CHRYSLER ACADEMY

SCHOOL OF TECHNICAL TRAINING

Engine Diagnosis

LIFETIME
POWERTRAIN WARRANTY

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Notes:

Engine Diagnosis

INTRODUCTION

This course is designed for a technician who has prior engine knowledge. It provides practical experience in understanding engine mechanical diagnosis and includes five areas of concern as described in the Student Learning Objectives, which are not caused by electrical, fuel or ignition problems.

As an automotive technician you must be able to quickly and accurately diagnose engine concerns. Simply replacing parts is not enough. Often a failed part is a symptom of a larger problem. If you install new parts without properly diagnosing the cause of the failure, the new parts could also fail. This makes it possible for a technician to replace an expensive, hard-to-service component, only to find that it does not correct the problem.

This instructor-led course is Phase 1 of the two-phase Engine Diagnosis series. Phase 2 of this series is a web-based training course. At the conclusion of the web-based course is a review test of both in-center course content and web-based content. This will test your knowledge of the material covered in both phases. You must pass this review test to receive credit for both Phase 1 and Phase 2 of Engine Diagnosis.

When diagnosing a vehicle concern, it is important to follow a logical procedure. By following a standard procedure you are less likely to miss a small, easy-to-fix item that can be the cause of a malfunction.

Engine diagnosis is done in six basic steps:

1. Verification of complaint
2. Verification of any related symptoms
3. Symptom analysis
4. Problem isolation
5. Repair problem
6. Verify proper operation

Engine Diagnosis

STUDENT LEARNING OBJECTIVES

Upon successful completion of this course, the student will be able to:

- Identify the characteristics of engine mechanical diagnosis, including the following eight areas:
  - Noises and Vibrations
  - Lubrication system
  - Mechanical system
  - Electronic diagnostic tools
  - Performance
  - Cooling system
  - Failed component analysis
  - Thread repair
- Operate standard diagnostic tools.
- Perform a diagnostic procedure following a logical sequence for diagnosing engine mechanical concerns.
- Perform diagnostic tests on oil systems.
- Perform diagnostic tests on cooling systems.
- Perform selected engine mechanical diagnostic tests and analyze test results to determine necessary repairs.
- Analyze the engine components to determine the extent of repairs needed.

ACRONYMS

The acronyms listed here are used throughout this course.

- **A/C** Air Conditioning
- **AFV** Alternative Fuel Vehicle
- **API** American Petroleum Institute
- **ASD** Automatic Shut Down
- **DRB III®** Diagnostic Readout Box Third Generation
- **DTC** Diagnostic Trouble Code
- **ECT** Engine Coolant Temperature
- **ECU** Electronic Control Unit
- **EELD** Evaporative Emissions Leak Detector
- **EGR** Exhaust Gas Recirculation
- **ETC** Electronic Throttle Control
- **FFV** Flexible Fuel Vehicle
- **GPEC** Global Powertrain Engine Controller
- **HOAT** Hybrid Organic Additive Technology
- **IAC** Idle Air Control
- **ILSAC** International Lubrication Standardization and Approval Committee
- **kPa** Kilopascals
- **MDS** Multiple Displacement System
- **MPa** Megapascals
- **NOx** Oxides of Nitrogen
- **NVH** Noise, Vibration, and Harshness
- **O_2** Oxygen
- **OBD II** On Board Diagnostic Second Generation
- **PCM** Powertrain Control Module
- **PEP** Peripheral Expansion Port
- **PCV** Positive Crankcase Ventilation

- **psi** Pounds per Square Inch
- **PWM** Pulse Width Modulation
- **ROM** Read Only Memory
- **rpm** Revolutions Per Minute
- **SAE** Society of Automotive Engineers
- **STI** Steel Thread Insert
- **TDC** Top Dead Center
- **TOT** Transmission Oil Temperature
- **VCT** Variable Cam Timing
- **VVT** Variable Valve Timing
- **wiTECH™** Wireless Technician (Chrysler's diagnostic PC application)

BODY CODE LIST (2004 MY - 2009MY)

CODE	DESCRIPTION	YEARS APPLICABLE
AN	Dakota	2004
CS	Pacifica	2004 - 2008
D1/DC	Ram 3500 Pickup	2006 - 2008
DH/DR	Ram 1500/2500	2007 - 2008
DH/DR	Ram Pickup/Ram Pickup HD	2004 - 2006
DM	Ram 4500	2006 - 2008
DS	Ram 1500	2009 - current
DX	Reg Cab Chassis (Mexico)	2008 - current
HB	Durango	2004 - 2008
HG	Aspen	2007 - 2008
JC	Journey	2009 - current
JK	Wrangler	2007 - 2008
JR	Sebring/Stratus	2004 - 2006
JS	Avenger/Sebring	2007 - 2008
JS41	Sebring Convertible	2007 - 2008
KA	Nitro	2007 - 2008
KJ	Liberty	2004 - 2006
KK	Liberty	2007 - current
LC	Challenger	2009 - current
LE	300 (Export)	2006 - 2008
LH	300M/Intrepid/Concorde	2004
LX	Charger	2006 - 2008
LX	300/Magnum	2005 - 2008
MK	Compass/Patriot	2006 - 2008
ND	Dakota	2005 - 2008
PL	Neon	2004 - 2005
PM	Caliber	2004 - 2008
PT	PT Cruiser	2004 - 2008
RG	Caravan/Town and Country/Voyager (BUX)	2004 - 2005
RS	Caravan/Town and Country	2004 - 2007
RT	Caravan/Town and Country	2008 - current
SR	Viper	2004 - 2006
ST	Sebring/Stratus (2-door coupe)	2004 - 2005
TJ	Wrangler	2004 - 2006
VA	Sprinter	2004 - 2006
VB	Sprinter	2007 - 2008

CODE	DESCRIPTION	YEARS APPLICABLE
WJ/WG	Grand Cherokee	2004
WK/WH	Grand Cherokee	2005 - 2008
XK/XH	Commander	2006 - 2008
ZB	Viper	2008 - current
ZH	Crossfire	2004 - 2008

LESSON 1 ENGINE NOISE / VIBRATION CONCERNS

OVERVIEW

There are many causes for engine noise and vibration. Because sound travels easily through metallic objects, it is sometimes difficult to identify engine noise. Vibration is the repetitive motion of an object, back and forth or up and down. Because vibrations typically happen only under certain driving conditions, their causes may be difficult to identify.

NOISES

When diagnosing engine noise, it is important to determine the type of noise and the conditions under which the noise may exist. Remember engine noise is usually synchronized with engine speed. In most cases this will be an important first step when testing for engine noise.

Specific noises can also relate to a specific component or condition. For example, a light tapping at half engine crankshaft speed can mean a valvetrain issue. Use such noise-to-component relationships to help diagnose engine noise.

Engine assembly noises can be difficult and time-consuming to diagnose. However, when performed correctly, you will find that spending a few more minutes thoroughly diagnosing the problem to determine its root cause will save you a great deal of time in the long run. It is important to diagnose the failure and its cause before beginning any repairs. A correct diagnosis helps you fix the problem right the first time, resulting in a satisfied customer.

VIBRATIONS

Vibratory motion is a function of time and is measured in Hertz or cycles per second. Vibration is described in various ways and using many words, including:

- Shake
- Shimmy
- Shudder
- Buzz
- Drone

Vibrations can be constant or variable. They can occur in every driving condition, or during a portion of the entire engine operating speed range. Vibrations are usually caused by some rotating component or components, or sometimes by the improper combustion of the air/fuel mixture in individual engine cylinders.

Engine Diagnosis

Under normal conditions, a rotating component will not produce a noticeable vibration. However, if the component is loose, misaligned, not properly balanced, or out-of-round, then a noticeable vibration can be produced. Engine vibrations that do not generate a noise are generally created by an out-of-round, out-of-balance or damaged component.

USING A STETHOSCOPE

Two types of stethoscopes can be used to isolate engine noises; mechanical and electronic. The mechanical stethoscope can be used with or without a metal probe. Without the probe, general locations of knocking noises can be found and vacuum leaks located. When the metal probe is used and placed against a suspected area, the sound is transmitted through the metal probe and amplified for identification.

If you hear a noise, go around the engine compartment with a stethoscope until you find the location where the noise is the loudest. Most likely this is where the noise is being produced.

WARNING: EXERCISE CAUTION WHEN USING AN ELECTRONIC STETHOSCOPE ON AN ENGINE THAT IS RUNNING. THIS TYPE OF STETHOSCOPE CAN GREATLY INTENSIFY NOISE, WHICH COULD IMPAIR YOUR HEARING.

Manual Stethoscope

Electronic Stethoscope

Figure 1 Stethoscope Listening Devices

USING WIRELESS LISTENING DEVICES

Commercially available wireless electronic listening devices can also be used. One such system is the ChassisEAR™, which can be valuable for locating squeaks and rattles that only occur when a vehicle is being driven.

ts0002

Figure 2 Wireless ChassisEAR™ System (PSE 223-97202 or Eqivalent)

The wireless multi-channel receiver shown can isolate up to 4 different microphone transmitters positioned at various locations within and under a running vehicle. The channels can be switched to listen to each one individually, either with the receiver's built in speaker or by plugging in a set of headphones.

NOTE: Care should be taken when using such devices because they can amplify normal noises, which could indicate false areas of concern.

VERIFYING CUSTOMER NOISE OR VIBRATION CONCERNS

The first in-shop tests for verifying customer engine noise or vibration concerns should be the Neutral Run-Up test and/or the Engine Load test.

Neutral Run-Up Test

This test is used to verify the noise or vibration is engine speed-related and not vehicle speed-related. The steps of this test include:

- Increasing rpm while in PARK, or in NEUTRAL on rear wheel drive vehicles, with the brakes applied.
- Measuring the frequency of the vibration with a vibration analyzer to determine if the vibration is related to crankshaft speed, engine accessory speed, or engine firing frequency.
- Isolating engine mounts and engine accessories.

NOTE: This test will rule out driveline or tire concerns that may be interpreted as an engine vibration to the customer. For information on diagnosing a driveline vibration refer to the Noise, Vibration, and Harshness (NVH) Course.

Engine Load Test

The engine load test is used to detect engine noise or vibration. This test can help reproduce engine speed-related concerns that cannot be identified with a neutral run-up test or a neutral coast down test.

NOTE: Vibrations that cause the crankshaft to fluctuate can also generate misfire Diagnostic Trouble Codes (DTCs).

The engine load test also identifies noise and vibration sensitive to engine load or torque demand. For this reason, these concerns often appear only during heavy acceleration or when climbing a hill.

NOTE: Inline 4-cylinder engines have a natural vibration that occurs at twice the speed of the crankshaft (2nd order). This is because for each crankshaft revolution two pistons are up and two pistons are down, two times. For this reason some inline 4-cylinder engines use a balance shaft.

ENGINE NOISE

Your first step in diagnosing any engine area noise should be:

- Check the engine oil level and condition
- Run the engine at various engine speeds and loads

Engine assembly noises can come from six different areas:

- Internal engine noise
- Engine mount noises
- Air intake noise
- Exhaust system noises
- Flexplate noise
- Engine accessory noises

Internal Engine Noise

Internal engine noises can be caused by:

- Lower end components such as pistons, wrist pins, main and connecting rod bearings
- Upper end components such as lifters, rocker arms, valves, and valve springs
- Timing sprocket components such as timing gears, idler, tensioners, belts, chains, and guides
- Water pump bearing
- Spark knock, detonation, or carbon knock in the combustion chamber

When diagnosing engine assembly noises, note that:

- Load affects lower end noises more than upper end noises
- Piston noises can occur on warm or cold engines
  - Piston slap noises are generally worse on a cold engine
  - Piston pin noises are generally worse on a warm engine
- Valvetrain noises may be associated with engine performance problems
- Timing drive components and/or water pump noises (rattles or whines) are more noticeable at idle
- Pinging caused by pre-ignition or detonation is worse on a hot engine under load
- Carbon knock can be caused by hardened carbon deposits formed in the combustion chamber
- Lower end noises are generally described as a "knock"

- Upper end noises are generally described as "ticking"
- Ticking may also be related to underhood electrical solenoids such as:
  - Purge solenoid
  - Exhaust Gas Recirculation (EGR)
  - Transmission
  - Fuel injectors

If you have concluded that the noise is internal to the engine, isolate the noise by performing the appropriate tests:

- LOWER END - Use a stethoscope to pinpoint the noise; check oil pressure and condition; to further isolate the noise perform an injector kill or cylinder balance test; disassemble and inspect internal engine components if required. Inspect and measure the following items to determine the cause of the failure and extent of the repair:
  - Bearing condition
  - Camshaft and crankshaft end play
  - Connecting rod side clearance
  - Main bearing bore diameter and condition
  - Cylinder bore out-of-round or taper
  - Piston to cylinder wall clearance
- UPPER END - Use a stethoscope to pinpoint the noise; check oil pressure and condition; to further isolate the noise perform an engine vacuum gauge test.
- TIMING CHAIN/BELT - Use a stethoscope to pinpoint the noise; check oil pressure and condition; check the timing chain for stretch (if an engine oil-fed hydraulic chain tensioner is used) or timing belt condition, tensioner pulley(s), timing chain/belt cover.
- COMBUSTION CHAMBER
  - Spark knock/detonation - Normally a fuel concern (not mechanical); refer to tests in Powertrain Diagnostic Test Procedure Information.

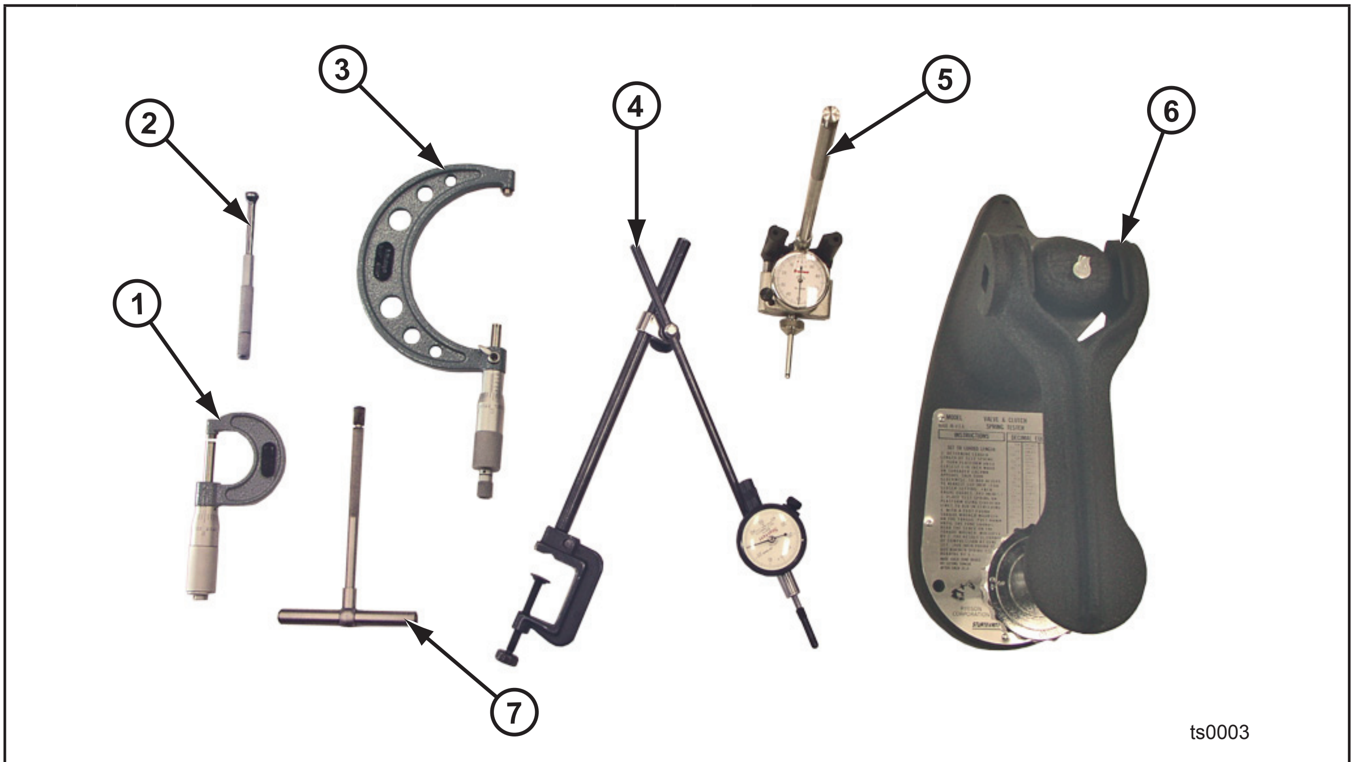
CAUTION: Do not use combustion chamber cleaner on electronic throttle body engines, damage to the throttle body may occur.

  - Carbon knock - Use a combustion chamber cleaning process and note changes in noise. Refer to the appropriate Service Information for the combustion chamber cleaning process and which engines it should not be performed on.

ENGINE DIAGNOSTIC TOOLS

When diagnosing an internal engine noise, measuring tools may need to be used to measure the tolerances of the engine parts. The tools used to diagnose and measure engine components are:

- Small bore gauge
- Micrometers
- Telescoping gauges
- Dial indicator (clamp or magnet base)
- Large bore gauge
- Valve spring tester



1	0-1 inch Micrometer	5	Large Bore Gauge
2	Small Bore Gauge	6	Valve Spring Tester
3	3-4 inch Micrometer	7	Telescoping Gauge
4	Dial Indicator		

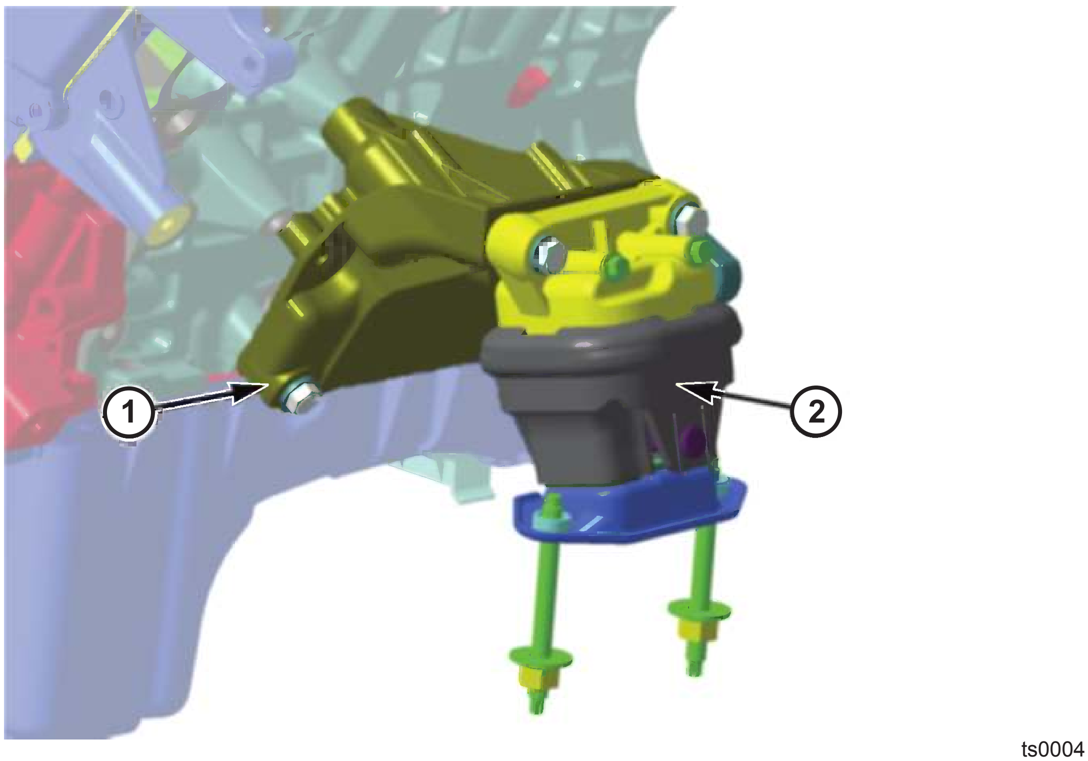
Figure 3 Measuring Tools

Table 1 Internal Engine Noise

TYPE OF NOISE	RPM	TEMP.	LOAD	SUSPECTED AREA OR COMPONENT	TEST
Ticking	Idle	All	0%	Upper End, Solenoids	Stethoscope, Isolate Solenoids
Knock	1200	Cold	Light	Lower End, Internal Engine	Injector Kill, Stethoscope, Combustion Chamber Cleaner
Ping	1500 and above	Hot	70%	Pre-ignition	Check Powertrain Diagnostic Information and TSBs
Rattle	Idle	All	0% 25%	Exhaust/Intake Flexplate	Loosen Exhaust, Isolate PCV, Brake Torque Engine
Squeal	1100	All	0%	Accessories	Belt Tension, Remove Belt, Water Mist, Stethoscope
Hiss	Idle	All	0%	Intake/Exhaust	Pinch Off Hoses; Check to See if this Noise is a Normal Characteristic
Drone	1400	All	25%	Mounts/Exhaust	Vehicle Speed or RPM Related, Brake Torque Test, Loosen Exhaust
Clunk	Idle	All	0%	Mounts	Engine Position, Brake Torque Front/Rear

Engine Mount Noises

The engine mounts are the first components that isolate vibration from the engine to the passenger compartment. Vehicles can be equipped with molded rubber mounts, hydraulic mounts, or a combination of the two.



1	Mount Bracket	2	Engine Mount

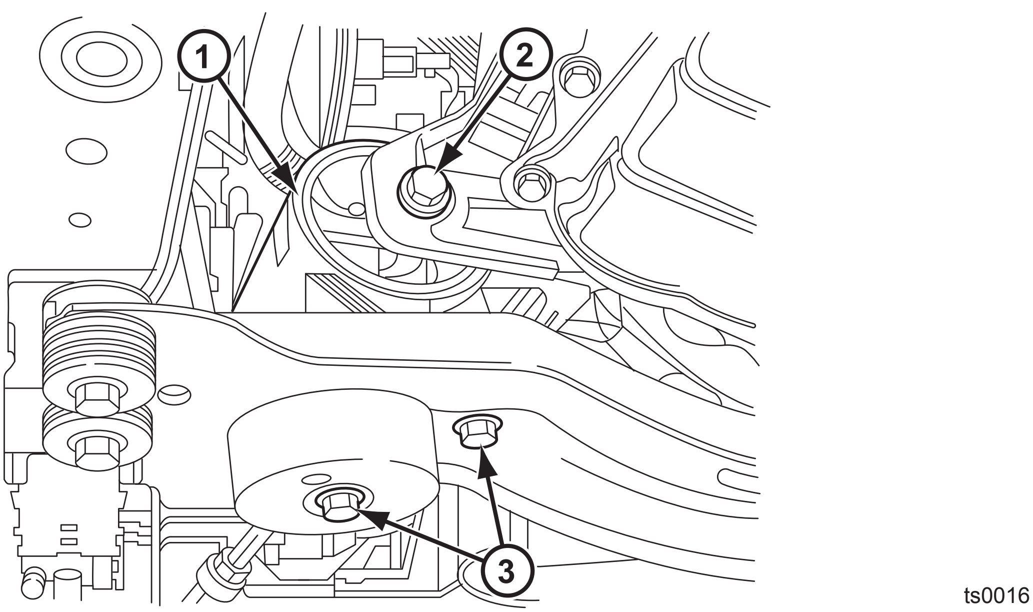
Figure 4 Typical Engine Mount

Engine mounts that are misaligned, broken, leaking, or grounded to the body or frame can cause a noise or vibration concerns and are generally worse under load. To determine if engine mounts are the cause of the concern:

- Visually inspect to locate damaged, loose, or misaligned components. If the vehicle has been in an accident, minor damage can cause a number of serious, engine-related alignment problems.
- Check the engine under load in different gear positions and at various engine speeds.

In addition to rubber or hydraulic mounts, some engines use torque struts to support the engine. These mounts consist of upper and lower struts mounted to upper and lower bracket assemblies. Both the upper and lower torque strut must be adjusted to ensure proper engine positioning and mount loading. Whenever a torque strut bolt is loose, perform the appropriate adjustment procedure as detailed in the Service Information.

Shown below is the front engine mount of a four-point mounting system that utilizes two load-carrying hydro-elastic mounts at each frame rail, and two torque controlling mounts located at the front and rear of the engine.



