Guide to Trouble Shooting

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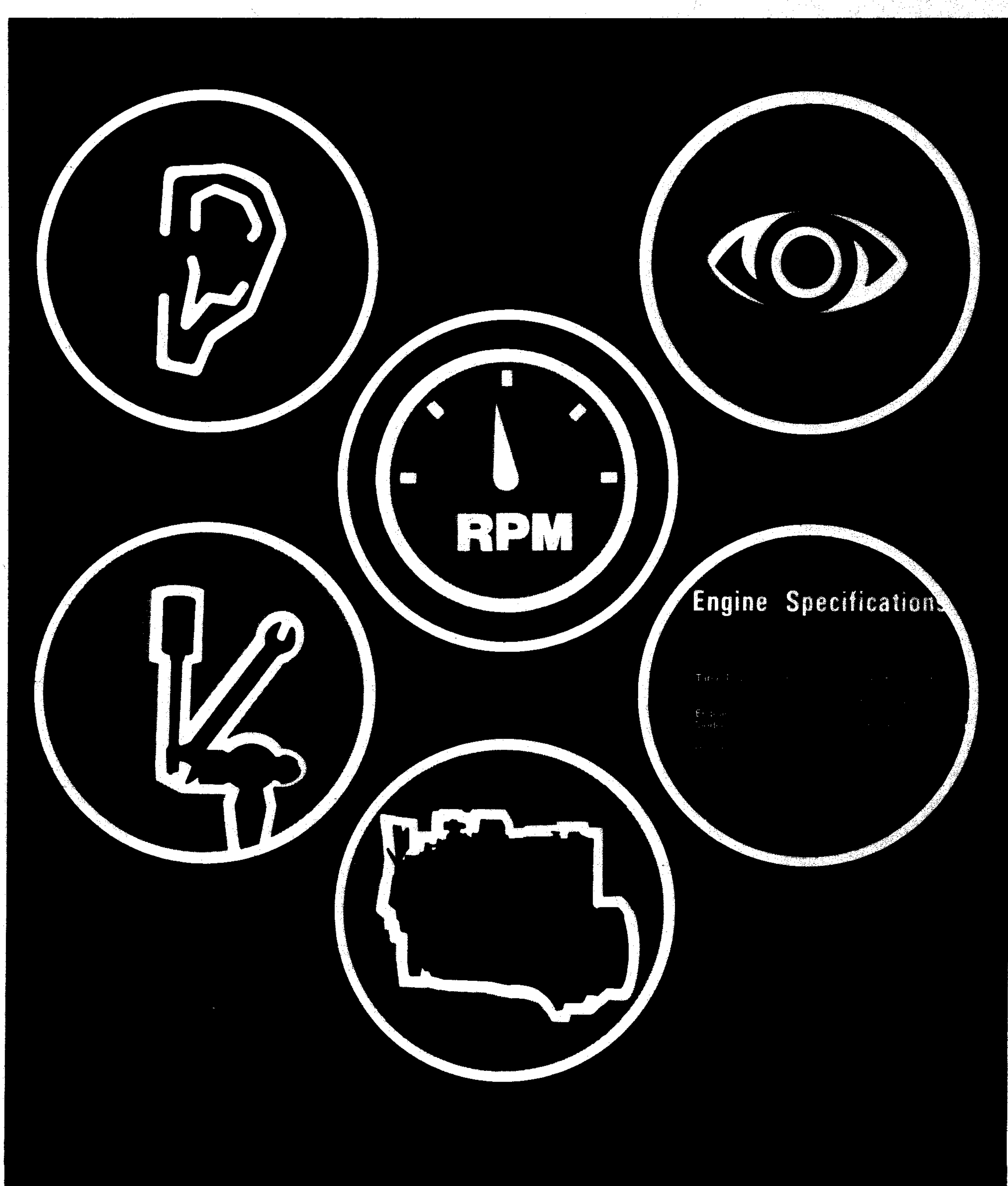

Introduction

Trouble Shooting

Cummins Diesel Engines

There is a tendency to regard a manual on trouble shooting as a never-fail reference that will quickly pinpoint any source of trouble. Fortunately, it often leads the way with information that helps locate the cause of what's wrong. If it does this, it has in part done its intended job.

A trouble shooting manual should do other things, also. Since it is impossible to list a cause for every source of trouble and compounded trouble, a manual should stimulate thought. It should also suggest avenues and plans to correct the trouble when it has been located.

Sooner or later, a problem appears that's just not in the books and there is no reference to a problem quite like it. The trouble shooter will then make use of past experience and knowledge of how systems and parts work. Actually, this is what all consistently successful trouble shooters rely upon. Identifying the cause and fixing it in the most efficient manner is the trouble shooter's ultimate goal.

Trouble shooting is defined as "an organized study of a problem and planning a procedure to investigate and correct". Notice there is no mention of a manual anywhere in the definition. This is because trouble shooting is a mental and physical activity. A manual on trouble shooting is a group of words and pictures arranged in a certain format that serves as a guide for action by the trouble shooter. It is for this purpose that this manual is made available. Inside, the most common troubles and problems have been listed. Background information on operation of parts and reasons for doing things have been included when necessary.

The manual assumes that the trouble shooter has a fair amount of knowledge in the general operation of Cummins engines. It is written to assist the trouble shooter to become more proficient in their analysis of the problem.

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Engine specifications are outlined in this manual. For all other pertinent information, refer to the applicable Shop and Operation Maintenance Manuals.

Trouble Shooting

The term "trouble shooting" as used in this section covers the investigation, analysis and corrective action required to eliminate faults in engine operation. It does not mean routine rebuilding, nor does this usage of trouble shooting cover complete failure analysis.

Procedures And Suggestions

In performing the trouble shooting function the engine is considered as a complete unit, rather than as a group of assemblies. The serviceman responds to a complaint by getting the full story from the operator, by observing the engine, and by making the necessary investigation and analysis which will reveal what is wrong with the engine that has caused the complaint.

The corrective repair follows, and a careful serviceman will check after repair to be sure the trouble has been corrected.

Listen To The Complaint

The first act of trouble shooting is to receive and understand the complaint.

Some complaints are vague and indefinite, while others are more specific. The serviceman starts the trouble shooting procedure with his first question.

Get All The Information

Although many complaints can be satisfied very quickly and simply, all servicemen can recall instances in which the first conclusion reached did not cure the trouble. In these instances, some important item of information was not obtained, or was disregarded.

It is necessary for the serviceman to question the customer or preferably the actual operator to fill in any gaps in the story of the complaint. Some of the answers may already be known to the serviceman, since there are few cases where the operation is entirely unknown to service management. There are some things that only the operator knows, and these questions must be asked. There are other items which can only be discovered by observing the engine, either running or after some disassembly.

The serviceman may recall similar complaints which were corrected by a particular course of action. However, the same complaint does not always require the same course of action.

The following questions are intended to suggest the type of information the serviceman requires to diagnose trouble properly.

1. The Operating Conditions:

Did any unusual noises precede the failure?

Was the engine under load or running light? Accelerating or decelerating?

Did oil pressure or water temperature vary?

Was any unusual dusty or smoky condition in existence at the time?

What were weather conditions? Wind?

What was the road grade at the time? How was the trouble first noticed?

What was oil consumption? Fuel? Coolant? Has there been any recent change?

How dense was the exhaust smoke? Fig. 1.

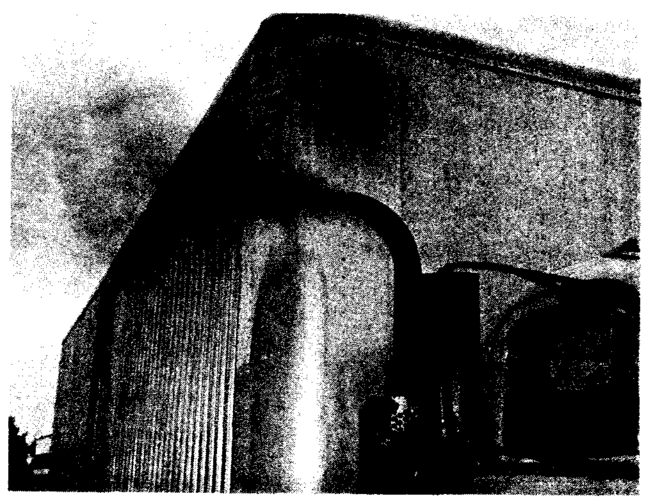


Fig. 1. Heavy exhaust smoke

Does the engine have good throttle response?

Is deceleration normal?

Does the engine shut down satisfactorily?

Does the engine start satisfactorily when cold?

Does the engine ever miss or skip?

What kind of fuel was being used? Grade and source?

Does the engine surge at idle or full speed?

Does the engine run at idle for long periods?

2. Maintenance History:

Has there been any recent work done on the engine? What?

Has this complaint occurred before?

When was the last tune-up?

When were the oil and fuel filters last changed?

Is the maintenance schedule loose or rigid?

How is fuel obtained and stored?

What brand and grade of oil is used?

How many miles or hours has the engine operated?

Who performs the maintenance and adjustments?

Is the full-flow oil filter element examined at changes? Has any metal been found?

3. Observed Information:

Is the engine clean or dirty? Fig. 2.

What is the condition of the belts? Are they loose?

Are there any oil, fuel or water leaks showing externally?

Does the engine appear to have been overheated?

Are any make-shift repairs on the engine? (Loose parts, wire-on parts, etc.)

How does the engine sound at idle?

Are any pulleys wobbling?

Do any parts appear to have been altered or repaired recently?

Are there any foreign or non-standard parts on the engine?

Does the engine have any bad plumbing?

Are oil level, water level and fuel level satisfactory? (If the problem concerns bearings, notice the condition of the oil. There have been cases where a bearing failure occurred from lack of oil, after which the operator refilled the crankcase with new oil.)

During disassembly, does the engine have unusual odors, carbon accumulations, dirt, or other conditions under the rocker covers?

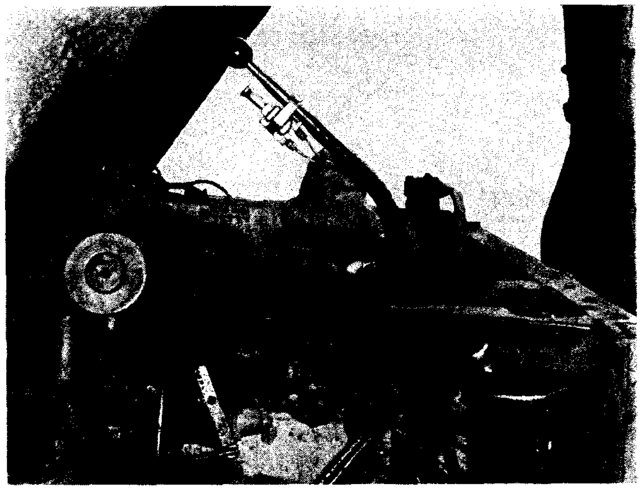


Fig. 2. Dirty engine in truck

Relate Your Information With The Symptoms

Simply asking questions and gathering information will not solve any problems. It is necessary to mentally relate the information to the complaint, placing each item in its proper relationship so a logical diagnosis may be made.

Use all applicable and available service gauges and instruments. These are aids to the mental process (thinking) but are not always a necessity.

The serviceman needs to have knowledge of the engine model, the equipment type, and the operating circumstances. The equipment on the engine, such as a torque converter cooler or a variable-speed governor, will always have to be considered.

Solve The Problem By Deduction

No one would welcome a surgeon's decision to perform an exploratory operation. We expect the medical profession to have enough knowledge of the human body and enough diagnostic ability to know exactly what they are going to do before any cutting is even planned.

