SECTION 15

PREVENTIVE MAINTENANCE – TROUBLESHOOTING – STORAGE

CONTENTS

LUBRICATION AND PREVENTIVE MAINTENANCE

The *Lubrication and Preventive Maintenance Schedule* is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from a Detroit Diesel engine. The intervals indicated on the Charts are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions* in Section 13.1.

EMISSION CONTROL MAINTENANCE SERVICE CHART (VEHICLE ENGINES)

DAILY											
1. — Lubricating Oil		Ⓘ									
2. — Fuel Tank		Ⓘ									
3. — Fuel Lines and Flexible Hoses		Ⓘ									
4. — Cooling System		Ⓘ									
5. — Turbocharger		Ⓘ									
3000 MILE INTERVALS											
6. — Battery		Ⓘ									
7. — Tachometer Drive		Ⓘ									
4000-6000 MILE INTERVALS											
8. — Air Cleaner (oil bath)		Ⓘ									
9. — Drive Belts		Ⓘ									
10. — Air Compressor		Ⓘ									
11. — Throttle Control		Ⓘ									
15,000 MILE INTERVALS											
(2.) — Fuel Tank		Ⓘ									
(8.) — Air Cleaner (oil bath)		Ⓘ									
25,000 MILE INTERVALS											
12. — Lubricating Oil Filter		Ⓡ									
6 MONTHS OR	**MONTHS**	**6**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**
10,000 MILE INTERVALS	**MILES (1000)**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
13. — Fuel Filter		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
14. — Coolant Filter & Water Pump*		Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ
15. — Starting Motor		Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ
(2.) — Fuel Tank			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(4.) — Cooling System (hoses)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(10.) — Air Compressor			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
16. — Air System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
17. — Exhaust System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
18. — Air Box Drain Tube				Ⓘ			Ⓘ			Ⓘ	
19. — Emergency Shutdown			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
20. — Engine (steam clean)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
21. — Radiator			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
22. — Shutter Operation			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
23. — Oil Pressure			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
24. — Governor						Ⓘ					Ⓘ
25. — Fuel Injector & Valve Clearance						Ⓘ					Ⓘ
26. — Throttle Delay						Ⓘ					Ⓘ
27. — Battery-Charging Alternator*											
28. — Engine & Transmission Mounts							Ⓘ				
29. — Crankcase Pressure							Ⓘ				
30. — Air Box Check Valves											Ⓘ
(1.) — Lubricating Oil*											
31. — Fan Hub*											
49. — Blower Bypass Valve											Ⓘ
ANNUALLY											
(3.) — Fuel Lines and Flexible Hoses		Ⓘ									
(4.) — Cooling System		Ⓘ									
(8.) — Air Cleaner (oil bath)		Ⓘ									
32. — Thermostats & Seals		Ⓘ									
33. — Blower Screen		Ⓘ									
34. — Crankcase Breather		Ⓘ									
35. — Fan (thermo-modulated)		Ⓘ									
AS REQUIRED											
36. — Engine Tune-Up											

Ⓘ = INSPECT, CORRECT OR REPLACE (IF NECESSARY)

Ⓡ = REPLACE

* = SEE ITEM

INDUSTRIAL OFF HIGHWAY AND MARINE	HRS. MILES	TIME INTERVALS									
		DLY.	8	50	100	150	200	300	500	700	1,000	2,000
			240	1,500	3,000	4,500	6,000	9,000	15,000	20,000	30,000	60,000
1. — Lubricating Oil		X				X						
2. — Fuel Tank		X							X	X		
3. — Fuel Lines and Flexible Hoses		X							X		X	
4. — Cooling System		X							X	X	X	
5. — Turbocharger		X										
6. — Battery					X							
7. — Tachometer Drive					X							
8. — Air Cleaners			X						X			
9. — Drive Belts			X				X					
10. — Air Compressor							X			X		
11. — Throttle and Clutch Controls							X					
12. — Lubricating Oil Filter									X		X	
13. — Fuel Strainer and Filter								X				
14. — Coolant Filter & Water Pump*									X			
15. — Starting Motor*												
16. — Air System										X		
17. — Exhaust System										X		
18. — Air Box Drain Tube											X	
19. — Emergency Shutdown										X		
21. — Radiator										X		
22. — Shutter Operation										X		
23. — Oil Pressure										X		
24. — Overspeed Governor									X			
26. — Throttle Delay*												
27. — Battery-Charging Alternator							X					
28. — Engine and Transmission Mounts												X
29. — Crankcase Pressure												X
30. — Air Box Check Valves*												
31. — Fan Hub*												
32. — Thermostats and Seals*										X		
33. — Blower Screen											X	
34. — Crankcase Breather											X	
36. — Engine Tune-Up*												
37. — Heat Exchanger Electrodes									X		X	
38. — Raw Water Pump		X										
39. — Power Generator					X			X				
40. — Power Take-Off			X	X					X			
41. — Marine Gear		X					X				X	
42. — Torqmatic Converter		X		X							X	
43. — Reduction Gear			X	X					X		X	
44. — Blower Bypass Valve*												

*See Item

Item 1 – Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately twenty (20) minutes to allow the oil to drain back to the oil pan. Add the proper grade oil, as required, to maintain the correct level on the dipstick (refer to Section 13.3).

NOTICE: Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

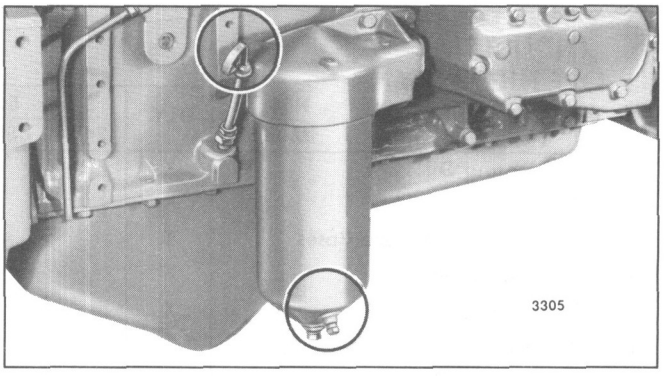
Change the lubricating oil at the intervals shown in the Chart. See Section 13.3 for drain intervals when using high sulfur fuel (above 0.50 mass percent).

ENGINE OIL CHANGE INTERVALS		
Service Application	Max. Engine Oil Change Interval	
	Diesel Fuel Sulfur Content % by Wt. Max.	
	0 to 0.50	
Hwy. Truck (Long Distance Hauls)	20,000 Miles	
City Transit Coaches	6,000 Miles	
Pickup Delivery Truck Service (Stop–and–go short distance)	12,500 Miles	
Industrial & Marine	150 Hours	

When using high TBN/ash oils, a rule of thumb for oil change intervals is to drain the oil when the TBN drops to one–half of the new oil TBN. *Since lubricant composition varies from brand to brand the time and rate of TBN reduction will vary.* These differences manifested by the various high TBN/ash oils will influence the drain interval.

The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined.

If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily. Select the proper grade of oil in accordance with the instructions given in the *Lubrication Specifications* in Section 13.3



Items 1 and 12

Item 2 – Fuel Tanks

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Fuel Specifications* in Section 13.3.

Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water and/or sediment.

Every 12 months or 20,000 miles (700 hours) tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the crossover fuel line. Repair or replace the parts, as necessary.

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Water accumulation can be controlled by mixing isopropyl alcohol (dry gas) into the fuel oil at a ratio of one pint (.5 liter) per 125 gallons (473 liters) fuel (or 0.10 by volume).

Marine units in storage are particularly susceptible to microbe growth. The microbes live in the fuel–water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non–turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commerically available biocides. There are two basic types on the market.

1. The water soluble type treats *only the tank* where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.

2. The diesel fuel soluble type, such as "Biobor" manufactured by U.S. Borax or equilvalent, treats *the fuel* itself, and therefore, the entire fuel system.

Marine units, or any other application, going into storage should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

Item 3 – Fuel Lines And Flexible Hoses

Make a visual check for fuel leaks at the crossover lines and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

The performance of engine and auxiliary equipment is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant and fuel oil. Diligent maintenance of hoses is an important step in ensuring efficient, economical and safe operation of the engine and related equipment.

Check hoses daily as part of the pre–start up inspection. Examine hoses for leaks and check all fittings, clamps and ties carefully. Make sure that hoses are not resting on or touching shafts, couplings, heated surfaces including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary.

Leaks

Investigate leaks immediately to determine if fittings have loosened or cracked or if hoses have ruptured or worn through. Take corrective action immediately. Leaks are not only potentially detrimental to machine operation, but they also result in added expense caused by the need to replace lost fluids.

CAUTION: Personal injury and/or property damage may result from fire due to the leakage of flamable fluids such as fuel or lube oil.

Service Life

A hose has a finite service life. The service life of a hose is determined by the temperature and pressure of the air or fluid within it, its time in service, its mounting, the ambient temperatures, amount of flexing and vibration it is subject to. With this in mind, all hoses should be thoroughly inspected at least every 500 operating hours (1,000 hours for the fire–resistant fuel and lube hoses and heat–insulating turbo/exhaust system blanket) and/or annually. Look for cover damage or indications of damaged, twisted, worn, crimped, brittle, cracked or leaking lines. Hoses having the outer cover worn through or damaged metal reinforcement should be considered unfit for further service.

All hoses in or out of machinery should be replaced during major overhaul and/or after a maximum of five years service.

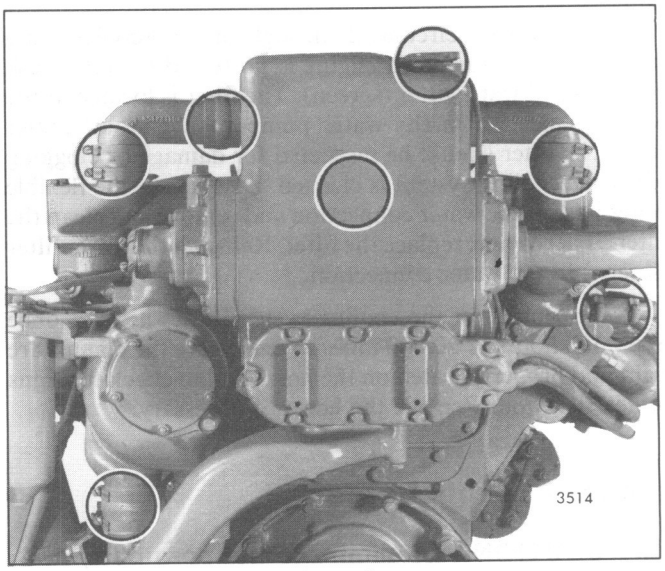
NOTICE: The new hose assemblies do not require automatic replacement after five years service or at major overhaul.

Item 4 – Cooling System

CAUTION: Do not remove the pressure control cap from the radiator or heat exchanger or attempt to drain the coolant until the engine has cooled. Once the engine has cooled, use extreme care when removing the cap. the sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

Check the coolant level daily and maintain it near the top of the heat exchanger tank or make sure it covers the radiator tubes. Add coolant, as necessary. *Do not overfill.*

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.



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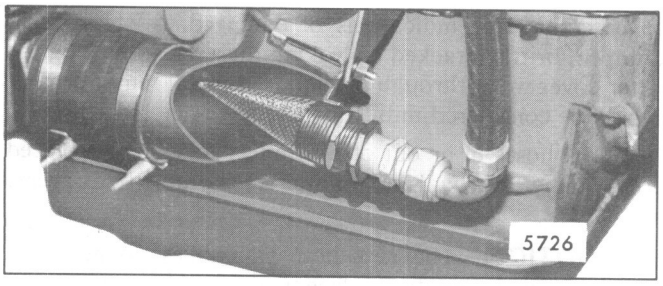
In order to assure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system (15–20 psi or 103–138 kPa) using radiator cap and cooling system tester J 24460–01. Do not exceed 20 psi (138 kPa). Any



Item 4

measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any incipient coolant leaks.

Clean the cooling system annually (vehicle engines) or every 1,000 hours or 30,000 miles (non–vehicle engines) using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then, fill the system with soft water, adding a good grade of rust inhibitor or an ethylene glycol base antifreeze (refer to *Coolant Specifications* in Section 13.3). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse flushed.

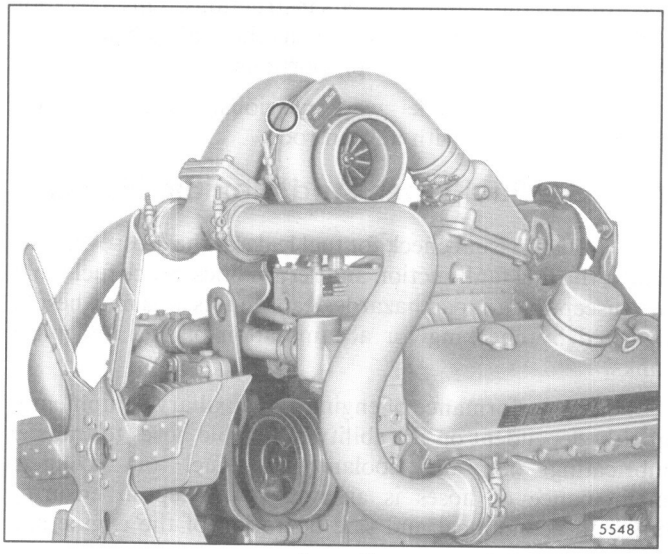
The coolant circulated through the intercoolers on a turbocharged intercooled engine is protected by a 20 mesh cone–shaped water filter (screen). The filter is located at the water connection in the water pump–to–engine oil cooler tube. The filter should be inspected for damage or clogging when the cooling system is cleaned. Disconnect the flexible water hose at the water connection and remove and clean the filter. If necessary, replace the filter. Reinstall the water filter (screen) in the water connection.

Inspect all of the cooling system hoses at least once every 700 hours or 20,000 miles to make sure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses, if necessary.

Item 5 – Turbocharger

CAUTION: To eliminate the possibility of personal injury when air inlet piping is removed, do not operate an engine with a blower–mounted or front center–mounted turbocharger unless the compressor inlet guard assembly or turbo inlet shield (J 26554–A) is installed.

