remaining gaseous vapor is discharged into the exhaust stack and vented to the atmosphere.



Figure 9-13. Lube Oil Separator

9.9.2 .TIER 3 LUBE OIL SEPARATOR COMPONENTS

The Tier 3 oil separator is a single bank, dual stack design as shown in Figure 9-14. The assembly houses two different filter elements.

The first stage is an element consisting of a wire mesh filter and is considered long life.

The second stage is a fiber glass/wire mesh co-knit element. This element is designed as a filter that has to be replaced on a periodic basis. The second stage filter element is housed in the upper aluminum housing. Access to the filter element is provided through a standard hand-hole cover. A filter retainer is also provided to prevent any unintended movement of the filter past the outlet port as shown in Figure 9-15. A step on ladder and a filter access door as shown in Figure 9-16 is included as part of the hood structure to get access to the filter element during servicing.

The ejector assembly contains a nozzle which controls the crankcase pressure. The ejector is charged by air from the left bank after cooler.

NOTE

Refer to locomotive trouble shooting guide TSG 01-006 for correcting low crankcase suction problems in field

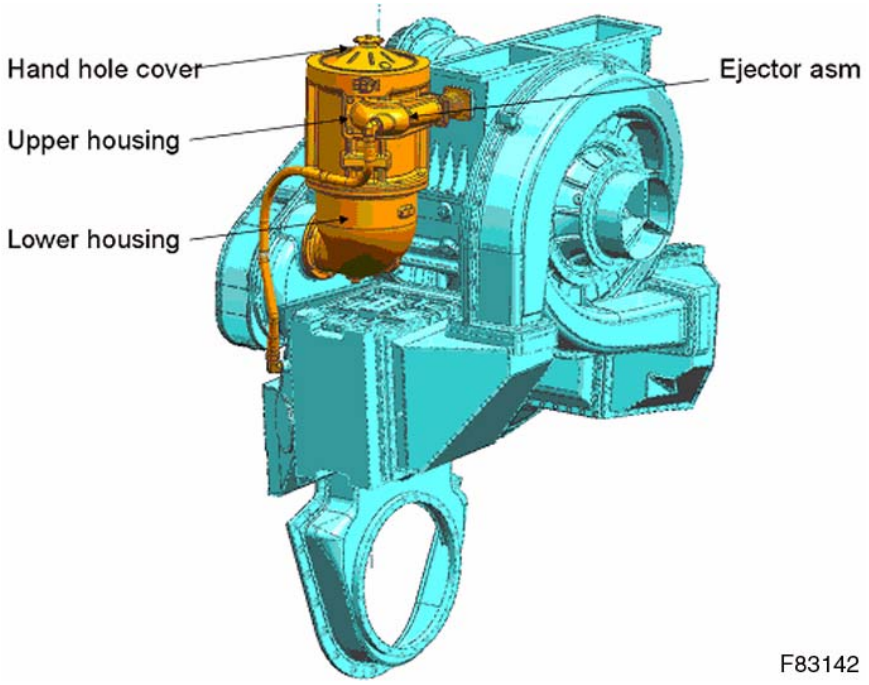


Figure 9-14. Oil Separator

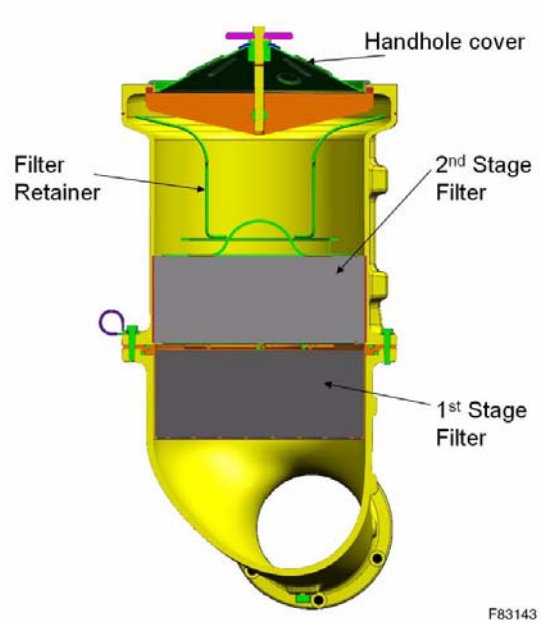


Figure 9-15. Filter Retainer 1st and 2nd Stage Filter

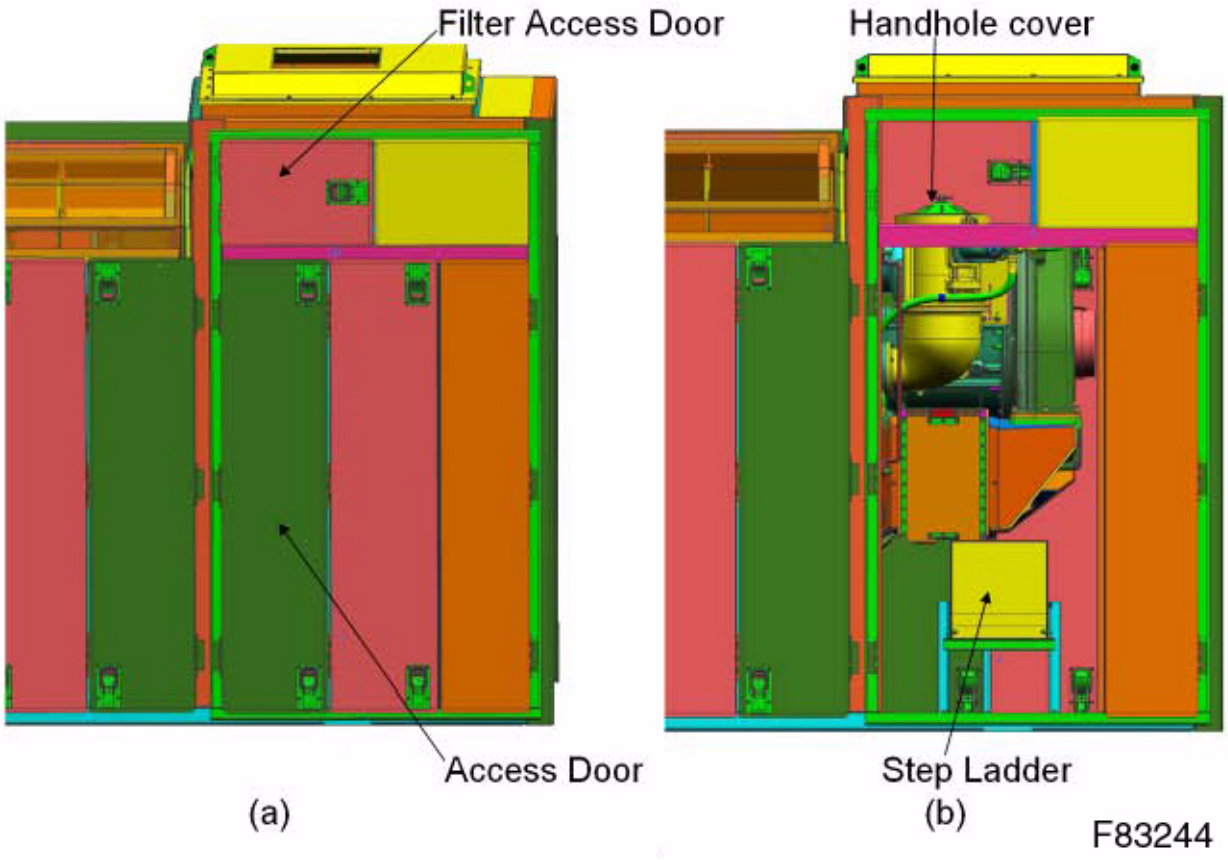


Figure 9-16. Filter Access

9.9.3 SECOND STAGE FILTER REPLACEMENT

The 2nd stage filter has to be inspected and replaced on a periodic basis.

1. Every 184 days (With engine stopped)
   Remove the inspection cover of the oil separator assembly and Inspect the second stage filters for any damage. Continue usage if no visual indications of damage is noticed.

2. Every year (With engine stopped)
   Replace the second stage filter element. Inspect the first stage filter element visually for damages.

   The recommended procedure for filter removal is as follows

CAUTION

Before following the procedure below, make sure the locomotive is properly locket out and flagged per your local procedures. Ensure the proper job briefing, safety procedures and Personal Protective Equipment required for the task was discussed.

	TASK	REFER
1.	Open the side access door and the filter access door in the turbo hood to reveal the hand hole cover and the step ladder	Figure 9-16
2.	Drop ladder into place and remove the hand hole cover **CAUTION: Ensure necessary fall prevention systems are in place before attempting to climb the ladder.**	
3.	Pull the cross bars in the filter retainer together till it clears the internal lip of the aluminum housing.	Figure 9-18
4.	Pull out the filter retainer	
5.	Pull out the second stage filter and discard	
6.	Inspect the first stage filter for any damage	
7.	Insert a new second stage filter guiding it past the hand hole cover seating face.	
8.	Push the filter down till it makes contact with the first stage filter.	
9.	Reinstall the filter retainer. • The filter retainer is designed not to make contact with the second stage filter in normal installed condition. • It is intended as a fail-safe system to prevent the movement of the second stage filter beyond the outlet hole in the housing during engine operation.	Figure 9-15
10.	Ensure the gasket in the hand hole cover is intact and not twisted	
11.	Reinstall the hand hole cover and torque to 20 ft-lbs	
12.	Bring ladder back to storage position and close both access doors.	

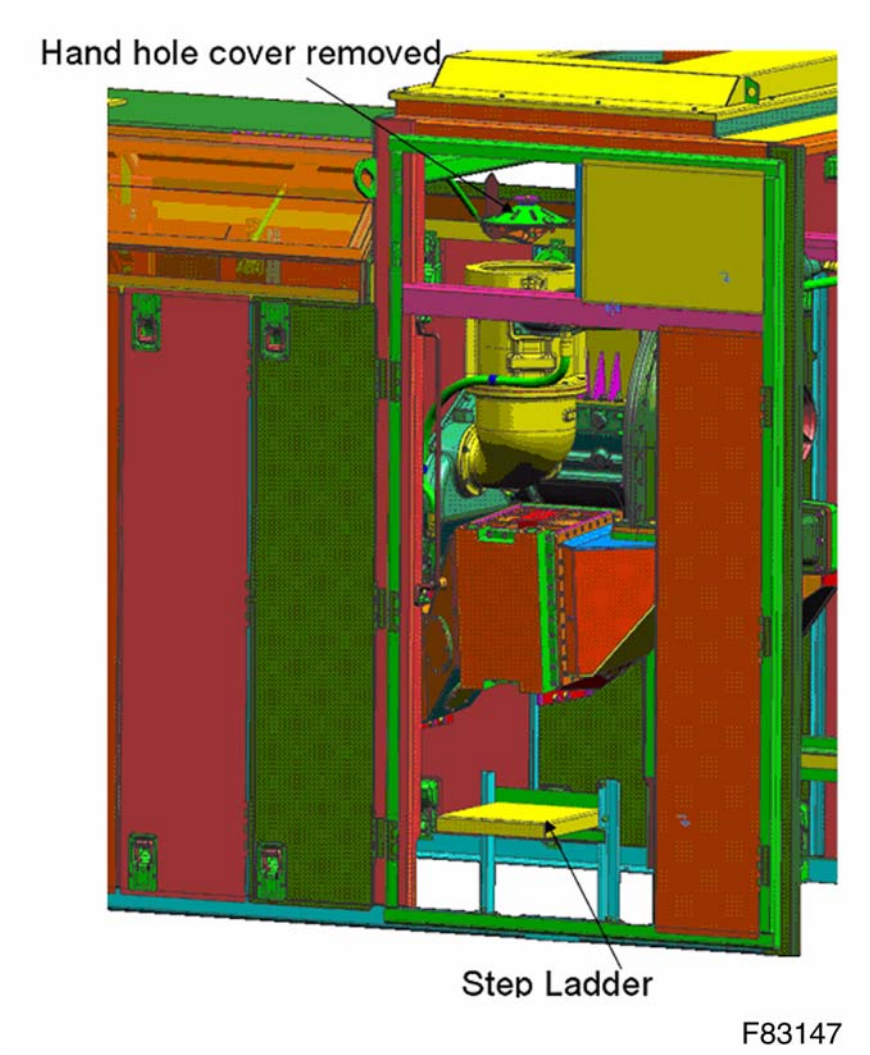


Figure 9-17. Hand hole cover removed - step ladder location

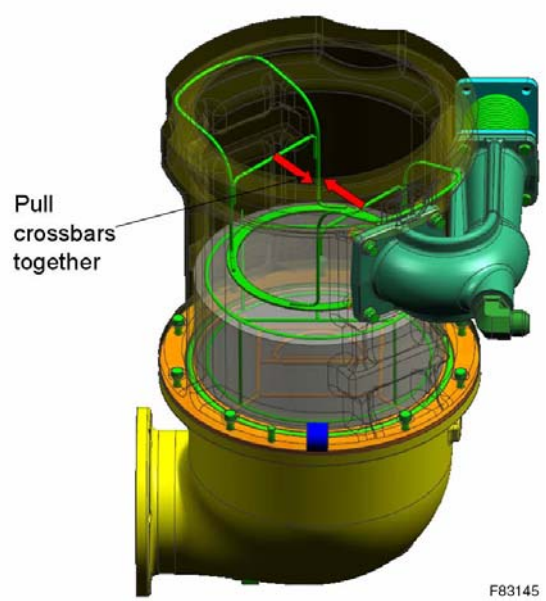


Figure 9-18. Filter Retainer

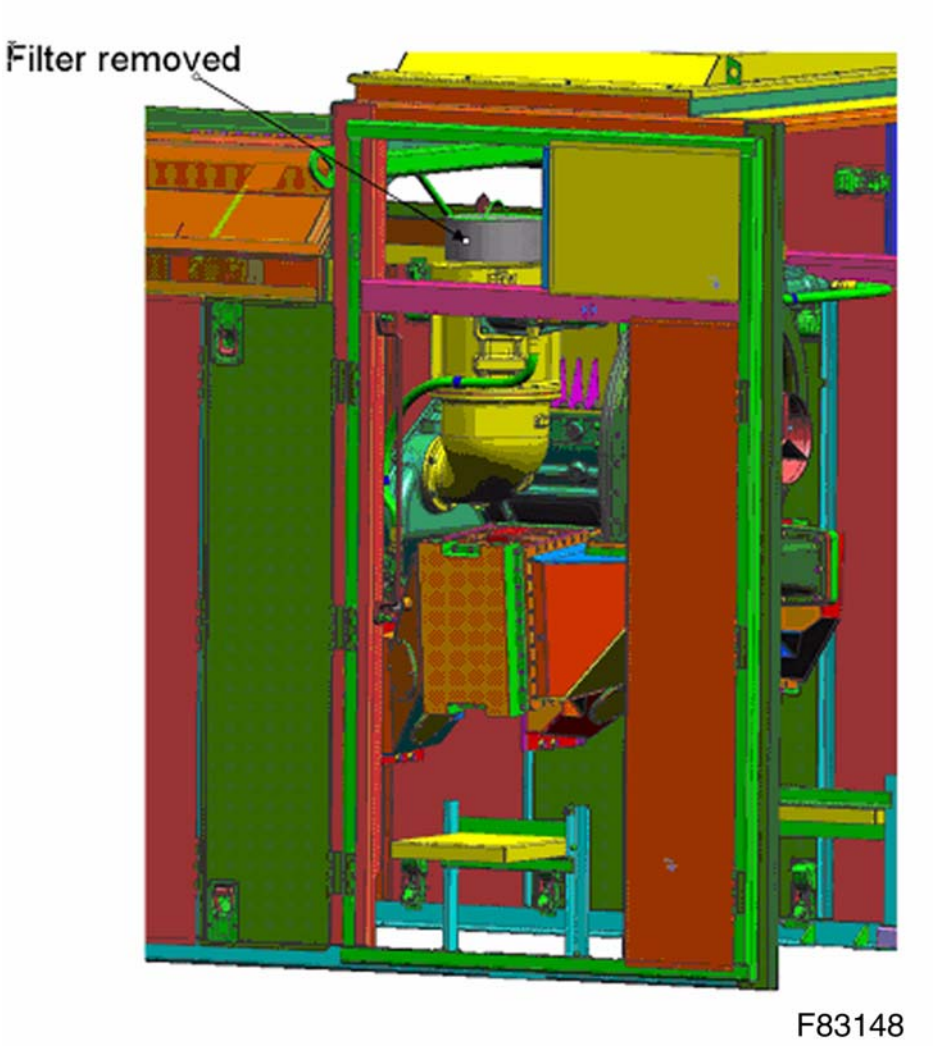


Figure 9-19. Filter Removed.

9.10 MAIN LUBE OIL AND PISTON COOLING OIL PUMPS

9.10.1 DESCRIPTION

The main lube oil and piston cooling oil pumps, Figure 9-20, are contained in one housing.

On 8, 12, and 16-cylinder engines, 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. This 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.

On 20-cylinder engines, the two sections of the pump perform the combined functions of the main lube oil, piston cooling, and scavenging oil pumps.

No spacer plate is used between the sections and the divided inlet and outlet openings connect to common “Y”-branch suction and discharge manifolds. This pump assembly mounts on the lower right side of the accessory drive housing and is driven by the accessory drive gear.

CAUTION

On 8, 12, and 16-cylinder engines, the piston cooling pump section of this assembly has been modified for use with a new piston cooling oil pipe used on 710G3B engines. Care must be used during any service or rebuild of these pumps to ensure that there is no intermix of parts with other EMD engine model oil pumps. Do NOT apply any of the 710G3B main lube oil and piston cooling oil pump assemblies to other EMD engines.

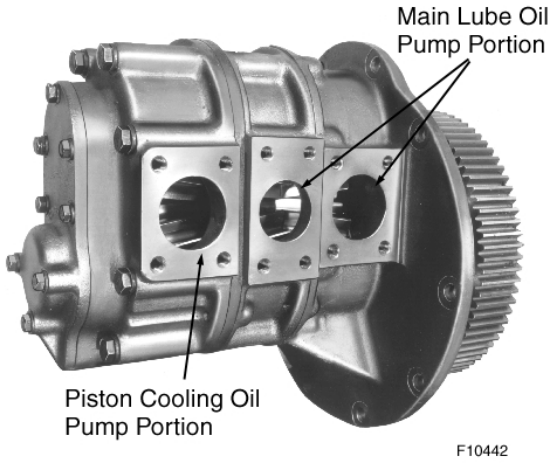


Figure 9-20. Main Lube Oil And Piston Cooling Oil Pumps - (12-Cyl. Shown)

9.10.2 MAINTENANCE

NOTE

In the following “Disassembly” and “Assembly” procedures, disregard references to “center body” for 8, 16 and 20-cylinder engines. Also, disregard “center gear” for 8-cylinder engines and “spacer” for 20-cylinder engines.

9.10.2.1 DISASSEMBLY

1. Clean the pump externally before disassembly.
2. Hold the pump in a suitable vise.

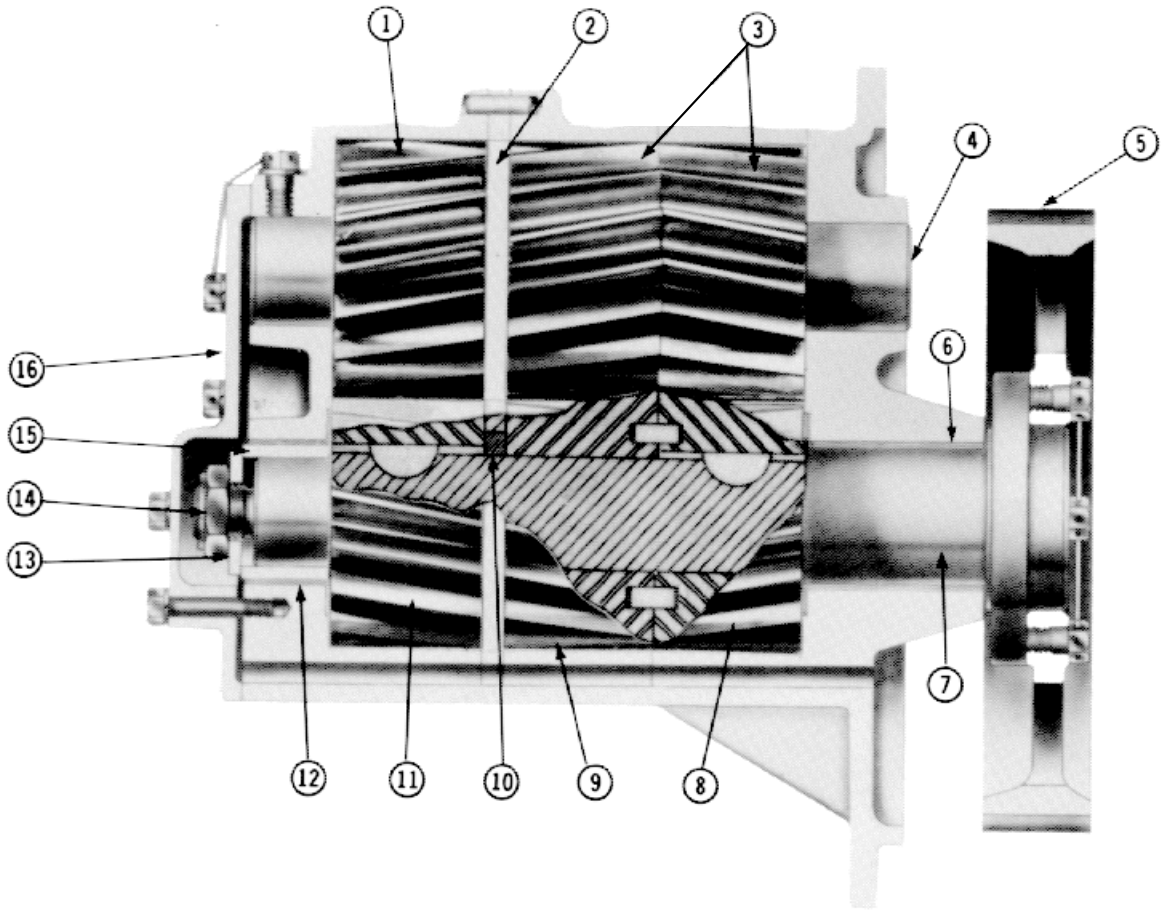
   As a safety precaution, provide an additional support at the center of the pump until the front body, bushing and piston cooling pump gears are removed.
3. Remove the long bolts holding the front body to the rear body.
4. Using a rawhide mallet, tap the front body at the inlet and outlet openings to remove the front body, cover, idler shaft, and outer driven gear as an assembly, Figure 9-21. on page 9-28.

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 to drive shaft and press the shaft down a maximum of 12.7 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 12.7 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 lube oil pump center driven gear and drive gear assembly.
13. Using a rawhide mallet, remove the center body portion of the pump.



1. Piston Cooling Driven Gear
2. Spacer Plate
3. Lube Oil Pump Driven Gears
4. Idler Shaft
5. Drive Gear
6. Inner Bushing
7. Drive Shaft
8. Lube Oil Pump Drive Gear
9. Lube Oil Pump Drive Gear Assy.
10. Collar
11. Piston Cooling Drive Gear
12. Front Bushing
13. Washer
14. Shaft Nut
15. Shaft Sleeve
16. Cover

Figure 9-21. Typical Main Lube Oil And Piston Cooling Oil Pump, Cross-Section (16-Cylinder Engine Shown.)

14. Remove the lube oil pump inner driven gear, drive gear, and key.
15. The pump drive gear and shaft assembly is then removed.

> **NOTE**
>
> Pump drive gear and shaft assembly should not be separated unless gear is being replaced or is required for use as a “dummy” gear during backlash adjustment of governor drive gear.

16. Keep all parts of the one pump assembly together. See note on page 9-20 regarding 710G3B oil pumps.

9.10.2.2 CLEANING

Clean all the individual parts of the pump using a petroleum solvent. After cleaning, dry the parts with compressed air.

9.10.2.3 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 or pitting.
3. Bushings with light scratches and small quantities of imbedded dirt may be reused after smoothing up, provided bore sizes are within the maximum limits.
4. Replace the bushings if any other adverse conditions exist. Details of construction and application of bushing installation and removal tools are shown in Figure 9-22. on page 9-30.
5. Using fine abrasive cloth on a smooth surfaced tool, clean off the gasket face of the pump bodies.

SPACER (Where Used):

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 Figure 9-23. on page 9-31.
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.

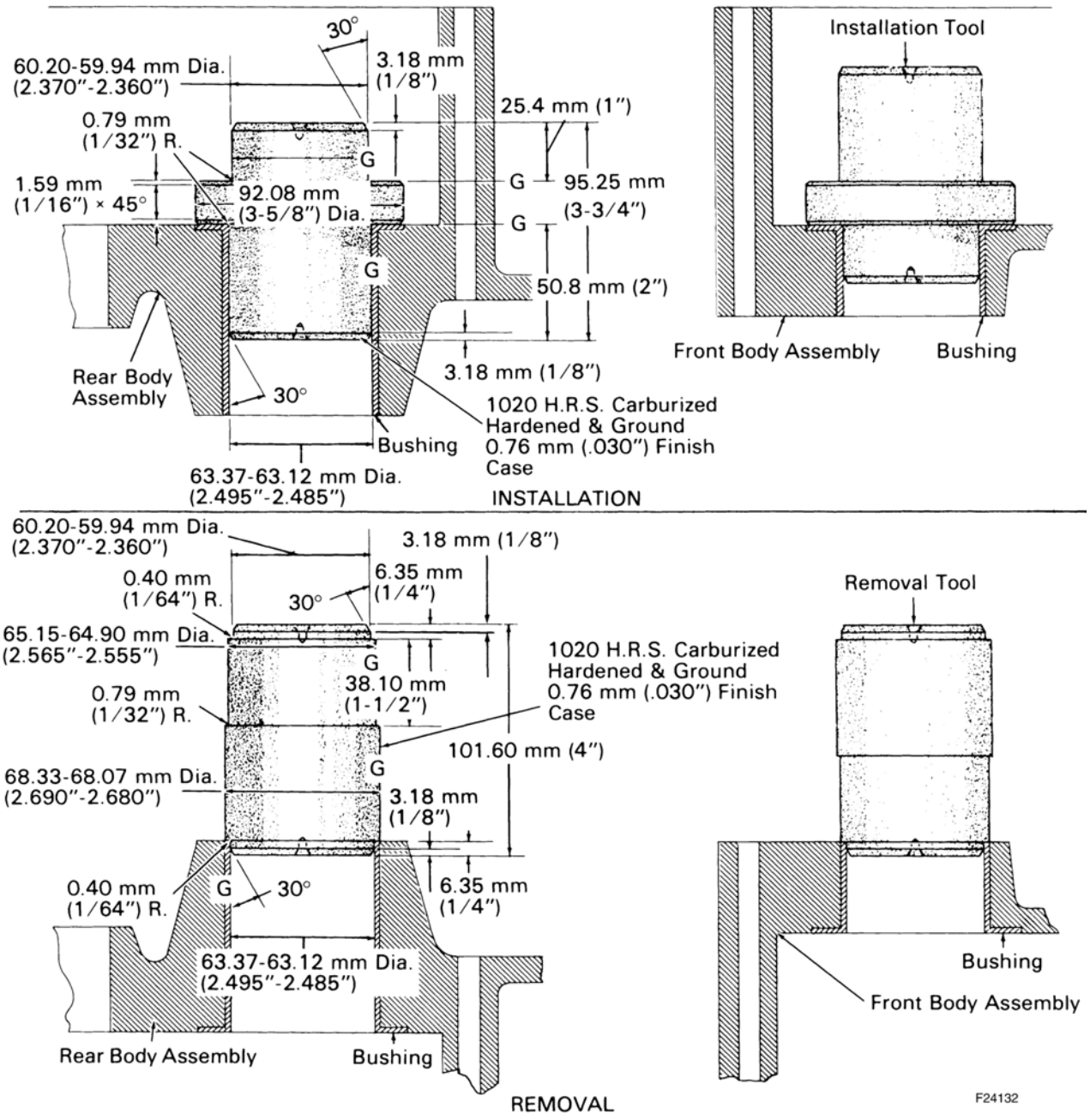


Figure 9-22. Oil Pump Body Bushing Tools

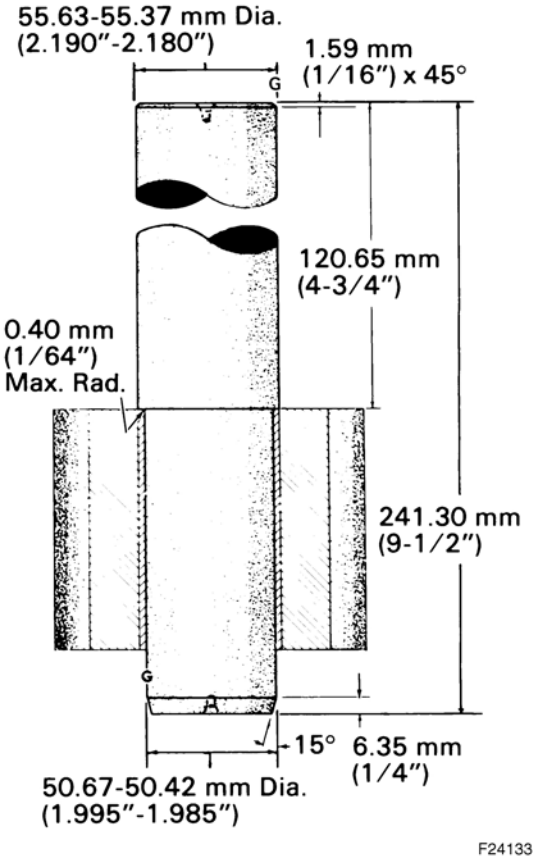


Figure 9-23. Oil Pump Driven Gear Bushing Tool

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.
3. Also, check the idler shaft to make certain that the shaft to bushing clearance is within maximum limits.

9.10.2.4 ASSEMBLY

1. Place the mounting flange of the cleaned and inspected rear body, Figure 9-21. on page 9-28, in the bench vise with the drive shaft bore facing up.

NOTE

If pump drive gear was removed from pump, reapply gear on drive shaft using four 1/2"-20 bolts. Apply thread lubricant to bolt threads and torque to 88 Nm (65 ft-lbs). Lockwire bolt heads together.

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.

NOTE

Refer to the 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 front body gasket and apply to the center body.
10. Apply the spacer plate to the center body and install the collar on 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 sealing compound, as described in the following Steps, does not apply to pumps used on 8-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. Re-spray 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 sealing 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

Sealing 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.
20. Complete assembly of the pump by installing the long bolts through the cover. Torque to specified value.
21. If possible, allow pump to remain unused for approximately 24 hours after torquing to ensure sleeve-to-shaft retention.

9.10.2.5 ASSEMBLY INSPECTION

1. After pump assembly, rotate the pump drive gear to check for gear noise or tight assembly.
2. Check the total 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, Figure 9-24. on page 9-33. 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. Clearance should be within specified limits.

CAUTION

Excessive thrust clearance (exceeding maximum limit), can cause the roll pins between the center and rear drive gears to shear off in service.

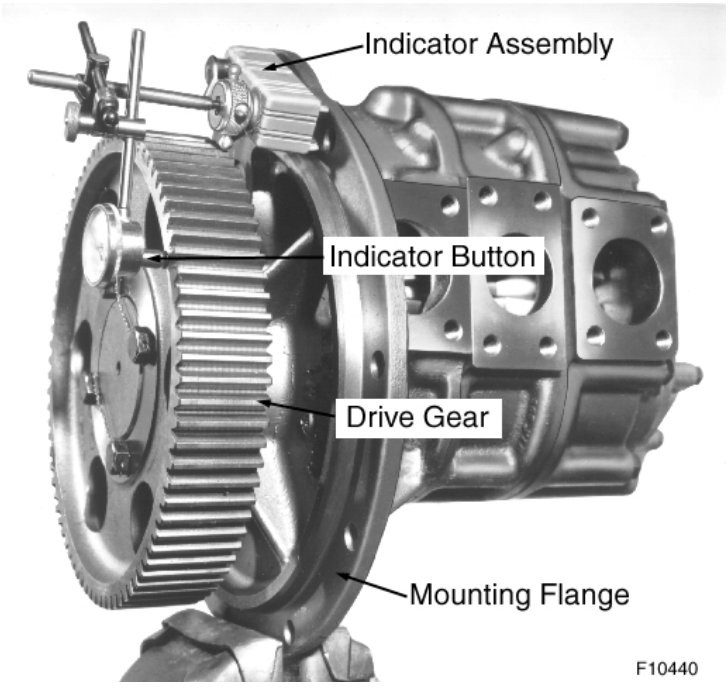


Figure 9-24. Checking Pump Drive Gear End Thrust

3. Leaving the indicator button on the outside 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 in contact with 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 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 teeth of the drive gear.

9.11 SCAVENGING OIL PUMP (8, 12, and 16-Cylinder Engines)

9.11.1 DESCRIPTION

The scavenging oil pump, Figure 9-25. on page 9-35, 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 onto 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.

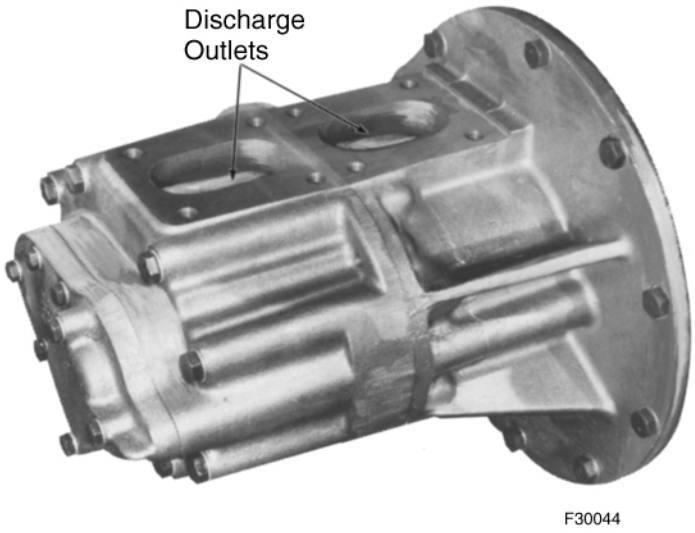


Figure 9-25. Typical Scavenging Oil Pump - (16-Cylinder Engine.)

9.11.2 MAINTENANCE

NOTE

In the following "Disassembly" and "Assembly" procedure, disregard references to "center body" for 8 & 16-cylinder engines. Also, disregard "center gear" for 8-cylinder engines.

Construction and maintenances 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 some of the main lube oil pumps.

9.11.2.1 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.

9.11.2.2 CLEANING

Clean all the individual parts of the pump using a petroleum solvent and rinse in hot water. Dry the parts, using compressed air.

9.11.2.3 INSPECTION

Refer to the corresponding procedures in the preceding “Main Lube Oil And Piston Cooling Oil Pumps” coverage. Also, refer to the Service Data at the end of the section. Check condition of star tolerance rings installed in counterbores of front body to dampen body bolt vibrations. If no signs of distress are apparent, rings may be reused when reassembling pump.

9.11.2.4 ASSEMBLY

1. Place the cleaned and inspected rear body in the vise with the drive shaft bore facing up.
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 the 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. Check to be certain star tolerance rings are in counterbores of front body, then 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.

9.11.2.5 ASSEMBLY INSPECTION

1. After pump assembly, rotate the pump drive gear to check for gear noise or tight assembly.
2. Check the total thrust of the pump drive gears. This is done using the same indicator arrangement shown in Figure 9-24. on page 9-33, 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 in contact with 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.

9.12 TURBOCHARGER OIL FILTER

9.12.1 DESCRIPTION

The turbocharger oil filter, Figure 9-26. on page 9-38, 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 assembly through a cast manifold and, after passing through the filter element, returns to the upper idler gear stubshaft and into the turbocharger. The filter element is of the disposable (spin-on) type that mounts directly to an adapter on the filter head assembly. The filter assembly is mounted on the camshaft drive housing at the right bank of the engine.

NOTE

If turbocharger oil filter is of the disposable (cartridge) type, element will be of pleated paper construction and is held in a removable container that mounts to the filter head assembly with two nuts.

The filter head contains two check valves, Figure 9-26. on page 9-38, 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.

9.12.2 MAINTENANCE

The turbocharger filter should be serviced as specified in the Scheduled Maintenance Program or more frequently if experience indicates it is necessary.

To replace a “spin-on” filter, unscrew element by hand to disengage it from the filter head adapter and discard. Fill replacement element housing with clean oil and apply a film of oil to the gasket. Apply new filter to adapter and turn by hand until gasket seats, then tighten it another half-turn ONLY.

To replace a “cartridge” type filter, 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, if required. Fill the container with clean oil and reassemble to the upper housing. Do <u>not</u> overtighten attaching bolts as the seal may be damaged.

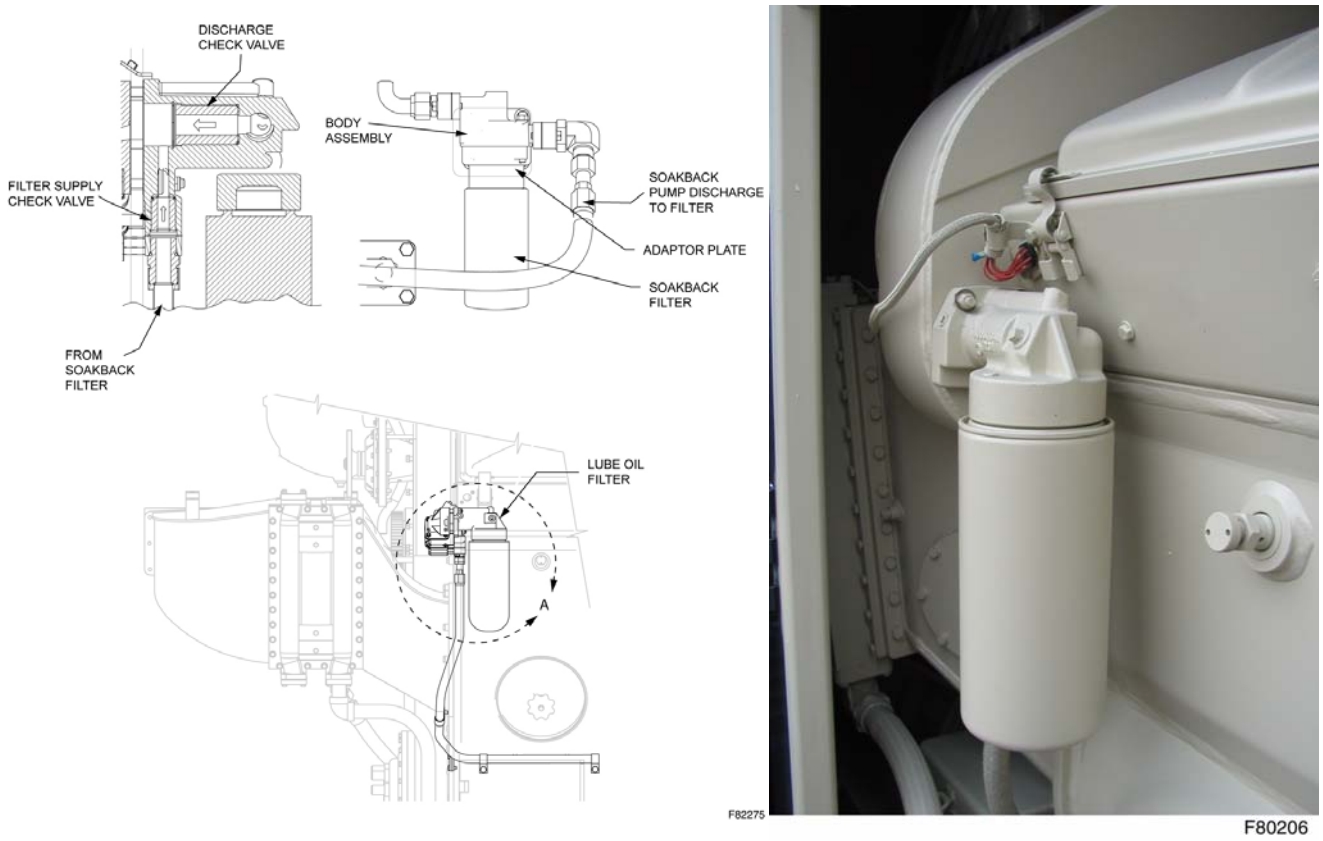


Figure 9-26. Turbocharger Oil Filter Assembly - (Spin On - Right)

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.

9.13 SOAK BACK OIL SYSTEM

9.13.1 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 AC (or DC) electric motor driven pump draws lube oil from the oil pan, pumps the oil through a soak back filter, Figure 9-27, and the head of the turbocharger oil filter assembly directly into the turbocharger bearing area, Figure 9-1. on page 9-3 or Figure 9-2. on page 9-4. The motor driven soak back pump and filter are mounted on the side of the oil pan, Figure 9-27.



Figure 9-27. Soak Back Oil Pump, Motor, And Filter Installation (Pump Shown W/ AC Electric Motor)

CAUTION

If the soak back pump should fail to operate when the engine is shut down, restart the engine immediately 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 within two minutes 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, Figure 9-27, set at 221 kPa (32 psi), is located in the head of the soak back filter assembly. When the engine starts, and the motor driven soak back pump is still running, main lube oil pressure from the engine driven pump becomes greater than the motor driven soak back pump pressure. As there is no outlet for the lower pressure oil, the relief valve will open when the pressure builds up to 221 kPa (32 psi), and the oil will return to the engine oil pan through a passage in the filter head mounting flange. Also located in the filter head is a bypass valve, Figure 9-27, set at 483 kPa (70 psi). This valve will open to permit motor driven soak back pump pressure to bypass a plugged soak back filter element so that lubrication can continue to be supplied to the turbocharger (through the turbocharger filter) in order to prevent turbo damage.

9.13.2 MAINTENANCE

The soak back oil filter element should be serviced as specified in the applicable Scheduled Maintenance Program, or more frequently if experience indicates it to be is necessary.

To remove the element from the soak back filter, Figure 9-27. on page 9-39, remove the two bolts from the top of the filter head and remove the bowl, element, and spring from the upper housing.

9.14 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 oil pipe.

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 (valve) mechanisms 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 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.

9.15 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.

9.16 SERVICE DATA - LUBRICATING OIL SYSTEM

9.16.1 REFERENCES

Flushing Diesel Engine Lubricating Oil System .....M.I. 1757
Lubricating Oil For Domestic Locomotive Engines.....M.I. 1752
Lubricating Oil For Export Locomotive Engines .....M.I. 1761

9.16.2 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Lube Oil Pressure Relief Valve

Valve guide inside diameter -Max. .....12.764 mm (.5025")
Valve stem outside diameter -Max. .....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 -
Min. .....0.038 mm (.0015")
Max..... 0.18 mm (.007")

Sleeve to bushing clearance -
Min. .....0.038 mm (.0015")
Max..... 0.18 mm (.007")

Idler shaft to gear bushing clearance -
Min. .....0.038 mm (.0015")
Max..... 0.18 mm (.007")

Driven gears - total thrust clearance

8 & 12-cyl. (scavenging pump assembled) -
Min. ..... 0.41 mm (.016")
Max..... 0.61 mm (.024")

16-cyl. (scavenging pump assembled) & 20-cyl. (lube oil pump assembled) -
Min. ..... 0.41 mm (.016")
Max..... 0.69 mm (.027")

Driven gears - total thrust clearance

8-cyl. (main lube oil and piston cooling pump gears) -
Min. ..... 0.46 mm (.018")
Max. ..... 0.56 mm (.022")

12-cyl. (main lube oil pump gears) -
Min. ..... 0.41 mm (.016")
Max. ..... 0.58 mm (.023")

12-cyl. (piston cooling pump gears) -
Min. ..... 0.48 mm (.019")
Max. ..... 0.58 mm (.023")

16-cyl. (main lube oil pump gears) -
Min. ..... 0.41 mm (.016")
Max. ..... 0.56 mm (.022")

16-cyl. (piston cooling pump gears) -
Min. ..... 0.48 mm (.019")
Max. ..... 0.61 mm (.024")

Thrust face of bushing to body clearance (front and rear) -
Min. ..... 0.02 mm (.001")
Max. ..... 0.18 mm (.007")

8, 12 and 16-cyl. Drive and driven gear backlash -
Min. ..... 0.30 mm (.012")
Max. ..... 0.76 mm (.030")

20-cyl. Drive and driven gear backlash -
Min. ..... 0.30 mm (.012")
Max. ..... 0.41 mm (.016")

Radial clearance of drive and driven gear to body -
Min. ..... 0.038 mm (.0015")
Max. ..... 0.25 mm (.010")

Drive shaft (gears) - total thrust clearance

8 & 12-cyl. (scavenging pump assembled) -
Min. ..... 0.20 mm (.008")
Max. ..... 0.41 mm (.016")

16-cyl. (scavenging pump assembled) & 20-cyl. (lube oil pump assembled) -
Min. ..... 0.20 mm (.008")
Max. ..... 0.48 mm (.019")

Drive shaft (gears) - total thrust clearance - continued

16-cyl. (main lube oil and piston cooling oil pumps assembled) -
Min. ..... 0.08 mm (.003")
Max. ..... 0.43 mm (.017")

12-cyl. (main lube oil and piston cooling oil pumps assembled) -
Min. ..... 0.10 mm (.004")
Max. ..... 0.46 mm (.018")

8-cyl. (main lube oil and piston cooling oil pumps assembled) -
Min. ..... 0.13 mm (.005")
Max. ..... 0.56 mm (.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")

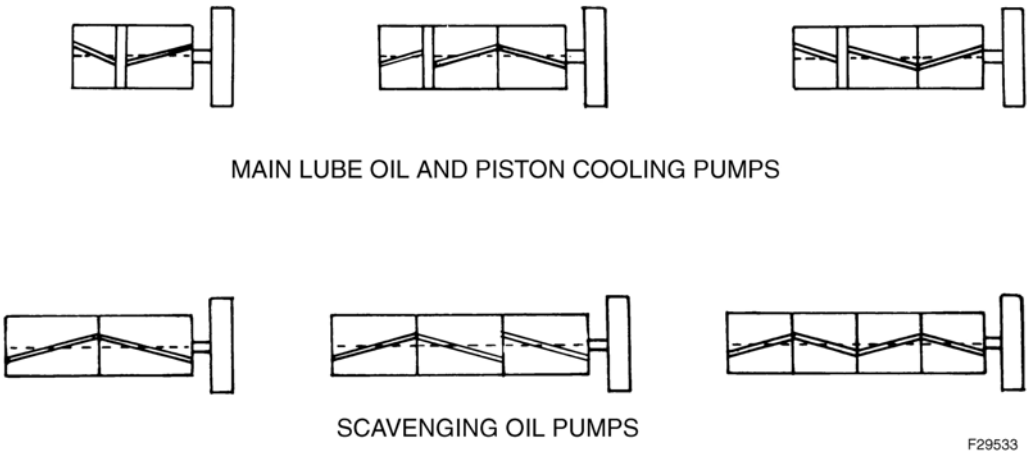
Pump flange pilot concentricity -
T.I.R. Limit ..... 0.05 mm (.002")

Pump drive gear to accessory drive gear backlash -
Min. ..... 0.20 mm (.008")
Max. ..... 0.64 mm (.025")

Pump/ motor assembly

Parallel coupling alignment - Max. ..... 0.38 mm (.015")
Axial clearance between jaw and spider -
Min. ..... 0.76 mm (.030")

9.16.3 HELIX ANGLE POSITION OF OIL PUMP GEARS



9.16.4 EQUIPMENT LIST

	PART NO.
Gauge - piston cooling oil pipe alignment	8071720
Cleaner - piston cooling oil pipe	8087086
Spray gun	8193041
Loctite cleaner activator -0.17 kg (6 oz.)	8352873
Loctite sealing compound -50cc Bottle	9505663
Air ejector nozzles	
.422" (standard)	40038706
.375" (over 8" H_2O)	40038707
.469" (under 2" H_2O)	40038708
.250" (over 8" H_2O)	40054086
.3125 (over 8" H_2O)	40054087

SECTION 10. COOLING SYSTEM

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10.1 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 centrifugal water pumps are mounted on the accessory drive housing and are driven by the governor drive gear (on 8, 12, and 16-cylinder engines) or by the accessory drive gear (on 20-cylinder engines). A representative illustration of the 8, 12, and 16-cylinder engine cooling system is shown in Figure 10-1. A similar representative illustration of the 20-cylinder engine and aftercooler cooling systems is shown in Figure 10-2. on page 10-4.

