

# SECTION 15

## TROUBLESHOOTING

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# ENGINE MAINTENANCE MANUAL

## TROUBLESHOOTING

This troubleshooting section is divided into three parts. The first part, ENGINE TROUBLESHOOTING, is intended as a general guide for troubleshooting all 645 engines. Within the context of this general guide, particular applications are noted. The second and third parts; GOVERNOR TROUBLESHOOTING, and TURBOCHARGER TROUBLESHOOTING, contain information applicable only to the specific model designated on the cover of the manual.

## ENGINE TROUBLESHOOTING

### ENGINE STARTING SYSTEMS

#### STARTER WILL NOT CRANK ENGINE

If the engine fails to crank, release the starting switch immediately and perform the following steps:

1. Test for proper battery charge and inspect cable connections of control circuit batteries.
2. Check that all switches and circuit breakers in the engine control and protective circuits are properly positioned.
3. If the equipment has an Isolation switch make sure it is in the START position.
4. On a turbocharged engine, make sure that the turbocharger lube pump circuit breaker is closed.

#### 5A. Engines with electric starting:

- a. Check that the battery switch is fully closed.
- b. Test the starting fuse for continuity.

#### 5B. Engines with air starting:

- a. Check that the starting reservoirs are fully charged to the proper pressure and are free of water accumulation.
- b. Check that all valves in the air line to the starter motors are open.

- c. If the engine is equipped with a turbo pump or priming pump security interlock, make certain that the pump has been activated and the interlock functions properly.

When these steps have been performed, another start can be attempted. If the engine still does not crank, release the starting switch immediately and proceed to the next step.

**NOTE:** No further starting attempt should be made until it is determined if the engine will rotate freely. This can be done by opening all the cylinder test valves and engaging the manual barring tool.

If the engine can be barred over one complete revolution, proceed to ENGINE CRANKING PREVENTED BY STARTER MALFUNCTION. If the engine cannot be barred over one complete revolution, proceed to ENGINE CRANKING PREVENTED BY MECHANICAL OBSTRUCTION.

#### ENGINE CRANKING PREVENTED BY MECHANICAL OBSTRUCTION

1. Remove all air box handhole covers and perform a complete visual inspection. Look at all assemblies for broken or damaged components. Check for debris in the air box and liner port area.

2. Remove all oil pan handhole covers and inspect for:
  - a. Damaged or bent connecting rods.
  - b. Damaged counterweights.
  - c. Evidence of overheated main bearings and supporting "A" frames.
  - d. Damage to the lower skirt of any cylinder liner.
3. Check that all piston cooling oil pipes are in place and intact. If a damaged piston cooling oil pipe is found, the related power assembly should be inspected closely for damage.

NOTE: If the engine was recently overhauled, then inspect all fork rod power assemblies for proper matching of serial numbers on the basket assemblies. A mismatched basket could result in a pinched connecting rod bearing shell.

- 4A. If the previous steps have not disclosed any evidence of a failure and it is not possible to rock the crankshaft back and forth, then a main bearing inspection should be performed. If the engine is turbocharged, proceed to Step 5.
- 4B. If the previous steps have not disclosed a failure and it is possible to rock the crankshaft back and forth, and there is no other evidence of bearing failure, then engine driven accessories and equipment should be examined for seizure. Check the air compressor for mechanical damage or loss of lubricant. Check the main generator (where applicable) for signs of bearing heating or rotor to stator contact. If both the air compressor and the main generator are in satisfactory condition, then inspect the front (accessory) and rear (auxiliary) gear trains of the engine. A failed component or gear bushing could cause the gear train to bind which might prevent the engine from cranking.
5. On turbocharged engines that cannot be barred over in the direction of normal rotation, reverse the direction of engine barring by installing the barring tool on the opposite side of the engine. If the engine can be barred over in the reverse rotation direction, then carefully inspect the turbocharger for rotor shaft binding.

NOTE: If the rotation of the turbocharger rotor is obstructed or the shaft has failed, the one-way

clutch will engage, preventing engine rotation in the normal turning direction. By reversing the direction of rotation, the clutch is disengaged, which takes the turbocharger out of the system.

## ENGINE CRANKING PREVENTED BY STARTER MALFUNCTION

Engine starting systems using separate electrical starting motors.

1. Establish whether or not there is voltage potential across the starting motors with the engine start switch in the START position.
- 2A. If voltage is present across the starter motors, then remove the starter motors and bench test in accordance with instructions in the engine maintenance manual.
- 2B. If voltage is not present across the starter motors, then determine whether or not the ST and STA (if so equipped) contactors have picked up.
- 3A. If the star starting contactor(s) has picked up, then check its internal contacts for damage, and check for loose starting cables.
- 3B. If the starting contactor(s) has not picked up, then trace the starting control circuit for open interlocks, or loose or broken wiring.

Engine starting systems using main generator for starting.

1. Establish if there is a voltage potential across the generator start winding terminals at the generator with the engine start switch in the START position.
- 2A. If voltage is present at the generator start winding terminals, examine the generator itself for damage to the bus bars connecting the starter windings, or possible loose connections to this circuit.
- 2B. If voltage is not present at the generator start winding terminals, determine whether or not the GS contactor has picked up.
- 3A. If the GS contactors has not picked up, check its internal contacts for damage, and check for loose starting cables.

- 3B. If the GS contactor has not picked up, trace the starting control circuit for possible open interlocks or broken wiring.

Engine starting systems using air starters.

1. Establish if there is air pressure available at the starter(s) with the engine start switch in the START position.
- 2A. If air pressure is available at the starter(s), then the starter(s) should be removed and bench tested in accordance with instructions in the engine maintenance manual.
- 2B. If air pressure is not available at the starter(s), check the air start control valve for failure to pick up, and check for closed valves or restrictions in the starter air supply lines.

### **STARTER ENGAGES BUT CRANKING SPEED IS TOO SLOW TO START ENGINE**

Engine starting systems using electrical starting motors.

1. Check for proper battery charge, preferably by testing each cell with a hydrometer.
2. Check battery cabling for loose connections or broken cable.
3. Check that the starting motors are of the proper voltage, and are connected correctly for the battery voltage in use.

NOTE: Installations with starter motors connected in parallel across the battery require that the starters have a voltage rating equivalent to battery voltage. Installations with starter motors connected in series across the battery (two motors) require motors which have an individual voltage rating 1/2 that of the battery. Starter motors with different operating voltage ratings are never mixed in the same installation.

Engine starting systems using main generator for starting.

1. Check for proper battery charge, preferably by testing each cell with a hydrometer.
2. Check battery cabling for loose connections or broken cable.

Engine starting systems using air starters.

1. Check that there is adequate air pressure in the reservoirs and that they are free of water accumulation.
2. Check that all air line valves are fully open.
3. Check that there is no restrictions in, or damage to the air supply lines to the starters.

### **ENGINE WILL NOT START WHEN CRANKED AT PROPER SPEED**

1. Check that the governor low oil button is not out. Reset if necessary.
2. Check that the engine was assisted in starting by advancing the injector control lever approximately 1/4 of the total rack travel.

NOTE: If no advance of the injector control lever was made, it takes about 30 seconds of engine cranking for the governor to move the injector rack from fuel off to idle position which allows the engine to start.

3. Check the fuel supply to the cylinders by opening each cylinder test valve and cranking the engine with the injector control lever advanced. A dense spray of fuel should be emitted from each cylinder.
- 4A. If a dense spray of fuel is observed at each cylinder then the following steps should be performed:
  - a. Check for correct injector timing and rack setting.
  - b. Inspect air box for evidence of broken rings or cylinder scoring. Either one can cause compression loss which could prevent starting.
  - c. If the previous checks disclose no problems, qualify the engine valve timing by performing an exhaust valve timing check (refer to EXHAUST VALVE TIMING in this section) on both banks of cylinders (only one power assembly on each bank need be checked). If the engine is out of time, check the condition of the timing gear train by performing an idler gear check (refer to EMM).

- 4B. If a dense spray of fuel is not observed at each cylinder then the following steps should be performed.
- a. Check that the overspeed trip lever is not in the tripped position. Reset if necessary.
  - b. On units with an electric fuel pump make certain that the control and fuel pump switch is on and that fuel flow can be seen in the return fuel sight glass when the pump switch is in the "FUEL PRIME" position. If no fuel flow is seen, check for adequate fuel level in the fuel tank and possible suction leaks, or a plugged suction strainer. If fuel flow is seen in the bypass fuel sight glass, change the engine mounted fuel filters.
  - c. On engine driven/manual prime fuel pump installations, make sure that the system was properly primed with the hand priming pump prior to starting. If no resistance was noticed while using the hand pump, check for adequate fuel level in the fuel tank, suction leaks, a plugged suction strainer, or a jammed fuel line check valve. If extreme resistance was noticed while using the hand pump, check for plugged fuel filters.
4. Check engine oil level to determine if fuel oil might be leaking into the engine lubricating oil system. Inspect the top deck area of both cylinder banks for leakage from injectors, injector jumper lines, or top deck fuel manifolds.
- 5A. Installations with no return fuel sight glass or with engine driven fuel pump:
- a. Inspect all suction lines for air leaks into the lines.
  - b. Check pipe connections and unions for proper tightness.
  - c. Remove and inspect the screen in the suction strainer. Clean if necessary.
  - d. Check that all suction piping is the recommended diameter or larger.
- 5B. Installations with a return fuel sight glass and electric fuel pump:

If bubbles are seen in the fuel sight glass while the engine is running, then shut the engine down, hold fuel prime/engine start switch in FUEL PRIME, and continue to observe the sight glass.

If the bubbles disappear after the engine is shut down, then the probable cause of the bubbles was an injector with tip leakage.

If the bubbles continue after the engine is shut down and the fuel prime/engine start switch is held in the FUEL PRIME position, then the probable cause is a fuel suction leak. This fuel suction leak may cause air binding of the system and loss of fuel pressure. The following steps should be followed to eliminate fuel suction leaks:

- a. Inspect all pipe connections and unions in the fuel suction line for proper tightness.
  - b. On locomotive installations, inspect the condition and check for tightness of all piping leading in and out of the fuel tank. Clean the screen or element of the fuel suction strainer if necessary.
6. On units equipped with a fuel preheater:
- a. Remove the body end caps and inspect the internal header bends for possible trapped material obstructing the flow of fuel through the heater.

## FUEL SYSTEM

### LOW FUEL OIL PRESSURE

1. Check for adequate fuel supply in main fuel or day tank.
- 2A. On locomotive installations and installations with engine mounted fuel sight glasses, observe the 60 psi bypass sight glass to make certain that the relief valve on the sight glass assembly was not stuck open.
- 2B. On other installations that have a bypass or pressure relief valve from the inlet side of the fuel filters to a tank return, check that the bypass or relief valve is not stuck open.
3. Observe pressure drop across the fuel filters. If pressure drop is near or above the changeout value given for the filters, replace the filter elements and again observe fuel pressure.

NOTE: Use only recommended filter elements.

- b. Inspect the supply and bypass circuits in the fuel suction lines for partially closed valves.
7. Inspect the fuel pump itself for leaks or damage. Inspect the pump drive coupling and check drive shaft keying or lock screws.
8. Foreign material in the fuel supply tank may be intermittently obstructing the pick-up of fuel. Drain the fuel tank. If that doesn't solve the problem, then it may be necessary to open the fuel tank and inspect for foreign material.

5. Remove several oil pan handhole covers and inspect the entire length of the oil suction line leading from the governor end of the engine into the oil sump. Any mechanical damage to this line must be repaired before operating the engine.

### START THE ENGINE AND OBSERVE THE OIL LEVEL IN THE STRAINER BOX

1. If the oil level in the strainer box does not return to approximately 51 mm (2") of the screen, within 45 seconds of engine start, then take a reading on the Michiana tank pressure gauge (at idle) and shut the engine down. The engine can be shut down by pulling out the oil trip button on the governor (rail engines) or by tripping the overspeed shutdown lever (marine engines).
  - a. If the pressure reading was low or zero, then the scavenging oil pump and its suction line to the strainer box should be inspected. If necessary the scavenging oil pump should be removed and overhauled.
  - b. If the pressure reading was higher than 69 kPa (10 psi), then change the oil filter elements and repeat the procedure. If the pressure is still high, then remove and clean the oil cooler core.
2. If the oil level in the strainer box does return to within 51 mm (2") of the screen after engine startup, then operate the engine and slowly increase the speed. Observe the oil level in the strainer box at all engine speeds. At maximum operating speed take a reading of the Michiana tank pressure.

## LUBRICATING OIL SYSTEM

NOTE: Many oil system problems, as well as overall engine troubleshooting problems, can be easily identified through lube oil analysis. Refer to Table 1 for interpretation of analysis statement.

### LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM

#### ALL INSTALLATIONS EXCEPT MARINE ENGINES WITH ENGINE MOUNTED RAW WATER PUMP

Preliminary set up for troubleshooting the scavenging oil system should include the installation of a pressure gauge (0-50 psi) at the quick disconnect fitting on the Michiana filter tank. An external source of clean engine lube oil must be supplied to the main oil gallery while troubleshooting the lube oil system. A sufficient quantity of lube oil is necessary to protect the engine bearings.

#### BEFORE STARTING THE ENGINE:

1. Check for adequate supply of oil in oil pan.
2. Make sure that the strainer housing is full of oil to within about 51 mm (2") of the screen under the large cover.
3. Also under the large cover, make sure that the Michiana tank drain valve (with the "T" handle) is fully closed.
4. Remove the scavenging pump coarse strainer element which is held into the strainer box by three bolts. Inspect the interior of the suction strainer for foreign material and clean if necessary. Make certain that the clean strainer is installed with a gasket and tighten securely.

NOTE: The pressure readings given here are applicable only to installations with radiator type oil cooler cores. For switcher locomotives and industrial engines with shell and tube type (bundle) coolers, use the alternate pressure readings provided in "Switcher Locomotive And Industrial Engines".

- a. If pressure reading is above 172 kPa (25 psi), change filter elements.

NOTE: Use only EMD oil filter elements or equivalent in the Michiana oil filter tank.

- b. If pressure reading is 69 kPa (10 psi) after changing filter elements, remove and clean the oil cooler core.
- c. If the pressure reading is 21 kPa (3 psi), check the Michiana tank bypass valve to determine if it is jammed open.

### **SWITCHER LOCOMOTIVES AND INDUSTRIAL ENGINES**

1. Change filter elements at 345 kPa (50 psi).
2. If pressure is above 138 kPa (20 psi) after filter change, then clean oil cooler.
3. If pressure is below 69 kPa (10 psi), then check bypass valve to determine if it is stuck open.

### **MARINE ENGINE INSTALLATIONS WITH ENGINE MOUNTED RAW WATER PUMP**

NOTE: These engines are considerably different from other EMD engines in that much of the oil system and piping is installed by outside contactors. These variations cause the normal pressure characteristics of the oil system to be altered.

Preliminary set up for troubleshooting the scavenging oil system should include the installation of a pressure gauge (0-50 psi) at the filter tank connection labelled INLET. An external source of clean engine lube oil must be supplied to the main oil gallery while troubleshooting the lube oil system. A sufficient quantity of lube oil is necessary to protect the engine bearings.

#### **BEFORE STARTING THE ENGINE:**

1. Check for adequate supply of oil in oil pan.
2. Remove the strainer(s) and check for any obstructions to oil flow. Clean strainers if necessary. Reinstall strainers with a good gasket and tighten securely.
3. Check scavenging pump suction line in the oil pan. Any mechanical damage to this line must be repaired before starting the engine.
4. Make sure that the lube oil system is primed (hand pump) and the drain valve is fully closed.

### **START THE ENGINE AND OBSERVE PRESSURE OUTPUT OF SCAVENGING PUMP ENGINE AT IDLE SPEED**

1. If pressure output is less than 69 kPa (10 psi), qualify the following components (in the order listed) and specifically check the valves to make certain they are not stuck open:
  - a. Main lube pump suction relief valve
  - b. Filter bypass relief valve
  - c. Lube oil cooler bypass relief valve
  - d. Scavenging oil pump
2. If pressure output is greater than 276 kPa (40 psi):
  - a. Check pressure differential across lube oil filter elements. If pressure differential exceeds 69 kPa (10 psi), then change filters and retest.
  - b. Check pressure differential across oil cooler. If pressure differential exceeds 69 kPa (10 psi), then clean oil cooler core.