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks and restriction to oil flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause.



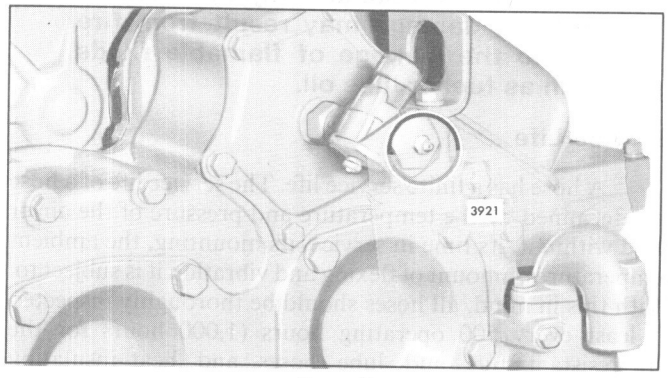
Item 5

Item 6 – Battery

Check the "eye" of maintenance–free batteries for charge. If lead–acid or low maintenance batteries are used, check the specific gravity of the electrolyte in each cell every 100 hours or 3,000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 7 – Tachometer Drive

Lubricate the tachometer drive every 100 hours or 3,000 miles with an all purpose grease at the grease fitting. At temperatures above 30°F (–1°C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.



Item 7

Item 8 – Air Cleaner

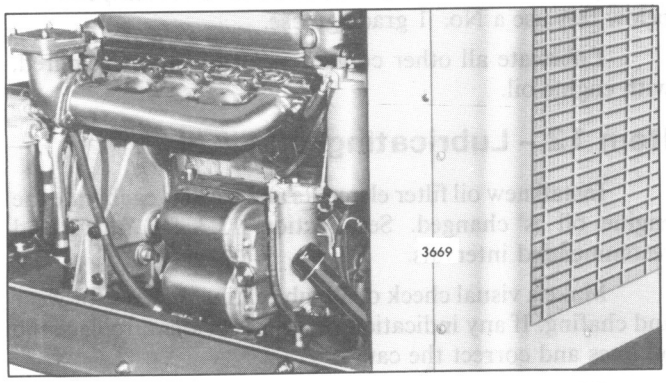
Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for non–turbocharged engines or 20 inches of water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Oil Bath

Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every 8 hours (every 6,000 miles for highway vehicle engines), or less if operating conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade and viscosity *heavy–duty* oil as used in the engine. The frequency of servicing may be varied to suit local dust conditions. If heavy rain or snow has been encountered, check the air cleaner for an accumulation of water.

Remove and steam clean the air cleaner element and baffle annually.

It is recommended that the body and fixed element in the heavy–duty oil bath type air cleaner be serviced every 500 hours or 15,000 miles or as conditions warrant.



Item 8

Dry Type

Dry type air cleaner elements (Donaldson, Farr, etc.) used in on–highway applications should be discarded and replaced with new elements after one year of service, after 100,000 miles (Donaldson's recommended mileage interval) or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. No attenpt should be made to clean or reuse on–highway elements after these intervals.

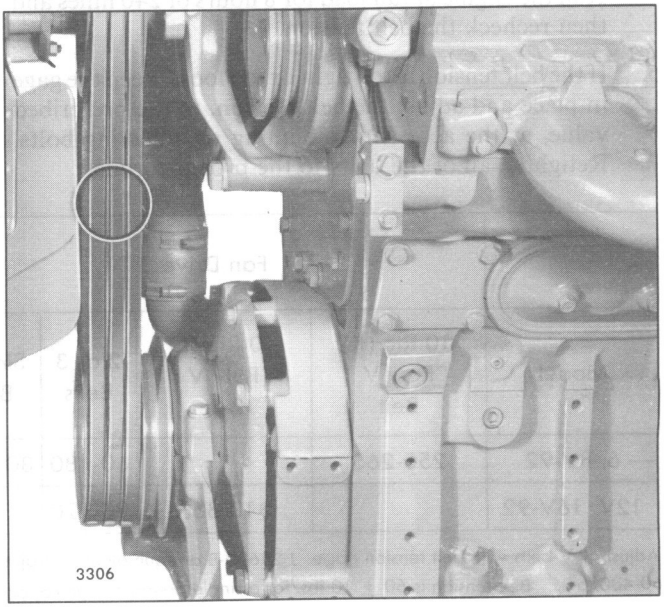
Dry type elements used in off–highway applications should be discarded and replaced with new elements after one year of service or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. In cases where the air cleaner manufacturer recommends cleaning or washing off–highway elements, the maximum service life is still one year or maximum restriction. Cleaning, washing and inspection must be done per the manufacturer's recommendations. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.

Item 9 – Drive Belts

New standard V–belts will stretch after the first few hours of operation. Run the engine for 15 *seconds* to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, pump drive, battery–charging generator or alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 240 miles of operation. Thereafter, check the tension of the drive belts every 200 hours or 6,000 miles and adjust, if necessary. Belts should be neither too tight nor too loose. Belts which are too tight impose excess loads on the crankshaft, fan and/or alternator bearings, shortening both belt and bearing life. Excessively overtightened belts can result in crankshaft breakage. A loose belt will slip.

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032" of their specified center distances.

Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2" to 3/4". If belt tension gage J 23600–B or equivalent is available, adjust the belt tension, as outlined in the Chart. When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.



Item 9

Adjust Poly–V Fan Belt (16V–92)

The fan belt should be neither too tight nor too loose. Carelessness in making a belt adjustment can be dangerous. Too tight a belt imposes an undue load on the fan bearings and shortens the life of the belt. Too loose a belt allows slippage and lowers the fan speed, causes excessive belt wear and leads to overheating of the cooling system.

Before a Poly–V belt is installed, it is very important that the crankshaft pulley (10 grooves) and the fan drive pulley (11 grooves) are in alignment. The extra groove in this fan drive pulley can be on the inside or the outside of the pulley, depending upon alignment requirements.

Misalignment between the crankshaft pulley and the fan drive pulley cannot be more than .009" per inch of center line distance, A straight line can be determined by placing a straight edge on the rims of the pulleys. A spacer is available to facilitate pulley alignment, if necessary. The spacer mounts between the crankshaft pulley and the vibration damper hub.

Poly–V belts require a special procedure for proper belt tension.

1. After the belts have been initially adjusted, run the engine under a light load for 1/2 hour.
2. Stop the engine and check the belt tension with the belt "hot"; use belt tension gage J 23586 or equivalent, which has a range of 60 to 400 pounds.
3. If the tension value is not between 280 and 360 pounds, readjust the belt tension. Because the allowable load the crankshaft bearing can carry is critical, do not exceed the maximum tension value of 360 pounds.
4. Run the engine at full load for 8 hours or 240 miles and then recheck the belt tension.
5. If the belt tension is too tight or too loose, keep the gage in place and adjust the belt tension, to the prescribed value, at the accessory mounting or adjusting bolts. Retighten all of the bolts to the proper torque.
6. The belt tension should be rechecked every 200 hours or 6,000 miles of engine operation and readjusted, if necessary.

Item 10 – Air Compressor

Remove and wash all of the polyurethane sponge strainer parts every 500 miles (150 operating hours). The strainer element should be cleaned or replaced. If the element is cleaned, it should be washed in a commercial solvent or a detergent and water solution. The element should be saturated in clean engine oil, then squeezed dry before replacing it in the strainer. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake.

For replacement of the air strainer element, contact the nearest Bendix Westinghouse or Midland–Ross dealer; replace with the polyurethane element, if available.

Every 12 months or 20,000 miles tighten the air compressor mounting bolts. If the air compressor is belt driven, check the belts for proper tension.

Item 11 – Throttle And Clutch Controls

Every 200 hours or 6,000 miles lubricate the throttle control mechanism. Use an all purpose grease (No. 2 grade) at temperatures ± 30°F (–1°C) and above. At temperatures below this use a No. 1 grade grease.

Lubricate all other control mechanisms, as required, with engine oil.

Item 12 – Lubricating Oil Filter

Install new oil filter elements and gaskets each time the engine oil is changed. See Section 13.3 for filters and recommended intervals.

Make a visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

When the engine is equipped with a turbocharger, pre–lubricate it as outlined under *Install Turbocharger* in Section 3.5.

	Fan Drive				Alternator or Generator Drive			AC Compressor Drive
Model	10 Rib (K) Poly V Belt	10 Rib (L) Poly V Belt	2 or 3 Belts	Single Belt	Two 3'8" or 1/2" Belts	One 1/2" Belt	8 Rib (K) Poly V Belts	4 Rib (K) Poly V Belts
6, 8V-92	255-265		60- 80	80-100	40-50	50-70	110-130	84-94
12V, 16V-92		310-360	90-120		40-50	50-70		

Adjust all V-belts with belt tension gage J 23600-B or equivalent. Adjust all Poly V-belts with belt tension gage J 23586 or equivalent *Range 60-400 lbs. Belt tension is 60 ± 10 lbs. for a single premium high capacity belt (.785" wide) used to drive a 12 cfm air compressor.

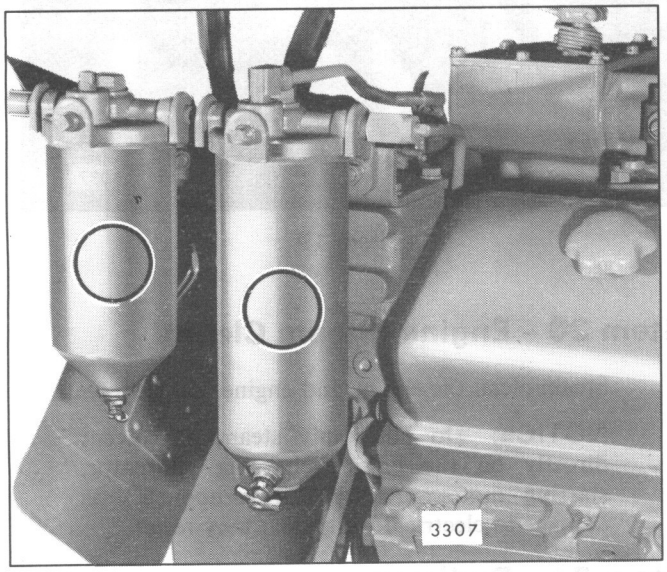
If the engine is equipped with a governor oil filter, change the element every 1,000 hours or 30,000 miles.

Check for oil leaks after starting the engine.

Item 13 – Fuel Strainer And Filter

Install new elements every 6 months or 10,000 miles (vehicle engines) and 300 hours or 9,000 miles (non–vehicle engines) or when plugging is indicated. See Section 13.3 for filter recommendations.

A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury (20.3 kPa). With 6V and 8V non–turbocharged engines, at normal operating speed and with .080" restriction fittings, the fuel pressure is 45–70 psi (310–483 kPa). With 12V and 16V non–turbocharged engine at normal operating speeds and with .070" restriction fittings, the fuel pressure is 30–65 psi (207–448 kPa). With turbocharged engines, at normal operating speeds and with either .080" or .070" restriction fittings, the fuel pressure is 50–70 psi (345–483 kPa). Change the fuel filter elements whenever the inlet restriction at the fuel pump reaches 12 inches of mercury (41 kPa) at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to the minimum fuel pressure shown above.



Item 13

Item 14 – Coolant Filter Water Pump

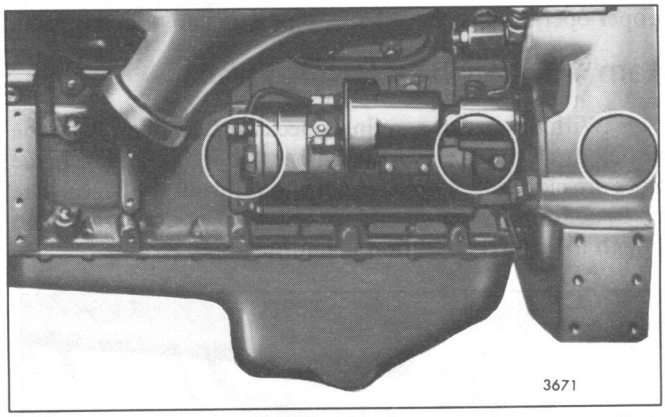
If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 6 months or 10,000 miles (vehicle engines) and 500 hours or 15,000 miles (non–vehicle engines). Select the proper coolant filter element in accordance with the instructions given under *Coolant Specifications* in Section 13.3. Use a new filter cover gasket when installing the filter element. After replacing the filter and cover gasket, start the engine and check for leaks.

Inspect the water pump drain hole every 6 months for plugging. If plugged, clean out the drain hole with a tool made from a front crankshaft seal or equivalent.

Replace the water pump seal after it has been in service for 200,000 miles or 6,000 hours.

Item 15 – Starting Motor

VEHICLE ENGINES – Starting motors which are provided with lubrication fittings (grease cups, hinge cap oilers oil tubes sealed with pipe plugs) should be lubricated every 6 months or 10,000 miles. Add 8 to 10 drops of oil, of the same grade as used in the engine, to hinge cap oilers; if sealed tubes are provided, remove the pipe plugs, add oil and reseal the tubes. Grease cups should be turned down one turn. Refill the grease cups, if necessary. However, some starting motors do not require lubrication except during overhaul.



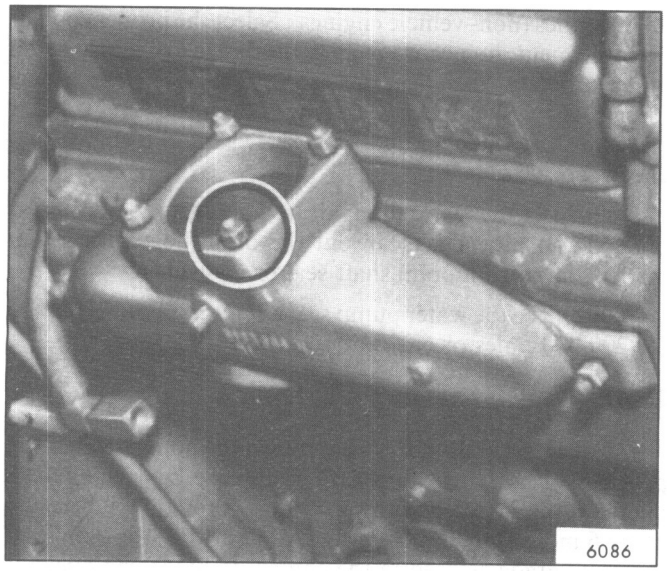
Item 15

NON–VEHICLE ENGINES – The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

Item 16 – Air System

Check all of the connections in the air system to be sure they are tight. Check all hoses for punctures or other damage and replace, if necessary.