1	Torque Controlling Mount	3	Mount Retaining Bolts
2	Mount Through Bolt		

Figure 5 Torque Controlling Front Engine Mount (2.4L JC)

Air Intake Noises

Air intake noises are created from air being drawn into the engine. Components in this area include the intake manifold, plenum, gaskets, vacuum lines, and intake air resonators. These noises are characterized by a rattling, whistling or "air rushing" noise.

The purpose of the intake air resonator is to help smooth out the pulses of air entering the engine, especially during medium to hard acceleration. This resonator not only lowers noise, but helps performance.

To determine if air intake noise is the cause of the concern:

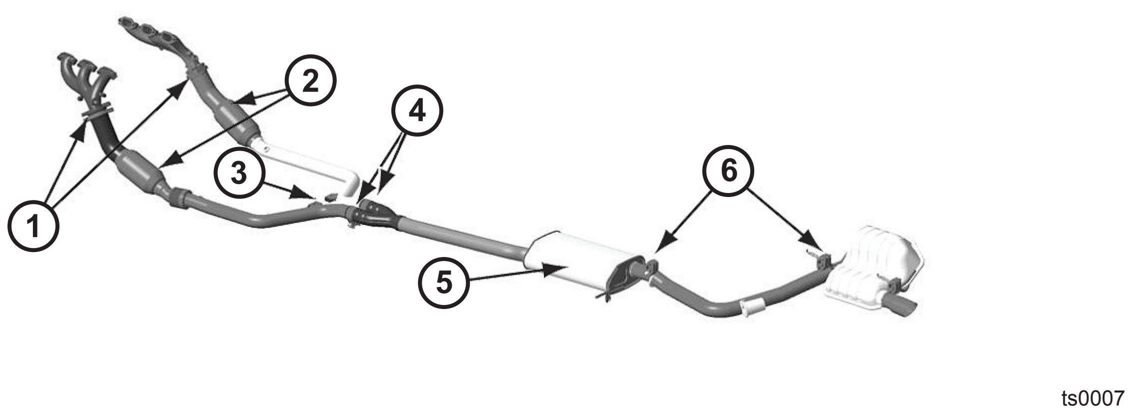
- Operate the engine at different temperatures and rpm
- Visually inspect the intake air ducts, resonators, and vacuum lines
- Determine if the noise is normal for the engine

1	Air Cleaner	2	Air Resonator

Figure 6 Typical Intake System (3.7L KK)

Exhaust System Noises

The exhaust system can also be a source of noise. The length and gauge of the exhaust system can easily magnify noises created by bending or twisting. Combined with catalytic converters, resonators, mufflers and heat shields, an exhaust system can create noise and vibration. The exhaust system can significantly increase the noise level in the passenger compartment.

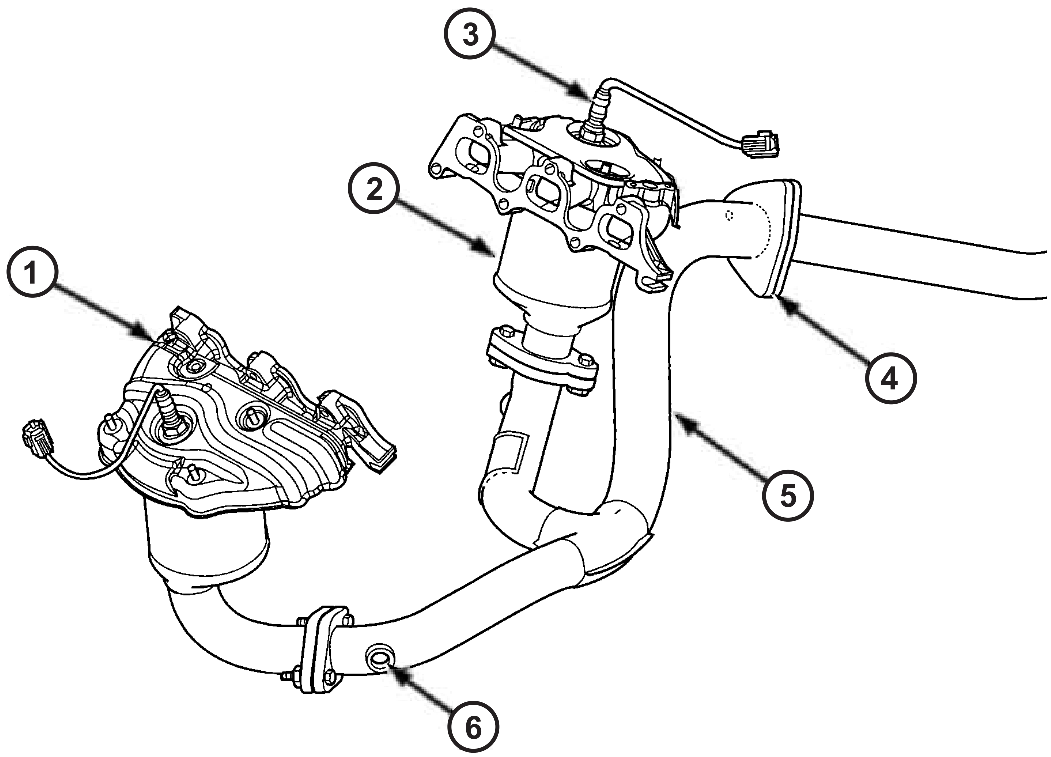


1	Ball Flanges	4	Band Clamps
2	Catalytic Converters	5	Muffler and Resonator
3	Cross Brace	6	Isolators

Figure 7 Typical Exhaust System (2.7L LX)

Typical exhaust system noises include ticking, hissing, whistling, droning, or rattling. These noises can be caused by:

- Grounded, misaligned, or binding exhaust system components
- Broken fasteners or hangers
- Bent components
- Leaking connections or joints
- Exhaust manifold, flange, or gaskets
- Defective catalyst, resonator, or muffler
- Loose or bent heat shields
- Normal resonance created by the engine firing pulses

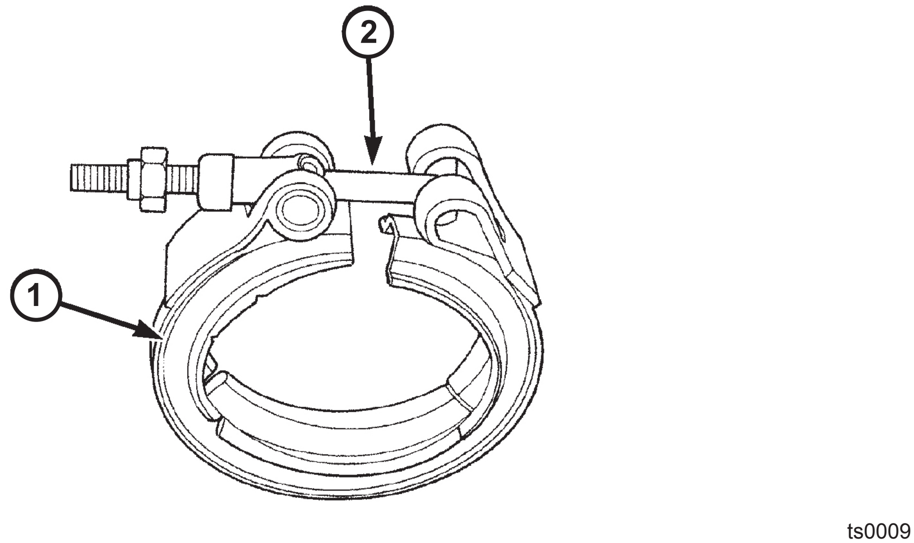


1	Exhaust Manifold	4	Flange
2	Catalytic Converter (Maniverter)	5	Crossover Pipe
3	Pre-catalyst O_2 Sensor	6	Post-catalyst O_2 Sensor

Figure 8 Typical Exhaust Manifold Flange

A V-band clamp secures the catalytic converter to the exhaust manifold connection. When the V-band clamp is tightened, it forces the flared mating surfaces of the manifold and the catalytic converter pipe together. This seals and supports the joint.

NOTE: When removed, V-band clamps must be replaced with new clamps



1	V-Band Clamp	2	T-Bolt

Figure 9 Typical V-Band Clamp

Tests or inspections include:

- Visually inspecting the exhaust components, including the EGR system
- Running the engine at various loads, rpm and temperatures
- Using a bore scope to check the catalyst for meltdown or break-up
- Tapping on exhaust system components
- Using a stethoscope to isolate the source
- Restricting or blocking the tailpipe and checking for leaks
- Loosening exhaust system hangers to verify misalignment by neutralizing the exhaust system noise
- Exhaust system back pressure test

Flexplate Concerns

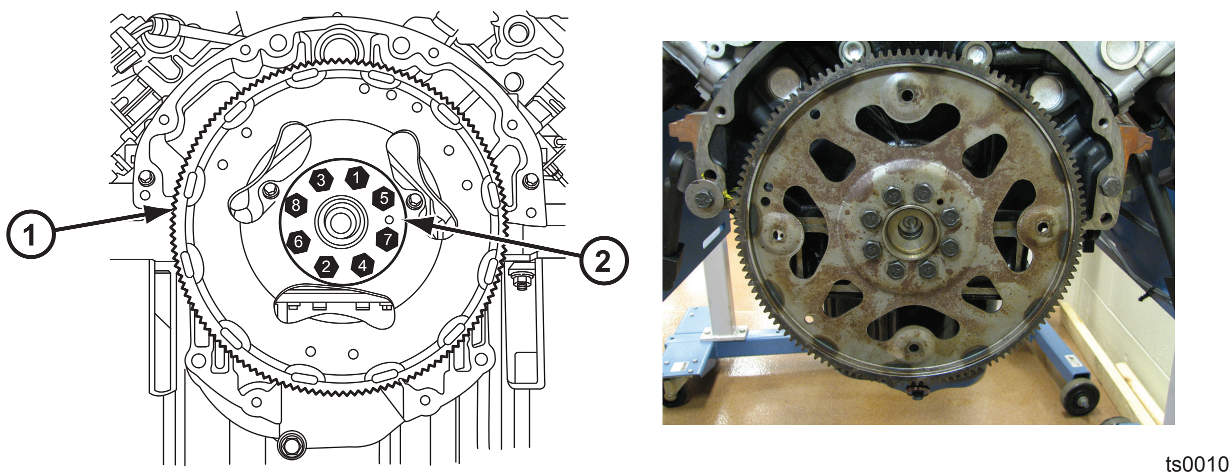
Noises from the flexplate are usually rattles, buzzing, popping, or clunking. The cause of these noises can be a cracked flexplate, loose or incorrect bolts, or the flexplate contacting the flexplate cover.

Performance concerns can be caused by the flexplate. When replacing the flexplate make sure that the correct flexplate is installed on the vehicle.

To determine if a flexplate is the source of the noise:

- Load the engine at various rpm, in park as well as drive and reverse
- Perform a visual inspection
- Use a stethoscope
- Spray a lubricant around the crank-to-flexplate joint. If the noise changes or goes away, the flexplate is probably cracked

NOTE: When replacing the flexplate make sure the correct one is installed with the correct torque converter bolts.



1	Flexplate	2	Flexplate Bolts

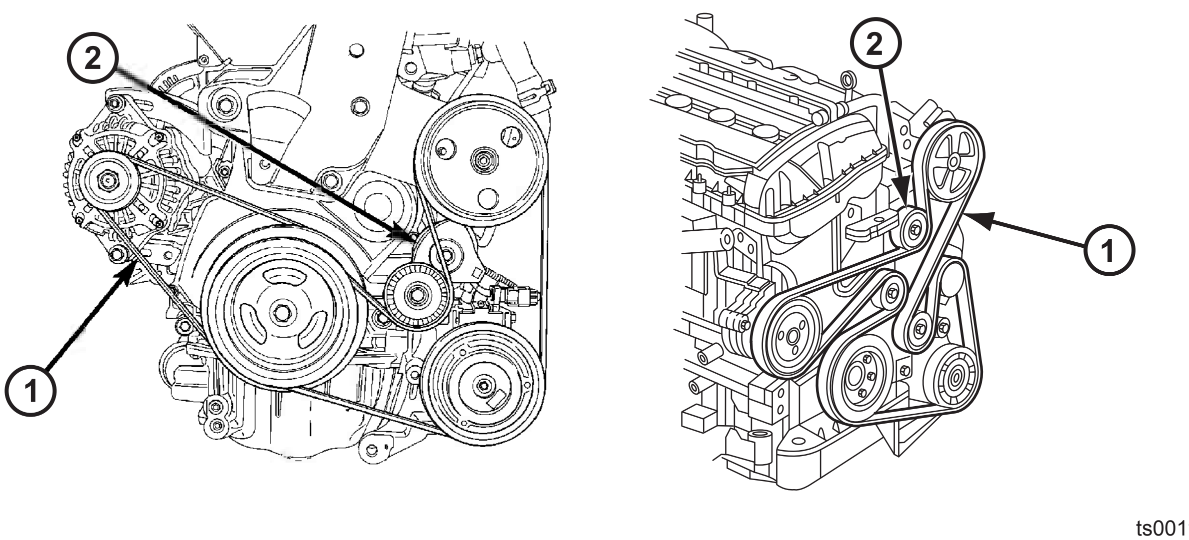
Figure 10 Flexplate Inspection

Engine Accessory Noises

Another source of engine noise can be from the engine accessory drive system.

When diagnosing accessory noise it is important to make sure the engine or engine-firing frequency is not the source of the noise. Engine firing frequencies can cause components to resonate and vibrate. The amplification of the noise may increase due to the load of the accessories. Sometimes, the most effective repair is to isolate the disturbance by interrupting its transfer path, rather than attempting to eliminate the source.

Serpentine belts used on today's engines can make it difficult to isolate the source of the noise since the belts are not removed individually. Because the serpentine belt usually drives all components, one component may affect another through resonance. If removing the serpentine belt eliminates the vibration, install the belt and operate each component separately. By operating the air conditioning, or turning the steering wheel, some components can be eliminated or isolated as sources of noise.



1	Belt	2	Belt Tensioner

Figure 11 Accessory Drive Belt (2.4L PT, 2.0/2.4L JS)

Another source of noise from the accessory drive belt can be the belt condition and belt tension. If a belt is cracked, frayed, or glazed this could cause a customer noise concern. Belt tension can also be a cause for noise, even though a majority of belt systems are automatically tensioned. When checking for accessory drive belt noise check the belt tension and adjust as needed. An overtightened accessory drive belt can cause other accessories to make noise, or cause them to fail prematurely.

Accessory drive belt tests include:

- Water misting the belt
- Using a stethoscope
- Checking belt tension with a DRB III® scan tool with a belt tension gauge adapter (8371 tool) connected, or a belt tension gauge
- Removing the belt and operating the engine without it

CAUTION: Limit engine run time when the belt is removed from the water pump.

Notes:

LESSON 2 ENGINE LUBRICATION SYSTEM

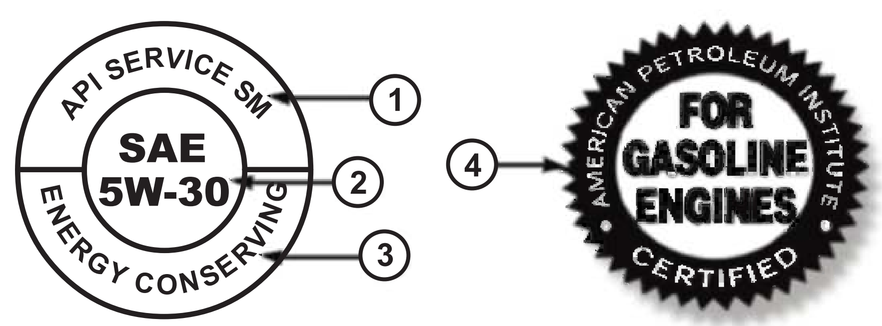
OIL TYPES

There are two labels on a bottle of oil. The first is the American Petroleum Institute (API) label, which contains the performance level, viscosity, and fuel economy rating of the oil.

API Certification Mark

An oil displaying this mark meets the current engine protection standard and fuel economy requirements of the International Lubrication Standardization and Approval Committee (ILSAC), a joint effort of US and Japanese automobile manufacturers. Most automobile manufacturers recommend using oils that carry the API Certification Mark.

The API Certification Mark starburst identifies engine oils recommended for a specific application, such as gasoline service. An oil may be licensed to display the starburst only if the oil satisfies the most current requirements of ILSAC minimum performance standard for this application, currently GF-4 for gasoline engines. The starburst symbol must be on the oil for the oil to comply with Chrysler engines.



1	Performance Level (API)	3	Fuel Economy Indicator
2	Viscosity (SAE)	4	API Certification Mark

Figure 12 Oil Labels

Performance Level

Oils designed for gasoline engines fall under API's S (Service) categories. Although service category SL and SJ are still listed as current, only service category SM should be used in today's (post-2004) automobiles.

- SM — For all automotive engines currently in use. Introduced in 2004, SM oils are designed to provide improved oxidation resistance, improved deposit protection, better wear protection, and better low-temperature performance over the life of the oil.
- SL — For 2004 and older automotive engines.
- SJ — For 2001 and older automotive engines.

Oils designed for diesel engines fall under API's C (Commercial) categories. Although there are other commercial service categories still listed as current, only service category CJ-4 should be used in today's (post-2006) diesel vehicles.

- CJ-4 — Introduced in 2006, CJ-4 oils are for diesel fuels ranging in sulfur content up to 0.05 percent by weight. Optimum protection is provided for control of catalyst poisoning, particulate filter blocking, engine wear, piston deposits, low and high temperature stability, soot handling properties, oxidative thickening, foaming, and viscosity loss due to shear.
- CI-4 — Introduced September 5, 2002 for high-speed, four-stroke engines designed to meet 2004 exhaust emission standards implemented in 2002. CI-4 oils are formulated to sustain engine durability where Exhaust Gas Recirculation (EGR) is used and are intended for use with diesel fuels ranging in sulfur content up to 0.5 percent by weight.
- CH-4 — Introduced in 1998 for high-speed, four-stroke engines designed to meet 1998 exhaust emission standards.

Viscosity

A Society of Automotive Engineers (SAE) viscosity grade is used to specify the viscosity of engine oil. Viscosity means the flowability of oil. More specifically, it is the property of an oil to offer continued resistance to flow at a wide range of temperatures. Thicker oils generally have a higher viscosity, and thinner oils a lower viscosity. These are the most important oil properties for an engine. If the viscosity is tool low, it can shear and lose film strength at high temperatures. If the viscosity is too high, it may not pump to the proper engine parts at low temperatures and the oil film may tear at high rpm. Engines need oil that is both thin enough for cold starts, yet thick enough to maintain viscosity when the engine is hot. For this reason multi-grade or multi-viscosity oils meet SAE specifications for both the low temperture requirements of a light oil as well as the high temperature requirements of a heavy oil.

The oil viscosity numbers for multi-grade 5W-30 represent the following:

- The 5 refers to how well the oil will flow at cold temperatures. A lower number will have a lower viscosity, and the oil will flow faster through the engine when first started. This is very important in cold weather starts as most engine wear occurs at this time. It is important to note that synthetic oils have much better low temperature flow characteristics.
- The W indicates winter and designates the oil as having good flow capability for cold weather starts.
- The 30 indicates the high temperature viscosity of the oil when the engine has reached operating temperature.

Fuel Economy Rating

The energy conserving rating applies to oils intended for gasoline engines. Widespread use of energy conserving oils may result in an overall savings of fuel.

OIL DEGRADATION

Engine oil sludge is typically a form of oil degradation. The most common form of oil degradation is caused by the interaction that takes place between the engine oil and internal contaminates. Engine oil degradation can also be the result of external contaminants added to the oil.

Sludge builds up when the oil is left in the engine beyond its useful life. Low quality engine oil that does not meet the minimum standards, can also cause sludging. Make sure the proper quality engine oil is used. Mopar engine oils exceed the latest API Certification requirements. Finally, engine oil sludge could also be an indication of a more serious mechanical concern such as a crankcase ventilation system not functioning properly.

Today's engines place higher demand on engine oil because they are designed to increase power and rpm, reduce emissions, and improve fuel economy. Adhering to the appropriate maintenance schedule is vitally important to prolonged engine life. Customer perception of driving type and time are major issues.

Oil Change Indicator System

Starting with 2008 models, Chrysler began installing oil change indicator systems to track driving habits and notifying the motorist with an indicator message when to change the vehicle's motor oil. The oil change indicator system will remind you that it is time to take your vehicle in for scheduled maintenance. On Electronic Vehicle Informantion Center (EVIC) equipped vehicles, "Oil Change Required" will be displayed in the EVIC and a single chime will sound, indicating that an oil change is necessary. On non-EVIC equipped vehicles, "Change Oil" will flash in the instrument cluster odometer and a single chime will sound, indicating that an oil change is necessary. Based on engine operating conditions, the oil indicator message will illuminate. This means that service is required for your vehicle. Have your vehicle serviced as soon as possible; within the next 805 km (500 mi).

The oil change indicator message does not monitor the time since the last oil change. Change your vehicle's oil if it has been six months since your last oil change even if the oil change message is not illuminated. Change your engine motor oil more often if you drive your vehicle off-road for an extended period of time. Under no curcumstances should oil change intervals exceed 10,000 km (6,000 mi) or six months, whichever comes first.

Table 2 Oil Change Intervals

Maintenance Items	**Perform Maintenance Every: (Where time and mileage are listed, follow the interval that occurs first)**		
	Miles	**Kilometers**	**or Months**
Change the engine oil and engine oil filter if using your vehicle under any of the following Severe Duty conditions: - Short trips - Stop and go driving - Dusty or off-road conditions - Police, Taxi, or Fleet use - Frequent trailer towing - E85 fuel	3,000	5,000	3
	or	or	or
Change your engine oil and engine oil filter if your vehicle is not operated under any of the conditions listed under Severe Duty	6,000	10,000	6

NOTE: Some Chrysler engines are exceptions to the oil change intervals listed above – always consult the service information for the correct service interval.

FLEX FUEL OIL REQUIREMENTS

Because ethanol produces more water during combustion, specific types of engine oil are required to keep the oil, water and alcohol mixed in the crankcase. If non-approved oils are used in E85 burning flex fuel engines, the water and alcohol can separate and reduce lubrication, eventually resulting in premature engine failure. For this reason, only oils rated with an SM (API) rating or a GF-4 (ILSAC) rating or above should be used.

SYNTHETIC OIL USE

The makers of synthetic oils have certified their performance with groups such as API, the automotive industry group ILSAC, and others. Introduced in the early 1970s for automotive use, synthetic oil manufacturer's claim greater lubricity on startup, better high and low temperature viscosity performance, improved chemical and shear stability, as well as resistance to evaporative loss, oxidation, thermal breakdowns, and oil sludge issues over conventional motor oils.

Early reports of potential breakdown of plastic engine components has been overcome by the manufacturers, as well as rumors that a new engine had to be broken in with conventional oil prior to using synthetic oil. For a number of years synthetic oil has been installed at the factory for some Chrysler vehicles, check with the Service Information if there is any doubt.

OIL CONSUMPTION

When a customer is concerned about oil consumption and there are no visible leaks or engine problems, an oil consumption test must be started. To perform an oil consumption test the customer needs to bring the vehicle in and the oil topped off and the mileage and date noted. The owner then brings the vehicle back at certain intervals to have the oil checked and the amount with the date and mileage recorded.

NOTE: As a general rule of thumb a vehicle that has over 12,070 kilometers (7,500 miles) and consumes more than a quart of oil every 1,609 kilometers (1,000 miles) should be diagnosed further.

A loss of oil can mean two things: engine oil is being burned in the combustion chamber (internal leakage) or oil is leaking externally. Oil can also contaminate the cooling system.

BURNING OIL

- Question customer about driving habits and type of oil used
  - Short trips
  - Towing
  - Wide open throttle
  - Oil viscosity
  - Oil brand
  - Change interval
- Look for bluish colored smoke on start up that indicates failed valve guides/ seals. Inspect the spark plugs for oil fouling
- Check the crankcase ventilation system
- Check for an overfilled crankcase
- Check for an intake manifold leak that is pulling a vacuum on the crankcase
- Check for worn or damaged piston rings

Tests include:

- Perform oil consumption test
- Cylinder compression test
- Cylinder leak test
- Oil dye test

EXTERNAL OIL LEAKS

- Operate the vehicle to identify the approximate location from the dripping. If necessary, clean the area to see exactly where the leak is originating
- After the suspect component is identified, check the component and the area around the component to determine the exact cause of the leak
- Check all gaskets, mating surfaces, and hoses
- Check for a plugged crankcase ventilation system

Be sure you have found the exact cause. Replacing a gasket will not repair a leak from a bent or damaged component. If you still cannot find the oil leak, perform either a Fluorescent Oil Dye Test or a Pressure Leak Detection Test.