#### **ENGINE AT FULL SPEED**

1. Check pressure differential across lube oil filter elements. Pressure differential must not exceed 138 kPa (20 psi).
2. Check pressure differential across oil cooler. Pressure differential must not exceed 138 kPa (20 psi).

NOTE: Due to greater oil system capacity and in-line strainer, the scavenging oil pump on 20 cylinder engines occasionally exhibits a non-linear oil pressure response (oil pressure does not follow engine RPM).

### **EXCESSIVE USE OF LUBRICATING OIL**

A preliminary inspection checklist is provided to indicate possible areas of oil loss.

1. Inspect stack and carbody roof for evidence of oil loss.
2. Inspect engine exterior for leaks.

3. Air box drain should be inspected for oil loss. 4. Cooling water expansion tank should be inspected for any indication of an oil film on top of the sight glass water surface.
5. Inspect all drains to determine if they are partially open or obstructed.
6. Check oil level in governor sight glass. Engine oil could be leaking into the governor oil which would raise the level in the sight glass. If this occurs considerable external oil leakage will also be visible.
7. On locomotive installations, inspect all external piping to the load regulator vane motors for oil leakage.
8. On marine and stationary installations using pedestal bearings, inspect the bearing housing and all external oil lines for any sign of oil leakage.

NOTE: The brand name and viscosity of the lubricating oil should be established. Use of oils should be confined to those that meet the qualifications published by EMD. Use of an improper oil or oil that is not the correct viscosity can be a contributing factor to excessive oil consumption.

## OIL LOSS OUT THE EXHAUST STACK

1. Perform an air box inspection and pay particular attention to the condition of the piston, rings, and liner. Worn rings should be replaced if wear exceeds recommended limits provided in Fig. 15-1. Broken rings should be replaced immediately regardless of their wear state.

NOTE: The condition of the piston crowns may be used as an indicator to isolate the troubleshooting procedure to a specific cylinder. Excessively wet crowns and carbon throwoff from the inlet ports may point out cylinders with oil control problems.

2. The oil separator should be disassembled to verify the presence of the separator screen. On a turbocharged engine, the absence of this screen can cause excessive oil consumption and oil out

the stack. On a blower engine, the absence of this screen can cause excessive oil consumption.

- 3A. On blower engines the air chutes from the blower to the air box should be inspected from inside the air box for any evidence of oil delivery down the chutes. If oil is found running down the chute, the blower should be removed and the blower rotor end seals replaced.

- 3B. On turbocharged engines the turbocharger screen and taper joint should be removed. The exhaust manifold interior should be inspected to determine if the oil loss is originating from the engine or the turbocharger.

NOTE: In many instances this exhaust manifold inspection will reveal a specific cylinder responsible for the oil loss.

4. On turbocharged engines, if inspection of the exhaust manifold indicates that the problem is originating in the turbocharger, then inspect the air inlet system for plugged filters. Plugged filters could cause a high inlet vacuum and draw oil past the turbocharger labyrinth seals. If the external systems are found to be in good condition, then changeout of the turbocharger may be necessary.

NOTE: Engines which are operated for extended periods of time under light or no load may experience varnishing of the cylinder walls. This varnishing greatly reduces the effectiveness of the oil control rings and can cause a condition known as "souping." "Souping" can cause light brown or tan deposits on cylinder liner walls. If light load operation is continued, then these varnish deposits may interfere with ring to liner seal effectiveness. In extreme instances of light load operation it may be necessary to load the engine either through temporary change of service or through use of a load box in order to remove these deposits and restore the efficiency of the ring set.

In instances where extremely severe oil loss through "souping" at the stack or through air box drainage is experienced, shop overhaul practices should be investigated. On EMD 645 engines, piston rings in the No. 4, No. 5, and No. 6 grooves are directionally

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

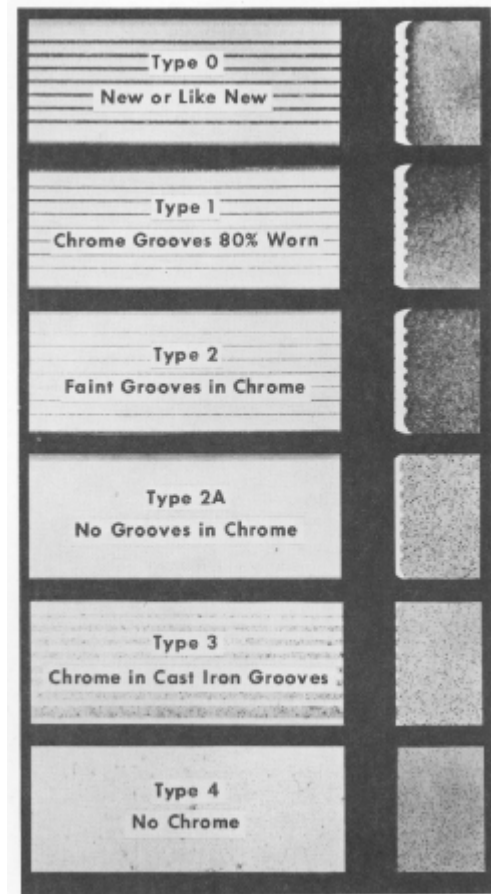
On a shallow groove ring, these classifications will be evident on the top ring for a relatively short time. On a deep groove ring, these classifications will be evident for the major portion of ring life.

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

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

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

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



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

Fig. 15-1 - Chrome Ring Wear Classification

sensitive at installation and all six rings in the set must be properly oriented in the correct slot. The installation and directional orientation of each ring is provided.

No. 1 ring is labeled "TOP GROOVE ONLY" and stamped with a part number. It may be installed with either side up.

No. 2 ring and No. 3 ring are identical. They are both stamped with a part number and may be installed with either side up.

No. 4 ring is labeled "TOP" and has a part number stamped on it. It must be installed with the "TOP" label upwards and only in the No. 4 slot. If this ring is installed upside down, its tapered face will tend to pump oil past the upper compression rings.

No. 5 ring is a double hook scraper and must be installed with the hooks pointing down. If this ring is installed upside down, it will cause heavy oil loss through the air ports and considerable oil draining from the air box.

No. 6 ring is a special spring loaded scalloped oil control ring and must be installed with the scallops downward. If this ring is installed upside down, its oil control efficiency will be greatly reduced and may result in excessive oil loss.

NOTE: At time of overhaul or if rings are removed while troubleshooting excessive use of lube oil, make certain that the oil drain holes under the oil control rings are not clogged.

## **EXTERNAL ENGINE LEAKS**

Leakage of oil from the engine will generally require tightening of the affected part or replacement of gaskets.

## **LOSS OF OIL FROM AIR BOX DRAIN**

1. Perform a complete air box inspection. Replace any power assemblies that are found to be scored or running with excessively worn rings.
2. Inspect the air delivery chutes for any sign of oil leakage into the air box from the roots blower or the turbocharger.
3. Investigate shop practices for proper installation of piston rings as noted under "OIL LOSS OUT THE EXHAUST STACK."

4. Inspect for excessive oil leakage from around the power assemblies or from the center gallery of the air box. Leakage here might indicate a failed or absent seal or component.
5. Inspect air box piping in the oil pan for any evidence of leakage or external damage to the piping which could cause oil loss.

## **OIL IN WATER EXPANSION TANK**

This indication is usually seen on installations with shell and tube type oil coolers because in these coolers the local oil pressure is higher than the cooling water pressure.

On installations with fin type oil coolers and pressure cooling systems the water pressure is higher than the oil pressure in the cooler. Because of these pressure differences inside the cooler, an internal leak usually results in water contamination of the lube oil. Pressure test and qualify the oil cooler core for leakage.

## **LEAKING SUMP DRAIN**

The pipe plug should be tightened and the valve (if so equipped) qualified or replaced.

## **LOSS OF OIL INTO GOVERNOR**

The low oil pressure actuating diaphragm of the governor should be replaced.

## **LOAD REGULATOR PIPING OR VANE MOTOR LEAKING**

Tighten or replace as applicable.

## **IMPROPER VISCOSITY OR OIL CONTAMINATION**

If either improper viscosity or oil contamination is suspected, immediately take a lube oil sample for analysis. Follow the specified corrective actions as indicated in Table 1 - "Interpretation of Lube Oil Sample Analysis." If necessary pressure test the fuel or cooling systems as required to isolate the source of contamination. Refer to Dilution of Lubricating Oil.

## **PEDESTAL BEARING LEAKAGE (MARINE)**

Replace the bearing seals and check the return line for continuity. Check that the orifice is in place on the supply line.

## LOW ENGINE OIL PRESSURE

When troubleshooting low engine oil pressure it must first be determined if the problem is an inadequate supply of oil to the pump input, a worn or defective pump, or some component in the pump output circuit causing the pressure loss.

NOTE: Lubricating oil should be qualified to ensure that it is not diluted, which could cause a pressure drop.

1. Check for adequate oil level in the engine oil pan.
2. Observe the level of oil in the strainer box (if so equipped). With the engine idling the oil should be visible about 51 mm (2") below the screen (inside the rectangular cover). If the oil level in the strainer box is low, then the scavenging oil system is suspect. Inspect the scavenging pump, the scavenging pump strainer, the Michiana filter tank, and the oil cooler as outlined in LACK OF OIL DELIVERY FROM THE SCAVENGING SYSTEM.

If the oil supply to the main pump is found to be adequate, an auxiliary oil pressure gauge (0-150 psi) should be installed at the outlet elbow on the main lube oil pump using the 3/4" NPT plug hole.

If the main pump pressure as read on the auxiliary gauge is still low, then the following checks should be made:

1. Remove the two fine screen strainers in the strainer housing. Clean the strainers and inspect the seals for possible suction leaks. Drain the strainer box and inspect the chamber for any foreign material. Remove and blow compressed air through the seal vent line to make certain that it is not obstructed.
2. Remove all oil pan handhole covers. Visually inspect the external surfaces of the main and connecting rod bearings for evidence of heating and look for missing or loose components.
3. Operate the engine at idle and remove the engine protector. Observe the pressure relief valve, located directly behind the engine protector, for excessive oil loss. If the valve is found to be stuck in the open position it should be removed and replaced with a qualified valve.

4. Check for suction leaks at the main pump inlet elbow where it mates to the main pump and to the strainer housing. Replace gaskets if necessary.
5. Remove and qualify the main oil pump.

If it was found that the main pump pressure was adequate after installation of the auxiliary gauge, then the following steps should be performed:

1. On turbocharged engines, change the turbo-charger oil filter element.
2. Qualify the main engine oil pressure gauge and inspect for any closed valves in the supply line to the gauge. There is a 1 / 8" diameter line leading through the right bank top deck of the engine to the pressure gauge. Inspect this line carefully for damage. If necessary disconnect the line at both ends and blow air through it to make certain it is clear of obstructions.

If the main engine oil pressure gauge is found to be correct, then a defective engine protective device could be causing a false oil pressure drop. The engine protective devices must be checked:

1. Disconnect and block the connecting line from the oil pressure sensing line to the engine protector and the hot oil shutdown device (if so equipped). If this results in restoration of a normal oil pressure reading on the main engine gauge it indicates one of the following areas:
  - a. The "O" ring seals on the engine protector plunger may have failed.
  - b. The activating section of the hot oil detector may be jammed open.
2. Qualify both of these devices.

If: -

1. The engine protective devices are found to be in proper operating condition.
2. The auxiliary oil pressure gauge indicates an adequate main pump output pressure.
3. The main oil pressure gauge is still indicating inadequate oil pressure.

Then investigate the rear gear train of the engine for possible causes of low oil pressure. This should include the following:

NOTE: The engine must be shut down for these checks.

1. Use the recommended tool to check the clearance in the No. 1 idler stubshaft bushing and, at the same time, inspect the interior of the end housing for debris under the gear train.
2. On turbocharged engines, remove the auxiliary generator drive (if so equipped) or the cover plate on the rear of the right bank. Inspect the manifolding to the turbocharger filter for loose or missing components or seals. Make certain that the upper pipe plug is installed in the gauge line connecting block, and inspect the cam manifolds.
3. On blower engines, remove the auxiliary generator drive (if so equipped) or the engine oil separator housing. Inspect the oil jumper lines to the camshaft bearing brackets for loose or missing components or seals.

## DILUTION OF LUBRICATING OIL

1. Check to make certain that all the fuel jumper tubes to the injectors are not cracked and are properly seated.
2. Inspect all brazed joints in the top deck fuel manifold and check all manifold pipe plugs for leakage.
3. Check injectors and injector filter cap gaskets for leaks.
4. Check for stuck piston rings.
5. Check for leaking valves in the fuel lines.
6. If water contamination of the lube oil is suspected, then visually inspect for water in the oil pan and on the top of the cylinder heads and take an oil sample for analysis.

## TURBOCHARGER PRELUBRICATION (SOAK BACK) SYSTEM

If the turbocharger soak back pump fails to operate when the engine is shut down, then immediately

restart the engine and allow it to idle for 15 minutes. This allows the oil temperature to drop which cools the turbocharger bearings. The engine can then be shut down and the electrical control and soak back pump circuits can be investigated to determine the cause of the malfunction.

If the engine cannot be restarted within 2 minutes of shutdown, then do not restart the engine until the operation of the soak back pump has been restored and the engine has been allowed to cool down.

1. Inspect the camshaft bearings on the engine top deck while the soak back pump is operating. If oil flow is observed around the bearings it is an indication that the check valve (located in the soak back filter housing) has jammed open. This is a very undesirable condition because it makes it possible to backflush oil contaminants into the main gallery. Remove the housing immediately and inspect the check valve.
2. The soak back pump filter is mounted in a small canister close to the pump itself. There is also a bypass valve and a pressure relief valve mounted above the filter canister.

CAUTION: There is no backup filtration for the soak back system. If the filter clogs, then the bypass will allow dirty oil to reach the turbocharger bearings. Never extend the changeout intervals of the soak back pump filter beyond those specified in the Scheduled Maintenance Program.

3. The turbocharger oil filter is in the large canister on the back of the right bank of the engine. There is no bypass valve for the turbocharger oil filter so clogging of the filter may result in a low oil pressure shutdown. This shutdown can occur because the oil pressure sensing line to the governor low oil pressure shutdown is taken off of the discharge side of the turbocharger element. Use only EMD recommended filter elements. These are resin coated cotton paper with a 30 micron rating. Never use a wood pulp filter in an EMD engine. (Note: The Michiana tank filter elements have a 13 micron rating and cannot be used in the turbocharger filter).

CAUTION: Changeout intervals for engine mounted turbocharger filter elements should never be extended beyond the recommendations given in the Scheduled Maintenance Program.

4. To check oil delivery from the soak back system while the pump is operating, first remove the rear oil pan handhole cover on the left bank of the engine. Inspect under the gear train for oil return draining from the turbocharger. If oil drainage is not evident, then check the motor to pump coupling, the motor brushes, and the pump itself for failure or restriction of oil delivery.

NOTE: Many installations are equipped with an indicator light to show that the soak back pump is being energized. Electrical power to the pump does not necessarily mean that the pump is delivering oil to the system.

5. Some installations are equipped with a security interlock which will not allow the engine to be cranked for starting unless the preliminary turbocharger soak back or priming pump sequences have been completed. If the engine fails to crank, then investigate these security interlocks for failures.

## COOLING SYSTEM

### LOW WATER PRESSURE (PRESSURE COOLING SYSTEMS ONLY)

Install a pressure gauge on the expansion tank and monitor the pressure rise at the tank as the engine heats up to normal operating temperature.

1. If the pressure reading was inadequate, then shutdown the engine. Test the manual vent valve (next to the expansion tank filler cap) for leaking when closed. This is done by placing a bucket of water so that the end of the vent line extends several inches below the surface of the water. The release of bubbles or coolant inhibitor through the water indicates that the vent valve is not seating properly and must be replaced.

WARNING: Do not get hands or face close to the water bucket while performing this test.

2. Blow down the tank pressure by opening the manual vent valve.
3. When the tank pressure is completely dissipated, remove and inspect the expansion tank fill valve. Check for proper seating of the snifter valve (metal disc) in the center of the cap and check the condition of the gasket. Make certain the pressure range marked on the cap is correct for the

installation. If there is any indication of a faulty filler cap, remove and check it on an external pressure tester. Replace cap if necessary.

WARNING: On installations with manual vent (blowdown) valves, use only the expansion tank caps with the crosswise bar. This is a protective system designed to prevent injury of personnel from expansion of hot coolant, its purpose is defeated if a plain expansion tank cap is used.