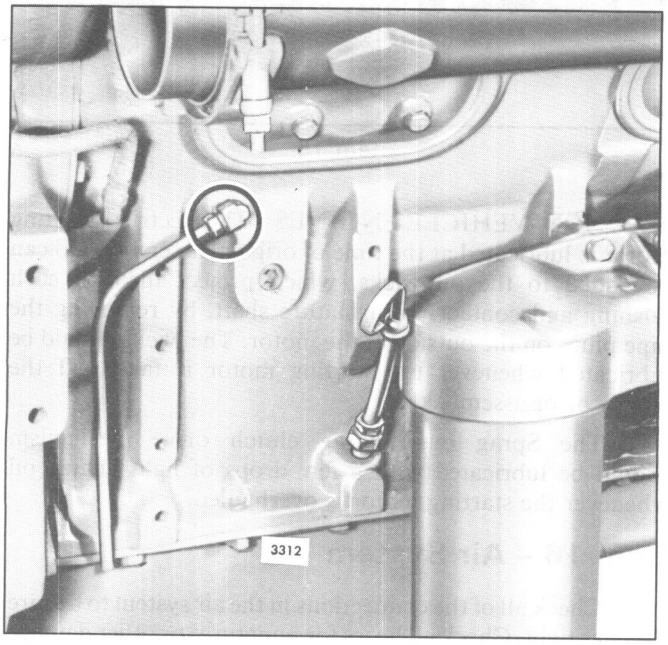
Item 17

Item 17 – Exhaust System

Check the exhaust manifold retaining nuts, exhaust flange clamp and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if one is used.

Item 18 – Air Box Drain Tube

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours or 30,000 miles. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent.

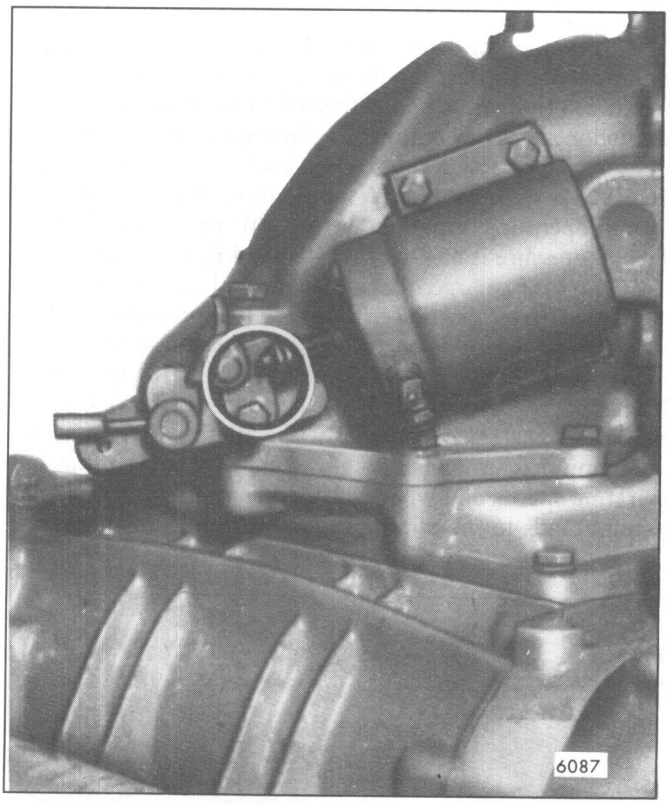


Item 18

If the engine is equipped with an air box drain tank, drain the sediment periodically.

Item 19 – Emergency Shutdown

With the engine running at idle speed, check the operation of the emergency shutdown every 700 hours or 20,000 miles. Reset the air shutdown valve in the *open* position after the check has been made.



Item 19

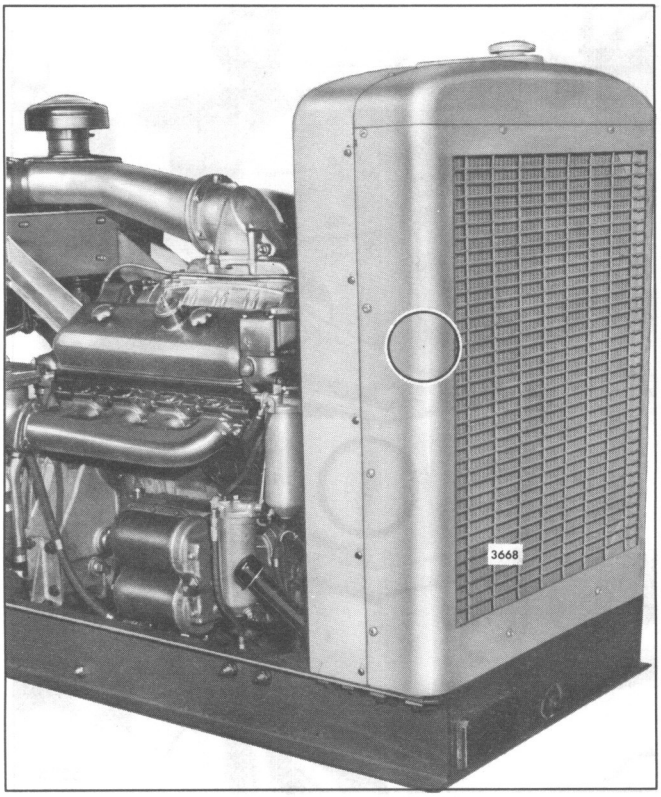
Item 20 – Engine (Steam Clean)

Steam clean the engine and engine compartment.

NOTICE: Do not apply steam or solvent directly on the battery–charging alternator, starting motor or electrical components as damage to electrical equipment may result.

Item 21 – Radiator

Inspect the exterior of the radiator core every 12 months or 20,000 miles (700 hours) and, if necessary, clean it with a quality grease solvent such as mineral spirits and dry it with compressed air. *Do not use fuel oil, kerosene or gasloine.* It may be necessary to clean the radiator more rrequently if the engine is being operated in extremely dusty or dirty areas.



Item 21

Item 22 – Shutter Operation

Check the operation of the shutters and clean the linkage and controls.

Item 23 – Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 700 hours or 20,000 miles.

Item 24 – Governor

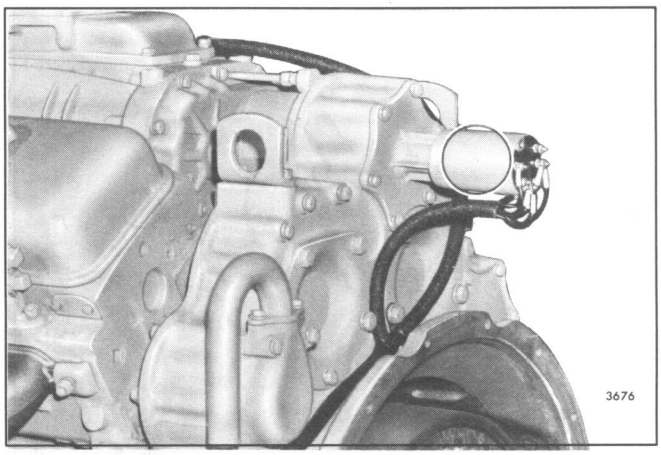
Check and record the engine idle speed and no–load speed. Adjust as necessary.

An idle speed lower than recommended will cause the engine to be accelerated from a speed lower than the speed at which the engine was certified.

A no–load speed higher than recommended will result in a full–load speed higher than rated and higher than the speed at which the engine was certified.

Overspeed Governor

Lubricate the overspeed governor, if it is equipped with a hinge–type cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours or 15,000 miles. Avoid excessive lubrication and do not lubricate the governor while the engine is running.



Item 24

Item 25 – Fuel Injectors And Valve Clearance

Check the injector timing and exhaust valve clearance as outlined in Section 14.2 and 14.1 every 50,000 miles. The proper height adjustment between the injector follower and injector body is of primary importance to emission control.

Item 26 – Throttle Delay Fuel Modulator

Inspect and adjust, if necessary, every 30 months or 50,000 miles.

The **Throttle Delay** system limits the amount of fuel injected during acceleration by limiting the rate of injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay (Section 14.14).

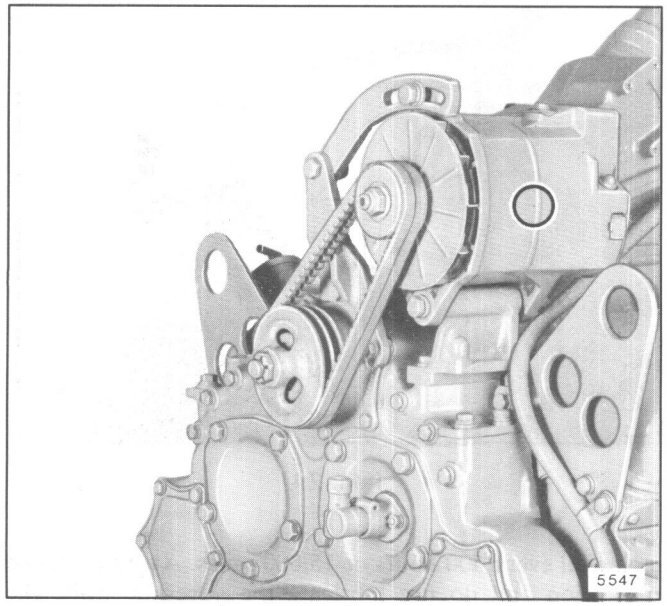
Inspect the check valve by filling the throttle delay cylinder with diesel fuel and watching for valve leakage while moving the throttle from the idle to the *full–fuel* position.

On the **Fuel Modulator**, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear and free operation. Also, inspect the operating surface of the lower roller, the roller pins at the cam pivot and the cam attachment to the piston. Replace parts, as required.

The fuel modulator must be set with the proper gage to achieve the correct fuel–to–air ratio (Section 14.14).

Item 27 – Battery–Charging Alternator

Battery–charging alternators are lubricated at time of manufacture and do not require further lubrication. Check terminals for corrosion and loose connections. Check for damaged or frayed insulation. Repair or replace wiring as required.



Item 27

Item 28 – Engine And Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 2,000 hours or 60,000 miles. Tighten and repair as necessary.

Item 29 – Crankcase Pressure

Check and record the crankcase pressure every 2,000 hours or 60,000 miles (refer to Section 15.2).

Item 30 – Air Box Check Valves

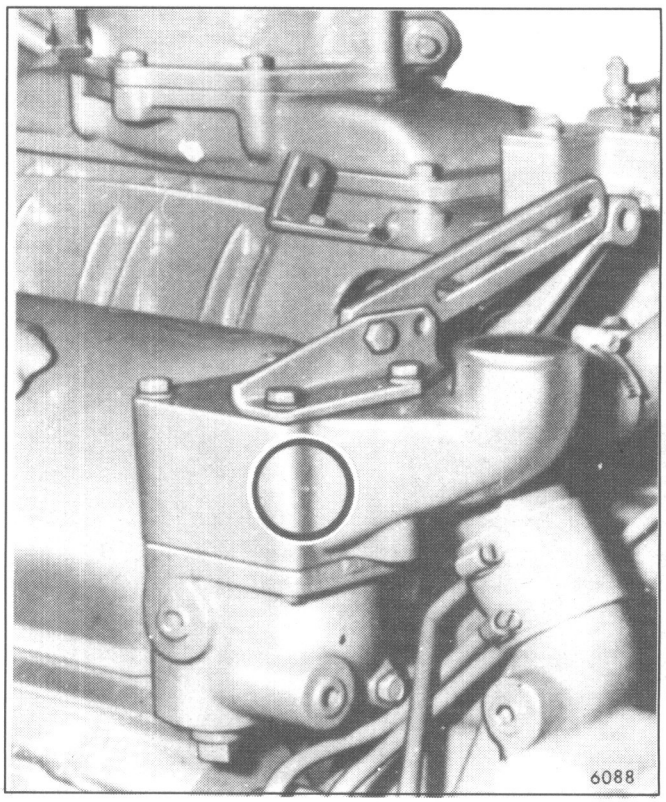
Every 100,000 miles or approximately 3,000 hours remove the air box check valves, clean them in solvent and blow out the lines with compressed air. Inspect for leaks after servicing.

Item 31 – Fan Hub

If the fan bearing hub assembly is provided with a grease fitting, use a hand grease gun and lubricate the bearings with one shot of Texaco Premium RB grease, or an equivalent Lithium base multi–purpose grease, every 20,000 miles (approximately 700 hours).

Every 2,500 hours or 75,000 miles (vehicle engines) or 4,000 hours (non–vehicle engines) clean, inspect and repack the fan bearing hub assembly with the above recommended grease (refer to Section 5.4).

At a major engine overhaul, remove and discard the bearings in the fan hub assembly. Pack the hub assembly, using new bearings, with Texaco Premium RB grease or an equivalent Lithium base multi–purpose grease.



Item 32

Item 32 – Thermostats And Seals

Check the thermostats (see Section 5.2.1) and seals at 5,000 hours (non–highway engines), 200,000 miles (highway engines) or once a year (preferably at the time the cooling system is prepared for winter operation). The thermostats and seals should *always* be replaced at overhaul.

