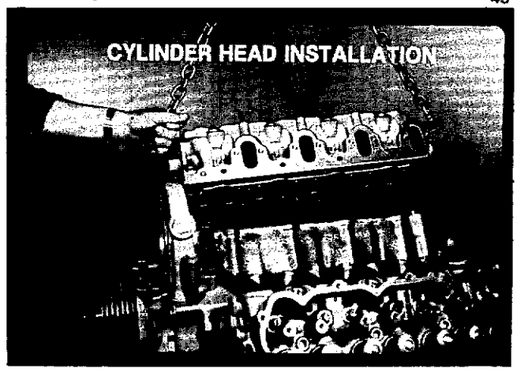
Cylinder Head Installation

43



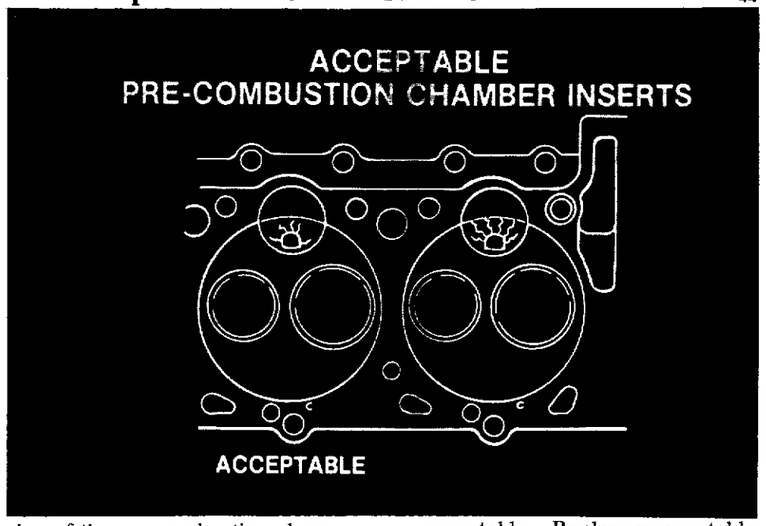
Utilize a lifting device (chain hoist or portable lift) to support cylinder head during installation and avoid damaging head gasket and head face.

Because the limited clearance does not permit use of guide studs on E-350 in-chassis cylinder head installation, the following method can be used to ensure gasket damage does not occur.

- Install cylinder head gasket on the crankcase.
- Place cardboard backing provided with the service part package over the cylinder head gasket for protection.
- Position cylinder head on crankcase dowels.
- Install one cylinder head bolt at each end.
- Raise cylinder head and remove cardboard protector.

Acceptable Pre-Combustion Chamber Inserts

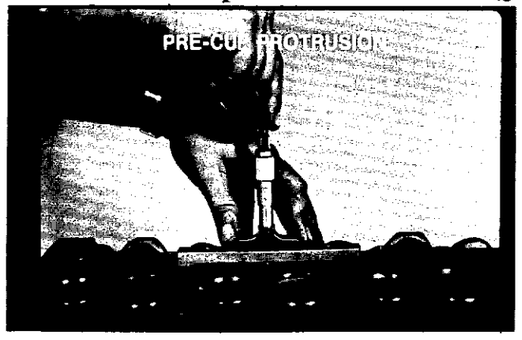
44



Cracking and burning of the pre-combustion chamber inserts is acceptable from the throat. However, cracking and burning past the fire ring mark is not acceptable. Replace unacceptable pre-combustion chambers. (Reference TSB 84-8-23).

Pre-Cup Protrusion

45



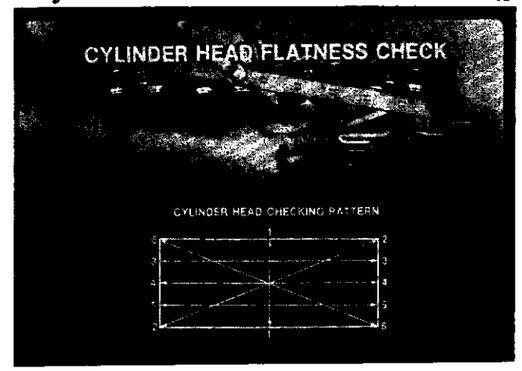
When installed, the pre-combustion chambers are acceptable with a 0.002" protrusion above the cylinder head deck or a 0.002" recession below the cylinder head deck.

NOTE

When servicing 6.9L cylinder heads, loose fitting pre-combustion chamber inserts in the cylinder head does not constitute criteria for pre-cup replacement. The pre-combustion chamber inserts are secured in place via the cylinder head bolt torque.

Cylinder Head Flatness Check

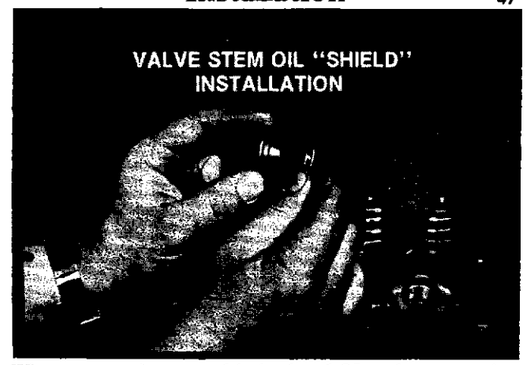
46



Pre-cups should be removed when checking head face flatness. As was previously discussed, the pre-cups can have 0.002" protrusion and if the straight edge is placed across a pre-cup, erroneous readings will result and unnecessary cylinder head replacements may occur.

Valve Stem Oil "Shield" Installation

47



When properly assembled, the 6.9L valve stems incorporate an oil "shield" which is snapped into the valve retainer. (Reference: TSB 84-19-20).

During disassembly of the cylinder head, the oil "shield" typically separates from the valve retainer, and gives the impression that the shield floats on the valve stem. Therefore, unless the technician is aware of this condition, during reassembly the oil shields are incorrectly installed, floating on the valve stem.

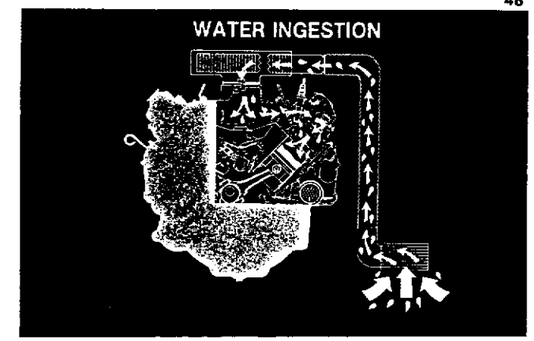
IMPORTANT

Valve stem oil shields must be snapped into the valve retainer. If not properly installed, intake valve stem oil seals get damaged and excessive oil consumption will result.

The oil shields can be obtained through service parts by ordering valve retainer assembly P/N E3TZ 6514 A. They are not serviced individually. The shields are also part of the upper (valve grind) gasket set P/N E5TZ 6079 B where it is a loose part (individual) and requires installation into the valve retainer as described above.

Water Ingestion

48



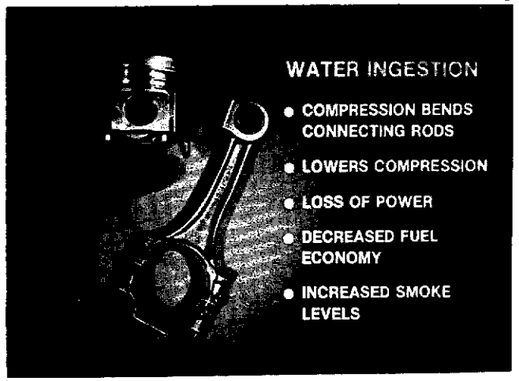
There are instances where water can be ingested through the air intake system and engine damage can result.

TSB 83-5-21 on early vintage 1983 model year vehicles addressed snow ingestion via drilling a 1/4 inch hole to drain the water from the air cleaner housing after the snow melted from around the air cleaner.