## HIGH COOLANT TEMPERATURE

### INSTALLATIONS WITH RADIATORS

1. Check coolant level in expansion or supply tank. Check for adequate cooling system pressure (some installations have quick disconnect fittings for this purpose). If the cooling system pressure is not adequate for the installation, then check the condition of the expansion tank filler cap (if used) and make sure the cap is marked with the proper pressure range.
2. Cycle the radiator shutters (if so equipped) with the temperature switch test button or the shutter test valve. Make certain that the shutters are opening completely. If necessary check the temperature at which the shutter control operates. This can be done by either operating the engine until it reaches the temperature at which the shutters open or by removing the temperature switch and testing it separately. The switch can be tested off the engine by placing the heat sensing element in a pan of hot water with a thermometer and noting the temperature where the switch operates.
3. Make certain that all radiator and water pump vent lines are in place and not obstructed. Disconnected radiator vent lines can cause air binding in the radiators which results in a loss of cooling efficiency. Water pump vent lines that are disconnected or not the correct size can cause cavitation of the water pump which results in a loss of coolant delivery pressure.

- 4A. On installations with electric cooling fans, check for proper operation of all fan motors and temperature control switches. Check all the fan fuses for continuity and proper rating.
- 4B. On installations with belt driven cooling fans, inspect the belts and make certain that they are properly tensioned.
- 5. Inspect the exterior of the radiators for clogging and restriction of air flow. Clean radiator baffles (fins) if necessary. Carefully check the cores for leaks.
- 6. Hydro-test the cooling system for leaks. Coolant leaks decrease cooling capacity and could introduce exhaust gases into the cooling system. Gases in the cooling system might cause air binding of the radiators or water pumps.

NOTE: Do not exceed 172 kPa (24 psi) during hydro-test. This limit is notably conservative to account for older equipment that might have some long service deterioration. The engine alone can be blanked off and tested with air and water at 620 kPa (90 psi).

## **INSTALLATIONS WITH HEAT EXCHANGERS (AND KEEL COOLERS)**

- 1. Check coolant level in expansion or supply tank. On pressure-type systems check both the cooling system pressure and the condition of the filler cap.
- 2. Check that all vent lines are in place and not obstructed. Make certain that all cooling system piping is physically located below the level of coolant in the tank.
- 3. Check that all cooling system piping connections are tight and that all gaskets are in good condition. Leakage on the pressure or output side of the water pump will cause coolant loss and decreased coolant pressure throughout the system. Leakage on the suction or input side of the water pump will draw air into the system which results in cavitation at the pump.
- 4. Check the operation of the temperature control (thermostatic) valve if the installation has this equipment.

- 5A. On installations with engine mounted raw water pumps, check the valve positioning on the suction and discharge circuits of the pump. Make certain that piping connections are properly sealed and tightened and that gaskets are in good condition.
- 5B. On installations with belt or shaft driven raw water pumps, check the shaft couplings and belt tension. Check that all valves are open in the suction and discharge lines to the pump.
- 6. Monitor the temperature change across the engine cooling side of the heat exchanger, and if possible, across the raw water pump from suction to discharge side. If the temperature change is too small across either the cooling side of the heat exchanger (drop) or the raw water pump (rise), then clean the radiating surfaces, or, it may be necessary to rod out the exchanger (shell and tube types).
- 7. Hydro-test the cooling system for leaks. Coolant leaks decrease cooling capacity and could introduce exhaust gases into the cooling system. Gases in the cooling system might cause air binding of the exchanger or water pumps.

NOTE: Do not exceed 172 kPa (25 psi) during hydro-test. This limit is notably conservative to account for older equipment that might have some long service deterioration. The engine alone can be blanked off and tested with air and water at 620 kPa (90 psi).

## **HIGH LUBRICATING OIL TEMPERATURE-RELATED TO OIL COOLER (COOLANT TEMPERATURE) PROBLEMS**

- 1. Check oil level in oil pan and monitor main oil pump pressure.
- 2. Remove the square cover from the scavenging delivery compartment in the strainer housing. Check for sufficient oil delivery from the scavenging oil pump. The oil level should not be more than two to three inches below the screen with the engine running. If scavenging oil delivery is inadequate, the Michiana filter tank pressure should be checked as a test for plugged filters and/or a jammed bypass valve.

NOTE: The purpose of the oil cooler is to use engine coolant to remove excess heat from the lubricating oil. This relationship leads to high oil temperature if engine coolant temperature becomes too high.

3. Determine if the engine has had high water temperature problems. High water temperature reduces the efficiency of the oil cooler thereby causing a higher oil temperature. If the engine has an above normal water temperature, follow the troubleshooting guide for that particular problem.
4. Marine and Stationary Power installations are frequently equipped with a temperature control (thermostatic) valve. If the engine has this equipment, then qualify the opening of the valve. On some installations, failure of the valve to function can deprive the oil cooler of coolant.
5. Put inline thermometers or temporary thermometers in the wells provided in the engine cooling water piping. Monitor temperatures in and out of both the oil and water sides of the oil cooler. Compare these readings with a standard chart (locomotive installations) or with installation records to determine oil cooler efficiency. Reduced efficiency is caused by oil cooler plugging, scale or corrosion. If oil temperature drop or coolant temperature rise through the cooler are not adequate, then remove the cooler for inspection and cleaning.

## ENGINE PERFORMANCE

### UNEXPECTED ENGINE SHUTDOWNS

NOTE: Quite often on startup, and occasionally on shutdown, the engine protector buttons may be activated by pressure differential transients. These may cause a false indication of engine problems during routine startup and shutdown.

If an engine shuts down unexpectedly while operating under load, the following steps should be performed:

1. Check the position of the overspeed trip lever and reset if necessary. Consult the applicable section of this troubleshooting guide for further investigative procedures.
2. Make certain that the engine did not run out of fuel and that the emergency fuel cutoff or engine stop switch was not activated.

3. On locomotive installations only: -
  - a. Check that the engine was not inadvertently shutdown by moving the throttle handle beyond the detent position at the right end of the quadrant.

NOTE: Moving the throttle handle to the right beyond the detent position will also shutdown all other locomotive units connected in tandem.

- b. Check the annunciator module for fault indications and look for an illuminated alarm indicator light on the engine control panel.
4. Observe the engine protector crankcase pressure button.

WARNING: If this button has popped out, do not work on the engine for at least two hours. Do not open any of the air box, oil pan, or top deck access covers.

After two hours has passed the engine can be opened up to inspect for the cause of the crankcase overpressure. Consult the applicable section of this troubleshooting guide for further investigative procedures.

5. Observe the engine protector differential water pressure button. If this button has popped out, check the engine coolant level in the supply or expansion tank. If the coolant level is low, carefully inspect the engine and piping for internal or external leakage. Pressure test the system if necessary but limit maximum pressure to 172 kPa (25 psi).

WARNING: Remove expansion tank filler cap cautiously as steam pressure may be present.

Check that all drain valves are fully closed on the engine and in the external piping. On locomotive installations, check that all cab heater drains are closed. Refill the cooling system with the proper coolant and attempt to restart the engine. Monitor the engine temperature after load is applied. If the temperature rises beyond the normal level, then consult the "HIGH COOLANT TEMPERATURE" section of this troubleshooting guide.

NOTE: The engine protector crankcase pressure and differential water pressure buttons shut down the engine by dropping all oil pressure to the governor engine oil pressure sensing diaphragm. Therefore, the governor low oil button should always pop out if one of the engine protectors is activated. This series of events takes place in the normal actuation of a crankcase overpressure or differential water pressure shutdown and has an entirely different significance than the governor low oil button popping out by itself.

6. Check the governor low oil button. If this button alone has popped out, then check the oil level in the engine oil pan and in the engine mounted oil strainer box.

WARNING: On locomotive installations, the hot oil detector can also cause the low oil button to pop out. When the low oil button is popped out, and a hot engine condition is suspected, wait two hours before checking the oil level.

- a. If the engine oil level is unusually low, check for a partially open oil pan drain valve and a loose or missing drain pipe plug.
- b. If low oil is evident in the chamber below the screen in the square section of the strainer box, check the scavenging oil system as indicated in the appropriate section of this troubleshooting guide.
- c. If the oil levels at both locations were adequate, inspect the inside of the oil pan for evidence of overheated metal surfaces or extruded metal around the main and connecting rod bearings. Inspect under the lower end of both gear trains for debris.

If all the preceding steps do not point out the reason for the governor low oil indication, then close up the engine and attempt to restart the engine. If the engine starts, then closely observe the engine oil pressure gauge. If the engine does not develop oil pressure on the gauge, then perform the procedure as indicated under "LOW ENGINE OIL PRESSURE" of this troubleshooting guide.

On locomotive installations only, if after the engine starts the oil pressure gauge builds up to normal, it could have been the hot oil detector that caused the low oil shutdown. The hot oil detector might have shut the

engine down and then reset itself during the cool off. Load the engine and watch the engine temperature gauge closely for possible overheating.

7. If after any of the preceding steps, the engine cranked over readily but failed to start, a fuel system failure is probable. Check for adequate fuel supply in the storage or day tank. Check for fuel pressure (duplex fuel filters) or for fuel flow (sight glass) at the engine. If fuel pressure or fuel flow is not evident, then perform the procedure outlined under "LOW FUEL OIL PRESSURE" in this troubleshooting guide.
8. On installations with electric fuel pumps, the shutdown could have been caused by an interruption or fault in the fuel pump control circuit. Use the appropriate wiring diagram to qualify switchgear and wiring connections and check for continuity through electrical interlocks.
9. On turbocharged engines only, if the engine unexpectedly shut down when the throttle was reduced, accompanied by bogging of the engine and heavy smoke, the turbocharger clutch may be failing to engage properly. Check the operation of the turbocharger clutch using the EMD turbocharger troubleshooting procedures.
10. On locomotive installations only, several unique characteristics of the control systems could cause an unexpected reduction in engine speed while operating under load:
  - a. Unexpected locomotive engine speed reductions can be caused by activation of THL or EFL protective relays. These relays function to reduce engine power if a hot engine or clogged air filter condition occurs. On most freight locomotive applications, pickup of THL or EFL will reduce No. 8 throttle engine speed to No. 6 throttle speed and reduce No. 7 throttle engine speed to No. 5 throttle speed. Check the annunciator indications and the fault lights on the engine control panel. Check the engine temperature control system or change the air filter elements as necessary to correct the problem.

- b. Qualify the control stand microswitches. Inspect the connection of the control wire flexible cable to the governor for tightness and terminal engagement.
- c. Pickup of the ground protective relay will cause engine speed to be reduced to idle regardless of throttle position. This action is accompanied by an annunciator indication, an engine control panel light, and an alarm.

#### LOSS OF POWER

NOTE: On installations with a load regulator or load control system, the correct injector is essential to the proper loading of the system. Whenever improper loading occurs with this type system, check the injector part numbers to make certain they are correct for the installation.

#### ENGINE RUNS WITH CLEAN STACK

1. Shut down the engine.
2. Open all top deck covers and visually inspect the injectors, racks, and followers. Make certain that all injector racks are engaged to the transfer arms and that all pins and linkages are in place and properly tightened. Observe fuel jumpers, rocker arms, and exhaust valve bridges for any abnormal conditions.
3. Close top deck covers and prepare for a normal startup. Check fuel supply. Prime engine fuel system and check for adequate return fuel flow (sight glass) or fuel supply pressure (duplex filters).
4. Start the engine and allow it to reach normal operating temperature. Observe fuel system pressure or delivery. If fuel system shows any indication of inadequate delivery, then follow the procedure outlined under "LOW FUEL OIL PRESSURE" in this troubleshooting guide. If bubbles are evident in the return fuel sight glass, see Section 5B of Low Fuel Oil Pressure Troubleshooting.

NOTE: The following procedures apply only to engines with notched or continuous throttles; Woodward PG, PGR, or PGA governors.

5. With the engine not under load, attempt to slowly increase engine speed from idle to maximum RPM. On installations with PG or PGR governors, check that all assigned engine speeds are properly activated. On installations with a PGA governor, check that the engine responds evenly to increased throttle throughout the operating range from idle to maximum RPM. Use a hand tachometer to check that the engine has reached maximum speed. If the engine failed to reach maximum RPM, check governor solenoids on PG or PGR governors and the control air supply and pressure settings on PGA governors. Return engine speed to idle and attempt to load the engine. Advance the throttle slowly and smoothly from minimum to maximum speed.

Qualify the maximum speed of the engine with a hand tachometer. If the engine cannot reach its maximum speed rating under load, examine the position of the rack as indicated by the quadrant on the governor and verify the following conditions (while under full load). If the governor rack is shorter than the specified maximum position on the governor nameplate (while under full load), and the engine is running at or below maximum rated RPM, then:

1. On locomotive installations, check the position of the load regulator.
  - a. If the load regulator has moved to minimum field position, the problem is most likely of a mechanical nature. Carefully inspect the mechanical condition of the injectors and check them for correct part numbers. The injectors should also be pressure tested. (Refer to INJECTOR PRESSURE TEST in this section.) The governor part number should be checked to make sure it is the right one for the installation. If necessary, the governor should be removed to check the load regulator.
  - b. If the load regulator has moved to maximum field position, the problem could be of either a mechanical or electrical nature. Injectors should be checked for proper part number and then pressure tested. The electrical excitation system should be qualified according to the procedures established in the appropriate locomotive service manual.

c. On a marine or power generating installation, an overload condition or a mechanical problem with the fuel injectors is most likely. Pressure test the injectors after checking them for correct part numbers. (Refer to INJECTOR PRESSURE TEST in this section.) Make certain that the governor part number is correct for the installation. If the governor and injectors are functioning properly and their part numbers are verified for the installation, then an electrical or mechanical overload condition is probable. On power generating installations, refer to load rating conditions in the applicable manuals. On marine gear box installations, refer to the applicable propeller cube curves to determine if an overload condition exists.

If the governor rack is longer than the specified maximum position on the governor nameplate, and the engine is operating below its maximum speed, attempt to increase fuel injection (shorten rack dimension) by manually advancing the layshaft lever.

1. If increased resistance prevented the injector control lever from being manually advanced to the specified maximum position, then suspect either an engine injector rack is binding or the governor stop adjustment on the power piston is improperly set.
2. If it was possible to manually advance the injector control lever to maximum fuel position, the engine speed increased, then suspect:
  - a. Improper governor setting (high speed unloader limit).
  - b. (Marine only) Deliberate speed limiting setting.
  - c. (Locomotive only) Improper adjustment of governor.

On PG and PGR governors (rail and drill rig), the governor should be removed from the engine and operated on a governor test stand to make adjustments. Check governor and injectors part numbers to make sure they are correct for that particular application.

## ENGINE RUNS WITH DIRTY STACK

1. Open top deck covers and perform a visual inspection of all injectors, racks, and followers. Make certain that all injector racks are engaged to the transfer arms and that all pins and linkages are in place and properly tightened. Check injectors for proper part number and pressure test injectors

for leakage. (Refer to INJECTOR PRESSURE TEST in this section.)

2. Close the top deck covers and prepare the engine for a normal startup. Observe fuel system pressure or delivery for any abnormal conditions. If fuel system delivery or pressure is low, refer to "LOW FUEL OIL PRESSURE" section of this troubleshooting guide. If bubbles are evident in the return fuel sightglass see Section 5B of "LOW FUEL OIL PRESSURE" troubleshooting.
3. With the engine at normal operating temperature and not under load, slowly advance the throttle from idle to maximum speed. Check that all engine speeds are reached smoothly and verify maximum engine speed with a hand tachometer.
4. With engine at maximum speed, with full load applied, use a water manometer to check exhaust back pressure.

On blower engines, the back pressure should not exceed 559 mm (22") of water.

On turbocharged engines, the back pressure should not exceed 127 mm (5") of water.

If the exhaust pressure is too high, then check for obstructions in the exhaust risers and stack extensions.

5. With engine at maximum speed, with no load applied, use a water manometer to check engine air inlet depression.

If inlet depression exceeds the value provided in "Air Filter Pressure Drop" data, either change or clean filters.

NOTE: All air filter pressure drops are measured in clean air plenum downstream of the filter elements.