Cooling water is circulated in a counter-flow direction through each aftercooler, Figure 10-1 and Figure 10-2, located in the turbocharger air discharge duct, to cool the air before it enters the engine air box.

NOTE

Aftercooler piping used on all 710G3B and 710G3C engines differs from that used on previous 645 and 710 engines in order to achieve water counter-flow through both aftercooler.

The engine (and aftercoooler) discharge water flows through an external cooling system to dissipate the heat taken up in the engine. This system consists of a water tank, water level gauges, temperature gauges, radiators, and connecting piping.

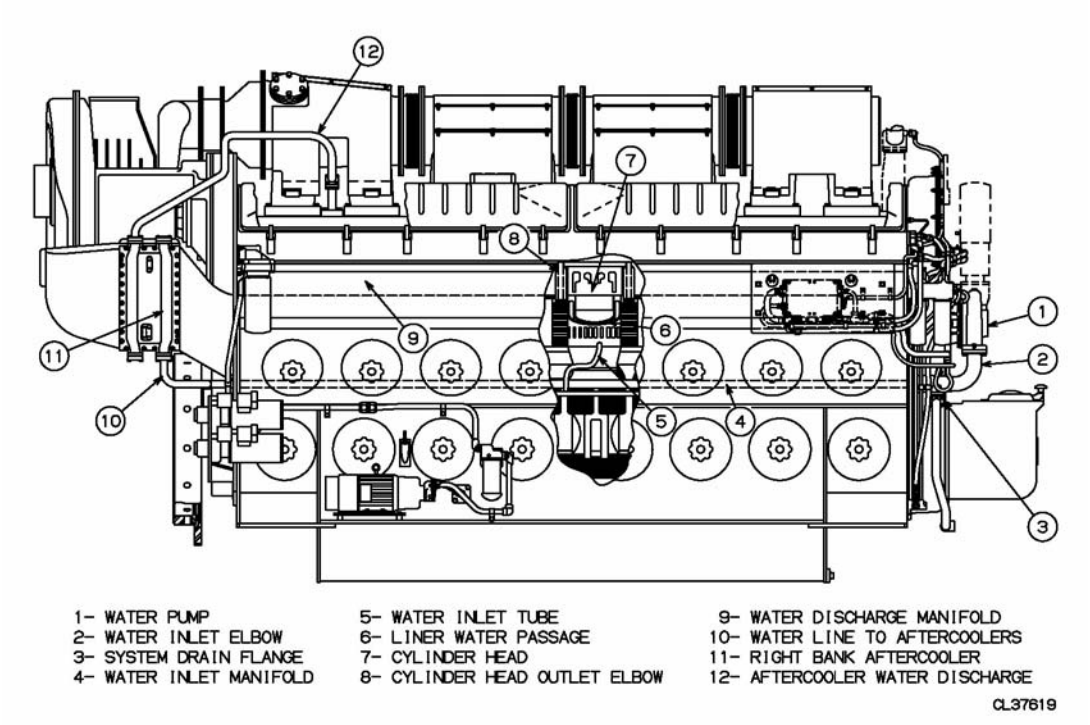


Figure 10-1. Typical Standard Jacket Water Cooling System Schematic

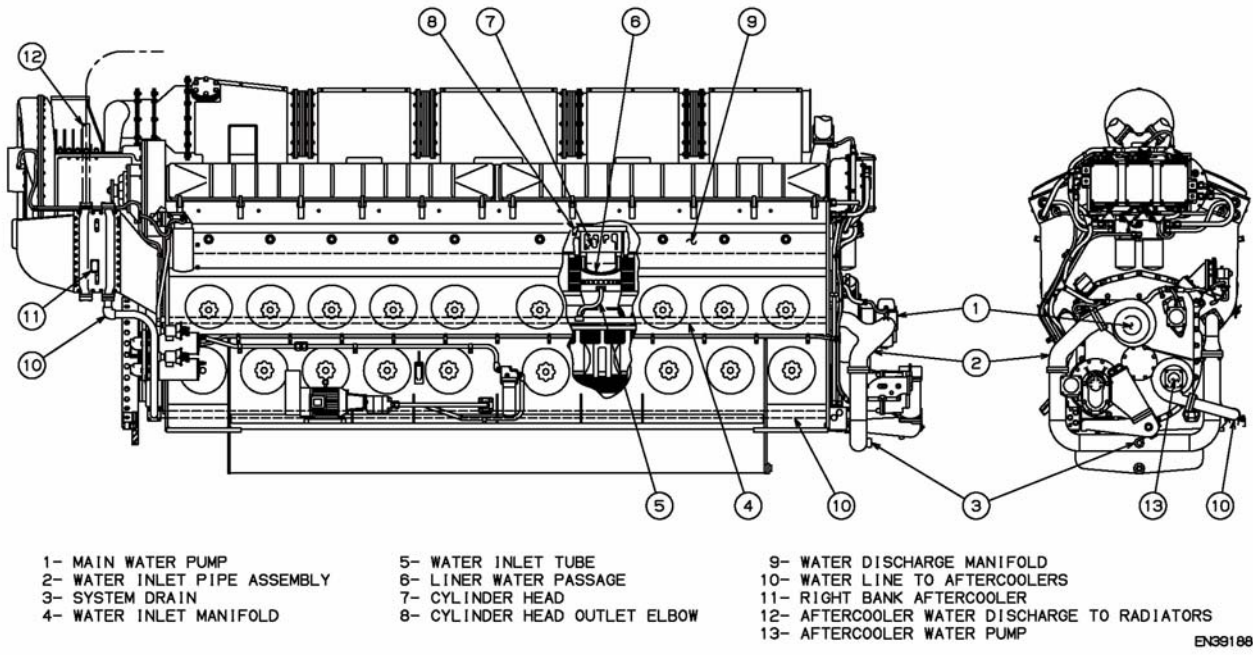


Figure 10-2. Typical Cooling System w/ Separate Aftercooling Schematic

10.2 MAINTENANCE

10.2.1 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.

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 full load operation, the cause of the hot engine water should be found and the condition corrected.

10.2.2 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 to ensure that the specific concentration of corrosion inhibitor is maintained.

10.3 COOLING SYSTEM PIPING

10.3.1 DESCRIPTION

Refer to Figure 10-3 and Figure 10-4. on page 10-6 for piping details. Pump outlet elbows (or piping) conduct water from the pump(s) to the removable water inlet manifolds located in each air box.

On engines with standard jacket water cooling systems, each water inlet manifold is connected at the rear end plate to an aftercooler water inlet pipe. The rear end flange of the inlet manifold is equipped with two seals which prevent the leakage of air from the air box. A flange at the front end of the inlet manifold contacts the outer face of the front end plate when the manifold is installed.

On engines with separate aftercooling water systems, separate aftercooler piping is used on the outside of the engine. The water inlet manifolds in each air box are blocked off at the rear end flange.

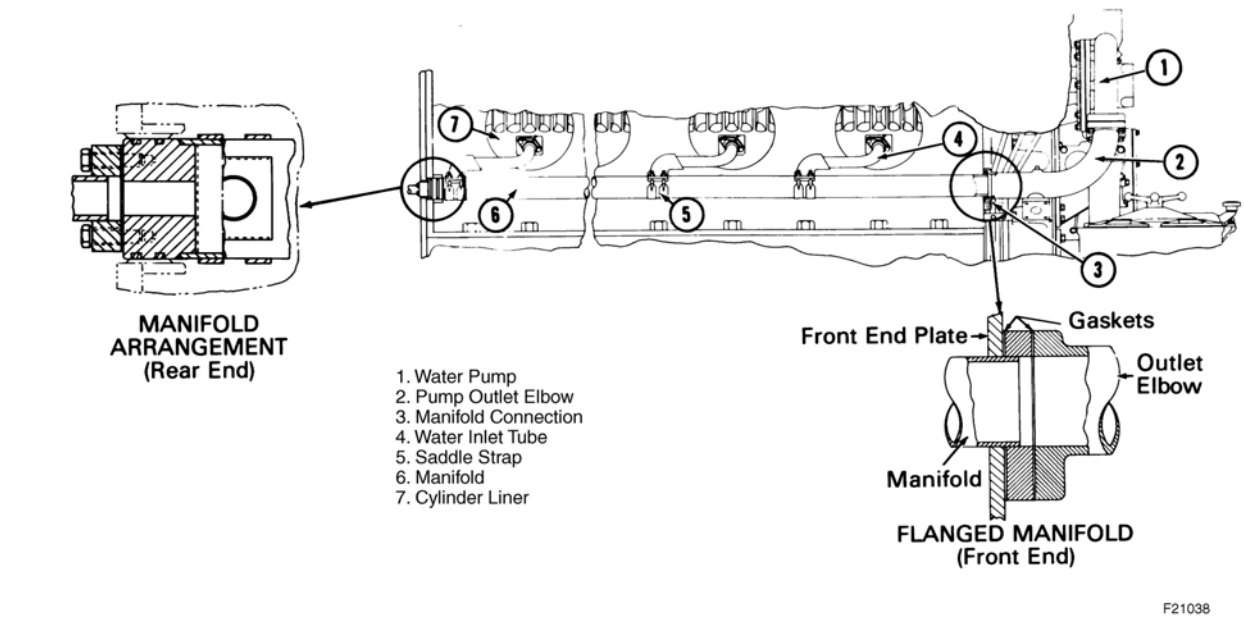


Figure 10-3. Typical Standard Jacket Water Cooling System Piping

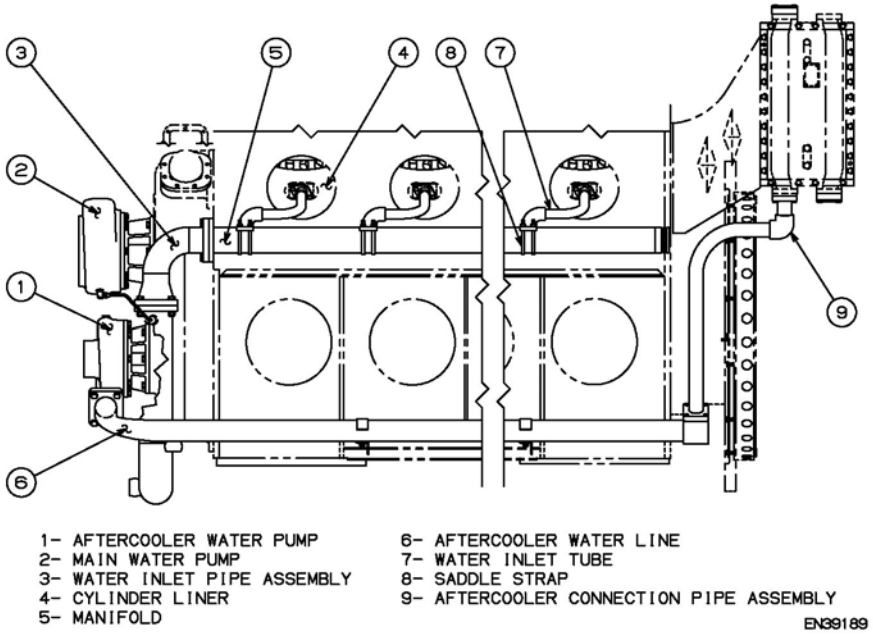


Figure 10-4. Typical Separate Aftercooling System Piping

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.

10.3.2 MAINTENANCE

10.3.2.1 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.

1. Inspect the water inlet manifold for any dirt or roughness in the area of the discharge holes and at the front end plate flange.
2. Place the inlet manifold flange gasket over the manifold and insert the inlet manifold into the air box.
3. Carefully guide the end of the water inlet manifold into the rear end plate so that seals are not damaged. When positioned correctly, the inlet manifold should be firmly supported at the end.

4. Apply and tighten the inlet manifold flange to front end plate bolts. Temporary bolts may be used if the water pump discharge elbow (or pipe assembly) is not ready to be applied.
5. On 16 and 20 cylinder engines, apply the water inlet manifold support bracket saddle strap with washers and stop nuts. Torque stop nuts to 20.3 Nm (15 ft lbs).
6. Place the new seal in the groove at the liner end of the water inlet tube.
7. Position saddle straps around the water inlet manifold, and through the inlet tube flange.
8. 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.
9. Take a new gasket and shape it to fit around the water inlet manifold. Insert the gasket between the tube flange and inlet 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.
10. Torque the strap nuts to specified value.
11. 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 inlet manifold; if no movement is detected, the tube to liner bolts and washers may be re-applied and torqued to specified value.
12. After all liner water inlet tubes are properly applied, the inlet manifold will be securely held and the temporary bolts, if applied, should be removed and the water pump discharge elbow (or pipe assembly) connected.

10.3.2.2 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 pour off 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.

10.4 AFTERCOOLER - TIER 2 ENGINES

An aftercooler, Figure 10-5, is located on each side of the turbocharger to cool the air entering the air box for 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.

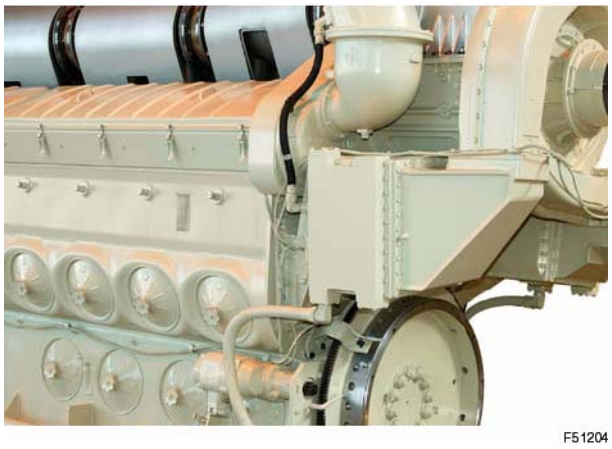


Figure 10-5. Tier 2 Engine Aftercooler

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 aftercooler water pump (discharge) piping which is on the outside of the engine. The water leaving the aftercoolers on these engines is piped to the engine aftercooling water radiators.

No valves are located in the aftercooler piping on any of these engines, so cooling water is provided whenever the engine is running.

10.4.1 AFTERCOOLER INSPECTION- TIER 2 ENGINES

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. This can be done by looking through the rear airbox handhole covers. Evidence of leakage will necessitate removal of the aftercooler.

A check for aftercooler plugging may be made by performing the following:

1. With engine shut down, remove two aftercooler inspection plugs (one on each side of the core) as shown in Figure 10-5, page 10-8. Install two drilled bolts fitted with hose stems into the bolt holes.

WARNING

Do NOT remove hoses with engine at high speed. Do NOT apply or remove hoses singly to prevent high pressure water discharge from manometer.

2. Connect a U-tube manometer, with a hose attached to each end, to the two hose stems previously applied.
3. Obtain a pressure differential reading with engine at full speed, with or without load. The maximum allowable pressure differential is listed in the Service Data.
4. Aftercoolers should be checked for excessive pressure differential and removed for cleaning, as specified in the Scheduled Maintenance Program.

10.4.2 AFTERCOOLER REMOVAL- TIER 2 ENGINES

1. After draining the engine water, disconnect the water discharge line flange at the top of the aftercooler.
2. Disconnect the water inlet line at the bottom of the aftercooler.
3. Apply a 3/4" lifting eye to the aftercooler duct assembly.
4. Remove the mounting bolts securing the aftercooler duct to the engine at the front, and to the turbo scroll at the rear.
5. When the aftercooler is free, remove the entire assembly from the engine.
6. The aftercoooler may be separated from the duct for cleaning once removed from the engine.

10.4.3 CLEANING - TIER 2 ENGINES

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.

10.4.4 AFTERCOOLER REPLACEMENT- TIER 2 ENGINES

The aftercooler assembly may be replaced using the following procedure:

1. In preparation for assembly, apply an aftercooler lifting tool to the assembly.
2. Using a suitable hoist, lift the aftercooler and duct assembly, apply a new gaskets, and position the assembly on the engine.
3. Align and secure the aftercooler and duct assembly to the engine.
4. Refill the cooling system and run the engine at idle until operating temperature has been reached. Check the cores and pipe work for leakage.

10.5 DRAINING THE COOLING SYSTEM

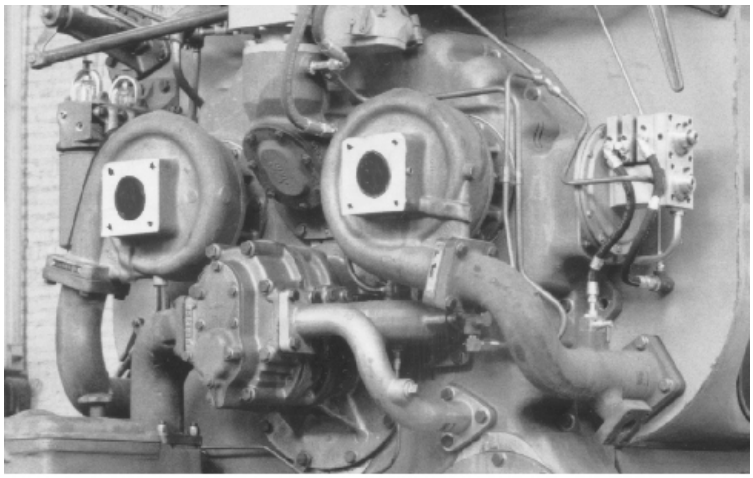
To drain the Cooling system:

1. Open the manual engine drain valve located at the sump between the engine and the equipment rack.
2. Loosen pressure cap on expansion tank. Once the pressure on the system has been released, if desired, the water tank filler cap may be removed to allow faster draining.

10.6 WATER PUMPS

10.6.1 DESCRIPTION

The engine cooling water pump(s), Figure 10-6, and Figure 10-7. on page 10-11, are self-draining centrifugal type pumps which rotate in the opposite direction of the engine crankshaft. Pumps used may be either standard or high capacity in combinations, depending on application. The components of a typical water pump are identified in Figure 10-8. on page 10-12.



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Figure 10-6. Typical Standard Jacket Water Pump Installation

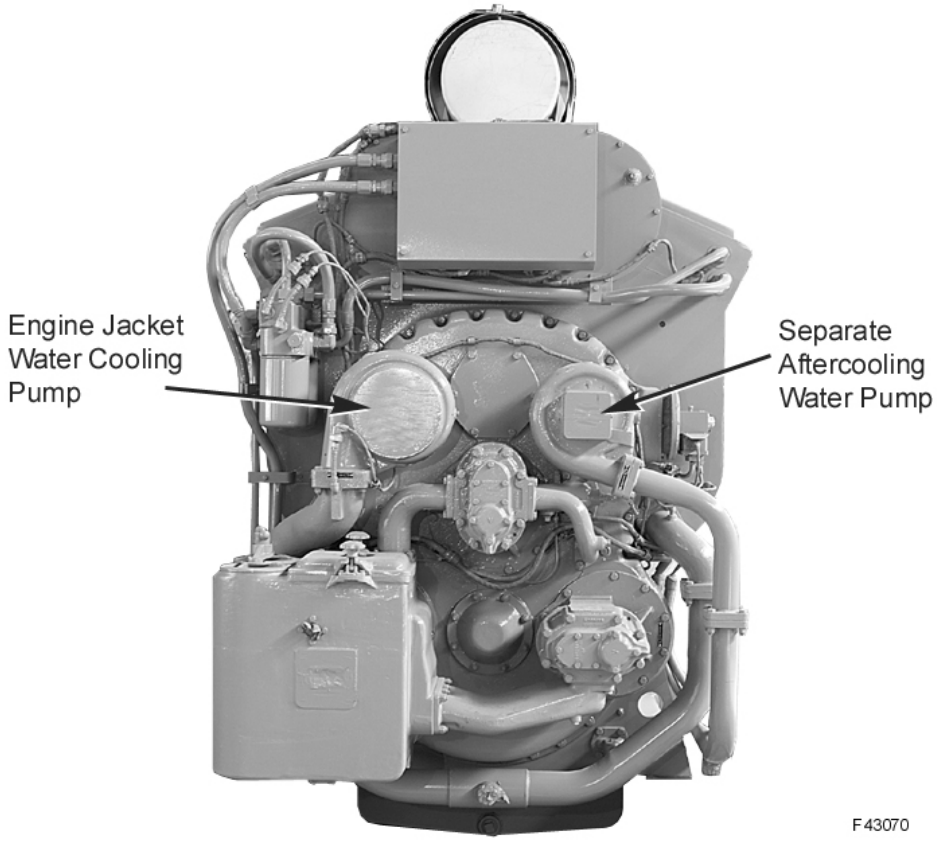


Figure 10-7. Typical Water Pump Installation (8, 12 & 16-Cylinder Engines w/ Separate Aftercooling)

The pump(s) used on engines with standard jacket water cooling systems are basically the same pump, but are carried under two part numbers in order to identify the right and left bank pumps. The only difference between the pumps is the position of the impeller housing in relation to the support housing. The position of the impeller housing may be changed on either pump to permit use on the opposite bank.

The pumps used on engines with separate aftercooling water systems include one high capacity pump (right bank), which supplies the engine jacket water cooling system, and one standard capacity (left bank) pump which supplies the aftercooling water system.

The pump drive shaft, on either the standard or high capacity pump, is supported in the main pump housing by two ball bearings separated by a steel spacer. The bearings are grease lubricated and permanently sealed. The outer bearing adjoins a water slinger which bears against a shoulder on the shaft. The inner bearing is held in place by a retainer and snap rings 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.

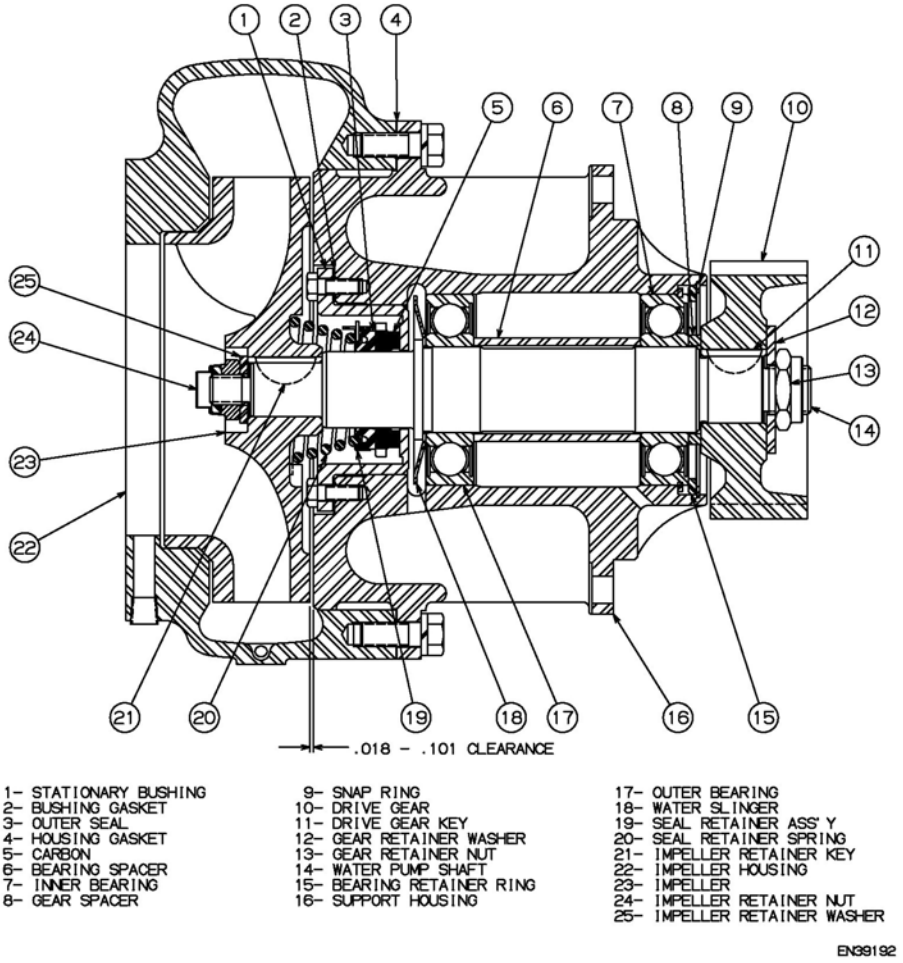


Figure 10-8. Typical Water Pump Cross-Section (High Capacity Shown)

The stationary bushing, Figure 10-8, is applied into the drive shaft support housing. The carbon inner seal of the seal assembly, Figure 10-9. on page 10-13, 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 support housing which permits runoff, and prevents water from reaching the engine side of the pump.

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 bolts (or studs and nuts).

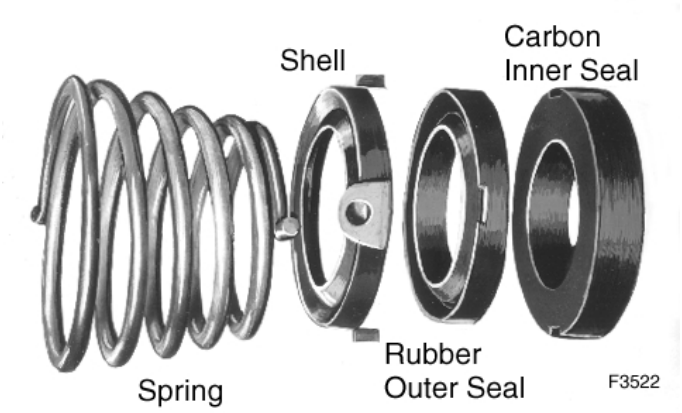


Figure 10-9. Spring And Seal Assembly

10.6.2 MAINTENANCE

10.6.2.1 PUMP REMOVAL

1. Drain cooling system.
2. Remove water pump inlet connection and engine protector sensing line (if used).
3. Disconnect pump discharge flange connection.
4. Remove mounting bolts and pump from engine.

10.6.2.2 PUMP DISASSEMBLY

1. Remove impeller end nut and washer.
2. Remove drive gear end nut and washer. Apply gear puller, Figure 10-10. on page 10-14, and remove pump drive gear and key.

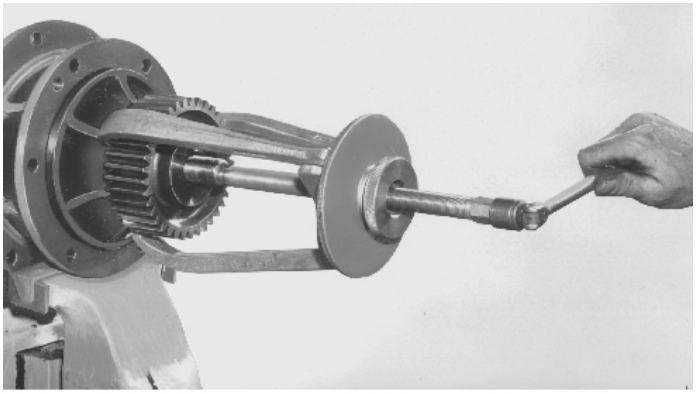


Figure 10-10. Drive Gear Removal

3. Remove snap ring and bearing retainer ring, Figure 10-8. on page 10-12.
4. Loosen bolts (or hex nuts) securing impeller housing to pump support housing. Remove all but two of the bolts (or nuts), leaving remaining two bolts (or nuts) on any pair of tapped holes (or studs) directly across from each other. This is necessary to prevent housings from separating completely before shaft and bearing assembly is free of impeller and support housing.
5. Insert adapter for pump disassembly tool over impeller shaft end, Figure 10-11, then mount disassembly tool to impeller housing with two 1/2"-13 x 1-1/2" hex head bolts across from each other.

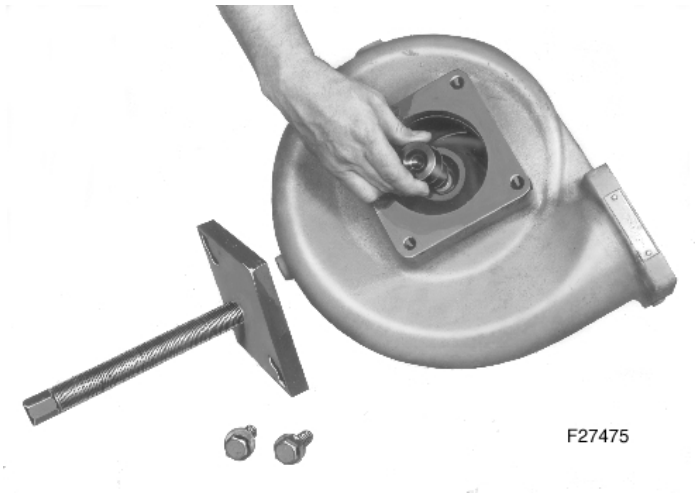


Figure 10-11. Disassembly Tool Application

6. Using a box end wrench or impact gun and socket, Figure 10-12. on page 10-15, run in drive screw of disassembly tool until shaft and bearing assembly is free.

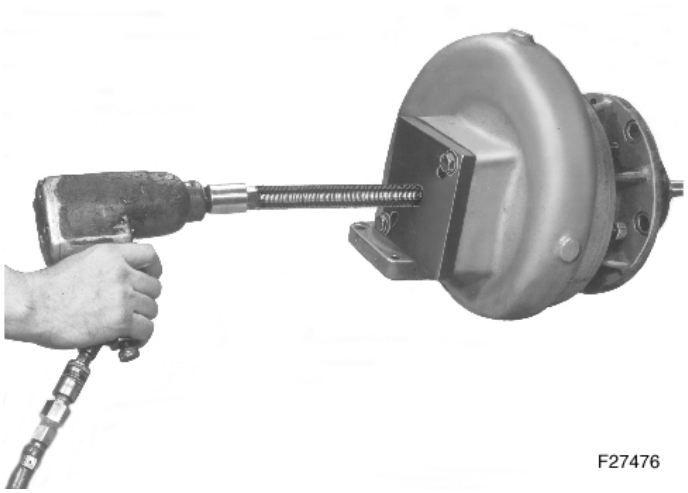


Figure 10-12. Removing Shaft Assembly

7. Remove remaining two housing bolts (or nuts) and continue to run in drive screw until support and impeller housings are separated.

> **NOTE**
> Drive screw should not be loosened during pump disassembly until housings have been completely separated. Relieving tension on screw may allow impeller to drop down, preventing further run in of screw.

8. Remove loose impeller from impeller housing and complete removal of shaft and bearing assembly from support housing - by hand, if possible. If not, some light tapping on shaft impeller end with a wood or brass block may be necessary to get outer (impeller end) shaft bearing clear of support housing.
9. Remove loose spring and seal assembly from support housing, Figure 10-9. on page 10-13.
10. Remove the bolts from stationary bushing. If the bushing is not easily removed from the support housing, 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.

    Discard the stationary bushing as this item should be replaced, along with seal assembly, whenever pump is disassembled for maintenance. Scrape any remaining gasket material from the bushing mounting surface in the support housing.
11. Place the shaft and bearing assembly in an arbor press and remove both bearings.

10.6.2.3 PUMP ASSEMBLY

NOTE

Damaged pump housing gasket surfaces (with scratches, gouges, or corrosion pitting) represent potential leak paths that a gasket may not seal entirely. An Anaerobic sealing compound, as listed in the Service Data, can be used in conjunction with the gasket to ensure a water tight seal on a damaged flange surface. The blemish should be no deeper than 0.51 mm (.020") and NOT across entire width of flange. Apply compound sparingly on clean, grease and corrosion free flange surface. Wipe away excess compound after tourqing mounting bolts and allow 24 hours cure time after assembly before placing pump in service.

1. Clean the pump shaft and inspect the bearing journal areas for signs of damage (i.e., nicks or scoring). Journal diameter should not be less than minimum limit listed in the Service Data at the end of the section.
2. Measure bearing bore and ensure compliance with the Service Data limits, given at the end of the section, relative to shaft journal and bearing bore fit. Also check that pump shaft diameter to gear bore fit is within the tolerance given in the Service Data.
3. Assemble water slinger, outer bearing, bearing spacer, and inner bearing to the pump shaft, making certain that inner (gear end) bearing with snap ring is positioned correctly with the snap ring to the outside. These parts are assembled, Figure 10-8. on page 10-12, first with the slinger next to the shoulder on the shaft, concave side toward the impeller end, followed by outer bearing (without snap ring), bearing spacer and inner bearing; abutting each other snugly.
4. Place the drive shaft support housing in a vise with jaw protectors.
5. Clean any dirt or oil from support housing bearing bores and outer race of each bearing.
   a. Measure bearing outside diameters and housing bores to ensure compliance with the Service Data limits at the end of this section.
   b. Apply a thin coating of silicone rubber sealing compound to outer (impeller end) bearing bore in housing.
3. Insert the shaft and bearing assembly, slinger end first, from the drive gear end of the support 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.
4. Insert bearing retainer ring into drive gear end of support housing with chamfered side in toward bearing. Apply snap ring over shaft to abut bearing inner race.

5. Place key in shaft and assemble drive gear to shaft, using a rawhide mallet. Apply retaining washer and a new gear nut. Torque nut to 359 Nm (265 ft-lbs).
6. Turn pump in vise to allow assembly of impeller end.
7. 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 seal surface of the bushing is clean and dry.
   a. Apply new stationary bushing gasket and bushing. Tighten the bolts evenly and torque to 11.3 Nm (100 in.-lbs).

CAUTION

The sealing surface of the stationary bushing must be absolutely smooth and flat to prevent wear of the carbon washer.

   b. After applying the stationary bushing, check run out of the carbon seal surface using an indicator mounted on the end of the pump shaft. See the Service Data limits, at the end of this section, for required stationary bushing seal seat squareness with drive 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, Figure 10-9. on page 10-13. Check carbon face for cleanliness. Apply carbon inner seal with the narrow end contacting the stationary bushing. Apply rubber outer seal to shell, and apply to carbon seal so ears 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.
4. Figure 10-13 shows the impeller installer being used to assemble the impeller to the drive shaft in the support 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 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.

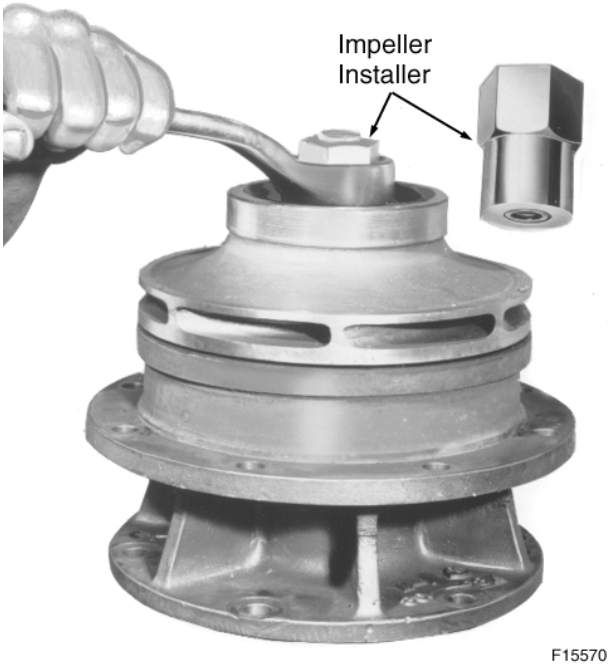


Figure 10-13. Pump Impeller Installer

5. Check the insert in the impeller shaft retaining nut to see that it is free from tears and disintegration. Apply the impeller retaining washer and nut. Torque value of the impeller nut is 108 Nm (80 ft-lbs).
6. Check that drilled drain passage is free of obstruction.
7. On standard capacity pumps, 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; 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 Figure 10-14.

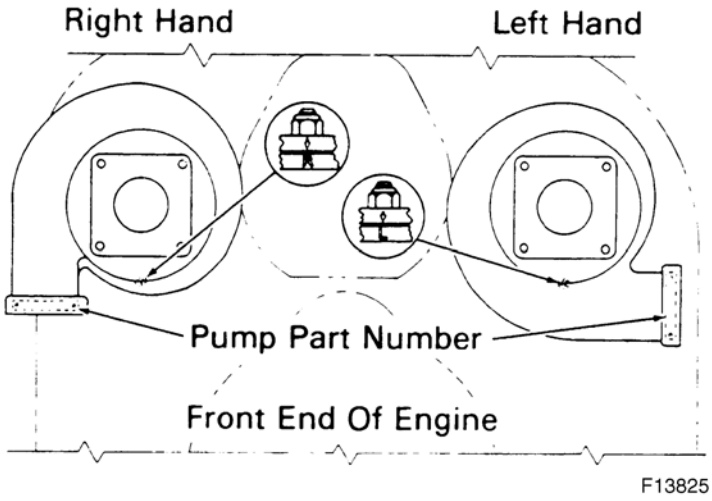


Figure 10-14. Standard Capacity Pump Housing Positioning

8. Install housing in the correct position, using new gasket between the impeller and shaft housing. Apply housing bolts (or nuts to studs) and tighten to 88 Nm (65 ft-lbs).

10.6.2.4 INSTALLING PUMP

1. Standard capacity pumps are installed in the positions shown in Figure 10-14 for the right and/ or left bank.

   Torque mounting bolts to specified value.

2. The part number of the pump is located on a plate attached to the pump discharge flange, as shown in Figure 10-14.

   It should also be noted, on pump installation, whether 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.

10.7 SERVICE DATA - COOLING SYSTEM

10.7.1 REFERENCES

Engine Coolant ..... M.I. 1748
Cooling System Radiators ..... M.I. 549
Guru-Style Drain Valves ..... M.I. 20001

10.7.2 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

Pump drive gear backlash -
Min. ..... 0.20 mm (.008")
Max. ..... 0.64 mm (.025")

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. ..... 0.005 mm (.0002")

Pump shaft bearing journal diameter -
Min. ..... 39.992 mm (1.5745")

Stationary bushing seal seat squareness with drive shaft -
T.I.R. Max. ..... 0.051 mm (.0020")

Maximum allowable pressure differential across aftercooler
Core (engine at full speed) ..... 635 mm (25") H_2O
W/ new or cleaned aftercooler ..... 381 mm (15") H_2O

10.7.3 EQUIPMENT LIST

	PART NO.
Impeller installer	8052959
Water pump impeller puller/ gear puller	8354367
Silicone rubber sealing compound -0.14 kg (5 oz)	8453256
Water pump mounting bolt wrench	9519601
Water pump disassembly tool	9549072
Sealant, Supplementary Anaerobic	
-50 ml container	40047938
-300 ml container	40047939
Gasket sealant, RTV	
- 300 ml container	40048258
- 85 gram container	40048259
Aftercooler lifting tool	File 690

SECTION 11. FUEL OIL SYSTEM

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11.1 DESCRIPTION

The basic engine fuel system consists of the fuel injectors, the engine mounted fuel filter, fuel supply and return manifolds, and engine mounted fuel lines.

Components external to the engine such as the motor driven fuel pump, fuel tank, fuel suction strainer, the primary fuel filter, and connecting fuel lines complete the system.

In operation, fuel from the fuel tank is drawn up by the fuel pump through a suction strainer and primary fuel filter for delivery to the engine mounted (secondary) filter. It then passes through the filter elements to the engine fuel supply lines and injector inlet filter at each cylinder - into the injector. A small portion of the 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.

With EMDEC controlled engines, the quantity of fuel injected by the Electronic Unit Injector (EUI) is determined by its integral solenoid operated poppet valve which is controlled by the master Electronic Control Module (ECM).

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 engine mounted fuel filter. This valve restricts the return fuel, maintaining a back pressure on the injectors. The fuel continues down through the return line to the fuel supply tank.

11.1.1 ELECTRONIC UNIT INJECTORS (EUI)

11.1.2 DESCRIPTION

The EUI injector, Figure 11-1. on page 11-4, is located and seated using an adapter collar within the 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 EUI 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 diagram of the EUI injector is shown in Figure 11-2. on page 11-5.

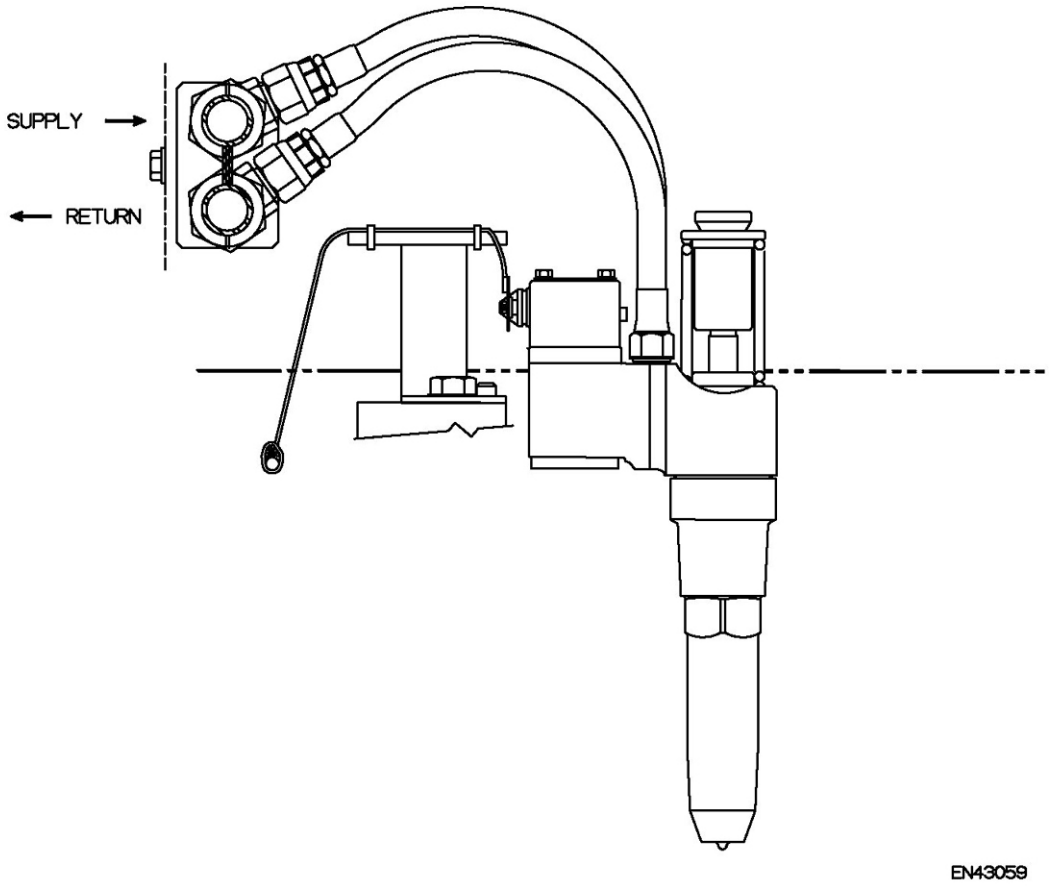


Figure 11-1. Typical Electronic Unit Injector (EUI)

The functions of the EUI injector are both electrical and mechanical. The metering and timing of the fuel supply is done electrically, while the pressurizing and atomizing of the fuel are done mechanically.

The metering and timing functions are controlled by the EMDEC system Electronic Control Modules (ECM) based on inputs received from the locomotive control computer through an interface. The primary input from the control computer is throttle position, while other inputs come from various engine sensors and feedback from the EUI itself. The ECM energizes the injector solenoid which causes a slight upward movement of the hollow poppet valve at a synchronized time and duration, based on inputs used to calculate the next injection event. Spring pressure acts to move the valve downward when the solenoid de-energizes. The movement of the poppet valve causes the fuel to flow into the injector's fuel delivery and bypass system.

The injector plunger is given a constant stroke reciprocating motion by the injector cam acting through the rocker arm and plunger follower. The initial pressurization of approximately 13 790 kPa (2,000 psi) causes the needle valve inside the injector spray tip to lift. This lifting action allows the fuel to flow around the needle valve and through the spray tip where it is atomized into the cylinder combustion chamber at 110 320 to 124 110 kPa (16,000 to 18,000 psi).

The timing (duration) of injector plunger stroke is set by an adjusting screw at the end of the injector rocker arm.

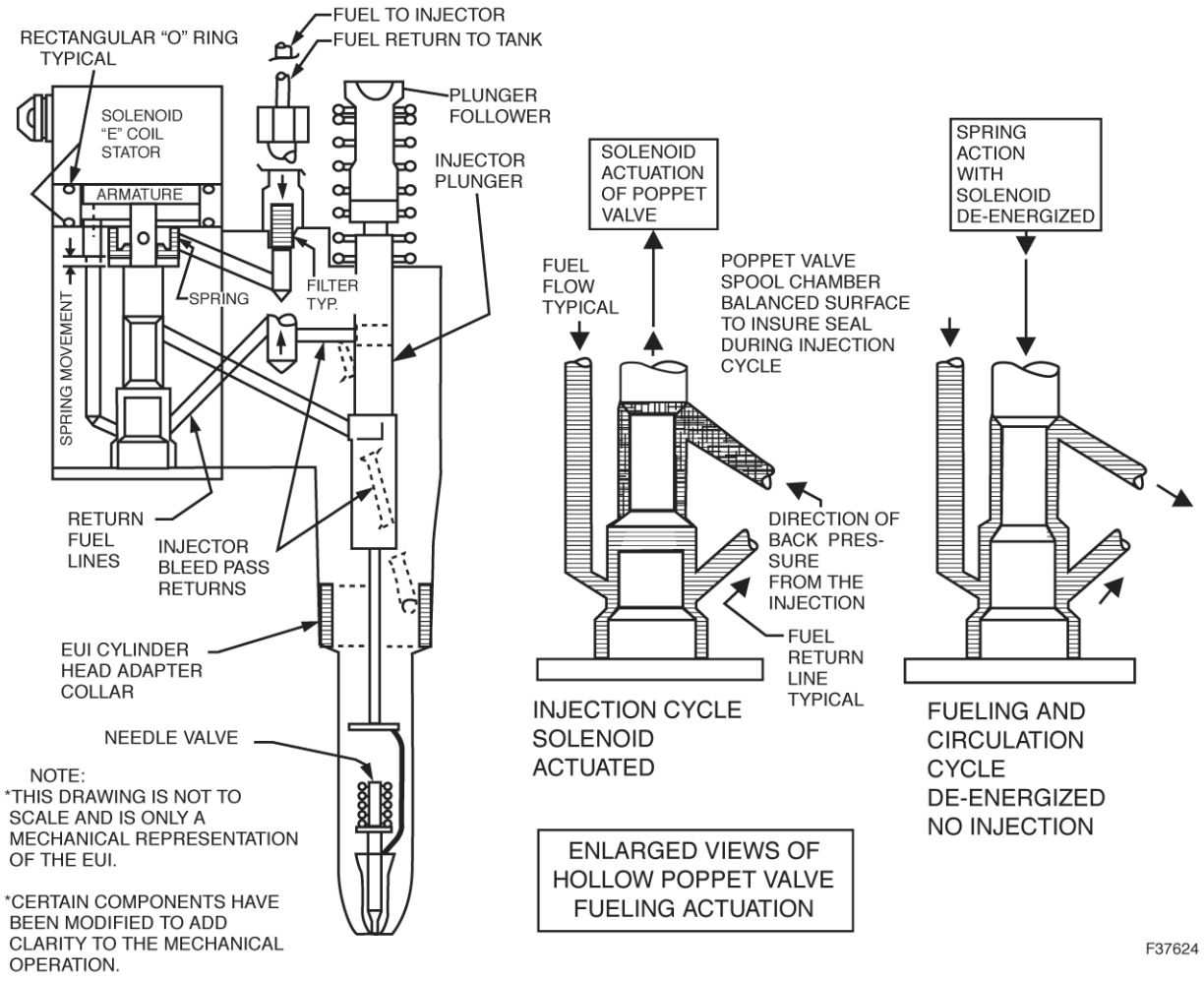


Figure 11-2. Typical EUI Injector Cross-Section Diagram

11.1.3 MAINTENANCE

11.1.3.1 EUI INJECTOR INSTALLATION

1. When installing an EUI 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 into adapter collar in the cylinder head. Check that the locating dowel is properly seated.
4. Lubricate the threads on the injector stud and nut, then apply injector crab, spherical washer and nut. Torque nut to specified value.

5. Connect fuel supply and return jumper lines from the injector to the fuel manifold. Use new “O” rings at the manifold ends and apply as follows:
   a. Apply a light coat of silicon based lubricant to the new “O” rings and place one in each “O” ring land of the supply and return fittings of the fuel manifold. The grease will prevent binding of the “O” ring and hold it in place during jumper line installation.
   b. Facing the injector from the side of the engine, loosely connect the supply (left) jumper line to the top rail and the return (right) jumper line to the bottom rail of the fuel manifold.