TSB 84-9-19 describes the addition of a splash shield that was added to vehicles during 1984 model year. The splash shield deflects water sprayed into the zip tube when driving through water puddles or in raining conditions.

Water Ingestion – Poor Performance

49

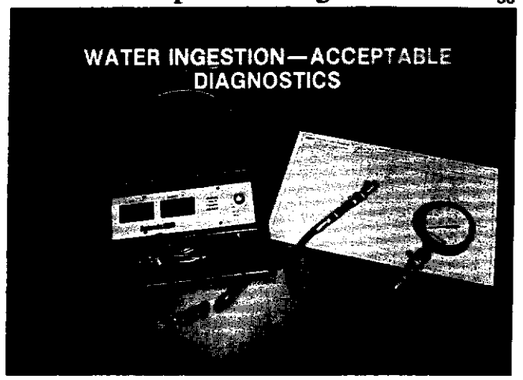


When water is ingested through the air induction system, the vehicle typically is not rendered inoperative. Water ingestion into the combustion chamber can bend one or more connecting rods and the engine will continue to run without a detectable miss.

The typical complaint from the vehicle owner will be a noticeable loss of power and fuel economy and an increase in the smoke levels (primarily white/blue) from the unit. A bent connecting rod lowers compression and therefore, the fuel that is provided to that cylinder does not burn completely. The end result being decreased power and economy and increased smoke levels.

Water Ingestion – Acceptable Diagnostics

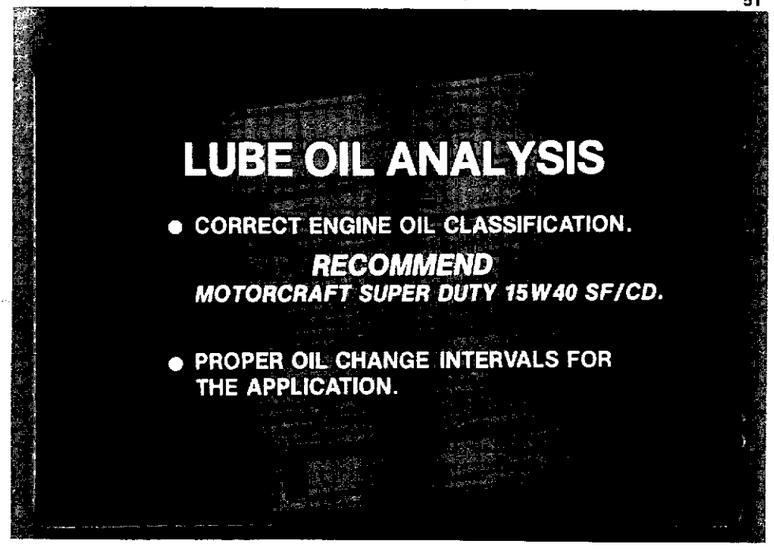
50



As with any performance complaint, the technician should complete diagnostic form FPS-8433C to ensure that the fuel, air induction, and exhaust systems are functioning properly. If all tests indicate no defects, a compression test should be performed. As described above, a bent connecting rod will result in a lower compression reading. (Typically 75-100 psi less than the other cylinders.)

Lube Oil Analysis

51



Some oil companies, engine manufacturers and testing laboratories have published concentration values for wear metals (iron, aluminum, copper, chromium, lead) which they use to indicate the start of abnormal wear. These values can be misleading, since they are based on averages of thousands of analyses from a wide variety of engine models operated in many different service types. However, because of basic differences in design and materials among various engine models, the normal wear patterns of each engine model are somewhat unique, like fingerprints.

In today's industry, oil analysis has to be used with discretion. The amounts in parts per million (PPM) of wear metals and % fuel vary from engine to engine and what is normal for one engine may be abnormal for another engine.

If oil analysis is used on the 6.9L a general rule of thumb to follow is:

- Create your own baseline from the oil analysis data obtained.
- Plot the data on each individual area i.e. wear metals, fuel % etc. and note any major changes.
- If a major change occurs in any test area, reduce the drain interval by half and perform another oil analysis.
- If the area in question falls within your baseline then go back to the original drain interval and continue.
- If it does not return to baseline, then corrective action must be taken.

REMEMBER

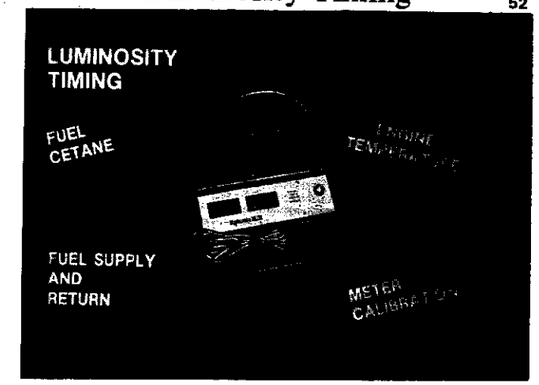
Two major factors affecting oil analysis are:

- *Correct engine oil classification*
  – Recommend Motorcraft 15W40 SF/CD.
- *Proper oil change intervals for the application.*
  – Remember 2500 miles (4000 kilometers) for severe duty service.

To summarize, every engine has its own signature and to avoid unnecessary engine repairs remember the general rule of thumb noted above.

Luminosity Timing

52



A brief review of how the luminosity timing meter measures timing will assist the technician in checking and adjusting timing.

- The luminosity meter actually senses the fire (light) of combustion and relates this to a given crank angle to provide the technician with a timing meter reading.

Realizing that the luminosity timing meter senses start of combustion, the "Precautions and Pitfalls" when using the luminosity meter can now be discussed.

Meter Calibration

To ensure that correct timing readings are obtained, meter calibration should be checked prior to each use. Meter calibration can only be checked by the technician and to perform this test, it is important that the technician refer to the instructions provided with the meter. The calibration procedure is the same for all meters. However, there are two different calibration test values. If the meter is found to be out of calibration, it must be returned to the manufacturer's designated service location per the instructions provided with the meter. Incorrect readings due to meter calibration can result in mis-set engine timing which in turn can cause poor performance or engine damage.

Timing Reading Precautions

Because the luminosity meter is sensing start of combustion, the reading obtained is effected by:

FUEL QUALITY. Cetane value should be measured to determine the correct specification that the injection timing should be set at. Dynamic timing readings obtained by the technician differ with a change in cetane value as is referenced by the timing specification ranges. Timing should not be adjusted to compensate for cetane changes.

COMBUSTION TEMPERATURE. If the engine is not at NORMAL operating temperature retarded timing readings will be obtained.

POWER CYLINDER. The condition of the power cylinder effects timing, however, this condition will be accompanied by an additional concern such as smoke or hard start.

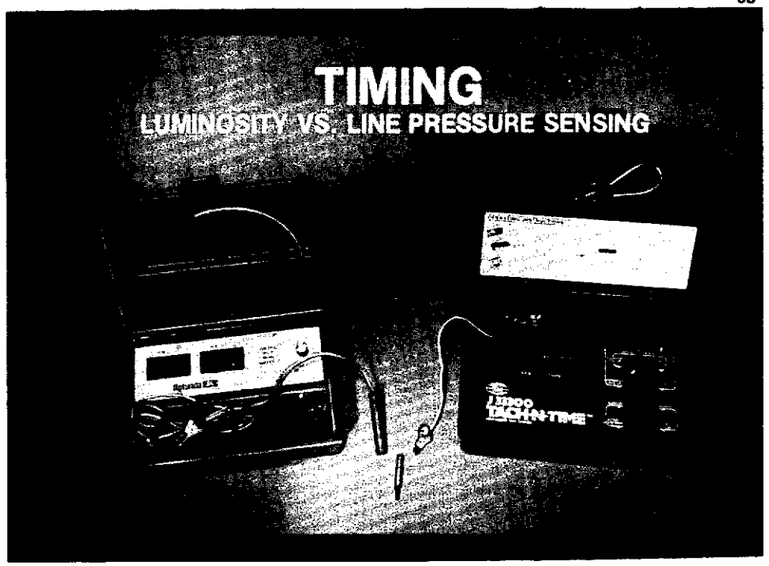
In addition, as previously described, the condition of the fuel supply and return systems can affect injection timing.

NOTE

If timing is adjusted without regards to cetane value or combustion temperature, timing can be over advanced and engine damage can occur.

Luminosity vs. Line Pressure Sensing Timing

53



There has been discussion of timing specifications provided to the field. The questions have been raised due to Ford and International Harvester dealers conversing in regards to injection pump timing.

There is a difference in the timing meters used between Ford and IH (reference TSB 85-16-24) and therefore there are different timing specifications. As was previously discussed, Ford uses a luminosity (light sensing) meter and International Harvester uses a line pressure sensing meter. The basic difference is:

- Line pressure measures start of fuel injection.
- Luminosity measures start of combustion.

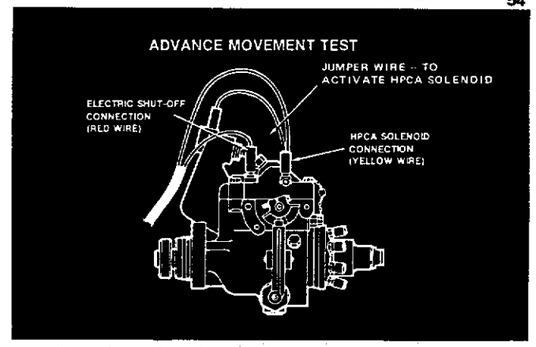
Because fuel has to be injected into the power cylinders before it can burn there are different timing specifications depending on the type of meter being used. Fuel is injected Before Top Dead Center (BTDC) and combustion starts After Top Dead Center (ATDC). Therefore, luminosity timing specifications are ATDC and line pressure sensing timing specifications are BTDC. Both specifications are correct and provide optimum performance if used with the applicable meter.

IMPORTANT

Setting injection timing to the wrong specification can result in poor engine performance and engine damage.

Advance Movement Test

54



Another functional test that can be performed on engine is to determine if fuel injection pump advance piston movement is occurring.

This test is outlined in the Shop Manual and the latest engine Performance Chart (Diagnostic Chart FPS 8433C) which consists of energizing the housing pressure cold advance (HPCA) solenoid and comparing the timing readings obtained at 1400 RPM with the reading obtained without the HPCA solenoid energized.

A minimum of 2.5° advance should be observed with the HPCA energized.

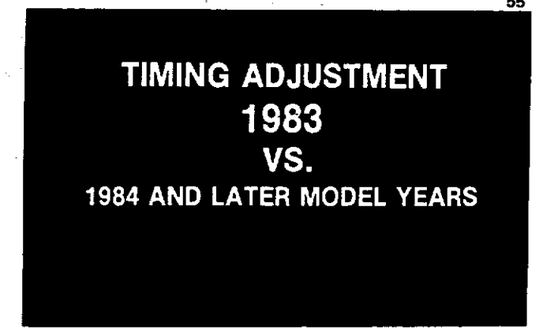
IMPORTANT

When the HPCA solenoid is energized, engine RPM should be reset to 1400 RPM to obtain the minimum 2.5° advance.

The foregoing functional test provides the technician the tool to determine that the injection pump advance is operating correctly. This will help eliminate unnecessary injection pump replacements.

Timing Adjustment 1983 versus 1984 and Later Model Years

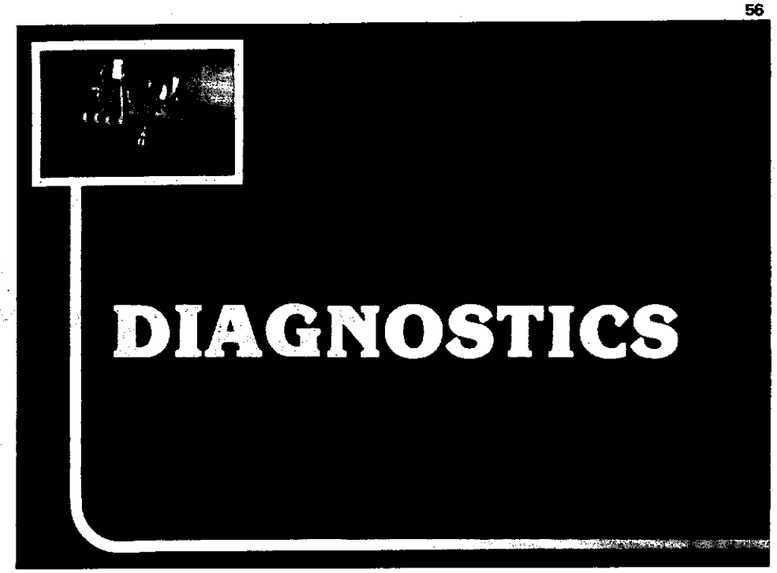
55



With 1983 "A" model engines, there were many instances where field timing adjustments were made to improve performance and/or economy. The 1984 "B" model engine, with increased compression ratio and fuel system changes desensitized the 6.9L to performance variance with a change in timing.

Therefore, if the timing of a 1984 or later engine (calibrations 468J-R00, 468X-R00) is within specification, adjusting it to the advanced side of the specification will not make a noticeable increase in economy or performance.

56

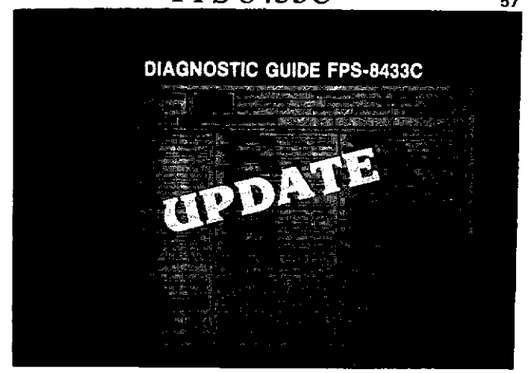


A brief discussion on updated diagnostic procedures and methods follows. This update does not supercede all previous manuals and/or diagnostic procedures and is only intended to supplement them. Areas that are addressed include:

- Revised Diagnostic Guide FPS-8433C August 1985 supercedes previous editions.
- 6.9 Diesel Engine Problem Solver
- Fast Start System Diagnostics – Repetitive Glow Plug Failures
- Engine Oil Pressure
- Oil Consumption
- Engine Performance and Fuel Economy
- Vehicle Performance Tests
- Vehicle Performance Evaluation
- Performance and Economy Relationship
- Lube Oil Fuel Dilution

Revised Diagnostic Guide FPS-8433C

57



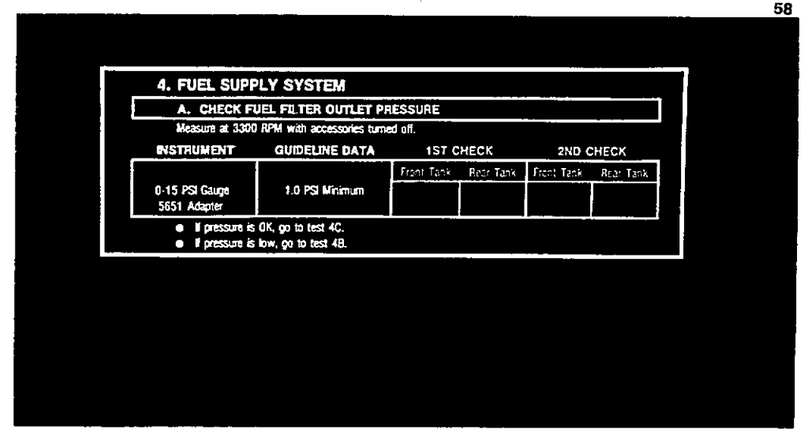
To promote the effectiveness of properly diagnosing engine performance concerns and provide the technician with the latest information, the Engine Performance Chart (FPS-8433C) has been updated.