OIL LEAK DETECTION, DYE METHOD

If your visual inspection does not locate the cause of an oil leak concern, a fluorescent oil dye leak test may help find the leak.

NOTE: Do not clean or degrease the engine before performing a fluorescent oil dye leak test. Some solvents can cause rubber to swell and temporarily stop the leak.

Add the fluorescent oil dye to the engine oil (using the procedure recommended by the oil dye leak test manufacturer).

1. Start the engine and let it idle for about 15 minutes.
2. Check the oil dipstick to make sure the dye has thoroughly mixed. The oil will be a bright yellow under a black light. This is best viewed with the special glasses supplied with the test kit.
3. Use a black light and inspect the entire engine for traces of the yellow dye.

If you do not see traces of the dye, drive the vehicle at various speeds for about 24 km (15 miles) and repeat the inspection.

If you suspect an internal leak on an engine burning oil, the backside of the valve(s) and/or the top of the piston may show traces of dye.

If you still cannot find the oil leak, proceed with the oil leak detection pressure method as follows.

OIL LEAK DETECTION, PRESSURE METHOD

This test can be done using the Evaporative Emissions Leak Detector (EELD), evaporative system pressure tester, or a pressure regulator capable of reducing the pressure to 21 kPa (3 psi).

CAUTION: Do not pressurize the crankcase more than 21 kPa (3 psi).

1. Using the dipstick tube, PCV grommet or the crankcase ventilation tube, pressurize the crankcase to not more than 21 kPa (3 psi). Use a shop towel to seal the pressurized supply hose and selected area. To verify the crankcase is pressurizing, remove the oil filler cap and listen for escaping air. If you can hear the escaping air, install the cap and continue.
2. Plug all remaining open crankcase holes so air cannot escape.
3. Add a solution of liquid detergent and water to suspected oil leak areas.
4. Watch for bubbles that indicate a leak.

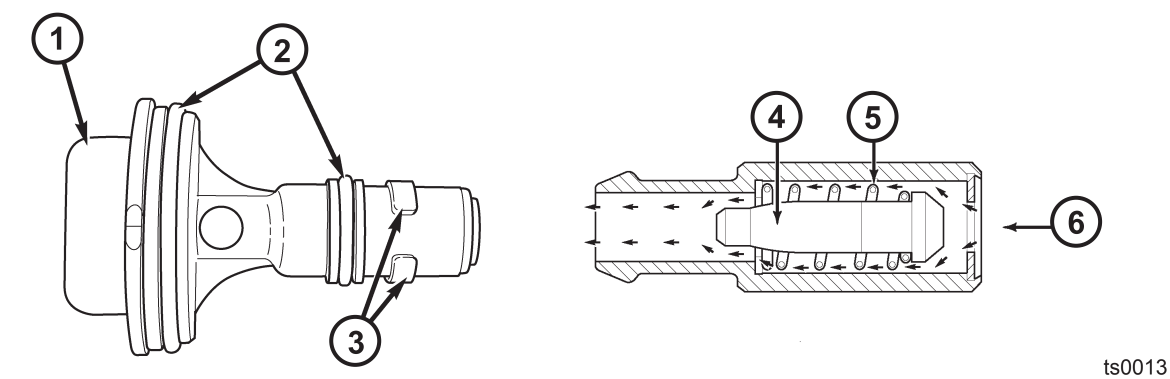
CRANKCASE VENTILATION SYSTEM

The reason for having a crankcase ventilation system is to:

- Recycle crankcase vapors
- Scavenge Oxides of Nitrogen (NOx) from the area where oil oxidation and polymerization is most likely to occur
- Remove heat from the crankcase
- Maximize oil change intervals
- Remove piston blow-by gases and fumes

The PCV system uses engine vacuum to establish air circulation and with it the removal of the unwanted vapor mixtures and burnt and partially burnt products of combustion.

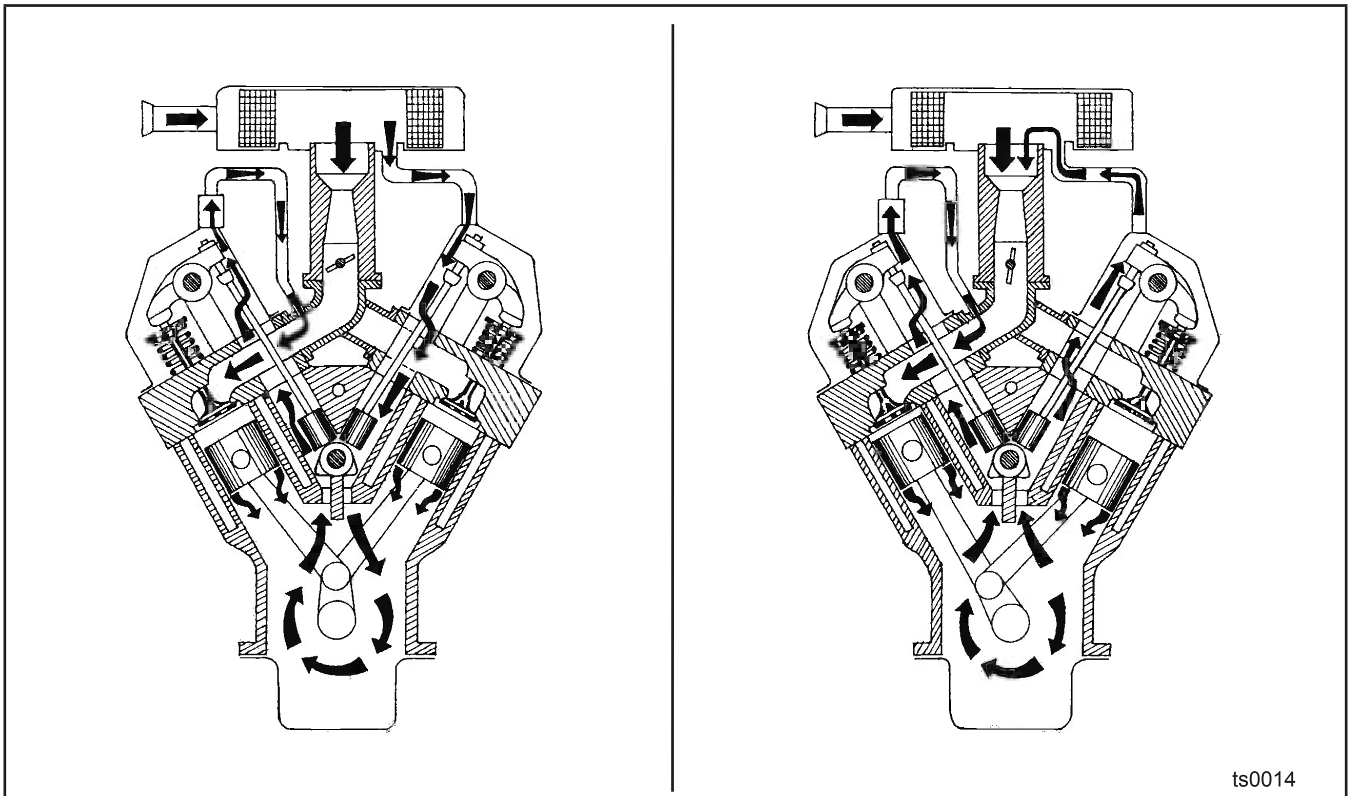
A plugged crankcase system can cause buildup of crankcase pressures that may lead to failure of an oil seal or gasket. System tests include checking for proper vacuum and basic component inspection. Refer to the appropriate vehicle Service Information for test procedures.



1	PCV Valve	4	PCV Check Valve
2	O rings	5	Spring
3	Locking Device	6	Crankcase Vapors

Figure 13 Cutaway PCV Valve

The following graphics shows the air flow through the crankcase both at idle and at high engine rpm. At idle, with low manifold vacuum, the engine channels outside air through the crankcase, up into the valve cover(s), then down into the pistons. At high rpm the high vacuum compresses the PCV valve spring, closing the valve and causing the engine to only circulate crankcase air into the pistons.



Idle	Full Throttle

Figure 14 V-6 Engine PCV System

Notes:

LESSON 3 ELECTRONIC DIAGNOSTIC SCAN TOOLS

wiTECH™ OVERVIEW

Using traditional scan tools for diagnostics has always been a navigation intensive task. However, this has changed for Chrysler with the introduction of the wiTECH™ system for diagnostic services. The wiTECH™ system was designed to be easier to read and much more intuitive to navigate. It also allows the technician to immediately begin diagnostics the moment the system connects to a vehicle, instead of sifting through page after page of preliminary data.

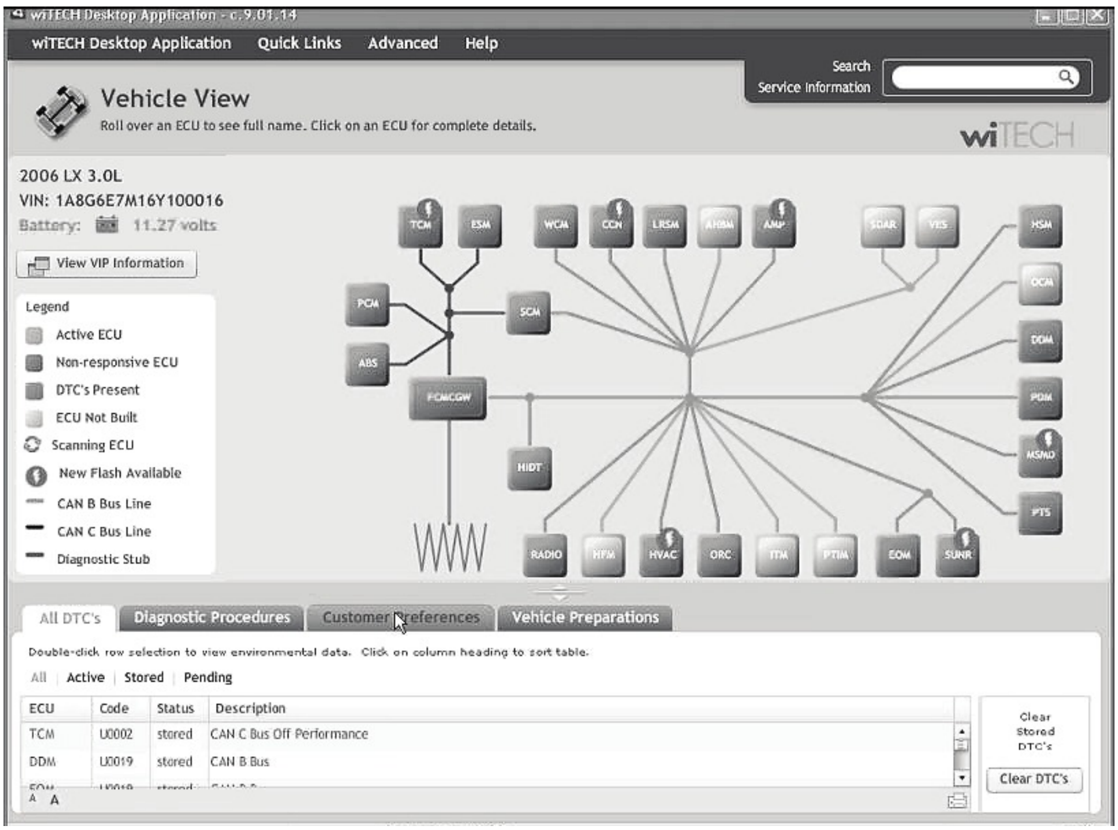


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Figure 15 wiTECH™ Screen Layout

Many of these system benefits become obvious when the initial system screen is viewed. The main screen is horizontally divided into two halves, with a sliding divider bar separating them. The top portion of the screen is the Vehicle View, the bottom portion is called ECU View. The Vehicle View includes a legend and a matrix of the vehicle's electronic components, called the topology. The ECU View is divided into tabs that show different diagnostic information. If the sliding bar is moved up to make the ECU View larger, the Vehicle View's topology will resize to fit the smaller space.

Vehicle View

The Vehicle View's high level perspective presents the technician with a snapshot of the current status for all of the vehicle controllers included in the build. The high resolution, color coded map graphically indicates which Electronic Control Units (ECUs) are responsive, which have DTCs, and which are out of date. An always-visible legend to the left of this map explains at a glance the current status of the ECU systems displayed.

ECU View

The ECU View on the bottom portion of the screen is divided into four tabs; All DTCs, Diagnostic Procedures, Customer Preferences, and Vehicle Preparations. A number of important functions can be performed from this view, without ever having to leave the main screen. These include some of the most common diagnostic tasks, such as:

- Reading and clearing DTCs, with the ability to view environmental data
- Generating various reports, such as Vehicle Scan
- Execute the most common routines, such as Customer Preferences and Vehicle Preparations

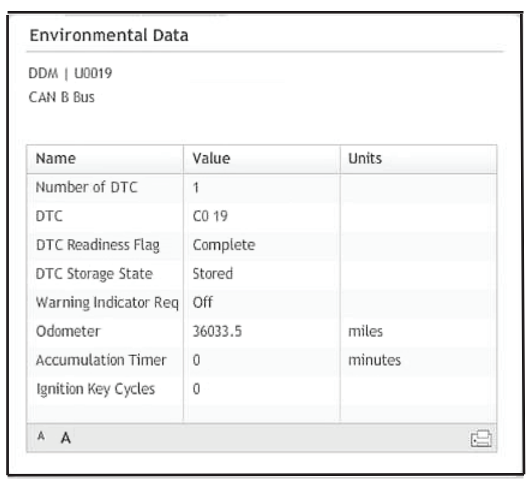

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Figure 16 Environmental Data Display

In ECU View, diagnosing an ECU in more detail is also just a click away. From this location a technician can:

- Flash an ECU
- View and graph data
- Start actuators
- Execute routines specific to an ECU

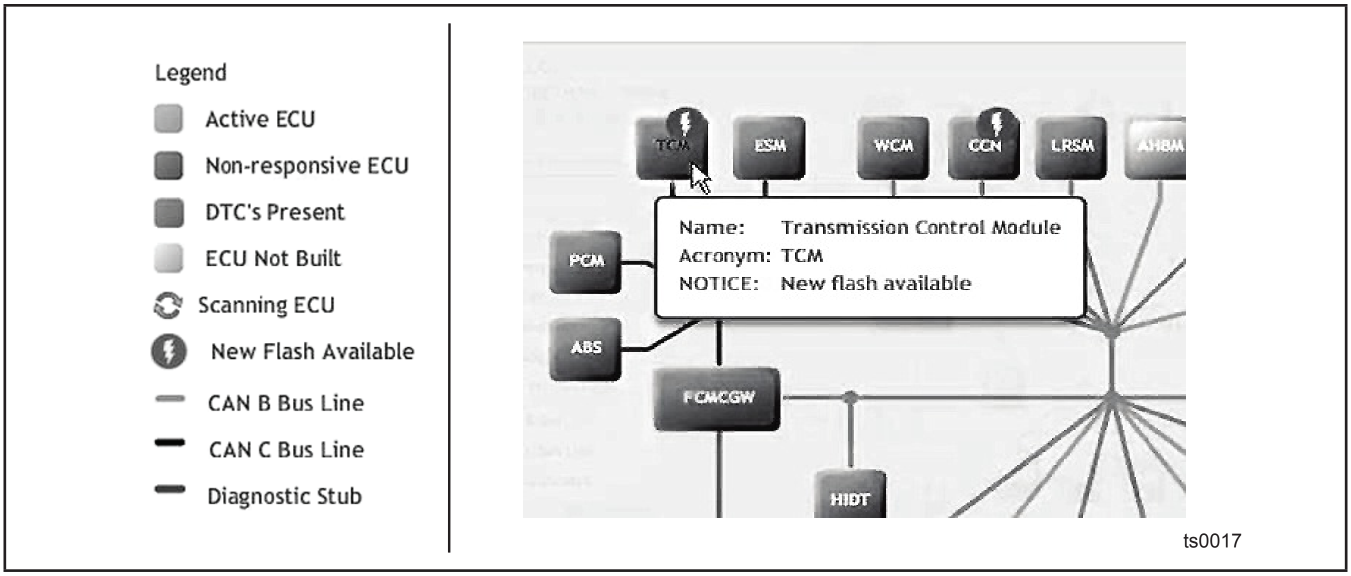


Figure 17 Legend and Topology View Closeups

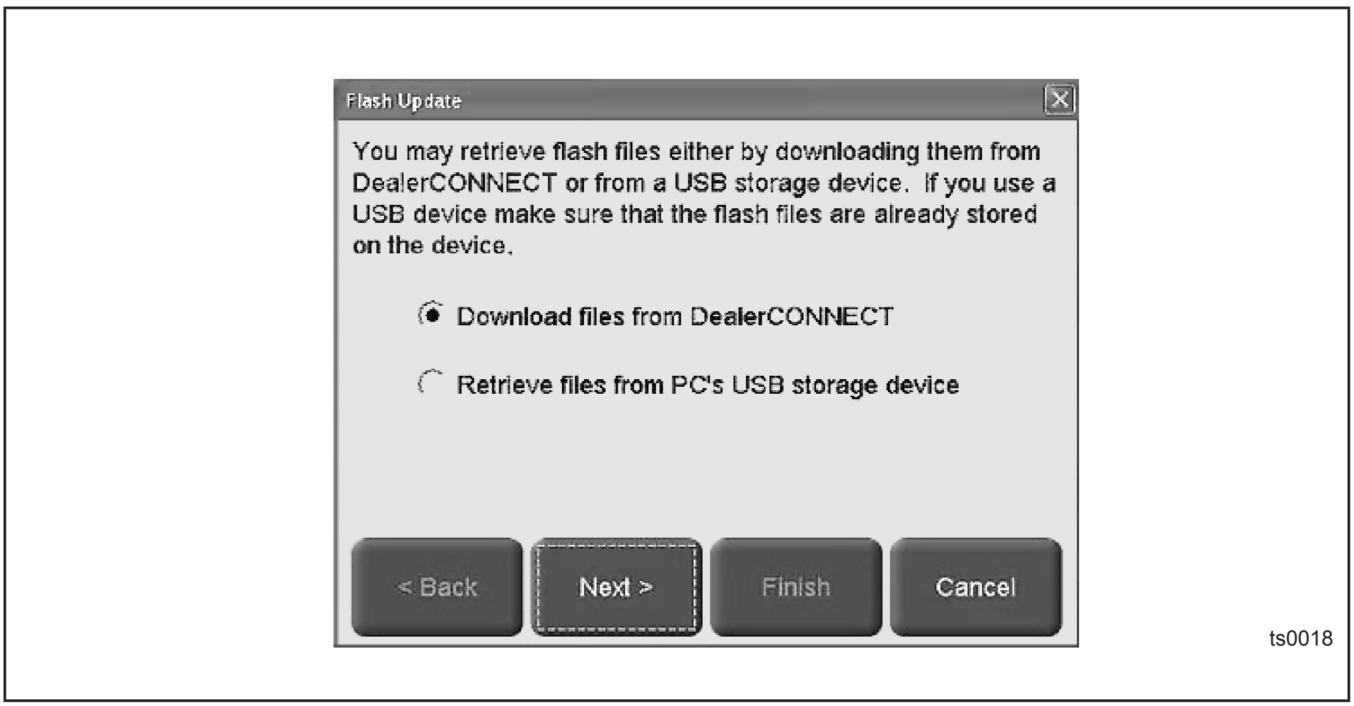


Figure 18 Retrieving Flash Files Wizard

But possibly the greatest advantage and time savings this system offers is instead of the technician having to find the applicable Service Information prior to accessing the vehicle's systems with the scan tool, wiTECH™ brings the service information right into the application. This single source approach helps eliminate the risk of missing or overlooking important information prior to performing a repair procedure.

For example, if an icon indicates the availibilty of a flash for a particular ECU, a technician can either immediately initiate the flash, or first pull up all of the relevant service bulletins explaining the reason for the update.

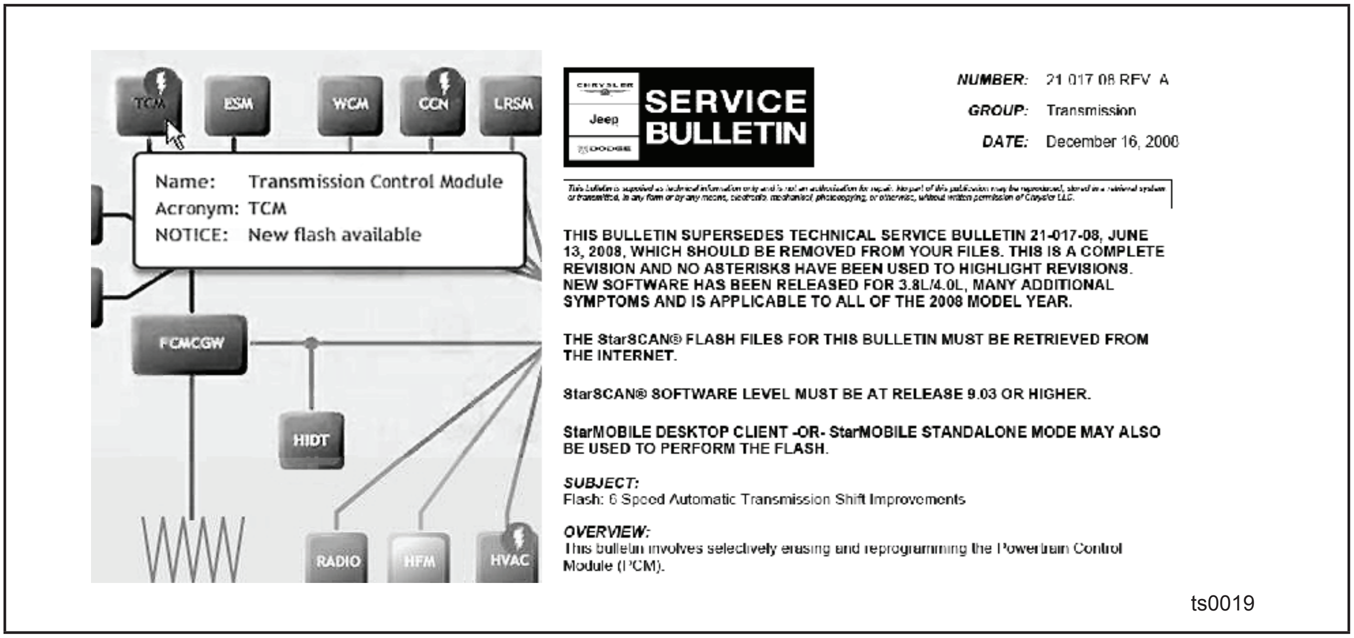


Figure 19 Diagnostics Linked with Service Information

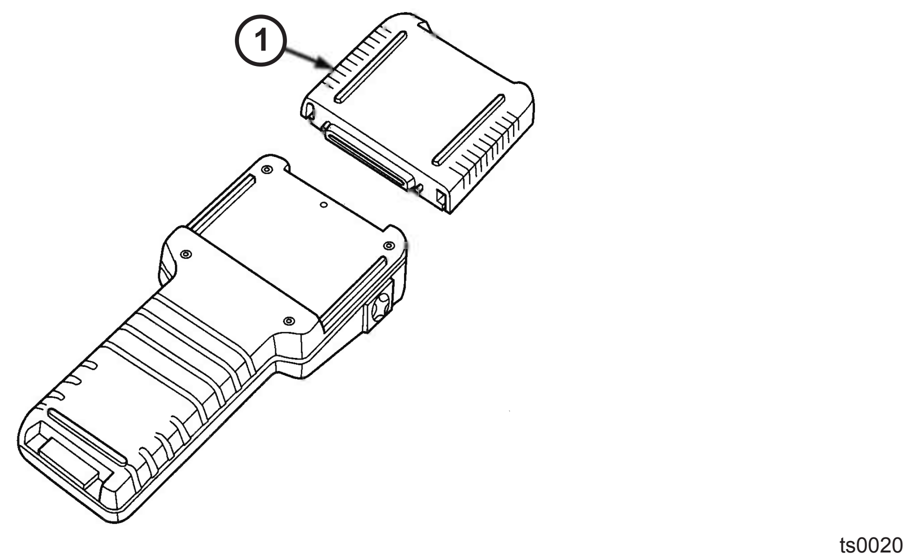
wiTECH™ acts as a gateway to both the diagnostic information detailed by StarSCAN® and StarMOBILE®, as well as the web-based information found at the DealerCONNECT site. By incorporating a rich and streamlined graphical user interface with an emphasis on linked diagnostics, wiTECH™ combines diagnostic and Service Information into one easy-to-use PC application.