CAUTION

Mismatching the fuel jumper lines will result in injector failure. Clearance between jumper lines and all operating mechanisms must be maintained at a minimum of 3.2 mm (1/8”). If any clearance is found to be less, jumper line must be repositioned before tightening.

   c. When tightening the jumper line fittings, use a 3/4” wrench to hold the hex of the jumper line connection in position, and tighten the hex swivel nut with a 15/16” wrench. Torque each jumper line fitting to specified value.

NOTE

It is imperative that the fuel jumper lines not be kinked or twisted during application.

4. Install rocker arm shaft and rocker arms. Loosen injector rocker arm locknut and back off on adjusting screw before tightening rocker arm shaft nuts.

NOTE

Carefully observe CAUTION note above regarding clearance between fuel jumper lines and operating mechanisms when applying rocker arm shaft assembly.

5. Re-connect the two wires with eyelet terminals to the injector and apply the cable tie and bracket to the cylinder head (if removed). Injector is now ready for timing.

NOTE

If injector rocker arm was assembled for use with Mechanical Unit Injector (MUI), adjusting screw will have an injector button attached with a spring clip. Before application with Electronic Unit Injector (EUI), remove and discard the injector button and retaining spring.

11.1.3.2 TIMING THE EUI INJECTOR

With the injector installed, make timing adjustment as follows:

1. Bar engine over in the normal direction of rotation until flywheel pointer indicates the correct crankshaft position in degrees relative to top dead center of the cylinder being timed. Refer to setting instructions on Injector Timing Plate (located on right rear side of engine crankcase).
2. Slowly run each injector follower adjusting screw down until it bottoms, then back off 1-1/2 turns.
3. Tighten adjusting screw locknut while holding adjusting screw in position with a screwdriver.

11.1.3.3 STICKING EUI INJECTORS

Engines may encounter sticking EUI injectors due to fuel, lube oil, or filter maintenance conditions. Since these conditions very often are momentary, injector removal should not be required. This sticking condition usually occurs on injectors which are held with the plungers down while the engine is stopped. If sticking persists, the injectors should be removed and replaced with operational injectors. In no case should injectors be “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.

11.1.3.4 SERVICING EUI 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 the injector is in storage, it is protected against harmful material by the filters and caps sealing the body openings, which are in turn protected by shipping blocks.

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.

11.1.3.5 REPLACING EUI INJECTOR FILTERS

EUI 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.

11.1.3.6 STORING EUI INJECTORS

When EUI injectors are not to be used for a considerable length of time, they should be protected against rust by using a stable, non-corrosive straight-run petroleum distillate in the kerosene volatility range.

Injectors should be stored in a protective container until needed. This container should accommodate an injector holding rack similar to that shown for Mechanical Unit Injectors (MUI) in Figure 11-3. on page 11-8.

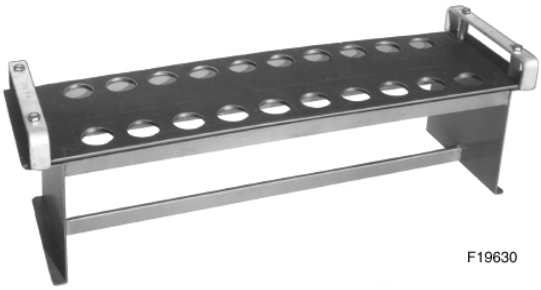


Figure 11-3. Injector Holding Rack

11.2 EMDEC FUEL SYSTEM

11.2.1 DESCRIPTION

The fuel delivery system used on EMDEC equipped engines is essentially the same as that used on governor equipped engines up to the engine mounted (secondary) fuel filters. Beyond this point the commonality ends, as shown in schematic diagrams in Figure 11-4, page 11-8 and Figure 11-5, page 11-9.

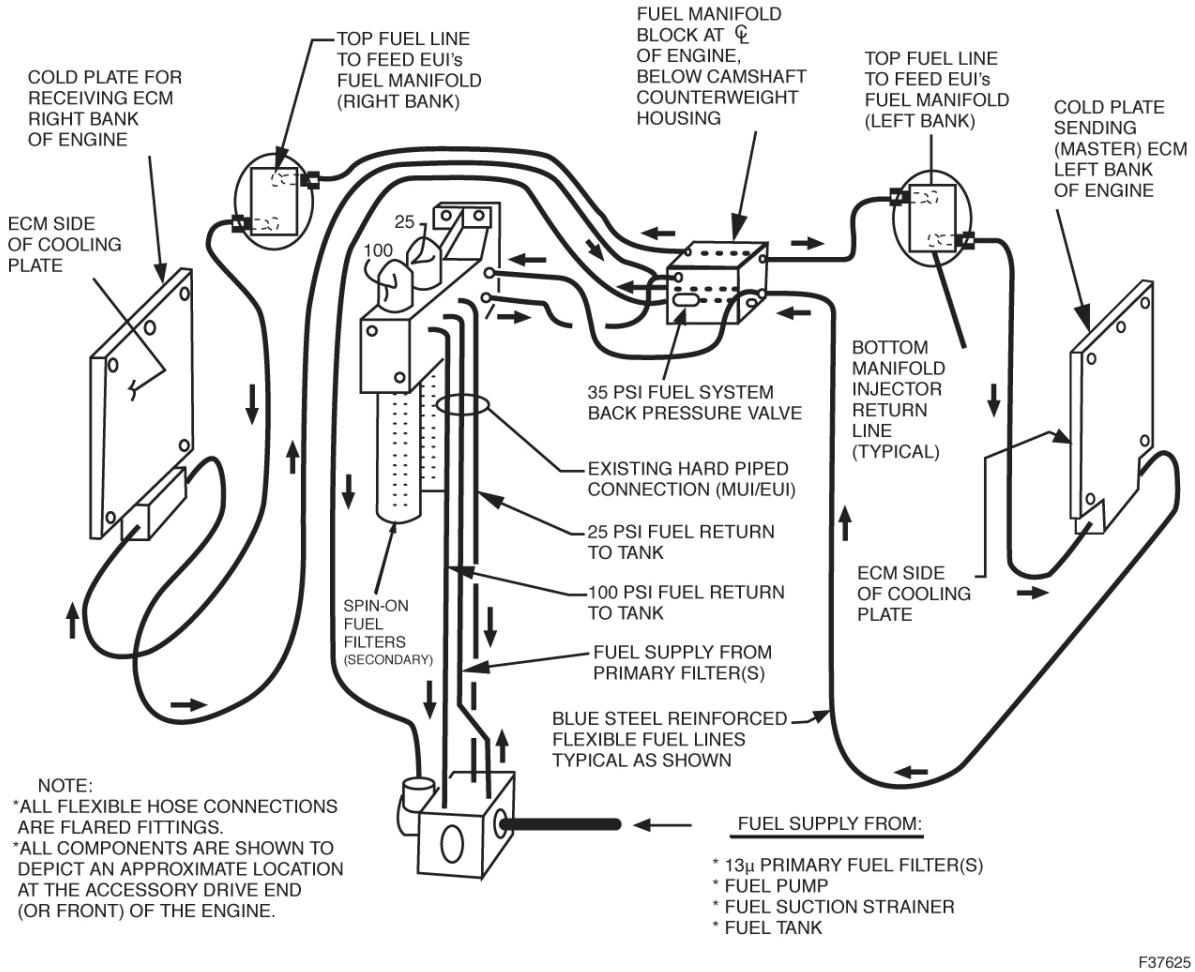


Figure 11-4. EMDEC Fuel Flow Schematic Diagram (Early Model 8, 12, and 16-Cylinder Engines)

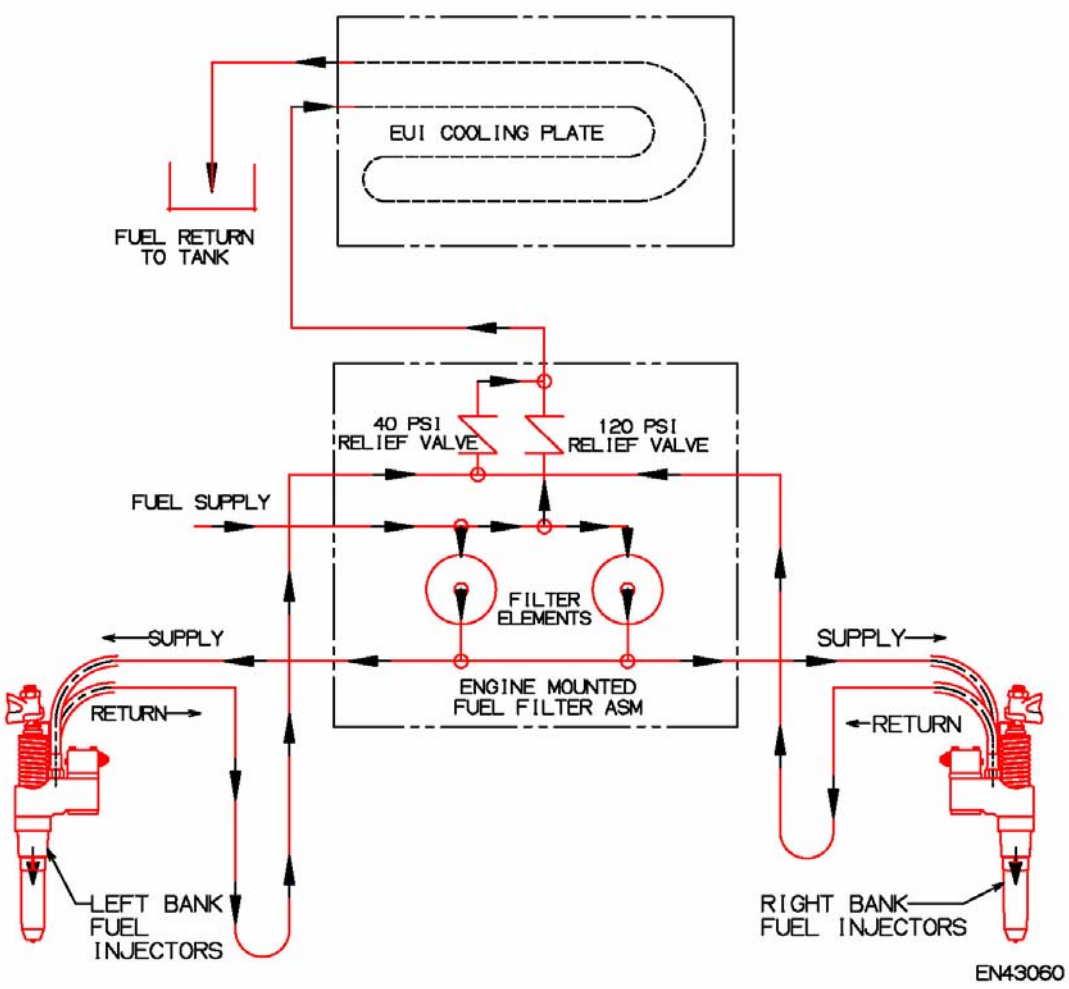


Figure 11-5. EMDEC Fuel Flow Schematic Diagram

The engine mounted filter assembly incorporates a number of different features for the EMDEC system, all of which are discussed later in this section under “FUEL FILTER ASSEMBLY”.

Fuel exiting the filter assembly manifold runs through a network of steel and/ or reinforced flexible hose fuel lines which connect the fuel distribution block of the assembly manifold to the left bank and right bank engine fuel manifolds. Return fuel is routed by the network back through the distribution block to the ECM “cooling plate(s)” at either the sides or front of the engine, and through the fuel return section of the filter assembly manifold. A second fuel return line from the distribution block, with a 241 kPa (35 psi) pressure relief valve, may be used on some applications to relieve excess pressure during engine idle conditions.

11.2.1.1 MAINTENANCE

When any steel fuel lines or flexible hoses need to be removed or replaced, the following guidelines should be observed:

- All fitting connections must be cleaned prior to removal. This is to help prevent contaminants and debris from entering the exposed internal fuel passages during removal and reassembly. All replacement fuel lines, fittings and components must be checked to be certain they are free of internal debris or other contaminants prior to installation. Failure to do so may result in damage to the fuel injectors.
- Depending on working conditions, it may be advantageous to pre-assemble the fuel distribution lines on the filter assembly manifold with its respective internal pressure relief (check) valves.

  IMPORTANT: Make certain that the check valves are installed in the proper "free-flow" orientation as shown on the original system application drawing.
- All components must be reassembled following the arrangement shown on the original system application drawing. **Do NOT substitute components or their locations.** Follow proper shop practices when installing steel fuel lines or flexible hoses.

CAUTION

Do NOT kink, twist or crush flexible fuel hoses. If a hose gets damaged, it must be replaced before completing the installation. Always use two (2) wrenches to tighten fuel hose connections; one to tighten the nut, and one to prevent the hose from twisting while the nut is being tightened.

- Use of supplementary sealing compounds on any fittings or on special edge-molded gaskets used on fuel manifold applications is NOT recommended.

CAUTION

Do NOT substitute conventional paper gaskets for special edge-molded ("metal") gaskets. Conventional paper gaskets are prone to compression set which can lead to flange bolt torque loss and subsequent fuel leaks. As always, avoid surface damage to the flanges on which the edge-molded gaskets are to be applied.

- The fitting adaptors used on fuel hose assemblies are supplied pre-assembled with "O" rings made from a fuel resistant elastomer. If an "O" ring becomes damaged or defective, it must be replaced by a new one. See listing of "O" rings typically used on fuel line connections in the Service Data.

- All fitting threads and seats are to be lubricated with a light coating of ***clean*** engine oil prior to final assembly. Excess oil must NOT be allowed to contaminate the internal fuel passages. Wet all "O" rings with fuel oil to prevent tearing.
- There are two recommended methods for tightening fuel fittings (non-flare type) and adaptors; the Torquing and the F.F.F.T. (Flats From Finger Tight) Methods. The torquing method must be done using a properly calibrated torquing device. The torque specification for all non-flare type fittings and adaptors is 81 ± 3 Nm (60 ± 2 ft-lbs). The F.F.F.T. specification for all fittings and adaptors is 1-1/2 to 2 flats, which may be done as follows:

    1. Hand-tighten the joint so that it is snug (no more than 3.4 Nm (30 in-lbs) of torque.
    2. Make a longitudinal mark on one of the flats of the hex (fitting to be turned to tighten) and continue it in a line onto the body hex (fitting being tightened on).
    3. Tighten the joint further with a wrench according to the specified number of hex Flats From Finger Tight (1-1/2 to 2 F.F.F.T.).
    4. Make a "displacement" mark on the body hex (fitting being tightened on) in a line with the mark on the hex (fitting turned to tighten) to provide a visual indication that the joint has been tightened.

NOTE

On elbow assembly fittings #40046718 and 40046719, both the locknut and backing washer must be fully backed-off in the counterclockwise (CCW) direction prior to installation. These fittings are to be threaded into their respective ports until the washers contact the face of the ports. Final tightening must then be made by one of the two recommended methods.

- When the installation of all components is completed, prime the fuel system as recommended in the Operator or Service Manual. Check for leaks at all connections and from flexible fuel hoses. Perform an established fuel system leak-down test. If any leaks are found, determine the cause and repair them in a permanent manner.

CAUTION

Do ***NOT*** attempt any temporary fixes to the fuel system connections using sealing compounds or tapes.

The following warning must be heeded at all times in conjunction with Flexible Fuel Hose applications:

WARNING

Under no circumstances are flexible fuel hoses to be used as "grab handles" or "steps" to climb onto the engine. Flexible fuel hoses are not designed to bear any load. If the hoses are damaged in any way during service, they must be replaced immediately; otherwise safety hazards can result.

11.3 FUEL SYSTEM DESCRIPTION - TIER 2 ENGINES

As shown in Figure 11-1, an AC fuel pump draws fuel from the fuel tank through a fuel suction strainer. The pump forces fuel through a thermostatic valve and fuel preheater to the primary fuel filter. Note that there is a bypass valve located between the fuel pump and the thermostatic valve to direct fuel to the tank in the event of plugged filters. From the fuel filter, the fuel is directed to the diesel engine.

The fuel flows through injector supply manifolds that extend along both banks of the engine. The fuel pump delivers more fuel than is required by the injectors. This excess fuel volume provides injector cooling and lubrication.

Return fuel from the injectors flows from the return piping to a back pressure valve. This valve imposes a nominal back pressure on the system, thereby maintaining a positive supply of fuel for the injectors.

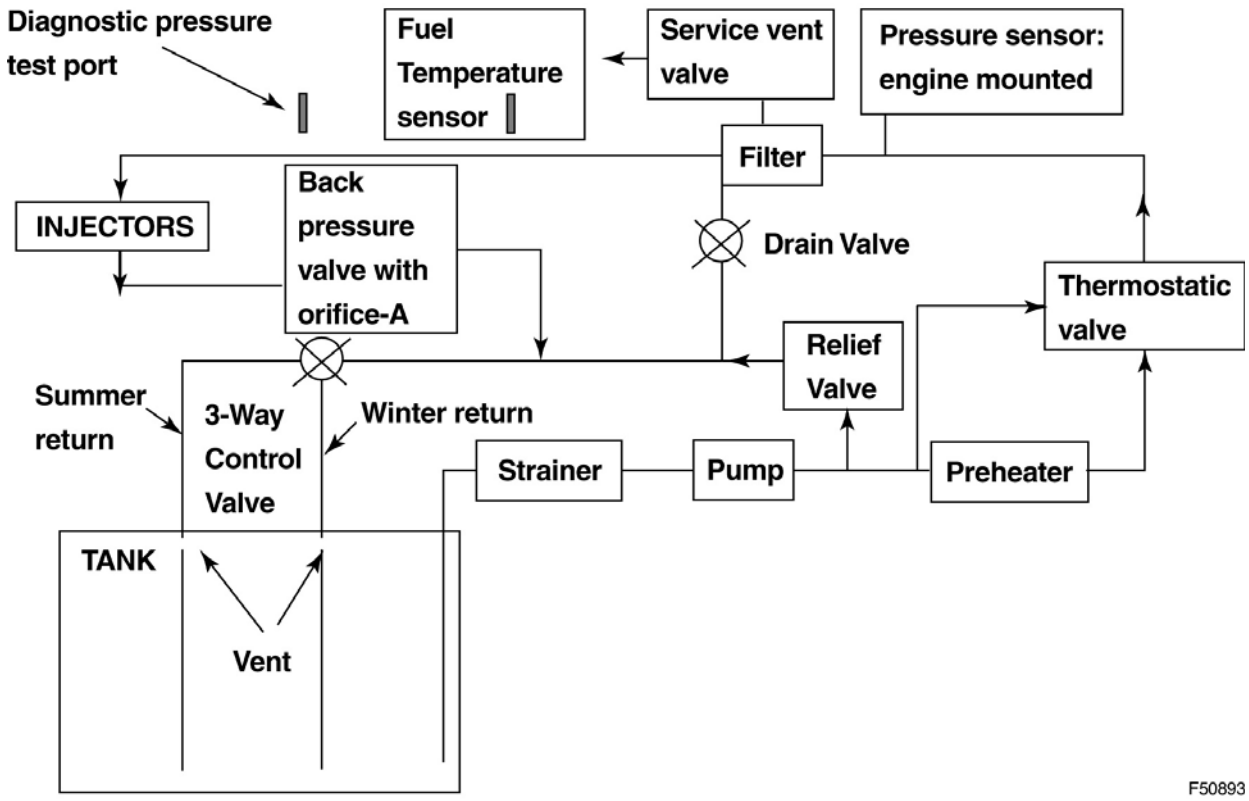


Figure 11-1. Fuel Oil System Simplified Flow Diagram

The fuel system is equipped with a manually operated 3-way valve, Figure 11-2, page 11-13, to direct return fuel to either the SUMMER return or the WINTER return. This valve should be positioned according to railroad maintenance procedures dictate.

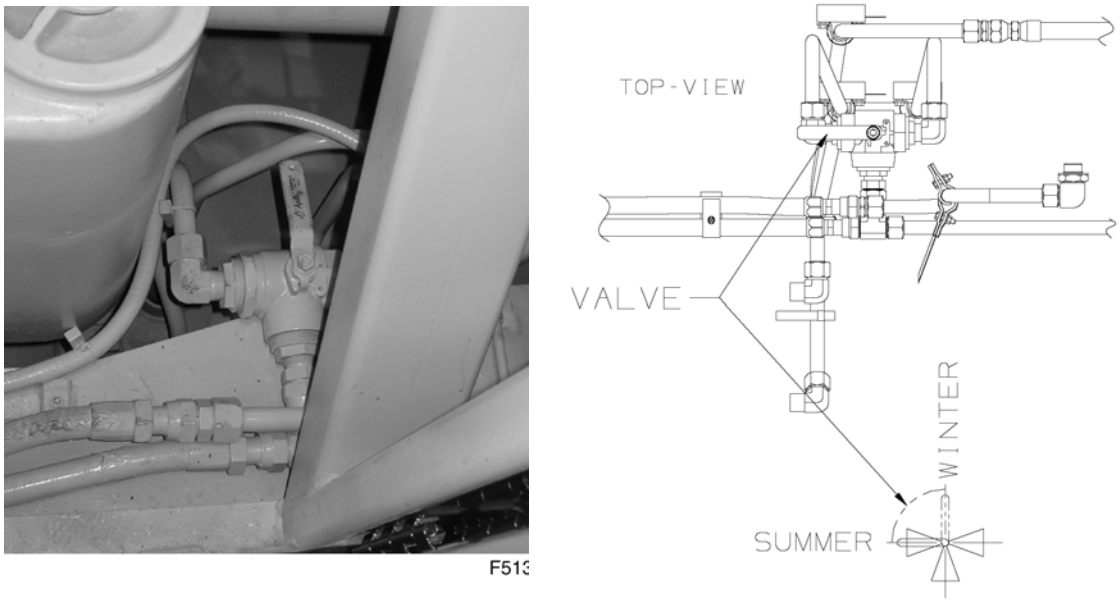


Figure 11-2. Summer/Winter Fuel Return Valve

The fuel pump relief valve, Figure 11-3, page 11-13, is located near the fuel pump. It must be installed as shown to provide over-pressure protection for the fuel pump.

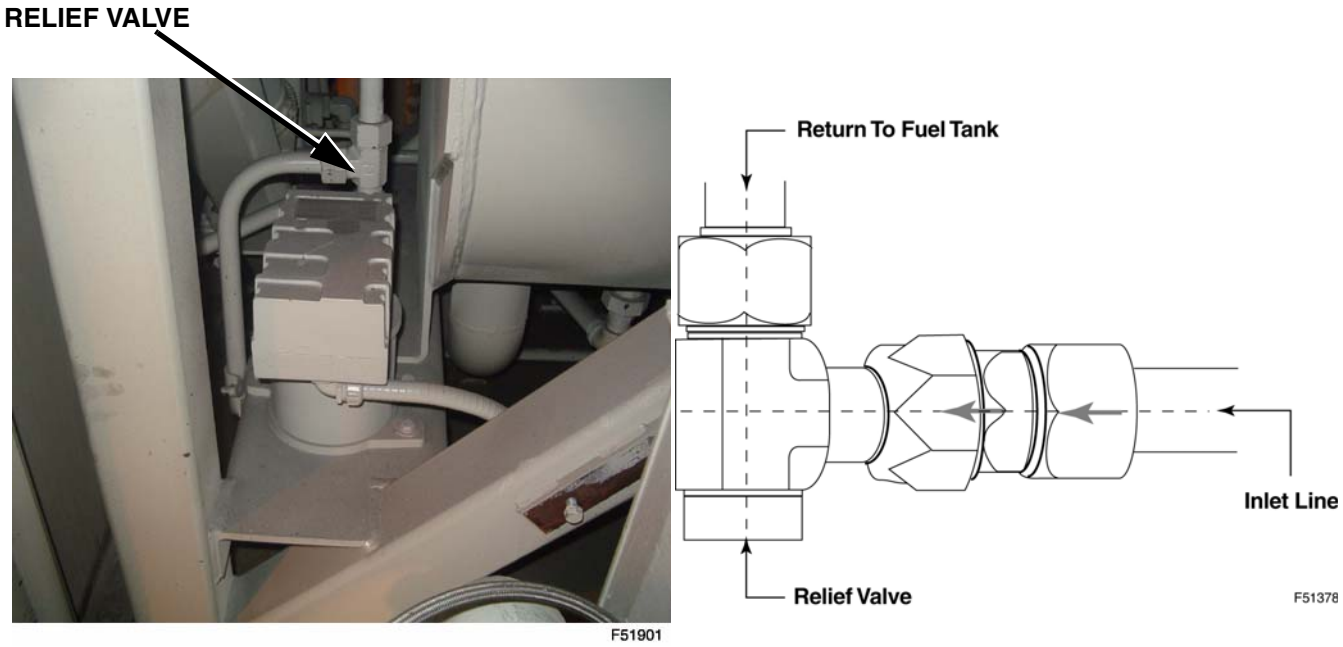


Figure 11-3. Fuel Pump Relief Valve

11.4 FUEL FILTER ASSEMBLY

11.4.1 DESCRIPTION (CURRENT MODEL ENGINES W/ EUI INJECTORS)

The engine mounted (secondary) fuel filter assembly on current model 8, 12, and 16-cylinder engines with EUI injectors, Figure 11-4. on page 11-14, mounts in the conventional position at the right front of the engine. A similar filter assembly used on 20-cylinder engines with EUI injectors, Figure 11-5. on page 11-15, functions in the same manner as the assembly used on 8, 12, and 16-cylinder engines, however, it is located at the front of the engine, immediately below the center of the counterweight housing. The flow diagram, Figure 11-5. on page 11-9, indicates fuel flow through this type of filter assembly.

Fuel returning from the injectors passes through the “return fuel” section of the filter assembly manifold (block). A relief valve at the inlet establishes a fuel back pressure at the injectors for improved operation. The “return fuel” relief valve is rated at 276 kPa (40 psi).

As the elements of the filter assembly become dirty, the fuel pressure will increase. When fuel pressure in the filter assembly manifold reaches the cracking pressure of the “by-pass” relief valve, the valve will open allowing fuel to return to the fuel tank, starving the engine. The “by-pass” relief valve is rated at 827 kPa (120 psi).

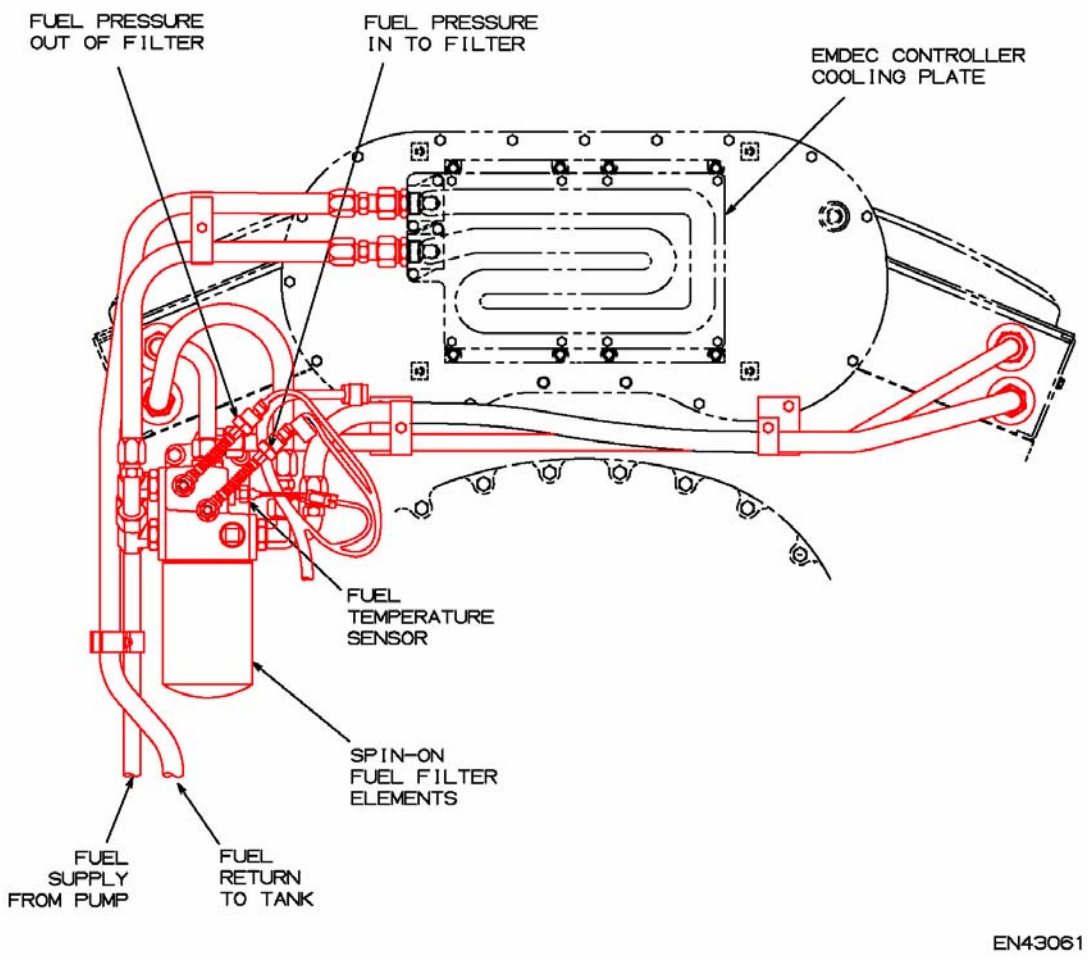


Figure 11-4. Typical Fuel Filter Assembly (8, 12, and 16-Cyl. Engines w/ EUI Injectors)

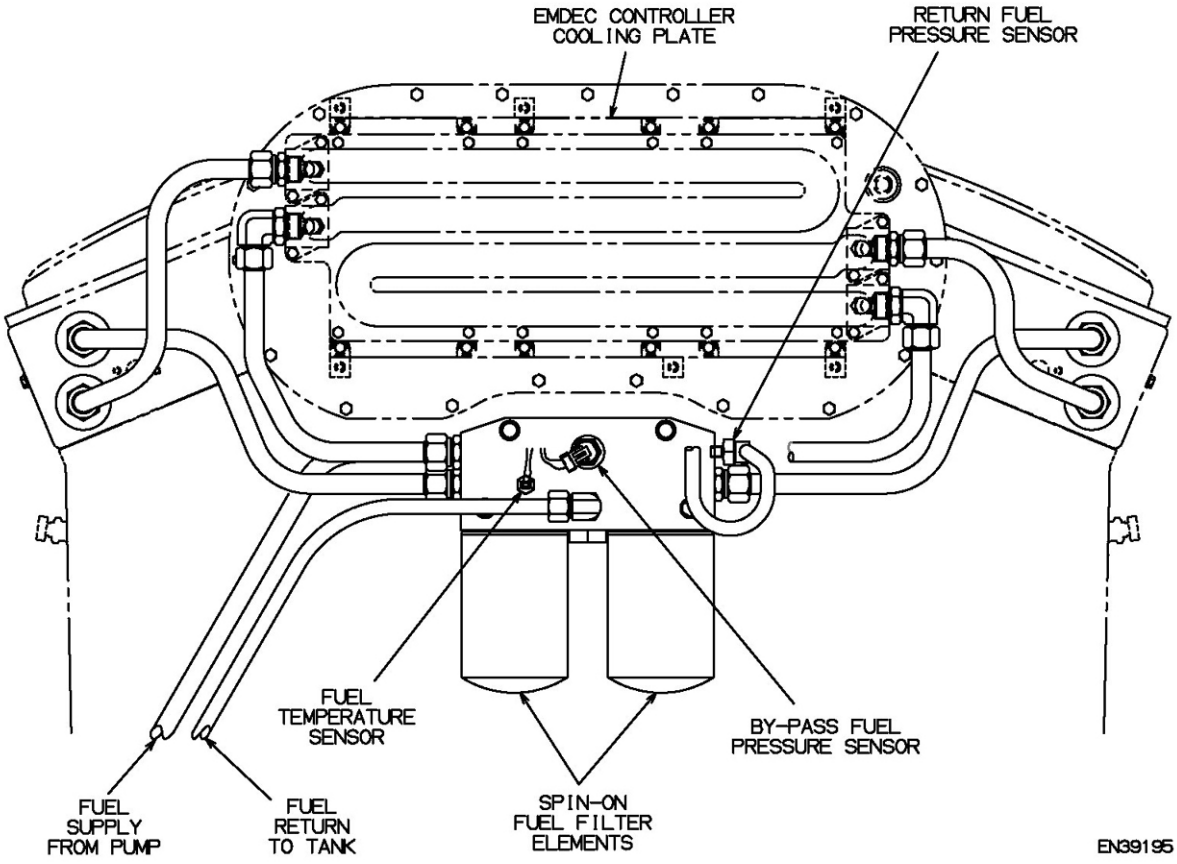


Figure 11-5. Typical Fuel Filter Assembly (20-Cyl. Engines w/ EUI Injectors)

11.4.2 DESCRIPTION (EARLY MODEL 8, 12, AND 16-CYLINDER ENGINES W/ EUI INJECTORS)

The engine mounted (secondary) fuel filter assembly on early model 8, 12, and 16-cylinder engines w/ EUI injectors, Figure 11-6. on page 11-16, 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, Figure 11-7. on page 11-16, indicates fuel flow through this type filter assembly.

Fuel returning from the injectors passes through the “return fuel” sight glass (nearest the engine) and returns to the fuel tank. Under normal operation, this glass is full of fuel. A relief valve at the inlet to the “return fuel” sight glass establishes a fuel back pressure at the injectors for improved operation. The valve is rated at 35 kPa (5 psi) for engines equipped with MUI injectors, and at 172 kPa (25 psi) for engines with EUI injectors.

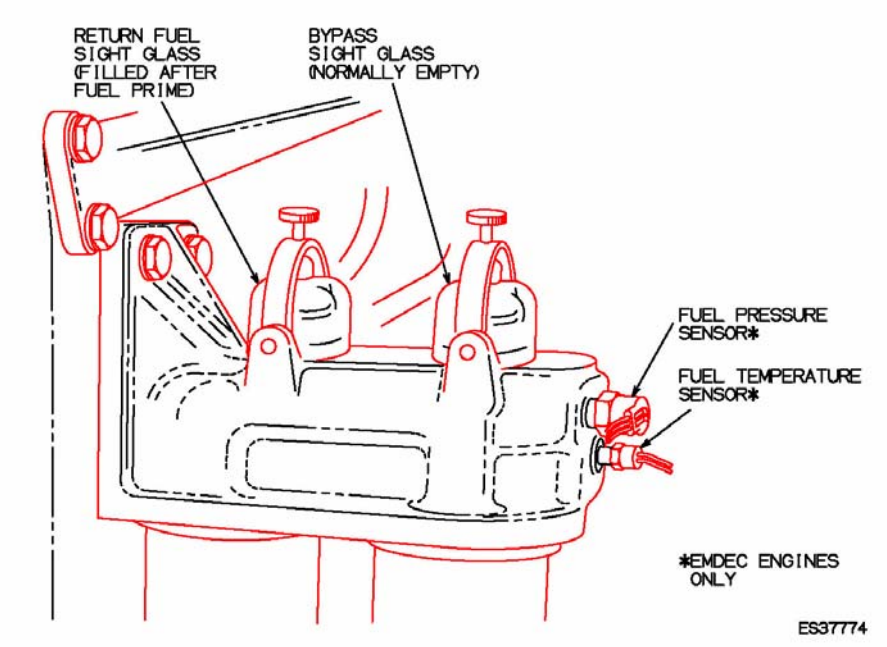


Figure 11-6. Typical Fuel Filter Assembly (Early Model 8, 12, and 16-Cylinder Engines w/ EUI Injectors)

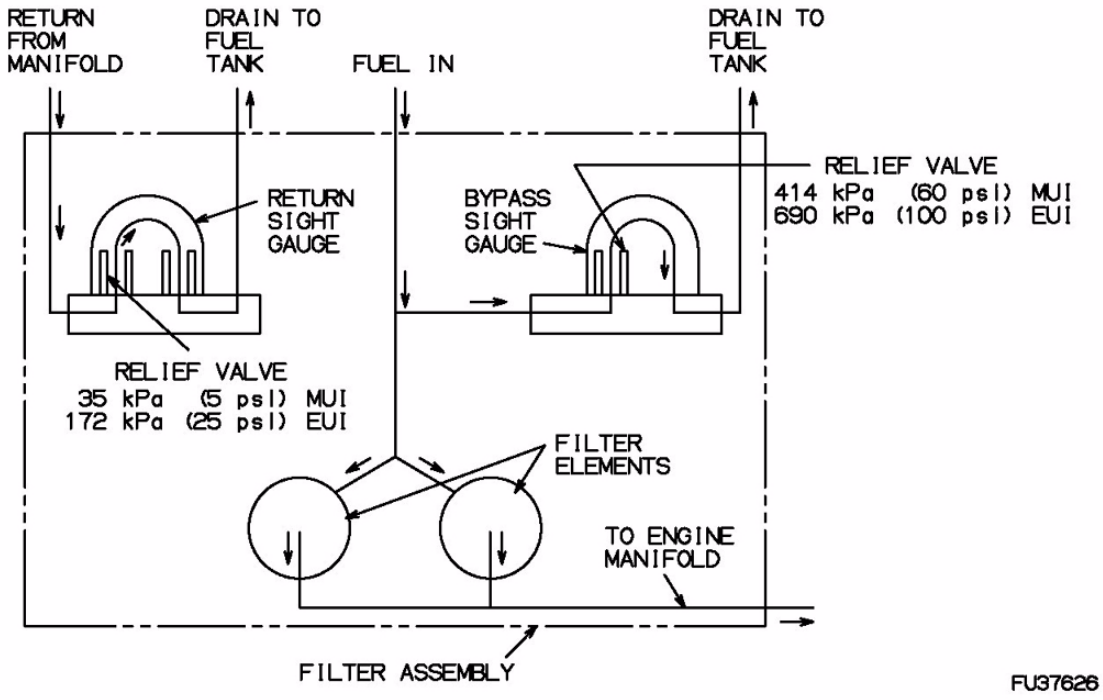


Figure 11-7. Fuel Flow Through Filter Assembly (Early Model 8, 12, and 16-Cylinder Engines w/ EUI Injectors)

NOTE

The following paragraph concerning air bubbles in the “return fuel” sight glass is still valid for governor controlled engines equipped with MUI injectors. EMDEC controlled engines with EUI injectors operate with a greater fuel supply pressure and will inherently display a certain amount of fuel turbulence in the “return fuel” sight glass during fuel prime and normal operation. Operators are advised to IGNORE BUBBLES IN THE RETURN FUEL SIGHT GLASS on engines equipped with EUI injectors.

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 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.

During normal operation, the “bypass” sight glass (farthest 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 reaches the cracking pressure of the relief valve under the glass, the valve will open, fuel will enter and fill the “bypass” sight glass, and then return to the fuel tank, starving the engine. The relief valve is rated at 414 kPa (60 psi) for engines equipped with MUI injectors, and at 690 kPa (100 psi) for engines with EUI injectors (except 20-cylinder).

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.

CAUTION

The filter elements used on EUI injector equipped engines are larger and of a different composition than those used on MUI injector engines. Do NOT interchange elements between these two engine applications.

On EMDEC equipped engines, the two pipe plugs installed in pressure tap passages in the filter assembly manifold (block) used with MUI injector engines are replaced by fuel system diagnostic sensors:

- The Fuel Pressure Sensor (FPS), located in the upper tap, uses a pressure transducer to sense the fuel pressure at a point immediately *before* the "bypass" relief valve and the filter elements. The EMDEC master Electronic Control Module (ECM) uses the input signal from the FPS to monitor the fuel supply pressure for advance warning of an impending power loss.
- The Fuel Temperature Sensor (FTS), located in the lower tap, uses a thermal sensor to measure fuel supply temperatures at a point immediately *after* the filter elements. The EMDEC master ECM uses the input signal from the FTS to calculate fuel consumption and make fuel input metering compensations.

11.4.3 MAINTENANCE

The filter elements should be removed and new ones installed at interval(s) specified in the applicable Scheduled Maintenance Program.

At the time of element replacement, the filter body (and sight glasses, if applied) 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 film of oil to the gasket of a new element and apply element to filter assembly manifold (block).
4. Hand tighten until the gasket contacts the manifold, then tighten 1/2 turn.
5. Check the condition of the sight glasses (if applied), and clean if necessary.
6. Check for leaks when the engine is started.

Refer to Troubleshooting Section 15 for detailed information to check EMDEC system operation (including FPS and FTS sensors, wiring harness, and ECM modules).

NOTE

Tier 2 engines do not have secondary fuel filters, filter housing or sight glasses. A back pressure valve with an orifice located in the return line piping at the front of the engine creates system back pressure. A pressure relief valve on the outlet of the fuel pump protects the system from over-pressure.

11.5 SERVICE DATA - FUEL OIL SYSTEM

11.5.1 REFERENCES

Reconditioning MUI Needle Valve Injectors.....M.I. 418
Diesel Fuel Recommendation .....M.I. 1750
Fuel And Soak Back Pumps.....M.I. 4110

11.5.2 EQUIPMENT LIST

PART NO.

MUI Injector timing gauge 8034638

Injector prybar 8041183

Plastic spray cup (extra - used with MUI injector test stand) . 8171780

Oil, injector test, storage, and rust prevention
-208 liters (55 gal.) drum..... 8203258
-19 liters (5 gal.) can 8219007

MUI Injector rack gauge..... 8339610

Injector holding rack..... 8431626

MUI Injector linkage setting jack 8432485

MUI Injector tester (complete) 9549055

EUI Replacement “O” rings -
- Fuel hose fittings (8, 12, & some 16-cylinder engines) .. 40047982
- Injector jumper hose-to-filter cap (all engines) 40061536

MUI replacement fuel filter element..... 8422132

EUI replacement fuel filter elements
- 8, 12, & some 16-cylinder engines 40052587
- 20-cylinder & some 16-cylinder engines..... 40053463

SECTION 12. EMDEC SYSTEM

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12.1 DESCRIPTION

The EMDEC system is an electronic engine speed control and fuel management system. It is designed to provide optimal control of critical turbocharged engine functions which affect fuel economy, smoke, and emissions. The system also provides the capability to protect the engine from serious damage resulting from extreme operating conditions, such as high engine temperatures or low oil pressure.

The major “on engine” sub-systems of EMDEC include:

- The Electronic Control Module(s) (ECM)
- The Electronic Unit Injectors (EUI)
- Engine Sensors
- Wiring Harnesses (External, Injector, Sensor and Power)

12.1.1 ELECTRONIC CONTROL MODULE(S)

The engine mounted Electronic Control Module(s) (ECM), as typically shown in 12-1, provides the control logic for overall engine management. The ECM receives electronic inputs from the locomotive throttle interface and sensors on the engine, and uses the information to control engine operation.

The ECM continuously performs self diagnostic checks and monitors the other system components. System diagnostic checks are made from the moment that the Engine Control circuit breaker is closed - on through engine start up and during all engine operating modes.

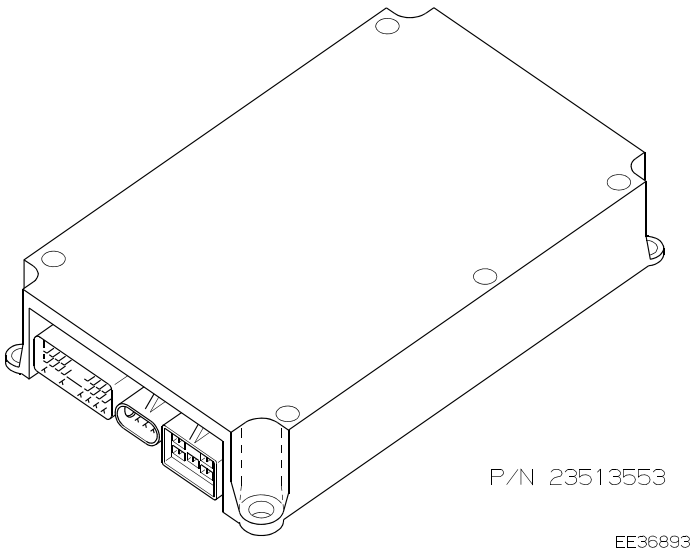


Figure 12-1. Typical Electronic Control Module (ECM)

The ECM's pre-programmed memory controls the basic engine functions, such as rated speed and power, timing and quantity of fuel injection, engine governing, cold start logic, transient fuel delivery, diagnostics, and engine protection. The control logic determines the duration and timing of fueling for precise fuel delivery and optimum fuel economy based on predetermined calibration tables in the ECM memory.

Multiple ECM units are employed on engines with twelve (12) or more cylinders. One ECM is called the master (or Sender), while the others are referred to as receivers. The master ECM is the primary controller of the engine. It receives input from the various sensors, then determines proper timing and communicates this information to the injectors it controls. The master ECM sends this information to receiver ECM(s). The receiver ECM(s) signal their injectors to operate in the same manner.

12.1.2 ELECTRONIC UNIT INJECTORS (EUI)

The Electronic Unit Injectors (EUI) perform the same basic function as the mechanical unit injectors (MUI). They both time, meter, pressurize and atomize the fuel. The metering and timing functions of the EUI are controlled electrically by the EMDEC system, while the pressurizing and atomizing are done mechanically with an injector plunger and follower actuated by the engine cam and rocker arm system.

Refer to Section 11 earlier in this manual for operation and maintenance information on the Electronic Unit Injectors (EUI) and the EMDEC fuel delivery system. Also see Section 15 for detailed troubleshooting information to check operation of the EUI injectors with the EMDEC system .

12.1.3 ENGINE SENSORS

The EMDEC system engine sensors provide information to the master ECM regarding various engine performance characteristics. The information sent to the ECM is used to regulate engine performance, activate the engine protection system, and provide diagnostic information.

The following engine sensors are currently provided with the EMDEC system:

- Timing Reference Sensor (TRS)
- Synchronous Reference Sensor (SRS)
- Air Inlet Temperature Sensor (ATS)
- Air Box (Turbo Boost) pressure Sensor (TBS)
- Air Box Temperature Sensor
- Oil Pressure Sensor (OPS)
- Oil Temperature Sensor (OTS)
- Crankcase Pressure Detector
- Coolant Pressure Sensors (2) (CPS)
- Fuel Pressure Sensors (2) (FPS)
- Fuel Temperature Sensor (FTS)

12.1.4 ENGINE PERFORMANCE SENSORS

12.1.4.1 TIMING AND SYNCHRONOUS REFERENCE SENSORS

The Timing Reference Sensor (TRS) indicates the crank position of every cylinder. The Synchronous Reference Sensor (SRS) indicates a specific cylinder in the firing order. See Figure 12-2 for a representative illustration of these sensors, and refer to “EMDEC TIMING TARGETS AND SENSORS” in Section 6 earlier in this manual for additional information on the application of these sensors.

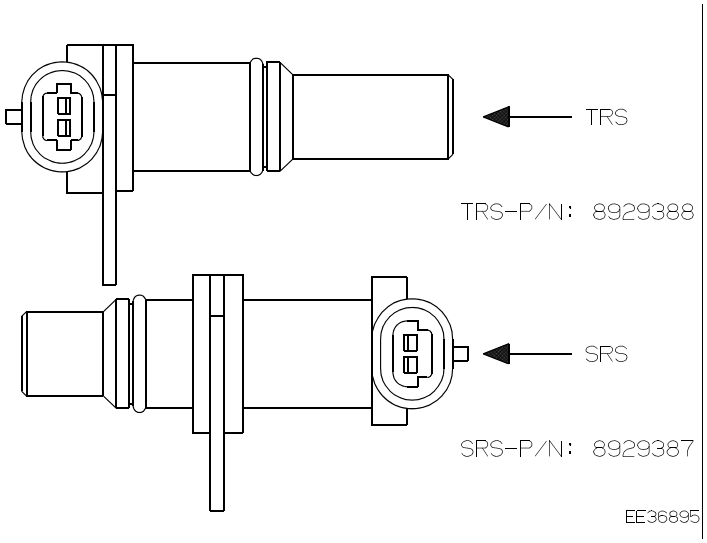


Figure 12-2. SRS and TRS Sensors

Refer to Troubleshooting Section 15 for detailed information to check operation of the SRS and TRS engine performance sensors with the EMDEC system .

12.1.4.2 AIR BOX (TURBO BOOST) PRESSURE SENSOR

The Air Box “Turbo Boost” Pressure Sensor (TBS), Figure 12-3, provides data to the ECM for use in smoke control. This device is mounted to the underside of the crankcase pressure detector, as shown in Figure 12-3, where it is connected by a short flexible line to the engine air box.