A copy of the updated form is included as an attachment in the appendix of this publication and our review will be limited to those areas of the form that have been updated.

This updated form and procedure supercedes all previously released 6.9L Engine Performance Charts and should be used for all model year vehicles as it reflects the most current information in diagnosing engine performance concerns. In addition, the updated procedure is commensurate with approved warranty policies covering diagnostics.

Front and Rear Tank Fuel Pressure and Restriction Checks

58



4. FUEL SUPPLY SYSTEM

A. CHECK FUEL FILTER OUTLET PRESSURE

Measure at 3300 RPM with accessories turned off.

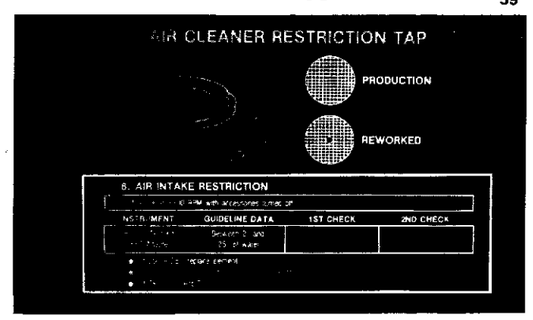
INSTRUMENT	GUIDELINE DATA	1ST CHECK		2ND CHECK	
		Front Tank	Rear Tank	Front Tank	Rear Tank
0-15 PSI Gauge 5651 Adapter	1.0 PSI Minimum				

- If pressure is OK, go to test 4C.
- If pressure is low, go to test 4B.

To eliminate the possibility of overlooking a suction leak or restriction isolated to only one fuel tank, the form has been modified to incorporate all fuel pressure and restriction tests on both tanks.

Air Intake Restriction Tap Plugged

59



A low or zero air cleaner restriction reading could be caused by a plugged sintered fitting (tap) located on the air cleaner cover. The fitting has a filter screen in it and the screen can become plugged and not allow a correct air cleaner restriction reading to be taken. If this type of fitting is found, drill the center of the screen with a 1/32" size drill. This fitting is secured to the air cleaner cover and is not a serviceable part.

IMPORTANT

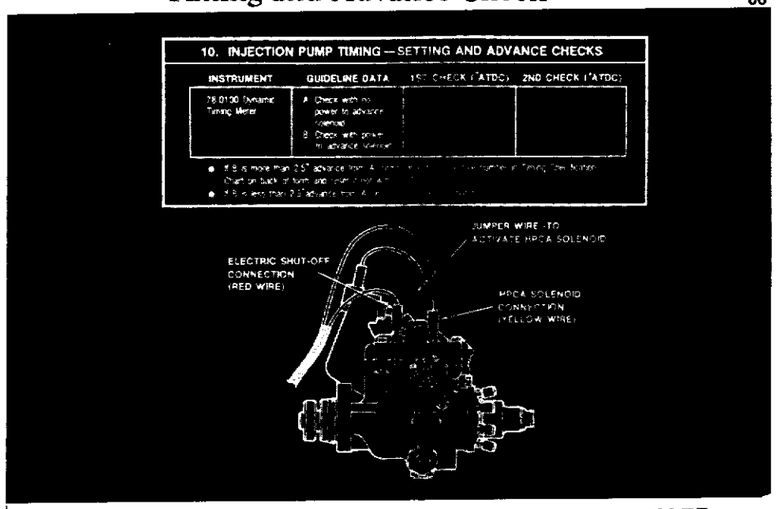
When reworking (drilling) the air cleaner restriction tap, remove the air cleaner cover from the engine to eliminate any shavings from falling into the intake manifold.

It is more effective to drill the fitting from the under side of the cover.

After tests and/or rework of the tap are completed, re-install the protective plastic cap (production) or a 1/8" pipe thread cap to avoid dusting the engine.

Timing and Advance Check

60



The method of functionally testing the advance mechanism that was previously included in the Diagnostic Manual has been incorporated into the updated Diagnostic Guide. The procedure is as follows:

1. Disconnect cold start advance solenoid from wiring harness (yellow wire) as illustrated.

2. Apply battery voltage to solenoid terminal to activate it.

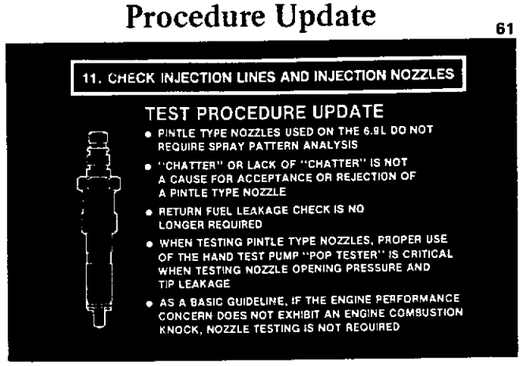
NOTE

Activating the cold start advance solenoid can result in engine speed increase. Adjust throttle control to attain 1400 rpm, if required.

3. Check timing at 1400 rpm. The timing should be at least 2.5 degrees advanced before the timing obtained without the solenoid being energized. If the advance is less than 2.5 degrees, check the HPCA solenoid. If HPCA solenoid is OK, then replace the injection pump. If the HPCA is inoperative, replace the injection pump top cover assembly which includes the solenoid.

6.9L Injection Nozzle Test Procedure Update

61



The Diagnostic Guide reflects the nozzle test procedures described in the 1986 Diagnostic Shop Manual (Vol. H). Extensive testing has confirmed the following revisions in determining an acceptable nozzle in the 6.9L diesel:

- Pintle type nozzles used on the 6.9L do not require spray pattern analysis. Therefore, the spray pattern test has been deleted from the test procedure.

- "Chatter" or lack of "chatter" is not a cause for acceptance or rejection of a pintle type nozzle.

- Return fuel leakage check is no longer required and has been deleted.

- When testing pintle type nozzles, proper use of the hand test pump "pop tester" is critical when testing nozzle opening pressure and tip leakage.

- AS A BASIC GUIDELINE, IF THE ENGINE PERFORMANCE CONCERN DOES NOT EXHIBIT AN ENGINE COMBUSTION KNOCK OR MISS, NOZZLE TESTING IS NOT REQUIRED.

The revised injection nozzle test procedures for the 6.9L diesel are published in the 1986 Diagnostics Shop Manual (Vol. H) and excerpts from it are contained in the following pages:

REVISED PROCEDURES:

1. Fill nozzle tester with calibrating oil that meets SAE J967 (latest revision) of ISO 4113.

2. Connect injection nozzle to test pump. Avoid "cross threading" The connector nut must be tightened securely with an open end wrench.

3. Bleed air from nozzle. Close pump valve and operate pump for several quick strokes to expel (bleed) air from injection nozzle. Fluid should discharge from the hole in nozzle tip.

CAUTION

KEEP HANDS AWAY FROM NOZZLE DISCHARGE. FLUID DISCHARGING FROM THE NOZZLE UNDER HIGH PRESSURE CAN PENETRATE THE SKIN AND CAUSE INFECTION. MEDICAL ATTENTION SHOULD BE PROVIDED IMMEDIATELY IN THE EVENT OF SKIN PENETRATION.

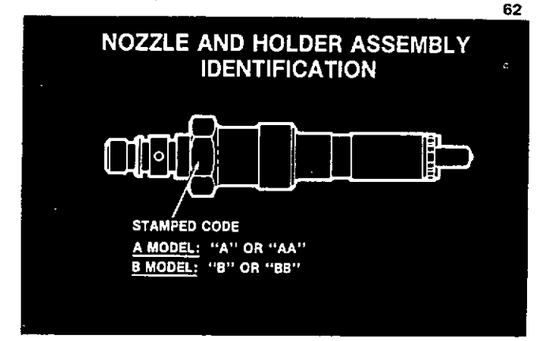
TEST 1

CHECK NOZZLE OPENING PRESSURE. Close the pump valve, then operate the pump handle in slow even strokes to bring the system pressure up. Note the highest pressure reached prior to the nozzle opening. Repeat operation, increasing handle speed if necessary, to establish consistent readings.

NOTE

DISREGARD TIP LEAKAGE DURING THIS TEST AND REMEMBER TESTING OF SPRAY PATTERN IS NO LONGER REQUIRED.

62



Identify "A" model vs. "B" model nozzles by the stamped code (as illustrated.)

Minimum permissible opening pressure for a used nozzle is:

"A" Model (Engine S/N 59208 and below): 1600 psi (11032 kPa)

"B" Model (Engine S/N 59209 and above): 1425 psi (9825 kPa)

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NOZZLE OPENING PRESSURE SPECIFICATIONS

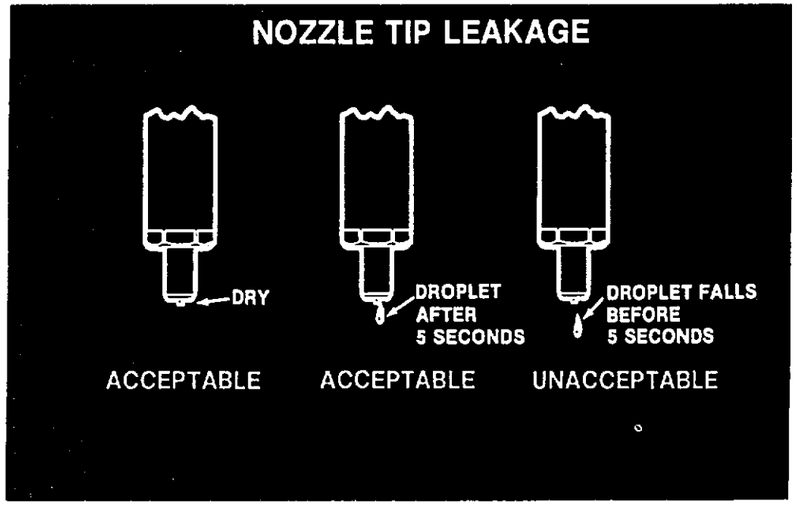
"A" MODEL	"B" MODEL
MINIMUM PERMISSIBLE 11,032 kPa (1,600 PSI)	MINIMUM PERMISSIBLE 9,825 kPa (1,425 PSI)

NOTE

New nozzles do not require pre-installation testing.

TEST 2

64



CHECK FOR TIP LEAKAGE. Blow nozzle tip dry using filtered compressed air. Operate test pump to maintain pressure at about 200 psi (1378 kPa) below the opening pressure obtained in Test 1. Wetting of the nozzle tip is acceptable as long as a drop does not fall within 5 seconds.

NOTE

Make sure that any fluid accumulation at the nozzle tip is not due to test fluid leaking down the outside of the nozzle body from the return openings. If questionable, wrap a shop cloth around the nozzle body to prevent fluid leaking down the outside of the nozzle body from reaching the tip.

IMPORTANT

Pintle type nozzles used in the 6.9L engine do not require spray pattern analysis. Extensive testing by International Harvester and Ford Motor Company has concluded that pintle nozzle spray pattern has no effect on actual nozzle or engine performance.

REMOVING NOZZLE FROM TESTER:

After testing is completed, make sure to open the pump valve to release the built up pressure prior to removing the nozzle from the tester. When nozzle is removed, cap the nozzle tip and inlet until reinstalled in the engine.

IMPORTANT

If the nozzle passes the nozzle opening pressure and tip leakage tests, it is suitable for further service in the engine.

Nozzles showing leakage at the nozzle tip spray hole or opening pressure below the minimum permissible limit, are defective and must be replaced.

Servicing the nozzles (disassemble, clean and rebuild), in lieu of replacement to correct nozzle tip leakage or low opening pressure, is not permitted during the warranty period. *Nozzles that are returned should be properly capped.*

6.9L Diesel Engine Problem Solver

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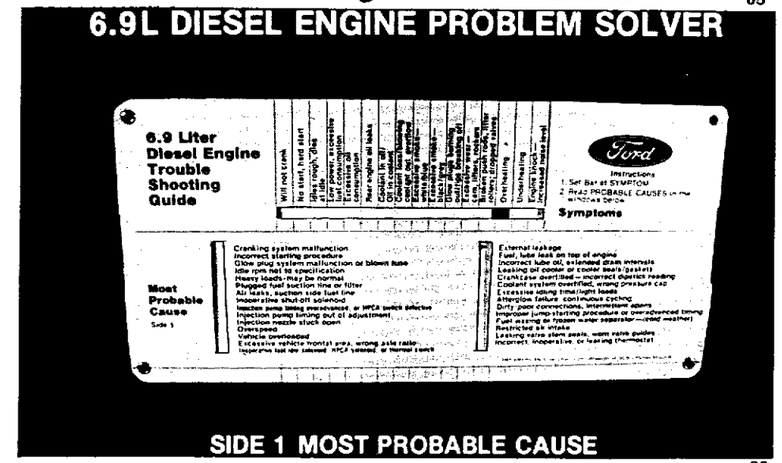

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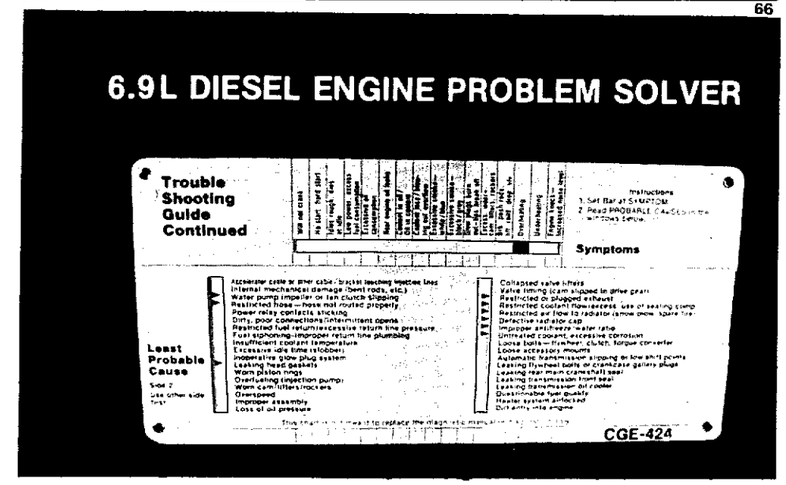


Illustrated above is the "slide rule" problem solver that can be used to supplement current diagnostic procedures. The "slide rule" addresses specific problem conditions and is available for quick reference in the following format:

- Problem symptoms are displayed on both sides at the top of the guide in the vertical boxes.
- MOST PROBABLE CAUSES are listed on the front side of the guide (Side 1).
- LEAST PROBABLE CAUSES are listed on the reverse side of the guide (Side 2).

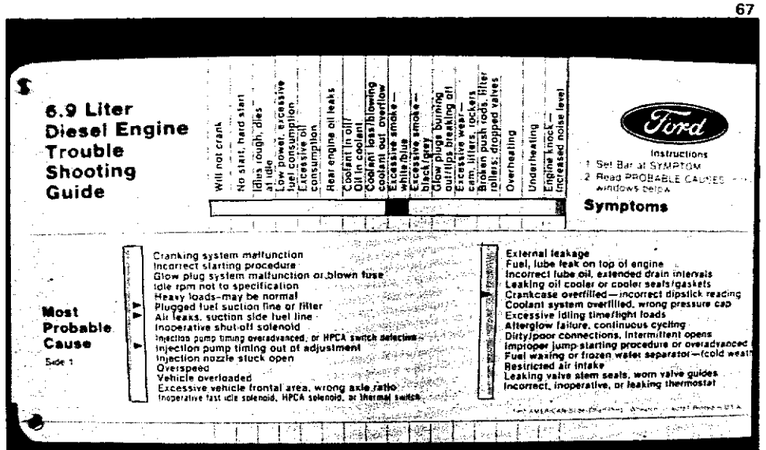
IMPORTANT

Refer to the "Most Probable Causes" first, as many of the least probable causes are only a remote possibility.

The "slide rule" diagnostic aid provides reference to the following problem conditions:

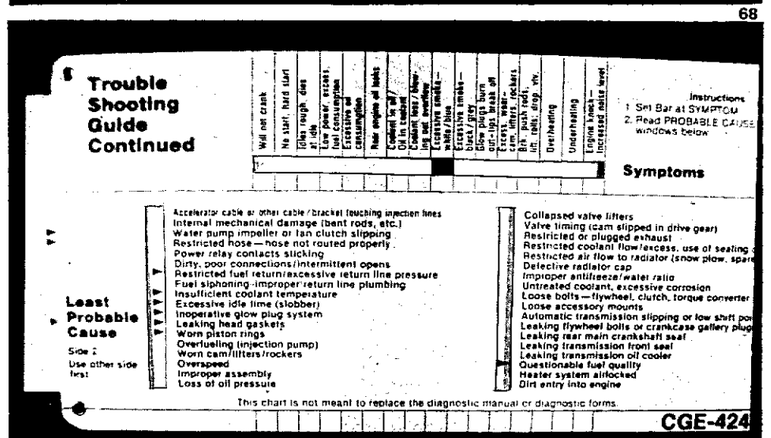
- Will not crank
- No start, hard start
- Idles rough, dies at idle
- Low power, excessive fuel consumption
- Excessive oil consumption
- Rear engine oil leaks
- Coolant in oil/oil in coolant
- Coolant loss/blowing coolant out overflow
- Excessive smoke – white/blue
- Excessive smoke – black/grey
- Glow plugs burning out/tips breaking off
- Excessive wear – cam, lifters, rockers
- Broken push rods, lifter roller; dropped valves
- Over heating
- Under heating
- Engine knock – increased noise level

67



***EXAMPLE:* MOST PROBABLE CAUSE**

68



***EXAMPLE:* LEAST PROBABLE CAUSE**

INSTRUCTIONS:

1. Set the slide bar at the symptom located in the horizontal box side 1.

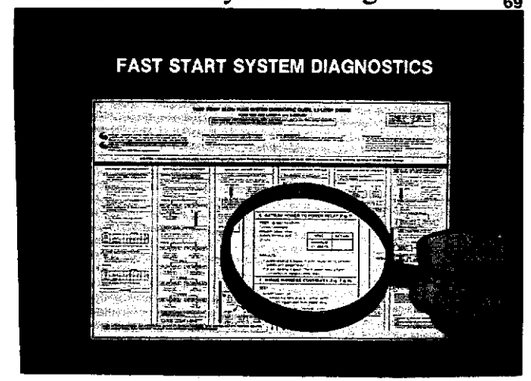
2. Find the Most Probable Causes in the vertical box (side 1 first) indicated by the arrows in the windows.

3. Turn the slide rule over to side 2 to find the Least Probable Causes.

The problem solver is intended as an additional service aid and supplements the current diagnostic forms and manuals. When submitting a performance related warranty claim, Diagnostic Form FPS-8433C must still be attached to the claim.

Fast Start System Diagnostics

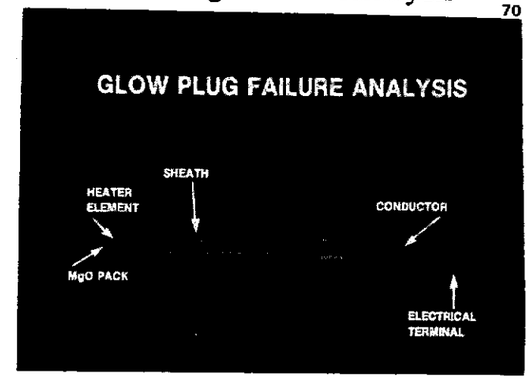
69



Where "multiple and repetitive" glow plug failures within the same vehicle are experienced, the following analysis and tips/suggestions will assist the technician in localizing the cause so an effective repair is performed.

Glow Plug Failure Analysis

70

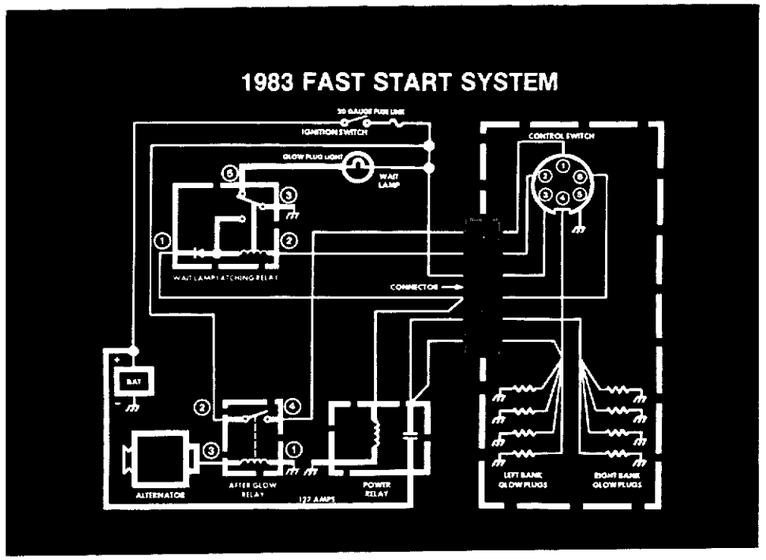


Before discussing individual or repetitive glow plug failure modes, a brief review of the glow plug construction and functional description is provided. The components identified for this discussion are:

- Electrical terminal
- Conductor
- Sheath
- Heater element
- MgO pack

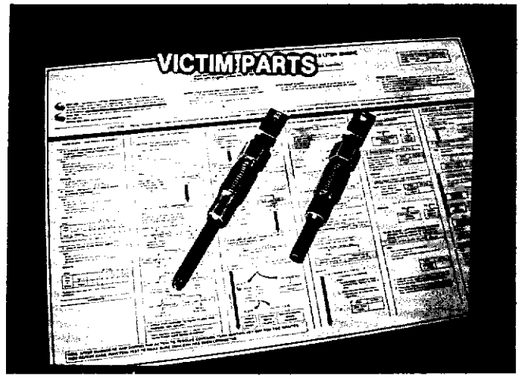
Current travels from the terminal to the heater element via the conductor. The heater element is a resistance wire insulated from the sheath by the magnesium oxide (MgO) pack. In addition the MgO pack transmits the heat of the heater to the glow plug tip. The plug is grounded through its mounting in the cylinder head.

71



The majority of fast start system failures experienced to date have been associated with the 1983 system. The after glow and latching relays caused control system malfunction resulting in repetitive failures due to the glow plugs being energized when the engine is at normal operating temperature. On 1983 vehicles repetitive failures were minimized when the latching and after glow relays were replaced with the repair.

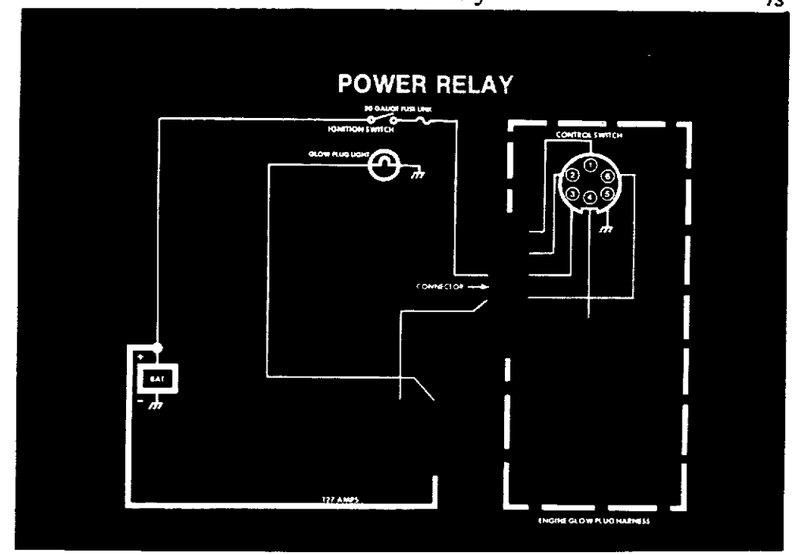
72



Where repetitive multiple glow plug failures are experienced on the current (1984 or later) fast start system, the glow plugs are victim parts and complete system analysis is necessary. If no defects were detected after completing the fast start system troubleshooting guide, the following areas should be considered.

Power Relay

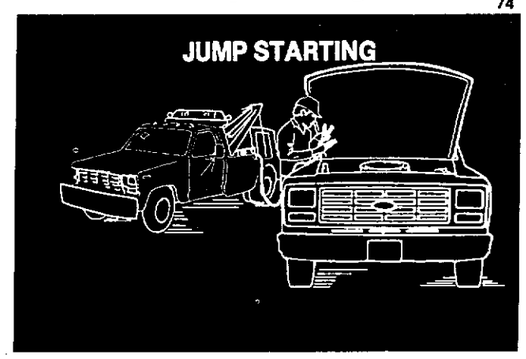
73



Intermittent power relay sticking, resulting in extended glow plug on time and multiple plug failures.

Jump Starting

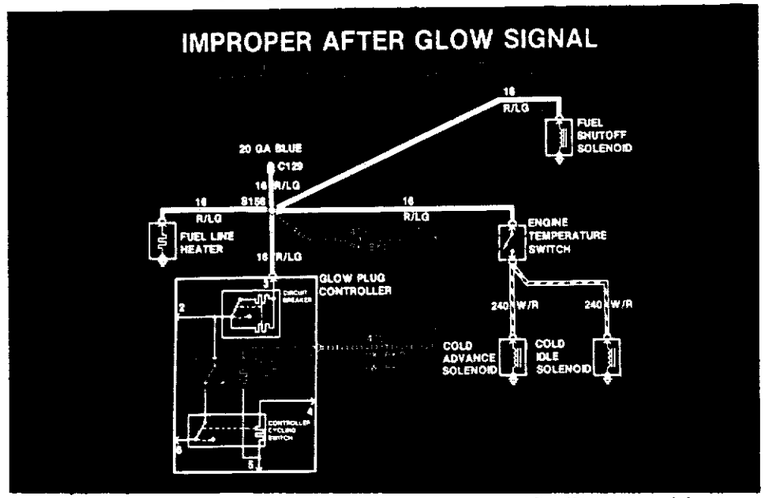
74



Jump starting with voltage supply greater than 12 volts.

Improper After Glow Signal

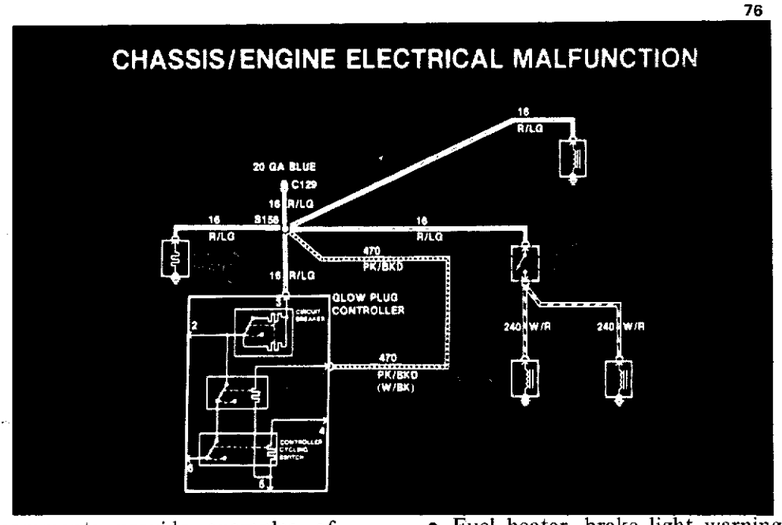
75



Energizing the glow plugs with engine at normal operating temperature and under load can cause glow plugs to become electrically open. Any chassis or engine electrical malfunction that can affect the signal to the after glow circuit (glow plug controller pin no. 1), permitting the glow plugs to start cycling while the engine is at normal operating temperature can cause multiple and repetitive glow plug failures.

More specifically, any wiring connection with excessive resistance causing a voltage drop to pin no. 1 of the controller or any other electrical component being supplied by the same wire supplying pin no. 1 that is creating an excessive draw and a reduced signal to pin no. 1.

76

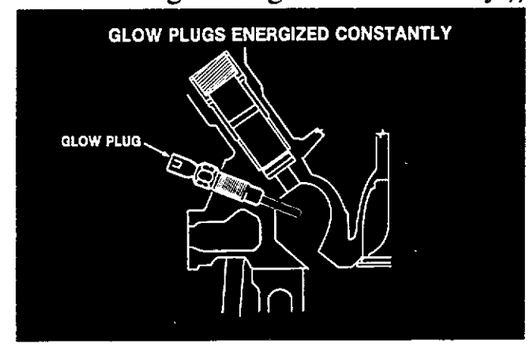


The following comments provide examples of potential causes than can result in a signal loss to pin no. 1 of the glow plug controller as stated above:

- Any poor connection, i.e., dirt, corrosion, loose fit or vibration causing excessive resistance or intermittent continuity loss.
- Fuel heater, brake light warning (low vacuum) switch or the temperature switch that controls the HPCA and cold idle solenoids (located in front of the right cylinder head) has a partial short creating excessive current draw.
- Unauthorized wiring of after market accessories into the fast start system circuitry.

Glow Plugs Energized Constantly

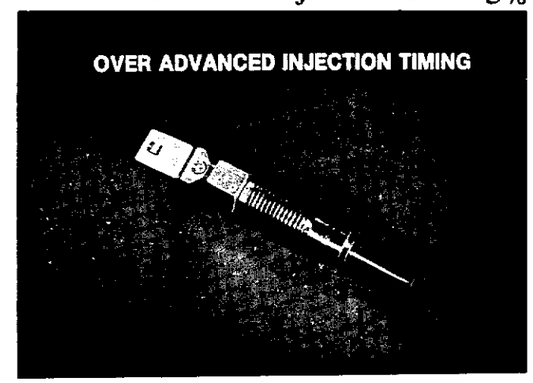
77



Any wiring defects that would bypass the controller and energize the glow plugs with a continuous 12 volts will result in glow plug failures.

Over Advanced Injection Timing

78



Over advanced fuel injection pump timing can cause the glow plug tips to be burnt off as illustrated above. The glow plug burning can be aggravated by an engine over-temp condition as well.

IMPORTANT

Normal engine operation will not cause glow plug concerns. Do not jump start with excess of 12 volts or use ether starting aids.

Engine Oil Pressure Verification

79

When a low oil pressure complaint is being diagnosed, check oil pressure with a manual gauge and engine at normal operating temperature to the following specifications:

10 PSI (69 kPa) min. @ 700 RPM.
40-70 PSI (276-482 kPa) @ 3300 RPM.

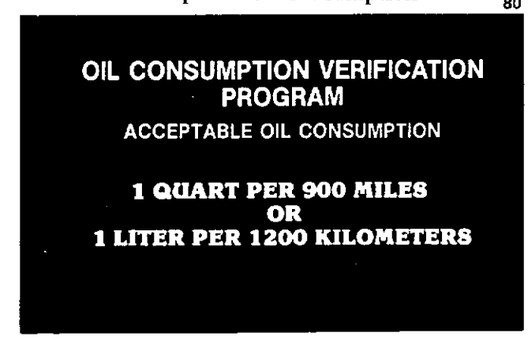
NOTE

Where service specifications refer to curb idle speed in conjunction with measuring oil pressure, it is important to test at 700 RPM engine speed. In addition, high oil pressure test measurements should be made at 3300 RPM rated engine speed and not 2200 RPM as stated in the 1983, 1984 and 1985 shop manual.

Oil Consumption Verification Program

Acceptable Oil Consumption

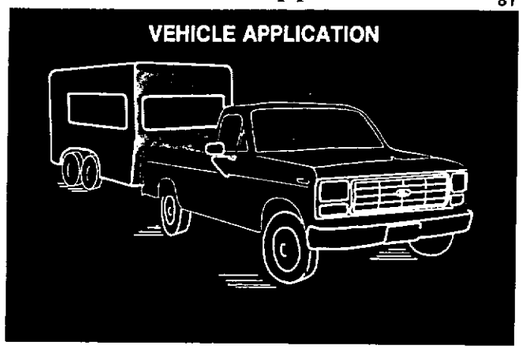
80



Acceptable oil consumption is one (1) quart per 900 miles (one [1] liter per 1200 kilometers) under normal use. Severe duty usage, i.e., trailer towing, extended vehicle operation with heavy loads or large frontal areas may cause the engine to use more oil.

Vehicle Application

81

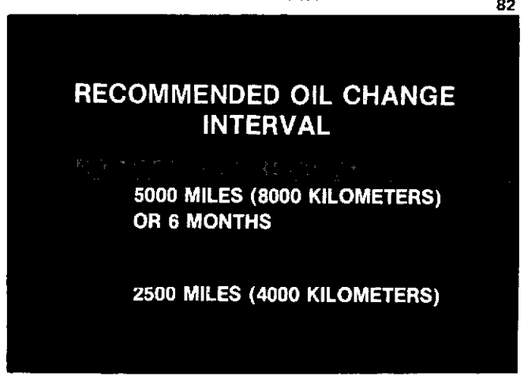


Verifying the vehicle application provides criterion for determining acceptable oil consumption. In addition, it also provides guidelines for correct oil change intervals.

Normal oil consumption varies with vehicle application.

Recommended Oil Change Interval

82



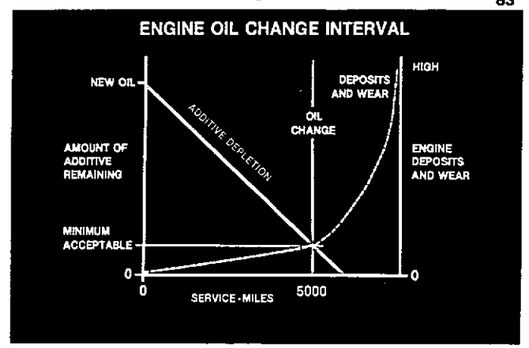
Normal Duty Usage:
– 5000 miles (8000 kilometers) or 6 months

Severe Duty Usage:
– 2500 miles (4000 kilometers)

Engine oil drain intervals are an important consideration when evaluating oil consumption. Verify that the proper engine oil change intervals and oil type and quality for the vehicle application are being followed.

Oil Change Interval

83



As can be seen by the accompanying graph, the depletion of the lube oil additive package is a limiting factor to the useful life of the lube oil. As the engine is operated the additive package breaks down and at the time the minimum acceptable level of additives is remaining, an oil change is required.

In addition, until the lube oil additive package is depleted, the engine wear and deposits remain at a constant and acceptable level. When the additive package reaches the minimum acceptable level and the lube oil is not changed, the engine wear and deposits increase exponentially (at a rapid, unacceptable rate) and can result in increased oil consumption and shortened engine life.

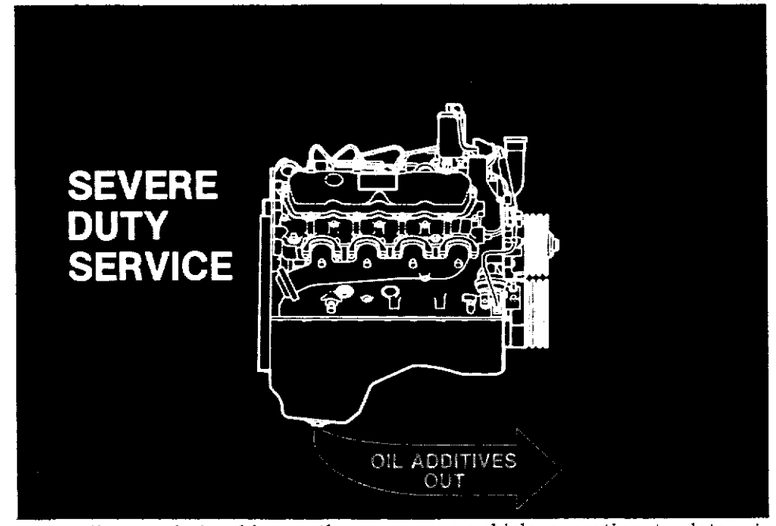
Oil breakdown (depletion of the oil additive package) can occur due to extended drain intervals and result in ring sticking, increased oil consumption and shortened engine life.

OIL CHANGE INTERVALS FOR SEVERE USAGE AS DESCRIBED UNDER "ACCEPTABLE OIL CONSUMPTION" SHOULD BE SHORTENED TO 2500 MILES (4000 KILOMETERS) IN ACCORDANCE WITH THE OWNER GUIDE.

As the illustration indicates, the break down or depletion of the lube oil additive package is a function of service. The service referenced is miles usage. Another means of measuring service is the amount of fuel consumed as indicated below.

Severe Duty Service

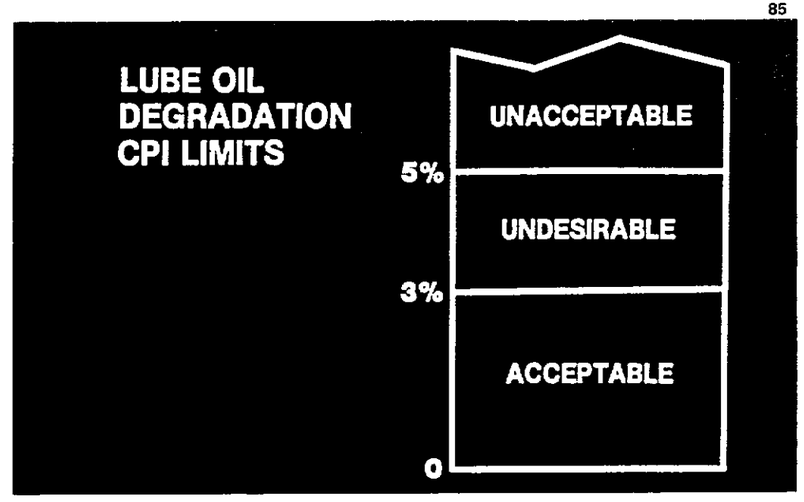
84



Oil breakdown has a direct relationship to the amount of fuel consumed. As the engine consumes fuel, the oil additive package is being depleted, resulting in oil breakdown. Therefore, when evaluating vehicle operation to determine severe service, fuel consumption can be used as a criteria.

A basic rule of thumb for the 6.9L is that the lube oil should be changed when 250 to 300 gallons (approx. 1000 liters) of fuel have been consumed.

85



Coagulated pentane insolubles (CPI) or soot, is another means of evaluating the useful life of the lube oil. CPI levels are measured through oil analysis and as the illustration depicts, 3% is the acceptable limit.