Application	Turbocharged				Blower Type Engines							
	Paper		Fiberglass		Oil		Paper		Fiberglass		Oil	
	In.	mm	In.	mm	In.	mm	In.	Mm	Im.	Mm	In.	mm
Marine	14*	356*	7	178	16*	406*	18**	457**	7	178	20**	508**
Marine Drill	14*	356*	7	178	16*	406*	18**	457**	7	178	20**	508**
Stationary	14*	356*	7	178	16*	406*	18**	457**	7	178	20**	508**
Drill Rig											20**	508**
	Inertial + Paper		Inertial + Fiberglass		Inertial+ Oil		Inertial + Paper		Inertial + Fiberglass		Inertial + Oil	
	In.	mm	In.	mm	In.	mm	In.	Mm	Im.	Mm	In.	mm
Locomotive	14	356	14	356	16	406	18	457	18	457	14.5	368

**NOTE**

Inertial filter readings should not exceed 5.5" (140 mm).

\*For remote mounted filter applications, subtract 3" (76 mm) H<sub>2</sub>O

\*\*For remote mounted filter application, subtract 10" (254 mm) H<sub>2</sub>O

#### Air Filter Pressure Drop

6. Attempt to load the engine. If the engine bogs and smokes, check for excessive air box accumulations blocking the inlet ports. On turbocharged engines only, check for a plugged exhaust screen and qualify the condition of the turbocharger by performing the inspections outlined in the Turbocharger Troubleshooting Section.
7. If all the preceding checks prove negative, qualify engine timing by checking exhaust valve timing on both cylinder banks.
3. On installations with fuel sight glasses, check for adequate fuel flow through the return sight glass. If fuel flow is inadequate, refer to the "LOW FUEL OIL PRESSURE" section of this troubleshooting guide. If bubbles are evident in the return fuel sightglass see section 513 of "LOW FUEL OIL PRESSURE" Troubleshooting.
4. On installations with fuel block and duplex filters, check for adequate fuel supply pressure. If fuel pressure is inadequate, refer to the "LOW FUEL OIL PRESSURE" section of this troubleshooting guide.

## CYLINDER MISFIRE

1. Pressure test all injectors using the appropriate EMD tool. This tool checks for free follower action and adequate injection force.
2. Inspect the part numbers on the bodies of all injectors to verify that the entire engine set is correct for the installation.

**CAUTION:** EMD does not make hollow rack injectors. Hollow rack injectors cannot be set correctly with an EMD injector rack tool. If they are mixed in an EMD engine set with EMD injectors, and set with EMD tool, then these cylinders will be too light on fuel volume (rack too long). This can result in misfire, vibration, poor overall fuel economy, and possibly, serious damage to the engine.

5. Inspect the exhaust valves and check for valves that are stuck partially open, operating with damaged heads, or misadjusted so that they cannot seal completely.

## ENGINE KNOCKS

2. Perform a complete top deck inspection. Check all injectors and injector control linkage. If bubbles are evident in the return fuel sightglass with engine running, see Section 513 of "LOW FUEL OIL PRESSURE" Troubleshooting.
2. Repair any injector linkage with loose adjusting and locknuts or missing pin clips. Make certain that all injectors are properly engaged between their racks and the control linkage. Pressure test all the injectors (refer to INJECTOR PRESSURE TEST in this section).

3. Set and time all injectors in accordance with procedures provided at the end of this section.
4. Check exhaust valve lash adjustment. Remove and test any valve bridge which shows inadequate lash adjuster tension or which operates loudly when the engine is running.
5. Check all injector part numbers to make certain that the entire engine set is correct for the installation.
6. Check for engine overloading or overheating problems. Observe the load and temperature gauges with engine in operation. If necessary, refer to the applicable section of this troubleshooting guide for corrective action.
7. If all the preceding steps prove negative, then perform the following steps; although these are more unlikely to be the cause of engine knocking:
  - a. Check the exhaust valve timing on both cylinder banks.
  - b. Carefully inspect the engine to make certain that 567 and 645 power assemblies have not been mixed in the same engine. 567 and 645 power assemblies cannot be operated, at the same time, in the same engine because the difference in weight make counterbalancing impossible.

NOTE: An entire set of 645 power assemblies can be used in certain 567 engines providing that all instructions in the EMD Modernization Recommendation on this subject are followed. Consult your dealer or EMD representative for more information.

- c. Make certain that blower-type pistons and turbocharger pistons are not mixed in the same engine by checking piston part numbers (bottom of piston skirt) from inside the oil pan.
- d. Take lead wire readings to check for bent rods or piston pin insert distress.

## EXCESSIVE VIBRATION

1. Open top deck covers and perform a visual inspection of all injectors, racks, and followers. Make certain that all injector racks are engaged to the transfer arms and that all pins and linkages are

in place and properly tightened. Pressure test injectors for leakage (refer to INJECTOR PRESSURE TEST in this section). If bubbles are evident in the return fuel sightglass with engine running, see Section 513 of "LOW FUEL OIL PRESSURE" Troubleshooting.

2. Inspect engine to generator coupling disc for any evidence of failure.
3. On marine installations, inspect torque tube couplings for evidence of failure.
4. Inspect all drive shafts that operate auxiliary equipment for any sign of failure.
5. Remove all oil pan handhole covers. Visually inspect crankshaft area for loose or damaged main bearing caps and connecting rod baskets. Look for signs of overheated or extruded metal.
6. Inspect for debris under the gear trains at both ends of the engine. Visually qualify the crankshaft damper. Check engine records to make certain that crankshaft damper is not past changeout date.
7. Inspect top deck on both banks of cylinder for broken rocker arms or broken rocker arm shaft mounting studs.
8. If installation has been subjected to any shock loadings, check engine to generator or engine to gearbox alignment.
9. If engine was recently overhauled, check camshaft counterweight timing.

## ENGINE SMOKING (DARK SMOKE)

1. Check the governor rack quadrant with the engine at maximum rated RPM and full load. If the indicated governor quadrant dimension is shorter than the limit specified on the governor identification plate, then the engine may be operating overloaded. If bubbles are evident in the return fuel sightglass see Section 513, of "LOW FUEL OIL PRESSURE" Troubleshooting.
2. Check maximum engine RPM with a hand tachometer on the end of the camshaft. If the engine is running below its maximum rated RPM and short on rack, then overloading is the most probable cause and the following steps should be taken:

- a. On locomotive and power generating installations, standardize horsepower output and check all calibrating and load control adjustments. If possible, adjust to obtain proper rated output.
  - b. On marine gear box installations, it may be necessary to adjust pitch or diameter of the propeller if continual overloading is experienced.
3. If the engine was operating below its load limit, then remove the load and run the engine to its maximum rated RPM without load.
    - a. Check the engine air filter inlet depression with a water tube manometer. If the inlet depression exceeds the value provided in "Engine Runs With Dirty Stack," then change or clean the air filters.
    - b. Check the exhaust back pressure. If the exhaust back pressure exceeds 127 mm (5") of water on turbocharged engines or 559 mm (22") of water on blower engines, then look for blockages or restrictions in the exhaust system.
  4. If the preceding checks prove negative, shut the engine down and perform a complete inspection of the injectors. Make certain that all injectors are the correct part number for installation. Check injector timing and rack setting. Pressure test all injectors for leakage. (Refer to INJECTOR PRESSURE TEST in this section.)
  5. Check the exhaust valve timing on both banks of cylinders.
  6. Perform a complete air box inspection. Check for broken compression rings. CAUTION: Never operate an EMD engine in routine service with broken compression rings. Ring fragments can be drawn through the liner air ports into the inlet air stream where they may damage the liner, piston, cylinder head, and exhaust valves. Pieces of ring can also be drawn up the exhaust stack where they could damage the turbocharger (if so equipped).
  - 7A. On blower engines only, check for leaking shaft end seals by observing the air box end of the air delivery chutes for oil flow. Leaking end seals can be an indication of impending bearing failure with possible rotor damage.

- 7B. On turbocharged engines only, remove the inlet boot and inspect the inlet impeller for damage. Remove the section of the exhaust manifold adjacent to the turbocharger. Examine the condition of the protective screen and clean if necessary. Inspect the interior of the exhaust manifold for debris. Have someone else rotate the turbo shaft from the inlet end while you inspect the exhaust blades with a flashlight. Refer to Turbocharger Troubleshooting in this section.

## **SPEED DEPARTURE (ENGINE SPEED HUNTING)**

1. Make certain that the injector control linkage is working properly. Replace any injector which shows evidence of rack binding. If bubbles are evident in fuel return sightglass, see Section 5B of "LOW FUEL OIL PRESSURE" Troubleshooting.
2. Check governor for correct oil level. Either too high or too low oil level in the governor may cause engine hunting. If the governor "manufactures" oil (oil level constantly rising) or if the governor oil becomes excessively dirty after a short operating time then engine lube oil is getting into the governor oil. Check for the following possibilities:
  - a. The governor oil pressure sensing diaphragm may be ruptured.
  - b. The load control pilot valve (if so equipped) may have a failed seal.

NOTE: These problems may require removal of the governor for correction or rebuild.

3. With the engine running, vent the air bleed screw in the governor body to remove any trapped air from the governor control passages. Adjust the compensating needle valve to limit the hunting condition as much as possible.
4. If hunting continues, the cause may be the following:
  - a. On locomotive installations, the operation of protective devices such as current overload relays and excitation limiting may be causing hunting. Check the electrical system to make certain that the excitation circuits are functioning properly.

- b. On drill rig and DC power generating installations, the cycling of calibrating and overload relays may cause hunting. Check the circuits for proper operation.

NOTE: Marine engine gear box installations may exhibit a load fluctuation in rough or shallow water which should not be confused with hunting.

## PROTECTIVE DEVICES

### CRANKCASE PRESSURE DETECTOR

WARNING: After a crankcase pressure detector shutdown, do not open any engine handhole cover, top deck cover, or oil strainer housing cover for at least two hours.

NOTE: Combustion is created in the oil pan when oil vapors come into contact with an overheated engine component. The force generated by this combustion frequently bends or damages the sensing diaphragm backup plates in the crankcase pressure detector. If oil pan combustion is suspected in a crankcase pressure shutdown, then the detector must be removed and qualified on a suitable test stand.

1. Check for plugged separator screen in the crankcase aspirator unit.

NOTE: Do not remove any of the calibrating orifices that are part of the total crankcase aspirator system installed at the factory.

2. Check oil level in the engine
3. On turbocharged units, check if there is carbon blocking the angled end of the eductor tube which projects into the stack riser.
4. After the engine has been shut down for two hours, remove the oil pan and air box handhole covers and check for the following problems:
  - a. Cracked pistons.
  - b. Broken cylinder crab studs.
  - c. Cracked cylinder head.

- d. Badly worn valve guides.
- e. Hardened lower liner seals.
- f. Inadequate injector crab nut torque.
- g. Extreme cylinder scoring which could allow air box blowdown past oil control rings.
- h. If engine was recently overhauled, investigate shop practices for installation of oil control rings on rebuilt power assemblies.
- i. Inspect the interior of the air box for evidence of carbon combustion which could cause seal hardening and component failure.
- j. Inspect oil pan for any indication of overheated metal surfaces.
- k. Check for debris under the gear trains at both ends of the engine.
1. If the preceding steps did not disclose the cause of the shutdown, then while the engine protector is still off the engine, examine the oil pressure relief valve. This valve is mounted on the oil distribution manifold directly behind the mounting opening of the engine protector. The port on the oil pressure relief valve should be facing downward and 90° away from the end sheet of the engine. If the relief valve is installed either facing the end sheet or at 180° to the end sheet, then the oil discharge may hit the actuating diaphragm of the engine protector causing a false actuation.

### OVERSPEED TRIP

1. Check the possibility that the load on the engine was suddenly dropped. Check the operation of overcurrent protective and excitation limiting relays. On locomotive or generating installations, look for annunciator or engine control cabinet indications.
2. Run the engine to maximum possible speed with no load and check the speed with a hand tachometer. Use the hand tachometer, through the access cover on the end of the camshaft counterweight cover, to read camshaft RPM.

This is a valid indication because the camshaft is in a 1:1 overall drive ratio to the engine crankshaft.

3. While the governor is maintaining the engine at maximum speed, increase fuel injection by manually overriding the governor with the injector control lever until the overspeed device trips. Note the speed that the overspeed device trips on the hand tachometer.
  - a. If the overspeed does not trip when engine RPM reaches approximately 10% over rated speed, back off the injector control lever and shut the engine down. With the engine shut down, remove the front cam counterweight cover and check the overspeed mechanism.
  - b. If the overspeed tripped at too low of an RPM, it may be necessary to increase the spring tension on the overspeed flyweight. This is mounted on the front camshaft counterweight on the right bank of the engine. Retest until proper RPM trip value is obtained. Correct trip speed should be approximately 10 percent over the maximum RPM rating of the engine. For example, a 645 engine with a maximum governor speed tolerance of 908 RPM should trip the overspeed at about 1000 RPM.
4. With the overspeed trip qualified, run the engine to full rated RPM under load and observe its operation. It may be necessary to bleed air from the governor or adjust the governor compensating needle valve if the governor shows any tendency to hunt. Consult the "SPEED DEPARTURE" section of this troubleshooting guide.
5. On locomotive installations, repeated overspeed tripping under load may be caused by electrical malfunction causing the load to be interrupted. Consult the appropriate locomotive service manual for troubleshooting the electrical excitation and protection systems.
6. On marine engines that are operated over extremely rough or shallow water, considerable load fluctuations are possible. This should not be confused with load hunting. These sudden load variations might cause the engine to overspeed. If this problem occurs, consult your service engineer or the EMD Service Department for recommendations based on the requirements of your installation.

## TRACING DEFECTIVE OR NOISY CYLINDERS

These are several checks and procedures which have proven useful to determine if a particular cylinder is experiencing mechanical or fuel supply problems. Cylinders with these difficulties may show symptoms of smoking, misfiring, or operating with an unusually low stack temperature. The following is a summary of cylinder problems and their related symptoms.

### EXHAUST TEMPERATURE

1. On marine engine installations with exhaust stack pyrometers, check readings between cylinders with the engine running under load.

NOTE: Exhaust pyrometers are unreliable indicators of engine malfunctions. Do not use only one set of pyrometer readings as a basis for an exploratory teardown of a power assembly. Always compare readings of the individual pyrometers by switching the sensing bulbs between the suspected defective cylinder and one cylinder which is indicating properly.

2. On locomotives and stationary power installations, an approximation of individual cylinder exhaust temperature can be obtained with a hand held pyrometer. The pyrometer must be used on individual riser legs with the engine under load. These readings are useful only for comparison between cylinders. Because the pyrometer is being positioned outside the manifold, the readings alone should not be used as a basis for power assembly teardown. Only the range relationship between cylinders is meaningful to detect a suspicious cylinder.

### STACK SOUND

1. Using a four foot length of 1/2" or 3/4" pipe held against the riser leg, listen to the sound of the exhaust in each stack riser. A defective exhaust valve or a cylinder with an injector not functioning can often be located this way.
2. Disconnect the injector rack link on the suspect cylinder. With the engine at idle speed, slowly open the rack for that cylinder and then return it to idle position. If the injector is functioning properly, a pronounced laboring of the cylinder will be evident with the rack advanced.

## INJECTOR TESTING

Refer to INJECTOR PRESSURE TEST in this section, to check injectors for leakage.

## AIR BOX INSPECTION

Heavy cylinder scoring or badly worn or broken compression rings can cause smoking, high oil consumption, or loading and operational problems. Consult the appropriate one revolution inspection sequence charts that are provided. These charts give detailed data about each period of crankshaft rotation for different engine configurations. This information is necessary to perform a thorough air box inspection and will also minimize the amount of engine barring needed to do the inspection.

## INJECTOR TIMING AND RACK SETTING

Injectors must all be set properly to achieve even loading of the engine. Unevenly set injectors can contribute to excessive vibration, smoking, and premature wear on power assemblies. To set the injectors refer to "SETTING INJECTOR RACKS."

NOTE: Do not rely on body grooves or any other superficial means of identifying injectors. Check the injectors only by part number and then make certain, through the appropriate EMD parts catalog, that all the injectors in an engine are correct for that installation.

## ENGINE WILL NOT SHUT DOWN

### INJECTOR CONTROL LEVER IN STOP POSITION

1. Injector linkage may be improperly adjusted.
2. Injector rack may be stuck or incorrectly meshed with injector gear.

## EMERGENCY SHUTDOWN PROCEDURE

### RAILROAD INSTALLATIONS

1. Push one of the three emergency fuel cutoff buttons. These are located one on either side of the locomotive on the catwalk edge above the fuel

tank and one in the locomotive cab. (The function of these buttons is not trainlined).