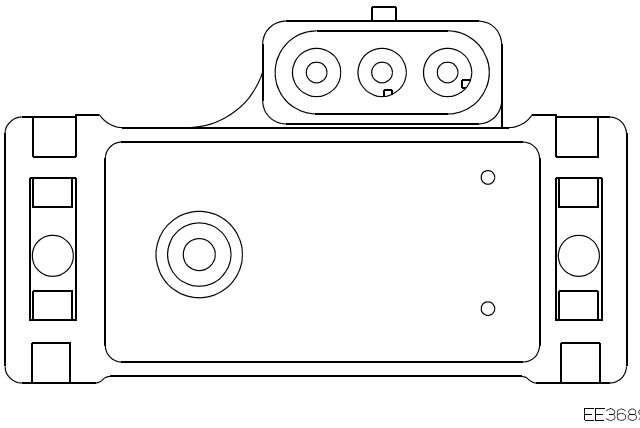


Figure 12-3. Turbo Boost Pressure Sensor (TBS)

Refer to Troubleshooting Section 15 for detailed information to check operation of the TBS engine performance sensor with the EMDEC system.

12.1.4.3 AIR INLET TEMPERATURE SENSOR

The Air Inlet Temperature Sensor (ATS) provides necessary data to the ECM to vary injection timing for cold starts and white smoke control.

Refer to Troubleshooting Section 15 for detailed information to check operation of the ATS engine performance sensor with the EMDEC system .

12.1.4.4 AIR BOX TEMPERATURE SENSOR

The Air Box Temperature Sensor is used to provide necessary data to the ECM to vary injection timing for smoke control.

Refer to Troubleshooting Section 15 for detailed information to check operation of the this engine performance sensor with the EMDEC system .

12.1.5 ENGINE PROTECTION SENSORS

See Engine Protection Section 13 for additional application information on each of the engine protection sensors. Refer to Troubleshooting Section 15 for detailed information to check operation of the engine protection sensors with the EMDEC system.

12.1.5.1 OIL PRESSURE SENSOR

The Oil Pressure Sensor (OPS) activates the engine protection if the engine lube oil pressure at the turbocharger drops to a predetermined setpoint.

12.1.5.2 OIL TEMPERATURE SENSOR

The Oil Temperature Sensor (OTS) will activate engine protection if oil inlet temperature exceeds a predetermined setpoint.

12.1.5.3 CRANKCASE PRESSURE DETECTOR

The Crankcase Pressure Detector, 12-4, activates engine protection if crankcase pressure increases to a predetermined positive setpoint.

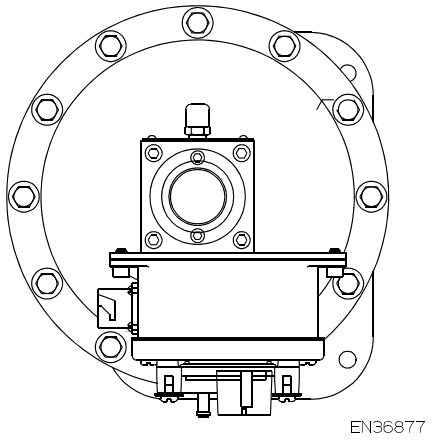


Figure 12-4. Crankcase Pressure Detector (Shown w/ TBS Sensor)

NOTE

If activated, the detector must be manually reset by pushing in the reset button.

WARNING

Following an engine shutdown caused by actuation of the crankcase pressure detector, 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 actuation 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 portion of the detector cannot be reset, do NOT operate the engine until the detector has been replaced, since the diaphragm backup plates may be damaged.

12.1.5.4 COOLANT PRESSURE SENSORS

The Coolant Pressure Sensors (CPS) monitor coolant pressure drop across the engine to activate the engine protection when the difference in pressure values is greater than a predetermined setpoint.

12.1.6 ENGINE DIAGNOSTIC SENSORS

See Fuel Oil System Section 11 for additional application information on the engine diagnostic sensors. Refer to Troubleshooting Section 15 for detailed information to check operation of the engine diagnostic sensors with the EMDEC system.

12.1.6.1 FUEL PRESSURE SENSOR(S)

The Fuel Pressure Sensor (FPS) monitors fuel supply pressure to warn of an impending power loss. On 20-cylinder engine applications where two (2) sensors are used, fuel pressure drop across the engine (filters and injectors) is monitored to detect when the difference in pressure values is greater than a predetermined setpoint.

12.1.6.2 FUEL TEMPERATURE SENSOR

The Fuel Temperature Sensor (FTS) measures fuel supply temperatures necessary for fuel consumption calculations and fuel input compensation by the ECM.

12.2 WIRING HARNESSES

12.2.1 EXTERNAL HARNESSES

An external wiring harness provides the communications link between the master ECM and the EMDEC interface module which is located “off engine” in an electrical cabinet. The interface module receives throttle signals from the locomotive computer and converts them to DC speed reference signals which it sends to the ECM. The interface also receives various engine diagnostic information back from the ECM to register any engine fault conditions on an annunciator panel or locomotive computer display, and to provide load information from EMDEC back to the locomotive computer so it can determine how well the engine is responding to the load.

Multiple ECM units are employed on engines with 12 or more cylinders. One ECM is designated as the master (or sender), while the others are referred to as receivers. The ECM units communicate to each other over a 2 way serial link over which the master unit can send and receive engine operational data signals.

12.2.2 EUI INJECTOR HARNESSES

There are two harnesses used to conduct signals from the ECM units to the EUI injectors to energize the solenoids which control the duration and timing of the injector fuel metering (poppet) valves.

12.2.3 SENSOR HARNESSES

Engine sensors are connected by harnesses to the master ECM to send various voltage signals relative to engine performance, protection and diagnostics - and are provided in the following 3 forms:

1. Magnetic pickups to sense targets mounted on the flywheel and provide synchronous (SRS) and timing (TRS) signals to each ECM computer for resetting and re calibration of the fuel injection on every revolution of the crankshaft. The SRS and TRS sensors are two wire devices.
2. Temperature sensors (Thermistors) are devices that react to an increase in temperature by reducing voltage. They operate within a range of 0 to 5 VDC and are used to provide oil (OTS), fuel (FTS), and air box and inlet temperature signals to the master ECM.
3. Pressure sensors (Capacitive Pressure Transducers) are devices that react to changes in pressure by changing capacitance, converting the capacitance to a voltage signal. They operate in a range of .5 to 4.5 VDC and are used to provide turbo boost (TBS), oil (OPS), coolant (CPS), fuel (FPS) pressure signals to the master ECM.

12.2.4 POWER HARNESS

Locomotive 74 VDC battery or auxiliary power is supplied to an isolated 74 to 24 VDC converter which is used exclusively to supply power to the EMDEC system. One feed provides this power to the EMDEC interface module located in an electrical cabinet, while a second feed connects to the engine mounted ECM units through the power harness.

12.2.4.1 MAINTENANCE

Most connectors and terminals in the wiring harnesses on (or connected to) the engine are protected against moisture and dirt which could create oxidation and deposits on the terminals. This protection is important due to the very low voltage and current levels found in the electronic system. If, in the course of troubleshooting the EMDEC system (as described in Troubleshooting Section 15), a problem with a wiring harness or connection is indicated or suspected, it may be appropriate to repair the harness instead of replacing it entirely.

CAUTION

Any fault condition that could cause the EMDEC protection system to shut down the engine can also occur due to a break (open) in the connections or wiring between an engine protection sensor and the master ECM. Therefore, it is important to exercise special care when working on the engine at or near the wiring harnesses to prevent damage to the EMDEC system components.

Use care when checking the integrity of the connections or replacing terminals in them. It is possible to short between opposite terminals and damage certain components. Always use jumper wires between connectors for circuit checking. NEVER *probe* through a connector.

When troubleshooting the harnesses, open circuits are often the most difficult to locate by sight as oxidation or terminal misalignment conditions are hidden by the connectors. Merely "wiggling" a connector on a sensor or in the wiring harness may serve to correct the open circuit condition. This should always be considered when an open circuit or failed sensor is indicated. Intermittent problems may also be caused by oxidation or loose connections.

EMDEC connectors should be disconnected using the proper un-latching tool. The appropriate repair procedure for changing a terminal or connector is as follows:

1. Use a Pick tool to remove the existing terminal by pushing in the locking ear on the terminal, and then pulling the terminal through the end of the connector that plugs into the sensor or ECM.

2. Detach the wire from the terminal close to the terminal (if still attached).

3. Strip back the wire 3.63 mm (1/7") and pull wire through the connector first before crimping on new terminal.

4. Crimp the wire to the core of the new terminal using crimping tool #12085271.

5. Crimp the terminal to the wire insulation using crimping tool #12085270.

6. Pull the wire back through the connector so the new terminal pulls back into the connector and "snaps" into place. See Service Data for a list of standard tools and connectors.

12.3 SERVICE DATA - EMDEC SYSTEM

12.3.1 ENGINE SPEED SCHEDULES

Engine	Throttle Position	Speed (RPM)	
		Engine Speed	Nom. HP
8-710G3B	N/A	N/A	N/A
12-710G3B	Stop		3200
	Low Idle	235± 4	
	Idle	299± 4	
	1	299± 4	
	2	405± 4	
	3	449± 4	
	4	554± 4	
	5	600± 4	
	6	706± 4	
	7	794± 4	
	8	904± 4	
12N-710G3B	Stop		3200
	Low Idle	200± 4	
	Idle	269± 4	
	1	269± 4	
	2	343± 4	
	3	490± 4	
	4	568± 4	
	5	651± 4	
	6	729± 4	
	7	829± 4	
	8	904± 4	

Engine	Throttle Position	Speed (RPM)	
		Engine Speed	Nom. HP
16-710G3B	Stop		4000
	Low Idle	200± 4	
	Idle	269± 4	
	1	269± 4	
	2	343± 4	
	3	490± 4	
	4	568± 4	
	5	651± 4	
	6	729± 4	
16-710G3C	7	820± 4	4300/4500
	8	904± 4	
	Stop		
	Low Idle	200± 4	
	Idle	290± 4	
	1	290± 4	
	2	370± 4	
	3	490± 4	
	4	600± 4	
	5	675± 4	
	6	760± 4	
	7	860± 4	
	8	950/1000± 4	
20-710G3B	Stop		5000
	Low Idle	200± 4	
	Idle	274± 4	
	1	274± 4	
	2	347± 4	
	3	490± 4	
	4	605± 4	
	5	651± 4	
	6	729± 4	
	7	820± 4	
	8	904± 4	
	Stop		
	Low Idle	200± 4	
	Idle	274± 4	
	1	274± 4	

Engine	Throttle Position	Speed (RPM)	
		Engine Speed	Nom. HP
20-710G3C	2	347± 4	5500
	3	490± 4	
	4	605± 4	
	5	651± 4	
	6	760± 4	
	7	860± 4	
	8	950± 4	

12.3.2 REFERENCES

EMDEC System Troubleshooting Guide..... N00012EP

12.3.3 EQUIPMENT LIST

PART NO.

Sensors/Terminals -

SRS sensor..... 8929387
TRS Sensor..... 8929388
FTS & OTS & Air Inlet/Box Temperature sensors (8, 12, & 16-cylinder engines)..... 40063567

FTS, OTS & Air Inlet/Box Temperature sensors (20-cylinder engines)..... 40052129
CPS sensors (20-cylinder engines & “Y” pipe)..... 40059278

FPS sensor 40059731

FPS, CPS & OPS sensors 40055333

- Terminals for above sensors 12103881
TBS sensor 16070629

- Terminal for TBS sensor..... 12089040

Crankcase pressure detector (w/o TBS sensor) 40051210

Crankcase pressure detector (w/ TBS sensor) 40071740

- Terminal for crankcase pressure detector..... 40051635

ECM & Injector Terminals -

Power harness (ECM end) 12077413
Injector harness (ECM end).....12089289
Injector harness (Injector end) 12034222
Engine harness (ECM end, from sensors) 12103881

External harnesses (ECM to ECM & from interface).....12103881

Tools -

Terminal pick ..... Standard hardware item

Terminal un-latching tool ..... NPN

Terminal to wire insulation crimping tool.....12085270
Terminal to wire core crimping tool) 12085271

SECTION 13. ENGINE PROTECTION

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13.1 GENERAL

This section contains the description and maintenance information for engine protective devices and systems. These devices or sensor inputs are designed to shut down the engine in the event of a malfunction occurring during engine operation.

13.1.1 LOW OIL PRESSURE SHUTDOWN (EMDEC)

13.1.1.1 DESCRIPTION

The EMDEC system Oil Pressure Sensor (OPS) uses a pressure transducer connected at the turbocharger filter head in order to sense the lowest oil pressure at the rear of the engine. The EMDEC master Electronic Control Module (ECM) monitors the input signal from the OPS and will respond, by shutting down the engine, when a true system low oil pressure condition is detected.

The ECM will, however, ignore the OPS signal for the first 60 seconds after engine start to allow operating pressure to be reached and to provide time to locate trouble spots in the event of a malfunction.

13.1.1.2 MAINTENANCE

Refer to Troubleshooting Section 15 for detailed information to check EMDEC system operation (including ORS sensor, wiring harness, and ECM modules).

13.1.2 CRANKCASE PRESSURE DETECTOR (EMDEC)

13.1.2.1 DESCRIPTION

The crankcase pressure detector used on engines equipped with the EMDEC system is a compact device used to sense malfunctions resulting in a positive, rather than the normally negative, engine crankcase pressure. If a positive pressure is determined, this device will trip to signal the EMDEC master Electronic Control Module (ECM) which will respond by shutting down the engine.

This switch type crankcase pressure detector, Figure 13-1, has a long stem held in a latched position until a positive pressure builds up in the crankcase. This pressure is applied to the large diaphragm which, in moving, releases the long stem. Outward movement of the stem operates a lever to close contacts in a switch mechanism attached to the bottom of the detector. This switch then provides the shutdown signal to the ECM.

NOTE

Tier 2 engines are equipped with a negative pressure sensor which is located in the pressure sensor box.

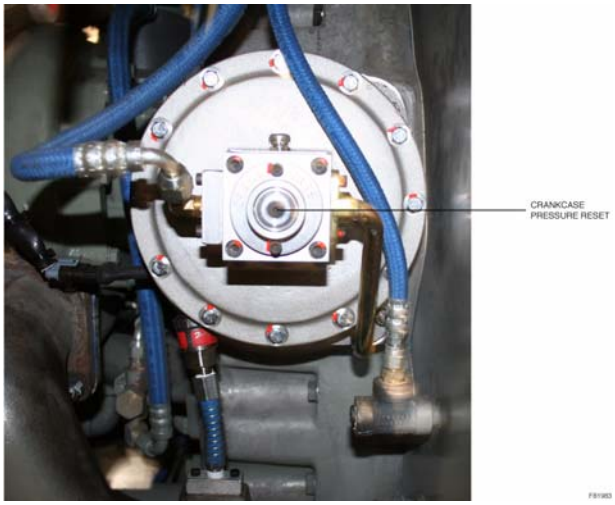


Figure 13-1. EMDEC Crankcase Pressure Detector

Crankcase ventilating equipment normally maintains a negative pressure in the crankcase. A malfunction, whether by plugging of crankcase ventilating system, excessive blowby, faulty seals or damaged components, or crankcase explosion, will result in positive pressure and crankcase pressure detector trip.

The following are conditions which can cause a pressure detector to trip:

- Blockage of oil separator or aspirator tube in exhaust;
- Cylinder compression leak into oil pan;
- Overheated part causing ignition of oil vapor;
- Incorrectly applied lube oil relief valve in accessory gear train which allows oil splash to reach the diaphragm of the detector;
- Excessive oil level in crankcase, resulting in blockage of oil separator;
- Air box leak to crankcase.

WARNING

Following an engine shutdown caused by tripping of the EMDEC crankcase pressure detector, 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 (2) 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 cannot be reset, do ***NOT*** operate the engine until the pressure detector has been replaced, since the diaphragm backup plates may be damaged.

NOTE

Replace or qualify the device any time that a true crankcase pressure trip has occurred.

When a shutdown occurs, the reset button must be manually reset. When pressing the reset button on a dead engine, the air pressure on the diaphragm is the same on both sides and only the light spring force is available to move the diaphragm to a latched position. With the reset button held in to release the diaphragm, air must enter at the front of the diaphragm through the vent fitting to permit the spring to move the diaphragm until the long stem and reset button remain latched. This takes several seconds when detector is cold. The reset button must therefore be depressed for several seconds to ensure complete latching.

13.1.2.2 MAINTENANCE

THE DETECTOR SHOULD BE TESTED PERIODICALLY TO ENSURE PROPER OPERATION.

Without starting the engine, remove the cap from the vent on top of the detector. Using a hydrometer bulb, create a suction on the vent tube. 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 the 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. Unscrew the vent tube on top of the detector and connect the vacuum pump to a tee in a line between the vent tube port 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 at the end of this section for limits.

13.1.3 OVERSPEED CONTROL

13.1.3.1 MECHANICAL OVERSPEED TRIP (GOVERNOR)

An overspeed trip mechanism, normally provided on governor controlled engines, is used to mechanically prevent the injection of fuel into the cylinders should the engine speed become excessive.

Figure 13-2 shows the mechanical overspeed trip mechanism. If the engine speed should increase to the specified limits, the overspeed mechanism will shut down the engine.

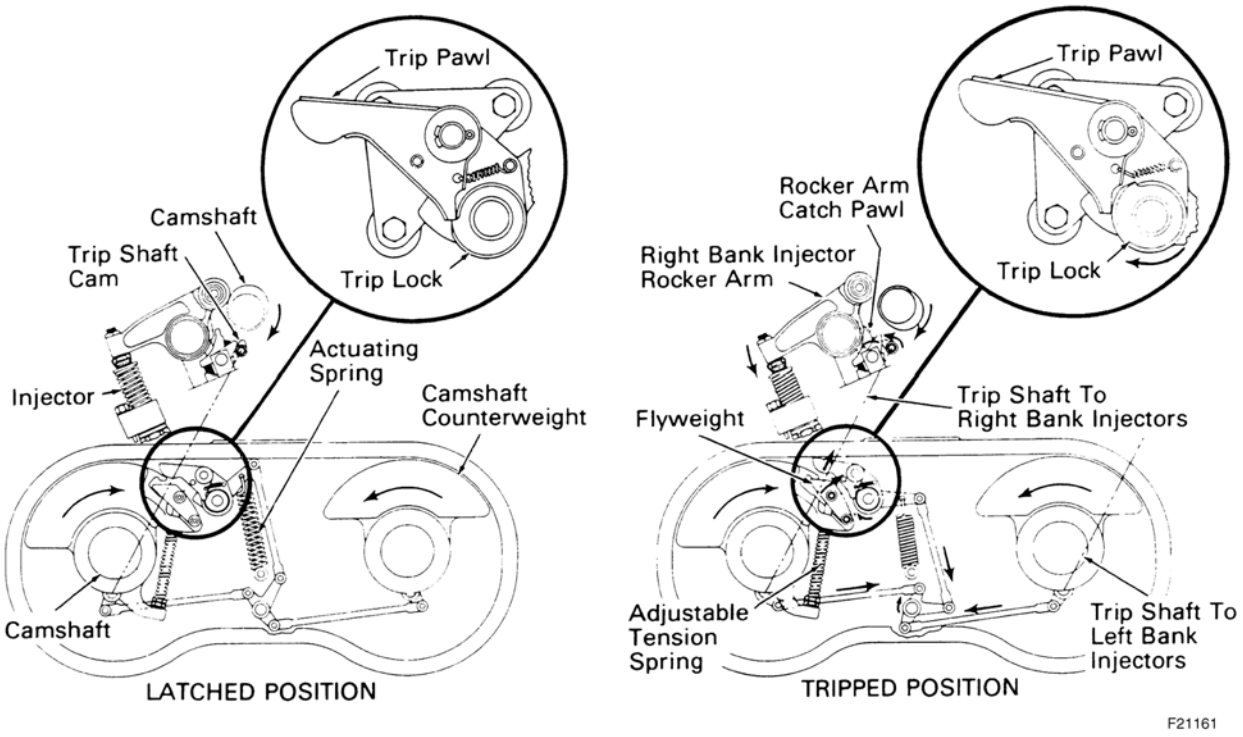


Figure 13-2. Overspeed Trip

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 spring-operated links and a lever mechanism. A reset lever on the trip lock shaft, when pulled towards the right bank, puts tension on an 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 pawl.

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, Figure 13-3, 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.

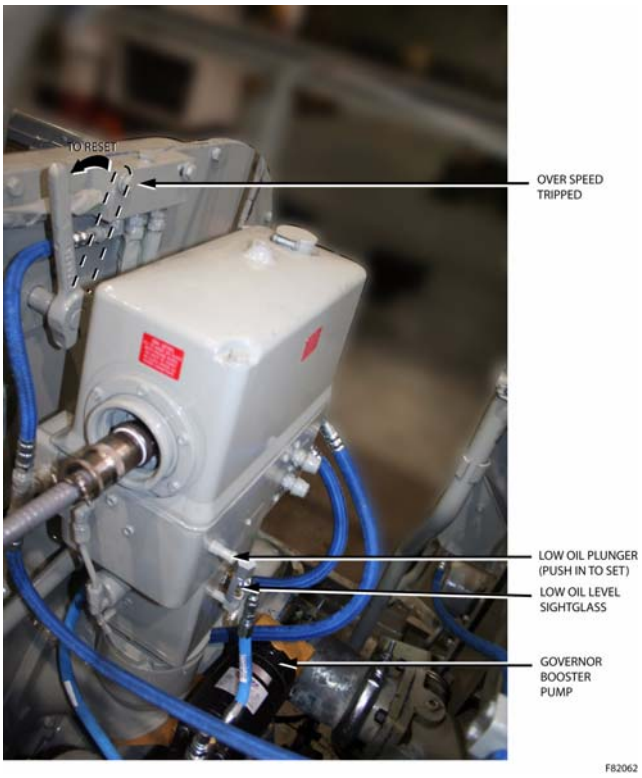


Figure 13-3. Reset Lever Positions

13.1.3.2 ADJUSTING MECHANICAL OVERSPEED TRIP:

To adjust the overspeed trip, shut engine down (if running) and remove inspection cover from right side of overspeed trip housing.

NOTE

In order to perform adjustment, two thin section jam-nut wrenches are required. If not available, standard open end wrenches can be modified for use by grinding head sides down equal to, or less than, the thickness of the jam-nuts.

1. Back off spring tension adjusting nuts, Figure 13-4. on page 13-8, several turns to decrease engine speed at which overspeed trip operates.

NOTE

Adjusting nut and locknut should always be tightened back together (locked) before running engine to test trip speed.

CAUTION

Always apply equal opposing force with wrenches when tightening adjusting nut and locknut - Improperly applied wrench force - all in one direction or at an angle to the nuts can damage the mechanism.

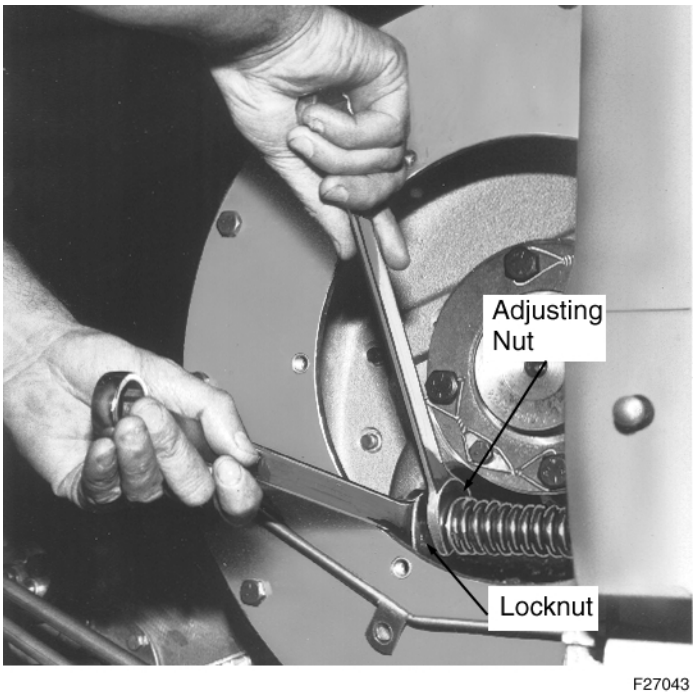


Figure 13-4. Overspeed Trip Adjustment

2. Set engine throttle controls to minimum idle speed and start the engine. Allow engine to warm up for a period of approximately 15 minutes, then slowly advance engine speed using injector hand control lever (layshaft) leaving governor speed set at idle.
3. Using a hand held tachometer set against the center of the right bank camshaft end, run engine speed up until overspeed trip functions to shut engine down. Note and record the speed at which this occurs as indicated on the tachometer. This initial trip speed, in itself, is not important except as a base reference for making actual adjustments.
4. Tighten adjustment nut on overspeed trip device in steps to increase spring tension. Make these adjustments in the tightening direction only. Tighten locknut and run engine to test trip speed. Repeat adjustment and test until trip function occurs in the range of setting limits specified in the Service Data at the end of this section.

NOTE

If adjustment is run past desired setting, back off nuts at least one full turn and begin to tighten again. If initial adjustment is only a few RPM too high, retest trip speed several more times before changing adjustment.

5. When satisfactory trip function is attained, replace right bank inspection cover using new cover gasket.

13.1.4 OVERSPEED CONTROL (EMDEC)

Overspeed control for engines equipped with the EMDEC system is a function of the control logic programmed into the Electronic Control Module(s) ECM which limits engine speed to a preset maximum. Any condition which could lead to an engine overspeed will cause the EMDEC system to reduce the fuel metered to the Electronic Unit Injectors (EUI) in order to maintain the preset maximum engine speed.

NOTE

The EMDEC system will not shut down the engine in response to a condition for overspeed unless another protected fault is detected during its occurrence.

13.1.4.1 TESTING EMDEC OVERSPEED CONTROL

The EMDEC overspeed control function can be tested using a PC computer with a special diagnostics program, connected to an EMDEC Reader Connector port on board the locomotive, to simulate an overspeed condition. This same test may be done on 70 series locomotives using a hand held Diagnostic Data Reader (DDR). Refer to appropriate Locomotive Service Manual.

13.1.5 HOT OIL TEMPERATURE SHUTDOWN (GOVERNOR)

13.1.5.1 DESCRIPTION

This hot oil shutdown device, Figure 13-5, is used with governor controlled engines. It consists of a thermostatic valve and the associated piping.

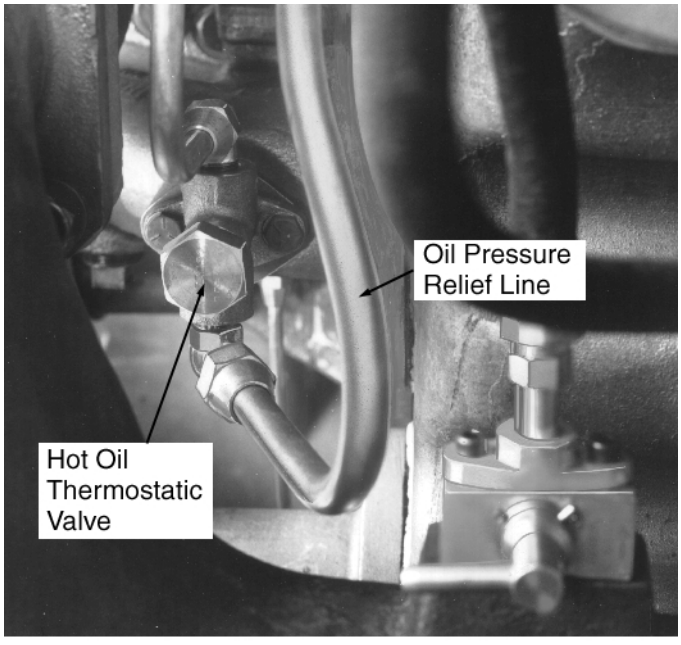


Figure 13-5. Hot Oil Shutdown Installation

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 low 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 121°-126°C (250°-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.

13.1.5.2 MAINTENANCE

The thermostatic valve should be removed and tested at the interval specified in the applicable Scheduled Maintenance Program. A new gasket should be used each time the hot oil valve is re-applied. It may be necessary to apply sealant to the mounting bolts to prevent oil leaks. See Service Data for listing of appropriate sealing compound for this purpose.

13.1.6 HOT OIL TEMPERATURE SHUTDOWN (EMDEC)

13.1.6.1 DESCRIPTION

The EMDEC system hot Oil Temperature Sensor (OTS) uses a thermal sensor located in the piston cooling oil supply manifold. The EMDEC master Electronic Control Module (ECM) monitors the input signal from the OTS and will respond, by shutting down the engine, when a true hot oil temperature condition is detected.

The ECM will, however, ignore the OTS signal for the first 60 seconds after engine start to allow operating pressures and temperatures to be reached, and to provide time to locate trouble spots in the event of a malfunction.

13.1.6.2 MAINTENANCE

Refer to Troubleshooting Section 15 for detailed information to check EMDEC system operation (including OTS sensor, wiring harness, and ECM modules).

13.1.7 LOW COOLANT PRESSURE SHUTDOWN (EMDEC)

13.1.7.1 DESCRIPTION

EMDEC system Coolant Pressure Sensors (CPS) are located in the discharge elbow(s) of the water pump(s) (*inlet* to the engine) and the discharge piping (*outlet* from the engine). The EMDEC master Electronic Control Module (ECM) monitors the input signals from the CPS sensors to determine the pressure drop through the engine cooling system. If the *outlet* pressure is a specified amount lower than the *inlet* pressure, the ECM will respond by shutting down the engine.

The ECM will, however, ignore the CPS signals for the first 60 seconds after engine start to allow operating pressures to be reached, and to provide time to locate trouble spots in the event of a malfunction.

13.1.7.2 MAINTENANCE

Refer to Troubleshooting Section 15 for detailed information to check EMDEC system operation (including CPS sensors, wiring harness, and ECM modules).

13.1.8 LOW FUEL PRESSURE KNOCKDOWN (EMDEC)

13.1.8.1 DESCRIPTION

On engines with EUI injectors, EMDEC system Fuel Pressure Sensors (FPS) are located in the “fuel in” and “fuel out” sections of the filter assembly manifold. The EMDEC master Electronic Control Module (ECM) monitors the input signals from the FPS sensors to determine the pressure drop across the engine fuel filters. If the *fuel in* pressure is a specified amount lower than the *fuel out* pressure, the ECM will signal the locomotive computer which in turn will reduce the load on the engine and knockdown the engine speed to throttle 6 limit..

The ECM will, however, ignore the FPS signals for the first 60 seconds after engine start to allow operating pressures to be reached, and to provide time to locate trouble spots in the event of a malfunction.

13.1.8.2 MAINTENANCE

Refer to Troubleshooting Section 15 for detailed information to check EMDEC system operation (including FPS sensors, wiring harness, and ECM modules).

13.1.9 SENSOR IN A BOX

The sensor box is located where the crankcase pressure sensor, or on previous engines the differential water and crankcase pressure detector was located, at the left front of the engine. This location provides protection for the sensors as well as easy access for troubleshooting. See 12.1.3 ENGINE SENSORS on page 12-4, for specific, individual sensor information.



Figure 13-6. Sensor in a box - Location

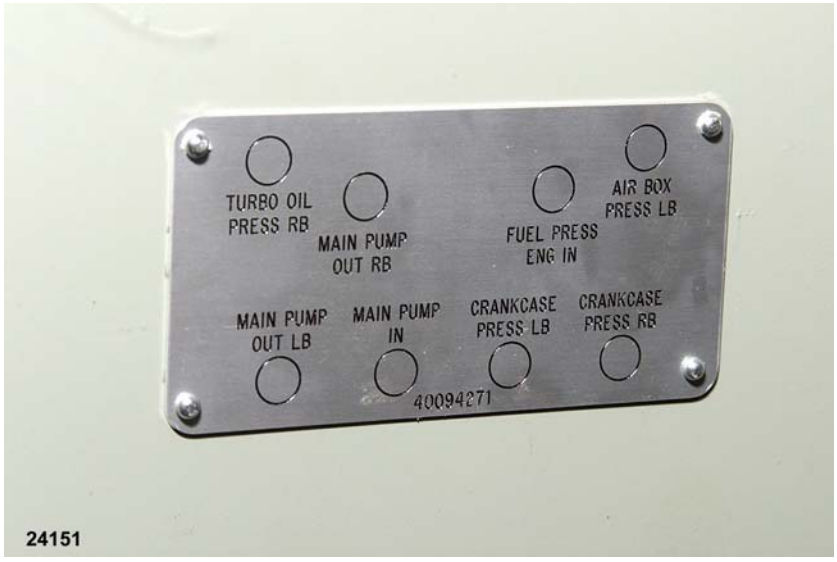


Figure 13-7. Sensor in a box - Sensor Locations



Figure 13-8. Sensor in a box - Cover Removed

On Tier 2 engines, all engine sensors have been moved to the “sensor in a box” location.

13.2 SERVICE DATA - PROTECTIVE DEVICES

13.2.1 REFERENCES

Differential Water Pressure Combination
Engine Protector ..... M.I. 260

13.2.2 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

Minimum, maximum, and tolerance measurements are provided as service limits for requalified parts. At time of engine overhaul 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. These limits are NOT intended to be used as a basis for component change-out on a running engine.

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 ..... 20-46 mm (0.8"-1.8") H_2O
Used ..... 20-76 mm (0.8"-3.0") H_2O

* Meaning new or rebuilt devices with less than three (3) months service.

Overspeed Trip

Clearance, trip latch to flywheel -Min. ..... 0.25 mm (.010")

Trip setting - Setting limits ..... 1010-1025 RPM

Checking limits ..... 990-1045 RPM

13.2.3 EQUIPMENT LIST

	PART NO.
Hydrometer bulb	8140866
Vacuum pump	8470956
Test panel	9339066
Loctite sealing compound - 50cc Bottle	9505663

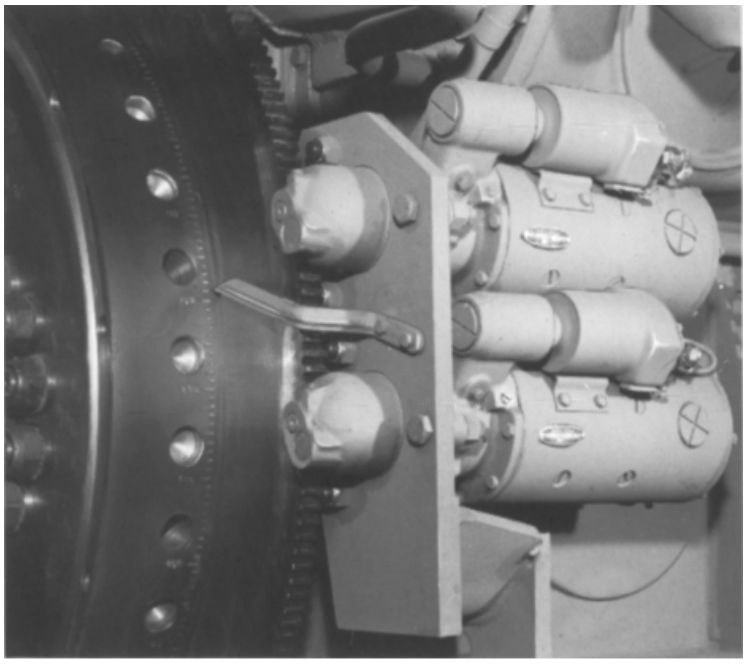
SECTION 14. STARTING SYSTEM

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14.1 GENERAL

The engine starting system consists of either dual electric starting motors (12 & 16-cyl. engines), or a single electric motor (8-cyl. engines) with heavy duty sprag drives, or a combination of dual electric starting motors along with dual air starting motors (20-cylinder engines), as well as associated electrical wiring and/or air piping and controls. The dual electric (and the dual air) starting motors are mounted one above the other and bolted to bracket assemblies which, in turn, are attached to the rear end plate at the sides of the engine, Figure 14-1. A single electric starting motor will mount in the upper position on a bracket assembly. A flywheel pointer is bolted on the face of the bracket assembly.



F14025

Figure 14-1. Typical Dual Electrical Starting Motor Application

14.2 ELECTRIC STARTING MOTOR(S)

14.2.1 DESCRIPTION

When an 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 made properly, 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 enables control circuits to energize an auxiliary starting contactor, which permits the starting motor to crank the engine.

CAUTION

Do ***NOT*** operate electrical starting motor(s) more than twenty (20) seconds at a time, and allow a two (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 electric motor, Figure 14-2. on page 14-4, 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.

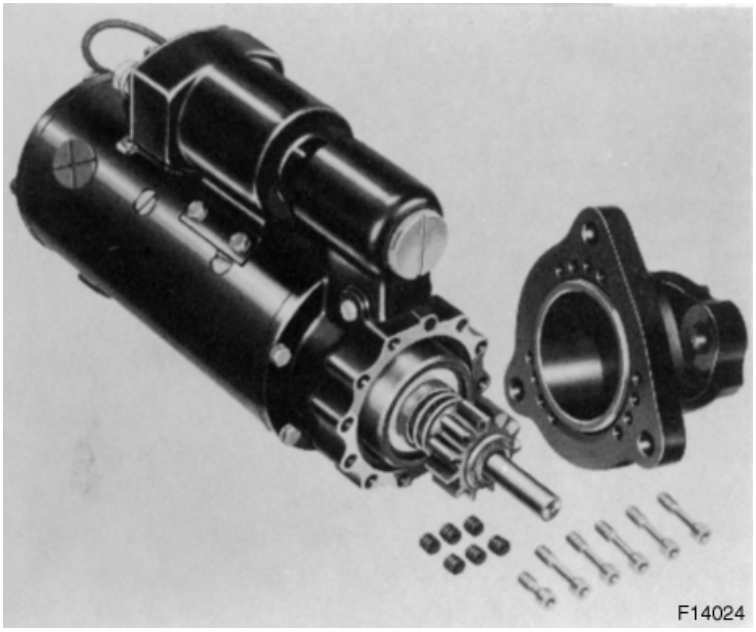


Figure 14-2. Typical Electric Starting Motor

The electric 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 the 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.

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.

14.3 MAINTENANCE

Under normal operating conditions, no maintenance should be required other than that suggested in the applicable Scheduled Maintenance Program.

14.3.1 INSPECTION

At periodic intervals, the electric 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. Check 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. Remove 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.

14.3.2 ADDITIONAL INSPECTION FOR AESS EQUIPPED LOCOMOTIVES

This information is for all AESS locomotive customers and field personnel of necessary electric starter front bushing inspection and oiling procedures.

14.3.2.1 STARTER INSPECTION:

1. Remove barring door access on conductor side on engine where electric starters are located.



Figure 14-3. Electric Starter Location

2. Inspect both electric starters at end housing where starter shaft and bronze bushing are located.

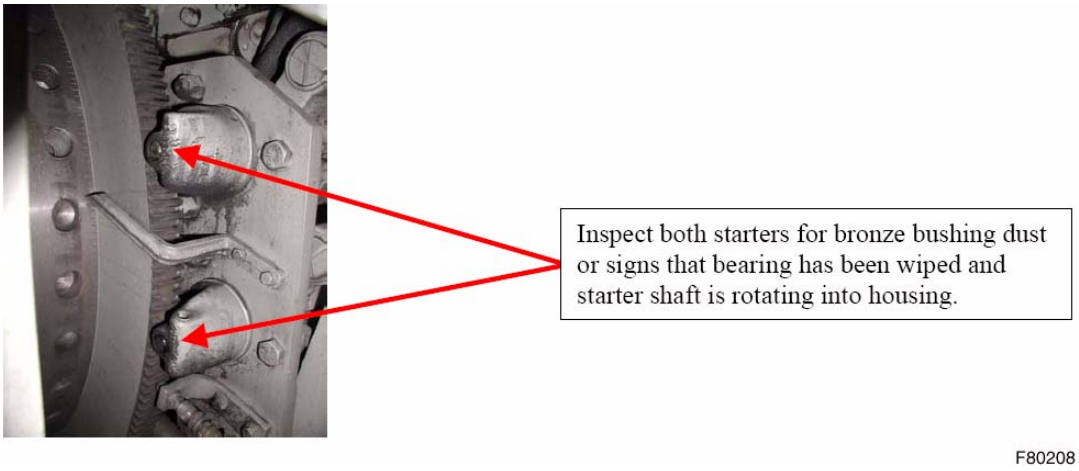


Figure 14-4. Electric Starter Inspection

3. If bronze bushing dust or extreme bushing bore wear is observed, the electric starter motor should be replaced immediately in order prevent any damage to ring gear.

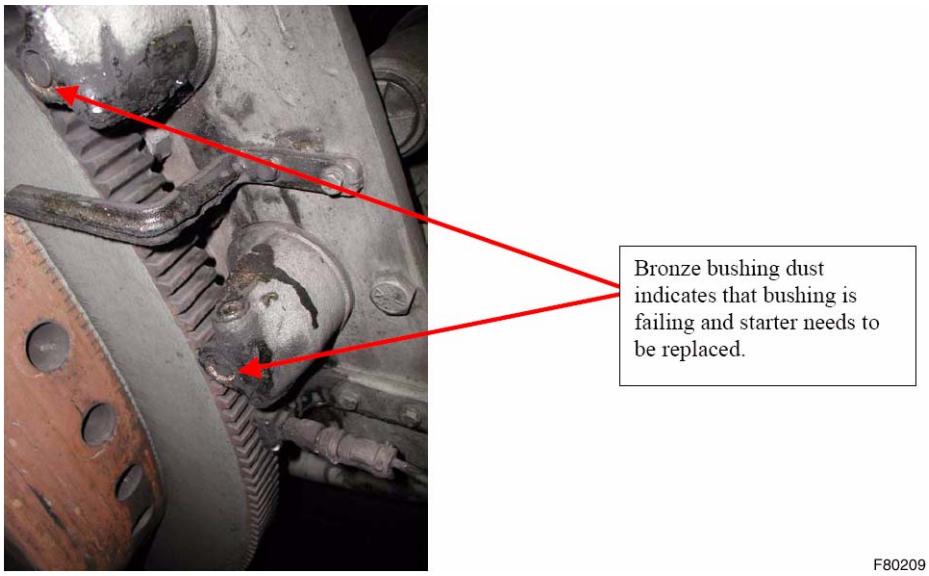


Figure 14-5. Electric Starter Inspection - Bronze Bushing Dust

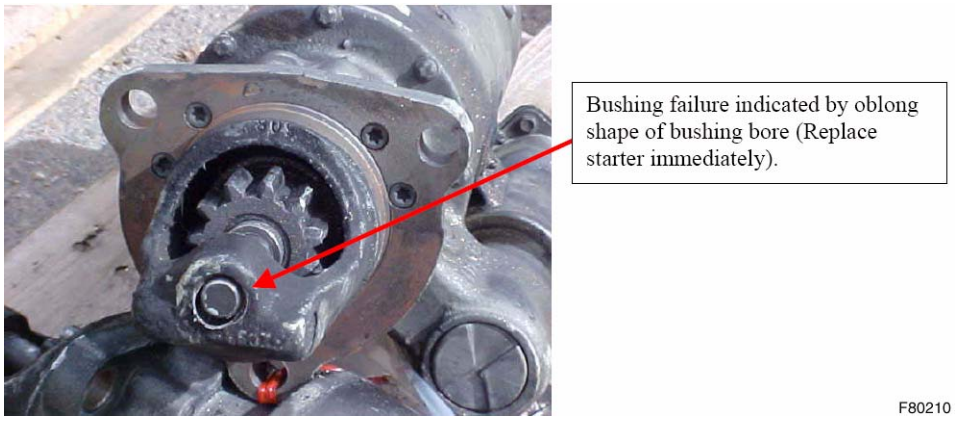


Figure 14-6. Electric Starter Motor Bushing Failure

4. If inspection of both starters does not reveal extreme bushing wear, it will be necessary to oil bushing oiling wick. Otherwise if either of the starters has failed the bushing and the shaft has burrowed into the end housing, it will be necessary to inspect all teeth of the ring gear for damage. Proceed to page 4 for ring gear inspection.
5. Remove oiling wick cap located on end housing.

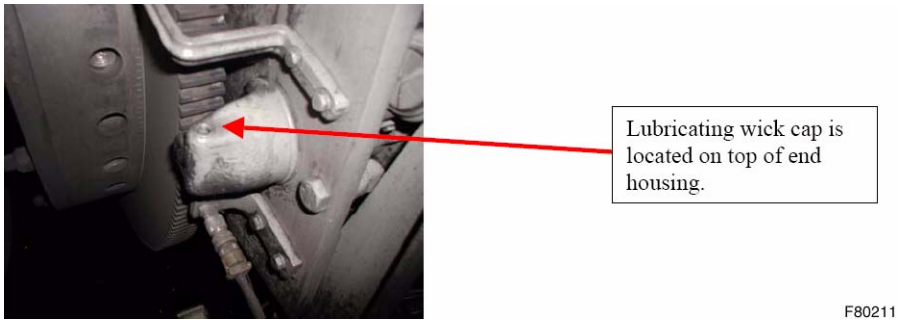


Figure 14-7. Electric Starter Motor Lubricating Wick Cap

6. Fill oiling wick reservoir to top with SAE 20W oil or SAE 10W oil (Governor Oil) and replace cap.
7. Oil should be added to the oiling wick reservoir every 6 months thereafter.

14.3.3 ELECTRIC STARTING MOTOR TESTS

NOTE

In some locomotive applications, the electric starting motors are 32V and are connected in series. In other locomotive applications, the electric starting motors are 64V and are connected in parallel. Where test procedures differ, the application (32V or 64V) will be shown. Where procedures are the same for both types, the application will not be shown.

To obtain full performance data on an electric 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 electric 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.

14.3.4 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 Figure 14-8. on page 14-9. 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.

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.

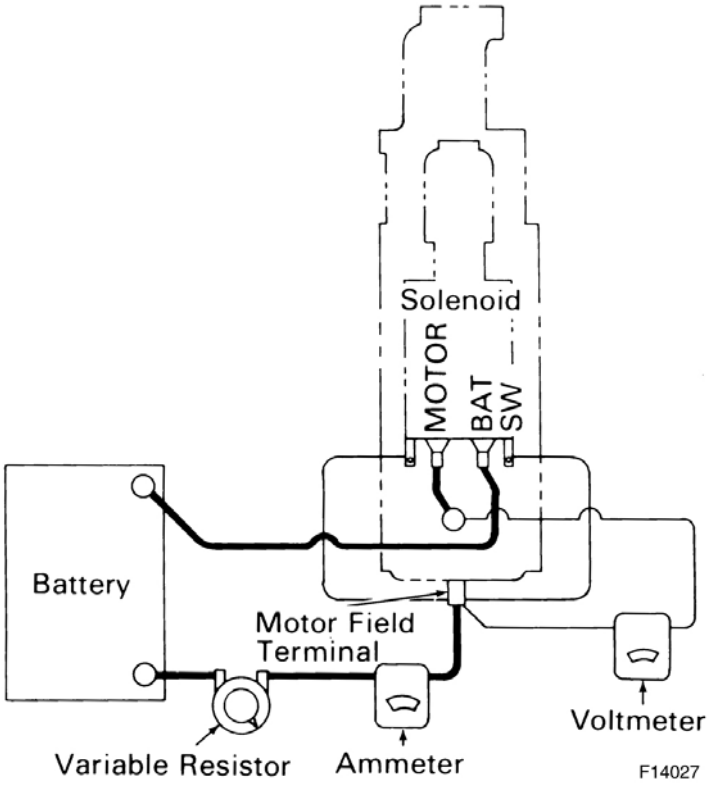


Figure 14-8. Motor Test Circuit

14.3.5 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.
4. 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.

3. 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 the commutator.
4. 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.
5. 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.

14.4 DISASSEMBLY

14.4.1 SOLENOID ASSEMBLY REMOVAL

1. Disconnect motor terminal lead from solenoid terminal, Figure 14-9. on page 14-11.
2. Remove plug from lever housing to expose nut securing plunger and spring assembly to shift lever.
3. Remove four (4) 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.

14.4.2 DRIVE CLUTCH REMOVAL

1. Mark position of nose housing in relation to lever housing and remove the six (6) 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.