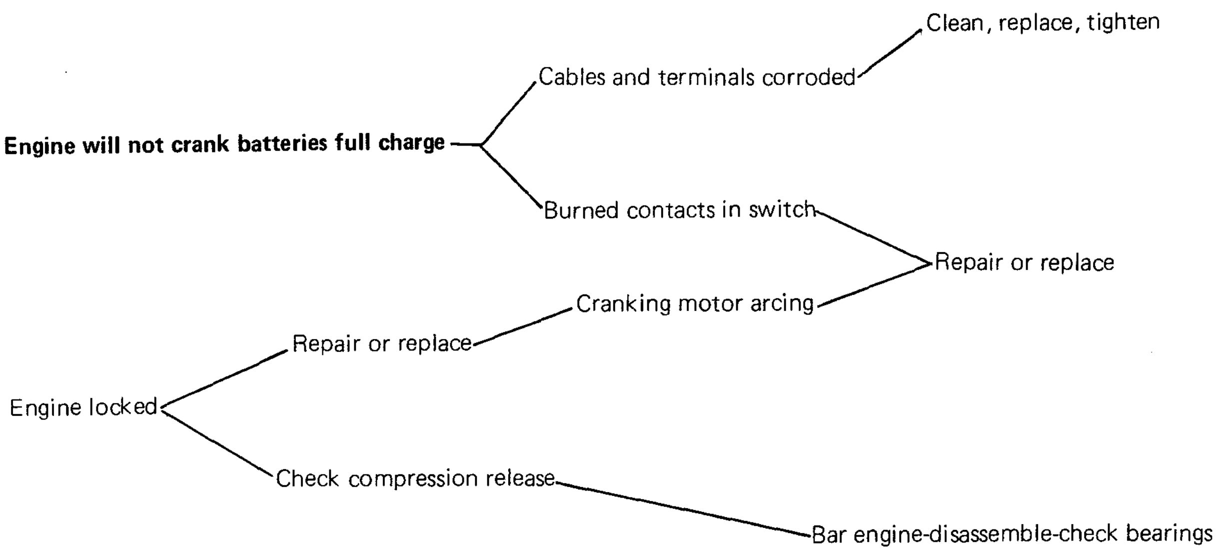
Likewise, most engine owners resent unnecessary down-time and expense caused by premature disassembly without thorough consideration, in the same way and for the same reasons that they resent having to pay for new parts which may be arbitrarily installed when the used parts are still serviceable. Conversely, a planned repair which is thorough and successful is appreciated.

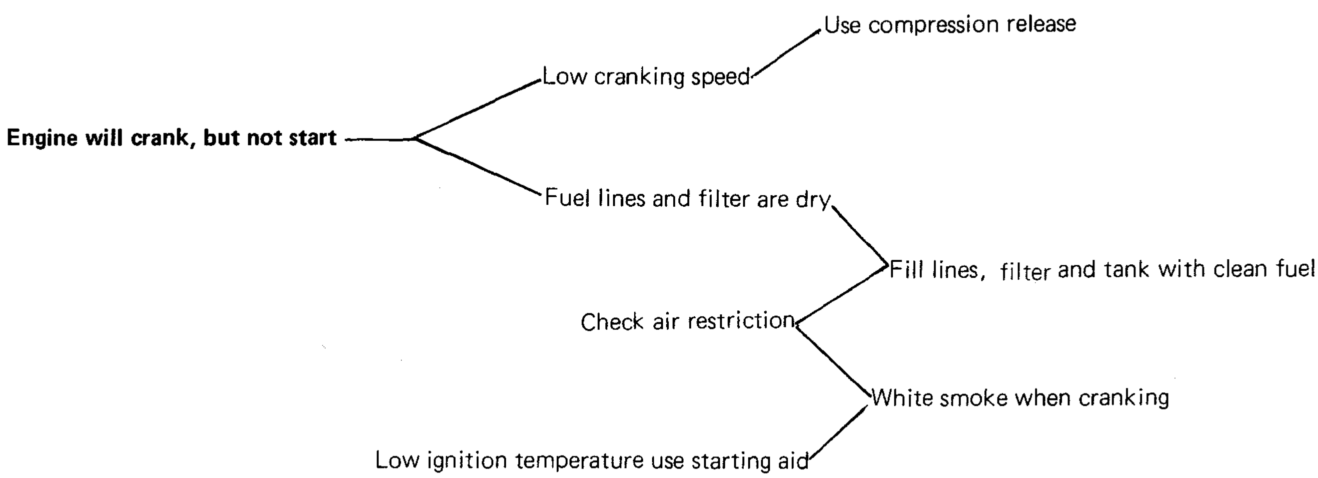
Since a malfunction of any part of the engine affects the operation of the engine as a whole, the serviceman needs a sound knowledge of engine operation. The essence of successful trouble shooting is the mental matching of the information of the complaint with a complete knowledge of how the engine and all its parts operate, and their interrelationship.

Trouble shooting involves certain checks, which are comparatively simple and easily performed, that will reveal the most frequently encountered causes of faulty operation. The data obtained must be related to the complaint. It cannot be assumed that the same thing has happened to this engine that happened to the one last week with the same complaint, unless the evidence that was uncovered indicates that such is the case. There are several possible causes of most complaints.

Thus far, this section has dealt with the general and basic rules for successful trouble shooting. Following are examples of trouble shooting two of the most common complaints, with appropriate suggestions and comments. These examples are not intended as complete instructions, but rather a stimulus and a demonstration of how to think about the problem.

Complaint, Cause, Conditions & Corrections





Charge or replace

Low batteries

Engine hard to start slow cranking

Corroded terminal and cables

Clean or replace and tighten

Check compression release setting

Open Compression

Starter binding

Check starter motor, repair or replace

Cold weather, oil too heavy

Change to lighter weight oil, install oil heater

Check, fill tank, lines, filter and pump

Out of fuel

Engine stops, not seized

Broken wire or shut down switch

Repair or replace

Broken fuel line

Replace, check for suction leaks

Install sight glass in line

Obstruction in fuel line

Clean or replace line

Rust or dirt floating in tank

Remove and clean

Plugged air vent

Clean or replace

Broken stand pipe inside tank

Replace stand pipe

Governor plunger seized

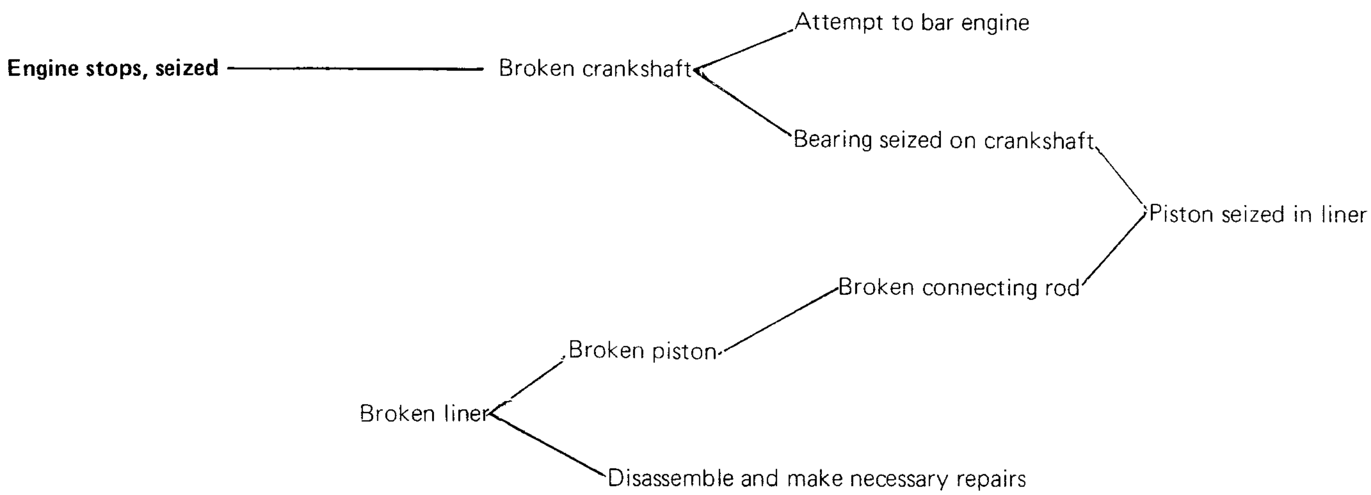
Repair or replace plunger

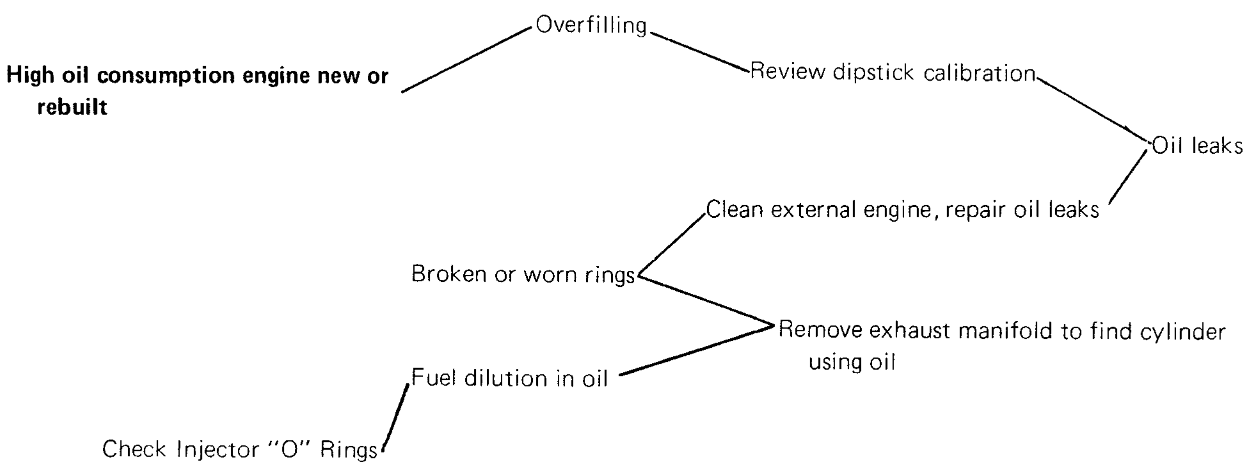
Broken gear pump shaft

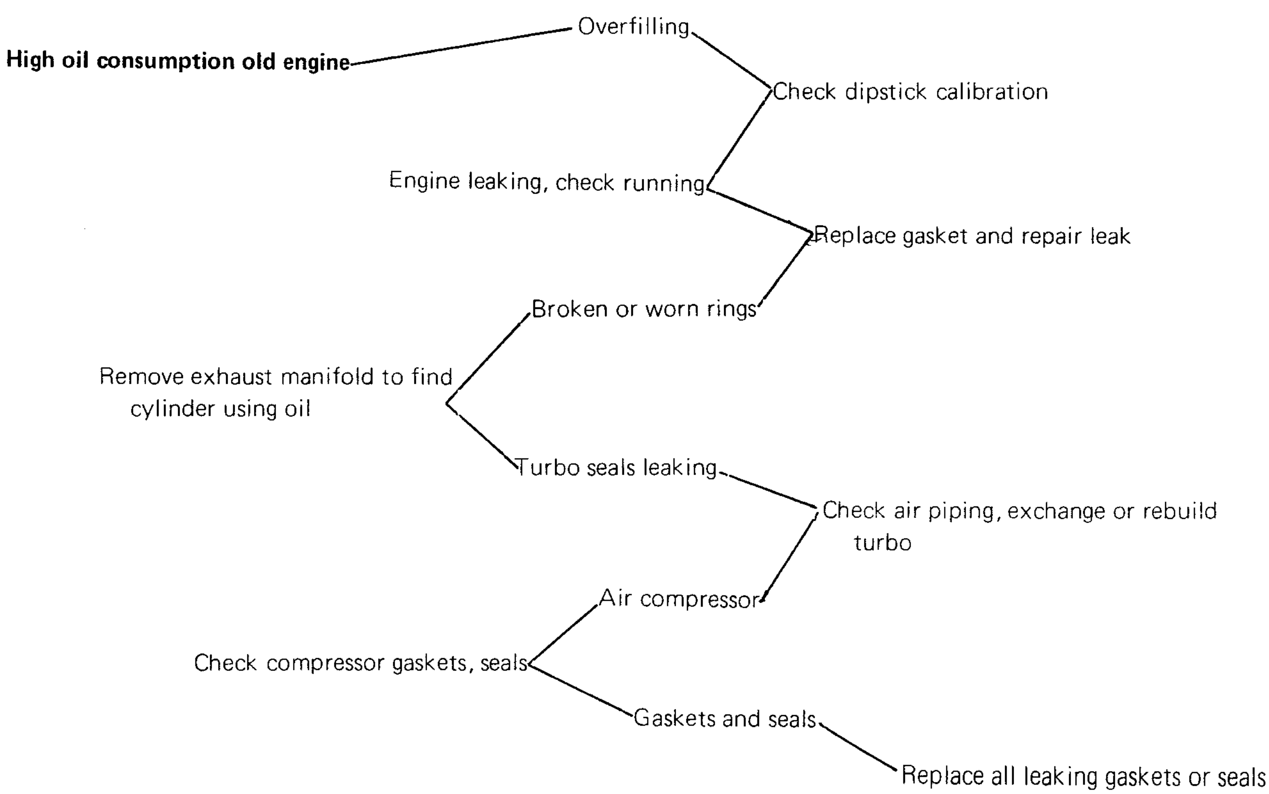
Replace shaft, check for other damage

Air restricted

Check air restriction


Engine stops, seized
Broken crankshaft
Attempt to bar engine
Bearing seized on crankshaft
Piston seized in liner
Broken connecting rod
Broken piston
Broken liner
Disassemble and make necessary repairs


High oil consumption engine new or rebuilt
Overfilling
Review dipstick calibration
Oil leaks
Clean external engine, repair oil leaks
Broken or worn rings
Remove exhaust manifold to find cylinder using oil
Fuel dilution in oil
Check Injector "O" Rings


High oil consumption old engine
Overfilling
Check dipstick calibration
Engine leaking, check running
Replace gasket and repair leak
Broken or worn rings
Remove exhaust manifold to find cylinder using oil
Turbo seals leaking
Check air piping, exchange or rebuild turbo
Air compressor
Check compressor gaskets, seals
Gaskets and seals
Replace all leaking gaskets or seals

Intermittent loss of power

Fuel inlet restricted

Remove, clean or replace

Water or floating matter in fuel tank

Remove tanks and clean

Plugged air vent

Clean vent or replace

Air in fuel line

Check for suction leak. bleed fuel line.

Fuel hose collapsed

Replace hose

Throttle linkage binds

Repair or adjust

Air filter dirty

Replace with clean filter

Collapsed air intake hose

Replace with new hose

Sudden loss of power

Loose baffles in muffler

Check back pressure, replace muffler

Idle spring and plunger sticking

Clean or replace

Out of fuel

Fill tank, filter, lines and pump

Throttle lever slipped on shaft

Reset and tighten

Aneroid bellows ruptured

Check by blocking off aneroid, replace

Suction hose collapsed

Replace with new hose

Congeled fuel (cold weather)

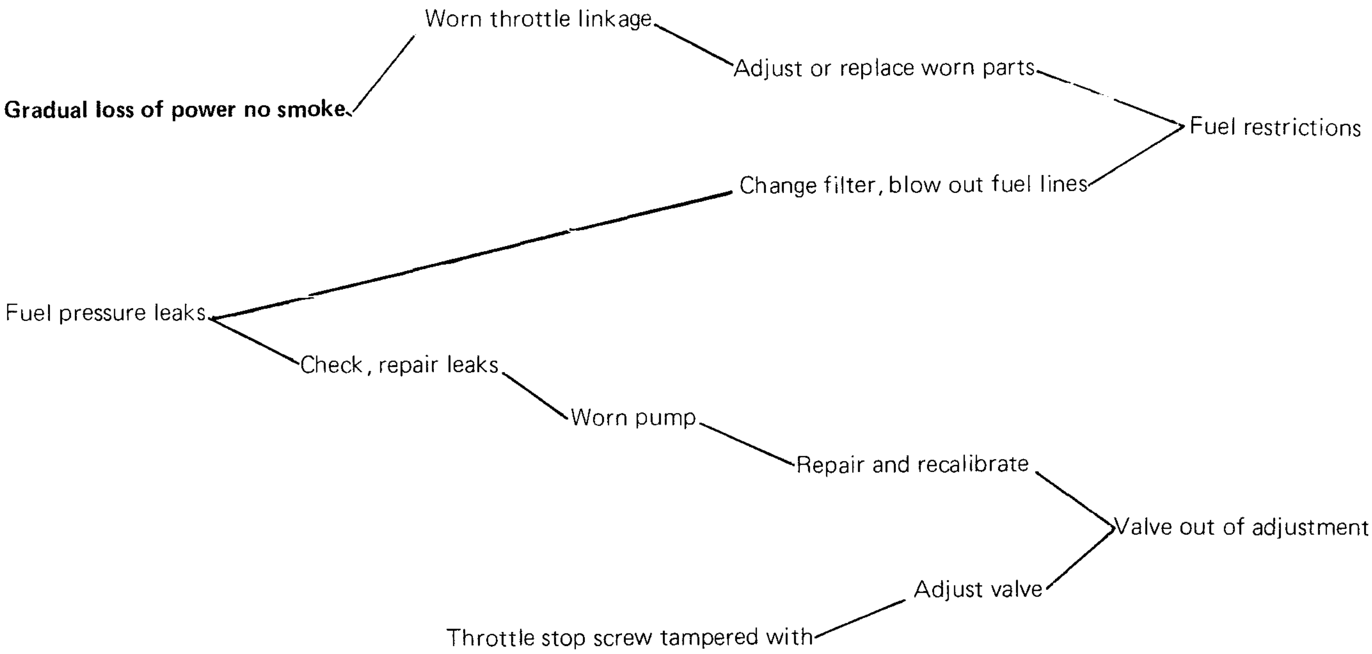
Take into warm area, advise operator check fuel spec.

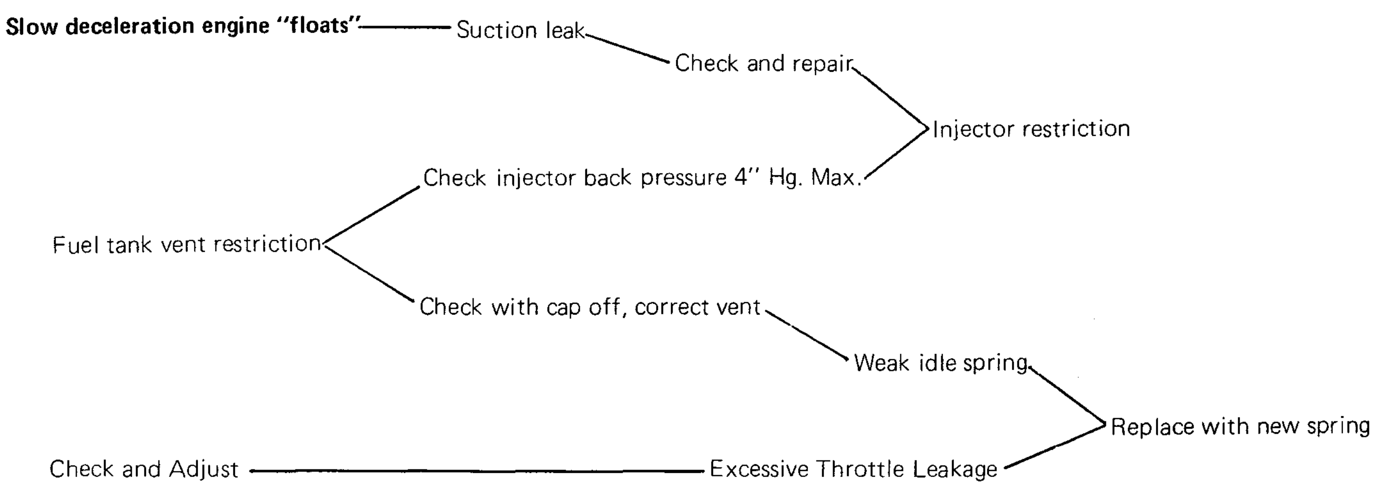
Water in fuel

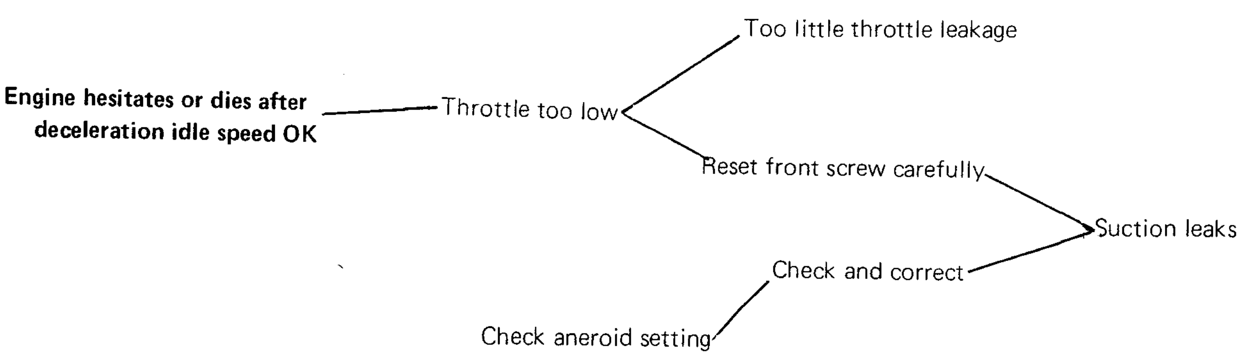
Drain tank and filter, check pump for damage

Turbo failure

Repair or replace turbo


Gradual loss of power no smoke
Worn throttle linkage
Adjust or replace worn parts
Fuel restrictions
Change filter, blow out fuel lines
Fuel pressure leaks
Check, repair leaks
Worn pump
Repair and recalibrate
Valve out of adjustment
Adjust valve
Throttle stop screw tampered with


Slow deceleration engine "floats"
Suction leak
Check and repair
Injector restriction
Check injector back pressure 4" Hg. Max.
Fuel tank vent restriction
Check with cap off, correct vent
Weak idle spring
Replace with new spring
Check and Adjust
Excessive Throttle Leakage


Too little throttle leakage
Engine hesitates or dies after
deceleration idle speed OK
Throttle too low
Reset front screw carefully
Suction leaks
Check and correct
Check aneroid setting

Erratic idle speed

Suction leaks

Check and Correct

Idle throttle leakage

Readjust idle governor and stop screw

Cracked pulsation damper diaphram

Check and repair diaphram

Faulty pump

Check, recalibrate

Exhaust smoke during acceleration — Overfueling

Calibrate fuel system

Excessive air restriction

Check air restriction

Weak cylinder

Check blow-by

Excessive exhaust back pressure

Check and correct

Check and replace — Plugged or faulty injector cup

Exhaust smoke at full speed — Overfueling

Calibrate pump

Air cleaner

Install new element in air cleaner

Air manifold leaks

Repair or replace

High fuel backpressure

Exhaust backpressure

Exhaust smoke throughout speed range — Dirty air cleaner

Clean or replace element

Injector loose or dirty

Clean and adjust injector

Poor fuel

Change fuel, inform operator

Loose valve setting

Adjust valves

Wrong injector cup

Check cup size by engine rating, replace cup

Overfueled

High fuel consumption — Injector dirty

Clean, flow and adjust

Poor quality fuel

Check fuel, inform operator

Excessive idle

Inform operator

High exhaust back pressure

Check under load – Correct

Rear axle geared too low

Review application – Correct

Intake air restriction

High fuel return back pressure
Max. 4 Hg.

Low oil pressure — Low on oil

Check — Be sure dipstick calibration is right

Plugged full flow filter

Change filter elements

Leaky by-pass valve

Clean or replace valve

Too much oil

Check dipstick calibration

Oversize orifice in by-pass filter

Check orfice and change

Worn bearings and bushings

Check, replace with new

Ruptured filter element

Replace with new filter

Wrong piston cooling nozzles

Faulty oil pump — Aeration of oil

Loose or damaged lube oil suction tube

Rough running weak cylinder — Leaky head gasket, broken capscrew

Replace with new gasket or capscrew

Leaky injectors (dirty)

Remove and clean injector

Leaky valve, misadjustment

Check blow-by

Adjust valve and crosshead

Steady misfire — Stuck injector plunger

Clean and replace

Bad injector or valve setting

Replace — adjust

Bent pushtube

Check by rolling on flat surface

Water in fuel

Drain tank, change filter

Cracked injector cup

Water in oil, large amount — Packing ring leaking

Check, repair

Leaky oil cooler, "O" Rings

Test element and replace

Porous head

Repair or replace

Water in oil, small amount — Cracked or damaged cylinder head

Pressure test heads, remove and repair

Porous Casting

Pressure test – Replace

Liners pitted through

Check coolant

Low oil temperature

Allowing condensation

Oil in coolant — Oil cooler leaking

Pressure test at 60 psi

Porous casting

Pressure test or use a penetrant

No cab heat — Heater valve shut off

Open valve

Heater air bound

Bleed air from heater

Low coolant level

Check for leaks and pressure build-up

Engine running cold

Check thermostat and thermal control

Complaint: Low Power

Where does the low power occur?

Suggestion: Low power occurring on a particular stretch of roadway may indicate a gradient which is not recognized by the operator.

Is the throttle linkage O.K.?

Suggestion: Throttle linkage which binds, is improperly adjusted, or changes length when the unit is loaded is a common source of low power complaints.

What is the smoke density?

Suggestion: Low power accompanied by heavy smoke indicates trouble in the cylinder due to failure to burn the fuel supplied. Check injectors, valves and air supply. Check turbocharger, if used. Fig. 3.

When was the fuel pump last calibrated?

Suggestion: If smoke is light or absent, check fuel filter, fuel rate, etc., for a low fuel supply.

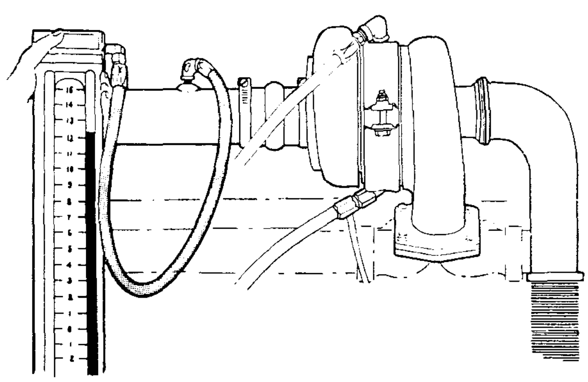


Fig. 3. Checking air cleaner restriction with manometer

Variations in test stands, work methods, etc., can cause improper fuel pump calibration. Be careful to see that you are not drawn into overfueling the engine to satisfy an unjustified complaint.

Loss of torque under particular grade and gear conditions may be due to an incorrect torque-assist spring or improper assembly and adjustment.

When were the injectors last cleaned?

Suggestion: Injectors which have been cleaned recently may need to be re-adjusted. If cleaning has been neglected, it may be required at this time.

Is the engine turbocharged? What is the condition of the air system?

Suggestion: On turbocharged engines, heavy smoke and low power are indicative of a turbocharger in poor condition, a plugged air cleaner element, or a similar cause of inadequate air supply. Fig. 4.

What were weather and wind conditions?

Suggestion: Very hot weather, high head winds and high altitude can cause a low-power complaint until the effect is understood.

How is the unit geared?

Suggestion: Units which are equipped with higher-than-normal gear ratios can be very sluggish and the engine may be blamed for a condition which is not its fault.

What kind of fuel is used?

Suggestion: Poor fuel may cause rough running and low power. A power check with engine running on good fuel will show nothing wrong.

What loads are pulled?

Suggestion: Overloading, or rather misapplication, is a fairly common source of low-power complaints.

What other units are on the same job?

Suggestion: Most operators tend to compare units in performance. Variations in engine timing, tire tread depth, unit rolling friction, and similar mechanical differences can be found in fleets of same-model units. Other considerations are different models in same fleet, driver technique, road advantages, etc.

How long has the engine had low power?

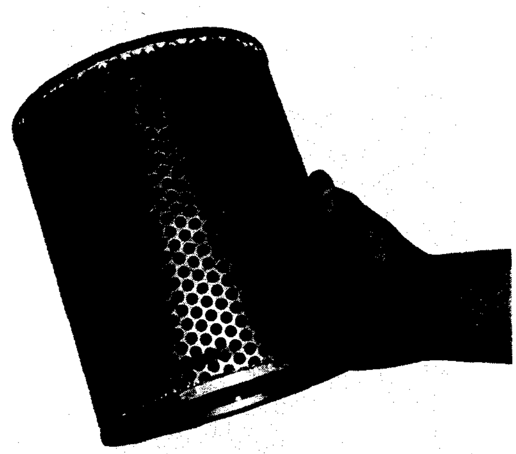


Fig. 4. Dirty air cleaner element

Suggestion: A low power complaint originating within one trip, or a similar short time, is more indicative of a genuine fault than a chronic complaint.

When was the fuel filter changed?

Suggestion: A neglected and plugged fuel filter can be easily checked by using ST-434 Vacuum Gauge provided the unit can be loaded. If no way of loading is available check the fuel filter record or change the filter.

How does the engine sound?

Suggestion: In most cases, the difference in sound between a correctly timed and adjusted engine and one which is out of adjustment is detectable.

Excessive Lubricating Oil Consumption

When, how and by whom is the oil level checked?

Suggestion: Improper oil level checking methods may lead to excessive oil use.

How many miles on engine?

Suggestion: An old engine using oil may have normal wear and need overhauling. A new engine using oil may not be broken in completely.

Did oil consumption increase gradually or suddenly?

Suggestion: Gradual increase in oil consumption is usually the result of wear. Sudden increase may be due to a scored liner, or other casualty. Fig. 5.

What brand and grade of oil is used?

Suggestion: All kinds of oil are used in Cummins engines. Most are suitable, while some are not. Compare the oil in use with your knowledge of various oil performances.

Has there been a change of viscosity of oil used?

Suggestion: A change in viscosity of oil may result in an immediate increase in consumption due to differences in vicsocity index.

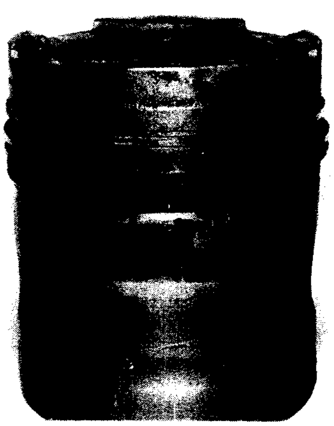


Fig. 5. Worn rings on piston

What is the oil change period?

Suggestion: Where oil change periods are too long, the oil may become diluted and lose "body". Naturally, oil consumption increases.

What is the condition of the oil filler cap and the crankcase ventilator?

Suggestion: Dirt may enter through any crankcase opening. The presence of grit and dirt in oil filler and crankcase breather is a good indication that the engine is worn.

How is the engine loaded? Low, normal or high?

Suggestion: Heavily loaded engines use more oil than normally loaded ones. Conversely, engines running with a very light load may form more than normal sludge, which can plug oil rings and piston drain holes.

Has the engine ever overheated?

Suggestion: No engine will withstand overheating without some damage. Resulting cylinder damage often causes high oil consumption.

Consider the operating routine, and if possible check a trip or cycle.

Suggestion: Observations made during operation may yield information that is very valuable.

Is there much carbon and sludge under the rocker covers?

Suggestion: Sludge and carbon found under the rocker covers and on the valve springs often indicate worn valve guides. Also, such findings raise the possibility of plugged rings.

What is the oil pressure? Can the oil be diluted?

Suggestion: Low oil pressure may indicate dilution or high oil temperature.

Are the exhaust ports carboned heavily?

Suggestion: Carboned exhaust ports indicate the presence of excessive oil in the combustion chamber. Carboned intake ports indicate excessive oil leaking between the intake valves and guides.

Is there heavy emission of crankcase vapors?

Suggestion: Excessive crankcase vapor or high blow-by indicates a poor ring seal in the cylinders. A regular puff as the engine idles may mean a scored cylinder.

Do you find gritty dirt in the intake piping?

Suggestion: Dirt found in the intake piping indicates dirt entering from the air system.

If turbocharged or supercharged, how much oil is in the intake air piping?

Suggestion: The inside of intake piping is normally damp with oil, but leaking seals in turbocharger or supercharger will allow a very wet intake with high oil consumption.

What is the condition of the air piping and air cleaner element?

Suggestion: Look the air system over for abrasion, leaks and evidence of plugging.

Are any leaks evident around hose and gasket joints?

Suggestion: Oil leaks show up best when the engine is hot. Look for traces under the unit.

What is the unit's past history?

Suggestion: The more you know of the engine's history, the better you can trace the complaint. Oil consumption

increase soon after an overhaul indicates a high wear rate. The combination of an oil bath air cleaner, high engine idling and a dusty atmosphere can wear rings out in a short period of time.

The same procedures prescribed for the preceding two examples will apply for the following section.

Make A Thorough Repair

As pointed out, a complaint may have a variety of causes, singly or in combination. A failure may be due to a chain of conditions that no one thought important enough to report. The repair must include the discovery of the true cause of the complaint, and the corrective measures necessary to correct that condition. In cases where operating conditions or maintenance practices are at fault, information given the customer may enable him to benefit by adjusting his practices. At least, the responsibility for the condition can be properly assigned.

In cases where internal engine parts have failed, the true cause usually can be found in one or more of the fluid systems, and less frequently in the parts themselves. Therefore, a thorough repair would include the investigation and ultimate discovery of the faulty system.

Follow-Up

After the repair, operating checks must be made to prove that the complaint is satisfied and the basic cause of failure has been located and corrected.

After a reasonable operating period, it may be desirable to again contact the customer to secure a report on the operation of the engine. The customer should know that the complaint has received proper attention.

Techniques Of Trouble Shooting

Method Of Detecting Oil, Fuel And Water Leaks

There are three methods that can be useful in detection and tracing of troublesome leaks and the transfer of one fluid to another.

These methods are listed as follows:

1. Use absorbent paper to detect seepage from a surface or joint. Clean the area suspected of leaking and apply a blotter, piece of filter paper or paper towel while engine is running. The leaking fuel will be detectable on the paper. Fig. 6.

2. The use of oil or water soluble dyes. These dyes are useful in detection of liquid transfers from one system to another. Water finder pastes are fairly well known which turn red in the presence of minute amounts of water in oil and fuel.

Oil soluble dyes are sold by most oil and chemical companies. A particularly useful one is made by DuPont and marketed as "Oil Red A Flakes". Small quantities of such dyes can be added to the oil where loss is suspected. This will color it enough to render it visible should any appear in another system.

3. Use of a black light on magnetic inspection equipment aids in the detection of fuel leakage into the oil, hydraulic oil into crankcase oil etc. The only requirement is that one fluid must have a different characteristic from the other.

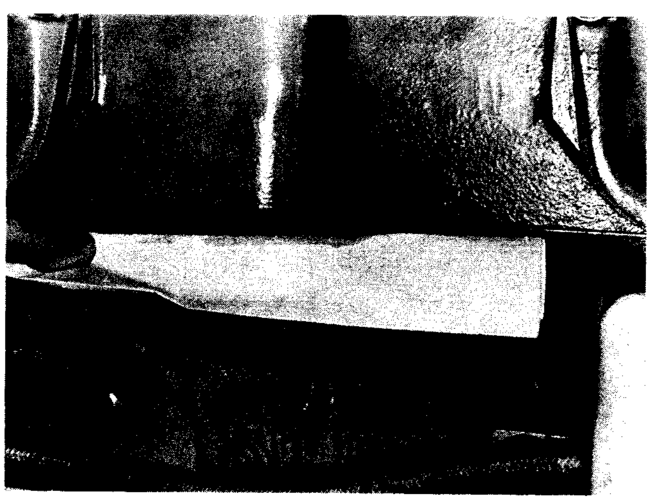


Fig. 6. Use absorbent paper for detecting leaks

While the black light can be a useful tool, the equipment is usually expensive and not available in service shops.

Where one fluid system can be pressurized relative to another system, the search for the source can be greatly simplified. This approach is practical for many problems.

Trouble Shooting With Contact Pyrometer

The exhaust temperature pyrometer, Fig. 7, has long been recognized as the standard method of locating faulty cylinders in multi-cylinder engines. On most large engines, thermocouples are furnished mounted in each cylinder's exhaust leg, and are wired during installation to a permanently mounted instrument.

Any variation in the operating enviornment of an engine cylinder will result in a change in the temperature of the exhaust gas. An accurate reading of these temperature variations furnishes the best possible evidence on which to base problem diagnosis.

The installation of thermocouples in the exhaust manifold is seldom possible on automotive-size engines because of cost, size restrictions, etc. Thus, this excellent diagnostic tool has not found acceptance in an industry where it is most needed.

Pyrometers are made in many forms. The most common form involves a pick-up or thermocouple, consisting of two

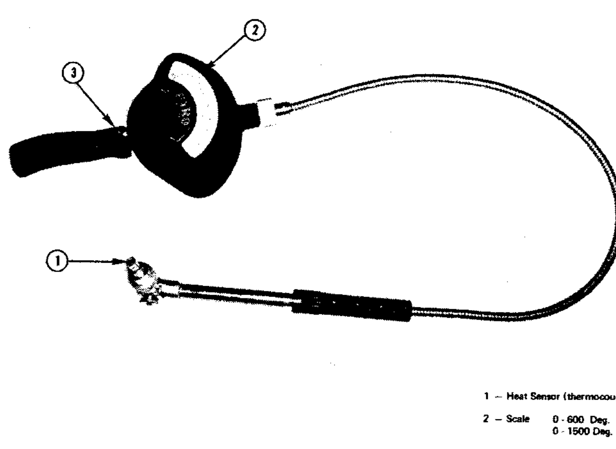


Fig. 7. Pyrometer

wires which are of different metals, welded together at their ends. This joint is commonly called the "hot junction".

Special metals are used in these wires, selected for their response to temperature and ability to withstand high heat. As the hot junction is exposed to a heat source, a small electric current is generated at the junction, and flows through the wires to the measuring instrument, which is a millivoltmeter. The current flow is proportionate to the heat at the junction.

By providing a scale for the millivoltmeter graduated in degrees F, or degrees C, we can read the temperature directly.

Instrument Selector

1. To be effective for trouble shooting purposes, the instrument must be usable by one man without aid, and must be of such scale capacity and marking that it may be easily read.

2. The range of the instrument must suit the normal idling temperature range of the engine. Usually, a range of 0 to 400 deg. F will suffice for idling temperature plus safety factor, and the hand movement is large enough to be easily seen.

3. These instruments range in price from $50 to $200. There is considerable variation in handling convenience, ruggedness, accuracy, etc. Price should not be the deciding factor.