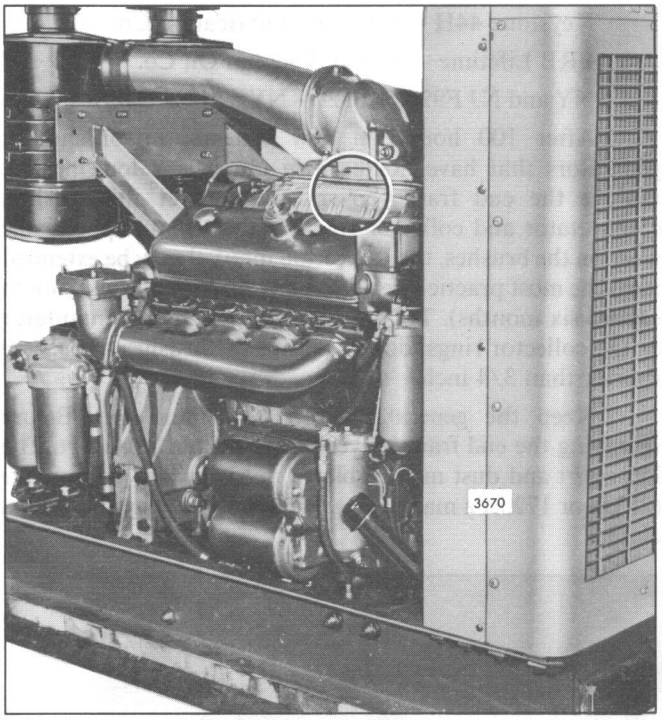
Item 33 – Blower Screen

Inspect the blower screen and gasket assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non–vehicle engines) and, if necessary, clean the screen in fuel oil and dry it with compressed air. Install the screen and gasket assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.

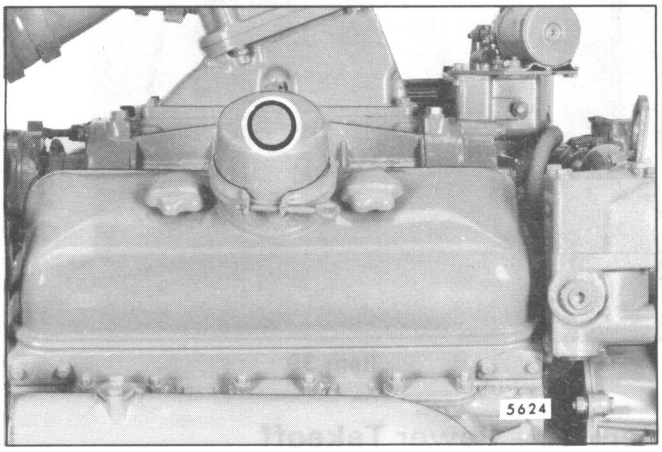
Item 34 – Crankcase Breather

Remove the externally mounted crankcase breather assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non–vehicle engines) and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.



Item 33



Item 34

Item 35 – Fan (Thermo–Modulated)

DRIVE FLUID LEVEL – Check the fan drive fluid level to avoid improper operation and damage to the drive components.

Current modulated fan drive housings have an inspection plug for checking the fluid level. Formerly partial disassembly of the drive was necessary to make the fluid level check. Former units can be updated by installing a current drive housing which includes the fluid inspection plug and a grease fitting for lubricating the bearing.

1. Check the fan drive fluid level after the unit has been idle for at least 1/2 hour.
2. Turn the fan drive so that the inspection plug is 3/4" below the horizontal center line, then allow the silicone fluid to drain down an additional five (5) minutes.
3. Remove the inspection plug. If fluid begins to flow from the inspection hole, the drive has sufficient fluid. Replace the inspection plug.
4. If the fluid does not flow from the hole, proceed as follows:
   a. Rotate the fan drive downward and observe when the fluid begins to flow from the hole. If it is necessary to lower the drain hole more than 2" below the horizontal center line, the fan drive should be removed from the engine, disassembled and inspected for possible damage to the components.
   b. Turn the fan drive back so the inspection hole is 3/4" below the horizontal center line and add fluid until the overflow point is reached. Replace the inspection plug.

   Use only the manufacturer's Special 20 Cenistroke fluid.

DRIVE BEARING LUBRICATION – The fan drive bearing should be lubricated as outlined in the chart with a Medium Consistency Silicone Grease (Dow Corning No. 44, or equivalent).

The bearing on current fan assemblies is lubricated through a grease fitting in the drive housing hub. Lubrication of the bearing in former assemblies requires the removal of the fan assembly and partial disassembly. The former assemblies can be updated to include a grease fitting by installing the current housing.

Item 36 – Engine Tune–Up

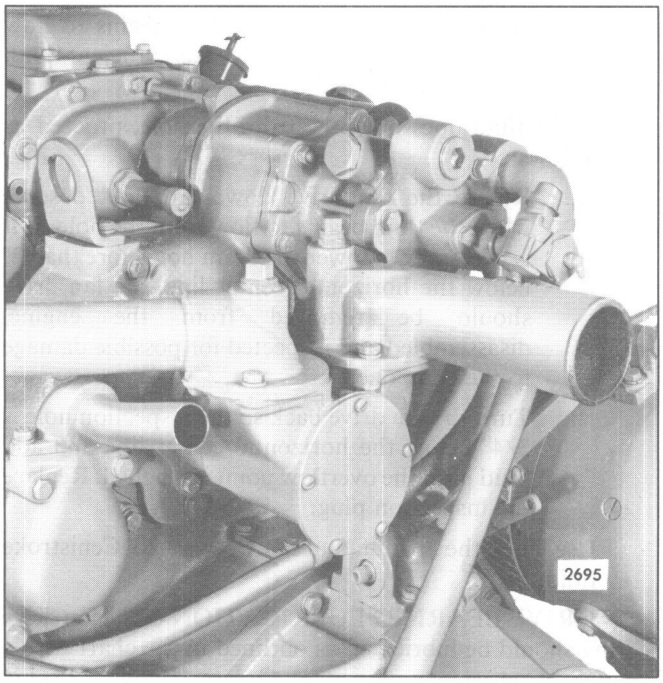
There is no scheduled interval for performing an engine tune–up. As long as the engine performance is satisfactory, no tune–up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc. should only be required periodically to compensate for normal wear on parts.

Item 37 – Heat Exchanger Electrodes And Core

Every 500 hours or annually, drain the water from the heat exchanger raw water inlet and outlet tubes. Then, remove the zinc electrodes from the inlet side of the raw water pump and the heat exchanger. Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Drain the cooling system, disconnect the raw water pipes at the outlet side of the heat exchanger and remove the retaining cover every 1,000 hours or 30,000 miles and inspect

the heat exchanger core. If a considerable amount of scale or deposits are present, contact a *Detroit Diesel Service Outlet*.



Item 37 and 38

Item 38 – Raw Water Pump

Check the prime on the raw water pump daily. The engine should not be operated with a dry pump. Prime the pump, if necessary, by removing the pipe plug provided in the pump inlet elbow and adding water. Reinstall the plug.

Item 39 – Power Generator

The power generator requires lubrication at only one point — the ball bearing in the end frame.

If the bearing is oil lubricated, check the oil level in the sight gage every 300 hours; change the oil every six months. Use the same grade and viscosity *heavy–duty* oil as specified for the engine. Maintain the oil level to the line on the sight gage. *Do not overfill.* After adding oil, recheck the oil level after running the generator for several minutes.

If the bearing is grease lubricated, a new generator has sufficient grease for three years of normal service. Thereafter, it should be lubricated at one year intervals. To lubricate the bearing, remove the filler and relief plugs on the side and the bottom of the bearing reservoir. Add grease until new grease appears at the relief plug opening. Run the generator a few minutes to vent the excess grease; then reinstall the plugs.

The following greases, or their equivalents, are recommended:

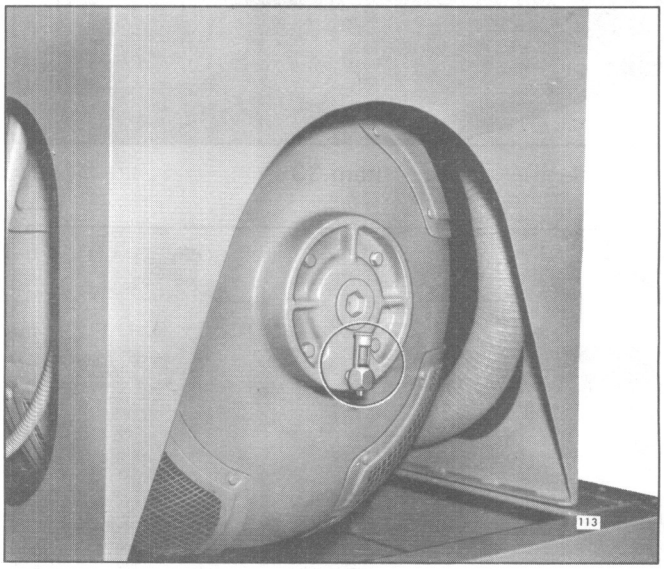
Keystone 44H – Keystone Lubrication Co.

BRB Lifetime – Socony Vacuum Oil Co.

NY and NJ F926 or F927 – NY and NJ Lubricant Co.

After 100 hours on new brushes, or brushes in generators that have not been in use over a long period, remove the end frame covers and inspect the brushes, commutator and collector rings. If there is no appreciable wear on the brushes, the inspection interval may be extended until the most practicable period has been established (not to exceed six months). To prevent damage to the commutator or the collector rings, do not permit the brushes to become shorter than 3/4 inch.

Keep the generator clean inside and out. Before removing the end frame covers, wipe off the loose dirt. The loose dirt and dust may be blown out with low pressure air (25 psi or 172 kPa maximum). Remove all greasy dirt with a cloth.



Item 39

Item 40 – Power Takeoff

Lubricate all of the power takeoff bearings with an all purpose grease such as Shell Alvania No. 2, or equivalent. Lubricate sparingly to avoid getting grease on the clutch facings.

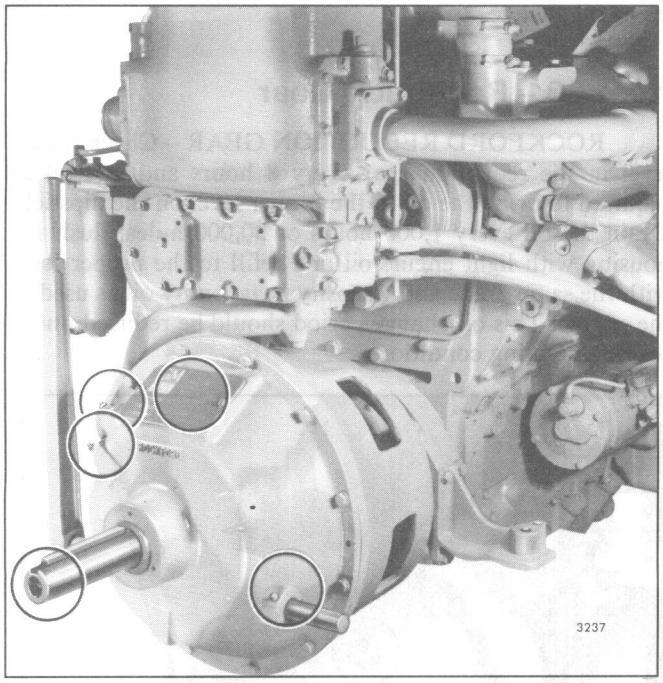
Lubricate the clutch release bearing and the disconnect mechanical rear drive shaft shielded bearing every 8 hours or 240 miles. The clutch release bearing in the 18" diameter clutch is pre–lubricated and is not provided with a grease fitting, since no further lubrication is required.

Lubricate the power takeoff main bearing, also the outboard bearing if the unit is so equipped, every 50 hours or 1,500 miles. Frequency of lubrication will depend on the working conditions of the bearing, shaft speeds and bearing loads. If may be necessary to lubricate this bearing more often than every 50 hours or 1,500 miles. Lubricate the front

power takeoff clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours or 1,500 miles. One or two strokes with a grease gun should be sufficient.

Remove the inspection hole cover and lubricate the clutch release levers and link pins sparingly every 500 hours or 15,000 miles. Lubricate the clutch release shaft through the grease fittings on the front of the housing every 500 hours or 15,000 miles.

Check the clutch facing for wear every 500 hours or 15,000 miles. Adjust the clutch, if necessary.

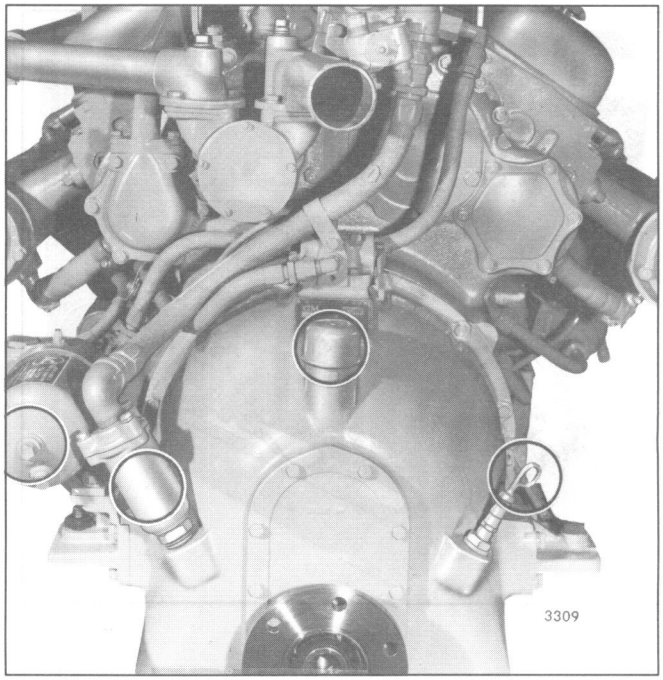


Item 40

Item 41 – Marine Gear

TORQMATIC MARINE GEAR (6V and 8V) – Check the oil level daily in the marine gear, with the controls in neutral and the engine running at idle speed. Add oil as required to bring it to the proper level on the dipstick. Use the same grade and viscosity *heavy–duty* oil as used in the engine. Series 3 oil should not be used in the marine gear. Drain the oil every 200 hours or 6,000 miles and flush the gear with light engine oil.

When refilling after an oil drain, bring the oil up to the proper level on the dipstick – approximately 6 quarts (5.7 liters) in the M type and 8 quarts (7.6 liters) in the MH type gear. Start and run the engine at light load for three (3) to five (5) minutes. Then, put the controls in neutral and run the engine at idle speed and check the oil level again. Bring the oil level up to the proper level on the dipstick.