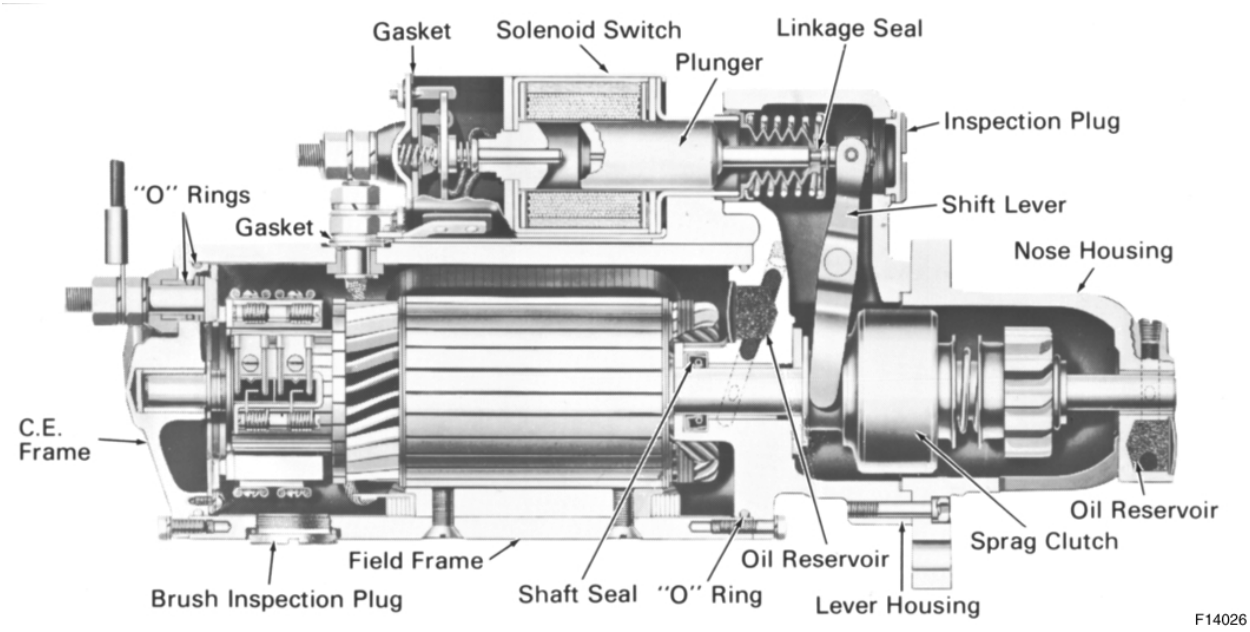


Figure 14-9. Typical Electric Starting Motor, Cross-Section

14.4.3 ARMATURE REMOVAL

1. Mark the relative position of lever housing and C. E. frame to the field frame.
2. Remove seven (7) 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.

14.4.4 C. E. HOUSING REMOVAL

1. Remove three (3) brush inspection plugs and remove brush lead screws. This will also disconnect the field leads to brush holders.
2. Remove six (6) screws securing C. E. frame to field frame and remove C. E. frame. Note condition of bushing and "O" ring at frame contact area.

14.4.5 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 field coils. All parts, except the clutch, should be cleaned with mineral 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**.

14.4.6 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 insulation should then be undercut 0.79 mm (1/32") wide and 0.79 mm (1/32") 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 remove 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 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 shorts can be eliminated by cleaning out the slots.
3. Grounds - Grounds in the armature can be detected by 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 placed 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.

14.4.7 FIELD COIL CHECKS

The field coils can be checked for grounds and opens by using a test lamp. See Figure 14-10. on page 14-13 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, field coils are open.

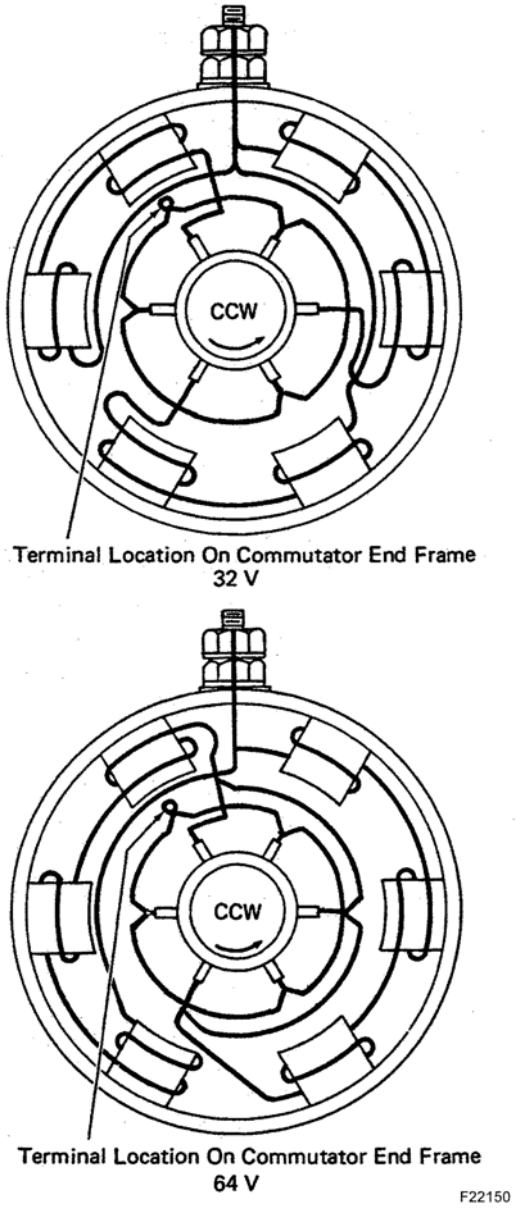


Figure 14-10. Wiring Diagram

14.4.8 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.

14.4.9 BEARING REPLACEMENT

If electrical starting motor tests indicated a need to renew bearings (overly tight, dirty, worn, or frozen), old bearings should be pressed out of the housings. Note condition of armature shaft at bearing contact areas.

Current design bearings used in the commutator end frame, shaft lever housing, and nose housing of the starting motor are of a sintered bronze (powdered) material. A characteristic of this material is that it is porous, which allows it to absorb and hold oil. New replacement bearings of this material have a dull finish and are supplied to size.

NOTE

No attempt should be made to resize sintered bronze bearings by drilling, reaming or machining in any way as this would seal over the bearing pores and negate their ability to pass lubricant to the bearing surfaces. It is not necessary to cross-drill these bearings when used with wick lubricators as the material is able to absorb oil from the wick by contact through its outer surface.

Before pressing replacement bearings into place, dip them and the lubricating wicks in non-detergent SAE No. 20 oil. Insert wicks into place first, then press bearings into position.

NOTE

Bearing in shift lever housing is the main armature support bearing which prevents deflection of the armature during cranking. As such, shaft clearance at this bearing is greater than at either end bearing and will provide for a loose fit when assembled.

14.5 ASSEMBLY

To assemble the electric motor, proceed as follows:

1. Lubricate armature bearings (if not previously lubricated during replacement) in commutator end frame, shift lever housing, and nose housing with non-detergent SAE No. 10 oil, Figure 14-9. on page 14-11.
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 (6) screws that hold the end frame to the field frame.
4. Connect the field and brush leads and install the three (3) 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 (7) screws which hold the lever housing to the field frame.
6. Apply a thin coating of the 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 (2) 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 (6) screws and tighten to 18-23 N·m (13-17 ft-lbs) torque.
9. Insert solenoid assembly in lever housing. Connect plunger and shift lever by screwing nut onto plunger shaft.
10. Install four (4) 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 non-detergent SAE No. 10 oil to each wick lubricator (if not previously oiled during bearing replacement) by removing plugs on the outside of the motor for the three (3) lubricating points.

14.5.1 PINION CLEARANCE

Check pinion clearance after assembly of motor to make sure the clearance is within limits. Refer to Figure 14-11.

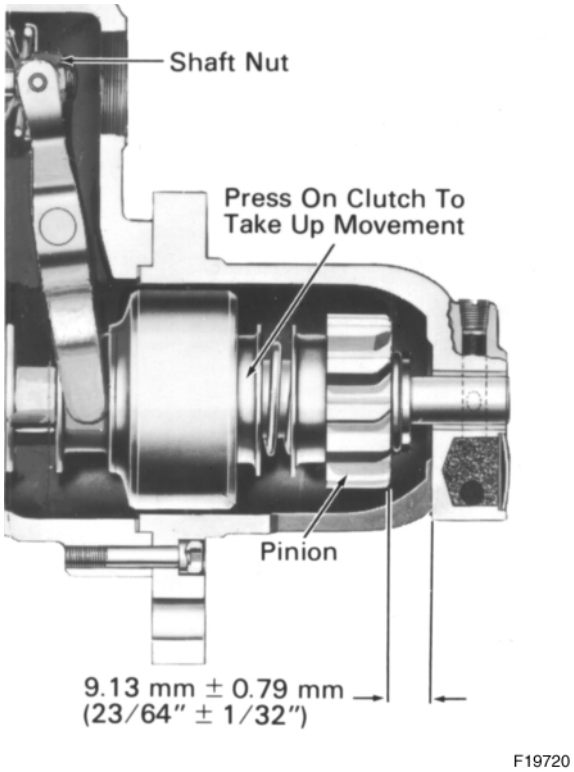


Figure 14-11. Checking Pinion Clearance

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.

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 "BAT" 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.

14.6 AIR STARTING MOTOR

14.6.1 DESCRIPTION

The engine air starting motor, Figure 14-12, page 14-18, consists of an air driven turbine wheel assembly positioned in a cylindrical housing, a planet type reduction gear train, and a clutch drive, all of which are supported by ball bearings. Air striking the turbine wheel rotates the planet gear set which turns an offset shaft through an intermediate pinion and drive gear set which turns the clutch drive. The clutch drive pinion gear meshes with the engine ring gear and cranks the engine.

1. Housing Exhaust Cover
2. Exhaust Cover Seal
3. Splash Deflector
4. Deflector Return Spring Retainer
5. Deflector Retaining Screw
6. Starter Assembly Capscrews (4)
7. Lock washers (4)
8. Motor Housing Retainer
10. Housing Plugs (2)
11. Housing Plug Inlet Boss
12. Motor Assembly

12A. Cylinder “O” Ring Seal

12B. Housing “O” Ring Seal

13. Intermediate Gear Case
14. Rear Gear Case “O” Ring
15. Front Gear Case “O” Ring Screw
16. Planet Gear Frame Shaft Seal
17. Front Gear Frame Bearing
18. Planet Gear Frame
19. Planet Gears (3)
20. Panet Gear Bearings (3)
21. Bearing Spacers (3)
22. Planet Gear Shafts (3)
23. Gear Shaft Retaining Washers (2)
24. Rear Gear Frame Bearing
25. Front Bearing Spacer
26. Intermediate Pinion
27. Intermediate Pinion Retaining Screw
28. Gear Case
29. Drive Gear
30. Front Drive Gear Bearing
31. Rear Drive Gear Bearing
32. Drive Gear Bearing Retainer
33. Drive Gear Shaft Bearing Retainer
34. Drive Gear Screw
35. Drive Gear Lockwasher
36. Drive Gear Cup
37. Drive Gear Screw “O” Ring
38. Drive Housing Capscrews (8)
39. Drive Housing Lockwashers (8)
40. Drive Housing
41. Drive Housing “O” Ring
42. Front Drive Shaft Bearing
43. Drive Housing Seal
44. Drive Housing Vent Plug
45. Bulkhead Retainer
46. Bulkhead
47. Outer Bulkhead “O” Ring
48. Inner Bulkhead “O” Ring
49. Clutch Spring Cup
50. Clutch Spring Cup
51. Clutch Spring
52. Clutch Jaw Set
53. Drive Shaft Bearing
54. Piston
55. Piston “O” Ring
56. Piston Seal
57. Drive Shaft
58. Rear Drive Shaft Bearing
59. Piston Return Spring
60. Seat
61. Drive Pinion Retaining
62. Drive Pinion Washer
63. Drive Pinion
64. Pinion Spring Sleeve
65. Pinion Spring
66. Inlet Flange Kit

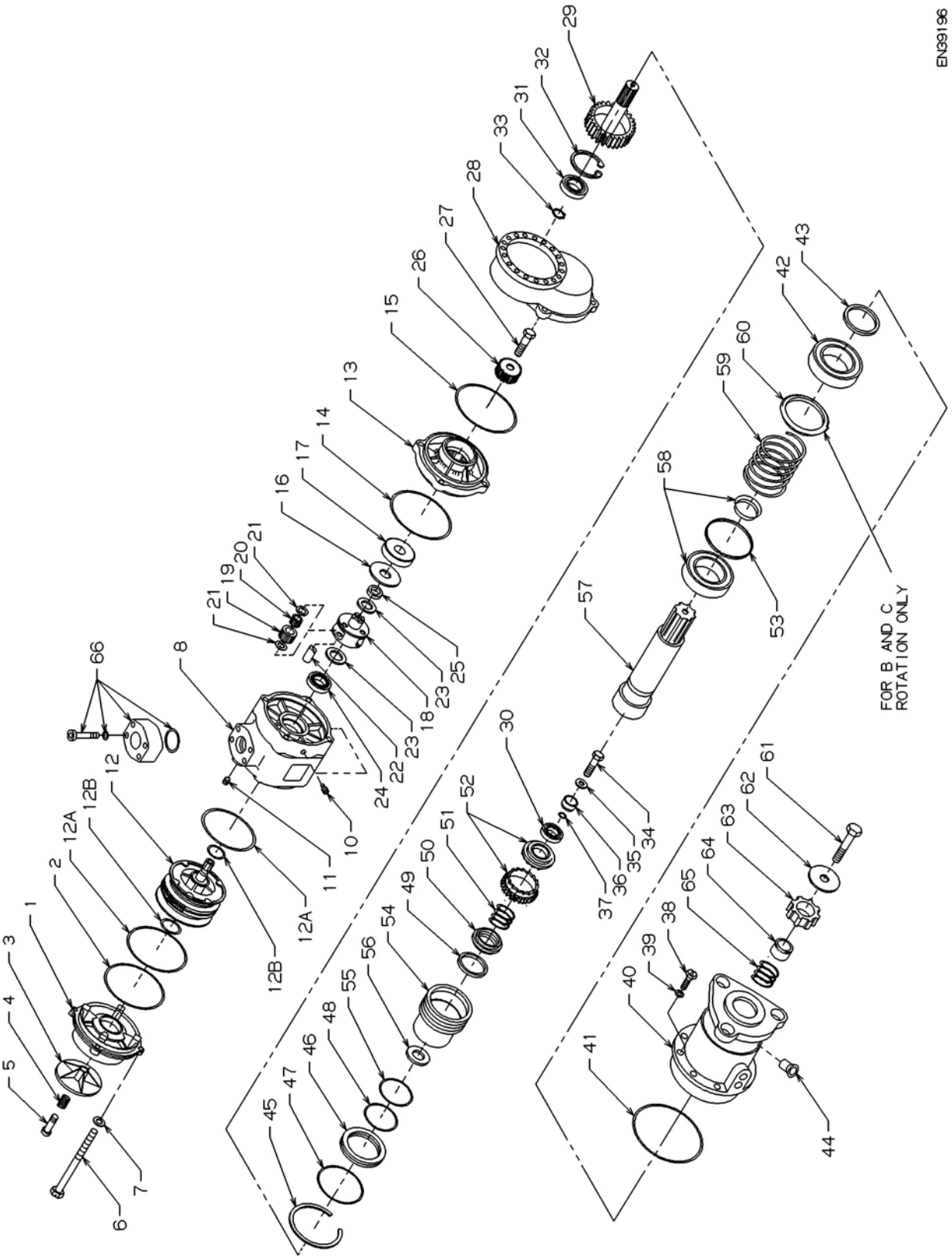


Figure 14-12. Typical Air Starting Motor

14.6.2 MAINTENANCE

The air starting motor requires no periodic maintenance. Any noticeable loss of power can usually be attributed to worn or damaged parts. Rapid wear of the motor rotating assembly is usually caused by the presence of rust, scale, dirt, excessive moisture, or other foreign matter in the air supply. Air and/or oil leakage can be caused by loose or leaking plugs, and by excessive high speed operation or a high number of start cycles. New parts can be easily and quickly installed by disassembling the motor as described in subsequent paragraphs.

14.6.2.1 LUBRICATION

Motor rotating assembly bearings are grease packed and sealed at original manufacture. Planet gear frame, drive gear, and clutch drive front and rear bearings are oil lubricated by a self contained oil supply in the gear case. The motor bearings are part of the sealed motor assembly which is replaced as an unit at time of major motor overhaul. Motor gear case and all internal parts should be cleaned and coated with a thin film of oil before installation at time of overhaul.

Before putting an air motor into storage or lay up, the motor should be fully lubricated with a light oil containing a rust inhibitor.

14.6.2.2 MOTOR REMOVAL

1. Disconnect air supply and control lines.
2. Remove three (3) bolts securing the motor and drive assembly to the motor mounting bracket.
3. Remove air starting motor and drive assembly.

14.6.2.3 MOTOR DISASSEMBLY

(Refer to Figure 14-12. on page 14-18).

GENERAL INFORMATION

1. Using a prick punch, mark adjacent spots on the Housing Exhaust Cover (1), Motor Housing (8), Intermediate Gear Case (13), Gear Case (28), and Drive Housing (40) so these members will be in the same relative position when the Starter is reassembled. **Do NOT disassemble the Starter any further than necessary to replace worn or damaged parts.**
2. Do NOT remove any part which is a press fit *in* or *on* a subassembly unless the removal of that part is necessary for replacement or repair.
3. Always have a complete set of seals and “O” rings on hand before starting any overhaul of a Turbine Starter. **NEVER reuse old seals or “O” rings.**
4. When grasping a part in a vise, always use copper-covered vise jaws to protect the surface of the part and help prevent distortion. This is particularly critical with threaded components.

HOUSING EXHAUST COVER, MOTOR ASSEMBLY &MOTOR HOUSING

1. If replacing the Motor Assembly (12), remove both Housing Plugs (10) and drain the oil from the Starter before beginning disassembly. Inspect the *magnetic* Housing Plugs (10) for metal particles. Very fine particles are normal. Remove particles and reinstall plugs. Large particles or chips are indications of a problem. Disassemble Gear Case (28) and inspect.
2. Unthread and remove the Starter Assembly Cap Screws (6) and Washers (7). Pull the Housing Exhaust Cover (1) from the Motor Housing (8).

NOTE

To dislodge the Housing Exhaust Cover; rotate it until the ears clear the Motor Housing, then tap the ears alternately using a plastic hammer until the Housing Exhaust Cover is clear of the Motor Housing.

3. Remove the Deflector Retaining Screw (5), Deflector Return Spring (4) and the Splash Deflector (3) from the Housing Exhaust Cover.
4. Tap the Motor Housing with a plastic hammer to dislodge it from the Intermediate gear Case (13).
5. Grasp the rear of the Motor Assembly (12) and pull it from the rear of the Motor Housing. If the Motor Assembly is difficult to remove, lightly push on the motor pinion (which is on the front of the Motor Assembly toward the exhaust side of the Motor Housing) in order to free the Motor Assembly.
6. Tap the Intermediate Gear Case with a plastic hammer to dislodge it from the Gear Case (28).
7. Place the Intermediate Gear Case on a workbench in a copper-faced vise so that the Intermediate Pinion (26) is secured in the jaws of the vise. Tighten the vise only enough to hold the Intermediate Pinion securely.
8. Loosen the Intermediate Pinion Retaining Screw (27) 1-1/2 turns only. **Do NOT remove**!

WARNING

If the Intermediate Gear Case is not supported on a workbench and if the Intermediate Pinion Retaining Screw is completely removed, the Intermediate Gear Case and components could fall and cause injury to personnel.

9. Remove the Intermediate Gear Case Assembly from the vise and remove the Intermediate Pinion. Remove the Rear Gear Case “O” ring (14) and Front Gear Case “O” ring (15) from the Intermediate Gear Case.

10. Remove the Planet Gear Frame Assembly from the Intermediate gear Case. Using a sleeve that contacts the outer race of the Front Gear Frame Bearing (17), press the Planet Gear Frame Shaft Seal (16) and the Front Gear Frame Bearing (17) from the front end and out of the rear of the Intermediate Gear Case.
11. Using a bearing puller, remove the Rear Gear Frame Bearing (24) from the Planet Gear Frame (18) and remove the Gear Shaft Retaining Washer (23).
12. Remove the Planet Gear Shafts (22), Planet Gears (19), Planet Gear Bearings (20) and Bearing Spacers (21).
13. Using a bearing puller, remove the Front Bearing Spacer (25) and the Gear Shaft Retaining Washer (23) from the front of the Planet Gear Frame by pressing on the front of the Planet Gear Frame Shaft.

NOTE

Remove the Gear Shaft Retaining Washer only if the Washer or Front Bearing Spacer is damaged.

DRIVE HOUSING

1. Grasp the Drive Pinion (63) in a copper-faced vise with the Starter supported on the workbench.
2. Remove the Drive Pinion Retaining Screw (61).
3. Remove the Starter from the vise, then remove the Drive Pinion Washer (62) and the Drive Pinion.
4. Slide the Pinion Spring Sleeve (64) and the Pinion Spring (65) of the Drive Shaft.
5. Using an impact wrench with a 8 mm (5/16”) x 203 mm (8”) long hex inserted into the end of the Drive Shaft, unthread the Drive Gear Screw (34).
6. Unthread and remove the Drive Housing Cap Screws (38) and Lock Washers (39).
7. Tap the Drive Housing (40) with a plastic hammer to help dislodge it from the Gear Case (28).

WARNING

Failure to follow this procedure could result in injury to personnel.

8. Place the Drive Housing in an arbor press, piston end up. Apply a load to the Piston (54) using the arbor press to compress the Piston Return Spring (59) before removing the Bulkhead Retainer (45). **Do NOT use compressed air to load the piston.**
9. Using a screwdriver, remove the Bulkhead Retainer. Ease off the pressure on the arbor press.

CAUTION

Make certain the tension of the spring pushes the Bulkhead out of the Drive Housing before removing the Drive Housing from the arbor press.

10. Remove the Bulkhead (46) from the Piston.
11. Remove the Outer Bulkhead "O" ring (47) and the Inner Bulkhead "O" ring (48).
12. Slide the Drive Shaft (57) from the Drive Housing.
13. Pull the Piston Return Spring (59) off the Drive Shaft.

NOTE

Do NOT remove the Front Drive Shaft Bearing (42) or the Drive Housing Seal (43) unless replacement is necessary and new parts are available. The Bearing and/or Seal will always be damaged when removed from the Drive Housing.

14. Remove the Piston "O" ring (55) from the Piston.
15. Insert a large screwdriver blade through the Piston Seal (56) so that it rests on top of the Clutch Spring Cup (50). Pry the Seal out of the Piston.

NOTE

This operation will damage the Piston Seal. Therefore, a replacement Piston Seal must be available.

16. Press the Clutch Spring Cup (50) down and remove the Clutch Spring Cup Retainer (49).
17. Remove the Clutch Spring Cup (50) and Clutch Spring (51).
18. Remove the two Clutch Jaws (52).
19. Remove the Front Drive Gear Bearing (30), Drive Gear Cup (46), Drive Gear Lock Washer (35), Drive Gear Screw "O" ring (37) and Drive Gear Screw (34).
20. Using a screwdriver, remove the large Drive Shaft Bearing Retainer (53).
21. Press the Rear Drive Shaft Bearing and Drive Shaft (57) out of the piston. If the Rear Drive Shaft Bearing needs to be replaced, proceed as follows:
    a. Using a small chisel, cut and remove the small drive shaft bearing retained in the Drive Shaft.
    b. Press the Rear Drive Shaft Bearing (58) off the Drive Shaft.
3. Place the Gear Case (28) on a workbench.
4. Using retaining ring pliers and working through the access holes in the gear web, remove the Drive Gear Bearing Retainer (32).
5. Pull the Drive Gear (29) out of the Gear Case (28).

NOTE

Do NOT disassemble the Drive Gear and Clutch parts of Turbine Starters. If the Drive Shaft is defective, install a new or factory rebuilt unit.

6. Using retaining ring pliers, remove the Drive Gear Shaft Bearing Retainer (33).
7. Remove the Rear Drive Gear Bearing (31) from the Drive Gear.

14.6.2.4 MOTOR ASSEMBLY

(Refer to Figure 14-12. on page 14-18).

GENERAL INFORMATION

1. Always press on the inner ring of a ball bearing when installing the bearing on a shaft.
2. Always press on the outer ring of a ball bearing when pressing the bearing into a bearing recess.
3. When ever grasping a part in a vice, always use copper-covered or leather-covered vise jaws to protect the surface of the part and help prevent distortion. This is particularly critical with threaded components.
4. Always clean every part, and wipe each piece with a thin film of oil before installation.

GEAR CASE

1. Place the Drive Gear Bearing Retainer (32) over the rear end of the Drive Gear.
2. Using an arbor press, press the Rear Drive Gear Bearing (31) onto the rear end of the Drive Gear.
3. Using a plastic hammer, seat the Rear Drive Gear Bearing into the Gear Case by tapping the opposite end of the Drive Gear.
4. Using retaining ring pliers, install the Drive Gear Shaft Bearing Retainer (33).
5. Using retaining ring pliers and working through the access holes in the gear web, install the Drive Gear Bearing Retainer.
6. Lubricate the Drive Gear with approximately 8 oz. (240 ml.) of Texaco RB or Ingersoll-Rand IR #28 grease.

DRIVE HOUSING

1. Press the Rear Drive Shaft Bearing (58) onto the Drive Shaft.
2. Slide the small bearing retainer, convex side first, onto the Drive Shaft. Press it into position in accordance with the instructions packaged with the new Retainer.

3. Assemble the Drive Gear Screw (34), Drive Gear Lock Washer (35), Drive Gear Cup (36) and Drive Gear Screw "O" ring (37).
4. Grasp the Drive Shaft (57) in a copper-covered vice, external splined end ***down***. Place assembled Drive Shaft Screw Unit into the Drive Shaft, screwhead ***down***. Lubricate the inside diameter of the Drive Shaft with Texaco RB or Ingersoll-Rand IR #28 grease.
5. Slide the Front Drive Gear Bearing (30) into the Drive Shaft.
6. Lubricate with Texaco RB or Ingersoll-Rand IR #28 grease and install the Driving Clutch Jaw teeth facing ***UP***, and Driven Clutch Jaw teeth facing ***DOWN*** into the Drive Shaft.
7. Insert the Clutch Spring (51) into the Drive Shaft followed by the Clutch Spring Cup (50).
8. Press the inserted parts into the Drive Shaft, and install the Clutch Spring Cup Retainer (49).
9. Using an arbor press, press the Piston Seal (56), cover side ***out***, into the Piston until it is flush with the piston face.
10. Install the Piston (54) onto the Drive Shaft until the Rear Drive Shaft Bearing seats into the piston.
11. Using a thin flat blade screwdriver to assist in this operation, "coil" the Large Drive Shaft Bearing Retainer (53) into the groove of the Piston to retain the outer race of the Drive Shaft Bearing.
12. Lubricate the piston "O" ring seal (55) with "O" ring lubricant and install it into the groove of the Piston.
13. Position the Drive Housing in an arbor press, pinion end ***down***, and install the Drive Housing Seal (43) into the Drive Housing. Using a pressing sleeve of proper size, press the Seal into the Drive Housing so that the lip of the Seal faces away from the Drive Pinion.
14. Using a sleeve that contacts the outer race of the Front Drive Shaft Bearing (4), press the Bearing into the Drive Housing until it seats. Drop the Piston Return Spring Seat (60) on top of the Front Drive Shaft Bearing.
15. Slide the Piston Return Spring (59) onto the Drive Shaft and snap it into the front of the Piston so that it is against the Large Drive Shaft Bearing Retainer (53).
16. Lubricate and insert the assembled Drive Shaft into the Drive Housing.
17. Lubricant the Outer Bulkhead "O" ring (47) and Inner Bulkhead "O" ring (48) with "O" ring lubricant and install them on the Bulkhead (45).
18. Slide the Bulkhead onto the Piston.

19. With the Drive Housing positioned in the arbor press, press down on the rear face of the Piston.

NOTE

Feel the underside of the Drive Housing to make certain the Drive Shaft passes through the Bearing.

20. Using a screwdriver, install the Bulkhead Retainer (45).

WARNING

Make certain the Bulkhead Retainer is properly seated in the Motor housing groove before easing off the arbor press. Failure to do so will allow improperly retained parts to separate when removed from the arbor press which could result in injury to personnel.

21. Remove the Drive Housing from the arbor press.
22. Lubricant the Drive Housing "O" ring (41) with "O" ring lubricant and install it into the groove of the Drive Housing.
23. Position the assembled Gear Case on a workbench, in an upright position, to accept the Drive Housing.
24. Carefully position the assembled Drive Housing (40) onto the Gear Case so as not to damage the Piston Seal. Align the punch marks of the Gear Case and Drive Housing.
25. Install the Drive Housing Cap Screw Lock Washers (39) and the Drive Housing Cap Screws (38) and tighten to 38 Nm (28 ft-lbs) torque.
26. Using a torque wrench with a 8 mm (5/16") x 203 mm (8") long hex socket wrench inserted into the end of the Drive Shaft, tighten the Drive Gear Screw (34) to 77 Nm (57 ft-lbs) torque.
27. Lubricate Pinion Spring (65) with Ingersoll-Rand IR #11 grease and slide it along with Pinion Spring Sleeve (64) over Pinion end of the Drive Shaft.
28. Lubricate the Pinion end of the Drive Shaft with Ingersoll-Rand IR #11 grease and install the Drive Pinion.
29. Grasp the Drive Pinion in the copper-covered jaws of a vise with the Starter supported on a workbench.
30. Place the Drive Pinion Washer (62) onto the Drive Pinion Retaining Screw (61).

CAUTION

Drive pinion retaining screw used on this model Starter will have left-hand (LH) threads due to it having a right hand (RH) rotation motor.

Install the Drive Pinion Retaining Screw into the end of the Drive Shaft and tighten it to 109 Nm (80 ft-lbs) torque.

INTERMEDIATE GEAR CASE, MOTOR HOUSING, MOTOR ASSEMBLY AND HOUSING EXHAUST COVER

1. Using a bearing pressing tool of the proper size, press the Front Gear Frame Bearing (17) into the rear of the Intermediate Gear Case (13).
2. Using a sleeve which contacts the outer ring of the seal, press the Planet gear Frame Shaft Seal (16) into the rear of the Intermediate Gear Case over the Front Gear Frame Bearing.

NOTE

Make certain that the flat side of the Seal is installed against the Bearing.

3. Install the Rear Gear Case "O" ring (14) into the groove at the rear of the Intermediate Gear Case and the Front Gear Case "O" ring (15) into the groove at the front of the Intermediate Gear Case. Coat each "O" ring with "O" ring lubricant before installing.
4. Install one Planet Gear Shaft Retaining Washer (23) on the front of the Planet Gear Frame (18). Press the Front Bearing Spacer (25) on the front shaft of the Planet Gear Frame to hold the Gear Shaft Retaining Washer snugly in position.

NOTE

Coat the Front Bearing Spacer with Dexron II before installing it. Be careful to avoid gouging or scratching the Front Bearing Spacer during installation as this could result in leakage between the Planet gear Frame and Gear Case.

5. Place Planet Gear Frame on a workbench, shaft side ***down***. Place a Planet Gear Bearing (20) inside a Planet Gear (19). Place Bearing Spacers (21) on the top and bottom of the Bearing and Gear. Slide the components into the slots of one position in the side of the Planet Gear Frame. Align holes in Spacers and Bearing with holes in Planet Gear Frame and insert a Planet gear Shaft (22), integral keyed end ***down***, through the Spacers and Bearing so that the larger portion of the keyed end of the Shaft contacts the Planet Gear Shaft retaining Washer. Repeat this procedure for the two remaining Planet Gears and Components.

NOTE

Do NOT move or turn over the Planet Gear Frame until the following steps 6 and 7 have been completed. Movement of the Planet Gear Frame Assembly could dislodge the assembled components, making it necessary to repeat step 5 above.

6. Install the other Planet Gear Shaft Retaining Washer (23) over the shaft at the rear of the Planet Gear Frame.

7. Using the proper sized bearing pressing tool, press the Rear gear Frame Bearing (24) on the shaft at the rear of the Planet Gear Frame.
8. Slide the Planet Gear Frame Assembly, coupling end first, into the rear of the Intermediate Gear Case (13), making certain that the Planet Gears mesh with the ring gear. Use care so as to avoid damaging the seal.
9. Install the Intermediate Pinion (26), making certain that the notches at the rear of the Pinion align with the notches and tangs in the shaft of the Planet Gear Frame.
10. Position the Intermediate Gear Case so the Intermediate Pinion is secured in the copper-covered jaws of a vise.
11. Clean the threads of the Intermediate Pinion Retaining Screw (27) and apply 2 to 3 drops of Permabond HM118 to the threads approximately 3 mm from the end of the Screw. Install the Screw and tighten to 122 N·m (90 ft-lbs) torque.
12. Remove the Intermediate Gear Case from the vise and set it on a workbench.

NOTE

The Intermediate Gear Case will work in only one orientation.

Align the punch marks on the Intermediate gear Case and the Gear Case and, using a plastic hammer, tap the Intermediate Gear Case until it seats in the rear of the Gear Case. Make certain the Intermediate Pinion meshes properly with the Drive gear.

13. Before installing the Motor Assembly, coat the “O” rings on the Motor Assembly and the inside of the Cylinder with “O” ring lubricant. Install the Motor Assembly through the rear of the Motor Housing with the splined end of the rotor toward the front.

NOTE

Turn the Intermediate Pinion so that the spline on the rotor meshes with the Planet Gears. Make certain that the rear of the Motor Assembly is installed flush with the rear of the cylinder.

14. Align the punch marks on the Motor Housing with the punch marks on the Intermediate Gear Case and, using a plastic hammer, tap the Motor Housing until it seats on the rear of the Intermediate Gear Case
15. Install the Splash Deflector (3), Deflector Retaining Spring (4) and Deflector Retaining Screw (5) in the rear of the Housing Exhaust Cover.

NOTE

Coat the threads of the Deflector Retaining Screw with Ingersoll Rand SMB-441 Pipe Sealant.

16. Coat the Exhaust Cover Seal (2) with "O" ring lubricant and install it into the groove on the Housing Exhaust Cover.
17. Align the punch marks on the Housing Exhaust Cover with the punch marks on the Motor Housing and, using a plastic hammer, tap the Housing Exhaust Cover until it seats.
18. Install the Housing Exhaust Cover on the rear of the Motor Housing using the Starter Assembly Cap Screws (6) and Cap Screw Washers (70), alternately tightening each a little at a time to a final torque of 75 N·m (55 ft-lbs) - in 27 N·m (20 ft-lbs) increments.

NOTE

Use Ingersoll Rand SMB-441 Pipe Sealant on all plugs.

19. Install bottom Housing Plug (10) and Housing Plug Inlet Boss (11). Place the Starter on its side with the side plug hole ***upward.*** Add 1.5 pt. (500 ml.) of Dexron II Automatic Transmission Fluid through the plug hole. Install the Housing Plug and tighten all plugs to 6.8 to 13.6 N·m (5 to 10 ft-lbs) torque.

14.6.2.5 RECOMMENDED TEST AND INSPECTION PROCEDURES

1. Clutch Ratcheting: Turn the Drive Shaft Pinion (63) by hand in the direction of Starter rotation. The clutch should ratchet smoothly with a slight "clicking" action.
2. Motor and Gearing Freeness: Turn the Drive Shaft Pinion (63) in the opposite direction of Starter rotation. The Drive Shaft Pinion should be turnable by hand.

CAUTION

Inadvertent connection of control air pressure to the "OUT" port on the Drive Housing will result in drive malfunction (Pinion will fail to retract). If this condition occurs, loosen Drive Housing Cap Screws (38) to vent the air from the Gear Case (28). Also, loosen Housing Plugs (10) and (11) to vent the air from the Motor Housing.

3. Pinion Engagement: Apply 345 kPa (50 psi) air pressure to the engagement "IN" port. Drive Shaft Pinion (63) should move outward and air should escape from the "OUT" port. Plug the "OUT" port and apply 1 034 kPa (150 psi) air pressure to the "IN" port. Check to be certain that no air is escaping. Measure the dimension from the face of the Drive Shaft Pinion (63) to the face of the Drive Housing (40) mounting flange and record. Remove the air pressure from the "IN" port and measure the dimension from the Pinion to the Housing again. The difference between the two dimensions should be 28.50 mm (1.12").
4. Motor Action: Secure Starter in a vise on a workbench and apply 620 kPa (90 psi) of air pressure using a 9 mm (3/8") supply line to the air inlet of the motor. Starter should run smoothly.

5. Motor and Gear Case Seals: Plug the exhaust and slowly apply 138 kPa (20 psi) air pressure to the inlet of the motor. Immerse the Starter for 30 seconds in a nonflammable, bubble-producing liquid. There should be no leakage in the housing joints in the Gear case area or in the shaft seal of the Intermediate gear section. If the Starter is properly sealed, no bubbles will appear.
6. Motor Rotation: Apply low air pressure to the motor and observe rotation. Drive Pinion (63) must rotate in the right-hand direction which should correspond to the direction stamped on the nameplate. The chamfer on the pinion teeth should be on the trailing edge of the gear tooth.
   Observe operation of Exhaust Deflector which should open when air is applied to the motor, and return to its normal position after Starter operation.
7. Drive Housing Functions: Apply 1 034 kPa (150 psi) air pressure to the "IN" port of the Drive Housing (40). Cycle the air "on" and "off" five times and observe. Air should exhaust from the "OUT" port during each cycle.
   Plug the "OUT" port of the Drive Housing (40) and apply the 1 034 kPa (150 psi) air pressure to the "IN" port to extend the Drive Shaft (57). There should be no leakage.
   Remove air pressure, then measure the distance from the mounting flange to the end of the Drive Shaft (57) which should be 44.45 mm (1-3/4") in the normal position. Apply 483 kPa (70 psi), or as needed to move pinion to its extended position. Measure the distance from the mounting flange to the end of the Drive Shaft which should be at 73.03 mm (2-7/8").
   While the Drive Shaft is extended, push Drive Pinion (63) back on the helical splined shaft. Rear face of Drive Pinion must be able to move back 11.94 ± 0.89 mm (.47" ± 0.035").
   Apply 620 kPa (90 psi) to the "IN" port, and 138 kPa (20 psi) to the vent hole in the Housing. After five seconds, there should be no leakage.

14.6.2.6 MOTOR INSTALLATION

1. Install the air starting motor and drive assembly in the proper position on the mounting bracket.
2. Install three bolts to secure the air motor to the mounting bracket and torque to 136 N·m (100 ft-lbs).
3. Connect air supply and exhaust lines to the proper ports.

CAUTION

Use extra care to be certain that the control air pressure line is connected to the "IN" port on the Drive Housing and ***NOT*** to the "OUT" port which, if done, will result in drive malfunction (Pinion will fail to retract). This is of special concern on applications with multiple starting motors that will allow an engine to start and run while the malfunctioning pinion remains engaged. This could result in damage to the Starter and the flywheel ring gear.

14.7 SERVICE DATA - STARTING SYSTEM

14.7.1 SPECIFICATIONS

Clearance and dimensional limits listed below are defined as follows:

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 -
- Min. .....55.45 mm (2.183")
- Max.....58.88 mm (2.318")

Mica groove depth .....0.64-0.81 mm (.025"-.032")
Mica groove width ..... 0.76 mm (.030")

Parallelism of pinion and ring gear teeth ..... 0.05 mm (.002")

Backlash between ring gear and starter pinion .....0.38-1.02 mm (.015"-.040")

Brush spring tension (with new brush) -
- Min. ..... 2.04-2.27 Kg (4-1/2 lbs)

14.7.2 EQUIPMENT LIST

	PART NO.
Ductor ohmmeter	8068118
Insulation resistance tester	8174880
Brush spring tension scale	8415805

SECTION 15. TROUBLESHOOTING

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15.1 INTRODUCTION

To derive the maximum benefits from this section, it is recommended that the reader refer to the section Table of Contents to locate the specific area of interest.

All references made to other sections of this Engine Maintenance Manual, or to applicable Maintenance Instructions (M.I.'s) should be reviewed for additional information.

15.2 STARTING SYSTEM

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
STARTER(S) WILL NOT CRANK ENGINE AT ALL	**UNKNOWN** - Whether due to fault in the starting system or a mechanical obstruction in the engine.	1. Note whether starting motors respond when starting switch is operated - If starters do not respond it is a starter malfunction. 2. Open all of the cylinder test valves and attempt to rotate crankshaft by engaging the manual barring tool in the flywheel. a. If the engine can be barred over one complete revolution, it is a starting system problem - See possible cause "Starter Malfunction." b. If the engine can not be barred over one complete revolution - See possible cause "Cranking Prevented By Mechanical Obstruction."
	STARTER MALFUNCTION 1. Starter control batteries are inoperative. 2. Starter controls are incorrectly set.	Test for proper battery charge and inspect cable connections of control circuit batteries. a. If the equipment has an isolation switch, make sure it is in the "START" position. b. Check that all switches and circuit breakers in the engine control and protective circuits are properly positioned. On a turbocharged engine, make sure that the turbocharger lube pump circuit breaker is closed. c. On engines with electric starting, make sure that the battery knife switch is closed and the starting fuse still has continuity.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
STARTER(S) WILL NOT CRANK ENGINE AT ALL - (continued)	2. Starter controls are incorrectly set - (continued)	d. On engines with air starting, check that the starting air reservoirs are fully charged to the proper pressure and are free of water accumulation. Check that all valves in the air line to the starting motors are open. If the starters still do not respond, check the following (depending on the system) while the start switch is in the start position. • Establish whether or not there is voltage across the starting motors (on units with separate electric starting motors). • Establish whether or not there is voltage across the generator start winding terminals (on units using main generator for starting). • Establish if there is air pressure available at the starters (on units with air start).
	3. Starting motors inoperative.	If voltage or air pressure is being supplied to the starting motors, remove the starting motors and bench test in accordance with instructions in the Engine Maintenance Manual. On main generator starting systems, examine the generator itself for damage to the bus bars connecting the starter windings, or possible loose connections to this circuit.
	4. Starter control circuit is inoperative. (No power or air is being supplied to starter.)	a. On engines with separate electrical starting motors, check whether or not the ST and STA (if so equipped) contactors have picked up. • If the starting contactor(s) has picked up, then check its internal contacts for damage, and check for loose starting cables. • If the starting contactor(s) has not picked up, trace the starting control circuit for open interlocks, or loose or broken wiring.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
STARTER(S) WILL NOT CRANK ENGINE AT ALL - (continued)	5. Starter control circuit is inoperative. (No power or air is being supplied to starter.)	b. On engines using the main generator for starting, check whether or not the GS contactor has picked up. • If the GS contactor has picked up, check its internal contacts for damage, and check for loose starting cables. • If the GS contactor has not picked up, trace the starting control circuit for possible open interlocks or broken wiring. c. On engines using air starters, check the air start control valve for failure to pick up, and check for restrictions in the starter air supply lines. 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.
	6. Starting motor pinions do not engage properly.	1. Check gear teeth on pinion and flywheel gear for damage or debris. 2. On air start systems, check air lines to engagement mechanism, the solenoid valve, and the control valve for proper operation. 3. Check that starting motors are mounted and aligned properly. 4. Bench test starting motors for proper engagement operation (See Engine Maintenance Manual).

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
STARTER(S) WILL NOT CRANK ENGINE AT ALL - (continued)	**MECHANICAL OBSTRUCTION** 1. Damaged engine assemblies or debris.	a. 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 airbox and liner port area, including possible loose carbon lodged between a piston and head. b. Remove all oil pan handhole covers and inspect for: • Damaged or bent connecting rods. • Damaged counterweights. • Evidence of overheated main bearings and supporting "A" frames. • Damage to the lower liner skirt of any cylinder liner.
		c. 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. d. 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.) If these steps have not disclosed any evidence of a failure, attempt to rock the crankshaft back and forth. If it is not possible to rock the crankshaft, perform a main bearing inspection. If it is possible, proceed to next possible cause.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
STARTER(S) WILL NOT CRANK ENGINE AT ALL - (continued)	**MECHANICAL OBSTRUCTION DAMAGED ENGINE ASSEMBLIES OR DEBRIS (continued)** 2. Accessory, equipment or gear train failure.	a. Check the engine driven air compressor for mechanical damage or loss of lubricant. b. Check the main generator (where Applicable) for signs of bearing over heating or rotor to stator contact. c. 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.
	3. Turbocharger failure.	On turbocharged engines that can not be barred over in the direction of normal rotation, reverse the direction of the 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. 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.
STARTER(S) ENGAGE - CRANKING SPEED TOO SLOW TO START ENGINE	On electric starting systems: 1. Inadequate power to starters (or main generator).	a. Check for proper battery charge, preferably by testing with a hydrometer. b. Check battery cabling for loose connections or broken cable.
	2. Incorrect starting motor application (if applicable).	Check that the starting motors are of the proper voltage, and are connected correctly for the battery voltage in use. Installations with starting motors connected in parallel across the battery require that the starters have a voltage rating equivalent to battery voltage. Installations with starting motors connected in series across the battery (two motors) require motors which have an individual voltage rating 1/2 that of the battery. Starting motors with different operating voltage ratings are never mixed in the same installation.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
STARTER(S) ENGAGE - CRANKING SPEED TOO SLOW TO START ENGINE (continued)	On air starting systems: 1. Inadequate air supply to starters.	Check that there is adequate air pressure in the reservoirs and that they are free of water.
	2. Restrictions in air lines.	1. Check that air line valves are fully open. 2. Check that there are no restrictions or damaged components in the air supply lines to the starters. 3. Check that there are no restrictions in the starter exhaust connections or obstructions in the exhaust deflector.
	3. Engine mechanical binding.	See the preceding section on “Mechanical Obstructions.” Some components may be binding without totally restricting engine rotation.
ENGINE WILL NOT START WHEN CRANKED AT PROPER SPEED	1. Engine protective devices tripped.	Check that governor low oil button is not out. Also check low water/ crankcase pressure detector and overspeed trip mechanism to make sure they have not tripped. Reset if necessary. **NOTE:** Refer to 15.8, “EMDEC SYSTEM DIAGNOSTICS” on page 15-83 for units w/ EMDEC electronic engine controls and protective devices.
	2. Improper starting procedure.	Check that the engine was assisted in starting by advancing the injector control lever approximately 1/4 of the total rack travel. 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 resulting in engine start. (On some units, the governor is equipped with an oil booster pump which eliminates the need to manually advance the lever.) If the previous steps have not solved the problem, 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. If a dense spray of fuel is observed, proceed to possible cause #3, if not, see cause #4.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
ENGINE WILL NOT START WHEN CRANKED AT PROPER SPEED (continued)	3. Cylinders are not firing with fuel applied.	a. Check for correct injector timing and rack setting. b. Inspect the air box for evidence of broken rings or cylinder scoring; either one can cause compression loss which could prevent starting. c. Qualify the engine valve timing by performing an exhaust valve timing check (See instructions in the Engine Maintenance Manual). Only one power assembly in each bank of cylinders needs to be checked. If the engine is out of time, check the condition of the timing gear train by performing an idler gear check in accordance with instructions in the Engine Maintenance Manual.
	4. No fuel is reaching cylinders.	a. On units equipped 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 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, possible suction leaks, or a plugged suction strainer. If fuel flow is seen in the bypass fuel sight glass, change the engine mounted filters. See “Fuel System.” b. On engine driven/ manual prime fuel pump installations, make sure the system was properly primed with the hand priming pump prior to starting. If no resistance was noted 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. See “Fuel System.”

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
ENGINE WILL NOT START WHEN CRANKED AT PROPER SPEED - (continued)	5. Lack of fresh air supply to the cylinders.	a. Check engine air filters for plugging or air restrictions. See appropriate service manual for instructions. b. Check air ducts for any mechanical damage or flow restrictions. Replace, repair, or clean as required. c. Remove air box handhole covers as required to check for any air intake restrictions. d. On blower type engines, check roots blower mechanisms for any damage or air flow restrictions. Repair or replace as necessary. e. On turbocharged engines: • Inspect aftercooler cores for restriction of air flow. Remove and clean, if necessary. • Check turbocharger mechanism for failure. See “turbocharger.”
	6. Exhaust system plugging.	Check for any major plugging of exhaust flow. It is possible that a major exhaust restriction could cause enough of a misfire condition to prevent engine starting. On turbocharged engines, check for exhaust inlet screen plugging.
	7. Engine performance causes shutdown.	Consult appropriate sections in “Engine Performance.”