2. Move the throttle handle in the controlling unit to the extreme right corner of the quadrant by pulling out the handle enough to clear the detent. This will shut down that unit and all units in an MU equipped consist which have isolation switches in the RUN position. This will not shut down other units that are isolated.
3. Turn off the control and fuel pump switch on a single unit or the lead unit in an MU consist. This will stop the fuel pump and result in engine shutdown from lack of fuel. This procedure will only shut down trailing units that have their control and fuel pump switches in the OFF position.
4. A unit can be shut down from the right catwalk by pulling the injector control lever all the way towards the outside of the unit and holding it there until the engine is completely stopped.  
  
A unit can be shutdown from the left catwalk by pulling out the low oil trip button on the governor.

### MARINE AND STATIONARY INSTALLATIONS

On installations with emergency fuel cutoff switches, this switch should be used for emergency shutdown only, otherwise any of the following procedures should be used.

1. Push the manual shutdown button on top of the governor (if so equipped).
2. Trip the overspeed shutdown with the manual lever on top of the camshaft counterweight housing.
3. Energize the governor shutdown solenoid (controlled electrically from primary control location).
4. If the governor did not go to the fuel shut off position, then override the control linkage with the injector control lever by pulling the lever out as far as it will go and holding it until the engine is completely stopped.
5. On marine engines, if the overspeed lever did not shut the engine down, then engage the ahead or astern clutch to stop the engine provided that the vessel is not in motion.

NOTE: In an extreme emergency an EMD engine can be shut down by depriving it of fuel by opening the suction strainer.

## INJECTOR PRESSURE TEST

Special tool 8414877 is used to pressure test injector for leakage while they are installed in the engine. Pressure test injectors as follows:

1. Ensure that engine fuel lines are fully charged.
2. Place straightedge across exhaust and injector cam rollers. If injector cam roller is higher than the exhaust cam rollers, bar engine over until injector roller is below the exhaust rollers.
3. Apply test tool to the injector rocker arm of the injector being tested. The tool should straddle the rocker arm with the lower end of tines under the rocker arm shaft and the top end of tool covering the rocker arm adjusting screw lock nut.
4. Remove retainer spring and clevis pin securing injector control lever to adjusting link.
5. Place injector rack in full fuel position.
6. Apply 1/2" drive torque wrench to pressure test tool and apply 107 N-m (80 ft-lbs) of torque.

Hold torque for a minimum of five seconds. If torque indication drops off, or wrench must be moved to maintain torque, the injector is leaking and must be replaced. If torque remains constant for five seconds without movement of the wrench, the injector is acceptable.

7. Remove torque wrench and pressure test tool from the injector rocker arm.
8. Connect adjusting link to injector control lever with clevis pin and retainer spring.
9. Test all remaining injectors.

## EXHAUST VALVE TIMING

### DESCRIPTION

Exhaust valve timing is very important as it ensures correct relationship of valve operation with the other events in the cylinder power cycle. To check or adjust exhaust valve timing, it is necessary to know the top dead center of each cylinder as shown in Table 2.

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

## MAINTENANCE

### LOCATING TOP DEAD CENTER

If it should become necessary to check the position of the flywheel or the flywheel pointer for top dead center, proceed as follows:

1. Remove an air box handhole cover at the No. 1 cylinder.
2. If necessary, bar the engine to position the No. 1 piston below the cylinder liner ports.
3. Insert a brass "stop-bar" (minimum 13 mm [1/2"] hexagonal or square preferred) of suitable length through the ports of the No. 1 cylinder so that the end of the bar passes through a port on the opposite side of the cylinder, Fig. 15-2.

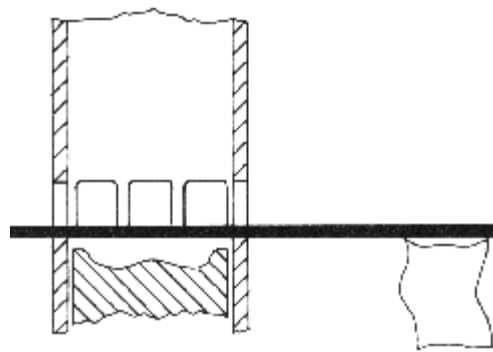


Fig. 15-2 -- "Stop-Bar" Inserted Through Cylinder Ports

NOTE: A bar of sufficient length to prevent reapplication of the handhole cover while the bar is in place is recommended. A flag on the end of the bar will caution against inadvertent rotation of the engine with the bar in place.

4. Manually bar the engine slowly in the normal direction of rotation until piston travel is stopped by the bar against the upper surfaces of the cylinder ports, Fig. 15-3.

CAUTION: Use extreme care to avoid excessive force.

5. Mark the position of the flywheel pointer on the flywheel, Fig. 15-4.

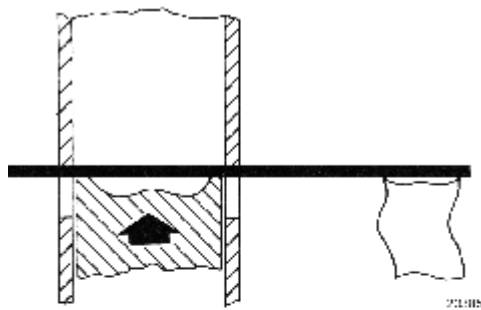


Fig. 15-3 - Piston Travel Limited By "Stop-Bar"

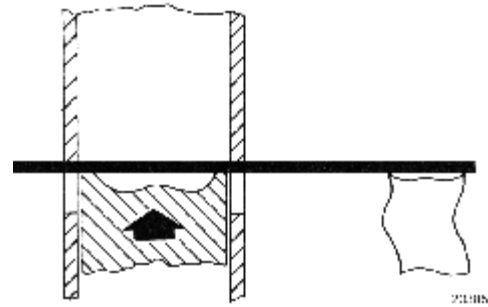


Fig. 15-3 - Piston Travel Limited By "Stop-Bar"

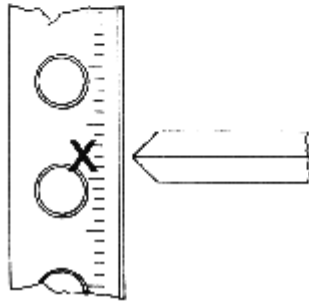


Fig. 15-4 - Limit of Piston Travel Marked On Flywheel

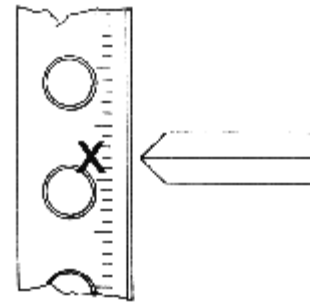
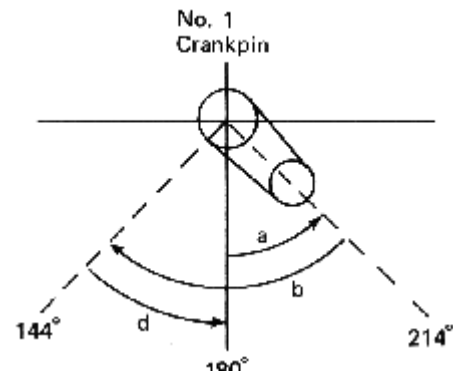


Fig. 15-5 -- Second Limit Of Piston Travel Marked On Flywheel

6. Manually bar the engine slowly in the opposite direction from normal rotation until piston travel is again stopped by the bar against the upper surfaces of the cylinder ports.
7. Mark the second position of the flywheel pointer on the flywheel, Fig. 15-5.
8. Determine the number of degrees between the two marks on the flywheel. Divide that number by 2. See Fig. 15-6 for a sample calculation.
9. Rotate the crankshaft in the normal direction of rotation the exact number of degrees determined in Step 8 above. Remove the brass "stop-bar" from the engine.
10. The pointer should indicate 180° (bottom dead center). If it does not, position the pointer so that it does indicate 180°. The pointer will now indicate top dead center for the No. 1 crankpin when the engine is rotated so that the pointer is at zero degrees (0°).



- 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.

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

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

Fig. 15-6 - Sample Calculation

## CHECKING EXHAUST VALVE TIMING

To check timing, place a dial indicator on the rocker arm adjusting screw as shown in Fig. 15-7. Valve end of rocker arm must be in its highest position, so that

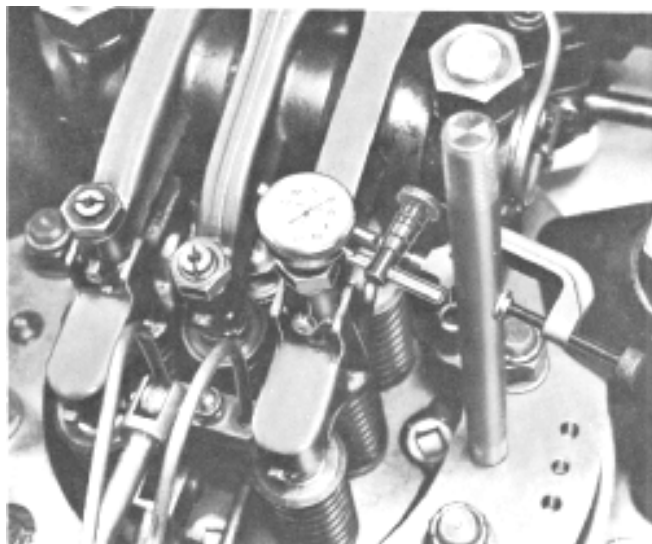


Fig. 15-7 -- Timing Exhaust Valves

the exhaust valves are closed. Press indicator down approximately 2.54 mm (.100") and set dial to zero.

Turn crankshaft in normal direction of rotation until flywheel is at 106° A.T.D.C. of cylinder being checked. If timing is correct, the valve bridge will have moved down 0.36 mm (.014"). Timing must not be later than 110° or earlier than 104° A.T. D.C. of cylinder being checked.

If timing is incorrect, check for:

1. Proper installation of camshaft.
2. Camshaft gear train correctly timed.
3. Excessively worn gears.

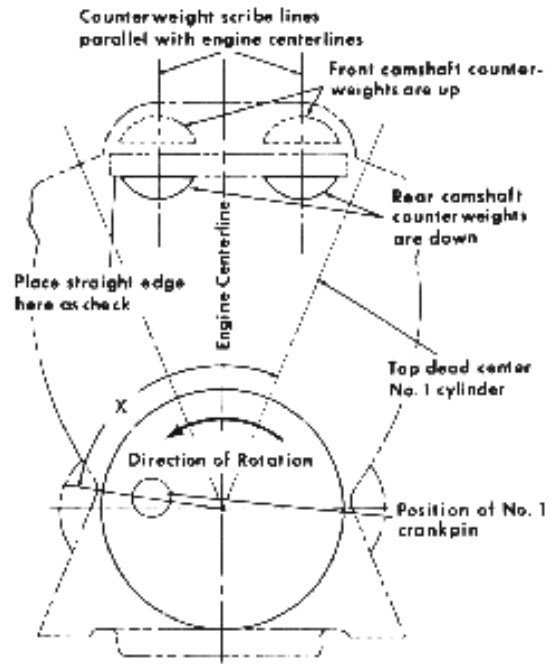
## TIMING EXHAUST VALVES

The exhaust valves should be timed when any gear or stubshaft of the camshaft gear train is replaced, with the exception of the No. 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. Refer to "Adjusting Hydraulic Lash Adjusters".

1. Apply dial indicator to the rocker arm adjusting screw, Fig. 15-7, as done in "Checking Exhaust Valve Timing."
2. Remove the dowels and bolts from the camshaft counterweight and remove counterweight and gear. The camshaft can be rotated by placing a socket and wrench on flange bolt nuts.
3. Rotate the camshaft in its normal direction of rotation until the valve bridge on which the dial indicator is resting moves down 0.36 mm (.014").
4. Turn the crankshaft in the normal direction of rotation until the flywheel pointer is at 105° after top dead center for the cylinder being checked. Install camshaft gear and counterweight on stubshaft, but do not tighten bolts at this time.
5. With flywheel at 105° A.T.D.C. of the cylinder being checked, the dowel holes in the camshaft drive gear, counterweight, and the camshaft stubshaft should be in line or approximately in line with each other. If by turning the crankshaft from 104° to 106° A.T. D.C., the dowel holes can be made to line up, then the bolts should be tightened.
6. If the dowel holes do not line up within this tolerance, remove the camshaft counterweight and gear from the stubshaft. Rotate the gear 180° and replace on 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 0.19 mm (.0075"), the holes may be reamed for installation of 0.005", 0.010", or 0.015" oversize dowels.  
  
If misalignment of dowel holes is greater than 0.19 mm (.0075) proceed to Step 17.
8. Insert 5/16"-24 bolts approximately 12.70 mm (1/2") into dowel pins.
9. Place dowels in dowel holes and drive into stubshaft. Remove dowel bolts from pins.
10. Remove counterweight to stubshaft bolts. 11. Install dowel retainer plate, and counterweight to stubshaft bolts. Torque bolts to 122 N-m (90 ft-lbs).

12. Install dowel pin bolts and torque to 23 N-m (17 ft-lbs).
13. Lockwire mounting bolts and dowel bolts in groups of three. (Two mounting bolts and one dowel bolt).
14. The crankshaft should now be rotated in its normal direction and the timing checked so that the valve bridge of the valve being checked has moved down 0.36 mm (.014") when the flywheel timing pointer is at 104°106° A.T.D.C.
15. Repeat the operation on one cylinder on the opposite bank.
16. After timing has been completed, the relative position of the mating parts should be identified similar to the method used on new engines. The mating parts are marked with No. 1 piston at top dead center. This completes valve timing procedures.
17. Remove counterweight and gear from stubshaft.



X = Degrees after T.D.C. of No. 1 cylinder. To get the crankshaft in this position, turn the flywheel until this number is at the pointer.

18. Plug dowel holes in stubshaft as follows:
  - a. Drill and tap the two dowel holes for 3/4"-16 NF thread with a minor diameter of 0.7031" + 0.005" - 0.000" and pitch diameter of 0.7094" + 0.0016" - 0.0000".
  - b. Countersink 1.6 mm (1/16") on gear mounting side.
  - c. Drive threaded, hex head plugs (8166882) into holes.
  - d. Cut plug head off and flare by peening into countersink.
  - e. Grind plugs flush with flange face.
  - f. Check 5.7495" + 0.000" - 0.001" flange O.D. for high spots and grind to proper dimension.

8-Cyl. Eng.	12-Cyl. Eng.	16-Cyl. Eng.	20-Cyl. Eng.
X = 184°	X = 249-1/2°	X = 105°	X = 149-1/2°

Fig. 15-8 -- Timing Relationship Between Crankshaft and Camshaft Counterweights

21. Remove gear mounting bolts and position gear and counterweights on stubshaft with counterweight in down position and counterweight scribe line parallel with engine centerline. Ensure that gear and counterweight dowel holes are aligned.
22. Install mounting bolts to secure gear and counterweight to stubshaft.
23. Drill and ream stubshaft dowel holes to 12.662 mm + 0.13 mm - 0.00 mm (.4985" + .005" - .000").
24. Perform Steps 8 thru 16.

CAUTION: If camshaft to crankshaft relationship has been disturbed, repeat Step 3.

19. Apply camshaft gear to stubshaft and secure with mounting bolts.
20. Rotate engine crankshaft to position indicated in Fig. 15-8.

## ADJUSTING HYDRAULIC LASH ADJUSTERS

Application of properly operating lash adjusters, correct setting, and subsequent inspection at regular maintenance intervals is very important to valve

operation. Improperly set or defective lash adjusters cause the exhaust valves to be subjected to increased stress which leads to ultimate failure and probable damage to the engine.

After complete cylinder head assembly or power assembly has been installed, the lash adjusters must be set.

1. Open cylinder test valve and rotate crankshaft so that piston is at or near top dead center of the cylinder being set.
2. Loosen rocker arm adjusting screw locknuts.
3. Turn rocker arm adjusting screw down until the last valve just touches the hydraulic lash adjuster plunger, or use a 0.03 mm (.001") shim between valve tip and adjuster plunger, and then turn it down 1-2 turns.
4. Check valve bridge spherical seat to be sure that it is spring-loaded against the cylinder head spherical seat. If the bridge spring spherical seat is not spring-loaded against the cylinder head spherical seat, turn down the rocker arm adjusting screw until no movement is felt, and then turn it another 1/4 turn.
5. Tighten rocker arm adjusting screw locknut.
6. After running the engine until lube oil reaches operating temperature, check the clearance between lash adjuster bodies and the end of the valve stems with the piston near top center. If the clearance is less than minimum, the cylinder head should be removed for reconditioning or rejection. Use minimum clearance gauge, Fig. 15-9, to gauge clearance between lash adjuster and exhaust valve. This gauge is 1.59 mm (1/16") thick and it should fit between lash adjuster body and valve stem top, to ensure the minimum clearance.