4. In connection with the convenience factor, a thermocouple connected to the instrument by an extension cable is more easily used in confined places than one attached solidly.

5. These instruments may be used for many miscellaneous temperature readings if suffiently accurate. Top radiator tank temperature, crankcase temperature, fuel temperature, etc., are conveniently determined. (On the other hand, an instrument to be used for tune-up and trouble shooting may use only unmarked reference lines on the dial, because no specific temperature readings are required.)

6. All such instruments require some protection, since they are sensitive to rough handling. The most costly instruments have jewelled bearings and compare in construction with a fine watch. Thermocouple leads should be cable-protected and the thermocouple itself should be sufficiently rugged to withstand the normal use.

7. Thermocouples are made in several forms, covering a wide range of subject configurations. Those for surface measurements are arranged so the hot junction is held in contact with the surface to be measured. Other forms are intended to be immersed in a fluid. Some have flat probes which can be inserted in dies or heated plates to measure the temperature. In general, the simplest one with exposed hot junction for surface readings will be found most useful.

Techniques of Use

Certain specific methods of using the contact pyrometer are necessary for accurate and time-saving trouble shooting.

1. Be sure the engine to be investigated has run long enough at idle to stabilize the exhaust manifold temperature.

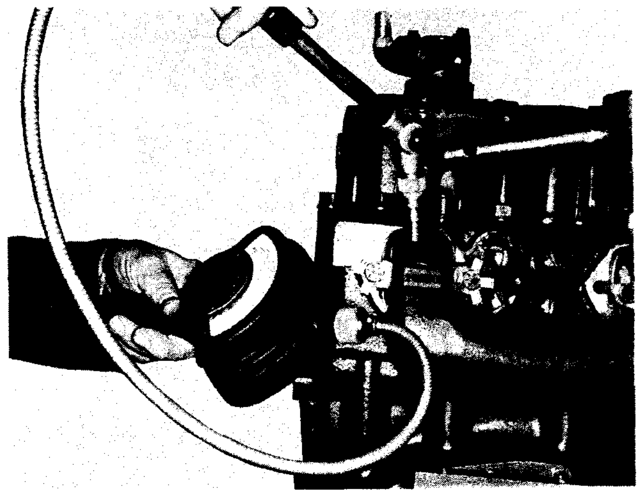


Fig. 8. Pyrometer in use

2. Hold the hot junction squarely and firmly on each exhaust leg. Fig. 8.

3. See that the hot junction is held at the same point on each exhaust leg relative to distance from the head surface.

4. Compare the cylinder temperatures with each other to pick out the ones which vary from the average.

5. A good instrument will give maximum reading in three to five seconds. Be sure the thermocouple is properly held and located.

6. Take all your readings while the air compressor is either loaded or unloaded. If it starts to pump between cylinder readings, the increase in temperature may cause a false reading.

7. There are no published standard exhaust temperatures for idle speed. A normal engine idling at 500 to 550 rpm will read 140 deg. F to 200 deg. F [60.0 deg. C to 93.3 deg. C]. However, these temperatures are not to be taken as limits, but are quoted to show the range to be expected.

Note: Contact Pyrometer readings are not accurate enough to judge actual gas temperature. Use readings as described to compare cylinders in a running engine. The analysis of a faulty cylinder is simplified by this instrument.

Note: Tempil Stik are also commonly used in finding cold cylinders.

Interpretation And Analysis

1. Let us assume that most of the cylinders read 145 deg F [62.8 deg C], with one reading 170 deg F [76.7 deg C]. Some of the problems to look for are:

a. Plugged or worn holes in the injector spray tip(s).

b. Injector "flowing" too high.

c. Burned exhaust valve.

d. Loose intake valve adjustment.

2. Suppose the readings are quite erratic, with some cylinders high, some low. The engine runs roughly but does not skip. Look for the following, in this order:

a. Check valve clearance. Loose intake clearance is likely. Perhaps the clearance was adjusted when the compression release shaft was out of adjustment; this condition would definitely interfere with valve adjustment.

b. Injectors in poor condition. Check injector plungers for carbon on the tip and cup contact and also for binding on the plunger sides.

3. This engine has fairly even exhaust temperature on five cylinders, all reading from 140 deg. F to 155 deg. F [60.0 deg. C to 68.3 deg. C], except one which reads 125 deg. F [51.7 deg. C]. Investigate as follows:

a. Remove the injector from the low-temperature cylinder. Clean and "flow," or use an exchange.

b. Check injector rocker lever socket. These have occasionally been found broken, which may weaken the cylinder.

c. Check plunger for wear and binding marks. Binding even slightly slows plunger up-stroke, shortening the metering cycle.

d. On cylindrical injectors, failure to seat fully in the copper sleeve may cause erratic plunger movement.

e. Check for dirt in adjustable orifice of cylindrical injectors.

f. Leaking ball check valves in PTB and PTC injectors may also reduce the amount of fuel injected, thereby lowering temperature.

Many other combinations of problems may be diagnosed quickly and accurately by the use of a good contact pyrometer. It is an instrument which gives information of cylinder condition. This information, plus good analysis and investigation, makes possible a higher level of shop efficiency and saves the customer time and money.

Specific Checking Procedures

Injector Plunger Inspection

1. Examine the plunger tip for cup seating pattern. A good seat is indicated by a continuous, clear, even, bright steel appearance on the cone-shaped surface tip. Other conditions may be interpreted as follows:

Note: Do not remove the plunger from a PT (type D) injector while injector is installed in engine. Retainer on PT (type D) injector traps oil and dirt. Removing the plunger with injector installed will allow oil and dirt to drain into injector.

a. The plunger cone is bright on one side and shaded to dark on the other. The cup has been assembled and tightened without using the plunger as a guide. Cleaning and reassembly is necessary for correction; however, if this method doesn't take care of the problem, replace with an exchange injector.

b. The plunger cone is bright at the smaller end, shading to darker at the larger diameter. The plunger sides show some bright areas close to the end, indicating contact. The cup has been over-torqued, resulting in distortion of the end of the body. Install an exchange injector, and return the defective one (having plunger marks as described) with appropriate information.

c. The plunger has bright areas close to the end, which appear on one side but not the other. The plunger cone shows almost complete seating. This appearance will be found on flanged injectors in NH-220 and smaller engines. It is usually due to uneven hold-down tension, which bends the body slightly and tends to bind the plunger. The hold-down tension may be checked for distortion by performing a drop test as follows:

1. Spot the cylinder, clear the push rod and rocker lever, and remove the plunger.

2. Remove the spring from the plunger.

3. Insert the plunger into the injector bore, allowing it to drop of its own weight.

4. If the plunger will not drop smoothly to the cup seat, loosen the hold-down capscrews and retighten in sequence to proper tension. Start with very light tension on the exhaust side, and divide the total torque into 3 passes.

Camshaft Injector Lobe Wear

Occasions arise in the field service which require determination of camshaft injector lobe wear. The following method makes extensive disassembly unnecessary, and allows an accurate determination of cam condition to be made without expensive tooling or unusual education level.

1. Tool list:

a. Starrett No. 196, or equivalent, dial indicator with one (1) inch [25.4 mm] travel.

b. Stud 3/8 - 16 inch, threaded 3/8 inch NC x 1 inch on one end, with locknut.

2. Inspection Method:

a. Bar engine to spot any cylinder at VS point.

b. Loosen injector rocker lever locknut, then back out adjusting screw one-half turn.

c. Mount 3/8 inch stud in rocker housing hole and secure with locknut. Assemble indicator on stud, with indicator point bearing on adjusting screw slotted end. Set indicator to about one-half travel and zero the dial.

d. Bar engine opposite normal rotation. Indicator will go plus, then minus. Record value reached at plus reading.

e. Reset injector and valves to correct values. Repeat procedure on all cylinders, recording all plus indicator readings.

f. Should any cylinders indicate 0.004 inch [0.1016 mm] or more below the others, the cam nose is worn. No great variation should be found on any single camshaft.

This checking method adds about one-half hour to a normal injector and valve adjustment.

Fuel System Suction Leaks

All diesel engine fuel systems require a solid, airless supply of fuel, available at all times. Suction leaks which permit air to become entrained in the fuel system are evidenced by poor throttle response, slow deceleration, intermittent misses and loss of power. Sharp detonation may be heard intermittently. A very wide range of effects results, and trouble shooting is complicated by the fact that a particular engine symptom may have more than one cause.

Internal Suction Leaks – PT (type G)

These leaks may occur in the fuel pump, fuel manifolds or injectors. The following method will aid in checking suction leaks on a running engine.

Connect a No. 4 or No. 5 flexible plastic line to the plug on the shut-down valve where the manifold pressure gauge is connected. Place the other end in the tank. Install a good quality valve in this tube. The gauge line for ST-445 Pressure Gauge is suggested. Start the engine with the valve closed. Open the valve carefully increasing the fuel flow. If a plastic section or liquid eye is connected in the suction line, enough fuel will move to make the air visible. The plastic line serves to bleed entrapped air so that it will be noticed. Fig. 9.

1. Leaking tachometer drive seal:

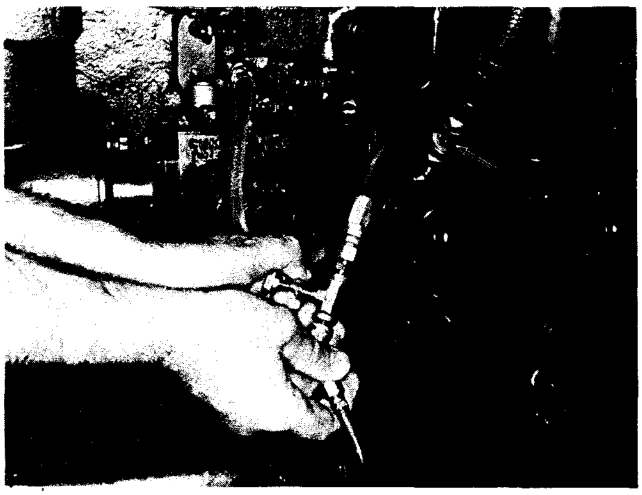


Fig. 9. Check suction leaks by bleeding fuel from shut-down valve

Check by removing cable, then filling housing with fuel. If fuel is drawn into the pump with the engine idling, the seal leaks. Press the drive rod sideways to check. Fig. 10.

2. Leaking front drive seal.

Check by filling vent hole in side of drive housing with soft grease. Idle the engine to see if grease is drawn in, proving a leak.

3. Leaking at priming plug:

The priming plug in top of pump body must seal. If a leak occurs because of a loose plug, or in cases where piping has been attached at this point, the engine will start very hard and will probably require a starting aid.

Oil may be used with a clean pump to check for a leak; however, the priming plug should be checked for tightness on any engine that is hard to start.

4. Leaking at governor spring pack cover:

A suction leak at the cover gasket can be found with oil, while engine is running at rated rpm, no load. The plug can be checked in a similar manner. The mechanic should be aware of recent work which may have resulted in a broken gasket or loose plug.

This cover plug is usually sealed, and a broken or missing seal is worth reporting.

5. Leaking shut-down valve:

While no suction leak can occur at this point, a leaking valve may allow the fuel pump and lines to drain to a low-mounted tank. The engine will be hard to start, but will run normally after starting. Be sure the manual over-ride is backed fully out. Check for solids embedded in the valve seal insert.

6. Leaking injector "O" rings on cylindrical injectors:

Should the lower body "O" ring on cylindrical injectors leak, the feed passage will become aerated upon coming to idle after a period of loaded operation. Leaking of compression into the injector sleeve through a poor seat will aggravate the condition. The engine runs normally until unloaded, then gives symptoms of air in the fuel system.