15.3 FUEL OIL SYSTEM

NOTE

Use only EMD fuel oil filter elements or an approved equivalent. Replace filter elements at the interval specified in the Scheduled Maintenance Program.

At the time of element replacement, the filter body and sight glasses (if used) should be cleaned.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW FUEL OIL PRESSURE	1. Inadequate fuel supply.	Check for adequate fuel supply in main or day tank.
	2. Stuck pressure relief valve.	a. On locomotive installations and installations with engine mounted fuel sight glasses, observe the 60 psi bypass sight glass (100 psi w/ EMDEC system) to make certain that the relief valve on the sight glass assembly is not stuck open. b. On installations that have a bypass or pressure relief valve in the sight glass from the inlet side of the fuel filters to a tank return, check that the bypass or relief valve is not stuck open.
	3. Fuel filters need to be replaced.	Observe the 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. Use only recommended filter elements.
	4. Fuel oil leak into lubricating system.	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.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW FUEL OIL PRESSURE (continued)	5. Suction leak or restriction.	a. On installations with no return fuel sight glass or with engine driven fuel pump: • Inspect all suction lines for air leaks into the lines. • Check pipe connections and unions for proper tightness. • Remove and inspect the screen in the suction strainer. Clean if necessary. • Check that all suction piping is the recommended diameter or larger. b. On installations with a return fuel sight glass and electric fuel pump: **NOTE:** A slight burst of bubbles during transient injector rack movement is normal. **Also, bubbles are normal on engines with Electronic Unit Injectors (EUI).** On units with Mechanical Unit Injectors, if bubbles are seen in the fuel sight glass while the engine is running, then shut the engine down, hold the fuel prime/ engine start switch in "FUEL PRIME," and continue to observe the sight glass. If 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, then the probable cause is a fuel suction leak. This fuel suction leak may cause air binding in the system and loss of fuel pressure. The following steps should eliminate this fuel suction leak: • Inspect all pipe connections and unions in the fuel suction line for proper tightness. • On locomotive installations, inspect the condition and check for tightness of all piping leading in or out of the fuel tank. • Clean the screen or element of the fuel suction strainer, if necessary.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW FUEL OIL PRESSURE - (continued)	5. Suction leak or restriction - (continued)	c. If no leak has been found, or the fuel system needs to be qualified, pressure test the system. Apply a static air pressure (414 kPa [60 psi] for installations with sight glasses and MUI injectors, 690 kPa [100 psi] for installations with sight glasses and EUI injectors, or 621 kPa [90 psi] for installations with duplex filters and MUI injectors, or 827 kPa [120 psi] for installations with duplex filters and EUI injectors) to system after fully charging with fuel. Check for the amount of pressure loss in 15 minutes. A pressure loss of 4 psi or greater indicates a leak in the engine. If this occurs, check the fuel system thoroughly for leaks. **WARNING:** **Pressures greater than rated maximum might fracture fuel sight glasses, on units so equipped. Beware of possible fire hazards due to fuel spillage.**
	6. Fuel pump malfunction.	a. Inspect the fuel pump for leaks. b. On installations with an engine driven fuel pump: • Inspect the pump drive coupling and check drive shaft keying or lock screws. • Remove pump and qualify pump operation. See an appropriate Maintenance Instruction. c. On installations using electric fuel pumps: • Check for an interruption or fault in the fuel pump control circuit. Use an appropriate wiring diagram to qualify switchgear and wiring connections. Check for continuity through electrical interlocks. • Remove pump and qualify pump operation. See an appropriate Maintenance Instruction.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW FUEL OIL PRESSURE - (continued)	7. Foreign material in the fuel tank.	Foreign material 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.
	8. Fuel line restrictions in the fuel preheater (if applicable).	a. Inspect the preheater supply and bypass circuits in the fuel suction lines for partially closed valves. b. If problem seems to be within the heater itself, shut off all fuel and water supply to the preheater. This can be done via cutoff and bypass valves. c. Remove the body end caps and inspect the internal header bends for possible trapped material obstructing the flow of fuel through the heater. Clean or repair as necessary.
LOW FUEL OIL PRESSURE - (EMDEC equipped engines):	1. Fuel oil leak at cooling plate(s).	Inspect EMDEC Controller cooling plate(s) for leaks at connections or cracks in plate surfaces.

15.3.1 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 applicable Maintenance Instruction for interpretation of the analysis statement.

Use only EMD oil filter elements or an approved equivalent in the Michiana oil filter tank.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM	1. Restriction in oil system such as plugged filters or plugged coolers.	The preliminary setup 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. Follow engine prelube procedures if necessary to ensure that engine bearings have an adequate supply of clean lube oil during troubleshooting. Follow one of the following procedures based on specific application: FOR ALL ENGINES EXCEPT MARINE WITH ENGINE MOUNTED RAW WATER PUMP OR LOCOMOTIVE WITH IN-LINE STRAINER HOUSING. Before starting the engine: a. Check for adequate supply of oil in the oil pan. b. Make sure the strainer housing is full of oil to within about 51 mm (2") of the screen under the large cover. c. Also under the large cover, make sure that the Michiana tank drain valve (with “T” handle) is fully closed. d. Remove the scavenging pump coarse strainer element which is held into the strainer box by three bolts. Inspect the interior of the strainer box for foreign material and clean if necessary. Make certain that the clean strainer is installed with a gasket and tighten securely.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM (continued)	1. Restriction in oil system such as plugged filters or plugged coolers - (continued)	e. 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. Check whether the oil level in the strainer box returns to approximately 51 mm (2") of the screen within 45 seconds. If it does not, take a pressure reading at the Michiana tank with the engine at idle. Shut the engine down by either pulling out the governor low oil pressure button or by tripping the overspeed shutdown lever. • 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. • 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, remove and clean the oil cooler core. If it does, operate the engine and slowly increase the speed. Observe the oil level in the strainer box at all speeds. At maximum operating speed, take a reading of the Michiana tank pressure.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM - (continued)	1. Restriction in oil system such as plugged filters or plugged coolers - (continued)	• If pressure reading is above 172 kPa (25 psi), change filter elements. (On switcher locomotives and industrial engines with tube bundle and shell [Heat Exchanger] type oil coolers, the applicable value is 345 kPa [50 psi]). • If pressure reading is 69 kPa (10 psi) or more after changing filter elements, temperature test the oil cooler core as discussed in the "High Lube Oil Temperature" section. If necessary, remove and clean the oil cooler. (On switcher locomotives and industrial engines with tube bundle and shell [Heat Exchanger] type oil coolers, the applicable value is 138 kPa [20 psi]). • If the pressure reading is 21 kPa (3 psi) or less, check the Michiana tank bypass valve to determine if it is jammed open. (On switcher locomotives and industrial engines with tube bundle and shell [Heat Exchanger] type oil coolers, the applicable value is 69 kPa [10 psi]). FOR ALL MARINE INSTALLATIONS WITH ENGINE MOUNTED RAW WATER PUMP AND LOCOMOTIVE WITH IN-LINE STRAINER HOUSING: Many of these engines are considerably different from other EMD engines in that much of the oil system and piping is installed by outside contractors. These variations cause the normal pressure characteristics of the oil system to be altered.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM - (continued)	1. Restriction in oil system such as plugged filters or plugged coolers - (continued)	Due to greater oil system capacity and in-line strainer, the scavenging oil pump on 20-cylinder engines (and some 16-cylinder engines) occasionally exhibits a non-linear oil pressure response (oil pressure does not follow engine RPM). Before starting the engine: a. Check for an adequate supply of oil in the oil pan. b. Remove the strainer(s) and check for any obstructions of oil flow. Clean strainer(s) if necessary. Reinstall strainer(s) with a good gasket and tighten securely. c. Check scavenging (oil) pump suction line in the oil pan. Any mechanical damage to this line must be repaired before starting the engine. d. Make sure that the lube oil system is primed (hand pump) and the drain valve is fully closed. Start the engine, set at idle, and observe the pressure output of the scavenging (oil) pump. If the pressure 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: • Main lube pump suction relief valve. • Filter bypass relief valve. • Lube oil cooler bypass relief valve. • Scavenging (oil) pump.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM - (continued)	1. Restriction in oil system such as plugged filters or plugged coolers - (continued)	If the pressure output is greater than 276 kPa (40 psi), perform the following checks: • Check pressure differential across the lube oil filter elements. If the pressure differential exceeds 69 kPa (10 psi), then change the filter elements and retest. • Check the pressure differential across the oil cooler. If the differential exceeds 69 kPa (10 psi), temperature test the oil cooler as discussed in the "High Lube Oil Temperature" section. Bring the engine up to full speed and check the following: • Check the pressure differential across lube oil filter elements. The pressure differential must not exceed 138 kPa (20 psi). Change filter elements if necessary. • Check the pressure differential across the oil cooler. The pressure differential must not exceed 138 kPa (20 psi). If the differential does exceed this value, temperature test the oil cooler core as described in "High Lube Oil Temperature" section. Remove and clean if necessary.
	2. Oil leakage.	See fault condition "Excessive Use Of Lubricating Oil."
HIGH LUBRICATING OIL TEMPERATURE	**WARNING** : **When engine shuts down due to hot oil, wait two (2) hours before attempting to inspect the engine. This will preclude the entry of fresh air which could ignite hot oil vapor.**	
	1. Inadequate oil supply.	Check oil level in the oil pan and monitor main oil pump pressure.
	2. Oil scavenging system/ oil filters malfunctioning.	See section on "Lack Of Oil Delivery From The Scavenging System." Poor oil flow could cause this problem.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
HIGH LUBRICATING OIL TEMPERATURE continued:	3. Oil cooler not functioning properly.	1. 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, see "Coolant System." 2. 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. 3. Temperature test the oil cooler as follows: 4. Put inline thermometers or temporary thermometers in the wells provided in the engine cooling water piping. a. Monitor temperatures in and out of both the oil and water sides of the oil cooler. b. 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.) c. If oil temperature drop or coolant temperature rise through the cooler are not adequate, then remove the cooler for inspection or cleaning
	4. Engine component overheating.	Inspect the interior 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.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
EXCESSIVE USE OF LUBRICATING OIL (See specific condition)	**OIL LOSS OUT OF THE EXHAUST STACK.** 1. Worn power pack assemblies.	a. Perform air box inspection and pay particular attention to the condition of the piston, rings, and liner. b. If ring wear exceeds the recommended limits, renew or replace power assembly. If rings are broken, renew or replace power assembly immediately, regardless of their wear state. c. Check the piston crown and port area for signs of oil problems in a specific cylinder. Excessively wet crowns and oil sludge throw off from the inlet ports may point out cylinders with oil control problems.
	2. Piston rings installed improperly.	See possible cause “Piston Rings Installed Improperly.”
	OIL LOSS OUT OF THE EXHAUST STACK - (continued) 3. Oil separator screen missing.	Disassemble the lube oil separator and check for a missing or disintegrated screen element. On the turbocharged engine, the absence of this screen can cause excessive oil consumption and oil out of the stack. Oil passage through the separator can occur when the flow rate through the separator exceeds design capacity. This is usually caused by combustion gases, ambient air, or pressurized air box air entering the crankcase. This condition is characterized by a reduction of crankcase vacuum, and can be detected by measurement with a manometer at the oil dipstick tube.
	4. Blower rotor end seals failed (on blower type engines).	Inspect the air ducts from the blower to the air box. If oil is found running down the ducts, the blower should be removed and the blower rotor end seals replaced.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
EXCESSIVE USE OF LUBRICATING OIL (continued)	5. Turbocharger seal failure (on turbocharger engines).	a. Remove the screen and taper joint in the exhaust manifold assembly. b. Inspect the manifold interior to determine if oil loss is originating from the engine or the turbocharger. In many instances, this inspection will reveal a specific cylinder responsible for the oil loss. c. If the exhaust manifold inspection 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 drain oil past the turbocharger labyrinth seals.) d. If the external systems are found to be in good condition, then changeout of the turbocharger may be necessary. See "Turbocharger."
	6. Cylinder wall varnishing.	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 rings and may, in some cases, cause a condition known as oil "souping" (which can result in an oil loss through the exhaust stack). Varnishing can be characterized by 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.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
EXCESSIVE USE OF LUBRICATING OIL (continued)	7. Excessively worn head retainer surfaces, worn or pounded head seat rings.	Cylinder head retainer surfaces and head seat rings are subject to wear during normal operation. Excessive wear or clearance due to "pounding" of seat rings from improperly torqued head crab nuts may allow oil to be drawn past the seat rings into the exhaust. These conditions can be minimized by following the Scheduled Maintenance program for in-service tightness checks of head crab nuts on new engines with non-plate crabs or by assuring that correct torque is applied when installing new or rebuilt power assemblies in engines with either plate or non-plate type crabs.
	PISTON RINGS INSTALLED IMPROPERLY	On EMD engines, piston rings in the No. 4, No. 5, and No. 6 grooves are directionally sensitive at installation and all six (6) rings in the set must be properly oriented in the correct groove. NO. 1 RING - Labeled "Top Groove Only" and stamped with a part number. It may be installed with either side up. NO. 2, 3 RING - Both rings are identical. They are both stamped with a part number and may be installed with either side up. NO. 4 RING - Labeled "Top" and has a part number stamped on it. It must be installed with the top label upward and only in the No. 4 groove. If this ring is installed upside down, its tapered face will tend to pump oil past the upper compression rings. NO. 5 RING - This is a double hook scraper and must be installed with the hooks pointed down. If this ring is installed upside down, it will cause heavy oil loss through the air ports and considerable oil loss into the air box. NO. 6 RING - This 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. At the 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.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
EXCESSIVE USE OF LUBRICATING OIL (continued)	**LOSS OF OIL FROM AIR BOX DRAIN**	
	1. Worn power pack assemblies.	See possible cause "Oil Loss Out Of The Exhaust Stack," Part 1.
	2. Piston rings installed improperly.	See possible cause "Piston Rings Installed Improperly."
	3. Turbocharger or blower seal malfunction.	See possible cause "Oil Loss Out Of The Exhaust Stack," Part 4 and 5.
	4. Failed power pack assembly external seal.	Inspect for excessive oil leakage from around the power pack assemblies or from the center gallery of the air box. Leakage here might indicate a failed or absent seal, a failed component, or an oil gallery structure failure.
	5. Damaged air box drain piping.	Inspect the air box drain piping in the oil pan for any evidence of leakage or external damage to the piping which could cause oil loss.
	BAD OIL	This indication is usually seen on installations with shell and tube type oil coolers because, in these coolers, the local oil pressure is sometimes higher than the cooling water pressure.
	1. Oil in water expansion tank.	On installation 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.
	2. Improper viscosity and oil contamination.	See fault condition "Diluted, Contaminated Or Improper Oil."
	OIL LEAKAGE 1. External engine leaks.	Leakage of oil from component connections will generally require tightening the affected part or replacement of gaskets.
	2. Loss of oil into the governor.	This condition will be evidenced by rising or overflowing oil from the governor oil level sight glass. Check the governor drive seal and replace if necessary. Check the low oil pressure actuating diaphragm of the governor and replace if necessary.
	3. Load regulator or vane motor leaking (if applicable).	Tighten or replace as necessary.
	4. Pedestal or generator bearing leakage (Marine).	Replace the bearing seals and check return lines for continuity. Check that the orifice is in place on the supply line.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW ENGINE OIL PRESSURE	1. Inadequate oil supply.	Check for adequate oil level in engine oil pan.
	2. Diluted oil supply.	See fault condition “Diluted, Contaminated Or Improper Oil.”
	3. Clogged turbocharger filter (if applicable).	Change the turbocharger oil filter element. (Make sure that the replaceable cartridge type element isn’t installed upside down, because this can cause low oil pressure.)
	4. Malfunction in lubricating oil scavenging system.	See fault condition “Lack Of Oil Delivery From Scavenging System.” If the oil supply to the main pump is found to be inadequate, install test oil pressure gauge (0-50 psi) on the outlet elbow of the main lube oil pump using the 3/4" NPT plug hole. If the pump pressure indicated on the gauge is adequate, proceed to possible cause #10. If not, proceed to possible cause #5.
	5. Clogged strainers or debris in strainer box (if applied).	a. Remove the two fine screen strainers in the strainer housing. Clean the strainers and inspect the seals for possible suction leaks. b. Drain the strainer box and inspect the chamber for any foreign material. c. Remove and blow compressed air through the seal vent line to make certain that it is not obstructed.
	6. Fault in bearing oil supply lines.	Remove all oil pan handhole covers. Visually inspect the piston pins, the external surfaces of the main and connecting rod bearings for evidence of overheating, and look for missing or loose components.
	7. Stuck pressure relief valve.	Operate the engine at idle speed. Remove the low water/ crankcase pressure detector, leaving oil lines intact, and swing the detector away from the accessory housing hole. (On older models, without flexible oil line connections on the detector, some oil lines may have to be capped or plugged.) Check the pressure relief valve (located directly behind the detector), 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.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW ENGINE OIL PRESSURE (continued)	8. Oil line leakage and suction leaks.	Check for suction leaks at the main pump inlet elbow where it mates to the main pump and to the strainer housing (if applicable). Replace gasket if necessary. See "Excessive Use Of Lubricating Oil."
	9. Main lube oil pump malfunction.	Remove and qualify the main lube oil pump per instructions in the Engine Maintenance Manual.
	10. Main oil pressure gauge malfunction.	a. Qualify the main engine oil pressure gauge. b. Check for any closed valves in the supply line to the gauge. c. Inspect the 1/8" diameter line leading through the right bank top deck of the engine to the pressure gauge (if used). Inspect this line carefully for damage. If necessary, blow air through it to be certain it is clear of obstructions.
	11. Defective engine protective device. (On units w/ Mechanical Unit Injectors.)	a. Disconnect and block the connecting line from the oil pressure sensing line to the low water/ crankcase pressure detector and the hot oil shut down device (if so equipped). If this results in restoration of normal oil pressure reading on the main engine gauge, it indicates that either: • The "O" ring seals in the low water/ crankcase pressure detector have failed. • The activating section of the hot oil detector may be jammed open. b. Qualify both of these devices.
	12. Rear gear train oil line malfunction.	a. Use the recommended tool to check the clearance in the No. 1 idler stubshaft bushing. Inspect the interior of the end housing for debris under the gear train.
	13. Rear gear train oil line malfunction. (continued)	b. On turbocharged engines, remove the auxiliary generator drive (if so equipped) or the cover plate on the rear right bank. Inspect the manifolding to the turbocharger filter for loose or missing components or seals. Make sure that the upper pipe plug is installed in the gauge line connecting block and inspect the camshaft manifolds.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
DILUTED, CONTAMINATED, OR IMPROPER OIL		Check for this condition as follows: a. The brand name and viscosity of the lubricating oil should be compared to EMD standards. Use of oils should be confined to those that meet qualifications published by EMD. b. Immediately take a lube oil sample for analysis. Follow the specified corrective action as indicated in applicable Maintenance Instruction.
	1. Fuel leakage into lubricating oil.	a. Check all fuel jumper lines to the injectors for cracks and proper seating. b. Inspect all brazed joints in the top deck fuel manifold and check all manifold pipe plugs for leakage. c. Check injectors and injector filter cap gaskets for leaks. d. Check for piston rings which are not free to rotate in the piston ring groove. e. Pressure test fuel system as required to isolate the source of leak. See “Fuel System.”
	2. Water contamination of the lube oil.	a. Visually inspect for water in the oil pan and on top of the cylinder heads. b. Visually check for leaks in water manifolds and piping. c. Pressure test as required to isolate the source of the leak. See “Coolant System.”

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
TURBOCHARGER PRELUBRICATION (Soak Back) SYSTEM FAILURE		If the 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 he malfunction.
	<u>CAUTION</u>: **If the engine can not be restarted within two (2) minutes of shutdown, the 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. Open lube oil check valve.	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 turbocharger filter housing) is jammed open. Remove the housing and inspect the check valve. (This condition will allow oil contaminants to be backflushed into the main oil gallery.)
	2. Oil bypassing soak back filters.	On most engine applications, the soak back pump filter is mounted in a small canister close to the pump. There is no backup filtration system. If the filter clogs, the bypass valve will allow dirty oil to reach the turbocharger bearings. Replace soak back pump filter. Use only EMD recommended filters.
	3. Clogged turbocharger oil filter.	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 shut down. Replace the filter element or cartridge using only EMD recommended filters.
	4. Lack of oil delivery from soak back pump.	a. 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. b. If oil drainage is not evident, check the following for failure or restriction of oil delivery: The motor to pump coupling, the pump, and the motor. (See Engine Maintenance Manual instructions.)

15.3.2 COOLING SYSTEM

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW WATER PRESSURE (ON PRESSURE COOLING SYSTEMS ONLY)		Install a pressure gauge in the cooling system and monitor the pressure rise at the expansion tank as the engine heats up to normal operating temperature. Check to see that the pressure reading matches the system or cap specifications. See an applicable service manual for pressure testing details. If pressure is low, check for:
	1. Failed expansion tank vent valve.	Place 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. Damaged filler components.	a. Shut the engine down. Blow down the tank pressure by opening the manual vent valve. b. When the tank pressure is completely dissipated, remove and inspect the expansion tank fill valve. c. Check the filler neck condition for any sign of damage. d. 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. 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, but its purpose is defeated if a plain expansion tank cap is used

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOW WATER PRESSURE (ON PRESSURE COOLING SYSTEMS ONLY)	3. Poor coolant delivery.	See fault conditions “Poor Coolant Delivery” and “Excessive Coolant Loss.”
POOR COOLANT DELIVERY	1. Inadequate coolant supply.	Check coolant level in expansion or supply tank.
	2. Coolant piping damage or flow restrictions.	a. Check all coolant manifolds and piping for mechanical damage which might restrict flow. b. Verify coolant flow in various locations of the coolant system in order to pinpoint any hidden flow restrictions.
	3. Coolant piping leakage.	See fault condition “Excessive Coolant Loss.”
	4. Water pump failure.	Remove and qualify the water pump(s) per instructions in the Engine Maintenance Manual.
EXCESSIVE COOLANT LOSS	1. Open drain valves.	Check that all drain valves and plugs are not leaking. Check that all vent valves on the expansion tank (if so equipped) are in the proper position. Check that coolant expansion or supply tank is adequately capped. On locomotives, check that all cab heater drains are closed.
	2. Missing or loose pipe connections.	Check that all coolant system piping connections are tight and that all gaskets are in good condition. Leakage on the pressure or output side of the water pump will cause coolant loss and decreased coolant pressure throughout the system. (Leakage on the suction or output side of the water pump will draw air into the system which results in cavitation at the pump.)
	3. Coolant system leaks.	Hydro-Test the cooling system for leaks. Do not exceed 172 kPa (25 psi) during the 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).

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
HIGH COOLANT TEMPERATURE	**ON INSTALLATIONS WITH RADIATORS:**	
	1. Inadequate coolant supply.	Check the coolant level in the expansion or supply tank.
	2. Low coolant pressure.	See fault condition “Low Coolant Pressure.” (Applicable to pressure cooling systems only.)
	3. Coolant is not flowing through system.	See fault condition “Poor Coolant Delivery.”
	4. Inoperative radiator shutters (if applicable).	a. Cycle the shutters with the temperature switch test button or the shutter test valve. Check that the shutters are opening completely. b. Check the temperature at which the temperature switch 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. Place the heat sensing element in a pan of hot water and check the operating point with a thermometer.
	5. Inoperative cooling fans.	a. 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. b. On installations with belt driven cooling fans, inspect the belts and make certain that they are properly tensioned.
	4. Poor air flow through radiators.	Inspect the exterior of the radiators for clogging and restriction of air flow. Clean radiator baffles (fins) if necessary. Carefully check cores for leaks.
	5. Improperly connected radiator and water pump vent lines.	Make certain that all radiator and water pump vent lines are in place and not obstructed. Poorly connected radiator vent lines can cause air binding in the radiators which results in a loss of cooling efficiency. Water pump vent lines that are loose or an incorrect size can cause cavitation of the water pump (which results in a loss of coolant delivery pressure).

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
HIGH COOLANT TEMPERATURE - (continued)	**ON INSTALLATIONS WITH HEAT EXCHANGERS, KEEL COOLERS, OR RAW WATER COOLING:**	
	1. Inadequate coolant supply.	Check coolant level in expansion or supply tank.
	2. Low coolant pressure.	See fault condition “Low Coolant Pressure.” (Applicable to pressure cooling systems only.)
	3. Poor coolant delivery.	See fault condition “Poor Coolant Delivery.”
	4. Inoperative temperature control valve.	Check the operation of the temperature control (thermostatic) valve (if so equipped). See instructions in the Engine Maintenance Manual.
	5. Poor raw water delivery.	a. Check that all valves are open in the suction and discharge circuits of the pump. b. Make certain that piping connections are properly sealed and tightened and that gaskets are in good condition. c. On installations with belt or shaft driven raw water pumps, check the shaft couplings and belt tension. d. If none of the above steps have located the problem, remove and qualify the raw water pump per instructions in the Engine Maintenance Manual.
	6. Clogged heat exchanger.	Monitor the temperature change across the engine cooling side of the heat exchanger and, if possible, across the raw water pump from suction to the discharge side. If the temperature change is too small across the cooling side of the heat exchanger (this is a temperature drop) or raw water pump (this should be a temperature rise), then clean the radiator surfaces. It may be necessary to rod out the exchanger (shell and tube types).

15.3.3 ENGINE PERFORMANCE

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
UNEXPECTED ENGINE SHUTDOWN	1. Engine was stopped.	a. Check that emergency fuel cutoff or the engine stop switch was not activated. b. On locomotive installations, check that the engine was not inadvertently shut down by moving the throttle handle beyond the detente to the "STOP" position or that the M.U. engine stop button was pressed (on units so equipped). Either of these control functions will also shut down all other locomotive units connected in a consist (tandem). Before proceeding with any further troubleshooting steps, check annunciator panel (if so equipped) or computer display for fault indications.
	2. Overspeed trip lever was activated.	Check the position of the overspeed trip lever. If it has tripped, see fault condition "Overspeed Shutdown."
	3. Inadequate fuel supply.	a. Check the fuel level in the supply or day tank. b. See "Fuel System."
	4. Crankcase pressure detector trips.	See fault condition "Crankcase Pressure Shutdown."
	5. Low water detector trips (if applicable).	See the appropriate sections in "Cooling System." **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.
	6. Hot oil detector tripped (if applicable).	See fault condition "High Lubricating Oil Temperature" in "Lubricating Oil System."
	WARNING: **When engine shuts down due to hot oil, wait two (2) hours before attempting to inspect the engine. This will preclude the entry of fresh air which could ignite hot oil vapor.**	

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
UNEXPECTED ENGINE SHUTDOWN (continued)	7. Low oil pressure shutdown.	This type of shutdown is either indicated by a governor low oil button which has popped out or an EMDEC annunciator indication, depending on the installation. In either case, perform the following: a. Check that the shutdown was not caused by another protective device. The other detectors function by dropping all oil pressure to the governor. See the appropriate possible cause.
	WARNING: **If the low oil button is popped and the hot engine condition is suspected, wait two (2) hours before attempting to inspect the engine. This will preclude the entry of fresh air which could ignite hot oil vapor.**	
		b. See the "Low Engine Oil Pressure" section of "Lubricating Oil System." c. If none of the above inspections disclose any reason for the low oil pressure shutdown on an installation with a hot oil detector, load the engine and watch the engine temperature gauge closely for possible over heating. The oil detector might have shut the engine down and reset itself during cool off.
	8. Turbocharger clutch failure.	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.
	9. Severe air intake plugging.	It may be possible in an extreme case of filter plugging, that the air supply could be cut off to the engine and shut it down. Check air intake filters for plugging. Check all air intake ducts for air flow restrictions. (This condition should be indicated by an annunciator light or computer indication.)

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
CRANKCASE PRESSURE SHUTDOWN	**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 (2) hours. Do NOT attempt to restart the engine until the cause of this 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 fresh air is allowed to enter. If crankcase pressure detector can not be reset, do NOT operate the engine until the pressure detector has been replaced, since the diaphragm backup plates may be damaged.**	
	1. Aspirator system malfunction.	a. Check for a plugged screen in the lube oil separator. b. Check for plugged or damaged aspirator piping. Repair or replace as required. **NOTE:** Do not remove any of the calibrating orifices that are part of the total crankcase aspirator system installed at the factory.
	2. High engine oil level.	Check oil level. High oil can cause a shutdown due to foaming action or from throw off oil hitting the actuating diaphragm of the engine protector causing a false crankcase pressure indication.
	3. Plugged eductor tube (if applicable).	On turbocharged units, check if there is carbon blocking the angled end of the eductor tube which projects into the exhaust stack riser.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
CRANKCASE PRESSURE SHUTDOWN - (continued)	4. Engine component failure.	After the engine has been shut down for two (2) hours, remove the oil pan and air box handhole covers. Check for: • Cracked pistons. • Broken and unseated cylinder crab bolts, and loose crab bolt retainers. • Cracked cylinder head. • Badly worn valve guides. • Hardened or broken lower liner seals. • Inadequate injector crab nut torque. • Extreme cylinder scoring which could cause air box blowdown past oil control rings. • Improperly installed or broken rings. • Evidence of carbon combustion in the air box which could cause seal hardening and component failure. • Any indication of over heated metal surfaces. • Debris under the gear train at both ends of the engine.
	5. Incorrectly installed oil pressure relief valve.	a. Remove the detector from the accessory drive housing. b. Check that the port on the oil pressure relief valve (located directly behind the detector) is 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 crankcase pressure indication.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
OVERSPEED SHUTDOWN	1. Engine load dropped.	a. Check the possibility that engine load was dropped. Look for annunciator, engine control cabinet or computer fault indications. b. Check the operation of overcurrent protective relays and excitation limiting relays. Check for other electrical malfunctions which might cause considerable load fluctuations. c. Marine operations in extremely rough or shallow water may cause considerable load fluctuations.
	2. Overspeed mechanism failure.	a. Run the engine to maximum speed with no load and check the engine speed with a hand held tachometer. This can be done via the access cover on the camshaft counterweight cover. b. Increase fuel injection with the injector control layshaft lever until the overspeed device trips. Note the speed at which the device trips. • If the overspeed does not trip when the engine RPM reaches 10% over rated speed, back off the injector control lever and shut the engine down. Remove the front cam counterweight cover and readjust the overspeed mechanism. See the Engine Maintenance Manual for instructions. • If the overspeed tripped at an RPM that was too low, remove the front cam counterweight cover and readjust the overspeed mechanism. See the Engine Maintenance Manual for instructions. Retest until proper RPM trip value is obtained.
	3. Engine speed hunting.	See fault condition “Engine Speed Hunting.”

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
ENGINE SPEED HUNTING (SPEED DEPARTURE)	1. Malfunctioning injector control linkage (on engines with Mechanical Unit Injectors).	Check that the injector control linkage is working properly. Replace any injector which shows evidence of rack binding.
	2. Fuel supply problems.	If bubbles are evident in fuel return sight glass (if so equipped), see "Fuel System." On other installations, check for proper flow through the fuel lines.
	3. Electrical control malfunction.	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. 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.
	4. Load fluctuation.	In some cases, a load fluctuation condition may cause an apparent hunting condition. Marine engine gear box installations may exhibit a load fluctuation in rough or shallow water which should not be confused with hunting.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
CYLINDER MISFIRE	**METHODS OF LOCATING A MISFIRING CYLINDER:**	1. Exhaust temperature check. a. On engine installations with exhaust stack pyrometers, check the readings between cylinders with the engine running under load. Do not use only one set of pyrometer readings as a basis for an exploratory teardown of a power assembly. Always compare the readings of individual pyrometers by switching the sensing bulbs between the suspected defective cylinder and one cylinder that is indicating properly. b. On engine installations without exhaust stack pyrometers, an approximation of individual cylinder exhaust temperature can be obtained with a hand-held pyrometer. Take a comparison reading at each riser leg while the engine is under load, 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. 2. Stack sound check. a. Using a four (4’) foot length of 1/2" to 3/4" pipe held against the riser leg, listen to the sound of the exhaust in each stack riser. Excessive or abnormal noise indicates the possibility of a misfiring cylinder or a defective exhaust valve. b. On units with mechanical unit injectors, disconnect the injector rack link on the suspected 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.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
CYLINDER MISFIRE (continued)		3. Cylinder pressure check. A cylinder with a pressure leak can be caused by a badly leaking exhaust valve, excessive ring blow-by, a cracked piston, etc. An exhaust valve can be detected, when standing beside an engine, by a pronounced blow in the exhaust stack, with engine idling. To locate the leaking cylinder, shut down the engine and remove the cylinder test valve from the cylinder to be checked. Using an exhaust valve tester, as shown in Figure 15-1, install the adapter and air gauge assembly in the cylinder test valve hole. Before attaching the air line to the adapter, turn on the air valve and regulate the air pressure to read 414 kPa (60 psi) on the line air gauge. Rotate the crankshaft until the piston of the cylinder being checked is at approximately top dead center. Attach the air line coupling to the adapter and note the adapter gauge pressure. Valve leakage is indicated if the gauge reads below 386 kPa (56 psi). Repeat the check on the remaining cylinders.  F14362 **Figure 15-1. Exhaust Valve Tester** **NOTE:** Details for construction of the exhaust valve tester can be obtained from the Electro-Motive Service Department by requesting a copy of file drawing No. 695.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
CYLINDER MISFIRE (continued)		Special tool 40021839 may be used to pressure test injectors for leakage while they are installed in the engine. Pressure test injectors as follows: a. Ensure that engine fuel lines are fully charged. b. Place a straight edge across the exhaust and injector cam rollers. If the injector cam roller is higher than the exhaust cam rollers, bar the engine over until the injector roller is below the exhaust rollers. c. Apply the test tool to the injector rocker arm of the injector being tested. The tool should straddle the rocker arm with the lower end of the tines under the rocker arm shaft and the top end of the tool covering the rocker arm adjusting screw lock nut. d. Remove the retainer spring and clevis pin securing the injector control lever to the adjusting link. e. Place the injector rack in the full fuel position. f. Apply 1/2" drive torque wrench to the pressure test tool and apply 107 Nm (80 ft-lbs) of torque. Hold the torque for a minimum of five (5) seconds. If the torque indication drops off, or if the wrench must be moved to maintain torque, the injector is leaking and must be replaced. If the torque remains constant for five (5) seconds without movement of the wrench, the injector is acceptable. 4. Air box inspection. Heavy cylinder scoring and badly worn or broken compression rings can cause smoking, high oil consumption, knocking or loading, and operational problems. Remove all air box handhole covers and inspect each power assembly through the liner air intake ports. (Consult the appropriate “One Revolution” inspection sequence charts provided.) Check for excessive component “sludge” deposits and any port blockage.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
CYLINDER MISFIRE (continued)	1. Wrong injectors.	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 can not be set correctly with an EMD injector rack tool. If they are mixed in an EMD engine set with EMD injectors, and set with an EMD tool, these cylinders will be too light on fuel volume (rack too long). This can result in misfire, vibration, poor overall fuel economy, and possible engine damage. Do not rely on body grooves or any other superficial means of identifying injectors. Check the injectors only by the part number and then make certain, through the appropriate EMD Parts Catalog, that all of the injectors in an engine are correct for that installation.**	
	2. Low fuel oil pressure.	a. On installations with fuel sight glasses, check for adequate fuel flow through the return sight glass. If the fuel flow is inadequate or bubbles are evident in the return fuel sight glass, see "Fuel System." b. On installations with fuel block and duplex filters, check for adequate fuel supply pressure. If the fuel pressure is inadequate, see "Fuel System."
	3. Injector timing is off.	See instructions in the Engine Maintenance Manual.
	4. Incorrect exhaust valve lash adjustment.	a. Check exhaust valve lash adjustment as described in the Engine Maintenance Manual. b. Remove and test any valve bridge which shows inadequate lash adjuster tension or which operates loudly when the engine is running.
	5. Injector malfunction.	Pressure test all injectors as described in "Methods Of Locating A Misfiring Cylinder."
	6. Power assembly damage (rings, valves, piston, etc).	a. Pressure test suspect cylinders as described in "Methods Of Locating A Misfiring Cylinder." b. Perform an air box inspection of all power assemblies as described in "Methods Of Locating A Misfiring Cylinder." Check closely for any sign of liner scoring.
	7. Exhaust valve timing is off.	Refer to 7.2.6 EXHAUST VALVE TIMING on page 7-15.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
CYLINDER MISFIRE (continued)	8. Mixed power assembly components.	In some cases, mixing components, such as between 567 and 645 engines or between blower and turbocharged type engines, may cause misfire or knocking condition. This may range from having no effect to rapid component destruction.
ENGINE KNOCKING	1. Engine overloading.	Check for engine overloading or overheating problems. Observe load and temperature gauges with the engine in operation. If necessary, refer to an applicable section of the troubleshooting guides for corrective action.
	2. Cylinder misfiring.	See fault condition “Cylinder Misfire.”
	3. Damaged connecting rods.	If none of the steps above provided a solution to knocking problems, take lead wire readings to check for bent rods or piston pin insert distress.
	4. Excessively worn cylinder liner or piston.	Perform an air box inspection of all power assemblies as described in “Methods Of Locating A Misfiring Cylinder.”
EXCESSIVE VIBRATION	1. Rotating equipment misalignment.	If the installation has been subjected to any shock loadings, check engine to generator or engine to gearbox alignment.
	2. Injector or fuel system malfunction.	Open top deck covers and perform a visual inspection of all injectors, racks, rocker arms, and rocker arm shaft mounting studs. Check that all injector racks are engaged to the transfer arms and that all pins and linkages are in place and properly tightened. See sections pertaining to injectors and the fuel system in the “Cylinder Misfire” fault section.
	3. Engine coupling failure.	Inspect the engine to generator or gearbox couplings and coupling discs for any sign of failure. Replace if necessary. On marine installations, inspect torque tube couplings for evidence of failure.
	4. Drive shaft failure.	Inspect all drive shafts for failure. Replace if necessary.
	5. Crankshaft component malfunction.	Remove all oil pan handhole covers. Visually inspect the crankshaft area for loose or damaged main bearing caps and connecting rod baskets or damaged crankshaft counterweights. Look for signs of overheating or extruded metal.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
EXCESSIVE VIBRATION (continued)	6. Gear train component failure.	Inspect for debris under the gear train at both ends of the engine. Visually qualify the crankshaft damper. Check engine records to make certain that the crankshaft damper is not past its changeout date.
	7. Camshaft counterweights are misapplied.	a. Check that counterweight size application is correct. Compare part numbers or weights to those listed in an appropriate EMD parts catalog. b. Check counterweight timing as shown in the Engine Maintenance Manual.
	8. Broken generator pole bolts.	Check for broken bolts on generator poles (if applicable). Replace if necessary.
	9. Loose mounting bolts.	Check engine and base mounting bolts for any damage or improper torque.
LOSS OF POWER (WITH A CLEAN STACK - NO SMOKE)	1. Top deck component failure.	With engine shut down, open all top 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. Check fuel jumpers, rocker arms and exhaust valve bridges for any abnormal conditions.
	2. Fuel supply system failure.	With top deck covers closed and engine prepared for normal startup, perform the following: a. Check fuel level in supply or day tank. b. Prime engine fuel system and check for adequate return fuel flow (on installations with sight glasses) or fuel supply pressure (on installations with duplex filters). c. Start the engine and allow it to reach normal operating temperature. Check fuel system delivery or pressure. If the fuel system shows any indication of inadequate operation, see “Fuel System.”

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOSS OF POWER (WITH A CLEAN STACK - NO SMOKE)	3. Governor malfunction or load regulator system malfunction (on governor controlled engines).	**NOTE:** The following procedures apply only to engines with notched or continuous throttles; and Woodward PG, PGR or PGA governors. 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 held tachometer to check that the engine has reached maximum speed. If the engine failed to reach maximum RPM, check the governor solenoids on PG or PGR governors and the control air supply and pressure settings on PGA governors. Check for a worn solenoid fulcrum plate mechanism. 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 held tachometer. If the engine can not reach its maximum speed rating under load, examine the position of the rack as indicated by the quadrant on the governor and refer to the following instructions as applicable. 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: a. On locomotive installations, check the position of the load regulator. 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. Pressure test the injectors as described under fault condition “Cylinder Misfire.” The governor part number should be checked to make sure it is correct for the installation. If necessary, the governor should be removed to check the load control pilot valve.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOSS OF POWER (WITH A CLEAN STACK - NO SMOKE)	4. Governor malfunction or load regulator system malfunction (on governor controlled engines).	• If the load regulator has moved to maximum field position, the problem could be of a mechanical or electrical nature. Injectors should be checked for proper part number and pressure tested as described under fault condition "Cylinder Misfire." The electrical excitation system should be qualified according to the procedures established in the appropriate Locomotive Service Manual. b. On marine or power generating installations, an overload condition or a mechanical problem with the fuel injectors is most likely. Check the injectors for correct part numbers and pressure test them as described under fault condition "Cylinder Misfire." Check that the governor part number is correct for the installation. If these checks have not solved the problem, 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 applicable propeller cube curves to determine if an overload condition has been caused by incorrect propeller pitch.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
LOSS OF POWER (WITH A CLEAN STACK - NO SMOKE) (continued)	4. Governor malfunction or load regulator system malfunction (on governor controlled engines). Continued.	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 injector rack layshaft lever. a. 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. b. If it was possible to manually advance the injector control lever to the maximum fuel position, and the engine speed increased, then suspect: • Improper governor setting (high speed unloader limit). • Deliberate speed limiting setting (marine only). • Improper governor adjustment (locomotive only). PG and PGR governors (rail and drill rig installations) should be removed from the engine and operated on a governor test stand to make adjustments.
ENGINE EMITTING BLACK OR GRAY SMOKE (MAY BE ACCOMPANIED BY A LOSS OF POWER)	1. Top deck component malfunction.	With the engine shut down, open the top deck covers and perform a visual inspection of all injectors, racks, and followers. Check that all injector racks are engaged to the transfer arms and that all pins and linkages are in place and are properly tightened. Check fuel jumpers, rocker arms and exhaust valve bridges for any abnormal conditions.
	2. Faulty injectors.	a. Check all injector part numbers to make certain that they are correct for the installation. b. Pressure test all injectors as described under fault condition “Cylinder Misfire” in “Methods Of Locating Misfiring Cylinder.”

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
ENGINE EMITTING BLACK OR GRAY SMOKE (MAY BE ACCOMPANIED BY A LOSS OF POWER) (continued)	3. Broken rings or failed power assembly component.	Perform a complete air box inspection. Check closely for broken compression rings. Consult the appropriate "One Revolution" inspection sequence charts.
	4. Air flow restrictions in the air box.	Check for excessive air box accumulations blocking liner air intake ports. Check air duct and air box areas for major air restrictions. On turbocharged units, make sure that aftercooler air passages are not blocked or plugged.
	5. Turbocharger malfunction.	On turbocharged engines, remove the inlet boot and inspect the inlet impeller for damage. Remove the section of exhaust manifold adjacent to the turbocharger. (If the engine is equipped with an exhaust screen inspection port, the manifold section does not have to be removed.) Examine the condition of the exhaust inlet screen and clean if necessary. Inspect the interior of the exhaust manifold for debris. Inspect the turbine exhaust blades and qualify the turbocharger per instructions in "Turbocharger." **NOTE:** A plugged turbocharger exhaust inlet screen may have been caused by a coolant leak. See "Coolant System."

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
ENGINE EMITTING BLACK OR GRAY SMOKE (MAY BE ACCOMPANIED BY A LOSS OF POWER) (continued)	6. Fuel system failure.	With top deck covers closed and engine prepared for normal startup, perform the following: a. Check fuel level in supply or day tank. b. Prime the engine fuel system and check for adequate return fuel flow (on installations with sight glasses) or fuel supply pressure (on installations with duplex filters). c. Start the engine and allow it to reach normal operating temperature. Check fuel system delivery or pressure. If the fuel system shows any indication of inadequate operation, see "Fuel System."
	7. Governor malfunction.	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 held tachometer. If performance is inadequate, see probable cause #3, under "Loss Of Power (with a clean stack - no smoke)."
	8. Engine overloading.	Check the governor rack quadrant with the engine at maximum speed and full load. If the governor rack dimension is shorter than the limit on the governor identification plate, then the engine is either overloaded or lacking fuel. See preceding checks for solving fuel problems. Check the maximum RPM with a hand held tachometer on the end of the camshaft. If the engine is running below its maximum rated RPM and short on rack, perform the following steps: a. On locomotive and power generating installations, set the system to rated horsepower output and check all calibrating and load control adjustments. b. On marine gearbox installations, it may be necessary to adjust pitch or diameter of propeller if continual overloading is experienced.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
ENGINE EMITTING BLACK OR GRAY SMOKE (MAY BE ACCOMPANIED BY A LOSS OF POWER) - (continued)	9. Plugged air filters.	With the engine at maximum speed, with no load applied, use a water manometer to check engine air inlet depression. If air inlet depression exceeds the value provided in the "Air Filter Pressure Drop" table, Figure 15-2, either change or clean filters. **NOTE**: All air filter pressure drops are measured in clean air plenum downstream of the filter elements.

Application	Turbocharged Engines						Blower-Type Engines					
	Paper		Fiberglass		Oil		Paper		Fiberglass		Oil	
	mm	In.	mm	In.	mm	In.	mm	In.	mm	In.	mm	In.
Marine	356*	14*	178	7	406*	16*	457**	18**	178	7	508**	20**
Marine Drill	356*	14*	178	7	406*	16*	457**	18**	178	7	508**	20**
Stationary	356*	14*	178	7	406*	16*	457**	18**	178	7	508**	20**
Drill Rig											508**	20**
	Inertial + Paper		Inertial + Fiberglass		Inertial + Oil		Inertial + Paper		Inertial + Fiberglass		Inertial + Oil	
	mm	In.	mm	In.	mm	In.	mm	In.	mm	In.	mm	In.
Locomotive	356	14	356	14	406	16	457	18	457	18	368	14.5

NOTE
Inertial filter readings should not exceed 140 mm (5.5").

*For remote mounted filter applications, subtract 76 mm (3") of water.
**For remote mounted filter application, subtract 254 mm (10") of water.

F24886

Figure 15-2. Air Filter Pressure Drop

ENGINE EMITTING BLACK OR GRAY SMOKE (MAY BE ACCOMPANIED BY A LOSS OF POWER) - (continued)

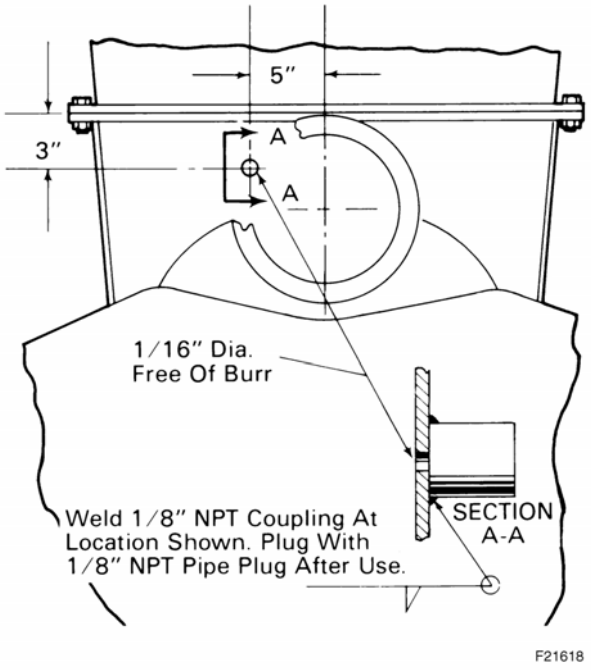
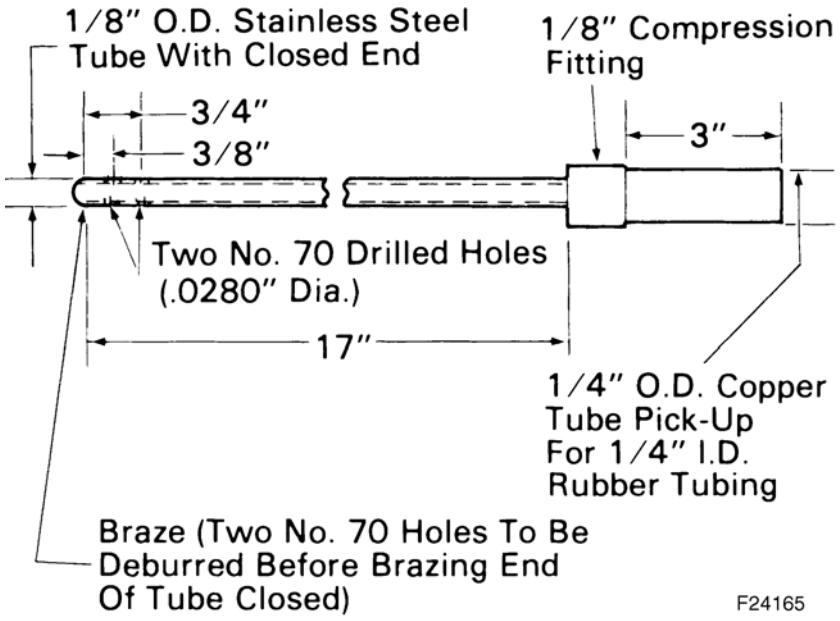


Figure 15-3. Pressure Tap Location

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
ENGINE EMITTING BLACK OR GRAY SMOKE (MAY BE ACCOMPANIED BY A LOSS OF POWER) - (continued)		**NOTE:** Consult your Electro-Motive representative for exhaust back pressure specifications on 710 engines.
ENGINE EMITTING BLACK OR GRAY SMOKE (MAY BE ACCOMPANIED BY A LOSS OF POWER) - (continued)	 **Figure 15-4. Static Pressure Pickup**	
	10. Faulty exhaust valve timing.	Check exhaust valve timing on both cylinder banks as described in the Engine Maintenance Manual.
ENGINE EMITTING BLUE SMOKE	Oil leaks or burning oil.	See fault condition "Excessive Use Of Lubricating Oil" in "Lubricating Oil System."