Item 41

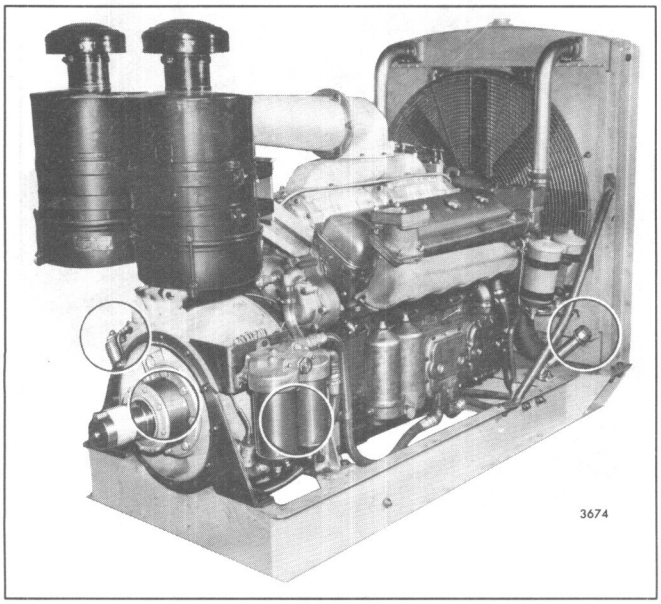
Every time the marine gear oil is changed, remove the oil strainer element, rinse it thoroughly in fuel oil, dry it with compressed air and reinstall it. Also, replace the full–flow oil filter element every time the marine gear oil is changed.

TWIN DISC MARINE GEAR (16V) – Check the oil level daily. Check the oil level with the engine running at low idle speed and the gear in neutral. Keep the oil up to the proper level on the dipstick. Use oil of the same *heavy–duty* grade and viscosity that is used in the engine.

Change the oil and the oil filter element every 1,000 hours or 30,000 miles. After draining the oil, thoroughly clean the removable oil screen and breather. Reinstall the breather and refill the marine gear with oil up to the full mark on the dipstick. Start the engine and, with the gear in neutral, run the engine at idle speed for three (3) to five (5) minutes. Then, stop the engine and check the oil level. If necessary, add oil to bring it up to the full mark on the dipstick.

Item 42 – Torqmatic Converter

Check the oil level in the Torqmatic converter and supply tank daily. The oil level must be checked while the converter is operating, the engine idling and the oil is up to operating temperature (approximately 200°F or 93°C). If the converter is equipped with an input disconnect clutch, the clutch must be engaged.



Item 42

Check the oil level after running the unit a few minutes. The oil level should be maintained at the proper level on the dipstick. If required, add hydraulic transmission fluid type "C–2" (see Chart). *Do not overfill* the converter as too much oil will cause foaming and high oil temperature.

Prevailing Ambient Temperature	Recommended Oil Specification
Above −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2.
Below −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2. Auxiliary preheat required to raise temperature in the sump to a temperature above −10°F. (−23° C)

OIL RECOMMENDATIONS

The oil should be changed every 1,000 hours or 30,000 miles for Series 400 through 900 converters. Also, the oil should be changed whenever it shows traces of dirt or effects of high operating temperature as evidenced by discoloration or strong odor. If the oil shows metal contamination, contact an authorized *Detroit Diesel Service Outlet* as this usually requires disassembly. Under severe operating conditions, the oil should be changed more often.

The converter oil breather, located on the oil level indicator (dipstick), should be cleaned each time the converter oil is changed. This can be accomplished by allowing the breather to soak in a solvent, then drying it with compressed air.

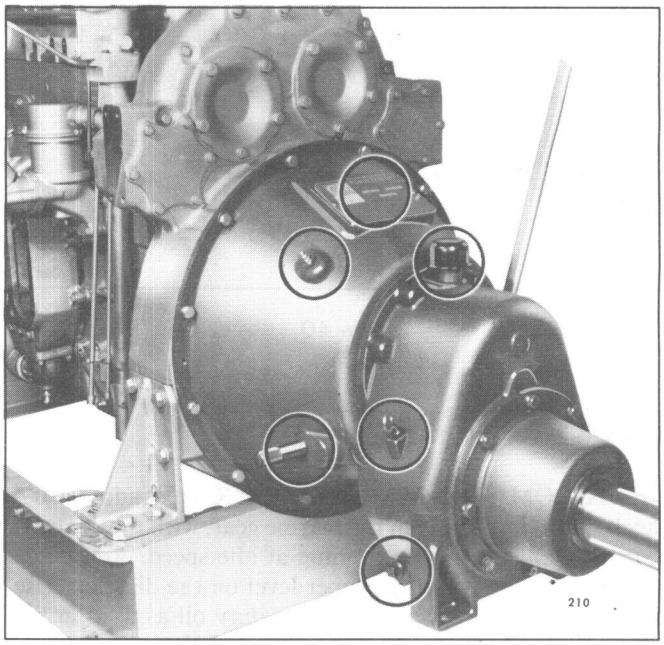
The full–flow oil filter element should be removed, the shell cleaned and a new element and gasket installed each time the converter oil is changed.

Lubricate the input clutch release bearing and ball bearing and the front disconnect clutch drive shaft bearing every 50 hours or 1,500 miles with an all purpose grease. Grease fittings are provided on the clutch housing. This time interval may vary depending upon the operating conditions. Over lubrication will cause grease to be thrown on the clutch facing, causing the clutch to slip.

The strainer (in the Torqmatic transmission) and the hydraulic system filters should be replaced or cleaned with every oil change.

Item 43 – Reduction Gear

ROCKFORD REDUCTION GEAR – Check the oil level in the reduction gear every 8 hours and add oil as required to bring the oil to the proper level on the dipstick. Drain the oil every 1,000 hours or 30,000 miles, flush the housing with light engine oil and refill to the proper level with the same grade and viscosity *heavy–duty* oil as used in the engine. This oil change period should be reduced under severe operating conditions.



Item 43

Lubricate the clutch release bearing through the grease fitting on the side of the housing every 8 hours or 240 miles of operation. The clutch release bearing in the 18" diameter clutch is pre–lubricated and is not provided with a grease fitting, since no further lubrication is required. Lubricate the front reduction clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours or 1,500 miles. One or two strokes with a grease gun should be sufficient.

Remove the inspection hole cover and oil the clutch release levers and link pins sparingly every 500 hours or 15,000 miles. Lubricate the clutch release shaft through the grease fittings on the front of the housing every 500 hours or 15,000 miles.

Item 44 – Blower Bypass Valve

Every 100,000 miles or approximately 3,000 hours, remove the bypass blower valve and clean it in solvent, if necessary. Inspect for free operation of the valve and any scoring of the piston, piston guide or sleeve assembly. Repair or replace, as required.

TROUBLESHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.
2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating A Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.
2. Stop the engine and remove the valve rocker covers.
3. Check the valve clearance (Section 14.1).
4. Start the engine. Then, hold an injector follower down with a screwdriver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short–circuiting a spark plug in a gasoline engine.
5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.
6. If the cylinder is misfiring, check the following:
   a. Check the injector timing (refer to Section 14.2).
   b. Check the compression pressure.
   c. Install a new injector.
   d. If the cylinder still misfires, remove the cam follower (refer to Section 1.2.1) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Mininum Compression Pressure at 600 rpm				Altitude above Sea Level		+ Air Density
Turbocharged Engines		Non-Turbocharged Engines				
psi	kPa	psi	kPa	feet	meters	
450	3101	500	3445	500	152	.0715
415	2859	465	3204	2,500	762	.0663
385	2653	430	2963	5,000	1,524	.0613
355	2446	395	2722	7,500	2,286	.0567
330	2274	365	2515	10,000	3,048	.0525

+ Air density at 500 feet altitude based on 85° F (29.4° C) and 29.38 in. Hg (99.49 kPa) wet barometer.

TABLE 1

Check the compression pressure as follows:

1. Start the engine and run it at approximately one–half rated load until normal operating temperature is reached.
2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.
3. Remove the injector and install an adaptor and pressure gage (Fig. 1) from Diagnosis Kit J 9531–01.

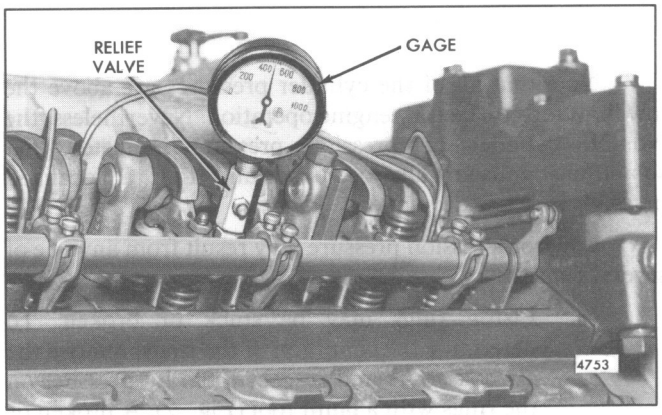


Fig. 1 – Checking Compression Pressure

4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.
5. Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gage. *Do not crank the engine with the starting motor to obtain the compression pressure.*

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In addition, the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

   EXAMPLES: – If the compression pressure readings were as shown in Table 2, it would be evident that No. 2L cylinder should be examined and the cause of the low compression pressure be determined and corrected.

The pressures in Table 2 are for a turbocharged engine operating at an altitude near sea level.

Cylinder	Gage Reading	
	Psi	kPa
1L	470	3239
1R	465	3204
2L	430	2963
2R	460	3170
3L	465	3204
3R	460	3170

TABLE 2

Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 2L cylinder compression pressure indicates that something unusual has occurred and that a localized pressure leak has developed.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool (Fig. 2). A broken or stuck ring will not have a "spring–like" action.

B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

Engine Out Of Fuel

The problem in restarting the engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

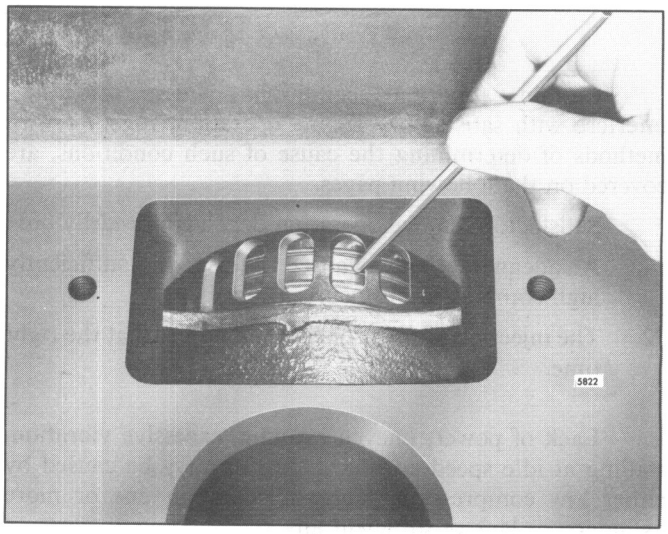


Fig. 2 – Inspecting Piston Rings

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten (10) gallons (38 liters) of fuel.
2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.
3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.
4. Start the engine. Check the filter and strainer for leaks.

   NOTICE: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover. Use a new gasket when reinstalling a valve rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter, as outlined in *Troubleshooting* (Section 2.0).

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow–by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder gaskets or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

The crankcase pressure may be checked with a manometer. The manometer should be connected to the oil level dipstick opening in the cylinder block.

Check the readings obtained at various engine speeds with the *Engine Operating Conditions* (Section 13.2). The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

The exhaust back pressure, measured in inches of mercury, may be checked with a manometer in the engine diagnosis test kit J 9531–01. Connect the manometer to an exhaust manifold (except on turbocharged engines) by removing the 1/8" pipe plug which is provided for that purpose. If there is no opening provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8" pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the rear face of the turbine. The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds with the *Engine Operating Conditions* (Section 13.2).

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen or a stuck *open* blower bypass valve.

High air box pressure can be caused by partially plugged cylinder liner ports or a stock *closed* blower bypass valve.

Lack of power or black or grey exhaust smoke are indications of low air box pressure.

To check the air box pressure, connect a manometer to an air box drain tube.

Check the readings obtained at various speeds with the *Engine Operating Conditions* in Section 13.2.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently, the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air intake ducting located 2" above the air inlet housing (non–turbocharged engines) or compressor inlet (turbocharged engines). When inserting a fitting at this point is impractical (non–turbocharged engines), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then, the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various no load speeds and compare the results with the *Engine Operating Conditions* (Section 13.2).