DRB III® AND PEP MODULE OVERVIEW

Although the wiTECH™ is the premier diagnostic scan tool for Chrysler vehicles, the DRB III®, an older electronic scan tool that predates the CAN bus, is extremely effective in performing certain engine diagnostic tests while the engine is running. This is because the DRB III® has a functionally-specific adapter that can link this scanning device to specific engine components, allowing the technician to perform certain tests on these components which can be useful for verifying or eliminating possible causes of symptoms reflecting a customer concern.

The DRB III® Peripheral Expansion Port (PEP) module plugs into the DRB III® to provide four plug-in cable ports for various testing adapters. The PEP module also provides four megabytes of additional Read Only Memory (ROM) when connected to the DRB III®.

In addition to the PEP module carrying case, plug-in accessories included with the PEP module include lab scope adapter leads, pressure transducer cable, pressure transducers (sensors), fittings, inclinometer (optional) and an exhaust gas analyzer (optional).



1	PEP Module (Plugs into DRB III®)

Figure 20 DRB III® with PEP Module

Located on the PEP module are ports for the Pounds per Square Inch (PSI) connection, two ports for the scope leads (SCOPE CH1 and CH2), and a single port for the inclinometer (INCL) or exhaust gas analyzer cable (EXH). These ports are labeled as shown.

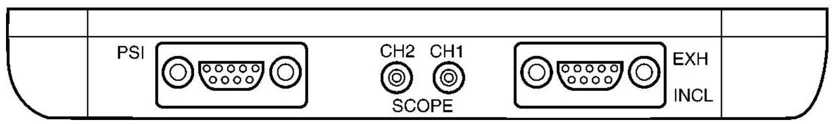


Figure 21 PEP Module Connection Ports

The PSI port must first be connected to the 6-way pressure transducer input cable, which can then be used with the various pressure sensors.

DRB III® PRESSURE/VACUUM DISPLAY

The Digital Pressure/Vacuum Display has a pressure sensor that attaches to the pressure source and sends digital signals by wire from the pressure transducer (sensor) to the DRB III® PEP module. This eliminates testing with pressurized lines and multiple gauges.

The signals can be sensed from up to six test points and are displayed on a bar graph with a numeric value for comparison. Diagnostic data can be recorded to allow review during diagnostics. Recordings can be saved for future reference.

CABLES

The CH7056/CE7056 power cable is used with the Lab Scope and Pressure/Vacuum Display. It connects to the vehicle cigar lighter receptacle and can be used to power the DRB III®.

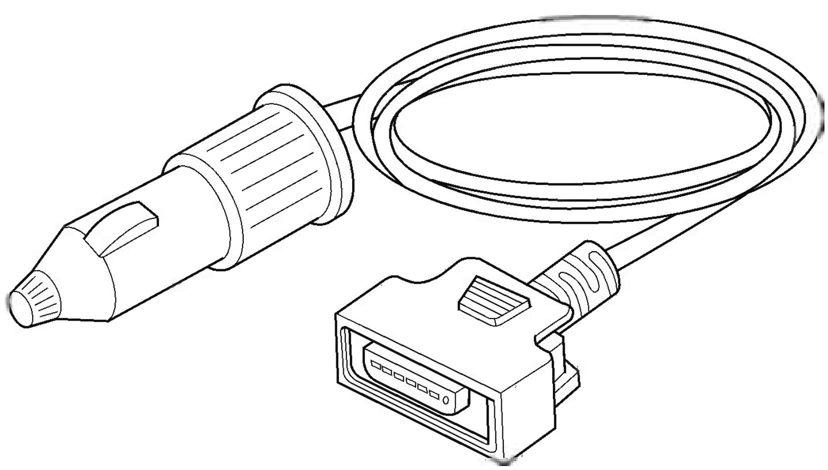


Figure 22 CH7056/CE7056 Power Cable

The CH7057/CE7057 6-way pressure transducer input cable connects to the PEP module Pounds per Square Inch (psi) port and is used for pressure measurement. Up to six sensor extension cables (CH7060) can be connected to the inlets of the 6-way pressure transducer input cable.

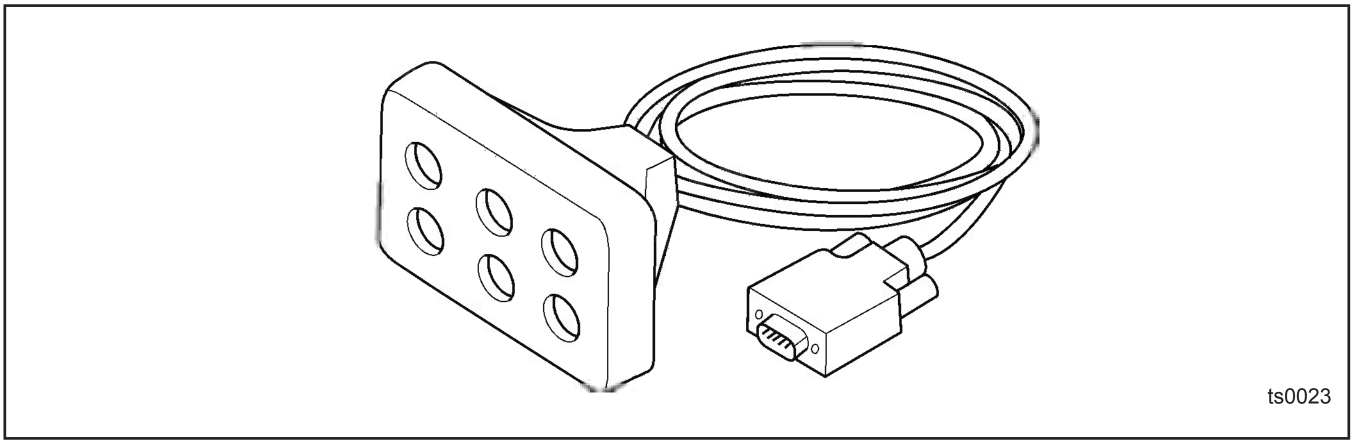


Figure 23 CH7057/CE7057 6-Way Pressure Transducer Input Cable

The CH7060/CE7060 is a 12 ft. transducer (sensor) extension cable used to connect pressure transducers to the 6-way pressure transducer input cable (CH7057). One CH7060 cable is needed for each pressure transducer that is connected to the 6-way pressure transducer input cable.

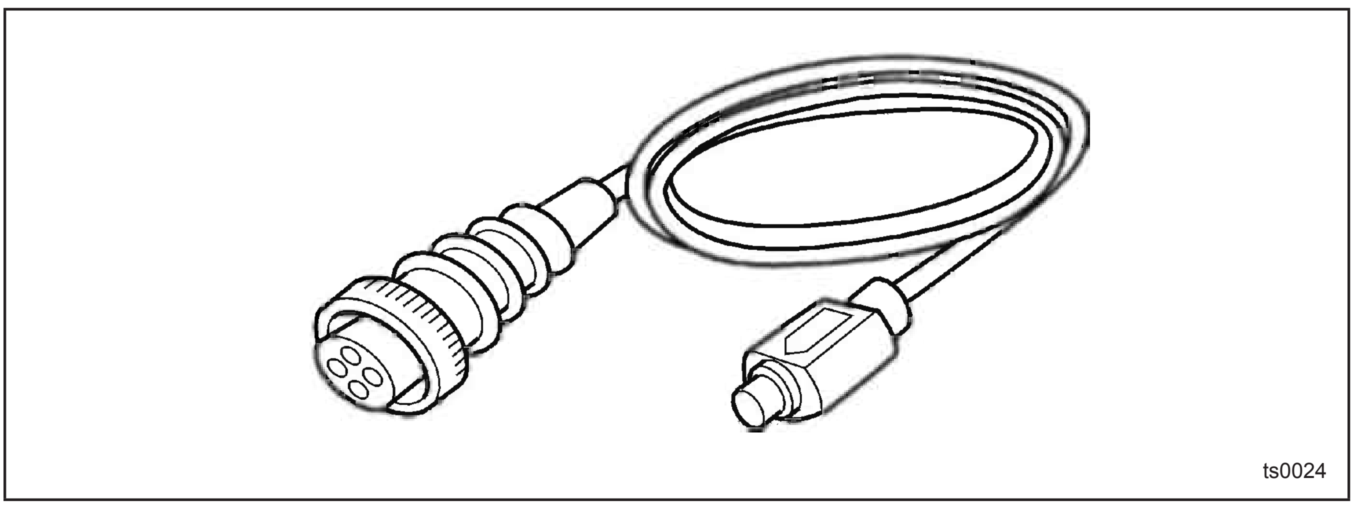
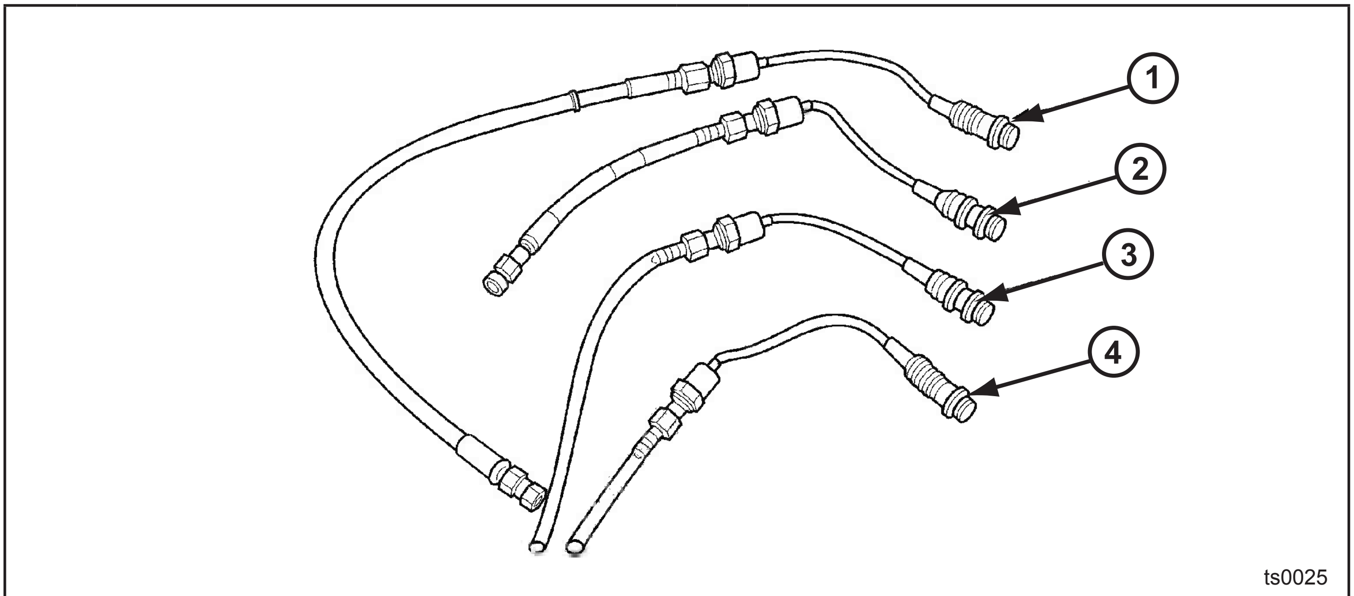


Figure 24 CH7060/CE7060 12 Ft. Transducer Extension Cable

PRESSURE FITTINGS

An assortment of pressure fittings and pressure transducers are used with the PEP Module Pressure/Vacuum Display.

CAUTION: Only use the CH7064 5000 psi pressure transducer for pressure readings on brake systems. Do not use this pressure transducer on any other vehicle system.



1	5000 psi, CH7064 (Red)	3	15 psi, CH7063 (Black)
2	500 psi, CH7059 (Blue)	4	2.5 psi, CH7069 (Green)

Figure 25 PEP Module Pressure Fittings and Pressure Transducers

The CH8519 pressure fitting is installed in the Oxygen (O_2) sensor port of the exhaust system and measures exhaust backpressure. A 12 ft. pressure transducer cable and the 15 psi (black) transducer must be used with the exhaust backpressure fitting. Typical exhaust backpressure with the vehicle in park/neutral at 2000 rpm is 3.45 kPa (0.5 psi); always refer to Service Information – Diagnosis and Testing – Restriction Test to obtain the maximum exhaust back pressure limits for a vehicle being tested.

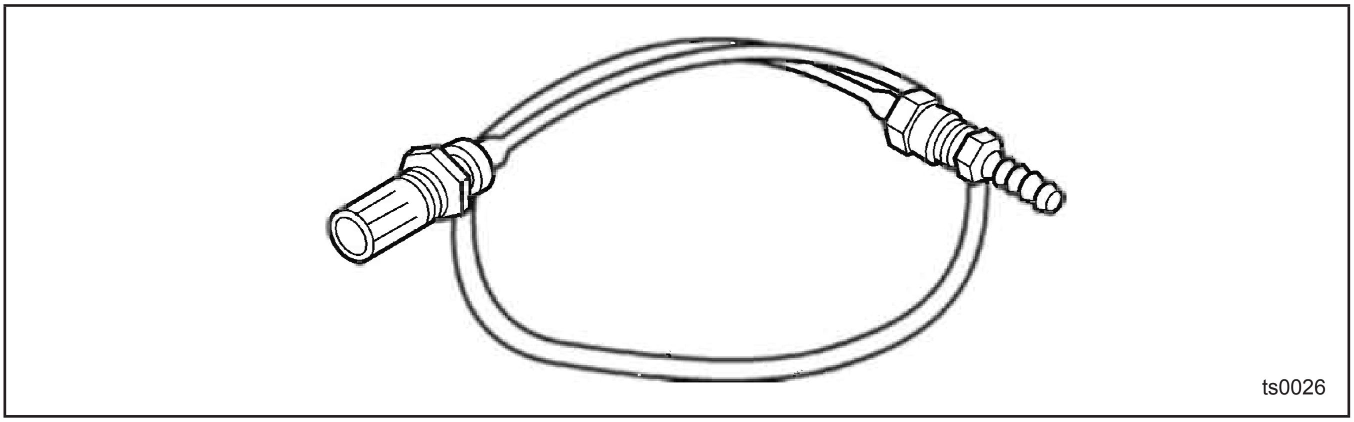


Figure 26 CH8519 Exhaust Backpressure Fitting

The cylinder head compression adapter is installed in a spark plug hole to measure the compression pressure of a cylinder.

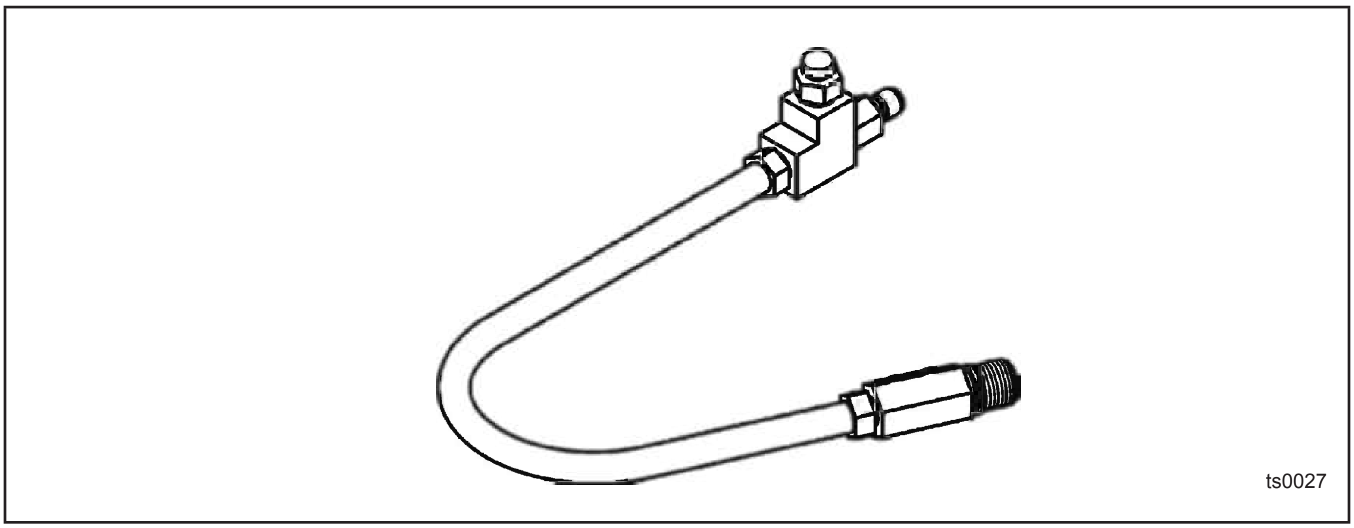


Figure 27 8116 Cylinder Head Compression Adapter

CAUTION: Always check to ensure the proper fitting adapter has been selected before screwing that fitting into the vehicle component being tested; forcing the wrong thread type (such as British threads) into a vehicle component will destroy its threads.

Notes:

LESSON 4 ENGINE PERFORMANCE CONCERNS

OVERVIEW

Engine performance concerns include problems like engine misfires, loss of power, and stalls. After checking the fuel and secondary ignition components, the following tests and inspection procedures can be performed to locate a mechanical concern with the engine:

- Injector kill test/cylinder balance test (power balance test)
- Cylinder compression test (dry and wet)
- Cylinder leak down test
- Checking the valve timing
- Vacuum gauge test
- Checking valvetrain components for weak springs, carbon deposits, incorrect seating of valves
- Intake mainfold leak test
- Exhaust backpressure test

INJECTOR KILL TEST / CYLINDER BALANCE TEST

An injector kill test / cylinder balance test (also called a power balance test) is used to determine if all cylinders are working equally well. This test is accomplished by comparing each cylinder's participation in engine rpm/power to the overall level of efficiency. Based on the results, a problem area is isolated and thus easier to diagnose.

For example, if a 60 rpm drop occurs on the first seven cylinders tested, but there is no rpm drop on number eight, then there is a mechanical problem with the eighth cylinder tested, such as a valve not sealing, or a cracked piston ring. This test can also be used to isolate lower engine noise to a particular cylinder.

Prior to running this test, make sure there are no fault codes regarding the fuel delivery system; fuel pump, pump relay, fuel filter, fuel lines, pressure regulator, and the injectors themselves. Problems with any of these components could falsify the injector kill test results.

If a customer complains of a loss of power, or the engine runs rough, you may have to perform a cylinder balance test. Rpm loss can vary depending on engine size, configuration and the extent of the miss. As one would expect, cutting out one cylinder on an eight cylinder engine will have much less drop than removing one cylinder on a four cylinder engine.

Refer to the wiTECH™, StarSCAN®, or StarMOBILE® for details on the fuel injector kill test. The test disables individual fuel injectors while monitoring the change in rpm.

NOTE: The fuel injector kill test does not work on all vehicles. Always check the Service Information before starting this test.

CYLINDER COMPRESSION TEST

The most common method of measuring compression is with a specially designed pressure gauge. A fitting attached to the gauge is put in place of the spark plug of the cylinder being tested (with all of the other spark plugs removed). The DRB III® with the PEP module and proper pressure sensor adapters can also be used for this test.

Standard Compression Test – Dry and Wet

For a dry compression test, first drive the vehicle until engine reaches normal operating temperature. Remove all of the spark plugs and insert the compression gauge adapter into the number 1 spark plug hole. Disable the ignition/fuel system by referring to the Service Information. Crank the engine until the maximum compression pressure for the cylinder is reached, and write this number down.

Repeat the test steps for all additional cylinders. If one or more cylinders have abnormally low compression readings, repeat the compression test on those cylinders to verify the results. If the same cylinder or cylinders again produce an abnormally low reading on the second compression test, perform a wet compression test on the cylinder or cylinders.

To perform a wet compression test, add 28.4 ml (1 oz.) of 30-weight oil to the cylinder being tested and perform the compression test again. Adding oil to the cylinder may temporarily seal worn rings to the cylinder walls. Thus, if the compression readings increase, the piston rings are probably worn. If the compression readings do not change, the valves may not be sealing properly.

Running Compression Test

When a standard compression test does not reveal any concerns, a running compression may be performed. This test can detect:

- Broken valve springs
- Worn valve guides
- Bent pushrods
- Worn cam lobes
- Sticking valves
- Intake or exhaust manifold restriction

The theory behind this test: When you perform a standard, static compression test, you are checking cylinder sealing, not breathing (volumetric efficiency). This test looks at an individual cylinder's ability to breathe.

Say the running engine is creating a vacuum of 18 inches of mercury, and the ambient barometric pressure is about 30 inches of mercury, so the difference (30 – 18 = 12) is what the engine is inhaling. 12 inches of mercury is equal to about 6 psi absolute air pressure. Compressed to about an 8:1 ratio, you should get 6 X 8 = 48 psi pressure if all of the available air makes it into the cylinder and all of that air gets exhaled from the cylinder. Therefore, your idle reading on a running compression test should be about 50 psi.

An engine idles at about 600-900 rpm, and the starter motor obviously cannot crank the engine as fast as the engine idles. In fact, most manufacturer's specifications require the engine to crank at only 80-250 rpm. Therefore, we are checking the compression of an engine at cranking speed to determine the condition of an engine that cannot actually run at that speed.

CAUTION: Removing the spark plugs on a hot aluminum cylinder head may cause damage to the spark plug thread holes.

In addition, some might think the compression at idle speed would be substantially higher than the compression at cranking speed because the valve overlap of the cam is more effective at higher engine speeds, and this would tend to increase the compression. However, the compression pressure of a running engine is actually much lower than cranking compression pressure. This results from the volumetric efficiency. When the engine is revolving faster, there is actually less time for air to enter the combustion chamber. Thus, with less air to compress, the compression pressure is lower.

Typically, the higher the engine rpm, the lower the running compression:

- Compression at cranking (80-250 rpm) 862-1,103 kPa (125-160 psi)
- Compression at idle (600-900 rpm) 414-621 kPa (60-90 psi)
- Compression at low speed (2,000 rpm) 207-414 kPa (30-60 psi)

Similar to the cranking compression test, the running compression of all cylinders should be equal. Therefore, a problem is not likely to be detected by the value of one cylinder, but by how far its running compression value varies from the values created by the other cylinders.

Use the procedure below to perform a running compression test.

NOTE: This test can be done with a conventional compression gauge or the PEP module.

1. Remove one spark plug.
2. Remove the Shrader valve from the bottom of the compression gauge.

NOTE: Leaving the Schrader valve in will affect your reading.

3. Screw the compression gauge into the spark plug hole.
4. Ground the spark plug wire, or unplug the coil for coil on plug engines, and disconnect the fuel injector.
5. Start the engine.
6. Record the gauge reading at maximum sweep of the needle.
7. Snap the throttle open and closed as quickly as possible, so the engine rpm does not raise, and record the highest reading. This forces the engine to take as much air in as possible. This test will detect a restriction in the intake or exhaust systems.

NOTE: A timing light, which may be helpful to stabilize readings, can be connected to the cylinder being tested to highlight the highest reading of the cylinder.

8. Turn off the engine.
9. Remove the compression gauge, reinstall the spark plug and wire, and connect the fuel injector.
10. Repeat steps 1-8 for the remaining cylinders.

Allow a 10 percent variance from the highest to the lowest cylinder.

CYLINDER LEAK TEST

The cylinder leak test is an accurate way to determine the condition of an engine. The cylinder leak test checks for any causes of combustion and compression pressure loss due to piston rings. This test also detects if exhaust and intake valves are not seating properly, plus checks for any leaks between adjacent cylinders or into the water jacket.

WARNING: DO NOT REMOVE THE COOLING SYSTEM PRESSURE CAP WITH THE SYSTEM HOT AND UNDER PRESSURE BECAUSE SERIOUS BURNS FROM COOLANT CAN OCCUR.