15.3.4 TURBOCHARGER

More than 50% of all 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. Perform the following inspections before proceeding to any further steps:

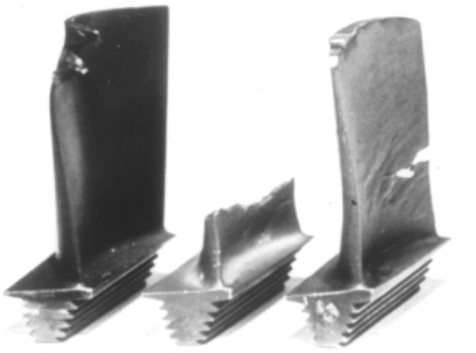
15.3.4.1 PRELIMINARY TROUBLESHOOTING INSPECTION

1. Inspect the entire housing for cracks and oil leaks. Some oil leaks can be repaired merely by tightening a pipe plug or by applying silastic rubber sealant. An excessive leak from a crack or from an inaccessible area requires turbocharger changeout.
2. Remove the rubber air intake boot and flange.
3. Inspect the impeller for broken or nicked vanes or any visible signs or 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.
4. Turn the impeller by hand to check for a locked-up condition or a badly damaged clutch. It should turn freely in the counter-clockwise direction, but engage when turned clockwise.
5. Displace the impeller laterally, vertically, fore and aft to determine excessive radial or end thrust clearance.
6. Inspect the clearance between the impeller and the cover to reveal any impeller contact.
7. If any defective condition was found in the preceding steps, the turbocharger must be replaced. If no defective condition is found, reinstall the flange and the boot.
8. Bar the engine over to determine if it is damaged before a starting attempt is made and inspection continued. (Often a reported turbocharger failure is actually a failure of some other engine component.)

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
TURBOCHARGER 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 noises such as 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 checked:
	1. Impeller damage.	Perform the "Preliminary Troubleshooting Inspection."
	2. Gear train failure.	Remove a handhole cover and check for metallic debris under the crankshaft gear. Such debris is indicative of a gear train problem.
TURBOCHARGER THROWING OIL OUT OF EXHAUST STACK		Inspect the exhaust stack to ensure that the oil is actually coming out of the stack. A plugged and leaking turbocharger seal can not be found through external inspection so it must be determined by process of elimination only if no other faulty condition is discovered. Troubleshooting steps for this fault condition can be found in the "Oil Loss Out Of The Exhaust Stack" cause under fault condition "Excessive Use Of Lubricating Oil," in the "Lubricating Oil System."

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
TURBOCHARGER EXHAUST LEAK		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 can not be repaired in the field and require turbocharger changeout. Improper application of lifting chains (allowing them to press against the exhaust duct while the turbocharger is suspended) can lead to bending of the lap joint between the exhaust duct and the compressor bearing support. Once this joint is deformed, a permanent exhaust leak may result.
TURBOCHARGER BURPING (HONKING) AND SMOKING EXCESSIVELY	**UNKNOWN** - preliminary check.	Compare the air box pressure to that of engines that are operating satisfactorily. Using the same gauge (0-270 kPa [0-30 psi]), take an air box pressure reading at full speed and no load on the engine being inspected and the references engines. Ideally, the readings should not vary more than 6.9 kPa (1 psi) if everything is in good condition. Based on the pressure results, make the following checks, after inspecting the impeller per “Preliminary Troubleshooting Inspection” instructions:
	HIGH AIR BOX PRESSURE - Gas flow restriction downstream of the air box causing momentary air flow reverses through the compressor.	
	1. Cylinder air intake.	Check for heavy air box deposits around the cylinder intake ports. Clean if necessary.
	2. Poor exhaust valve timing.	Check exhaust valve timing as described in the Engine Maintenance Manual. Adjust if necessary.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
TURBOCHARGER BURPING (HONKING) AND SMOKING EXCESSIVELY (continued)	**HIGH AIR BOX PRESSURE (continued)** 3. Plugged turbocharger exhaust screen.	Remove the section of the exhaust manifold adjacent to the turbocharger. (If the engine is equipped with an exhaust screen inspection port, the manifold section does not have to be removed.) Examine the condition of the exhaust inlet screen and clean if necessary. **NOTE:** A common cause of exhaust screen plugging is extended operation under light load. This plugging is due to "souping," which is the tendency of relatively cold, viscous engine lube oil to bypass the oil control rings on the pistons. Under light load operation, frequent exhaust screen inspection and cleaning may be necessary.
TURBOCHARGER BURPING (HONKING) AND SMOKING EXCESSIVELY (continued)	4. Turbocharger exhaust turbine damage or plugging.	Examine the nozzles and the leading edges of the turbine blades for foreign material damage or deposits. This may be done by viewing through the turbine inlet scroll. The leading edges of the blades can be viewed through the nozzles located between the 1:00 and 2:00 o'clock positions, and all blades can be viewed by rotating the impeller. Examine for nicked blades, broken blades, and blades that have stretched and are rubbing on the shroud, Figure 15-5 and Figure 15-6, page 15-56. These conditions require turbocharger changeout. If nozzles and turbine blades appear encrusted or plugged with carbon deposits, cleaning can be done using a "blast washing" method with a soft media. **NOTE**: On Unit Exchange turbochargers, do not confuse smooth blends with sharp nicks caused by foreign material.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
TURBOCHARGER BURPING (HONKING) AND SMOKING EXCESSIVELY - (continued)	**HIGH AIR BOX PRESSURE (continued)** 4. Turbocharger exhaust turbine damage or plugging. (continued)  F20972 **Figure 15-5. View Of Blades Through The Nozzles Between The 1:00 And 2:00 O'Clock Positions**  F20973 **Figure 15-6. Stretched, Broken, And Nicked Blades**	

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
TURBOCHARGER BURPING (HONKING) AND SMOKING EXCESSIVELY - (continued)	**LOW AIR BOX PRESSURE** - pressure leak or air intake restriction.	
	1. Impeller damage.	This should have been found in previous impeller inspections.
	2. Air filter plugging.	Check engine air filters for restrictions or a plugged condition. See the air filter section under “Engine Emitting Black Smoke” in “Engine Performance.”
	3. Air box leak.	Check for any signs of air box leaks at handhole covers at crankcase structural members, and at the turbocharger discharge scroll gaskets.
	4. Aftercooler plugging.	Inspect aftercooler air passages for plugging or debris accumulation. Check the pressure drop action across the aftercoolers and correct if necessary.
	5. Exhaust leaks.	Check for exhaust leaks at manifold mounting flanges, manifold joints, and expansion joints. Check for leaky gaskets or a leaking pipe plug on top of the turbocharger exhaust inlet scroll.
	6. Failed turbocharger clutch.	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. A failed clutch requires turbocharger changeout on 567 and 645 engines. On 710 engines, turbocharger must be removed to repair or replace clutch drive gear assembly.

FAULT CONDITION	POSSIBLE CAUSE	RECOMMENDED CHECK OR CORRECTIVE ACTION
TURBOCHARGER BURPING (HONKING) AND SMOKING EXCESSIVELY - (continued)	**NORMAL AIR BOX PRESSURE** - failed turbocharger clutch.	It is usual for a malfunctioning clutch to slip only intermittently, therefore only occasionally causing burping and smoking by its failure to engage. Check for clutch failure by performing the following: 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 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 a maximum of 6 times or until the clutch fails to engage. A worn clutch may fail to engage only once in as many as thirty (30) attempts. When it fails to engage, the injector racks will move toward "FULL FUEL" position and the engine will produce heavy black smoke and rumbling noises.

15.4 TROUBLESHOOTING ENGINE WITH FAILED TURBOCHARGER

After turbocharger failure has been verified, it is very important to determine the cause of failure and take preventative measures to ensure that the replacement turbocharger will not fail. After the turbocharger is removed from the engine, inspect the turbocharger 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 passage).

Any sign 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.

15.4.1 FOREIGN MATERIAL DAMAGE TO THE IMPELLER

This failure, Figure 15-7, usually results from one of the following:

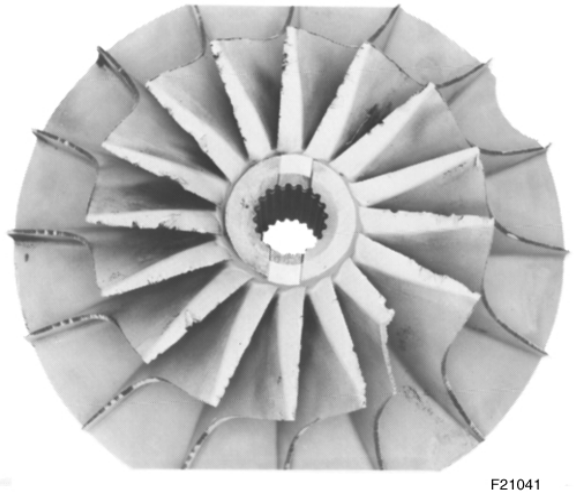


Figure 15-7. Impeller Damaged By Foreign Material

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.

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.

15.4.2 FOREIGN MATERIAL DAMAGE TO TURBINE BLADES

Foreign material damage can be found by inspecting blades and nozzles as detailed in this 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, Figure 15-8.



Figure 15-8. Nicked Impeller Blades

The mechanical breakup of any part of the power assemblies or the exhaust system may result in 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 is 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.

The later design screens have a trap built into the bottom of the assembly. The trap collects foreign material and prevents it from continuously hitting the screen, breaking up, and entering the turbocharger. This screen assembly is applied to all current model EMD turbocharged engines and is available for retrofitting on older model engines through Electro-Motive Parts Centers.

Failures can be reduced by performing preventive maintenance to:

1. Preclude ring breakage. Top ring side clearance measurement can be used as a method to determine when the ring is entering a dangerous wear 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.

15.4.3 OVERHEAT/ OVERSPEED

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 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, Figure 15-9.

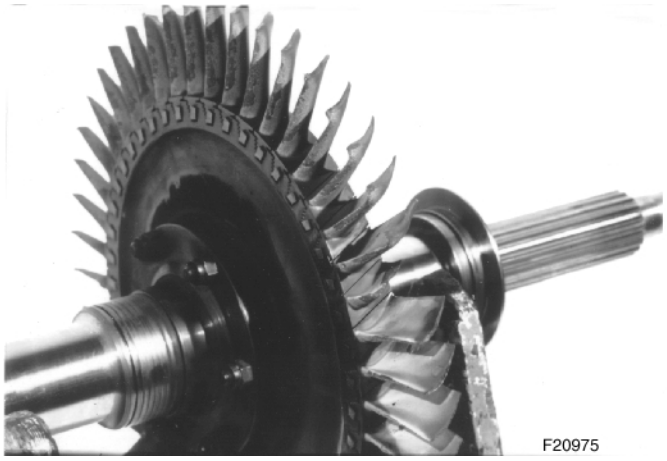


Figure 15-9. Stretched Blades That Have Rubbed The Shroud

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, Figure 15-10 below and Figure 15-11, page 15-62.

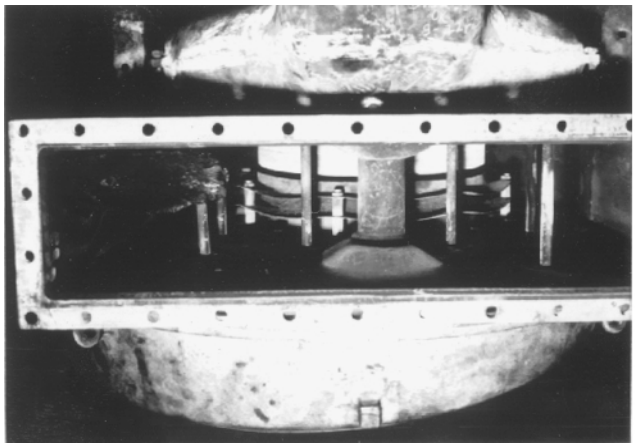


Figure 15-10. View Down The Exhaust Stack (Warped Diffuser)

NOTE

Units with exhaust duct connected to an elbow or silencer which prevents viewing diffuser down duct can be inspected by removing eductor tube assembly and using a light and mirror through the eductor tube connection.

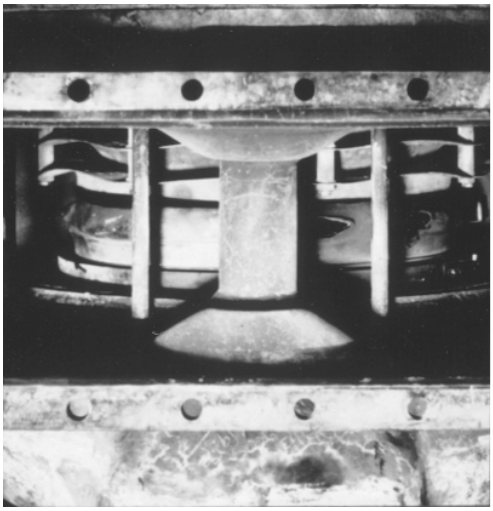


Figure 15-11. View Down The Exhaust Stack (Of A Warped Diffuser From Broken Blades)

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 pulling 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.
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 (sometimes causing damaged injectors).
4. Mistimed engine, valves, and injectors.
5. Exhaust manifold fire.
6. Excessive electrical overload.

15.4.4 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 hydro-dynamic bearings when the engine is started or stopped. At engine start, the oil cools the bearing and, after engine shutdown, the oil cools the bearing and protects against residual heat in the turbocharger.

Scheduled monthly inspections 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 de-activates 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.

15.4.5 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, including clutch drive gear assembly on 710 engines, to determine when gears require replacement. For engines using spring drive or clutch drive gear assemblies, the gear retaining bolts should be checked for tightness. Discard any loose bolts and apply new bolts.

NOTE

The eight (8) bolts holding the turbocharger drive gear to the spider on spring drive gear assemblies or doweling assembly on clutch drive gear units should be 31.8 mm (1-1/4") long, with hardened washers between the gear and bolt heads.

15.5 GOVERNOR AND GOVERNOR RELATED TROUBLESHOOTING

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
INSUFFICIENT TRAVEL OF INJECTOR ADJUSTING LINK TO OBTAIN CORRECT INJECTOR RACK SETTING.	1. Wrong terminal shaft lever applied to governor.	Change terminal shaft lever. Lever should measure 106.4 mm (4-3/16") between hole centers.
	2. Terminal shaft lever improperly applied to governor.	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.	Replace governor. Missing serration should be at 3 o’clock position.
	4. Wrong terminal shaft scale on governor.	Replace governor. Scale should be graduated from 1.96" to .62".

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
GOVERNOR LOW OIL PLUNGER TRIPS WHEN STARTING ENGINE.	1. Governor low oil time delay too short, or engine slow in developing oil pressure.	Reset governor low oil plunger immediately, and crank engine again. With engine operating at idle, check and reset time delay, if necessary. See Governor Section of Engine Maintenance Manual.
	2. Differential water or crankcase pressure detector tripped.	Check detector reset buttons to ensure they are in the set position.
	3. Engine oil pressure line to governor broken or crimped.	Replace oil line.
	4. Hot oil shutdown valve stuck open or leaking.	Replace valve if defective. See Lubricating Oil Section of Locomotive Service Manual.
	5. *True* low engine oil pressure.	See Lubricating Oil Section of Engine Maintenance Manual.
GOVERNOR FAILS TO CONTROL ENGINE SPEED WHEN STARTING ENGINE **IDLE SPEED APPROXIMATELY 50 RPM LOW.**	1. Insufficient fuel. (Terminal shaft goes to full-fuel position.)	Replace fuel filter elements. Clean fuel strainer element.
	2. Insufficient oil in governor. (Terminal shaft goes to no-fuel position.)	Check governor sight glass for proper oil level. See Governor Section in Engine Maintenance Manual for procedure and M.I. 1764 for correct lubrication oil.
	3. Governor shutdown bushing not properly adjusted. (Terminal shaft goes to no-fuel position.)	Remove governor cover and check that shut down bushing to speed setting piston extension is 1/32" when the speed indicating pointer moves to IDLE as engine is cranked. If not, remove governor and reset per Governor Section instructions in the Engine Maintenance Manual.
	4. Defective governor. (Terminal shaft goes to no-fuel position.)	Remove governor cover and check to see that speed indicating pointer moves from STOP to IDLE position when cranking engine. Replace governor if speed indicating pointer does not move.
	5. Incorrect injector rack setting.	Reset injector racks. See Governor Section in the Engine Maintenance Manual.
	The cap under the “D” solenoid plunger rod is not installed correctly.	See Governor Section in the Engine Maintenance Manual.
GOVERNOR HUNTS	1. Compensating needle valve not properly adjusted.	See Governor Section in the Engine Maintenance Manual.

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
	2. Too much or too little oil in the governor.	See Governor Section in the Engine Maintenance Manual for procedure, and M.I. 1764 for correct oil.
	3. Governor hunts for a short time when engine oil and governor oil are cold.	Run engine for a short period of time to warm the oil.
	4. Insufficient fuel.	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. Binding injector control shaft linkage or sticking injector.	Make certain that all control shaft linkage is free. (Replace sticking injector or free up linkage.)
	6. Governor binding internally. a. Dirt in governor. b. Scored buffer piston.	Replace governor. • Drain oil from governor, flush and refill. See Governor Section in the Engine Maintenance Manual for procedure, and M.I. 1764 for correct oil. • Replace buffer piston.
GOVERNOR HUNTS ONLY AT FULL LOAD	1. Insufficient fuel to maintain engine speed at full load. Partial fuel restriction.	Replace fuel filter elements. Clean fuel strainer element. Fuel return sight glass must be full.
	2. Plugged turbocharger exhaust inlet screen or aftercoolers.	See “TROUBLESHOOTING RUNNING TURBOCHARGER.”
	3. Defective load regulator rheostat.	Qualify rheostat.
	4. Other electrical problems.	See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual.
ENGINE OVERLOADED. GOVERNOR TERMINAL SHAFT AT FULL FUEL POSITION, BUT ENGINE SPEED BOGS DOWN. LOAD REGULATOR IN MINIMUM FIELD POSITION	1. Insufficient fuel.	Check fuel filter and strainer. Return fuel sight glass must be full.
	2. Over excitation of main generator. Fault in power control circuits. a. Dirt in governor. b. Scored buffer piston.	See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual. • Drain oil from governor, flush and refill. See Governor Section in the Engine Maintenance Manual for procedure, and M.I. 1764 for correct oil. • Replace buffer piston.

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 REGULATOR 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 SPECIFIED RACK LENGTH. **LOAD REGULATOR IS BALANCED.**	1. Governor terminal shaft quadrant pointer off location.	With engine shut down, quadrant scale should indicate 1.96". If not at 1.96", disconnect injector linkage and check: • If quadrant scale now indicates 1.96", search for injector(s) with extended outward travel of calibrating slide. • If quadrant scale still does not indicate 1.96", relocate quadrant pointer and reset injector racks.
	2. Low air box pressure.	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: • Turbocharger impeller for damage. • Aftercooler and filters for plugging. • Aftercooler duct for leakage. • Exhaust manifold for leakage.
	3. Leak or restriction in air line from air box to governor.	Remove air line and check. Replace if necessary.
	4. Locknut on overriding solenoid backed off, holding rebalancing rocker arm up.	Readjust governor overriding solenoid and tighten locknut. See Governor Section in the Engine Maintenance Manual.
	5. Improperly set governor.	Replace governor.

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
ENGINE IS LOADED AND RUNS AT RATED SPEED, BUT GOVERNOR TERMINAL SHAFT IS AT SHORTER THAN SPECIFIED RACK LENGTH. LOAD REGULATOR IS BALANCED.	1. Governor terminal shaft quadrant pointer off location.	With engine shut down, quadrant scale should indicate 1.96". Relocate quadrant pointer, and reset injector racks.
	2. Improperly set governor.	Replace governor.
LOAD REGULATOR STAYS IN MINIMUM FIELD POSITION WITH THE ENGINE AT IDLE.	1. Insufficient fuel.	Check fuel filter and strainer. Return fuel sight glass must be full.
	2. One or more injectors defective.	Qualify injector(s). See Fuel Section in the Engine Maintenance Manual.
	3. Governor overriding solenoid stuck, or spring under overriding solenoid plunger broken.	Replace governor.
	4. Injector rack length not properly set at 1.00" on governor terminal shaft scale.	Reset injector rack length. See Fuel Section in the Engine Maintenance manual.
	5. Governor to load regulator lines reversed.	Reapply lines correctly.
GOVERNOR FILLS WITH OIL.	1. Ruptured low oil pressure diaphragm.	Replace diaphragm or change out governor.
	2. Defective seal on load control pilot valve plunger.	Replace governor.
	3. Porous column casting.	Replace governor.
GOVERNOR LOSES OIL	1. Defective drive shaft seal.	Replace drive shaft seal or replace governor.
	2. Defective terminal shaft seal.	Replace governor.

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
GOVERNOR DOES NOT CHANGE SPEED WHEN THROTTLE IS CHANGED	1. Loose governor plug.	Check governor plug for looseness.
	2. Solenoids do not respond to throttle setting.	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 solenoid(s) in once energized.	Correct control circuit problem.
ENGINE SPEED WILL NOT INCREASE BEYOND 6TH THROTTLE SPEED	1. Engine air filters clogged.	Replace engine air filter elements.
	2. Engine filter switch defective.	Replace engine air filter switch.

15.6 "ONE REVOLUTION" INSPECTION CHARTS

The following engine "One Revolution" inspection sequence charts are designed to speed up air box inspection of power assembly components and minimize required engine manual barring. The charts show the power assembly checks that can be made during one revolution of the crankshaft.

Select the chart which is applicable to the number of cylinders and the direction of rotation of the engine to be inspected. (The right-hand rotation charts are applicable only to right-hand rotation marine engines only.)

The column headings can be interpreted as follows:

FLYWHEEL DEGREES: Flywheel location as indicated by the flywheel pointer.

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 MUI INJECTOR: The number appearing in this column opposite "flywheel degrees" indicates that the Mechanical Unit Injector of that cylinder can be timed.

CAUTION

This instruction is for engines with Mechanical Unit Injectors only. Do NOT set Electronic Unit Injectors at these flywheel degree positions. Refer to setting instructions on EUI Injector Timing Plate (located on right rear side of engine crankcase).

NO. 1 RING: This indicates that the top compression ring of that cylinder can be inspected.

UP: 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.

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.

15.6.1 MECHANICAL UNIT INJECTORS

Table 1: 8-CYLINDER ENGINE (LEFT-HAND ROTATION)
"ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES									
BLOWER	STD. TURBO-CHARGED	A.T.D.C.		SET MUI INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
		+1°	+2°		UP	DOWN			
356	0	1	2	1					4
18 1/2	22 1/2	23 1/2	24 1/2		7	2			
41	45	46	47	5					8
63 1/2	67 1/2	68 1/2	69 1/2		4	6	4-6	1-7	
86	90	91	92	3					2
108 1/2	112 1/2	113 1/2	114 1/2		8	1			
131	135	136	137	7					6
153 1/2	157 1/2	158 1/2	159 1/2		2	5	2-5	3-8	
176	180	181	182	4					1
198 1/2	202 1/2	203 1/2	204 1/2		6	3			
221	225	226	227	8					5
243 1/2	247 1/2	248 1/2	249 1/2		1	7	1-7	4-6	
266	270	271	272	2					3
288 1/2	292 1/2	293 1/2	294 1/2		5	4			
311	315	316	317	6					7
333 1/2	337 1/2	338 1/2	339 1/2		3	8	3-8	2-5	

Table 2: 12-CYLINDER ENGINE (LEFT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES									
BLOWER	STD. TURBO-CHARGED	A.T.D.C. +1°	A.T.D.C. +2°	SET MUI INJECTOR	NO. 1 RING UP	NO. 1 RING DOWN	PISTON COOLING OIL PIPE	PISTON	LINER
356	0	1	2	1	3	2	3-2	8	
15	19	20	21	12	10	11	10-11	4	
									5
41	45	46	47	7	9	8	9-8	3-6	
									2
66	70	71	72					10-1	
									11
90	94	95	96	4	5	6	5-6	9-12	
									8
116	120	121	122	3	2	1	2-1	7	
135	139	140	141	10	11	12	11-12	5	
									6
161	165	166	167	9	8	7	8-7	2-4	
									1
186	190	191	192				11-3		
									12
210	214	215	216	5	8	4	8-4	8-10	
									7
236	240	241	242	2	1	3	1-3	9	
255	259	260	261	11	12	10	12-10	6	
									4
281	285	286	287	8	7	9	7-9	1-5	
									3
306	310	311	312					12-2	
									10
330	334	335	336	6	4	5	4-5	7-11	
									9
356	0	1	2	1	3	2	3-2	8	

Table 3: 16-CYLINDER ENGINE (LEFT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES									
BLOWER	STD. TURBO-CHARGED	A.T.D.C.		SET MUI INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
		+1°	+2°		UP	DOWN			
356	0	1	2	1	6	13	6-13	7-16	4
18 1/2	22 1/2	23 1/2	24 1/2	8	11	2			5
41	45	46	47	9	14	7			12
63 1/2	67 1/2	68 1/2	69 1/2	16	4	10	4-10	1-11	13
86	90	91	92	3	5	15	5-15	8-14	2
108 1/2	112 1/2	113 1/2	114 1/2	6	12	1			7
131	135	136	137	11	13	8			10
153 1/2	157 1/2	158 1/2	159 1/2	14	2	9	2-9	3-12	15
176	180	181	182	4	7	16	7-16	6-13	1
198 1/2	202 1/2	203 1/2	204 1/2	5	10	3			8
221	225	226	227	12	15	6			9
243 1/2	247 1/2	248 1/2	249 1/2	13	1	11	1-11	4-10	16
266	270	271	272	2	8	14	8-14	5-15	3
288 1/2	292 1/2	293 1/2	294 1/2	7	9	4			6
311	315	316	317	10	16	5			11
333 1/2	337 1/2	338 1/2	339 1/2	15	3	12	3-12	2-9	14

Table 4: 20-CYLINDER ENGINE (LEFT-HAND ROTATION) "ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES			SET MUI INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
STD. TURBO-CHARGED	A.T.D.C.							
	+1°	+2°		UP	DOWN			
0	1	2	1	15	3	15-6	4	10
9	10	11	19	17	6	15-6	16	12
36	37	38	8	17	6	17-4	9	3
45	46	47	11	12	4	17-4	14	20
72	73	74	5	12	4	12-9	1	6
81	82	83	18	20	9	12-9	19	13
108	109	110	7	20	9	20-1	8	4
117	118	119	15	13	1	20-1	11	16
144	145	146	2	13	1	13-8	5	9
153	154	155	17	16	8	13-8	18	14
180	181	182	10	16	8	16-5	7	1
189	190	191	12	14	5	16-5	15	19
216	217	218	3	14	5	14-7	2	8
225	226	227	20	19	7	14-7	17	11
252	253	254	6	19	7	19-2	10	5
261	262	263	13	11	2	19-2	12	18
288	289	290	4	11	2	11-10	3	7
297	298	299	16	18	10	11-10	20	15
324	325	326	9	18	10	18-3	6	2
333	334	335	14	15	3	18-3	13	17
360	361	362	1	15	3	15-6	4	10

15.6.2 ELECTRONIC UNIT INJECTORS

Table 5: 8-CYLINDER 710G3B-T2 ENGINE (LEFT-HAND ROTATION)
INSPECTION SEQUENCE

Flywheel Deg.	Set EUI Inj. & Exhaust Valves	Inspect Liner & Piston Crown	Inspect #1 Ring		Inspect Piston Skirt
			Up	Down	
8.5	6	4			
22.5			7	2	
53.5	1	8			
67.5			4	6	1 & 7
98.5	5	2			
112.5			8	1	
143.5	3	6			
157.5			2	5	3 & 8
188.5	7	1			
202.5			6	3	
233.5	4	5			
247.5			1	7	4 & 6
278.5	8	3			
292.5			5	4	
323.5	2	7			
337.5			3	8	2 & 5

Table 6: 12N-710G3B-T2 Engine (Left-hand Rotation)
"One Revolution" Inspection Sequence

Flywheel Deg.	Set EUI Injector & Exhaust Valves	Inspect Liner & Piston Crown	Inspect #1 Ring		Inspect Piston Skirt
			UP	DOWN	
0		6	2	3	5
38.5	11				
45		12	8	9	11
53.5	1				
60		3	6	5	1
98.5	7				
105		9	12	11	7
113.5	4				
120		5	3	1	4
158.5	10				
165		11	9	7	10
173.5	2				
180		1	5	4	2
218.5	8				
225		7	11	10	8
233.5	6				
240		4	1	2	6
278.5	12				
285		10	7	8	12
300		2	4	6	3
338.5	9				
345		8	10	12	9
353.5	5				

Table 7: 16-CYLINDER 710G3C-T2 ENGINE (LEFT-HAND ROTATION "ONE REVOLUTION" INSPECTION SEQUENCE)

Flywheel Deg.	Set EUI Inj. & Exhaust Valves	Inspect Liner & Piston Crown	Inspect #1 Ring		Inspect Piston Skirt
			Up	Down	
8.5	10	4	6	13	7 & 16
31	15	5	11	2	
53.5	1	12	14	7	
76	8	13	4	10	1 & 11
98.5	9	2	5	15	8 & 14
121	16	7	12	1	
143.5	3	10	13	8	
166	6	15	2	9	3 & 12
188.5	11	1	7	16	6 & 13
211	14	8	10	3	
233.5	4	9	15	6	
256	5	16	1	11	4 & 10
278.5	12	3	8	14	5 & 15
301	13	6	9	4	
323.5	2	11	16	5	
346	7	14	3	12	2 & 9

Table 8: 20-CYLINDER 710G3C-T2 ENGINE (LEFT-HAND ROTATION "ONE REVOLUTION" INSPECTION SEQUENCE)

Flywheel Deg.	Set EUI Inj. & Exhaust Valves	Inspect Liner & Piston Crown	Inspect #1 Ring		Inspect Piston Skirt
			Up	Down	
17.5	9	12		2 & 17	16
26.5	14	3	6 & 13		7
53.5	1	20		10 & 12	14
62.5	19	6	4 & 16		2
89.5	8	13		3 & 20	19
98.5	11	4	9 & 14		10
125.5	5	16		6& 13	11
134.5	18	9	1 & 19		3
161.5	7	14		4 & 16	18
170.5	15	1	8 & 11		6
197.5	2	19		9 & 14	15
206.5	17	8	5 & 18		4
233.5	10	11		1 & 19	17
242.5	12	5	7 & 15		9
269.5	3	18		8 & 11	12
278.5	20	7	2 & 17		1
305.5	6	15		5 & 18	20
314.5	13	2	10 & 12		8
341.5	4	17		7 & 15	13
350.5	16	10	3 & 20		5

15.7 LINER/ PISTON VISUAL INSPECTION GUIDE

During an “in engine” liner/ piston inspection, a correct diagnosis is important to prevent the unnecessary removal of still serviceable parts, or the continued operation of a non-serviceable part, possibly resulting in a complete failure.

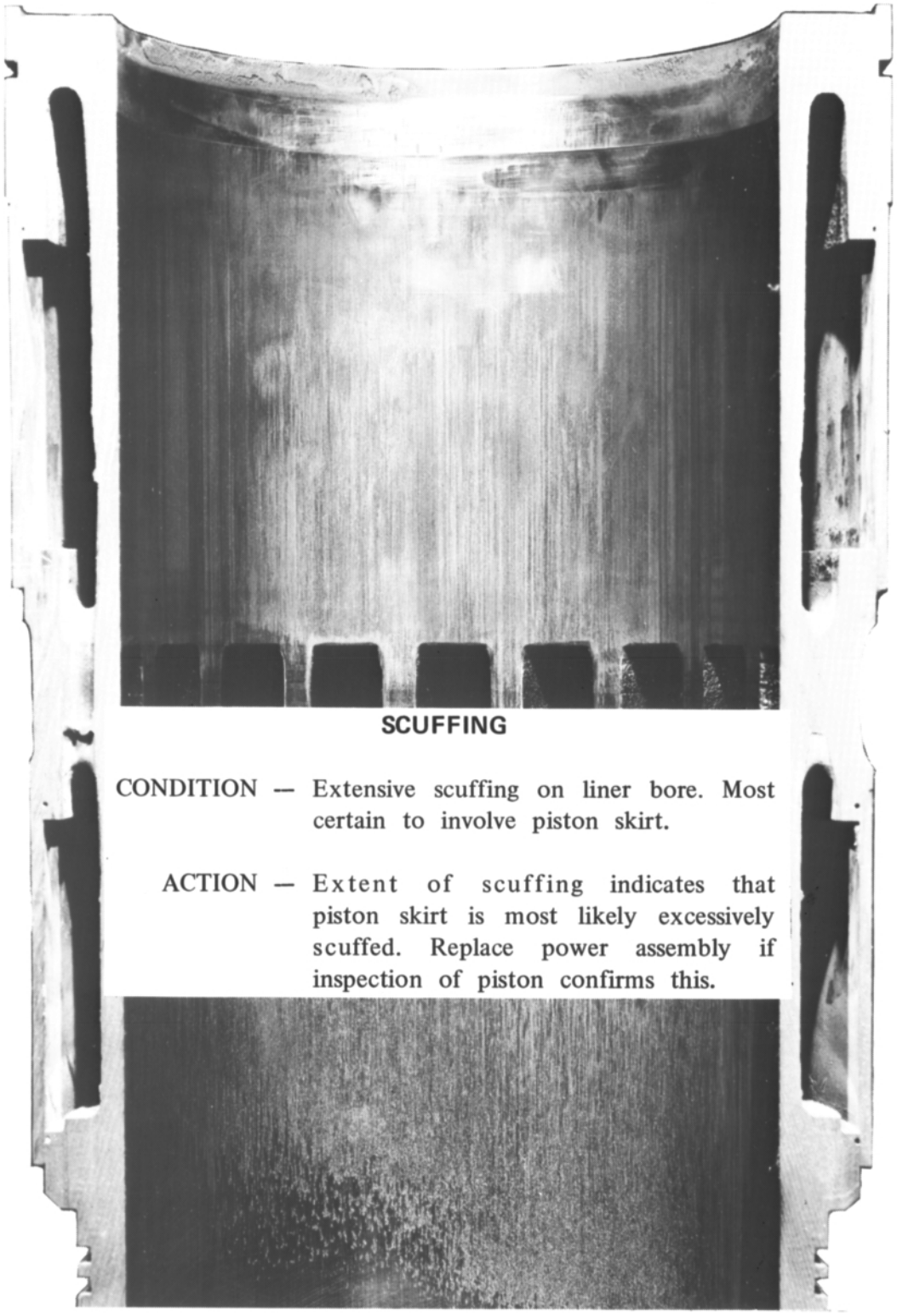
The illustrations show the conditions most likely to be observed, and the captions give the correct terms to define them. Consistent use of these terms, when describing liner and piston conditions, will permit an accurate evaluation of the problem at hand, and be understandable to anyone familiar with such conditions.

When liner bores are inspected and abnormal conditions are observed, check piston ring and piston skirt condition **BEFORE** changing out a power assembly. Do not remove an assembly based on liner appearance only. Refer to the applicable illustration in the guide for the action to be taken based on the observed conditions.

Continued usage or replacement of the liner and/ or piston, based on the recommended “**ACTION**,” can contribute significantly to extended component service life and the prevention of engine damage.

NOTE

Pistons used in late model EMD turbocharged engines have a tin plate skirt treatment, the color of which turns from silver matte to a dull flat pewter gray during service. This pewter gray coloring may be mistaken for scuffing during inspections. Scuffing indications that are valid include distressed skirt surfaces where obvious metal tearing can be seen and felt, and similar liner distress is apparent when viewed through the ports.



SCUFFING

CONDITION — Extensive scuffing on liner bore. Most certain to involve piston skirt.

ACTION — Extent of scuffing indicates that piston skirt is most likely excessively scuffed. Replace power assembly if inspection of piston confirms this.

F24175


NORMAL WEAR
CONDITION — Normal wear pattern.
ACTION — Continue in service.
F24176

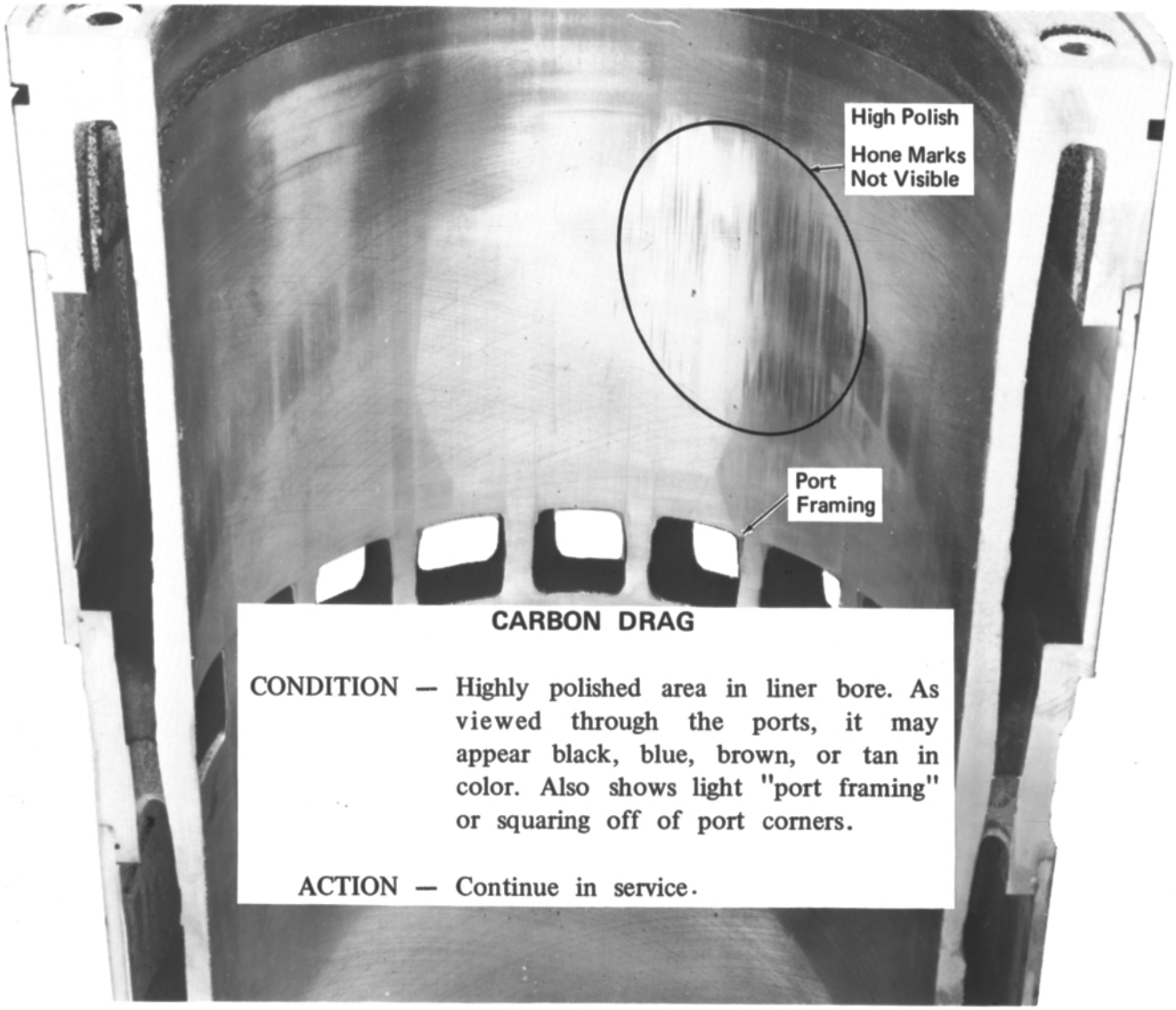


SCUFFING

CONDITION — Excessive scuffing.

ACTION — Replace power assembly.

F24178



F24180

CARBON DRAG

CONDITION — Highly polished area in liner bore. As viewed through the ports, it may appear black, blue, brown, or tan in color. Also shows light "port framing" or squaring off of port corners.

ACTION — Continue in service.

15.8 EMDEC SYSTEM DIAGNOSTICS

15.8.1 ANNUNCIATOR (FAULT) PANEL (WHEN APPLIED)

The annunciator (fault) panel, Figure 15-12, normally located on the side of an electrical cabinet in the locomotive engineroom, is the “center” of the EMDEC Engine Protection and Diagnostics system on most current production model locomotives *. It contains the LED indicating lights and switches available to the operating (or maintenance) crew to control the EMDEC system operation and diagnostic functions.

*Prototype and new 80 and 90 series locomotives incorporate the annunciator (fault) panel functions into computer displays and controls in the unit’s cab.

15.8.1.1 FAULT INDICATING LIGHTS

The fault indicating lights are used to determine if a specific fault condition has caused an engine protection shutdown.

CAUTION

Following an engine shutdown, do NOT attempt to restart the engine until the cause of the shutdown has been determined and action taken to correct the fault condition

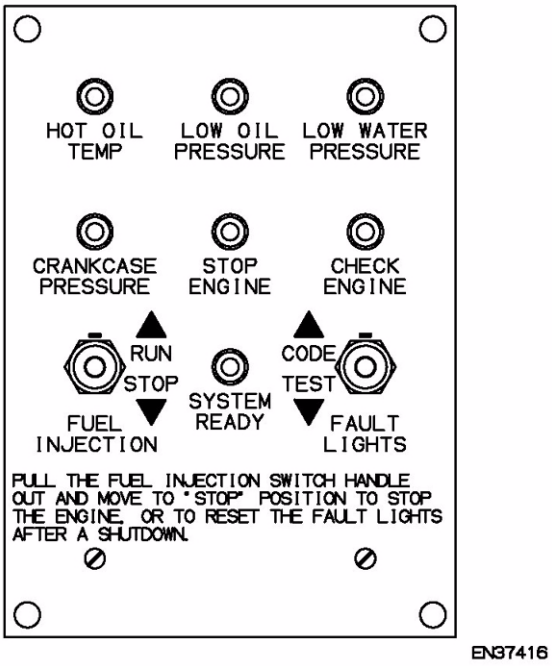


Figure 15-12. Typical Annunciator (Fault) Panel

HOT OIL TEMP Light: The “red” hot oil temperature light will come **ON** and ***blink*** (along with the **STOP ENGINE** Light) to indicate that a high engine oil temperature condition has caused an engine shutdown. The EMDEC Engine Protection system determines this fault when engine oil temperature exceeds a specified trip level for a minimum of 10 seconds.

LOW OIL PRESSURE Light: The "red" low oil pressure light will come ON and *blink* (along with the STOP ENGINE Light) to indicate that engine lube oil pressure has dropped to a dangerously low level and caused an engine shutdown. The Engine Protection system determines this fault when engine oil pressure remains below the specified trip level after a time delay which will vary according to engine speed.

LOW WATER PRESSURE Light: The "red" low water pressure light will come **ON** and ***blink*** (along with the **STOP ENGINE** Light) to indicate that a low water flow condition has caused an engine shutdown. The Engine Protection system determines this fault when the difference in pressures between sensing points in the engine cooling system is greater than a specified value after a time delay relative to engine speed.

CRANKCASE PRESSURE Light: The "red" crankcase pressure light will come **ON** and ***blink*** (along with the **STOP ENGINE** Light) to indicate that a positive crankcase pressure condition has caused an engine shutdown. This fault is determined when crankcase pressure increases to a specified positive trip level. In addition to the fault light, a protruding button on the crankcase pressure detector indicates the device has tripped and caused the engine to shut down

WARNING

Following an engine shutdown caused by actuation of the crankcase pressure detector, make no further engineroom inspections until engine has been allowed to cool off for at least two hours. The action of the pressure detector indicates the possibility of a condition within the engine that could ignite hot oil vapors with an explosive force. Do NOT attempt to restart the engine until the cause of the detector trip has been determined and corrected.

When activated, the detector must be manually reset by pushing in the reset button. If button cannot be reset, do NOT operate engine until pressure detector has been replaced as it may have internal damage.

NOTE

When the engine is shut down by the EMDEC engine protection system, the actual fault condition is automatically reset in the ECM. To reset the annunciator function of the system, it is necessary to pull outward on the handle of the FUEL INJECTION switch, placing it in the STOP (down) position. When switch handle is returned to the RUN (up) position, the fault light indicating cause of shutdown should go OFF. The system ready light will remain ON when the engine has been shut down by the EMDEC engine protection system. If freezing temperatures are possible during the shutdown, the cooling system and the flush toilet (if provided) should be drained or otherwise protected from freezing.

ENGINE DIAGNOSTIC LIGHTS: The engine diagnostic lights provide the means to access the EMDEC Self Diagnostic system. The system continuously monitors itself and other system components including sensors, injectors, connectors, and associated wiring. If a fault is detected during locomotive operation, one or both of the diagnostic lights will be illuminated depending on the severity of the fault. Any faults that occur are stored as codes in the system ECM memory. The stored codes may be accessed by placing the **FAULT LIGHTS** switch on the panel in the ***CODE*** position (up) and observing the "flashing" displayed on one or both of the diagnostic lights, provided that power is being supplied to the EMDEC system (with the engine at idle or shutdown) and the engine is not in a protection condition.

STOP ENGINE LIGHT (SEL): The "red" stop engine light (SEL) will come **ON** and ***blink*** to indicate that a potential engine damaging condition has been detected. If the system is programmed to shut down for this condition, the engine will shut down automatically and a corresponding fault indicating light on the annunciator panel will come **ON** and ***blink***.

This light is also used to "flash out" the *active* fault codes using the **FAULT LIGHTS** switch on the annunciator panel. An *active* code is a fault that is currently keeping one or both of the diagnostic lights **ON**, as well as a corresponding fault light. *Active* codes are displayed (flashed) in order from the "most recent" to the "least recent" based on engine running hours. *Active* codes are immediately stored in the ECM memory as *inactive* codes when the *Active* fault condition is corrected.

NOTE

The stop engine light (SEL) should also come **ON** when the **FAULT LIGHTS** switch is placed in the ***TEST*** (down) position, with power applied to the EMDEC system, as a test of the light and system circuit.

CHECK ENGINE LIGHT (CEL): The "yellow" check engine light (CEL) will come ON to indicate that a fault has occurred and lasted at least 2 seconds in duration. If the fault goes away, the light will go out, but a fault code will be stored in the ECM memory as an *inactive* code. The condition should be diagnosed at the next unit service or maintenance check point.

This light is also used to "flash out" the *inactive* fault codes using the **FAULT LIGHTS** switch on the annunciator panel. All *inactive* codes are faults that previously occurred. *Inactive* codes are displayed (flashed) in order from the "most recent" to the "least recent" based on engine running hours.

NOTE

The check engine light (CEL) should also come **ON** when the **FAULT LIGHTS** switch is in the ***TEST*** (down) position, with power applied to the EMDEC system, as a test of the light and system circuit.

FUEL INJECTION SWITCH: This device is a two position latching toggle switch. It must be pulled outward and up to be placed in the ***RUN*** position in order to start and operate the diesel engine (enable fuel injection). The engine will shut down whenever this switch is pulled outward and down into the ***STOP*** position (disable fuel injection). The ***STOP*** position is also used to reset the EMDEC engine protection system after a shutdown. The fault indicating lights should go **OFF** and stay off when the switch is returned to the ***RUN*** position.

NOTE

This switch provides the only means to stop the diesel engine from within the engineroom.

Disregard any instructions that refer to stopping the engine using the "layshaft" as the manual injector control lever has been eliminated by the EMDEC system.

NOTE

Placing the **FUEL INJECTION** switch in the ***STOP*** position also allows engine to be cranked without firing the cylinders.

SYSTEM READY LIGHT: The "green" LED system ready light will be **ON** whenever "ignition" power is being supplied to the EMDEC system (any combination of throttle valves "A", "B" or "C" energized, except "D" only) and the **FUEL INJECTION** switch is set in the ***RUN*** position. This light will remain **ON** if the engine is in an EMDEC protection (shutdown) condition.

This light will not be **ON,** if the engine has been shut down (throttle valve "D" only energized) using the ***STOP*** position of the **FUEL INJECTION** switch, an Emergency Fuel Cut-Off (EFCO) switch, the M.U. Engine stop switch (on units with control console) or the throttle handle **STOP** position (on units with control stand), and the engine shutdown circuit has not been reset**.**

NOTE

Shutdown circuit is reset by momentarily placing the Fuel Prime/Engine Start switch in either the **FUEL PRIME** or **ENGINE START** position.

FAULT LIGHTS SWITCH: This device is a toggle type switch with two momentary contact positions; ***CODE*** (up) and ***TEST*** (down), and a spring return to the center (release) position. ***This switch may also be referred to as a Diagnostic Request switch.***

Placing the switch in the ***CODE*** (up) position activates the EMDEC Self Diagnostic "flash code" system. This can be done any time power is being supplied to the EMDEC system (with the engine at idle or shutdown), provided that the engine is not in a protection condition. *Active* codes will be flashed on the stop engine light (SEL) first, followed by *inactive* codes on the check engine light (CEL).

To deactivate the EMDEC "flash code" system, cycle the **FAULTS LIGHTS** switch to the ***TEST*** position and release. With this switch in the ***TEST*** position, all of the indicating lights on the panel should come **ON,** and then reset to **OFF** when switch is released**.** If any light fails to come **ON,** the annunciator panel needs to be replaced.

To clear a fault indication from the annunciator panel, the **FUEL INJECTION** switch must be placed momentarily in the ***STOP*** position, and then returned to the ***RUN*** position to enable an engine restart. The fault light should go **OFF** and the **SYSTEM READY** light should be **ON.**

NOTE

Correcting the condition that caused the fault code and resetting the annunciator function does NOT clear the code from the ECM memory. Actual clearing of codes can only be done by authorized maintenance personnel using a DDR or PC reader with a special diagnostics program.

NOTE

Since the Self Diagnostics of the EMDEC system do not detect all possible faults, the absence of a fault code does not mean there are no problems in the system. Fault conditions that could cause the EMDEC system to shut down the engine can also occur due to a break (open) in the connections or wiring between an engine protection sensor and the Electronic Control Module (ECM). Therefore, it is important to inspect the EMDEC system harness wiring and connectors, and to perform circuit continuity checks.

15.8.2 EMDEC DIAGNOSTIC CODES

FLASH CODE 14 (SAE 175/3)

- Oil Temperature Sensor (OTS) input voltage to the ECM is high.

FLASH CODE 15 (SAE 175/4)

- Oil Temperature Sensor (OTS) input voltage to the ECM is low.

FLASH CODE 23 (SAE 174/3)

- Fuel Temperature Sensor (FTS) input voltage to the ECM is high.

FLASH CODE 24 (SAE 174/4)

- Fuel Temperature Sensor (FTS) input voltage to the ECM is low.

FLASH CODE 25 (SAE N/A)

- No codes are set.

FLASH CODE 32 (SAE 238/4)

- Stop Engine Light (SEL) circuit is open or shorted to ground.

FLASH CODE 32 (SAE 239/3)

- Check Engine Light (CEL) circuit is shorted to battery (+) and the ECM is unable to turn on the Stop Engine Light (SEL).

FLASH CODE 32 (SAE 239/4)

- Check Engine Light (CEL) circuit is open or shorted to ground.

FLASH CODE 33 (SAE 102/3)

- Turbo Boost Sensor (TBS) input voltage to the ECM is high.

FLASH CODE 34 (SAE 102/4)

- Turbo Boost Sensor (TBS) input voltage to the ECM is low.

FLASH CODE 35 (SAE 100/3)

- Oil Pressure Sensor (OPS) input voltage to the ECM is high.

FLASH CODE 36 (SAE 100/4)

- Oil Pressure Sensor (OPS) input voltage to the ECM is low.

FLASH CODE 37 (SAE 94/3)

- Fuel Pressure Sensor (FPS) input voltage to the ECM is high.

FLASH CODE 38 (SAE 94/4)

- Fuel Pressure Sensor (FPS) input voltage to the ECM is low.

FLASH CODE 41 (SAE 21/0)

- Synchronous Reference Sensor (SRS) has detected extra pulses, or Timing Reference Sensor (TRS) has detected missing pulses.

FLASH CODE 42 (SAE 21/1)

- Synchronous Reference Sensor (SRS) has detected missing pulses, or Timing Reference Sensor (TRS) has detected extra pulses.

FLASH CODE 44 (SAE 175/0)

- Oil Temperature Sensor (OTS) has detected high engine oil temperature (above safe operating range).

FLASH CODE 45 (SAE 100/1)

- Oil Pressure Sensor (OPS) has detected low engine oil pressure (below safe operating range).

FLASH CODE 46 (SAE 168/1)

- ECM has detected low locomotive battery supply voltage (below required operating range).

FLASH CODE 47 (SAE 94/0)

- Fuel Pressure Sensor (FPS) has detected high fuel supply pressure (above safe operating range).

FLASH CODE 52 (SAE 254/12)

- ECM internal Analog to Digital (A/D) Convertor has malfunctioned. Note: This is an Intermittent condition usually caused by faulty external electrical system.

FLASH CODE 53 (SAE 253/2 or 12)

- ECM unable to read (2) or update (12) an engine data record (calibration, faults, or accumulators) stored in nonvolatile memory.

FLASH CODE 55 (SAE 248/8 or 9)

- Master ECM has stopped receiving status information from one (or both) Receiver ECM(s). **OR** Receiver ECM has stopped receiving fueling information from Master ECM.

FLASH CODE 56 (SAE 250/12)

- ECM unable to transmit over data link circuit due to an open or short in the system wiring.

FLASH CODE 61 (SAE xxx/0)

- Time from ECM request to turn on injector to when injector solenoid valve closes exceeds high limit of expected range. Injector Subsystem IDentifier (SID) will indicate which cylinder has injector with long response time. Wide variations in response time at steady RPM usually indicate electrical problem. Consistently long response times may indicate sticking solenoid valve.

FLASH CODE 67 (SAE 109/3 or 4)

- Coolant Pressure Sensor (CPS) input voltage to the ECM is high.
  OR
  Coolant Pressure Sensor (CPS) input voltage to the ECM is low.

FLASH CODE 71 (SAE xxx/1)

- Time from ECM request to turn on injector to when injector solenoid valve closes is less than lower limit of expected range. Injector Subsystem IDentifier (SID) will indicate which cylinder has injector with short response time. Wide variations in response time at steady RPM usually indicate electrical problem. Consistently short response times may indicate failed solenoid valve.

FLASH CODE 75 (SAE 168/0)

- ECM has detected high locomotive battery supply voltage (exceeds required operating range).

FLASH CODE 81 (SAE 101/3)

- Crankcase Pressure Detector input voltage to the ECM is high.

FLASH CODE 82 (SAE 101/4)

- Crankcase Pressure Detector input voltage to the ECM is low.

FLASH CODE 83 (SAE 101/0)

- Crankcase Pressure Detector has detected high engine crankcase pressure (above safe operating range).

FLASH CODE 84 (SAE 101/1)

- Crankcase Pressure Detector has detected low engine crankcase pressure (below safe operating range).

FLASH CODE 88 (SAE 109/1)

- Coolant Pressure Sensor (CPS) has detected low engine coolant pressure (below safe operating range).

15.9 TROUBLESHOOTING w/ ANNUNCIATOR (FAULT) PANEL & DDR READER

15.9.1 ENGINE WON'T START

15.9.1.1 NO LIGHTS ILLUMINATED ON EMDEC ANNUNCIATOR (FAULT) PANEL.

- ⇨C heck that **ENGINE CONTROL** Circuit Breaker is closed.
- ⇨Check that the **INJECTOR RUN** Switch located on the EMDEC annunciator (fault) panel is in the ***RUN*** position.
- ⇨Place the Fuel Prime/Engine Start (FP/ES) switch in the ***FUEL PRIME*** position for a few seconds. If an Emergency Fuel Cut-Off (EFCO) switch was used to stop the engine, the EMDEC system will be disabled until the FP/ES switch is used to bring it back up.
- ⇨Make sure the **M.U. ENGINE STOP** Switch is in the ***RUN*** position.
- ⇨Check for a "green" light on the power supply. If no light is present, proceed to Step **15.9.1.2**.
- ⇨Check the AN plug on the interface board for proper connection.
- ⇨Check the AD plug at annunciator (fault) panel for proper connection.
- ⇨Disconnect plug P from the interface board. Check pin 1 for +24V and pin 3 for -24V.
- ⇨Disconnect and check AD plug, pin 13 at annunciator (fault) panel for +24V. Check AD plug, pin 2 for -24V.
- ⇨Check if DDR reader can access the EMDEC system at the reader port. If it can, the annunciator (fault) panel or interface board may be suspect.

15.9.1.2 NO LIGHTS ON 24V POWER SUPPLY IN AC ELECTRICAL CABINET.

- ⇨Check that the battery knife switch is closed.
- ⇨Check that **ENGINE CONTROL** Circuit Breaker is closed.
- ⇨Disconnect and check PI plug. Pins 1 & 2 should be +74V. Pins 5 & 6 should be -74V.
- ⇨If power is present, change the power supply. If power is not present, refer to the locomotive wiring diagram, and trace the wiring back for the source of possible disconnect or open.

15.9.1.3 RED LIGHT GLOWS ON 24V POWER SUPPLY IN AC CABINET.

The "red" light indicates a protective shutdown has occurred. This can be attributed to either *overvoltage* on the input side or *overcurrent* on the output side.

- ⇨Cycle the **ENGINE CONTROL** Circuit Breaker and check if the light has returned to "green". If "green", the power supply is okay and the condition that made it shut down has disappeared.
- ⇨If the light remains "red", disconnect the PO plug from the power supply and cycle the **ENGINE CONTROL** Circuit Breaker. If the light remains "red", there is no short on the output side of the power supply. Therefore, the power supply is bad and should be replaced.
- ⇨If the light turns "green", but goes back to "red" upon replacement of the PO plug, disconnect the power plug from each ECM and check the "blue" PS and PR1 wire harnesses that run from the power supply to each ECM controller for a short. If the harness is okay, change the ECM.

15.9.2 ON ANNUNCIATOR (FAULT) PANEL, GREEN SYSTEM READY LIGHT IS ON, BUT ENGINE WON'T START.

- ⇨ Check to be certain that the starting motors are cranking the engine sufficiently. The EMDEC system will not allow the electronic injectors to meter fuel into the power assemblies until the crankshaft is turning at least 30 RPM.
- ⇨ Check the TRS and SRS sensors that are mounted behind the flywheel on the left side of the engine. If damaged, change out and restart.
- ⇨ Check the air gap between each sensor and the target plate. Each gap should be 3.81 mm (0.150”).

  Note: The SRS air gap appears larger, but it should be measured against the Position Indicator Pointer (PIP) mounted at the 180º degree mark of the flywheel.

- ⇨ If the sensors are not damaged, open the **ENGINE CONTROL** Circuit Breaker, disconnect each plug and check the resistance across each sensor. The resistance should be between 100 and 200 ohms. If not, replace the sensor and restart.
- ⇨ If the sensors are okay, check the wire harness for a short.
- ⇨ Open the **ENGINE CONTROL** Circuit Breaker and remove the EHC connector from both the Sender and Receiver ECMs. It is recommended that the metal guard plates that cover the ECMs be removed to provide easier access to the EHC.
- ⇨ Disconnect the plug to the sensor and measure the resistance across Pin 1T and Pin 2T on the EHC connector on the Sender ECM. If it is less than or equal to 10,000 ohms, the wire harness is shorted.
- ⇨ Replug the connector to the sensor and measure the resistance. If it is greater than 10,000 ohms, check the wire harness for opens.
- ⇨ Disconnect the plug from the sensor. Connect a jumper between Pin A and Pin B to short out the plug at the sensor. Check the resistance across Pin 1T and Pin 2T on the EHC connector on the Sender ECM. If it is greater than 5 ohms, the wire harness is open.
- ⇨ Check the EHC connector on the Receiver ECM using the instructions above.
- ⇨ Disconnect the injector harness plug from the Receiver ECM and try restarting. A grounded wire could cause enough “noise” to disturb the TRS/SRS signal. If okay, replace the Receiver injector harness plug and unplug the injector harness plug from the sender ECM. Try restarting. If okay, continue the process by unplugging and replugging each sensor to see if a sensor is grounded.
- ⇨ If the wire harnesses and sensors are good, the ECM is at fault.

15.9.3 ON ANNUNCIATOR (FAULT) PANEL, YELLOW CHECK ENGINE LIGHT IS ON, AND GREEN ENGINE READY LIGHT IS OFF. ENGINE WON'T START.

- ⇨Toggle the **INJECTOR RUN** Switch on the annunciator (fault) panel.
- ⇨Cycle the **ENGINE CONTROL** Circuit Breaker.
- ⇨Check the AN plug on the interface board for good connection. Check the AD plug on the annunciator (fault) panel for good connection.
- ⇨If the wiring is okay, either the interface board or annunciator (fault) panel may be suspect.

15.9.4 ENGINE PROTECTION SHUTDOWN

15.9.4.1 ON ANNUNCIATOR (FAULT) PANEL, RED STOP ENGINE AND LOW WATER PRESSURE LIGHTS ARE BOTH ON. ENGINE IS STOPPED.

- ⇨Use an EMDEC DDR reader, or toggle the **FAULT LIGHTS** Switch on the annunciator (fault) panel to do a read out of the fault code(s). If active fault is #**88, COOLANT PRESSURE LOW**, proceed to next step. If fault code is #**67, COOLANT PRESSURE CIRCUIT HIGH OR LOW**, or a combination of #**67** and #**88**, proceed to Step**15.9.2**.
- ⇨Use the DDR reader to verify EMDEC software version is at least V1.5 (see Step **15.9.6**). If not, upgrade the software and clear the faults. Start the engine and release the unit for service.
- ⇨Look at EM2000 computer archive memory; did a **HOT ENGINE** fault occur that would indicate a coolant problem? Check for any throttle position, water temperature or shutter/fan faults that would be indicative of cooling system problems.
- ⇨Is unit low on water? Inspect the coolant system for obvious leaks.
- ⇨If water level is okay and no leaks are apparent, open **ENGINE CONTROL** Circuit Breaker, disconnect the plug to the #1 coolant pressure sensor. Inspect both the sensor pins and terminals for signs of corrosion. If corrosion is evident, change the coolant pressure sensor and replace the terminals in the coolant pressure plug.
  Fill the coolant pressure sensor receptacle with dielectric grease and reconnect the harness. Close the **ENGINE CONTROL** Circuit Breaker and toggle the **FUEL INJECTION** Switch on the annunciator (fault) panel to clear the faults. Start the engine and release the unit for service.
- ⇨If no corrosion is evident, use a voltmeter to check sensor resistance. Open the **ENGINE CONTROL** Circuit Breaker. Check the resistance between the pins in the sensor receptacle. The readings should be as follows:
  - A to B 12.8 kohm
  - B to C 1.4 kohm
  - A to C 11.5 kohm
  - If the readings vary by ±30%, change the sensor.

⇨If the resistance is okay, install the breakout plug between the harness and sensor. With the **ENGINE CONTROL** Circuit Breaker closed, check for +5V input. The Signal wire (B, or middle) should read 0.5V. Bleed the air pressure from the coolant system. The coolant pressure value on the DDR reader should be 0 psi. Toggle the **FUEL INJECTION** Switch on the annunciator (fault) panel to clear the fault and restart the engine.

⇨Check for +5V input into the sensor. Rev the engine to throttle 5. The sensor value on the DDR reader should be approximately 30 psi. If the pressure value varies by more than 20%, change the sensor.

⇨If the +5V input to the sensor is not within tolerance, check that the signal wire shows 0.5V and 0 psi with the engine stopped and 4.5V at throttle 8. If the readout is correct, the sensor is good. The continuity of the wire harness should be checked next.

⇨Check the continuity of the wires from the ECM to the coolant pressure sensor as follows:

Plug terminal A to EHC 1W
Plug terminal B to EHC 2L
Plug terminal C to EHC 2Y

⇨If open or grounded, replace the harness.

⇨If no defect is found with any EMDEC components, put the unit in load test at throttle 8 for one-half hour to see if the fault repeats. If no fault reoccurs, release the unit to service.

Note: If the water was over 93.3º C (200º F), with a HOT ENGINE shutdown archived, replace the 20 lb. cooling system pressure cap.

15.9.5 ON ANNUNCIATOR (FAULT) PANEL, RED STOP ENGINE AND LOW WATER PRESSURE LIGHTS ARE BOTH ON. ENGINE STOPPED. FAULT CODE IS #67, OR BOTH #67 AND #88.

⇨If the fault code is #**67**, or both #**67** and #**88**, it is probably an electrical problem.

⇨Use a DDR reader to verify EMDEC software version is at least V1.5 (see Step #**15.9.13.1**). If not, upgrade the software and clear the faults. Start the engine and release the unit for service.

⇨Disconnect the plug to the #1 coolant pressure sensor and inspect both the sensor pins and terminals for signs of corrosion. If corrosion is evident, change the coolant pressure sensor and replace the terminals in the coolant pressure plug. Fill the coolant pressure sensor receptacle with dielectric grease and reconnect the harness. Close the **ENGINE CONTROL** Circuit Breaker and toggle the **FUEL INJECTION** Switch on the annunciator (fault) panel to clear the faults. Start the engine and release the unit for service.

⇨If no corrosion is apparent, check the wire harness for grounds or opens. Open the **ENGINE CONTROL** Circuit Breaker. Disconnect the plug from the coolant pressure sensor and install a jumper wire between sockets A and B. Disconnect the EHC plug from the Sender ECM and check the resistance between terminals 2L and 1W. If the resistance is less than or equal to 5 ohms, change the sensor.

⇨Check the continuity of the wires from the ECM to the coolant pressure sensor as follows:

Plug terminal A - EHC 1W

Plug terminal B - EHC 2L

Plug terminal C - EHC 2Y

⇨ If open or grounded, replace the harness.

⇨If continuity is okay, install the breakout plug between the harness and sensor. With the **ENGINE CONTROL** Circuit Breaker closed, check for +5V input. Toggle the **FUEL INJECTION** Switch to clear the fault(s) and obtain the "green" **SYSTEM READY** Light.

15.9.6 FALSE ANNUNCIATOR INDICATIONS

15.9.6.1 ON ANNUNCIATOR (FAULTS) PANEL, YELLOW CHECK ENGINE AND GREEN SYSTEM READY LIGHTS ARE BOTH ON.

⇨Use an EMDEC DDR reader to determine both the source of the **CHECK ENGINE** Light, and the EMDEC software level (see Step #**8.1**).

⇨A **CHECK ENGINE** Light typically indicates a prior fault that is no longer active. Investigate the source of the reported inactive fault and if no defect found, clear the faults from the EMDEC archive and release the unit for service.

⇨If the fault shown is an ECM Calibration Memory Error, replace the ECM and reprogram the unit.

15.9.6.2 ON ANNUNCIATOR (FAULT) PANEL, RED STOP ENGINE AND HOT OIL LIGHTS ARE BOTH ON. ENGINE STOPPED. FAULT CODE IS #14 OR #15.

⇨Connect an EMDEC DDR reader and view active codes.

⇨Clear the active codes.

⇨Disconnect the plug from the sensor and examine both for corrosion or damage. If corrosion is evident, replace both the terminals and sensor. If none is evident, proceed to the next step.

⇨If flash code is #14, disconnect the oil temperature sensor plug and install a jumper wire between sockets A and B. If the active code on the DDR reader is #14, the oil temperature circuit failed high (usually a broken wire fault): disconnect the jumper and plug the connector back into the sensor.

⇨Disconnect the EHC plug from the Sender ECM. Use a voltmeter to read the resistance between Pin 2R and Pin 2Y. If the resistance is greater than or equal to 10,000 ohms or open, replace the sensor.

⇨If the flash code is #15, disconnect the oil temperature sensor plug from the sensor after clearing the active faults.

⇨If the active code on the DDR reader is no longer #15, replace sensor.

⇨Check the continuity of the wires from the Sender ECM to the oil temperature sensor as follows:

Plug terminal A - EHC 2Y

Plug terminal B - EHC 2R

⇨If open or grounded, replace the harness.

⇨It is also possible that other sensors may have a short or ground that is causing the oil temperature sensor to have electrical problems (see **15.9.6.3** below).

15.9.6.3 ON ANNUNCIATOR (FAULT) PANEL, RED STOP ENGINE AND HOT OIL LIGHTS ARE BOTH ON. ENGINE STOPPED. FAULT CODE IS #44.

⇨Check the Locomotive computer fault archive for shutdown information. If the archive information indicates that the oil could have been above the safe operating range, (i.e. hot engine water) check the engine for the source of the hot oil condition. Refer to HIGH LUBRICATING OIL TEMPERATURE on page 15-19.

⇨If the fault is suspect, note the EMDEC failure information and clear the EMDEC faults.

⇨Disconnect the connector from the sensor and examine both for corrosion or damage. If corrosion is evident, replace both the terminals and sensor. If none is evident, proceed to the next step.

⇨Restart the engine and monitor the oil temperature. If possible, load test the unit to see if the condition repeats.

⇨The sensor can be checked by unplugging the connector and noting the oil temperature on the DDR reader. Using a voltmeter, check the resistance across the two sensor pins and verify whether it falls within ± 10% of the resistance/temperature curve shown in Figure 15-13.

⇨If the sensor resistance is within tolerance, check the wiring harness per information provided in Step **15.9.6.1**.

15.9.7 ON ANNUNCIATOR (FAULT) PANEL, ONE OR MORE FAULT LIGHTS ILLUMINATED, AND ENGINE READY LIGHT IS OFF. SENSOR VALUES CONSTANTLY CHANGING ON DDR READER WHILE IN SET THROTTLE POSITION.

⇨Remove the plug from any sensor (except TRS & SRS) and check for steady +5V input. If the voltage is less than +5V, begin isolating each sensor and monitoring the voltmeter to see if one of the sensors is grounded.

⇨Begin by removing the Injector Harness Plug from the Receiver ECM and checking the sensor input on the voltmeter to see if it returns to +5V. If it doesn't, replug the Receiver Injector harness and unplug the Sender Injector harness. Continue this process from sensor to sensor until the grounded sensor is either confirmed or eliminated as a possibility.

⇨If a sensor is not the problem, check the +5V supply wire (EHC1W) and -5V supply wire (EHC2Y) for continuity from the Sender ECM to each sensor.

- ⇨ If the continuity and sensors are okay, swap the Sender ECM with the Receiver ECM, reprogram the system and recheck. The +5V power supply in the ECM was probably bad.
- ⇨ If the +5V to the sensor is steady but other sensor values are floating, begin isolating each sensor and monitoring the DDR reader to see if one of the sensors is grounded. Begin by removing the Injector Harness Plug from the Receiver ECM and checking the sensor values on the DDR reader to see if they stabilize. If they don't, replug the Receiver Injector harness and unplug the Sender Injector harness. Continue this process from sensor to sensor until the grounded sensor is discovered. Replace the sensor.
- ⇨ If the sensors are okay, begin checking the +5V supply wire (EHC1W) and -5V supply wire (EHC2Y) from the Sender ECM to each of the sensors to check continuity. If the problem cannot be isolated to a particular terminal, replace the sensor wire harness.

15.9.8 ANNUNCIATOR (FAULT) PANEL CRANKCASE PRESSURE DETECTOR LIGHT IS ON, BUT CRANKCASE PRESSURE DETECTOR BUTTON NOT TRIPPED.

- ⇨ Shop the locomotive and inspect it as if the button had tripped.
- ⇨ The normal crankcase pressure setting indicated by the EMDEC DDR reader is 8.0 psi. At 15.0 psi it trips. These are simply **ON/OFF** values for the microswitch and have nothing to do with actual crankcase pressure.
- ⇨ If no defect is found with the engine, check the sensor wire harnesses and sensors for short or grounds as outlined in Step**15.9.6.1**. The microswitch on the detector sends a signal voltage to the ECM of 2.2 volts when the button is latched. A signal voltage of 0.6 volts will be sent when the button is tripped. The EMDEC system will shut down if a data valid fault is detected for 2 seconds.
  If an *overvoltage* or *undervoltage* condition occurs continuously for 32 seconds in the sensor circuit, the detector will send out the shutdown signal to EMDEC. If corrosion is evident on the connector pins, either clean the contact surfaces or replace both the sensor and terminals.
- ⇨ If no corrosion is evident, use a voltmeter to check sensor resistance. Open the **ENGINE CONTROL** Circuit Breaker. Check the resistance between the pins in the sensor receptacle. The readings should be as follows:

SET	TRIPPED
A to B 6.8 kohm	A to B 6.8 kohm
B to C 6.8 kohm	B to C 46.1 kohm
A to C 13.6 kohm	A to C 39.3 kohm

- ⇨ If the readings vary by ±30%, change the sensor.

15.9.8.1 AN ANNUNCIATOR (FAULT) PANEL FAULT LIGHT IS ON WHILE THE ENGINE READY LIGHT IS ON.

⇨A **CHECK ENGINE** or **STOP ENGINE** Light must be **ON** when any sensor fault light is **ON**. If a sensor fault light is **ON** without a **CHECK ENGINE** or **STOP ENGINE** Light and yet the **ENGINE READY** Light is **ON**, either the annunciator (fault) panel or the Interface Board is bad.

15.9.9 EMDEC COMMUNICATION FAILURE

15.9.9.1 LOCOMOTIVE LOADING AT 90% AND EM2000 MESSAGE READS: EMDEC COMMUNICATION FAILURE

⇨Enter the Programmable Meter on the EM2000 screen and pull up the *EngineR* value.

⇨Verify that the *EngineR* value exists and continues to change rapidly. The value should range from 0.1 to 0.875.

⇨If the above condition is satisfied, the serial link is in place and functioning.

⇨If the above test shows the EMDEC system and EM2000 are not communicating, the serial link must be traced to find the source of the disconnect or ground.

⇨Check the 8B plug located on the back of the module chassis and trace “white” wire tagged SER to plug 3NA located at the back of the HVC.

⇨Trace “green” wire tagged EUI from HVC plug 3NA to plug S which should be connected to the EMDEC interface board.

⇨If the wiring is not identified as the source, the EMDEC interface board may be suspect.

15.9.10 INCORRECT OR NO THROTTLE RESPONSE

15.9.10.1 THROTTLE REQUEST PROBLEMS

⇨If the EM2000 computer fails, the engine will continue to run in a high idle or Throttle 1 position because the interface board will be receiving a **NO VALVE** signal.

⇨If the EM2000 computer is not failed and throttle requests are not being acknowledged, remove the L plug from the interface board and, using a voltmeter, check for approximately +0V input to the requested valve(s) (the A, B, C & D valve-to-RPM information can be found in the locomotive electrical schematics). If +74V is registered on the voltmeter, the valve is de-energized. The valve locations are as follows:

L1 - A valve
L2 - B valve
L3 - C valve
L6 - D valve
L11- Negative

⇨If approximately +0V is not coming into the requested valve location, verify the functionality of the EM2000 DIO module and controller microswitches.

⇨ If approximately +0V is present, reconnect the L plug and remove the metal guard plate that covers the Sender ECM. Disconnect the VHC plug from the Sender ECM and check for approximately +1V at the desired valve by placing one lead of the voltmeter into the desired socket and touching the other lead to the metal skin of the ECM. The ECM is isolated so it is important that the other lead not touch carbody ground, such as the metal cover.

⇨ The following socket locations on the VHC connector match governor valves:

VHC1E - A valve

VHC1H - B valve

VHC2H - C valve

VHC2K - D valve

⇨ If the desired valve is not de-energized, replace the interface board. If it is, replace the ECM.

15.9.11 UNIT NOT MAKING HORSEPOWER

15.9.11.1 UNIT NOT MAKING HORSEPOWER - CHECKING INDIVIDUAL INJECTOR RESPONSE TIME.

Injector response time is defined as the amount of time it takes for the armature/control valve to open when the ECM energizes the solenoid. Normal response time is 1.4ms.

⇨ Make sure the **FUEL INJECTION** Switch on the annunciator (fault) panel is in the ***RUN*** position.

⇨ Connect a DDR reader to the EMDEC reader port.

⇨ When screen comes up showing engine sensor values, hit **FUNCTION**.

⇨ A choice will be offered between **ENGINE** or **PRO-LINK**. Use arrows to choose **ENGINE** and hit **ENTER**.

⇨ Use arrows to scroll to **FUEL INJECTOR INFO** and hit **ENTER**.

⇨ Use arrows to scroll to **INJECTOR RESPONSE TIMES** and hit **ENTER**.

⇨ Use arrows to scroll the injector positions. The positions are coded as follows:

• 12-cylinder engines

Cylinder No.1 - 5L	Cylinder No. 7 - 1L
Cylinder No.2 - 4L	Cylinder No. 8 - 3L
Cylinder No.3 - 6L	Cylinder No. 9 - 2L
Cylinder No.4 - 4R	Cylinder No.10 - 3R
Cylinder No.5 - 5R	Cylinder No.11 - 1R
Cylinder No.6 - 6R	Cylinder No.12 - 2R

• 16-cylinder engines

Cylinder No.1 - 8L	Cylinder No. 9 - 1L
Cylinder No.2 - 7L	Cylinder No.10 - 3L
Cylinder No.3 - 6L	Cylinder No.11 - 2L
Cylinder No.4 - 5L	Cylinder No.12 - 4L
Cylinder No.5 - 7R	Cylinder No.13 - 3R
Cylinder No.6 - 5R	Cylinder No.14 - 4R
Cylinder No.7 - 8R	Cylinder No.15 - 1R
Cylinder No.8 - 6R	Cylinder No.16 - 2R

⇨ Injector not firing has a default reading of 0.55ms. If the injector response time is long (1.6+ms), it may be symptomatic of a sticking armature/control valve and the injector should be changed.

⇨ When changing an injector, make certain the injector adapter ring stays in the head and that all components are properly torqued. The injector crab nut should be torqued to 68 Nm (50 ft-lbs), the fuel fitting nuts on the top of the injector should be torqued to 34 Nm (25 ft-lbs) and the fuel jumper bolt torqued to 54 Nm (40 ft-lbs).

15.9.11.2 UNIT NOT MAKING HORSEPOWER - INJECTOR RESPONSE TIMES ARE OKAY.

⇨ Check the Fuel Inlet pressure value on the EMDEC reader. If the value is below 434 kPa (63 psi) in throttle six, check the 207 kPa (30 psi) relief valve located in the “return fuel” sightglass.

⇨ If the Fuel Inlet pressure is okay, check the “bypass” sightglass to see if the fuel is bypassing.

- ⇨ If the fuel is bypassing, replace the two spin-on fuel filters and recheck the sightglass.
- ⇨ If the fuel continues to bypass, replace the 827 kPa (120 psi) relief valve.
- ⇨ If the relief valves are both okay, check the “Allowed Torque” value on the reader - which should be at 100%. If the value is lower than 100%, the sensor is cutting back the fuel because of inadequate air box pressure. Refer to 15.3.3 ENGINE PERFORMANCE on page 15-33.
- ⇨ If the unit still will not make horsepower, proceed to perform an injector cutout test as described in step **15.9.11.3** below.

15.9.11.3 UNIT NOT MAKING HORSEPOWER - CHECKING INDIVIDUAL INJECTORS, USING EMDEC DDR READER CYLINDER CUTOUT FEATURE.

- ⇨ Make sure the **FUEL INJECTION** Switch on the annunciator (fault) panel is in ***RUN*** position.
- ⇨ Connect the DDR reader to the EMDEC reader port.
- ⇨ When screen comes up showing engine sensor values, hit **FUNCTION**.
- ⇨ A choice will be offered between **ENGINE** or **PRO-LINK**. Use arrows to choose **ENGINE** and hit **ENTER**.
- ⇨ Use arrows to scroll to **FUEL INJECTOR INFO** and hit **ENTER**.
- ⇨ Use arrows to scroll to **CYLINDER CUTOUT** and hit **ENTER**.
- ⇨ Use arrows to select **NEW TEST**.
- ⇨ Use arrows to select **IDLE**.
- ⇨ Select either **MANUAL** or **AUTO** and hit **ENTER**.
- ⇨ Put locomotive in Load Test and set throttle to notch 5.
- ⇨ Start the Cylinder Cutout test and notice that a base pulse width will be displayed. If the base pulse width increases when a particular injector is cutout, the injector is good. If it does not increase, the engine is already compensating for that injector and the injector is probably bad.
- ⇨ The injector location code that is given if an injector fault is logged does not match the codes listed in Step **15.9.11.1**. If a fault is indicated, the EMDEC DDR reader should be used to view the injector response times to identify the offending injector.

15.9.12 DAMAGED INJECTORS

15.9.12.1 LOCATING AN INJECTOR WITH A DAMAGED TIP

- ⇨ If injector cutout test described in step **15.9.11.3** above does not serve to locate a suspect injector, inspect the top of each piston for signs of a wet crown.
- ⇨ Remove the Engine Start fuse and open cylinder test valves.
- ⇨ Remove air box hand hole covers to permit viewing the top of each piston through the liner ports.
- ⇨ Bar the engine over while the fuel pump is running.
- ⇨ The system fuel pressure will cause fuel to leak if the injector tip is damaged.

15.9.13 SOFTWARE LEVEL IDENTIFICATION

15.9.13.1 USING THE DDR READER TO OBTAIN EMDEC SOFTWARE LEVEL

- ⇨ Make sure the **FUEL INJECTION** Switch on the annunciator (fault) panel is in the ***RUN*** position.
- ⇨ Connect a DDR reader to the EMDEC reader port.
- ⇨ When screen comes up showing engine sensor values, hit **FUNCTION**.
- ⇨ A choice will be offered between **ENGINE** or **PRO-LINK**. Use arrows to choose **ENGINE** and hit **ENTER**.
- ⇨ Use arrows to scroll to **VIEW CALIBRATION** and hit **ENTER**.
- ⇨ Use arrows to scroll to **ENGINE CONFIGURATION** and hit **ENTER**.
- ⇨ Use arrows to scroll down to **SOFTWARE LEVEL**.

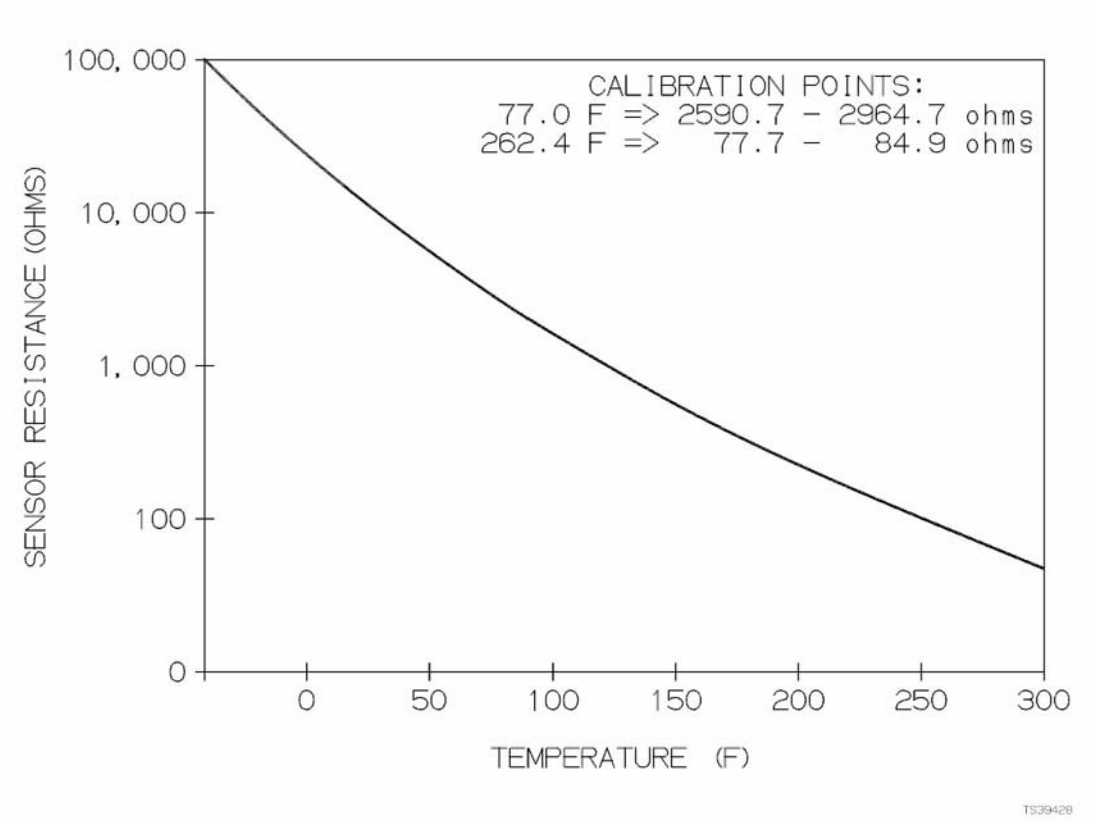


Figure 15-13. Temperature Sensor Resistance

15.10 EMDEC PC READER KIT

The PC Reader Kit was developed to replace the DDR hand held reader. The kit provides the necessary hardware to connect a PC computer to the reader port(s) on all EMDEC equipped locomotives, and the software which allows display of all required engine information on one screen (kit does not include a PC). The PC reader software, as currently written, duplicates most of the capabilities of the DDR reader with a few exceptions:

- Injector response times are displayed by actual cylinder number instead of by code.
- The first software releases (through Phase III) do not include an Injector Cutout feature. Subsequent versions have the cutout capability.

NOTE: The DDR reader can only be used with 12 and 16-cylinder engines. The PC reader can be used with all EMDEC equipped engines, but must be used with 20-cylinder engines.

The minimum requirement for use of this kit is a 386SX/DX-type laptop PC with at least one (1) megabyte of RAM. The kit consists of a Translator Box, a 15D-R plug, a PCT-R cable and a 9 Pin male-to-9 Pin female cable, along with the PC Reader software disk.

15.10.1 LOADING PC READER SOFTWARE

To load the PC Reader software, proceed as follows:

1. Escape out of Windows to get to the **C:\>** prompt. It is imperative that Windows not be active or the program will not function properly. Press **Alt+F4** or double click the cursor on the upper left bar on the Windows screen to exit Windows.
2. Create a new directory. For example: **C:\> md pcreader**
3. Change the directory to the pcreader. For example: **C:\> cd pcreader**
4. Once in the directory, copy the files from the disk into the directory. For example: **C:\pcreader> copy a:*.***

15.10.2 CONNECTION & USE OF PC READER

To utilize the PC Reader program on the locomotive, proceed as follows:

1. Connect the 9 Pin cable from the PC computer to the Translator Box.
2. Connect the 15D-R plug to the PCT-R cable and the other end of the cable to the Translator Box.
3. Connect the 15D-R plug into the EMDEC reader port and note that both the “red” and “green” LED’s on the side of the Translator Box are illuminated. The program will not work if the hardware is not connected to the locomotive reader port.

4. Change the directory on the PC to **C:\pcreader>** and type: **EMMON <RET>** to start the program.

5. Once in the program, the parameters displayed can be changed by pressing the **F1** key.

Two columns will appear on the PC screen. The left column is a list of parameters that are displayed, and the right column is a choice of parameters available. The operator can shift between the columns by using the arrow keys. Moving the cursor to the desired column and the specific item will be displayed in bold print. Pressing the **DELETE** key will remove items selected from the left column. Pressing the **INSERT** key will insert items selected from the right column into open lines on the left column. The operator cannot insert parameters into the left column unless blank lines are available. Hitting the **ESC** (escape) key will return the operator to the display screen.

15.10.3 INJECTOR CALIBRATION W/ PC READER

Each EUI injector requires the correct calibration be entered into the ECMs to compensate for tolerance stack in the mechanical portion. This calibration changes the output of each individual injector in order to arrive at a nominal standard for all of the injectors. This operation is similar to setting the rack on an MUI injector equipped engine.

To enter EUI injector calibration codes using the PC reader:

1. Make certain that the PC reader software copied into the *pcreader* directory has at least a Phase III or later designation on the label. If the disk is not available to check this, the revision level can be confirmed by viewing the *pcreader* directory to see if an **EMMON8** or later file exists.

2. Shutdown the engine and open each of the top deck covers. Record (1) the two-digit number that is scribed on the top of each injector solenoid and (2) record the corresponding cylinder number. Do not enter “0” before a single digit number.

3. Bring up the PC reader display and verify that the EMDEC software version is at least V1.5. The calibration code cannot be utilized on older EMDEC revisions.

4. From the PC reader display, press **F2 Injectors.** A list of cylinders from one (1) to twelve (12), sixteen (16) or twenty (20) will appear. If the calibration numbers displayed match the numbers recorded, the unit has had the calibration codes entered and it does not need to be done.

5. If the calibration numbers do not match, enter the numbers for each cylinder using the arrow keys, but do NOT hit **ENTER**.

6. Upon completion of all entries, hit **F2 Write To ECMs** to write the calibration codes to each ECM. A box will appear requesting a password. Type in **0000** and hit **<RET>**. The system will then upload the calibration codes automatically into each ECM.

7. To verify the upload, hit **F1 Read From ECMs** to read the injector calibration codes that have been stored. The codes stored should match the codes just entered.

15.11 INSPECTION FOR FUEL LEAKS INSIDE TOP DECK (EMD Engines Equipped w/ Electronic Unit Injectors and EM2000)

The following procedure describes the use of long-wave ultra-violet (black) light to determine if a fuel injector is leaking while still installed in the engine. To successfully complete this inspection use a black-light such as (or similar to) McMaster model 6760T11 (light intensity of 230 $\mu w/cm^2$ at a distance of 3 inches) or model 8519T17 (light intensity of 1000 $\mu w/cm^2$ at a distance of 3 inches). For reference, both have a wavelength of 365 nm. Since diesel fuel is readily fluorescent in contrast to engine lube oil under black lighting, the use of any additional dyes are not needed or recommended.

Obeying all shop and safety rules, inspection should be done as follows:

1. Allow engine to idle for at least 20 minutes and check lube oil level prior to shutting it down. An excessively high level of engine lube oil or a strong odor of diesel fuel in the oil are characteristic signs of a failed fuel line, leaking connection or leaking injector.

2. With engine shut down, open all top deck covers and do a preliminary black light inspection of the fuel manifold, fuel jumper lines, and the injector body. Pay particular attention to any typical signs of leaking such as a strong odor of diesel fuel or oil being washed-off the top deck hardware (i.e. rocker arms, valve bridges, etc.). Wipe suspect areas and record location.

3. Under the EM2000 Maintenance Menu, select “Fuel System Pressure Check”. This function will energize the fuel pump and pressurize the fuel system for at least 5 minutes. Re-inspect the areas described in Step 2 above. (5 minutes, or approximately 15 seconds per injector, is an adequate length of time to complete the inspection). A condemning condition exists if fuel is observed to be seeping at any location other than the body-plunger spring seat area where weeping at the plunger base is normal. A leak will be visible as a grayish white color with a definite flow pattern.

NOTE: *During fuel pressure testing, weeping will be evident at the body plunger spring seat area. This is normal on EUI injectors* due to the engine oil acting as a seal in the plunger bore. This will become more pronounced as inspection time increases with the engine shut down and this oil is forced out by the fuel pressure. Therefore, it is imperative that time be used efficiently during pressure testing to provide accurate results.

Refer to Figure 15-13 and Section 11 “Fuel Oil Systems” for additional EUI injector information.

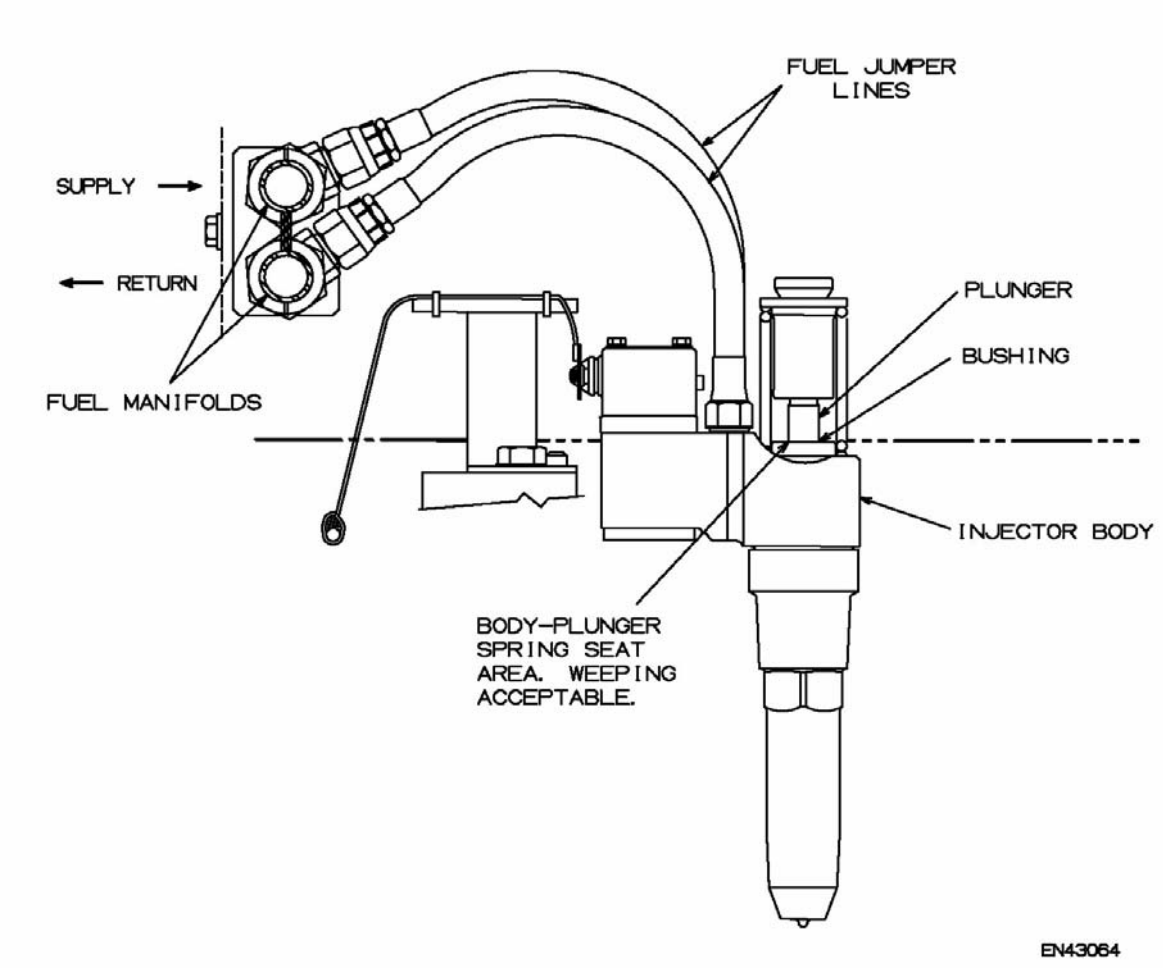


Figure 15-14. Typical EUI Injector Application

15.12 SERVICE DATA - EMDEC SYSTEM DIAGNOSTICS

EQUIPMENT LIST

	PART NO.
EMDEC PC Reader Kit-	
Complete Kit (consisting of the following)	40055368
EMDEC Translator Box	40055363
PC Reader Software Disk	40055362
15D-R Plug	40055365
PCT-R Cable	40055364
9 Pin Male-to-9 Pin Female Cable	40055366
PC Carrying Case	40055367

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