PROPER USE OF MANOMETER

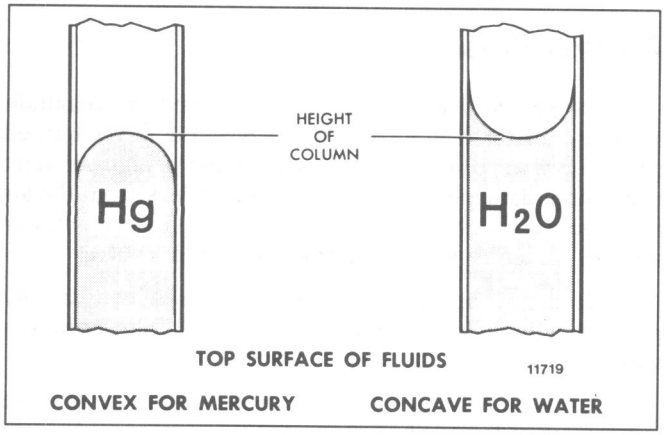


Fig. 3 – Comparison of Column Height for Mercury and Water Manometers

The U–tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 3) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

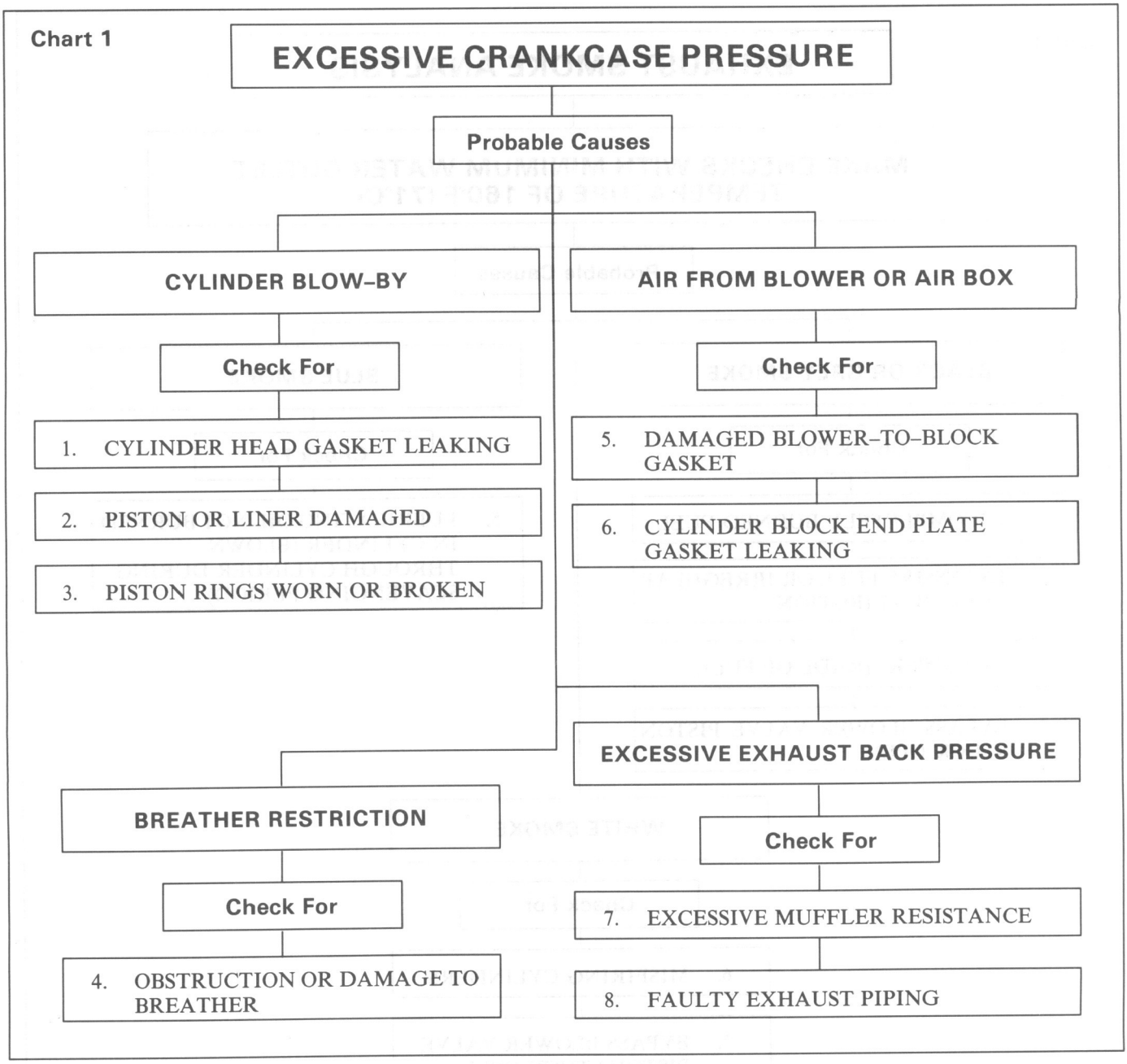
Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.

PRESSURE CONVERSION CHART		
1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	13.6000" water
1" mercury	=	.4910 psi
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury
1 psi	=	6.895 kPa
1 kPa	=	.145 psi

TABLE 3

Chart 1



SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.
2. Inspect the piston and liner and replace damaged parts.
3. Install new piston rings.
4. Clean and repair or replace the breather assembly.
5. Replace the blower–to–block gasket.
6. Replace the end plate gasket.
7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

Chart 2

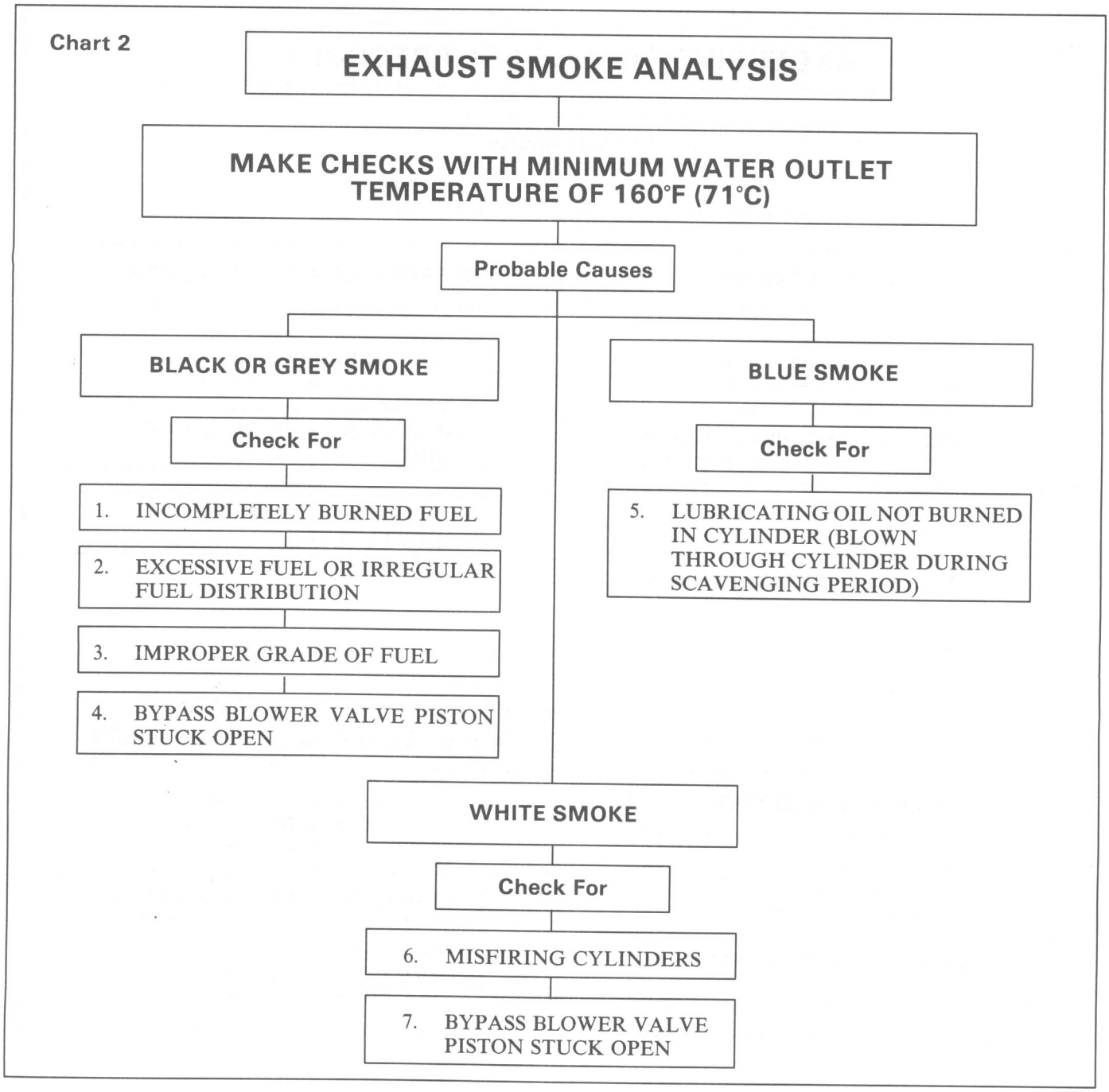


Chart 2

EXHAUST SMOKE ANALYSIS

SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

2. If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

If the engine is equipped with a fuel modulator, check the cam to determine if it is stuck in the *full fuel* position. Verify tightness of the roller lever clamp on the control tube. Determine correctness (refer to Section 14.14) of the installed fuel modulator piston spring and check if the spring has taken a permanent "set" or if the spring rate is too low.

The above affects only excessive acceleration smoke, but does not affect smoke at constant speed.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune–up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune–up.

Avoid lugging the engine as this will cause incomplete combustion.

3. Check for use of an improper grade of fuel. Refer to *Fuel Specifications* in Section 13.3.

4. Check the blower bypass valve piston (if so equipped) to determine if it is stuck in an *open* position. Check for scoring of the valve piston or piston guide. Replace the valve assembly if the above conditions are noted.

5. Check for internal lubricating oil leaks and refer to the *High Lubricating Oil Consumption* Chart.

6. Check for faulty injectors and replace as necessary.

White smoke or misfire at idle may occur when any one or more injector's idle output is considerably higher or lower than the remainig injectors operated by the same control tube. Significant differences in injector idle output will affect firing impulses since some cylinders are receiving too much fuel while others are receiving little or no fuel at idle. The cylinder that is not firing at idle may be detected by shorting out the injector with a screwdriver. Depress the injector follower to prevent injector operation. If there is a change noted in the engine (i.e., noise or RPM), the injector can be considered operational. If no change is noted in the engine, one cause could be that the injector is not providing sufficient fuel at idle for combustion. The rack screw should then be adjusted to increase fuel output. Turn the injector rack screw slightly (no more than 1/8 of a turn) to change the idle output. This adjustment should only be made after any heavy hitting injectors have been identified and adjusted to reduce idle output. Heavy hitting injectors generally contribute to a louder cylinder firing impulse/sound. After adjusting the suspected problem injectors, accelerate the engine several times and allow it to return to idle.

Check for low compression and consult the *Hard Starting* Chart.

The use of low cetane fuel will cause this condition. Refer to *Fuel Specifications* in Section 13.3.

7. (Same as Step 4).

Chart 3

HARD STARTING

Probable Causes

ENGINE WILL NOT ROTATE

Check For

1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE

LOW CRANKING SPEED

Check For

4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER

NO FUEL

Check For

7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL–FUEL POSITION WHEN STARTING AID SCREW IS NOT USED

LOW COMPRESSION

Check For

9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
14. BLOWER BYPASS VALVE STUCK OPEN

INOPERATIVE STARTING AID AT LOW AMBIENT TEMP

Check For

15. IMPROPER OPERATION OF FLUID STARTING AID

Chart 3

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.
2. Replace the starting motor switch.
3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.
4. Refer to *Lubrication Specifications* in Section 13.3 for the recommended grade of oil.
5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

   Replace terminals that are damaged or corroded.

   At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.
6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.
7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* Chart.
8. Check for bind in the governor–to–injector linkage. Readjust the governor and injector controls, if necessary.
9. Remove the cylinder head and recondition the exhaust valves.
10. Remove the air boxcovers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.
11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.
12. Adjust the exhaust valve clearance.
13. Remove the flywheel housing cover at the blower drive support. Then remove the snap ring and withdraw the blower drive shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (refer to Section 3.4.1).
14. Check the blower bypass valve piston (if so equipped) to determine if it is stuck in an *open* position. Check for scoring of the valve piston or piston guide. Replace the valve assembly if the above conditions are noted.
15. Operate the starting aid according to the instructions under *Cold Weather Starting Aids*.

Chart 4

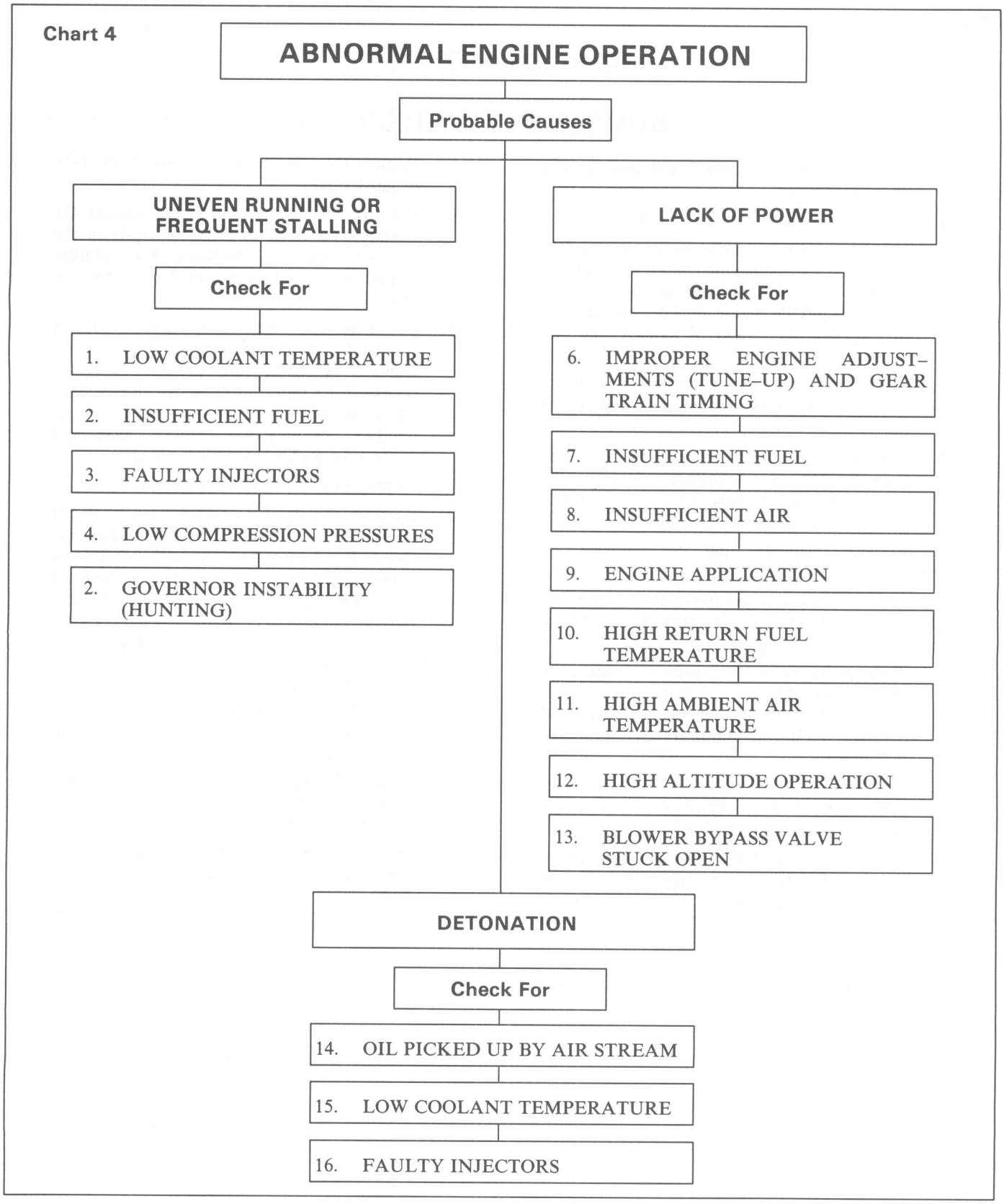


Chart 4

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and, if the temperature does not reach 160°–197°F (71°–92°C) while the engine is operating, consult the *Abnormal Engine Coolant Temperature* Chart.
2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* Chart.
3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune–up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.
4. Check the compression pressures within the cylinders and consult the *Hard Starting* Chart if compression pressures are low.
5. Erratic engine operation may be caused by governor–to–injector operating linkage bind or by faulty engine tune–up. Perform the appropriate engine tune–up procedure as outlined for the particular governor used.
6. If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

If equipped with a fuel modulator, determine if there is any interference with the roller assembly or roller contact with the cam at *wide open throttle (WOT)* position. Check for burrs and binding on the piston and bracket bore. Determine correctness (refer to Section 14.14) of the installed fuel modulator spring and check if the spring has taken a permanent "set", or if the spring rate is too high.

Perform an engine tune–up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* Chart.
8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* Chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.
10. Check the engine fuel spill–back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.
11. Check the ambient air temperature. An increase in fuel inlet temperature above 90°F (32°C) will result in a brake horsepower loss of approximately 2% per 20°F (11°C) increment of fuel temperature increase. Relocate the engine air intake to provide a cooler source of air.
12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.
13. Check the blower bypass valve piston (if so equipped) to determine if it is stuck in an *open* position. Check for scoring of the valve piston or piston guide. Replace the valve assembly if the above conditions are noted.
14. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

Check for a defective blower–to–block gasket. Replace the gasket, if necessary.

15. Refer to Item 1 of this chart.
16. Check injector timing and the position of each injector rack. Perform an engine tune–up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the check valve as follows:

a. Disconnect the drain tube between the check valve and the air box drain tube nut at the air box cover.
b. Run the engine and note the air flow through the valve at idle engine speed.
c. If the check valve is operating properly, there will be no air flow at engine speeds above idle.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Chart 5

NO FUEL OR INSUFFICIENT FUEL

Probable Causes

AIR LEAKS

Check For

1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY

FAULTY FUEL PUMP

Check For

7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING

FLOW OBSTRUCTION

Check For

5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURES LESS THAN 10°F. (6°C.) ABOVE POUR POINT OF FUEL

FAULTY INSTALLATION

Check For

10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart 5

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.
2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.
3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element.
4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
5. Perform a *Fuel Flow Test* and replace the fuel strainer and filter elements and the fuel lines, if necessary.
6. Consult the *Fuel Specifications* in Section 13.3 for the recommended grade of fuel.
7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.
8. Replace the gear and shaft assembly or the pump body.
9. Check the condition of the fuel pump drive and blower drive and replace defective parts.
10. Replace with larger tank–to–engine fuel lines.
11. Install a restricted fitting in the return line.
12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve, if necessary. If the valve is inoperative, replace it with a new valve assembly.
13. Check the engine fuel spill–back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

Chart 6

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. AUTOMATIC OIL FILLER
4. OIL PULLOVER – AIR COMPRESSOR
5. OVERFILLED CRANKCASE
6. PLUGGED BREATHERS
7. HIGH CRANKCASE PRESSURE
8. BLUE EXHAUST SMOKE
9. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

10. BLOWER OIL SEALS LEAKING
11. TURBO OIL SEALS LEAKING
12. OIL COOLER CORE LEAKING
13. WORN EXHAUST VALVE GUIDES

OIL CONTROL AT CYLINDER

Check For

14. LOW COMPRESSION
15. PISTON PIN RETAINER LOOSE
16. OIL CONTROL RINGS WORN, BROKEN, IMPROPERLY INSTALLED OR SCORED
17. EXCESSIVE OIL IN AIR BOX
18. DIRT IN AIR INTAKE SYSTEM
19. SCORED LINERS OR PISTONS
20. EXCESSIVE INSTALLATION ANGLE
21. EXCESSIVE OIL IN CRANKCASE

Chart 6

HIGH LUBRICATING OIL CONSUMPTION

SUGGESTED REMEDY

NOTE: Lube oil consumption must be verified after each repair is made.

1. & 2. Repair oil leaks by replacing necessary gaskets, seals or tightening connections. Steam cleaning the engine and operating at no–load rpm, (engine at operating temperature) will often reveal excessive oil leaks.
3. Consult the original equipment manufacturer for proper repair of the automatic oil filler system.
4. Check the air compressor for oil pullover and/or remove and replace the compressor.
5. Check dipstick and tube for proper oil pan levels to correct overfilled crankcase.
6. Check crankcase pressure. Clean breathers and recheck crankcase pressure.
7. Overhaul blower, turbocharger or rekit engine (refer to Items 10, 11, 15 and 16). Also, refer to the *Excessive Crankcase Pressure* Chart.
8. Remove and inspect exhaust manifolds and stacks for wetness or oil discharge. Excessive clearance between the valve stem and the valve guide can produce oil in the cylinders and stack. Repair the valve guides and/or install valve stem seals.
9. Refer to the *Abnormal Engine Operation* Chart.
10. Remove the piping from the air inlet housing and remove from the to blower. Operate the engine at approximately one–half throttle and at idle and inspect blower end plates for evidence of oil leakage past the seals. Use a flashlight to illuminate the end plates. If excessive oil leakage is evident on the end plates, overhaul blower.

    CAUTION: The blower rotors are exposed and rotating during the test. Contact with the rotors must be avoided as personal injury could result.

11. Check for indications of oil on compressor or turbine sides of the turbocharger. Refer to Section 3.5 of the Service Manual for the proper procedure to determine turbocharger oil seal leakage.
12. Pressure test cooling system. If leak is found, remove and replace the oil cooler. Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then, use a good grade of cooling system cleaner to remove the oil from the cooling system.
13. Replace worn exhaust valve guides.
14. Take compression test – refer to Item 16.
15. Run engine at idle speed with the air boxcover removed (one at a time) to determine if oil is uncontrolled as evidenced by slobbering out the liner ports. Inspect all cylinders as more than one may be slobbering. Repair affected cylinders. Slobbering can also be caused by worn oil control rings.

    CAUTION: Hot lubricating oil could be blown out the air box during this test. Contact with the hot oil could cause severe burns.

16. Check for faulty engine air induction system allowing contaminated air to enter the engine. A compression test with excessively low readings will indicate worn out cylinders. Remove and replace cylinder kits.
17. Refer to Items 10, 11, 15 and 16.
18. Refer to Item 16.
19. Check the crankshaft thrust washers for wear. Replace wore and defective parts.
20. Decrease the installation angle.
21. Fill the crankcase to the proper level only.

Chart 7

LOW OIL PRESSURE

MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F (71°C)

Probable Causes

LUBRICATING OIL

Check For

1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY

POOR CIRCULATION

Check For

3. COOLER CLOGGED
4. COOLER BY–PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING

PRESSURE GAGE

Check For

8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY

OIL PUMP

Check For

12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

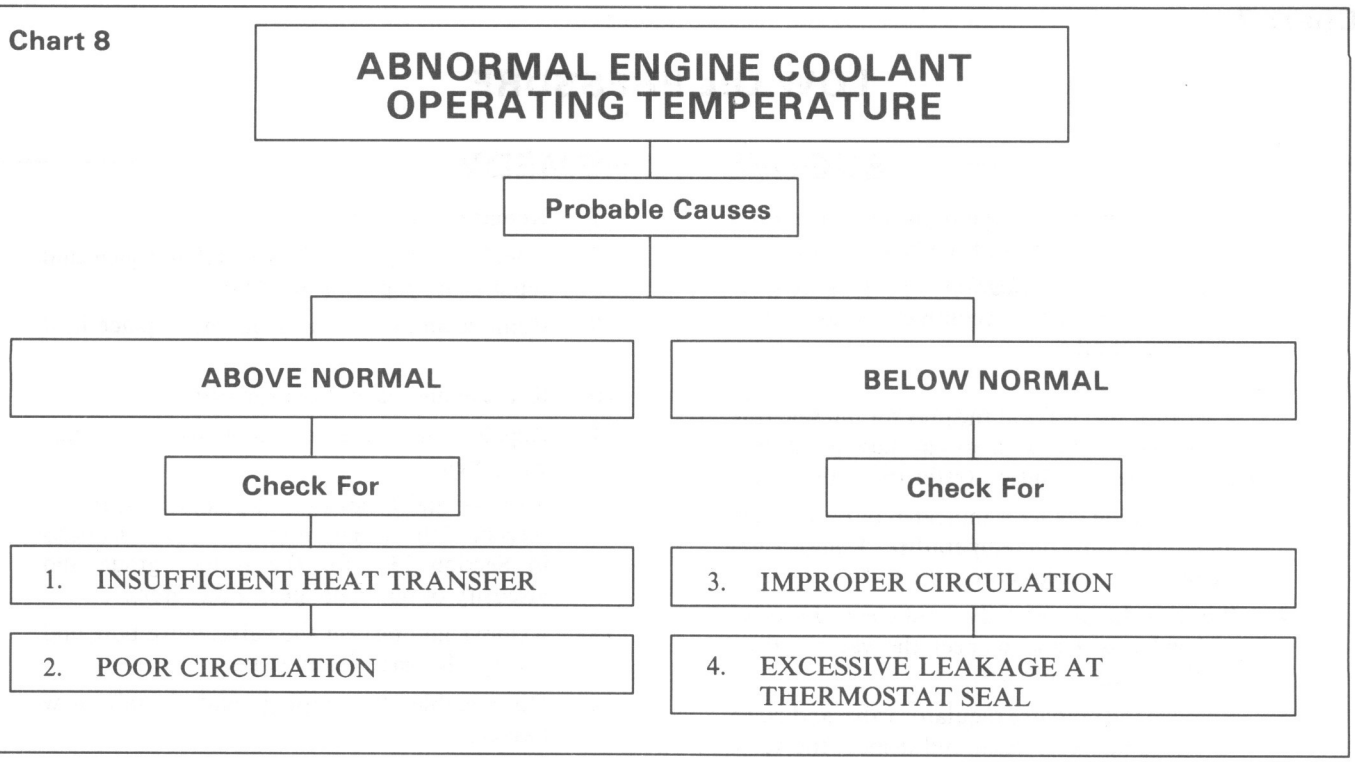
SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.
2. Consult the *Lubrication Specifications* in Section 13.3 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution (refer to Section 2.0).

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.
4. Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.
5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.
6. Change the bearings. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.
7. Replace missing plugs.
8. Check the oil pressure with a reliable gage and replace the gage if found faulty.
9. Remove and clean the gage line; replace it, if necessary.
10. Remove and clean the gage orifice.
11. Repair or replace defective electrical equipment.
12. Remove and clean the oil pan and oil intake screen. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.
13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.
14. Disassemble the piping and install new gaskets.
15. Remove the pump. Clean and replace defective parts.
16. Remove the oil pan and tighten the oil pump end cover bolts.
17. Remove the flange and replace the gasket.

Chart 8



SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature–controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

VEHICLE LOW POWER/PERFORMANCE AT LOW MILEAGE

1. **Determine the basis for the concern.** Does the concern indicate slow acceleration from a stop or slow engine recovery when changing gears? The answers to these questions often provide the proper information for the investigation.
   a. Is the truck being driven according to recommended procedures? For example, down shifting an engine with a throttle delay at high speed (rather than at low speed) will cause the engine to recover power slowly, creating an impression of low power. Driver training would help.
   b. Are the driver's expectations of vehicle performance realistic, considering truck gear ratios, loads and engine rated speed and power? The distributor or regional office should be consulted to assist in evaluation of vehicle performance (shift points and gradability, for example).
2. **Check customer engine and vehicle order specifications and vehicle road speeds, if necessary.**
   a. Determine if the engine no–load speed (rpm) and horsepower meet customer order specifications. The O.E.M. truck dealer or Detroit Diesel Regional Office can assist in this area.
   b. It is normal for the actual engine no–load speed to be slightly less (5 to 20 rpm) than the no–load speed set at Detroit Diesel due to engine accessories (air compressor, power steering pump, etc.) installed by the O.E.M. There is a ± 25 rpm manufacturing tolerance for no–load speed setting. It would be normal, therefore, for an engine order specification of 2050 rpm no–load speed to check out at 2025 to 2075 rpm in the vehicle.
   c. The rated full–load engine speed will not change because of a slight change of no–load speed (rpm) resulting from the addition of O.E.M. accessory loads.
   d. Engine speed combined with rear axle ratios and tire size provide the resultant vehicle geared road speed which may be a basis for customer concern.
   e. Vehicle highway speed is a result of the gear ratios, engine speed and gross vehicle weight. For purposes of discussion, geared speed is the speed the truck would reach with the transmission in direct drive and the engine at rated speed. Geared speed (GS) in Miles Per Hour (mph) can be computed as follows:

$$GS = \frac{\text{Full Load engine RPM} \times 60}{\text{Axle ratio} \times \text{tire revolutions/mile}}$$

EXAMPLE:

$$GS = \frac{1900 \text{ rpm} \times 60}{4.11 \times 504} = 55 \text{ mph}$$

The vehicle could be expected to have a maximum road speed somewhat more than 55 mph (2050 x 55/1900 = 59.3) mph on level pavement with 2050 rpm no–load engine speed. This maximum vehicle speed of 59.3 mph may not be reached because of parasitic and frictional power losses. These power losses are a result of the vehicle power train and engine–driven accessories. At speeds over 50 mph *wind resistance* can be responsible for the greatest engine power or road speed loss.