To perform a cylinder leak test:

1. Check the coolant level and fill as necessary. Do not install the cooling system pressure cap.
2. Start the engine and operate it until it reaches normal operating temperature.
3. Turn off the engine.
4. Remove all of the spark plugs.
5. Remove the oil filler cap.
6. Remove the air cleaner.
7. Calibrate the tester according to the manufacturer's instructions.

WARNING: EACH PISTON MUST BE EXACTLY TDC WHEN CHECKED, OTHERWISE THE ENGINE COULD SPIN A HALF TURN WHEN A CYLINDER IS PRESSURIZED AND CAUSE INJURY.

8. Test for cylinder leakage with each piston at TDC, as this is when all valves are closed. The top of the cylinder is where the piston makes all of its power, and is also typically where the greatest cylinder wear occurs.
9. Perform the test procedures on each cylinder according to the tester manufacturer's instructions.

While testing, listen for the following:

- Pressurized air escaping through the throttle body, tailpipe, and oil filler cap opening.
- A hissing sound coming from the throttle, which can mean air is escaping past the intake valve(s).
- A hissing sound coming from the valve cover or dipstick tube, which can mean air is escaping past the piston rings.
- A hissing sound coming from the exhaust sytem, which can mean that air is escaping past the exhaust valve(s).

In addition, check for any bubbles in the radiator coolant, which can indicate concerns such as a head gasket leak.

All gauge pressure indications should be equal, with no more than 25 percent variance due to leakage.

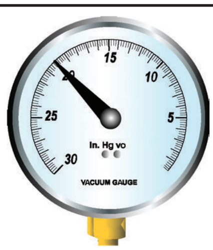
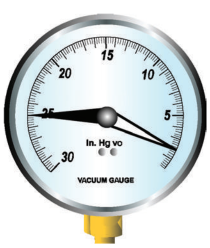
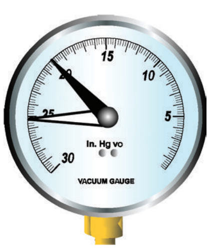
VALVE TIMING

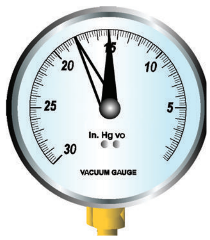
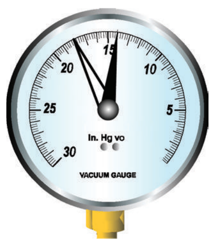
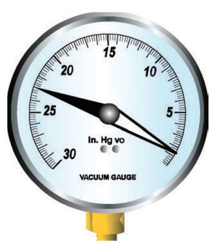
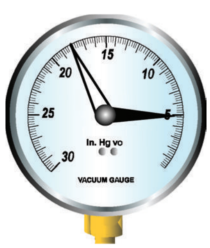
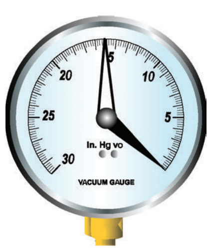
An engine with misfires, lack of power, or no start could be suffering from a serious crankshaft/camshaft alignment problem. If the timing is incorrect valves can contact the pistons and the engine will misfire. If the engine timing marks are aligned, this does not always mean the valve timing is correct. To check the timing mark alignment, refer to the Service Information section on "Valve Timing Verification."

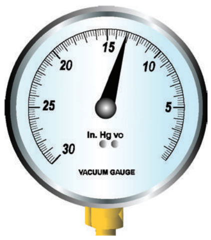
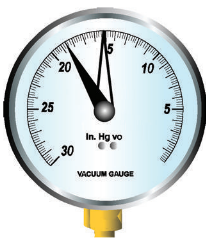
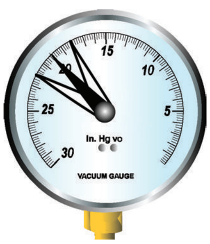
VACUUM GAUGE DIAGNOSIS

A vacuum test is used to detect vacuum leaks or loss of vacuum. A vacuum gauge is connected to the intake manifold and measures the vacuum. It is important to watch the movement of the needle when reading the vacuum gauge. The movement of the needle is as important as the reading itself. An erratic or jerky movement can be an indication of a problem, even though the reading itself appears to be correct. Table 2 shows how to interpret various vacuum gauge readings.

Table 3 Vacuum Gauge Readings and their Implications

READING	INTERPRETATION	IMPLICATION
	Normal Engine Reading at Idle	When running the engine at idle and connecting a gauge to a manifold vacuum port, the needle reads between 18 and 22 inches of mercury and holds steady.
	Normal Engine Reading During Rapid Acceleration	During a fast acceleration, the needle drops to almost zero. During continued acceleration the gauge will slowly return to near normal readings.
	Normal Engine Reading During Rapid Deceleration	When the throttle is suddenly released during acceleration, the needle will jump to a higher than normal reading before returning to normal readings.

READING	INTERPRETATION	IMPLICATION
	Sticking Valve	The needle has a rapid intermittent drop from a normal needle indication. This is different from a burned or leaking valve reading, which drops at regular intervals. This can be caused by a tight stem-to-guide clearance.
	Worn Valve Guides	The needle swings back and forth over a 3 to 4 inches of mercury range at idle speed. As the speed of the engine increases, the needle steadies.
	Leaking Piston Rings	When the engine is accelerated hard, the needle drops to zero inches of vacuum. Upon deceleration, the needle only runs slightly higher than a normal high vacuum reading. A compression test will verify a leaking piston ring.
	Blown Cylinder Head Gasket	The vacuum reading consistently drops to 10 to 15 inches of mercury below normal at regular intervals and then returns to normal. If this occurs, check the cylinder head gasket or a warped head-to-block surface.
	Restricted Exhaust System	At idle, the vacuum reading is normal. When engine rpm is increased, the backpressure caused by the restriction causes the needle to slowly drop to zero. At that point, the needle slowly rises. The distance the needle rises depends on the severity of the restriction.

READING	INTERPRETATION	IMPLICATION
	Late Ignition or Valve Timing	Late valve timing could cause a steady but low reading.
	Poor Valve Seating	A small but regular drop and a flickering needle can mean one or more valves are not seating, or possible external misfire.
	Weak Valve Springs	Weak valve springs are indicated by the needle swinging back and forth over less than a 4 inch range during idle, but the range increases as the engine speed is increased.

UPPER END INSPECTION

Valve/Spring Inspection and Testing

The valvetrain of an engine is one of the most critical components for engine performance. The smallest amount of wear or buildup on valvetrain components can have a dramatic negative effect on engine performance. With this in mind, the correct measurement and repair of the valvetrain and related components is vital in determining the cause of reduced engine performance and possible misfires.

Perform the following:

- Carbon buildup inspection
- Valve face and seat inspection
- Valve spring height measurement
- Valve spring pressure measurement
- Valve stem-to-guide clearance measurement

Refer to the Service Information for test procedures and specifications.

NOTE: If the valves and valve seats were serviced and their surfaces remachined the valve stem height could be incorrect, which would result in a valve not sealing correctly. For proper valve stem height specifications refer to the Service Information.

Intake Manifold Leak Diagnosis Tests

Intake manifold leaks on earlier engines with open valleys could cause various concerns, such as oil consumption, noise, rough idle, or high idle, depending on where the leak occurs. Methods used to perform a vacuum leak diagnosis include:

- Propane enrichment test
- Water mist method
- O_2 sensor feedback

Refer to the test in the Service Information before starting a manifold leak diagnosis.

EXHAUST SYSTEM RESTRICTION TEST

Excessive exhaust backpressure can cause engine back firing, misfires and lack of power concerns. The exhaust system restriction test can be performed on most vehicles using a vacuum pressure gauge or a DRB III® with PEP module.

Notes:

LESSON 5 COOLING SYSTEM CONCERNS

COOLING SYSTEMS AND ENGINE PERFORMANCE

Improperly configured, faulty, or leaking cooling systems will seriously impact engine performance. When diagnosing a cooling system concern, a first critical step can be ensuring that the proper coolant is being used in the vehicle.

COOLANT TYPES

The cooling system is designed around the properties of the coolant itself. The coolant must accept heat from the engine block, as well as the cylinder head area near the exhaust valves. The coolant then carries this heat to the radiator, where the tube/fin arrangement transfers the heat to the air.

Today's heavy use of aluminum for components such as cylinder blocks, cylinder heads, and water pumps, requires special corrosion protection. For this reason Mopar antifreeze/coolant 5 year/100,000 mile formula, or equivalent ethylene glycol base coolant with Hybrid Organic Additive Technology (HOAT), is recommended. These coolants offer the best engine cooling without corrosion when mixed with 50 percent distilled water to obtain a freeze point of -37° C (-34° F). If the coolant loses color or becomes contaminated, drain, flush, and replace with a fresh, properly mixed coolant solution.

Green coolants **must not be mixed** with HOAT coolants. When replacing the coolant, perform a complete system flush prior to coolant replacement.

CAUTION: Never use HOAT coolant with a concentration greater than 60 percent coolant and 40 percent distilled water. Mopar antifreeze/coolant, 5 year/100,000 mile formula may not be mixed with any other type of antifreeze. Doing so reduces the corrosion protection and may result in premature water pump seal failure. If non-HOAT coolant is introduced into the cooling system in an emergency, it should be replaced with the manufacturer specified coolant as soon as possible.

CHECKING COOLANT CONCENTRATION

Coolant concentration should be checked when any additional coolant is added to the system or after a coolant drain, flush, and refill. The coolant mixture offers optimum engine cooling and protection against corrosion when mixed to a freeze point of -37° C (-34° F). Either a hydrometer or a refractometer can be used to test coolant concentration.

A hydrometer tests the amount of glycol in a mixture by measuring the specific gravity of the mixture. The higher the concentration of ethylene glycol, the greater the number of balls that will float, and the higher the freeze protection (up to a maximum of 60 percent by volume glycol).

A refractometer (8286) tests the amount of glycol in a coolant mixture by measuring the amount a beam of light bends as it passes through the fluid.

Some coolant manufacturers use other types of glycol in their coolant formulations; propylene glycol is a common coolant. However, propylene glycol-based coolants do not provide the same protection from freezing.

NOTE: Make sure that the correct coolant is used, and that coolant types are not mixed together.

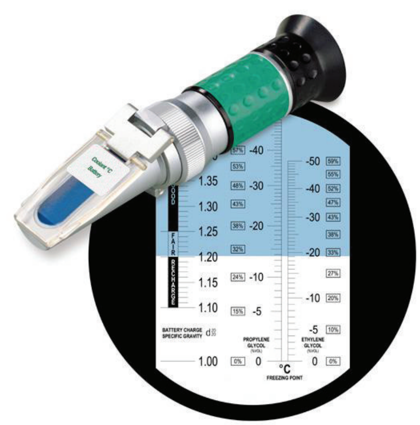
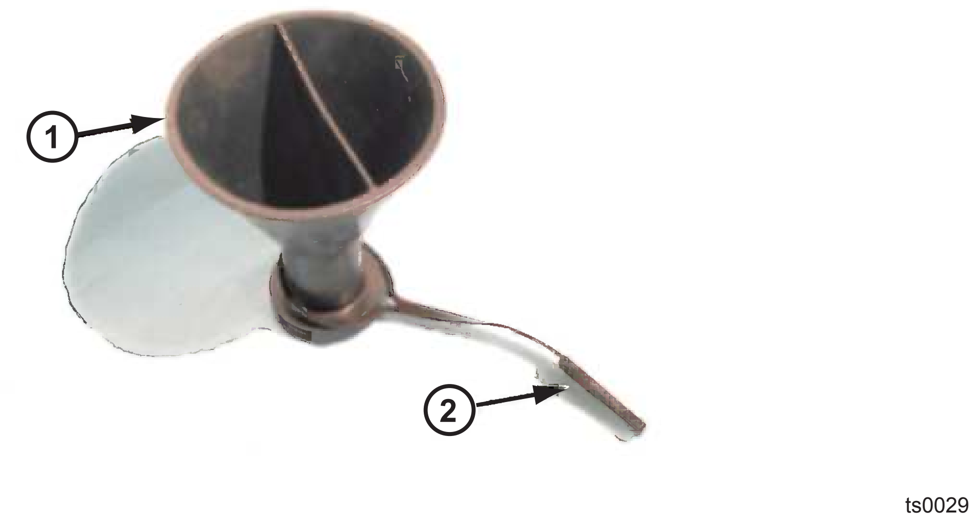
	
Hydrometer	Refractometer

Figure 28 Coolant Concentration Measuring Tools

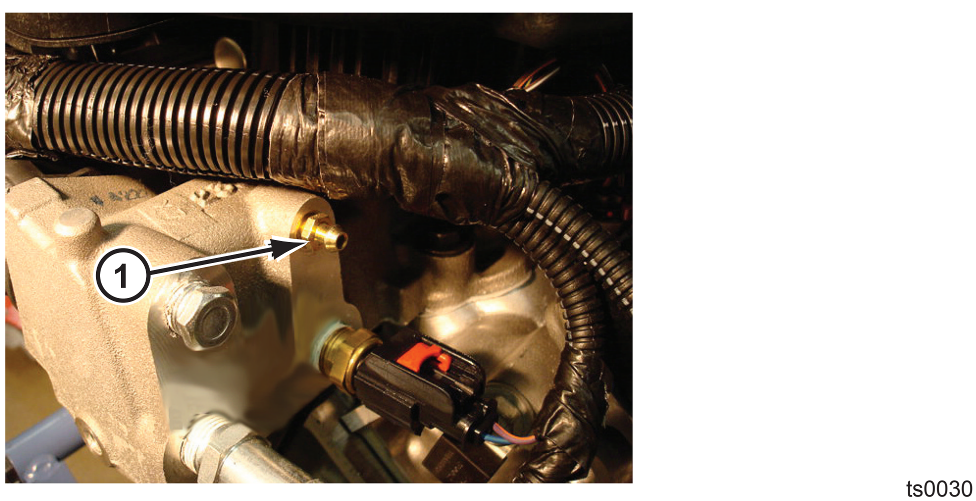
Coolant Bleed Procedure

Some vehicles require special bleed procedures for different engines; always refer to the appropriate Service Information for the correct procedure. The illustrations below show the special fill tool 8195 and an air bleed location.



1	Special Tool 8195	2	Pinch for Overflow Hose

Figure 29 Special Tool for Bleed Procedure (callouts to be added to art)



1	Cooling System Bleed Valve

Figure 30 A Cooling System Bleed Valve Location (callout to be added to art)

Coolant Refill Procedure

The optimum way to refill coolant in a vehicle is with a refiller kit. A coolant refiller uses shop air to remove all air from the cooling system and prepare it for quick refilling. Other benefits of using a coolant refiller kit include:

- Detection of any leaks in the system
- Vacuum-refill of coolant into the system helps prevents air locks
- Faster refills which dramatically reduce service times.

ts0031

Figure 31 Coolant Refiller (PSE 85-15-0650 or Equivalent)

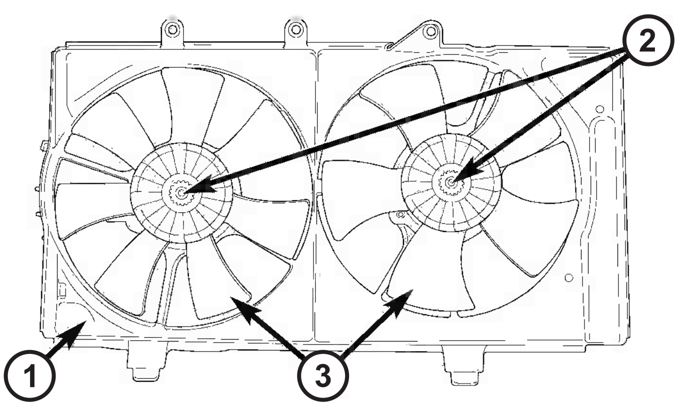
COOLING FAN SYSTEM TYPES

There are various cooling fan systems used in Chrysler vehicles. They are:

- Electric fans
- Viscous fan
- Electric and mechanical fan – hybrid systems (some trucks)
- Electric viscous fan (diesel vehicles)
- Hydraulic fans

Electric Fans

Electric cooling fans, often mounted in pairs with different blade/pitch configurations as shown, are used on front wheel drive vehicles due to the positioning of the engine under the hood. Electric cooling fans are controlled by the Powertrain Control Module (PCM) and are only commanded on when needed to cool the engine and/or A/C. This reduces the power consumption of the fan when it is not needed to cool the engine.



1	Shroud	3	Fans
2	Nut		

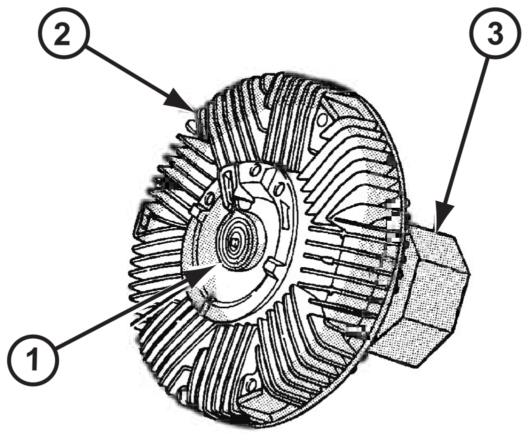
Figure 32 Electric Fans

Viscous fan

A thermostatic bimetallic spring coil is located on the front face of a viscous fan's drive unit. This spring coil reacts to the temperature of the radiator discharge air. If the air temperature coming from the radiator rises above a certain point the spring coil engages the viscous fan.

The viscous fan drive engages only when sufficient heat is present. This is when the air flowing through the radiator core causes a reaction to the bimetallic coil. It then increases fan speed to provide the necessary additional engine cooling.

Once the engine has cooled, the radiator discharge temperature drops. The bimetallic coil again reacts and the fan speed reduces.



1	Thermostatic Spring	3	Mounting Nut to Water Pump Hub
2	Viscous Fan Drive		

Figure 33 Viscous Fans

Electric and Mechanical Fan (Hybrid Systems)

This fan system, which is **not** referring to hybrid vehicles, is used on various vehicles when additional cooling is required due to vehicle use. The advantage of this system is to increase the cooling capacity when the vehicle is carrying additional weight or towing heavy loads. When the engine starts to go above normal operating temperature the PCM commands the electric fan on to help maintain the proper engine temperature.

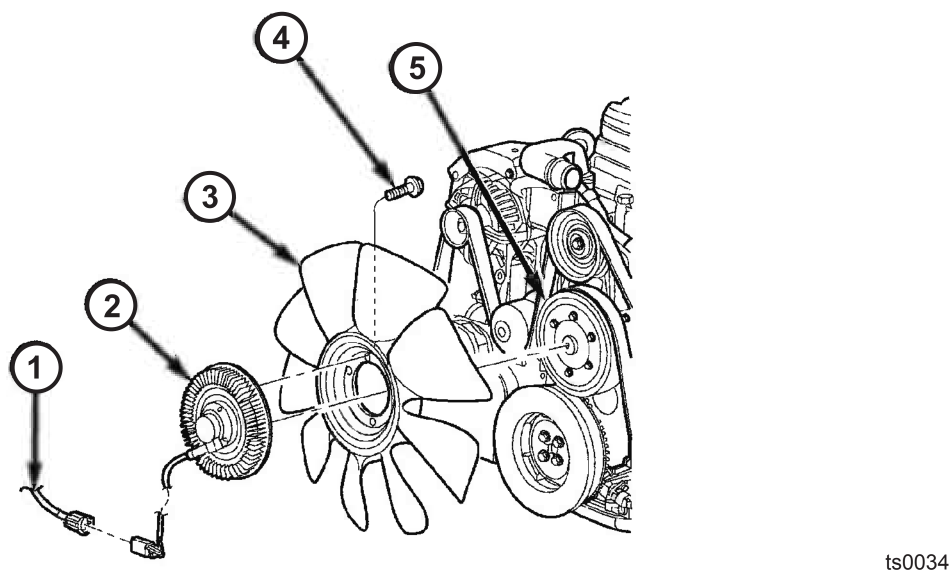
Electric Viscous Fan

The electronically controlled thermal viscous fan drive is attached to the fan drive pulley mounted to the engine. This coupling allows the fan to be driven by the pulley in a normal manner.

The fan's electronics are controlled by the PCM. The PCM controls the level of engagement of the electronically controlled viscous fan clutch by monitoring coolant temperature, intake manifold temperature, and air conditioning status. Based on these cooling requirements, the PCM sends a Pulse Width Modulated (PWM) signal to the viscous fan clutch to increase or decrease the fan's speed.

Fan speed is monitored by the PCM. Both fan speed and duty cycle percent can be monitored with the scan tool.

NOTE: When diagnosing a concern with the PWM viscous fan make sure the wire harness is properly attached to the radiator to prevent the wires from being pulled into the fan.



1	Electrical Connector	4	Bolt
2	Viscous Fan Drive	5	Fan Drive
3	Fan Blade		

Figure 34 Electric Viscous Fans

Hydraulic Fans

The advantage of this arrangement over the two-fan system is that it provides the control of an electric fan with the power of an engine-driven fan. This "fan on demand" strategy helps prevent unnecessary power draw from the engine.

This high power provides the vehicle with enough flow to handle heavy trailer tow capability. Because the power steering system and the fan system share the same pump, the hydraulic fan drive must maintain the required flow to the steering system and use the remainder as needed to drive the cooling fan.

WARNING: BECAUSE THIS HYDRAULIC FAN PLACES AN ADDITIONAL LOAD ON THE POWER STEERING SYSTEM, ONLY MOPAR® HYDRAULIC POWER STEERING FLUID (P/N 05142893AA) CAN BE USED WITH THESE SYSTEMS; USE OF A DIFFERENT POWER STEERING FLUID WILL ULTIMATELY LEAD TO SYSTEM FAILURE.

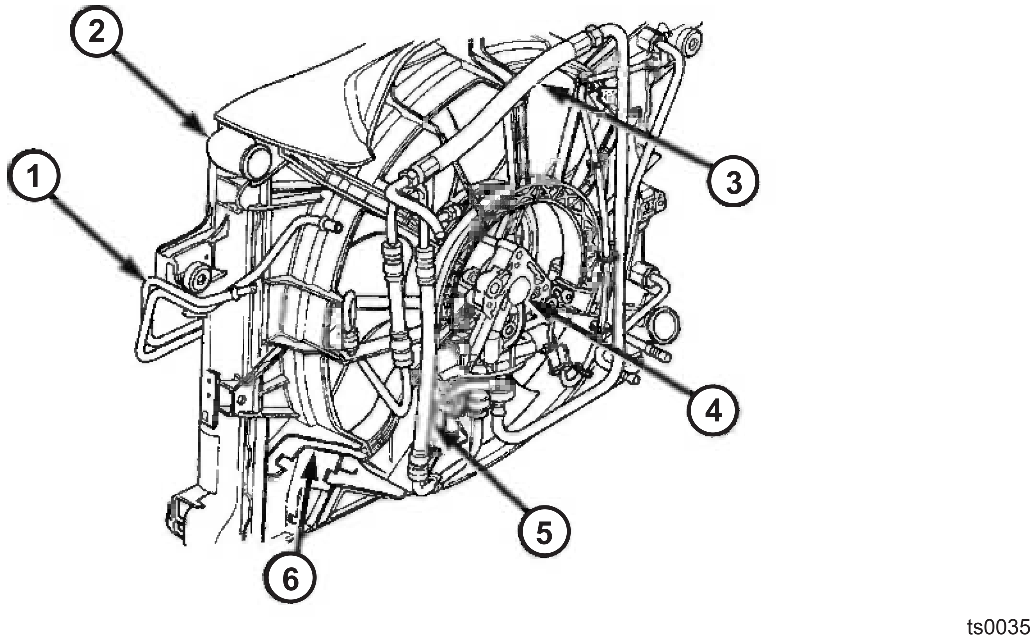
Since the hydraulic fan drive controls the steering system flow the same way a typical power steering pump controls it, the fan system is virtually invisible to the steering system. With infinite control of the fan speed, only the required airflow is provided for any given driving condition.

The hydraulic fan drive is electronically controlled by the PCM. A PWM signal from the PCM controls the fan from 0 to 100 percent of the available fan speed. Four inputs to the PCM determine what fan speed percentage is required by the vehicle at any given time:

- Engine Coolant Temperature (ECT)
- Transmission Oil Temperature (TOT)
- Battery temperature
- A/C system pressure

By monitoring these four inputs, the PCM can determine the amount of cooling airflow required. If airflow is called for, the PCM slowly ramps up the hydraulic fan speed until the input requirements are under control. When the temperature or pressure is reduced to an acceptable level the fan ramps up, ramps down, or holds its speed to maintain the temperature or pressure requirements.