2. Insert injector timing gauge into the hole provided for it in the injector body, Fig. 15-10.

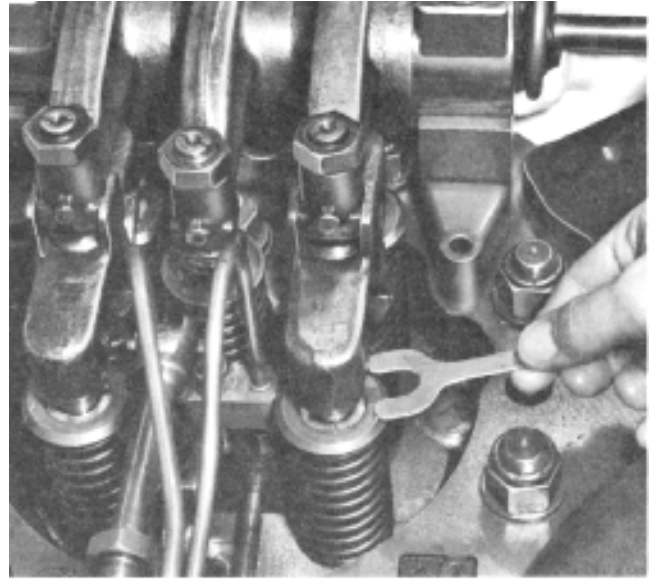


Fig. 15-9 - Checking Lash Adjuster To Valve Clearance

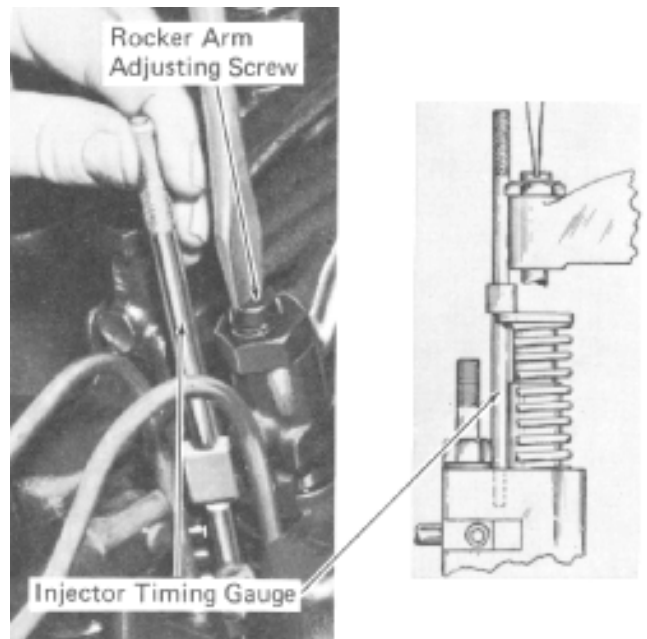


Fig. 15-10 - Timing Injector

## TIMING THE INJECTOR

With the injector installed, make timing adjustment as follows:

- 1A. On a blower engine, set the flywheel at 4° before top dead center of the cylinder being timed.
- 1 B. On a turbocharged engine, set the flywheel at 0° top dead center of the cylinder being timed.

NOTE: Refer to Table 2 for top dead center settings.

3. Loosen locknut and turn the rocker arm adjusting screw until the shoulder of the gauge just passes over the injector follower guide.

NOTE: Injectors cannot be timed if the overspeed has been tripped. It must first be reset and the engine crankshaft barred over at least one revolution.

4. Tighten adjusting screw locknut, holding adjusting screw in position with a screwdriver.
5. Recheck setting.

## SETTING INJECTOR RACKS

Injector racks should be set with the engine at operating temperature. If racks are set when engine is not at operating temperature, the settings should be rechecked when operating temperature is reached. As engine temperature increases, the right bank rack length shortens and the left bank rack length increases. The change on the left bank is insignificant, but the change on right bank may shorten the racks beyond the minus 0.40 mm (1 / 64") tolerance.

NOTE: Every time a governor is installed on an engine the injector rack setting should be checked. Due to manufacturing tolerances in governor mounting bolt holes, the position of the governor in relation to the injector linkage can change the rack setting.

Set the injector rack on the engine as follows:

1. Install the applicable injector linkage setting jack, Fig. 15-11.
2. For engines equipped with PG or EGB-10 governors, adjust the setting jack until the pointer

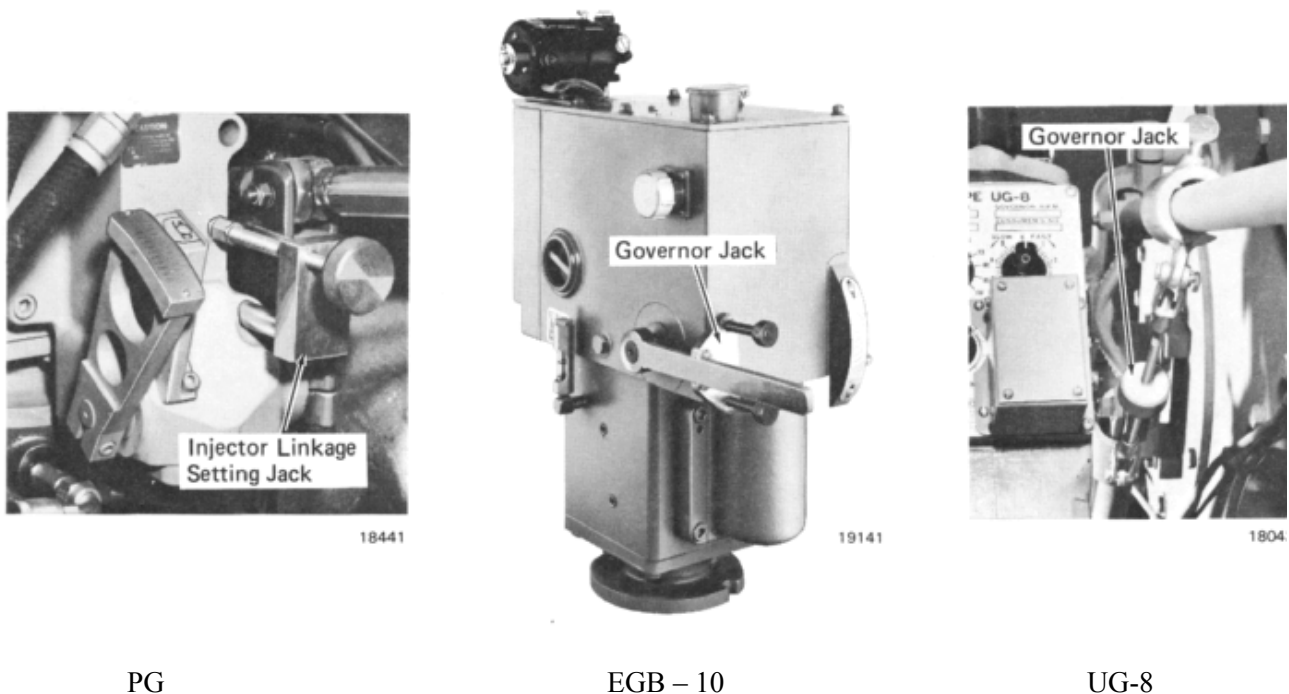
on the governor aligns with governor terminal shaft scale at the 1.00 mark.

For engines equipped with UG-8 governors, turn the LOAD LIMIT knob on the governor to the maximum load position. Adjust the setting jack until the terminal shaft is in full fuel position.

3. Use the rack gauge, without the adapter, Fig. 15-12, for setting the rack on engines having PG or EGB-10 type governors. Set the rack within the setting range marks on the gauge. Use the rack gauge with the adapter, Fig. 1512, for setting the racks on engines having UG-8 governors. Set the rack within the setting range marks on the gauge.

The rack setting gauge is an 8 to 1 multiplying gauge which indicates the 0.40 mm (1/64") tolerance by marks 3.18 mm (1/8") each side of the center mark on the gauge scale.

It is important that the proper rack gauge be used, as previous model rack gauges will measure the rack length from the body of the injector instead of from the face of the calibrating slide. The correct gauge for setting injectors with calibrating slides can be readily identified by a single locating button on the front face of the gauge. This gauge can be used for all injectors.



PG

EGB – 10

UG-8

Fig. 15-11 - Injector Rack Positioning

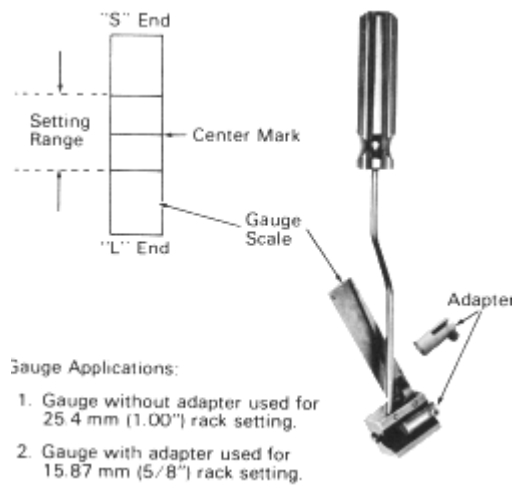


Fig. 15-12 - Injector Rack Gauge

4. Place the gauge over the injector rack and hold the gauge firmly against the face of the calibrating slide on the injector, Fig. 15-13, and check the gauge pointer. If the pointer is at the short ("S") end of gauge scale, outside of the setting range, the rack is not extending out far enough from the injector. Loosen the locknut on the adjusting link and turn adjusting nut on link until pointer is at the long ("L") end of the scale; then reverse pointer travel until it is within the scale setting range. Hold the adjusting nut and tighten locknut. The reason for exceeding the setting range when making adjustment is so that, in setting of the racks, the backlash will be taken up in the same direction.
5. When pointer is at the long ("L") end of scale, set pointer within the setting range. The accuracy of the injector rack gauge can be checked by inserting the master block in the gauge body. Pointer should align with center mark on scale.

## "ONE REVOLUTION" INSPECTION SEQUENCE CHARTS

The following engine "one revolution" inspection sequence charts show the power assembly checks that can be visually made during one revolution of the engine crankshaft. Select the chart which is applicable to the number of cylinders and the direction of rotation of the engine to be inspected.

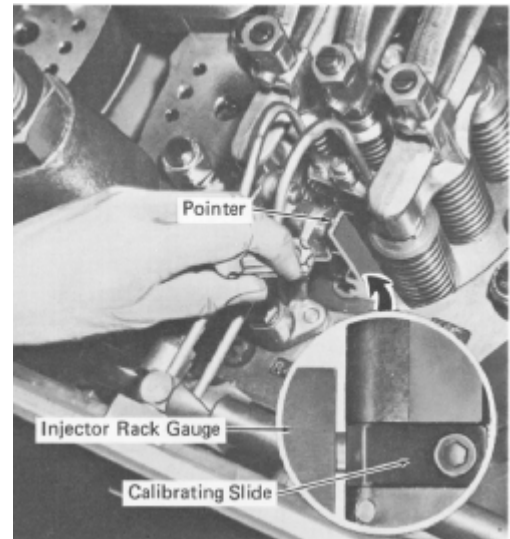


Fig. 15-13 - Injector Rack Gauge Application

NOTE: The right-hand rotation charts are applicable only to right-hand rotation marine engines.

Start with the engine flywheel at "0" degrees on the pointer. Bar the engine over slowly in the normal direction of rotation and read the chart to the right of "flywheel degrees" for the cylinder number and the check to be made. Column headings are as follows:

### FLYWHEEL DEGREES

**BLOWER** - Indicates the flywheel setting required on a blower-type engine to perform the applicable inspections.

**TURBOCHARGED** - Indicates the flywheel setting required on a turbocharged engine to perform the applicable inspections.

**SET INJECTOR** - The number appearing in this column opposite "flywheel degrees" indicates that the injector of that cylinder can be timed.

### No. 1 RING

**U P** - The number appearing in this column indicates that the compression rings in that cylinder are moving upward past the ports of the liner, and can be inspected.

**DOWN** - The number appearing in this column indicates that the compression rings in that cylinder are moving downward past the ports of the liner, and can be inspected.

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.

**8-CYLINDER ENGINE (LEFT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE**

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1					4
18 ½	—		7	2			
41	45	5					8
63 ½	67 ½		4	6	4-6	1-7	
86	90	3					2
108 ½	112 ½		8	1			
131	135	7					6
153 ½	157 ½		2	5	2-5	3-8	
176	180	4					1
198 ½	202 ½		6	3			
221	225	8					5
243 ½	247 ½		1	7	1-7	4-6	
266	270	2					3
288 ½	292 ½		5	4			
311	315	6					7
333 ½	337 ½		3	8	3-8	2-5	

**12-CYLINDER ENGINE (LEFT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE**

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1	3	2	3-2	8	
15	19	12	10	11	10-11	4	
							5
41	45	7	9	8	9-8	3-6	
							2
66	70					10-1	
							11
90	94	4	5	6	5-6	9-12	
							8
116	120	3	2	1	2-1	7	
135	139	10	11	12	11-12	5	
							6
161	165	9	8	7	8-7	2-4	
							1
186	190					11-3	
							12
210	214	5	8	4	8-4	8-10	
							7
236	240	2	1	3	1-3	9	
255	259	11	12	10	12-10	6	
							4
281	285	8	7	9	7-9	1-5	
							3
306	310					12-2	
							10
330	334	6	4	5	4-5	7-11	
							9
356	0	1	3	2	3-2	8	

**16-CYLINDER ENGINE (LEFT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE**

FLYWHEEL		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO- CHARGED		UP	DOWN			
356	0	1	6	13	6-13	7-16	4
18 <sup>1</sup> / <sub>2</sub>	22 <sup>1</sup> / <sub>2</sub>	8	11	2			5
41	45	9	14	7			12
63 <sup>1</sup> / <sub>2</sub>	67 <sup>1</sup> / <sub>2</sub>	16	4	10	4-10	1-11	13
86	90	3	5	15	5-15	8-14	2
108 <sup>1</sup> / <sub>2</sub>	112 <sup>1</sup> / <sub>2</sub>	6	12	1			7
131	135	11	13	8			10
153 <sup>1</sup> / <sub>2</sub>	157 <sup>1</sup> / <sub>2</sub>	14	2	9	2-9	3-12	15
176	180	4	7	16	7-16	6-13	1
198 <sup>1</sup> / <sub>2</sub>	202 <sup>1</sup> / <sub>2</sub>	5	10	3			8
221	225	12	15	6			9
243 <sup>1</sup> / <sub>2</sub>	247 <sup>1</sup> / <sub>2</sub>	13	1	11	1-11	4-10	16
266	270	2	8	14	8-14	5-15	3
288 <sup>1</sup> / <sub>2</sub>	292 <sup>1</sup> / <sub>2</sub>	7	9	4			6
311	315	10	16	5			11
333 <sup>1</sup> / <sub>2</sub>	337 <sup>1</sup> / <sub>2</sub>	15	3	12	3-12	2-9	14

**20-CYLINDER ENGINE (LEFT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE**

FLYWHEEL DEGREES		NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
TURBO- CHARGED	SET INJECTOR	UP	DOWN			
0	1	15	3	15-6	4	10
9	19	17	6	15-6	16	12
36	8	17	6	17-4	9	3
45	11	12	4	17-4	14	20
72	5	12	4	12-9	1	6
81	18	20	9	12-9	19	13
108	7	20	9	20-1	8	4
117	15	13	1	20-1	11	16
144	2	13	1	13-8	5	9
153	17	16	8	13-8	18	14
180	10	16	8	16-5	7	1
189	12	14	5	16-5	15	19
216	3	14	5	14-7	2	8
225	20	19	7	14-7	17	11
252	6	19	7	19-2	10	5
261	13	11	2	19-2	12	18
288	4	11	2	11-10	3	7
297	16	18	10	11-10	20	15
324	9	18	10	18-3	6	2
333	14	15	3	18-3	13	17
360	1	15	3	15-6	4	10

(MARINE ONLY) 8-CYLINDER ENGINE (RIGHT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1					4
18 ½	22 ½		8	3			
41	45	6					
63 ½	67 ½		4	5	4-5	1-8	
86	90	2					3
108 ½	112 ½		7	1			
131	135	8					5
153 ½	157 ½		3	6	3-6	2-7	
176	180	4					1
198 ½	202 ½		5	2			
221	225	7					6
243 ½	247 ½		1	8	1-8	4-5	
266	270	3					2
228 ½	292 ½		6	4			
311	315	5					8
333 ½	337 ½		2	7	2-7	3-6	
356	0	1					4

(MARINE ONLY) 12-CYLINDER ENGINE (RIGHT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1	2	3	2-3	8	
							9
22	26	6	5	4	5-4	7-11	
							10
46	50					2-12	
							3
71	75	8	9	7	9-7	1-5	
							4
97	101	11	10	12	10-12	6	
116	120	2	3	1	3-1	9	
							7
142	146	5	4	6	4-6	8-10	
							12
166	170					11-3	
							1
191	195	9	7	8	7-8	2-4	
							6
217	221	10	12	11	12-11	5	
236	240	3	1	2	1-2	7	
							8
262	266	4	6	5	6-5	9-12	
							11
286	290					10-1	
							2
311	315	7	8	9	8-9	3-6	
							5
337	341	12	11	10	11-10	4	
356	0	1	2	3	2-3	8	

(MARINE ONLY) 16-CYLINDER ENGINE (RIGHT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES		SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
BLOWER	TURBO-CHARGED		UP	DOWN			
356	0	1	13	6			4
18 ½	22 1/2	15	12	3			14
41	45	10	5	16	5-16	8-13	11
63 ½	67 ½	7	4	9	4-9	1-12	6
86	90	2	14	8			3
108 ½	112 ½	13	11	1			16
131	135	12	6	15	6-15	7-14	9
153 ½	157 ½	5	3	10	3-10	2-11	8
176	180	4	16	7			1
198 ½	202 ½	14	9	2			15
221	225	11	8	13	8-13	5-16	10
243 ½	247 ½	6	1	12	1-12	4-9	7
266	270	3	15	5			2
288 ½	292 ½	16	10	4			13
311	315	9	7	14	7-14	6-15	12
333 ½	337 ½	8	2	11	2-11	3-10	5
356	0	1	13	6			4

(MARINE ONLY) 20-CYLINDER ENGINE (RIGHT-HAND ROTATION)  
"ONE REVOLUTION" INSPECTION SEQUENCE

FLYWHEEL DEGREES	SET INJECTOR	NO. 1 RING		PISTON COOLING OIL PIPE	PISTON	LINER
		UP	DOWN			
0	1	20	7	13-7	5	10
27	14	20	7	20-5	11	17
36	9	12	5	20-5	8	2
63	16	12	5	12-8	19	15
72	4	17	8	12-8	1	7
99	13	17	8	17-1	14	18
108	6	15	1	17-1	9	5
135	20	15	1	15-9	16	11
144	3	18	9	15-9	4	8
171	12	18	9	18-4	13	19
180	10	11	4	18-4	6	1
207	17	11	4	11-6	20	14
216	2	19	6	11-6	3	9
243	15	19	6	19-3	12	16
252	7	14	3	19-3	10	4
279	18	14	3	14-10	17	13
288	5	16	10	14-10	2	6
315	11	16	10	16-2	15	20
324	8	13	2	16-2	7	3
351	19	13	2	13-7	18	12
0	1	13	7	13-7	5	10

INTERPRETATION OF LUBE OIL SAMPLE ANALYSIS

LUBE OIL ANALYSIS	BASIS FOR ANALYSIS	NORMAL No Action Required	BORDERLINE Take Extra Oil Samples	HIGH Correct Condition	RECOMMENDED ACTION WShut Down Engine. Drain Lube Oil. Change Filters.
Fuel Leak	Viscosity & Flash Point -- Check for dilution if flash point less than 400° F or oil viscosity drops 15% or more.	0 to 2%	2 to 5%	Above 5%	Borderline find and fix fuel leak. High - check main bearings per maintenance manual.
Water Leak	Free Water	None		Any	Resample with dry container. Find and fix leak. Check main bearings per maintenance manual.
	Chromate Inhib.	0 to 20 PPM	20 to 40 PPM	Above 40 PPM	Find and fix water leak. Check lube oil filter
	Boron Inhibitor	0 to 10 ppm	10 to 20 ppm	Above 20 ppm	tank pressure.
Air Filtration	Silicon	0 to 5 ppm	5 to 10 ppm	Above 10 ppm	Improved air filter maintenance required.
Excessive Oxidation	Viscosity Rise, TBN, pH (per ASTM D664 method), & Pentane Insol.	Normal		Viscosity 30% rise, TBN 0.5 min., pH 5.0, P.I. 2% max. Change oil.	If short oil life persists, check lube oil quality, fuel sulphur content, oil cooler efficiency, engine temperature controls, power output (governor and rack settings), engine condition (worn rings, cracked pistons, poor combustion), oil filtration, or oil pump suction leak.
Contaminated fuel (cracking catalyst)	Aluminum Magnesium		Above 5 PP m		Check fuel cleanliness. Notify fuel supplier. If engine smokes, check injector calibration and tip erosion. Check if piston rings are excessively worn.
Oil Contamination	Zinc	0 to 10 ppm	Above 10 dangerous values.	ppm becomes more with increasing	Check if oil is contacting galvanized or zinc painted surfaces. Check if make up oil in stock is within specifications. Notify lube oil supplier. Check for silver bearing failures. Check if oil contains zinc or is corrosive to silver. Check for broken piston cooling tubes, inefficient oil cooler, or improper temperature control. Feel sides of insert bearings for signs of distress. Measure piston to head clearance with lead readings. Oil draining is not mandatory. Check strainers and bottom of oil pan for debris. Consider turbo bearing condition.
	Silver	0-1 ppm	1-2 ppm	Above 2 ppm	
Abnormal Wear or Corrosion (Rapid increases within normal range should be considered borderline condition) condition)	Chromium (Not applicable if chromate coolant inhibitor is used)	0 to 10 ppm	10 to 20 ppm	Above 20 ppm	Check for rapid wear of rings & liners.
	Copper	0 to 75 ppm	75 to 150 ppm	Above 150 ppm	Measure piston to head clearance with lead readings to locate worn piston thrust washers.
	Iron	0 to 75 ppm	75 to 125 ppm	Above 125 ppm	Check for rapid wear of rings & liners.
	Lead	0 to 50 ppm	50 to 75 ppm	Above 75 ppm	Most likely lead flash is dissolving off bearings. Premature lead removal, before bearings are broken in, can lead to bearing distress. Inspect and replace upper con rod bearings in service less than 6 months if lead flash has been removed from the unloaded area of the fishback bearing surface on turbocharged engines. If con rod bearings require replacement, wrist pin bearings should also be checked and replaced if lead
In Combination	Copper Iron Lead		Two out of in borderline three elements or high range.		Check for debris under crankshaft gear indicative of gear train bushing distress. Check idler gear bearing clearances. Check main and con rod bearings per maintenance manual. Oil draining is not mandatory.

\*In areas where fuel sulfur content exceeds 0.5%

{a TBN (D664) level of 1.0 should be maintained  
{a TBN (D2896) level of 3.0 should be maintained.

Table I - Interpretation 01- Lube Oil Sample Analysis

Firing Order	8-Cylinder Top Dead Center	Firing Order	8-Cylinder Top Dead Center
1	0'	1	0'
5	45'	6	45"
3	90'	2	90'
7	135'	8	135'
4	180'	4	180°
8	225°	7	225°
2	270°	3	270'
6	315°	5	315'
12-cylinder Firing Order	Top Dead Center	Firing Order	12-Cylinder Top Dead Center
1	0'	1	0'
12	19'	6	26'
7	45*	8	75*
4	94'	11	101'
3	120°	2	120°
10	139°	5	146°
9	165°	9	195°
5	214°	10	221°
2	240°	3	240'
11	259°	4	266'
8	285°	7	315'
6	334°	12	341'
Firing Order	16-Cylinder Top Dead Center	Firing Order	16-Cylinder Top Dead Center
8	22-1/2'	15	22-1/2'
9	45'	10	45'
16	67-1/2'	7	67-1/2'
3	90'	2	90'
6	112-1/2'	13	112-1/2'
11	135'	12	135'
14	157-1/2'	5	157-1/2'
4	180'	4	180'
5	202-1/2'	14	202-1/2'
12	225'	11	225'
13	247-1/2'	6	247-1/2'
2	270'	3	270'
7	292-1/2'	16	292-1/2'
10	315'	9	315'
15	337-1/2'	8	337-1/2'
Firing Order	20-Cylinder Top Dead Center	Firing Order	20-Cylinder Top Dead Center
19	9"	14	27'
8	36'	9	36"
11	45,	16	63°
5	72"	4	72°
18	81'	13	99'
7	108°	6	108°
15	117'	20	135'
2	144°	3	144°
17	153	12	171°
10	180	10	180°
12	189	17	207°
3	216°	2	216°
20	225°	15	243'
6	252'	7	252°
13	261°	18	279°
4	288'	5	288°
16	297°	11	315°
9	324'	8	324°
14	333,	19	351°

**Note**

Locomotive, drilling rig, and power generating installations are available only with left-hand rotating engines. Only marine and industrial installations are available with either a left or righthand rotating engine.

Table 2 - Firing Order And Top Dead Center For 645 Engines

## GOVERNOR AND GOVERNOR RELATED TROUBLESHOOTING

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
<p>Insufficient travel of injector adjusting link to obtain correct injector rack setting.</p> <p>Governor low oil plunger trips when starting engine.</p>	<ol style="list-style-type: none"> <li>1. Wrong terminal shaft lever applied to governor.</li> <li>2. Terminal shaft lever improperly applied to governor.</li> <li>3. Wrong terminal shaft on governor.</li> <li>4. Wrong terminal shaft scale on governor.</li> <li>1. Governor low oil time delay too short, or engine slow in developing oil pressure.</li> <li>2. Differential water or crankcase pressure detector tripped.</li> <li>3. Engine oil pressure line to governor broken or crimped.</li> <li>4. Hot oil shutdown valve stuck open or leaking.</li> <li>5. True low engine oil pressure.</li> </ol>	<ol style="list-style-type: none"> <li>1. Change terminal shaft lever. Lever should measure 106.4 mm (4-3/16") between hole centers.</li> <li>2. If lever has no double serration, apply new lever. Lever should have double width serration matched with missing serration of terminal shaft.</li> <li>3. Replace governor. Missing serration should be at 3 o'clock position.</li> <li>4. Replace governor. Scale should be graduated from 1.96" to .62".</li> <li>1. Reset governor low oil plunger immediately, and crank engine again. With engine operating at idle, check and reset time delay, if necessary. See EMM Governor Section.</li> <li>2. Check detector reset buttons to ensure they are in the set position.</li> <li>3. Replace oil line.</li> <li>4. Replace valve if defective. See LSM Lubricating Oil Section.</li> <li>5. See EMM Lubricating Oil Section.</li> </ol>



<p>Governor hunts.</p>	<ol style="list-style-type: none"> <li>1. Compensating needle valve not properly adjusted.</li> <li>2. Too much or too little oil in governor.</li> <li>3. Governor hunts for a short time when engine oil and governor oil are cold.</li> <li>4. Insufficient fuel.</li> <li>5. Binding injector control shaft linkage or sticking injector.</li> <li>6. Wheel slip action due to variations in locomotive wheel diameter.</li> <li>7. Governor binding internally.</li> </ol>	<ol style="list-style-type: none"> <li>1. See EMM Governor Section.</li> <li>2. See EM M Governor Section for procedure, and M. I. 1764 for correct oil.</li> <li>3. Run engine for a short period of time to warm the oil.</li> <li>4. Fuel return sight glass must be full and relatively clear at all speeds and loads. Replace fuel filter elements and clean fuel strainer element. Check that fuel pump is of adequate capacity.</li> <li>5. Make certain that all control shaft linkage is free. (Replace sticking injector or free up linkage.)</li> <li>6. Match wheel diameters.</li> <li>7. Replace governor.</li> </ol>
<p>Governor hunts only at full load.</p>	<ol style="list-style-type: none"> <li>1. Insufficient fuel to maintain engine speed at full load. Partial fuel restriction.</li> <li>2. Defective load regulator rheostat.</li> <li>3. Other electrical problems.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace fuel filter elements. Clean fuel strainer element. Fuel return sight glass must be full.</li> <li>2. Qualify rheostat.</li> <li>3. See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual.</li> </ol>
<p>Engine overloaded. Governor terminal shaft at full fuel position, but engine speed bogs down. Load regulator in minimum field position.</p>	<ol style="list-style-type: none"> <li>1. Insufficient fuel.</li> <li>2. Over excitation of main generator. Fault in power control circuits.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check fuel filter and strainer. Return fuel sight glass must be full.</li> <li>2. See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual.</li> </ol>

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
<p>Engine underloaded. (Not producing proper horsepower.) Engine at rated speed.</p> <p>Governor terminal shaft at longer than specified rack, and load regulator in maximum field position.</p> <p>Engine is loaded and runs at rated speed, but Governor terminal shaft is at longer than specified rack length.</p> <p>Load regulator is balanced.</p>	<p>Under excitation of the main generator. Fault in power control circuits.</p> <p>1. Governor terminal shaft quadrant pointer off location.</p> <p>2. Low air box pressure.</p> <p>3. Leak or restriction in air line from air box to governor.</p> <p>4. Locknut on overriding solenoid backed off, holding rebalancing rocker arm up.</p> <p>5. Improperly set governor.</p>	<p>See Electrical Qualification procedures in Troubleshooting Guide and Locomotive Service Manual.</p> <p>1. With engine shut down, quadrant scale should indicate 1.96". Relocate quadrant pointer and reset injector racks.</p> <p>2. Run engine at 8th throttle, no load. Air box pressure should be within one-half psi of that of similar unit at 8th throttle, no load. If air box pressure is low check:</p> <ul style="list-style-type: none"> <li>a. Turbocharger impeller for damage.</li> <li>b. Aftercooler and filters for plugging.</li> <li>c. Aftercooler duct for leakage.</li> <li>d. Exhaust manifold for leakage.</li> </ul> <p>3. Remove air line and check. Replace if necessary.</p> <p>4. Readjust governor overriding solenoid and tighten locknut. See EMM Governor Section.</p> <p>5. Replace governor.</p>

<p>Engine is loaded and runs at rated speed, but Governor terminal shaft is at shorter than specified rack length.</p>	<ol style="list-style-type: none"> <li>1. Governor terminal shaft quadrant pointer off location.</li> <li>2. Improperly set governor.</li> </ol>	<ol style="list-style-type: none"> <li>1. With engine shut down, quadrant scale should indicate 1.96". Relocate quadrant pointer, and reset injector racks.</li> <li>2. Replace governor.</li> </ol>
<p>Load regulator is balanced.</p>	<ol style="list-style-type: none"> <li>1. Insufficient fuel.</li> <li>2. One or more injectors defective.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check fuel filter and strainer. Return fuel sight glass must be full.</li> <li>2. Qualify injector. See EMM Fuel Section.</li> </ol>
<p>Load regulator stays in minimum field position with the engine at idle.</p>	<ol style="list-style-type: none"> <li>3. Governor overriding solenoid stuck, or spring under over riding solenoid plunger broken.</li> <li>4. Injector rack length not properly set at 1.00" on governor terminal shaft scale.</li> <li>5. Governor to load regulator lines reversed.</li> </ol>	<ol style="list-style-type: none"> <li>3. Replace governor.</li> <li>4. Reset injector rack length. See EMM Fuel Section.</li> <li>5. Reapply lines correctly.</li> </ol>
<p>Governor fills with oil.</p>	<ol style="list-style-type: none"> <li>1. Ruptured low oil pressure diaphragm.</li> <li>2. Defective seal on load control pilot valve plunger.</li> <li>3. Porous column casting.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace diaphragm or change out governor.</li> <li>2. Replace governor.</li> <li>3. Replace governor.</li> </ol>
<p>Governor loses oil.</p>	<ol style="list-style-type: none"> <li>1. Defective drive shaft seal.</li> <li>2. Defective terminal shaft seal.</li> </ol>	<ol style="list-style-type: none"> <li>1. Replace drive shaft seal or replace governor.</li> <li>2. Replace governor.</li> </ol>

TROUBLE REPORT	I POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
<p>Governor does not change speed when throttle is changed.</p> <p>Engine speed will not increase beyond 6th throttle speed.</p>	<ol style="list-style-type: none"> <li>1. Loose governor plug.</li> <li>2. Solenoids do not respond to throttle setting.</li> <li>3. Locomotive in consist does not reduce engine speed for corresponding throttle reduction. Low voltage feed in trainline holds solenoids(s) in once energized.</li> </ol> <ol style="list-style-type: none"> <li>1. Engine air filters clogged.</li> <li>2. Engine filter switch defective.</li> </ol>	<ol style="list-style-type: none"> <li>1. Check governor plug for looseness. Replace governor.</li> <li>2. Replace governor.</li> </ol> <p>Make certain that control circuits are providing power to energize solenoids.</p> <ol style="list-style-type: none"> <li>3. Correct control circuit problem.</li> </ol> <ol style="list-style-type: none"> <li>1. Replace engine air filter elements</li> <li>2. Replace engine air filter switch.</li> </ol>

# TURBOCHARGER TROUBLESHOOTING

## GENERAL

More than 50% of turbocharger failures are caused by conditions external to the turbocharger. If these conditions are not corrected, the replacement turbocharger may also fail in a very short time. In other cases, an engine problem is attributed to a failed turbocharger, while in fact, nothing is wrong with the turbocharger. Therefore, troubleshooting a turbocharger requires two decisions.

1. Whether or not the turbocharger has actually failed and requires replacement.
2. The actual cause of the failure.

Any turbocharger suspected of being defective should be inspected for obvious damage. The entire housing should be inspected for cracks and oil leaks. Some oil leaks can be repaired merely by tightening a pipe plug or by applying silastic rubber sealant, but an intolerable leak from a crack or from an inaccessible area requires turbocharger changeout.

## INSPECTION BEFORE ENGINE START

### IMPELLER INSPECTION

An impeller inspection should be made on all turbochargers suspected of a failure except those suspected of exhaust gas leaks.

1. Remove the rubber air intake boot and flange.
2. Inspect the impeller for broken or nicked vanes or any visible signs of rubbing. On Unit Exchange turbochargers do not confuse smooth blends in the impeller surface or on the vane with sharp nicks caused by foreign material.
3. Turn the impeller by hand to check for a locked up condition or a badly damaged clutch. It should turn freely in the counterclockwise direction, but engage when turned clockwise.
4. Displace the impeller laterally, vertically, fore, and aft to determine excessive radial or end thrust clearance.
5. Inspect the clearance between the impeller and the cover to reveal any impeller contact.

Any defective condition found during this inspection requires turbocharger replacement. If no defective condition is found, reinstall the flange and boot.

## ENGINE INSPECTION

Often a reported turbocharger failure is actually a failure of some other engine component. The engine should be barred over to determine if it is damaged before a starting attempt is made and inspection continued.

## INSPECTIONS AFTER ENGINE START

### TURBOCHARGER REPORTED MAKING UNUSUAL NOISE

Identical turbocharger components can make varied sounds due to the tolerances within which the components are manufactured. The sum of these individual sounds results in a wide range of noise such 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 performed.

1. Inspect the impeller as outlined above.
2. Remove a handhole cover and check for metallic debris under the crankshaft gear. Such debris is indicative of a gear train problem.

### TURBOCHARGER REPORTED THROWING OIL OUT OF THE EXHAUST STACK

Inspect the exhaust stack to ensure that the oil is actually coming out of the stack.

A plugged and leaking turbocharger seal cannot be found through external inspection, so it must be determined by process of elimination only if no other faulty condition is discovered.

1. Shut the engine down and remove the expansion joint and turbocharger exhaust inlet screen from the engine. Varnish, oil, and heavy carbon on the screen indicates the oil is not coming from the turbocharger, but from the engine.
2. Inspect for blocked air filters and renew paper or fiberglass elements if necessary. Clean oil bath filters. A portion of the turbocharger

- b. Check for an air box leak, especially at the turbocharger discharge scroll gaskets and the air box covers.
  - c. Check the pressure drop across the after-coolers, and correct if necessary.
  - d. Check for exhaust leaks at manifold or expansion joints. Check for leaky gaskets or a leaking pipe plug on top of the turbocharger exhaust inlet scroll.
  - e. A low pressure reading can occur when a clutch is in extremely bad condition so that it will slip when the turbocharger is driven by the gear train. This condition may cause poor starting as well as smoking or burping. Take off the rubber boot and clear the area around the turbocharger inlet of all foreign material. Observe the impeller while attempting to start the engine. A badly damaged clutch will slip consistently.
4. If the pressure readings taken on the unit under inspection and the reference unit are equal, and there is a definite malfunction, the problem may be a slipping turbocharger clutch or some external malfunction. It is usual for a malfunctioning clutch to slip only intermittently, therefore only occasionally causing burping and smoking by its failure to engage. A failed clutch requires turbocharger changeout.
- a. Idle the engine.
  - b. Operate the injector rack manual control lever to increase engine speed to about 700 RPM. Then pull the manual control lever to the "no fuel" position. This action will allow the turbocharger to spin free from the decelerating engine and disengage the clutch.
  - c. When the engine has almost stopped, return the injector rack manual control lever to the idle position. The engine will accelerate and the clutch should engage.
  - d. Repeat the procedure until the clutch fails to engage. A worn clutch may fail to engage only once in as many as 30 attempts. When it fails to engage, the injector racks will move toward "full fuel" position, the engine will produce heavy black smoke, and rumbling noises may come from the engine.

## **TURBOCHARGER EXHAUST LEAK REPORTED**

Start the engine and determine if it is actually leaking exhaust. Some turbochargers look sooty because of exhaust leaks at expansion joints or manifold gaskets. Most turbocharger exhaust leaks occur at cracks in the exhaust inlet scroll or at the sealing areas on either side of the exhaust duct. These types of leaks cannot be repaired in the field and require turbocharger changeout.

## **FAILURE PREVENTION**

After turbocharger failure has been verified, it is very important to determine the cause of the failure and take preventive measures to ensure that the replacement turbocharger will not fail.

While the turbocharger is removed from the engine, inspect all open areas.

1. Impeller.
2. Exhaust duct.
3. Inlet scroll (nozzles and turbine blades).
4. Gear train (also inspect for debris at both turbo oil drain passages).

Any sign indicating that failure was caused by an external source should be investigated and corrective action taken before the unit is returned to service. The following paragraphs list some common failures.

## **FOREIGN MATERIAL DAMAGE TO THE IMPELLER**

This failure, Fig. 15-16, usually results from one of the following.

1. Previous Turbocharger Failure - When a turbocharger is operating and pieces are broken off the impeller, the force drives the pieces into the air filter. Later, they may be pulled loose and damage the new impeller.
2. Misapplication Of The Compressor Inlet Boot - If the boot travels, a clamp may enter the impeller and destroy it.
3. Loose Material In The Air Filter Housing - Material left in the housing can enter the impeller.

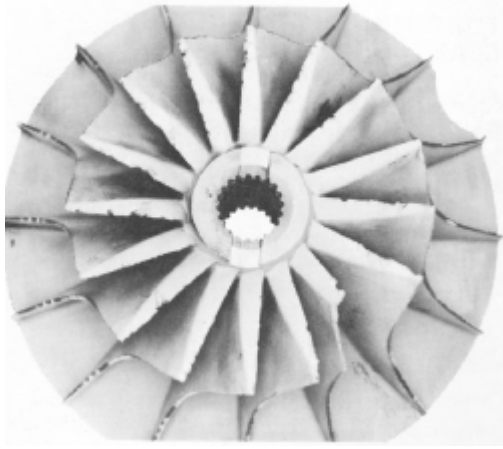


Fig. 15-16 - Impeller Damaged By Foreign Material

If an impeller has rubbed the cover or has pieces broken out, the air filter housing, ducts, and filters should be inspected. Paper or fiberglass elements should be scrapped if the inspection reveals aluminum in the air duct, filter housing, or in the filters.

As the turbocharger rotating assembly slows down during a failure, pieces of the impeller may enter the air duct and damage the aftercoolers. The aftercooler area should be inspected following damage to the impeller.

**CAUTION:** In many cases, rubbing and loss of pieces from the impeller are caused by an unbalanced condition within the turbocharger. Therefore, the turbocharger should be inspected for other defects which cause imbalance when impeller rubbing and loss of pieces are found.

## FOREIGN MATERIAL DAMAGE TO TURBINE BLADES

Foreign material damage can be found by inspecting blades and nozzles as detailed in the section under "Turbocharger Reported Burping And Smoking Excessively". The nozzles may be dented or closed, and at times, larger pieces of foreign material may be stuck in them. If the rotating assembly is not frozen, inspect the leading edges of all the blades by turning the impeller. The leading edges of some or all of the blades will be nicked and, in some cases, a blade may break at a nick, Fig. 15-17. The mechanical breakup of any part of the power assemblies or the exhaust system may result in

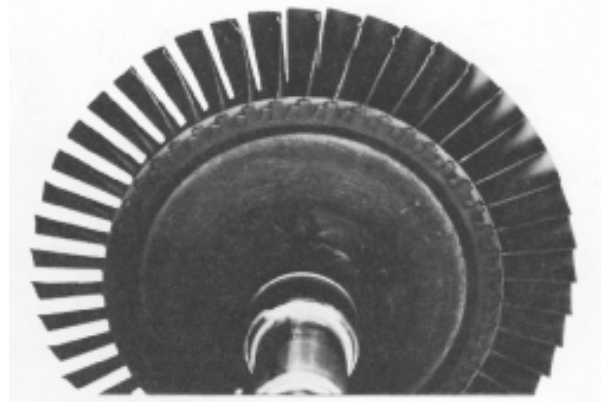


Fig. 15-17 - Nicked Blades

foreign material damage to the turbine blades and nozzles. The most common sources are broken exhaust valves and broken piston rings. The turbocharger is protected from this material by the inlet screen, but the screen 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.

A newly designed screen with a trap at the bottom is now available. The trap collects foreign material and prevents it from continuously hitting the screen, breaking up, and entering the turbocharger. The screen assembly is now applied to new engines and is available from Electro-Motive Part Centers.

Failures can be reduced by performing preventive maintenance to:

1. Preclude ring breakage. Top ringside clearance measurement can be used as a method to determine when the ring is entering a dangerous stage.
2. Prevent valve blow from progressing to valve breakage. Maintain valve and injector timing as specified in the Engine Maintenance Manual.
3. Determine if power assembly or exhaust system pieces are missing, and locating and removing them from the exhaust system.

## OVERHEAT/ OVER SPEED

Overheat/ overspeed is the most destructive and costly type of failure and may result in almost total destruction of the turbocharger. Since it is caused by excessive heat energy in the exhaust system which increases turbine

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wheel speed to an unacceptable level, the only cure is to remove the source of the heat energy.

An overheat/ overspeed failure can be recognized by:

1. Turbine blades that are stretched and have rubbed the shroud; some of the blades may have pulled apart. Often the turbocharger is frozen and the impeller cannot be rotated, therefore, only a limited view of the blades is available, Fig. 15-18.

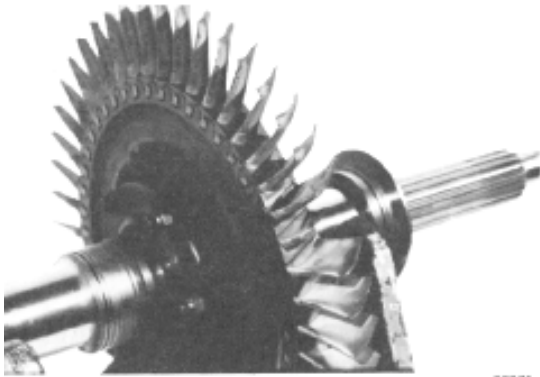


Fig. 15-18 - Stretched Blades That Have Rubbed The Shroud

2. Viewing down the exhaust duct; the exhaust diffuser may be warped and the shroud may be bulged. Both may be torn by broken blades, Figs. 15-19 and 15-20.
3. An impeller that rubs the cover; the overheat/ overspeed condition may result in a bearing failure that allows the impeller to move forward, or an unbalanced condition may occur when blades are pulled apart.

The usual sources of excess heat are:

1. Air box fire. White ash should be visible in the inner air box, on the stress plates, end plates, or liners. The paint on the handhole covers may be blistered. Clean if necessary.

Any condition that increases either the air box temperatures or the amount of deposit formation in the air box should be corrected. These conditions are:

- a. Dirty aftercoolers.
- b. Broken compression rings.

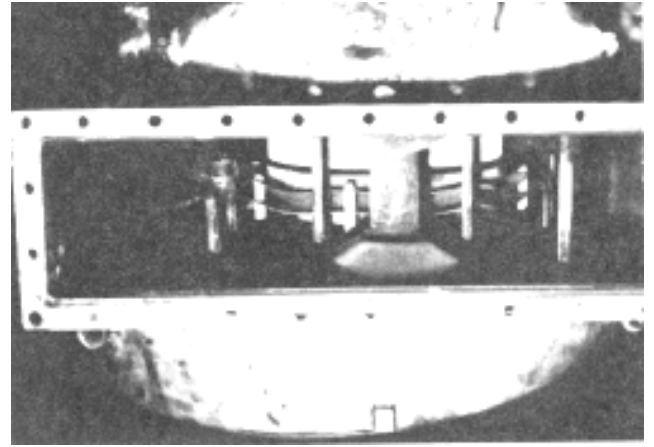


Fig. 15-19 - View Down The Exhaust Stack - Warped Diffuser

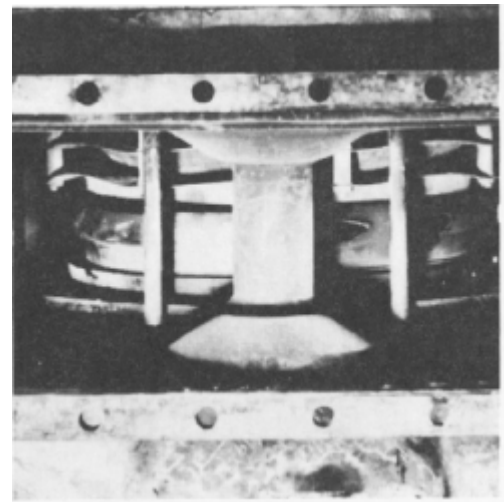


Fig. 15-20 - View Down The Exhaust Stack Of A Warped Diffuser And Damage From Broken Blades

- c. Late injector timing.
  - d. Incorrect valve timing.
  - e. Plugged turbocharger exhaust inlet screen.
  - f. Plugged air filters or other restrictions in the air intake system.
2. Damaged injectors.
  3. Broken valves (sometimes causing damaged injectors).
  4. Mis-timed engine, valves, and injectors.
  5. Exhaust manifold fire.
  6. Excessive electrical overload.

## BEARING FAILURE

A bearing failure is characterized by:

1. Heavy rubbing of the impeller vanes.
2. Excessive rotor end thrust.
3. Possible excessive up and down play in the rotor bearings.
4. No sign of turbine overheat/ overspeed or foreign material damage.

Some bearing failures are avoidable. Starting or stopping the engine with no turbo lube pump oil flow can result in a bearing failure. The turbo lube pump provides oil to the turbocharger's hydrodynamic bearings when the engine is started or stopped. At engine start the oil lubricates the bearing and, after engine shutdown, the oil cools the bearing and protects against residual heat in the turbocharger.

Scheduled monthly inspection should include visual inspection through a rear oil pan handhole cover to verify oil flow down the gear train after the engine is shut down. A check at the top deck should also be made to ensure that oil is not flowing from the camshaft bearings, indicating an inoperative check valve that is allowing oil from the turbo lube pump to backflush the turbocharger filter into the engine bearings. Also, when an engine is shut down, any battery switch, fuse, or circuit breaker that deactivates the turbo lube pump must remain closed until the bearing has cooled.

Bearing failures can also occur due to turbocharger housing distortion from misalignment of the aftercooler air ducts. Follow the procedures outlined in the Engine Maintenance Manual when installing the air ducts.

## GEAR TRAIN FAILURE

When turbocharger gear train damage is evident, the following should be performed:

1. Check for debris in the lube oil system, oil pan, strainers, and filters.
2. Inspect the timing gear housing for debris.
3. Inspect the entire engine gear train to determine which gears require replacement. For engines using spring drive gears, the gear retaining bolts should be checked for tightness. Discard any loose bolts and apply new bolts.

NOTE: The eight bolts holding the turbocharger drive gear to the spider should be 31.8 mm (1-1/4") long, with hardened washers between the gear and bolt heads.

## EXHAUST LEAKS

Improper application of lifting chains (allowing them to press against the exhaust duct when the turbocharger is suspended) can lead to bending of the lap joint between the exhaust duct and the compressor bearing supply. Once this joint is deformed, a permanent exhaust leak may result.