These vehicle speed calculations can be used to compare designed performance with actual performance. In the example it would be expected that the vehicle should operate between approximately 55 and 59 mph with typical loads and on level pavement. If during tests the loaded vehicle operates at calculated road speeds on level pavement (without a head wind), re–evaluate the source and reason for the power concern. Average the speeds attained on a two or three mile level run both into the wind and with the wind, to determine maximum possible road speed with vehicle unloaded.

   f. Accuracy of the vehicle speedometer and tachometer is important. Low–reading instruments have caused some low power concerns. These instruments should be checked for accuracy at both high and low speed.

3. **Check for improper assembly of engine related parts and accessories installed by the vehicle manufacturer (O.E.M.).** Parts and accessories that can contribute to low power/performance are:
   a. Throttle linkage and governor shut down (adjustment).
   b. Fuel supply and return line (size and installation).
   c. Fuel filters (leaking or contaminated).
   d. Fuel tanks (construction, return and supply line installation; fuel temperature should not exceed maximum allowable) – (see Section 2.5.1).
   e. Air intake and exhaust components (size and installation).
   f. Jacobs brake (installation and adjustment). See Items 11 thru 14.
   g. Fuel heater (restriction).
   h. Water separator (restriction).

4. **Check governor throttle and shutdown linkage adjustment as follows:**
   a. Improper adjustment of vehicle throttle linkage and governor shut down are the most frequent causes of low power/performance concerns. When the vehicle throttle (accelerator pedal) is fully depressed, the governor throttle lever should move from *idle* to the *full–throttle* position. Low power will result if the vehicle throttle linkage cannot reach the *full–throttle* position.
   b. The governor run–stop lever (mechanism) normally installed by the O.E.M. must be adjusted to allow an air gap or clearance (.020 min.) between the stop lever and the air or electric solenoid. Improper adjustment (lack of air gap) of the run–stop lever mechanism will not allow the injector control rack(s) to reach the *full–fuel* position, thus resulting in low power/performance.
5. **Check fuel system for pressure and flow as follows:**
   a. First, start and run the engine. Check for proper fuel pressure at specified engine speeds (refer to Section 13.2). Checking fuel pressure will reveal conditions related to fuel flow restriction, fuel pump relief valve operation and performance conditions caused by high or low fuel pressure.
   b. If fuel pressures are according to specifications, disconnect the fuel return line from the fitting at the fuel tank and check return flow rate. Hold open end in a clean container. Start and run the engine at 1000 rpm. Place the end of the fuel return line beneath the fuel level in the receptacle. After a few minutes no air or gas bubbles should be present. If any bubbles are detected, determine the cause for air entering the fuel system and repair, as required. Air in the fuel system is normally caused by a leak at fuel connections and/or filters between the suction side of the fuel pump to the supply tank and not between the pressure side of the pump and engine. Minimum fuel return rates are provided in Section 2.0.
   c. If no air bubbles are present and return rate is below minimum specifications, check for fuel flow restrictions which can be caused by fuel heaters, water separators, undersize, improperly routed or damaged fuel lines, contaminated fuel filters or high fuel pressure resulting from a plugged restricted fitting.
   d. *Always make sure there is sufficient fuel supply (at lead 1/3 of normal capacity) in the fuel tanks.*
6. **Check crankcase for lube oil overfill.** Overfilled engine crankcase can cause low power and higher–than–normal lubricating oil temperature. Normally, oil levels should be at or slightly below the oil pan–to–block split line with vehicle on level ground.
7. **Check engine horsepower, if necessary.** First, insure engine is at the proper operating temperature. The horsepower measurement before and after corrective action can be used to evaluate the results of the troubleshooting and repair effort. Record this power at appropriate time while troubleshooting. The actual horsepower reading should not be used to judge if engine performance is satisfactory but used only to see if a noticeable power change has taken place. Fuel quality, engine–driven accessories, drive line or tires can contribute to low power readings. It should be noted that No. 1 diesel fuel can produce up to 7% less horsepower than No. 2 fuel. Blends of No. 1 and No. 2 (common in winter) will produce less horsepower, depending on the percent of the blend.
8. **Check for evidence of brake dragging, bad driveline bearings or misaligned axles.**
9. **Check for excessive air intake restriction.** Undersize or dirty air cleaner elements, damaged or obstructed air inlet piping can also cause low power.
10. **Check turbocharger exhaust connections and exhaust system components**. A damaged, undersized or otherwise restricted muffler or exhaust system can result in high exhaust back pressure and subsequent loss of engine power.
11. **Check for proper location of rocker cover(s).** If the cover(s) has been pushed towards the injector control tube assembly (inboard on Vee engines), the injector control lever movement may be restricted by the cover. This condition will not allow injectors to reach full fuel, thereby causing a low power/performance condition. Situations that can cause this condition are:
    a. Use of engine lifting apparatus that contacts the rocker cover(s).
    b. Incorrect reinstallation of rocker cover(s) after removal for various reasons (Jacobs brake installation, for example).
12. **Check throttle delay or fuel modulator operation.** If the engine is equipped with a throttle delay, check for the proper setting and a plugged discharge orifice. If the engine is equipped with a fuel modulator, check for a pinched air supply line. Determine if there is any interference with the roller assembly or improper roller–to–cam contact when governor throttle lever is in the *full–throttle* position. Check for smooth operation of the piston in the bore. Check for excessive air leakage between the piston and cylinder which may be caused by excessive piston clearance due to wear.

13. **Check governor–to–injector linkage**. Removal of the governor and rocker cover(s) will be necessary to detect any binding or restriction of linkage movement.

14. **Check engine tune–up and make necessary corrections**. If all previous steps do not reveal cause for a confirmed low power/performance condition, engine tune–up settings may be considered a probable cause. It is normal for tune–up settings to vary when using correct setting procedures. Some items influencing tune–up measurements are differences in gages, individuals and mechanical variations.

At Detroit Diesel Corporation, engine tune–up settings are conducted using electronic and dial indicator gaging equipment. Finally, to determine that tune–up is within accepted tolerances, the engine is tested to assure that horsepower output is to published specifications.

Jacobs brake installation or adjustment errors can cause low power/performance conditions.

When making tune–up adjustments, refer to Section 14 for specifications.

Periodic inspection of tune–up gages is necessary to determine if damaged or worn. Injector timing gages are marked with the timing dimensions and have an allowable tolerance of ± .001". Rack gages are marked with the specific dimension and have an allowable tolerance of ± .002".

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 DAYS OR LESS)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

   NOTICE: Do not drain the fuel system or the crankcase after this run.
4. Check the air cleaner and service it, if necessary, as outlined in Section 3.1.
5. If freezing weather is expected during the storage period, add an ethylene glycol base antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the drain cocks open.
6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.
7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission and priming the raw water pump, if used.

EXTENDED STORAGE (MORE THAN 30 DAYS)

To prepare an engine for extended storage, (more than 30 days), follow this procedure:

1. Drain the cooling system and flush with clean, soft water. Refill with clean, soft water and add a rust inhibitor to the cooling system (refer to *Corrosion Inhibitor* under *Coolant Specifications* in Section 13.3).
2. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.
3. Reinstall the injectors, time them and adjust the exhaust valve clearance.
4. Circulate the coolant by operating the engine until normal operating temperature is reached (see Section 13.2).
5. Stop the engine.
6. Drain the engine crankcase, then reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.
7. Fill the crankcase to the proper level with a 30 weight preservative lubricating oil MIL–L–21260C, Grade 2.
8. Drain the fuel tank. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it isn't convenient to drain the fuel tank (i.e., marine) use a separate portable supply of the recommended fuel.

   NOTICE: If engines in vehicles or marine units are stored where condensation of water in the fuel tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of one pint (0.5 liter) to 125 gallons (473 liters) of fuel or .010% by volume. Where biological contamination of fuel may be a problem, add a biocide such as Biobor JF, or equivalent, to the fuel. When using a biocide, follow the manufacturer's concentration recommendations and observe all cautions and warnings.

9. Drain and disassemble the fuel filter and strainer. Discard the used elements and gaskets. Wash the shells in clean No. 1 diesel fuel or pure kerosene and insert new elements. Fill the cavity between the element and shell with No. 1 diesel fuel or pure kerosene and reinstall on the engine. If spin–on fuel filters and strainers are used, discard the used cartridges, fill the new ones with No. 1 diesel fuel or pure kerosene and reinstall on the engine.
10. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine.
11. Refer to *Section 3.1* and service the air cleaner.
12. MARINE GEAR
    a. Drain the oil completely and refill with clean oil of the recommended grade and viscosity. Remove and clean or replace the strainer and filter elements.
    b. Start and run the engine at 600 rpm for 10 minutes to coat all of the internal parts of the marine gear with clean oil. Engage the clutches alternately to circulate clean oil through all of the moving parts.

NOTICE: The performance of this step is not necessary on torque converter units.

13. TORQMATIC CONVERTER
    a. Start and operate the engine until the temperature of the converter oil reaches 150°F (66°C).
    b. Stop the engine, remove the converter drain plug and drain the converter.
    c. Remove the filter element.
    d. Start the engine and stall the converter for **twenty seconds** at 1000 rpm to scavenge the oil from the converter. *Due to lack of lubrication, do not exceed the 20 second limit.*
    e. Install the drain plug and a new filter element.
    f. Fill the converter to the proper operating level with a commercial preservative oil which meets specification MIL–L–21260C, Grade 2. Oil of this type is available from the major oil companies.
    g. Start the engine and operate the converter for at least 10 minutes at a minimum of 1000 rpm. Engage the clutch, then stall the converter to raise the oil temperature to 225°F (107°C).

NOTICE: Do not allow the oil temperature to exceed 225°F (107°C). If the unit does not have a temperature gage, *do not stall the converter for more than thirty seconds.*

    h. Stop the engine and allow the converter to cool to a temperature suitable to the touch.
    i. Seal the breather and all of the exposed openings with moisture proof tape.
    j. Coat all exposed, unpainted surfaces with preservative grease. Position all of the controls for minimum exposure and coat them with grease. The external shafts, flanges and seals should also be coated with grease.
14. POWER TAKEOFF
    a. Use an all purpose grease such as Shell Alvania No. 2, or equivalent, and lubricate the clutch throwout bearing, clutch pilot bearing, drive shaft main bearing, clutch release shaft and the outboard bearings (if so equipped).
    b. Remove the inspection hole cover on the clutch housing and lubricate the clutch release lever and link pins with a hand oiler. *Avoid getting oil on the clutch facing.*
    c. If the unit is equipped with a reduction gear, drain the gear box and flush with light engine oil. If the unit is equipped with a filter, clean the shell and replace the filter element. Refill the gear box to the proper level with the grade of oil indicated on the name plate.
15. TURBOCHARGER

Since turbocharger bearings are pressure lubricated through the external oil line leading from the engine cylinder block while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

16. HYDROSTARTER SYSTEM

Refer to Section 12.6.1 for the lubrication and preventive maintenance procedure.

17. Apply a *non–friction* rust preventive compound to all exposed parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

    NOTICE: Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat" out during operation and cause the clutch to slip.

18. Drain the engine cooling system.
19. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.
20. Remove and clean the battery and battery cables with a baking soda solution and rinse them with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32°F or 0°C) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

21. Insert heavy paper strips between the pulleys and belts to prevent sticking.
22. Seal all engine openings, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.
23. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.
24. Protect the engine with a good weather–resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

Detroit Diesel Corporation does not recommend the outdoor storage of engines (or transmission). Nevertheless, DDC recognizes that in some cases outdoor storage may be unavoidable. If units must be kept out–off–doors, follow the preparation and storage instructions already given. Protect units with quality, weather–resistant tarpaulins (or other suitable covers) arranged to provide air circulation.

NOTICE: *Do not use plastic sheeting for outdoor storage.* Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*
2. Wash the exterior of the engine with fuel oil to remove the rust preventive.
3. Remove the rust preventive from the flywheel.
4. Remove the paper strips from between the pulleys and the belts.
5. Remove the drain plug and drain the preservative oil from the crankcase. Reinstall the drain plug. Then, refer to *Lubrication System* in Section 13.1 and fill the crankcase to the proper level, using a pressure prelubricator, with the recommended grade of lubricating oil.
6. Fill the fuel tank with the fuel specified under *Fuel Specifications* (Section 13.3).
7. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a solution of water and an ethylene glycol base antifreeze (refer to Coolant Recommendations in Section 13.3).
8. Install and connect the battery.
9. Service the air cleaner as outlined in Section 3.1.
10. POWER GENERATOR

Prepare the generator for starting as outlined under *Operating Instructions* in Section 13.

11. MARINE GEAR

Check the marine gear; refill it to the proper level, as necessary, with the correct grade of lubricating oil.

12. TORQMATIC CONVERTER

a. Remove the tape from the breather and all of the openings.

b. Remove all of the preservative grease with a suitable solvent.

c. Start the engine and operate the unit until the temperature reaches 150°F (66°C). Drain the preservative oil and remove the filter. Start the engine and stall the converter for twenty seconds at 1000 rpm to scavenge the oil from the converter.

NOTICE: A Torqmatic converter containing preservative oil should only be operated enough to bring the oil temperature up to 150°F (66°C).

d. Install the drain plug and a new filter element.

e. Refill the converter with the oil that is recommended

under *Lubrication and Preventive Maintenance* (Section 15.1).

13. POWER TAKE–OFF

Remove the inspection hole cover and inspect the clutch release lever and link pins and the bearing ends of the clutch release shaft. Apply engine oil sparingly, if necessary, to these areas.

14. HYDROSTARTER

a. Open the relief valve on the side of the hand pump and release the pressure in the system.

b. Refer to the filling and purging procedures outlined in *Hydraulic Starting System* (Section 12.6.1). Then drain, refill and purge the hydrostarter system.

15. TURBOCHARGER

Remove the covers from the turbocharger air inlet and turbine outlet connections. Refer to the lubricating procedure outlined in *Preparation for Starting Engine First Time* in Section 13.1.

16. After all of the preparations have been completed, start the engine.

NOTICE: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune–up.