NOTE: Even when the PCM is not requesting fan speed, the fan spins between 100 to 500 rpm when the vehicle is at idle. This is because of the minimum oil flow going through the fan drive motor at all times.



1	Power Steering Fluid Cooler Lines	4	Hydraulic Fan Motor
2	Radiator	5	High Pressure Power Steering Line to Steering Gear
3	High Pressure Power Steering Line to Hydraulic Fan Motor	6	Fan Shroud

Figure 35 Hyrdaulic Cooling Fan

COOLING SYSTEM PROBLEMS

Cooling system problems are divided into three areas:

- Overheating
- Internal coolant leaks
- External coolant leaks

The first tasks to be completed are:

- Check the coolant level and condition
- Top off the coolant
- Verify the driving condition that caused the overheating concern

WARNING: MAKE SURE ENGINE COOLING SYSTEM IS COOL BEFORE SERVICING. DO NOT REMOVE ANY CLAMPS OR HOSES, OR OPEN A PRESSURE CAP OR RADIATOR DRAINCOCK. WHEN THE SYSTEM IS HOT AND UNDER PRESSURE SERIOUS BURNS FROM COOLANT CAN OCCUR.

OVERHEATING

There can be several reasons for an engine to overheat. The engine can be low on coolant because of internal or external coolant leaks, the thermostat could be malfunctioning, a hose can be restricted, the coolant mix could be wrong or the temperature gauge could be reading incorrectly. Perform the following when checking for an overheating concern:

- Perform a visual inspection of the radiator, shroud, and condenser and check for external leaks
- Check for collapsed hoses
- Check the overflow pressure bottle for correct fill
- Make sure the proper pressure cap is installed on the vehicle
- Check for incorrect coolant mix
- Perform a pressure cap test
- Check the cooling fan system
- Perform a gauge/sensor test
- Perform a water pump test (coolant flow test)
- Check for internal coolant leaks
- Test the thermostat
- Check for add-on or aftermarket A/C components

EXTERNAL COOLANT LEAKS

- Check coolant level and top off as necessary
- Perform a visual inspection and move hoses to check for leaks
- Perform a cooling system pressure test
- Perform a cooling system dye test

NOTE: It is normal for the water pump to weep a small amount of coolant from the weep hole which, over time, can cause a black stain on the water pump body. Do not replace the water pump if this condition exists. However, if a heavy deposit or steady flow of engine coolant is evident on the water pump it will need to be replaced, as this indicates a shaft seal failure. Always perform a thorough analysis before replacing a water pump.

INTERNAL COOLANT LEAKS

- Check the condition of the engine oil. Is it mixed with coolant?
- Check for a failed engine oil cooler, if equipped
- Check transmission fluid, if equipped with an in-tank transmission oil cooler
- Perform a cooling system pressure test, cooling system chemical test, and cylinder leak test

If exhaust fumes leak into the coolant, they immediately destroy inhibitors in the coolant and set up an acid condition. A galvanizing reaction begins among the various kinds of metals in the cooling system. This erodes the radiator and other parts of the system from the inside. If combustion gases leak into the coolant the following can happen:

- Combustion leaks in the valve area force coolant away during heavy acceleration, causing excessive heat buildup. When acceleration stops, the diverted coolant rushes back to the area, resulting in damage to the valve seats.
- The radiator can be damaged.
- Leaking head gaskets or internal leaks can allow exhaust fumes to enter the cooling system, and sometimes allow coolant to enter the cylinders.
  - If coolant enters the cylinders, the result is a poorly running engine, reduced engine life, coolant-contaminated engine oil, and/or engine failure due to hydrostatic lock.

A cooling system chemical test is used to determine if there is an engine or cooling system concern. Perform the test when:

- There is a loss of coolant or overheating.
- Oxidation or corrosion in the radiator.
- Head gasket problems are suspected.
- The engine oil is contaminated with coolant.
- A cracked block is suspected.

If there is a leak, pinpoint the leak and make the necessary repairs. Although a leaky head gasket is often the cause of combustion gas concerns, the head or block could be warped, cracked or corroded.

After the repair has been made, flush the block to get rid of any accumulated gases and then test the system again for a final check.

Cooling System Pressure Test

The cooling system pressure test is used to detect coolant leaks. The cooling system is pressurized when the engine is running. Sometimes it is difficult to detect leaks because of engine noise, fan noise, and air from the cooling fan. It is hard to find small leaks if you cannot run the engine and pressurize the cooling system.

With a cooling system pressure tester you can pressurize the system without running the engine. This eliminates engine noise and unwanted air from an operating fan. It also allows you to check for small leaks by moving hoses and looking more closely at a specific area.

NOTE: Some leaks may only be detected when the engine is cold. It may be necessary to allow the engine to cool and retest to locate the leak.

ts0036

Figure 36 Cooling System Pressure Tester Kit (7700 or Equivalent)

Cooling System Dye Test

For this test, a leak detection additive is added to the cooling system. The additive is highly visible under ultraviolet light (black light) with yellow goggles. For this test:

- Add about 28 ml (1 oz.) of additive to the cooling system.
- Place the heater control unit in the HEAT position.
- Start the engine and operate it until the radiator hose is warm to the touch.
- Direct a black light toward the components that are being checked.

If leaks are present, the black light causes the additive to glow a bright green.

NOTE: The use of yellow goggles aids in diagnosis on aluminum components.

WARNING: THE BLACK LIGHT IS A ULTRAVIOLET LIGHT SOURCE; DO NOT STARE DIRECTLY INTO THE BEAM.

COOLING SYSTEM CHEMICAL TEST

This test is used to determine if exhaust gases are present within the cooling system. This test includes a test tool, fluid and instructions. If a combustion leak is present the chemical in the tool turns from blue to yellow in less than 1 minute.

WARNING: BEFORE SERVICING, MAKE SURE THE ENGINE COOLING SYSTEM IS COOL. WHEN THE SYSTEM IS HOT AND UNDER PRESSURE, DO NOT REMOVE ANY CLAMPS OR HOSES, PRESSURE CAP, OR OPEN THE RADIATOR DRAINCOCK. COOLANT IN A WARM ENGINE CAN BE ABOVE THE BOILING POINT OF WATER. SERIOUS BURNS FROM COOLANT CAN OCCUR.

1. With the engine warm and idling, remove the radiator cap.
2. Determine that the radiator fluid level is low enough so coolant will not enter the tester unit. If necessary, remove coolant from the radiator to achieve the proper level.
3. Fill the block tester through the top plug opening with combustion leak test fluid to the Fill to here line.
4. Insert the lower plug end of the tester firmly into the radiator opening.
5. Rapidly squeeze and release the top aspirator bulb, pressurizing the radiator and forcing air from the radiator up through the test fluid for 60 seconds before the test is completed.
6. If the test fluid turns from blue to yellow, a combustion leak is present. Never return test fluid back from block tester to the test fluid bottle.

ts0037

Figure 37 Block Tester and Blue Fluid

LESSON 6 FAILED COMPONENT ANALYSIS

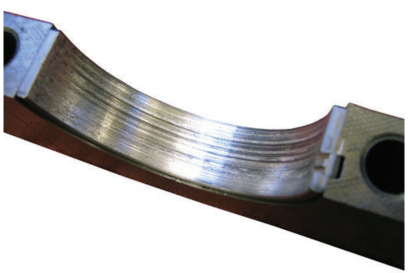
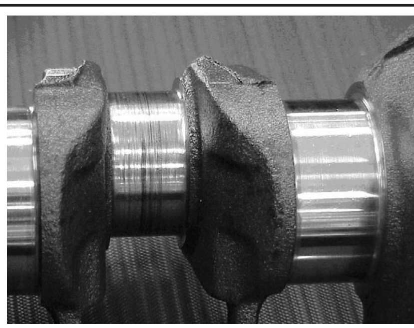
In diagnosing a vehicle, it is not only important to get the diagnosis right, but equally important to be able to analyze failed engine components and understand which components need to be replaced. Properly analyzing failed engine components prevents you from replacing components unnecessarily. For example, you might replace an entire short block assembly when only new bearings and a crankshaft are needed.

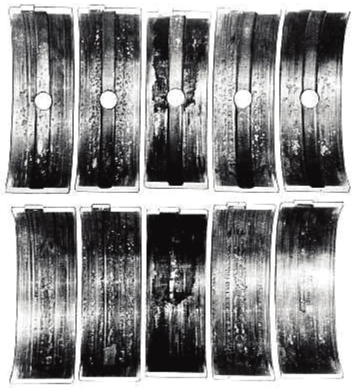
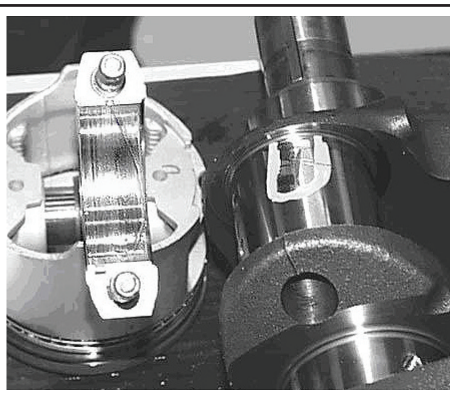
Failure analysis of engine parts is important. Failing to replace all of the parts that are needed to repair a concern can result in merely setting up the problem to fail again. For example, you may replace only the bearings in the engine, when the cause of the failed bearings is a machining problem on the crankshaft. If this were the case, the new bearings will fail again. Another example would be putting a new piston in a cylinder with a bore out of specification.

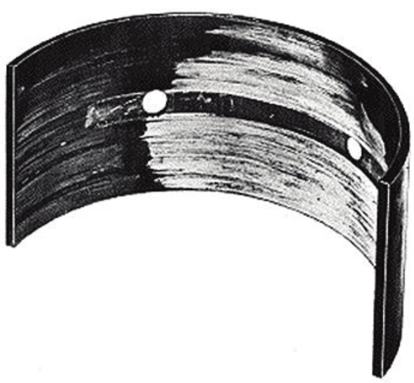
BEARINGS

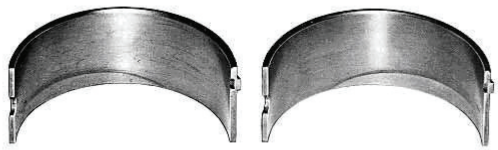
Bearings are usually of a bimetal or tri-metal construction. As the different layers of metal wear off the bearing areas, the bearing may appear shinier, duller, or change color.

Table 4 Bearing Failure

EXAMPLE	DESCRIPTION
 Bearing Wear	The bearing itself is seldom the cause of the failure; another cause is usually at fault. If one or more bearings have failed it is probably due to faulty oil flow or contamination.
 Chatter or a Bumpy Grind on Crankshaft	Light to heavy horizontal lines called chatter or bumpy grind cause a bearing to fail. Sometimes these lines can be faint and not easily noticed, but over time they destroy a bearing.

EXAMPLE	DESCRIPTION
 Bearing Failure Due to Improperly Machined Crankshaft	The final machining process of the crankshaft journal, if not done properly, can cause the condition shown here.
 Damage Due to Coarsely Ground Crankshaft	This condition is caused by a coarsely ground journal. Never reuse a crankshaft that has caused a bearing to fail.
 Bearing Failure Due to an Out-of-Round Journal	A taper and/or out-of-round condition of a journal causes a bearing to fail. This type of damage is caused by an uneven distribution of load on the bearing surface that increases heat and accelerates bearing wear.

EXAMPLE	DESCRIPTION
 Bearing Failure Due to Dirt and/or Foreign Material	Dirt or foreign material in the bearing lining also damages a bearing. Foreign material on the back of the bearing shell distorts the bearing and causes it to wear unevenly. This problem is seen as shiny spot on the bearing, where the bearing has been raised up and is wearing more rapidly than the rest of the bearing surface. Dirt or foreign material embedded into the bearing material also causes the bearing material to rise up and give a similar appearance.
 Bearing Failure Due to Lack of Lubrication	If the engine lubrication system fails or if there is insufficient oil clearance, the bearings will fail. Connecting rod bearings generally fail before main bearings because they are lubricated after the main bearings. However, if there is a failure of the main engine bearings due to lack of lubrication, most likely there are other engine component failures.
 Bearing Failure Due to Improper Line Boring	Improper line boring also causes wear on the bearings. To correct this condition, a cylinder block replacement would be required.

EXAMPLE	DESCRIPTION
 Bearing Failure Due to Twisted Connecting Rod	Bearing damage due to a twisted connecting rod is localized in one portion of the bearing surface, with little or no damage on the remainder. A bent or twisted connecting rod results in misalignment of the bore, causing the bearing to be cocked so that it makes metal-to-metal contact with the journal.

Some of the most common causes of engine bearing failure are incorrect bearing installation or misalignment issues. After a bearing failure, it is important to know which components to replace. For example:

- If metal pieces have been found when disassembling an engine, the metal pieces may have gotten into the engine oil galleries. Should the whole block be replaced or just the parts that were damaged?
- If during a visual inspection of the bearings the tangs are still on the bearings the bearings have not spun, the connecting rods and/or cylinder block may be reused.
- If only the tin plating has been removed from the bearing surface, the cylinder block and/or connecting rods may not be the cause of the failure and you may be able to reuse the cylinder block.

PISTONS AND CONNECTING RODS

When a piston and connecting rod fail, how do you know what components need to be replaced? First, you have to know how the parts go together. For instance, some pistons have full-floating wrist pins and others have pressed-in wrist pins.

Noise from the connecting rods can be caused by:

- Not enough lubricating oil
- Low oil pressure
- Thin or diluted oil
- Excessive bearing clearance
- Connecting rod journal out-of-round
- Misaligned connecting rods
- Excessive clearance at the small end of the rod

The piston should be slightly offset to the major thrust side of the engine (the right side of the engine as viewed from the back). If the piston is offset incorrectly, there will be a piston slapping noise.

Usually there is some type of oil squirter on the connecting rod that is used to lubricate the cylinder walls. If the squirter is not positioned correctly the cylinder walls will not be lubricated properly.

Some connecting rods have a "fractured cap" design to ensure an exact fit. The area between the cap and the connecting rod is very rough looking. Handle this type of connecting rod with care. Any distortion in the fractured surface causes the bearing shell to crush improperly.

ts0038

Figure 38 Fractured Cap Design Connecting Rod

NOTE: Most engines require the pistons and rods to be serviced as an assembly.

The following table can help you analyze failed pistons and connecting rods.

Table 5 Piston and Connecting Rod Failure Analysis

EXAMPLE	DESCRIPTION
 Uneven Piston Wear Due to an Out-of-Round Cylinder	A cylinder that was out-of-round caused the wear on this piston.

EXAMPLE	DESCRIPTION
 Overheated Piston	There are two types of overheating that can occur on a piston: Overheating from a lack of coolant, and overheating from clearances being too tight. Usually there is more wear on the component when the clearances are too tight. If the piston overheated because of a lack of coolant, inspect the cooling system and make necessary repairs.
 Piston Damaged From Contacting a Valve	If the engine is out-of-time, the piston can contact a valve and cause severe damage to both.

Piston Friction Coating

The condition of the top surface of a piston can indicate a serious engine problem. So too can the friction reduction coating on a piston's side skirts.

Modern pistons have a dark solid dry film coating on both side skirts that acts as a lubricant. This surface helps minimize any piston knock noise after startup; before a cold piston has expanded to its optimum size for normal operation. In an engine teardown, the condition of this dry film coating can also provide important clues as to why an engine has failed.

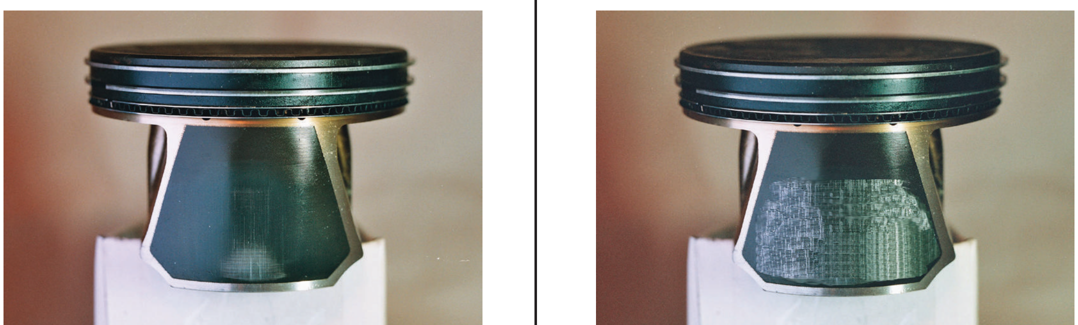
A coating with small vertical scratches across its surface indicates small metal particles of a failed component or foreign object has worked its way into the oil, and has caused damage. This can also be the reason an oil pump has failed.

ts0039

Figure 39 Piston Friction Reduction Coating Vertical Abrasion Pattern

Another clue can be the wear pattern on the film coating itself. Over time, a small circular wear pattern occurs on the bottom of both side skirts. About the size of a penny, it reveals the shiny metal underneath it. This amount of wear is normal.

However, if the friction reduction coating is significantly worn off both side skirts of the piston, this can indicate the engine is running too hot, with the pistons expanded to a larger-than-optimum size. A restriction in the cooling system can be the cause of this concern. If this is the case, further diagnosis may be required.


ts0040

Normal Film Wear Pattern	Overheated Film Wear Pattern

Figure 40 Piston Friction Reduction Coating Normal and Overheated Wear Patterns

VALVETRAIN

The valvetrain of an engine is one of the most critical systems for engine performance. The smallest amount of wear or buildup on the valvetrain components can have a dramatic effect on engine performance. With this in mind, proper inspection and analysis of valvetrain components is essential.

Engine problems requiring upper engine services are mainly limited to the valvetrain, gaskets and cracks that develop in the manifolds and cylinder heads. Valvetrain problems are usually evident and can create noise. The sounds produced by the valvetrain occur at one-half the engine speed.

Today's vehicles that run leaner mixtures and have on-board diagnostic controls cause valve operation to be critical. Misfires that trigger a CHECK ENGINE light can be caused by slight carbon deposits, which act like a sponge and absorb fuel intended for the combustion chamber. Sticking valves can also trigger a CHECK ENGINE light. The following table describes some valvetrain component failures and the possible causes.

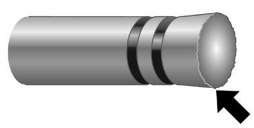
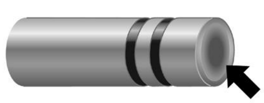
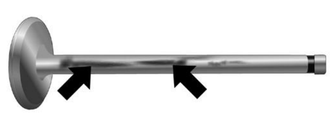
Table 6 Valvetrain Component Failures and Causes

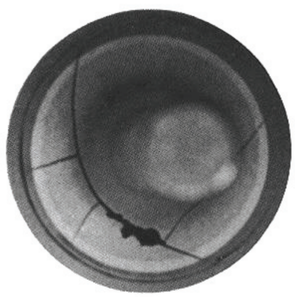
CONDITION	POSSIBLE CAUSES
Burned Valve	Lack of valve rotation, overheated engine, lack of coolant in a localized area near the valve head or detonation result in a knocking noise. Whether it is an intake or exhaust valve that is burned, the engine runs rough and possibly backfires.
Heavy Carbon Deposits on Valve	Low quality fuel used over extended period of time results in a pinging or knocking noise and can also cause misfires.
Incorrect Valve Seating	Incorrect valve or seat grinding creates hot spots on the valve face or seat. This results in loss of compression, poor fuel economy and engine misfires.
Pitted Valve	Contaminated airflow due to no air cleaner, torn air cleaner or an air cleaner installed incorrectly can allow debris to pit the valve. Carbon deposits can break loose and cause pitting as well.
Worn Valve Guides	Insufficient lubrication and normal valve forces result in excessive oil consumption, valve stem and face wear.
Sticky Valves	Overheated oil deposits form a sticky varnish between the valve guide and the stem. The varnish prevents the valve from closing, because the spring cannot shut the valve fast enough or at all. As a result, compression is reduced and the engine misfires. Only one sticky valve can cause these conditions. The valve is easily burned on all sides because the valve is in the flame of combustion. The valve cannot dissipate the heat to the head and cooling system because it is not closing.

CONDITION	POSSIBLE CAUSES
Failed Valve Seals	Overheating causes the seal to crack. Broken garter springs cause the seal to release from the stem. Oil enters the combustion chamber through the valve guide and burns.
Failed Pushrods	Lack of lubrication causes the pushrods to bend or break. This condition is rare. If the pushrod fails, replace the pushrod, rocker arm and lifter.
Weak Valve Spring/Incorrect Spring Installed Height	Loss of tension prevents the valve from closing because the spring cannot shut the valve fast enough or at all. This condition can create intermittent misfires.
Failed Lifters	Clogged oil passages inside the lifter stop the movement of the piston inside the lifter. Damaged lifters prevent the valve from seating which can be identified by a ticking noise.
Non-rotating Valve	Constant operation of the engine at low rpm, when the engine is idled or operated at lower speeds for a long time, cause the valves not to rotate. The rocker arm strikes the valve in the same place over and over again. The valve constantly seats in the same place and results in uneven wear, which can lead to carbon buildup and intermittent misfires.

The following table describes engine valve failures and their causes.

Table 7 Engine Valve Failures and Their Causes

EXAMPLE	FAILURE	DESCRIPTION	CAUSES
	Valve Head Fracture	Valve fracture at stem-to-head radius	Engine overheating, excessive exhaust valve temperature.
	Valve Stem End Failure	Stem end impact damage and mushrooming	Worn rocker arms or bent stud, non-end hardened valve, excessive valve clearance.
	Valve Stem End Failure	Stem fracture at keeper groove	Excessive spring pressure, worn keepers installed, rocker arm misalignment, valve spring coil binding, worn valve guides, incorrect installed height.
	Valve Stem End Damage	Stem end worn on outside edge	Incorrect valve installed height, wrong valve installed, lack of rotation.
	Valve Stem Galling / Guide Wear	Stem galled in guide area	Inadequate lubrication, dirt contamination, insufficient stem-to-guide clearance, seat to guide alignment problem, excessive combustion temperatures.

EXAMPLE	FAILURE	DESCRIPTION	CAUSES
	Valve Stem Galling / Guide Wear	Valve scuffed at top on one side and bottom on the other. Valve guide worn in corresponding area	Valve guide not concentric to seat.
	Valve Head Cracks	Cracks in valve head	Combustion pressure too high, wrong valve installed.
	Valve Face Problems	Pie-shaped hole burned into valve seat	Head/valve seat distortion, deposit buildup on valve face, hot spot created by seat-to-head contact area, valve margin too thin.
	Valve Face Problems	Face of valve rounded over with no contact area visible, stem blackened	Seat wear causing valve to wander off seat, often accompanied by severe guide wear allowing combustion gases to flow up guide.
	Valve Face Cupping	Face of valve grooved at contact point with valve seat	Excessive spring pressure, soft seat in head, excess combustion pressure, detonation.

LESSON 7 HEX BOLT IDENTIFICATION, THREADED HOLE REPAIR, TORQUE TO YIELD AND TORQUE PLUS ANGLE

HEX BOLT IDENTIFICATION

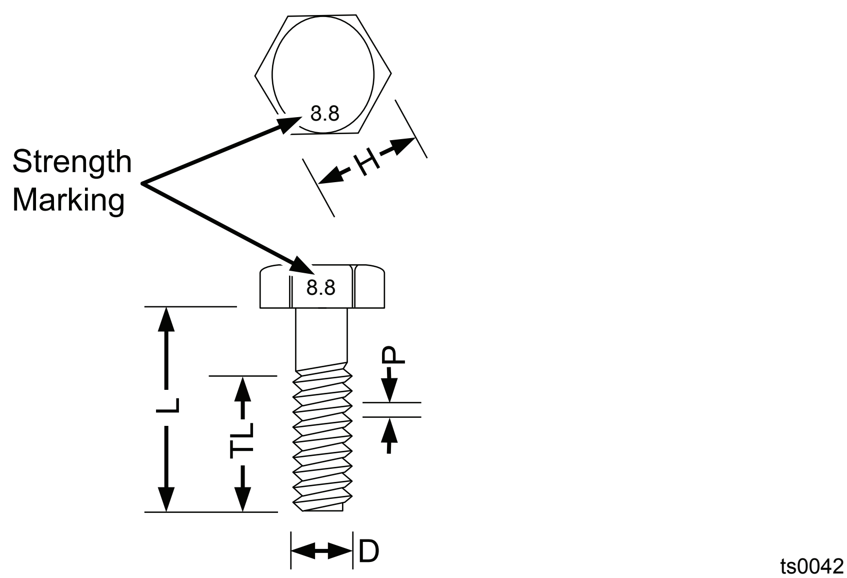
For a number of critical engine repair applications, the original bolts must not be reused. This is especially true in fastening applications that utilize the "torque to yield" technique, which will be covered later in this Lesson. Replacing bolts requires using one with exactly the same specifications as the original. ISO (metric) bolt sizes are designated by a string of letters and numbers in the format shown below.