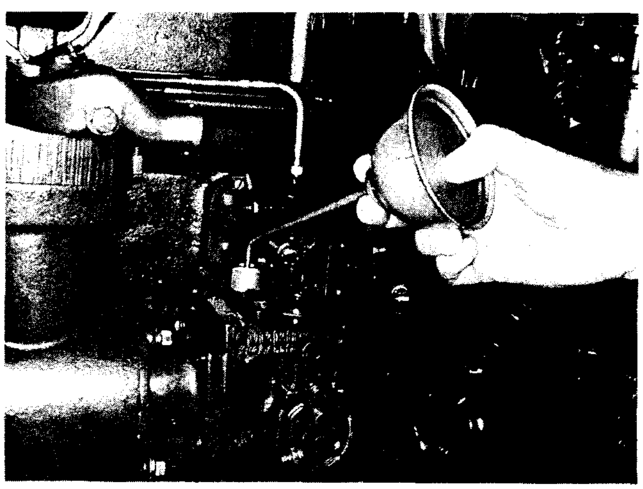


Fig. 10. Tachometer drive filled with fuel

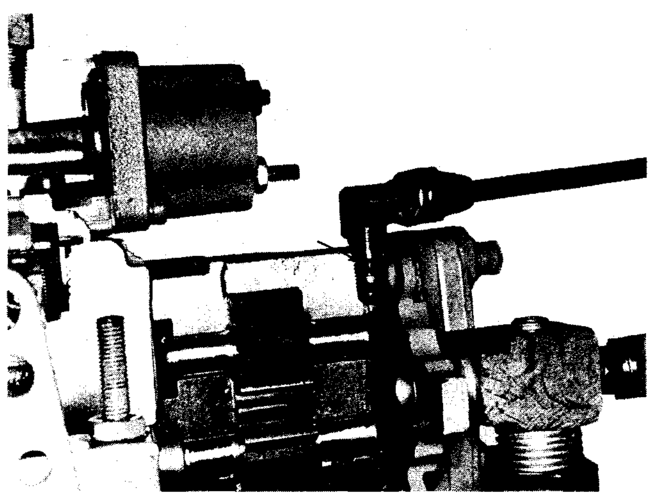


Fig. 11. Fuel by-pass line check valve – cut-away

Diagnosis is made by gaining information on operating symptoms. Changing injector "O" rings and cleaning the copper seats will stop the trouble. Use an exchange injector if the cup seat has had severe leakage. An extreme case may require injector sleeve replacement.

7. Leaking check valve in fuel by-pass line:

The small check valve in the fuel by-pass line elbow on top of gear pump will permit air to enter the system if it leaks. Remove elbow and inspect check valve. Replace as needed. Fig. 11.

8. Damaged or distorted throttle shaft seal ring:

Remove throttle and replace seal ring. Lubricate to install throttle properly. Fig. 12.

External Suction Leaks

An engine which runs as though air was present in the fuel system may be quickly checked to determine whether the leak is internal, on the engine, or external, from the fuel pump to the tank.

1. Remove the suction line from the gear pump.

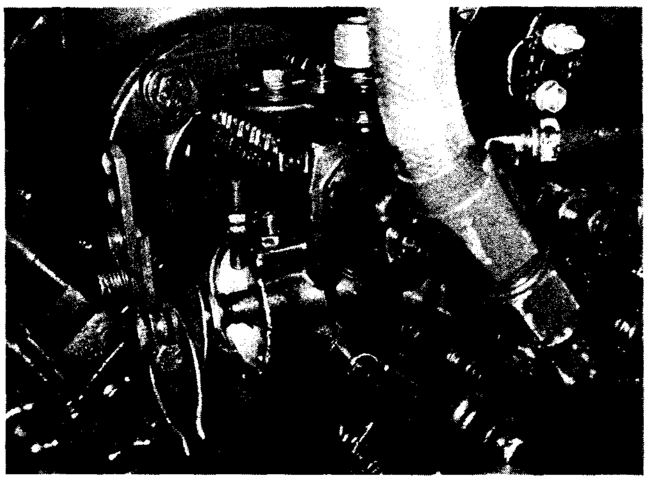


Fig. 12. Throttle shaft seal ring

2. Install a suitable length of No. 10 hose so fuel may be drawn from a 5-gallon oil can.

3. Operate the engine from the can. If the symptoms of air subside, the suction leak is in the external line.

4. Move the hose to the fuel filter inlet. Run the engine, drawing fuel through the filter. If air is still present, check the filter for proper assembly, cracks in the filter head, excessive tightness of capscrews and fittings, and poor gasket condition. A sight glass in the gear pump connection will aid in finding the air.

Note: A partially plugged fuel filter will cause power loss and magnify suction leaks in the fuel pump seals.

5. Move the auxiliary hose and can to the suction connection at the fuel tank. If no air shows up running out of the can, but the engine shows air running out of the

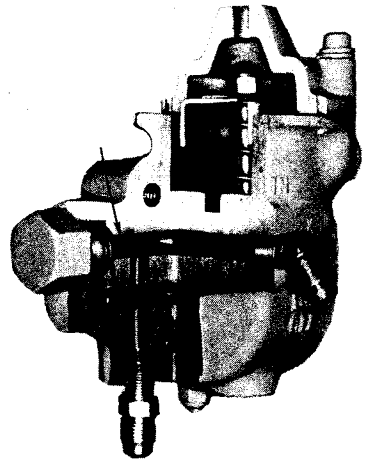


Fig. 13. Aneroid starting valve

tank, check tank connections, standpipes, equalizer lines, etc., for loose or broken fittings.

GENERAL NOTES:

1. Should a suction hose lining come loose, an engine stoppage may occur from a shut-off suction. Examine hose for this condition and replace as necessary. This condition will rarely cause an engine to be hard to start, but will shut off the fuel during operation.

2. Loose objects in the fuel tank are a common cause for fuel stoppages. Such obstructions will cause intermittent missing or stopping of the engine.

3. Engines equipped with aneroid controls sometimes give starting trouble, due to a sticking starting valve in the aneroid. This may be mistaken for a suction leak, causing much time to be lost in troubleshooting.

When working with turbocharged engines equipped with aneroids, always check the small valve under the 7/8 inch hex nut on side of aneroid body. Clean any burrs off with nothing coarser than crocus cloth. Check for free action, examine the cap seal ring for damage, and lubricate the seal with oil. Assemble the valve, tightening the cap to no more than 30 ft-lbs [41 N• m] torque. Fig. 13.

Fuel suction leaks can be found and corrected, provided an organized approach is taken.

Engine Specifications

Engine Firing Order

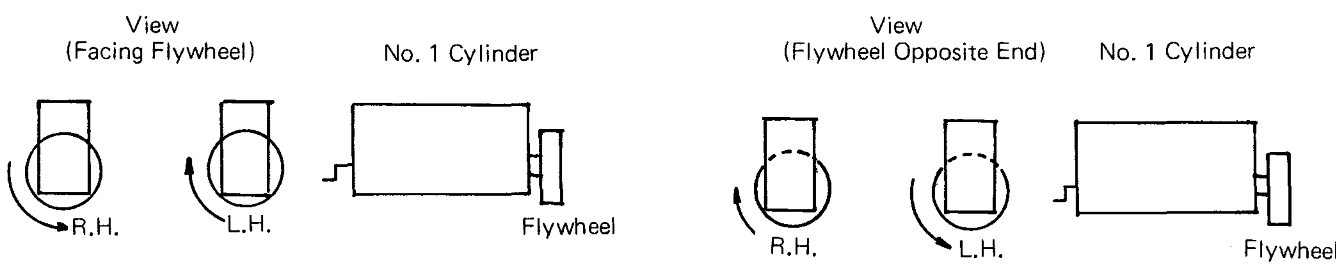
Engine Model	Right Hand Rotation	Left Hand Rotation
H, NH-4 Cyl., C, J-4 Cyl.	1-2-4-3	1-3-4-2
H, NH, J, JT, KT/KTA-6, NT	1-5-3-6-2-4	1-4-2-6-3-5
KT/KTA-12	1R-6L-5R-2L-3R-4L-6R-1L-2R-5L-4B-3L	
V/VT-12-1710	1L-6R-2L-5R-4L-3R-6L-1R-5L-2R-3L-4R	1L-4R-3L-2R-5L-1R-6L-3R-4L-5R-2L-6R
V-352 (Val.), V-378	1-4-2-5-3-6	1-6-3-5-2-4
V-470 (Vale), V-504	1-5-4-8-6-3-7-2	1-2-7-3-6-8-4-5
V/VT-903, V/VT-555	1-5-4-8-6-3-7-2	

Definitions of Right and Left Hand Engine Rotation

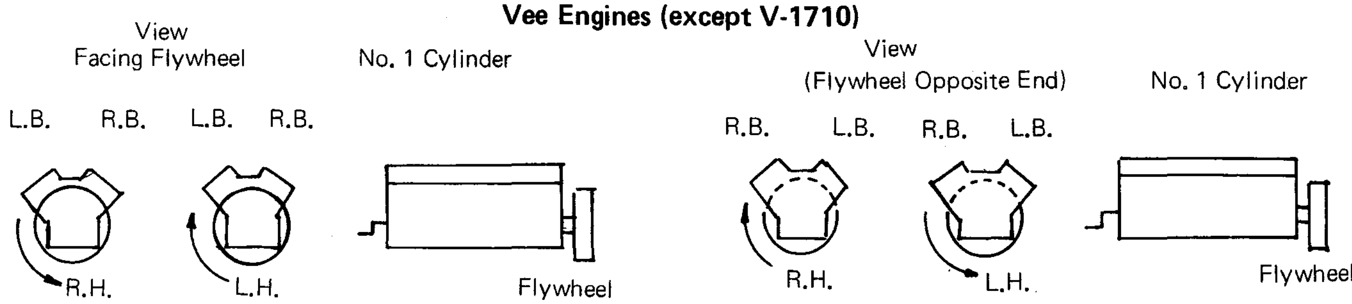
Right Hand (standard rotation). Counterclockwise rotation as viewed from the principal output end. If power can be delivered from either end, rotation shall be viewed from the flywheel end.

Left Hand (opposite rotation) Clockwise rotation as viewed from the principal output end. If power can be delivered from either end, rotation shall be as viewed from the flywheel end.

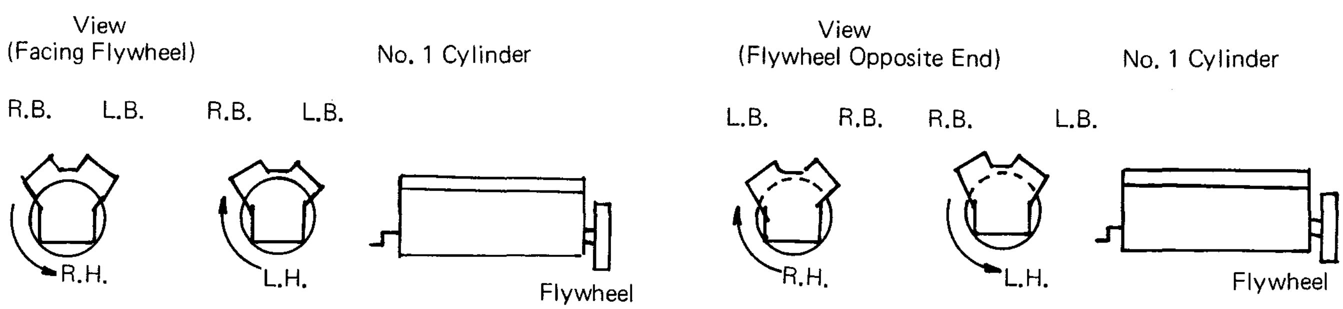
In-Line Engines



Vee Engines (except V-1710)



V-1710 Engines



Note: Determine left bank and right bank as viewed from flywheel end.

Valve Clearance (Inches) - All Engine Series

Engine Model	Intake Valves Cold Set	Intake Valves Hot Set	Exhaust Valves Cold Set	Exhaust Valves Hot Set
H, NH, NT and V12-1710 Aluminum Rocker Hsgs.	0.014 [0.36]	0.014 [0.36]	0.027 [0.69]	0.027 [0.69]
Cast Iron Rocker Hsgs.	0.016 [0.41]	0.014 [0.36]	0.029 [0.74]	0.027 [0.69]
V-352, V-378, V-470, V-504, V-555 and VT-555	.012 [.30]	.010 [.25]	.022 [.56]	.020 [.51]
V-903, VT-903	.012 [.30]		.025 [.63]	
KT/KTA-6 and 12	0.014 [0.36]	0.014 [0.36]	0.027 [0.69]	0.027 [0.69]
C and J	0.017 [.43]	0.015 [.38]	0.027 [0.69]	0.025 [0.63]

Injector and Valve Set Position NH, NT Series Engines

Bar in Direction	Pulley Position	Set Cylinder Injector	Set Cylinder Valve
Start	A or 1-6VS	3	5
Adv. To	B or 2-5 VS	6	3
Adv. To	C or 3-4 VS	2	6
Adv. To	A or 1-6 VS	4	2
Adv. To	B or 2-5 VS	1	4
Adv. To	C or 3-4 VS	5	1

Uniform Plunger Travel Adjustment Limits NH, NT Series Engines

Oil Temp.	Injector Plunger Travel Inch [mm] Adj. Value	Injector Plunger Travel Inch [mm] Recheck Limit	Valve Clearance Inch [mm] Intake	Valve Clearance Inch [mm] Exhaust
Aluminum Rocker Housing				
Cold	0.170 [4.32]	0.169 to 0.171 [4.29 to 4.34]	0.011 [0.28]	0.023 [0.58]
Hot	0.170 [4.32]	0.169 to 0.171 [4.29 to 4.34]	0.008 [0.20]	0.023 [0.58]
Cast Iron Rocker Housing				
Cold	0.175 [4.45]	0.174 to 0.176 [4.42 to 4.47]	0.011 [0.28]	0.023 [0.58]
Hot	0.175 [4.45]	0.174 to 0.176 [4.42 to 4.47]	0.008 [0.20]	0.023 [0.58]

Adjustment Limit Using Indicator Method of Adjustment for V-903 Series Engines — Inch [mm]

Injector Plunger Travel	Valve Clearance Intake	Exhaust
1.2 to 1 Rocker Lever Ratio — Injector Lever P/N 196565		
0.180 ± 0.001 [4.57 ± 0.003]	0.012 [0.30]	0.025 [0.64]
1 to 1 Rocker Lever Ratio — Injector Lever P/N 211319		
0.187 ± 0.001 [4.75 ± 0.03]	0.012 [0.30]	0.025 [0.64]

Injector and Valve Set Position K Series Engines

Bar in Direction	Pulley Position	Set Cylinder Injector	Set Cylinder Valve
Start	A	3	5
Adv. To	B	6	3
Adv. To	C	2	6
Adv. To	A	4	2
Adv. To	B	1	4
Adv. To	C	5	1

Firing Order 1-5-3-6-2-4

Uniform Plunger Travel Adjustment — K Series Engines

Injector Plunger Travel — Inch [mm]	Recheck Limit Inch [mm]	Valve Clearance Inch [mm] Intake	Valve Clearance Inch [mm] Exhaust
K-6 Engines			
0.304 [7.72]	0.303 to 0.305 [7.70 to 7.75]	0.014 [0.36]	0.027 [0.69]
K-12 Engines			
0.308 [7.82]	0.307 to 0.309 [7.82 to 7.85]	0.014 [0.36]	0.027 [0.69]

Injection Timing Specifications

Engine Model Camshaft, Nom. Key	Crank Angle	Piston Travel In.	[mm]	Push Tube Travel Nominal In.	[mm]	Fast In.	[mm]	Slow In.	[mm]
J-6, JF, JN, JNR, JNF, JS,	19 deg BTC	–0.1711	[–4.3459]	–0.0295	[–0.7493]	–0.0265	[–0.6731]	–0.0315	[–0.8051]
JT-6, C-160	12 deg BTC	–0.0689	[–1.7500]	–0.0162	[–0.4114]	–0.0137	[–0.3479]	–0.0172	[–0.4368]
(121580 Camshaft)	5 deg BTC	–0.0120	[–0.3048]	–0.0055	[–0.1397]	–0.0037	[–0.0939]	–0.0067	[–0.1701]
S-302 Key									
JNS (121120 Cam) S-302 Key	19 deg BTC	–0.1711	[–4.3459]	–0.0295	[–0.7493]	–0.0265	[–0.6731]	–0.0315	[–0.8051]
J-70, J-80, C-90, C-105	12 deg BTC	–0.0689	[–1.7500]	–0.0162	[–0.4114]	–0.0137	[–0.3479]	–0.0172	[–0.4368]
(112407 Cam) S-302 Key	5 deg BTC	–0.0120	[–0.3048]	–0.0055	[–0.1397]	–0.0037	[–0.0939]	–0.0067	[–0.1701]
J-120, C-140	19 deg BTC	–0.1711	[–4.3459]	–0.0402	[–1.0210]	–0.0372	[–0.9448]	–0.0422	[–1.0718]
(112407) Camshaft 200706	12 deg BTC	–0.0680	[–1.7500]	–0.0255	[–0.6477]	–0.0230	[–0.5842]	–0.0265	[–0.6731]
	5 deg BTC	–0.0120	[–0.3048]	–0.0128	[–0.3251]	–0.0110	[–0.2794]	–0.0140	[–0.3556]
C-175, C-180, C-200,	19 deg BTC	–0.1711	[–4.3459]	–0.0378	[–0.9601]	–0.0348	[–0.8839]	–0.0398	[–1.0109]
R-160, C-195	12 deg BTC	–0.0689	[–1.7500]	–0.0234	[–0.5943]	–0.0209	[–0.5308]	–0.0244	[–0.6199]
(121580 Camshaft) 200704	5 deg BTC	–0.0120	[–0.3048]	–0.0115	[–0.2921]	–0.0097	[–0.2463]	–0.0127	[–0.3225]
CF-160	19 deg BTC	–0.1711	[–4.3459]	–0.0236	[–0.5994]	–0.0206	[–0.5232]	–0.0256	[–0.6502]
(121580 Camshaft) 200704	12 deg BTC	–0.0680	[–1.7500]	–0.0112	[–0.2844]	–0.0087	[–0.2209]	–0.0122	[–0.3098]
	5 deg BTC	–0.0120	[–0.3048]	–0.0017	[–0.0431]	+0.0001	[+0.0025]	–0.0029	[–0.0736]

Camshaft Keys

Current Key Part No.	Replaces Key Part No.	Arrow Position	Result	Engine Model
200703	103725 & 117349	Front	Retard	J-(401) C-(309) C-(464)
200704	120602 & 146135	Front Rear	Retard Advance	(464) C-175, C-180, C-200, CR-160, CF-160
200705	124969	Rear	Advance	J-(401), C-(309) 464
*200706	134088	Front	Retard	J4 cyl., (309) C-140
S-302	– –	Straight	Straight	J, JF, JN, JS, JT-6, C-160, J-70, j-80, C-90, C-105, JNS

*Used with 112407 Camshaft only.

Note: Camshaft and key combinations listed above are standard; however, in rare cases other combinations may be used to bring a particular engine or camshaft into proper injection timing tolerances.

Injection Timing NH Series Engines

Engine Model	Crank Angle (Degrees)	Piston Travel (Inches)	Push Tube Travel (Inches) Nominal	Fast	Slow
NHC-4, N-495-130, H-6, HR-175, H-743-145, H-743-160, H-743-175, H-743-190, H-743-L, NH-200, NH-220, N-743-220, NHH-220	19 deg. BTC	–0.2032	–0.0290	–0.0280	–0.0300
NHE-180, NHE-195	19 deg. BTC	–0.2032	–0.0285	–0.0275	–0.0295
HRS-240, HS-743-240, NHS-6, NS-743-290, NS-743-L, NHRS-6, NHRS-320, NS-743-320	19 deg. BTC	–0.2032	–0.0335	–0.0315	–0.0355
NHHTO-6, NHHRTO-6 (Auto)	19 deg. BTC	–0.2032	–0.0360	–0.0340	–0.0380
NHHRTO-6,	19 deg. BTC	–0.2032	–0.0415	–0.0395	–0.0435

Injection Timing NH Series Engines

Engine Model	Piston Travel (Inches)	Push Tube Travel (Inches) Nominal	Fast	Slow
NH-855 Series, 230 through 265 Super 250/270 N-927 (Non Turbocharged) N-855-L, N-855-R, NHH-250	–0.2032	–0.0290	–0.0280	–0.0300
NHC-250 (Military) C.P.L. 0172	–0.2032	–0.0300	–0.0290	–0.0310
NT-855 Series, 270 through 295 (Pre-1975) (Turbocharged) NTC-270-E NTF-365, NTC-290-R, NTC-290-F, Power Torque 330D, NHHTC-290, NTC-290, NTF-NTC-250, NTC-250-S, NTC-230 (C.P.L. 0188), NTC-230-S (C.P.L. 0188), NHHTC-250, NTF-255 (C.P.L. 0188)	–0.2032	–0.0335	–0.0315	–0.0355
NT-855-310 (All) NT-855 Series 320 through 380 (Auto and Marine) NT-855-C-280 through 360 NTC-335, NTC-350 (Pre-1975), NTA-855-380 (Auto) NTC-927-E, NHCT-CT, NHHTC-335 NTC-290 R, NHHTC-290	–0.2032	–0.0360	–0.0340	–0.0380
NT-855 Series, 320 through 400 (Off-Highway) NTA-855-370 (Auto) NTA-855 Series, 370 through 420 NT-855-C-380 (Off-Highway) NT-855-L1, L2, NT-855-R1, R2	–0.2032	–0.0415	–0.0395	–0.0435
NTC-270-CT, Power Torque 270	–0.2032	–0.0390	–0.0370	–0.0410
Super 250	–0.2032	–0.0280	–0.0270	–0.0290
NTCC-335, NHHTC-335, NTCC-290-R, NTCC-290	–0.2032	–0.0460	–0.0450	–0.0470
Power Torque 270 (1975 C.P.L. 0207)	–0.2032	–0.0420	–0.0410	–0.0430
Formula 290, NHHTC-290 (1975 C.P.L. 0217) Power Torque 270 (1975 C.P.L. 0217)	–0.2032	–0.0500	–0.0490	–0.0510
NTC-230 (C.P.L. 0220), NTC-230-S (C.P.L. 0270), NTF-255 (C.P.L. 0220)	–0.2032	–0.0400	–0.0390	–0.0400
NTC-350 (1975), NTC-350-Y	–0.2032	–0.0350	–0.0340	–0.0360
NTA-400 (1975 C.P.L. 0162)	–0.2032	–0.0410	–0.0400	–0.0420
NTA-400 (1975 C.P.L. 0205)	–0.2032	–0.0490	–0.0480	–0.0500
NTCC-350	–0.2032	–0.0450	–0.0440	–0.0460

Note: Procedures and values for timing horizontal engines are identical with corresponding standard models.

V6-200, V8-265, V-903 Series Engine

Engine Model	2100 or Below	Between 2100 and 2600	Above 2600
V6E-195	F	G	H
V-588-B-195	F	G	H
V6-200	F	G	H
V-588-C-200	F	G	H
V6-215-M	F	G	H
VT6-280-M	I	I	I
V-785-C-220	F	G	H
V8E-235	F	G	H
V-785-B-235	F	G	H
V8-265	F	G	H
V-785-B-265	F	G	H
V-785-C-265	F	G	H
V-785-P-265	F	G	H
V8-300	F	G	H
V8-300-M	F	G	H
V-785-B-300	F	G	H
VT-785-B-340	I	I	I
VT8-370-M	I	I	I

V6-200, V8-265, V-903 Series Engines Cont'd.)

Engine Model	2100 or Below	Between 2100 and 2600	Above 2600
V-903	J	J	J
V-903-M		J	
V-903-C-320	J	J	J
Vine-ATAC			L
VT-903		Q	
VT-903		AB, AG	

V6-140, V6-155, V8-185, V8-210, V-555 Series Engines

Engine Model	2500 rpm or Below	Above 2500 rpm
V6-352-140	DB	DA
V6-378-155	DC	DC
V8-470-185	DB	DA
V8-504-210	DC	DC
V-555	DD	DD
VT-555		DE

Injection Timing Specifications V-1710 Series Engine

Engine Model	Crank Angle Degrees	Piston Travel Inches [mm]	Push Tube Travel Inch [mm] Nominal	Fast	Slow
V-1710-460, 500, V-1710-L	19 deg. BTC	–0.2032 [–5.161]	–0.034 [–0.086]	–0.032 [–0.81]	–0.036 [–0.91]
V-1710-500M, GS, GC, PG	19 deg. BTC	–0.2032 [–5.161]	–0.030 [–0.76]	–0.028 [–0.71]	–0.032 [–0.81]
VT-1710-635, 700, VT-1710-L, M, GS, GC, PG	19 deg. BTC	–0.2032 [–5.161]	–0.045 [–1.14]	–0.042 [–1.07]	–0.047 [–1.19]
VTA-1710-800 VTA-1710-L, M, GS, GC, PG	19 deg. BTC	–0.2032 [–5.161]	–0.0525 [–1.333]	–0.050 [–1.27]	–0.055 [–1.40]
VTA-12-800-GS, GC, VTA-1710-PGC 800	19 deg. BTC	–0.2032 [–5.161]	–0.0745 [–1.892]	–0.071 [–1.85]	–0.076 [–1.93]

Injection Timing Specifications V-VT-903 Series Engine

Model	Crank Angle	Piston Travel Inch [mm]	Push Rod Travel Inch [mm] Nominal	Fast	Slow
V-903	21.0 deg. BTC	–0.2032	–0.049	–0.046	–0.052
VT-903	21.0 deg. BTC	–0.2032	–0.054	–0.051	–0.057
VT-903-C-350	21.0 deg. BTC	–0.2032	–0.066	–0.063	–0.069
VT-903-C-265	21.0 deg. BTC	–0.2032	–0.066	–0.063	–0.069

Torque Wrench Method Of Injector Adjustment

Injector and Valve Adjustment Values for V-352, V-378, V-470, V-504, V-555, VT-555 Series Engines

Adjust Injector Plunger

Injector plungers must be adjusted with an inch-lb [N• m] torque wrench and a screwdriver adapter to a definite torque setting.

1. Turn adjusting screw down until plunger just contacts cup, then advance an additional 15 deg. to squeeze oil from cup.

2. Loosen adjusting screw one turn.

3. Torque adjusting screw to specifications shown for cold setting as outlined in table below. Tighten locknut to 40 to 45 ft-lb [54 to 61 N• m] or to 30 to 35 ft-lb [41 to 47 N• m] torque when using ST-669 Adapter.

Injector Plunger Adjustment – Torque

Oil Temperature 70 deg. F [21 deg. C]	Oil Temperature 140 deg. F [60 deg. C]
60 inch -lb [6.8 N• m]	60 inch-lb [6.8 N• m]

4. Bar engine in direction of rotation until "VS" mark on pulley is aligned with pointer on front cover or gear case cover. In this position, both intake and exhaust valves will be closed for one of two cylinders indicated. Make adjustments on this cylinder.

Note: Do not use fan to rotate engine.

5 Adjust injector plunger, crossheads and valves of each cylinder. Turn crankshaft in direction of rotation to next "VS" mark corresponding to engine firing order.

Note: Two complete revolutions of crankshaft are required to adjust all injector plungers, crossheads and valves, by the torque wrench method. Injectors, crossheads and valves can be adjusted for only one cylinder at any one "VS" mark.

Adjust Valve Crossheads

1. Loosen valve crosshead adjusting screw locknut and back off screw two to three turns until screw is free from valve stem.

2. Use light finger pressure at rocker lever contact surface to hold crosshead in contact with valve stem (without adjusting screw).

3. Turn adjusting screw down until it just contacts its mating valve stem. Hold adjusting screw in this position and tighten locknut to 25 to 28 ft-lb [34 to 38 N• m] with a torque wrench. When using ST-669 Torque Wrench Adapter, torque to 22 to 26 ft-lb [30 to 35 N• m].

4. Check clearance between crosshead and valve spring retainer with a feeler gauge. There should be a minimum of 0.025 inch [0.64 mm] clearance. Valve collet to crosshead (2) should be 0.050 inch [1.27 mm].

Note: Insure that crosshead retainers on exhaust valves are positioned on crossheads and valve springs properly.

Adjust Valve Clearance

The same engine position used in setting injectors is used for setting intake and exhaust valves.

1. Loosen locknut and back off adjusting screw. Insert proper feeler gauge, between rocker lever and top of crosshead, turn screw down until lever just touches gauge. Lock adjusting screw nut in this position.

2. Torque locknut to 40 to 45 ft-lb [54 to 61 N• m] with torque wrench. Torque to 30 to 35 ft-lb [41 to 47 N• m] when using ST-669 Adapter.

3. After all injectors, valves and crossheads have been adjusted, secure valve covers to heads with new gaskets.

Cooling System Capacity in Quarts

Engine Series	Engine Only	Engine Series	Engine Only
J-401	13	V-903	28
C-464	13	N-495	16
V-352	10	NH-473	20
V-470	14	NH-855	20-22
V-504	14	NHT-855	20-22
V-555	16	KT/KTA-6	36
V-588	20	V12-1710	84-90
V-785	20	KT/KTA 12	100

Oil Pressure PSI [kPa] Automotive

Engine Series	Idle Speed	Rated Speed
C-J	10/30 [69/207]	40/75 [276/517]
NTC 230-290	15 [103]	50/70 [345/483]
NH-NT	5/20 [34/138]	40/75 [276/517]
VT-350	5/25 [34/172]	40/65 [276/448]
V-903, VT-903	5/25 [34/172]	40/65 [276/448]
V-378, V-504,	15/30 [103/207]	55/85 [379/586]
V-555, VT-555	10/30 [69/207]	45/85 [310/586]
KT-450, KTA-600	15 [103]	45/70 [310/483]

Oil Pressure PSI [kPa] Industrial

Engine Series	Idle Speed	Rated Speed
NH, NT, 855-R, 855-L	5/20 [34/138]	40/75 [276/517]
V-903, VT-903	5/25 [34/72]	40/65 [276/448]
V-378, V-504, V-555	15/30 [103/207]	55/85 [379/586]
V-1710, V-1710-L	15/30 [241]	50/90 [620]
KT/KTA-6	15 [103]	45/70 [310/483]
KT/KTA-12	20 [138]	45/55 [310/379]

Injection Timing Chart Using ST-593 or ST-840

Timing Code	Timing Method	Piston Travel — Inches	Push Rod Travel — Inches Fast	Slow
	Cambox			
A	138808	–.2032	–.0395	–.0435
B	44035	–.2032	–.0275	–.0315
C	44035	–.2032	–.0315	–.0355
D	44035	–.2032	–.0340	–.0380
E	44035	–.2032	–.0280	–.0300
Y	138808	–.2032	–.0370	–.0410
Z	44035	–.2032	–.0240	–.0280
AA	44035	–.2032	–.030	–.032
AC	44035	–.2032	–.027	–.029
AF	138808, 200713 Key	–.2032	–.044	–.046
AH	44035	–.2032	–.034	–.036
AK	138808	–.2032	–.040	–.042
AN	138808, 200723 Key	–.2032	–.045	–.047
AQ	138808, 200713 Key	–.2032	–.041	–.043
AS	44035	–.2032	–.035	–.037
AT	44035	–.2032	–.029	–.031
AU	138808, 208746 Key	–.2032	–.048	–.050
AV	138808, 208746 Key	–.2032	–.049	–.051
AW	3000098, 69550 Key	–.2032	–.059	–.061
AX	3000098, 69550 Key	–.2032	–.054	–.056
AY	138808	–.2032	–.039	–.041
AZ	3000098, 69550 Key	–.2032	–.057	–.059
	Key			
DA	S-313	–.2032	–.048	–.052
DB	S-313	–.2032	–.059	–.063
DC	S-313	–.2032	–.054	–.058
DD	200717 (arrow to front)	–.2032	–.060	–.064
DE	200717 (arrow to front)	–.2032	–.076	–.080
DF	S-313	–.2032	–.063	–.067
DG	S-313	–.2032	–.041	–.045
F	200709 (arrow to front)	–.2032	–.0580	–.0640
G	200711 (arrow to rear)	–.2032	–.0460	–.0520
H	200709 (arrow to rear)	–.2032	–.0440	–.0500
I	S-302	–.2032	–.0500	–.0560
J	S-302	–.2032	–.0460	–.0520
K	– –	–.2032	–.0620	–.0680
L	200708 (arrow to front)	–.2032	–.0575	–.0645
Q	200709 (arrow to front)	–.2032	–.0510	–.0570
AB	200709 (arrow to rear)	–.2032	–.0750	–.0810
AG	S-302	–.2032	–.063	–.069
M	S-302	–.1711	–.0265	–.0315
N	200704 (arrow to front)	–.1711	–.0348	–.0398
O	200704 (arrow to rear)	–.1711	–.0206	–.0256
AE	S-302	–.2032	–.106	–.110
AM	– –	–.2032	–.116	–.120
R	208746 (arrow to rear)	–.2032	–.071	–.076
S	200722 (arrow to rear)	–.2032	–.032	–.036
T	202600 (arrow to rear)	–.2032	–.042	–.047
U	200707 (arrow to front)	–.2032	–.050	–.055
V	– –	–.2032	–.0285	–.0325
AD	200712 (arrow to front)	–.2032	–.028	–.032
AJ	– –	–.2032	–.124	–.128
AL	– –	–.2032	–.106	–.110

Note: On left hand rotation engines, reverse arrow for same timing effect.

Injection Timing Chart

Timing Code	Push Rod Travel (Inches)	Cam Box	Key No.	Engine Series
A	–.0395/–.0435	138808		NH
B	–.0275/–.0315	44035		NH
C	–.0315/–.0355	44035		NH
D	–.034/–.038	44035		NH
E	–.023/–.030	44035		NH
F	–.058/–.064			VV
G	–.046/–.052			VV
H	–.044/–.050			VV
I	–.050/–.056			VV
J	–.046/–.052			VV
K	–.062/–.068			VV
L	–.0575/–.0645			VV
Q	–.051/–.057			VV
R	–.071/–.076			V12-1710
S	–.032/–.036			V12-1710
T	–.042/–.047			V12-1710
U	–.050/–.055			V12-1710
V	–.0285/–.0325			V12-1710
Y	–.037/–.041	138808		NH
Z	–.024/–.028	44035		NH
AA	–.030/–.032	44035		NH
AB	–.075/–.081			VV
AC	–.027/–.029	44035		NH
AD	–.028/–.032			V12-1710
AE	–.106/–.110			KT/KTA-6 (450)
AF	–.044/–.046	138808	200723	NH
AG	–.063/–.069		200711	VV
AH	–.034/–.036	44035		NH
AI	–.033/–.035	44035		NH
AJ	–.124/–.128			KT/KTA-12 (1200)
AK	–.040/–.042	138808	200707	NH
AL	–.106/–.110			KT/KTA-12 (1050)
AM	–.116/–.120			KT/KTA-6 (600)
AN	–.045/–.047	138808	200723	NH
AQ	–.041/–.043	138808	200713	NH
AS	–.035/–.037	44035		NH
AT	–.029/–.031	44035		NH
AU	–.048/–.050	138808	208746	NH
AV	–.049/–.051	138808	208746	NH
AW	–.059/–.061	3000098	69550	ANH
AX	–.054/–.056	3000098	69550	ANH
AY	–.039/–.041	138808		NH
AZ	–.058/–.060	3000098	69550	ANH
BA	–.027/–.029	3000098	202600 (arrow to front)	ANH
BB	–.099/–.101	3005421	69550	ANH(290 and 350)

All Push Rod Travel At –.2032 Piston Travel

DA through DZ have been assigned to Darlington.

Engine Timing Specifications Per Application

J and C Engine Series

Model	Auto (Old B)	B (BI) B (G)	C (CI)	P (I) P (G)	IF	M	L GS/GC
J-401-110				M			
J-401-130		M	M	M			
JN-130						M	
C-160	M					M	
C-464-160		M	M	M			
CF-160	O						
CS-464-160			N				
C-175	N						
CT-464-175		N	N	N			
C-180	N					N	
CS-464-180		N	N	N			
C-190	N						
CS-464-195			N				
JS-6		M					
JT-6		M					

H, NH, NT Engine Series

Model	Auto (Old B)	B (BI) B (G)	C (CI)	P (I) P (G)	IF	M	L GS/GC
NHC-4							E
N-495-130		E	E	E			
H-6					E		
HR-6							E
HR-175						E	
H-743-145			E				
H-743-160			E	E			
H-743-175		E	E	E			
H-743-190		E	E	E			
H-743-L							E
HRS-240						C	
HS-743-240				C			
NH-200	E						
NHK-205	Z						
NHK-220	Z						
NH-220	E						
N-743-220		E	E	E	E	E	E
NHH-220	E	E					
NHS-6					C		
NS-743-290		C	C	C			
NS-743-L							C
NHRS-6					C		
NHRS-320		C	C	C		C	
NHHTO-6	D	D					
NHHRTO-6	D	A					
N-927	E						
NH-230	E						
N-855-230		E					
NHD-230	E						
NHF-240	E						
NH-250	E					E	
NHC-250	E						
N-855-250		E	E	E			
N-855-L, R	E						E
NHH-250	E						
Super 250	AC						
Super 250/270	E						
NHF-265	E						
NT-270							C
NT-855-270				C			
NHCT-270	C						
NHCT-CT	D						
NTC-270-E	C						
NTC-270-CT	Y						
NT-280					C		
NT-855-280		C	C				

Engine Timing Specifications Per Application (Cont'd.)

Model	Auto (Old B)	B (BI) B (G)	C (CI)	P (I) P (G)	IF	M	L GS/GC
			H, NH, NT Engine Series (Cont'd.)				
NTC-290	C						
NTF-295	C						
NHTF-295	C						
NT-310							D
NT-855-310		D	D	D			
NT-855-320			A				
NT-335						D	A
NTC-335	D						
NT-855-335		A	A	A			
NHHTC-335	D						
NT-855-L1, R1							A
NT-855-L2, R2							A
NTC-350	D, AI						
NTF-365	D						
NTA-370	A						
NTA-855-370		A					
NT-380	D				A	D	
NT-855-380				A			
NTA-855-380		A	A				
NTA-855-L							A
NT-400							A
NTA-400	A, AF(2200)						
NTA-855-400				A			
NTA-420	A, AF(2200)						
NTA-855-420			A				
NTC-929-E	D						
			V-12 Engine Series				
V-1710-460	S						
V-12-500						AD	AD
V-1710-500			S	S			
V-1710-L							S
VT-12-635						T	T
VT-1710-635			T	T			
VT-12-700						T	T
VT-1710-700			T	T			
VT-1710-L							T
VT-12-800						U	U
VTA-12-800							R
VTA-1710-800			U	U			U
VTA-1710-L							U
VT-12-900						U	

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HS, NHS-743 Parts Catalog	967124	2.50		
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