ISO (Metric) Bolt: M8-1.25 x 25

M8-1.25 x 25

Thread diameter in millimeters (D)
Distance between threads in millimeters (P)
Bolt length in millimeters (L)

Figure 41 Identifying ISO (Metric) Bolts



H	Hex Size (Wrench Size)	D	Nominial Diameter
L	Length	P	Pitch (Distance Between Threads)
TL	Thread Length		

Figure 42 Key Measurements of ISO (Metric) Bolts

Bolt Head Markings

The strength of automotive threaded fasteners are classified by industry standards. Previously in North America these were SAE standards, but with international standardization, especially for engine components, the metric system of measurement and International Standards Organization (ISO) classifications have come to be widely used. The metric system is often abbreviated as "SI," which stands for System of International Units.

Typically there are two markings visible on ISO bolt heads:

1. A marking which identifies the company that manufactured (or imported) the fastener. This will usually consist of a symbol or the initials of the company validating that the fastener meets specific standards.
2. A number representing its ISO class specification, which designates its strength.

ts0043

Company Marking ("LM")	ISO Class Marking ("8.8")

Figure 43 Markings Visible on ISO Bolt Heads

ISO Bolt Classification

ISO bolts are graded into class specifications. The class specification consists of two numbers separated by a decimal point. These numbers identify the strength designation of the threaded fastener.

Common bolt classes used in critical automotive applications are 8.8, 10.9 and 12.9.

NOTE: Some bolt manufacturers don't include the decimal point, just the numbers; such as 88, 109, and 129. Care should be taken not to confuse these bolts with other standards markings, such as mistaking a BB for an 88.

The different classes utilize various alloys and treatments to make the bolts tougher. A bolt class is chosen by automotive engineers based on the proof load calculated for the joint, which is then used to determine the required yield strength and tensile strength of the fastener. Obviously, cylinder head, connecting rod, and main bearing fasteners are among the most critical attachment points in an engine. Other ISO bolt classes may be used for less-critical fastening, such as class 4.6 and 5.8, but often these bolts will not have any identifying class numbers stamped on them.

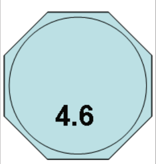
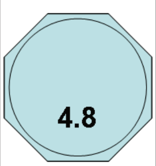
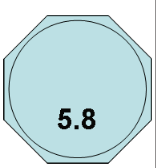
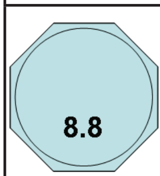
The class number stamped atop the ISO bolt is the key to both the minimum tensile strength of that class of bolt, as well as its minimum yield strength. Per ISO, the number to the left of the decimal designates one percent of the tensile strength in megapascals (MPa). The number to the right of the decimal, including the decimal, designates the yield strength, also in megapascals, based on the given tensile strength.

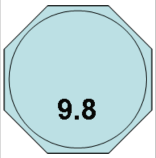
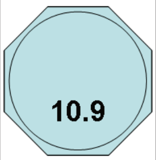
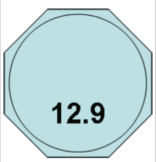
Table 8 Calculating Tensile and Yield Strength from the ISO 12.9 Class Number

Left digit: 12	Tensile strength (1% of)	Right digit: .9	Yield strength
12 x 100 =	1200 MPa	.9 x 1200 =	1080 MPa
	Approx. conversion factor for psi: x 145		Approx. conversion factor for psi: x 145
	174,000 psi		156,600 psi

When replacing bolts, the same measurement specifications and ISO class must be used. Some critical engine bolts have features unique to their application, such as a custom bolt head length or reduced shank dimension, and must only be replaced through official parts channels.

Table 9 Identification and Properties of Common ISO Bolts

Grade Mark	**ISO R898 Specification (Common Sizes M5 – M16)**	**Bolt Material**	**Proof Load (Minimum)**	**Yield Strength (Minimum)**	**Tensile Strength (Minimum)**
	Class 4.6	Low Carbon Steel	225 MPa (32,000 psi)	240 (35,000 psi)	400 MPa (58,000 psi)
	Class 4.8	Low Carbon Steel, Annealed	310 MPa (44,000)	340 MPa (49,000)	420 MPa (60,000)
	Class 5.8	Low Carbon Steel, Cold Worked	380 MPa (55,000 psi)	400 MPa (58,000 psi)	500 MPa (72,000 psi)
	Class 8.8	Medium Carbon Steel	600 MPa (87,000 psi)	640 MPa (92,000 psi)	800 MPa (116,000 psi)

Grade Mark	ISO R898 Specification (Common Sizes M5 – M16)	Bolt Material	Proof Load (Minimum)	Yield Strength (Minimum)	Tensile Strength (Minimum)
	Class 9.8	Medium Carbon Steel	650 MPa (94,000 psi)	720 MPa (104,000 psi)	900 MPa (130,000 psi)
	Class 10.9	Alloy Steel	830 MPa (120,000 psi)	900 MPa (130,000 psi)	1000 MPa (145,000 psi)
	Class 12.9	Alloy Steel	970 MPa (140,000 psi)	1080 MPa (156,000 psi)	1200 MPa (174,000 psi)

NOTE: Bolt torque values listed in the Service Information are based on both the threads being lubricated during insertion, as well as the contact area under the bolt head. Unless specified otherwise, motor oil is the standard lubricant for automotive fasteners.

The Service Information will specify either how to examine bolts to determine which should be replaced, or which installations will always require replacement of the fasteners. Critical fastening applications requiring multiple bolts will call for a specific tightening pattern and procedure, which must also be followed exactly.

THREADED HOLE REPAIR

Chrysler recommends using HeliCoil® type kits for repairing most stripped threaded holes. A number of companies make and sell similar STI (steel thread insert) repair kits. HeliCoil® inserts are precision formed screw thread coils that replace the original threads in a stripped hole. Thread repair inserts are typically made from high-quality stainless steel, such as 304 (18-8), with a diamond-shaped cross section. Many, but not all, of these coils incorporate a "tang" – a diagonal coil that crosses the end diameter of the insert. This tang is used with a special tool to screw the coil down to the bottom of the hole. Once fully inserted, this tang has indents that allow it to be broken off, giving clearance for the threaded fastener to penetrate to the bottom of the hole. When HeliCoil® type inserts are installed into newly enlarged and specially tapped threaded holes, they provide new permanent screw threads designed to accommodate the original bolt, stud, or screw size.

1	HeliCoil® Type Insert	3	Removable Tang
2	Tang Break-off Indent		

Figure 44 HeliCoil® Type Threaded Hole Repair Insert

HeliCoil® Type Inserts

In addition to repairing a threaded hole, HeliCoil® inserts can also make the threads stronger than they were prior to the repair. This is accomplished in three ways:

- An enlarged threaded hole provides more surface area and thus greater fastening strength than the original connection.
- In many threaded fastener joints only the top two threads carry between 65- and 75-percent of the load. Because the coil provides an improved distribution load factor over all of the newly tapped static threads, each coil thread can carry a share of the overall load.

- The toughness and smooth finish of the new stainless steel threads can both reduce surface erosion and increase the thread life for the hole, even after repeated assembly and disassembly operations.

For these reasons, if there is evidence of thread damage in more than one hole of a critical multi-fastener joint, such as a manifold assembly, it is often recommended that all of the connection holes be refurbished with thread repair inserts.

The most critical part of repairing a threaded hole is ensuring that both the drilling procedure used to enlarge the hole, as well as the tapping operation for the screw thread coils, maintain the same centerline as the original hole. Plus, during the enlarging and tapping of the hole being repaired, it is critical to ensure that the tooling is consistently machining perpendicular to the surface of the base material. If the threaded hole being repaired has a base surface perpendicular to the hole centerline, an appropriately sized tapping guide may facilitate the tapping operation.

During hole enlargement, it is necessary to repeatedly remove the drill and clean chips from the hole and the flutes of the drill to ensure the proper direction of the drill bit as well as maintain the proper hole size. In addition:

- Do not drill any deeper than the original hole depth.
- Make sure all chips have been removed from the hole prior to the tapping operation.
- Always use adequate amounts of cutting fluid to facilitate both the hole enlargement and tapping operations.

If the component being repaired cannot easily be removed from the vehicle and put on a bench or fixture, make sure all openings surrounding the repair are covered to keep chips and cutting fluid from getting into them during the thread repair procedure.

Measure the damaged hole thread size and depth. Order the appropriate number of HeliCoil® inserts for the repair, plus some extras. Based on the size of the hole being repaired, the drill size for enlarging the hole will be published by the repair kit vendor. Make sure you have or acquire the exact drill bit size specified for the hole enlargement. Never use a substitute size. The drill bit must be in good condition; if the cutting edges of the drill are worn or damaged, replace or resharpen the bit before use.

Also order the required tap, insertion and extraction tools, plus a tang removal tool if a tanged insert is used for this application (some larger inserts don't require a tang removal tool; needle nose pliers are used to accomplish this). The required tools are typically available from the supplier as a complete kit. Threaded hole repair requires a custom-sized tap. Standard taps cannot be used for HeliCoil® thread repairs because the outer dimension of the threaded coil is typically a non-standard thread size.

HeliCoil® Thread Repair Procedures

Step 1 – Enlarge the stripped hole by drilling it out to the proper enlarged size, as designated by the HeliCoil® vendor. Use adequate amounts of cutting fluid throughout the drilling process, and remove and clean chips from the hole and the flutes of the drill at regular intervals. Make sure the drill is kept perpendicular to the original hole surface throughout the drilling process. Go down to the original depth of the hole, but no further. Chamfer (bevel) the rim of the hole opening to facilitate tapping and threaded insert installation.

ts0045

Figure 45 Drilled Out and Chamfered (Beveled) Repair Hole

Step 2 – Tap the hole using the special tap required by the size of the threaded inserts. Make sure the tap is kept perpendicular to the original hole surface throughout the tapping process; the use of an appropriately sized tapping guide may help with this.

ts0046

Figure 46 Using a Tap Guide

Use adequate amounts of cutting fluid throughout the tapping procedure, and remove and thoroughly clean chips from the hole and the flutes of the tap at regular intervals.


ts0047

Figure 47 Using Special Tap to Accommodate HeliCoil® Threaded Insert

Step 3 – Once the hole is tapped and thoroughly cleaned of chips and cutting fluid the HeliCoil® is then inserted into the threaded hole, tang first, using a special insertion tool.


ts0048

Figure 48 Special HeliCoil® Insertion Tool

This tool grabs onto the tang on the end, and as the insert is screwed in the coil actually winds-up a bit. Because this winding action minimizes the size of the coil, it greatly assists in getting the insert to the bottom of the hole. Once the tang is released by the special tool, the coil will unwind and thus exert a uniform outward pressure on the inside diameter of the enlarged threaded hole.

CAUTION: When fully inserted, no steel threads can extend beyond the surface of the threaded hole. If a fully seated insert leaves any thread coils remaining above the attachment surface, the coil must be removed with the special removal tool, and the obstructing raised thread coil(s) cut off.

Figure 49 Stripped Hole Repaired with HeliCoil® Type Threaded Insert

Step 4 – With the insert fully seated to the bottom of the hole, and no threads jutting above the surface of the mating surface, the tang can be removed from the bottom of the hole using the tang removal or (if the insert is big enough) needle nose pliers. Lifting the tang up and down multiple times will break it off at the indents. Never leave a broken tang in a repaired hole.

HeliCoil® type threaded inserts are available in many different configurations for different applications and joint materials. In addition, they are made from many different alloys, in addition to stainless steel, and with special platings, including a dry film lubricant. They can be ordered with or without the tang (tangless), and as free-running or with a special, polygon-shaped center thread called a screw lock or thread lock. The purpose of this locking thread is to grip the threads of the installed screw to help prevent loosening due to vibration or impact.

TORQUE-TO-YIELD AND TORQUE-PLUS-ANGLE

All engine joints using threaded fasteners can be divided into two general categories: critical and non-critical. Critical fasteners include rod bolts, main bolts and head bolts. They will usually have high ISO class numbers, and may be custom-manufactured for a particular engine assembly. The repair procedure for critical engine fasteners will always include specific bolt tightening information.

Included in these repair procedures may also be a reference to a specific tightening requirement, such as "torque-to-yield" or "torque-plus-angle." Both of these tightening requirements are referring to a single critical fact: all bolts are elastic.

Bolt Stretch

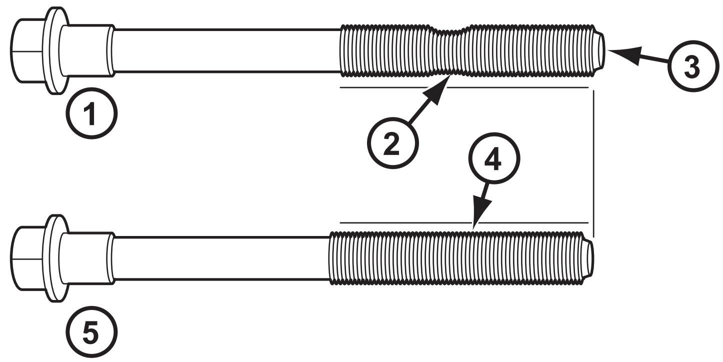
When a critical bolt is tightened to its proper specification, the bolt is actually being stretched. A stretched bolt wants to return to its original length. Based on the type and quality of steel used in the fastener, the diameter of the fastener, and how far the fastener gets stretched during tightening, the load (force) applied to the joint will change. If a critical bolt is not stretched, resulting in the bolt not being put under load, there will be reduced force present in the joint resulting in reduced clamping load.

Yield

Not only do bolts stretch, they will only stretch so far. There is a limited amount of elasticity in fasteners. This limit to a fastener's elasticity is its threshold of yield, commonly referred to as the "yield point." Up to this yield point, if the load on a fastener is released, the fastener will normally return to its original length.

However, when a fastener is stretched beyond its yield point and into its yield zone, some of the fastener's elasticity is permanently lost, and the fastener will remain somewhat elongated when the load is removed. Bolts in this condition are often referred to as being "stressed," and should never be reused. The further a fastener is stretched into its yield zone, the more elongation will result.

Severe elongation of fasteners is referred to as "necking down." Necking down generally occurs in the threaded area of the fastener, where its diameter is smallest, and just outside the area where the fastener engages into solid material. Stretched too far into the yield zone, a fastener can pull into two pieces.



1	Cylinder Head Bolt, Bad Condition	4	Uniform Thread Height
2	Necking Down Damage	5	Cylinder Head Bolt, Good Condition
3	Bolt Elongation		

Figure 50 Stressed Bolt with "Necking Down" Damage

The maximum clamp load from a fastener comes exactly at its threshold of yield. If a fastener is stretched beyond its yield zone, very little additional clamp load will be generated, and the risk of ultimate failure will become much greater. Ideally, all fasteners are to be tightened to the optimum point of elasticity required for the load, with no yield.

Tightening Methods

Torque wrenches tighten critical threaded fasteners with great reliability and repeatability. They accomplish this by measuring the fastener's resistance to turn. The friction on the threads and head of a bolted joint is the biggest factor causing resistance to turn. Approximately 90 percent of the effort required to tighten a critical engine bolt is used to overcome this friction, with the remaining ten percent then used to stretch the fastener up to its yield point. However, the greater the effort required to overcome this friction means there will be less stretch on the fastener, resulting in less load on the joint.

On a critical joint with multiple fasteners, such as a cylinder head, any variances in load on the bolts are referred to as "load scatter." Load scatter can cause uneven loads on the head gasket, which can subsequently cause the gasket to fail prematurely. For this reason it is critical to minimize the variables between bolts when using conventional "resistance to turn" methods to tighten fasteners.

One way to minimize this variable is by always lubricating the fastener thread and under the head of the fastener with motor oil; the standard lubricant for automotive fasteners.

NOTE: Certain fasteners with a special gray coating called Dacromet® should **not** be lubricated with motor oil prior to insertion. Dacromet® is a special baked-on finish designed to increase a fastener's resistance to corrosion; such as the bimetallic reaction that occurs between steel and aluminum. In addition, impact tools should **not** be used to insert fasteners coated with Dacromet®.

Bolt inspection includes inspecting the length of the bolt for signs of stretch, measuring it for uniform thread height, necked down areas, and damaged threads. Damaged threads will always increase a fastener's resistance to turning (friction), and as a result decrease the fastener's load. Tightly controlling these friction variables is critical to ensure an even load across a joint.

Torque-to-Yield

The further a fastener is stretched toward, but not into, its threshold of yield, the more clamping load it will exert on the joint. One way to achieve more load is with bigger diameter fasteners, but in fact it is more of an advantage on critical joints to keep the fastener diameter small and use maximum stretch to maintain the integrity of the joint. In addition, the longer in length a fastener is, the more it can stretch to achieve the desired load. For this reason most head bolts are long yet relatively small in diameter, with ideally all of the bolts being the same length.

Because of all of these variables, in the mid 1980s a tightening process called torque-to-yield started to be used on critical fasteners such as head bolts. The theory behind torque-to-yield is the further a fastener can be stretched toward its threshold of yield, the more load it will exert on the joint, and the better the connection.

However, critical fasteners such as head bolts can inadvertently end up being stretched further than their installation requirement. Typically this will be due to thermal expansion over time, such as the difference in expansion rates between aluminum head material versus the expansion rates of its steel fasteners. This issue can be made worse with a fastener installed at the threshold of yield that incorporates a replacement gasket material that does not relax (such as a one made of multi-layer steel) to the same extent as the previous gasket material.

Torque-to-yield fasteners are not "special," metallurgically speaking. But they are high-grade fasteners, typically class 10.9 for metric applications. Fasteners referred to as "true" torque-to-yield devices are bolts designed with a reduced shank area (Cummins rod bolts, for example). The only difference between these devices and the standard high-graded threaded fasteners used in other torque-to-yield applications is the reduced shank style was specifically designed to direct bolt elongation to the shank area instead of the threaded area. Both types of high-grade fasteners are used in torque-to-yield applications.

Regardless of using torque-to-yield fasteners, however, the most critical aspect of any bolted connection is accurately tightening all of the fasteners to, but not into, their threshold of yield. Being able to do this requires an optimum method of measuring resistance to turn that minimizes the impact of friction generated during the tightening process, as friction variances between fasteners can ultimately cause a critical joint failure.

Torque-Plus-Angle

For this reason, a method for tightening a fastener that many believe is more accurate than just measuring the fastener's resistance to turn is called torque-plus-angle.

With the torque-plus-angle method, a relatively low torque is used to run down and align the fastener. Typically, for multiple fasteners on a critical joint, such as a cylinder head, this is done in a specific pattern or sequence, and in multiple stages. Using torque-plus-angle, then only a single measured turn – **not** using a torque wrench – is used to tighten the fastener to the desired level. The goal of the torque-plus-angle method is to completely remove the variable of friction from the tightening equation.

If using a specification of 90 degrees of torque-plus-angle, for example, 90 degrees of turn will always be 90 degrees of turn; no matter the condition of the bolt, type of materials being joined, etc. Thus, the amount of stretch will be extremely uniform from bolt to bolt across this joint, with load scatter kept to a minimum.

For this reason many engine designers believe that torque-plus-angle is a superior method for tightening critical fasteners, regardless of whether all of the bolts actually end up being tightened to their yield point or not. This is because the consistency between bolts can maximize the overall integrity of the joint, as opposed to ending up with only some bolts in a multi-bolt connection actually being tightened to their correct yield point.

NOTE: Whether they use torque to-yield or torque-plus-angle as a tightening method, critical joints with multiple fasteners require a specific tightening pattern – or sequence – for the fasteners, as well as multiple tightening stages. Always refer to the Service Information prior to tightening multiple fasteners in a critical joint.

Reusing Critical Threaded Fasteners

For all of the reasons mentioned above, it should be obvious that reusing critical connection bolts, if these bolts were ever stretched beyond their yield point (even momentarily), could lead to premature joint failure. Never reuse bolts that the Service Information indicates must be replaced. In applications where reusing bolts is acceptable, thoroughly inspect the bolts for signs of stretch, necking down, uneven thread height, and damaged threads before reusing them. If any if these conditions are found, immediately dispose of them to make sure they never end up being reused for a repair operation.

Notes:

GLOSSARY OF TERMS

304 Stainless Steel – 304 (type 18-8) is the most versatile and the most widely used of all stainless steels because of its mechanical properties, weldability and corrosion/oxidation resistance. It also has excellent low temperature properties and responds well to hardening by cold working. Many HeliCoil® type steel thread repair inserts are made from 304 stainless.

321 Stainless Steel – Typically used where high temperature-resistant materials are required, as in automotive exhaust systems. 321 refers to a grade of steel where the titanium content is five times that of the carbon content. Titanium content reduces carbon build-up, resists oxidation and corrosion, and performs well under high temperatures.

Advance – (1) Any automatic or manual adjustment of the ignition system that produces ignition spark earlier in relation to the location of the piston. (2) Any automatic or manual adjustment of a fuel injection pump that produces fuel injection earlier in relation to the location of the piston.

After Top Dead Center (ATDC) – The location of the piston after it has reached the top of its stroke. Piston location is measured in degrees of crankshaft rotation. Ignition timing may, in some cases, be specified in terms of degrees ATDC (example: 1° ATDC).

Angular Position – Piston position given in degrees, usually in relation to its position before or after top dead center (example: 12° BTDC).

Anaerobic – In the absence of oxygen.

Anodizing – An oxidation process in which a component's surfaces are converted to a hard and porous oxide layer that provides wear and corrosion resistance. Anodizing is also used as a decorative finish.

Babbitt – A low-friction metal alloy, up to 90 percent tin, to which copper, antimony, lead, zinc and sometimes other metals are added. Babbitt is a soft material with a low 316° C (600° F) melting point. It is widely used to coat friction bearings of harder material. Originally, Babbitt was used for casting journals or sleeve bearings.

Backfire – Combustion of the air/fuel mixture in the intake or the exhaust manifold. Backfire occurs if the intake or exhaust valves are open when there is a mistimed ignition spark, or if there is a problem in the air pump system.

Backpressure – A resistance to the free flow of gases or liquid. For example, a plugged catalytic converter causes backpressure in the exhaust system which exerts a force back to the engine. Excess backpressure is used in some heavy truck applications as an engine brake to assist the normal braking system.

Balance Shaft – A shaft located in the cylinder block valley of some engines. It is driven by the timing chain or belt and is used to cancel engine vibration and roughness.

Ball Stud – A stud with a ball-shaped end. Often used in valvetrains (adjusting screw) and in steering linkages.

Barrel-Shaped Piston – A piston that is machined so that a small amount of material (not visible to the naked eye) is removed just below the oil ring so that the skirt area looks like a barrel. This reduces the possibility of the piston scuffing the cylinder wall.

Base Circle – On a camshaft, the side opposite a lobe (or cam) that is basically the center of the camshaft from which the lobe rises.

Bearing – A device placed between a moving part and a non-moving part to reduce friction. Typically bearings reduce friction by virtue of their shape and wear-resistant material, plus often by containing a fluid between the moving and non-moving surfaces.

Bearing Clearance – The space between a bearing and moving component where a lubrication film can be maintained.

Before Top Dead Center (BTDC) – The location of the piston before it has reached the top of its stroke. The location of the piston is measured in degrees of crankshaft rotation. Ignition timing is normally specified in degrees BTDC (example 12° BTDC).

Bell Mouthing – The uneven wear of a valve guide, brake drum or similar mechanism toward the open end. Flared wear pattern usually resembles the mouth of a bell. Also called “bell wear.”

Big End – The large end of the connecting rod that fits on the crankshaft. The rod cap attaches to the big end of a connecting rod.

Billett – A semi-finished piece of metal, or ingot, usually cast to a rectangular, hexagonal or round cross section.

Billett Camshaft – A camshaft machined from a billett of steel.

Billett Crankshaft – A crankshaft machined from a billett of steel.

Bore Out – Increasing the size of a cylinder by removing metal from the parent block or sleeve with a cutting tool (boring bar). Sometimes referred to as "reboring." After a cylinder is bored out, an oversize piston must be installed.

Bottom Dead Center (BDC) – The location of the piston at its lowest point of travel.

Brake Horsepower – Actual horsepower delivered by an engine at the crankshaft. Normally measured by means of a dynamometer or pony brake.

Break-In – The wearing in process between surfaces of two new or reconditioned parts.

Brinell Hardness – The Brinell scale characterizes the indentation hardness of materials by measuring the penetration of an indenter loaded onto a test-piece. It is one of several definitions of hardness in materials science. (See also "Rockwell Hardness.")

Bucket Tappet – Valve lifter design that is hollow, cylindrical, and closed at one end (like an upside-down bucket); used on certain overhead camshaft-design engines. The flat, closed end of the tappet rides against the camshaft; the top of the valve spring and valve stem is enclosed within the bucket.

Burned Valve – A valve that has been deformed or damaged by excessive heat. Burned valves should not be reused.

Burnish – (1) To smooth or polish with a moving tool. (2) A condition caused by honing stones that do not cut correctly, get too hot and cause oxidation of the honing oil. (3) A condition in which the cylinder wall is a brown color as a result of improper honing.

Bushing – A removable, circular, one-piece component placed between two parts, either or both of which may move. The bushing may absorb shock, perform bearing-like functions or help to position parts.

Cam Shaped Piston – A piston machined to a slightly oval shape which, under the heat of operation, becomes round.

Camshaft – A rotating shaft with lobes (cams) that open intake and exhaust valves.

Carbon Buildup – A substance that can prevent the transfer of heat from the combustion chamber.

Carbon-Fouled – The buildup of carbon deposits on spark plug electrodes. Fouled spark plugs are likely to misfire which causes a loss of power, poor performance and inferior fuel economy.

Cast Iron – A commercial alloy of iron, carbon and silicon that is cast in a mold. It is hard, brittle, nonmalleable and cannot be hammer welded, but is more easily fusible than steel.

Cavitation – (1) The formation of partial vacuums in a liquid by a quickly moving solid body, such as a propeller (or impeller). (2) The pitting and wearing away of solid surfaces (such as metal) as a result of the collapse of these vacuums in surrounding liquid.

Chrome Silicon Steel – An alloy steel often used in high stressed parts such as valve springs. Contains chromium and silicon as key alloying elements.

Combustion Chamber – That portion of the cylinder between the piston and cylinder head in which combustion takes place.

Composite Manifold – A manifold made of composite material. Composite materials are man-made materials that offer a combination of desirable engineering properties.

Compression – Increasing the pressure of a gas by reducing its volume.

Compression Ratio – The volume of an engine cylinder and combustion chamber with the piston at BDC, as compared to the volume when the piston is at TDC.

Compression Ring – A type of piston ring that is fitted into the uppermost grooves of a piston to prevent gases from passing into the crankcase. Most automotive pistons have two compression rings.

Compression Stroke – The upward movement of a piston that squeezes the air/fuel mixture into a tiny space, raising its pressure and causing it to explode with greater force when ignited.

Connecting Rod – Or "conrod," a steel component that connects the piston to the crankshaft. Failure of a connecting rod results in a catastrophic engine failure.

Coolant – A mixture, usually an ethylene glycol solution and water, used to carry excess heat from the engine to the radiator.

Coolant Recovery Tank – An auxiliary tank that receives the overflow when the coolant in the radiator expands. When coolant in the radiator contracts, the overflow is drawn back from the recovery tank.

Core Plug – A small metal disc that is force-fit into an opening in the water jacket of an engine block. If the coolant freezes, one or more core plugs may pop out to relieve pressure so that the block does not fracture. Also called a "freeze plug."

Crankcase – A component that houses the crankshaft and related components, one of which is the oil pan.

Crankcase Dilution – When unburned fuel gets past the rings in the crankcase and dilutes (thins) the lubricating oil.

Crankshaft – The component in an engine that converts the reciprocating power produced by the pistons, into rotary power that is transmitted to the drive wheels. It is named for the offsets called "cranks" or "crank throws," to which connecting rods are attached.

Cubic Inch Displacement (CID) – Represented in inches. The product of stroke, size of the cylinder bore and number of cylinders of an engine. The number represents the ideal volume of air/fuel mixture that can be drawn into a cylinder with each induction stroke, multiplied by the number of cylinders.

Cylinder Sleeve/Liner – A sleeve or tube inserted between the piston and cylinder wall or cylinder block to provide a durable and easily-renewable wear surface for the piston. Cylinder liners that contact coolant are called wet liners. Cylinder liners that only contact the bore of the block are called dry liners.

Dacromet® – A gray, corrosion resistant coating applied to screws, bolts, and other small bulk items for automotive use. Dacromet® is comprised mainly of metal oxides plus overlapping zinc and aluminum flakes in an inorganic binder.

Dead Center – Extreme upper or lower position of crankshaft throw where the piston is not moving in either direction.

Deep Skirt Block – A cylinder block whose skirt goes below the centerline of the crankshaft.

Detonation – In a gasoline engine, a sound created by ignition occurring before the spark. Detonation commonly occurs in a recess in the combustion chamber and upsets the normal pressure pulse occuring in the combustion chamber. Also known as knock, dieseling, after-run and run-on.

Die Cast – A metal forming process that consists of forcing molten metal into a mold or die.

Dieseling – A situation where a gasoline engine continues to run after the key is turned off. Often referred to as "afterrunning."

Displacement – See "Cubic Inch Displacement."

Double Overhead Camshaft (DOHC) – An engine design in which two camshafts are located on top of the cylinder head. One camshaft operates the intake valves, and a second operates the exhaust valves.

Drop Forged – A type of forging produced by impact or pressure that forces hot, pliable metal to conform to the shape of a die. Drop forging uses a steam hammer or gravity drop hammer in combination with closed impression dies.

Dry Sump – A type of engine lubricating system in which lubricant is stored in a remotely mounted reservoir, rather than in an oil pan. A pump circulates oil through tubing that connects the engine to the reservoir.

Ductile Iron - Also called "Nodular Iron," is a type of cast iron which is ductile, i.e. less brittle due its ability to stretch/bend before it breaks.

Dynamic Timing – Timing an engine while the engine is operating.

Eutectic – A mixture of two or more elements that has a lower melting point than any of its constituents. Used especially in alloys.

Exhaust Port – An opening in the cylinder head through which exhaust gases leave a cylinder.

Exhaust Valve – As the rotation of the crankshaft pushes the piston back up the cylinder, the exhaust valve opens and allows the burned gases to leave the cylinder.

Forged – (1) A process of forming metal by heating and hammering. (2) A process of forming metal using a mechanical or hydraulic press with or without heat.

Four-Cycle Engine (Four-Stroke) – An engine in which combustion in a cylinder occurs every other revolution of the crankshaft. The strokes are: intake, compression, power and exhaust. This cycle is also called the Otto Cycle.

Freewheeling – An engine that is designed so that there is no chance for the valves to contact the pistons or other valves, regardless of engine timing. (Originally this term referred to disengaging the drive wheels when a vehicle was rolling faster than the engine was turning over.)

Gallery – A passageway through which a liquid flows. In automotive engines, this liquid is normally lubricating oil.

Galvanic Corrosion – Based on the Galvanic Series (a ranking of metals and alloys and their relative electrochemical reaction with seawater). The lower rated metal in the series will corrode. For example: Steel screws corrode when they contact brass in a marine environment; or if copper and steel tubing are joined in a home water heater, the steel will corrode near the junction.

Glaze – An extremely smooth or glossy engine cylinder surface, polished over a long time by friction from the piston rings.

Glaze Breaker – A tool for removing the glaze on an engine cylinder.

Glow Plug – An electrical device (electronically controlled) used to heat a precombustion chamber air to help in starting.

Grey Cast Iron – A type of cast iron containing graphite. The graphite material within grey cast iron causes it to be a dark color, resistant to corrosion, resistant to wear, and easily machined.

Harmonic Balancer – A device used to reduce torsional vibration in the crankshaft of an engine with multiple cylinders.

Header – A specially designed tubular exhaust manifold designed to decrease backpressure and increase the flow of exhaust gases. Used to improve performance.

High Swirl Combustion Chamber (HSC) – A combustion chamber that features a masked intake port and central spark location. This creates a high swirl and turbulence as the air/fuel mixture is drawn into the combustion chamber and provides better mixing of the fuel charge, allowing faster burning and more complete combustion.

HOAT Coolant – An ethylene glycol-based coolant with a Hybrid Organic Acid Technology (HOAT) inhibitor. HOAT coolants use both inorganic and organic inhibitors: Inorganic to provide fast-acting aluminum engine protection from boiling and erosion, and organic for non-depleting, long term protection.

Hot Spot – An area of a cooling system with above average temperatures, possibly due to an air bubble or not enough coolant flow.

Hydraulic Lash Adjuster – A valvetrain component used to automatically and continuously compensate for valve dry lash by way of controlled hydraulics during engine operation.

Hydraulic Lifter – A valve lifter that uses oil pressure to keep the lifter in contact with the camshaft on one end and the valve stem on the other. This eliminates all clearance in the valvetrain when the engine is running.

Hydraulic Tappet – A valve tappet that uses oil pressure to keep the tappet in contact with the camshaft on one end and the valve stem on the other. This eliminates all clearance in the valvetrain when the engine is running.

Hydro-elastic Engine Mount – An engine mount filled with a viscous fluid that absorbs and deadens engine vibrations. The mount has two separate chambers with a space between. The fluid moves between the chambers as it absorbs engine and driveline vibrations; much like a conventional shock absorber.

Ignition – (1) The beginning of the burning of the air/fuel mixture in a combustion chamber. (2) Slang for the electromechanical system that produces the spark at the spark plugs.

Ignition Coil – Part of the ignition system that acts as a transformer. It changes pulsed, low-voltage direct current in the primary windings to a high-voltage, spark impulse in the secondary winding. It does this by a collapsing of the magnetic field in the coil.

Impeller – An internal wheel with blades that is used to move a liquid or a gas.

Indicated Horsepower (HP) – The power developed in the cylinders. It is equal to the brake horsepower plus the horsepower loss to friction.

Indirect Injection – Fuel injection into a prechamber or cell in which ignition is initiated before the burning mixture enters the main combustion chamber.

Intake Manifold – An engine component that guides the air/fuel mixture from the throttle body assembly to the cylinders.

Intake Port – The opening in the cylinder head of an engine through which the air or air/fuel mixture enters the cylinder.

Intake Valve – The valve that opens the intake port which allows the air or air/fuel mixture to enter an engine cylinder, and then closes, trapping the mixture in the cylinder.

Intercooler – A device used to cool air compressed by a turbocharger or supercharger before the air enters the intake manifold. Intercoolers rely on engine coolant (jacket water intercooler or air-to-air intercooler) to cool the air going through them.

Intercooling – A term applied to the cooling of air by an intercooler before entering the intake manifold, after a turbocharger or supercharger has pressurized the air.

Internal Combustion Engine – An engine that gets its power from fuel that is burned in the engine.

Internal Energy – The energy that a body possesses due to its condition, such as pressure and temperature.

Inverted Tooth Chain – A common type of timing chain known for superior sound control.

Jet – A tube or opening of a calibrated size through which air and/or fuel flows.

Journal – The smoothly finished part of a shaft that turns within a bearing.

Knock – An undesirable sound produced when the air/fuel mixture is ignited by something other than the spark plug, such as a hot spot in the combustion chamber. Light knock is normal in modern engines during heavy acceleration or under high load conditions, such as climbing steep grades. Severe knock can be caused by fuel with too low an octane rating or by improper adjustment of the ignition system, and it will damage the engine. Knock is also called "detonation" or "ping."

Laminated Steel – Thin, bonded layers of steel, as used in some gasket designs.

Lash – The amount of play or free movement (slack) between interacting parts, such as a set of gear teeth or valvetrain components.

Leakdown Rate – The time it takes for a valve tappet to collapse when being tested on a leakdown tester.

Lifter – A cylindrical metal component that contacts a camshaft lobe on one end and the pushrod, rocker arm or valve stem on the other. Oil inside the lifter transfers the up and down action of the cam to the pushrod, rocker arm or valve stem using hydraulic action.

Lobes – Elliptical projections on a rotating camshaft that create open/close valve movement.

Main Bearings – The bearings in which the crankshaft turns.

Manifold Vacuum – Low pressure in the intake manifold caused by the evacuating action of the pistons and cylinders.

Martensitic – Refers to a very hard form of steel crystalline structure created by rapidly cooling (quenching) a molten solution of iron containing up to 1% carbon.

Mechanical Efficiency – The ratio of brake horsepower output of an engine to the indicated horsepower in the cylinders.

Misfiring – When one or more cylinders are not producing power.

Multiple Displacement System – a system (MDS) that automatically disables four cylinders of a V8, as on certain 5.7L Hemi® engines, during light engine loads.

Mushroom Lifter – A lifter with a large head area that provides a greater load-bearing surface to ride against the camshaft.

Mushroom Tappet – A tappet with a large head area that provides a greater load-bearing surface to ride against the camshaft (usually only used on pushrod-type engines).

Napier Piston Ring – This type of piston ring has a tapered hook face or groove. The design of the groove functions as a scraper to provide a consistent thickness of oil film. A micro-Napier piston ring has a smaller hook face or groove.

Nodular Iron – A gray iron that produces stronger and more ductile castings with characteristics similar to steel. While most varieties of cast iron are brittle, ductile iron is much more flexible and elastic due to its nodular graphite inclusions. Typically this material is used for valves, pump bodies, crankshafts, gears and other automotive and machine components. Also called "Ductile Iron," it is composed of gray iron, silicon, plus a small amount of magnesium and/or cerium for ductility.

Non-freewheeling – An engine in which if the timing belt breaks, unlike a

"Freewheeling" design, the valves may strike the pistons, potentially causing serious engine damage.

Normally Aspirated – An engine without a turbocharger or supercharger. The cylinder air charge pressure at the start of the compression cycle is very near, or slightly below atmospheric pressure.

OHC – An abbreviation for Overhead Camshaft.

OHV – An abbreviation for Overhead Valve.

Oil Cooler – A small radiator that is used to cool oil.

Oil Pan – The metal housing at the bottom of the engine, which serves as an oil reservoir and is part of the crankcase.

Oil Pump – A device that forces lubricating oil through the engine.

Oil Ring – The bottom piston ring that prevents excess oil from going up past the piston. Also called an oil scraper because it wipes oil from the cylinder walls and lets it drain back into the oil pan.

Oil Seal – A component that prevents oil from leaking along a shaft or other moving part.

Oil Strainer – A screen mounted at or near the oil pump to prevent the passage of large solid impurities into the engine.

Oil Squirter – A steel tube attached to the engine block at the bottom of each cylinder that is connected to the lubrication system. A nozzle on the end of this tube sprays oil up into the cylinder to help cool the underside of the piston crown.

Oil Squirt Hole (in a Connecting Rod) – A hole on one side of a connecting rod that sprays oil from the rod bearing upwards to help lubricate the thrust side of the cylinder wall.

Ovate Wire – Oval-shaped wire. Valve springs can be made of ovate wire or round-shaped wire. Ovate springs have more spring material occupying the same vertical area as round-shaped wire springs.

Overhead Camshaft (OHC) – Engine design in which the camshaft is mounted on top of the cylinder head.

Overheating – An abnormal condition in which coolant temperature becomes excessive. Symptoms include activation of the temperature warning light, the temperature gauge in the overheated range, or coolant overflowing the overflow tank.

Over Square – An engine design in which the diameter of the bore is more than the length of the stroke of the piston.

Perforated Core Graphite Gasket – A multi-layered gasket containing a graphite core. "Perforated" refers to die cutting a number of holes in a single gasket sheet.

Phosphor Bronze – An alloy of copper, tin and lead. Sometimes used as a material for heavy-duty engine bearings.

Ping – An undesirable sound that may be related to pre-ignition or detonation noise from a hot engine under load.

Piston – A metal component tightly fitted within a cylinder which moves under hydraulic, mechanical, or combustion pressures. In an automobile engine, a piston moves under combustion pressure and is attached to a rod which transfers this energy to the crankshaft.

Piston Boss – The portion of the piston that supports the piston pin.

Piston Crown – The top of a piston. Sometimes called the "Piston Head."

Piston Displacement – The volume of air moved or displaced by the movement of the piston from BDC to TDC.

Piston Head – The part of the piston above the piston rings.

Piston Lands – The parts of the piston between the piston rings.

Piston Ring Expander – A piston ring placed behind the piston oil ring designed to force the ring against the cylinder wall. Also known as a "spacer."

Piston Ring Gap – The clearance between the ends of the piston ring. Piston rings have a break in them to allow for installation and removal from the "Piston Ring Groove."

Piston Ring Groove – The groove formed in a piston into which a piston ring fits.

Piston Rings – Metal rings mounted in grooves in a piston that push against the walls of the cylinder. Designed to prevent compression forces from leaking past the pistons into the crankcase, and to keep excess oil from leaking past the pistons into the combustion chamber. Usually made of steel, cast iron or a long-wearing alloy.

Piston Skirt – The portion of the piston below the piston pin that is designed to bear the side thrust of the piston.

Plenum – The chamber in the intake manifold where air is directed by intake runners to the ports in the cylinder head.

Pony Brake – A machine for measuring the brake horsepower of an engine.

Port – An opening in the cylinder head through which the air/fuel mixture or exhaust gases flow.

Positive Twist – An asymmetric change in the piston ring cross section that causes it to twist in an upward direction (towards the piston crown), aiding ring sealing at the top and bottom of the ring groove.

Positive Valve Rotator – A device at the base or top of a valve spring that slightly turns the valve each time the valve opens. Turning the valve prevents the buildup of carbon on the face of the valve and valve seat.

Powdered Metal – A substance used in the manufacture of metal pieces that have precise shapes. Made by compacting metal powders, followed by high-temperature heat-treating (sintering).

Power Stroke – Downward movement of the piston after the ignition of the air/fuel mixture in an engine cylinder.

Pre-Ignition – Ignition of the air/fuel mixture before the spark occurs at the spark plug. Often caused by glowing carbon deposits or hot spots in the combustion chambers. Also called knocking ("Knock") or pinging ("Ping"), it can be harmful to an engine.

Pushrod – A rod or tube in overhead valve engines that is fitted between the rocker arm and the valve lifter or tappet. Sometimes referred to as a "push-tube."

Resonator – A sound-reduction device normally positioned behind the muffler in an exhaust system, or before the throttle in an air intake system.

Retard – Any automatic or manual action that delays ignition spark or fuel injection, in relation to the position of the piston.

Rockwell Hardness – The Rockwell scale characterizes the indentation hardness of a material. It is one of several definitions of hardness in materials science. (See also "Brinell Hardness.")

Rocker Arm – A valvetrain component that pivots (rocks) on a shaft or on a ball-shaped stud. In some valvetrains rocker arms are used to change upward force on one end into downward force on the other.

Rolled Fillet – A fillet is a round joint between two parts connected at an angle. A rolled fillet has a strip to reinforce the corner where the two surfaces meet.

Roller Chain – A common type of timing chain known for superior wear resistance.

Roller Tappet – A specially designed tappet that uses a roller bearing to contact the camshaft, thus substantially reducing friction when compared to a conventional tappet.

Roller Vane Pump – Uses a rotor with six to ten vanes that rotate in an elliptical pump ring. Fluid trapped between the vanes is forced out under pressure as the vanes move from the long diameter of the pump ring to the short diameter.

Seat – (1) The surface on which a part, such as a valve, rests. (2) The final mating of parts after break-in.

Serpentine Drive Belt – A single drive belt that drives all, or most, of the engine-powered accessories.

Single Overhead Camshaft (SOHC) – An engine design with a single camshaft placed on top of the cylinder head.

Sinter Bonded – A process of powder metallurgy in which particles of powdered metal fuse together when heated to a high temperature (sintered).

Sintered Metal – Metal in the form of compressed powder that has been melted under high temperature (sintered), allowing the individual particles to bond together.

Skirt – The hollow, lower part of a piston located below the "Piston Rings."

Slap – An undesirable sound made by a loose fitting piston as it strikes the cylinder wall.

Small End – The end of the connecting rod that fits into the piston.

Sodium-Cooled Valve – An engine valve designed with a hollow stem filled with sodium crystals that function to conduct heat away from the valve head.

Spark Knock – Abnormal combustion that is accompanied by an undesirable pinging noise, or "Ping."

Squish – The action in the combustion chamber in which some of the air/fuel mixture is swirled (squished) to create turbulence during the compression stroke.

Static Timing – The timing status of an engine when it is not running.

Stratified Charge – A method of drawing the air/fuel mixture into the combustion chamber in layers with a layer at the spark plug rich enough to be ignited by a spark, but progressively leaner layers away from the spark plug.

Stroke – The distance the piston travels from TDC to BDC.

Supercharger – A horsepower-enhancing device driven by a mechanical means, such as an engine drive belt, chain or gear. The device is used to draw in air and compress it, then distribute it under high pressure to the intake manifold. Often referred to as a "blower."

Swirl – A turbulent rotation of the air/fuel mixture as it enters the cylinder.

Tappet – A solid valve lifter with no hydraulic fluid. See Lifter.

Throttle Body – The section of a fuel injection system that contains the throttle valve.

Throttle Body Fuel Injection – A simplified fuel injection system built into a housing that resembles a carburetor.

Timing – The relationship between the firing of the spark plug and the position of the piston. Usually expressed in crankshaft degrees before or after TDC on the compression stroke (example: 15° BTDC).

Timing Belt – A belt with cogs (squared teeth) that drives an overhead camshaft. On some diesels, the belt also drives a fuel injection pump.

Timing Chain – A crankshaft-driven chain that turns the camshaft to open and close cylinder valves at the proper time.

Timing Gear – Can refer to both the gear attached to the camshaft(s) and the gear on the crankshaft. Their purpose is to provide a means of driving the camshaft, generally using either a timing chain or a cog belt.

Top Dead Center (TDC) – The position of the piston at its highest point of travel.

Torque-to-angle – Using a relatively low torque to run down a threaded fastener, then a single measured turn to tighten it to the desired level.

Torque-to-yield – Tightening a bolt to but not beyond its threshold of yield.

Turbocharger – An assembly with a turbine wheel that is driven by the exhaust from an engine. The turbine wheel drives a compressor that draws in air and routes it to the engine air intake system. Often shortened to "turbo."

Turbulence – An irregular motion of gases necessary for the proper mixing of air and fuel in a combustion chamber.

Ultrasonic Welding – A process of welding that uses a transducer with an externally supplied energy to create lateral vibrations at the tool tip. Used extensively in the auto industry for lap welding of sheets, foil and thin wire.

Valve Clearance – The free play between a valve and a rocker arm, as measured with feeler gauges. Also referred to as "valve lash" and "valve dry lash."

Valve Float – A condition in which the valves cannot close before combustion begins.

Valve Guide – A passage in which the valve stem slides.

Valve Overlap – The interval between the intake and exhaust strokes when both the exhaust and intake valves are open. This helps with the removal of exhaust gases from the cylinder.

Valve Relief – Indentations in the top surface of a piston that allow for increased valve opening configuration with no valve/piston contact.

Valve Seat Insert – A replaceable valve seat.

Valve Stem – The rod-like portion of a valve that moves in the valve guide.

Valve Stem (Oil) Seal – The seal around the valve stem that prevents too much oil from passing down into the valve guide.

Vibration Damper – A weighted device, attached to a crankshaft that smoothes out power flow and prevents torsional vibration.

Waste Gate – A component of a turbocharger that relieves excess boost pressure.

Water Jacket – The hollow areas around an engine head and cylinders through which coolant flows to collect excess combustion heat.

Windage Tray – An oil control component that reduces oil aeration and improves power output. It does this by directing oil away from the crankshaft as it drains from the heads and chain case down into the oil pan sump.

Wrist Pin - A short rod that secures the connecting rod to the piston. It fits into a hole in the side of the piston, passes through the small end of the connecting rod and through to the hole in the other side of the piston. Some wrist pins are press fit; some are secured with C-clips.

Notes: